



Midpeninsula Regional Open Space District Integrated Pest Management Program Guidance Manual

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Midpeninsula Regional Open Space District Integrated Pest Management Program Guidance Manual

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ACRONYMS AND ABBREVIATIONS

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AHAS	Acetohydroxyacid Synthase
BAEDN	Bay Area Early Detection Network
BMP	Best Management Practice
Cal-IPC	California Invasive Plant Council
CDFA	California Department of Food and Agriculture
CDFW	California Department of Fish and Wildlife (formerly Department of Fish and Game)
CEQA	California Environmental Quality Act
DE	Diatomaceous Earth
DNA	Deoxyribonucleic Acid
EDRR	Early Detection and Rapid Response
EIR	Environmental Impact Report
EPA	Environmental Protection Agency
ESA	Endangered Species Act
GGNRA	Golden Gate National Recreation Area
IGR	Insect Growth Regulator
IPM	Integrated Pest Management
IPMP	Integrated Pest Management Program
MSDS	Material Safety Data Sheets
OSMRP	Open Space Maintenance and Restoration Program
OSP	Open Space Preserve
PCA	Pest Control Advisor
PCR	Pest Control Recommendation

ACRONYMS AND ABBREVIATIONS

PPE	Personal Protective Equipment
PSIS	Pesticide Safety Information Series leaflets
QAC	Qualified Applicator's Certificate
QAL	Qualified Applicator's License
SPCA	Structural Pest Control Applicator
SPCO	Structural Pest Control Operator
SOD	Sudden Oak Death
UC IPM	University of California State Integrated Pest Management Program
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
WFRP	Wildland Fire Resiliency Program

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1 Overview

1.1 Introduction

Integrated Pest Management (IPM) is a process of efficiently managing pests while protecting human health and environmental quality. In September of 2014, the Midpeninsula Regional Open Space District (District; Midpen) first developed and adopted their IPM Program (Program or IPMP) and released an IPMP Guidance Manual following the release of the 2014 Environmental Impact Report (EIR) for the Program. The IPMP Guidance Manual included several proposed program policies and identified specific pest management actions including preventative and maintenance measures, damage assessment procedures, tolerance levels and thresholds for action, and treatment options. As part of the 10-year Program update, the District is revising their IPM Guidance Manual and adopting a revised comprehensive IPM approach throughout all its preserves, other properties, and associated buildings and facilities in compliance with other existing Midpen plans and programs including the Service Plan for the San Mateo Coastal Annexation Area. The District's definition of IPM is described in Chapter 2.

The updated 2025 IPMP Guidance Manual will be considered by the Board of Directors for adoption in conjunction with the Addendum to the 2014 EIR addressing the 10-year Program update. Once adopted, the Program will be updated as necessary through the District's annual reporting process (refer to Section 3.8). The Guidance Manual is intended to have a 10-year planning timeframe before another more comprehensive update is initiated. The Guidance Manual is split into two main sections: chapters that deal with program-wide processes (Chapters 1-4), and chapters that guide individual pest management decisions (Chapters 5-8).

The IPM Coordinator and the IPM Coordination Team will play key roles in reviewing pest management projects for consistency with the Guidance Manual and overseeing licensing, training, and safety (Chapter 3) in carrying out the IPM Program. Other processes undertaken by the IPM Coordinator or staff throughout each year include planning, notification, and monitoring of the projects (Chapters 3 and 4). The Guidance Manual primarily emphasizes the review, prioritization, and approval of pest management activities through the development of an Annual IPM Work Plan (Chapter 3). Any new pest management activities not originally included in the Annual IPM Work Plan will be reviewed on an individual basis throughout the year.

An Annual IPM Report will summarize the work completed in the previous year (Chapter 3), evaluate the program's progress in meeting overall goals, and recommend any modifications (Chapter 4).

IPM DEFINITION AND POLICY

To adopt a comprehensive IPM Program that emphasizes prevention and monitoring, the implementation of certain tasks are prioritized and phased. Since adoption of the 2014 IPMP, Midpen has modified the Program according to District needs through its annual reporting process, which it will continue to do each year. Specifically, Midpen releases an annual report of pest management activities occurring on District land. These reports present the results of the previous year's pest management activities for the District and identify any changes to the Program that occurred in the given year. This process is discussed in greater detail in Section 3.8.

The most important decisions regarding IPM are made when individual projects are designed. This Guidance Manual identifies specific approaches to pest management including: preventative and maintenance measures; damage assessment procedures; tolerance levels and thresholds for action; and treatment options. Within the District, situations that trigger the need for pest control fall into four distinct pest management categories. Chapters 6 through 8 guide specific pest management decisions in these four major categories of work:

- Buildings (Chapter 5),
- Recreational facilities (Chapter 6),
- Rangelands and agriculture properties (Chapter 7), and
- Natural areas (Chapter 8).

Human health, environmental quality, and effective and efficient management of District property is a concern across all categories. Pests and treatment options are somewhat unique in each of the four work categories because each category represents not only a different purpose under the District's mission, but also a different type of environment. In general, the first two categories represent areas where conditions have been altered to a greater degree for human purposes, are more frequently occupied or visited by humans, and where the District has greater concerns for human safety. The latter two categories are areas in a more natural state and environmental quality is of great importance.

1.2 Background on Changes to the IPMP

Since adoption of the 2014 IPMP, Midpen has modified the Program according to District needs through its annual reporting process. A summary of these changes follows:

- In **2015**, Midpen established a project ranking system to evaluate and prioritize new pest control projects and developed a pest control project submission process utilizing a standardized form.
- In **2018**, Midpen added three insect repellent active ingredients to the List of Approved Pesticides, specifically for staff and volunteer vector protection.
- In **2019**, Midpen released an Addendum to the 2014 EIR, which included the following modifications to the 2014 Program:
 - The following pesticides were added to the List of Approved Pesticides for the Program as analyzed in the 2019 Addendum: 1) Garlon® 4 Ultra [active

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ingredient: triclopyr-2-butoxyethyl ester (active ingredient: triclopyr BEE)], 2) Capstone® [active ingredient: triclopyr triethylamine (TEA) salt and aminopyralid triisopropanolamine (TIPA) salt] for the control of broadleaf weeds and woody plants, and 3) PT® Wasp-Freeze® II (prallethrin) for the control of wasps and hornets;

- Protections for two new species of special concern (California giant salamander [*Dicamptodon ensatus*] and the Santa Cruz black salamander [*Aneides niger*]);
- New manual and mechanical treatment methods; and
- A portion of the allowable treated acreage covered under the Recreational Facilities IPM category was reallocated to the Natural Lands and Fuel Management IPM categories to allow greater flexibility in meeting vegetation management objectives, although the total acreage analyzed in the original 2014 EIR was not increased (however, it should be noted that those reallocated acres are now returned to the Recreational Facilities IPM category as part of the 10-year Program update).
- In **2020**, Midpen added Waxie 730 (hydrogen peroxide) to the Approved List of Pesticides specifically for disinfecting surfaces.
- In **2023**, Midpen adopted the Wildland Fire Resiliency Program (WFRP), which focuses on preventing, preparing for, and responding to wildfires, including addressing flammable vegetation near facilities, as a key part of the District's land stewardship. The WFRP promotes environmentally sensitive vegetation management in response to increasingly intense fire seasons driven by dense forest regrowth, historical fire suppression, and climate change. The WFRP includes goals for reducing wildfire risks, enhancing fire response and safety, supporting healthy, fire-adapted ecosystems, incorporating Native American land management practices, and establishing an adaptive framework to adjust strategies based on evolving climate conditions, knowledge, and technology. The 2014 IPMP included a fuel management category, which addressed staff selection of options for required and ongoing maintenance of fuel management activities in relation to IPM. The dedicated fuel management category, however, has been removed from the IPMP and incorporated into the WFRP.

While the Program has developed over time, as discussed, the primary purpose of the 10-year Program update is to bring the 2014 and 2019 amended IPMP up to date with the current regulatory and physical environmental conditions, as well as incorporating adaptive management recommendations and improvements. Additionally, as the District continues to expand its coverage area, the overall scale of pesticide use under the IPMP must also increase to meet the growing treatment and coverage needs.

1.3 The IPM Approach

This IPM Program emphasizes pest prevention as a first approach, followed by actions to discourage or reduce pest populations from reaching levels where active control may be

required. Tolerance levels are described to help staff determine when pest populations have reached levels where active pest control should be considered. A wide array of physical (e.g., separation of the pest from the public), biological (e.g., bio-control agents), and cultural (e.g., education and human behavior modification) actions are provided before chemical treatments can be considered. Pest treatment options are provided, including the most effective and least environmentally harmful options, by pest type. Monitoring and adaptive management principles, both on the project level and on the program level, are provided to help ensure improvements in efficiency and effectiveness of pest control over time.

Certain vegetation management projects are primarily undertaken to meet legal requirements or District-adopted specifications (e.g., clearance adjacent to trails and roads for hikers, bicyclists, equestrians and vehicles), and these types of projects are undertaken on a routine basis at the same locations primarily by mechanical methods without the need to conduct detailed analysis or monitoring of the appropriate treatment method every time.

1.4 Quick Reference to the IPM Guidance Manual by Pest Types

The following provides a quick cross-reference by types of pests to specific sections in the Guidance Manual.

- **Rodents, insects, or other animals in buildings and vehicles** – Chapter 5, Section 5.8.2, Structural Animal Pests.
- **Rattlesnakes or stinging insects outside and near people** – Chapter 6, Section 6.7.4, Nuisance Animals.
- **Invasive animals in natural areas or rangelands** – Chapter 8, Section 8.3.1 Invasive Animals In Natural Lands (cross referenced in Chapter 7, Section 7.2.1-Types of Rangeland Pests).
- **Vegetation encroaching on trails, roads, parking lots, and other outside recreational facilities** – Chapter 6, Section 6.7.5, Vegetation Management of Trails and Other Recreational Facilities
- **Landscaping around buildings** – Chapter 6, Section 6.4.2, Retrofit.
- **Weeds on rangelands or in agriculture fields** – Chapter 7, Sections 7.3, Agricultural Farms and Fields and 7.2 Rangelands (cross referenced to Chapter 8, Section 8.8.2, Invasive Plants in Natural Lands)
- **Invasive plants in natural areas** – Chapter 8, Section 8.8.2, Invasive Plants in Natural Lands.
- **Forest diseases** - Chapter 8, Section 8.8.3, Forest Diseases.

2 IPM Definition and Policy

2.1 Defining IPM and Pests

IPM is a long-term, science-based, decision-making system that uses a specific methodology to manage damage from pests. The District defines pests in its Resource Management Policies as “Animals or plants that proliferate beyond natural control and interfere with the natural processes which would otherwise occur on open space lands,” and target pests as “Plant or animal species that have a negative impact on other organisms or the surrounding environment and are targeted for treatment (Midpen 2022).” This IPM Guidance Manual addresses plant, animal, and disease pests that occur on or in District properties including preserves and buildings or on lands otherwise managed by the District.

IPM requires monitoring site conditions before, during, and after treatment to determine if objectives are being met and if the IPM methods need to be revised. IPM can be used for the control of many types of pests, including invasive species, structural and agricultural pests, and other nuisance species (e.g., rattlesnakes and stinging insects). This IPM methodology includes the following elements:

- Correctly identify the pest and understand its life cycle.
- Determine the extent of the problem or infestation.
- Evaluate the site conditions.
- Establish the tolerance level for control actions.
- Utilize the least harmful suite of treatment methods to control the pest at the most vulnerable stages of its life cycle.
- Monitor pest populations and effectiveness of treatment methods.

IPM requires knowledge of the biology of pests, the available techniques for controlling them, and an understanding of the secondary effects of the control techniques (e.g., soil erosion, pesticide drift, and bioaccumulation). Control of a pest is only undertaken once a “tolerance level” has been exceeded. A tolerance level, also referred to in IPM systems as a “tolerance threshold,” is the level below which pests can be present without causing substantial economic damage, degradation of intended uses or human enjoyment of facilities, disturbance of natural processes, or unacceptable human health risks.

The effectiveness, safety, and efficiency of control methods are important considerations as they apply to the specific site conditions and life history of the target pest. IPM requires monitoring site conditions before, during, and after treatment to determine if objectives are being met and if methods need to be revised. IPM requires that non-chemical methods be considered in addition to chemical methods (i.e., pesticides).

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Pesticides is a broad term defined by the United States Environmental Protection Agency (EPA) as (EPA 2025):

“Any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest... Any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant...Any nitrogen stabilizer.”

Pesticides include *insecticides* (substances intended to control insect pests), *rodenticides* (substances intended to control rodents), *herbicides* (substances intended to control plant pests), and *fungicides* (substances intended to control fungi). Pesticides often include *surfactants* or *adjuvants* that are substances intended to adhere and spread pesticides on a surface, typically an insect’s exoskeleton, a plant’s leaf, or dry soil.

Disinfectants, are also considered pesticides because they are intended to kill pests, specifically microorganisms including pathogens (EPA 2020). Disinfectants are used to decontaminate all equipment, including but not limited to, wading, dive, and sampling equipment (e.g., water quality probes, nets, buckets, substrate samples, etc.); fishing gear; and watercraft.

Repellents are not substances used to eliminate pests, but are designed to dissuade or repel pests and are therefore considered pesticides. For example, in the case of skin-applied repellents (e.g., “bug spray”), the product makes people less attractive to the pest (US EPA 2024).

If the use of chemical methods is necessary to meet a pest control objective, the potential for harm to workers and the public is carefully considered, as are effects on the environment. The least harmful and most effective, efficient, and target-specific method is chosen.

IPM was originally developed in the 1960s for agricultural pests and then urban landscapes. Somewhat different approaches are needed when implementing an IPM approach on natural lands. For purposes of managing pests on District land, IPM is:

- An adaptive process that takes into account new science, technology, and understanding of pests and their environment.
- A program to ensure judicious use of pesticides. It is not necessarily intended to eliminate pesticide use; however, well-developed, science-based IPM programs typically reduce pesticide use per acre over time because they employ a wider array of pest management techniques (i.e., physical, biological, and cultural pest control as well as chemical control) that are more effective at eliminating pest issues.
- A decision-making system that adapts to changing conditions. Control methods are determined based on the pest and site-specific conditions, and methods are not universally applied to all pest problems or work categories.

2.2 IPM Policy

The District's IPM Policy, originally adopted in 2009, guides staff in defining, preventing, and managing pests on District lands. The IPM goal, policies, and implementation measures were reviewed in 2013 and were approved as part of the 2014 Guidance Manual by the Board of Directors. In May of 2022, the District formally published its Resource Management Policies (RMPs), which include the proposed IPM policy statements presented in the 2014 IPMP Guidance Manual. The goal and policies were included in the 2014 IPMP Guidance Manual and remain applicable under the 10-year Program update (refer to Appendix D for the full list of RMPs).

2.3 IPMP Best Management Practices

The District originally developed IPMP Best Management Practices (BMPs) as part of the 2014 Program, which were updated in 2019. These IPMP BMPs consisted of management actions that the District incorporated into IPM proposals and projects for the purpose of protecting human health and preventing environmental effects. The 2014 IPMP BMPs were developed in conformance with District policies, based on the District's existing BMPs, and addressing relevant regulations. Some of the 2014 IPMP BMPs were adapted from publications of the California Invasive Plant Council and were originally developed by a technical advisory team made up of experts in California with experience in invasive plant control and land management. The list of IPMP BMPs included under the 10-year Program update are similar to those included in the 2014 IPMP and 2019 Addendum; however, changes to the existing BMPs and additional BMPs are included in the 10-year Program update. Additions and revisions to the BMPs were made for consistency and clarity, and to address changes to the regulatory environment. The District implements the IPMP BMPs as part of individual IPMP projects District-wide, as required and relevant, consistent with the current IPMP. The IPMP BMPs incorporated into the 2025 IPMP are included in Appendix C.

Midpen adheres to its Open Space Maintenance and Restoration Program (OSMRP), which was approved in 2021 and first implemented in 2022. The OSMRP streamlines the permitting process and allows for an integrated approach to (1) routine maintenance, (2) small-scale facility improvements, and (3) restoration and enhancement projects. The OSMRP's programmatic permits authorize IPM work in jurisdictional areas, as it is considered routine maintenance. The applicable OSMRP BMPs required as part of permitting processes are implemented when and where appropriate, in accordance with the programmatic permits.

Midpen also implements the WFRP, as previously discussed in Section 1.2. The District prioritizes removal of invasive species over removal of native species during vegetation management. Vegetation is managed primarily manually, mechanically, with prescribed herbivory (using goats, sheep, or other livestock to reduce fuels in a specific area), and to a limited extent, herbicides. Midpen employs a series of BMPs for each management activity. Herbicides allowed are only those identified in the IPMP, which are implemented in accordance with the IPMPs BMPs.

3 The IPM Program

This chapter describes the IPM Program, including roles and responsibilities, management systems, and organizational processes that will be used to implement IPM on District lands. To illustrate this, refer to Figure 3-1 for a diagram of the decision-making process to be used by staff when implementing IPM in various work situations.

3.1 Roles and Responsibilities

3.1.1 Roles

This section describes roles and responsibilities for implementing the IPM Program. The Board of Directors is responsible for approving the IPM Policy. The General Manager is responsible for ensuring the implementation of the IPM Policy through District managers and supervisors who train all staff on the IPM Guidance Manual and guide its implementation within the departments. The IPM Coordinator implements the District's IPMP.

3.1.2 IPM Coordination Team

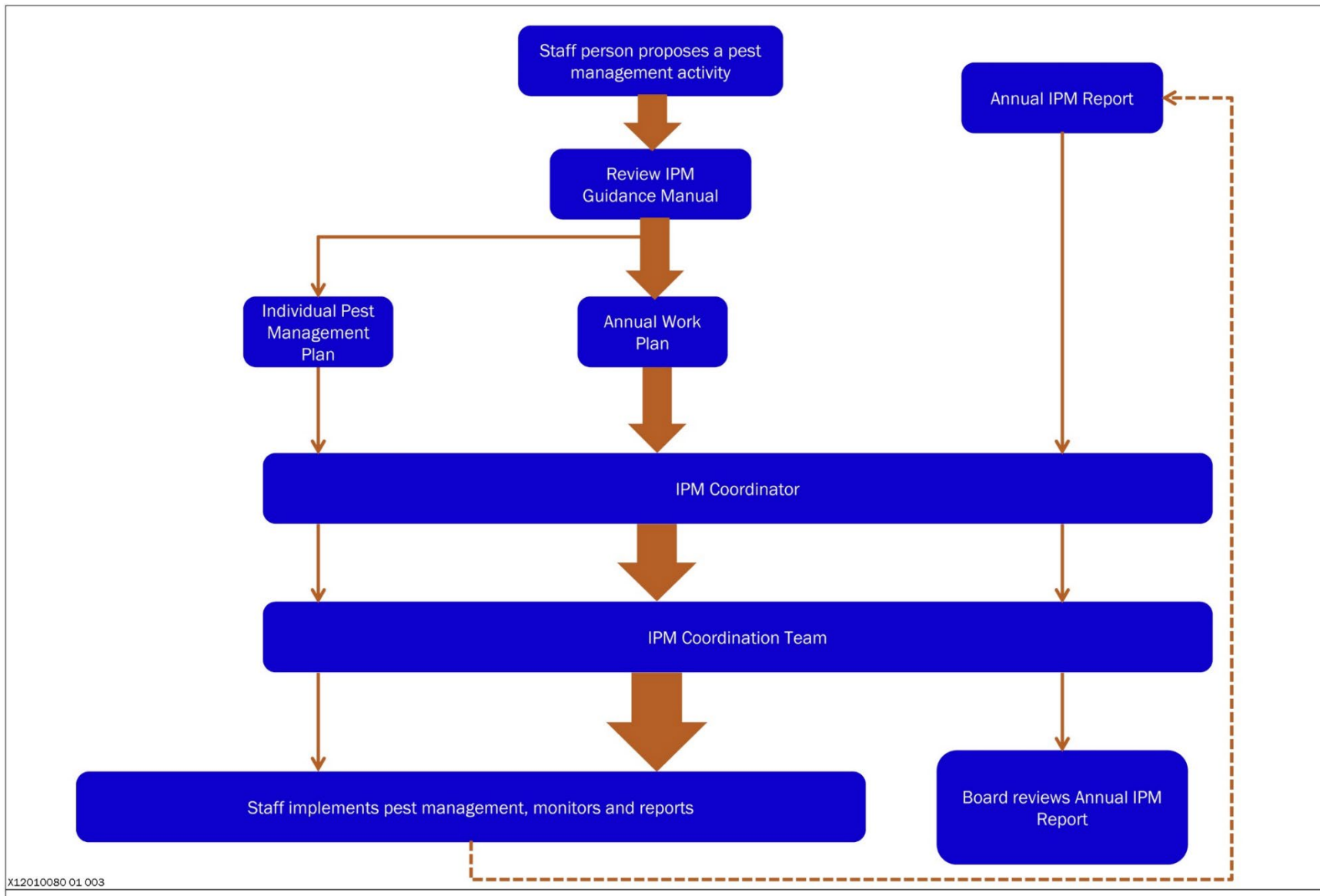
The District will continue maintaining an IPM Coordination Team. The team is comprised of District staff working with the advice of technical pest control experts. At a minimum, the team will include one staff representative from the following Departments: Lands Stewardship & Trails, Natural Resources, Fleet & Facilities, and Visitor Services. As necessary, the IPM Coordination Team will consult with the Rangeland Ecologist and the Conservation Grazing Manager regarding rangeland and agricultural practices and properties, and with the Planning Department regarding long-range plans and construction and maintenance of capital projects.

The IPM Coordination Team is responsible for the following:

- Review and approve an Annual IPM Work Plan that is consistent with this Guidance Manual, feasible and within the District's projected staff and budget capabilities, and balances the District's pest management and other responsibilities while providing consistency from year-to-year so that effective progress can be made on multi-year projects;
- Provide ongoing expertise and staff assistance to complete tasks outlined in Annual IPM Work Plan (refer to Section 3.8) to ensure that the District's approach to IPM principles and processes are continually improved;
- Review and approve Individual Pest Management Plans throughout the year that were not included in the Annual IPM Work Plan;
- Assess the IPM Program for safety and effectiveness on an annual basis or whenever urgent changes are indicated;

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Figure 3-1 Flow Chart of the District's IPM Decision-Making Process



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- Develop, periodically review, and recommend changes to the District's List of Approved Pesticides (Section 3.10 and Table 3-3) for initial approval by the General Manager; additions to the District's List of Approved Pesticides will be brought to the Planning and Natural Resources Committee before approval by the full Board of Directors;
- Investigate lower risk/least hazardous alternatives to current practices described in this Guidance Manual, and make recommendations for revising or updating District procedures as described herein;
- Review the Annual IPM Report to ensure that it accurately represents pest management work completed in the previous year and that any recommendations for change are consistent with the District's adopted IPM Policy; and
- Oversee and peer review the IPM Coordinator position.

3.2 IPM Coordinator

Each District Department will report pesticide use (quantities of each pesticide product per toxicity classification) to the IPM Coordinator. The IPM Coordinator will have day-to-day oversight of the integrated pest management practices at the District, including the following:

- Prepare the Annual Work Plan and Annual IPM Report for review by the IPM Coordination Team;
- Coordinate the meetings and tasks of the IPM Coordination Team;
- Coordinate staff, contractor, and volunteer IPM training;
- Coordinate/implement the annual safety training program for pesticide handlers;
- Educate and respond to the public;
- Prepare other required reports, such as pesticide use reports to the County Agricultural Commissioner; and
- Undertake tasks outlined in the Annual Work Plan, as required by the District, to assist the IPM Coordination Team and other staff, contractors, and/or consultants as appropriate.

The IPM Coordinator will report directly to the Senior Resource Management Specialist who leads the IPM Program for the District and who will have the overall responsibility for ensuring that the program guidelines are followed. The District will maintain an IPM Coordinator who will need to have experience with pests in natural settings such as invasive plants and animals, insects, and pathogens; and will need to have or gain experience with pest management in agricultural crops, rangelands, forests, park facilities (such as non-crop lawn and landscape areas), rights-of-way, and aquatic environments.

The IPM Coordinator will have either a Pest Control Advisor (PCA), Qualified Applicator's Certificate (QAC), or Qualified Applicator's License (QAL) certification, or will obtain one or more of these certifications within 1 year of hire date.

A PCA will prepare a pest control recommendation (PCR) annually (in accordance with the IPMP BMPs) on the recommended use of pest control products or techniques (refer to

Appendix E for a copy of the PCR form). All pesticides and adjuvants will be used consistently with written PCRs. The PCA will ensure that all pesticide applications are performed at the time of year and phenological window for maximum effectiveness, thereby increasing treatment efficacy and reducing the need for follow-up applications, unless constraints limit application at the optimal time (refer to the IPMP BMPs included in Appendix C). The IPM Coordinator must keep records of all pesticide recommendations for a minimum of 2 years. Recommendations may be site-specific or programmatic (cover multiple sites within the same property or preserve). Each written recommendation must include the following information (pesticide application for buildings are addressed separately in Section 3.3):

- Category, active ingredient, pesticide formulation (i.e. brand name or common name) and dosage of each pesticide to be used;
- Identity of each pest to be controlled by a name of common usage;
- Property owner and location on the property that will be treated;
- Description of commodity, crop, or site to be treated. This includes specific crops (e.g., wine grapes) or descriptions of non-crop sites such as wildlands, roadsides, forests, etc.;
- Suggested schedule, time, or conditions for the pesticide application or other control method;
- Any warnings of the possibility of damages by the pesticide application that reasonably should have been known by the PCA to exist;
- Signature and address of the person making the recommendation, the date, and the name of the business such person represents;
- Total acreage or units to be treated;
- Concentration and volume per acre or other units;
- Worker reentry interval, if one has been established; pre-harvest or pre-slaughter interval, if relevant; and label restrictions on use or disposition of the treated commodity, by-products or treated area;
- Criteria used for determining the need for the recommended treatment (tolerance level or tolerance threshold); and
- Certification that alternatives and BMPs that would substantially lessen any significant adverse impact on the environment have been considered and, if feasible, incorporated during planning and implementation of IPM activities.

3.3 Structural Pest Control Operator

The District will designate an employee with an active California Structural Pest Control Operator (Operator) license, or will retain the services of a licensed Branch I (fumigation), II (General Pest), or III (Wood Destroying Pest and Organisms) Structural Pest Control Operator as needed. The Operator will be responsible for reviewing the Annual Work Plan, Individual Pest Management Plans, and developing guidelines for the control of pests in all buildings within the District. Operator guidelines will be forwarded to the IPM Coordinator for a consistency review with the IPM Program before implementation.

In the event the District engages the services of a structural pest management company to operate in this capacity, the company will be required to comply with all applicable provisions of the state of California's Department of Consumer Affairs Structural Pest Control Act and last amended as of July of 2025 or as updated (available online at <https://www.pestboard.ca.gov/pestlaw/act.shtml>). The District will require proof of company registration and proof of the companies' qualifying Operators' license information before engaging in a contract. The company should be licensed in the applicable Branch of the work being performed (as specified above). The District will monitor the work being done by the company to ensure quality workmanship and compliance with the District's IPMP.

3.4 Qualified Applicator

Pesticides will be applied in all areas except buildings by or under the supervision of a California licensed Qualified Applicator (QAC/QAL) who will be licensed in categories relevant to the type of pest control work. The QAC/QAL will be responsible for pesticide use records, work hours, and compliance with the Annual IPM Work Plan, Individual Pest Management Plans, and pesticide labels. Qualified applicators may include District field staff, contractors, and farmer/rancher tenants. Non-QAC or QAL certified District staff can apply pesticides, but only under direct supervision of the QAC or QAL and after completing the District's annual safety training program for pesticide handlers (Section 3.9).

All contract pest control applicators, the IPM Coordinator, and designated field supervisors must have a valid California QAC or QAL license in one or more of the following categories:

- Residential, industrial, institutional (A);
- Landscape maintenance (B);
- Right-of-way (C);
- Plant agriculture (D)¹;
- Aquatic (F); and/or
- Forestry (E)

Field supervisors who hold a QAC/QAL license or another certified trainer must train all staff who apply and handle pesticides on an annual basis as described in the Training section below (see Section 3.9).

3.5 Structural Pest Control Applicator

Household and structural pesticides will be applied under the supervision of a California licensed Branch I, II, or III Structural Pest Control Applicator (SPCA). SPCA's will be responsible for pesticide use records, work hours, and compliance with written recommendations in the approved Annual Work Plan, Individual Pest Management Plans, and

¹ A pest control applicator with a valid California QAC or QAL in the plant agriculture (D) category is authorized to work in all wildland settings.

compliance with pesticide labeling instructions. SPCA's may include a combination of District field staff and contractors. No unlicensed staff, contractors, volunteers, or tenants will perform structural or household pest control except for the limited use of District approved ant/roach bait stations.

Structural pesticide applications made on District property by an outside vendor will be by a registered structural pest control company in accordance with the state of California's Structural Pest Control Act, last amended July of 2025 or as updated over the life of this program. Structural pesticide applications made by District staff will be carried out by trained applicators under the supervision of the IPM Coordinator or designated field supervisors. All applications on District property will be made in compliance with the Annual Work Plan, Individual Pest Management Plans, and pesticide labeling instructions. No untrained staff, volunteers, or tenants will make structural pesticide applications.

3.6 Decision-Making and Record-Keeping

This section describes the procedures that the District will follow to make decisions and track pest management throughout its lands and departments. The primary process by which pest management decisions will be made and evaluated is through an Annual IPM Work Plan. Pesticide use record-keeping completed by each department will be kept by the IPM Coordinator, who will be responsible for consolidating this information into the Annual IPM Report, as described below.

3.6.1 Development of the Annual IPM Work Plan

The IPM Coordinator and the IPM Coordination Team will prepare an Annual IPM Work Plan each year that describes planned pest control projects in the upcoming year. Working through department supervisors, staff will provide the IPM Coordinator with a standardized spreadsheet or similar summary form describing upcoming pest control for the following basic types of activities:

- Routine minor pest control actions;
- Ongoing pest control projects; and
- New pest control projects.

Using this staff information, the Annual IPM Work Plan will be prepared by the IPM Coordinator, then reviewed and approved by the IPM Coordination Team. Information in the Annual IPM Work Plan will also be used to inform the Annual IPM Report (described below in Section 3.8.1).

The Annual IPM Work Plan will include the following basic information:

- Summary (e.g., Excel spreadsheet) of routine minor and ongoing pest control projects;
- Detailed descriptions of new pest control projects;
- Projected amounts of pest control in the next year (acres, hours, acres treated per gallon, total gallons used); and

- Any new approaches to be implemented as a result of the adaptive management review in the Annual IPM Report of the preceding year.

These types of pest control activities are described in more detail below. Refer to Appendix E for sample forms.

3.6.2 Early Detection and Rapid Response

An Early Detection and Rapid Response (EDRR) Program is a formalized monitoring program that utilizes active and passive land surveillance as a method to discover and identify new invasive species or their symptoms before they become widely established. This can be accomplished with 1) active detection, 2) passive detection, and 3) syndromic surveillance as defined by the National Invasive Species Working Group (National Invasive Species Council 2003; U.S. Department of the Interior (DOI) 2025)

- **Active Detection:** Active detection programs have structure, staffing, and dedicated funding to accomplish land surveillance (landscape-level invasive plant monitoring). Dedicated staff, volunteers, or contractors under a specific set of goals may run these programs. Active detection programs for invasive species often have limited dedicated resources to conduct the work, so it is important to be focused on high-priority targets, such as high-risk locations, high-value resources, important pathways, and populations and species of concern.
- **Passive Detection:** Passive detection programs have more limited goals and structures that are embedded into existing programs and activities. These programs fortuitously detect invasive species as staff, volunteers, or contractors conduct other activities.
- **Syndromic Surveillance:** Syndromic surveillance uses the analysis of other resource management problems to detect invasive species indirectly through their direct damage or other ecosystem disruption. Detecting the damage associated with invasive species may be the first indication of a new invasion. This is often the case with invasive pathogens and parasites that are difficult to otherwise detect.

Midpen will continue to implement its EDRR Program as part of the 2025 IPMP (refer to Appendix F for the entire EDRR Program). The goal of EDRR is to detect new populations of invasive plants while populations are still small, and eradication is achievable. The key components of the EDRR Program are prioritizing areas to be surveyed, performing surveys to identify new populations and inventory existing populations, and rapid response treatments for any significant discoveries.

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The objectives for the District's EDRR Program are to:

1. Identify potential threats in time to control or mitigate;
2. Detect new invasive species in time to allow efficient and safe eradication or control decisions to be made;
3. Respond to invasions effectively to prevent the spread and permanent establishment of invasive species;
4. Educate staff, partners, and the public about emerging threats from invasive species, and encourage public participation in the program; and
5. Adaptively implement early detection and early response strategies over time.

As part of EDRR, Midpen maintains an EDRR Species List, which is designed to be adaptable. The list is revisited and revised regularly by Midpen staff. Maintenance of this list allows the District to easily communicate target species to a wide audience for passive early detection.

Detection Strategies

New invasive species may arrive in the District through sudden, unpredictable pathways (e.g., boots on a traveler) and more constant, predictable pathways (e.g., roads, trails, and/or horticultural escapees from neighboring properties). District lands are scattered throughout the San Francisco Peninsula, with boundaries adjacent to rural private residences and community land uses, county public roadways and two-lane highways, and productive agricultural landscapes including rangelands with pasture grazing cattle, livestock pens, commercial nurseries, orchards, vineyards, and row and cereal crops. Each of these land uses account for possible introductions of invasive species along preserve borders, interior ranch roads, narrow trails, and easements.

The most efficient way to prevent routine introductions of invasive species into District lands is to use vigilant patrol and monitoring protocols along District boundaries. Trails, ranch roads, and waterways intersecting District lands are the most likely routes of invasion for new species. Many of these common pathways have been confirmed through District mapping and planning work (Midpen 2014)

Modeling Invasive Pathways

The District maintains approximately 518 miles of ranch roads and trails and has a geographic border (not including adjacent District parcels) totaling approximately 436 miles, as of 2025. Not all of these trails, roads, and edges have the same potential to introduce new invasive species into District properties. Locations within the District that receive the most intense impacts from disturbance, visitation, utility maintenance, and neighboring land uses are the most likely sources for new species introductions. Simple models can be used on a local preserve level to analyze probable pathways for key invasive species the District may expect to encounter. The District can identify routine and sporadic activities that have a high probability of introducing invasive species, as well as the types of species anticipated.

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Table 3-1 defines a ranking system for the District to identify activities on preserves that are most likely to promote invasive species introductions. Table 3-2 provides a ranking system for monitoring based on suitability for invasion and volume of new plant material (seeds, etc.) likely to be introduced. By understanding both the activities that promote invasions and the candidate species for likely invasion, the District can more successfully plan for prevention, detection, and control activities.

Table 3-1 Ranking of Most Likely Pathways of Invasive Species Introductions (Identification of Areas and Activities to Prioritize for Early Detection Monitoring)

Ranking of Vectors' Probability to Import/Distribute Invasive Plants	
1	Heavy equipment from outside District
2	Topsoil importation for construction
3	Sand or gravel for road construction
4	Work activities along rights-of-way external to District (e.g., PG&E, CalWater)
5	Work activities of District employees or contractors
6	Grazing lessees/livestock grazing
7	Visitor vehicle traffic
8	Wind
9	Visitors hiking
10	Wildlife
11	Water

Table 3-2 Prioritization of Specific Areas for Monitoring Based on Suitability for Invasion and Volume of New Plant Material (Seeds, etc.) likely to be Introduced

Areas for Monitoring	
Very high priority	
1	Construction/maintenance areas
2	District offices, structures
3	Buildings, houses at the urban/rural development interface
4	Paved areas (e.g., roads/parking lots/trailheads)
5	Landscaped areas
6	Disturbance from human intervention (e.g., emergency fuel breaks during fires)
7	Trails
8	Areas of high visitor use
9	Utilities (e.g., cell towers, powerline corridors)
10	Pastures/agricultural areas

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Areas for Monitoring	
Medium priority	
11	Riparian areas
12	Natural disturbances with no human intervention (e.g., fire, rockfall)
Low priority	
13	Off-trail wilderness areas

Source: adapted from (Gerlach et al. 2003)

Staff Training

Early detection monitoring can be accomplished by staff, volunteers, preserve visitors, or contractors. The utilization of existing natural resource management and maintenance staff and volunteers provides the best value for the District. With limited training, existing staff resources can be utilized and repurposed for early detection monitoring at minimal additional cost although it will not be a comprehensive effort. Refer to Section 3.6.2 for a more detailed description of planned IPM trainings.

Detecting a new arrival can sometimes be a challenge since very few people have adequate training to identify foreign and unfamiliar species. However, there is potential to train staff and volunteers familiar with District habitats to notice and report when species are found that appear unusual or out-of-place. In addition to new invasive species, other resource management targets such as rare plants and animals may also be discovered through this type of observation.

Rapid Response Strategies

Small infestations of invasive species generally offer the greatest number of treatment method options for successful eradication. Many times, hand removal of individuals is the control method with the greatest selectivity and cost effectiveness, with the least amount of indirect impacts. Individual specimens or small patches identified incidentally or during regular monitoring can often be immediately removed. For vegetation removal, hand digging, cutting, or pulling are all examples of selective hand removal. For vertebrate species, hand removal usually means trapping or shooting. Small-scale removal is most effective on newly-established and small populations with limited distributions.

Pesticides may also be an efficient treatment method for rapid response actions. In some cases, a specific pesticide may be identified to abate an immediate invasive species hazard when it is found. Pesticides may be especially effective for species where hand removal actions are impractical (e.g., steep cliffs) or where hand or mechanical removal methods would risk spread of the species (e.g., plants that can spread from broken root fragments). Herbicides must be on the List of Approved Pesticides (Table 3-3) for expeditious use under rapid response.

In all cases, the District will map the occurrence before control and then revisit the control site several times to ensure full control was achieved. Eradication may require multiple visits in a year, or possibly multiple years of monitoring and treatment.

Individual Pest Management Plans

If a project is proposed during the year that was not included in the Annual Work Plan, then a description of the project will be prepared for review and approval by the IPM Coordinator and the IPM Coordination Team. Examples of when Individual Pest Management Plans might be required are when new properties are acquired or new pests of high priority are discovered in the course of a year, such as when implementing the EDRR Program (refer to Section 3.6.2).

3.6.3 Routine Minor Pest Control

Routine minor pest control activities include maintenance activities that generally use the same pest control methods at the same site from year to year. These are primarily non-chemical methods, such as brush cutting of trails and mowing for fuel management, but also include minor use of pesticides in cut-stump or spot-spraying application at recreational facilities and fuel management areas, the use of approved insecticide baits in buildings, or wasp spray for stinging insects in trails or bathrooms. Staff will provide a brief projection of routine minor pest control activities in a spreadsheet (or similar format) that is included in the Annual Work Plan. This spreadsheet is maintained by the Fleet & Facilities Department.

3.6.4 Ongoing Pest Control Projects

Ongoing pest control projects are existing projects that are expected to have an end date (even if it takes 10 years) such as treatment of brush on rangelands or French broom on natural lands. Because these are ongoing projects, they will have already been surveyed for site conditions and a multiple-year strategy will have been developed. Tracking and monitoring these ongoing projects will be important to determine if treatment is effective and at what stage treatment methods should be adjusted (such as switching from herbicide to pulling when the density of invasive weeds has substantially decreased). Ongoing pest control projects will be summarized in the Annual Work Plan and tracked for staffing, costs, and adaptive management (effectiveness of selected pest control) purposes.

Staff will provide a projection of ongoing pest control projects in a spreadsheet (or similar format) for inclusion in the Annual Work Plan and will specifically note any changes that are to be made to specific ongoing projects in the upcoming year (e.g., change in treatment method, change in level of effort, requirements for periodic pre-treatment surveys).

3.6.5 New Pest Control Projects

New pest control projects will receive a more detailed review and assessment by the IPM Coordinator and IPM Coordination Team. Staff will prepare a description of newly proposed projects for inclusion in the Annual Work Plan and will specifically note how the recommended treatment is consistent with the IPM Guidance Manual, IPMP BMPs, and mitigation measures. These descriptions will be included in the aforementioned spreadsheet.

Staff proposing new pest control actions will provide the following information as part of the description:

- Name and purpose of the proposed pest control activity;

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- Location (i.e., preserve name, building or trail name, or location including map where appropriate);
- Pest identification and the population size, location, life cycle, and density;
- A brief assessment of damage caused by the pest, including the perceived threshold for action (e.g., severity of the infestation/amount and type of damage);
- Site conditions, per the required pre-treatment surveys (refer to Section 2.3 which discusses IPMP BMPs), including the presence of aquatic areas, rare species, steep slopes, access and other environmental conditions that are relevant to the effectiveness of pest control and avoidance of environmental impact;
- A description of prevention, options that were considered/previously implemented before the active pest control project was proposed;
- Proposed pest treatment options (e.g., grazing, brushing, mowing, herbicide application) and amount of each type of treatment (e.g., acres to be treated), project duration, project timing, performance standards, and remedial actions;
- Proposed labor force (staff, contractor, volunteers, or special groups), projected labor hours or special materials or equipment required, and direct costs for the next year. If new pest control projects are determined outside of the Annual IPM Work Plan, then an Individual Pest Management Plan will likewise be prepared and reviewed and approved by the IPM Coordinator.

3.7 Prioritization

As part of the 10-year Program update, the District has revised the pesticide prioritization system for IPM on rangeland, agricultural lands, and natural lands in relation to weed control. The prioritization framework includes a structured yet adaptable approach to managing pest species and focuses efforts based on ecological benefit. Midpen's approach will use spatial data (i.e. geographic information system (GIS)) to integrate ecological value, species risk, and management feasibility into management activities. Midpen regularly reviews any new data, emerging threats, and on-the-ground lessons for incorporation into the prioritization approach. This approach ensures the District can respond to changing conditions while maintaining focus on the most pressing threats and capturing field efficiencies. Midpen considers the following objectives when prioritizing and scheduling pest species management activities:

- Protect what matters most – priorities are driven by the value of the site's ecological resources.
- Address the greatest threats – species are ranked by ecological impact, spread potential, and risk of irreversible change.
- Adapt to local conditions – adjust ratings to reflect site-specific evidence of pest and elevate EDRR targets as needed (refer to Section 3.6.2)
- Work efficiently – include opportunities to address multiple species during a single site visit when feasible.

The following factors are considered during prioritization: accessibility, ability to contain, treatment timing, non-target impact risk, and relative cost of treatment. When crews are

mobilized to treat primary target pest species, they may also address secondary pest species present in the same area if the treatment window overlaps, control methods are compatible, the primary work will not be compromised, and risks to sensitive resources remain acceptable. This approach increases efficiency and ecological benefit by reducing the need for repeated mobilizations. Secondary treatments are chosen based on qualitative assessments of pest species, spread potential, and proximity to high-value resources.

3.8 Reporting

3.8.1 Annual IPM Report

The District will prepare an Annual IPM Report each year that describes past pest control activities (both chemical and non-chemical) on District Lands. The draft Annual IPM Report will be prepared by the IPM Coordinator and reviewed by the IPM Coordination Team. Once approved by the IPM Coordination Team, the final report will be presented to the General Manager for initial approval. The report will then be forwarded to the Board of Directors for review, and where necessary, approval (e.g., changes to the List of Approved Pesticides).

At a minimum, the Annual IPM Report will include the following basic information:

- A change log documenting proposed annual updates or adjustments to the Program.
- A summary of pest problems that the District has encountered during the year, and a comparison to past years.
- A summary of District pest control treatments, presented by type of control (e.g., mowing, herbicide use).
- Wherever possible, a comparison of units treated (e.g., acres, square feet, linear feet or miles) in the current year versus previous years with a cost per acre for major pest control treatment types.
- A qualitative assessment of effectiveness of the District's pest control program, and suggestions for increasing future effectiveness (see Chapter 4 for additional details).
- A summary of pesticide use, presented by category (e.g., herbicide, insecticide), active ingredient or formulation (e.g., imazapyr), or product name (e.g., Stalker™, Polaris™).
- A summary of public notifications and public inquiries about IPM on District lands.
- Assessment of compliance with the Guidance Manual including:
 - An evaluation of the effectiveness of any changes in practices that were implemented in the past 12 months.
 - A description of any experimental pest control projects (test studies) and the results, including a cost/benefits analysis.
 - Suggested changes to the IPM Program or the Guidance Manual's pest control practices proposed for adoption included as part of the aforementioned change log within the next 12 months including:

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- Any proposed substitute pesticides to replace phased out pesticides (additions to the List of Approved Pesticides).
- Any proposed alternative pesticides (additions to the List of Approved Pesticides) or pest control methods proposed for adoption.

3.8.2 District Pesticide Reporting

As required by regulations of the California Department of Pesticide Regulation (California Code of Regulations, Title 3, Division 6), the IPM Coordinator will report all pesticide use on a monthly basis to the County Agriculture Departments (San Mateo, Santa Clara and Santa Cruz Counties); will prepare, or obtain PCRs from a licensed PCA on an annual basis; will annually renew the District's Operator Identification with the County Agriculture Departments; and will most likely require designated field supervisors to obtain either a QAL or a QAC. The IPM Coordinator will also collect monthly pesticide reporting from its contractors who apply pesticides on District lands (See Section 3.8).

3.8.3 Contractor Reporting

The District will ensure that all pest control contractors working on District-managed lands comply with the Guidance Manual, including restricting use of pesticides to products on the District's List of Approved Pesticides (Table 3-3). As required by regulations of the California Department of Pesticide Regulation (California Code of Regulations, Title 3, Division 6), contractors will report all pesticide use on a monthly basis to the County Agriculture Departments (San Mateo, Santa Clara and Santa Cruz Counties); will obtain PCRs from a licensed Pest Control Advisor (either from the District's IPM Coordinator or from an independent PCA); will renew its Operator Identification with the County Agriculture Departments; and require Contractor's field supervisors to obtain either a QAL or a QAC. The Contractor will provide copies of its reports to the IPM Coordinator.

Contractors who trap certain pest animal species must also obtain and comply with predation permit requirements from California Department of Fish and Wildlife (CDFW) to record the species, pounds captured, and final destination of the animals (to prove that the species were not transported live or re-released elsewhere in California).

3.9 Training and Safety

3.9.1 Training

The IPM Coordinator is responsible for coordinating staff training across departments, and for overseeing safety procedures. In general, two types of trainings will be provided:

- Pest identification training (for staff involved in pest control), and
- Annual pesticide safety training (for staff that use/apply pesticides).

Pest Identification Training

The pest identification training will be prepared by District staff, with assistance from the IPM Coordinator, then provided to staff, particularly those who work in natural areas, rangelands, and agricultural properties. This training will most likely be provided on an as needed basis (as determined by the IPM Coordinator and department supervisors).

Pest identification training will include procedures for identifying and reporting pest sightings. Color photographs of several life stages (e.g., seedling, flowering, fruiting stages or larval and adult stages), a brief description and life history of each pest, associated habitat types, map of where the pest is known to be found on District preserves and summaries of the relevant IPMP BMPs for working in and around infested areas will be covered in this training. It may take several years to comprehensively develop information and train staff on all pests in District preserves. The District's Invasive Plant Control Notebook, managed and routinely updated by University of California State Integrated Pest Management Program (UC IPM), already contains information on invasive plants of the region and is used as a key training and identification tool by the staff.

Annual Pesticide Safety Training

The annual pesticide safety training is intended to help supervisors, managers, and other staff involved in pest control applications become familiar with non-chemical pest control actions; limit exposure and risk associated with the use of pesticides; and understand the IPMP BMPs for environmental protection. The District's annual safety training program for pesticide handlers will also describe regulatory requirements of the California Department of Pesticide Regulation's pesticide application requirements and CDFW's special-status wildlife handling procedures.

The annual pesticide safety training will be performed by the IPM Coordinator (if they are a licensed PCA QAL and/or QAC), or a PCA-, QAL/QAC-licensed contractor who is familiar with District resources, pest management issues, and staff work procedures.

The annual pesticide safety training must include the following at a minimum:

- Pesticide product labeling format and meaning of information, such as precautionary statements about human health hazards.
- Hazards of pesticides (acute, chronic, delayed, and sensitization effects) identified in pesticide product labeling, Material Safety Data Sheets (MSDS), or Pesticide Safety Information Series (PSIS) leaflets.
- Pesticide safety requirements and procedures in regulation, PSIS leaflets, MSDS.
- Engineering controls (closed systems, enclosed cabs) for handling, transporting, storing, and disposing of pesticides.
- Environmental concerns (drift, runoff, and endangered species BMPs to reduce risks to sensitive natural resources).
- Routes by which pesticides can enter the body.
- Common signs/symptoms and emergency first aid for pesticide exposure.
- How to obtain emergency medical care.

- Routine and emergency decontamination procedures, including spill cleanup and the need to thoroughly shower with soap and warm water after the exposure period.
- Use and care of any required personal protective equipment.
- Prevention, recognition, and first aid for heat-related illness.
- Notification requirements.

Records of annual training will be retained by the IPM Coordinator or the District's Training and Safety Specialist and will be kept for 2 years in a location accessible to employees. Training records must indicate the topics covered during training, the materials used for training, the name and qualifications of the trainer, and the signature and date of all employees who received the training.

3.9.2 Safety Procedures for Herbicide Application

Section 17.005 of the District's Operations Maintenance Manual provides guidelines to the staff for safely handling and applying pesticides. Upon adoption of the IPM Guidance Manual, those procedures will be updated to be consistent with the IPM Guidance Manual and will be subsequently included herein.

3.10 List of Approved Pesticides

3.10.1 Pesticide List

A List of Approved Pesticides was developed specifically for use on District lands. Refer to Table 3-3 for a focused list of the approved pesticides under the 10-year Program update. Table 3-3 presents pesticides by *IPM Management Category* (e.g., IPM in Buildings, IPM in Natural Lands, etc.), *category* (e.g., herbicide, insecticide), and *active ingredient* (e.g., imazapyr, triclopyr, clopyralid). Refer to Appendix A for the full List of Approved Pesticides, which includes formulation information and product name, purpose of respective pesticide, annual application, and timing of application. Refer to Appendix B for a detailed toxicological analysis and results of newly added pesticides under the 10-year Program update.

This List of Approved Pesticides is intended only for use on the pests, environment, and microclimates of properties and buildings managed by the District. Each product on this list has been (and new proposed products will be):

- Screened for human toxicology, ecological toxicity environmental fate and transport, and proven efficacy against target pests;
- Reviewed for human safety and efficacy;
- Reviewed annually by the District's IPM Coordinator and IPM Coordination Team;
- Reviewed and approved by the Board of Directors;
- Presented for public comments at public hearings; and

- Included in the environmental documentation and public notification procedures that are being prepared for the IPMP (i.e. the list is adopted as part of environmental review and approval process).

This list encompasses mostly products already in use by the District, as well as a few new pest control products as part of the 2025 IPMP Update. As the District continues to expand its coverage area, the overall scale of pesticide use under the IPMP must also increase to meet the growing treatment and coverage needs. Additional details about the District's screening process are provided below.

3.10.2 Pesticide Screening Process

The District, using toxicologists, its IPM Coordinator, and IPM Coordination Team and other licensed experts, has or will screen pesticides prior to approval by following these three steps:

1. Conduct a toxicological analysis of each pesticide under consideration (Appendix B).
2. Assess the risk to human health and safety of workers and visitors on District lands, as well as the risk to the environment from proposed pesticide use.
3. Review the List of Approved Pesticides and associated background materials, then reject, modify, or adopt the list for use by District staff, contractors, and tenants.

3.10.3 Updating the List of Approved Pesticides

The List of Approved Pesticides is intended to change over time as the science of pest control advances and more effective, safer, and less harmful pesticides are developed; as manufacturers update, discontinue, or substitute products; and as the District's target pests change over time. The process for updating the List of Approved Pesticides is as follows:

- **Product Substitutions:**
 - When a new manufacturer creates the same formulation or manufacturers substitute a product or change a product name or formulation, but when the *active ingredient stays the same*, the new product can be substituted for the old product on the List of Approved Pesticides. In general, this type of change to the list would not trigger a change in condition or result in the need for additional environmental documentation. Therefore, this change typically will require a simple update to the List of Approved Pesticides (Table 3-3). Additional environmental review would only be required if the change results in a potentially substantive change in human health exposure, environmental fate, or toxicity.
 - For simple substitutions of products from the List of Approved Pesticides, the IPM Coordinator will, as necessary, seek the advice of technical experts and independent Pest Control Advisors; keep the IPM Coordination Team informed; and include such changes in the Annual IPM Work Plan, which is approved by the Board of Directors.
- **Product Eliminations:**

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- In instances where products on the list are no longer available from the manufacturer, are found to be ineffective against the District's target pests, or if new risks are discovered that were not previously evaluated by the District (see Table 3-3), a product may be eliminated from the List of Approved Pesticides. This type of change requires an update to the List of Approved Pesticides (Appendix A) but does not require additional environmental review.
- For simple eliminations of products from the List of Approved Pesticides, the same process as the substitutions process will be followed and changes will be included in the Annual IPM Work Plan, which is approved by the Board of Directors.
- **Product Additions:**
 - In instances where new products with new active ingredients are found to be safer, more effective, and/or less costly than products on the List of Approved Pesticides, the District may elect to add new pesticides. This type of change typically requires additional toxicological review, and depending on the results, may also require additional environmental review.
 - In instances where new pesticide formulations (products) are being recommended for addition to the List of Approved Pesticides, the IPM Coordinator will, with assistance from technical experts such as independent PCAs, conduct the same analysis on the proposed new pesticide formulation as was conducted on the approved pesticide formulation (Appendix A). All new pesticide formulations (products) under consideration will be evaluated using the same standards for human and environmental safety, and efficacy on the District's target pest species (refer to Appendix A)

Based on the results of the processes outlined above, the IPM Coordinator will then present the findings to the IPM Coordination Team, along with a recommendation to add or eliminate the new pesticide formulation from consideration. The IPM Coordinator can also recommend a test study to provide additional information. Based on the information provided by the IPM Coordinator, the IPM Coordination Team will advance the new pesticide formulation (product) plus any required environmental review for consideration by the Board of Directors for approval. The Board may request additional information or eliminate the new pesticide formulation from consideration. If the IPM Coordination Team recommends advancement, the IPM Coordinator will provide pertinent information about the new pesticide formulation, including a description of why the new pesticide formulation is being considered, risk, efficacy, cost, application standards and limitations for use, results of test studies (where available), and environmental review to the Board of Directors for consideration. Approval of all new pesticide formulations is the responsibility of the Board of Directors. If approved, the new pesticide formulations will be added to the List of Approved Pesticides included in Appendix A, which will be formally revised as part of the Annual IPM Report (refer to Section 3.8.1).

In the event of an emergency situation, such as a human health disease outbreak, pesticides that are not included on the List of Approved Pesticides may be used for short periods of time. In

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these unusual situations the District will comply with required regulatory procedures, then will evaluate the emergency response pesticide use and determine if its IPM Program needs to be modified to accommodate similar future emergencies.

Table 3-3 List of Approved Pesticides Split by Management Category

IPM Management Category	Active Ingredient/Formulation	Method of Application
Buildings	Insecticidal soap	Spray
	Diatomaceous earth	Crack & crevice
	Boric acid	Crack & crevice
	S-Hydroprene	Impregnated disc
	Indoxacarb (0.1%)	Crack & crevice
	Indoxacarb (0.5%)	Crack & crevice
	Sodium tetraborate decahydrate	Bait station
	Fipronil	Bait station
	Fipronil	Spot treatment
	Cholecalciferol	Bait station
	Prallethrin	Spray
	Chlorantraniliprole ^a	Perimeter
	Dinotefuran ^a	Perimeter
	Sulfuryl fluoride/ chloropicrin ^a	Tenting
	d-limonene ^a	Spot treatment
Recreational	Disodium octaborate tetrahydrate ^a	Spot treatment, prevention
	Prallethrin	Spray
	Glyphosate IPA	Cut-stump, spot spray, wick, frill/injection
	Glyphosate K	Cut-stump, spot spray, wick, frill/injection
	Clopyralid MEA	Spot spray, cut-stump, frill/injection
	Imazapyr IPA	Cut-stump, spot spray, frill/injection
Rangelands and Agricultural Properties	Triclopyr ^a	Spot spray, basal bark
	Aminopyralid TIPA	Spot spray, cut-stump, basal bark, wick, frill/injection
	Clopyralid MEA	Spot spray, cut-stump, frill/injection
	Glyphosate IPA	Spot spray, cut-stump, wick, frill/injection
	Glyphosate K	Spot spray, cut-stump, wick, frill/injection

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IPM Management Category	Active Ingredient/Formulation	Method of Application
	Triclopyr BEE	Spot spray, cut-stump, basal bark
	Triclopyr TEA/ Aminopyralid TIPA	Spot spray, cut-stump, frill/injection
	Clethodim ^a	Spot spray
	Triclopyr ^a	Spot spray, basal bark
	Imazamox ^a	Spot spray ^b
	Glufosinate ^a	Spot spray
Natural Lands	Glyphosate IPA	Spot spray, cut-stump, wick, frill/injection
	Glyphosate K	Spot spray, cut-stump, wick, frill/injection
	Clethodim	Spot spray
	Aminopyralid TIPA	Spot spray, cut-stump, basal bark, wick, frill/injection
	Clopyralid MEA	Spot spray, cut-stump, frill/injection
	Imazapyr IPA	Spot spray, cut-stump, frill/injection
	Phosphite K Salts, mono-/di-	Spray, inject
	Triclopyr BEE	Spot spray, cut-stump, basal bark
	Triclopyr TEA/ Aminopyralid TIPA	Spot spray, cut-stump, frill/injection
	Triclopyr ^a	Spot spray, basal bark
	Imazamox ^a	Spot spray ^b
	Glufosinate ^a	Spot spray
General Chemical Disinfectants	Sodium dichloroisocyan-urate dihydrate ^a	Spot spray/water additive
	Sodium hypochlorite ^a	Spot spray
	Ethanol or isopropyl alcohol ^a	Spot spray
	Dodecyl dimethyl ammonium chloride ^a	Spot spray
	Hydrogen peroxide ^a	Spot spray
Chemical Repellant	N,N-diethyl-meta-toluamide (DEET) ^a	Spot spray
	Picaridin ^a	Spot spray

Notes:

^a indicates a pesticide that is newly incorporated as part of the 10-year Program update.

^b Imazamox is used as a spot spray in aquatic or riparian environments.

Sources: (Yun Cang, n.d.; Midpen 2018)

3.11 Notification

The District has developed notification procedures for use of pesticides (Section 17.006 of the District's Maintenance Operations Manual will be updated accordingly). District procedures are summarized below.

Prior, during, and after the application of a pesticide (including herbicides, insecticides, or other types of pesticides) on District preserves, employees or contractors will post signs at the ends of each treatment area notifying the public, employees and contractors of the District's pesticide use. Posting periods designated below are the minimum requirements; signs may be posted earlier and left in place for longer periods of time if it serves a public purpose or if it provides staff flexibility in accessing remote locations.

- For pesticide application in outdoor areas of all District-owned preserves and in buildings that are not occupied or are rarely visited (e.g., pump houses), signs will be posted at the treatment areas 24 hours before the start of treatment until 72 hours after the end of treatment. Signs stating "Pesticide Use Notification" will be placed at each end of the outdoor treatment area and any intersecting trails.
- For urgent application of pesticides to control stinging insects, signs will be posted at the treatment area for the 72-hour period after the end of treatment, but no pre-treatment posting is required.
- For pesticide applications in occupied buildings such as visitor centers, offices, and residences, notification will be provided to building occupants (employees, visitors, residents) 24 hours before the start of treatment by email, letters or telephone calls. Additionally, for buildings which might be visited by more than just a single family, signs stating "Pesticide Use Notification" will be placed at the entrances to the building 24 hours before the start of treatment and remain in place until 72 hours after the end of treatment. The use of approved insecticidal baits in tamper-proof containers will require notification 24 hours before the start of treatment by email, letters or telephone calls, but will not require posting of signs.
- The information contained in the pesticide application signs will include product name, EPA registration number, target pest, preserve name and/or building, date and time of application, and contact person with telephone number. The contact person will usually be the IPM Coordinator.
- On lands that the District manages but does not own (e.g., Rancho San Antonio County Park), the District will provide notification of pesticide use in the same manner and applying the same actions as it does with its properties, unless the contracting agencies have adopted more restrictive management standards. In those cases, the more restrictive management standards are implemented by the District.
- In the event of an immediate public safety concern, notification will occur at the time of treatment but pre-posting may not be possible.

All contractors and lessees need to also notify the District before application on any property and comply with requirements for notification and posting of signs described above. At the

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discretion of the District staff and depending on the site conditions, neighboring landowners will be notified if the District is conducting pest management near a property line. At the discretion of the District staff, pest management activities that do not require pesticides (e.g., mowing) may or may not be posted, depending on the level of visitor use and the potential for conflicts between site uses and planned pest management actions. Additional notification may also be provided in emails, newsletters, and public meetings, depending on the level of public safety concerns, public interest, and the size and duration of the planned pest control action.

4 Assessing the IPM Program and Updating the Guidance Manual

This chapter describes procedures for assessing the effectiveness of the IPMP as a whole using adaptive management, and the process for updating this Guidance Manual. Adaptive management is a tool that allows natural resource managers to make good decisions and effective action plans based on limited information, and provides a means of reducing uncertainty over time through assessing the results of an action and changing subsequent actions (The Nature Conservancy 2007). Adaptive management is often described as “learning by doing.” Given the types and rates of change observed on District preserves resulting from global, regional, and local factors (many of which are beyond the District’s control), adaptive management is an important tool to help the District implement IPM in the face of change and uncertainty.

Adaptive management encompasses the following steps: establishing assessment criteria, collecting information, evaluating the program, and undertaking program modifications to make the program safer, more effective, and efficient.

4.1 Criteria to Assess the IPM Program

These criteria are intended to quantitatively and qualitatively measure and evaluate changes in the District’s IPM Program over time:

- **Compliance with the Guidance Manual and List of Approved Pesticides.** The Guidance Manual’s procedures are designed to select the least harmful pest control methods. When chemical control is selected, the Guidance Manual requires the selection of the least harmful effective pesticides (through the review and approval process).
- **Demonstrated use of lower pesticide worker health/exposure classifications in buildings and recreational structures** (as measured by totaling use of pesticides using the U.S. EPA Classifications I, II, III, and IV).
- **Reduction of pesticide use in buildings** (i.e., in areas where human use levels are high and the potential for human exposure to pesticides is greater than in other areas). The District will seek to comprehensively oversee all pesticide use in and around District buildings, including use by tenants, which is expected to result in an overall reduction of pesticide use in buildings, and in particular, eliminate use of pesticides not appropriate for use around human occupants or visitors, or which can inadvertently escape into the surrounding wildland environment. Pesticide use in buildings will be measured in units of product used per treatment area (each

building), or by units of product used per total square footage for District buildings.

- **Reduction in per-acre herbicide use at individual sites in natural areas over time.** The District will seek a reduction in per-acre usage of herbicides over time at individual sites, but acknowledges that in some instances, use will initially increase, followed by a reduction in herbicide use when the pest is eliminated or reduced. As an example, as new properties are acquired or new invasive plant infestations are discovered, overall herbicide use may initially go up, however, they are anticipated to drop over time as pests are controlled or eliminated.
- **Preservation of biodiversity and natural resource values** in natural areas, rangelands, and agricultural properties. District staff will provide an annual qualitative assessment of natural resource conditions of IPM projects in natural areas, rangelands, and agricultural properties in the Annual IPM Report.
- **Provide a brief summary of public notifications and responses to inquiries from the public.** District staff will provide a summary of public notifications in the Annual IPM Report. The District will also record public inquiries made by telephone or in person regarding the IPM Program, and will briefly summarize inquiries and their responses to such inquiries on an annual basis.
- **Provide an annual summary of public participation in pest control.** The public is seen as an integral part of the success of the IPM Program. In particular, volunteers who assist with invasive plant identification and control are a valuable asset to the IPM Program. The District will tally volunteer hours spent on invasive plant control, and where possible, will identify future activities for volunteers, and/or new ways that the public can participate in the IPM process.
- **Provide an annual summary of staff training, public outreach, and educational activities related to IPM.** The District will summarize staff trainings, public outreach efforts, and educational outreach efforts such as working with tenants to use appropriate pesticides in structures and rangeland/agricultural areas.

4.2 Tracking the Program

Using the criteria described above, District staff will monitor pest control projects, and tally quantitative and qualitative results on an annual basis. The IPM Coordinator will present results in the Annual IPM Report.

- Each District Department will report pesticide use to the IPM Coordinator, as described in Section 3.2 of Chapter 3.
- District staff will regularly update the District's Pest Database, including a summary of District pests of concern, pest control activities, acres treated, and geographic (mapping information) treatment locations. The IPM Coordinator will use this information to prepare an annual assessment of units of herbicides per acre treated, as well as non-chemical treatments of pests.

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- The IPM Coordinator will qualitatively describe the condition of natural areas and managed landscape areas, identifying problem pests or areas requiring further investigation or treatment.
- The volunteer coordinators will tally volunteer hours spent on invasive plant control and provide this information to the IPM Coordinator.
- The IPM Coordinator will track and record public inquiries, questions, comments, and concerns about the IPM Program and summarize in the Annual IPM Report.

4.3 Program Evaluation

Using the information described above, the IPM Coordinator, with input from District staff, will evaluate the IPM Program as a whole on the basis of:

- **Safety** (i.e., did the IPM Program reduce risks and help ensure the safety of people and the environment?);
- **Effectiveness** (i.e., were pests controlled or eliminated in a cost effective and safe manner?); and
- **Purpose** (i.e., are District buildings; recreational facilities; and agricultural lands, rangelands, and natural areas functioning as intended?).

The results of the evaluation will be presented in the Annual IPM Report. The Annual IPM Report will be presented to the IPM Coordination Team for review and approval. Using the monitoring protocol described above in Section 4.1, the IPM Coordination Team will assess the effectiveness of the IPM Program, and recommend changes to the program intended to increase effectiveness and efficiency of pest control activities.

The final Annual IPM Report, which will include the IPM Coordination Team recommendations, will then be submitted to the General Manager for initial approval and to the Board of Directors for review and acceptance, including any changes to the Approved Pesticide List.

4.4 Program Modifications

The Annual IPM Report, as approved by the General Manager and accepted/approved by the Board of Directors will be the basis for making changes to the Guidance Manual, including modification of any IPM procedures or changes to the List of Approved Pesticides.

Each year following Board of Directors review of the Annual IPM Report, the IPM Coordinator will implement recommended changes to the Guidance Manual and IPM Program.

4.5 Updating the IPM Guidance Manual

This Guidance Manual is intended to be a “living document,” in which minor changes that do not trigger additional environmental effects can be made without needing to complete

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additional environmental analysis. The document will continue to be updated approximately every 10 years, and as necessary, supplemental CEQA and other environmental analysis will also be prepared as appropriate. The IPM Coordinator and IPM Coordination Team will review proposed changes to determine if they would result in changes to adopted IPM Policy and guidance procedures (see Section 4.4 above). This review will include assessment of changes to the lists of target pest species, pest control methods, and pesticide use trends.

When changes to the Guidance Manual are required, the IPM Coordinator will initiate a review process to determine whether the proposed changes are minor (as defined under the CEQA Guidelines Section 15164, the approval process for the project as not resulting in substantial new information or new significant environmental impacts). If the changes are confirmed to be minor, these changes can be addressed through the IPM Coordination Team review and approval process (described above). Examples of minor changes that would not likely trigger a new environmental review include process updates and simple interchangeable product substitutions for products on the District's List of Approved Pesticides (see Section 3.10).

5 IPM in Buildings

5.1 Definition and Purpose

District properties include approximately 330 buildings and structures, including field offices, residences, and numerous outbuildings such as barns and sheds in the preserves. Certain animals and plants may be incompatible with human use of these structures or may harm the building itself. For example, rodents, ants, and similar structural pest species are typically controlled in buildings when their population numbers may result in structural damage or health risks to humans. Management of pests in buildings may be conducted by District staff or by residential, commercial, or agricultural/rangeland tenants at some level almost every year. For purposes of this management category, rodent infestation of vehicles that are parked for extended periods of time on District preserves (reported by staff to occur regularly in ranger and crew trucks) will be treated similarly to rodent infestations of buildings.

For the purposes of this manual, structural pests include common insects, plants, and animals that routinely occupy the open interiors and immediate exteriors of buildings. Structural pests that live within the soil and wood components of these structures such as termites, wood beetles, and wood decaying fungi are included in the IPMP as part of the 10-year Program update. Structural pests were generally included under the 2014 Program; however, as part of the 10-year Program update, the IPMP now includes additional chemical and physical treatment actions for structural pests.

The purpose of pest control in District buildings is to manage pests for human health and safety, and to preserve the intended uses of the building structure. Most structural pests only become problematic when there are extra resources readily available to sustain them (food, water, shelter) in and around the structure. Many of these types of outbreaks can be managed with cultural control options such as changing human behavior (e.g., securing garbage, cleaning up food) or engineered control options within structures (e.g., sealing up entrance area, securing garbage disposal areas).

5.2 Types of Structural Pests

Organisms of all kinds, whether vertebrate or invertebrate, are living creatures with specific biological needs and behavioral preferences. They all require food, water, safety, and a point of entry to become a structural pest. Cutting off access to any one of these resources can often be sufficient to prevent or reduce a structural pest problem.

Structural pests include insect, plant, fungi, and animal pests that damage occupied buildings and other structures, or pests that are a health threat to humans working in, living in, or visiting the buildings. Nuisance structural pests addressed within the District's IPMP include ants, cockroaches, flies, mice, rats, skunks, opossums, raccoons, bats, subterranean termites, drywood termites, wood beetles, stinging insect nests, and fungus/dry rot. These pests may be present throughout District lands, but they may only be incompatible with planned District uses when their proximity or behavior conflict with human uses in buildings. Some structural pests can only survive in a human-modified environment (e.g., German cockroaches) versus others are opportunistic visitors from nearby wildlands (e.g., deer mice).

The definition of a structural pest can be highly variable between individuals and groups of people based on the perception of damage versus any true damage to structures. Care must be exercised when defining tolerance levels for each pest species. One must consider the actual damage potential of the organism, the cultural acceptance of the organism to humans who may have to live and work nearby, and any broader environmental consequences to the natural environment. For example, deer mice may be tolerated if they occupy the exteriors of human-occupied buildings, but once they penetrate the structure and begin to occupy building interiors, they become unacceptable pests for potential damage and threats to human health and safety. The traditional approach to structural pest control is modified in the District's IPMP because District structures are located in natural areas. Native species (e.g., deer mice) that can move freely between the inside (pest) environment and outside (native/natural) environment must be treated in a manner that achieves control of the pest without compromising the natural resources around the structure. The District's structural IPM decision-making must always balance health and human safety concerns with District's goal of protection of natural resources.

Structural IPM focuses on first modifying the behavior of humans or the structure of our environment to moderate or eliminate pest problems. The District can use familiar planning and building tools to engineer pests out of conflict areas such as structures through the use of physical barriers, materials selection, and site modifications. Tolerance levels for this category of pests take into consideration the risks of economic damage along with the fact that these species will inevitably occur in the built environment.

5.3 Pest Identification

Structural pests are generally identified when routine building inspections are conducted by IPM professionals, but are also commonly identified by the building occupants themselves. Because buildings are much more intensively utilized than the District's surrounding natural areas, structural pests can usually be identified relatively quickly before major infestations become problematic. Visual inspections will focus on identifying conditions where excess food, shelter, and access can support pests (e.g., the break room); signs of pest damage or entry (e.g., holes in the building exterior); or on observations of the pest itself.

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Some District buildings could benefit from routine inspections from IPM professionals who have specialized training to find structural pests and their associated damage. Professionals may utilize special monitoring traps for specific organisms to monitor the population thresholds of common pest species (e.g., “sticky” bait traps for ants). These types of monitoring devices are useful in scenarios where the presence of the pest is inevitable, and the pest population must be maintained at an acceptable tolerance level. Other buildings and structures that are less intensively utilized will rely on the observations of the District’s employees, tenants, and visitors to identify pests.

Employees, tenants, and visitors will have clear communication pathways to the IPM Coordinator to report structural pest presence and damage in a timely manner. Structural pest problems will be reported to the IPM Coordinator at any time during the year via telephone, email, or meetings; in an Individual Pest Management Plan; or as part of Annual IPM Reporting. The IPM Coordinator can problem-solve structural pest situations by providing the following types of assistance:

- Assist with the identification of pest type,
- Assist with determining pest control treatment threshold levels,
- Provide recommendations for building or human use modifications to reduce pest problems below threshold levels,
- Review the Individual Pest Management Plan and facilitate the implementation by staff or tenants, and/or
- Recommend professional assistance such as use of a structural pest control advisor or structural pest control operator to actively control pests.

5.4 Preventive and General Maintenance Activities

5.4.1 Overview

Modern IPM programs for buildings rely on prevention (i.e., building design and human behavior modification) as the primary structural pest control treatment options to eliminate pest problems. Active pest control is used only as a last resort. Because humans occupy a highly engineered environment, use of such control options as physical barriers, materials selection, and site modifications provide the primary means to eliminate pests from buildings and other structures without the need to use pesticides that cause mortality or other lethal control (e.g., snap traps, bait stations).

If structural pest control in vacant structures is expensive, time-consuming, or otherwise damaging to the surrounding natural environment, demolition of the buildings will be considered as part of the Annual IPM Work Plan (See Chapter 3). Demolition activities will be subject to separate permitting processes through respective County planning departments. A discussion of preventive and general maintenance activities is summarized below.

5.4.2 Prevention

Preventing structural, insect, and wildlife pests in buildings include general guidelines that promote pest-resistant materials, block common access points to buildings, and promote the modifications of common structures to repel rather than attract common pests. These guidelines may include landscape design practices that can be incorporated at District facilities in natural areas. For example, defensible space around structures should not be planted with dense ground covers and/or climbing vines like ivy that could attract structural pests such as mice and skunks.

Pests need a place to live – or harborage; most prefer a hidden space where they will not be disturbed. Preventing access to hidden spaces can, therefore, assist pest management efforts: cracks, crevices, gaps, holes, loose structural elements, and dense vegetation can all act to hide small pest organisms. In some cases, the materials present in District structures can create potential harborage, such as when rigid foam insulation - a material that is known to attract termites - is used on the outside of foundations.

Incorporating some preventive measures will be simple, while others (like discontinuing the use of rigid foam insulation) may directly conflict with building codes and other design goals for the structure. Generally, the inclusion of standard pest prevention practices during the building design and construction or retrofit phase can dramatically reduce pest problems in the future while still fulfilling all the requirements for modern building codes. For example, proper placement of exterior lighting can significantly reduce the attraction of night flying insects into the building. Eliminating ledges under roof eaves can discourage pigeons and swallows from taking up residence. Planting and maintaining landscaping so that it does not touch building walls can help reduce the transmission of pests inside the structure. Applying pesticides with the active ingredient of disodium octaborate tetrahydrate to accessible exposed wood members of the attic can help prevent drywood termite and wood beetle infestations. All these retrofit, design, and construction practices can help prevent the establishment of pests in District structures, thereby reducing the need for pest management.

5.4.3 Retrofit

Architects, planners, and engineers have only recently begun to consider pest control and building maintenance in the design of new structures and within the retrofitting of existing structures. New local green building ordinances and elective building rating systems now incorporate methods for enhancing modern buildings to be more energy efficient and less toxic beyond modern building codes. Reducing the need for toxic pesticides to control structural pests is especially feasible because much of their damage can be prevented by improved design.

Designing pests out of new and existing structures may include structural materials selection and the addition of non-structural components to reduce building access or utilization by pest species. Design guidelines are available from the International Code Council/San Francisco Department of the Environment (Geiger and Cox 2012). Much of the focus of these guidelines is on the building envelope and the building interface with soil and landscaping. This allows

buildings to repel ground-dwelling insects and rodents and significantly reduce their access to the building interior. For example, treating the full perimeter of the structure and any additional entry points by, and not limited to, trenching and/or rodding soil adjacent to the foundation, drilling through concrete/veneer surfaces abutting the foundation, trenching around pier blocks and plumbing pipes in the subarea reduces use by pest species. Maintenance practices that can reduce structural pest impacts are summarized in Section 5.5.

5.5 Maintenance Practices to Prevent and Reduce Structural Pests²

Pest impacts to wooden structures often result from the introduction of moisture. Subterranean termites, carpenter ants, most wood beetles, and fungal rots only impact wood that is already impacted by moisture. Maintaining structures so they always remain dry, especially in the high humidity of the Santa Cruz Mountains and Central Coast, will reduce the potential for pest outbreaks in the structure. Maintenance of older structures should focus on keeping the building envelope functional to minimize leaks and moisture accumulation.

Other general maintenance practices in and near structures involve general cleanliness and vigilance in preventing access to resources that encourage pests. For example, equipment that attracts rodents or provides harborage should not be left in natural areas for long periods of time. Landscape maintenance should focus on elimination of vegetation touching the building envelope, or reduction or elimination of the types of landscaping that are known to provide harborage for structural pests.

The following maintenance activities will be undertaken to prevent structural pests, or reduce their presence and thus threats or damage that they can cause:

- **Minimize moisture.** Moisture in and near structures can provide harborage for insect pests such as termites, wood beetles, cockroaches, flies, carpenter ants, silverfish, and millipedes. Use the following procedures to minimize building moisture during construction or general maintenance and repairs:
 - Check for proper ventilation of crawl spaces; add vapor barriers in crawl spaces.
 - Ensure appropriate slopes and drainage next to structures.
 - Downspouts and gutters should discharge at least 1 foot away from walls; splash guards, rain barrels, or gutter extensions may be added to reduce accumulation of moisture near structural walls.
 - Ensure that landscape irrigation does not introduce moisture to foundations – use drip irrigation and position sprinklers to avoid structures.
- **Maintain landscaping** next to structures.

² Recommendations selected from 2012 Pest Prevention By Design: Authoritative guidelines for designing pests out of structures, which remains the most current design guideline document (Geiger and Cox 2012).

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- Prune vines, shrubs, and trees at least 6 feet away from roofs and exterior walls, as rodents can use these for access into buildings and shelter next to foundations.
- Remove and avoid planting Algerian or English ivy, star jasmine, or honeysuckle vines, which provide shelter and food sources for rats and other urban pests. Remove and avoid planting bamboo, cherry laurel, fig, pine, and roses near buildings, which encourage scale, aphid, and ant populations.
- Clear landscaping away from vent openings to crawlspaces to prevent moisture buildup.
- Remove plants and wood mulch within several inches of foundations to minimize ants and other nests. A gravel strip around foundations at least two feet wide and 0.5 feet deep of one-inch gravel or larger discourages rodent burrowing and other insect nesting.
- Select plants that attract beneficial insects such as parasitic wasp, native bees, and ladybugs.
- **Move stored materials** away from structures.
 - Store compost and trash bins away from structures, as these can attract rodents, insects, and other nuisance pests.
 - Store woodpiles and debris away from structures to prevent rodent, beetle, and termite infestation.
- **Seal off openings.**
 - Inspect openings to crawlspaces and other ventilation features to ensure screens are intact.
 - Inspect, maintain, and use elastomeric sealant, polyurethane foam, and weather-stripping to seal all small cracks in structures, around countertops and windows, pipe breaks, and areas where pipes enter walls. Use stainless steel wool and mesh and fire block foam to re-seal larger openings in buildings and below decks.
 - Add door sweeps or high-density pest brushes to seal gaps greater than ¼" below doors.
- **Block access for rodents** to climb pipes and gutters.
 - In areas with Norway rats or other rodent issues, various items can be installed to prevent the rodents from climbing downspouts and pipes, including flap valves or screens in downspouts, 12"-diameter downward-facing cones or 18"-diameter discs, or a 12" band of glossy paint on exterior vertical pipes.
- **Exclude rodents from refuse and recycling areas.**
 - Enclose refuse and recycling areas with metal, concrete, or similar materials to prevent wildlife from climbing, burrowing, or chewing into the enclosure. Do not plant ivy around the enclosure.
 - Use refuse containers that are heavy duty, rust resistant, rat and damage resistant, and equipped with tight-fitting lids.

- **Add bird exclusion materials** to lighting and other horizontal surfaces.
 - Bird spikes, wires, netting, or similar materials should be installed to prevent birds from roosting or nesting on structures or on light poles.
- **Reduce or move exterior lighting.** Exterior lighting may encourage insects to gather near doors and windows.
 - Timers and motion detectors can be installed to minimize unnecessary lighting.
 - Use reflected light instead of direct light to illuminate entryways, as insects are more attracted to direct light.
 - Use yellow (sodium) bulbs to reduce insect attraction in exterior areas.

5.6 Sanitation and Waste Management

5.6.1 Overview

Many pest species are present because of improper handling and storage of food and food waste or improperly cleaning up food scraps and dishes. Uncovered garbage containers, both inside and adjacent to buildings can attract rats and other pests. Storing native plant seeds in paper envelopes rather than hard sealed plastic containers may encourage mice to take up residence in storage areas. All these types of pest attractants can be eliminated with human behavioral modification as a prevention method. Optimally managing human behavior can drastically reduce or even eliminate the need for pesticide products in District structures and landscapes.

Recommendations for structural pest prevention measures to be implemented by District staff and volunteers in food and waste storage areas are listed below. If behaviors cannot be easily modified, hire a janitor or cleaning service for common area cleaning.

5.6.2 Additional Residential/Office Unit Prevention Strategies

The following additional measures may be applied in District residential and office buildings:

- Train staff, including building occupants and janitorial staff on safe food and trash handling procedures;
- Store all food and food wastes in sealed containers;
- In communal spaces, provide extra containers, sealed cabinets, or a refrigerator for temporary food storage;
- Do not allow food waste to remain in open areas overnight;
- Regularly clean dishes, floors, and counter tops;
- Use sealed garbage cans, or alternatively place them on a crawling insect-proof platform;
- Rinse out cans and bottles before they are placed in a recycling bin; and
- Do not leave pet food out overnight.

5.6.3 Industrial Unit Prevention Strategies

The following types of additional measures may be applied in District storage buildings, livestock structures such as corrals, and for District projects using contractors and outside construction materials such as fill dirt or erosion control materials:

- Train staff in proper storage of work supplies in non-occupied buildings.
 - Store all pet food, animal grains, and other consumable agricultural supplies in sealed containers (metal/plastic).
 - Store plant seeds used for habitat restoration and landscaping in sealed containers.
- Monitor landscaping and rooted plant materials for pests, and treat as necessary to prevent pest outbreaks.
- Position attractive harborage areas, such as rock piles, soil storage piles, hay, and erosion control materials away from buildings.
- Control food waste in contractor work areas, outbuildings, storage areas, and other non-occupied structures.
- Provide sealed garbage containers in or near such areas to prevent inadvertent disposal.
- Reduce, monitor, and where possible, eliminate use and import of natural materials that could introduce pests onto District lands, such as reducing use of off-site fill (soil, gravel, and rock) and livestock feeds (hay) that may contain weed seeds. Where possible, include requirements to use on-site fill, require balanced cut and fill projects on District lands, and require use of certified weed-free erosion control materials for construction projects on District lands.

5.7 Damage Assessment

Damage assessments should be undertaken once a pest control problem is identified. The District will determine what, if any, damage to the structure is present. To the extent possible, quantify the damage (square feet affected or number of occurrences) and qualitatively describe the perceived damage in its context. As an example, a staff person could estimate the square footage of a building affected by ants and evaluate if the ants are always present at observed levels or if the incident is just a temporary outbreak.

5.8 Tolerance Levels/Threshold for Action

If there is no structural damage, but a pest is present that conflicts with human use or enjoyment of the structure, determine the tolerance level for each pest species to assess if control is warranted. Tolerance levels vary greatly for structural pests depending on the true or perceived impact of the pest on the structure or human experience. Some species, such as cockroaches, are unwelcome guests but present no real damage to either people or structures. Other species, such as woodrats, can seem more acceptable because they are attractive native animals, but they can also carry deadly, incurable human diseases. The District's IPM approach

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for structural pest species begins with establishing human and structural tolerance levels that balance human safety, enjoyment, and comfort within the build environment with the ability to conserve natural resources and cost/benefit assessment.

Human safety and enjoyment are the primary metric for establishing tolerance levels in structures. Although structural pests can be both native, protected species, and non-native invasive species, staff and visitor safety is paramount in regulating treatment actions. Tolerance levels will consider conservation goals and impacts to the larger surrounding natural system in determining treatment actions.

5.8.1 Management Thresholds for Structural Insect Pests

Refer to Table 5-1 for establishing management thresholds and treatment options for nuisance insects in buildings.

Table 5-1 Management Thresholds and Treatment Options for Nuisance Insects in or Around Building

Pest Category	Management Threshold (Population Size/Conditions)	Treatment
Ants	Colonies near structures and occasional trails indoors	Use a combination of the following • Clean up ant trails with soapy water or sticky lint rollers. • Ensure all food sources are in sealed containers. • Fill entry points with caulk, silicone, or expanding foam.
	Heavy invasion, more than occasional seasonal nuisance	Use a combination of the following: • Inject diatomaceous earth dust into cracks before sealing if there are multiple entry points. • Use boric acid bait. • Use fipronil bait as last resort (extreme infestations, fast control)
	Homopteran insect populations on plants (aphids, etc.) that support ants invading structures	Use a combination of the following: • Prune vegetation that supports ants and/or Homopteran insects away from structures. • Control Homopteran insects by dusting the infested vegetation with diatomaceous earth. • Treat the infested vegetation with a soap and water solution.
Cockroaches	Occasional presence indoors in low numbers	Use a combination of the following: • Fill entry points with caulk, silicone, or expanding foam. • Ensure all food and water is unavailable.

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Pest Category	Management Threshold (Population Size/Conditions)	Treatment
	Heavy invasion, more than occasional seasonal nuisance	Use a combination of tools and alternate to avoid resistance: • Inject diatomaceous earth dust into cracks before sealing if there are multiple entry points. • Use boric acid dust in walls, cracks, and other inaccessible areas. • Use baits: - Hydropene - Indoxacarb bait - Fipronil bait as last resort
Flies	Heavy invasion, more than occasional individual nuisance indoors or in and/or around picnic areas	Use a combination of the following: • Fill entry points with caulk, silicone, or expanding foam. • Install sticky fly traps indoors. • Install baited electric traps outdoors. • Remove food and breeding sources.
Stinging Insects (Nests)	Nest occurrence(s) on buildings or structures that pose threat to humans	Implement the following: • Use of Pyrethrin Aerosol Sprays for eliminating single, or problem wasp nests that threaten District staff or visitors.^a
Subterranean Termites	Moderate or heavy invasion, more than occasional individual nuisance in or adjacent to structures	Use a combination of the following: • Treat the full perimeter of the home and any additional entry points. • Remove or destroy accessible subterranean termite tubes/tunnels. • Seal drill holes and back fill trenches, if applicable. • Prior to tenting, the District will removal all plant and rake back all rock and debris along the foundation (8-10 inches). • Patch all injection holes, cover, or remove accessible termite evidence. • Spot treatment. • Treat the infested area with active ingredient fipronil, chlorantraniliprole, and/or dinotefuran for the control of subterranean termites.
Drywood Termites/ Wood Beetles	Moderate or heavy invasion, more than occasional individual nuisance in structures	Use a combination of the following: • Spot treatment. • The entire structure will be sealed and fumigated with sulfuryl fluoride. Tear gas will be used as a warning agent. • Apply disodium octaborate tetrahydrate to accessible exposed wood members of the attic.

IPM IN BUILDINGS

Pest Category	Management Threshold (Population Size/Conditions)	Treatment
Dry rot/Fungus	First evidence of dry rot/fungus	Use a combination of the following: • Wire brushing or scraping the infected area, • Treat the infected area with disodium octaborate tetrahydrate.

Note:

- ^a Use of chemical methods for stinging insect nest control is discussed in detail in Chapter 7.

5.8.2 Structural Animal Pests

Refer to Table 5-2 for establishing management thresholds and treatment options for animal nuisance pests in buildings.

Table 5-2 Management Thresholds and Treatment Options for Nuisance Animals in and Around Buildings

Pest Category	Management Threshold (population size/conditions)	Treatment
	Occasional presence indoors in low numbers (< 10 individuals)	Use a combination of the following tools and alternate to avoid resistance: • Snap traps 6 feet apart for initial population control and maintenance. Prebait for up to several weeks for rats. • Box traps for mice – inspect daily.
Mice & rats	Moderate to Heavy infestation (> 10 individuals of house mice, Norway rats, or roof rats ONLY) AND infestations posing risk to human health that do not respond to preventative and non-chemical methods	Use a combination of the tools and alternate to avoid resistance: • Tools listed above for occasional presence. • Cholecalciferol – during instances when human health and safety are in jeopardy.
	Moderate to Heavy infestation (> 10 individuals) of dusky-footed woodrats	Use exclusion methods to prevent entry of native rats into structures.
Skunks, opossums & raccoons	Individual animals invading structures	Implement trapping. Animals must be released or euthanized immediately. Relocation requires a permit from CDFW.
Feral Pets	Aggressive animals or resident populations that cause nuisance or impede resource protection goals	Implement live trapping with city or county animal control departments or animal shelters.

Pest Category	Management Threshold (population size/conditions)	Treatment
Bats	Roosting in structures that allows access to human-occupied rooms	Use a combination of the following: • Implement strategic exclusion. • Block entry to spaces where roosting causes conflict with human health and safety.

5.9 Active Pest Control Treatment Options

When thorough prevention measures have been undertaken and human health and safety dictates, District staff may determine active pest control is required in buildings. The basic steps for planning active pest control in buildings include:

- Identification of a potential pest problem by trained professionals, staff, or tenants;
- Inspections to establish pest activity and treatment options;
- Identifying a preferred pest control approach;
- Implementing the selected pest control;
- Monitoring the results of pest control; and
- Reviewing results to inform and improve future pest control actions (adaptive management). Some pest management options include:
 - Indoor monitoring/trapping stations (non-chemical options such as snap traps are preferred over other chemical control options);
 - Natural pest controls (e.g., diatomaceous earth); and/or
 - Other active IPM controls (as described above in Table 5-1 and Table 5-2).

Where pesticide use is determined to be the only viable treatment option to address the specific infestation of concern, selection of least harmful products is required. Only pesticides on the District's List of Approved Pesticides (Table 3-3) may be used. As an example, structural pest infestation that poses an immediate threat to human health or public safety would exceed District tolerance levels and warrant use of pesticides if non-chemical control could not protect the public. The chemical control options presented in this Chapter represent the least harmful, most efficient treatment methods for controlling structural pests. For example, a wasp nest in a public restroom may require use of a pyrethroid wasp spray to immediately eliminate the hazard of wasp injury to visitors. The inclusion of a variety of pest treatment method in the IPM Program allows the District to respond with the necessary tools based on actual risk to the District, its visitors, workers, structures, and lands.

5.9.1 Insects

Overview

Structural insects found on District lands include ants, cockroaches, flies, subterranean termites, drywood termites, wood beetles, and wasps/stinging insects. As described above, these species can be deterred from establishing in District structures through design, maintenance, and

behavioral modifications. However, some structural and nuisance pests may exceed tolerance levels for their presence in buildings. The following section discusses treatment methods for populations that exceed tolerance levels.

The presence of insects in buildings is very unappealing to most facility users. Their occurrence tends to suggest unsanitary conditions or deferred maintenance. Though these insect species usually do not pose a threat of direct harm to humans, their presence is almost always deemed to be unacceptable in our homes and landscapes. In the absence of immediate public health and safety risks, prevention and physical controls are the first treatment methods implemented in an IPM program, and these methods typically provide the most long-term effective control. Sanitation and cleanliness are the most effective methods for preventing and managing these insect pests. Chemical treatment methods are generally only used if the other methods prove inadequate to bring the insect pest population to within tolerance levels.

IPM strategies for common insect pests must use a spectrum of different control techniques to avoid problems with pesticide resistance. For example, both Argentine ants and German cockroaches have developed resistance to a few common pesticides. For this reason, no single treatment or product can be recommended for complete control. All products that have chemical modes of action – both natural and synthetic – can promote resistance if used indiscriminately. All chemical products must only be used in the most appropriate and effective manner and in parallel for consistent results.

Ants

The most common nuisance ant species in District structures is the Argentine ant (*Iridomyrmex humilis*). The Argentine ant is a non-native species from South America that likely arrived in California in the early 1900s and quickly spread throughout the state's citrus growing regions. Argentine ants have largely replaced native ant species in the urban environments that they have invaded (Holway 1998). Although the species is usually considered a nuisance pest in structures, the Argentine ant has eliminated nearly all native ant species in natural areas as well. Other native insects and some populations of native birds, lizards, and salamanders may have been similarly affected by the Argentine ant (Randall et al. 2011). Many native plants rely on insect pollination and insect-related seed dispersal; the loss of native insects resulting from the invasion of the Argentine ant has most likely also reduced native plant seed production, dispersal and other mutualistic relationships between insects and their host plants (Gómez et al. 2003; Nygard et al. 2008).

Argentine ants have four life stages: egg, larva, pupa, and adult. Argentine ants are social insects that live in organized colonies where different adults have specialized duties. Unlike native ants, Argentine have numerous queens and worker ants, which mix freely between colonies without any intraspecific competition and thus are capable of reaching unnaturally high population densities compared to native ant species (Silverman and Brightwell 2008). For this reason, eradication of Argentine ant populations is impossible; if a sub-colony collapses, other nearby queens will shift to fill the void. Argentine ants are omnivorous, preferring high protein sources until those resources are exhausted and then shifting to plant and nectar-based

resources. They are especially fond of honeydew produced by Homopteran insects (e.g., aphids, scale) and the pest problems of each of these species in gardens and structures are often linked.

Pest Management Strategies for Ants

Prevention

- Clean all kitchen and food storage surfaces regularly; sweep and vacuum kitchen floors daily. Shared-use appliances such as sinks, microwaves, and vending machines should be cleaned regularly to eliminate spills.
- Store all food properly. Argentine ants are especially small creatures that can easily crawl along the threads of a screw-top jar and enter the container if there is no silicone or rubber seal on the lid. Store all food in containers with tight fitting lids, or in the refrigerator or freezer.
- Rinse recycling waste if it is temporarily stored in open bins. Alternatively, store all waste in containers with tight fitting lids/seals or place open bins on insect-proof bases (e.g., Antser™) and always line trash bins with plastic bags. Regularly take out the garbage to an outside storage area/dumpster.
- Do not leave pet food in open bowls overnight. Wash pet food bowls after the pet is done eating.
- Inspect potted plants for ant nests regularly. If ant nests are found, remove the potted plant. If potted plants become a frequent harborage for ant nests, use ant-proof platforms (e.g., Antser™) or use a double saucer system (inside saucer – water – outside saucer – soapy water) for all inside/outside potted plants. Flooding the pot for several days can treat ant-infested potted plants.
- Inspect landscaping for aphids, scale, and other honeydew producing insects. If found, treat plants for insect pests, and manage ants in a coordinated effort to eliminate both problems.

Physical Control

- Clean up ant trails when they are found with soapy water or sticky lint rollers. Note the location the ants were headed and the location where they were coming from. Clean-up whatever attracts the ants, if possible.
- Use caulking, silicone, or expanding foam to fill cracks, holes, or other entry points where ant trails originate. If multiple entry points are suspected, inject diatomaceous earth dust into cracks before sealing.
- Prune outside vegetation that is touching the structure if it supports ants, aphids, or scale. Some species, such as Citrus, are especially susceptible to sucking Homopteran insects that in turn attract ants. Consider replacing these species of plants with others that do not attract Homopteran pests. Treat infested vegetation by spraying with soapy water or insecticidal soap sprays, dusting with diatomaceous earth, or physically removing insects.

Chemical Control

Chemical control of ants includes two options: 1) direct control using sprays for instant, but temporary knockdown of individual ants and the treatment of Homopteran pests that attract

ants, and 2) baits for colony control. Sweet liquid baits are useful throughout the year because adult Argentine ants only feed on sugary liquids. High protein baits are generally only useful to treat colonies during the periods of the year when they are actively expanding because such solid food is typically used by the ants to feed larvae. Baiting is generally a slower process than direct control, but it has a much greater long-term impact on controlling the entire local colony. Baits are taken back to feed larvae and shared with other adults and queens so they potentially can eliminate the entire colony rather than just a few individuals. Modern baits are designed to be extremely host-specific compared to generalist insect sprays. Baits target the pest directly, rather than being applied to the environment. Never use direct control (spray) around a bait station, as the spray will impede the bait's ability to attract the target insects. Baits can only be used indoors in tamper-proof stations.

For the control of insects, multiple baits with different modes of action are recommended to prevent local populations from developing resistance to the pesticide. Every structural insect management program should include a few products to use in rotation to prevent resistance.

- **Insecticidal Soap Spray.** Insecticidal soaps are specially designed mixes of fatty acids that are made to penetrate an insect's covering and dissolve its cell membranes causing dehydration and mortality. Generally, the soaps are formulated to not dissolve plant cell membranes, and therefore are safe to apply directly to plants. Insecticidal soaps are not effective on all insects, but soft bodied insects, such as Homopterans, are highly susceptible. When used for ant control, soaps are most effective in controlling the Homopteran insects on plants that attract and sustain ant colonies.
- **Boric Acid Bait.** Boric acid is a naturally occurring compound found in many fruits and vegetables, but at concentrated doses it can be an effective stomach poison for insects. Baits use low concentrations of boric acid – sodium tetraborate decahydrate – in the range of 0.5 – 5% to allow for ants to ingest the bait and take it back to the colony to share with other workers before there is a lethal effect. Higher concentrations risk killing the individual before it has time to take the bait back to the colony. Studies show that the lowest concentrations (<1%) are optimum for Argentine ant preference (Klotz et al. 2000).
- **Fipronil.** Fipronil is a broad-spectrum insecticide common in household cockroach/ant baits and flea sprays for pets. When used as an ant bait, it is toxic to insects through ingestion where it blocks chloride channels in the central nervous system, resulting in excess neuronal stimulation and death of the target insect pest. It has higher binding affinity in insect receptor sites versus mammalian receptors so it is considered highly selective for insects and safe to use in human environments (D. Jackson et al. 2009). It is considered one of the most effective baits for colony control of Argentine ants in situations when boric acid-based baits are less effective (Hooper-Bui and Rust 2000; Mathieson et al. 2012). Fipronil is relatively quick-acting compared to other natural pesticides. It should be used as a last-resort option when extremely high populations of ants must be controlled quickly. Only small amounts of bait are necessary to control ants compared to

knockdown sprays, which must be applied more widely in the environment to be effective. Small amounts of fipronil will be used as a last-resort option when extremely high populations of ants must be controlled quickly.

- **Diatomaceous Earth.** Diatomaceous earth (DE) is a silica-based, naturally occurring mineral product that works as a generalist insect pesticide. It is composed of fossilized silica cases of marine diatoms that have been mined from ancient marine sediments. The dust is considered non-toxic, although care should be taken to not inhale large amounts of dust during application as all mineral and wood dusts are considered hazardous in extremely large amounts. Food-grade DE is available to mix directly in human and pet foods to manage pests that occur in bulk food storage. DE works by mechanically abrading an insect's exoskeleton that leads to dehydration and eventual death of the insect. DE is non-selective so it must be used only in specific areas where the target pests travel. The dust is not eaten – so must be applied in areas where they will contact the bodies of insect pests. For ant control, it is often applied to cracks and crevices and may also be used in conjunction with caulks and foams to fill problem areas.

Cockroaches

One of the most common structural nuisance insect pests in North America is the cockroach (Olkowski et al. 1991). Though rarely carrying disease or causing major economic damage to our structures, it is typically considered unacceptable in our homes and workplaces; triggering psychological distress, embarrassment, and general feelings of disgust. Cockroaches do consume human foodstuffs and wastes, and can contaminate them with saliva and excrement. In some cases, they carry disease and may be linked to increased asthma rates (CDC 2024).

Cockroaches are scavengers of plant materials, as a result, they prefer carbohydrates over fats and proteins. They consume any human food or food waste that contains significant carbohydrates in addition to materials such as pastes, glues, and soaps. Most common cockroach species can only exist in high humidity and high temperature environments such as those present in human structures.

Several different species of cockroaches occur as pests in Northern California, and each has separate behaviors and habitat preferences that dictate different types of pest management. The non-native German cockroach (*Blattella germanica*) is the most common pest species in the counties in which the District is located. The German cockroach is the smallest and most widely spread pest cockroach in North America and has three life stages: egg, nymph, and adult. German cockroaches prefer dark, warm, and humid hiding places and they are common in basements, kitchens, and bathrooms. They are thigmotactic, meaning they prefer to rest in small cracks where their stomach and back touches surfaces during most of the day, so regular inspection of crack areas can sometimes aid in cockroach detection in buildings. Unlike ants, they are solitary insects but since preferred habitats are rare in buildings, it is common to find large numbers of cockroaches hiding in the same general areas.

German cockroaches are ubiquitous in human environments that occur in temperate climates, so complete pest eradication is almost never achievable. Cockroaches regularly disperse in cartons, boxes, and other containers coming to and from grocery stores, warehouses, flower shops, and other shipments, and are thus likely to always be present in human environments. Strategies such as sealing exterior cracks/holes in buildings and strict sanitation measures both inside and out of buildings will help maintain their populations at nearly indiscernible levels which should be sufficient for most District properties.

Pest Management Strategies for Cockroaches

Prevention

- Clean all kitchen and food storage surfaces regularly; sweep and vacuum kitchen floors daily. Shared-use appliances such as sinks, microwaves, and vending machines should be cleaned regularly to eliminate spills.
- Store all food properly. Store all food in containers with tight-fitting lids, or in the refrigerator or freezer.
- Rinse recycling waste if it is temporarily stored in open bins. Alternatively, store all waste in containers with tight fitting lids/seals or place open bins on insect-proof bases (e.g., Antser™ bases) and always line trash bins with plastic bags. Regularly take out the garbage to an outside storage area/dumpster.
- Do not leave pet food in open bowls overnight. Wash pet food bowls after the pet is done eating.
- Ensure all exterior windows that open have insect screens to prevent roaches from entering structures.

Physical Control

- Use caulking, silicone, or expanding foam to fill cracks, holes, or other entry points where cockroaches are known to hide or enter structures. If multiple entry points are suspected, inject diatomaceous earth dust into cracks before sealing.
- If hiding places are unknown, use a sticky-trap monitoring program to determine where in the building roaches are hiding.

Chemical Control

Only bait in tamper-proof stations will be used indoors.

- **Diatomaceous Earth.** As described above, DE is a silica-based, naturally occurring mineral product that works as a generalist insect pesticide. Refer above under “ants” for details regarding DE. For cockroach control, they are often applied to cracks and crevices and may also be used in conjunction with caulks and foams to fill problem areas.
- **Boric Acid Dusts.** Boric acid is a naturally occurring compound found in many fruits and vegetables, but in concentrated doses, can be an effective stomach poison for insects. Boric acid dusts are highly effective for cockroach control when applied to cracks and crevices where cockroaches are known to occur. The dusts (when kept dry) have a long service life and provide control for many years after

application. They are practically non-detectable to cockroaches, so unlike many other chemical products that cockroaches can detect and avoid, they offer one of the more effective methods for cockroach control (Gore and Schal 2004). Since they have such a long service life, they are effectively applied inside building walls, plenum (false) ceilings, crawlspaces and other relatively inaccessible areas where cockroaches can occur. Boric acid dusts are relatively slow acting compounds that take up to 10 to 15 days to achieve effective elimination of problem insects so they should generally be used in compliment with a baiting program to achieve full control of cockroach outbreaks.

- **Hydroprene.** Hydroprene is a synthetic insect growth regulator (IGR) that mimics juvenile insect hormones to regulate insect pest populations. Although they do not poison an insect directly to cause a lethal effect, they do interrupt the development cycle of juvenile cockroaches so they do not ever reach a reproductive stage. This mode of action can be important to reduce adult populations by preventing young insects from reaching adulthood and breeding in a long term control strategy. For this same reason, hydroprene is considered highly specific to insect pests and has low toxicity for birds and mammals, species that do not possess these same types of growth hormones. IGRs are not an ideal stand-alone control, but they are effective when used in combination with other methods to reduce populations of troublesome insects.
- **Fipronil insecticidal baits.** As described above, fipronil is toxic to insects, including cockroaches, through ingestion where it blocks chloride channels in the central nervous system resulting in death of the target insect pest. It should be used as a last-resort option when extremely high populations of cockroaches must be controlled quickly. As it is insecticidal bait, only small amounts of bait are necessary to control cockroaches effectively compared to knockdown sprays that must be applied much more widely in the environment.
- **Indoxacarb insecticidal baits.** Indoxacarb is a synthetic, non-systemic insecticide effective on chewing and sucking insects. When used as cockroach bait, it is toxic through ingestion where it blocks sodium channels in the central nervous system resulting in paralysis and elimination of the target insect pest. It replaces more hazardous organophosphate insecticides while still providing a fast acting, quick knockdown pest control option. Indoxacarb is a quick acting insecticide and offers exceptional German cockroach control potential. In laboratory conditions, small amounts of gel baits can provide several generations of control when the product is re-consumed through feces, regurgitates, and through bodily contact from the primary exposed individual cockroach (Buczowski et al. 2008). This product is recommended for last-resort options in challenging cockroach pest control scenarios.

Flies

Flying insect pests such as flies can be problematic inside buildings. In the District's region, the most common pest fly species, also referred to as filth flies, are common house, stable, and

greenbottle flies (*Calliphoridae* and *Muscidae* families). Common houseflies and greenbottle flies tend to be the most problematic groups of filth flies that cause pest problems in buildings and other public spaces. The presence of filth flies is generally indicative of unsanitary conditions. They can also carry disease pathogens to humans through feces and regurgitation.

Pest flies breed in animal wastes and decaying organic material from which they can pick up bacteria and viruses that may cause human diseases. In addition, adult stable flies feed on mammalian (livestock) blood and can offer a painful bite. All flies undergo complete metamorphosis with egg, larva, pupa, and adult stages in their development. The female fly deposits her eggs in animal waste or moist organic material where the larvae, or “maggots,” complete their development, feeding on wastes until they pupate in a dry location.

Pest Management Strategies for Filth Flies

Prevention

- Clean all kitchen and food storage surfaces regularly; sweep and vacuum kitchen floors daily. Shared use items such as sinks, microwaves, and vending machines should be cleaned regularly to eliminate spills.
- Store all food properly. Store all food in containers with tight fitting lids, or in the refrigerator or freezer.
- Rinse recycling waste if it is temporarily stored in open bins. Alternatively, store all waste in containers with tight fitting lids/seals or place open bins on insect-proof bases (e.g., Antser™ bases) and always line trash bins with plastic bags. Regularly take out the garbage to an outside storage area/dumpster.
- Ensure outside garbage cans and dumpsters have tight-fitting lids to prevent flies from completing their life-cycles in waste cans.
- If garbage cans do not have tight fitting lids, use cedar sawdust to layer over wet/organic waste in the trash bins to prevent flies from accessing food waste.
- Clean trash bins regularly with pressure washer or soap/water to ensure no thick layers of organic waste build up in the bottom of cans.
- Ensure all exterior windows that open have tight-fitting insect screens to prevent flies from gaining entry from outside.
- For stables and other livestock areas, remove animal waste on a regular basis and dispose in sealed containers or in managed compost piles.

Physical Control

- Use caulking, silicone, or expanding foam to fill cracks, holes, or other entry points in building exteriors where flies can gain entry.
- In problem areas, use sticky fly traps (ribbons) to capture excess adult flies and remove them from building interiors.
- Use baited electric traps for problem outside areas such as picnic grounds, barns, or livestock areas.

Chemical Control

In most residential and commercial situations, pesticides are not needed or recommended for control of flies, as they are not effective. Sanitation methods along with screens to keep flies out of buildings should be sufficient for nuisance fly control outside of agricultural facilities with livestock. Fly traps and strips used in problem trash areas may be effective in reducing the number of adult flies if proper sanitation practices are followed.

Stinging Insects

Buildings and structures on District lands may attract stinging insects, such as wasps, to form nests on suitable structures. For nest control, pyrethrin-type aerosol sprays containing prallethrin, and phenothrin are recommended where immediate threats exist to human health and safety. These aerosol sprays are extremely effective at immediately eliminating single problem wasp nests that threaten District staff or visitors. The pyrethrin-type sprays work as a contact neuro-poison that results in near immediate mortality of any insect (D. Jackson et al. 2011). The sprays offer a relatively safe and effective means for rangers and maintenance workers responding to immediate threats of wasp nests. Contact pyrethrins are completely non-selective, so care must be taken to target only the pest wasp and not to impact other beneficial insects. Contact sprays do not offer population-level control for wasps; diligent sanitation and early seasonal queen trapping are the only known methods to effectively reduce populations of stinging wasps in open landscapes.

Subterranean Termites, Drywood Termites, and Wood Beetles

Subterranean termites are common throughout California and tend to infest fallen trees, stumps, or other dead wood, including structural lumber in our houses. Signs of a subterranean termite infestation in buildings include the presence of shelter tubes, and evidence of tunneling in wood. Drywood termites tend to infest dry, sound wood, including structural lumber, dead limbs on trees, utility poles, decks, fences, stored lumber, and furniture. Evidence of drywood termites also includes channels or tunneling in wood structures (UC IPM 2014). Wood beetles invade and damage wood furniture as well as structural and decorative wood inside of buildings. Infestations can occur if beetles or larvae are brought into a building in furniture, firewood, or wooden decorative articles (UC IPM 2010).

Physical Control

- Treat the full perimeter of the home and any additional entry points by, and not limited to, trenching and/or rodding soil adjacent to the foundation, drilling through concrete/veneer surfaces abutting the foundation, trenching around pier blocks and plumbing pipes in the subarea.
- Remove or destroy accessible subterranean termite tubes/tunnels.
- Seal drill holes and back fill trenches, if applicable.
- Prior to tenting, the District will remove all plants, as feasible, and rake back all rock and debris along the foundation (8-10 inches) to create a proper seal for chemical work.
- Patch all injection holes, cover, or remove accessible termite evidence.

Chemical Control

- Spot Treatment (subterranean termites): Treat the affected area with fipronil. Drill into concrete if/as needed. Fill holes with concrete sealer. Treat all probable access points as needed. Remove accessible termite tubes.
- Spot Treatment (drywood termite and wood beetle): Exterminate the drywood termites by drilling small holes into the infested wood member and injecting the appropriate chemical control (e.g., fipronil, d-limonene) into the termite channels.
- Full perimeter (subterranean termite): Treat the infested area with fipronil, chlorantraniliprole, and/or dinotefuran for the control of subterranean termites.
- Tenting (drywood termite and wood beetle): The entire structure will be sealed and fumigate with sulfuryl fluoride (Vikane). Tear gas (Chloropicrin) will be used as a warning agent.
- Prevention (drywood termite and wood beetle): Apply disodium octaborate tetrahydrate to accessible exposed wood members of the attic.

5.9.2 Structural Dry Rot/Fungus

Dry rot is a wood-destroying fungus that attacks and digests the timber in buildings. Dry rot can spread without a moisture source due to its ability to generate moisture through the digestion of timber. Once spread, dry rot damages the structural integrity of buildings (Permagard, n.d.).

Treatment of dry rot includes physical and chemical control measures, which first involves wire brushing or scraping the infected area and then applying a chemical treatment of disodium octaborate tetrahydrate to the affected area. Removal and replacement of affected materials may be necessary to prevent dry rot reoccurrence and spread.

5.9.3 Structural Wildlife Pests

Structural animal pests are a diverse group of native and non-native mammals and reptiles that are especially tolerant and even attracted to human behaviors and structures. This group includes common urban pests such as house mice and roof rats as well as native forest dwellers such as woodrats, deer mice, skunks, raccoons, bats, and rattlesnakes. House mice, roof, and Norway rats typically invade urban structures. More rural, natural areas may be invaded by deer mice and woodrats. Some species (house mice, woodrats) can be controlled relatively easily in single structures as they typically establish single, temporary colonies in human structures. Others (roof and Norway rats) can be especially challenging since they have much larger, regional populations that interconnect. In all cases, the presence of increased shelter or food availability derived from the human world attracts these animals to buildings, including residential buildings, offices, and landscaped areas where they can be problematic.

District structures have the potential to be invaded by numerous species of rodents – some of which are native species that are naturally occurring in the natural areas surrounding District structures, while others are typical urban pests. Because many of the District properties occur in natural areas, the natural populations of these pest species can reinvade and repopulate the

treated areas. Most native wildlife species that are common structural pests are classified as non-game animals in California's Fish and Game Code and can be controlled with any method at any time they are found to be injuring human property. Some wildlife species have special protections and additional regulations covering their management such as game species (e.g., grey squirrels, deer), furbearers (e.g., skunks, raccoons) and special-status species (e.g., San Francisco Dusky-footed woodrat).

The following sections present pest management information by species.

House and Deer Mice

The house mouse (*Mus musculus*) and deer mouse (*Peromyscus* sp.) are both small rodents that readily invade human structures, including vehicles, in search of shelter and food. The house mouse is a widespread species that has been linked to human culture for over 1,000 years (Timm et al. 1994). It is now found on every continent except Antarctica. Deer mice are native to California and most other parts of North America. They are common in nearly every habitat in their range – from deserts to forests, as well as urban and suburban areas that interface with natural areas.

Both types of mice are omnivorous but generally prefer grain, seeds, and nuts. Both are nocturnal, have similar reproductive traits and reside in nests composed of fibrous materials. All mice species that are considered pests are capable of extremely high reproductive rates anytime during the year, making control difficult. House mice are rather plain looking versus deer mice that have light/dark fur color schemes, white feet, large eyes, and large ears.

Mouse damage includes the consumption of human foods, building nests in human structures, defecation, physical gnawing, damage to paper, clothing and other textiles and the vectoring of disease. House mice are known to carry salmonellosis, leptospirosis, and a variety of other diseases but transmission to humans is rare.

Deer mice, on the other hand, frequently carry Hantavirus. Since its first identification in 1993, there have been approximately 70 hantavirus infections in California and about 30 percent of those cases have been fatal (Egel 2017).

Prevention

- Ensure outside garbage cans and dumpsters have tight-fitting lids to prevent mice from foraging on human food waste. This is especially important in public gathering areas in parks and open spaces. Cans with domed lids and self-closing, hinged lids are preferred in these outside areas.
- Clean all kitchen and food storage surfaces regularly; sweep and vacuum kitchen floors daily. Shared use items such as sinks, microwaves, and vending machines should be cleaned regularly to eliminate spills.
- Store all food properly, in containers with tight fitting lids, or in the refrigerator or freezer.
- Store native seeds, hay, and other vegetation-based materials that can attract mice properly in sealed containers or designated sealed storage facilities.

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- Do not leave pet food in open bowls overnight. Wash pet food bowls immediately after feeding.

Habitat Modification

- Use silicone caulking and stainless steel/bronze mesh to plug/fill cracks and holes greater than ¼" in the exterior of building where mice could gain entry. Focus especially on utility penetrations, as mice are known to travel along pipes/wires. Avoid using carbon steel wool and expandable foams that degrade quickly and require repeat maintenance.
- Ensure all exterior windows that open have tight-fitting insect screens to prevent mice from gaining entry from the outside when windows are opened.
- Use galvanized sheet metal to create climbing barriers and exclude mice from travelling up vertical posts where necessary (pet cages/food storage tables/etc.).
- Mouse-proof storage facilities and seasonal buildings after visitor season ends to reduce possible nesting areas.

Physical Control

- **Box Traps (live trap).** Several types of box traps are available that are capable of trapping multiple individual mice per trapping event. These traps operate on the principle that mice are attracted to small openings and are naturally inquisitive. These traps are most successful for house mouse control. Traps should be inspected daily so live trapped mice can be humanely dispatched. In the event that repeated attempts of removal of non-native mice are not successful in a human occupied structure, lethal removal may be required as a control method.
- **Snap Traps.** Basic hardware store mouse traps offer one of the most effective means for mouse population control when executed with enough preparation, time, and effort. When uncontrolled mouse populations are present, snap traps can be used to "knockdown" large populations and then maintained to keep the population under control. Mice generally travel very short distances throughout their life – space traps approximately every 6 feet where mice are active. Time must be invested in determining where mice are active and then setting traps in appropriate locations. Pre-baiting will help prevent trap shyness and allow for the operator to test appropriate baits. Only highly desired baits should be used in the actual trapping program. Most mice species are not as trap shy as roof and Norway rats.

Chemical Control

Chemical control of mice should not be considered except under very unusual circumstances (human health and safety considerations). In the unlikely event that chemical control of mice is deemed necessary, refer to the Chemical Control section for roof, Norway and woodrats below.

Roof, Norway, and Woodrats

Roof rat (*Rattus rattus*), Norway rat (*Rattus norvegicus*), and Dusky-footed woodrat (*Neotoma fuscipes*) are medium sized rodents that readily invade human structures, including vehicles, in search of shelter and food. With the exception of the native woodrat, rats represent some of the

most challenging pest rodents to control in urban environments (Timm et al. 1994). Roof and Norway rats can be present in very large numbers in urban areas. Their home ranges are much larger than those of mice so effective treatment is challenging and may require treatment of more than a single structure. Both the roof and Norway rat are a widespread pest species that have co-evolved with humans for thousands of years.

Dusky-footed woodrats are native California mammals that are occasionally considered pests when they invade structures from nearby wildlands. All woodrats found on District lands are the San Francisco Dusky-footed woodrat (*Neotoma fuscipes annectens*), which is a CDFW Species of Special Concern. Control of woodrats, as with all native species, should first focus on prevention instead of physical or chemical control.

Like cockroaches, rats trigger general feelings of disgust in humans as they are thought to be representative of dirty living conditions and squalor. They do bite, and many people in the U.S. suffer from rat bites each year. Rats are known to carry diseases that can be transmitted to humans. Most of the actual rat damage in the United States is structural damage caused by burrowing (Norway rats), or contamination of food products, textiles, and living spaces resulting from defecation (Norway/roof/woodrats), and damage to agricultural crops and landscaping (roof rats). Woodrats typically build elaborate nests in wildland areas but can also be nuisance pests in structures where they make nests and cache food. Woodrats also are the only species of rat known to carry Hantavirus and Arenavirus in North America, both of which can be deadly to humans (Timm et al. 1994).

Prevention

- Ensure outside garbage cans and dumpsters have tight-fitting lids to prevent rats from foraging on human food waste. This is especially important in public gathering areas in parks and open spaces. Cans with domed lids and self-closing, hinged lids are preferred in these outside areas.
- Clean all kitchen and food storage surfaces regularly; sweep and vacuum kitchen floors daily. Shared use items such as sinks, microwaves, and vending machines should be cleaned regularly to eliminate spills.
- Store all food properly, in containers with tight fitting lids, or in the refrigerator or freezer.
- Do not leave pet food in open bowls overnight. Wash pet food bowls immediately after feeding.

Habitat Modification

- Inspect building exterior for possible rodent entryways. Especially inspect attics for signs of rat occupation and openings or gaps between the structure and roofs or foundations. Use silicone caulking and stainless steel/bronze mesh to plug/fill cracks and holes greater than ½" in the exterior of buildings where rats could gain entry. Focus especially on areas where utilities enter the buildings, as rats are known to travel along pipes/wires. Avoid using carbon steel wool and expandable foam that degrade quickly and require repeated maintenance.

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- Ensure all exterior windows that open have tight-fitting insect screens to prevent rats from gaining entry from outside when windows are opened.
- Use galvanized sheet metal to create climbing barriers and exclude rats from travelling up vertical posts where necessary (e.g., utility poles, pet cages, food storage areas, tables).
- Rodent-proof storage facilities and seasonal buildings after visitor use season ends to reduce possible nesting areas.
- If they appear to be a constant source of infestation, woodrat nests within 100 feet of buildings will be moved after consultation with the CDFW.

Physical Control

- **Box Traps (live trap).** Several types of box traps are available that are capable of trapping multiple individual mice per trapping event. These traps operate on the principle that rats are attracted to small openings and are naturally inquisitive. These traps are most successful for rat control. Traps should be inspected daily so live trapped rats can be humanely dispatched. In the event that repeated attempts of removal of non-native rats are not successful in a human occupied structure, lethal removal may be required as a control method.
- **Snap Traps.** Basic hardware store rat traps offer one of the most effective means for rat population control in small structures with small rodent populations. Where large rat populations are present, snap traps can be used to “knock down” the population size in conjunction with other management techniques (prevention, habitat modification) to keep the population under control. Time must be invested in determining where rats are active and then setting traps in appropriate locations. Roof and Norway rats are inherently wary of new objects in their environment, including rat traps. Pre-baiting is essential to allow rats to associate rat traps with feeding stations, a process that may take several weeks. Only after rats have become used to traps should the trapping portion of the control effort move forward.

Chemical Control

The District is aware of the potential for secondary effects of rodenticide use in and near natural lands on native wildlife species, and is committed to strictly regulating rodenticide uses on its lands to the full extent possible. The District intends to use all non-chemical control options before selecting rodenticides as a treatment option, except in instances where rodent infestations are determined to present a public health issue. The District’s goal is to reduce all rodenticide use on its lands over time to the full extent possible, while still protecting human health. The following section carefully lays out the effects and limitations of each type of rodenticide product, and provides guidance for selection of the least toxic effective treatment option if chemical control of rodents must be used.

Primary Versus Secondary Poisoning

Non-target poisoning is divided into two scenarios: 1) a non-target animal intercepts the bait – referred to as “primary exposure”; and 2) a non-target animal ingests a prey species that has

been exposed to the toxicant – referred to as “secondary exposure.” Rodenticides typically have high degrees of mammalian toxicity compared to other types of pesticides, so it is important to control how these compounds are presented to target rodent pests. Acute toxicant baits can attract non-target mammals and birds so these baits must be presented in environments where only rodents have a chance of encountering them.

Sealed box bait stations are now common for nearly all rodent baits used in structures to prevent pets and people from encountering baits. Bait stations are usually designed for urban environments and they offer little protection to stronger wildlife species such as raccoons and badgers, that can easily open them (Erickson and Urban 2004). To better protect non-target wildlife species in the urban-wildlife interface, custom protective devices can be installed to shield bait stations from non-target wildlife species. Because predators generally prefer to catch and eat live prey, acute toxicants (the products that work quickly on the target animal resulting in a quick mortality) rarely cause secondary exposures to predators and scavengers.

Acute Rodenticide – Cholecalciferol (Vitamin D3)

Cholecalciferol is a natural form of Vitamin D that is industrially synthesized from lanolin (sheep’s wool) to produce human dietary supplements and rodent poison. In very high doses, it causes mobilization of calcium from the bone matrix to blood plasma, causing hypercalcemia and death. It is especially toxic to rodents and a single dose of toxicant acts as an acute poison. It is the only current rodenticide in California labeled for organic food production (OMRI 2025). Cholecalciferol is considered a novel mode of action for rodenticides and can be used in urban areas where rodents have developed resistance to other anticoagulants (Marshall 1984). It is considered a low risk for secondary poisoning in wildlife but can be a hazard to non-target pets that directly consume the bait. Rodenticides will only be used inside buildings in tamper-proof anchored containers.

Skunks, Opossums, and Raccoons

Skunks, opossums, and raccoons are native mammals that have the potential to take residence in District structures as unwelcome guests. All these species are exceptionally common on District lands and generally will not bother humans. On rare occasions, they may invade trash cans, open kitchens, or den under and within structures. CDFW regulates these species as nongame or furbearer animals so they all may be controlled without permits if found causing agricultural damage or nuisance problems.

Prevention

- Ensure outside garbage cans and dumpsters have tight-fitting lids to prevent foraging on human wastes. This is especially important in public gathering areas in parks and open spaces. Cans with domed lids and self-closing, hinged lids are preferred in these outside areas.
- Clean all kitchen and food storage surfaces regularly; sweep and vacuum kitchen floors daily. Shared use items such as sinks, microwaves, and vending machines should be cleaned regularly to eliminate spills.

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- Do not leave pet food in open bowls overnight. Wash pet food bowls immediately after feeding.

Habitat Modification

- Use stainless steel/bronze mesh or welded wire to plug/fill cracks and holes in the exterior of buildings where large animals could gain entry.
- For larger openings, such as under decks and porches, fully enclose with plywood, concrete, or wire mesh to prevent animals from making dens under structures. If animals are already denning in the area, use one-way, hinged doors to allow them out but preventing them from returning. Confirm there are no juvenile animals in the den before using one-way doors.
- For raccoons in challenging areas, a single electrified strand of wire elevated eight inches from the ground can be used to deter them from entering the area.

Physical Control

- **Box and Cage Traps.** All skunks, opossum, and raccoons are easily trapped with live box or cage traps. Trap design varies but solid wall traps are preferred for skunks to shield the trapper from skunk spray during the control operation. The use of live trapping methods ensures that non-target animals can be released unharmed. Current CDFW trapping regulations require that trapped animals are either released immediately or euthanized; live animals may not be relocated without a permit from CDFW.

Chemical Control

Currently there are no toxicants or fertility control agents available in California for these species.

Bats

Bats are California's only flying mammal. There are a wide variety of bats (more than 16 species) that inhabit all habitats in the Bay Area; some are solitary and others colonial. All California bat species are insectivorous and they provide an ecologically valuable service of consuming vast quantities of insect pests such as mosquitoes (Gannon 2003). Though they generally benefit humans greatly, bats secretive nature, nocturnal habits, ability to fly, and habitation near humans have contributed to folklore, superstition, fear and ultimately persecution.

Some species of colonial bats can become structural pests when they establish colonies in homes or other human structures. Some species prefer dark open spaces, such as attics and basements and others prefer small cracks/crevices, such as between roof tiles/shingles or behind shutters (Greenhall and Frantz 1994). One human structure can support a wide diversity of bat species. Though many bat species are tolerant of humans, many humans are not tolerant of bats.

Common damages caused by bats are noise coming from bat roosts, smell of their urine and guano, potential disease such as rabies and histoplasmosis, and discomfort anytime their presence is too close to humans in structures (CDFW 2015). Most bat damage can be mitigated

with prevention and habitat modification techniques to make human structures less inviting or completely exclude bat roosting.

Prevention and Habitat Modification

- Carefully assess where bats are entering structures and modify the building to exclude future entry. Since bats are extremely small, fly, and can squeeze into very small spaces, assessing bat entry points can be a tedious and challenging exercise. Evaluate spaces during day/nighttime hours; use infrared cameras to assist in detecting breeches to the building envelope (smoke pens may be permitted in structures with a verified absence of bats). Consult bat exclusion specialists for challenging structural projects.
- Install flashing, screening, or netting in obvious roof/gable areas where bats can roost.
- Caulk cracks in masonry, especially chimneys.
- Use one-way trap doors to allow bats to escape roost areas after exclusionary methods are completed. Bat exclusion requires CDFW approval. Bat exclusion work will be avoided during the winter torpor period (November 15 through February 15) and summer maternity roosting season (April 15 through August 31).

Trapping

Trapping is not recommended as it is more time consuming and less effective than strategic exclusion as discussed above.

Chemical Control

Currently there are no toxicants or fertility control agents available in California acceptable for use on bat species.

5.9.4 Feral Domestic Pets

Domestic pets such as feral cats and dogs can sometimes become structural pests. Uncontrolled feral domestic pets, unlike most wildlife, are often highly habituated to humans and therefore much more likely to come in very close contact with District staff, tenants, visitors, and livestock (Information Services Division 2012). These close encounters can lead to increased chances of physical injury, disease transmission, contamination of District facilities, and injury to tenant livestock.

Cats and dogs are generally considered private personal property when ownership can be established through collars, registration tags, microchips, tattoos, brands, or other proof of ownership. Pets without identification can be considered free roaming, uncontrolled private property, or feral animals. In California, both state and local laws govern domestic animal damage control under Fish and Game code, agriculture codes and local ordinances.

District staff consult local city and county ordinances and animal control departments when conducting any domestic animal control actions.

Prevention and Habitat Modification

- Feral domestic pets are often relics of old structures/settlements. If the District inherits older buildings/infrastructure, consider demolition or wildlife exclusion retrofitting so the structures can no longer support animals.
- Control of excessive rodent populations in structures can also help control feral cat populations.
- Ensure outside garbage cans and dumpsters have tight-fitting lids to prevent foraging on human food waste. This is especially important in public gathering areas in parks and open spaces. Cans with domed lids and self-closing, hinged lids are preferred in these outside areas.
- Ensure District staff and tenants have properly placed any bird feeders or bird nest boxes such that they do not also serve as cat feeding stations.
- Prohibit staff and tenants from feeding feral domestic pets on District property. Develop education programs to encourage the public not to feed wildlife or feral animals on District property.

Trapping

Live trapping is effective to capture problem cats but generally ineffective for dogs in California (Green and Gipson 1994; Fitzwater 1994). Because feral domestic pets may be private property, District staff conduct all trapping in conjunction with local animal control departments and/or animal shelters.

6 IPM for Recreational Facilities

6.1 Definition and Purpose

Human use is typically concentrated on preserves at the recreational facilities provided by the District. Recreational facilities within District preserves currently include approximately 518 miles of access roads and trails as well as associated infrastructure (e.g., bridges, culverts, drainage ditches, parking lots, gates, stiles, bathrooms, picnic areas, one campground, off-leash dog zones, managed turf and landscaped recreation areas, pond viewing and dam areas, and Deer Hollow Farm).

Nuisance pests in and around recreational facilities include plants, insects, and wildlife that can temporarily affect the District's visitor experience in a negative manner. Sometimes nuisance pests at recreational facilities become problematic when there are extra resources readily available (e.g., food, water, shelter) and therefore can be managed with physical control options (e.g., controlling food-trash in picnic and camping areas).

The purpose of pest control in and around recreational facilities is to manage pests for human enjoyment of the natural and scenic qualities of the preserves while also minimizing human exposure to pests. The maintenance of vegetation alongside roads and trails and the control of stinging or biting insects or reptiles at recreational facilities must incorporate protection of the surrounding natural resources as a primary consideration. Unlike buildings, recreational facilities are almost always located in natural (undeveloped) areas, therefore, pest control solutions must also consider protection of the surrounding natural resources as a primary consideration.

6.2 Type of Pests

Nuisance pests include native and naturalized plants, insects, and wildlife that are present throughout the region and are generally compatible with the District's mission and goals. Conflict only occurs when these species become overabundant or exceptionally close to staff and visitors. For example, native stinging insects in outside areas are normally tolerated, but a stinging insect nest in a public bathroom is considered an unacceptable risk to visitor health and enjoyment of District lands. Recreational facility pests include mosquitoes, stinging insects, ticks, rattlesnakes, and other native and domestic animals, as well as vegetative pests such as poison oak.

The determination of a nuisance pest can be quite variable depending on the tolerance of staff or the visitor to any real or perceived harm. Care must be exercised when defining tolerance levels

for each pest species. One must consider the actual damage potential of the organism versus the cultural acceptance to the risk that the organism poses. For example, poison oak is an important native plant that occurs throughout District lands and is quite common along trails. Educating the public about the effects of poison oak exposure to humans (dermatitis) is the first option to reducing perceived risk of exposure to this pest. When visitors complain about incidences of poison oak exposure, District staff must consider the context of the poison oak exposure risk. At trailheads, campgrounds, and other areas where potential for frequent visitor interactions is high, staff may elect to routinely control poison oak. In contrast, infrequent brushing and/or installation of educational signs may be appropriate for poison oak at remote, backcountry trails that are rarely visited. The District's recreational facility IPM decision-making must always balance health and human safety concerns with the District's goals to protect natural resources.

6.3 Pest Identification

Nuisance pests are generally identified by chance encounters by District staff, tenants, and visitors. Because recreational facilities have more intensive use than the District's surrounding natural areas, nuisance pests can usually be identified relatively quickly before the problem reaches levels where active pest management is required. Routine inspections of recreational facilities should focus on identifying conditions where visitor use levels are high, and where conditions can result in excess food, shelter, and access that support pest problems.

Many nuisance pests can be anticipated and their management scheduled based on an understanding of their biology and behavior. For example, some types of native vegetation grow outwards onto roads and trails in search of light and space, and preventative treatment (brushing) can be scheduled on an annual or periodic basis. District staff can identify problem areas with excess vegetation along trails each year, and schedule abatement accordingly. Other pests may present themselves randomly and/or rarely. For example, a rattlesnake denning along a trailside is a relatively infrequent occurrence. These infrequent pest problems are usually best reported when the staff and/or visitors encounter them.

6.4 Prevention and Retrofit

Nuisance pest control in recreational facilities focuses on first modifying the behavior of humans or the environment structure to reduce or eliminate the problem. The District's IPM Program relies on cultural pest control practices, such as product design or retrofit and behavior modification as the primary pest control treatments, with active chemical or lethal controls used only as a last resort.

This section describes general operational procedures intended to prevent or minimize the need for pest control in recreational facilities. The District will undertake some or all of the following to help prevent pest infestation from reaching action thresholds:

- Staff training,

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- Public education regarding identification and avoidance of naturally-occurring nuisance pests,
- Structural changes intended to pest-proof recreational facilities,
- General sanitation and maintenance actions,
- Landscape maintenance, and
- Waste management procedures.

District procedures for these preventative actions are described in more detail below.

6.4.1 Prevention

Many pest outbreaks can be managed with cultural control options such as changing human behavior (e.g., promoting removal of food-related trash, installing educational signs promoting human avoidance of naturally occurring pests, temporary closures of facilities during periods pests are most likely to be present to physically separate visitors and pests) and engineered control options within our recreational facilities (e.g., securing garbage cans, managing vegetation around heavily used recreational facilities, sealing off buildings and structures). Many open space and park districts throughout the nation have dramatically reduced human-wildlife encounters by simply making food and garbage unavailable with wildlife-proof garbage cans (Decker et al. 2008; Herrero et al. 2005). This simple, single engineering solution reduces wildlife habituation to humans, ultimately reducing human conflicts with stinging insects, raccoons, skunks, coyotes, and other naturally-occurring nuisance pest species.

Feeding wildlife can significantly increase nuisance wildlife problems in the District. Using postings and other educational materials in District picnic areas, parking lots, and trailheads can help inform the public that feeding wildlife ultimately causes them great harm. Postings should emphasize that passive feeding (i.e., poor sanitation) is as detrimental to wildlife as active feeding, and that visitors should remove their food-related trash at the end of their visit. Educational postings for conservation related topics are best supported by both active and passive enforcement, or otherwise tend to be ineffective (Baruch-Mordo et al. 2011).

Recreational facility pest problems are often temporary in nature. Rattlesnakes and skunks may temporarily occupy a facility, but otherwise remain unseen by visitors. Instead of actively managing the pest itself, the District can install educational signs promoting human avoidance of naturally occurring pests, or the facility can be temporarily closed (for buildings and other facilities) or rerouted (for trails) so District staff or visitors remain safe during time periods when pests are most likely to occur.

6.4.2 Retrofit

The District will train staff to regularly assess and manage the areas within recreational facilities that are known to attract pests. Some examples of such areas include:

- Storage areas for tools, seeds and plant materials, food, research supplies;
- Waste management areas: trash cans, trash compactors, dumpsters, etc.;
- Drainage areas;

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- Plumbing (faulty plumbing such as leaky pipes can support pests);
- Entryways and windows (ensure tight seals to prevent pest entry);
- Landscaped areas, especially immediately adjacent to buildings; and
- Storage areas (such as woodpiles) located next to buildings.

District supervisors should regularly inspect such areas and provide additional training or educational materials to encourage staff to keep such areas clean and pest free. Additionally, in buildings used for storage of equipment and vegetation materials, items such as seed, hay, or livestock feeds, and all other materials that could attract rodents, will be sealed in plastic or metal containers with tight fitting lids. Actions to prevent or reduce nuisance pests in recreational facilities include:

- Train staff in proper storage of work supplies in non-occupied buildings.
 - Store all pet food, animal grains, hay, and other consumable agricultural supplies in sealed containers metal/plastic containers.
 - Store plant seeds used for habitat restoration and landscaping in sealed containers.
- Position attractive harborage areas, such as rock piles, soil storage piles, hay, and erosion control materials away from recreational facilities.
- Control food waste in contractor work areas, outbuildings, storage areas, and other non-occupied recreational facilities. Provide sealed garbage containers in or near such areas to prevent inadvertent disposal.
- Reduce, monitor, and where possible, eliminate use and import of natural materials that could introduce pests onto District lands, such as reducing use of off-site fill (soil, gravel, and rock) and livestock feeds (hay) that may contain weed seeds. Where possible, include requirements to use on-site fill, require balanced cut and fill projects on District lands, and require use of certified weed-free erosion control materials for construction projects on District lands.

In addition, landscaping around recreational facilities can harbor pests. Maintenance staff should prune back or remove dense vegetation such as ivy and any landscape vegetation that touches buildings, providing a physical pathway for pests such as ants to access the building. In addition, maintenance of healthy landscapes through proper fertilization, watering, pruning, and aeration is also thought to reduce potential for pests to reach problematic levels.

Landscape design and good landscape maintenance practices can discourage pests and encourage healthy plantings that may resist pest establishment. Some options for pest prevention and reduction in landscaped areas include:

- Appropriate cleaning and maintenance of tools and equipment;
- Selection of new landscape design intended to discourage landscape pest species;
- Replacement of older landscaping design when it is found to harbor pests (e.g., dense vegetation such as ivy near buildings);

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- Monitoring of landscaping plants for secondary pests (such as aphids or scale), and treatment as necessary to prevent nuisance pest outbreaks (such as ants).
- Ensuring new planting materials are clean of pests and disease;
- Selection of pest-resistant plants for landscape maintenance projects;
- Positioning planting sites away from buildings; and
- Proper irrigation design, and proper watering practices.

In the event of a pest outbreak in landscaped areas, choose least environmentally disruptive and harmful, effective treatments for landscape pest species.

6.4.3 Timed Maintenance

Many nuisance pests can be managed through preventative treatments based on an understanding of their biology and behavior. This is especially true for the District's routine maintenance needs for horticultural landscaping and native vegetation along gates, stiles, trails, and access roads. Native vegetation grows vigorously after being cut because of plant hormone responses and changes in the availability of soil nutrients (Parr and Way 1988). Vegetation types that are regularly mowed with mechanical equipment have predictable regrowth times that can be measured and incorporated into routine District maintenance schedules. To prevent road and trailside vegetation from becoming a nuisance pest, mechanical brushing can be scheduled for specific times of year to abate the hazard before it becomes a problem. Roadside brushing also serves as secondary control for other nuisance insect and wildlife species. The reduction of cover near trails reduces the chances that visitors and staff will encounter ticks and rattlesnakes.

Some native perennial vegetation (e.g., poison oak or stinging nettles) is less tolerated by humans than other types of native vegetation. The presence of such vegetation may not be appropriate for some trailside locations that have high visitation rates. These special circumstances require the use of more complex management tools for perennial plants such as chemical control. Refer to vegetation management options presented for perennial plants, as detailed in Chapter 8, Table 8-5 for such special circumstances.

6.4.4 Plant Healthcare

Many nuisance pests in horticultural landscaping and turf (e.g., as mildews, rusts, aphids, whiteflies) can be controlled with routine and proper horticultural practices. Proper watering, fertilization, and cutting/pruning can ensure horticultural plants have sufficient resources to grow well without providing support to fungal, insect and mammalian pests. Horticultural plants that are especially susceptible to nuisance landscaping pests should be considered for replacement with more suitable varieties. Often pests can be 'designed' out of the landscape by choosing more appropriate species or varieties for a specific location.

6.5 Damage Assessment

Determine what, if any, damage to recreational facilities or the visitors using them is present. To the extent possible, quantify the damage (square feet or number of occurrences affected) and qualitatively describe the perceived damage.

6.6 Tolerance Levels/Thresholds for Action

If there is no damage to a recreational facility, but a nuisance pest is present that conflicts with human use or enjoyment of the structure, determine the tolerance level for each nuisance pest species to assess if control is warranted. Recreational facility IPM focuses on modifying the structure of the environment to balance nuisance pest conflicts with visitor needs. In recreational facility pest management, often small retrofits or facility modification can reduce risk of exposure or manage the pest population down to acceptable tolerance levels.

Tolerance levels vary greatly for nuisance pests in recreational facilities. Most nuisance pest species are native species that are compatible with the District's goals for conservation. The District's IPM approach for nuisance pest species begins with establishing tolerance levels that balance human safety, enjoyment, and comfort within visitor facilities with the ability to conserve natural resources, meet regulatory requirements and cost/benefit assessment. Human safety and enjoyment is the primary metric for establishing tolerance levels in visitor facilities. Staff and visitor safety is paramount in regulating treatment actions for nuisance pests. Tolerance levels will consider conservation goals and impacts to the larger surrounding natural system in determining treatment actions.

Refer to Table 6-1 below for management thresholds, and possible treatment options for nuisance pests in and near recreational facilities, presented by pest category.

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Table 6-1 Management Thresholds and Treatment Options for Nuisance Insect, Animal, and Plant Pests in Recreational Facilities

Pest Category	Management Threshold (Population Size/Conditions)	Treatment
Mosquitoes	Detection of pest at levels that could cause human health problems, populations causing visitor discomfort, or as required by local regulatory agencies.	Use a combination of the following: • Inspect areas in vicinity of problem area for standing water and other potential mosquito breeding sites. Where possible, repair or drain /eliminate potential breeding habitats. • Educate visitors about mosquitoes and human health risks by posting temporary signs in problem areas. • Protect workers by requiring use of protective clothing when working in affected areas. • Use BTI (<i>Bacillus thuringiensis israelensis</i>) discs in water troughs. For ongoing pest issues, contact a local county Mosquito and Vector Control District to schedule treatment (District to comply with legal requirements to control mosquitoes for human health and safety).
	Populations causing conflict with humans near structures or other high use visitor areas	Use a combination of the following: • Remove or enclose attractants in well-sealed containers (trash cans, etc.) • Use baited non-toxic water traps (late winter and early spring) • Use non-toxic lure traps set approximately 200 feet apart.
Stinging Insects	Nests determined to pose immediate threat to human safety	Use a combination of the following: • Physically remove problem nests with water jets or by digging • Use Pyrethrin aerosol spray to target individual nests.

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Pest Category	Management Threshold (Population Size/Conditions)	Treatment
Ticks	Detection of multiple individual in work areas or offices, tick populations causing visitor discomfort.	Use a combination of the following: • Remove and destroy individual ticks. • (See also preventative trail maintenance for native vegetation below.)
Rattlesnakes	Individuals within structures or recreational facilities where contact with humans is likely	Use a combination of the following: • Trap and relocate (obtain appropriate permits from CDFW). • Block access to structures and remove hiding places adjacent to structures and high public use areas.
Native vegetation along trails and roads (poison oak, stinging or scratching plants, brush)	Conditions could cause severe discomfort or health hazards to visitors, volunteers, and staff, or vegetation that is blocking emergency access.	Follow District guidelines for trail clearing in various habitats and slopes. • Mow and prune buffers along trails and roads to reduce direct contact by visitors. • Herbicide use on perennial species only if permanent control is needed.

6.7 Treatment Options

In recreational facilities, pest tolerance levels are based on ensuring the health and enjoyment of visitors, in addition to human health and safety requirements, by following the District adopted details and specifications for trail and other recreational facilities.

When the presence of pests in recreational facilities is determined to require action, pest prevention actions the District may consider in recreational facilities include:

- Reducing the attractiveness of the recreational facilities areas to pests. For example, remove rock and brush piles that are attractive to snakes; seal small burrows and holes that attract ground-dwelling pests; regularly remove food debris that can attract wildlife (e.g., skunks, ravens).
- Educating the public about interactions with wild creatures such as snakes and ticks, and providing suggestions for avoiding unpleasant or dangerous interactions. Support this action with proactive enforcement.
- Sealing up entrances in and near recreational facilities to discourage pest occupation (e.g., screening air vents to bathrooms, screening in overhangs to prevent pests from entering the facility).

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- Cutting back unwanted brush, such as poison oak, along trailheads and high use trails to reduce potential for visitor interaction.
- Mowing high grasses along heavily used trails where ticks tend to congregate.

Pest management options for nuisance pests in and around recreational facilities are the same for insect and wildlife pests in buildings that is described above in Chapter 5. The following section describes additional nuisance pests that are not covered in Chapter 5.

Where pesticide use is determined to be the only viable treatment option to address the specific infestation of concern in and around recreational facilities, selection of least harmful products is required. In these limited instances, only pesticides on the District's List of Approved Pesticides (Table 3-3) may be used.

The chemical control options presented in this Chapter represent the least harmful, most efficient treatment methods for controlling structural pests. For example, a wasp nest in a public restroom may require use of a pyrethroid wasp spray to immediately eliminate the hazard of wasp injury to visitors. The inclusion of a variety of pest treatment method options in the IPM Program allows the District to respond with the necessary tools based on actual risk to the District, its visitors, workers, structures, and lands.

6.7.1 Mosquitoes

Definitions

Mosquitoes are a family of small, midge-like flies in the *Culicidae* family. Most mosquitoes are considered a pest species because they consume blood from vertebrates, including humans and can transmit diseases and cause uncomfortable dermatitis. Mosquitoes go through four life stages: egg, larva, pupa, and adult. The first three life stages are largely aquatic and last approximately 14 days. Control of wet areas, including stagnant standing rainwater, stock ponds, and even ponded water from leaky pipes is therefore an effective control strategy for controlling this pest species. The females of many, but not all species of mosquitoes consume blood during a portion of their life cycle. In feeding on blood, some species of mosquitoes can transmit extremely harmful human and livestock diseases, such as West Nile virus and Malaria. Therefore, pest control focuses on elimination of stagnant water and wet area habitats, and on control of adults' population numbers where a health concern is detected.

Although mosquitoes are members of the ecosystems of natural areas, the threat of mosquito bites makes them unwelcome in and near buildings and recreational facilities. Mosquitoes are generally only considered pests when their population numbers are incompatible with human health and safety, at which point the District will contact the appropriate county Mosquito and Vector Control District. The county Mosquito and Vector Control District is the agency responsible for monitoring disease outbreaks and implementing necessary pest control for human health and safety.

Pest Management Strategies for Mosquitoes

Prevention

In addition to actions taken by local county Mosquito and Vector Control District to detect and control mosquito populations in natural areas, the District can also implement many non-chemical, cultural control methods to prevent infestation or reduce the number of adult mosquitoes that come into contact with workers and visitors. Depending on the situation, the most important usually include:

- Source reduction (e.g., removing nearby stagnant water), and
- Education (e.g., posting public information signs to inform visitors about mosquitoes and human health risks).

Physical Control

- Install and maintain window screening in recreational buildings.
- Train staff to protect themselves from exposure by wearing long-sleeved clothing, tucking pant legs into socks and/or taping pant cuffs close to the body.

Biological Control

The District places *BTI* discs (*Bacillus thuringiensis israelensis*) in watering troughs throughout the preserves to control mosquitoes. *BTI* is a specific type of bacteria that prevents mosquito larvae from developing.

Chemical Control

Where chemical control is determined to be the only viable treatment option to address the specific infestation of concern in and around recreational facilities, the District will contact the appropriate county Mosquito and Vector Control District for assistance and will comply with legal requirements to control mosquitoes for human health and safety.

Repellents (active ingredient: N,N-diethyl-meta-toluamide (DEET) or picaridin) can be applied to the skin or clothing, to dissuade insect pests, including mosquitoes, from attacking District staff or workers. Use of repellents will be limited and infrequent.

6.7.2 Stinging Insects

Definitions

Stinging insects are a large group that generally include social wasps such as yellow jackets, hornets, and mud daubers. Wasps' yellow and black color schemes and social behavior are shared with distantly related bees. Like bees, wasps are an important group of native insects that perform valuable ecological functions in our natural world (Dennis Pittenger 2015). Most of the species in this group are generalist insect predators that are essential in their natural environments to aid in decomposition, control populations of other insects, and some even pollinate flowers like bees. Although wasps are important members of the ecosystems of natural areas, the threat of wasp stings makes them unwelcome intruders in and near buildings and recreational facilities. Stinging insects are generally only considered pests when their nests are in areas where they are incompatible with human use. For example, when stinging insects

nest under the eaves of buildings or alongside trails, they can sometimes exhibit aggressive protective behaviors that can threaten humans with painful and sometimes dangerous stings. Where multiple stinging incidents occur, District staff will consider control of wasp nests.

Wasps belong to a large group of insects in the order *Hymenoptera* that includes ants, bees, and wasps. Many genera and species within *Hymenoptera* are difficult to tell apart as they share similar body shapes and color schemes. Because many of these *Hymenopteran* insects have protective stings and bites, even some other species outside the family like flies have adapted their body styles to mimic wasps. For this reason, staff must be careful to properly identify the pest to species to ensure that it is an actual nuisance pest species that can sting, rather than a similarly shaped or colored harmless species.

Like honeybees, wasps are social organisms that live together in colonies where individuals have specialized roles. Queens emerge from hibernation each spring to build nests and start larger colonies composed of workers. Pupae are raised in cell-like structures within paper or mud nests that are tended by workers and queens. Different species build different types of nests – from small mud structures that are attached to ledges to aerial and underground paper-type nests. Different species also have different foraging habits. Some prefer hunting for carrion and sweet liquids while others prefer hunting live prey. The species that forage for carrion and sweet liquids are often the most problematic individuals that disturb picnickers.

Pest Management Strategies for Stinging Insects

Prevention

- Ensure outside garbage cans and dumpsters have tight-fitting lids to prevent wasps from foraging on human food wastes. This is especially important in public picnic and gathering areas in parks and open spaces. Cans with domed lids and self-closing, hinged lids are preferred in these outside areas.
- Periodically clean the hinged-lids of garbage and recycling bins so spilled sweet liquids do not attract wasps to picnic areas.
- Ensure all exterior windows that open have tight-fitting insect screens to prevent wasps from gaining entry from the outside when windows are opened.
- If concessionaires sell soft drinks and other sweet liquids on District properties, require drinks to be sold with straws and tight-fitting lids to prevent wasps from entering drinking containers while in use.

Physical Control

- Install baited non-toxic water traps in late winter and early spring to reduce queens in problem areas where wasps are known to be regularly problematic.
- Install pesticide-free lure traps set approximately 200 feet apart in outside problem areas where human/wasp conflicts are known to occur (e.g., picnic areas, outside amphitheaters). Place traps between the center of human activity and natural areas to attract wasps away from humans instead of attracting more wasps to human areas.

- Physically remove problem wasp nests with water jets or by digging them out of underground locations. Ensure pest control workers wear protective beekeeper suits to reduce the potential for dangerous stings.

Chemical Control

Pyrethrin-type aerosol sprays containing prallethrin, and phenothrin are only recommended where immediate threats exist to human health and safety. These aerosol sprays are extremely effective at immediately eliminating single, problem wasp nests that threaten District staff or visitors. The pyrethrin-type sprays work as a contact neuro-poison that results in near immediate mortality of any insect (D. Jackson et al. 2011). The sprays offer a relatively safe and effective means for rangers and maintenance workers responding to immediate threats of wasp nests. Contact pyrethrins are non-selective, so care must be taken to target only the pest wasp and not to impact other beneficial insects. Contact sprays do not offer population-level control for wasps; diligent sanitation and early seasonal queen trapping are the only known methods to effectively reduce populations of stinging wasps in open landscapes.

6.7.3 Ticks

Definition

The western black-legged tick (*Ixodes pacificus*) is a native arachnid (i.e., spider relative) that is very common in grasslands, scrub, and woodlands throughout District lands. Black-legged ticks are common parasites of native mammals such as deer, but they can also be problematic parasites of District visitors and staff. To complete their life cycles, ticks must feed on blood and for this reason can also be dangerous vectors that can transmit blood-borne diseases such as Rocky Mountain spotted fever, Lyme disease, and tularemia (CDC 2022). Ticks are an important part of the natural environment and are present on District lands in abundance. Due to their prevalence in naturally occurring deer populations that move through District lands, eradication of ticks in natural areas is impossible; however, some level of preventative control may be warranted in high visitor use areas in and around recreational facilities and buildings. Ticks can be especially problematic indoors where field staff work and store clothing; staff returning from field work can unknowingly introduce ticks into buildings where they can be transmitted to unsuspecting office workers.

Pest Management Strategies for Ticks

Prevention

- In high visitor use areas, regularly cut or mow alongside trails and picnic areas to reduce the chance of visitors and staff picking up ticks. Ticks often summit tall grass blades and shrub branches to “catch” or brush against a passing animal. Keeping vegetation cut low and pruned reduces the opportunities for ticks to implement this strategy in areas with high pedestrian use.
- Post tick educational materials in District offices and at major trailheads and parking areas.
- Regularly vacuum carpeted areas where District employees work.

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- Ensure all exterior windows that open have tight-fitting insect screens to prevent ticks from gaining entry from outside when windows are opened.

Physical Control

- Install carbon dioxide traps daily to collect ticks in field offices where field staff regularly begin and end field days. This may be especially effective in staff changing rooms where field clothes are shed, changed, and stored.
- Train staff to protect themselves from exposure by wearing light colored long-sleeved clothing, tucking pant legs into socks and/or taping pant cuffs close to the body; performing regular inspections of clothing and exposed areas such as the head and neck; and showering or bathing and inspecting their bodies as soon as possible upon completion of work.
- Post educational signs with the information above to inform visitors of tick prevention and detection strategies they can employ before and after using recreational facilities.
- As ticks are found, remove and destroy individuals.

Chemical Control

No chemical control strategies are recommended for ticks; however, repellents (active ingredient: DEET or picaridin) will be applied to the skin or clothes to dissuade insect pests, including ticks, from attacking District staff and workers. Use of repellents will be limited and infrequent.

6.7.4 Nuisance Animals

Rattlesnakes

Definition

Rattlesnakes are the only type of venomous snake found in California. They are native to California and are important predators that help keep rodent populations under control. Rattlesnakes are generally extremely wary of humans and tend to shy away from human activities. They are not aggressive towards humans unless cornered, surprised, or stepped-on. Occasionally, they can be considered nuisance pests when they find themselves too close to recreational facilities, occupied buildings, or other areas where human encounters are likely. Though important to the natural world, the threat of rattlesnake bites makes them unwelcome pests in certain portions of District lands.

Pest Management Strategies for Rattlesnakes

Prevention

- District field staff can protect themselves from rattlesnake bites during workdays by wearing high-top leather boots and snake-resistant chaps or gaiters. Snake gaiters are also useful in preventing the dispersal of non-native weed seeds, since weed seeds usually do not penetrate the gaiters.

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- Educational materials can warn visitors about rattlesnake hazards and suggest preventative actions such as wearing protective clothing, as described above for District field staff.

Habitat Modification

- Eliminate hiding places for snakes by trailheads and parking areas with brushing, removing rock and brush piles near busy human use areas especially those with children, and filling cracks and holes in publicly accessible buildings. Use stainless steel/bronze mesh or welded wire to plug/fill cracks and holes in the exterior of buildings where snakes could gain entry.
- Where rattlesnake sightings are common, manage recreational facilities during the spring and summer months to reduce suitable habitat, and especially eliminate hiding places for snakes (e.g., brushing trailheads and parking areas, removing rock and brush piles, managing localized prey populations near known snake problem areas, filling cracks and holes in public accessible buildings).

Physical Control

- **Tongs and Funnel Traps.** In certain areas (especially in structures and recreational facilities where humans gather and there is potential for snakebites), the District may elect to capture and relocate, or eliminate single problem snakes.
 - Using snake tongs, snake hooks, or shovels, trained individuals may capture and relocate or eliminate problem rattlesnakes. Captured rattlesnakes can be placed in a secure container for relocation in the preserve to nearby suitable habitat away from people. Occasionally, because of the urgency of the situation, a staff member or tenant may need to kill a rattlesnake via decapitation with a shovel.
 - Funnel traps can be used to collect problem snakes. Traps must be checked daily to ensure that non-target wildlife is not trapped accidentally.

Chemical Control

Currently there are no toxicants or fertility control agents available in California for rattlesnakes.

Other Native and Domestic Mammals

See discussion of skunks, raccoons, opossum, and feral cats/dogs in the subsequent Sections 5.9.3 and 5.9.4.

6.7.5 Vegetation Management of Trails and other Recreational Facilities

Definition

The majority of IPM activity associated with recreational facilities is annual brushing (i.e., pruning of vegetation along roads and trails), which keeps them open for vehicular, horse, bicycle, and human foot traffic, and furthermore provides a buffer area to separate humans from pests like ticks, rattlesnakes, and poison oak. The District maintains guidelines for road and trail brushing that prescribe different treatments for different vegetation types and slope conditions (Midpen 2021). Mowers and saws may be used by District staff to maintain grass

and shrubs near roads and trails in short stature, limb up overhanging tree branches, and remove dead or decadent vegetation. Wider strips of brushing occur along certain roads to provide access for emergency vehicles.

The following section outlines typical vegetation management actions conducted in right of way areas on District lands.

Pest Management Strategies for Vegetation Rights-of-Way

Prevention

- Prepare an annual treatment schedule for maintaining designated trail and roadside rights-of-way based on use and vegetation types. Mechanically mow and brush annually to prevent nuisance vegetation from impeding roads and trails.

Habitat Modification

- Where possible, pave trailheads, parking lots, or other heavily used rights-of-way to reduce annual maintenance needs.
- Eliminate roads, trails, or other rights-of-ways that are determined to be redundant or not necessary.

Physical Control

Manual/mechanical control treatment options include maintenance of existing recreational facilities within District preserves via brushing and/or mowing:

- **Road and trail brushing.** Mechanical mowing is used to prevent nuisance vegetation from impeding roads and trails. Vegetation along approximately 518 miles of trails and road edges is cut back to maintain an open corridor for trail and road use. Typically, the District mows over 100 miles of roadside annually to eliminate weeds and encroaching vegetation and, where applicable, to allow access for Wildland Type 3 fire engines. This work is primarily mechanical work done with brush cutters (i.e., weed-whips), hedgers, chainsaws, polesaws, chippers, and tractor-operated mowers (mowing decks either pulled by a tractor or attached to the tractor as part of an articulated arm). All roads are mowed one to four times per year depending on the rainfall/vegetation growth in any one year. Most trails are mowed or brush cut on an annual basis; some trails may need to be brushed up to four times a year if there is a lot of rain and it is a trail heavily used by the public. Some more remote trails may not be brushed every year.
- **Parking lots, gates, and stiles.** On an annual basis, a strip of land around 40 to 50 parking lots and approximately 200 to 300 gates and stiles in the preserves are sprayed to maintain an open area for parking and visibility. A few of the locations are brush or mowed instead if they are large grassy areas or if there is water too close to allow spraying. Islands in the middle of parking lots or parking lots with narrow grassy edges and bioretention basins are mowed.
- **Miscellaneous recreational areas.** A few miscellaneous recreational areas are mowed one to five times a year with a tractor pulling a mowing deck. This includes a model airplane field and three meadow areas along Rogue Valley Trail

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maintained at Rancho San Antonio Open Space Preserve (OSP), the picnic table area at the top of Anniversary Trail on Windy Hill OSP, picnic tables at Picchetti Ranch Preserve, and the hang gliding takeoff and landing areas at the top and bottom of Spring Ridge Trail of Windy Hill OSP. In addition, special events occur in the preserves each year (e.g., Volunteer Recognition Event, summer camps, and other public gatherings) that require mowing of grassy areas. At Deer Hollow Farm in Rancho San Antonio OSP, pastures, animal pens, and the Ohlone village are mowed four to five times per year with a tractor mower or brush cutter.

- **Campsite.** The Black Mountain campsite is mowed once a year to provide a comfortable camping experience and to reduce the risk of wildfire encroaching either into or out of the campground.
- **Pond viewing areas and dams.** At some ponds, aquatic and terrestrial vegetation is managed at viewing areas and on dams. Windows of cattails and other tall wetland vegetation are removed in small select areas to allow public viewing of these water bodies. The California Division of Dam Safety requires all woody material be removed and tall herbaceous vegetation be cut on both faces of certain pond dams to improve visibility to see possible failure hazards. Vegetation on the water side of the dam is clipped with mowers and brush cutter; vegetation on the dry side of the dam is controlled with mowers and selective use of herbicides to maintain a light grassy vegetation cover. Woody vegetation is cut in pond spillway to prevent blockage of water flow. Duckweed or azola (aquatic fern) skimming has been done, with limited success, to prevent these plants from covering the entire surface of some ponds. Downed trees that have fallen in a pond can require removal for aesthetic or other management reasons.
- **Streambed alteration.** The District follows conditions of an annual routine maintenance Streambed Alteration Agreement from CDFW for manual/mechanical vegetation management activities located within CDFW's jurisdiction.
- **Hazard and downed trees.** An estimated 50 to 150 standing hazard trees are limbed or removed every year with chainsaws, pole saws and chippers because they are blocking roads, trails, and parking lots or are otherwise hazardous to visitors, staff, tenants, or contractors. They may be alive or dead. Midpen also removes downed trees, as appropriate, under the IPMP. Stumps of live hazard trees may be treated with herbicide to prevent re-growth.

Chemical Control

Chemical control is typically not used for right-of-way clearing unless perennial plants require permanent treatment. For example, some problem vegetation, such as poison oak, can be eliminated from specific locations with spot application of herbicides.

- **Glyphosate** is a broad-spectrum non-selective systemic herbicide used to control a wide variety of plants, including annual broadleaf weeds, grasses, perennials, and woody plants. It is absorbed through foliage and translocated to growing points. Glyphosate's mode of action is to inhibit an enzyme involved in the synthesis of aromatic amino acids, making it effective on all herbaceous and woody growing

plants. It is a rather slow-acting herbicide with symptoms typically appearing within a week, including yellowing and stunting of young leaves and growing points, however it may take up to several weeks for a plant to die.

- **Imazapyr**, is a non-selective herbicide used to control a broad range of weeds including grasses, broadleaf herbs, woody plants, riparian plants, and emergent aquatic species. Imazapyr has a similar mode of action as glyphosate but acts on a different suite of essential amino acids. Imazapyr is absorbed by leaves and roots, and moves to growing points; it disrupts protein synthesis and interferes with cell growth and deoxyribonucleic acid (DNA) synthesis; plants die from acetohydroxyacid synthase (AHAS) inhibition. To be effective on aquatic plants, most plant parts must be accessible above the waterline. Imazapyr can be useful for difficult-to-control species when glyphosate is less effective, and with much lower application rates.
- **Triclopyr** is a selective systemic herbicide used to treat woody and herbaceous broadleaf plants and can be used to treat aquatic and riparian weeds. Triclopyr's mode of action is to mimic the plant hormone auxin, causing uncontrolled plant growth (Tu et al. 2001). The most effective application of triclopyr is to directly apply the herbicide when woody plants and weeds are actively growing (Alligare 2021).

7 IPM for Rangelands and Agricultural Properties

7.1 Definition and Purpose

Some District lands encompass rangelands, crop fields, and orchards that are actively managed as grazing or agricultural operations. Rangeland and agriculture activities on District preserves are primarily managed by lessees who will typically operate under an Agricultural Management Plan, which is inclusive of Rangeland Management Plans prepared for rangelands, that is attached to their lease. These site-specific management plans guide the rangeland and agricultural activities to ensure compatibility with natural resource protection and low-intensity public recreation.

This IPMP does not replace the requirements of the existing or new individual Agricultural Management Plans developed in the future, nor does it present the full range of agricultural or range management options. Rather, it seeks to provide staff with tools that are consistent with IPM principles to select the safest, least harmful, and most effective treatment options for rangeland and agricultural pests.

7.2 Rangelands

IPM in rangelands focuses on maintaining land uses (e.g., grazing) while also managing for the long-term functioning and stability of high value natural resources (e.g., grasslands, creeks) that surround the rangelands and agriculture. This requires landscape level monitoring to determine when pests such as agricultural pests and invasive plants are present in sufficient numbers to reduce the intended land uses or quality of the managed habitats.

The District established a Conservation Grazing Program in February 2007 with the goal of managing District land with livestock grazing that is protective of natural resources, compatible with public access, maintaining or enhancing the diversity of native plant and animal communities, managing vegetation fuel for fire protection, helping to sustain the local agricultural economy, and preserving or fostering appreciation for the region's rural agricultural heritage.

As of 2025, there are 13 properties, totaling approximately 15,480 acres, managed under the District's Conservation Grazing Program. Stocking rates and either year-round or seasonal grazing are prescribed for each property based on site-specific factors such as soil fertility, terrain, plant composition, water availability, and available infrastructure.

The IPM Coordinator is responsible for reviewing Agricultural Management Plans and periodically reviewing existing rangeland practices to make sure they are implemented using current IPM practices outlined herein, and, if pesticides are used, follow the District's List of Approved Pesticides.

7.2.1 Types of Rangeland Pests

Typical pests on rangelands include weeds poisonous to livestock or otherwise detrimental to productive pastures, primarily invasive thistles, Harding and velvet grass, poison hemlock, and encroaching brush.

7.2.2 Pest Identification in Rangelands

Because the extent of grassland communities on District lands is so large and interconnected with leased rangeland properties, rangeland pests are inherently difficult to detect. The District will assess a subset of grasslands in and adjacent to leased rangelands on a routine basis to detect problem pests (most commonly to be conducted during a lease renewal or establishment of a new lease). Monitoring rangelands should focus on:

- Sites most likely for pests to invade (e.g., corrals and areas around water troughs and feed stations).
- High value areas (e.g., grassland areas that support special-status species).
- Mapping pests of concern, recording in the District's Pest Database, and evaluating, as discussed in Section 4.2.

7.2.3 Tolerance Levels in Rangelands

Determining tolerance levels for pests in grazing lands is largely done by the grazing lessee, in consultation with District staff and rangeland experts. Active pest management would only occur where the lessee determines that tolerance level for a pest is exceeded, for example, where livestock forage quality is severely reduced, resulting in a loss of livestock production value. In some limited instances, the District may assess leased grazing land pests and determine a tolerance level, for example, when the presence of the pest is a target invasive species or particularly if it threatens the persistence of a special-status species or other high value area. Refer to Table 7-1 for an overview of management thresholds and treatment options available for use on District rangelands.

Table 7-1 Management Thresholds and Treatment Options for Rangeland Pests

Pest Category	Management Threshold (Population Size/Conditions)	Treatment
Grasslands	Site-specific management needs are determined by lessee and the District in Agricultural Management Plans based on assessment of rangeland condition, type of livestock to be used, and stocking rates/seasons of use. District to work with individual rangeland lessees when rangeland forage values decrease such that stocking rates decline, and or when lessees identify pests that warrant control.	Lessee to monitor forage values in grasslands. In coordination with District, lessee responsible for detection, District notification, and control of rangeland pests such as French broom and invasive thistles that lower value of forage and grassland habitat.
Shrublands (coastal scrub, chaparral)		Lessee to monitor brush encroachment in grasslands. Lessee to work with District to thin brush in grasslands when brush encroachment significantly reduces value of forage and grassland habitat. In shrublands, increase spacing between shrub clusters.

7.3 Agricultural Farms and Fields

The purpose of IPM on agricultural properties is to manage pests to maintain the specific land uses (e.g., crop production), while also providing natural resource protection and visitor access. Agricultural pests that may be encountered include weeds, pathogens, and insects in croplands, and rodents in farm fields and buildings.

Some District managed and leased properties contain agriculture fields. Agricultural Management Plans are anticipated to require that best practices as defined by the University of California Cooperative Extension Service and the USDA Natural Resources Conservation Service for farm production be followed, and specifically, that IPM techniques, as defined by the crop specific University of California Cooperative Extension Service are employed along with the relevant IPMP BMPs. Methods for controlling weeds on sites covered by the Agricultural Management Plan are mowing, grazing, flaming, or the use of an approved herbicide.

Lessees use District land for various operations, including a Christmas tree farm and chestnut orchard at Skyline Ridge OSP, and a vineyard at Picchetti OSP. A historic fruit orchard is maintained by District staff and volunteers on the Stevens Canyon property. The City of Mountain View operates an educational farm (Deer Hollow Farm) located in the Rancho San Antonio OSP that offers classes and camps for thousands of schoolchildren in farm, garden, native peoples and history.

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The IPM Coordinator is responsible for reviewing existing Agricultural Management Plans and periodically reviewing existing agricultural practices to implement current IPM practices outlined herein and, if pesticides are used, follow the District's list of approved pesticides. As new agricultural lands are acquired, District staff will help draft new Agricultural Management Plans that follow the procedures outlined in this Guidance Manual.

7.3.1 Types of Agricultural Pests

The types of agricultural pests that can be encountered on District preserves include agricultural insect pests, rodents and other small burrowing mammals, forest pathogens, aquatic invasive animals and pathogens, and invasive plants.

7.3.2 Regulated Agricultural Pests

Though the definition of a 'pest' can depend on perspective and location, some species are regulated as various types of pests by state and federal laws. Plants classified as 'noxious' are regulated by the California Department of Food and Agriculture (CDFA) and the United States Department of Agriculture (USDA). Wildlife species classified as 'Injurious' are regulated by the CDFW and United States Fish and Wildlife Service (USFWS). Other species that transmit diseases may be regulated by local, state, or federal health departments. Regulated pests pose a risk to the environment, public health, or economic resources. Most often the acceptable IPM tolerance level of regulated pests is zero, so that any detected individual initiates a management action. These are species that the District has a legal responsibility to control per state and federal laws and regulations, though control is often conducted by other agencies.

7.3.3 Pest Identification in Agricultural Farms and Fields

Due to the limited number of agricultural lands on District property, pest identification is the responsibility of the lessee, who is to report significant pest infestations to the District. Once pests are reported, they should be mapped and recorded in the District's Pest Database (refer to Section 4.2) and evaluated for their impacts to the surrounding natural areas.

7.3.4 Tolerance Levels in Agricultural Farms and Fields

Active pest management would only occur where tolerance levels are exceeded, for example, where agricultural crop production is greatly reduced, or where the presence of the pest threatens the persistence of a special-status species occurring in adjacent areas. Refer to Table 7-2 for an overview of management thresholds and treatment options available for use on District rangelands.

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Table 7-2 Management Thresholds and Treatment Options for Agricultural Pests

Pest Category	Management Threshold (Population Size/Conditions)	Treatment
Agricultural insect pests	Site-specific management needs to be determined by lessee and District in individual Agricultural Management Plans based on assessment of farm and field conditions, type of crops, and anticipated crop yields. District to work with individual lessees when crop yields decrease such that economic damage or environmental damage warrant control. Assessments made by the Agricultural Commission's Office supersedes any decisions made by the District and lessees.	Lessee to monitor insect damage of crops. Agriculture insect pest management to be addressed in future Agriculture Management Plans. Staff and tenants to consult crop-specific IPM guidebooks published by University of California Davis - http://www.ipm.ucdavis.edu for both organic and conventional crop production and include pest management actions in the Agricultural Management Plan for individual parcels.
Rodents and other nuisance pests in agricultural areas	Site-specific management needs to be determined by lessee and District in individual Agricultural Management Plans based on assessment of farm and field conditions, type of crops, and anticipated crop yields. District to work with individual rangeland lessees when crop yields decrease such that economic damage or environmental damage warrant control.	Lessee to monitor rodent damage. In coordination with District, lessee is responsible for detection, District notification, and control of problem rodents in farm buildings or crop fields using procedures in the Buildings section above (Chapter 6).
Forest pathogens	Site-specific management needs to be determined by lessee and District in individual Timber Harvesting Plan (THP) based on assessment of forest conditions and habitat type. District to work with a Registered Professional Forester when environmental damage warrants control.	Lessee to use disinfectants to kill or inactivate pathogens (e.g., <i>Phytophthora</i>), before plant infection may occur through the decontamination of tools, equipment, vehicles, and footwear in accordance with the latest Guidelines for Minimizing Phytophthora Contamination at Midpeninsula Regional Open Space District Preserves. Strategic removal of vectoring species to protect ecosystem integrity and function and improve wildland fire resiliency.

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Pest Category	Management Threshold (Population Size/Conditions)	Treatment
Aquatic invasive animals and pathogens	Management thresholds for aquatic invasive species and pathogens are preventative and risk-based. Site-specific management needs to be determined by the District based on assessment of aquatic habitat type, hydrologic connectivity, and the potential for introduction or spread associated with District or lessee activities. The threshold for management action is met when there is a reasonable risk of environmental damage, at which point the District will require implementation of preventative measures, including cleaning and disinfection protocols, and coordinate additional response actions as appropriate.	Lessee to use disinfectants to prevent the spread of invasive aquatic animals, such as small invasive aquatic snails (e.g., New Zealand mudsnail), and pathogens to sensitive aquatic species, particularly amphibians (e.g., chytridiomycosis disease). Lessee to use disinfectants to decontaminate equipment, boots, and clothing before and after entering a waterbody, as appropriate. The CDFW aquatic invasive species decontamination protocol provides details on the procedures and best practices (CDFW 2013).
Invasive plants in agricultural farms and fields	Site-specific management needs to be determined by lessee and District in individual Agricultural Management Plans based on assessment of farm and field conditions, type of crops, and anticipated crop yields. District to work with individual lessees when crop yields decrease such that economic damage or environmental damage warrant control.	Cultural Control Options: • Crop rotation • Cover crops and smother crops • Late-season planting • Planting rates and crop density • Water and nutrient management • Crop variety selection • Covering/soil sterilization • Mulching • Soil sterilization Physical Control Options: • Mowing • Pulling • Green Flaming • Mulching • Use of weedmats • Hoeing • Cultivating with tractor implements Chemical Control Options: • To be determined by lessee and District in Agricultural Management Plans. Staff and tenants to consult crop-specific IPM guidebooks published by University of California Davis - http://www.ipm.ucdavis.edu

Pest Category	Management Threshold (Population Size/Conditions)	Treatment
		for both organic and conventional crop production and include pest management actions in the Agricultural Management Plan for individual parcels.

7.4 Prevention

Using existing or new Agricultural Management Plans, the District will work with lessees to encourage management practices that prevent the establishment of pest species. Prevention strategies for District lands in agricultural production may include:

- During development of new Agricultural Management Plans, encourage lessees to keep lands healthy through soil management, proper irrigation, and by providing sufficient habitat (refugia) for natural insect pest predators (natural enemies) in and near crop production areas.
- During development of new Agricultural Management Plans, and as practical, incorporate good stewardship practices such as rotational cropping, integrating annuals into perennial crops (such as Christmas tree farms), implementing no-till cropping, and, where possible, promoting organic farming practices to reduce annual disturbance and increase farm biodiversity (Rodale Institute, n.d.).
- During acquisition planning for new preserve lands, encourage landscape mosaics (i.e., plan for a mixture of natural and agricultural or grazing lands) to help maintain natural pest predator populations.
- During lease renewal periods, monitor pest invasions at the edges of agricultural and grazing lands, especially in and near roads, trails, and fuel breaks. Determine if tolerance thresholds are exceeded (both in and adjacent to leased lands) and develop pest control requirements accordingly in the new lease requirements.
- During preparation of new Agricultural Management Plans and lease renewals, monitor livestock feeding locations, corrals, watering troughs, and livestock feeding for pests. Consider rotational grazing, changing livestock stocking rates, and/or requiring different types of grazing animals to prevent spread of pests and to promote healthy, diverse grassland areas.

7.5 Treatment Options

Working with lessees, the District will determine a site-specific solution that meets the needs of the lessee, maintains natural resource values and District lands, and addresses the identified pest issue. The general steps involved in implementing IPM in rangelands and agricultural properties are similar, but not identical to those described for buildings and natural areas, and generally include the actions described below.

7.5.1 Wildlife and Pathogen Pest Control

Mechanical Control

Mechanical control treatment options for rangeland and agricultural properties on District lands include:

- **Rodents.** For rodents in farm buildings or crop fields, refer to the procedures for controlling rodents under the Buildings section above (Chapter 5).

Chemical Control

Chemical control treatment options for rangeland and agricultural properties on District lands include:

- **Rodents.** For rodents in farm buildings or crop fields, refer to the procedures for controlling rodents under the Buildings (Chapter 5) and Natural Areas sections (Chapter 8), respectively.
- **Forest Pathogens.** Disinfectants, namely sodium dichloroisocyanurate dihydrate, sodium hypochlorite, ethanol or isopropyl alcohol, and dodecyl dimethyl ammonium chloride, will be used to kill or inactivate pathogens (e.g., *Phytophthora* spp.), through the decontamination of tools, equipment, vehicles, and footwear.
- **Aquatic invasive animals and pathogens.** Disinfectants, namely sodium dichloroisocyanurate dihydrate, sodium hypochlorite, ethanol or isopropyl alcohol, and dodecyl dimethyl ammonium chloride, will be used to prevent the spread of invasive aquatic animals, such as small invasive aquatic snails (e.g., New Zealand mud snail), and pathogens to sensitive aquatic species, particularly amphibians (e.g., chytridiomycosis disease).

7.5.2 Invasive Insect Control

Because the District has few properties that currently support row crops, agriculture insect pest management for agricultural fields is not covered under the IPMP. If new pesticides are proposed for agricultural insects, they will be 1) evaluated, 2) included in future Agriculture Management Plans, and 3) environmentally reviewed, and the IPMP will be revised to include the new pesticide, new treatment method, and any required precautions. Staff and tenants should consult crop-specific IPM guidebooks published by University of California Davis (<http://www.ipm.ucdavis.edu>) for both organic and conventional crop production and include pest management actions in the Agricultural Management Plan for individual parcels.

7.5.3 Invasive Plant Control

Rangelands

Consistent with existent management plans, grazing and agricultural lessees are allowed to control pests through grazing, mowing, pulling, and careful application of District-approved herbicides. Brush, commonly the native coyote brush, limits the available forage for livestock, reduces grassland habitat areas, and creates an increased wildfire fuel load. Grazing tenants

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typically treat brush encroachment with herbicide and then use a tractor and drag bar to break up dead vegetation for the following season.

Manual/mechanical control treatment options for invasive plants on rangelands include:

- **Mow/Cut.** A brush cutter, disc, brushrake or other motorized cutting machine can be selected for mowing weeds and cutting brush based on the size of the infestation. Most species require repeated cutting throughout the growing season (generally late spring through mid-summer), or they re-sprout from their base and continue to grow, flower, and produce seed. Mowing will be carefully timed according to the phenology of each plant species to minimize the amount of re-sprouting and to avoid spreading ripe seed. Mowing is a temporary measure that controls reproductive spread and can eventually reduce populations of annual plants, but other subsequent treatments (e.g., pulling, herbicide) will be necessary to eradicate perennial plants. Mowing cannot be used on steep slopes or in locations with desirable native plants unless the timing of the mowing can be selected to affect only target plants.
- **Grazing Regime Modifications.** Invasive plants can also be partially or fully controlled using carefully timed grazing rotation, and/or manipulating the types and seasons of grazing livestock (e.g., using goats instead of cattle to forage on invasive thistle species in spring before seed set). Possible modifications to be considered include:
 - Changing types of livestock to include browsing livestock that eat shrubs (e.g., goats);
 - Installing physical barriers (cross fencing);
 - Controlling brush through hand or mechanical treatments;
 - Applying pesticides in a specific location (e.g., directly onto individual plants or small patches of brush); or
 - Implementing a combination of mowing, foliar spraying, and hand removal (for very large brush encroachments).
- **Chemical Control Treatment Options.** Any of the herbicides approved under the IPM Program may be used to treat weeds on rangelands or agricultural fields if cultural or mechanical methods are not effective.

The herbicides referenced in Table 3-3 under the Agriculture and Rangelands category are the herbicides anticipated for use for chemical control of thistles and brush on rangelands, and for weeds in agriculture fields and orchards.

Agricultural Farms and Fields

Cultural weed control includes crop rotations, water and nutrient management, late-season planting, and cover/smothering crops (Gunsolus et al. 2010; R. Smith et al. 2000). Cultural methods are the first line of defense in weed management and primary tools for organic crop

production. Manual/mechanical control treatment options for invasive plants on agricultural lands include the following cultural, mechanical, and manual weed control options:

- **Crop Rotation.** Diversifying a rotation is one of the most effective tools against weeds. Over time, routine planting and cultivation dates will select for weeds that are adapted to these strategies. Varying crops by different planting date or growing perennial crops in rotation with row crops can prevent weeds from adapting to the planting regimen.
- **Cover Crops and Smother Crops.** Offseason cover crops and smother crops are effective strategies to outcompete weeds. Cover crops occupy vacant space in an ordinarily fallow field and displace weeds that would otherwise occupy the space. Some species also have allelopathic effects on weeds.

Smother crops are vigorously growing crops that growers use to suppress weeds. Generally, a smother crop is not harvested but plowed down instead. The primary risk in using smother crops is that their effectiveness in weed control may be inconsistent and unpredictable or they may become weeds themselves.
- **Late-Season Planting.** Delayed planting past the traditional planting times is an option in weed management, but depending on growing season and crop, may also reduce crop yields. Later season planting allows crop seedlings to bypass the competitive flush of weed seedlings and allows for additional time for mechanical weed control operations.
- **Planting Rates and Crop Density.** Increasing the planting rate is another common strategy for weed management. Higher crop densities can lead to greater competitiveness against weeds. In addition, higher planting rates can compensate for crop losses that occur during mechanical weed control operations.
- **Water and Nutrient Management.** Effective water and nutrient management can ensure crops benefit from farming practices rather than weeds. Switching to drip irrigation from flood or broadcast styles, monitoring nutrient requirements instead of blanket fertilization, timing compost applications, and burying irrigation pipe may all help to reduce weed problems.
- **Crop Variety Selection.** Selecting the proper variety of a specific crop that is best adapted for local conditions can reduce the resources necessary for production and consequently reduce weed management problems. If the crop is better adapted to local conditions than the weed, the site will favor the crop over the weed.
- **Mechanical weed control.** Mechanical weed control is the most widely used weed control method for agriculture fields and can occur before, during, and after the crop is planted. This method includes primary tillage, row crop cultivating tillage, use of mulches (e.g., plastic sheeting, straw, wood chips, and sawdust), and/or soil sterilization techniques that use heat to kill weeds and weed seeds in soil. Passive sterilization uses clear plastic tarps to foster the germination of weeds under the tarp and then exposes the seedlings to hostile growing conditions, causing them to perish, while active sterilization uses extremely high temperature steam to

eliminate weed seeds and bulbs with direct contact. Both processes are expensive and require specialized equipment and/or high labor output.

- **Primary Tillage.** Primary tillage is the initial step in seedbed preparation. It incorporates residues from the previous crop and can incorporate compost, manures, and other nutrients. It buries some weed seeds so deeply they cannot germinate, but it also brings other seeds to the surface, allowing them greater opportunity for germination. Tillage is best combined with a forced germination program, where multiple tillage and watering events are coupled to force the germination of weeds and then eliminate them. The timing of primary tillage will encourage different weed species to predominate so the farmer must time the actions to correspond with the primary weed targets.

A fundamental aspect to consider in seed bed preparation is the concept of providing the crop with an “even start.” An even start means controlling weeds that germinate before the crop germinates. Once seed bed preparation is complete, the crop must be planted as soon as possible because if crop planting is delayed, weeds can germinate and get a head start on the crop.

- **Cultivation.** Row crop cultivating tillage is performed after the crop is planted. Cultivation kills weeds by digging them out, burying them, breaking them apart, or drying them out. In addition to controlling weeds, cultivation can break up soil crusting and thus can increase crop emergence, water infiltration, mineralization of nutrients, and soil aeration during the growing cycle.

A short window of time usually exists for timely use of cultivation. Weeds that emerge before or with the crop are the most critical to eliminate. Weeds that emerge after crop emergence will have less negative impact on yield, but may still contribute to the weed seed bank for problems in future years. When it comes to weeds that emerge with the crop, it is best to be proactive, rather than reactive. Waiting until weeds are noticeable will limit the control options.

- **Mulches.** Mulch is any artificial or natural soil cover. Plastic sheeting, straw, wood chips, and sawdust are all common types of mulches for crop production. Mulches work by eliminating light availability to small weeds. The larger the weed, the deeper the mulch needs to be for effective control. Mulches have the added benefit of also conserving soil moisture and reducing soil erosion. Many organic types of mulch ultimately decompose into necessary plant nutrients for the following growing season.
- **Sterilization.** Soil sterilization uses heat to kill weeds and weed seeds in soil. Two types are common in agriculture, 1) passive soil sterilization with clear plastic tarps, and 2) active soil sterilization with injected steam. Passive sterilization uses clear plastic tarps to foster the germination of weeds under the tarp and then exposes the seedlings to hostile growing conditions and they perish. Active sterilization uses extremely high temperature steam to eliminate weed seeds and bulbs with direct contact. Both processes are expensive and require specialized equipment and/or high labor output.

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- **Manual Weed Treatment.** Specific manual weed treatment methods allowed under Agricultural Management Plans are mowing, pulling, flaming, mulching, weedmats, and hoeing.

8 IPM in Natural Lands

8.1 Definition and Purpose

Natural areas make up the majority of District lands and typically experience minimal levels of human use. The purpose of IPM in natural areas is to preserve and restore natural resources while also maintaining safe and enjoyable human access for visitors and staff.

IPM in the District's natural areas focuses primarily on the control of pests that threaten the long-term viability of natural resources on District preserves. Pests that are commonly encountered on natural areas include invasive plants and invasive animals, including regulated species (e.g., plants and wildlife that are regulated under state and federal law or Fish and Game Code, and feral pets). The District spends the majority of its IPM management efforts in natural areas on control of invasive plants.

- **Invasive plants** are implicated in many natural resource and conservation problems and are considered by most land managers to be a threat to their resource management goals. When transplanted to a foreign landscape, invasive plants leave behind their associated predators, prey, and diseases that previously helped to balance their growth and abundance. In addition, many invasive plants have inherent biological traits that allow them to rapidly reproduce and colonize new areas faster than the native plants of the invaded habitat. Some of these invasive plants become problematic because of abundance – they displace native species by outcompeting them for space and resources (CCC 2005; County of San Mateo, CA 1983; State of Washington 2004). Some invasive plants can alter ecosystem processes, such as reducing or changing seasonal food sources for wildlife, hydrological patterns, fire regimes, or soil chemistry (D'Antonio and Vitousek 1992; Keeley 2006; Vitousek and Walker 1989).

CDFA designates a plant species as a noxious weed if they find it to be “troublesome, aggressive, intrusive, detrimental, or destructive to agriculture, silviculture, or important native species, and difficult to control or eradicate” (CDFA 2014). CDFA designates a rating for each noxious weed species based on the present distribution of the pest within the state and the likelihood that eradication or control efforts will be successful. The ratings are not laws, but are policy guidelines that indicate the appropriate actions to take against pests. The District works closely with the Agricultural Commissioners for San Mateo and Santa Clara Counties to address state-designated noxious weeds on preserves. The California Invasive Plant Council maintains an Invasive Plant Inventory that rates the threat of non-native plant species by evaluating their ecological impacts,

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invasive potential and ecological distribution (California Invasive Plant Council, n.d.-a). The Bay Area Early Detection Network along with the San Mateo County Weed Management Area and the Santa Clara County Weed Management Area set regional priorities for eradication of invasive plants in the San Francisco Bay Area, particularly those for which early action could substantially reduce future risk between 2006 to 2011 (California Invasive Plant Council, n.d.-b). District staff members are active with these organizations and further apply local knowledge to evaluate the invasive risk of existing and new non-native plants found on District preserves and to determine the best responses.

- **Invasive animals** pose another threat to natural areas. Escaped/released domestic animals and other non-native wildlife species can thrive in the favorable climate of the San Francisco peninsula. Once established in a preserve, they compete for valuable resources and disturb the sensitive balance of natural food webs. Bullfrogs and feral pigs are examples of invasive, introduced animals found in District preserves that physically displace or consume the native plants and wildlife that normally inhabit natural areas, or otherwise alter natural processes.

Feral pigs are an example of an invasive wildlife species with obvious impact on District lands. They have been widespread in the central coast of California since about 1970, reproduce rapidly, dig up meadows and wetlands, and carry diseases that can affect people and livestock. They eat acorns, bulbs, and roots in soil, and are difficult to control. Feral pigs were abundant in the South Skyline region in the 1990s. The District has been trapping feral pigs since 2000 and has substantially reduced their population and damage from their rooting.

The management of invasive species may sometimes involve eradication (i.e., the removal of all of the pest species, typically only achievable for new invasive species and small populations of pests), but more common natural area management methods involve incremental reduction of pest numbers (control), removal of individuals that have the greatest impact on critical resources, or the exclusion of a pest species from a defined sensitive area (containment). Programs to control invasive plant and animal species often require a long-term commitment. With many invasive species, short-term lapses in active management can negate years of expensive control programs.

First steps in all invasive species management focus on preventing the establishment of any new pest populations. Prevention or detection actions can minimize many invasive species problems in the future, reducing the need for more active management and costly treatment methods (refer to Section 3.6). In the future, the pest prevention tactics identified below will be based on minimizing dispersal or reacting quickly to new invasions through anticipation and surveillance.

8.2 Regulatory Background

Invasive species are regulated to some extent by state and federal laws. The USDA, CDFA, USFWS, and CDFW all regulate the importation, sale, transportation, and control of designated invasive species.

8.2.1 Regulated Wildlife

Under the Lacey Act, the Secretary of the Interior is authorized to regulate the importation and transport of species, including offspring and eggs, determined to be injurious to the health and welfare of humans, the interests of agriculture, horticulture or forestry, and the welfare and survival of wildlife resources. Wild mammals, birds, fish, mollusks, crustaceans, amphibians, and reptiles are the only organisms that can be added to the injurious wildlife list. The current 2025 list includes 785 species, many of which are kept as pets around the world (USFWS n.d.). All species listed as injurious may not be imported or transported between states or any United States territory without a permit issued by the USFWS. The importation of any live amphibians from outside the United States (such as bullfrogs imported from China) has been petitioned by environmental groups for inclusion on the list to prevent the importation of the chytrid fungal pathogen. Since publication of the 2014 Guidance Manual, the USFWS issued a final ruling that formally prohibits the importation and interstate transport of genera listed under the Lacey Act due to the risk of fungus (2016), and as of January 2025, this list has been expanded to include additional injurious amphibians (FedCenter.gov 2025).

8.2.2 Regulated Plants

Some species of invasive plants are regulated as noxious weeds by the CDFA and USDA. Because the two agencies work cooperatively, California's classification scheme is representative of both federal and state regulations. Most recently, CDFA revised this list in 2021 to now include 184 invasive plant species as noxious weeds (CDFA 2021). Control actions are determined by a ranking system based on a species' threat to economic or environmental resources. The following is California's ranking system for invasive pest plant species (CDFA n.d.-b):

- **Class A Noxious Weed** – A pest of known economic or environmental detriment which is either not known to be established in California or has limited distribution that allows for the possibility of eradication or successful containment. A-rated pests are prohibited from entering the state because, by virtue of their rating, they have been placed on the Plant Health and Pest Prevention Services Director's list of organisms "detrimental to agriculture" in accordance with the FAC Sections 5261 and 6461. The only exception is for organisms accompanied by a CDFA or USDA live organism permit for contained exhibit or research purposes. If found entering or established in the state, A-rated pests are subject to state (or commissioner when acting as a state agent) enforced action involving eradication, quarantine regulation, containment, rejection, or other holding action.
- **Class B Noxious Weed** – A pest of known economic or environmental detriment that, if present in California, has a limited distribution. B-rated pests are eligible to

enter the state if the receiving county has agreed to accept them. If found in the state, they are subject to state endorsed holding action and eradication only to provide for containment, as when found in a nursery. At the discretion of the individual county agricultural commissioner, they are subject to eradication, containment, suppression, control, or other holding action.

- **Class C Noxious Weed** – A pest of known economic or environmental detriment that, if present in California, is usually widespread. C-rated organisms are eligible to enter the state as long as the commodities with which they are associated conform to pest cleanliness standards when found in nursery stock shipments. If found in the state, they are subject to regulations designed to retard spread or to suppress at the discretion of the individual county agricultural commissioner. There is no state enforced action other than providing for pest cleanliness.
- **Class D Noxious Weed** – An organism known to be of little or no economic or environmental detriment, to have an extremely low likelihood of weediness, or is known to be a parasite or predator. There is no state enforced action.
- **Class Q Noxious Weed** – An organism or disorder suspected to be of economic or environmental detriment, but whose status is uncertain because of incomplete identification or inadequate information.
- **Class W Noxious Weed** – This notation indicates that a plant is included in the CCR Section 4500 list of California State Noxious Weeds.

8.3 Type of Pests

Pests in natural areas include invasive plants and invasive animals. This section presents an overview of IPM practices presented for each type of pest.

Traditional IPM concepts can be difficult to apply to invasive species. The ecosystems invaded by these species normally do not support the same predators and parasites that may regulate the species populations in its native range, so simply facilitating increased natural controls may not be effective. Modern IPM strategies for invasive species emphasize use of standardized decision-making processes supported by science-based understanding of invasive species biology and ecological interactions with their host environment. Tolerance levels may vary greatly for invasive species; invasive species impacts range in severity and extent, and some species may be so widespread or complexly woven into their host environment that control is not technically or economically feasible. Monitoring is a critical part of the District's IPM Program; prevention and early detection/eradication strategies can be implemented to prevent new invasive species pest problems before they become unmanageable.

Programs to control invasive plant and animal species require long-term commitment. With many invasive species, short-term lapses in management activity may negate years of expensive control programs. IPM is considered an integral part of a strategy to efficiently and effectively control invasive species on District lands.

8.3.1 Invasive Animals in Natural Lands

Invasive animal management in natural areas focuses on first modifying the behavior of humans or the habitat of natural areas to moderate or eliminate invasive animal pest problems. After these prevention actions are exhausted, invasive animal populations will be managed to a defined tolerance level. Tolerance levels focus on reducing the pest population down to a level that does not cause substantial harm to the natural resource; does not cause severe economic harm; and/or does not cause disruption of natural processes or severe displacement of native species. The District's goal is to maintain the long-term stability and resiliency of its natural areas.

State regulations concerning invasive animals are complex. Some invasive animals in California are regulated for sport and commercial purposes (e.g., feral pigs and bullfrogs), others are expressly prohibited (e.g., northern pike fish), and others are currently unregulated (e.g., snapping turtles and parrots). Some invasive wildlife species can be difficult to manage where adjacent landowners manage the same species for sport or profit. The District prioritizes specific invasive animals for management that have the greatest potential to impact natural areas.

Some regulated game species (e.g., feral pigs) must be controlled under special permits obtained from CDFW.

8.3.2 Invasive Plants in Natural Lands

The District has identified numerous species of invasive plant species present on District lands; specifically, 156 invasive plants are known to occur on District lands as of 2025 (see Table 8-1 below). The list of invasive plant species changes over time and will continue to be updated throughout the life of the IPMP. The following section presents IPM strategies for these target invasive plant species, organized by general life history (e.g., annual and biennial, perennial, aquatic plants). Because there is a great diversity of invasive plant species managed on District lands, specific treatments and management strategies must also consider the life history traits of each species in the context of its specific environment – the details of which cannot be outlined in a single document.

Ultimately, land managers, biologists, and pest control professionals must develop site-specific management for individual projects and species. The District's goal is to maintain the long-term stability and resiliency of its natural areas.

8.4 Pest Identification

Pest identification for invasive plants and wildlife can be readily undertaken using existing District resources such as invasive plant identification materials, and field guides. Staff should identify the pest to species, and then investigate its life history and life cycle, and document the distribution, density, population size, and population structure (i.e., percentage of each population in immature, adult, and reproductive stages) within the natural areas. Use the target pest list presented in Table 8-1 as a starting point of identifying pests that currently occur on

District lands. New pest species may invade District lands over time: if the pest is not listed in Table 8-1, staff should then do basic web searches to determine if the pest is regulated by statute, by which agency it is regulated, or determine if it is an unregulated pest on District lands.

8.5 Prevention

IPM in natural areas focuses first on preventative actions. Preventative actions include modifying human behavior and land use practices to minimize conditions that favor invasive plant infestation and establishment. When combined with landscape-level invasive plant monitoring and early detection/rapid response methods, this approach ensures that invasive plants can be managed when they are small, rather than large populations.

Many invasive plants establish themselves in ruderal or disturbed areas, for example, freshly graded, flooded, or mechanically cleared land, while others exploit more subtle disturbance areas, such as edges of trails and roads or overgrazed rangelands. Management of these species can often be accomplished by implementing better land use practices. Landscape management changes such as restoring natural processes (e.g., fire and flooding), reducing stocking rates/using rotational grazing on rangelands, increasing biodiversity in croplands, or altering forestry practices on timber tracts, can reduce invasive species populations to a level where active management is not required (L. E. Jackson et al. 2007). Other invasive species can invade stable, intact landscapes. These competitive species usually require active management to achieve effective control.

Seeds, insects, pets, and pathogens from anywhere in the world can easily arrive on District lands via numerous sources. The District's mission includes providing recreational access to approximately 72,000 acres of public open space, so visitors are one of many sources of potential new pest infestations. For example, a nature-loving tourist may take a plane from another region of the world with a climate similar to California's, and visit one of the District's properties for a hike, inadvertently introducing seeds from invasive species on their hiking boots.

Agricultural pest prevention programs have been implemented by governments throughout the world, with point-of-entry and trade distribution inspections, insect trap monitoring, and nursery certification. CDFA estimates that in California more than 20 million vehicles are monitored annually at California agricultural inspection stations when entering the state (CDFA n.d.-a). From these inspection stations, tens of thousands of prohibited materials are intercepted and seized annually which include a wide variety of agricultural pest species. Similar inspection systems are in place in many international ports of entry throughout the state, including airports, ports, and border crossings. Only more recently have regional entities and local governments begun to develop similar programs for species of local interest. These programs face many challenges in locations with defined borders where effective monitoring can occur do not exist.

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Table 8-1 Invasive Plant Species Documented as Present on the District Lands as of 2025

Scientific Name	Common Name	Life Form	Cal-IPC Invasive Status (2025) ^a	Midpen Rating ^b	Final Rating
<i>Acacia baileyana</i>	Cootamundra wattle	Tree, Shrub	High Risk	--	High Risk
<i>Acacia dealbata</i>	Silver wattle	Tree, Shrub	Moderate	--	Moderate
<i>Acacia decurrens</i>	Green wattle	Tree	--	Limited	Limited
<i>Acacia mearnsii</i>	Black wattle	Tree, Shrub	--	Limited	Limited
<i>Acacia melanoxylon</i>	Blackwood acacia	Tree, Annual herb	Limited	--	Limited
<i>Acacia pycnantha</i>	Golden wattle	Tree, Shrub	High Risk	--	High Risk
<i>Acacia retinodes</i>	Ever blooming acacia	Tree, Perennial herb	--	Limited	Limited
<i>Acacia verticillata</i>	Star acacia	Tree, Shrub	--	Limited	Limited
<i>Acaena novae-zelandiae</i>	Biddy biddy	Shrub (stem succulent)	High Risk	--	High Risk
<i>Aegilops cylindrica</i>	Jointed goatgrass	Annual grass	High Risk	--	High Risk
<i>Aegilops triuncialis</i> <i>Carduus pycnocephalus</i>	Goatgrass	Annual grass	High	--	High
<i>Ageratina adenophora</i>	Thoroughwort	Perennial herb	Moderate	--	Moderate
<i>Agrostis avenacea</i>	Pacific bentgrass	Perennial grass	Limited	--	Limited
<i>Ailanthus altissima</i>	Tree of heaven	Tree	Moderate	--	Moderate
<i>Alopecurus pratensis</i>	Meadow foxtail	Perennial grass	High Risk	--	High Risk
<i>Anthoxanthum odoratum</i>	Sweet vernal grass	Annual, Perennial grass	Limited	--	Limited
<i>Anthriscus caucalis</i>	Bur chervil	Annual herb, Vine	--	Limited	Limited
<i>Arctotheca prostrata</i>	Prostrate cape weed	Annual, Perennial herb	Moderate	--	Moderate
<i>Arrhenatherum elatius</i>	Tall oatgrass	Perennial grass	--	Limited	Limited
<i>Arum italicum</i>	Italian lords and ladies	Perennial herb	High Risk	--	High Risk
<i>Arundo donax</i>	Giant reed	Perennial grass	High-Moderate	--	High

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Scientific Name	Common Name	Life Form	Cal-IPC Invasive Status (2025) ^a	Midpen Rating ^b	Final Rating
<i>Avena barbata</i>	Slim oat	Annual grass	Moderate	--	Moderate
<i>Avena fatua</i>	Wildoats	Annual grass	Moderate	--	Moderate
<i>Bassia hyssopifolia</i>	Fivehorn smotherweed	Annual herb	Limited	--	Limited
<i>Bellardia trixago</i>	Mediterranean linseed	Annual herb	Limited	--	Limited
<i>Brachypodium distachyon</i>	Purple false brome	Annual, Perennial grass	Moderate	--	Moderate
<i>Brachypodium sylvaticum</i>	Slender false brome	Perennial grass	--	High	High
<i>Brassica nigra</i>	Black mustard	Annual herb	Moderate	--	Moderate
<i>Brassica rapa</i>	Common mustard	Annual herb	Limited	--	Limited
<i>Briza maxima</i>	Rattlesnake grass	Annual grass	Limited	--	Limited
<i>Bromus catharticus</i>	Rescue grass	Annual, Perennial grass	--	Limited	Limited
<i>Bromus diandrus</i>	Ripgut brome	Annual grass	Moderate	--	Moderate
<i>Bromus hordeaceus</i>	Soft chess	Annual grass	Limited	--	Limited
<i>Bromus madritensis</i>	Foxtail chess, foxtail brome	Annual grass	--	Limited	Limited
<i>Bromus tectorum</i>	Downy chess	Annual grass	High	--	High
<i>Buddleja davidii</i>	Butterfly bush	Tree, Shrub	High Risk	--	High Risk
<i>Carduus pycnocephalus</i>	Italian thistle	Annual herb	Moderate- Limited	--	Moderate
<i>Carduus tenuiflorus</i>	Slender flowered thistle	Annual herbTree	Limited	--	Limited
<i>Carex pendula</i>	Hanging sedge	Perennial grass	High Risk	--	High Risk
<i>Carpobrotus edulis</i>	Iceplant	Perennial herb	High	--	High
<i>Carthamus lanatus</i>	Woolly distaff thistle	Annual herbTree	High	--	High
<i>Centaurea calcitrapa</i>	Purple star thistle	Annual, Perennial herb	Moderate	--	Moderate

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Scientific Name	Common Name	Life Form	Cal-IPC Invasive Status (2025) ^a	Midpen Rating ^b	Final Rating
<i>Centaurea melitensis</i>	Tocalote	Annual herb	Moderate	--	Moderate
<i>Centaurea solstitialis</i>	Yellow starthistle	Annual herb	High	--	High
<i>Centaurea stoebe ssp. micranthos</i>	Spotted knapweed	Perennial herb	High	--	High
<i>Centranthus ruber</i>	Jupiter's beard	Annual, Perennial herb	--	Limited	Limited
<i>Cirsium vulgare</i>	Bullthistle	Perennial herb	Moderate	--	Moderate
<i>Clematis vitalba</i>	Old man's beard	Vine	Moderate	--	Moderate
<i>Conium maculatum</i>	Poison hemlock	Perennial herb	Moderate	--	Moderate
<i>Cortaderia jubata</i>	Andean pampas grass	Perennial grass	High	--	High
<i>Cortaderia selloana</i>	Pampas grass	Perennial grass	--	Moderate	Moderate
<i>Cotoneaster franchetii</i>	Cotoneaster	Shrub	Moderate	--	Moderate
<i>Cotoneaster lacteus</i>	Milkflower cotoneaster	Shrub	Moderate	--	Moderate
<i>Cotoneaster pannosus</i>	Woolly cotoneaster	Shrub	Moderate	--	Moderate
<i>Crataegus monogyna</i>	Hawthorn	Shrub	Limited	--	Limited
<i>Crocasmia Xcrocsmiiflora</i>	Monbretia	Perennial herb	Limited	--	Limited
<i>Cupressus macrocarpa</i>	Monterey cypress	Tree	Limited	--	Limited
<i>Cynodon dactylon</i>	Bermuda grass	Perennial grass	Moderate	--	Moderate
<i>Cynosurus echinatus</i>	Dogtail grass	Annual grass	Moderate	--	Moderate
<i>Cytisus multiflorus</i>	Spanish broom	Shrub	High Risk	--	High Risk
<i>Cytisus scoparius</i>	Scotch broom	Shrub	High	--	High
<i>Cytisus striatus</i>	Portuguese broom	Shrub	Moderate	--	Moderate
<i>Dactylis glomerata</i>	Orchardgrass	Perennial grass	Limited	--	Limited

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Scientific Name	Common Name	Life Form	Cal-IPC Invasive Status (2025) ^a	Midpen Rating ^b	Final Rating
<i>Delairea odorata</i>	Cape ivy	Perennial herb	High	--	High
<i>Digitalis purpurea</i>	Foxglove	Perennial herb	Limited	--	Limited
<i>Dipsacus fullonum</i>	Wild teasel	Perennial herb	Moderate	--	Moderate
<i>Dipsacus sativus</i>	Indian teasel	Annual, Biennial herb	Moderate	--	Moderate
<i>Dittrichia graveolens</i>	Stinkwort	Annual herb	Moderate	--	Moderate
<i>Echium candicans</i>	Pride of madeira	Shrub	Limited	--	Limited
<i>Ehrharta erecta</i>	Upright veldt grass	Perennial grass	Moderate	--	Moderate
<i>Elymus caput-medusae</i>	Medusa head	Annual grass	High	--	High
<i>Erodium cicutarium</i>	Coastal heron's bill	Annual herb	Limited	--	Limited
<i>Eucalyptus camaldulensis</i>	Red gum	Tree	Limited	--	Limited
<i>Eucalyptus globulus</i>	Blue gum	Tree	--	Moderate	Moderate
<i>Euphorbia lathyris</i>	Gopher plant	Annual, Perennial herb	High Risk	--	High Risk
<i>Euphorbia oblongata</i>	Eggleaf spurge	Perennial herb	Limited	--	Limited
<i>Festuca arundinacea</i>	Reed fescue	Perennial grass	Moderate	--	Moderate
<i>Festuca myuros</i>	Rattail sixweeks grass	Annual grass	Moderate	--	Moderate
<i>Festuca perennis</i>	Italian rye grass	Annual, Perennial grass	Moderate	--	Moderate
<i>Ficus carica</i>	Common fig	Tree	Moderate	--	Moderate
<i>Foeniculum vulgare</i>	Fennel	Perennial herb	Moderate	--	Moderate
<i>Gazania linearis</i>	Gazania	Perennial herb	Moderate	--	Moderate
<i>Genista monosperma</i>	Bridal broom	Shrub	Moderate	--	Moderate
<i>Genista monspessulana</i>	French broom	Shrub	High	--	High
<i>Geranium dissectum</i>	Wild geranium	Annual herb	Limited	--	Limited

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Scientific Name	Common Name	Life Form	Cal-IPC Invasive Status (2025) ^a	Midpen Rating ^b	Final Rating
<i>Geranium lucidum</i>	Shining geranium	Annual, Biennial herb	High Risk	--	High Risk
<i>Geranium purpureum</i>	little Robin	Annual, Biennial herb	Limited	--	Limited
<i>Geranium robertianum</i>	herb Robert	Annual herb	--	--	Limited
<i>Grevillea robusta</i>	Silkoak	Tree	High Risk	--	High Risk
<i>Hedera canariensis</i>	Canary ivy	Vine	High	--	High
<i>Hedera helix</i>	English ivy	Vine, Shrub	High	--	High
<i>Helminthotheca echioides</i>	Bristly ox-tongue	Annual, Perennial herb	Limited	--	Limited
<i>Hirschfeldia incana</i>	Mustard	Perennial herb	Moderate	--	Moderate
<i>Holcus lanatus</i>	Common velvetgrass	Perennial grass	Moderate	--	Moderate
<i>Hordeum marinum</i>	Seaside barley	Annual grass	Moderate	--	Moderate
<i>Hordeum murinum</i>	Foxtail barley	Annual grass	Moderate	--	Moderate
<i>Hypericum canariense</i>	Canary island st john's wort	Shrub	Moderate	--	Moderate
<i>Hypericum perforatum</i>	Klamathweed	Perennial herb	--	Moderate	Moderate
<i>Hypochaeris glabra</i>	Smooth cats ear	Annual herb	Limited	--	Limited
<i>Hypochaeris radicata</i>	Hairy cats ear	Perennial herb	Moderate	--	Moderate
<i>Ilex aquifolium</i>	Holly	Tree, Shrub	Limited	--	Limited
<i>Iris pseudacorus</i>	Yellowflag iris	Perennial herb	Limited	--	Limited
<i>Kniphofia uvaria</i>	Redhot poker	Perennial herb	High Risk	--	High Risk
<i>Lactuca serriola</i>	Prickly lettuce	Annual herb	--	Limited	Limited
<i>Lathyrus latifolius</i>	Sweet pea	Perennial herb	High Risk	--	High Risk
<i>Lepidium chalepense</i>	Lens-podded hoary cress	Annual, Perennial herb	Moderate	--	Moderate

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Scientific Name	Common Name	Life Form	Cal-IPC Invasive Status (2025) ^a	Midpen Rating ^b	Final Rating
<i>Lepidium draba</i>	Whitetop	Perennial herb	Moderate	--	Moderate
<i>Lepidium latifolium</i>	Perennial pepperweed	Perennial herb	High	--	High
<i>Leucanthemum vulgare</i>	Oxe eye daisy	Perennial herb	Moderate	--	Moderate
<i>Ligustrum lucidum</i>	Glossy privet	Tree, Shrub	Limited	--	Limited
<i>Limonium ramosissimum</i>	Algerian sealavender	Perennial herb	Limited	--	Limited
<i>Lythrum hyssopifolia</i>	Hyssop loosestrife	Annual, Perennial herb	Moderate	--	Moderate
<i>Marrubium vulgare</i>	White horehound	Perennial herb	Limited	--	Limited
<i>Maytenus boaria</i>	Mayten	Tree, Shrub	High Risk	--	High Risk
<i>Medicago polymorpha</i>	California burclover	Annual herb	Limited	--	Limited
<i>Mentha pulegium</i>	Pennyroyal	Perennial herb	Moderate	--	Moderate
<i>Mesembryanthemum nodiflorum</i>	Small flowered iceplant	Annual herb	Limited	--	Limited
<i>Myoporum laetum</i>	Ngaio tree	Tree, Shrub	Moderate	--	Moderate
<i>Myosotis latifolia</i>	Wide leaved forget me not	Perennial herb	Limited	--	Limited
<i>Myriophyllum aquaticum</i>	Parrot's feather	Perennial herb (aquatic)	High	--	High
<i>Nassella tenuissima</i>	Mexican feathergrass	Perennial grass	Limited	--	Limited
<i>Nicotiana glauca</i>	Tree tobacco	Tree, Shrub	Moderate	--	Moderate
<i>Olea europaea</i>	Olive	Tree, Shrub	Limited	--	Limited
<i>Oxalis pes-caprae</i>	Bermuda buttercup	Perennial herb	Moderate	--	Moderate
<i>Paspalum urvillei</i>	Vasey's grass	Perennial grass	High Risk	--	High Risk
<i>Phalaris aquatica</i>	Harding grass	Perennial grass	--	High	High
<i>Phoenix canariensis</i>	Canary island date palm	Tree	Limited	--	Limited

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Scientific Name	Common Name	Life Form	Cal-IPC Invasive Status (2025) ^a	Midpen Rating ^b	Final Rating
<i>Pinus radiata</i>	Monterey pine	Tree	Limited	--	Limited
<i>Pittosporum undulatum</i>	Victorian box	Tree, Shrub	High Risk	--	High Risk
<i>Plantago lanceolata</i>	Ribwort	Perennial herb	Limited	--	Limited
<i>Polypogon monspeliensis</i>	Annual beard grass	Annual grass	Limited	--	Limited
<i>Prunus cerasifera</i>	Cherry plum	Tree	Limited	--	Limited
<i>Pyracantha angustifolia</i>	Firethorn	Shrub	Limited	--	Limited
<i>Pyracantha coccinea</i>	Scarlet firethorn	Shrub	Limited	--	Limited
<i>Raphanus sativus</i>	Jointed charlock	Annual, Biennial herb	Limited	--	Limited
<i>Robinia pseudoacacia</i>	Black locust	Tree	Limited	--	Limited
<i>Romulea rosea</i>	Rosy sandcrocus	Perennial herb	High Risk	--	High Risk
<i>Rubus armeniacus</i>	Himalayan blackberry	Shrub	High	--	High
<i>Rumex acetosella</i>	Sheep sorrel	Perennial herb	Moderate	--	Moderate
<i>Rumex crispus</i>	Curly dock	Perennial herb	Limited	--	Limited
<i>Rumex pulcher</i>	Fiddleleaf dock	Perennial herb	--	Limited	Limited
<i>Rytidosperma penicillatum</i>	Purple awned wallaby grass	Perennial grass	Limited	--	Limited
<i>Salsola soda</i>	Alkali russian thistle	Annual herb	Moderate	--	Moderate
<i>Schinus molle</i>	Peruvian pepper tree	Tree	Limited	--	Limited
<i>Silybum marianum</i>	Milk thistle	Annual, Perennial herb	Limited	--	Limited
<i>Spartium junceum</i>	Spanish broom	Shrub	High	--	High
<i>Stipa miliacea</i>	Smilo grass	Perennial grass	Limited	--	Limited
<i>Torilis arvensis</i>	Field hedge parsley	Annual herb	Moderate	--	Moderate

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Scientific Name	Common Name	Life Form	Cal-IPC Invasive Status (2025) ^a	Midpen Rating ^b	Final Rating
<i>Trifolium hirtum</i>	Rose clover	Annual herb	Limited	--	Limited
<i>Ulex europaeus</i>	Gorse	Shrub	High	--	High
<i>Urospermum picroides</i>	Bristly tail seed	Annual, Perennial herb	High Risk	--	High Risk
<i>Verbascum thapsus</i>	Woolly mullein	Perennial herb	Limited	--	Limited
<i>Verbena bonariensis</i>	Purple top vervain	Annual, Biennial herb	High Risk	--	High Risk
<i>Vinca major</i>	Vinca	Perennial herb	Moderate	--	Moderate
<i>Washingtonia robusta</i>	Mexican fan palm	Tree	Moderate	--	Moderate
<i>Zantedeschia aethiopica</i>	Callalily	Perennial herb	Limited	--	Limited

Notes:

^a **CalIPC Invasive Status Definitions:**

- High – These species have severe ecological impacts on physical processes, plant and animal communities, and vegetation structure. Their reproductive biology and other attributes are conducive to moderate to high rates of dispersal and establishment. Most are widely distributed ecologically.
- Moderate – These species have substantial and apparent—but generally not severe—ecological impacts on physical processes, plant and animal communities, and vegetation structure. Their reproductive biology and other attributes are conducive to moderate to high rates of dispersal, though establishment is generally dependent upon ecological disturbance. Ecological amplitude and distribution may range from limited to widespread.
- Limited – These species are invasive but their ecological impacts are minor on a statewide level or there was not enough information to justify a higher score. Their reproductive biology and other attributes result in low to moderate rates of invasiveness. Ecological amplitude and distribution are generally limited, but these species may be locally persistent and problematic.

- ^b **Midpen ratings:** The rating that District vegetation staff has given a specific species follows the same definitions as Cal-IPC, however, if their rating differs from Cal-IPC, then District staff's rating takes priority and is used for final rating values.

Source: Species documented by Midpen staff as of 2025.

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There is no clear regulatory oversight for local programs, and there is little funding and staffing available. The most successful examples of local control programs have so far been limited to the management of aquatic pest species of restricted distribution (e.g., California's quagga/zebra mussel quarantines using boating restrictions in recreational waterways) (California State Parks, n.d.).

Although the District may have limited opportunities to restrict the flow of invasive species into its preserves from world trade and tourism, prevention is possible at smaller scales. IPMP BMPs and improved planning can help prevent inadvertent species introductions by requiring staff training on new invasive species that could invade District lands; inspection of outside materials, equipment, and vehicles; and requiring staff and contractors to only use clean materials, equipment, and vehicles on District lands. These BMPs intended to prevent introduction or establishment of new invasive species should be incorporated into the construction and maintenance of facilities, road maintenance, fire prevention, firefighting, and routine tool maintenance. Section 8.8 identifies specific preventative actions to reduce the potential to introduce and spread invasive species to District lands. Likewise, District visitors can be trained to identify, look for, and report new invasive species that can invade District lands. Educational materials and boot cleaning stations at key entrance points can help prevent inadvertent introductions, or catch them early. And finally, managing lands in a manner that monitors and reduces areas of soil disturbance, reduces unnecessary and redundant trails and roads, and helps promote larger, intact areas of undeveloped natural areas can also make District lands more resilient to new invasive species invasions.

8.6 Damage Assessment

Staff will determine what, if any damage to the natural area and its natural resource value, has resulted from the presence of the pest species. To the extent possible, quantify the damage (in acres, square feet, or numbers of occurrences affected) and qualitatively describe the perceived damage in its context. As an example, a staff person could determine that a certain percentage of the District's native perennial grassland acres are infested with yellow star-thistle, a target pest species, resulting in displacement native species and degradation of a large percentage of the natural resources on District lands. Ultimately, the District's goal is to maintain the long-term stability and resiliency of its natural areas, therefore damage assessments must consider the long-term effects of the pest infestation.

8.7 Tolerance Levels/Thresholds for Actions

Tolerance levels vary greatly for invasive species; some species have much greater impacts on the environment than others, or they may be so completely mixed with native species such that control methods would result in unacceptable damage to native habitats or rare species, or simply be technologically impossible. The District's IPM approach for invasive species begins with establishing site-specific conservation goals, leading to a determination of the targeted

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actions with which specific individuals or populations can be managed to achieve the stated goals.

Tolerance levels and treatment methods for invasive species are based on the potential of the invasive species to degrade wildlife habitat and other natural resource values such that the long-term stability and resiliency of its natural areas are compromised. To do so, staff must consider worker health and safety, visitor safety, and the technical feasibility of meaningful control (i.e., a cost/benefits analysis). Because many of the District's invasive species populations are present across multiple preserves or present throughout the entire region, scale is an important variable in determining the feasibility and need for control and the selection of a treatment method. Unlike pest management in structural landscapes, invasive species tolerance levels must factor in the scale at which a management tool is both appropriate and effective. Treatments such as hand removal may have minimal negative unintended impacts when a few individuals are removed, but substantially greater impacts (e.g., soil erosion or damage to non-target species, injury to staff) when the same treatment is applied to large areas. Similarly, the control of large populations of invasive plants using mechanical control methods can be cost prohibitive, impractical, and dangerous. The population size and habitat conditions for which each management technique is useful and appropriate is discussed for each section below. Tolerance levels not only differ by species, but also location and spatial scales. All treatment method selections will balance the net negative impacts to the natural environment, safety of the public, District workers and contractors, and the visitor experience.

Establishing tolerance level for insipient and widespread invasive plants in common, widespread natural communities (e.g., yellow star-thistle in annual grasslands or French broom in oak woodlands) will be established on a case-by-case basis by comparing the anticipated benefit against the cost and potential for success of the target invasive control efforts. As an example, tolerance levels for French broom in oak woodlands will be determined based on the total amount of infested areas within total oak woodlands on the subject preserve. As a general rule of thumb, the tolerance level for invasive plants will be exceeded where infestations exceed more than 10 percent of the total amount of a sensitive vegetation type, or 25 percent of the total amount of a common vegetation type. When tolerance levels are exceeded, District staff will then assess if active control is feasible by conducting a quick cost/benefit analysis. If staff determines that control is technically feasible and can be accomplished using existing staff and budgeting parameters, an Individual Pest Plan will be prepared (Chapter3). If however, available pest control options are not likely to be successful, staff may elect not to implement active pest control.

For federal and state listed species, certain protections are required under the state and federal Endangered Species Acts (ESAs), and tolerance levels will be linked to compliance with the ESAs. For wetlands, tolerance levels are linked to federal regulations under the federal Section 404 Clean Water Act and to state regulations as described in Section 401 Clean Water Act and in the Porter-Cologne Act. For natural communities, tolerance levels will be related to degree of rarity in the region (as indicated by experts such as the state California Natural Diversity

Database, California Native Plant Society, and local experts); the relative rarity of the community on District lands; the technical and cost feasibility of the pest to be controlled; and the sensitivity of the natural community to pest damage.

Following procedures outlined in this Chapter, District staff will qualitatively and quantitatively determine the degree of pest damage to the natural resource, then determine if action is warranted.

8.8 Treatment Options

When all other options for preventing or actively reducing pest population levels to below specified tolerance levels have been exhausted, District staff will determine treatment options. Because natural area pest control (typically control of invasive plants) is one of the most expensive and time-consuming aspects of District preserve management, special attention will be given to selecting proven, technically feasible, and cost-efficient least environmentally disruptive and harmful pest control solutions. Refer to Chapter 3 for project prioritization procedures intended to maximize the effectiveness and efficiency of District pest control actions.

Staff will evaluate pests in natural areas as follows:

- Pests will be treated (eradicated or controlled) when their presence could directly threaten the health and safety of visitors and staff.
- For pest infestations that are affecting listed species, pest species will be treated to comply with state and federal ESAs, and tolerance levels will be linked to compliance with the ESAs.
- For pests in wetlands, pest species will be treated to comply with the Federal Section 404 Clean Water Act, and state wetland regulations as described in Section 401 Clean Water Act and in the Porter-Cologne Act.
- Pest species may be considered for treatment (eradicated, controlled, or contained) if and when District staff determines that their presence is likely to result in the loss of the long-term stability and resiliency of the natural areas as a whole.
- Pest species may be considered for treatment (eradicated, controlled, or contained) if and when District staff determines that the pest could displace or degrade individual natural resources (e.g., where the presence of an invasive species is displacing a rare plant or animal population).
 - For natural communities, tolerance levels will be related to the sensitivity of the natural community to pest damage and the degree of rarity of the individual natural community in the region (as indicated by experts such as the state California Natural Diversity Database, California Native Plant Society, and local experts).
 - For native species, tolerance levels will be related to the sensitivity of the individual species to pest damage and the relative rarity of the individual

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species in the region or on District preserves. (Note: rarity to be determined by experts such as the state California Natural Diversity Database, California Native Plant Society, and local experts)

- Pest species may not receive treatment when their presence is not likely to result in the loss or severe displacement or degradation of natural resources and/or when treatment is considered technically infeasible, unsafe, or harmful to the environment.

If the target pest exceeds specified tolerance levels, the District will begin to investigate pest control options. This includes the following general steps involved in pest control planning:

- Delineate a project area;
- Determine pest control objectives;
- Identify any dispersal routes or mechanisms that may have helped the pest enter or spread onto district lands;
- Identify a range of possible pest control options using information presented below;
- Select a preferred pest control approach;
- Prepare an individual pest management plan (if necessary, see Chapter 3);
- Implement the selected pest control approach; and
- Using adaptive management, monitor, report (see Chapter 3) and adjust the selected pest control approach to achieve project objectives.

8.8.1 Invasive Animals in Natural Lands

Skunks, Opossums, and Raccoons

Skunks, opossums, and raccoons can be nuisances in natural lands, in addition to buildings as discussed in Chapter 5, due to their digging and foraging behaviors, which can disturb soils, damage native vegetation, and degrade natural lands. Skunks, opossums, and raccoons also prey on sensitive wildlife, are attracted to human food sources that increase conflicts, and can damage infrastructure such as trails; additionally, their presence can raise disease risks and lead to unsafe human–wildlife interactions. CDFW regulates these species as nongame or furbearer animals so they all may be controlled without permits if found causing nuisance problems.

Pest Management Strategies for Skunks, Opossums, and Raccoons

Physical Control

Box and Cage Traps. Install one-way door, live box, or cage traps. Trap design varies but solid wall traps are preferred for skunks to shield the trapper from skunk spray during the control operation. The use of live trapping methods ensures that non-target animals can be released unharmed. Current California Department of Fish and Wildlife (CDFW) trapping regulations require that trapped animals are either released immediately or euthanized, live animals may not be relocated without a permit from CDFW.

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Chemical Control

Currently there are no toxicants or fertility control agents available in California for these species.

Non-Native Fish

Known species of non-native fish in the District include black bass (*Micropterus* sp.), sunfish (*Lepomis* sp.), catfish (*Ameiurus/Ictalurus* sp.), and mosquitofish (*Gambusia* sp.) (Tokatlian 2026b). These species are generally found in man-made stock ponds and reservoirs but some also occur in natural sag ponds. The District does not actively manage non-native fish in man-made water bodies unless the water body also supports protected native species such as the California red-legged frog. In special cases where protected species are present, ponds are typically drained for sufficient time to eliminate all non-native fish species and then refilled. As most non-native fish species are managed as game fish by the CDFW, special permits are typically obtained for their control.

Bullfrogs

The American bullfrog (*Rana [Lithobates] catesbeiana*) is a large, brilliant green amphibian that is native to eastern North America. Its natural range does not extend west of the Rocky Mountains and Great Plains, but it is an increasingly common invasive animal in the western United States. Bullfrogs are sold throughout the world as food, pets, fish bait, and for educational purposes. They sometimes become unwanted pets or escape from frog farms and grocery stores, and as a result have readily established themselves in all suitable habitats throughout California.

Bullfrogs are classified by the CDFW as a game amphibian and are regulated by state fishing regulations. As a game amphibian, commercial and sport collection is permitted with commercial and sport fishing licenses, but individuals cannot be controlled as an invasive species unless they are specifically used for a purpose (i.e., wanton waste is prohibited by statute). State fishing regulations do not include any depredation conditions, so all bullfrog control efforts and programs require a specific Memorandum of Understanding or Special Permit from the CDFW (Tokatlian 2026a).

American bullfrogs are most problematic in the District because they directly affect the federally Threatened California red-legged frog (*Rana draytonii*) and San Francisco garter snake (*Thamnophis sirtalis tetrataenia*) (Lawler et al. 1999; Kim et al. 2021). In habitats where they exist together, large, overwintering bullfrog tadpoles can compete with California red-legged frog tadpoles or even consume them directly. Adult bullfrogs consume California red-legged frogs in all forms (i.e., as tadpoles, metamorphs, or as adult frogs), in addition to other native wildlife species such as newts, salamanders, garter snakes, birds, and bats. Their voracious appetites have been implicated in the declines of many North American amphibian species.

In addition to competition and predation, bullfrogs spread chytrid fungus – a lethal skin disease known as chytridmycosis that impacts many of California’s native amphibians (Schloegel et al. 2009). Chytrid fungus is a non-native fungal pathogen from Asia that has spread resulting in amphibian population decline all over the world. Because bullfrogs are domestically raised for

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food and educational purposes worldwide, many that are imported to California each year carry the chytrid fungus from unregulated foreign frog farms. As these individual frogs are accidentally or intentionally released into the wild, they help to spread the fungal disease throughout native amphibian populations.

Prevention and control of American bullfrogs is discussed below. Tolerance levels and treatment methods are also outlined in Table 8-2.

Prevention

- **Education.** Education can be an important tool for the District in preventing captive frogs from being intentionally released onto District lands. Some people feel ethically motivated to release captive pets and food animals back into natural environments for humane reasons or when they no longer wish to care for them. Public outreach and judiciously placed educational materials such as signs and brochures in District preserves with wetlands may be a useful strategy to curb intentional releases of animals.

Physical Control

- **Gigging or shooting.** Gigging or shooting American bullfrogs (a pest species not native to California) are two methods that are implemented with small caliber air rifles and lead-free ammunition to eliminate individual adult bullfrogs. Gigging is the targeted spearing of fish or frogs with barbed tines mounted on a long pole. Both gigging and shooting are effective and humane methods for selective removal of target adult bullfrogs. However, this treatment method alone will rarely eradicate bullfrogs from the target area because only a portion of adults are usually found, and it does not control eggs or larval stages. Some studies have indicated that adult metamorph removal (i.e., removal of immature bullfrogs) is the most economical removal method for population suppression (Govindarajulu et al. 2005). Egg masses can also be collected to remove additional life stages at the appropriate time of year.
- **Trapping.** Submerged funnel traps and floating cage traps can be used to control different life stages of American bullfrogs. Funnel traps designed for catching baitfish can be used to live capture bullfrog tadpoles. Floating cage traps have been successfully used to catch adult frogs. Trap designs for bullfrog removal are relatively recent and mainly rely on modifying Australian cane toad traps. Methods designed to trap multiple life stages of frogs in parallel have proven to be effective for bullfrog management (Snow and Witmer 2011). Though trapping is a recently developed treatment method for bullfrogs, it may be effective especially where other sensitive amphibian species are present to which impacts must be avoided.
- **Electrical currents.** Use of electrical currents (electroshocking) to temporarily disable frogs in netting and gigging operations have proved to be effective in some control programs (Orchard 2011). Twelve volt (12v) direct current (DC)

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electroshockers that are typically used in fisheries management are mounted either on small boats or on backpacks, then the electroshock current applied to the surface of the wetland. This treatment is non-specific, and will affect all aquatic species within the range of the electroshocking ‘wand’. Electroshocking is not lethal, rather it shocks and lifts the affected individuals to the surface where they can be netted or otherwise collected. This treatment method, therefore, must be followed by another treatment method such as hand removal or gigging. Even with follow-up control of individuals found by electroshocking, this treatment method alone will rarely eradicate bullfrogs from the target area because only a portion of adults are usually found, and it does not control eggs or larval stages.

- **Habitat Manipulation.** Pond draining is one of the most common methods used for bullfrog control in California, especially in projects where protected species may be present such as the native California red-legged frog. American bullfrogs need a perennial water source to complete their lifestyle. In contrast, California red-legged frogs only need water during their breeding cycle. The *USFWS California Red-legged frog Recovery Plan* and others recommend draining ponds that contain both bullfrog and California red-legged frog species every other year to reduce the habitat suitability for bullfrogs (Gray 2009). Type conversion of permanent stock ponds to ephemeral wetlands can also reduce bullfrog populations across a landscape scale.

Chemical Control

No toxicants or fertility control treatments are registered for use in controlling bullfrogs in California (Table 8-2).

Table 8-2 Treatment Methods for American Bullfrogs

Pest Category	Treatment Method Thresholds	Timing	Treatment	Treatment Constraints
American Bullfrogs	Incipient: < 25 individuals	Adults present in breeding ponds (February -October)	Hand removal of adults; gigging, shooting adults and metamorphs, dipnet collection of larvae, egg mass collection	Small populations - accessible water bodies only
	Medium - Expanding Population	Adults and juveniles present in breeding ponds (February - August)	Funnel and cage trapping	Requires combined trapping of tadpoles and adults

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Pest Category	Treatment Method Thresholds	Timing	Treatment	Treatment Constraints
	Large - established populations in managed ponds	Adults present in breeding ponds (April - October)	Pond draining	Not possible in wetlands or where other natural resource may be damaged by draining

Other Non-Native Amphibians and Reptiles

Several species of non-native turtles are known to occur in District ponds and water bodies. These species are common food items for Bay Area ethnic communities and/or pet species. The red-eared slider (*Trachemys scripta elegans*) is the most common species known to occur within the District and an eastern snapping turtle (*Chelydra serpentina serpentina*) and river cooter (*Pseudemys concinna*) have been documented in at least one District pond. Red-eared sliders are managed as game fish species and snapping turtles are a restricted species in California. The District does not actively manage red-eared sliders unless the water body also supports protected, native species such as California red-legged frogs. The District will attempt to trap non-native turtles and remove them in compliance with CDFW when they share habitat with protected, native species. The District will attempt to trap restricted amphibian and reptile species in compliance with CDFW, and send applicable species to wildlife sanctuaries, as appropriate. Traps are designed specific to the target species and meant to capture the turtles without harm. Traps are checked daily for release and documentation of any native species and removal of any non-native species. A qualified biologist determines if any native species are present in the trapping area and consults with CDFW and USFWS if special-status species are present. A qualified biologist complies with CDFW recommendations for restricted species since they are illegal to possess in California without a special permit. In special cases, ponds are drained for sufficient time to collect and eliminate non-native amphibian species (in compliance with the Fish and Game Code) and then refilled. See information on pond draining presented above for bullfrogs.

Feral Pigs

Feral pigs (*Sus scrofa*) are one of the most destructive wildlife species in California and continue to expand their range throughout the entire United States. Feral domestic and wild Eurasian pigs are not native to North America but have been introduced in multiple events. These wild pigs have hybridized to become unique, abundant invasive pests in California, and they are thought to be one of the most prolific large mammals on earth (West et al. 2009)

Any pig living unassisted in the wild in California is classified as a game animal by current the Fish and Game Code, which regulates the sport harvest of game animals in California. Pigs have extremely generous allowable methods of sport take, and can be harvested year-round in unlimited quantities with a hunting license and valid pig tag. Because they are also regulated as an agricultural pest in California by the USDA – APHIS Wildlife Damage Control Services and the CDFA, their management is often regulated by depredation permits from the CDFW. These

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permits can be obtained by private growers, ranchers, or other landowners and public agencies when proof of economic damage can be documented to the CDFW.

Pigs are mammals that are capable of extremely high reproductive rates when environmental conditions are favorable. In California's Coast Ranges, they can reach high populations densities because of cool weather, year-round access to water, and food (including acorns, a favored food source) through the winter months. Their invasive potential is largely because of their ability to quickly increase population size; they reach sexual maturity at young ages, females can have multiple litters each year, and natural mortality rates are generally low with few native predators. They can also disperse over large distances to invade new habitats and so cannot be managed effectively on a local basis.

Pigs cause damage to California agriculture and native fish and wildlife. Their destructive rooting behavior is visible in many natural areas. Rooting increases erosion and soil sedimentation, decreases water quality, directly reduces native plant species (e.g., ingestion of tubers, acorns), and promotes the establishment of non-native and invasive plants in disturbed soils (Kotanen 1995; Seward et al. 2004). They also create competition for food resources that would normally be consumed by native wildlife (especially winter acorns), spread disease to wildlife, and consume ground nesting birds, reptiles, amphibians, and small mammals (Barrett 1982; Conservation Biology Institute 2009). Feral pigs also cause significant crop damage through the direct consumption and damage to crops, transmission of disease to livestock, and other damages to property and agricultural infrastructure (U. S. Department of Agriculture 2011). The District has in the past conducted feral pig predation under a CDFW permit.

Pest Management Strategies and Wild Pigs

Under the direction of the California Department of Fish and Wildlife, the District has developed a management program to capture feral pigs using baited traps and humane termination (shooting). As part of the program, the District coordinates with other regional land management agencies that are controlling feral pig populations.

Feral pig rooting, damage, and sightings have substantially decreased on District lands in recent years. Prevention and control of feral and wild pigs is discussed below. Tolerance levels and treatment methods are also outlined in Table 8-3.

Table 8-3 Treatment Methods for Feral and Wild Pigs

Pest Category	Treatment Method Threshold	Timing	Treatment	Treatment Constraints
Feral and Wild Pigs	Incipient: ≤ 2 individuals	Year-round	Shooting incidentally observed individuals	Not possible in heavy visitor use areas
	Medium to large populations	Year-round	Cage and corral trapping program	--

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Prevention

- **Fencing.** Exclusion of pigs with pig-proof fencing can be effective in preventing high value areas from being invaded by pigs. Fencing must be maintained annually to be effective. Pig-proof fencing is usually very expensive to install and maintain and also has the possibility of restricting the movement of native animal species. It is an effective strategy for protecting extremely high value natural areas, agricultural lands, or archeological sites in small areas.

Physical Control

- **Shooting.** Shooting (either hunting or professional depredation) is the most common method for feral pig control throughout California (CDFW n.d.) Though state sport hunting is regulated in such a way to offer some control of pig populations, there can still be a population increase above target levels because pigs often change their behaviors to avoid hunting pressure. Permitted depredation hunting with the assistance of tracking dogs or using nighttime vision aids and thermal imaging can increase the effectiveness of managing populations. Shooting methods should only employ lead-free, copper-based ammunition to reduce non-target mortality to pig carcass scavengers. Shooting has limited public appeal in and near recreational facilities and may not be a practical option for the District.
- **Trapping.** Trapping is the most effective means for regulating wild pig populations on a small landscape scale, although it must be done in perpetuity to maintain low population numbers. Cage- or corral-type traps are the most commonly used trap design in California. Snares have been found to be highly successful in Hawaii and Texas. Cage traps function by attracting single or multiple pigs into traps with bait through a one-way or guillotine trap door. Since pigs have large home ranges and they can disperse over large landscapes, effective trapping must focus on areas pigs are actively using. This requires the trapper to scout large landscapes or use a network of camera-traps to identify locations where pigs are actively travelling and feeding. Pre-baiting increases the effectiveness of live-catch traps. Trapping requires great effort and costs are typically high, but it is currently one of the most effective methods available for population control. All cage trap and snaring methods must be permitted through the CDFW on a project-by-project basis.

Chemical Control

- **Toxicants.** No toxicants are currently registered for the control of pigs, although some are in development (e.g., warfarin and sodium nitrite) for Federal registration through the EPA (M. Smith 2020).
- **Contraception.** Currently, no immuno-contraceptives are registered for use on wild pigs although some are in development. The Wildlife Society considers wild pig contraception controls to be impractical in the field (Fagerstone et al. 2002) so

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they are likely not a viable treatment method for managing feral pigs on District lands.

Feral Pets

As with non-native turtles, domestic animals are sometimes released by preserve visitors, or wander into preserves on their own. Some people feel ethically motivated to release captive pets and food animals back into natural environments for humane reasons or when they no longer wish to care for them. As a result, domestic cats, dogs, rabbits and other species end up living in preserves, and consuming native rodents, plants, and insects.

Prevention

Education can be an important tool for the District in preventing pets from being intentionally released onto District lands. Public outreach and judiciously placed educational materials such as signs and brochures in District preserves may be a useful strategy to curb intentional releases of animals.

Live Capture

Use catch pole or otherwise trap feral dogs, cats, turtles, rabbits and other domesticated animals found escaped or released in the preserves and return them to their owners or turn them over to local animal control departments or animal shelters.

8.8.2 Invasive Plants

The selection of physical control, chemical control, or other treatment methods for the District's target invasive plant species on over 72,000 acres of terrestrial and aquatic habitats in natural areas, various rangelands, and agricultural properties is an extremely complex task. This document is only intended to summarize generalized options for simplified management scenarios, and to provide decision-making tools for the thoughtful implementation of an IPM strategy. Staff who are selecting a project-level IPM strategy must consider site-specific conditions, detailed life history information for a target invasive plant, project history, an understanding of the native vegetation where these plants occur, the impacts of the target plant, and the feasibility for safe and effective long-term control. Maintaining pest levels below a desired tolerance level will ultimately rely on several integrated methods for various stages of the project; rarely will a single method, pesticide or otherwise, suffice to achieve long-term success.

Annual and Biennial Invasive Plants

Annual plants live for one growing season and germinate from seed. Only the dormant seed bridges the gap between one generation and the next. Biennial plants have a similar life history except they can live for several growing seasons before flowering and death. After germination, many species develop into prostrate (i.e., ground-hugging) basal rosettes. This growth form allows the plant to suppress germination of other plants near its root zone to maximize the solar energy reaching its leaves. After a critical amount of energy is collected and stored in the basal rosette form, the plant initiates its final growth stage and elongates or 'bolts' to produce a flowering stalk. Environmental cues that initiate bolting, flowering, and seed production

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include changes in day length, light and temperature, soil moisture and other stresses to the plant (California Weed Science Society 2002).

Many annual plants, both native and non-native, are considered 'weedy' because they have generalist rather than specialist life history traits. Annuals may be self-fertile or require pollination, or may use a combination of both pollination strategies. Often, invasive plants are highly successful because they produce many viable seeds with or without specialized pollination. In contrast, many native plants rely on specific native pollinators such as solitary native bees and cannot compete with the volume of seed production of invasive plants. Since annuals rely entirely on seed production for survival, the most successful invasive annual plants typically produce tremendous amounts of seeds each year. Many invasive (and native) species also have specialized seed coats that aid in seed dormancy in the soil, allowing the seed bank of a plant to persist in the soil for many years. Seed dormancy allows the plant to germinate only when environmental conditions ideal for growth are present and allows for seedling emergence over several decades instead of just one or a few years. The extended germination period of some invasive species can be problematic for control efforts, as follow-up treatments for new seedlings may be required for many years.

Within District lands there are two main growing seasons for annual and biennial invasive plants: referred to as early season and late season. Early season annuals and biennials germinate, flower, and seed between November and June, while late season annuals and biennials germinate, flower, and seed between February and September. Common annual invasive plants that the District currently manages include yellow star-thistle (*Centaurea solstitialis*), wooly distaff thistle (*Carthamus lanatus*), and Italian thistle (*Carduus pycnocephalus*). Biennials include purple star-thistle (*Centaurea calcitrapa*) and poison hemlock (*Conium maculatum*).

Perennial Invasive Plants

Perennial plants persist for many growing seasons and have a great diversity of growth strategies. Perennials include ferns, bulbs, herbaceous plants, woody shrubs, and trees. Herbaceous perennial plants typically go dormant, die back, and or lose their leaves each winter and regrow from the root system the following spring. Evergreen perennial plants retain their above-ground stems and leaves throughout their life, except sometimes in cases of extreme stress (e.g., drought). Deciduous perennial plants retain their aboveground stems but lose their leaves seasonally when they are not actively growing. Trees and shrubs are perennial plants with woody stems and can be either evergreen or deciduous.

Understanding the biology and reproduction method of perennials is essential to developing effective control strategies. Perennial plants can have multiple reproduction methods, including seeds, re-growing from vegetation fragments, or resprouting or colonizing from roots. In some cases, species may use a combination of all these reproductive strategies for successful establishment and expansion. Perennial plants can spread vegetatively from many different portions of the plant (e.g., from runners, tubers or bulbs, root fragments) depending on species.

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Preventing seed production in perennial invasive species that rely exclusively on seeds for regeneration can deplete the existing seed bank, (as with annuals), but this strategy does not address the parent population which must also be controlled. Control of perennial plants often focuses on removal of the roots or other underground storage tissues, where energy reserves are stored. However, this treatment method may result in ground disturbance and/or soil erosion that must also be mitigated or avoided.

Pest Management Strategies for Invasive Plants

Prevention and control of invasive plants is discussed below. Tolerance levels and treatment methods are also outlined in Table 8-4 (Annual Plants), Table 8-5 (Perennial Plants), and Table 8-6 (Aquatic Plants).

Prevention

- Implement an employee and contractor prevention training program (refer to Appendix C for the IPMP BMPs and Section 3.9); include invasive plant identification and cleaning protocols for clothing, tools, and vehicles.
- Inspect recreational facilities (e.g., parking lots, trails, visitor centers) that experience high visitor use often during target invasive plant flowering and seed production times. Treat any detected target invasive plant populations to prevent spread from the facility into the preserves.
- Establish and maintain cleaning and prevention facilities (e.g., boot cleaning stations) and post educational materials in parking lots and trailheads to encourage visitors to clean their boots, socks, pants, etc. before entering District lands.
- If target invasive plants have already begun to flower and set seed before management, consider manual control methods (e.g., cutting and bagging the flower/seed heads) intended to reduce the number of new seeds released. This type of active management is only feasible for small populations.
- Prevent the spread of plant fragments (roots, stems) of certain perennial species that can produce new plants from these plant fragments during soil disturbing activities such as trail and road maintenance.

Physical Control

Physical control of invasive plants includes actions that physically remove plants in part or in their entirety, including (but not limited to) hand pulling using weed wrenches; shovels; mechanical controls using brush cutters, chainsaws, mowers, pole pruner, chippers, masticators, and other similar equipment, and other types of control to remove plants such as green flaming (i.e., use of a propane torch on emergent seedlings), or grazing the plant using livestock. These types of controls are described in more detail below.

- **Pulling of individual plants by hand before flowering and seed development.**
Given the stout taproot of many annuals and biennials, it is best to undertake hand removal after regular periods of rain when the soil is moist and the entire taproot can be easily removed. Grasp the plant at the base and pull straight up.

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- **Leaving the portion of the root deeper than a quarter to a half inch below the surface is usually acceptable for annual species as they are not likely to re-sprout from a remaining root fragment.** Digging tools can also be used to loosen the root out of the soil, however, limit the amount of soil disturbance as much as possible.
- **Cutting plants below the root crown with a pick or shovel before flowering or seed set** (to be applied only to crown-sprouting plant species). Perennial invasive plants with large amounts of vegetative material are often easier to control once the mass of above-ground vegetation is cut to near-ground level (e.g., large perennial grasses and shrubs) to improve access to the root system. For plants that can regenerate from underground root fragments, root and/or stem material will be carefully collected, then disposed of in compost or garbage offsite or completely covered (composted, solarized) onsite to prevent it from re-establishing onsite.
- **Mowing of late season annuals/biennials when a very small percentage of plants are beginning to flower.** Mow as close to the ground as is safe (hitting rocks with mowing equipment may cause sparks and risk starting a fire). Follow-up mowing may be required at four- to six-week intervals. Mowing early season annuals/biennials, or mowing late season annuals/biennials too early will likely result in resprouting and formation of multiple flowering stalks during bolting (thereby increasing seed production).
- **Green flaming of young seedlings with a hot propane flame immediately following germination.** This method is typically applied in early winter, during or immediately after a rain event to reduce potential for wildfires. “Green flaming” is only effective on some species of non-fire adapted herbaceous and shrub species (dicots), and it is not effective on grasses (monocots).
- Selective grazing to remove or suppress some species when grazing is timed for periods when the plants are both palatable to the selected type of livestock (e.g., goats for brush, cattle or sheep for grasses) and susceptible to grazing effects (i.e., when plants are very young and do not have substantial underground energy reserves built up to support re-sprouting).
- **Hand removal of small insipient populations of perennial invasive plants.** Hand-removal of mature plant parts will be accomplished using a weed wrench, or by digging up individual plants, including as much of the root system as possible. Multiple re-treatments will be required for the control of most invasive perennials, because their root systems are often large and challenging to pull manually and many species have regenerating roots, stolons, and rhizomes that can break off during the removal effort and regrow. Digging can also promote soil disturbance, a secondary effect that can promote the germination of new seedlings in disturbed soils areas.
- **Burning to reduce green waste.** After large stands of broom are pulled, the green plants will be stacked in piles no greater than six feet by six feet to dry out. The piles will be located on mineral soils with a 4-inch by 12-foot wide trench to catch

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debris and will not be located under the drip line of trees. Brush piles will be burned during the wet season on days that the Bay Area Air District (Formerly the Bay Area Air Quality Management District) designates as “open burn status” and the piles will be monitored to ensure that all combustible material is consumed before leaving the site. Open Burning Regulation 5 Notification Form will be filed with the Air District, and all conditions of the Air District regulations will be followed.

- **Use of tractor-mounted implements.** Jawz is a hydraulic implement mounted onto an excavator or other tractor. Opposing jaws pinch the stalk of the plant and the arm of the excavator pulls the plant out by its roots and then drops it in a pile for future burning, chipping, or composting. The use of Jawz will be limited in steep terrain and areas where there is excessive soil. Removal of coyote brush is the most common species that Jawz are used for on District lands.
- **Use of a masticator for brushing.** A masticator is a high-rotation drum with fixed teeth mounted on the hydraulic arm of an excavator that pulverizes vegetation. A masticator will be used for structure brushing, road brushing, parking lot brushing, fuel breaks, and brush removal in grasslands. The masticator will cut vegetation ranging from grass to 6-inch diameter trees and can reach up to 22 feet horizontally. Masticators leave behind mulch and pieces of shattered wood up to approximately 12 inches long and can require, depending on vegetation, follow-up use of chainsaws by field staff. Use of a masticator is limited by terrain and soil moisture (i.e., soft ground). A masticator will be used less than four miles per year.

Biological Control

Hairy weevils are used as biocontrol insects for yellow star-thistle, which involves the release of approximately 20,000 hairy weevils (*Eustenopus villosus*) on approximately 800 acres per year at Fremont Older, Monte Bello, Rancho San Antonio, Russian Ridge, Skyline Ridge and St. Joseph’s Hill and possibly biocontrol at other preserves in the future. This form of biocontrol is intended to control seed production of yellow star-thistle. Selected areas are typically heavily infested with yellow star-thistle, and other forms of control were determined to be infeasible due to site access limitations, labor costs or staffing safety issues. In these instances, biocontrol is intended to keep the infestations from spreading or becoming denser, until such time as other methods can be used.

Table 8-4 Treatment Thresholds and Methods for Annual and Biennial Invasive Plants

Pest Category	Treatment Method Thresholds	Phenology	Timing	Treatment	Treatment Constraints - Assets
Annual/Biennial Invasive Plants	Incipient/sm all: < 100 individuals	Basal rosette or bolting before seed production	February - May	Manual (Hand removal)	Use for small infestations only; worker hazards may occur when applied at larger scales

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Pest Category	Treatment Method Thresholds	Phenology	Timing	Treatment	Treatment Constraints - Assets
	Small to medium: <5 acres	Bolt stage – flowering	March - June	Cutting (Mowing)	Not effective on most species - especially not biennials; to be used for suppression/containment goals only
	Small to medium: <5 acres	Early seedling - from germination to appearance of first true leaves	November-January	Propane Torch (Green Flaming)	Narrow timing window; only appropriate for sparse vegetation with low ignition potential. Usually applied during rain events to reduce wildfire risk.
		Seedling to pre-flowering grasses	December-April	Herbicide: clethodim	Highly selective to monocots only; rate selective for annual grasses only
		Seedling stage through late flowering/bud stage	December-April	Herbicide: glyphosate IPA and glyphosate k	Spot treatments; non-selective
	Medium to large: >5 acres	Pre-germination to flowering stage	November-July	Herbicide: imazapyr (pre/post emergent)	Spot treatments where residual control of seedlings is desired; non-selective
		Ranging plant size	March-November	Herbicide: triclopyr BEE (post emergent)	Spot treatment for control of annual and perennial broadleaf weeds and woody plants
		Ranging plant size	Anytime	Herbicide: triclopyr TEA (post emergent)	Spot treatment for control of annual and perennial broadleaf weeds and woody plants
		Pre-germination to dicot seedling stage	December-February	Herbicide: aminopyralid (pre/post emergent)	Moderately selective for specific dicot plant families only; promotes grass and unaffected dicot species
	Large: >5 acres	Later dicot seedling stages – bolting	January - March	Herbicide: clopyralid (pre/post emergent)	Highly selective for specific dicot plant families only; promotes grass and unaffected dicot species

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Pest Category	Treatment Method Thresholds	Phenology	Timing	Treatment	Treatment Constraints - Assets
		Bolt stage – flowering	March - June	Grazing	Effective on only some species; effectiveness varies by stock type, grazing season, grazing rotation, and intensity
		Ranging plant size	March-November	Herbicide: triclopyr BEE (post emergent)	Spot treatment for control of annual and perennial broadleaf weeds and woody plants
		Ranging plant size	Anytime	Herbicide: triclopyr TEA (post emergent)	Spot treatment for control of annual and perennial broadleaf weeds and woody plants

Table 8-5 Treatment Thresholds and Methods for Perennial Invasive Plants

Pest Category	Treatment Method Thresholds	Phenology	Timing	Treatment	Treatment Constraints - Assets
	Incipient/sm all: < 100 individuals	Herbaceous perennials seedling to mature	Any time	Manual (Hand removal)	Use for small infestations only; worker hazards may occur when applied at larger scales
	Incipient/sm all: woody plants with trunk diameter < 2"	Woody plants/trees - Seedling to mature	Any time	Manual (Digging - Leveraged Pulling)	Use for small infestations only; worker hazards may occur when applied at larger scales
Perennial Invasive Plants	Small to medium: < 5 acres	Flowering to bud stage	December-July	Cutting (Mowing)	Not effective on most species; for suppression/containment/pre-treatment goals only
	Small to medium: < 5 acres	Early seedling – from germination to appearance of first true leaves	November-January	Propane Torch (Green Flaming)	Narrow timing window; only appropriate for bare ground areas with no ignition potential
	Medium to large: > 5 acres	Seedling to pre-flowering grasses	December-April	Herbicide: clethodim	Highly selective to monocots

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Pest Category	Treatment Method Thresholds	Phenology	Timing	Treatment	Treatment Constraints - Assets
		Seedling stage OR late flowering/bud stage	December-July	Herbicide: glyphosate IPA and glyphosate k	Spot treatments; non-selective
		Seedling or actively growing	December-June	Herbicide: aminopyralid (pre/post emergent)	Moderately selective for specific dicot plant families only; good for difficult to control vines/brambles
		Seedling or actively growing	December-June	Herbicide: clopyralid (pre/post emergent)	Highly selective for specific dicot plant families only; good for difficult to control vines/brambles
		Pre-germination to flowering stage	November-October	Herbicide: imazapyr	Spot treatments where residual control of seedlings is desired or difficult to control species; non-selective
		Ranging plant size	March-November	Herbicide: triclopyr BEE (post emergent)	Spot treatment for control of annual and perennial broadleaf weeds and woody plants
		Ranging plant size	Anytime	Herbicide: triclopyr TEA (post emergent)	Spot treatment for control of annual and perennial broadleaf weeds and woody plants
	Trees > 6" stump diameter	Actively growing, post-flowering	Anytime	Herbicide: glyphosate IPA and glyphosate k	Spot treatments; non-selective
		Actively growing, post-flowering	Anytime	Herbicide: imazapyr	Spot treatments where residual control of seedlings is desired or difficult to control species; non-selective; basal bark treatments
		Conifers – mature	Anytime	Cutting	Hand methods time consuming; mechanical harvesters for large areas > 10 acres

Chemical Control

Chemical control of annual and biennial weeds includes two strategies to treat different life stages: 1) post-emergent (i.e., direct application of herbicide to eliminate the plant), and 2) pre-emergent (i.e., treatment to prevent the germination of seeds). Herbicides are also classified as either selective or non-selective. Selective herbicides control plants in specific plant families or life stages, while allowing other plants to survive uninjured. Using selective herbicides can be a powerful tool in balancing active management with protecting desirable, native vegetation types. Non-selective herbicides and application methods injure all plant species that are directly exposed to treatment, so should be directed only to the target species. Selectivity may be based on the chemistry of the herbicide, but can change with the timing of the application.

- **Aminopyralid** is a selective herbicide used to control broadleaf invasive plants, especially sunflower and bean plant families. The pesticide product is considered to have low exposure risks associated with wildlife and humans, especially in natural areas where exposure levels will be of short duration and low total exposure rates (Table 3-3). Plants in the nightshade, bean, rose, and sunflower families are particularly sensitive to this herbicide. However, grasses are not affected by the herbicide when used after grass seed germination, making it an attractive IPM option for annual plant control in grasslands. Aminopyralid disrupts the normal hormone balance, targeting auxins, and causing uncontrolled growth in susceptible plants. Symptoms of effective aminopyralid application include bending and twisting of stems and petioles, swelling at nodes, stem elongation, leaf curling, chlorosis (yellowing) of growing points, and plant mortality within three to five weeks. Aminopyralid persists in the soil and is absorbed by plant roots, and thus prevents germination of new seeds after an initial treatment. It can be used before an invasive plant species germinates in a known population area, or well after seedlings emerge, making it a nimble tool for invasive species plant control.
- **Clethodim** is a selective herbicide that provides post-emergent control of grasses. It does not affect broadleaf plants or sedges and has no uptake through roots or pre-emergent effect. Clethodim is a lipid-synthesis regulating herbicide that impacts chemical pathways that are only present in some monocots (e.g., grasses). Clethodim is most effective on young grasses, especially annuals, and thus is recommended for early season application only. Grass-specific herbicides are highly effective tools for invasive grasses growing in complex native vegetation. They are effective tools for the elimination of annual and perennial grasses in broadleaf (dicot) dominated environments or in eliminating annual grasses from some perennial grassland systems.
- **Clopyralid** is a selective herbicide used to control broadleaf invasive plants, especially thistles and clovers, and woody leguminous plants. Plants in the nightshade, bean, and sunflower families are particularly sensitive to this herbicide. Grasses are not affected by it, making it an attractive IPM option for annual invasive plant control of these susceptible broadleaf plants in grasslands. Clopyralid is a growth regulator, rapidly transported through plants primarily

through the phloem, and accumulates in growing points. It is absorbed into the plant by leaves, stems, and roots. Symptoms of effective clopyralid application include bending and twisting of stems and petioles, swelling at nodes, stem elongation, leaf curling, chlorosis (yellowing) of growing points, and plant mortality within three to five weeks. Clopyralid can travel through soil and should not be used where soils have very rapid permeability, such as loamy sand to sand.

- **Glufosinate** is a non-selective foliar herbicide with no soil residual. After application, glufosinate is only weakly translocational, meaning it moves inefficiently within the plant and primarily affects the treated foliage rather than being readily transported to roots or other plant organs. Glufosinate provides control of many annual broadleaf and grass weeds; however, the herbicide is less successful at control of large or well-tillered annual grasses. Glufosinate also provides suppression of some perennial (Minnesota Department of Agriculture n.d.).
- **Glyphosate (IPA and K)** is a non-selective herbicide used to control a wide variety of plants, including annual broadleaf plants, grasses, perennials, and woody invasive plants. It is absorbed through foliage and moves throughout the plant's growing points. Glyphosate's mode of action is to inhibit an enzyme involved in the synthesis of aromatic amino acids, making it effective on all herbaceous and woody growing plants, but not effective as a pre-emergent herbicide. It is a rather slow-acting herbicide with symptoms appearing within about a week, including yellowing and stunting of young leaves and growing points, however it may take up to two weeks for complete plant mortality. Young, actively growing plants are most susceptible to glyphosate treatments when applied during warm weather. Perennial woody plants are best treated in the late summer or fall when plants are moving carbohydrates into their underground storage tissues. Glyphosate is the most commonly used herbicide in invasive plant control in natural areas, and herbicide resistance is a growing problem in some annual species (Monsanto 2018)
- **Imazamox** is a selective, broad-spectrum herbicide applied post-emergence to control both broadleaf and grass weeds. It acts through contact activity and also provides residual control in the soil, allowing it to affect newly emerging plants after application. It is a systemic herbicide that moves throughout the plant tissue and prevents plants from producing an essential enzyme for growth (PubChem, n.d.).
- **Imazapyr** is a non-selective herbicide used to control a broad range of invasive plants including grasses, broadleaf herbs, woody plants, riparian plants, and emergent aquatic species. Imazapyr has a similar mode of action as glyphosate but acts on a different suite of essential amino acids. Imazapyr is absorbed by leaves and roots, and moves to growing points; it disrupts protein synthesis and interferes with cell growth and DNA synthesis, causing plant mortality. Unlike glyphosate, imazapyr has pre- and post-emergent effects. It also has moderate soil persistence, which can be useful for difficult-to-control species for which

glyphosate is less effective or when parallel treatments of the parent population and seedlings are desired.

- **Triclopyr (TEA and BEE)** is a selective systemic herbicide used to treat woody and herbaceous broadleaf plants and can be used to treat aquatic and riparian weeds. Triclopyr's mode of action is to mimic the plant hormone auxin, causing uncontrolled plant growth (Tu et al. 2001).

Aquatic Invasive Plants

Aquatic invasive plants, like terrestrial invasive plants, can arrive on District preserves from a variety of sources including migrating birds, animals, and humans, or they are already present on properties that the District purchases. Often, a small seed or plant fragment stuck to a duck's foot or canoe paddle is all that is necessary to expose a wetland habitat to a new invasive aquatic species. Aquatic invasive plants are divided into two major groups: 1) emergent invasive plants and 2) submerged invasive plants. Each group requires a different control strategy. Emergent invasive plants, in general, are rooted in soil below shallow water from one inch to 24 inches deep, and extend leaves above the water surface at least seasonally; or they can grow in neighboring upland areas as long as their roots can easily reach the water table (California Weed Science Society 2002). Some emergent invasive plants are actually floating plants that need no soil contact. Submerged invasive plants are those that grow on the bottom of lakes, rivers, and streams, and do not need exposure to the air to complete their life cycles.

Aquatic invasive plants can compromise both fish and wildlife habitat, promote flooding, provide breeding habitat for mosquitoes, and can impede or slow the distribution of water in irrigation canals/ditches (Thunberg et al. 1992). All aquatic invasive plant control requires specialized expertise and equipment to effectively manage the target pest. Submerged invasive plants are especially difficult to control and often require specialty floating equipment and boats to access the plants.

Native aquatic plants can require management as well to maintain navigational, recreational, and agricultural uses of water bodies. Native vegetation in ponds and other static water bodies decomposes to naturally fill-in to a point where they eventually cease to be water bodies. At times, the District manages water bodies to support aquatic wildlife and agriculture that requires occasional maintenance. Plants and sediments are mechanically removed to increase shoreline areas and sustain open water habitats.

Pest Management Strategies for Aquatic Invasive Plants

Prevention and control of aquatic invasive plants is discussed below. Tolerance levels and treatment methods are also outlined in Table 8-6.

Table 8-6 Treatment Thresholds and Methods for Aquatic Invasive Plants

Treatment Method Thresholds	Phenology	Timing	Treatment	Treatment Constraints - Assets
Incipient/small: < 10 individuals	Emergent perennials - seedling to mature	Varies by species	Manual (Hand removal)	Small amounts only; worker hazards at larger scales
Small to medium: < 5 acres	Emergent perennials - mature	Varies by species	Cutting (Mowing)	Not effective on most species; for suppression/ containment/ pre-treatment goals only
Small to medium: < 5 acres	All stages	Varies by species	Pond draining, pond skimming	Non-selective. Can be combined with aquatic animal control.
Large: ≥ 5 acres	Floating perennials - mature	Varies by species	Harvesting	Requires specialized aquatic weed control machines

Prevention

- Implement an employee and contractor training program; include aquatic invasive plant identification and cleaning protocols for clothing, tools, vehicles, and boats.
- Inspect recreational facilities that contain aquatic features often during target invasive plant flowering and seed production times. Treat any detected target invasive plant populations to prevent spread into District lands.
- Prevent the spread of plant fragments (roots, stems) of certain species that can produce new plants in irrigation ditches, canals, and streams.

Physical Control

- Pulling aquatic plants is similar to pulling terrestrial weeds, and requires removing the entire plant, including leaves, stems, and roots, and disposing of the material away from the shoreline. In wetlands and shallow water less than three feet deep, no special tools are required. Deeper water may require SCUBA divers equipped with mesh bags to collect plant fragments as they work. Additional precautions are required for staff working in aquatic locations to protect both the habitat and the staff.
- Specialized equipment can be used to excavate or 'harvest' floating or submerged aquatic vegetation. Generally, these types of control efforts seek to clear waterways for adequate water flow or boat access rather than eliminate the problem plant. They can be effective tools for the removal of biomass from flood control channels and navigable waterways.
- Pond draining may be implemented for small water bodies to eliminate invasive aquatic plants and invasive animals such as bullfrogs concurrently. Some plants have propagules that can remain viable during dry periods, so this method is only effective on some aquatic plant species. All projects that temporarily divert water

and discharge sediment may require permits from regulatory agencies, and may require additional monitoring and reporting.

Chemical Control

Some of the herbicides included in the IPMP include those that are formulated for use in and near aquatic habitats. The District, on rare occasions, may need to use chemical treatments within or very near to aquatic habitats including treatments in seasonal wetlands (during the dry season) to control pest species (e.g., to remove slender false brome or cattails). In these situations, the District will use herbicides suitable for aquatic habitats. The aquatic formulations for selected herbicides in the IPMP will most often be used in upland habitats within the District. These formulations are useful in upland areas for certain pest species because the surfactants included in the formulation provide increased adhesion to selected target plant species than the non-aquatic formulations and are, therefore, more effective at providing the desired control of the pest species.

- **Glyphosate** is dissolved in water with no surfactant, and is recommended for use on plants in aquatic, riparian, and other sensitive habitats.
- **Imazapyr** is a non-selective herbicide used to control a broad range of invasive plants including grasses, broadleaf herbs, woody plants, riparian plants, and emergent aquatic species.
- **Disinfectants** (refer to Table 3-3) are used to decontaminate equipment, boots, and clothing before and after entering a waterbody, as appropriate. The CDFW aquatic invasive species decontamination protocol provides details on the procedures and best practices.

Aquatic Invasive Animals

Aquatic invasive animals, like aquatic invasive plants, can be introduced to District wetlands, rivers, lakes, and other aquatic habitats through a variety of pathways, such as the transport of larvae, eggs, or small organisms attached to boats and recreational gear (US EPA 2016). Once introduced, these species may establish populations and spread rapidly due to the absence of natural predators. These animals can disrupt native ecosystems by preying on native species, competing for resources, altering habitat structures, degrading water quality, and interfering with recreation, and other human uses (National Invasive Species Information Center, n.d.; Wiedemer and Chan, n.d.).

Pest Management Strategies for Aquatic Invasive Animals

Chemical Control

For prevention of aquatic invasive animals entering District lands, district staff may have to use chemical means.

- **Disinfectants** (refer to Table 3-3) are used to decontaminate equipment, boots, and clothing before and after entering a waterbody, as appropriate. The CDFW aquatic invasive species decontamination protocol provides details on the procedures and best practices. Disinfectants are used to decontaminate equipment, boots, and clothing before and after entering a waterbody, as appropriate. The CDFW aquatic

invasive species decontamination protocol provides details on the procedures and best practices.

8.8.3 Invasive Insects in Natural Lands

In general, insects are considered a natural component of the District's natural areas and do not warrant control. In some limited circumstances, such as restoration of a native habitat through active planting, short term insect control may be warranted (for example, to control stinging insects or Argentine ants within a specified area during clearing or planting to protect worker or volunteer safety, plant health, and promote native insect pollination). For information regarding control treatment options for insect pests in natural areas, refer to the Buildings section (Chapter 5).

8.8.4 Forest Diseases

At present, the District manages forests primarily for ecological and recreational values (rather than for timber value), therefore management actions are focused on maintaining the long-term stability and resiliency of forests to disruptive changes such as climate change and forest diseases. The threshold for active management of forest diseases and invasive species focuses on the level of damage from a forest disease that could result in a substantial alteration in the forest species composition, extent, or density.

Forest Pathogens

Sudden oak death (SOD) is a plant disease caused by an exotic water mold (*Phytophthora ramorum*) that has been implicated in native oak and tanoak deaths throughout coastal California and Oregon (National Park Service 2022). The pathogen often results in mortality of certain oak species, specifically coast live oak (*Quercus agrifolia*), black oak (*Quercus kelloggii*), canyon live oak (*Quercus chrysolepis*), and Shreve oak (*Quercus parvula* var. *shrevei*), as well as tanoak (*Notholithocarpus densiflorus*). The pathogen can also cause twig and foliar disease symptoms in many other native plant species, most notably in California bay laurel (*Umbellularia californica*), which is a species that can act as a vector for this pathogen. The wholesale loss of oak tree species in coastal forests can cause major ecosystem disruptions, especially because so many native species depend on oaks and their fall acorn masts. Sick and dying trees also greatly increase the wildfire risk in native coastal forests dominated by oaks.

. Methods such as selective removal of California bay laurel trees (known to harbor the pathogen), pesticide applications, and promoting conifers over hardwoods have all been proposed for local and landscape scale management of the SOD pathogen (Filipe et al. 2013). The SOD pathogen is extremely difficult to detect until advanced infection and symptoms are visible in individual plants. Because this pathogen is a water mold, it can move great distances through the landscape using wind (e.g., windborne transport of spores) or through water (e.g., transport of spores in waterways and through fog drip), making management very difficult at any scale (Filipe et al. 2012). The landscape scale management of high value forested areas (e.g., selective removal of diseased trees, selective removal of host plants such as California bay laurel, replanting conifers and other disease-resistant trees) may be one of the few ways to slow

the spread of the disease. District staff should consult the California Oak Mortality Task Force (<http://www.suddenoakdeath.org>) for the most recent information on effective control of SOD.

Pest Management Strategies for Forest Pathogens

At present, the District maintains a SOD inventory and monitors for SOD occurrences throughout the approximately 72,000 acres of District lands, including monitoring for new or emerging strains of SOD. It is unclear whether the vegetation composition shift is a temporary phenomenon, or a more permanent result of the disease infestations. Because the long-term effect of the disease on California's forests are unknown, the District is working with the California Oak Mortality Task Force to further study and monitor the impacts of the disease on District lands.

The following list outlines general steps that District staff will follow when managing forest pathogens, such as *Phytophthora*:

- Track the effects of SOD disease (mapping dead oaks as staffing and budgeting permit), and share this information with the California Oak Mortality Task Force (www.suddenoakdeath.org) as staffing and funding allow.
- Removal of California bay trees or their branches within 15 feet of the trunks of high value oaks. Ongoing research at the District and other locations in the state are evaluating whether California bay laurel removal is effective for managing larger stands or forests infested with SOD or to prevent or slow down the spread of SOD. This option is costly and requires regular maintenance and monitoring and, therefore, is implemented in limited areas.
- For individual high value oaks such as very large mature oaks near picnic facilities, consider spot treatment of individual oaks with pest control sprays intended to reduce potential for SOD infection. Due to high cost, this option should not be applied on a landscape level.
- Use of disinfectants to kill or inactivate pathogens, before plant infection may occur through the decontamination of tools, equipment, vehicles, and footwear in accordance with the latest *Guidelines for Minimizing Phytophthora Contamination at Midpeninsula Regional Open Space District Preserves*.
- Treatments such as solarization or steam treatments will be used in targeted areas to remediate *Phytophthora*-infected soils.

9 Glossary

Active management — Physical actions intended to manage natural resources or built facilities for a desired outcome. Active management may include physical control (hand, mechanical control), or chemical control of pests or manipulation of their habitats. For example, mowing yellow star-thistle to remove it from an infested rangeland is considered active management. In contrast, *passive management* includes design and cultural practices intended to change human behavior or the physical environment in a manner that discourages pests from occurring. For example, installing boot cleaning stations, or requiring ranchers to inspect feed for yellow star-thistle seeds is considered passive management.

Active Ingredient — The specific chemical or substance in a product that directly controls, prevents, destroys, repels, or mitigates pests, or functions as a plant growth regulator, desiccant, or defoliant.

Agricultural Property — Any land, pasture, building, or other real estate primarily used for farming or other agricultural purposes, such as growing crops, raising livestock, or cultivating timber.

Allelopathy/Allelopathic effect — The suppression of growth of one plant species by another because of the release of toxic substances. The effect of suppressing the growth around a plant resulting from the release of toxic substances.

Auxin — A class of hormones that, in minute amounts, regulate or modify the growth of plants, especially root formation, bud growth, and fruit and leaf drop.

Basal bark — Using this treatment method, an oil mixture containing herbicide is applied to the lower 12 to 15 inches of brush and tree trunks (including the entire stem, root collar area, and exposed roots) via low-pressure backpack sprayer. This method is used to selectively control woody plants with basal stems less than six inches in diameter.

Basal rosette — A cluster of leaves spreading outward from the base of a low-growing plant. In thistles, such as yellow star-thistle, a basal rosette forms just before the plant bolts (i.e., sends up a main stem on which flowers are produced). Often, the timing of pest control treatment of plants is recommended for the “basal rosette stage.”

Biological Monitor — An individual who has academic and professional experience in biological sciences and related resource management activities, experience with construction-level biological monitoring, is able to recognize species that may be present within the Project area, and is familiar with the habits and behavior of those species.

Bolt stage — A plant developmental stage during which a young plant sends up a main stem on which flowers are produced. The timing of pest control treatment of plants is often recommended for either just before or just after “bolt stage.”

Broadleaf — Plants possessing broad (as opposed to needlelike or grass-like) leaves. Most of the trees and shrubs on District preserves are broadleaves. Pest control treatments prescribe different treatments for broadleaf plants than for grasses, sedges, and needle-bearing trees such as pine trees.

Cut-stump application — Under this treatment, the woody plant is cut close to the ground at a 90-degree or 45-degree angle with a chainsaw or pole saw. Debris is removed from the cut stump and herbicide immediately applied to the circle of living cells. Cut-stump application is used to selectively eliminate woody trees and shrubs. Woody plants tend to re-sprout frequently when cut unless treated with herbicide.

Chlorosis — A condition in which leaves produce insufficient chlorophyll. As chlorophyll is responsible for the green color of leaves, chlorotic leaves are pale, yellow, or yellow-white. The affected plant has little or no ability to manufacture carbohydrates through photosynthesis and typically dies. Some pest control of plants induces chlorosis, thereby eliminating the pest plant’s ability to survive and reproduce.

Containment — A pest control strategy that focuses on establishing a pest-free area (e.g., a mowed or cleared area around a well-established population of invasive plants), and ensuring, through active management, that the target pest does not move past the defined area into the surrounding (pest free) areas. Containment is typically used when eradication of a target pest is no longer considered a viable option.

Control — A pest control strategy that focuses on reducing the number, amount, or extent of a pest over time to achieve a defined tolerance level. Control may result in full eradication of a pest, or reduction in the pest such that it no longer causes economic or environmental damage, or human health concerns.

Dicot — Dicotyledons, (also known as dicots), are a group of flowering plants whose seed typically produce two embryonic leaves or cotyledons when first germinating. Pest control techniques often prescribe different treatment for dicot plants than for *monocots* (e.g., grasses, sedges, and bulbaceous plants that only produce one embryonic leaf).

Eradicate — A pest control strategy that focuses on eliminating all members of a target pest population.

Frill/injection — A drill or sharp tool such as a hatchet is used to create holes or cut through the exterior bark of a tree and into the sapwood. Each penetration point into the sapwood is then filled with the label-recommended amount of concentrated herbicide solution using an injection system, squirt bottle, or brush. This application method is often used for the control of trees that cannot be managed via basal bark application.

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Pesticide formulation — A mixture of active ingredients, which control pests, and other ingredients that aid in delivery and application for pest control purposes.

Gigging — A pest control method typically used to kill bullfrogs, fish, and other aquatic pests whereby the animal is speared with a trident or spear while in water.

Herbicide — A pesticide (see definition below) intended for preventing, destroying, or controlling plant pests.

Herbivory — A type of predation typically used to describe the consuming of plants by animals. Herbivory has an impact on the health, structure, and diversity of natural plant communities. For example, low level herbivory can remove aging roots and leaves, allowing new growth of young roots and shoots resulting in healthy plant growth. At high levels, herbivory can damage plants, changing the composition, and reducing the quality of the natural plant community.

Homopteran Insect — A suborder of insects, including cicadas, aphids, and scale insects, having wings of a uniform texture held over the back at rest.

Hypercalcemia — An abnormally high level of calcium in the blood. In pest control, hypercalcemia is usually associated with rodenticide use.

Injurious — The term “injurious wildlife” refers to a defined list of species identified in either the federal Lacey Act (18 U.S.C. 42) or related implementing regulations (50 CFR 16). The U.S. Fish and Wildlife Service Office of Law Enforcement plays a role in preventing the introduction of invasive species into the U.S. through the enforcement of the Lacey Act which makes it illegal in the United States to import injurious wildlife, or transport such wildlife between states without a permit. Species are placed on the list when they are determined to be injurious to human beings; the interests of agriculture, horticulture, forestry, or wildlife; or wildlife resources in the U.S.

Insecticide — A pesticide (see definition below) intended for preventing, destroying or controlling insect pests.

Insipient (invasive population) — A population (usually referring to an invasive plant) that is small, but is beginning to reproduce and become established in a location or a region.

Metamorph (amphibian) — A major change in the form or structure of some animals or insects that happens as the animal or insect becomes an adult. For amphibians, a metamorph refers to the stage of development between larval and adult. For example, the stage between a tadpole and adult frog. Some pest control techniques recommend treatment timing before or after the metamorph stage.

Monocot — Monocotyledons, (also known as monocots), are a group of plants whose seed typically produce only one embryonic leaf or cotyledon when first germinating (e.g., grasses, sedges, and bulbaceous plants). Pest control techniques often prescribe different treatment for

monocot plants than for *dicots* (i.e., plants that produce two embryonic leaves when first germinating)

Non-Native Species — An introduced, alien, exotic, or non-indigenous species. Includes species living outside their native distributional range, which have arrived by human activity, either deliberate or accidental. Some introduced species are damaging to the ecosystem they are introduced into, others have no negative effect and can, in fact, be beneficial. Refer to the definition of *pest* and *invasive species* (below) to differentiate non-native species that cause harm from other non-native species.

Noxious weeds — A plant species that has been designated by country, state, provincial, or national agricultural authority as one that is injurious to agricultural and/or horticultural crops, natural habitats and/or ecosystems, and/or humans or livestock. These weeds are typically agricultural pests, though many also have impacts on natural areas. Many noxious weeds have come to new regions and countries through contaminated shipments of feed and crop seeds or intentional introductions such as ornamental plants for horticultural use.

Pest Species — Insects, animals, or plant species that are incompatible with the District's goal of protecting and restoring the natural environment, and with providing opportunities to enjoy and learn about the natural environment. Several categories of pest species are defined below:

- **Invasive species** are plant or animals that invade and dominate sufficiently large areas, causing a reduction in biodiversity. They proliferate in the absence of natural control and interfere with the natural processes that would otherwise occur in natural areas. Once established, invasive species can become difficult to manage and can eliminate native species or otherwise alter the ecosystem. Invasive species are targeted in natural areas and rangelands. Invasive species can alter ecosystem processes by changing biotic ecosystem characteristics (such as plant community composition, structure, and interactions; trophic relationships; and genetic integrity) and abiotic characteristics and processes (such as fire regimes, erosion, sedimentation, hydrological regimes, nutrient and mineral conditions, and light availability).
- **Structural and agricultural pests** include insect, plant, and animal pests that damage occupied buildings, formal landscapes, or agricultural crops, or pests that are a health threat to humans working in, living in, or visiting the buildings. Examples of structural pests include termites, ants, rodents, and stinging insects in buildings, and weeds in formal landscaped areas. Examples of agricultural pests include insects, weeds, and burrowing mammals such as moles and voles that damage crops. Structural and agricultural pests are targeted in buildings, recreational facilities, and agricultural properties.
- **Nuisance pest species** include species that commonly occur on District lands, such as stinging insects, but whose presence can be incompatible when their proximity or behavior conflict with human use of buildings and recreational facilities in the preserves. For example, hornets that locate their ground nests in trails must be

removed if they are stinging hikers and horses using the trail. Branches and other types of vegetation must be trimmed back from trails, parking lots, picnic tables, and benches to allow safe visitor use. Similarly, vegetation must be cut back from the sides of roads to keep them open for patrol, maintenance, and emergency vehicles. Problem pest species are targeted in areas with focused visitor use.

Pesticide — A substance or mixture of substances intended for preventing, destroying, or controlling any pest, including vectors of human or animal disease, unwanted species of plants or animals causing harm during or otherwise interfering with the production, processing, storage, transport or marketing of food, agricultural commodities, wood and wood products or animal feedstuffs, or substances which may be administered to animals for the control of insects, arachnids, or other pests in or on their bodies.

Pesticide is a broad term that encompasses:

- **Herbicides** (substances intended to control plant pests),
- **Insecticides** (substances intended to control insect pests),
- **Rodenticides** (substances intended to control rodent pests),
- **Other Substances**, such as **Fungicides** (substances intended to fungus pests) and **Surfactants** (substances that adhere pesticides to surfaces such as plant leaves) and other substances often used with other pesticides to increase treatment results.
- **Disinfectants**, such as quaternary ammonium solutions, are used to decontaminate all equipment, including but not limited to, wading, dive, and sampling equipment (e.g., water quality probes, nets, buckets, substrate samples, etc.); fishing gear; and watercraft.
- **Repellents** are not substances used to eliminate pests, rather, they are designed dissuade pests.

Phloem — The living tissue in plants that carries soluble organic material made during photosynthesis – in particular, sucrose, to all parts of the plant where it is used for growth and reproduction. Many pest control treatments focus on disrupting the phloem through mechanical or chemical means, thereby disrupting the flow of nutrients to the plants, causing plant death.

Pre-bait — A substance used to attract pests (e.g., rodents or other animals) to a feeding site as a preliminary step to use of a rodenticide or other pesticide to control the target pest.

Propagule — Any vegetative portions of a plant, such as a bud, stolon, root, tuber, rhizome, or other offshoot, that aids in the dispersal of the species and from which a new plant may grow. In pest control, follow-up treatments for invasive plants often focus on prevention and control of propagules after the initial mature plants are treated.

Qualified Biologist — An individual who has a minimum of five (5) years of academic training and professional experience in biological sciences and related resource management activities, with a minimum of two survey seasons years (e.g., two seasons during the blooming season of sensitive plants) conducting surveys for each species that may be present within the Project area.

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Rangeland — A large expanse of natural land that is covered primarily by native plants such as grasses, forbs, and shrubs, and is suitable for grazing animals.

Rhizome — A modified subterranean stem of a plant that is usually found underground from which a new plant may grow. Plants often send out roots and shoots from these modified stems, resulting in vegetative (asexual) reproduction of a plant. In pest control, follow-up treatments for invasive plants often focus on prevention and control of rhizomes after the initial mature plants are treated.

Root Crown — The junction between the root and shoot portion of a plant. Crown sprouting is the ability of a plant to regenerate its shoot system after destruction of the above-ground portions of the plant. Crown sprouting plants typically have extensive root systems in which they store nutrients, allowing them to survive after damage to the above-ground parts of the plant. In pest control, follow-up treatments for crown-sprouting plant species often focus on control of resprouting vegetation after the initial mature plants are treated.

Sensitive Natural Community — Plant or animal species that are listed to the California Department of Fish and Wildlife (CDFW) California Natural Diversity Database (CNDDDB) due to the rarity of the community in the state or throughout its entire range (globally) (The California Biologist's Handbook, n.d.).

Seed Bank — In natural systems, the natural storage of seeds, often dormant, within the soil below the parent plant. In invasive plant control, treatment often focuses on long-term management of plants that germinate from the seed bank, often years after the initial removal of mature invasive plants.

Shooting — A plant that sends up shoots (new growth) from the underground portions of the plant. In pest control, recommended treatments are often timed for when invasive plants are actively 'shooting' or sending up new growth.

Spray application — Depending on the size of the infestation, herbicide is applied with a 5-gallon backpack sprayer or, for larger areas, a 14-gallon tank mounted on an all-terrain vehicle or 150-gallon truck with a hose that is directly controlled by an operator. All methods of spraying under this program are selective, that is, the operator (who is trained in identifying plants) is in direct control of the sprayer, will point the spray tip directly at the target weed or pest, and will manually turn the spray equipment on and off to control the amount and direction of spray.

Stolon — A prostrate plant stem, at or just below the surface of the ground, that produces new plants from buds at its tips or nodes. In pest control, treatments for plants that produce stolons often focus on removal of existing stolons, and retreatment of new plants produced from any remaining stolons.

Suitable- Special Status Species Habitat — Habitat of a special status species including plant and animal species that are legally protected under environmental regulations, and include

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species that are considered sufficiently rare by the scientific community to qualify for such status.

Taproot — A large, somewhat straight to tapering plant root that grows downward forming a center from which other roots sprout laterally. The taproot system contrasts with fibrous root system, which typically has many branched roots. Pest control of invasive plants often focuses on removal of the entire taproot to kill the target invasive plant.

Tolerance Levels — The level at which pests can be present without disturbing or disrupting natural processes, causing economic damage, degrading intended uses or human enjoyment of built facilities, or resulting in ecological or public health impacts.

Tenting — Tenting involves sealing the entire structure with a material that can serve as a secure enclosure and fumigating with sulfuryl fluoride (Vikane). Tear gas (chloropicrin) is incorporated into the fumigant gas to serve as a warning agent for humans and animals, since Vikane gas has no warning properties (e.g., odors, eye irritation)

Treatment Site(s) — The entire area where pest control measures are applied, which includes the pest and its nonliving and living surroundings.

Wipe application — Under this treatment, herbicide is applied to the target plant using a sponge for selective treatment. This method generally results in less potential for herbicide drift than spraying, although care must be taken that the applicator does not drip or overlap onto non-target plants. This method works best on plants that form a basal rosette of leaves.

Wick application — A wick or rope is saturated in herbicide and attached to a reservoir containing a concentrated herbicide solution. The wick or rope is used to wipe herbicide directly onto target plants, typically weeds that are taller than surrounding non-target plants. Wick applicators may range in size from hand-held to truck-mounted.

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APPENDIX A

List of Approved Pesticides

APPENDIX A: LIST OF APPROVED PESTICIDES

List of Approved Pesticides Split by Management Category

IPM Management Category	Active Ingredient/ Formulation	Product Name	Manufacturer	Method of Application	Purpose	Annual Application ^{a,b}	Timing of work	Frequency of Work
Buildings	Insecticidal soap	Equivalent labeled products containing this active ingredient	Various	Spray	Structural pests	Approximately 330 buildings	Spring/ summer/ fall	--
	Diatomaceous earth	Diatomaceous Earth	Diatomaceous Earth	Crack & crevice	Structural pests	Approximately 330 buildings	Spring/ summer/ fall	--
	Boric acid	Equivalent labeled products containing this active ingredient	Various	Crack & crevice	Structural pests	Approximately 330 buildings	Spring/ summer/ fall	--
	S-Hydroprene	Gentrol Point Source [®]	Wellmark International	Impregnated disc	Structural pests	15 fl oz over 8 applications over approximately 330 buildings	Spring/ summer/ fall	--
	Indoxacarb (0.1%)	Advion [®] Gel Baits	DuPont	Crack & crevice	Structural pests	7 fl oz over 20 applications over approximately 330 buildings	Spring/ summer/ fall	--
	Indoxacarb (0.5%)	Advion [®] Gel Baits	DuPont	Crack & crevice	Structural pests	51 fl oz over 23 applications over approximately 330 buildings	Spring/ summer/ fall	--
	Sodium tetraborate decahydrate	Prescription Treatment Baits, Terro [®] Ant Killer II	BASF, Terro	Bait station	Structural pests	11 fl oz over 17 applications over approximately 330 buildings	Spring/ summer/ fall	--

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IPM Management Category	Active Ingredient/ Formulation	Product Name	Manufacturer	Method of Application	Purpose	Annual Application ^{a,b}	Timing of work	Frequency of Work
	Fipronil	Maxforce® Bait Stations	Bayer	Bait station	Structural pests	16 fl oz over 7 applications over approximately 330 buildings	Spring/ summer/ fall	--
	Fipronil	Product as specified in current Pest Control Recommendations	Various	Spot treatment	Termites	5 gal over 1-5 residences	--	1x per year
	Cholecalciferol	Cholecalciferol baits	Cholecalciferol baits	Bait station	Vertebrate pests	50 oz over approximately 330 buildings	Spring/ summer/ fall	--
	Prallethrin	PT Wasp-Freeze II	BASF	Spray	Stinging insects	70 oz (4 cans of spray)	Spring/ summer/ fall	--
	Chlorantraniliprole	Product as specified in current Pest Control Recommendations	Various	Perimeter	Structural pests, termites	8.5 gallons over 1-5 residences	--	1x per year
	Dinotefuran	Product as specified in current Pest Control Recommendations	Various	Perimeter	Structural pests	14 ounces over 1-5 residences	--	1x per year

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Recreational	Sulfuryl fluoride/ chloropicrin	Product as specified in current Pest Control Recommendations	Various	Tenting	Structural pests, termites	240 oz over 1-5 residences (sulfuryl fluoride) 10 fluid oz over 1-5 residences (chloropicrin)	--	1x per year
	d-Limonene	Product as specified in current Pest Control Recommendations	Various	Spot treatment	Structural pests, termite	2 gal over 1-5 residences	--	1x per year
	Disodium Octaborate Tetrahydrate	Product as specified in current Pest Control Recommendations	Various	Spot treatment, prevention	Structural pests, fungus & dry rot, termite	5 gal over 1-5 residences	--	1x per year
	Prallethrin	PT Wasp-Freeze II	BASF	Spray	Stinging insects	350 oz (20 cans of spray)	Spring/ summer/ fall	--
	Glyphosate isopropylamine (IPA)	Roundup ProMax	Monsanto	Cut-stump, spot spray, wick, frill/injection	Dam faces, parking lots, gates & stiles, facilities	3.4 gal	Spring/ summer/ fall	1x per year
	Glyphosate potassium (K)	Roundup Custom	Monsanto	Cut-stump, spot spray, wick, frill/injection	Roads, trails, parking lots, gates & stiles, facilities	1.1 gal	Spring/ summer/ fall	1x per year
	Clopyralid monoethanolamine (MEA)	Transline	Dow AgroSciences	Spot spray, cut-stump, frill/injection	Parking lots, gates & stiles, facilities	0.4 gal	May through August	1x per year

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IPM Management Category	Active Ingredient/ Formulation	Product Name	Manufacturer	Method of Application	Purpose	Annual Application ^{a,b}	Timing of work	Frequency of Work
Rangelands and Agricultural Properties	Imazapyr IPA	Polaris/Stalker	Nufarm/ BASF	Cut-stump, spot spray, frill/injection	Roads, trails, parking lots, gates & stiles, facilities	0.5 gal	Spring/ summer/ fall	--
	Triclopyr	Vastlan	Corteva Agriscience	Spot spray, basal bark	Invasive plant control in aquatic and riparian weeds.	0.6 gal	Spring/ summer/ fall	1x per year
	Aminopyralid triisopropanolamine (TIPA)	Milestone	Dow AgroSciences	Spot spray, cut-stump, basal bark, wick, frill/injection	Rangeland weeds, invasive plant control; brush control	2.4 gal	--	1x per year
	Clopyralid MEA	Transline	Dow AgroSciences	Spot spray, cut-stump, frill/injection	Rangeland weeds, invasive plant control	1.8 gal	Spring/ summer	1x per year
	Glyphosate IPA	Roundup ProMax	Monsanto	Spot spray, cut-stump, wick, frill/injection	Rangeland weeds, brush control, agricultural weeds, invasive plant control	1.1 gal	Spring/ summer	1x per year
	Glyphosate K	Roundup Custom	Monsanto	Spot spray, cut-stump, wick, frill/injection	Rangeland weeds, brush control, agricultural weeds, invasive plant control	62.7 gal	Spring/ summer	1x per year

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IPM Management Category	Active Ingredient/ Formulation	Product Name	Manufacturer	Method of Application	Purpose	Annual Application ^{a,b}	Timing of work	Frequency of Work
	Triclopyr butoxyethyl ester (BEE)	Garlon 4 Ultra	Dow AgroSciences	Spot spray, cut-stump, basal bark	Rangeland weeds, brush control, agricultural weeds, invasive plant control	3.4 gal	Spring/ summer/ fall	1x per year
	Triclopyr TEA/ Aminopyralid TIPA	Milestone	Dow AgroSciences	Spot spray, cut-stump, frill/injection	Rangeland weeds, invasive plant control; brush control	22.8 gal	--	1x per year
	Clethodim	Envoy Plus	Valent	Spot spray	Invasive plant control	2.8 gal	Winter/ spring/ summer	1x per year
	Triclopyr	Vastlan	Corteva Agriscience	Spot spray, basal bark	Invasive plant control in aquatic and riparian weeds; brush control.	4 gal	Spring/ summer/ fall	1x per year
	Imazamox	ClearCast	SePro	Spot spray aquatic/riparian	Invasive plant control. Riparian and terrestrial weed control.	0.5 gal	Spring/ summer/ fall	1x per year
	Glufosinate	Lifeline/Cheetah Pro	Nufarm	Spot spray	Invasive plant control. Early season annual plant control.	3.2 gal	Spring	2 x per year
Natural Lands	Glyphosate IPA	Roundup ProMax	Monsanto	Spot spray, cut-stump, wick, frill/injection	Invasive plant control; brush control	1.1 gal	Spring/ summer	1x per year

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IPM Management Category	Active Ingredient/ Formulation	Product Name	Manufacturer	Method of Application	Purpose	Annual Application ^{a,b}	Timing of work	Frequency of Work
	Glyphosate K	Roundup Custom	Monsanto	Spot spray, cut-stump, wick, frill/injection	Invasive plant control, sudden oak death; brush control	81.5 gal	Spring/ summer	1x per year
	Clethodim	Envoy Plus	Valent	Spot spray	Invasive plant control	2 gal	Spring/ summer	1x per year
	Aminopyralid TIPA	Milestone	Dow AgroSciences	Spot spray, cut-stump, basal bark, wick, frill/injection	Invasive plant control; brush control	2.3 gal	--	1x per year
	Clopyralid MEA	Transline	Dow AgroSciences	Spot spray, cut-stump, frill/injection	Invasive plant control	1.9 gal	Spring/ summer	1x per year
	Imazapyr IPA	Polaris/Stalker	Nufarm/ BASF	Spot spray, cut-stump, frill/injection	Invasive plant control, sudden oak death; brush control	0.4 gal	Spring/ summer	1x per year
	Phosphite K (Salts, mono-/ di-)	Agri-Fos	AgBio	Spray, inject	Sudden oak death	45 gal concentrate	April/ May or October/ November	1x per year
	Triclopyr BEE	Garlon 4 Ultra	Dow AgroSciences	Spot spray, cut-stump, basal bark	Invasive plant control; brush control	22.8 gal	Spring/ summer/ fall	1x per year
	Triclopyr TEA/ Aminopyralid TIPA	Capstone/ Milestone	Dow AgroSciences	Spot spray, cut-stump, frill/injection	Invasive plant control; brush control	20 gal	--	1x per year

APPENDIX A: LIST OF APPROVED PESTICIDES

IPM Management Category	Active Ingredient/ Formulation	Product Name	Manufacturer	Method of Application	Purpose	Annual Application ^{a,b}	Timing of work	Frequency of Work
	Triclopyr	Vastlan	Corteva Agriscience	Spot spray, basal bark	Invasive plant control; brush control	20 gal	Spring/ summer/ fall	1x per year
	Imazamox	ClearCast	SePro	Spot spray aquatic/ riparian	Invasive plant control	2 gal	Spring/ summer/ fall	1x per year
	Glufosinate	Lifeline/Cheetah Pro	Nufarm	Spot spray	Invasive plant control. Early season annual plant control.	3.2 gal	Spring	2x per year
Surfactants/ Adjuvants	Canola Oil, Ethyl and Methyl Esters	Competitor	Wilbur-Ellis	Spot spray	Increase delivery and efficacy of pesticides to targets	--	--	--
	Lecithin	Liberate	Loveland Products, Inc.	Spot spray	Increase delivery and efficacy of pesticides to targets	--	--	--
	Alcohol ethoxylates	Liberate	Loveland Products, Inc.	Spot spray	Increase delivery and efficacy of pesticides to targets	--	--	--
	Alkylphenol ethoxylate (APE)	Pentra-Bark	Quest	Spot spray	Increase delivery of Agri-Fos to trees	--	--	--
General Chemical Disinfectants	Sodium dichloroisocyan -urate dihydrate	Equivalent labeled products containing this active ingredient	Various	Spot spray/water additive	Disinfect equipment, water bodies and surfaces	5 kg	--	--

APPENDIX A: LIST OF APPROVED PESTICIDES

IPM Management Category	Active Ingredient/ Formulation	Product Name	Manufacturer	Method of Application	Purpose	Annual Application ^{a,b}	Timing of work	Frequency of Work
	Sodium chloride	Liquid Bleach	Clorox	Spot spray	Minimize or eradicate presence of microorganisms	16 gal	--	--
	Sodium hypochlorite	Equivalent labeled products containing this active ingredient	Various	Spot spray	Disinfect equipment	16 gal	--	--
	Ethanol or isopropyl alcohol	Equivalent labeled products containing this active ingredient	Various	Spot spray	Disinfect equipment	100 gal	--	--
	Dodecyl dimethyl ammonium chloride	Equivalent labeled products containing this active ingredient	Various	Spot spray	Disinfect equipment	5 gal	--	--
	Hydrogen peroxide	Equivalent labeled products containing this active ingredient	Various	Spot spray	Disinfect equipment	4 gal concentrate	--	--
Chemical Repellant	N,N-diethyl-meta-toluamide (DEET)	Equivalent labeled products containing this active ingredient	Various	Spot spray	Impairs insect's ability to detect target(s)	200 cans (6 oz)	--	--
	Picaridin	Equivalent labeled products containing this active ingredient	Various	Spot spray	Makes insects less likely to bite	200 cans (5 oz)	--	--

Sources: (Yun Cang, n.d.; Midpen 2018)

APPENDIX A: LIST OF APPROVED PESTICIDES

Notes:

- ^a As the District continues to expand its coverage area, the overall scale of pesticide use under the IPMP must also increase as part of the 10-year update to meet the growing treatment and coverage needs, therefore acreage estimates are excluded and only application values (e.g., ounces, gallons) are presented. Application would occur in accordance with the 2025 Program and IPMP BMPs.
- ^b All applications are made according to product label instructions and may include methods not listed here.

fl= Fluid

oz= Ounce

gal= Gallon

APPENDIX B

Literature Review and Toxicology Assessment

Appendix B.1	Toxicology Assessment of the New Pesticides Included in the 10-Year Program Update (2025)
Appendix B.2	Regulatory and Literature Review of Approved Pesticides in 2019 Program Addendum and 2014 Program (2025)
Appendix B.3	Screening-Level Ecological Risk Assessment for the New Pesticides in the 2019 Program Addendum (2019)
Appendix B.4	Pesticide Technical Background Information for Pesticides in 2014 Program (2014)

APPENDIX B1

Toxicology Assessment of the New Pesticides Included in the 10-Year Program Update (2025)

Toxicological Assessment of Pesticides

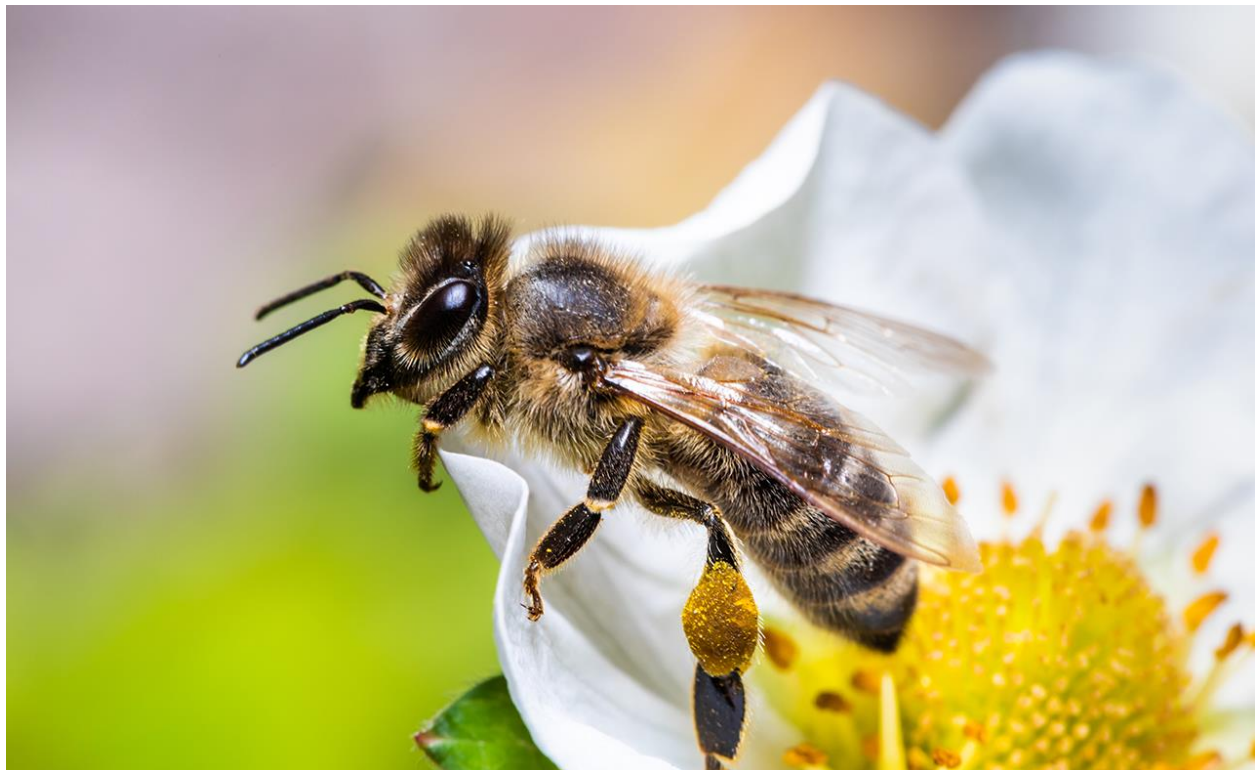
This report documents toxicological findings and recommendations for additional pesticides under consideration by Midpeninsula Regional Open Space District.

Prepared for:
Midpeninsula Regional Open Space District

Date:
November 17, 2025

Prepared by:
Stantec Consulting Services Inc.

Project/File:
Toxicological Assessment of Pesticides



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The conclusions in the Report titled Toxicological Assessment of Pesticides are Stantec's professional opinion, as of the time of the Report, and concerning the scope described in the Report. The opinions in the document are based on conditions and information existing at the time the scope of work was conducted and do not take into account any subsequent changes. The Report relates solely to the specific project for which Stantec was retained and the stated purpose for which the Report was prepared. The Report is not to be used or relied on for any variation or extension of the project, or for any other project or purpose, and any unauthorized use or reliance is at the recipient's own risk.

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Executive Summary

The Midpeninsula Regional Open Space District (Midpen) manages ecologically diverse lands along the Santa Cruz Mountains in the San Francisco Bay Area, where urbanization, climate change, wildfire risk, and invasive species pose significant challenges. To support environmental resilience and public well-being, Midpen preserves open space, protects biodiversity, and offers low-impact public access. To address pest issues while minimizing potential harm to ecological or human health, Midpen employs a science-based Integrated Pest Management (IPM) Program across its preserves and facilities, targeting invasive weeds, insects, rodents, and nuisance wildlife.

Midpen is considering adding 14 pesticides to its approved list: three herbicides, five insecticides, four disinfectants, and two repellents. To support Midpen's decision-making and to ensure alignment with Midpen's commitment to safe, responsible pest management, Stantec Consulting Services Inc. (Stantec) was retained to assess the (1) human health endpoints (acute/short-term toxicity, subchronic/chronic toxicity, carcinogenicity and genotoxicity, developmental and reproductive toxicity, endocrine disruption, sensitization and irritation, neurotoxicity, and immunotoxicity), (2) ecological toxicity (across plants, bees, amphibians, reptiles, birds, mammals, and aquatic organisms), and (3) environmental fate for each of these 14 pesticides.

This assessment supports the safe and responsible integration of these pesticides into Midpen's IPM Program, balancing effective pest control with protection of human health and the environment. The findings for each pesticide are depicted in **Figure 1** (human health endpoints) and **Figure 2** (ecological toxicity).

Herbicides (triclopyr, imazamox, and glufosinate) showed low acute and chronic toxicity to humans, with no evidence of carcinogenicity, genotoxicity, or endocrine disruption, and minimal risk of developmental or reproductive toxicity at labeled use rates. However, all three are highly toxic to terrestrial and aquatic plants, and additional studies are warranted for non-target plant species. Toxicity in other ecological receptors (bees, amphibians, reptiles, birds, mammals, fish) was generally low, though some data gaps remain for pollinators and chronic aquatic exposures. These herbicides are moderately to highly mobile in the environment, with low potential for bioaccumulation, and degrade primarily via microbial activity and photolysis.

Insecticides (chlorantraniliprole, dinotefuran, and sulfuryl fluoride / chloropicrin, d-limonene, and disodium octaborate tetrahydrate) exhibited low acute and chronic toxicity to

humans, with no evidence of carcinogenicity or significant endocrine, neurotoxic, or immunotoxic effects under labeled use. Notably, dinotefuran is highly toxic to bees, and chlorantraniliprole and dinotefuran are moderately to highly toxic to aquatic invertebrates, warranting careful application to minimize environmental exposure. Sulfuryl fluoride / chloropicrin may cause adverse effects in humans via inhalation or eye contact, and in mammals and some ecological receptors if exposed, but risks are limited under anticipated use scenarios. d-Limonene and disodium octaborate tetrahydrate are generally low risk, with skin irritation and sensitization as the main human hazards.

Disinfectants (sodium dichloroisocyanurate dihydrate, sodium hypochlorite, isopropyl alcohol / ethanol, and dodecyl dimethyl ammonium chloride) were found to have low acute and chronic toxicity to humans at labeled use rates, though some (notably sodium dichloroisocyanurate dihydrate and dodecyl dimethyl ammonium chloride) can cause eye and skin irritation and are highly toxic to aquatic organisms. Environmental persistence is generally low for alcohols and hypochlorite, but dodecyl dimethyl ammonium chloride is persistent and not readily degradable. Risks to ecological receptors are minimal with proper use and mitigation, but aquatic toxicity warrants precautions to prevent environmental release.

Repellents (N,N-diethyl-meta-toluamide and picaridin) showed low toxicity to humans and ecological receptors under labeled use, with no evidence of carcinogenicity, genotoxicity, or significant endocrine, neurotoxic, or immunotoxic effects. Neither pesticide is expected to persist or bioaccumulate in the environment.

The following are recommended should the aforementioned pesticides be added to Midpen's IPM Program:

- Always consult and comply with the latest U.S. Environmental Protection Agency (EPA)-stamped label for each pesticide.
- Implement mitigation measures [e.g., buffer zones from freshwater features (see **Figure 3**), application timing, and/or spot treatments to minimize off-target impacts and environmental release], especially for herbicides and insecticides with high plant or aquatic organism toxicity.
- Conduct periodic environmental monitoring in treated areas to assess pesticide persistence, mobility, and potential non-target effects.
- Address data gaps through targeted studies, particularly for chronic toxicity in aquatic organisms and pollinators.
- Ensure staff and contractors are trained in safe handling, personal protective equipment (PPE) use, and best management practices.



Toxicological Assessment of Pesticides

Executive Summary

- Communicate with stakeholders about potential risks, environmental behavior, and the importance of responsible pesticide use.
- Reassess pesticide approvals as new scientific data become available, maintaining an adaptive management approach.

Overall, the 14 pesticides can be added to Midpen's approved list, provided their use aligns with the most recent

EPA-stamped labels, is consistent with Midpen's IPM principles, and Stantec's recommendations are considered. For pesticides with higher hazard potential or data gaps (notably for non-target plants, pollinators, and aquatic organisms), additional precautions and ongoing review of new data are warranted.

A

	Herbicides			Insecticides					Disinfectants					Repellents		
	Triclopyr	Imazamox	Glufoisinate	Chlorantraniliprole	Dinotefuran	Sulfuryl Fluoride	Chloropicrin	d-Limonene	DOT	Sodium Dichloroisocyanurate Dihydrate	Sodium Hypochlorite	Isopropyl Alcohol	Ethanol	DDAC	DEET	Picaridin
Acute Toxicity (Oral)																
Acute Toxicity (Dermal)																
Acute Toxicity (Inhalation)																
Irritation (Eye)																
Irritation (Skin)																
Sensitization																

Non-skin sensitization

Category I

Category II

Category III

Category IV

Not available

Skin sensitization

Skin sensitizer

Possible skin sensitizer

Not considered/classified as a skin sensitizer

Not a skin sensitizer



B

	Herbicides			Insecticides							Disinfectants				Repellents		
	Triclopyr	Imazamox	Glufosinate	Chlorantraniliprole	Dinotefuran	Sulfuryl Fluoride	Chloropicrin	d-Limonene	DOT	Sodium Dichloroisocyanurate	Dihydrate	Sodium Hypochlorite	Isopropyl Alcohol	Ethanol	DDAC	DEET	Picaridin
Subchronic & chronic toxicity	Yellow	Green	Yellow	Yellow	Yellow	Orange	Orange	Yellow	Yellow	Red	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Green
Carcinogenicity & Genotoxicity	Green	Green	Green	Green	Green	Green	Light Green	Green	Green	Green	Green	Green	Green	Orange	Green	Green	Green
DART	Yellow	Green	Light Green	Green	Light Green	Green	Green	Green	Light Green	Light Green	Green	Green	Green	Light Green	Green	Light Green	Green
Endocrine Disruption	Green	Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green
Neurotoxicity	Green	Green	Light Green	Green	Light Green	Orange	Green	Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green
Immunotoxicity	Green	Green	Green	Green	Green	Green	Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green

Toxic

Toxic, but effect(s) not expected based on use

Low toxicity and/or effects at high doses

Adverse effect(s) not expected

No evidence, testing not required, not relevant, no concern, or equivalent

Not toxic or equivalent

No information or insufficient data

Figure 1. Toxicological Findings in Humans. A. Acute Health Endpoints Consistent with EPA's Categories for Ranking of Pesticide Toxicity. B. Additional Health Endpoints



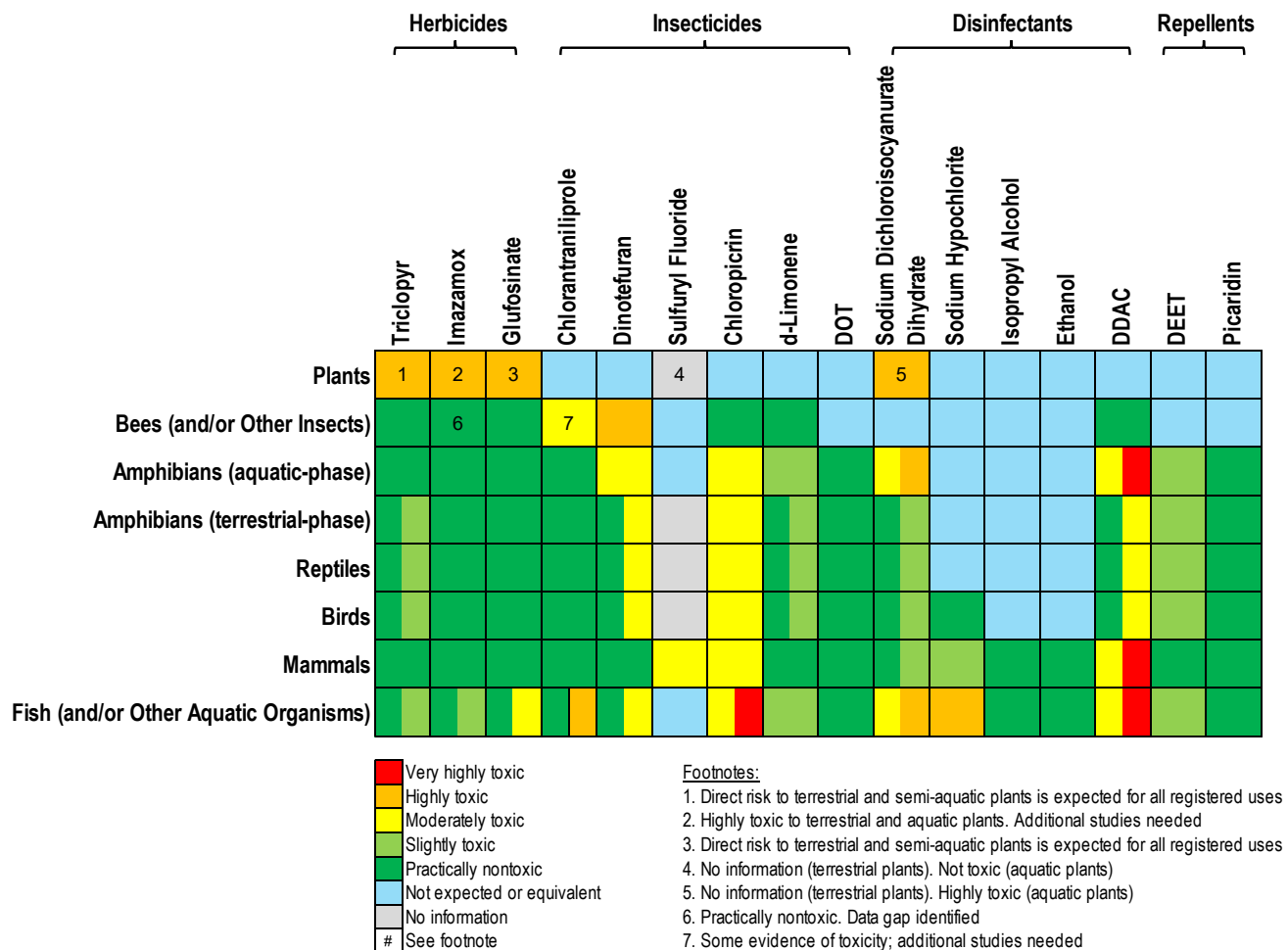


Figure 2. Toxicological Findings in Ecological Receptors



	Buffer zone specified?
<u>Herbicides</u>	
Triclopyr	● Aquatic use allowed; potable water intake restrictions apply (shutoff until <0.4 ppm). Avoid drift.
Imazamox	● Aquatic use allowed; potable water intake restrictions apply (shutoff if >50 ppb within ¼ mile). Avoid drift.
Glufosinate	● Spray drift buffer zones under ESA mitigation: ≥10 ft for ground applications; ≥50 ft for aerial applications.
<u>Insecticides</u>	
Chlorantraniliprole	● Structural use; avoid runoff and direct application to water.
Dinotefuran	● Structural use; no aquatic buffer zones; avoid discharge to water.
Sulfuryl Fluoride	● Structural fumigation; no freshwater buffer zones; indoor-focused mitigation.
Chloropicrin	● Structural fumigation; no freshwater buffer zones; indoor-focused mitigation.
d-Limonene	● Structural use; no aquatic buffer zones; avoid discharge to water.
DOT	● Structural use; label notes toxicity to fish but no buffer zone requirement.
<u>Disinfectants</u>	
Sodium Dichloroisocyanurate Dihydrate	● Disinfectant; avoid direct discharge; no buffer zone requirement.
Sodium Hypochlorite	● Disinfectant; avoid direct discharge; no buffer zone requirement.
Isopropyl Alcohol	● Disinfectant; no buffer zone requirement; avoid direct discharge.
Ethanol	● Disinfectant; no buffer zone requirement; avoid direct discharge.
DDAC	● Disinfectant; avoid direct discharge; no buffer zone requirement.
<u>Repellents</u>	
DEET	● Personal repellent; no buffer zone requirement.
Picaridin	● Personal repellent; no buffer zone requirement.
Legend: ● Yes	
● No	

Figure 3. Summary EPA Recommendations on Buffer Zone from Freshwater Features



Acronyms / Abbreviations

Acronym / Abbreviation	Full Name
BEE	Butoxyethyl ester (Triclopyr BEE)
CAS	Chemical Abstracts Service
CEQA	California Environmental Quality Act
CHO	Chinese Hamster Ovary
DART	Developmental and Reproductive Toxicity
DDAC	Dodecyl dimethyl ammonium chloride
DEET	N,N-diethyl-meta-toluamide
DOT	Disodium octaborate tetrahydrate
DPR	Department of Pesticide Regulation (California)
EC ₅₀	Effective concentration 50%
EDSP	Endocrine Disruptor Screening Program
ECHA	European Chemicals Agency
EPA	U.S. Environmental Protection Agency
EXTOXNET	Extension Toxicology Network
FAS	Fetal Alcohol Syndrome
FFDCA	Federal Food, Drug, and Cosmetic Act
GD	Gestation Day
GRAS	Generally Recognized as Safe
IC ₂₅	25% Inhibitory concentration
IARC	International Agency for Research on Cancer
IPM	Integrated Pest Management
K _{oc}	Organic carbon-water partition coefficient
LD ₅₀	Lethal dose 50%
LC ₅₀	Lethal concentration 50%
LOAEC	Lowest-observed-adverse-effect concentration
LOAEL	Lowest-observed-adverse-effect level
LOEL	Lowest-observed-effect concentration
LOEC	Lowest-observed-effect level
M/F	Male/Female
Midpen	Midpeninsula Regional Open Space District
NOAEC	No-observed-adverse-effect concentration
NOAEL	No-observed-adverse-effect level
NOEC	No-observed-effect concentration
NOEL	No-observed-effect level
OCSP	Office of Chemical Safety and Pollution Prevention
OECD	Organisation for Economic Co-operation and Development
OPPTS	Office of Prevention, Pesticides, and Toxic Substances
PPE	Personal Protective Equipment
QAC	Quaternary Ammonium Compound
RfD	Reference Dose
TCP	3,5,6-Trichloro-2-pyridinol
TEA	Triethylamine
UC	University of California
USDA	United States Department of Agriculture



1 Introduction

The Midpeninsula Regional Open Space District (henceforth referred to as Midpen or District) operates within an ecologically rich region along the Santa Cruz Mountains in the San Francisco Bay Area. The area faces complex pressures from urban development, climate change, wildfire risk, and invasive species, making Midpen's mission to preserve open space, protect biodiversity, and provide low-impact public access vital to the region's environmental resilience and quality of life.

Midpen conducts management activities to control noxious and invasive pests [i.e., weeds, insects, rats, mice, and certain wildlife (e.g., skunks, raccoons)] that are nuisances or can cause potential health risks to human and ecological receptors on Midpen's lands. Because of the importance of providing needed pest control without adversely impacting ecological and human health, Midpen implemented an Integrated Pest Management (IPM) Program, which is a comprehensive, science-based approach for management of pests across its preserves, facilities, and associated lands. The program's primary goals are to protect human health, ensure environmental quality, and efficiently manage its property. The IPM policy emphasizes prevention, monitoring, and the use of the least harmful and most effective pest control methods, that prioritize non-chemical approaches before considering pesticides. Key elements of the program include:

- **Prevention First:** IPM program prioritizes pest prevention via habitat modification, education, and maintenance practices to reduce the likelihood of pest issues.
- **Monitoring and Thresholds:** Regular monitoring is conducted to identify pests, assess damage, and determine when pest populations exceed established tolerance thresholds that warrant action.
- **Integrated Methods:** A range of physical, biological, cultural, and, when necessary, chemical controls are considered. Chemical controls (i.e., pesticides) are only used when other methods are insufficient, and only products from a carefully screened and approved list are permitted.
- **Site-Specific Decision-Making:** Pest management strategies are tailored to the unique needs of five major categories: buildings, recreational facilities, fuel management areas, rangelands/agricultural properties, and natural lands.
- **Oversight and Accountability:** An IPM Coordinator and an IPM Coordination Team oversee program implementation, training, safety, and annual planning. All pest management activities are documented in an Annual IPM Work Plan and evaluated in an Annual IPM Report.

- **Transparency and Public Notification:** Midpen provides public notification before, during, and after pesticide applications, and maintains open communication with stakeholders.
- **Adaptive Management:** IPM program is designed to be adaptive, using annual assessments and reports to refine practices, update the list of approved pesticides, and incorporate new science and technology.
- **Safety and Training:** Staff and contractors receive regular training in pest identification, safe pesticide use, and best management practices to minimize risks to people and the environment.

Consistent with the IPM Program, Midpen is considering adding 14 pesticides to its list of approved pesticides (Table 1). This report details the toxicological evaluation, human and ecological risk assessment, and environmental fate assessment for each pesticide to provide a scientifically sound basis for determining whether each product aligns with Midpen's commitment to least toxic, ecologically responsible pest management. The pesticide evaluations are grouped by the general categories of herbicide, insecticide, disinfectant, and repellent.

To complete the toxicological assessment, previous assessments conducted by the U.S. Environmental Protection Agency (EPA) were reviewed and relied upon as the primary resource. If needed, information from other authoritative sources was also considered, including the California Department of Pesticides Regulation (DPR) resources and University extension materials [e.g., University of California (UC) Statewide Integrated Pest Management Program (IPM), the EXtension TOXicology NETwork (EXTOXNET)]. Additionally, the information available in the European Chemicals Agency (ECHA) dossiers, EPA ECOTOX Knowledgebase, and peer-reviewed scientific literature was considered. The available toxicity information was used to conduct qualitative risk assessments.

For human assessments, risk potential was derived from the chemical doses/concentrations causing acute and short-term toxicity, subchronic and chronic toxicity, carcinogenicity and genotoxicity, developmental and reproductive toxicity (DART), endocrine disruption, and/or sensitization in animal studies. Several toxicity thresholds were recorded when available (Table 2). Additionally, when available, EPA's pesticide toxicity ranks were noted (Table 3). The health risks were described qualitatively (e.g., "no evidence of carcinogenicity, acute or chronic toxicity, endocrine disruption but possible reproductive toxicity at very high doses").



Toxicological Assessment of Pesticides

1 Introduction

For ecological assessments, the toxicity thresholds for various ecological receptors [plants, bees (and/or other insects), amphibians and reptiles, birds, mammals, and fish (and/or other aquatic organisms)] were recorded (**Table 2**). Additionally, when available, EPA's categories of toxicity were noted (**Table 4**). The risks for each organism were described qualitatively (e.g., "practically nontoxic in fish").

The physicochemical properties [e.g., water solubility, half-life in environmental media (e.g., sediment, water, soil), photolytic half-life, volatilization] and environmental

Table 1 in Midpen IPM's List of Approved Pesticides, the following were prepared based on the toxicological assessments:

1. A summary matrix ranking relative risks (i.e., high / medium / low) by category,
2. Product-specific narratives highlighting key findings, data gaps, and recommendations,

concentrations, if available, were recorded to assess environmental fate. Qualitative descriptors were used for each pesticide (e.g., "Nonpersistent in water and soil. Breaks down rapidly in water. Half-life is about 0.6 days due to photolysis. Very low persistence with aerobic half-life of 103 days. Due to its low persistence and rapid excretion in animals it is not likely to impact food chain uptake").

To support IPM decision-making on the inclusion of the 14 pesticides (active ingredients and formulated products) noted in

3. Conclusions about each product's suitability for inclusion in the IPM Program. These conclusions are based on a combined consideration of hazard of the pesticide and the anticipated use scenario, and
4. Recommendations when considering the additions of these pesticides to Midpen's list.

Table 1. *Pesticides Evaluated in this Report*

Category (Target Pest)	Proposed Application by Midpen	Active Ingredient	Product Formulations (Manufacturer)
Herbicide (Invasive plants)	Annual application of ~0.5 gal over 100 acres via spot spray and basal bark applications. Once per year in spring/summer/fall. Pesticide to control invasive plants in aquatic and riparian weeds	Triclopyr ¹	Choline salt aquatic formulation (Vastlan)
Herbicide (Invasive plants)	Annual application of (1) ~0.5 gal over 100 acres or (2) 2 gal over 300 acres via spot spray aquatic riparian application. Once per year in spring/summer/fall. Pesticide to control invasive plants in aquatic and riparian weeds	Imazamox	Aquatic formulation (ClearCast)
Herbicide (Broadleaf weeds)	Annual application of ~3.2 gal over 100 acres via spot spray applications. Twice per year in the spring. Pesticide to control invasive plants	Glufosinate	Lifeline / Cheetah Pro
Insecticide (Structural pests, termites, and lepidopteran pests)	Annual application of ~8.5 gal over 1-5 residences via perimeter applications. Once per year. Pesticide to control structural pests, termites	Chlorantraniliprole	Altriset
Insecticide (Structural pests (termites and ants)	Annual application of ~14 oz over 1-5 residences via perimeter applications. Once per year. Pesticide to control structural pests	Dinotefuran	Alpine Foam
Insecticide (Structural pests, termites)	Annual application ~240 oz over 1-5 residences via tenting. Once per year. Pesticide to control structural pests and termites	Sulfuryl fluoride / Chloropicrin	Vikane
Insecticide (Structural pests, termites)	Annual application of ~2 gal over 1-5 residences via spot treatment applications. Once per year. Pesticide to control structural pests and termites	d-Limonene	XT-2000 Insecticide
Insecticide (Structural pests, fungus and dry rot, termites)	Annual application of ~5 gal over 1-5 residences via spot treatment or prevention applications. Once per year. Pesticide to control structural pests, fungus and dry rot, and termites	Disodium octaborate tetrahydrate (DOT)	Bora-Care; Tim-Bor
Disinfectant (Various microorganisms)	Annual application ~5 kg via spot spray or addition to water. Pesticide to disinfect equipment, water bodies, and surfaces	Sodium dichloroisocyanurate dihydrate	Granular Chlorine Bleach (Leslie's Chlor Brite, EZ Chlor)
Disinfectant (Various microorganisms and biofilms)	Annual application ~16 gal via spot spray. Pesticide to disinfect equipment	Sodium hypochlorite	Liquid Bleach (Clorox)
Disinfectant (Various microorganisms)	Annual application ~100 gal via spot spray. Pesticide to disinfect equipment	Isopropyl alcohol or ethanol	Rubbing Alcohol
Disinfectant (Various microorganisms)	Annual application ~5 gal via spot spray. Pesticide to disinfect equipment	Dodecyl dimethyl ammonium chloride (DDAC)	Quaternary ammonium compounds (Quat 128 or Physan 20)



Toxicological Assessment of Pesticides

1 Introduction

Category (Target Pest)	Proposed Application by Midpen	Active Ingredient	Product Formulations (Manufacturer)
Repellent (Insect repellent)	Annual application ~200 cans (6 oz. each) via spot spray. Pesticide applied to human body and/or clothing, shoes, and headwear	N,N-diethyl-meta-toluamide (DEET)	Various
Repellent (Insect repellent)	Annual application ~200 cans (5 oz. each) via spot spray. Pesticide applied to human body and/or clothing, shoes, and headwear	Picaridin	Various

¹ Triclopyr BEE and Triclopyr TEA have already been evaluated and are approved for Midpen use. In this report, the toxicological assessment for triclopyr focuses on the choline salt

Table 2. List of Toxicity Thresholds Considered in this Report

Toxicity Threshold Abbreviation	Toxicity Threshold Name	Definition
EC ₅₀	Effective concentration 50%	Concentration of a substance that produces 50% of its maximal effect
IC ₂₅	25% Inhibitory concentration	Concentration of a substance that causes 25% inhibition of a specified biological or biochemical function
LC ₅₀	Lethal concentration 50%	Concentration of a substance that is lethal to 50% of a test population
LD ₅₀	Lethal dose 50%	Dose of a substance that is lethal to 50% of a test population
LOAEC	Lowest-observed-adverse-effect concentration	The lowest concentration of a substance at which statistically or biologically significant adverse effects are observed in the exposed population compared to a control group
LOAEL	Lowest-observed-adverse-effect level	The lowest dose or exposure level of a substance at which statistically or biologically significant adverse effects are observed in the exposed population compared to a control group
LOEC	Lowest-observed-effect concentration	The lowest concentration of a substance at which statistically or biologically significant effects are observed in the exposed population compared to a control group
LOEL	Lowest-observed-effect level	The lowest dose or exposure level of a substance at which statistically or biologically significant effects are observed in the exposed population compared to a control group
NOAEC	No-observed-adverse-effect concentration	The highest concentration of a substance at which no statistically or biologically significant adverse effects are observed in the exposed population compared to a control group
NOAEL	No-observed-adverse-effect level	The highest dose or exposure level of a substance at which no statistically or biologically significant adverse effects are observed in the exposed population compared to a control group
NOEC	No-observed-effect concentration	The highest concentration of a substance at which no statistically or biologically significant effects are observed in the exposed population compared to a control group
NOEL	No-observed-effect level	The highest dose or exposure level of a substance at which no statistically or biologically significant effects are observed in the exposed population compared to a control group

Table 3. EPA Categories for Ranking of Pesticide Toxicity

Hazard Indicator	High Toxicity (Category I)	Moderate Toxicity (Category II)	Low Toxicity (Category III)	Very Low Toxicity (Category IV)
Oral LD ₅₀ (mg/kg)	≤ 50	> 50 – 500	> 500 – 5000	> 5000
Dermal LD ₅₀ (mg/kg)	≤ 200	> 200 – 2000	> 2000 – 20000	> 20000
Inhalation LC ₅₀ (mg/L)	≤ 0.2	> 0.2 – 2	> 2 – 20	> 20
Eye Irritation	Corrosive; corneal opacity not reversible within seven days	Corneal opacity reversible within seven days; irritation persisting for seven days	No corneal opacity; irritation reversible within seven days	No irritation
Skin Irritation	Corrosive	Severe irritation at 72 hours	Moderate irritation at 72 hours	Mild or slight irritation at 72 hours

Source: <https://www.ecfr.gov/current/title-40/chapter-I/subchapter-E/part-156/subpart-D/section-156.62>

Table 4. EPA Categories of Toxicity for Aquatic and Terrestrial Organisms

Species	Hazard Indicator	Very Highly Toxic	Highly Toxic	Moderately Toxic	Slightly Toxic	Practically Nontoxic
Aquatic Organisms	LC ₅₀ (ppm)	≤ 0.1	> 0.1 – 1	> 1 – 10	> 10 – 100	> 100
Terrestrial Organisms	Oral LD ₅₀ (mg/kg)	< 10	10 – 50	51 – 500	501 – 2000	> 2000
	Dietary LC ₅₀ (ppm)	< 50	50 – 500	501 – 1000	1001 – 5000	> 5000
Bees	Contact LD ₅₀ (µg/bee)	Not applicable	< 2	2 – 10.99	Not applicable	≥ 11

Source: <https://www.ecfr.gov/current/title-40/chapter-I/subchapter-E/part-156/subpart-D/section-156.62>



2 Herbicides

Three herbicides (triclopyr, imazamox, glufosinate) were evaluated in this report. Their toxicity in humans and ecological receptors is summarized in **Table 5** and **Table 6**, respectively. Overall, the herbicides were found to pose low risk to human health, with no evidence of carcinogenicity, genotoxicity, or endocrine disruption, and minimal risk of developmental or reproductive toxicity at labeled use rates. However, all three are highly toxic to terrestrial and aquatic plants, and additional studies are warranted for non-target plant species. Risks to other ecological receptors (bees, amphibians, reptiles, birds, mammals, fish) were generally low, though some data gaps remain for pollinators and chronic aquatic exposures. These herbicides are moderately to highly mobile in the environment, with low

potential for bioaccumulation, and degrade primarily via microbial activity and photolysis.

On the basis of this review, imazamox generally offers the lowest hazard profile across both human and ecological populations of the three herbicides, though the minor differences are not likely to be meaningful. In deciding which herbicides to incorporate into their IPM, Midpen should consider specific target species, application methods, and label requirements. As all three herbicides are highly toxic to aquatic and terrestrial plants (as is anticipatable for herbicides), care should be taken in selecting and applying the chosen herbicide(s) considering these factors.

Table 5. Human Toxicity Summary of Herbicides

Endpoint	Triclopyr	Imazamox	Glufosinate
Acute Toxicity (Oral)	Category III	Category IV	Category III
Acute Toxicity (Dermal)	Category III	Category III	Category III
Acute Toxicity (Inhalation)	Category III	Category IV	Category III
Subchronic and chronic toxicity	Low toxicity. Effects, if any, only at high doses	Not toxic via oral and dermal routes. Inhalation studies not required	Some effects noted at doses much higher than aggregate exposure dose for general population
Carcinogenicity and Genotoxicity	No evidence	No evidence	No evidence
Developmental and Reproductive Toxicity	Not expected. Effects only observed at maternally toxic and/or high doses	No evidence	Not expected at labeled use rates
Endocrine Disruption	No evidence	No evidence based on information to date	No information. Not on EPA's priority list for EDSP
Irritation (Eye)	Category I	Category III	Category III
Irritation (Skin)	Category IV	Category IV	Category IV
Sensitization	Skin sensitizer	Not a skin sensitizer	Not a skin sensitizer
Neurotoxicity	No evidence	Testing not required	Not expected
Immunotoxicity	No evidence	Testing not required	No concern

Table 6. Ecotoxicity Summary of Herbicides

Ecological Receptor	Triclopyr	Imazamox	Glufosinate
Plants	Direct risk to terrestrial and semi-aquatic plants is expected for all registered uses	Highly toxic to terrestrial and aquatic plants. Additional studies needed	Direct risk to terrestrial and semi-aquatic plants is expected for all registered uses
Bees (and/or Other Insects)	Practically nontoxic	Practically nontoxic. Data gap identified	Practically nontoxic
Amphibians and Reptiles	Slightly toxic or practically nontoxic (terrestrial-phase amphibians and reptiles). Practically nontoxic (aquatic-phase amphibians)	Practically nontoxic	Practically nontoxic
Birds	Slightly toxic or practically nontoxic	Practically nontoxic	Practically nontoxic
Mammals	Practically nontoxic	Practically nontoxic	Practically nontoxic
Fish (and/or Other Aquatic Organisms)	Practically nontoxic (freshwater fish and invertebrates). Slightly toxic (estuarine/marine fish)	Practically nontoxic (freshwater fish and invertebrates). Slightly toxic (estuarine/marine fish)	Practically nontoxic (fish). Moderately toxic (aquatic invertebrates)



2.1 Triclopyr

Pesticide to control invasive plants in aquatic and riparian weeds

Formulation: Choline salt aquatic formulation (Vastlan)

Typical Target Pests: Invasive plants

Application: Annual application of ~0.5 gal over 100 acres via spot spray and basal bark applications. Once per year in spring/summer/fall.

Human Toxicity: *Acute and Short-term Toxicity:*

Category III (oral, dermal, and inhalation toxicity);

Subchronic and Chronic Toxicity: Low toxicity. Effects, if

any, only at high doses; *Carcinogenicity and Genotoxicity:*

No evidence; *DART:* Not expected. Effects only

observed at maternally toxic and/or high doses;

Endocrine disruption: No evidence; *Sensitization and*

irritation: Category I (eye). Category IV (skin). Skin

sensitizer; *Neurotoxicity:* No evidence; *Immunotoxicity:*

No evidence.

Ecological Toxicity: *Plants:* Direct risk to terrestrial

and semi-aquatic plants is expected for all registered

uses; *Bees (and/or other Insects):* Practically nontoxic;

Amphibians and Reptiles: Slightly toxic or practically

nontoxic (terrestrial-phase amphibians and reptiles).

Practically nontoxic (aquatic-phase amphibians); *Birds:*

Slightly toxic or practically nontoxic; *Mammals:*

Practically nontoxic; *Fish (and/or other Aquatic*

Organisms): Practically nontoxic (freshwater fish and

invertebrates). Slightly toxic (estuarine/marine fish).

Environmental Fate: Highly soluble and mobile.

Triclopyr choline salt is rapidly converted to triclopyr

acid, which is non-persistent in aerobic environments

but can persist under anaerobic conditions. Main

concern is formation of the more persistent and toxic

degradate TCP but environmental concentrations are

typically well below levels of concern for non-target

organism.

Conclusions and Recommendations: Eye irritation

and skin sensitization are the main hazards associated

with triclopyr choline salt use in humans. Adverse

effects in ecological receptors, besides plants, are not

expected. Triclopyr choline salt can be added to

Midpen's list of approved pesticides with appropriate

precautions.

2.1.1 Background

Triclopyr (CAS # 55335-06-3) is a selective systemic herbicide used primarily for post-emergent control of broadleaf and woody plants in both terrestrial and aquatic environments (EPA, 1998b). It was first registered in the U.S. in 1979, with subsequent registrations expanding its

use to turf, rangeland, and rice fields (EPA, 1998b).

Triclopyr is approved for use in a variety of settings, including forests, rights-of-way, pastures, conservation reserve program (CRP) lands, ornamental turf, and aquatic areas such as lakes and canals (SERA, 2016). In agriculture and land management, triclopyr is commonly applied to control invasive species like Eurasian watermilfoil, purple loosestrife, and woody shrubs such as autumn olive and honeysuckle (SERA, 2016). Triclopyr acts by mimicking the plant hormone auxin, disrupting normal growth processes and leading to uncontrolled cell division and eventual plant death (EPA, 1998b). It is classified as a WSSA Group 4 herbicide and does not inhibit acetylcholinesterase, distinguishing it from organophosphate insecticides (EPA, 2014b).

EPA-approved triclopyr-containing formulations are available in various forms, including soluble liquids, emulsifiable concentrates, granules, and ready-to-use pressurized sprays. A common formulation, Triclopyr 4E Select, contains 61.6% triclopyr butoxyethyl ester, equivalent to 4 pounds of acid per gallon (SERA, 2016). Renovate 3®, a TEA-based formulation, contains 44.4% triclopyr triethylamine salt and is approved for aquatic applications (SERA, 2016). There are over 200 EPA-registered products containing triclopyr, which reflect its widespread use in vegetation management across diverse ecosystems (SERA, 2016).

Commercial formulations of triclopyr include its acid form, triethylamine (TEA) salt (CAS # 57213-69-1), and butoxyethyl ester (BEE; CAS # 80082-06-0), with TEA being approved for aquatic use and BEE restricted to terrestrial applications due to its toxicity to aquatic life (EPA, 2014b). Some products also contain triclopyr choline salt (CAS # 1048373-85-8), which are formulated primarily as soluble liquids for foliar application and are approved for use in aquatic and terrestrial environments (EPA, 2020d).

Previously, triclopyr BEE and triclopyr TEA have been evaluated and approved for Midpen use. In this report, the toxicological assessment for triclopyr focuses on triclopyr choline salt.

2.1.2 Exposure Considerations

Triclopyr choline salt is a selective herbicide used for post-emergent control of broadleaf and woody plants in terrestrial and aquatic environments (EPA, 2020d). It can be applied via aerial and ground spray methods, with aerial applications typically used in forestry, rights-of-way, and large-scale vegetation management programs (EPA, 2020d). Ground applications may involve boom sprayers, backpack sprayers, or hand wands, depending on the site and target species (Strid et al., 2018). For broadcast applications, triclopyr choline is typically applied in 10 to 100



gal per acre by ground or 1 to 25 gallons per acre by air, ensuring thorough coverage of target vegetation (Alligare, 2021). Triclopyr choline is approved for use in forests, industrial non-crop areas, aquatic sites, and residential landscapes, though label restrictions may limit use near potable water sources and sensitive habitats (SERA, 2016; UF/IFAS, 2024). For aquatic applications, treated water should not be used for irrigation for up to 120 days unless triclopyr levels are confirmed to be below 1.0 ppb (UF/IFAS, 2024).

Midpen's annual application of triclopyr choline salt (Choline salt aquatic formulation by Vastlan) is estimated at 0.5 gal over 100 acres, once per year in spring/summer/fall. The methods of application are spot spray and basal bark. Vastlan is formulated as a soluble liquid and contains 4 lbs acid equivalent per gallon of triclopyr choline salt. It can be applied via ground equipment, aerial methods, or foliar broadcast or spot treatment. Use of PPE, including protective eyewear, long-sleeved shirt, and waterproof gloves, is required.

2.1.3 Human Toxicity and Risk Assessment

According to EPA (2014b), toxicology studies for triclopyr were performed using both the free acid and the TEA salt form. Bioequivalency of the two chemical forms of triclopyr was addressed through the conduct of special studies on the TEA form. These studies included data on comparative disposition, plasma half-life, tissue distribution, hydrolytic cleavage under physiological and environmental conditions and were found to adequately address the issue of bioequivalency. In addition, subchronic toxicity studies supported the pharmacokinetics data in demonstrating bioequivalence. Therefore, the Agency concluded that studies conducted with any one form of triclopyr can be used to support the toxicology database as a whole. Regarding triclopyr choline salt, in 2012 the Agency determined that triclopyr choline and triclopyr acid are bioequivalent; thus concluding that the existing toxicological database is appropriate to support the triclopyr choline evaluation (EPA, 2014b). Based on EPA's determination for bioequivalence of triclopyr forms, the sections below include information for other triclopyr forms when no specific information was identified for triclopyr choline salt.

2.1.3.1 Acute and Short-term Toxicity

No specific acute and short-term toxicity information was identified for triclopyr choline salt. Based on the information available for other triclopyr forms (EPA, 2020d), triclopyr choline salt exhibits low acute toxicity and is classified as Category III for acute oral, dermal, and inhalation routes. The oral LD₅₀ values were identified as: triclopyr acid – 729 mg/kg (males) and 630 mg/kg (females), triclopyr TEA – 1847 mg/kg (males and females), and triclopyr BEE – 803 mg/kg (males and females). The dermal LD₅₀ values were > 2000 mg/kg for triclopyr acid, triclopyr TEA, and triclopyr BEE. The inhalation LC₅₀ values were >2.6 and >4.8 mg/L for triclopyr TEA and triclopyr BEE, respectively (EPA, 2020d).

2.1.3.2 Subchronic and Chronic Toxicity

No specific subchronic and chronic toxicity information was identified for triclopyr choline salt. According to EPA (1998b), multiple studies on various forms of triclopyr, including the technical acid, TEA, and BEE were reviewed (**Table 7**). In a 13-week subchronic oral study in rats with triclopyr technical acid (98% a.i.), the NOAEL was 5 mg/kg/day and the LOAEL was 20 mg/kg/day, based on histopathological changes in the kidneys. In chronic studies, triclopyr technical acid was used in dogs and rodents, with NOAELs ranging from 5 to 12 mg/kg/day and LOAELs from 10 to 36 mg/kg/day, with effects including decreased body weight gain, changes in hematological parameters, increased liver and kidney weights, and histopathological changes in the liver and kidneys. In a two-generation reproductive toxicity study in rats, triclopyr technical acid (99.4% a.i.) was used, with a parental systemic NOAEL of 5 mg/kg/day and a LOAEL of 25 mg/kg/day, based on increased incidence of proximal tubular degeneration in the kidneys. Subchronic and chronic studies in dogs also used triclopyr technical acid. The EPA established a chronic reference dose (RfD) of 0.05 mg/kg/day for triclopyr, based on the NOAEL from the reproductive study and an uncertainty factor of 100. Aggregate dietary exposure estimates for the general U.S. population were well below the RfD, and no adverse subchronic or chronic effects are anticipated at expected exposure levels (EPA, 1998b). The Agency stated that all aggregate risk estimates for triclopyr were not of concern (EPA, 2020d), suggesting that triclopyr choline salt would not pose a risk when applied per label directions.



Table 7. Subchronic and Chronic Toxicity of Triclopyr

Triclopyr Form	Species (Sex)	Route	Duration	Doses/ Concentrations	Findings	Toxicity Thresholds
Acid	Rat (M/F)	Oral	90 days	0, 5, 20 mg/kg/day	Degeneration of proximal kidney tubules	• NOAEL = 5 mg/kg/day • LOAEL = 20 mg/kg/day
Ester	Rat (M/F)	Oral	90 days	0, 7, 28 mg/kg/day	Increased kidney weight (M), decreased RBC (F), tubule degeneration	• NOAEL = 7/<7 (M/F) mg/kg/day • LOAEL = 28/7 (M/F) mg/kg/day
Acid/Ester	Dog (M/F)	Oral	183 days	0, ≤2.5, >2.5 mg/kg/day	Decreased PSP excretion (not toxicologically significant)	• NOAEL ≤2.5 mg/kg/day • LOAEL >2.5 mg/kg/day
Acid/Ester	Rabbit (M/F)	Dermal	21 days	0, 1000 mg/kg/day	Decreased alkaline phosphatase, Increased liver weight (marginal)	• NOAEL = 1000 mg/kg/day • LOAEL > 1000 mg/kg/day
Ester	Rat (F)	Oral	Prenatal	0, 100, 300 mg/kg/day	Maternal: mortality; Developmental: hydrocephalus, cleft palate	• NOAEL = 100 mg/kg/day • LOAEL = 300 mg/kg/day
Ester	Rabbit (F)	Oral	Prenatal	0, 30, 100 mg/kg/day	Maternal: mortality; Developmental: decreased number of live fetuses, increased fetal deaths	• NOAEL = 30 mg/kg/day • LOAEL = 100 mg/kg/day
Salt	Rabbit (F)	Oral	Prenatal	0, 30, 100 mg/kg/day	Maternal: mortality, abortions; Developmental: decreased number live fetuses	• NOAEL = 30 mg/kg/day • LOAEL = 100 mg/kg/day
Salt	Rat (F)	Oral	Prenatal	0, 100, 300 mg/kg/day	Maternal: mortality; Developmental: increased fetal weight, increased incidence of anomalies	• NOAEL = 100 mg/kg/day • LOAEL = 300 mg/kg/day
Acid	Rat (F)	Oral	Prenatal	0, <50, 50, 100, 200 mg/kg/day	Maternal: clinical signs; Developmental: cleft palate, ossification delay	• NOAEL (maternal) < 50 mg/kg/day • LOAEL (maternal) = 50 mg/kg/day • NOAEL (develop.) = 100 mg/kg/day • LOAEL (develop.) = 200 mg/kg/day
Acid	Rat (M/F)	Oral	Reproduction	0, 5, 25 mg/kg/day	Increased tubular degeneration; Increased exencephaly/ anophthalmia in pups	• NOAEL = 5 mg/kg/day • LOAEL = 25 mg/kg/day
Acid	Dog (M/F)	Oral	228 days	0, 10, 20 mg/kg/day	Decreased weight gain, decreased hematology, liver histopathology	• NOAEL = 10 mg/kg/day • LOAEL = 20 mg/kg/day
Acid	Dog (M/F)	Oral	1 year	0, ≤5, >5 mg/kg/day	Clinical chemistry changes (physiologic)	• NOAEL ≤ 5 mg/kg/day • LOAEL > 5 mg/kg/day
Acid	Rat (M/F)	Oral	Chronic/ Carcinogenicity	0, 12, 36 mg/kg/day	Increased kidney degeneration, adrenal tumors (M), mammary tumors (F)	• NOAEL = 12/≤36 (M/F) mg/kg/day • LOAEL = 36/>36 (M/F) mg/kg/day
Acid	Mouse (M/F)	Oral	Carcinogenicity	0, 84, 109.5, 143, 135 mg/kg/day	Decreased weight gain, increased mammary tumors (F)	• NOAEL = 84/109.5 (M/F) mg/kg/day • LOAEL = 143/135 (M/F) mg/kg/day

Source: (EPA, 2020d)

2.1.3.3 Carcinogenicity and Genotoxicity

No specific carcinogenicity and genotoxicity information was identified for triclopyr choline salt. According to EPA (2020d), triclopyr (including choline salt) was not classified as a human carcinogen. Although, increases in tumors were observed in two carcinogenicity studies on triclopyr acid (Table 7), these effects were not considered treatment-related or relevant to humans at expected exposure levels. Triclopyr (including choline salt) was not mutagenic or genotoxic based on standard assays conducted using triclopyr acid and BEE (EPA, 2020d).

2.1.3.4 Developmental and Reproductive Toxicity

No specific developmental and reproductive toxicity information was identified for triclopyr choline salt. According to EPA (2020d), triclopyr (including choline salt) was not a developmental toxicant, with effects observed at maternally toxic doses. In a two-generation reproductive toxicity study, significant reductions in F1 and F2 generation

litter sizes were observed, with a LOAEL set at 250 mg/kg/day and a NOAEL at 25 mg/kg/day. The Agency concluded that triclopyr (including choline salt) did not pose a reproductive risk at expected exposure doses, with effects in animal studies noted only at high doses (EPA, 2020d).

2.1.3.5 Endocrine Disruption

No specific information was identified on endocrine disruption potential of triclopyr choline salt. According to EPA (2020d), no effects indicative of endocrine disruption were observed in available studies for other triclopyr forms.

2.1.3.6 Sensitization and Irritation

No specific sensitization or irritation toxicity information was identified for triclopyr choline salt. Based on the information available for other triclopyr forms (EPA, 2020d), triclopyr choline salt is a skin sensitizer based on classification for triclopyr TEA. It is also classified as Category I for eye irritation and Category IV for skin irritation based on classifications for triclopyr TEA (EPA, 2020d).



2.1.3.7 Neurotoxicity

No specific information on neurotoxicity was identified for triclopyr choline salt. Based on the information available for other triclopyr forms (EPA, 2020d), there was no evidence of neurotoxicity, and triclopyr was not considered a neurotoxicant (EPA, 2020d).

2.1.3.8 Immunotoxicity

No specific information on immunotoxicity potential of triclopyr choline salt was identified. According to EPA (2020d), no effects indicative of immunotoxicity were observed in available studies for other triclopyr forms.

2.1.4 Ecological Toxicity and Risk Assessment

2.1.4.1 Plants

No specific information on triclopyr choline salt toxicity in plants was identified; however, it is an herbicide and is designed to kill invasive plants. According to EPA (2019e), triclopyr-based herbicides are toxic to terrestrial plants. The 25% effect concentration (IC₂₅) value of triclopyr acid (0.0054 lbs/A) is three orders of magnitude lower than the maximum single application rate of 9 lbs/A. The most sensitive dicot species is approximately 10-times more sensitive compared to monocots based on the vegetative vigor study with triclopyr BEE. However, the most sensitive dicot and monocots are of similar sensitivity based on seedling emergence with triclopyr BEE. Regarding aquatic plants, triclopyr acid and TEA are toxic between 4.2 and 6.3 mg/L, whereas triclopyr BEE is toxic about an order of magnitude lower (0.1 to 0.88 mg/L) (EPA, 2019e).

2.1.4.2 Bees (and/or Other Insects)

No specific information on triclopyr choline salt toxicity in bees was identified. ECOTOX did not have entries for studies on triclopyr choline salt. According to EPA (2019e), triclopyr acid and BEE were “Practically nontoxic” to honeybees via contact exposure, and triclopyr acid was also “Practically nontoxic” to honeybees via oral exposure. Regarding chronic toxicity of triclopyr, adult honeybees were less sensitive (NOAEL = 22 µg/bee/day) compared to larvae (0.58 µg/bee/day) (EPA, 2019e).

2.1.4.3 Amphibians and Reptiles

No specific information on triclopyr choline salt toxicity in amphibians and reptiles was identified. ECOTOX did not have entries for studies on triclopyr choline salt. According to EPA (2019e), birds can be used as surrogates for

terrestrial-phase amphibians and reptiles, whereas freshwater fish can be used as surrogates for aquatic-phase amphibians. Triclopyr toxicity information in birds and freshwater fish is provided in the sections below. In birds, triclopyr was “Slightly toxic” to “Practically nontoxic”, indicating that same conclusion would be applicable to terrestrial-phase amphibians and reptiles. In fish, triclopyr was “Practically nontoxic”, indicating that a similar conclusion would be applicable to aquatic-phase amphibians (EPA, 2019e).

2.1.4.4 Birds

No specific information on triclopyr choline salt toxicity in birds was identified. ECOTOX did not have entries for studies on triclopyr choline salt. According to EPA (2019e), triclopyr was “Slightly toxic” to “Practically nontoxic” to birds. The acute oral LD₅₀ values ranged from 1698 to 2271 mg/kg and LC₅₀ values ranged from 2934 to >7151 ppm. In chronic studies, exposure of Mallard ducks to 200 ppm triclopyr acid resulted in a significant (14%) reduction in 14-day old survivors, with a NOAEC noted as 100 ppm (EPA, 2019e).

2.1.4.5 Mammals

No specific information on triclopyr choline salt toxicity in mammals was identified. ECOTOX did not have entries for studies on triclopyr choline salt. According to EPA (2019e), triclopyr was “Practically nontoxic” to mammals. The acute oral LD₅₀ values ranged from 630 to 1321 mg/kg. In a two-generation reproductive toxicity study, significant reductions in F1 and F2 generation litter sizes were observed, with a LOAEL set at 250 mg/kg/day and a NOAEL at 25 mg/kg/day (EPA, 2019e).

2.1.4.6 Fish (and/or Other Aquatic Organisms)

No specific information on triclopyr choline salt toxicity in fish (and/or other aquatic organisms) was identified. ECOTOX did not have entries for studies on triclopyr choline salt. According to EPA (2019e), triclopyr acid and TEA were “Practically nontoxic” to freshwater fish and “Slightly toxic” to estuarine/marine fish indicate, with LC₅₀ values ranging from 93 to 172 mg/L. Triclopyr acid and TEA were “Slightly toxic” to “Practically nontoxic” to aquatic invertebrates, with LC₅₀/EC₅₀ ranging from 42 to 554 mg/L. It was noted that the chronic toxicity of triclopyr acid or TEA to freshwater fish and invertebrates was relatively similar to their acute toxicity values (i.e., the chronic NOAECs were within a factor of 2 of the acute LC₅₀), with NOAECs ranging from 24.4 to 74.4 mg/L (EPA, 2019e).



2.1.5 Environmental Fate Assessment

According to EPA (2019e), triclopyr choline salt is highly soluble, highly mobile, and rapidly dissociates to triclopyr acid in the environment. Triclopyr acid is non-persistent in aerobic conditions but can be moderately persistent in anaerobic environments. The main environmental concern is the formation of 3,5,6-trichloro-2-pyridinol (TCP), a more persistent and toxic degradate in aquatic systems. However, monitoring data indicate that environmental concentrations are generally well below levels of concern for non-target organisms (EPA, 2019e).

2.1.6 Conclusions and Recommendations

Based on the information reviewed for triclopyr, eye irritation and skin sensitization were the primary hazards associated with use of triclopyr choline salt in humans. In ecological receptors, adverse effects were anticipated in plants, but not in other organisms. The Agency acknowledged that triclopyr is toxic to plants, and thus Midpen is recommended to exert caution in electing to use triclopyr, if other pesticides may be equally effective to accomplish the same function. Furthermore, if triclopyr choline salt represents the most suitable option for some applications, appropriate precautions must be taken when applying triclopyr choline salt formulation Vastlan to limit environmental release, especially near sensitive habitats and potable water sources. Applicators should use appropriate PPE and be trained in first aid for eye and skin exposure, and all applications should comply with the latest EPA-stamped label (https://www3.epa.gov/pesticides/chem_search/ppls/062719-00687-20171206.pdf).



2.2 Imazamox

Pesticide to control invasive plants in aquatic and riparian weeds

Formulation: Aquatic formulation (ClearCast)

Typical Target Pests: Invasive plants

Application: Annual application of (1) ~0.5 gal over 100 acres or (2) 2 gal over 300 acres via spot spray aquatic riparian application. Once per year in spring/summer/fall.

Human Toxicity: *Acute and Short-term Toxicity:* Category IV (oral and inhalation toxicity). Category III (dermal); *Subchronic and Chronic Toxicity:* Not toxic via oral and dermal routes. Inhalation studies not required; *Carcinogenicity and Genotoxicity:* No evidence; *DART:* No evidence; *Endocrine disruption:* No evidence based on information to date; *Sensitization and irritation:* Category III (eye). Category IV (skin). Not a skin sensitizer; *Neurotoxicity:* Testing not required; *Immunotoxicity:* Testing not required.

Ecological Toxicity: *Plants:* Highly toxic to terrestrial and aquatic plants. Additional studies needed; *Bees (and/or other Insects):* Practically nontoxic. Data gap identified; *Amphibians and Reptiles:* Practically nontoxic (terrestrial-phase amphibians and reptiles). Practically nontoxic (aquatic-phase amphibians); *Birds:* Practically nontoxic; *Mammals:* Practically nontoxic; *Fish (and/or other Aquatic Organisms):* Practically nontoxic (freshwater fish and invertebrates). Slightly toxic (estuarine/marine fish).

Environmental Fate: Moderately persistent and highly mobile in the environment. Low potential for bioaccumulation. Degradation primarily through microbial activity and photolysis, though it remains stable in dark aquatic conditions and does not hydrolyze or volatilize.

Conclusions and Recommendations: Adverse effects in humans are not anticipated. Adverse effects in ecological receptors, with exception of plants, are not anticipated. Imazamox can be added to Midpen's list of approved pesticides with appropriate precautions.

2.2.1 Background

Imazamox (CAS # 114311-32-9), also known as (2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-(methoxymethyl)-3-pyridinecarboxylic acid), is a broad-spectrum herbicide in the imidazolinone, targeting broadleaf weeds, annual and perennial grasses, and vine species (EPA, 2018). It was first registered in 1997 under the tradename Raptor Herbicide (EPA, 2019b). Imazamox is approved for use in agricultural areas, commercial and

residential turf (e.g., athletic fields, parks, lawns, golf course), forestry, pasture, rights-of-way, aquatic areas, and utility corridors (EPA, 2018, 2019b). In agriculture, it is registered for use on crops such as alfalfa, dry beans, canola, chicory, clover, lentils, peas, rice, soybeans, sunflowers, wheat, fallow, and pastureland (EPA, 2019b). Imazamox functions by inhibiting the acetolactate synthase enzyme, also known as acetohydroxyacid synthase, which disrupts the synthesis of essential branched-chain amino acids, leading to impaired protein and DNA synthesis and cell growth (EPA, 2018).

EPA-approved imazamox-containing formulations are primarily available as aqueous solutions or dispersible granules intended for foliar spray applications. A common formulation includes 12.1% ammonium salt of imazamox, equivalent to 11.4% of the acid, while technical grade products may contain up to 95-97% active ingredient. These formulations are registered for use on a variety of agricultural and non-agricultural sites, including soybeans, alfalfa, wheat, pastures, and rights-of-way. As of the most recent EPA data, there are multiple active registrations for imazamox-containing products, such as GCS Imazamox 1SL and ARG Imazamox Technical (https://ordspub.epa.gov/ords/pesticides/f?p=113:6:::P6_X_CHEMICAL_ID:2565).

2.2.2 Exposure Considerations

Imazamox is registered in a variety of formulations, including aqueous solutions and dispersible granules, and may be applied using several methods such as groundboom sprayers, aerial application, and handheld equipment (EPA, 2019b). It is typically used for early post-emergence weed control in crops like soybeans, wheat, and alfalfa. Application rates vary depending on crop and method, with typical ground or aerial application rates of ~0.040 lbs per acre. Ground applications are generally made with 10 or more gallons of water per acre, whereas aerial applications use five or more gallons per acre (EPA, 2019b). Personal protective equipment (PPE) requirements vary by product and use site, but may include long-sleeved shirts, long pants, chemical-resistant gloves, and protective eyewear, especially when handling concentrated formulations (EPA, 2014d). Mandatory spray drift mitigation measures to reduce off-site environment and non-target plant species exposure were requested by the EPA, including, but not limited to, a change in label, temperature and wind speed requirements, height above ground requirements, restriction in droplet size, and groundwater and surface water advisory statements (EPA, 2019b).

Midpen's annual application of imazamox (Aquatic formulation ClearCast) is estimated at (1) 0.5 gal over 100 acres or (2) 2 gal over 300 acres, once per year in spring/summer/fall for control of invasive plants. The



method of application is noted as spot spray aquatic riparian application. ClearCast contains 12.1% imazamox (or 11.4% acid equivalent). It is intended for aquatic and terrestrial weed control, and is commonly used in vegetation management programs for rights-of-way, aquatic sites, and non-crop areas.

2.2.3 Human Toxicity and Risk Assessment

2.2.3.1 Acute and Short-term Toxicity

According to EPA (2014d) and EPA (2018), imazamox was classified as Category IV for acute oral and inhalation toxicity and Category III for acute dermal toxicity. The classifications were based on oral LD₅₀ of > 5000 mg/kg,

dermal LD₅₀ of > 4000 mg/kg, and inhalation LC₅₀ of > 6.3 mg/L reported in rats (EPA, 2014d, 2018).

2.2.3.2 Subchronic and Chronic Toxicity

According to EPA, imazamox had low toxicity in mammalian species, and a quantitative risk assessment was not required for imazamox (EPA, 2014d, 2018). Several subchronic and chronic oral and dermal studies in rats, mice, or dogs, were reviewed by EPA (2014d), with no adverse effects observed in any of the studies (**Table 8**). The highest doses tested were 1068 mg/kg/day in rats, 1348 mg/kg/day in mice, and 1333 mg/kg/day in dogs. Reported concentrations in the oral toxicity studies exceeded the limit-dose in long-term studies in the three species. The Agency noted that subchronic inhalation studies were deemed not required for the Registration Review (EPA, 2014d, 2018).

Table 8. Subchronic and Chronic Toxicity of Imazamox

Guideline No.	Species (Sex)	Route	Duration	Doses/ Concentrations	Findings	Toxicity Thresholds
870.3100	Rats (unspecified)	Oral	90 days	0, 81, 833, 1661 mg/kg/day	No adverse effects	NOAEL = 1661 mg/kg/day
870.3150	Dogs (unspecified)	Oral	90 days	0, 34, 329, 1333 mg/kg/day	No adverse effects	NOAEL = 1333 mg/kg/day
870.3200	Rats (unspecified)	Dermal	28 days	0, 250, 500, 1000 mg/kg/day	No adverse effects	NOAEL = 1000 mg/kg/day
870.4100b	Dogs (unspecified)	Unspecified	Unspecified (chronic study)	0, 9.5, 282.5, 1165 mg/kg/day	No adverse effects	NOAEL = 1165 mg/kg/day
870.4300	Rats (unspecified)	Unspecified	Unspecified (chronic/ carcinogenicity study)	0, 52, 528, 1068 mg/kg/day	No adverse effects. No evidence of carcinogenicity	LOAEL = 1068 mg/kg/day
870.4200	Mice (M/F)	Unspecified	Unspecified (carcinogenicity study)	0, 73/96, 535/664, 1053/1348 mg/kg/day	No adverse effects. No evidence of carcinogenicity	NOAEL = 1053/1348 (M/F) mg/kg/day

Source: (EPA, 2014d)

2.2.3.3 Carcinogenicity and Genotoxicity

According to EPA (2014d), imazamox was classified as not likely to be carcinogenic to humans. No evidence of carcinogenicity was observed in studies in rats and mice exposed to imazamox at doses up to 1348 mg/kg/day. Imazamox also tested negative for mutagenicity in *S. typhimurium* and *E. coli* strains and in a micronucleus assay in bone marrow cells (EPA, 2014d).

2.2.3.4 Developmental and Reproductive Toxicity

According to EPA (2014d), imazamox was not considered developmentally toxic. In a two-generation study on reproduction and fertility effects, no adverse effects were noted in rats (parent and offspring) exposed to imazamox at

doses up to 1705 mg/kg/day in females and 1469 mg/kg/day in males, with no LOAELs established. In two prenatal developmental toxicity studies, no developmental effects were observed in rats and rabbits exposed to imazamox doses up to 1000 and 900 mg/kg/day, respectively (EPA, 2014d).

2.2.3.5 Endocrine Disruption

Imazamox is subject to the EPA's Endocrine Disruptor Screening Program (EDSP) under the Federal Food, Drug, and Cosmetic Act (FFDCA) section 408(p) (EPA, 2019b). According to EPA (2019b), no endocrine-related concerns were identified for imazamox at the time of the 2019 registration review, and a final determination will be made upon completion of the review. In the updated 2024 EDSP chemical list, imazamox was placed in Group 3, indicating



that no estrogen or androgen receptor agonist or antagonist activity was found based on computational modeling. However, chemicals in Group 3 may still be subject to additional endocrine data requirements (EPA, 2024c).

2.2.3.6 Sensitization and Irritation

According to EPA, imazamox was not a skin sensitizer (EPA, 2014d, 2018). It was classified as Category III for eye irritation and Category IV for skin irritation (EPA, 2014d, 2018).

2.2.3.7 Neurotoxicity

Based on a weight-of-evidence approach, neurotoxicity testing (acute and chronic) was deemed not required by EPA for Registration Review (EPA, 2014d, 2018).

2.2.3.8 Immunotoxicity

Based on a weight-of-evidence approach, immunotoxicity testing was deemed not required by EPA for Registration Review (EPA, 2014d, 2018).

2.2.4 Ecological Toxicity and Risk Assessment

2.2.4.1 Plants

According to EPA (2014g), imazamox is highly toxic to certain terrestrial and aquatic plants at low concentrations. Sensitive terrestrial species, such as cabbage, tomato, and oat, exhibited adverse effects on dry weight and plant height at IC_{25} values as low as 0.0008–0.0020 lbs/A, with NOAECs down to 0.0004–0.0015 lbs/A. For aquatic plants, duckweed (*L. gibba*) was particularly sensitive, with an IC_{50} of 0.008 mg/L and a NOAEC of 0.0045 mg/L, whereas other algae and aquatic plants showed no significant effects at concentrations up to 0.037–0.038 mg/L. The Agency noted that most studies used technical grade imazamox and a surfactant, not end-use products, and requested new studies using end-use formulations to better characterize risks to non-target plants. Additionally, minor crop injury incidents have been reported in the field, supporting the need for further evaluation of imazamox's phytotoxicity (EPA, 2014g). In 2016, the EPA requested additional toxicity data for *Lemna* spp., algae, and cyanobacteria (EPA, 2015a). The Agency acknowledged receipt of these data in 2019, but the review was not yet available at the time of reporting (EPA, 2019b).

2.2.4.2 Bees (and/or Other Insects)

According to EPA (2014g), imazamox was "Practically nontoxic" to honeybees under acute contact exposure conditions, and no additional bee toxicity data were identified as necessary for risk assessment at the time of the EPA evaluation. Based on an acute contact toxicity study, 5% mortality was observed and the LD_{50} was derived at $> 25 \mu\text{g}/\text{bee}$ (EPA, 2014g).

At the time of the ecological risk assessment, a data gap in potential toxicity to bees was identified. In 2016, EPA requested several toxicity studies on bees, including tests on adults and larvae, as well as semi-field and full-field studies (EPA, 2015a). By 2019, some of the requested studies had been submitted. However, field testing for pollinators remained a data gap, and a determination on whether to request additional data had not yet been made, pending review of the submitted toxicity data (EPA, 2019b).

2.2.4.3 Amphibians and Reptiles

No specific information on imazamox toxicity in amphibians and reptiles was identified in EPA (2014g) or ECOTOX. According to EPA (2014g), birds can be used as surrogates for terrestrial-phase amphibians and reptiles, whereas freshwater fish can be used as surrogates for aquatic-phase amphibians. Imazamox toxicity information for birds and freshwater fish is provided in the sections below. In birds, imazamox was "Practically nontoxic", indicating that same conclusion would be applicable to terrestrial-phase amphibians and reptiles. In fish, imazamox was "Practically nontoxic", indicating that a similar conclusion would be applicable to aquatic-phase amphibians (EPA, 2014g).

2.2.4.4 Birds

According to EPA (2014g), technical grade imazamox, was classified as "Practically nontoxic" to terrestrial birds based on acute oral study and subacute dietary studies conducted in the Bobwhite quail (*C. virginianus*) and the Mallard duck (*A. platyrhynchos*). No mortality or sublethal effects were observed in either study. The corresponding NOAEC, LD_{50} , and LC_{50} values were estimated at $>2000 \text{ ppm}$, $>1846 \text{ mg/kg}$, and $>5572 \text{ ppm}$, respectively (EPA, 2014g).

2.2.4.5 Mammals

According to EPA (2014g), technical grade imazamox was "Practically nontoxic" to mammals based on an acute oral study in rats. No mortality or clinical signs of toxicity were observed, except for a transient decrease in activity in female rats during the first two hours of exposure. Toxicity via inhalation was considered low, with an LC_{50} of $> 6.3 \text{ mg/L}$. Reproductive toxicity was not observed in chronic



studies in rats exposed to up to 1469 mg/kg (male) or 1705 mg/kg (female) (EPA, 2014g).

2.2.4.6 Fish (and/or Other Aquatic Organisms)

According to EPA (2014g), technical grade imazamox was classified as “Practically nontoxic” to freshwater, estuarine, and marine fish. No mortality or sublethal effects were observed in acute toxicity studies with bluegill sunfish (*L. macrochirus*), sheepshead minnow (*C. variegatus*), and mysid shrimp (*A. bahia*) at concentrations up to 119, 94, and 94 mg/L, respectively. Less than 5% mortality was observed in water flea (*D. magna*) exposed to concentrations up to 122 mg/L. Based on these results and the herbicide’s mode of action, no acute toxicity data gap was identified for freshwater invertebrates at the time of the ecological risk assessment. However, chronic toxicity data were not available for freshwater fish and invertebrates (EPA, 2014g).

2.2.5 Environmental Fate Assessment

Imazamox is moderately persistent and highly mobile in the environment (EPA, 2014g). It is particularly mobile in soils, with a K_d range of 0.05-2.7 and a K_{oc} range of 5-143 observed in soils containing 0.29-2.59% organic carbon. Primary degradation pathways include microbial degradation in soil and photolysis in clear water, with an

average photolysis half-life of 6.8 hours. Imazamox is expected to be persistent in dark aquatic environments due to limited photolytic activity. Imazamox is not expected to hydrolyze at pH 5, 7, or 9, and has low volatility, with a Henry’s Law constant indicating minimal potential for volatilization. Bioaccumulation in fish is not expected; concentrations of imazamox were below detection limits in bluegill sunfish (EPA, 2014g).

2.2.6 Conclusions and Recommendations

Based on the information reviewed for imazamox, no adverse effects were anticipated in humans. In ecological receptors, adverse effects were anticipated in plants, but not in other organisms. The Agency acknowledged that imazamox is highly toxic to plants; thus, Midpen is recommended to exert caution in electing to use imazamox, if other pesticides may be equally effective to accomplish the same function. Furthermore, if imazamox represents the most suitable option for some applications, appropriate precautions must be taken when applying imazamox formulation ClearCast to limit environmental release, especially to non-target plants. Drift reduction techniques and avoidance of application before heavy rainfall are recommended to reduce off-site movement. Periodic review of new toxicity data, especially for aquatic plants and pollinators, is advised, and all applications should follow the most recent EPA-stamped label (<https://www.cdms.net/ldat/ld7J8009.pdf>).



2.3 Glufosinate

Pesticide to control invasive plants

Formulations: Lifeline / Cheetah Pro

Typical Target Pests: Broadleaf weeds

Application: Annual application of ~3.2 gal over 100 acres via spot spray applications. Twice per year in the spring.

Human Toxicity: *Acute and Short-term Toxicity:*

Category III (oral, dermal, and inhalation toxicity);

Subchronic and Chronic Toxicity: Some effects noted at doses much higher than aggregate exposure dose for general population; *Carcinogenicity and Genotoxicity:* No evidence; *DART:* Not expected at labeled use rates;

Endocrine disruption: No information. Not on EPA's priority list for EDSP; *Sensitization and irritation:*

Category III (eye). Category IV (skin). Not a skin sensitizer; *Neurotoxicity:* Not expected; *Immunotoxicity:* No concern.

Ecological Toxicity: *Plants:* Direct risk to terrestrial and semi-aquatic plants is expected for all registered uses; *Bees (and/or other Insects):* Practically nontoxic; *Amphibians and Reptiles:* Practically nontoxic (terrestrial-phase amphibians and reptiles). Practically nontoxic (aquatic-phase amphibians); *Birds:* Practically nontoxic; *Mammals:* Practically nontoxic; *Fish (and/or other Aquatic Organisms):* Practically nontoxic (fish). Moderately toxic (aquatic invertebrates).

Environmental Fate: Moderately to highly mobile, non-volatile herbicide that primarily degrades via aerobic soil metabolism, but persists in the water column due to stability against hydrolysis and photolysis. Unlikely to bioaccumulate in fish or sediments, and may result in chronic aquatic exposure through off-site transport.

Conclusions and Recommendations: Adverse effects in humans are not anticipated. Adverse effects in ecological receptors, with exception of plants, are not anticipated. Glufosinate can be added to Midpen's list of approved pesticides with appropriate precautions.

2.3.1 Background

Glufosinate (CAS # 51276-47-2) is a broad-spectrum herbicide used for pre-plant and post-emergent control of broadleaf weeds (EPA, 2008b). It was first registered in the U.S. in 2000 (EPA, 2008b). Glufosinate is approved for use in a wide range of settings, including agricultural fields, recreational areas (e.g., golf courses), residential lawns, and various industrial and public spaces (EPA, 2016b). In agriculture, glufosinate is primarily applied to crops such as soybean, cotton, corn, pistachios, canola, almonds, grapes,

and hazelnut (EPA, 2016b). In commercial formulations, glufosinate is found as an ammonium salt (CAS # 77182-82-2). Glufosinate acts by inhibiting the glutamine synthetase enzyme, resulting in the accumulation of toxic levels of ammonia within plant tissues, which ultimately leads to plant death (EPA, 2008b). Although glufosinate shares some structural features with organophosphate compounds, it is not classified as an organophosphate pesticide and does not inhibit acetylcholinesterase, the primary mode of action for traditional organophosphate insecticides (EPA, 2014a).

The EPA-approved glufosinate-containing formulations are primarily available as soluble liquid or aqueous concentrates intended for foliar spray. The standard formulation typically includes 24.5% glufosinate-ammonium. There are 307 active, EPA-approved glufosinate-containing formulations (https://ordspub.epa.gov/ords/pesticides/f?p=113:6:.....P6_X_CHEMICAL_ID:2458).

2.3.2 Exposure Considerations

Glufosinate can be applied via aerial and ground spray methods. Aerial application is limited and primarily used on crops such as canola, corn, cotton, potato, and soybean (EPA, 2016b). For ground applications, equipment may utilize a low boom and medium droplet size to maximize coverage of the target plants. Depending on the situation, application methods may also include hand wands and backpack sprayers. Glufosinate may be applied more than once per year, depending on the crop, land use, and effectiveness of the initial application. For example, caneberries, table grapes, hazelnut, and sweet corn may be treated on average more than twice a year (EPA, 2016b). Following human health risk assessments by EPA (EPA, 2008b, 2016b), voluntary restrictions have been placed on glufosinate use for full residential lawn renovation. For residential lawns (other than bermudagrass renovation), glufosinate use is limited to spot treatments with a maximum application rate of 4 fl oz per gallon of water per 1000 ft² (equivalent to 0.0312 lbs per 1000 ft²) (EPA, 2016b). Spot treatment restrictions also apply to parks or recreational fields. For bermudagrass, glufosinate application is only permitted during cool weather when the grass is dormant. In agriculture, a voluntary request has been submitted to terminate glufosinate use on rice (EPA, 2016b). Previously, dietary exposure assessments by EPA were primarily driven by glufosinate use on rice (EPA, 2012a), but this is no longer the case following the request to discontinue rice applications.

Midpen's annual application of glufosinate (Lifeline and Cheetah Pro formulations) is estimated at 3.2 gal over 100 acres, twice per year in spring. The method of application is noted as spot spray. Both formulations contain 24.5% glufosinate-ammonium and are intended for foliar spray



applications. Use of PPE, including long-sleeved shirt, long pants, chemical-resistant gloves, shoes, socks, and protective eyewear, is noted for both products.

2.3.3 Human Toxicity and Risk Assessment

2.3.3.1 Acute and Short-term Toxicity

According to EPA (2012a), glufosinate-ammonium was classified as Category III for acute oral, dermal, and inhalation toxicity. The oral LD₅₀ values of 4010 and 3030 mg/kg were noted in male and female rats, respectively, whereas a dermal LD₅₀ of > 2000 mg/kg was noted in both male and female rats. Regarding inhalation, an LC₅₀ of 4.42 mg/L was determined in rats following a short-term exposure, with a LOAEL noted as 12.5 mg/kg/day (56 mg/m³) based on lung/bronchial congestion and increased weight in female rats and increased kidney and liver weights (EPA, 2012a).

The Agency also noted that no dietary risks of concern were identified (EPA, 2016b). Acute dietary toxicity information was not specifically provided for the general population in

EPA reports (EPA, 2008b, 2012a); however, an acute RfD of 0.063 mg/kg/day was established for females aged 13 to 49 years, which was below the level of concern (EPA, 2012a). This RfD was based on a NOAEL of 6.3 mg/kg/day and a LOAEL of 20 mg/kg/day in a rabbit developmental toxicity study (increased fetal death) (EPA, 2012a).

2.3.3.2 Subchronic and Chronic Toxicity

Multiple subchronic and chronic oral, dermal, and inhalation studies in rats, mice, or dogs, were reviewed by EPA (2012a). According to these studies, the NOAELs ranged from 2.2 to 192 mg/kg/day, whereas the LOAELs ranged from 5.5 to 300 mg/kg, with a variety of effects reported, including inhibition of glutamate synthase in the brain, clinical signs, retinal atrophy, increased liver and kidney weights, increased mortality, etc. (**Table 9**). Importantly, the Agency estimated an aggregate glufosinate exposure dose of 0.00762 mg/kg/day for the general U.S. population (EPA, 2012a). Based on the estimated exposure dose and the noted NOAELs and LOAELs in animal studies, no adverse subchronic or chronic effects could be anticipated. The Agency also derived a chronic RfD of 0.006 mg/kg/day for the general population (EPA, 2012a).

Table 9. Subchronic and Chronic Toxicity of Glufosinate

Guideline No.	Species (Sex)	Route	Duration	Doses/ Concentrations	Findings	Toxicity Thresholds
870.3100	Rats (M)	Oral	90 days	0, 6.2-8.8, 64-90 mg/kg/day	Inhibition of glutamine synthetase in the brain	• NOAEL = 6.2-8.8 mg/kg/day • LOAEL = 64-90 mg/kg/day
870.3100	Mice (M/F)	Oral	90 days	0, 12, 48, 192 mg/kg/day	Changes in clinical biochemistry and liver weights in males	• NOAEL = 48/192 (M/F) mg/kg/day • LOAEL = 192 (M) mg/kg/day
870.3200	Rats (unspecified)	Dermal	Unspecified (repeated dose study)	0, 100, 300, 1000 mg/kg/day	Clinical observations (aggressive behavior, piloerection, and a high startle response)	• NOAEL = 100 mg/kg/day • LOAEL = 300 mg/kg/day
870.3465	Rats (M/F)	Inhalation	28 days	0, 2.2, 5.5, 12.6 mg/kg/day	Clinical signs, decreased lung weight, increased body weight (female), tonic-clonic convulsions (2 males). At the highest dose, 4 deaths noted	• NOAEL = 2.2 mg/kg/day (8 mg/m ³) • LOAEL = 5.5 mg/kg/day (20 mg/m ³)
879.3465	Rats (M/F)	Inhalation	28 days	0, 12.5, 25 mg/kg/day	Lung/bronchial congestion in females, some clinical signs (isolated and transient), and increased kidney and liver weights	• LOAEL = 12.5 mg/kg/day (0.56 mg/m ³)
870.4100b	Dogs (unspecified)	Unspecified	Unspecified (chronic study)	0, 2.0, 5.0, 8.5 mg/kg/day	Mortality (week 2); alterations in the electrocardiogram at 6 months	• NOAEL = 5.0 mg/kg/day • LOAEL = 8.5 mg/kg/day
870.4200	Rats (M/F)	Unspecified	Unspecified (carcinogenicity study)	0, 45.4/57.1, 228.9/281.5, 466.3/579.3 (M/F) mg/kg/day	Increased incidence of retinal atrophy. No evidence of carcinogenicity	• NOAEL = 45.4/57.1 (M/F) mg/kg/day • LOAEL = 228.9/281.5 (M/F) mg/kg/day
870.4300	Rats (M/F)	Unspecified	Unspecified (chronic/ carcinogenicity study)	0, 1.9/2.4, 6.8/8.2, 24.4/28.7 (M/F) mg/kg/day	Inhibition of brain glutamate synthase in females at week 130. No evidence of carcinogenicity	• NOAEL = 24.4/8.2 (M/F) mg/kg/day



Guideline No.	Species (Sex)	Route	Duration	Doses/ Concentrations	Findings	Toxicity Thresholds
870.4300	Mice (M/F)	Unspecified	Unspecified (carcinogenicity study)	0, 2.83/4.23, 10.82/16.19, 22.60/66.96 (M/F) mg/kg/day	Increased mortality and glucose levels and consistent changes in glutathione levels in males, increased glucose levels and decreased albumin and total proteins. No evidence of carcinogenicity	• LOAEL = 28.7 (F) mg/kg/day • NOAEL = 10.82/16.19 (M/F) mg/kg/day • LOAEL = 22.60/63.96 (M/F) mg/kg/day

Source: EPA (2012a)

2.3.3.3 Carcinogenicity and Genotoxicity

According to EPA (2012a), glufosinate was classified as not likely to be carcinogenic to humans. Based on carcinogenicity studies in rats and mice exposed to glufosinate ammonium at doses up to 579.3 mg/kg/day, there was also no evidence of carcinogenicity. Furthermore, glufosinate tested negative for mutagenicity in *S. typhimurium*, *B. subtilis*, mouse lymphoma L5179Y cells, a mouse micronucleus assay, and primary rat hepatocytes (EPA, 2012a).

2.3.3.4 Developmental and Reproductive Toxicity

According to EPA (2012a), glufosinate, at labeled use rates, did not pose a developmental or reproductive toxicity risk to humans. Several studies were reviewed by the Agency. In a multigenerational reproductive toxicity study in rats, decreased number of viable offspring was noted at the highest dose tested of 18 mg/kg/day, with no parental toxicity observed. The observation of pup mortality in the absence of parental toxicity indicated a quantitatively increased sensitivity in the offspring. However, this increased susceptibility was only seen at the highest dose tested, which was more than three times greater than the point of departure used for risk assessment. The parental/systemic NOAEL was established at 18 mg/kg/day (the highest dose tested), while the reproductive NOAEL and LOAEL were derived at 6 and 18 mg/kg/day, respectively (EPA, 2012a).

In a developmental toxicity study in rats, exposure to glufosinate-ammonium resulted in dilated renal pelvis and hydroureter (EPA, 2012a). These effects were observed at doses that also caused increased hyperactivity and vaginal bleeding in the mother rats. The maternal NOAEL and LOAEL were determined at 10 and 50 mg/kg/day, respectively, whereas the developmental NOAEL and LOAEL were derived at 50 and 250 mg/kg/day, respectively (EPA, 2012a).

In a developmental toxicity study in rabbits, a dose of 20 mg/kg/day of glufosinate-ammonium led to reduced fetal body weight and higher fetal mortality; however, this dose also resulted in adverse maternal effects, including

decreased food intake, body weight, and weight gain (EPA, 2012a). The increased fetal mortality in rabbits occurred at maternally toxic doses. The maternal and reproductive NOAEL and LOAEL were established at 6.3 and 20 mg/kg/day (the highest dose tested), respectively (EPA, 2012a).

2.3.3.5 Endocrine Disruption

No information was available on the endocrine disruption potential of glufosinate. This chemical was not on EPA's priority lists for EDSP tier 1 (<https://www.regulations.gov/document/EPA-HQ-OPPT-2004-0109-0080>) or tier 2 (<https://www.regulations.gov/document/EPA-HQ-OPPT-2009-0477-0074>) screening. Glufosinate was not classified as an endocrine disruptor and did not appear on the Endocrine Society's list of chemicals with known endocrine-disrupting activity or on the ECHA Endocrine Disruptor Assessment List (ECHA, 2025a; Endocrine Society, 2025).

2.3.3.6 Sensitization and Irritation

According to EPA (2012a), glufosinate-ammonium was not a skin sensitizer. It was classified as Category III for eye irritation and Category IV for skin irritation (EPA, 2012a).

2.3.3.7 Neurotoxicity

According to EPA (2012a), glufosinate-ammonium presented evidence of neurotoxicity, particularly developmental neurotoxicity, and increased sensitivity in young animals. The risk assessment conducted by the Agency incorporated additional safety factors to account for these findings, and the selected endpoints were considered protective of neurotoxic effects. It was noted that no additional toxicity studies were required (EPA, 2012a).

As reviewed by EPA, based on an acute neurotoxicity study in rats, a NOAEL of > 500 mg/kg was established in males and females (EPA, 2012a). Neurotoxicity was not reported in White Leghorn hens exposed to an acute dose of up to 10000 mg/kg glufosinate-ammonium. However, several other neurotoxicity studies indicated neurotoxic effects for



glufosinate exposure at doses lower than the NOAEL of 500 mg/kg noted in an acute study.

In a developmental neurotoxicity study in rats, alterations in brain morphometrics were observed in adult offspring exposed *in utero* or during lactation at doses that did not result in maternal toxicity (EPA, 2012a). In this study, the maternal NOAEL and LOAEL were established at 69 and 292 mg/kg/day, respectively, based on decreased body weight, body weight gain, and food consumption during gestation and lactation. In contrast, the developmental LOAEL was set at 14 mg/g/day, based on observed changes in brain morphogenics, with no developmental NOAEL identified. In a 90-day dietary neurotoxicity study in rats, reduced exploratory behavior, reduced alertness and startle response, heightened fearfulness, increased pain sensitivity, and meiosis were observed. The LOAELs were derived at 521.45 and 573.79 mg/kg/day in male and female rats, respectively (EPA, 2012a).

In other studies, retinal atrophy and altered glutamine synthetase concentrations in brain were noted in rats, whereas in dogs, altered electrocardiograms were observed, indicating potential for neuromuscular effects (EPA, 2012a). In a dermal subchronic toxicity study, clinical signs (e.g., aggressive behavior, heightened startle response, and piloerection) were reported. Lastly, tonic-clonic convulsions were reported in two male rats during a 28-day inhalation study (EPA, 2012a).

2.3.3.8 Immunotoxicity

According to EPA (2012a), there was no concern for immunotoxicity with regard to glufosinate-ammonium exposure, based on an unspecified immunotoxicity study. No further details were provided.

2.3.4 Ecological Toxicity and Risk Assessment

2.3.4.1 Plants

According to EPA (2014a), glufosinate is a broad-spectrum, non-selective herbicide that poses significant risk to non-target terrestrial and semi-aquatic plants, consistent with its intended use as an herbicide. Ecological risk assessment conducted by the Agency found that glufosinate can cause adverse effects such as reduced seedling emergence, stunted growth, and dry weight reduction in both monocot and dicot species at low application rates, with the most sensitive endpoints observed in onion and cucumber or lettuce. Screening-level risk quotients for many labeled uses—especially those involving aerial application or affecting plants in wetland or semi-aquatic areas—exceeded EPA's levels of concern for both listed and non-

listed plant species. Across the registered uses, according to the labels, the maximum number of applications per year is two to three (EPA, 2014a).

While glufosinate was less toxic to aquatic vascular plants, some uses resulted in risk quotients exceeding EPA's concern for aquatic nonvascular plants (e.g., blue-green algae). EPA concluded that direct risk to terrestrial and semi-aquatic plants is expected for all registered uses of glufosinate, and incidents of crop damage consistent with off-site movement have been reported (EPA, 2014a).

2.3.4.2 Bees (and/or Other Insects)

According to EPA (2014a), technical and formulated glufosinate were classified as "Practically nontoxic" to young adult honeybees (*A. mellifera*) based on two acute oral and contact toxicity studies. Mortalities and sublethal effects were not reported following exposure of the young adult honeybees to technical glufosinate (95.3%) at the rate of 329.3 µg/bee and formulated glufosinate (20.4%, Basta) at a rate of 100 µg/bee. The LD₅₀ values for both studies were determined to be > 100 µg/bee. Toxicity data for the bee larvae were not available. Although adverse effects were not observed in the studies, environmental glufosinate concentrations were estimated to be relatively high for registered uses; therefore, the Agency concluded that potential risk to terrestrial invertebrates was uncertain (EPA, 2014a).

2.3.4.3 Amphibians and Reptiles

No toxicity data in amphibians or reptiles were available in EPA (2014a). According to ECOTOX, no studies in reptiles were identified; however, a single study in Great Plains Toad and Mexican Spadefoot (amphibians) reported a mortality NOEC of 138 mg/L for both species, with no LC₅₀ specified. According to EPA (2014a), birds can be used as surrogates for terrestrial-phase amphibians and reptiles, whereas freshwater fish can be used as surrogates for aquatic-phase amphibians. Glufosinate toxicity information in birds and freshwater fish is provided in the sections below. In birds, glufosinate was "Practically nontoxic", indicating that same conclusion would be applicable to terrestrial-phase amphibians and reptiles. In fish, glufosinate was "Practically nontoxic", indicating that a similar conclusion would be applicable to aquatic-phase amphibians (EPA, 2014a).

2.3.4.4 Birds

According to EPA (2014a), glufosinate formulation was classified as "Practically nontoxic" to terrestrial birds, based on acute oral and subacute dietary toxicity studies in the Bobwhite quail (*C. virginianus*) and the Mallard duck (*A.*



platyrhynchos). Mortality was not observed in either of the acute toxicity studies, and the corresponding LD₅₀ values were established to be > 2000 mg/kg. Sublethal effects such as lethargy and diarrhea were observed in Mallard ducks acutely exposed to up to 2000 mg/kg glufosinate; however, these effects were not observed in a sub-acute dietary toxicity study at glufosinate concentrations of up to 5000 ppm. Additionally, no chronic toxicity was observed in bobwhite quail or mallard duck exposed up to 400 ppm glufosinate. However, in reproduction study, exposure to 956 ppm glufosinate significantly affected the ratio of live-to-viable embryos, and the resulting NOAECs were established at 665 and 400 ppm for the Bobwhite quail and Mallard duck, respectively (EPA, 2014a).

2.3.4.5 Mammals

According to EPA (2014a), technical glufosinate was classified as “Practically nontoxic” to mammals based on acute oral and chronic two-generation reproductive toxicity studies in Norway rats (*R. norvegicus*). The acute oral LD₅₀ was determined to be 3030 mg/kg. In the reproductive study, reductions in the number of viable offspring per litter were observed in both F₁ and F₂ generations. The NOAEC and LOAEC were established at 120 and 360 ppm, respectively. It was noted that the results of a developmental neurotoxicity study, in which brain morphometry alterations were observed at concentrations of 200 ppm and above, aligned with the reproductive toxicity study. Additional adverse effects in offspring, including decreased body weight and body weight gain, were observed at 1000 ppm, and increased postnatal mortality was reported at 4500 ppm (EPA, 2014a).

According to EPA (2014a), formulated glufosinate was classified as “Moderately toxic” to mammalian species based on an acute oral toxicity study, in which female Norway rats were exposed to Liberty 280® SL Herbicide (24.3%) at two nominal dose levels of 72.9 and 486 mg/kg. The resulting LD₅₀ was determined at 243 mg/kg (EPA, 2014a).

As mentioned previously, the potential for acute toxicity is higher with Liberty 280® SL Herbicide. The EPA concluded that all registered uses are expected to result in chronic risk to mammalian species (EPA, 2014a). However, it is noted that potential risk to granivores and frugivores is not expected (EPA, 2014a).

2.3.4.6 Fish (and/or Other Aquatic Organisms)

According to EPA (2014a), technical glufosinate was classified as “Practically nontoxic” to freshwater, estuarine, marine fish, and freshwater invertebrates; however, it was

classified as “Moderately toxic” to estuarine and marine invertebrates, including mollusks. Based on available studies, the LC₅₀ values ranged from 312 to > 963 mg/L in fish (freshwater, estuarine, and marine), whereas in aquatic invertebrates (freshwater, estuarine and marine), the EC₅₀ values ranged from 7.50 to 651 mg/L (EPA, 2014a).

According to EPA (2014a), formulated glufosinate was “Slightly toxic” to “Highly toxic” to fish and aquatic invertebrates based on acute toxicity studies. One acute toxicity study in the Eastern oyster and Quahog clam reported EC₅₀ values of 0.5 and 0.69 mg/L, respectively (EPA, 2014a).

Where data were available, the potential for direct effects of glufosinate to freshwater, estuarine, and marine organisms was limited (EPA, 2014a). Data for several species and lifestages were not available. Glufosinate has the potential to persist in the water column. Based on the available toxicity data, the potential risk to aquatic animals is considered low unless organisms are exposed directly to undiluted glufosinate. It was noted that two incidents of fish mortality were reported to be potentially associated with glufosinate use in agriculture areas; however, it was unknown whether these mortalities resulted from direct or indirect effects (EPA, 2014a).

2.3.5 Environmental Fate Assessment

Glufosinate exhibits moderate to high mobility in the environment, with aerobic soil metabolism serving as its primary degradation pathway (EPA, 2014a). The herbicide is non-volatile but can be transported off-site via spray drift, runoff, and leaching. Once glufosinate reaches surface waters, it remains stable to hydrolysis and photolysis, degrading slowly through both aerobic and anaerobic aquatic metabolic processes. As a result, glufosinate residues may persist in aquatic environments, potentially leading to chronic exposure for aquatic organisms. Due to its mobility, glufosinate is unlikely to accumulate significantly in benthic sediments; instead, it tends to remain in the water column, where dilution and gradual metabolic breakdown reduce its concentration over time. Glufosinate is not expected to bioaccumulate in fish (EPA, 2014a).

2.3.6 Conclusions and Recommendations

Based on the information reviewed for glufosinate, no adverse effects in humans were anticipated; the available mammalian toxicity data suggest that although chronic exposure may result in risk from glufosinate, the annual application scenario anticipated from Midpen is not likely to result in chronic exposure and/or corresponding risk to



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2 Herbicides

humans. In ecological receptors, adverse effects were anticipated in plants, but not in other organisms. The Agency acknowledged that direct risk is expected for plants for all registered uses, and thus Midpen is recommended to exert caution in electing to use glufosinate, if other pesticides may be equally effective to accomplish the same function. Furthermore, if glufosinate represents the most suitable option for some applications, appropriate precautions must be taken when applying Lifeline / Cheetah Pro to limit environmental release. It is also essential to review and comply with the EPA-stamped labels (Lifeline: https://www3.epa.gov/pesticides/chem_search/ppls/070506-00310-20240314.pdf; Cheetah Pro: https://labelsds.com/images/user_uploads/Cheetah%20Pro%20Label%205-16-19.pdf).



3 Insecticides

Five insecticides (chlorantraniliprole, dinotefuran, sulfuryl fluoride / chloropicrin, d-limonene, DOT) were evaluated in this report. Their toxicity in humans and ecological receptors is summarized in **Table 10** and

Table 11, respectively. Overall, the insecticides exhibited low acute and chronic toxicity to humans, with no evidence of carcinogenicity or significant endocrine, neurotoxic, or immunotoxic effects under labeled use. Notably, dinotefuran is highly toxic to bees, and chlorantraniliprole and dinotefuran are moderately to highly toxic to aquatic invertebrates, warranting careful application to minimize environmental exposure. Sulfuryl fluoride / chloropicrin may cause adverse effects in humans via inhalation or eye contact, and in mammals and some ecological receptors if exposed, but risks are limited under anticipated use scenarios. d-Limonene and DOT are generally low risk, with skin irritation and sensitization as the main human hazards.

On the basis of this review, of the five insecticides, chlorantraniliprole and dinotefuran offer the lowest hazard profiles across human-relevant endpoints, whereas d-limonene and DOT offer the lowest hazard profiles across ecological populations. When considering hazard potential in humans and ecological receptors, chlorantraniliprole offers the lowest hazard profile, whereas sulfuryl fluoride / chloropicrin offers the highest hazard profile; however, exposure to the latter pesticide is expected to be minimal in humans and in most ecological receptors given its use in tenting applications. In deciding which insecticides to incorporate into their IPM, Midpen should consider specific target species, application methods, and label requirements. Because the five insecticides vary in their application and hazard and exposure potentials, care should be taken in selecting and applying the chosen insecticide(s) considering these factors.

Table 10. Human Toxicity Summary of Insecticides

Endpoint	Chlorantraniliprole	Dinotefuran	Sulfuryl Fluoride	Chloropicrin	d-Limonene	DOT
Acute Toxicity (Oral)	Category IV	Category III	Category II	Category II	Category III	Category III
Acute Toxicity (Dermal)	Category IV	Category IV	Category IV	Category II	Category III	Category III
Acute Toxicity (Inhalation)	Category IV	Category IV	Category I	Category I	Low toxicity (category not derived)	Category II
Subchronic and chronic toxicity	Low toxicity via oral and dermal routes	Low toxicity via oral, inhalation, and dermal routes. Effects, if any, only at high doses/concentrations	Toxic (inhalation) but effects not expected based on use	Toxic (inhalation) but effects not expected based on use	Low toxicity potential	Effects at high doses
Carcinogenicity and Genotoxicity	No evidence	No evidence	No evidence	No evidence for carcinogenicity. Mixed genotoxicity results	No evidence	No evidence
Developmental and Reproductive Toxicity	No evidence	Not expected	No evidence	No evidence	No evidence	Not expected
Endocrine Disruption	Subject to the EPA's EDSP. Data available but no decision made	No information. Subject to the EPA's EDSP but not on EPA's priority list for EDSP	No information. Not on EPA's priority list for EDSP	No information. Included on EPA's priority list for EDSP tier 1	No information. Not on EPA's priority list for EDSP	Not expected
Irritation (Eye)	Category IV	Category IV	Category I	Category I	Category not provided	Category I
Irritation (Skin)	Category IV	Category IV	Category IV	Category I	Category II	Category IV
Sensitization	Not a skin sensitizer	Not a skin sensitizer	Not a skin sensitizer	Possible skin sensitizer	Skin sensitizer	Not classified as a skin sensitizer
Neurotoxicity	No evidence	Not expected	Neurotoxic (inhalation) at high concentrations	Not a concern	No evidence	Not expected



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3 Insecticides

Endpoint	Chlorantraniliprole	Dinotefuran	Sulfuryl Fluoride and after prolonged use	Chloropicrin	d-Limonene	DOT
Immunotoxicity	No evidence	No evidence	Not a concern	Not a concern	No information	No information

Table 11. *Ecotoxicity Summary of Insecticides*

Ecological Receptor	Chlorantraniliprole	Dinotefuran	Sulfuryl Fluoride	Chloropicrin	d-Limonene	DOT
Plants	Low toxicity (terrestrial and aquatic plants)	Low toxicity (terrestrial and aquatic plants)	No information (terrestrial plants). Not toxic (aquatic plants)	Not phytotoxic	No information. Not classified as phytotoxic under registered uses	Not expected
Bees (and/or Other Insects)	Some evidence of toxicity; additional studies needed	Highly toxic	No information. Exposure expected to be minimal	Practically nontoxic	Practically nontoxic	Not expected
Amphibians and Reptiles	Practically nontoxic	Moderately toxic or practically nontoxic (terrestrial-phase amphibians and reptiles). Practically nontoxic (aquatic-phase amphibians)	No information (terrestrial-phase amphibians and reptiles). No effects anticipated (aquatic-phase amphibians)	Moderately toxic	Slightly toxic or practically nontoxic (terrestrial-phase amphibians and reptiles). Slightly toxic (aquatic-phase amphibians)	Practically nontoxic
Birds	Practically nontoxic	Moderately toxic or practically nontoxic	No information	Moderately toxic	Slightly toxic or practically nontoxic	Practically nontoxic
Mammals	Practically nontoxic	Practically nontoxic	Moderately toxic	Moderately toxic	Practically nontoxic	Practically nontoxic
Fish (and/or Other Aquatic Organisms)	Practically nontoxic (fish). Moderately to highly toxic (aquatic invertebrates)	Practically nontoxic (fish). Moderately toxic (aquatic invertebrates)	No information. Exposure not anticipated based on use	Moderately toxic or very highly toxic	Slightly toxic	Practically nontoxic



3.1 Chlorantraniliprole

Pesticide to control structural pests, termites

Formulation: Altriset

Typical Target Pests: Structural pests, termites, and lepidopteran pests

Application: Annual application of ~8.5 gal over 1-5 residences via perimeter applications. Once per year.

Human Toxicity: *Acute and Short-term Toxicity:* Category IV (oral, dermal, and inhalation toxicity); *Subchronic and Chronic Toxicity:* Low toxicity via oral and dermal routes. *Carcinogenicity and Genotoxicity:* No evidence; *DART:* No evidence; *Endocrine disruption:* Subject to the EPA's EDSP. Data available but no decision made; *Sensitization and irritation:* Category IV (eye and skin). Not a skin sensitizer; *Neurotoxicity:* No evidence; *Immunotoxicity:* No evidence.

Ecological Toxicity: *Plants:* Low toxicity (terrestrial and aquatic plants); *Bees (and/or other Insects):* Some evidence of toxicity; additional studies needed; *Amphibians and Reptiles:* Practically nontoxic (terrestrial-phase amphibians and reptiles). Practically nontoxic (aquatic-phase amphibians); *Birds:* Practically nontoxic; *Mammals:* Practically nontoxic; *Fish (and/or other Aquatic Organisms):* Practically nontoxic (fish). Moderately to highly toxic (aquatic invertebrates).

Environmental Fate: Persistent and moderately mobile in the environment. Degrades rapidly in alkaline and well-lit aquatic conditions. Does not volatilize or bioaccumulate in fish. Its dissipation is strongly influenced by pH, light, and temperature.

Conclusions and Recommendations: Adverse effects in humans are not anticipated. Adverse effects in honeybees and aquatic invertebrates may occur. Chlorantraniliprole can be added to Midpen's list of approved pesticides with appropriate precautions.

3.1.1 Background

Chlorantraniliprole (CAS # 500008-45-7) is an anthranilic diamide insecticide that targets insects, with primary efficacy against lepidopteran pests (EPA, 2020a). First registered in 2008, chlorantraniliprole is approved for a wide range of uses, including agricultural crops, recreational turf (e.g., golf courses), residential lawns, landscape ornamentals, interiorscapes, seed treatments, greenhouses, and nurseries. It is also registered as a termiticide for post-construction treatment of residential, commercial, public, and institutional structures. In agriculture, chlorantraniliprole is labeled for use on a variety of crops, such as berries, vegetables, cereal grains, cotton, cucurbits, fruits, grapes, grass feedstuffs, herbs and spices, hops, legumes,

oilseeds, root and tuber vegetables, tea, tobacco, and tree nuts (EPA, 2020a). Chlorantraniliprole selectively activates the ryanodine receptor in insects, causing unregulated release of calcium from internal stores, which disrupts normal muscle contraction and leads to paralysis and death (EPA, 2020a, 2020b). It is highly selective for the insect ryanodine receptors over mammalian receptors, resulting in low toxicity to mammals (EPA, 2020a).

Chlorantraniliprole is available in several formulations, including suspension concentrate, flowable concentrate, water-dispersible granule, and granular forms (EPA, 2020a). Chlorantraniliprole concentrations in EPA-approved formulations range from 0.058% in granular fertilizer blends to 47.87% in suspension concentrates for professional use. There are 214 active, EPA-approved chlorantraniliprole-containing formulations (https://ordspub.epa.gov/ords/pesticides/f?p=113:6:::P6_X_CHEMICAL_ID:1786).

3.1.2 Exposure Considerations

Chlorantraniliprole is registered in a wide range of formulations and may be applied using various methods, including chemigation, groundboom and handheld sprayers, seed treatment, aerial application, and specialized termiticide techniques such as trenching and sub-slab injection (EPA, 2020a). Maximum application rates vary substantially, from as low as 0.0000016 lbs active ingredient per acre for field corn seed treatment, up to 57.96 lbs/A for pre-construction ground termite treatments. For agricultural crops, chlorantraniliprole is typically applied seasonally at rates ~0.2 lbs/A (EPA, 2020a). According to the Pesticide Label Use Summary report, single foliar application rates range from 0.059 to 0.098 lbs/A for ground applications and from 0.05 to 0.23 lbs/A for aerial applications (EPA, 2020b). PPE requirements vary by product and use site, but may include chemical-resistant gloves, coveralls, and a single layer of clothing (EPA, 2020a).

Midpen's annual application of chlorantraniliprole (Altriset formulation) is estimated at 8.5 gal over 1-5 residences, once per year. The method of application is noted as perimeter application. The Altriset formulation contains 18.4% chlorantraniliprole and is intended for use by licensed professionals. The formulation is meant to be mixed in water (to approximately 0.05%) and subsequently applied to soil (typically 4 gal per 10 linear ft of trench). Altriset should not be applied directly to water or areas where runoff may occur. Appropriate PPE (long sleeves, long pants, shoes, and socks) should be used during application.



3.1.3 Human Toxicity and Risk Assessment

3.1.3.1 Acute and Short-term Toxicity

According to EPA (2020a), chlorantraniliprole was classified as Category IV for acute oral, dermal, and inhalation toxicity. Oral and dermal LD₅₀ values of > 5000 mg/kg were reported in rats, whereas an inhalation LC₅₀ of > 5.1 mg/L was in rats (EPA, 2020a).

3.1.3.2 Subchronic and Chronic Toxicity

According to EPA (2020a), chlorantraniliprole had low toxicity potential following subchronic or chronic exposures. Several studies in rats, mice, rabbits, or dogs were reviewed

by EPA, and only one of the studies had an established LOAEL (**Table 12**). Oral exposure to chlorantraniliprole in rats, mice, and dogs resulted in increased liver weight and elevated cytochrome (CYP) activity; however, these changes were not associated with adverse histopathological effects in the liver, and no LOAELs were established in these studies. In dermal and oral toxicity studies in rats, an increased incidence of adrenal cortex microvesiculation was noted in males; however, a follow-up study found no adverse effect on adrenal function, as measured by the adrenal gland's capacity to produce corticosterone. In an 18-month carcinogenicity study in mice, mild effects were observed, including eosinophilic foci, hepatocellular hypertrophy, and increased liver weight in males, and a LOAEL of 935 mg/kg/day was determined for male mice (EPA, 2020a).

Table 12. Subchronic and Chronic Toxicity of Chlorantraniliprole

Guideline No.	Species (Sex)	Route	Duration	Doses/ Concentrations	Findings	Toxicity Thresholds
870.3050	Rats (M/F)	Oral	28 days	0, 20.7/24, 106/128, 584/675 (M/F) mg/kg/day	Increased liver weight and hepatocellular hypertrophy were observed in females but did not correspond to histopathological adverse effect in the liver	NOAEL = 584/675 (M/F) mg/kg/day
870.3050	Mice (M/F)	Oral	28 days	0, 52/64, 182/206, 538/658, 1443/1524 (M/F) mg/kg/day	Increased liver weight was observed in females in a dose-dependent manner. Increased in CYP content and decreased of hepatic β -oxidation in a males and females for some doses. These observations did not correspond to histopathological adverse effects in the liver	NOAEL = 1443/1524 (M/F) mg/kg/day
Nonguideline	Dogs (unspecified)	Oral	28 days	0, 300, 1000 mg/kg/day	Increased CYP activity at highest dose. No adverse histopathology in the liver	NOAEL = 1000 mg/kg/day
Nonguideline	Dogs (M/F)	Oral	28 days	0, 26/28, 138/138, 266/298, 797/888, 1302/1240 (M/F) mg/kg/day	No adverse effects	NOAEL = 1302/1240 (M/F) mg/kg/day
870.3100	Rats (M/F)	Oral	90 days	0, 36.9/47, 120/157, 359/460, 1188/1526 (M/F) mg/kg/day	Slight increased liver weight at highest dose and decreased in bilirubin in a dose-dependent manner were observed in females but did not correspond to histopathological adverse effect in the liver	NOAEL = 1188/1526 (M/F) mg/kg/day
870.3100	Mice (M/F)	Oral	90 days	0, 32.6/40.7, 115/158, 345/422, 1135/1529 (M/F) mg/kg/day	Slight increased liver weight at highest dose and were observed in males and females but did not correspond to histopathological adverse effect in the liver. Hyper(re)activity was observed at the end of the study for the highest dose with convulsion in one male	NOAEL = 1135/1529 (M/F) mg/kg/day



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Guideline No.	Species (Sex)	Route	Duration	Doses/ Concentrations	Findings	Toxicity Thresholds
870.3150	Dogs (M/F)	Oral	90 days	0, 32.2/36.5, 119/133, 303/318, 1163/1220 (M/F) mg/kg/day	Slight increased liver weight at highest dose was observed in males but did not correspond to histopathological adverse effect in the liver	NOAEL = 1163/1220 (M/F) mg/kg/day
870.3200	Rats (M)	Dermal	21/28 days	0, 100, 300, 1000 mg/kg/day	Increased incidence of adrenal cortex microvesiculation observed in males but did not correspond to changes in adrenal function and was not considered as an adverse effect	NOAEL (systemic and skin irritation) = 1000 mg/kg/day
Nonguideline	Rats (M)	Dermal	28 days	0, 1000 mg/kg	No effects on adrenal function	Unspecified
870.4100b	Dogs (M/F)	Unspecified	Unspecified (chronic study)	0, 32/34, 112/113, 317/278, 1164/1233 (M/F) mg/kg/day	Slight increased liver weight was observed in males and females at highest dose but did not correspond to histopathological adverse effect in the liver	NOAEL = 1164/1233 (M/F) mg/kg/day
870.4300a	Rats (M/F)	Unspecified	Unspecified (chronic/ carcinogenicity study)	0, 7.71/10.9, 39.0/51.0, 156/212, 805/1076 (M/F) mg/kg/day	Increased in reporting of adrenal cortex microvesiculation was observed in males but did not correspond to changes in adrenal function and was not considered as an adverse effect. Increased liver weight was observed in females but did not correspond to histopathological adverse effect in the liver. No evidence of carcinogenicity	NOAEL = 805/1076 (M/F) mg/kg/day
870.4200	Mice (M/F)	Unspecified	Unspecified (carcinogenicity study)	0, 2.60/3.34, 9.20/11.6, 26.1/32.9, 158/196, 935/1155 (M/F) mg/kg/day	Mild eosinophilic foci in 5/70 males. At the highest doses, increased liver weight and minimal to mild hepatocellular hypertrophy were observed in both sexes. No evidence of carcinogenicity	• NOAEL = 158/1155 (M/F) mg/kg/day • LOAEL = 935 (M) mg/kg/day

Source: EPA (2020a)

3.1.3.3 Carcinogenicity and Genotoxicity

According to EPA (2020a), chlorantraniliprole was classified as not likely to be carcinogenic to humans. No evidence of carcinogenicity was noted in rats and mice exposed to chlorantraniliprole at doses up to 1155 mg/kg/day. Chlorantraniliprole also tested negative for mutagenicity and genotoxicity in several *S. typhimurium* and *E. coli* strains, Chinese Hamster Ovarian cells, human lymphocytes, and mouse erythrocytes (EPA, 2020a).

3.1.3.4 Developmental and Reproductive Toxicity

According to EPA (2020a), chlorantraniliprole was not a developmental or reproductive toxicant. No adverse effects on reproduction or in offspring were observed in a two-generation reproduction and fertility study. It was noted that an increase in adrenal weights, microvesiculation incidence,

and liver weight (females only) occurred but were not associated with adverse effects in adrenal function or liver; thus, LOAELs were not established. In two prenatal developmental toxicity studies, no developmental effects were observed in rats and rabbits exposed to chlorantraniliprole doses up to 1000 mg/kg/day; thus, LOAELs were not established (EPA, 2020a).

3.1.3.5 Endocrine Disruption

Chlorantraniliprole is subject to the EPA's EDSP under the Federal Food, Drug, and Cosmetic Act (FFDCA) section 408(p) (EPA, 2020a). The available two-generation reproductive toxicity study was classified by EPA as providing adequate information to assess potential estrogen- and androgen-mediated endocrine effects (EPA, 2020b). As no adverse reproductive effects were reported in this study, chlorantraniliprole is not likely to be identified as an endocrine disruptor. Chlorantraniliprole was not



classified as an endocrine disruptor and did not appear on the Endocrine Society's list of chemicals with known endocrine-disrupting activity or on the ECHA Endocrine Disruptor Assessment List (ECHA, 2025a; Endocrine Society, 2025).

3.1.3.6 Sensitization and Irritation

According to EPA (2020a), chlorantraniliprole was not a skin sensitizer. It was classified as Category IV for eye and skin irritation (EPA, 2020a).

3.1.3.7 Neurotoxicity

According to EPA (2020a), chlorantraniliprole was not considered neurotoxic based on the results of one acute and one subchronic neurotoxicity study in rats exposed to chlorantraniliprole doses up to 2000 mg/kg/day. No evidence of neurotoxicity was observed in either study. Consequently, a developmental neurotoxicity study was not required (EPA, 2020a).

3.1.3.8 Immunotoxicity

According to EPA (2020a), chlorantraniliprole was not considered immunotoxic based on one study in rats and one study in mice exposed to chlorantraniliprole doses up to 1601 mg/kg/day.

3.1.4 Ecological Toxicity and Risk Assessment

3.1.4.1 Plants

According to EPA (2020b), chlorantraniliprole did not cause adverse effects to terrestrial plants at concentrations exceeding maximum labeled application rates, based on available seedling emergence and vegetative vigor studies. No additional data needs were identified for terrestrial plant toxicity. The Agency noted that a single incident was reported, in which more than 45% of a customer's trees and shrubs were killed following application of the Grubex1 product in spring 2012 (EPA, 2020b).

According to EPA (2020b), chlorantraniliprole did not cause adverse effects in aquatic plants at concentrations tested, which exceeded expected environmental concentrations from labeled use rates. No additional data needs were identified for aquatic plant toxicity (EPA, 2020b).

3.1.4.2 Bees (and/or Other Insects)

According to EPA (2020b), chlorantraniliprole is practically non-toxic to adult honeybees; however, there were acute

and chronic risk concerns for honeybee larvae at labeled use rates. Thus, additional higher-tier studies were recommended to refine the risk assessment for bee larvae (EPA, 2020b).

Previous EPA assessments concluded that the likelihood of acute risk to adult honeybees from chlorantraniliprole was low (EPA, 2020b). However, the Agency noted uncertainty due to limited data on larval toxicity. Acute oral and contact toxicity studies in adult honeybees, including three formulations (20SC, 35WG, and 5SC), did not indicate acute toxicity. However, an acute oral toxicity study with the 5SC formulation suggested that bumblebees (*B. terrestris*) may be more sensitive, with a 48-hour LD₅₀ of 0.459 µg/bee (EPA, 2020b).

Although no larval toxicity studies were conducted using technical chlorantraniliprole, two 22-day larval toxicity studies were performed with the 20SC and 35WG formulations (EPA, 2020b). Decreased adult emergence and increased mortality rates were reported in exposed larvae. The most sensitive larval NOAEC and LOAEC were 0.043 µg/L and 0.087 µg/L, respectively, based on a 70% reduction in emergence and 92% mortality at the LOAEC. Additional laboratory and field studies did not reveal treatment-related effects on brood, mortality, behavior, or flight intensity, but were considered insufficient to fully assess impacts on larvae. EPA's preliminary Tier 1 risk assessment concluded there is potential risk for acute and chronic toxicity to bee larvae, and recommended further data collection, including a colony feeding study (EPA, 2020b). In 2024, EPA issued a call for additional toxicity data on honeybees (larvae and adults) and field testing for pollinators (EPA, 2024a).

3.1.4.3 Amphibians and Reptiles

No toxicity data in amphibians or reptiles were available for chlorantraniliprole from EPA (2020b) or ECOTOX. According to EPA (2020b), birds can be used as surrogates for terrestrial-phase amphibians and reptiles, whereas freshwater fish can be used as surrogates for aquatic-phase amphibians. Chlorantraniliprole toxicity information in birds and freshwater fish is provided in the sections below. In birds, chlorantraniliprole was "Practically nontoxic", indicating that same conclusion would be applicable to terrestrial-phase amphibians and reptiles. In fish, chlorantraniliprole was "Practically nontoxic", indicating that a similar conclusion would be applicable to aquatic-phase amphibians.

3.1.4.4 Birds

According to EPA (2020b), chlorantraniliprole technical, formulation (20 SC and 35 WG), and the degradate IN-EQW78 were classified as "Practically nontoxic" to



terrestrial birds. This classification was based on acute oral and subacute dietary toxicity studies in the Zebra Finch (*P. guttata*), the Bobwhite quail (*C. virginianus*), and the Mallard duck (*A. platyrhynchos*). No mortality was observed, and the corresponding LD₅₀ values exceeding 2000 to 5620 mg/kg (EPA, 2020b).

Chronic exposure studies identified sublethal effects (EPA, 2020b). In Bobwhite quail, a reduction in eggshell thickness was observed at a dose of 20.7 mg/kg, with a NOAEL estimated as 10.1 mg/kg. In Mallard duck, a 10% decrease in live three-week-old embryos was observed at a concentration of 1000 ppm, with a corresponding NOAEC of 500 ppm (EPA, 2020b).

Previous Agency assessments concluded that likelihood of chronic risk to birds—and by surrogate, to terrestrial-phase amphibians and reptiles—was low (EPA, 2020b).

3.1.4.5 Mammals

According to EPA (2020b), no adverse effects in rats were identified in the available acute and chronic toxicity studies on chlorantraniliprole. The following toxicity values were determined: an LD₅₀ of > 5000 mg/kg (the highest dose tested), a NOAEC of 20,000 ppm (1563/1886 M/F mg/kg/day), and an LC₅₀ of > 5.1 mg/L (EPA, 2020b). Based on the oral LD₅₀, chlorantraniliprole could be classified as “Practically nontoxic”.

3.1.4.6 Fish (and/or Other Aquatic Organisms)

According to EPA (2020b), chlorantraniliprole (technical and formulated) was classified as “Practically nontoxic” to freshwater, estuarine, and marine fish (and by surrogate, to aquatic-phase amphibians). Non-definitive 96-hour LC₅₀ values ranged from > 1.09 to > 15.1 mg/L. However, increased larval abnormalities, decreased larval survival and survival at hatching, and decreased wet weight and total length were observed during 90-day and 36-day flow through studies in Rainbow trout (*O. mykiss*) and Sheepshead minnow (*C. variegatus*), respectively (EPA, 2020b).

In estuarine and marine invertebrates, chlorantraniliprole (technical) was classified as “Moderately to highly toxic” based on acute toxicity observed in the mysid shrimp (*A. bahia*) and the Eastern oyster (*C. virginica*) (EPA, 2020b). In the shrimp, a 96-hour LC₅₀ was determined at 1.15 mg/L based on 85% mortality observed at the highest dose. Lethargy in mysid shrimps was also observed. A 48-hour EC₅₀ of 0.0399 mg/L was determined for oysters based on 37% shell growth reduction. Only one toxicity study was available, which determined a NOAEC of 0.695 mg/L and a

LOAEC of 1.38 mg/L, based on total mortality in the mysid shrimp at the highest dose tested (EPA, 2020b).

An acute toxicity study was conducted in water flea *D. magna* exposed to chlorantraniliprole technical and two formulated products (EPA, 2020b). The three products were considered “Highly toxic” to freshwater invertebrates, with 48-hour EC₅₀ values ranging from 0.0071 to 0.116 mg/L. Decreased survival, dry weight, lengths, and delay in first day of reproduction in *D. magna* were observed during a chronic toxicity study. The resulting 21-day NOAEC and LOAEC were determined at 0.00302 and 0.00477 mg/L of chlorantraniliprole technical, respectively. Additional acute toxicity studies in the rotifer (*B. calyciflorus*), mayfly (*C. triangulifer*), caddisfly (*C. atterima*), a cyclopoida copepod, the Carolina forest fly/stonefly (*S. carolinensis*), grammar (*G. pseudolim-naus*), amphipod (*H. azteca*), and the crayfish (*O. virilis*) were reviewed by EPA. Mortality was observed in the mayfly, the caddisfly, the Carolina forest fly/stonefly, and the grammar with corresponding 48-hour LC₅₀ values ranging from 0.0116 to > 0.978 mg/L (EPA, 2020b).

Acute toxicity was also observed in benthic invertebrates with a 48-hour LC₅₀ of 0.0859 mg/L (EPA, 2020b). Midge (*C. riparius*) survival was reduced to 10% at a concentration of 0.107 mg/L. The California blackworm (*L. variegatus*) was not affected by chlorantraniliprole technical with a resulting 48-hour LC₅₀ of > 1.49 mg/L. One chronic toxicity study was reported in the midge in which an 8% reduced emergence ratio was estimated at 0.010 mg/kg sediment. Adverse effects on developmental rate and time were also observed. Based on these results, 28-day NOAEC and LOAEC were determined for sediment (0.005 and 0.010 mg/kg, respectively), overlying water (0.042 and 0.108 µg/L, respectively) and pore water exposures (0.741 µg/L and 1.55 µg/L, respectively) (EPA, 2020b).

3.1.5 Environmental Fate Assessment

Chlorantraniliprole demonstrates persistence and moderate mobility in the environment with dissipation rates strongly influenced by environmental conditions such as pH, light, and temperature (EPA, 2020b). For example, chlorantraniliprole remains stable at pH 4 and 7 but degrades rapidly at pH 9. Photodegradation is a significant degradation pathway in shallow, well-lit aquatic environments with an aqueous photolysis half-life of approximately 7.4 hours (0.31 days). In contrast, soil photolysis is slower with a half-life of 43 days.

Chlorantraniliprole is expected to persist in deeper, poorly lit aquatic environments. Chlorantraniliprole is not expected to volatilize based on its low vapor pressure and Henry’s Law constant. It is also not expected to bioaccumulate in fish



with a bioconcentration factor of 14 in whole fish. Depuration studies showed that chlorantraniliprole levels in fish were reduced by 50% within 1.5 days after transfer to uncontaminated water (EPA, 2020b).

3.1.6 Conclusions and Recommendations

Based on the information reviewed for chlorantraniliprole, adverse effects in humans were not anticipated. In ecological receptors, adverse effects may occur in honeybees and aquatic invertebrates. Given Midpen's anticipated application to residential perimeters (once annually, 1-5 residences) potential impacts on these species are likely limited. If chlorantraniliprole represents the most suitable option for some applications, appropriate precautions must be taken when applying Altriset as an insecticide to minimize exposure to pollinators and aquatic environments, such as avoiding application during pollinator activity periods. It is also essential to review and comply with the EPA-stamped label

(https://www3.epa.gov/pesticides/chem_search/ppls/000352-00829-20120926.pdf).



3.2 Dinotefuran

Pesticide to control structural pests

Formulation: Alpine Foam (BASF)

Typical Target Pests: Structural pests (termites and ants)

Application: Annual application of ~14 oz over 1-5 residences via perimeter applications. Once per year.

Human Toxicity: *Acute and Short-term Toxicity:*

Category III (oral toxicity). Category IV (dermal and inhalation toxicity); *Subchronic and Chronic Toxicity:* Low toxicity via oral, inhalation, and dermal routes. Effects, if any, only at high doses/concentrations; *Carcinogenicity and Genotoxicity:* No evidence; *DART:* Not expected; *Endocrine disruption:* No information. Subject to the EPA's EDSP but not on EPA's priority list for EDSP; *Sensitization and irritation:* Category IV (eye and skin). Not a skin sensitizer; *Neurotoxicity:* Not expected; *Immunotoxicity:* No evidence.

Ecological Toxicity: *Plants:* Low toxicity (terrestrial and aquatic plants); *Bees (and/or other Insects):* Highly toxic; *Amphibians and Reptiles:* Moderately toxic or practically nontoxic (terrestrial-phase amphibians and reptiles). Practically nontoxic (aquatic-phase amphibians); *Birds:* Moderately toxic or practically nontoxic; *Mammals:* Practically nontoxic; *Fish (and/or other Aquatic Organisms):* Practically nontoxic (fish). Moderately toxic (aquatic invertebrates).

Environmental Fate: Highly water-soluble and environmentally mobile. Moderate soil persistence, low volatility, low bioaccumulation potential.

Conclusions and Recommendations: Adverse effects in humans are not anticipated. Adverse effects in honeybees and aquatic invertebrates may occur. Dinotefuran can be added to Midpen's list of approved pesticides with appropriate precautions.

3.2.1 Background

Dinotefuran (CAS # 165252-70-0) is a neonicotinoid insecticide belonging to the nitroguanidine subclass, widely utilized for the control of various insect pests; it is approved for both agricultural and non-agricultural applications (EPA, 2017b). Dinotefuran acts on the nicotinic acetylcholine receptors of the central nervous system via competitive modulation. It is a xylem and phloem-mobile systemic chemical that is readily taken up by the roots of the plant and translocated throughout the plant via the transpiration stream, and in plants it is absorbed via the roots, stems and foliage (EPA, 2017b).

Dinotefuran formulations include ready-to-use, pressurized liquids, dust, emulsifiable concentrates, granules, soluble concentrates, pellets/tablets, impregnated material, and water-soluble packaging (EPA, 2017b). EPA lists 184 active and approved formulations containing 0.05% to 40% dinotefuran (https://ordspub.epa.gov/ords/pesticides/f?p=113:6:::::P6_XCHEMICAL_ID:2180).

3.2.2 Exposure Considerations

In agricultural settings, dinotefuran is used on sites with field crops, fruits, vegetables, as well as Christmas tree plantations (EPA, 2017b). Dinotefuran is applied through soil and foliar applications (by ground and by air) or through tree/trunk injections. The maximal usage rate for dinotefuran is 0.54 lbs/A/season. In non-agricultural settings, dinotefuran is used in indoor residential and commercial sites, such as food handling establishments, residential and commercial sites such as gardens, lawns and ornamental plantings, and pets and livestock. Dinotefuran is applied by pest control operators and homeowners with surface space, directed crack and crevice sprayers and aerosol sprays (EPA, 2017b).

Midpen's annual application of dinotefuran (Alpine Foam formulation) is estimated at 14 oz over 1-5 residences, once per year. The method of application is noted as perimeter. Alpine Foam is meant to be applied by inserting the applicator straw into crevices, wall voids, etc. and dispensing the foam.

3.2.3 Human Toxicity and Risk Assessment

3.2.3.1 Acute and Short-term Toxicity

According to EPA (2017b), dinotefuran was classified as Category III for acute oral toxicity and Category IV for acute inhalation and dermal toxicity. The oral and dermal LD₅₀ values in rats were 2450 and >2000 mg/kg, respectively, whereas the 4-hour inhalation LC₅₀ was >4.09 mg/L. The NOAEL and LOAEL for acute exposure to dinotefuran were 125 and 300 mg/kg/day (EPA, 2017b).

3.2.3.2 Subchronic and Chronic Toxicity

According to EPA (2017b), several subchronic and chronic studies evaluated dinotefuran toxicity (**Table 13**). Based on the reported NOAELs and LOAELs, dinotefuran had low toxicity potential via oral, dermal, and inhalation routes with effects, if any, observed only at high doses. No additional chronic toxicity data were required for dinotefuran by EPA.



Table 13. Subchronic and Chronic Toxicity of Dinotefuran

Guideline No.	Species (Sex)	Route	Duration	Doses/ Concentrations	Findings	Toxicity Thresholds
870.3100	Rats (M/F)	Oral	90 days	0, 34/38, 336/384, 1623/1871, 3156/3616 (M/F) mg/kg/day	Decreased body weight and body weight gain and histopathological lesions of adrenal glands in female rats	• NOAEL = 336/384 (M/F) mg/kg/day • LOAEL = 1623/1871 (M/F) mg/kg/day
870.3100	Mice (M/F)	Oral	90 days	0, 81/102, 884/1064, 4442/5414, 10,635/11,560 (M/F) mg/kg/day	Decreased body weight and body weight gain	• NOAEL = 4442/5414 (M/F) mg/kg/day • LOAEL = 10,635/11,560 (M/F) mg/kg/day
870.3150	Dogs (M/F)	Oral	90 days	0, 58/58, 307/323, 862/950 (M/F) mg/kg/day	Decreased body weight gain in males and decreased body weight and body weight gain in females	• NOAEL = 307 mg/kg/day • LOAEL = 862 mg/kg/day
870.3200	Rats (M/F)	Dermal	28 days	0, 40, 200, 1000 mg/kg/day	No effects in males; acanthosis/ hyperkeratosis in high dose females (lower doses not evaluated histopathologically)	• NOAEL (systemic) = 1000 mg/kg/day • NOAEL (dermal) = 1000/ ≤200 (M/F) mg/kg/day • LOAEL (dermal) = ≤1000 (F) mg/kg/day
870.3465	Rats (M/F)	Inhalation	28 days	0, 0.22, 0.66, 2.08 mg/L	No effects observed in male or female rats	• NOAEC = 2.08 mg/L

Source: EPA (2017b)

3.2.3.3 Carcinogenicity and Genotoxicity

According to EPA (2017b), there was no evidence for dinotefuran carcinogenicity or genotoxicity. Dinotefuran did not induce tumor formation in rats and mice and was classified as “not likely to be carcinogenic to humans” by the Agency. Dinotefuran tested negative for mutagenicity and genotoxicity in standard assays, including *in vitro* and *in vivo* mutagenicity, chromosome aberration, and mammalian cell mutation (EPA, 2017b).

3.2.3.4 Developmental and Reproductive Toxicity

According to EPA (2017b), dinotefuran was not expected to be a reproductive or a developmental toxicant. The reproductive toxicity NOAELs were 241 and 268 mg/kg/day in male and female rats, respectively, with some effects noted at high doses (**Table 14**). The developmental toxicity NOAELs were 1000 and 300 mg/kg/day in rats and rabbits, respectively, with no LOAELs established.

Table 14. Reproductive/Developmental Toxicity of Dinotefuran

Guideline No.	Species (Sex)	Route	Doses/ Concentrations	Findings	Toxicity Thresholds
870.3800	Rats (M/F)	Oral	0, 24.1/26.8, 79.9/90.1, 241.0/267.9, 822.1/907.0 (M/F) mg/kg/day	• Systemic: Decreased food consumption and premating weight gain (F0 males), soft feces (F0 females), and decreased thyroid weight (F1 females) • Offspring: Decreased body weights, body weight gains, and forelimb grip strength (F1 males) or hindlimb grip strength (F1 females) • Reproductive: Decreased uterine weights and microscopic alterations in uterus and vagina (F0 females), decreased numbers of primordial follicles (F1 females), altered estrous cycle (F0 and F1 females), increased abnormal sperm morphology (F0 and F1 males), and decreased sperm count (F0 males) and sperm motility (F1 males)	• NOAEL (systemic, offspring, and reproductive) = 241/268 (M/F) mg/kg/day • LOAEL (systemic, offspring, and reproductive) = 822/907 (M/F) mg/kg/day
870.3700a	Rats (F)	Oral	0, 100, 300, 1000 mg/kg/day	No developmental toxicity observed	• NOAEL (maternal and developmental) = 1000 mg/kg/day



Guideline No.	Species (Sex)	Route	Doses/ Concentrations	Findings	Toxicity Thresholds
870.3700b	Rabbits (F)	Oral	0, 52, 125, 300 mg/kg/day	No developmental toxicity observed. Clinical signs indicative of neurotoxicity observed in maternal rabbits at high dose	• NOAEL (maternal) = 125 mg/kg/day • LOAEL (maternal) = 300 mg/kg/day • NOAEL (developmental) = 300 mg/kg/day

Source: EPA (2017b)

3.2.3.5 Endocrine Disruption

No information was available on endocrine disruption potential of dinotefuran. Dinotefuran is subject to the EPA's EDSP under the Federal Food, Drug, and Cosmetic Act (FFDCA) section 408(p) (EPA, 2017b); however, it is not on EPA's priority list for EDSP screening. Dinotefuran was not classified as an endocrine disruptor and did not appear on the Endocrine Society's list of chemicals with known endocrine-disrupting activity or on the ECHA Endocrine Disruptor Assessment List (ECHA, 2025a; Endocrine Society, 2025).

3.2.3.6 Sensitization and Irritation

According to EPA (2017b), dinotefuran was not a skin sensitizer. It was classified as Category IV for eye and skin irritation, although it may cause mild skin irritation (EPA, 2017b).

3.2.3.7 Neurotoxicity

According to EPA (2017b), exposure to high doses of dinotefuran resulted in neurotoxic effects, including decreased motor activity and grip strength, as observed in animal studies. However, increased sensitivity was demonstrated in developing animals, and developmental neurotoxicity studies did not reveal adverse effects. The Agency concluded that the neurotoxic potential of dinotefuran was adequately considered and did not consider additional safety factors to account for these effects during risk assessment (EPA, 2017b).

3.2.3.8 Immunotoxicity

According to EPA (2017b), dinotefuran was not considered immunotoxic, and no additional safety factors were applied for immunotoxicity in risk assessments. Some toxicity studies noted changes in spleen and thymus weight; however, the Agency did not consider these effects to be immunotoxic because no corroborating immune system effects were observed (EPA, 2017b).

3.2.4 Ecological Toxicity and Risk Assessment

3.2.4.1 Plants

According to EPA (2017a), Tier I terrestrial plant studies on ten species using dinotefuran (0.54 lbs/A) showed no significant effects, with inhibition below 25%; thus, Tier II testing was not required. The EC₂₅ and NOAEL values were both ≥ 0.54 lbs/A, indicating low phytotoxicity at the maximum application rate. Furthermore, aquatic plant toxicity testing showed no treatment-related effects for *L. gibba* and *P. subcapitata* exposed to dinotefuran degradants, with EC₅₀ and NOAEC values ranging from >98.7 to 110 mg/L. However, testing with technical grade dinotefuran showed minor effects on algal cell density at high concentrations, yielding a NOAEC of 25 mg/L, while EC₅₀ values remained >97.6 mg/L (EPA, 2017a).

3.2.4.2 Bees (and/or Other Insects)

According to EPA (2017c), dinotefuran had the potential to pose a significant risk to honeybees through foliar applications to crops such as cotton, cucurbits, citrus, stone fruit, pome fruit, berries/small fruits, and ornamentals (including non-bearing nut trees). The contact and oral LD₅₀ values were noted as 0.024 and 0.0076 µg/bee with chronic effects observed at low doses (EPA, 2017c). Based on the contact LD₅₀, dinotefuran could be classified as "Highly toxic". Furthermore, a colony-level feeding study established a NOAEC of 124 ng/g with transient reductions in adult bee numbers, suggesting potential colony-level impacts (EPA, 2017c). Residue data showed that dinotefuran concentrations in nectar and pollen often exceed this NOAEC, particularly in crops such as cotton, stone fruit, berries and ornamentals, and, in some cases, the residue remains for weeks-months. The Agency also noted that dinotefuran soil application posed a lower risk than foliar application. Additionally, off-field exposure from spray drift can affect bees up to 1000 feet from treated areas. Although no toxicity data currently exist for non-Apis bees, there were incident reports of bumblebee deaths linked to dinotefuran. Lastly, the greatest risks determined for dinotefuran were



associated with pre-bloom foliar and trunk injection uses on bee attractive crops, and thus, post-bloom and non-bee attractive crop uses were recommended to lower potential risks (EPA, 2017c).

3.2.4.3 Amphibians and Reptiles

No acute toxicity data for amphibians or reptiles were available for dinotefuran from EPA (2017c) or ECOTOX. According to EPA (2017a), birds can be used as surrogates for terrestrial-phase amphibians and reptiles, whereas freshwater fish can be used as surrogates for aquatic-phase amphibians. Dinotefuran toxicity information in birds and freshwater fish is provided in the sections below. For birds, the Agency noted that dinotefuran had low toxicity, and based on lethality, dinotefuran could be classified as “Moderately toxic” or “Practically nontoxic”, indicating that same conclusion would be applicable to terrestrial-phase amphibians and reptiles. For fish, the Agency noted that dinotefuran was “Practically nontoxic”, indicating that a similar conclusion would be applicable to aquatic-phase amphibians.

3.2.4.4 Birds

According to EPA (2017a), dinotefuran was considered to have low toxicity in birds. In oral studies, the LD₅₀ values were 334 (zebra finch), > 2000 (Japanese quail), and >2250 (bobwhite quail) mg/kg. In dietary studies, the LC₅₀ values were >5000 ppm in both Japanese quail and mallard duck (EPA, 2017a). Based on these LD₅₀ and LC₅₀ values, dinotefuran could be classified as “Moderately toxic” or “Practically nontoxic”. In chronic reproduction studies, no significant effects were noted in bobwhite quail, whereas reductions in hatchlings, eggs set, and 14-day survival were noted in mallard duck at the highest concentration of 5270 ppm (EPA, 2017a).

3.2.4.5 Mammals

According to EPA (2017a), dinotefuran was “Practically nontoxic” to mammals. As mentioned, dinotefuran had an oral LD₅₀ of 2450 mg/kg in rats. Additionally, subchronic and chronic, as well as developmental and reproductive toxicity studies in rats, mice, and rabbits supported the low toxicity potential for dinotefuran in mammals with effects, if any, observed at high doses.

3.2.4.6 Fish (and/or Other Aquatic Organisms)

According to EPA (2017a), dinotefuran was “Practically nontoxic” to fish and was “Moderately toxic” to aquatic

invertebrates with a broad range of sensitivity to dinotefuran across aquatic invertebrates. The reported LC₅₀s in fish and crustaceans were >99 mg/L, whereas in mysid, the LC₅₀ was > 0.79 mg/L (EPA, 2017a).

3.2.5 Environmental Fate Assessment

According to EPA (2017a), dinotefuran dissipates in the environment primarily through aqueous photolysis with a short half-life of approximately 1.8 days, particularly in clear, shallow waterbodies where sunlight penetration is high. In deeper or turbid aquatic systems where light is limited, microbial aquatic metabolism becomes the dominant degradation pathway. Dinotefuran is highly water-soluble, which enhances its mobility and transport potential in aquatic environments. In soil, dinotefuran is considered moderately persistent with aerobic degradation half-lives ranging from nine to 113 days, and an anaerobic half-life of about 62 days. Its low adsorption coefficients ($K_{oc} = 6-45$) indicate very high mobility, making it susceptible to leaching and runoff. Dinotefuran has low volatility, suggesting it is unlikely to evaporate from soil or water surfaces. It degrades into several transformation products, including UF, MG hydrogen chloride, DN-2-OH, DN-3-OH, and BCDN succinate. A key degradant, MNG, further breaks down into NG, and some degradants (e.g., MGN) are more persistent and may accumulate in aquatic environments. Despite its mobility, dinotefuran has a low potential for bioaccumulation, due to its low octanol-water partition coefficient. The primary environmental dissipation routes are photolysis, leaching, and runoff, which also represent key exposure pathways for humans and aquatic organisms, particularly through spray drift, runoff, and direct contact with granules (EPA, 2017a).

3.2.6 Conclusions and Recommendations

Based on the information reviewed for dinotefuran, adverse effects in humans were not anticipated. In ecological receptors, adverse effects may occur in honeybees and aquatic invertebrates. If dinotefuran represents the most suitable option for some applications, appropriate precautions must be taken when applying Alpine Foam as an insecticide to limit environmental release, particularly near pollinator habitats and water bodies. Restricting use to non-flowering periods, using soil or trunk injection methods, and educating staff on pollinator protection are recommended. It is also essential to review and comply with the EPA-stamped label

(https://ordspub.epa.gov/ords/pesticides/f?p=PPLS:102::N O::P102_REG_NUM:499-526).



3.3 Sulfuryl Fluoride / Chloropicrin

Pesticide to control structural pests and termites

Formulation: Vikane (sulfuryl fluoride)

Typical Target Pests: Structural pests, termites

Application: Annual application ~240 oz over 1-5 residences via tenting. Once per year.

Human Toxicity: *Acute and Short-term Toxicity:* Category II (oral toxicity). Category IV (dermal toxicity). Category I (inhalation toxicity); *Subchronic and Chronic Toxicity:* Toxic (inhalation) but effects not expected based on use; *Carcinogenicity and Genotoxicity:* No evidence; *DART:* No evidence; *Endocrine disruption:* No information. Not on EPA's priority list for EDSP; *Sensitization and irritation:* Category I (eye). Category IV (skin). Not a skin sensitizer; *Neurotoxicity:* Neurotoxic (inhalation) at high concentrations and after prolonged use; *Immunotoxicity:* Not a concern.

Ecological Toxicity: *Plants:* No information (terrestrial plants). Not toxic (aquatic plants); *Bees (and/or other Insects):* No information. Exposure expected to be minimal; *Amphibians and Reptiles:* No information (terrestrial-phase amphibians and reptiles). No effects anticipated (aquatic-phase amphibians); *Birds:* No information; *Mammals:* Moderately toxic; *Fish (and/or other Aquatic Organisms):* No information. Exposure not anticipated based on use.

Environmental Fate: Highly volatile with long atmospheric half-life. Potentially widespread distribution across atmosphere. Rapidly hydrolyzed in aquatic systems.

Conclusions and Recommendations: Adverse effects in humans may occur via inhalation or contact with eyes. Adverse effects in mammals may occur. No information on toxicity in other ecological receptors, but for some receptors, exposure was anticipated to be minimal or negligible. Sulfuryl fluoride can be added to Midpen's list of approved pesticides with appropriate precautions.

Formulations: Vikane (chloropicrin)

Typical Target Pests: Not applicable. A warning odorant

Application: Annual application ~10 fl oz over 1-5 residences via tenting. Once per year.

Human Toxicity: *Acute and Short-term Toxicity:* Category II (oral and dermal toxicity). Category I (inhalation toxicity); *Subchronic and Chronic Toxicity:* Toxic (inhalation) but effects not expected based on use; *Carcinogenicity and Genotoxicity:* No evidence for carcinogenicity. Mixed genotoxicity results; *DART:* No evidence; *Endocrine disruption:* No information. Included on EPA's priority list for EDSP tier 1; *Sensitization and irritation:* Category I (eye and skin). Possible skin sensitizer; *Neurotoxicity:* Not a concern; *Immunotoxicity:* Not a concern

Ecological Toxicity: *Plants:* Not phytotoxic; *Bees (and/or other Insects):* Practically nontoxic; *Amphibians and Reptiles:* Moderately toxic (amphibians and reptiles); *Birds:* Moderately toxic; *Mammals:* Moderately toxic; *Fish (and/or other Aquatic Organisms):* Moderately or very highly toxic

Environmental Fate: Highly volatile and is distributed to air. Relatively quick degradation in soil. Not expected to bioaccumulate significantly in aquatic organisms

Conclusions and Recommendations: Adverse effects in humans may occur via inhalation or contact with eyes and skin. Adverse effects in amphibians, reptiles, birds, mammals, and aquatic organisms may occur. Chloropicrin can be added to Midpen's list of approved pesticides with appropriate precautions

3.3.1 Background

Sulfuryl fluoride (CAS # 2699-79-8) is an active ingredient used as a biocide and fumigant for pest control of indoor stored food, farm structures, residential structures, road and water transportation vehicles and ships, warehouses and sheds (EPA, 2009b). Primarily, it is used to control drywood termites; however, it is also used for control of powder post beetles, old house borers, bedbugs, carpet beetles, clothes moths, cockroaches, mice, and rats (EPA, 2009c). The proposed mode of action of sulfuryl fluoride is its ability to

penetrate the exoskeleton or epidermal membrane of the pest and release of fluoride anion via hydrolysis (EPA, 2009b). The fluoride anion then disrupts glycolysis and fatty acid cycle, resulting in deficiencies in protein and amino acid production and ultimately leading to mortality.

Sulfuryl fluoride is restricted to indoor use and there are no outdoor pre-plant soil incorporated uses (EPA, 2009c). Tolerances associated with application to structures or containers of food and direct application range from 0.01 to 15 ppm. The vast majority of sulfuryl fluoride uses in states such as California are structural uses (EPA, 2009b). Sulfuryl



fluoride is generally contained as a solution in pressurized steel cylinders; its concentrations in such products are high, ranging from 99.3% to 99.8%. Upon release, sulfuryl fluoride volatilizes and diffuses into the environment. Because sulfuryl fluoride is odorless, chloropicrin (CAS # 76-06-2) is added in small amounts as an odorant warning agent to alert people to the presence of sulfuryl fluoride. Exposure to chloropicrin causes temporary eye and respiratory irritation (EPA, 2009b).

3.3.2 Exposure Considerations

Sulfuryl fluoride is applied primarily to structures, food containers, and directly to food (EPA, 2021). Inhalation exposure is expected to be the primary exposure route for sulfuryl fluoride, and dermal exposures are not expected. According to EPA (2021), oral exposure should be assessed as fluoride anion due to the rapid hydrolysis of sulfuryl fluoride in foods and on food surfaces. Exposure to sulfuryl fluoride is most common for occupational handlers, occupational post-application workers, and non-occupational bystanders near fumigation sites and from ambient residues in the air. Labeling recommendations indicate no maximum application rates for sulfuryl fluoride; however, a minimum aeration time of six to eight hours is required. It is recommended that certified applicators wear splash-resistant goggles or full-face shield when handling the pressurized liquified gas product of sulfuryl fluoride when working around any lines containing the pressurized fumigant. Additionally loose fitting or well-ventilated long-sleeve shirts, long pants, shoes, and socks are recommended. Gloves and boots are not recommended for wear. Per EPA, the use of buffers around active fumigation events may help reduce occupational exposure to not only bystanders but also to handlers and post-application workers (EPA, 2021).

Midpen's annual application of sulfuryl fluoride (Vikane formulation) is estimated at 240 oz over 1-5 residences, once per year. The method of application is tenting and therefore limited potential exposure is anticipated for humans and most ecological receptors.

3.3.3 Human Toxicity and Risk Assessment

3.3.3.1 Acute and Short-term Toxicity

According to EPA (2009c), sulfuryl fluoride was classified as Category I for acute inhalation toxicity and Category II for acute oral toxicity. The inhalation LC₅₀ values were 17.5 mg/L in rats and 2.56 and 2.49 mg/L in male and female

mice, respectively. The oral LD₅₀ was 100 mg/kg in male and female rats. For dermal acute toxicity, the study requirement was waived based on the physical properties of sulfuryl fluoride; therefore, the chemical was assumed to be Category IV for acute dermal toxicity (EPA, 2009c).

According to EPA (2008a), chloropicrin could be classified as Category I for acute inhalation toxicity and Category II for acute oral and dermal toxicity. The inhalation LC₅₀ was noted as 18 ppm in rats, whereas the oral and dermal LD₅₀ values were 250 mg/kg (rat) and 400 mg/kg (rabbit), respectively.

3.3.3.2 Subchronic and Chronic Toxicity

According to EPA (2009c), sulfuryl fluoride was moderately toxic via oral exposure; however, no subchronic or chronic oral toxicity studies were described. Multiple repeated dose inhalation toxicity studies in rats, mice, dogs, and rabbits were reviewed by EPA (2009c). In two-week inhalation studies, the primary target organs included the kidney (severe histopathological lesions reported in rats), upper respiratory tract (minimal inflammation noted in dogs), and brain (necrosis and vacuolation in the cerebrum of rabbits). Upper respiratory tract inflammation was also observed in rabbits, and intermittent tremors and tetany were noted in dogs (EPA, 2009c). In 90-day and one-/two-year inhalation studies, the brain was a major target organ across rats, mice, dogs, and rabbits with necrosis and/or vacuolation being observed in the brain's white matter across all species (EPA, 2009c). Clinical signs of neurotoxicity were observed in rabbits and dogs, whereas inflammation of the nasal passages and histiocytosis of the lungs were observed in rats and rabbits. Follicular cell hypertrophy of the thyroid gland was noted in mice. Furthermore, decreased body weight and body weight gain were noted in rats, dogs, and rabbits. Dental fluorosis was the most sensitive effect observed across subchronic and chronic inhalation studies in rats, dogs, and rabbits (EPA, 2009c). Additional details on these studies are provided in **Table 15**. Based on these studies, sulfuryl fluoride may have adverse effects following subchronic or chronic exposure at relatively high concentrations; however, this finding is not applicable to a potential exposure scenario resulting from its application during tenting.

According to EPA (2009a), the chronic toxicity of chloropicrin was not a concern due to volatility and short exposure durations. It was noted that in 90-day inhalation studies, dose-dependent respiratory tract irritation, decreased body weight gain, and histopathological changes in respiratory epithelium were observed; however, these effects were reversible upon exposure cessation (EPA, 2009a).



Table 15. Subchronic and Chronic Toxicity of Sulfuryl Fluoride

Guideline No.	Species (Sex)	Route	Duration	Doses/ Concentrations	Findings	Toxicity Thresholds
Nonguideline	Rats (M/F)	Inhalation	2 weeks	0/0, 83/89, 249/267, 498/534 (M/F) mg/kg/day	Slightly increased kidney weights, decreased thymus weights, and minimal histopathology in kidney, including epithelial hyperplasia in collecting ducts and proximal tubules	• NOAEL = 83/89 (M/F) mg/kg/day • LOAEL = 249/267 (M/F) mg/kg/day
Nonguideline	Dogs (M/F)	Inhalation	2 weeks	0/0, 7.9/8.0, 26/27, 79/80 (M/F) mg/kg/day	Intermittent tremors and tetany during exposures, minimal inflammation in upper respiratory tract, and decreased body weight in females only	• NOAEL = 26/27 (M/F) mg/kg/day • LOAEL = 79/80 (M/F) mg/kg/day
Nonguideline	Rabbits (M/F)	Inhalation	2 weeks	0, 30, 90, 180 mg/kg/day	Necrosis and vacuolation of the cerebrum and moderate inflammation of respiratory tissues	• NOAEL = 30 mg/kg/day • LOAEL = 90 mg/kg/day
870.3100	Rats (M/F)	Inhalation	90 days	0/0, 24/25, 80/83, 240/250 (M/F) mg/kg/day	Dental fluorosis	• NOAEL = 24/25 (M/F) mg/kg/day • LOAEL = 80/83 (M/F) mg/kg/day
870.3100	Mice (M/F)	Inhalation	90 days	0/0, 12.5/12.1, 38/36, or 125/121 mg/kg/day (M/F)	Microscopic lesions in caudate-putamen nucleus and external capsule, decreased body weight and body weight gain, and follicular cell hypertrophy of the thyroid	• NOAEL = 38/36 (M/F) mg/kg/day • LOAEL = 125/121 (M/F) mg/kg/day
870.3150	Dogs (M/F)	Inhalation	90 days	0/0, 7.5/7.6, 25/26, or 50/51 mg/kg/day (M/F)	Slight histopathology of the caudate nucleus of the basal ganglia, transient neurological signs (including lateral recumbency, tremors, incoordination, salivation, tetany, and inactivity), on Day 19, and decreased body weight and body weight gain	• NOAEL = 25/26 (M/F) mg/kg/day • LOAEL = 50/51 (M/F) mg/kg/day
870.3150	Rabbits (M/F)	Inhalation	90 days	0/0, 8.6/8.5, 29/28, or 86/85 mg/kg/day (M/F)	Decreased body and liver weight, dental fluorosis, and vacuolation of white matter of the brain in females only	• NOAEL = 8.6/8.5 (M/F) mg/kg/day • LOAEL = 29/28 (M/F) mg/kg/day
870.4300	Rats (M/F)	Inhalation	2 years	0/0, 3.5/3.9, 14/16, 56/62 (M/F) mg/kg/day	Dental fluorosis, increased mortality due to severe kidney toxicity, histopathology in the brain (including vacuolation in the cerebrum and thalamus/hypothalamus), adrenal cortex, eyes, liver, nasal tissues, and respiratory tract, and dental fluorosis	• NOAEL = 3.5/16 (M/F) mg/kg/day • LOAEL = 14/62 (M/F) mg/kg/day
870.4100	Dogs (M/F)	Inhalation	1 year	0/0, 5.0/5.1, 20/20, 50/51 (M/F) mg/kg/day	Mortality, decreased body weight in females, necrosis of the cerebrum, hepatocellular atrophy, clinical signs of respiratory distress, pale foci and darkened consolidated areas of the lungs, pulmonary inflammation, and thyroid follicular cell hypertrophy	• NOAEL = 5.0/5.1 (M/F) mg/kg/day • LOAEL = 20/20 (M/F) mg/kg/day

Source: (EPA, 2009c, 2021)

3.3.3.3 Carcinogenicity and Genotoxicity

According to EPA (2009c), sulfuryl fluoride was classified as not likely to be carcinogenic to humans based on carcinogenicity studies performed in rats and mice. In an 18-month inhalation study, sulfuryl fluoride was administered to male mice at 0, 5.3, 25, or 1010 mg/kg/day and female mice at 0, 6.3, 25, or 1010 mg/kg/day. Cerebral

vacuolation of the brain and decreased body weight gain were noted for both males and females of the highest dose group. Follicular cell hypertrophy of the thyroid was observed in males of the highest dose group, while increased mortality, heart thrombus, and lung congestion were observed in females of the highest dose group. Overall, there was no evidence of carcinogenicity (EPA, 2009c). In a two-year inhalation study, sulfuryl fluoride was



administered to male rats at 0, 3.5, 14, or 56 mg/kg/day and female rats at 0, 3.9, 16, or 62 mg/kg/day. Dental fluorosis was observed in males and females at 14 and 62 mg/kg/day, respectively. Increased mortality was noted in males and females at the highest dose and was concomitant with severe kidney toxicity and kidney failure and histopathological changes in the brain, adrenal cortex, eyes, liver, nasal tissue, and respiratory tract, as well as vacuolation in cerebrum and thalamus/hypothalamus. However, no evidence of carcinogenicity was noted in males or females (EPA, 2009c).

According to EPA (2009c), there was no evidence for mutagenicity *in vivo* or *in vitro* for sulfuryl fluoride. Specifically, sulfuryl fluoride was negative for mutagenicity in *S. typhimurium*, mouse bone marrow cells, and primary rat hepatocytes (EPA, 2009c). However, sulfuryl fluoride was positive for genotoxicity in an *in vitro* mammalian chromosome aberration test and weakly positive for mutagenicity in an *in vitro* mouse lymphoma assay (EPA, 2021).

According to EPA (2008a), no evidence of carcinogenicity was noted in a 78-week inhalation study in mice or in a 108-week inhalation study in rats exposed to up to 1.0 ppm chloropicrin for six hours per day and five days per week. According to ECHA dossier for chloropicrin, there was no evidence of carcinogenicity in a two-year carcinogenicity study performed according to OECD Guideline 451, in which rats were exposed to up to 2.4 mg/kg via oral gavage (ECHA, 2025f).

Chloropicrin tested positive for mutagenicity in Ames assays in *S. typhimurium* and *E. coli* with and without metabolic activation (ECHA, 2025f; EPA, 2008a); however, chloropicrin was negative for mutagenicity in a forward mutation assay in mouse lymphoma cells to (EPA, 2008a) and negative for genotoxicity in a micronucleus assay in mice (ECHA, 2025f). Chloropicrin tested positive in a chromosomal aberrations assay in Chinese hamster ovary cells, whereas in an unscheduled DNA synthesis assay in rat hepatocytes, it tested negative (EPA, 2008a).

3.3.3.4 Developmental and Reproductive Toxicity

Although maternal toxicity was observed in some studies assessing the developmental and reproductive toxicity potential of sulfuryl fluoride, no evidence of developmental or reproductive toxicity was noted (EPA, 2009c). In a two-generation reproductive toxicity study, male and female rats were administered 0, 3.6, 14, or 108 mg/kg/day sulfuryl fluoride via inhalation. NOAELs were 3.6 and 14 mg/kg/day in parental rats and offspring, respectively. The parental LOAEL was 14 mg/kg/day based on pale foci and increased alveolar macrophages in the lungs, whereas the offspring

LOAEL was 109 mg/kg/day based on decreased pup weights in both the F₁ and F₂ generations (EPA, 2009c).

In a developmental toxicity study performed according to OPTTS Guideline 870.3700, rats were administered 0, 25, 75, or 225 ppm (equivalent to approximately 0, 27, 81, or 243 mg/kg/day) sulfuryl fluoride via inhalation (EPA, 2009c). Both the maternal and developmental NOAELs were 243 mg/kg/day, the highest dose tested. However, "significant" maternal toxicity was observed at 300 ppm sulfuryl fluoride in the associated range-finding study; no further details were provided (EPA, 2009c).

In a developmental toxicity study in rabbits performed according to the Office of Prevention, Pesticides, and Toxic Substances (OPPTS) Guideline 870.3700, sulfuryl fluoride was administered at doses of 0, 9.5, 29, or 86 mg/kg/day via inhalation (EPA, 2009c). The maternal NOAEL was 29 mg/kg/day. Decreased body weight and body weight gain were observed in the highest dose group throughout the treatment period; therefore, maternal LOAEL was 86 mg/kg/day. The developmental NOAEL was also 29 mg/kg/day. The developmental LOAEL was 86 mg/kg/day based on decreased fetal body weight, decreased crown-rump length, and pale liver (EPA, 2009c).

Based on studies reviewed by EPA (2008a), chloropicrin was not a reproductive or developmental toxicant. In a multigeneration reproductive/fertility study, rats were exposed via whole-body inhalation to 0, 0.5, 1.0, or 1.5 ppm chloropicrin (equivalent to 0, 3.4, 6.7, or 10 mg/m³, respectively) for two generations through the weaning of the second generation F₂ pups. Slight inflammatory changes occurred in the lungs at 1.5 ppm in the F₁ adult females. There were no treatment-related effects in pups or reproductive effects in dams at any exposure concentration. In an unpublished developmental toxicity study, rat dams were exposed to chloropicrin at concentrations of 0, 0.4, 1.2, or 3.5 ppm via whole-body inhalation for six hours per day from gestation day (GD) 6 through 15. The resulting maternal NOAEC was 0.4 ppm and the LOAEC was 1.2 ppm based on decreased food consumption, body weight, and body weight gain, as well as increased clinical signs. A significant increase in total fetal skeletal variations was noted in pups of the 1.2 and 3.5 ppm groups; however, on a per-litter-basis, no statistically significant increases were observed. The developmental NOAEC was noted as 1.2 ppm. In another developmental study, pregnant New Zealand White rabbits were exposed via whole-body inhalation to 0, 0.4, 1.2, or 2 ppm chloropicrin for six hours per day on GD 6-18. The maternal NOAEC was 0.4 ppm. Two dams died in the 1.2 ppm group and 10 died in the 2 ppm group. Abortions, pulmonary edema, and decreased body weight and food consumption were observed at ≥ 1.2 ppm. Dyspnea, nasal staining, salivation, and decreased activity occurred in a dose-dependent manner. The



maternal LOAEC was 1.2 ppm based on decreased body weight and food consumption. The developmental NOAEC and LOAEC were 0.4 and 1.2 ppm, respectively to (EPA, 2008a).

According to the ECHA dossier for chloropicrin, no reproductive toxicity was observed in a two-generation reproductive study in male and female rats exposed to 0, 0.3, 0.9, or 2.7 mg/kg chloropicrin via oral gavage; thus, the NOAEL was 2.7 mg/kg (ECHA, 2025f). Further, no developmental effects were observed in rat dams exposed to 0, 12, 24, or 45 mg/kg chloropicrin via oral gavage on GD 5-19; the maternal toxicity NOAEL was 12 mg/kg, whereas the developmental NOAEL was 48 mg/kg. In another developmental study, pregnant New Zealand White rabbits were exposed to 0, 5, 10, or 20 mg/kg chloropicrin via oral gavage from GD 6 to 28; the maternal and developmental NOAELs were 20 mg/kg (ECHA, 2025f).

3.3.3.5 Endocrine Disruption

No information was available on the endocrine disruption potential of sulfuryl fluoride. This chemical was not on EPA's priority lists for EDSP tier 1

(<https://www.regulations.gov/document/EPA-HQ-OPPT-2004-0109-0080>) or tier 2

(<https://www.regulations.gov/document/EPA-HQ-OPPT-2009-0477-0074>) screening. Sulfuryl fluoride was not classified as an endocrine disruptor and did not appear on the Endocrine Society's list of chemicals with known endocrine-disrupting activity or on the ECHA Endocrine Disruptor Assessment List (ECHA, 2025a; Endocrine Society, 2025).

No specific information on endocrine disruption potential of chloropicrin was available. This chemical was included on the EPA's priority list for EDSP tier 1

(<https://www.regulations.gov/document/EPA-HQ-OPPT-2004-0109-0080>) screening. Chloropicrin was not classified as an endocrine disruptor and did not appear on the Endocrine Society's list of chemicals with known endocrine-disrupting activity or on the ECHA Endocrine Disruptor Assessment List (ECHA, 2025a; Endocrine Society, 2025).

3.3.3.6 Sensitization and Irritation

According to EPA (2009c), studies for skin sensitization and irritation as well as eye irritation were waived for sulfuryl fluoride. It was assumed to be a non-sensitizer, Category I eye irritant, and Category IV skin irritant (EPA, 2009c).

No information on chloropicrin skin sensitization was specified in EPA reports reviewed. According to the ECHA dossier, chloropicrin may be classified as a skin sensitizer based on a mouse local lymph node assay that showed positive reactions at concentration of 5% or 10%

chloropicrin (ECHA, 2025f). Regarding irritation, chloropicrin induced eye irritation in human volunteers at concentrations as low as 0.9 ppm following very brief (seconds) exposure to the chemical to (EPA, 2008a) and was considered to have the potential to cause irreversible eye damage based on its skin corrosive potential (ECHA, 2025f). EPA did not classify chloropicrin for eye and skin irritation; however, based on the information in the ECHA dossier, chloropicrin could be classified as Category I for eye and skin irritation.

3.3.3.7 Neurotoxicity

According to EPA (2021), inhalation of sulfuryl fluoride primarily targets the nervous system. However, mixed results were noted in the available neurotoxicity studies reviewed by EPA. In an acute neurotoxicity study, sulfuryl fluoride was administered to female rats at 0, 118, or 354 mg/kg/day (EPA, 2009c). No effects were noted on the electrophysiological parameters assessed. Thus, the NOAEL was 354 mg/kg/day. In a 90-day neurotoxicity study, sulfuryl fluoride was administered to male rats at 0, 24, 80, or 240 mg/kg/day and to female rats at 0, 25, 83, or 250 mg/kg/day. With respect to neurotoxic effects, disturbances in electrophysiological parameters, including slowing of VER and SER waveforms in females and slowing of ABR waveforms in males, were observed in the second highest dose group. Slowing of all waveforms (except CNAP) and vacuolation of white matter in the caudate putamen of the cerebrum were observed in males and females of the highest dose group. Thus, neurotoxicity NOAELs of 24 and 25 mg/kg/day and neurotoxicity LOAELs of 80 and 83 mg/kg/day were established in male and female rats, respectively. In a one-year neurotoxicity study, sulfuryl fluoride was administered to male rats at 0, 3.5, 3.9, 14, or 56 mg/kg/day and female rats at 0, 3.9, 16, or 62 mg/kg/day via inhalation. No signs of neurotoxicity were observed; therefore, the neurotoxicity NOAELs were 56 and 52 mg/kg/day in male and female rats, respectively (EPA, 2009c). Based on these studies, sulfuryl fluoride may cause neurotoxicity at high concentrations and after prolonged exposure; however, this finding is not applicable to a potential exposure scenario resulting from its application during tenting.

According to EPA (2008a), chloropicrin was not identified as having neurotoxic effects and neurotoxicity was not listed as an endpoint of concern. EPA also did not require developmental neurotoxicity study for chloropicrin, indicating that neurotoxicity was not a suspected hazard for this chemical to (EPA, 2008a).

3.3.3.8 Immunotoxicity

According to EPA (2021), there was no concern for immunotoxicity with regard to sulfuryl fluoride exposure; no



further details were provided. Similarly, immunotoxicity was not identified as an endpoint of concern for chloropicrin to (EPA, 2008a).

3.3.4 Ecological Toxicity and Risk Assessment

3.3.4.1 Plants

No data were available regarding the toxicity of sulfuryl fluoride to terrestrial plants (EPA, 2009b). According to EPA (2009b), exposure is possible during the aeration phase after structural fumigation and the general mechanism of action indicates that sulfuryl fluoride may have toxicity to terrestrial plants but not aquatic plants. The Agency concluded that insufficient information exists to preclude concerns for direct toxic effects to terrestrial plant species (EPA, 2009b).

According to EPA (2009a), chloropicrin is not phytotoxic to crops when used according to label. The Agency did not report direct toxicity to plants because chloropicrin is not used on growing vegetation, and its toxicity to plants was not a major concern under approved use scenarios (EPA, 2009a).

3.3.4.2 Bees (and/or Other Insects)

According to EPA (2009b), no toxicity data for the honeybee or other insects were available for sulfuryl fluoride. The pesticide is used to control target insects; thus, it is likely that the compound is toxic to non-target terrestrial invertebrates. However, given the non-crop use of sulfuryl fluoride, exposure to pollinating insects such as honeybees and non-target terrestrial invertebrates is expected to be minimal (EPA, 2009b). According to ECOTOX, no toxicity data were available for bees. However, LC₅₀ values of 33.9 and 85.5 mg/L were reported in cadelle beetle larvae exposed to an unspecified formulation of sulfuryl fluoride, whereas in exposed confused flour beetles, LC₅₀ values of 11.8 and 12 were noted.

According to EPA (2008a), direct exposure of chloropicrin to bees was minimal, and the Agency did not classify chloropicrin as a high-risk pesticide for pollinators. In a tiered risk assessment, chloropicrin did not trigger a significant concern because of its application method to (EPA, 2008a). According to ECOTOX, a contact LD₅₀ of >100 µg/bee was noted. Based on this LD₅₀, chloropicrin could be classified as "Practically nontoxic".

3.3.4.3 Amphibians and Reptiles

No toxicity data for amphibians or reptiles were available for sulfuryl fluoride from EPA (2009b) or ECOTOX. According

to EPA (2009b), birds can be used as surrogates for terrestrial-phase amphibians and reptiles, whereas freshwater fish can be used as surrogates for aquatic-phase amphibians. Sulfuryl fluoride toxicity information in birds and freshwater fish is provided in the sections below. For birds, the Agency noted that there was insufficient information to preclude concerns for direct toxic effects to birds, indicating that same conclusion would be applicable to terrestrial-phase amphibians and reptiles. For fish, the Agency noted that no adverse impacts were anticipated, indicating that a similar conclusion would be applicable to aquatic amphibians.

No toxicity data for amphibians or reptiles were available for chloropicrin from EPA (2008a) or ECOTOX. The Agency noted that chloropicrin was classified as toxic to wildlife to (EPA, 2008a). According to EPA, birds can be used as surrogates for terrestrial-phase amphibians and reptiles, whereas freshwater fish can be used as surrogates for aquatic-phase amphibians. Chloropicrin toxicity information in birds and freshwater fish is provided in the sections below. Based on information in birds and mammals, chloropicrin could be classified as "Moderately toxic" to amphibians and reptiles.

3.3.4.4 Birds

Due to the highly volatile nature of sulfuryl fluoride and the fact that it is gaseous at room temperature and standard pressure, inhalation of vapor during the aeration phase following fumigation is a major potential exposure pathway for non-target birds (EPA, 2009b). However, no data were available on sulfuryl toxicity in avian species. The Agency concluded that there was insufficient information to preclude concerns for direct toxic effects to birds (EPA, 2009b). According to ECOTOX, no toxicity data were available for birds.

According to EPA (2020c), chloropicrin was toxic to birds. An oral LD₅₀ of 258 mg/kg was noted for bobwhite quail, based on which, chloropicrin could be classified as "Moderately toxic" (EPA, 2020c).

3.3.4.5 Mammals

According to (EPA, 2009b), inhalation of sulfuryl fluoride vapor during the aeration phase following fumigation was a major potential exposure pathway for mammals (EPA, 2009b). Sulfuryl fluoride LC₅₀ values of 642 ppm and 660 ppm were noted in male and female rats, respectively, and the Agency classified it as "Highly toxic" via inhalation. The oral LD₅₀ in rats was reported to be 100 mg/kg (EPA, 2009b); based on this LD₅₀, sulfuryl fluoride could be classified as "Moderately toxic". The Agency also noted that exposure concentrations to sulfuryl fluoride were high



enough to create a potential risk to non-target mammalian species (EPA, 2009b).

According to EPA (2008a), chloropicrin's oral LD₅₀ in rats was 250 mg/kg. Based on this LD₅₀, chloropicrin could be classified as "Moderately toxic".

3.3.4.6 Fish (and/or Other Aquatic Organisms)

No toxicity data were available for freshwater fish or invertebrates or estuarine/marine fish or invertebrates from EPA (2009b) or ECOTOX. However, the Agency noted that adverse impacts to aquatic species were not expected given the labeled uses of sulfuryl fluoride and its physical properties, which would result in limited deposition of sulfuryl fluoride in water for short periods of time (EPA, 2009b).

According to EPA (2008a), chloropicrin was toxic to fish and aquatic invertebrates. Based on information in ECOTOX, chloropicrin's LC₅₀ values ranged from 0.03 to 0.26 mg/L in crustacea and from 0.005 to 0.11 mg/L in fish. Based on these LC₅₀ values, chloropicrin could be classified as "Moderately" to "Very highly toxic".

3.3.5 Environmental Fate Assessment

Sulfuryl fluoride is released as a gas into the atmosphere following its use in fumigation applications (EPA, 2009b). Due to its high vapor pressure and long atmospheric half-life, sulfuryl fluoride primarily remains in the air compartment and is capable of long-range atmospheric transport, potentially leading to widespread distribution across the global atmosphere. Although highly volatile, sulfuryl fluoride may disperse to ground level through atmospheric mixing and dispersion processes. Its low affinity for partitioning to aerosols or organic matter, combined with its rapid hydrolysis in aquatic environments, suggests that sulfuryl fluoride exposure in aquatic ecosystems is expected to be minimal (EPA, 2009b).

Chloropicrin has high volatility, which facilitates its movement from soil to air following application, raising

concerns about off-site transport and bystander exposure (EPA, 2009a). In soil, chloropicrin degrades relatively quickly through hydrolysis and microbial activity, limiting its persistence. It has low mobility in soil, reducing the potential for groundwater contamination, although surface water contamination via runoff remains a possibility. Chloropicrin does not strongly bind to soil particles or organic matter and is not expected to bioaccumulate in aquatic organisms. To mitigate environmental transport risks, EPA mandates buffer zones, tarping, and fumigant management plans to minimize emissions and protect surrounding ecosystems (EPA, 2009a).

3.3.6 Conclusions and Recommendations

Based on the information reviewed for sulfuryl fluoride, adverse effects in humans may occur via inhalation or contact with eyes. In ecological receptors, adverse effects in mammals may occur if exposed, whereas in birds, exposure during the aeration phase following fumigation was identified as a major exposure pathway. No information on toxicity was available in other ecological receptors, but for many receptors, exposure was anticipated to be minimal or negligible.

Based on the information reviewed for chloropicrin, adverse effects in humans may occur via inhalation or contact with eyes and skin. In ecological receptors, adverse effects may occur in amphibians, reptiles, birds, mammals, and aquatic organisms; however, in most receptors, exposure was anticipated to be minimal or negligible given the tenting application.

If sulfuryl fluoride / chloropicrin represent the most suitable option for some applications, strict precautions should be followed when using Vikane, such as use of appropriate PPE, adequate ventilation, adherence to aeration and re-entry intervals, notification of nearby residents (if applicable), and maintenance of buffer zones. It is also essential to review and comply with the EPA-stamped label (https://ordspub.epa.gov/ords/pesticides/f?p=PPLS:102:::NO::P102_REG_NUM:1015-78).



3.4 d-Limonene

Pesticide to control structural pests and termites

Formulation: XT-2000 Insecticide

Typical Target Pests: Structural pests, termites

Application: Annual application of ~2 gal over 1-5 residences via spot treatment applications. Once per year.

Human Toxicity: *Acute and Short-term Toxicity:*

Category III (oral and dermal toxicity). Low inhalation toxicity (category not derived); *Subchronic and Chronic*

Toxicity: Low toxicity potential; *Carcinogenicity and*

Genotoxicity: No evidence; *DART:* No evidence;

Endocrine disruption: No information. Not on EPA's

priority list for EDSP; *Sensitization and irritation:*

Category not provided (eye). Category II (skin). Skin

sensitizer; *Neurotoxicity:* No evidence; *Immunotoxicity:*

No information.

Ecological Toxicity: *Plants:* No information. Not

classified as phytotoxic under registered uses; *Bees*

(and/or other Insects): Practically nontoxic; *Amphibians*

and Reptiles: Slightly toxic or practically nontoxic

(terrestrial-phase amphibians and reptiles). Slightly toxic

(aquatic-phase amphibians); *Birds:* Slightly toxic or

practically nontoxic; *Mammals:* Practically nontoxic; *Fish*

(and/or other Aquatic Organisms): Slightly toxic.

Environmental Fate: Not expected to persist or

accumulate significantly in the environment.

Conclusions and Recommendations: Skin irritation

and sensitization may occur in humans. Adverse

effects in ecological receptors are not anticipated. d-

Limonene can be added to Midpen's list of approved

pesticides with appropriate precautions.

3.4.1 Background

d-Limonene (CAS # 5989-27-5) is naturally occurring compound found in citrus fruits and certain vegetables, spices, and meats (EPA, 2016c). Known for its lemon-like aroma and flavor, it is widely used in food products, soaps, perfumes, and pesticides. As a pesticide, d-limonene functions both as an active ingredient—serving as an insecticide, herbicide, insect repellent, and animal repellent—and as an inert ingredient, acting as a solvent or fragrance. It is registered for use on terrestrial food or feed crops, as well as in insect-repellent products, such as treated tablecloths and strips used in food or feed-handling establishments. d-Limonene is considered by FDA to be Generally Recognized as Safe (GRAS) when used as a synthetic flavoring substance and adjuvant (EPA, 2016c). d-Limonene was first registered as an insecticide in 1958 (EPA, 2016a). Its precise mode of action is not fully

characterized; however, it is thought to act as a contact insecticide by disrupting the waxy cuticle of insects, leading to desiccation and death. It is also suggested that d-limonene may affect sensory nerves or neurological function (EPA, 2016a).

d-Limonene is used in insecticide sprays, insect-repellant products, and flea and tick control formulations for pets (EPA, 2016a). Its registered pesticide formulations include ready-to-use solutions, emulsifiable concentrates, granulars, and impregnated materials (EPA, 2016a). According to EPA, as an active ingredient, d-limonene concentrations in approved formulations typically range from 1% to 10%, although some pet products may contain up to 30% d-limonene.

3.4.2 Exposure Considerations

According to EPA (2016c), d-limonene is registered in numerous pesticide products for residential use, including outdoor spot treatments, indoor crack and crevice applications, insect-repellent materials such as clothing and tablecloths, structural injections into wood, and pet shampoos for flea and tick control. In addition to its pesticide use, d-limonene is commonly found in foods, soaps, and perfumes (EPA, 2016c). Thus, exposure to d-limonene can occur in occupational and non-occupational settings. Application rates vary widely across the diverse formulations available (EPA, 2014c).

Midpen's annual application of d-limonene (XT-2000 Insecticide) is estimated at 2 gal over 1-5 residences, once per year. The method of application is noted as spot treatment.

3.4.3 Human Toxicity and Risk Assessment

3.4.3.1 Acute and Short-term Toxicity

According to EPA (2016c), d-limonene exhibited low acute toxicity via oral and dermal routes of exposure and was not considered acutely toxic via inhalation. In d-limonene's ECHA dossier, it was noted that d-limonene did not need to be classified for acute toxicity under CLP Regulation (EC) No 1272/2008 or GHS because the oral LD₅₀ in rats exceeded 2000 mg/kg and the dermal LD₅₀ in rabbits exceeded 5000 mg/kg (ECHA, 2025d). Based on the LD₅₀ values, d-limonene could be classified as Category III for acute oral and dermal toxicity.

3.4.3.2 Subchronic and Chronic Toxicity

According to EPA (2016c), rats exposed to d-limonene via oral gavage for 103 weeks exhibited no observed adverse



effects, while 30-day oral exposures resulted only in adaptive liver changes, such as marginal increases in liver enzymes and liver weights. These adaptive effects were consistently observed across multiple studies and were not considered toxicologically significant (EPA, 2016c). According to information in the ECHA dossier, d-limonene did not require classification for repeated dose toxicity under CLP Regulation (EC) No 1272/2008, with oral LOAELs of 1000 mg/kg/day in rats (90-day study) and dogs (180-day study) (ECHA, 2025d). Based on this information d-limonene was considered to have low toxicity potential.

3.4.3.3 Carcinogenicity and Genotoxicity

According to EPA (2016c), d-limonene was negative for mutagenicity and clastogenicity in multiple assays. In its ECHA dossier, it was noted that d-limonene did not require classification for mutagenicity or genotoxicity based on negative results in Ames tests, *in vitro* chromosome aberration and gene mutation assays, and *in vivo* comet assays (ECHA, 2025d). Additionally, d-limonene was not classified as a carcinogen, as no increased tumor incidence was observed in mice or female rats in two-year oral studies and the kidney tumors observed in male rats were attributed to a species-specific mechanism not relevant to humans (ECHA, 2025d).

3.4.3.4 Developmental and Reproductive Toxicity

According to EPA (2016c), d-limonene was not considered a developmental toxicant with effects observed only at very high doses (> 500 mg/kg/day) and in the presence of maternal toxicity in developmental toxicity studies. In d-limonene's ECHA dossier, it was noted that d-limonene did not require classification for reproductive or developmental toxicity, as all observed effects were either not dose-related or attributable to maternal toxicity (ECHA, 2025d).

3.4.3.5 Endocrine Disruption

No information was available on the endocrine disruption potential of d-limonene. This chemical was not on EPA's priority lists for EDSP tier 1 (<https://www.regulations.gov/document/EPA-HQ-OPPT-2004-0109-0080>) or tier 2 (<https://www.regulations.gov/document/EPA-HQ-OPPT-2009-0477-0074>) screening. d-Limonene was not classified as an endocrine disruptor and did not appear on the Endocrine Society's list of chemicals with known endocrine-disrupting activity or on the ECHA Endocrine Disruptor Assessment List (ECHA, 2025a; Endocrine Society, 2025).

3.4.3.6 Sensitization and Irritation

According to EPA (2016c), d-limonene was a dermal sensitizer and a skin and eye irritant. In its ECHA dossier, it was noted that d-limonene was classified as a skin irritant (Category 2) and a skin sensitizer (Category 1B), but it was not classified as an eye irritant under CLP Regulation (EC) No 1272/2008 (ECHA, 2025d).

3.4.3.7 Neurotoxicity

According to EPA (2016c), d-limonene was not considered a neurotoxicant. In a 13-week oral toxicity study in mice, doses of 1000 mg/kg/day led to decreased motor activity, but this effect was attributed to systemic toxicity from the high dose rather than direct neurotoxic effects (EPA, 2016c).

3.4.3.8 Immunotoxicity

According to EPA (2016c), d-limonene was not identified as an immunotoxicant based on a nine-week oral toxicity study in mice.

3.4.4 Ecological Toxicity and Risk Assessment

3.4.4.1 Plants

No information was available on d-limonene toxicity potential in plants. It was not classified as phytotoxic to terrestrial plants under registered uses.

3.4.4.2 Bees (and/or Other Insects)

According to EPA (2014c), potential risks to terrestrial invertebrates were noted due to d-limonene's use as an insecticide, but no pollinator-specific toxicity data were submitted for formal evaluation. Studies available in ECOTOX reported a topical LD₅₀ of 1695 µg/bee and a fumigation LC₅₀ of 10.4 µg/mL. Based on the LD₅₀, d-limonene could be classified as "Practically nontoxic" to bees.

3.4.4.3 Amphibians and Reptiles

According to EPA (2014c), effects to amphibians were not expected under registered uses of d-limonene. For reptiles, no adverse effects were anticipated at small-scale or lower application rates, but uncertainty remains at higher application rates (e.g., 34 and 55 lbs/A) due to limited toxicity data (EPA, 2014c). A single reptile study was available in ECOTOX, according to which a NOEL of 1% (w/w) active ingredient was noted in brown tree snakes



following a single spray dose, based on approximately five minutes of observation for movement. Additionally, per EPA (2014c), birds can be used as surrogates for terrestrial-phase amphibians and reptiles, whereas freshwater fish can be used as surrogates for aquatic-phase amphibians. d-Limonene toxicity information in birds and freshwater fish is provided in the sections below. In birds, d-limonene was considered “Practically nontoxic”, indicating that same conclusion would be applicable to terrestrial-phase amphibians and reptiles. In fish, d-limonene was considered “Slightly toxic”, indicating that a similar conclusion would be applicable to aquatic-phase amphibians.

3.4.4.4 Birds

According to EPA (2014c), adverse effects to birds were not expected from small-scale applications or lower application rates of d-limonene, although uncertainty remains at higher application rates (e.g., 34 and 55 lbs/A). Additionally, chronic risk to birds could not be fully assessed due to a lack of long-term toxicity data. Based on sub-acute dietary exposure, d-limonene was considered “Practically nontoxic” to birds with an LC₅₀ of > 5,600 ppm (EPA, 2014c).

3.4.4.5 Mammals

According to EPA (2014c), effects to mammals were not expected from small-scale applications such as aerosol sprays or crack and crevice treatments. However, acute and chronic risk were identified at high application rates (i.e., up to 55 lbs/A) used in broadcast or directed spray applications. d-Limonene was considered “Practically nontoxic” to mammals on an acute exposure basis and the chronic NOAEL in rats was determined to be 250 mg/kg/day, based on reduced body weight gain observed at the LOAEL of 500 mg/kg/day in a developmental toxicity study (EPA, 2014c).

3.4.4.6 Fish (and/or Other Aquatic Organisms)

According to EPA (2014c), effects to fish, aquatic invertebrates, and other aquatic animals were not expected under registered use conditions. An LC₅₀ of 80 mg/L was reported in rainbow trout and an EC₅₀ of 39 mg/L was reported in water flea, indicating that d-limonene was “Slightly toxic” to freshwater fish and invertebrates (EPA, 2014c).

3.4.5 Environmental Fate Assessment

Volatilization is the primary route of environmental dissipation for d-limonene, supported by its high vapor pressure (2 mmHg at 20°C) and Henry’s Law constant (2.6×10^{-2} atm-m³/mol), which enable rapid loss from soil and water surfaces (EPA, 2014c). Additional dissipation processes include runoff transport, soil sorption, aerobic microbial metabolism, and photodegradation in air. Although d-limonene strongly binds to soil ($K_{oc} > 1000$ mL/goc), reducing its mobility, volatilization remains a competing pathway. It is biodegradable under aerobic conditions with a half-life of approximately 38.5 days but is persistent under anaerobic conditions. Although its log K_{ow} (4.23–4.83) suggests potential for bioaccumulation, its bioconcentration factor (246–262) indicates low bioaccumulation potential in aquatic organisms (EPA, 2014c).

3.4.6 Conclusions and Recommendations

Based on the information reviewed for d-limonene, skin irritation and sensitization may occur in humans. In ecological receptors, no adverse effects were anticipated. If d-limonene represents the most suitable option for some applications, appropriate precautions must be taken when applying XT-2000 Insecticide to limit skin contact. Applicators should be trained to recognize and manage adverse skin reactions. Rotating with other insecticides may help minimize sensitization risk. It is also essential to review and comply with the EPA-stamped label (https://www3.epa.gov/pesticides/chem_search/ppls/071986-00002-20150219.pdf).



3.5 Disodium Octaborate Tetrahydrate (DOT)

Pesticide to control structural pests, fungus and dry rot, and termites

Formulations: Bora-Care; Tim-Bor

Typical Target Pests: Structural pests, fungus and dry rot, termites

Application: Annual application of ~5 gal over 1-5 residences via spot treatment or prevention applications. Once per year.

Human Toxicity: *Acute and Short-term Toxicity:* Category III (oral and dermal toxicity). Category II (inhalation toxicity); *Subchronic and Chronic Toxicity:* Effects at high doses; *Carcinogenicity and Genotoxicity:* No evidence; *DART:* Not expected; *Endocrine disruption:* Not expected; *Sensitization and irritation:* Category I (eye). Category IV (skin). Not classified as a skin sensitizer; *Neurotoxicity:* Not expected; *Immunotoxicity:* No information.

Ecological Toxicity: *Plants:* Not expected (terrestrial and aquatic plants); *Bees (and/or other Insects):* Not expected; *Amphibians and Reptiles:* Practically nontoxic (terrestrial-phase amphibians and reptiles). Practically nontoxic (aquatic-phase amphibians); *Birds:* Practically nontoxic; *Mammals:* Practically nontoxic; *Fish (and/or other Aquatic Organisms):* Practically nontoxic.

Environmental Fate: Highly soluble, environmentally stable, and naturally occurring, with low volatility, minimal bioaccumulation.

Conclusions and Recommendations: Adverse effects in humans may occur via inhalation or contact with eyes and skin. Adverse effects in ecological receptors are not anticipated. DOT can be added to Midpen's list of approved pesticides with appropriate precautions.

3.5.1 Background

Disodium octaborate tetrahydrate (DOT; CAS # 12280-03-4) is a sodium salt of boric acid registered with EPA for use as a broad-spectrum fungicide and insecticide in both agricultural and non-agricultural settings (EPA, 1994). It is a colorless, odorless, crystalline solid that is stable under normal environmental conditions and readily soluble in water (PubChem, 2025). Boric acid and borate salts, including DOT, are naturally occurring forms of the element boron found in rocks, soils, water, and various plants such as fruits, vegetables, and forage crops (EPA, 1994). DOT is approved for use in a wide range of environments, including non-food aquatic systems, agricultural and non-agricultural lands, residential areas (both indoor and outdoor), medical

facilities, and industrial sites such as distribution centers (EPA, 1994). As an insecticide, DOT functions primarily through a stop-feed mode of actions, disrupting the enzymatic and digestive systems of insects, thereby preventing nutrient absorption and leading to starvation and death (Cloutier et al., 2018; EPA, 1994). It also exhibits abrasive properties that damage the insect exoskeleton (EPA, 2014h). Target organisms include decay fungi (e.g., brown rot, white rot), wood rot fungi, ants, cockroaches, fleas, house flies, soldier flies, latrine flies, silverfish, termites, and wood-boring insects (EPA, 1994).

DOT is registered in multiple formulations, including soluble concentrates (liquid and solid) and solid products (EPA, 1994). EPA lists 109 active and approved formulations containing 10%-23% DOT (ready-to-use or diluted for application; e.g., Bora-Care) or 98%-99% DOT (powdered formulations applied as dusts or mixed with water for liquid application; e.g., Tim-Bor)

(https://ordspub.epa.gov/ords/pesticides/f?p=113:6:::P6_X_CHEMICAL_ID:1583).

3.5.2 Exposure Considerations

According to the DOT product label, exposure to dust or spray mist may cause mild respiratory irritation during mixing, loading, or application of powder or dust formulations. DOT eye contact may cause moderate to serious eye irritation. Although DOT is poorly absorbed through intact skin and is generally not a skin irritant, direct skin contact should be minimized. DOT is harmful if swallowed, with gastrointestinal symptoms possible following accidental ingestion. Handlers and applicators should use long pants, long-sleeved shirt, socks and shoes, waterproof gloves, safety glasses, and respiratory protection.

Midpen's annual application of DOT (Bora-Care or Tim-Bor) is estimated at 5 gal over 1-5 residences, once per year. The method of application is noted as spot treatment and prevention.

3.5.3 Human Toxicity and Risk Assessment

Note: According to EPA (1994), the toxicity of boric acid and its sodium salts, including DOT, is expected to be similar.

3.5.3.1 Acute and Short-term Toxicity

EPA classified boric acid—a surrogate for DOT—as Category III for acute oral and dermal toxicity (EPA, 1994). The acute oral LD₅₀s were 3450 mg/kg in male mice, 4080 mg/kg in female mice, and 2660-5140 mg/kg in rats (EPA, 1994; Harper et al., 2012). The dermal LD₅₀ was > 2000



mg/kg in rabbits. Inhalation toxicity studies were limited; however, one study reported an inhalation LC₅₀ of > 0.16 mg/L with no mortality observed (EPA, 1993; Harper et al., 2012). Based on the LC₅₀, DOT could be classified as Category II for acute inhalation toxicity.

3.5.3.2 Subchronic and Chronic Toxicity

Subchronic and chronic toxicity studies of boric acid and sodium tetraborate decahydrate (borax)—used as categorical read-across surrogates for DOT—consistently identified testicular effects and systemic changes in animals at high doses. In a three-month feeding study in dogs, borax was administered at up to 268 mg/kg/day (males) and 192 mg/kg/day (females) (EPA, 1994). The systemic NOELs were 35 mg/kg/day (males) and 22 mg/kg/day (females) with LOELs based on hematological changes, organ pathology, and testicular effects (EPA, 1994).

For chronic exposure in humans, workers at a borax processing plant experienced temporary respiratory irritation at exposures ≥ 4.5 mg/m³, but no long-term respiratory effects were observed (Harper et al., 2012). Chronic oral exposure to boric acid was associated with gastrointestinal and neurological symptoms and severe cases led to organ dysfunction and death, particularly in infants (Harper et al., 2012).

Chronic toxicity studies in animals consistently identified testicular effects and systemic changes at high doses (EPA, 1994; Harper et al., 2012). In a two-year study in beagle dogs, borax had a NOEL of 77 mg/kg/day with testicular atrophy and reduced testicular weight observed at higher doses. Chronic oral studies in rats exposed to borax at up to 515 mg/kg/day revealed a NOEL of 154 mg/kg/day and a LOEL of 515 mg/kg/day with effects including reduced body weight, anemia, and testicular tubular atrophy (EPA, 1994; Harper et al., 2012).

In B6C3F1 mice, boric acid administered at up to 5000 ppm (approximately 1150 mg/kg/day) in feed caused testicular atrophy and interstitial cell hyperplasia, along with splenic lymphoid depletion and pulmonary hemorrhage (EPA, 1994). The LOEL for systemic toxicity was 2500 ppm (approximately 450 mg/kg/day) (EPA, 1994). A lifetime exposure study in mice receiving 0.95 mg boron/kg/day as sodium metaborate showed no changes in body weight or lifespan (Harper et al., 2012).

3.5.3.3 Carcinogenicity and Genotoxicity

The U.S. EPA Office of Prevention, Pesticides and Toxic Substances classified boric acid and its sodium salts, such as DOT, as non-carcinogenic to humans (Group E carcinogen) (EPA, 1994). This classification was supported by chronic feeding and oncogenicity studies in rodents

(EPA, 1994; Harper et al., 2012). In a two-year study in rats, dietary administration of borax at 0, 65, 154, or 515 mg/kg/day resulted in no observed carcinogenic effects (EPA, 1994; Harper et al., 2012). Similarly, in a two-year study in B6C3F1 mice receiving boric acid at dietary levels of 0, 2500, or 5000 ppm in feed (approximately 0, 450, or 1150 mg/kg/day), no evidence of carcinogenicity was observed at any dose tested (EPA, 1994). Furthermore, based on multiple studies, including a bacterial reverse mutation assay, *in vitro* and *in vivo* chromosomal aberration assays, and micronucleus assays, there was no evidence of mutagenicity or genotoxicity for boric acid, borax, or DOT (EPA, 1993).

3.5.3.4 Developmental and Reproductive Toxicity

The reproductive and developmental toxicity of boric acid and sodium tetraborate decahydrate (borax) was extensively studied in animals, including rats, mice, dogs, and rabbits (Harper et al., 2012). In repeated dose toxicity studies in which reproductive effects were reported, testicular atrophy and spermatogenic arrest were observed in dogs at a dose of 29.2 mg boron/kg/day for up to 38 weeks and in rats at 17.5 mg boron/kg/day for 90 days (EPA, 2004). Male mice exposed to boric acid for 27 weeks showed degeneration of seminiferous tubules, reduced sperm motility, and decreased litter size, with similar effects noted at 288 mg boron/kg/day over 13 weeks (Harper et al., 2012).

In a developmental toxicity studies in rat dams administered the test substance from GD 0 to GD 20, decreased fetal body weights at 78 mg boric acid/kg/day (13.6 mg boron/kg-day) and skeletal malformations at higher doses were reported (EPA, 2004; Harper et al., 2012). Additionally, maternal treatment-related effects included a statistically significant and dose-related increase in relative liver and kidney weights and absolute kidney weight at 163 mg boric acid/kg/day, as well as a significant decrease in body-weight gain at 330 mg boric acid/kg/day (EPA, 2004). Therefore, the maternal NOAEL and developmental LOAEL were defined as of 78 mg boric acid/kg/day; a developmental NOAEL was not reported (EPA, 2004). In a mouse study with the same experimental design as the aforementioned rat study, mice were less sensitive in developmental toxicity studies, with a NOAEL of 248 mg boric acid/kg/day (43.4 mg boron/kg/day) and a LOAEL of 452 mg boric acid/kg/day (79 mg boron/kg/day) on the basis of decreased average fetal body weight and an increase in the percentage of malformed fetuses per litter (EPA, 2004). In rabbits, fetal malformations were observed at 250 mg boric acid/kg/day (43.7 mg boron/kg/day), with a NOAEL of 125 mg/kg/day (21.9 mg boron/kg/day) (Harper et al., 2012).



In humans, data from occupational exposures, poisonings, and epidemiological studies did not provide conclusive evidence of reproductive or developmental toxicity (Harper et al., 2012). Under anticipated exposure scenarios, boric acid and its salts were not expected to exhibit biologically significant reproductive or developmental effects in humans (Harper et al., 2012).

3.5.3.5 Endocrine Disruption

Boric acid, borate salts, and elemental boron were not studied for endocrine disruption potential in humans, and these substances did not appear on EPA's EDSP list of compounds undergoing evaluation (Harper et al., 2012). Mechanistic data on boron-related endocrine activity was limited, and the absence of screening designation and human data suggested that boric acid and its salts were not expected to exhibit biologically significant endocrine-disrupting effects under anticipated exposure scenarios (Harper et al., 2012).

3.5.3.6 Sensitization and Irritation

According to EPA (1994), boric acid was classified as Category III for eye irritation; however, borax was considered corrosive and highly toxic to the eye and was classified as Category I. In the absence of information on DOT-specific eye irritation potential, DOT was assumed to be Category I for eye irritation. For skin irritation, borax was classified as Category IV, although mild redness or inflammation could occur with prolonged exposure (Harper et al., 2012). DOT was not classified as a skin sensitizer (EPA, 1994).

3.5.3.7 Neurotoxicity

There was insufficient empirical evidence to assess the neurotoxicity of DOT or related borate compounds. However, clinical observations from chronic oral exposure to boric acid in humans documented neurological symptoms, including headache, fever, tremors, twitching, lethargy, and weakness (Harper et al., 2012). In severe poisoning cases, coma and seizures were reported with infants being more susceptible to seizures and fatal outcomes than adults. No biologically significant neurotoxic effects were reported under anticipated exposure conditions (Harper et al., 2012).

3.5.3.8 Immunotoxicity

Limited information was available on immunotoxicity potential of DOT. According to EPA (1994), in a two-year chronic feeding and oncogenicity study, mice were administered boric acid at dietary levels of 0, 2500, or 5000 ppm (approximately 0, 450, or 1150 mg/kg/day). A dose-

related increase in splenic lymphoid depletion was observed in male mice at both dose levels. This effect was considered to be associated with stress rather than direct immunotoxicity. The biological significance of this finding was unclear (EPA, 1994).

3.5.4 Ecological Toxicity and Risk Assessment

Note: According to EPA (1993), boric acid and its sodium salts, including DOT, are considered to pose low ecological risk due to their natural occurrence and essential role in biological systems.

3.5.4.1 Plants

Boric acid, borate salts, and elemental boron are essential micronutrients for plant growth, but excessive concentrations can lead to phytotoxicity. According to EPA (1994), boron salts may adversely affect seed germination, seedling emergence, and vegetative vigor, particularly in sensitive crops such as citrus and stone fruits. Studies show that plants primarily absorb boron as undissociated boric acid (Harper et al., 2012). At low soil concentrations, uptake is active; at higher concentrations, passive diffusion predominates. Once absorbed, boron is transported to the leaves, where it accumulates due to evaporation. Because boron is largely immobile in the phloem, redistribution to other tissues such as stems and fruits is limited. Most vegetables are tolerant of elevated boron levels, while tuber and cereal crops are semi-tolerant, and citrus, stone fruits, and nut trees are highly sensitive. In aquatic environments, boron-containing compounds can affect aquatic plant species such as *S. capricornutum*, *L. gibba*, *S. costatum*, *A. flos-aquae*, and *N. pelliculosa*. Although boron is naturally present in low concentrations in most unpolluted waterways, elevated levels may lead to uptake in some organisms (Harper et al., 2012). Under typical environmental conditions, plants generally do not concentrate boron to toxic levels (EPA, 1994).

3.5.4.2 Bees (and/or Other Insects)

According to EPA (1994), no risks were anticipated to beneficial insects from boric acid use, particularly because most applications were limited to indoor environments with outdoor uses being infrequent. In a study reviewed by EPA, the acute contact LD₅₀ for honeybees was >362.58 ppm, indicating low toxicity (EPA, 1994).

3.5.4.3 Amphibians and Reptiles

No information was available on DOT toxicity potential in amphibians or reptiles. Per EPA (1994), birds can be used



as surrogates for terrestrial-phase amphibians and reptiles, whereas freshwater fish can be used as surrogates for aquatic-phase amphibians. DOT toxicity information in birds and freshwater fish is provided in the sections below. In birds, DOT was considered “Practically nontoxic”, indicating that same conclusion would be applicable to terrestrial-phase amphibians and reptiles. In fish, DOT was considered “Practically nontoxic”, indicating that a similar conclusion would be applicable to aquatic-phase amphibians.

3.5.4.4 Birds

According to EPA (1994), no adverse impacts in avian species were anticipated due to outdoor use patterns of boric acid, and no field mortalities associated with boric acid use were documented. In acute oral toxicity studies on boric acid, the LD₅₀ for bobwhite quail was > 2510 mg/kg. In eight-day dietary studies on boric acid, the LC₅₀ values were > 5620 ppm for mallard duck and >10,000 ppm for bobwhite quail (EPA, 1994). Based on these LD₅₀ and LC₅₀ values, boric acid, and likely DOT, could be classified as “Practically nontoxic” to birds.

3.5.4.5 Mammals

According to EPA (1994), the oral LD₅₀ values for boric acid ranged from 2660 to 5140 mg/kg in rats. Based on these LD₅₀s, boric acid, and likely DOT, could be classified as “Practically nontoxic”. Adverse impacts on mammalian wildlife populations were not expected under typical environmental exposure scenarios (EPA, 1994; Harper et al., 2012).

3.5.4.6 Fish (and/or Other Aquatic Organisms)

According to EPA (1994), boric acid was “Practically nontoxic” to freshwater fish and crustaceans, with LC₅₀ values of > 1100 and > 1021 mg/L reported in rainbow trout and bluegill sunfish, as well as EC₅₀ values of 133 to 226 mg/L noted in water flea *D. magna*. The Agency concluded that the risk to aquatic organisms from outdoor use patterns of boric acid compounds was minimal due to low toxicity, infrequent use, and the natural occurrence of boron in surface waters (EPA, 1994).

3.5.5 Environmental Fate Assessment

DOT, like other boron-containing salts, is highly soluble in water and, in dilute aqueous solutions, boron exists predominantly as undissociated boric acid (B(OH)₃) (EPA, 1994). DOT is stable in water and does not readily volatilize, indicating low potential for atmospheric transport. Boron salts, including DOT, occur naturally and are widely distributed in soil and water with boron concentrations in surface soils averaging around 50 ppm, in fresh surface waters ranging from 0.001 to 0.1 mg/L, and in seawater typically 4-5 mg/L. DOT and related boron salts are not expected to bioaccumulate significantly. Although some uptake into tissues may occur at elevated concentrations, plants generally do not concentrate boron. DOT is not expected to undergo direct photolysis or hydrolysis in soil, water, or air. Weathering of boron minerals may gradually release borates into the environment. Fractionation between dissolved and suspended solids has been observed with the soluble fraction being environmentally relevant. Overall, DOT is considered environmentally stable with low volatility and minimal ecological accumulation under typical use conditions (EPA, 1994).

3.5.6 Conclusions and Recommendations

Based on the information reviewed, adverse effects of DOT in humans may occur via inhalation or contact with eyes. No adverse effects in ecological receptors were anticipated. If DOT represents the most suitable option for some applications, appropriate precautions must be taken when applying Bora-Care or Tim-Bor to limit inhalation and contact with eyes. These may include use of appropriate PPE, adequate ventilation, minimizing dust generation, and conducting periodic health surveillance for applicators. It is also essential to review and comply with the EPA-stamped labels (Bora-Care:

https://www3.epa.gov/pesticides/chem_search/ppls/064405-00001-20250924.pdf; Tim-Bor: https://labelsds.com/images/user_uploads/Tim-bor%20Label%204-1-20.pdf).



4 Disinfectants

Four disinfectants (sodium dichloroisocyanurate dihydrate, sodium hypochlorite, isopropyl alcohol / ethanol, DDAC) were evaluated in this report. Their toxicity in humans and ecological receptors is summarized in

Table 16 and **Table 17**, respectively. Overall, the disinfectants were found to have low acute and chronic toxicity to humans at labeled use rates, though some (notably sodium dichloroisocyanurate dihydrate and DDAC) can cause eye and skin irritation and are highly toxic to aquatic organisms. Environmental persistence is generally low for alcohols and hypochlorite, but DDAC is persistent and not readily degradable. Risks to ecological receptors are minimal with proper use and mitigation, but aquatic toxicity warrants precautions to prevent or minimize environmental release.

On the basis of this review, of the four disinfectants, isopropyl alcohol / ethanol offers the lowest hazard profile when considering hazard potential in humans and ecological receptors. The hazard profiles of the other, particularly DDAC, showed potential for hazard in humans and some ecological receptors; however, given their application to disinfect equipment, exposure to these pesticides is expected to be minimal in humans and in most ecological receptors. Notably, sodium dichloroisocyanurate dihydrate is also noted as a disinfectant for water bodies, and given its toxicity potential in aquatic species, appropriate precautions should be considered during application. In deciding which disinfectant to incorporate into their IPM, Midpen should consider specific target species, application methods, and label requirements. Because the four disinfectants vary in their hazard potential, care should be taken in selecting and applying the chosen disinfectant(s) considering these factors.

Table 16. Human Toxicity Summary of Disinfectants

Endpoint	Sodium Dichloroisocyanurate Dihydrate	Sodium Hypochlorite	Isopropyl Alcohol	Ethanol	DDAC
Acute Toxicity (Oral)	Category III	Category IV	Category III	Category IV	Category II
Acute Toxicity (Dermal)	Category IV	Category IV	Category IV	Category IV	Category III
Acute Toxicity (Inhalation)	Category II	Category IV	Category IV	Category IV	Category II
Subchronic and chronic toxicity	Effects at high doses (oral). Toxic via inhalation	No subchronic or chronic toxicity studies needed. No consequence to human health at low levels	No effects (dermal exposure). Some effects at high concentrations/doses (inhalation/oral exposure)	Minor effects after prolonged dermal exposure. No effects (inhalation exposure). Some effects at high doses (oral exposure)	Relatively low toxicity, with some effects noted at doses higher than would be anticipated from typical DDAC use as a disinfectant
Carcinogenicity and Genotoxicity	No evidence	No evidence	No evidence	Class I carcinogen (alcoholic beverages). Not definitive carcinogen (disinfectants). Not mutagenic/genotoxic	No evidence
Developmental and Reproductive Toxicity	Not expected	No evidence	Not expected from registered uses	Not expected from registered uses	No unique reproductive toxicity risk and no evidence of increased susceptibility in offspring
Endocrine Disruption	No information. Not on EPA's priority list for EDSP	No information. Not on EPA's priority list for EDSP	No information. Included on EPA's priority list tier 1 for EDSP	Insufficient data. Not on EPA's priority list for EDSP	No information. Included on EPA's priority list tier 1 for EDSP
Irritation (Eye)	Category I	Category I	Category III or IV	Category IV	Category I
Irritation (Skin)	Category IV	Category I	Category IV	Category IV	Category I
Sensitization	Not a skin sensitizer	Not a skin sensitizer	Not considered a skin sensitizer	Not considered a skin sensitizer	Not a skin sensitizer
Neurotoxicity	No information	No information	Not considered a neurotoxicant under typical exposure conditions	Not expected under typical use conditions	Not considered a neurotoxicant



Toxicological Assessment of Pesticides

4 Disinfectants

Endpoint	Sodium Dichloroisocyanurate Dihydrate	Sodium Hypochlorite	Isopropyl Alcohol	Ethanol	DDAC
Immunotoxicity	No information	No evidence	No evidence	No evidence	No biologically significant effects reported under typical exposure conditions

Table 17. *Ecotoxicity Summary of Disinfectants*

Ecological Receptor	Sodium Dichloroisocyanurate Dihydrate	Sodium Hypochlorite	Isopropyl Alcohol	Ethanol	DDAC
Plants	No information (terrestrial plants). Highly toxic (aquatic plants)	Not expected based on use	Not expected based on use	Not expected based on use	Low toxicity in terrestrial plants. Toxic to aquatic plants, but findings not relevant to DDAC use as a disinfectant for equipment
Bees (and/or Other Insects)	No information. Exposure unlikely	Not expected based on use	Not expected based on use	Not expected based on use	Practically nontoxic
Amphibians and Reptiles	Slightly toxic or practically nontoxic (terrestrial-phase amphibians and reptiles). Moderately or highly toxic (aquatic-phase amphibians)	Not expected based on use	Not expected based on use	Not expected based on use	Moderately toxic to practically nontoxic (terrestrial-phase amphibians and reptiles). Moderately to very highly toxic (aquatic-phase amphibians)
Birds	Slightly toxic or practically nontoxic	Practically nontoxic	Not expected based on use	Not expected based on use	Moderately toxic to practically nontoxic
Mammals	Slightly toxic or practically nontoxic	Slightly toxic	Practically nontoxic	Practically nontoxic	Moderately toxic
Fish (and/or Other Aquatic Organisms)	Moderately or highly toxic	Highly toxic. No risks anticipated based on use and mitigation	Practically nontoxic	Practically nontoxic	Moderately to very highly toxic



4.1 Sodium Dichloroisocyanurate Dihydrate

Pesticide to disinfect equipment, water bodies, and surfaces

Formulations: Granular Chlorine Bleach (Leslies Chlor Brite, EZ Chlor)

Typical Target Pests: Various microorganisms

Application: Annual application ~5 kg via spot spray or addition to water.

Human Toxicity: *Acute and Short-term Toxicity:* Category III (oral toxicity). Category IV (dermal toxicity). Category II (inhalation toxicity); *Subchronic and Chronic Toxicity:* Effects at high doses (oral). Toxic via inhalation; *Carcinogenicity and Genotoxicity:* No evidence; *DART:* Not expected; *Endocrine disruption:* No information. Not on EPA's priority list for EDSP; *Sensitization and irritation:* Category I (eye). Category IV (skin). Not a skin sensitizer; *Neurotoxicity:* No information; *Immunotoxicity:* No information.

Ecological Toxicity: *Plants:* No information (terrestrial plants). Highly toxic (aquatic plants); *Bees (and/or other Insects):* No information. Exposure unlikely; *Amphibians and Reptiles:* Slightly toxic or practically nontoxic (terrestrial-phase amphibians and reptiles). Moderately or highly toxic (aquatic-phase amphibians); *Birds:* Slightly toxic or practically nontoxic; *Mammals:* Slightly toxic or practically nontoxic; *Fish (and/or other Aquatic Organisms):* Moderately or highly toxic.

Environmental Fate: Not expected to persist or accumulate significantly in the environment.

Conclusions and Recommendations: Adverse effects in humans may occur via inhalation or contact with eyes and skin. Adverse effects in aquatic plants and aquatic organisms may occur. Sodium dichloroisocyanurate dihydrate can be added to Midpen's list of approved pesticides with appropriate precautions.

4.1.1 Background

Sodium dichloroisocyanurate dihydrate (CAS # 51580-86-0), also known as sodium dichloro-s-triazinetrione dihydrate, is a white crystalline solid that is stable and relatively inert when dry (EPA, 2019a). Sodium dichloroisocyanurate dihydrate is a chlorinated isocyanurate and can be used as a disinfectant, sanitizer, virucide, microbiocide, bactericide, fungicide, and algicide in various sites, including institutional, commercial, industrial, residential, food processing, agricultural, and animal facilities (EPA, 2019a, 2019d). When dissolved in water, sodium dichloroisocyanurate dihydrate is hydrolyzed, forming a

mixture of chlorinated and non-chlorinated isocyanurates, with hypochlorous acid being the key antimicrobial agent released (FAO, 2004).

At the time of the 2013 Chlorinated Isocyanurates Registration Review Final Work Plan from EPA, there were 122 registered products containing the active ingredient sodium dichloroisocyanurate dihydrate at concentrations ranging from 1% to 100% (EPA, 2019a). The products are available in a variety of formulation types, including granules, soluble powder, dust, water soluble packaging, and tablets/pellets.

4.1.2 Exposure Considerations

The maximum application rate of sodium dichloroisocyanurate dihydrate as an active ingredient is 5953 ppm (expressed in available chlorine) for use as a sanitizer and disinfectant at institutional, commercial, industrial, residential, food processing, and agricultural facilities (EPA, 2019d). The maximum application rate of sodium dichloroisocyanurate dihydrate as an active ingredient is 105 ppm (expressed in available chlorine) for use in egg washing/sanitizing and 89 ppm (expressed in available chlorine) in animal drinking water (EPA, 2019d). According to various labels, chlorinated isocyanurates can be applied using open pour and closed systems, sprayers, foamers, mops, wipes, immersion, and fogging (EPA, 2019a). When used as a sanitizer on food contact surfaces, the final use concentration cannot exceed 100 ppm based on total available chlorine, according to the tolerance exemption (EPA, 2019a).

Midpen's annual application of sodium dichloroisocyanurate dihydrate is estimated at 5 kg for disinfecting equipment, water bodies, and surfaces. The method of application is noted as spot spray/water additive. The exact formulation proposed for use is specified as Granular Chlorine Bleach (Leslies Chlor Brite, EZ Chlor).

4.1.3 Human Toxicity and Risk Assessment

4.1.3.1 Acute and Short-term Toxicity

According to EPA (2015b), the oral and dermal toxicity of sodium dichloroisocyanurate dihydrate was low, whereas its inhalation toxicity was high. Specifically, oral LD₅₀ values of 1671 and 2094 mg/kg were reported in female and male rats, respectively, which would classify sodium dichloroisocyanurate dihydrate as Category III for oral toxicity. The dermal LD₅₀ for sodium dichloroisocyanurate dihydrate was > 5000 mg/kg in rats, which would classify it as Category IV for dermal toxicity. No inhalation LC₅₀ was noted by EPA for sodium dichloroisocyanurate dihydrate,



but an LC₅₀ of > 0.27 mg/L and < 1.17 mg/L was noted for sodium dichloroisocyanurate (i.e., anhydrous form). Thus, sodium dichloroisocyanurate dihydrate would be classified as Category II for inhalation toxicity (EPA, 2015b). The categories for oral, dermal, and inhalation toxicity were not specified by EPA, rather they were derived based on the LD₅₀ and LC₅₀ values noted by EPA (2015b).

4.1.3.2 Subchronic and Chronic Toxicity

According to EPA (2015b), the available repeated dose toxicity studies on sodium dichloroisocyanurate dihydrate and a supporting chemical sodium cyanurate indicated that adverse effects (e.g., mortality, clinical signs, decreased

body weight, hyperplasia) in rats and mice typically occurred at the higher doses tested following exposures via drinking water; in these studies the NOAELs ranged from 97 to 2201 mg/kg (**Table 18**). No repeated dose inhalation studies were identified for sodium dichloroisocyanurate dihydrate; however, a 28-day inhalation study on trichloroisocyanurate (a supporting chemical) reported rales, nasal discharge, salivation, lacrimation, and labored breathing in rats exposed to concentration of 0.01 and 0.03 mg/L. Thus, the NOAEC was noted as 0.001 mg/L (**Table 18**). These studies suggested that sodium dichloroisocyanurate dihydrate displayed minimal toxicity via the oral route, except at high concentrations, but may be potentially toxic at some concentrations via inhalation.

Table 18. Subchronic and Chronic Toxicity of Sodium Dichloroisocyanurate Dihydrate and Supporting Chemicals

Chemical	Species (Sex)	Route	Duration	Doses/ Concentrations	Findings	Toxicity Thresholds
Sodium dichloroisocyanurate dihydrate	Rats (M/F)	Oral	59 days	0, 100, 300, 1000, 2000 mg/kg	Mortality and clinical signs at ≥ 1000 mg/kg; decreased body weight at ≥ 1000 mg/kg	• NOAEL = 300 mg/kg • LOAEL = 1000 mg/kg
Sodium cyanurate (supporting)	Rats (M/F)	Oral	59 days	0, 62, 187, 311, 622 (M); 0, 68, 203, 339, 677 (F) mg/kg	No mortality or clinical signs; decreased urea nitrogen; no treatment-related pathology	• NOAEL = 622/677 mg/kg (M/F)
Sodium cyanurate (supporting)	Mice (M/F)	Oral	13 weeks	0, 252, 522, 1994 (M); 0, 298, 610, 2201 (F) mg/kg	Bladder calculi, hyperplasia, congestion/hemorrhage in males at high dose	• NOAEL = 522/2201 mg/kg (M/F) • LOAEL = 1994 mg/kg (M)
Sodium cyanurate (supporting)	Rats (M/F)	Oral	13 weeks	0, 101, 214, 710 (M); 0, 130, 265, 870 (F) mg/kg	Bladder epithelium hyperplasia in males	• NOAEL = 101/870 mg/kg (M/F) • LOAEL = 214 mg/kg (M)
Sodium cyanurate (supporting)	Mice (M/F)	Oral	104 weeks	0, 24, 97, 307, 1523 (M); 0, 26, 100, 315, 1582 (F) mg/kg-bw/day	Swollen/enlarged abdomens, rough hair coat, increased urine sodium	• NOAEL = 97/100 mg/kg (M/F) • LOAEL = 307/315 mg/kg (M/F)
Sodium cyanurate (supporting)	Rats (M/F)	Oral	104 weeks	0, 25, 76, 154, 371 (M); 0, 42, 129, 266, 634 (F) mg/kg-bw/day	Urinary tract lesions, heart lesions, urolithiasis, splenic hemosiderosis in high-dose males	• NOAEL = 154/266 mg/kg (M/F) • LOAEL = 371/634 mg/kg (M/F)
Trichloroisocyanurate (supporting)	Rats (M/F)	Inhalation	28 days (6 h/day, 5 day/week)	0.003, 0.010, 0.030 mg/L	Rales, nasal discharge, salivation, lacrimation, labored breathing at mid/high doses	• NOAEC = 0.003 mg/L • LOAEC = not set

Source: (EPA, 2015b)

4.1.3.3 Carcinogenicity and Genotoxicity

Based on the studies for supporting chemicals reviewed by EPA, there was no evidence that sodium dichloroisocyanurate dihydrate was carcinogenic or genotoxic (EPA, 2015b). It was noted that sodium cyanurate

did not increase the incidence of tumors in rats or mice in two 104-week studies. Sodium dichloroisocyanurate was not mutagenic in *S. typhimurium*, whereas sodium cyanurate was not mutagenic in *S. typhimurium* or mouse lymphoma cells and did not induce chromosomal aberrations in rats (EPA, 2015b).



4.1.3.4 Developmental and Reproductive Toxicity

Based on the studies for supporting chemicals reviewed by EPA, sodium dichloroisocyanurate dihydrate was not expected to be a reproductive or developmental toxicant (EPA, 2015b). In a three-generation drinking water reproductive toxicity study in rats, sodium cyanurate, did not adversely affect reproduction and the NOAELs were 614/730 (male/female) mg/kg, the highest doses tested. In a prenatal developmental toxicity study in rats exposed to sodium cyanurate via oral gavage, no maternal toxicity or developmental effects were observed and the NOAEL for maternal and developmental toxicity was 5000 mg/kg (the highest dose tested). In a similar study in rabbits, no adverse effects were observed in does, and the NOAEL for maternal toxicity was 500 mg/kg; furthermore, post-implantation losses and hydrocephaly were noted at 500 mg/kg, and the NOAEL for developmental toxicity was 200 mg/kg. However, EPA (2015b) noted that hydrocephaly is not uncommon for the rabbit strain tested, and that the mean post-implantation loss was within the range of historical control data.

4.1.3.5 Endocrine Disruption

No information was available on the endocrine disruption potential of sodium dichloroisocyanurate dihydrate. This chemical was not on EPA's priority lists for EDSP tier 1 (<https://www.regulations.gov/document/EPA-HQ-OPPT-2004-0109-0080>) or tier 2 (<https://www.regulations.gov/document/EPA-HQ-OPPT-2009-0477-0074>) screening. Sodium dichloroisocyanurate dihydrate was not classified as an endocrine disruptor and did not appear on the Endocrine Society's list of chemicals with known endocrine-disrupting activity or on the ECHA Endocrine Disruptor Assessment List (ECHA, 2025a; Endocrine Society, 2025).

4.1.3.6 Sensitization and Irritation

According to EPA (2015b), sodium dichloroisocyanurate dihydrate was not a skin sensitizer because no sensitizing reactions were observed in a guideline study in guinea pig. Severe eye irritation involving the cornea, iris, and conjunctivae was observed in all rabbits administered 0.5 g sodium dichloroisocyanurate dihydrate into the conjunctival sac. On day 7, the corneas of all rabbits were not observable due to the nictitating membrane that was adhered to the cornea; in some rabbits, the cornea appeared to be ruptured. Skin irritation was noted following application of 0.5 g sodium dichloroisocyanurate dihydrate onto an unspecified area of skin in rabbits for 24 hours. It was noted that very slight to moderate erythema and very slight to slight edema were observed at 30-60 minutes after

dosing; however, all sites had cleared at 96 hours. Other dermal effects included thickening, blanching, necrosis, epidermal scaling, raw areas, and dichloroisocyanurate dihydrate adhering to the skin. All irritation cleared by 21 days (EPA, 2015b). EPA did not assign categories for eye and skin irritation; however, based on the studies described, sodium dichloroisocyanurate dihydrate could be classified as Category I and Category IV for eye and skin irritation, respectively.

4.1.3.7 Neurotoxicity

No information was available on the neurotoxicity potential of sodium dichloroisocyanurate dihydrate.

4.1.3.8 Immunotoxicity

No information was available on the immunotoxicity potential of sodium dichloroisocyanurate dihydrate.

4.1.4 Ecological Toxicity and Risk Assessment

4.1.4.1 Plants

No information was available on sodium dichloroisocyanurate dihydrate toxicity potential in terrestrial plants. According to EPA (2015b), a 96-hour EC₅₀ of 0.60 mg/L was noted for green algae (*P. subcapitata*) exposed to sodium dichloroisocyanurate dihydrate at nominal concentrations of 0, 0.06, 0.13, 0.25, 0.50, or 1.0 mg/L for 96 hours. Based on this EC₅₀, sodium dichloroisocyanurate dihydrate would be considered "Highly toxic" to aquatic plants.

4.1.4.2 Bees (and/or Other Insects)

No studies were identified that assessed sodium dichloroisocyanurate dihydrate toxicity in bees or other insects. According to EPA (2019a), exposure to insects was unlikely based on the fate of the chlorinated isocyanurates and their degradants.

4.1.4.3 Amphibians and Reptiles

No studies were identified that assessed sodium dichloroisocyanurate dihydrate toxicity in amphibians and reptiles. According to EPA (2019a), birds can be used as surrogates for terrestrial-phase amphibians and reptiles, whereas freshwater fish can be used as surrogates for aquatic-phase amphibians. As detailed in sections below, sodium dichloroisocyanurate dihydrate was classified as "Slightly toxic" or "Practically nontoxic" to birds and



“Moderately or Highly toxic” to fish, suggesting that it could be considered “Slightly toxic” or “Practically nontoxic” to terrestrial-phase amphibians and reptiles and “Moderately or Highly toxic” to aquatic-phase amphibians.

4.1.4.4 Birds

According to EPA (2019a), sodium dichloroisocyanurate dihydrate was “Slightly toxic” or “Practically nontoxic” to birds. An LD₅₀ of 1766 mg/kg (northern bobwhite) and LC₅₀ of > 5000 ppm (northern bobwhite and mallard) were reported for sodium dichloroisocyanurate dihydrate (EPA, 2019a).

4.1.4.5 Mammals

According to EPA (2015b), oral LD₅₀ values of 1671 and 2094 mg/kg were reported for sodium dichloroisocyanurate dihydrate in female and male rats, respectively. Based on these values, sodium dichloroisocyanurate dihydrate would be classified as “Slightly toxic” or “Practically nontoxic” to mammals.

4.1.4.6 Fish (and/or Other Aquatic Organisms)

According to EPA (2019a), sodium dichloroisocyanurate dihydrate was “Moderately or Highly toxic” to fish and “Highly toxic” to aquatic invertebrates. In fish, the LC₅₀ values ranged from 0.25 to 1.72 mg/L, whereas in water flea an EC₅₀ of 0.28 mg/L was noted (EPA, 2019a).

4.1.5 Environmental Fate Assessment

According to EPA (2015b), sodium dichloroisocyanurate is expected to have high mobility in soil, and volatilization is expected to be low; however, the rapid rate of hydrolysis indicates that volatilization, mobility in soil, and biodegradation are not important environmental fate processes. Although its rate of atmospheric photooxidation is slow, sodium dichloroisocyanurate will likely react with moisture in the atmosphere. Thus, sodium dichloroisocyanurate is expected to have low persistence and low bioaccumulation potential (EPA, 2015b). Additionally, the Agency noted that chlorinated isocyanurates (including sodium dichloroisocyanurate dihydrate) are not persistent and rapidly degrade to cyanurate/isocyanurate and hypochlorous acid (EPA, 2019a). Both chlorinated isocyanurates and cyanurate/isocyanurate are highly water-soluble and weakly sorb to sludge, soil, and sediment. Cyanuric acid breaks

down to carbon dioxide and ammonia, which can be released into air or incorporated into microbial biomass (EPA, 2019a).

4.1.6 Conclusions and Recommendations

Based on the information reviewed, adverse effects of sodium dichloroisocyanurate dihydrate in humans may occur via inhalation or contact with eyes and skin. Additionally, adverse effects in aquatic plants and aquatic organisms may occur, which is relevant for Midpen’s anticipated use of sodium dichloroisocyanurate dihydrate as a disinfectant of water bodies. If sodium dichloroisocyanurate dihydrate represents the most suitable option for some applications, appropriate precautions must be taken when applying sodium dichloroisocyanurate dihydrate as a disinfectant, particularly if applying to water bodies. These include use of appropriate PPE, monitoring treated water for residual chlorine, and limiting use in natural water bodies where feasible. It is also essential to review and comply with the EPA-stamped labels (Leslie’s Chlor Brite: https://www3.epa.gov/pesticides/chem_search/ppls/011411-00015-20130708.pdf; EZ Clor Granular Chlorine Bleach: https://www3.epa.gov/pesticides/chem_search/ppls/008791-00007-19770118.pdf).



4.2 Sodium Hypochlorite

Pesticide to disinfect equipment

Formulation: Liquid Bleach (Clorox)

Typical Target Pests: Various microorganisms and biofilms

Application: Annual application ~16 gal via spot spray.

Human Toxicity: *Acute and Short-term Toxicity:*

Category IV (oral, dermal, and inhalation toxicity);

Subchronic and Chronic Toxicity: No subchronic or chronic toxicity studies needed. No consequence to human health at low levels; *Carcinogenicity and*

Genotoxicity: No evidence; *DART:* No evidence;

Endocrine disruption: No information. Not on EPA's priority list for EDSP; *Sensitization and irritation:*

Category I (eye and skin). Not a skin sensitizer;

Neurotoxicity: No information; *Immunotoxicity:* No

evidence.

Ecological Toxicity: *Plants:* Not expected based on

use; *Bees (and/or other Insects):* Not expected based on

use; *Amphibians and Reptiles:* Not expected based on

use; *Birds:* Practically nontoxic; *Mammals:* Slightly toxic;

Fish (and/or other Aquatic Organisms): Highly toxic. No risks anticipated based on use and mitigation.

Environmental Fate: Not expected to persist or accumulate significantly in the environment.

Conclusions and Recommendations: Adverse effects in humans may occur via contact with eyes and skin. Aquatic organisms are highly sensitive, but no risks are anticipated based on use and mitigation. Sodium hypochlorite can be added to Midpen's list of approved pesticides with appropriate precautions.

4.2.1 Background

Sodium hypochlorite (CAS # 7681-52-9), also known as hypochlorous acid, sodium salt, is an inorganic sodium salt with hypochlorite as the negatively charged counterpart (CDC, 2008; EPA, 1992). It has a broad spectrum of antimicrobial activity and is registered for use as a sanitizer and disinfectant for surfaces and water, as well as a microbial control agent for certain foods and industrial processes (CDC, 2008; EPA, 1992). The typical target species of sodium hypochlorite include dried or fixed organisms and biofilms (CDC, 2008). Sodium hypochlorite is used across a wide range of settings including household environments, industrial manufacturing sites, and municipal water treatment systems (Chung et al., 2022; EPA, 1992). In an aqueous solution, sodium hypochlorite releases hypochlorite ions that oxidize and kill bacteria (CDC, 2008).

Products containing sodium hypochlorite are registered in various formulations including formulation intermediates,

granular forms, wettable powders, emulsifiable concentrates, soluble concentrates, and ready-to-use solutions (EPA, 1992). According to EPA, no additional scientific data are necessary to register or reregister products containing 5.25% to 12.5% sodium hypochlorite (EPA, 1991).

4.2.2 Exposure Considerations

Sodium hypochlorite is primarily applied to indoor and outdoor surfaces, including institutional and household areas, swimming pools, ponds, drinking water systems, and wastewater treatment facilities (EPA, 1991). Sodium hypochlorite is commonly used in products such as liquid bleach (Clorox).

Midpen's annual application of sodium hypochlorite is estimated at 16 gal for disinfecting equipment. The method of application is noted as spot spray. The exact formulation to be used is specified as Liquid Bleach (Clorox).

4.2.3 Human Toxicity and Risk Assessment

4.2.3.1 Acute and Short-term Toxicity

According to EPA (1986), sodium hypochlorite was classified as Category IV and Category III for acute oral and dermal toxicity. The Agency also classified a formulated product (Clorox PUMA) containing 8% sodium hypochlorite as Category IV for acute oral, dermal, and inhalation toxicity (EPA, 2010). The available studies support low acute toxicity of sodium hypochlorite at concentrations expected in disinfectant products (i.e., 5.25%-12.5%). In oral toxicity studies, an LD₅₀ of 8.83 g/kg (range: 8.2-9.51 g/kg) was reported in male rats administered a 12.5% sodium hypochlorite solution (NICNAS, 2014) (NICNAS, 2014). This LD₅₀ was noted to be equivalent to 626 mg/kg as available chlorine (NICNAS, 2014); however, the same LD₅₀ was estimated to be equivalent to 1100 mg/kg as available chlorine in the ECHA dossier for sodium hypochlorite (ECHA, 2025e). According to the United Kingdom (UK) Health Security Agency (HAS), clinical symptoms associated with ingestion of products containing sodium hypochlorite included nausea, vomiting, burning sensation in the mouth, and in severe cases, gastrointestinal burns, metabolic acidosis, hypernatremia, and hyperchloremia (UKHSA, 2025). Regarding dermal exposure, an LD₅₀ of > 20 g/kg (2500 mg/kg as available chlorine) was noted in rabbits (ECHA, 2025e), whereas in rats exposed to 5.25% sodium hypochlorite solution, an LD₅₀ of > 2000 mg/kg was reported (NICNAS, 2014). For acute inhalation toxicity, the one-hour LC₀ in rats was > 10.5 mg/L, indicating low toxicity; however, inhalation was not considered to be a



primary route of exposure for sodium hypochlorite except in cases of aerosol formation (ECHA, 2025e; NICNAS, 2014).

4.2.3.2 Subchronic and Chronic Toxicity

According to EPA (1991), no subchronic or chronic studies on sodium hypochlorite were needed. The Agency also noted that based on the toxicity profile and exposure scenarios, the risks from subchronic or chronic exposure to “low levels” of sodium hypochlorite were minimal and without consequence to human health (EPA, 1991). The low chronic toxicity of sodium hypochlorite is supported by a 90-day oral toxicity study identified in the ECHA dossier, in which male and female were exposed to 0, 0.025, 0.05, 0.1, 0.2, or 0.4% sodium hypochlorite in drinking water (equivalent to 0, 12.5, 25, 50, 100, or 200 mg/kg in males and 0, 14.3, 28.6, 57.2, 114.4, or 228.8 mg/kg in females) (ECHA, 2025e). No mortality or exposure-related histological changes were observed. However, body weight gain was decreased in males at 0.2% and 0.4% and in females at 0.4%, and absolute weights of several organs were decreased in males and females at 0.4%. NOAEL values of 50 and 57.2 mg/kg were derived for males and females, respectively (ECHA, 2025e).

4.2.3.3 Carcinogenicity and Genotoxicity

There was no evidence that sodium hypochlorite was carcinogenic or genotoxic. The International Agency for Research on Cancer (IARC) classified sodium hypochlorite as Group 3 (not classifiable as to carcinogenicity to humans), indicating inadequate evidence for carcinogenicity in both humans and experimental animals (UKHSA, 2025). In animal studies summarized by UKHSA, rats exposed to sodium hypochlorite at concentrations of 500 or 1000 mg/L over a 104-week period did not develop tumors attributable to the chemical (UKHSA, 2025). In a two-year bioassay evaluating the carcinogenicity of chlorinated drinking water (up to 275 ppm) in mice and rats, no evidence of carcinogenic activity was observed (ECHA, 2025e; NTP, 1992; UKHSA, 2025). Notably, some studies involving female mice suggested that sodium hypochlorite could act as a tumor promoter; however, this effect was found to be highly dependent on the specific initiator used (UKHSA, 2025).

Regarding genotoxicity, in bacterial mutation assays, sodium hypochlorite showed positive results in one of three Ames tests with *S. typhimurium* strain TA100 in the presence of metabolic activation, whereas the other two tests showed negative results (ECHA, 2025e; NICNAS, 2014). In mammalian cell studies, equivocal or weakly positive results were observed in chromosome aberration tests and sister chromatid exchange assays. *In vivo* studies demonstrated that sodium hypochlorite was without effect in

two mouse micronucleus tests, a bone marrow chromosomal aberration assay, and an 8-hydroxyguanosine assay in rats, all yielding negative results. Based on the weight of evidence, sodium hypochlorite was not considered to be genotoxic or mutagenic (ECHA, 2025e; NICNAS, 2014).

4.2.3.4 Developmental and Reproductive Toxicity

According to UKHSA (2025), no reproductive or teratogenic effects were observed in animal studies on sodium hypochlorite. In a one-generation study, hypochlorous acid administered by gavage to rats at doses of 0, 1, 2, and 5 mg chlorine/kg/day before and during mating, gestation, and lactation did not induce sperm abnormalities and did not affect fertility or the appearance of reproductive organs; the NOAEL was noted as 5 mg chlorine/kg/day for reproductive effects (ECHA, 2025e; NICNAS, 2014; UKHSA, 2025). In a multi-generation study, highly chlorinated water containing 100 mg/L available chlorine (corresponding to 5 and 5.7 mg/kg/day in males and females, respectively) was administered in rats via drinking water for seven consecutive generations; no significant differences in lifetime, fertility, breeding outcome, clinical signs, organ weights, hematological parameters, histopathology, or neoplastic lesions were noted and the NOAEL was ≥ 5 mg chlorine/kg/day (ECHA, 2025e). In a sperm head abnormality test, male mice administered sodium hypochlorite orally at doses of 0, 1.6, 4, or 8 mg chlorine/kg/day for five consecutive days showed a small increase in sperm head abnormalities at mid- and high doses; however, this effect was independent of dose and only the mid-dose group fell outside the highly variable background incidence of abnormalities. Observations of increased sperm-head abnormalities at three weeks post treatment, but not at one or five weeks suggested that the effect could be specific to late primary spermatocytes (ECHA, 2025e; NICNAS, 2014).

In a developmental toxicity study, female rats were exposed to 0, 1, 10, or 100 mg/L hypochlorous acid (equivalent to 0, 0.057, 0.57, and 5.7 mg available chlorine/kg/day) in drinking water for 2.5 months prior to mating and continuing throughout gestation until day 20 (ECHA, 2025e). There were no treatment-related effects on fetal viability, body weight, or external appearance. Skeletal and soft-tissue defects were observed in the normal range for all dose groups. When combined, a statistically significant increase in total defects was observed in the highest dose group; however, in the absence of a clear dose-response relationship and a relatively high incidence of defects in control animals, these findings were not considered treatment-related. Maternal toxicity was not evaluated. The NOAEL for developmental toxicity was ≥ 5.7 mg



chlorine/kg/day (ECHA, 2025e). In a single generation study, hypochlorous acid administered by gavage to rats at doses up to 5 mg chlorine/kg/day before and during mating, gestation, and lactation showed no effects on litter size, perinatal mortality, pup growth, or other developmental landmarks, and the NOAEL for developmental toxicity was considered to be 5 mg chlorine/kg/day (NICNAS, 2014).

4.2.3.5 Endocrine Disruption

No information was available on the endocrine disruption potential of sodium hypochlorite. This chemical was not on EPA's priority lists for EDSP tier 1 (<https://www.regulations.gov/document/EPA-HQ-OPPT-2004-0109-0080>) or tier 2 (<https://www.regulations.gov/document/EPA-HQ-OPPT-2009-0477-0074>) screening. Sodium hypochlorite was not classified as an endocrine disruptor and did not appear on the Endocrine Society's list of chemicals with known endocrine-disrupting activity or on the ECHA Endocrine Disruptor Assessment List (ECHA, 2025a; Endocrine Society, 2025).

4.2.3.6 Sensitization and Irritation

Sodium hypochlorite was not a skin sensitizer based on negative results in guinea pig Buehler tests and human repeated insult patch tests (NICNAS, 2014). According to EPA (2010), Clorox PUMA formulation containing 8% sodium hypochlorite was not a skin sensitizer either. As noted by EPA, sodium hypochlorite was corrosive and classified as Category I for eye and skin irritation (EPA, 1986, 1991). According to EPA (2010), Clorox PUMA formulation was also classified as Category I for eye and skin irritation. Sodium hypochlorite was noted to cause severe skin burns and eye damage upon contact with mucous membranes and skin (ECHA, 2025e; UKHSA, 2025). In guinea pig studies, no effects on epidermal proliferation were observed following daily application of 0.125% sodium hypochlorite solution for up to eight weeks, whereas marked epidermal hyperplasia was observed with 0.1% solution applied for 14 days; a concentration threshold of approximately 0.5% was identified for effects on basal cell viability with continuous exposure (ECHA, 2025e).

4.2.3.7 Neurotoxicity

No information was available on the neurotoxicity potential of sodium hypochlorite.

4.2.3.8 Immunotoxicity

There was no evidence that sodium hypochlorite was immunotoxic under typical exposure conditions. In a repeated dose study, male rats administered drinking water

containing 0, 5, 15, or 30 mg/L sodium hypochlorite from weaning to 12 weeks of age for nine weeks showed no significant effects on body weights, thymus weight, antibody response, natural killer cell cytotoxicity, interleukin production, or phagocytic activity (ECHA, 2025e). However, reductions in spleen weight and delayed-type hypersensitivity reactions were observed at the highest dose (approximately 1.5 mg/kg/day), while reductions in macrophage oxidative metabolism and increased prostaglandin E2 production were observed at 15 and 30 mg/L. In a separate study, mice exposed to sodium hypochlorite in drinking water at concentrations of 15 or 30 mg/L as available chlorine for 120 days showed no significant differences in antibody titers (hemagglutination), reticuloendothelial clearance, or spleen weight compared to controls, suggesting that sodium hypochlorite did not significantly affect immune function in mice (ECHA, 2025e).

4.2.4 Ecological Toxicity and Risk Assessment

4.2.4.1 Plants

No toxicity data relevant to terrestrial or aquatic plants were identified. However, based on the pesticide use/application and rapid degradation in the environment, significant risk to this ecological receptor was not anticipated. This is consistent with EPA's determination that all environmental fate and ecological effects data requirements for sodium hypochlorite were satisfied and that the currently registered uses of the hypochlorites would not result in unreasonable adverse effects to the environment (EPA, 1991).

4.2.4.2 Bees (and/or Other Insects)

No toxicity data relevant to bees or other insects were identified. However, based on the pesticide use/application and rapid degradation in the environment, significant risk to this ecological receptor was not anticipated. This is consistent with EPA's determination that all environmental fate and ecological effects data requirements for sodium hypochlorite were satisfied and that the currently registered uses of the hypochlorites would not result in unreasonable adverse effects to the environment (EPA, 1991).

4.2.4.3 Amphibians and Reptiles

No toxicity data relevant to bees or other insects were identified. However, based on the pesticide use/application and rapid degradation in the environment, significant risks to these ecological receptors were not anticipated. This is consistent with EPA's determination that all environmental fate and ecological effects data requirements for sodium hypochlorite were satisfied and that the currently registered



uses of the hypochlorites would not result in unreasonable adverse effects to the environment (EPA, 1991).

4.2.4.4 Birds

According to EPA (1992), sodium hypochlorite was “Practically nontoxic” to birds. In acute oral toxicity studies, the LD₅₀ values were > 2510 mg/kg for sodium hypochlorite. In subacute dietary studies, sodium hypochlorite showed an LC₅₀ of > 5000 ppm, indicating that the substance was practically non-toxic to upland game birds and waterfowl (EPA, 1992). Further, based on the pesticide use/application and rapid degradation in the environment, significant risk to this ecological receptor was not anticipated. This is consistent with EPA’s determination that all environmental fate and ecological effects data requirements for sodium hypochlorite were satisfied and that the currently registered uses of the hypochlorites would not result in unreasonable adverse effects to the environment (EPA, 1991).

4.2.4.5 Mammals

In oral toxicity studies, an LD₅₀ of 8.83 g/kg (range: 8.2-9.51 g/kg) was reported in male rats administered a 12.5% sodium hypochlorite solution (NICNAS, 2014). This LD₅₀ was noted to be equivalent to 626 mg/kg as available chlorine (NICNAS, 2014); however, the same LD₅₀ was estimated to be equivalent to 1100 mg/kg as available chlorine in the ECHA dossier for sodium hypochlorite (ECHA, 2025e). Based on this LD₅₀, sodium hypochlorite could be classified as “Slightly toxic” to mammals. Further, based on the pesticide use/application and rapid degradation in the environment, significant risk to this ecological receptor was not anticipated. This is consistent with EPA’s determination that all environmental fate and ecological effects data requirements for sodium hypochlorite were satisfied and that the currently registered uses of the hypochlorites would not result in unreasonable adverse effects to the environment (EPA, 1991).

4.2.4.6 Fish (and/or Other Aquatic Organisms)

According to EPA (1992), sodium hypochlorite was “Highly toxic” to freshwater fish and invertebrates. In fish, 96-hour LC₅₀ values ranged from 0.132 to 1.35 ppm for cold-water species (such as rainbow trout) and from 0.28 to 2.1 ppm for warm-water species (such as Bluegill sunfish). In

invertebrates, 48-hour LC₅₀ values ranging from 0.037 to 2.3 ppm were reported in water flea (*D. magna*). In marine organisms, sodium hypochlorite would also be classified as “Highly toxic” based on LC₅₀ values of 0.38 mg/L (*C. variegatus*) and 0.16 mg/L (*A. bahia*), and an EC₅₀ of 0.20 mg/L (*C. virginica*) (EPA, 1992). However, the Agency stated that risks to aquatic species were mitigated by adequate precautionary labeling and permit requirements (EPA, 1992).

4.2.5 Environmental Fate Assessment

According to EPA (1992), sodium hypochlorite is a non-volatile, highly water-soluble inorganic salt that undergoes photolysis in aqueous solutions with degradation rates increasing under higher light intensity. Although specific long-term photolysis data are limited, environmental degradation is expected to occur rapidly with half-lives ranging from minutes to hours depending on light intensity and pH. In marine environments, residual chlorine levels decline quickly, followed by slower degradation. Sodium hypochlorite reacts rapidly with bromide ions in seawater to form hypobromite, which is acutely toxic to aquatic organisms but degrades quickly. Sodium hypochlorite is not expected to result in unreasonable adverse environmental effects under current registered uses (EPA, 1992).

4.2.6 Conclusions and Recommendations

Based on the information reviewed, adverse effects of sodium hypochlorite in humans may occur via contact with eyes and skin. Additionally, aquatic organisms are highly sensitive to sodium hypochlorite, but no risks are anticipated based on pesticide use and mitigation. If sodium hypochlorite represents the most suitable option for some applications, appropriate precautions must be taken when applying it as a disinfectant, particularly if applying it in the vicinity of aquatic life. These include using appropriate PPE during application, avoiding direct discharge into natural water bodies, and using secondary containment. It is also essential to review and comply with the EPA-stamped label (https://www3.epa.gov/pesticides/chem_search/ppls/005813-00001-20070725.pdf).



4.3 Isopropyl Alcohol or Ethanol

Formulations: Rubbing Alcohol (isopropyl alcohol)

Typical Target Pests: Various microorganisms

Application: Annual application ~100 gal via spot spray. Pesticide to disinfect equipment.

Human Toxicity: *Acute and Short-term Toxicity:*

Category III (oral toxicity). Category IV (dermal and inhalation toxicity); *Subchronic and Chronic Toxicity:* No effects (dermal exposure). Some effects at high concentrations/doses (inhalation/oral exposure); *Carcinogenicity and Genotoxicity:* No evidence; *DART:* Not expected from registered uses; *Endocrine disruption:* No information. Included on EPA's priority list tier 1 for EDSP; *Sensitization and irritation:* Category III or IV (eye). Category IV (skin). Not considered a skin sensitizer; *Neurotoxicity:* Not considered a neurotoxicant under typical exposure conditions; *Immunotoxicity:* No evidence.

Ecological Toxicity: *Plants:* Not expected based on use; *Bees (and/or other Insects):* Not expected based on use; *Amphibians and Reptiles:* Not expected based on use; *Birds:* Not expected based on use; *Mammals:* Practically nontoxic; *Fish (and/or other Aquatic Organisms):* Practically nontoxic.

Environmental Fate: Not expected to persist or accumulate significantly in the environment.

Conclusions and Recommendations: No risks in humans or ecological receptors expected from labeled use. Isopropyl alcohol can be added to Midpen's list of approved pesticides.

Formulations: Rubbing Alcohol (ethanol)

Typical Target Pests: Various microorganisms

Application Rates: Annual application ~100 gal via spot spray. Pesticide to disinfect equipment

Human Toxicity: *Acute and Short-term Toxicity:*

Category IV (oral and inhalation toxicity); *Subchronic and Chronic Toxicity:* Minor effects after prolonged dermal exposure. No effects (inhalation exposure). Some effects at high doses (oral exposure); *Carcinogenicity and Genotoxicity:* Class I carcinogen (alcoholic beverages). Not definitive carcinogen (disinfectants). Not mutagenic/genotoxic; *DART:* Not expected from registered uses; *Endocrine disruption:* Insufficient data. Not on EPA's priority list for EDSP; *Sensitization and irritation:* Category IV (eye and skin). Not considered a skin sensitizer; *Neurotoxicity:* Not expected under typical use conditions; *Immunotoxicity:* No evidence

Ecological Toxicity: *Plants:* Not expected based on use; *Bees (and/or other Insects):* Not expected based on use; *Amphibians and Reptiles:* Not expected based on use; *Birds:* Not expected based on use; *Mammals:* Practically nontoxic; *Fish (and/or other Aquatic Organisms):* Practically nontoxic.

Environmental Fate: Not expected to persist or accumulate significantly in the environment

Conclusions and Recommendations: No risks in humans or ecological receptors expected from labeled use. Ethanol can be added to Midpen's list of approved pesticides

4.3.1 Background

Isopropyl alcohol (CAS # 67-63-0) and ethanol (CAS # 64-17-5) are highly volatile, broad-spectrum, and fast-acting antimicrobial liquid agents registered for use as disinfectants in agricultural and non-agricultural settings (EPA, 1995). Typical target species of isopropyl alcohol and ethanol include bacteria, viruses, and fungi (EPA, 1995). The antimicrobial action of both chemicals is mediated by their ability to denature proteins in the cell membrane, leading to cell death (CDC, 2008).

Isopropyl alcohol and ethanol are registered in various formulations, including pressurized liquid, ready to use liquid, and soluble concentrate or liquids; however, isopropyl alcohol is also registered as an impregnated material (EPA, 1995). Isopropyl alcohol the most common type of rubbing alcohol. Ethanol can also be used in rubbing alcohol, albeit less commonly. Alcohol-based disinfectants typically contain

60%-90% isopropyl alcohol or 60%-95% ethanol (EPA, 1995).

4.3.2 Exposure Considerations

Isopropyl alcohol and ethanol are applied across a wide range of food crops, animal handling environments, and residential and institutional settings and are used in agricultural drainage, sanitation systems, and indoor medical and commercial facilities (EPA, 1995). Isopropyl alcohol is used for a variety of antimicrobial treatments, including enclosed premise and water recirculating systems. It is also used in combination with other active ingredients to kill fleas, ticks, and other insects. Ethanol is commonly used as an antimicrobial treatment and can also be used as a plant regulator. Dermal and inhalation exposures to isopropyl alcohol and ethanol can occur, especially during their use as disinfectants, sanitizers, and other hygiene-related applications; however, EPA considers such



exposures minimal and incidental in the context of their use in personal and commercial hygiene products. Both chemicals are well-known and have a wide range of human uses. Thus, although exposure is possible, routine use does not pose unreasonable risks to human health under approved conditions (EPA, 1995).

Midpen's annual application of isopropyl alcohol or ethanol is estimated at 100 gal for disinfecting equipment. The method of application is noted as spot spray. The formulation to be used is specified as rubbing alcohol but no brand is specified.

4.3.3 Human Toxicity and Risk Assessment

4.3.3.1 Acute and Short-term Toxicity

According to EPA (1995), isopropyl alcohol was classified as Category III for acute oral toxicity and Category IV for acute inhalation and dermal toxicity. Oral LD₅₀ values of 4384 and 3600 mg/kg were reported in rats and for mice, respectively. Inhalation LC₅₀ values were 46.7 mg/L (male rats; eight-hour exposure), 55.3 mg/L (female rats; eight-hour exposure), and 68.5 mg/L (male and female rats; four-hour exposure). A dermal LD₅₀ of 16,370 mg/kg was noted in an unspecified species (EPA, 1995).

According to EPA (1995), ethanol was classified as Category IV for acute oral and inhalation toxicity. Oral LD₅₀ values of 7060 and 7500 mg/kg were reported in rats and mice, respectively. Inhalation LC₅₀ values were 38 mg/L (rats; 10-hour exposure) and 39 mg/L (mice; four-hour exposure). No acute dermal LD₅₀ was specified by EPA; however, based on its routine use, dermal exposure was not expected to pose unreasonable risks to human health under approved conditions (EPA, 1995), indicating that ethanol was not acutely toxic via dermal exposure.

4.3.3.2 Subchronic and Chronic Toxicity

Based on subchronic and chronic studies reviewed by EPA (1995), isopropyl alcohol has low toxicity. No treatment-related effects were observed in male albino rats after a 187-day dermal exposure to the facial area to 50% isopropyl alcohol aqueous solution. In an inhalation study in rats and mice, the NOEC and LOEC values for systemic toxicity were 500 and 1500 ppm, respectively, based on clinical signs of ataxia, narcosis, hypoactivity, and a lack of startle response. In an oral study, exposure of male rats to 5% isopropyl alcohol in drinking water (estimated dose equivalent to 1.87 mL/kg/day or 1470 mg/kg/day) for 304 days resulted in lower body weight, decreased activity, and impaired maze learning ability (EPA, 1995).

Based on subchronic and chronic studies reviewed by EPA (1995), ethanol had low toxicity. In a 21-day dermal study, human volunteers continuously exposed to ethanol-saturated patches under an occlusive dressing showed no dermal irritation through day 14; however, very slight edema and erythema were noted from days 15 to 18, and well-defined edema and erythema were noted from days 19 to 21. In a 90-day inhalation study in rats, guinea pigs, rabbits, monkeys, and dogs, no histopathological changes, deaths, or clinical signs of toxicity were observed after continuous exposure to up to 86 mg/m³ ethanol. In a 304-day oral study, no treatment-related mortality occurred following exposure to 5% ethanol in drinking water in rats (estimated dose equivalent to 2.1 mL/kg/day); however, decreased activity and impaired maze learning ability were noted in ethanol-exposed rats. In a 12-week oral study, no gross or histopathological changes, except for a decreased mean body weight and a high degree of fatty degeneration in the liver, were observed in male rats administered drinking water containing 3.26 M of ethanol. However, it was estimated that the exposure regimen translated into an average dose of 10,200 mg/kg/day ethanol (EPA, 1995).

4.3.3.3 Carcinogenicity and Genotoxicity

No evidence of isopropyl alcohol carcinogenicity or genotoxicity was found in the inhalation toxicity studies reviewed by EPA (1995). The EPA Office of Chemical Safety and Pollution Prevention (OCSPP) did not classify isopropyl alcohol as carcinogenic (EPA, 1995). According to IARC, isopropyl alcohol was classified as Group 3 (not classifiable as to its carcinogenicity to humans). In a variety of mutagenicity and genotoxicity assays, isopropyl alcohol tested negative (EPA, 1995).

According to EPA (1995), ethanol used as disinfectant was not definitively classified as carcinogenic and, in most assays, ethanol tested negative for mutagenicity/genotoxicity. According to IARC, ethanol used in alcoholic beverages was classified as a Group 1 carcinogen based on oral ingestion data (WHO, 2010). Ethanol was negative in *in vitro* mutagenicity assays. In an *in vivo* mutagenicity assay using the rodent dominant lethal test, ethanol tested positive; however, it should be noted that the dominant lethal assay was removed from the standard test guidelines for mutagenicity by OECD. As for other genotoxicity assays, ethanol was consistently negative (EPA, 1995).

4.3.3.4 Developmental and Reproductive Toxicity

EPA did not classify isopropyl alcohol as a developmental or reproductive toxicant under typical exposure conditions. Several oral and inhalation studies were reviewed by EPA,



in which some effects occurred at high doses/concentrations (**Table 19**) (EPA, 1995).

According to EPA (1995), ethanol was recognized as a human developmental neurotoxicant, particularly in the context of Fetal Alcohol Syndrome (FAS), due to chronic maternal alcohol consumption during pregnancy. It was noted that FAS was associated with severe outcomes such as growth retardation, mental retardation, and

microencephaly. Behavioral effects included developmental delays, increased activity, and learning deficits. Importantly, these effects were typically linked to high oral doses of ethanol consumed by the mother (EPA, 1995).

EPA concluded from their review of the literature that there is no expectation of developmental or reproductive effects from the potential dermal and inhalation exposures from the registered uses of the aliphatic alcohols (EPA, 1995).

Table 19. *Developmental and Reproductive Toxicity of Isopropyl Alcohol*

Species (Sex)	Route	Duration	Doses/ Concentrations	Findings	Toxicity Thresholds
Rats (M/F)	Oral gavage	2 generations	0, 100, 500, 1000 mg/kg/day	Increased liver/kidney weights in males at mid/high doses; Increased offspring mortality first 2 days postpartum; no clinical signs or gross pathology	• NOEL (systemic) = 500 mg/kg • NOEL (reproductive) = 1000 mg/kg
Rats (dams)	Oral gavage	GD 6-15	0, 400, 800, 1200 mg/kg/day	Maternal mortality and decreased fetal body weights at ≥800 mg/kg	• NOEL (systemic) = 400 mg/kg • NOEL (developmental) = 400 mg/kg
Rabbits (does)	Oral gavage	GD 6-18	0, 120, 240, 480 mg/kg/day	Maternal mortality and decreased body weight at 480 mg/kg; no developmental toxicity	• NOEL (maternal): 240 mg/kg/day • LOEL (maternal): 480 mg/kg/day • NOEL (developmental): 480 mg/kg/day
Rats (dams)	Oral gavage	GD 6 – PPD 21	0, 200, 700, 1200 mg/kg/day	One maternal death at high dose; no other toxicity or neurobehavioral effects	NOEL (developmental): 1200 mg/kg/day
Rats (dams)	Inhalation	GD 1-19, 7 h/d	0, 3500, 7000, 10000 ppm	Decreased fetal body weights at all doses; Increased resorptions and skeletal malformations at ≥7000 ppm	LOEC (developmental): 3500 ppm

Source: EPA (1995)

4.3.3.5 Endocrine Disruption

No specific information on endocrine disruption potential of isopropyl alcohol was available. This chemical was included on the EPA's priority list for EDSP tier 1

(<https://www.regulations.gov/document/EPA-HQ-OPPT-2004-0109-0080>) screening. However, isopropyl alcohol was not classified as an endocrine disruptor and did not appear on the Endocrine Society's list of chemicals with known endocrine-disrupting activity or on the ECHA Endocrine Disruptor Assessment List (ECHA, 2025a; Endocrine Society, 2025).

Although some literature suggested that ethanol could interfere with hormonal pathways under conditions of chronic or high-level exposure following oral exposure, there was insufficient empirical data to support a formal classification (Endocrine Society, 2021; Rachdaoui & Sarkar, 2017). Ethanol was not on EPA's priority lists for EDSP tier 1 (<https://www.regulations.gov/document/EPA-HQ-OPPT-2004-0109-0080>) or tier 2 (<https://www.regulations.gov/document/EPA-HQ-OPPT-2009-0477-0074>) screening. It was also not classified as an

endocrine disruptor and did not appear on the ECHA Endocrine Disruptor Assessment List (ECHA, 2025a).

4.3.3.6 Sensitization and Irritation

According to EPA (1995), no sensitization studies on isopropyl alcohol were available; however, EPA did not classify it as a skin sensitizer. Isopropyl was classified as Category IV for skin irritation and Category III or IV for eye irritation. It was noted that the primary eye irritation studies in rabbits demonstrated slight-to-moderate irritation and the primary dermal irritation studies in rabbits indicated that isopropyl alcohol was non-irritating. No treatment-related effects were observed in rats after chronic dermal exposure to isopropyl alcohol (EPA, 1995).

According to EPA (1995), no sensitization studies on ethanol alcohol were available; however, EPA did not classify it as a skin sensitizer. Ethanol was classified as Category IV for skin and eye irritation. It was noted that acute primary eye irritation studies in rabbits showed mild irritation, chemosis, and redness, whereas the primary dermal irritation studies in rabbits demonstrated that ethanol



was non-irritating. Regarding subchronic toxicity, in human volunteers continuously dermally exposed to ethanol-saturated patches, no dermal irritation was observed through 14 days, with very slight edema and erythema observed from days 15 to 18, and well-defined edema and erythema noted from days 19 to 21 (EPA, 1995).

4.3.3.7 Neurotoxicity

EPA did not classify isopropyl alcohol as a neurotoxicant under typical exposure conditions. In an acute neurotoxicity study, rats were exposed to up to 10,000 ppm isopropyl alcohol for six hours via whole body inhalation (EPA, 1995). Based on the neurobehavioral effects, the NOECs were determined to be 500 and 1500 ppm in males and females, respectively, whereas the LOECs were 1500 and 5000 ppm in males and females, respectively. In a subchronic neurotoxicity study, no treatment-related changes were observed in the functional observational battery or neuropathological evaluations in rats exposed to up to 5000 ppm for six hours per day, five days per week, for 13 weeks.

However, in female rats, motor activity was increased at a concentration of 5000 ppm with recovery occurring 42-days post treatment. Further, in an oral study, exposure to 5% isopropyl alcohol in drinking water for 304 days resulted in decreased body weight, decreased activity, and impaired maze learning ability in male rats (EPA, 1995).

Ethanol was recognized as a human developmental neurotoxicant, particularly in the context of FAS, due to chronic maternal alcohol consumption during pregnancy. It was noted that FAS was associated with severe outcomes such as growth retardation, mental retardation, and microencephaly. Behavioral effects included developmental delays, increased activity, and learning deficits. Importantly, these effects were typically linked to high oral doses of ethanol consumed by the mother. In non-developmental studies, neurotoxic effects were observed at high doses/concentrations (**Table 20**) (EPA, 1995). Thus, ethanol is only expected to be neurotoxic at high doses via chronic oral exposure and is not expected to be neurotoxic under typical use conditions as a disinfectant at low doses.

Table 20. Neurotoxicity of Ethanol

Species (Sex)	Route	Duration	Doses/ Concentrations	Findings	Toxicity Thresholds
Rat (M)	Oral gavage	Single dose	0, 0.16, 0.79, 3.95 g/kg	Decreased rearing, flaccid body tone, reduced reflexes; at 5 g/kg, decreased motor activity	LOEC = 0.16 g/kg
Rat (M)	Drinking water	12 weeks	10.2 g/kg (average)	Decreased mean body weights, fatty liver degeneration; no other gross/histopathology	Not specified
Rat (M)	Drinking water	304 days	5% (2.1 mL/kg)	Decreased body weight (30% lower at week 36), decreased activity, impaired maze learning	Not specified
Rat (M)	Dermal	187 days	50% aqueous solution	No treatment-related effects	NOEL = 50% solution

Source: EPA (1995)

4.3.3.8 Immunotoxicity

There was insufficient empirical evidence to fully assess the immunotoxicity of isopropyl alcohol. However, no biologically significant immunotoxic effects have been reported under typical exposure conditions, such as those encountered during its use as a disinfectant or solvent.

No definitive conclusions could be drawn regarding the immunotoxicity of ethanol due to limitations in study design, consistency, and relevance to human exposure scenarios. The evidence reviewed in the ECHA dossier for ethanol did not indicate a biologically significant immunotoxic effect from ethanol when used as a disinfectant.

4.3.4 Ecological Toxicity and Risk Assessment

4.3.4.1 Plants

Isopropyl alcohol was not anticipated to be toxic to plants. EPA (1995) did not report any specific phytotoxicity concerns for isopropyl alcohol. According to the United States Department of Agriculture (USDA), isopropyl alcohol is permitted in organic crop production as a disinfectant and sanitizer, including for irrigation system cleaning (USDA, 2014). As noted in its ECHA dossier, isopropyl alcohol is not considered to be acutely toxic to aquatic algae, cyanobacteria, or microorganisms. Specifically, the seven-day toxicity thresholds of isopropyl alcohol in algae and



microorganism were determined at 1800 and 1050 mg/L, respectively (ECHA, 2023b).

Ethanol was not anticipated to be toxic to plants. EPA (1995) did not report any specific phytotoxicity concerns for ethanol. According to the EPA, ethanol is registered for use as a plant growth regulator and disinfectant (EPA, 1995). As noted in its ECHA dossier, ethanol is considered to be of very low toxicity to plants when exposure is through the soil and the aquatic environment. According to studies covering multiple freshwater and saltwater algal species, ethanol toxicity to aquatic algae is generally quite low, though sensitivity varies considerably among species. Among the freshwater species tested (including *C. vulgaris*, *S. capricornutum*, *C. eugametos*, *S. obliquus*, and others), *C. vulgaris* was found to be the most sensitive with a 72-hour EC₅₀ of 275 mg/L and a 72-hour EC₁₀ of 11.5 mg/L, whereas *S. capricornutum* tolerated concentrations 40 times higher. For saltwater species (including *S. costatum*, *Cyclotella* sp., *Cylindricotheca* sp., *Navicula* sp., and various *Nitzschia* species), *Cylindricotheca* was most sensitive with an EC₅₀ of 1970 mg/L and NOEC of 1580 mg/L, confirming that although some individual species show sensitivity, the broad range of algal species tested demonstrates that ethanol toxicity to algae is typically low (ECHA, 2025b).

4.3.4.2 Bees (and/or Other Insects)

No toxicity data relevant to bees or other insects were identified for isopropyl alcohol or ethanol. However, based on their uses/applications and rapid degradation in the environment, significant risk to this ecological receptor was not anticipated.

4.3.4.3 Amphibians and Reptiles

No toxicity data relevant to amphibians and reptiles were identified for isopropyl alcohol or ethanol. However, based on their uses/applications and rapid degradation in the environment, significant risks to these ecological receptors were not anticipated.

4.3.4.4 Birds

No toxicity data relevant to birds were identified for isopropyl alcohol or ethanol. However, based on their uses/applications and rapid degradation in the environment, significant risk to this ecological receptor was not anticipated.

4.3.4.5 Mammals

Isopropyl alcohol and ethanol were classified as practically non-toxic to terrestrial mammalian organisms under acute exposure conditions (EPA, 1995). For isopropyl alcohol, the

oral LD₅₀ values of 4384 and 3600 mg/kg were reported in rats and mice, respectively, whereas for ethanol, an oral LD₅₀ of 7060 mg/kg in rats was indicated (EPA, 1995).

4.3.4.6 Fish (and/or Other Aquatic Organisms)

Isopropyl alcohol and ethanol were considered to be practically non-toxic to freshwater species. For isopropyl alcohol, the toxicity studies reviewed by EPA noted an LC₅₀ of 6550 ppm in fathead minnows and an EC₅₀ of 2280 ppm in water flea *D. magna* (EPA, 1995). In addition, according to the studies summarized in ECHA dossier for isopropyl alcohol, acute toxicity values included 96-hour LC₅₀ values of 9640-10,000 ppm, and a 24-hour LC₅₀ of >10,000 ppm in aquatic invertebrates (ECHA, 2025c). For ethanol, toxicity studies reviewed by EPA included LC₅₀ values of 13,000 ppm in rainbow trout, 14,200 ppm in fathead minnows, >100 ppm in *D. magna*, and >250 ppm in *P. kadiakensis* (EPA, 1995).

4.3.5 Environmental Fate Assessment

Isopropyl alcohol and ethanol are highly volatile liquids that are stable in water (EPA, 1995). Both chemicals are expected to be readily biodegraded by microbes in water, so bioaccumulation is not expected (ECHA, 2025b, 2025c; EPA, 1995). In addition, ethanol present in ambient air is expected to be present entirely in the vapor phase and is not expected to absorb ultraviolet light or undergo direct photolysis in the soil, atmosphere or in aquatic environments (ECHA, 2025b). Although ethanol is considered resistant to hydrolysis, it may undergo indirect photolysis at a slow to moderate rate (ECHA, 2025b). Isopropyl alcohol has a low octanol-water partition coefficient, indicating high mobility in soil (ECHA, 2025c).

4.3.6 Conclusions and Recommendations

Based on the information reviewed, no risks to human or environmental health were identified for isopropyl alcohol or ethanol. Because both pesticides are flammable and volatile, they should be stored away from ignition sources and used in well-ventilated areas. It is also essential to review and comply with the EPA-stamped labels (<https://www.epa.gov/pesticide-registration/selected-epa-registered-disinfectants>).



4.4 Dodecyl Dimethyl Ammonium Chloride (DDAC)

Pesticide to disinfect equipment

Formulations: Quaternary ammonium compounds (Quat 128 or Physan 20)

Typical Target Pests: Various microorganisms

Application: Annual application ~5 gal via spot spray.

Human Toxicity: *Acute and Short-term Toxicity:*

Category II (oral and inhalation toxicity). Category III (dermal toxicity); *Subchronic and Chronic Toxicity:*

Relatively low toxicity, with some effects noted at doses higher than would be anticipated from typical DDAC

use as a disinfectant; *Carcinogenicity and Genotoxicity:* No evidence; *DART:* No unique reproductive toxicity risk

and no evidence of increased susceptibility in offspring;

Endocrine disruption: No information. Included on EPA's priority list tier 1 for EDSP; *Sensitization and irritation:*

Category I (eye and skin). Not a skin sensitizer;

Neurotoxicity: Not considered a neurotoxicant;

Immunotoxicity: No biologically significant effects

reported under typical exposure conditions.

Ecological Toxicity: *Plants:* Low toxicity in terrestrial plants. Toxic to aquatic plants, but findings not relevant to DDAC use as a disinfectant for equipment; *Bees*

(and/or other Insects): Practically nontoxic; *Amphibians*

and Reptiles: Moderately toxic to practically nontoxic

(terrestrial-phase amphibians and reptiles). Moderately

to very highly toxic (aquatic-phase amphibians); *Birds:*

Moderately toxic to practically nontoxic; *Mammals:*

Moderately toxic; *Fish (and/or other Aquatic Organisms):*

Moderately to very highly toxic.

Environmental Fate: Persistent. Not readily degradable. Not expected to bioaccumulate in aquatic organisms.

Conclusions and Recommendations: Adverse effects in humans may occur via contact with eyes and skin. Aquatic organisms are highly sensitive, but risks can be mitigated. DDAC can be added to Midpen's list of approved pesticides with appropriate precautions.

4.4.1 Background

Dodecyl dimethyl ammonium chloride (DDAC, C-12s) is a straight alkyl chain quaternary ammonium compound (QAC) registered for broad-spectrum use as a disinfectant (EPA, 2006c). QACs that are used across a wide range of agricultural and non-agricultural settings including industrial water systems, swimming pools, aquatic and agricultural areas, wood treatment, residential and public premises, medical and institutional facilities, commercial and

transportation hubs, and food handling and storage establishments. QACs act by disrupting bacterial cytoplasmic membranes and the outer coatings of viruses, leading to cell lysis and death (Cocks et al., 2023). Typical target species for straight-chain alkyl QACs include slime-forming bacteria, odor causing/staining bacteria, Gram-negative and Gram-positive bacteria, *P. aeruginosa*, pathogenic fungi (such as *T. mentagrophytes*), viruses, mold/mildew, and algae (EPA, 2006c).

DDAC may be registered in various formulations, including pressurized liquid, soluble concentrate or tablets, aerosols, impregnated wipes, ready-to-use solution, pressurized liquid, and wettable powder (EPA, 2006c). In EPA-approved surface disinfectants, DDAC concentrations range from 0.05% to 0.3% (w/w or w/v). DDAC is often used in synergistic blends with other QACs (e.g., alkyl dimethyl benzyl ammonium chloride, dioctyl dimethyl ammonium chloride, octyl decyl dimethyl ammonium chloride) (EPA, 2006c).

4.4.2 Exposure Considerations

QACs are primarily applied via spray to indoor surfaces, including institutional areas, household areas, and recirculating colling towers (EPA, 2006c). It is also used outdoors on disconnected waterbodies such as ponds and pools to control algae. DDAC, C-12s are commonly used in QACs such as Quat 128 and Physan 20. Exposure to QACs may occur via dermal (cleaning, mopping, wiping, etc.), inhalation (spraying, fogging, etc.), or oral (hand-to-mouth, incidental ingestion) routes (EPA, 2006c).

Midpen's annual application of DDAC (C-12s) is estimated at 5 gal for disinfecting equipment. The method of application is noted as spot spray. The formulation to be used is specified as Quaternary ammonium compounds (Quat 128 or Physan 20).

4.4.3 Human Toxicity and Risk Assessment

Note: a group read-across approach was used for DDAC by EPA in accordance with PR Notice 88-2, which permits the use of a complete toxicity dataset for didecyl dimethyl ammonium chloride (DDAC, C-10s; CAS # 7173-51-5) in place of individual studies for other Group I quaternary ammonium compounds, including dodecyl dimethyl ammonium compounds, due to their shared straight-chain alkyl or hydroxyalkyl structure.

4.4.3.1 Acute and Short-term Toxicity

According to EPA (2006b), DDAC (C-10s) was classified as Category II for acute oral and inhalation toxicity and



Category III for acute dermal toxicity. In the studies reviewed by the Agency, oral LD₅₀ values ranged from 238 to 262 mg/kg in rats, depending on the active ingredient concentrations, which ranged from 65% to 80%. An inhalation LC₅₀ of 0.7 mg/L was reported in rats. In two acute dermal studies conducted in rabbits, dermal LD₅₀ values were 3140 and 2730 mg/kg in males and females, respectively (EPA, 2006b).

4.4.3.2 Subchronic and Chronic Toxicity

Based on the repeated dose toxicity studies reviewed by EPA, DDAC (C-10s) appeared to have relatively low toxicity, with some effects noted at doses higher than would be anticipated from typical DDAC use as a disinfectant. In 21-day dermal toxicity studies in rats and guinea pigs reviewed by EPA, repeated application of DDAC (C-10s) resulted in local skin irritation, including erythema, edema, exfoliation, and ulceration. The systemic NOAEL values ranged from >12 to > 1000 mg/kg/day, whereas dermal NOAEL values for local skin effects ranged from 2 to 30 mg/kg/day (EPA, 2006b).

In a 90-day oral toxicity study, male and female rats were administered diets containing up to 3000 ppm DDAC (C-10s) (or approximately 175 and 225.5 mg/kg/day in males and females, respectively) for 13 weeks (EPA, 2006b). Increased mortality, reduced mean body weight, weight gain, and food consumption, as well as increased incidence of gross pathological findings and non-neoplastic lesions, including hepatic glycogen depletion and contracted spleens, were observed among rats in the high-dose group. Additionally, females in the high-dose group demonstrated sinus erythrocytosis and lymphoid hyperplasia of the mesenteric lymph nodes. Thus, the NOAELs were 60.7 and 74.3 mg/kg/day in male and female rats, respectively, and the LOAELs were 175.4 and 225.5 mg/kg/day in male and female rats, respectively.

In another 90-day oral study, beagle dogs received doses up to 50 mg/kg/day DDAC (C-10s); marked decreases in body weight gain, food consumption, and food efficiency were observed at 50 mg/kg, whereas there were no treatment-related effects regarding clinical chemistry, hematology, urinalysis, and pathological evaluations. Thus, the NOAEL was 15 mg/kg/day in male and female dogs, and the LOAEL was 50 mg/kg/day (EPA, 2006b).

In a one-year oral study, beagle dogs were administered up to 20 or 30 mg/kg/day DDAC (C-10s) (the 30 mg/kg/day dose was discontinued after day 36 due to poor tolerance and thereafter was reduced to 20 mg/kg/day). No treatment-related mortality occurred, and hematology, urinalysis, and histopathological assessments revealed no treatment-related effects. However, high-dose animals frequently exhibited clinical signs such as soft or mucoid feces and

emesis, and high-dose females showed significantly decreased total cholesterol levels. Based on these findings, the NOAEL was determined to be 10 mg/kg/day for both sexes, with a LOAEL of 20 mg/kg/day (EPA, 2006b).

4.4.3.3 Carcinogenicity and Genotoxicity

According to EPA's OCSPP, DDAC (C-10s) was not classified as carcinogenic (EPA, 2006c). The carcinogenic potential of DDAC has not been evaluated by IARC. Multiple long-term studies were reviewed by EPA (2006b). In a two-year carcinogenicity study, rats were fed diets containing up to 1500 ppm (or approximately 64 and 83 mg/kg/day in males and females, respectively). High-dose animals showed slight decreases in mean body weight (<10%) and increased incidence of sinusoidal blood, hemosiderosis, and histiocytosis in the mesenteric lymph nodes. Although an increase in testicular interstitial cell adenomas was observed, it was not considered treatment-related, as the incidence remained within historical control ranges. In a 78-week carcinogenicity study, mice received diets containing up to 1000 ppm (or approximately 155.5 and 193.1 mg/kg/day in males and females, respectively). No treatment-related effects on clinical signs, mortality, or histopathological findings were observed; however, decreased body weights and decreased body weight gains were noted at the highest concentration, resulting in a NOAEC of 500 ppm (or approximately 76.3 and 93.1 mg/kg/day in males and females, respectively) (EPA, 2006b).

Regarding genotoxicity, DDAC (C-10s) tested negative across a variety of mutagenicity and genotoxicity assays (EPA, 2006b). DDAC was negative for mutagenicity in an Ames assay in *S. typhimurium* both with and without metabolic activation (S9 fraction). The HGPRT locus in Chinese hamster ovary (CHO/HGPRT) forward gene mutation assay was also negative at concentrations up to 10 µg/mL without S9 and 26 µg/mL with S9. The *in vitro* chromosomal aberration assay in CHO cells was negative at concentrations up to 8 µg/mL, regardless of S9 activation. In an unscheduled DNA synthesis (UDS) assay in primary rat hepatocytes, no genotoxicity was noted at concentrations up to 2 µg/mL with higher concentrations resulting in cytotoxicity (EPA, 2006b).

4.4.3.4 Developmental and Reproductive Toxicity

According to EPA, DDAC (C-10s) did not pose a unique reproductive toxicity risk and no evidence of increased susceptibility in offspring compared to adults was found. In a two-generation study reviewed by EPA (2006b), rats were fed diets containing DDAC (C-10s) at concentrations up to 1500 ppm (or approximately 113-122 mg/kg/day) throughout



the premating, mating, gestation, and lactation periods in both the F₀ and F₁ generations. No treatment-related mortality or clinical signs were observed in either sex or generation. Parental and reproductive toxicity was observed only at the highest dose level, characterized by decreased body weight, reduced weight gain, and lower food consumption in parental rats, as well as decreased pup body weight and weight gain. The NOAEC for parental and reproductive toxicity was noted as 750 ppm (or 56 mg/kg/day) and the LOAEC was 1500 ppm (or 113 mg/kg/day) (EPA, 2006b).

In developmental toxicity studies reviewed by EPA, DDAC (C-10s) was administered via oral gavage during gestation at doses up to 20 and 10 mg/kg/day in rats and rabbits, respectively (EPA, 2006b). In rats, maternal toxicity occurred at ≥ 10 mg/kg/day, characterized by audible respiration, decreased body weight gain, and reduced food efficiency; a NOAEL of 1 mg/kg/day was noted for maternal effects. Developmental effects such as increased skeletal variations were observed in offspring at 20 mg/kg/day, and a developmental NOAEL of 10 mg/kg/day was estimated. In rabbits, maternal toxicity was observed at ≥ 3 mg/kg/day. The effects included hypoactivity, labored/audible respiration, decreased body weight gain, and increased mortality at the highest dose (10 mg/kg/day), and a NOAEL of 1 mg/kg/day was noted for maternal toxicity. Developmental toxicity in rabbits occurred at 10 mg/kg/day, manifesting as decreased fetal body weight and increased fetal mortality; a NOAEL of 3 mg/kg/day was noted for developmental toxicity (EPA, 2006b).

4.4.3.5 Endocrine Disruption

DDAC (C-10s) was not considered to be an endocrine disrupter and was not included on EPA's priority lists for EDSP tier 1 (<https://www.regulations.gov/document/EPA-HQ-OPPT-2004-0109-0080>) or tier 2 (<https://www.regulations.gov/document/EPA-HQ-OPPT-2009-0477-0074>) screening. DDAC was not classified as an endocrine disruptor and did not appear on the Endocrine Society's list of chemicals with known endocrine-disrupting activity or on the ECHA Endocrine Disruptor Assessment List (ECHA, 2025a; Endocrine Society, 2025).

4.4.3.6 Sensitization and Irritation

According to EPA, DDAC (C-10s) was not a skin sensitizer based on studies in guinea pigs; however, it was classified as Category I for eye and skin irritation based on studies in rabbits (EPA, 2006b, 2006c). Additionally, Luz et al. (2020) indicated that DDAC (C-10s) concentrations as low as 0.1% to 0.5% can be irritating to the eye in rabbits.

4.4.3.7 Neurotoxicity

According to EPA (2006b), DDAC (C-10s) was not considered to be a neurotoxicant based on available toxicity data.

4.4.3.8 Immunotoxicity

There was insufficient empirical evidence to fully assess the immunotoxicity of DDAC (C-10s). However, no biologically significant immunotoxic effects have been reported under typical exposure conditions, such as those encountered during its use as a disinfectant.

4.4.4 Ecological Toxicity and Risk Assessment

4.4.4.1 Plants

According to EPA (2006c), non-target plant phytotoxicity testing (e.g., seedling emergence test using rice) was outstanding or required. Based on information from other sources, DDAC (C-10s) had low toxicity in terrestrial plants, whereas QACs were toxic to aquatic plants. However, the findings in aquatic plants were not relevant to the use of DDAC as a disinfectant for equipment, which would involve limited environmental release into aquatic media.

According to the ECHA dossier, DDAC (C-10s) exhibited variable toxicity across different species of terrestrial plants and soil conditions, as reported in studies conducted according to OECD Guideline 208 – Terrestrial Plant Test-Seedling Emergence and Seedling Growth Test. Under natural soil conditions, the most sensitive species was red clover (*T. pratense*) with a 14-day EC₅₀ of 148 mg/kg dry soil based on growth effects. In contrast, wheat (*T. aestivum*) demonstrated greater tolerance with an EC₅₀ of 1172 mg/kg based on growth effects. Mustard (*S. alba*) showed intermediate sensitivity with an EC₅₀ of 346 mg/kg for wet weight growth effects. Significant differences in toxicity between natural soil and sand substrates have been demonstrated with toxic effects occurring at much lower concentrations in sand. This was attributed to reduced bioavailability in natural soil due to stronger adsorption of the active ingredient to soil particles. NOEC values for seedling emergence in natural soil ranged from 857.1 mg/kg for red clover to >5001.3 mg/kg for wheat (ECHA, 2023a).

Studies investigating the effects of QACs on unicellular green algae *Chlorella* and duckweed *S. oligorhiza* were summarized by Henderson (1992); it was reported that various types of QACs were strongly phytotoxic with suppressed plant growth evident at concentrations above 10⁻⁵ M (approximately 1.6 to 5 ppm). A commercial formulation of DDAC, Bardac 22, at 3.0 to 5 ppm



suppressed plant growth in both species after a three-day exposure. In duckweed, sublethal levels of QACs caused yellowing or browning of the frond margins and the production of smaller sized fronds. In *Chlorella*, the size, shape, and internal organization of the cell were affected, with death appearing to be due to disruption of chloroplast structure (Henderson, 1992).

4.4.4.2 Bees (and/or Other Insects)

Based on available information, DDAC (C-10s) would be considered practically nontoxic to bees via contact exposure. In a 48-hour toxicity study conducted in accordance with Ecological Effects Test Guidelines OCSPP 850.3020, the LD₅₀ was > 100 µg/bee. At the limit test dose of 100 µg/bee, mortality was noted at 10% mortality (3 out of 30 bees), and no behavioral symptoms were observed (EPA, 2019c).

4.4.4.3 Amphibians and Reptiles

No studies were identified that assessed DDAC (C-10s) toxicity in amphibians and reptiles. According to EPA, birds can be used as surrogates for terrestrial-phase amphibians and reptiles, whereas freshwater fish can be used as surrogates for aquatic-phase amphibians. As detailed in sections below, DDAC (C-10s) was classified as “Moderately toxic” to “Practically nontoxic” to birds and “Moderately to very highly toxic” to fish, suggesting that it could be considered “Moderately toxic” to “Practically nontoxic” to terrestrial-phase amphibians and reptiles and “Moderately to very Highly toxic” to aquatic-phase amphibians.

4.4.4.4 Birds

According to EPA (2006a), DDAC (C-10s) was practically nontoxic to mallard duck and bobwhite quail in dietary avian studies; however, in acute oral studies in bobwhite quail, DDAC (C-10s) was found to be moderately toxic. No additional details were provided by EPA.

According to Henderson (1992), DDAC had moderate to low toxicity in avian species. It was noted that in an acute oral toxicity study, an LD₅₀ of 3300 mg/kg was reported for mallard ducks. Additionally, in eight-day dietary studies, the LC₅₀ values were 975 and 1950 ppm in bobwhite quail, depending on the formulation tested, whereas in mallard duck, the LC₅₀ values were >1750 and >3600 ppm for different DDAC formulations.

4.4.4.5 Mammals

According to EPA (2006b), oral LD₅₀ values for DDAC (C-10s) ranging from 238 to 262 mg/kg were reported for rats,

depending on the active ingredient concentrations, which ranged from 65% to 80%. On the basis of these LD₅₀ values, DDAC (C-10s) could be classified as “Moderately toxic”; however, the use of DDAC as a disinfectant for equipment would presume limited environmental release.

4.4.4.6 Fish (and/or Other Aquatic Organisms)

According to EPA (2006a), DDAC (C-10s) was “Moderately to highly toxic” in freshwater fish, “Very highly toxic” in freshwater aquatic invertebrates, and “Very highly toxic” to mysid shrimp. It was noted that DDAC (C-10s) was toxic to freshwater alga at “microgram concentrations”. The Agency noted that DDAC (C-10s) persistence and toxicity in aquatic environments indicated that environmental release, especially in waterbodies, could pose risks to non-target aquatic organisms and recommended precautions, such as containment of runoff water from treated wood and careful management of aquatic uses (EPA, 2006a).

According to Henderson (1992), DDAC (C-10s) demonstrated varying levels of toxicity across different aquatic species. The most sensitive species was bluegill sunfish, with a 24-hour LC₅₀ of 0.60 ppm. In a 48-hour study, an LC₅₀ of 0.63 ppm was noted for rainbow trout. In other fish species, the LC₅₀ values ranged from 0.30 to 1.25 ppm. In 96-hour acute toxicity studies, the LC₅₀ values in various fish species ranged from 0.27 to 2.48 ppm. In aquatic invertebrates, LC₅₀ values of 0.094 and 0.069 ppm were reported in *Daphnia* and mysid shrimp, respectively. NOECs were also noted for several aquatic species, ranging from 0.052 ppm in mysid shrimp to 0.59 ppm in coho salmon (Henderson, 1992).

4.4.5 Environmental Fate Assessment

DDAC (C-10s) is a non-volatile, photolytically stable salt, which is highly soluble in water under abiotic conditions, ranging from moderately acidic through moderately alkaline environments (EPA, 2006c; Henderson, 1992). DDAC (C-10s) is immobile in the soil with a strong tendency to bind to sediment or soil. It is stable to photodegradation in neutral buffered aqueous solutions (pH 7) even in the presence of photosensitizers, such as acetone. According to Biomonitoring California, under aerobic conditions, QACs such as DDAC (C-10s) and DDAC (C-12s), may exhibit biodegradability (Biomonitoring California, 2020). However, EPA classifies DDAC (C-10s) as not readily degradable with an estimated half-life of 227 days based on an OECD 301 series of tests. In addition, DDAC (C-10s) is stable to microbial degradation under aerobic and anerobic conditions in aquatic metabolic studies. It is also photolytically stable in soil with a calculated half-life of 132



days (EPA, 2006c). DDAC is not expected to bioaccumulate in aquatic organisms (EPA, 2006a).

4.4.6 Conclusions and Recommendations

Based on the information reviewed, adverse effects of DDAC in humans may occur via contact with eyes and skin. Additionally, aquatic organisms are highly sensitive to DDAC, but risks can be mitigated. If DDAC represents the most suitable option for some applications, appropriate precautions must be taken when applying it as a disinfectant. These include using appropriate PPE, preventing runoff into storm drains and water bodies, and limiting use to well-ventilated areas. It is also essential to review and comply with the EPA-stamped labels (Quat 128: https://ordspub.epa.gov/ords/pesticides/f?p=PPLS:8::::P8_PUID,P8_RINUM:203973,47371-130-559; Physan 20: https://www3.epa.gov/pesticides/chem_search/ppls/055364-00005-20241009.pdf).



5 Repellents

Two repellents (DEET, picaridin) were evaluated in this report. Their toxicity in humans and ecological receptors is summarized in **Table 21** and **Table 22**, respectively. Overall, the repellents showed low toxicity to humans and ecological receptors under labeled use, with no evidence of carcinogenicity, genotoxicity, or significant endocrine, neurotoxic, or immunotoxic effects. Both are not expected to persist or bioaccumulate in the environment.

On the basis of this review, both repellents offer low hazard profile when considering hazard potential in humans and ecological receptors. Additionally, given their application, exposure to these pesticides is expected to be minimal in humans and in ecological receptors. In deciding which repellent to incorporate into their IPM, Midpen should consider specific target species, application methods, and label requirements.

Table 21. Human Toxicity Summary of Repellents

Endpoint	DEET	Picaridin
Acute Toxicity (Oral)	Category III	Category III
Acute Toxicity (Dermal)	Category III	Category III
Acute Toxicity (Inhalation)	Category IV	Category IV
Subchronic and chronic toxicity	Minor effects at high doses. Chronic exposure not expected	No treatment-related effects up to the highest dose
Carcinogenicity and Genotoxicity	No evidence	No evidence
Developmental and Reproductive Toxicity	Not expected from labeled use	No evidence
Endocrine Disruption	Not selected for Tier 2 testing per EDSP. Possible endocrine-related effects noted in some studies, but insufficient mechanistic data	No evidence
Irritation (Eye)	Category III	Category III
Irritation (Skin)	Category IV	Category IV
Sensitization	Not a skin sensitizer	Not a skin sensitizer
Neurotoxicity	Not expected from labeled use	No evidence
Immunotoxicity	Not relevant	Studies not required

Table 22. Ecotoxicity Summary of Repellents

Ecological Receptor	DEET	Picaridin
Plants	Toxicity testing not required. Exposure expected to be inconsequential	Exposure expected to be inconsequential
Bees (and/or Other Insects)	No potential direct or indirect effects	No potential direct or indirect effects
Amphibians and Reptiles	Slightly toxic	Practically nontoxic
Birds	Slightly toxic	Practically nontoxic
Mammals	Practically nontoxic	Practically nontoxic
Fish (and/or Other Aquatic Organisms)	Slightly toxic	Practically nontoxic



5.1 N,N-diethyl-meta-toluamide (DEET)

Formulations: Various

Typical Target Pests: Insect repellent

Application: Annual application ~200 cans (6 oz. each) via spot spray. Pesticide applied to human body and/or clothing, shoes, and headwear.

Human Toxicity: *Acute and Short-term Toxicity:*

Category III (oral and dermal toxicity). Category IV

(inhalation toxicity); *Subchronic and Chronic Toxicity:*

Minor effects at high doses. Chronic exposure not

expected; *Carcinogenicity and Genotoxicity:* No evidence;

DART: Not expected from labeled use; *Endocrine*

disruption: Not selected for Tier 2 testing per EDSP.

Possible endocrine-related effects noted in some

studies, but insufficient mechanistic data; *Sensitization*

and irritation: Category III (eye). Category IV (skin). Not

a skin sensitizer; *Neurotoxicity:* Not expected from

labeled use; *Immunotoxicity:* Not relevant.

Ecological Toxicity: *Plants:* Toxicity testing not

required. Exposure expected to be inconsequential; *Bees*

(and/or other Insects): No potential direct or indirect

effects; *Amphibians and Reptiles:* Slightly toxic; *Birds:*

Slightly toxic; *Mammals:* Practically nontoxic; *Fish*

(and/or other Aquatic Organisms): Slightly toxic.

Environmental Fate: Limited environmental release

based on use. Not expected to persist or accumulate

significantly in the environment.

Conclusions and Recommendations: No risks to

humans or ecological receptors expected from labeled

use. DEET can be added to Midpen's list of approved

pesticides.

5.1.1 Background

DEET (CAS # 134-62-3) is an active ingredient in personal insect repellents that are commonly applied to the human body and/or clothing, shoes, and headwear (EPA, 2012b). It is also used as a body treatment on horses to repel biting flies, biting midges, black flies, chiggers, deer flies, fleas, gnats, horse flies, mosquitoes, no-see-ums, sand flies, stable flies, and ticks (EPA, 2012b). The suggested mode of action by which DEET repels insects is its interference with sensory receptors that insects rely upon to follow warm and moist air currents given off by warm-blooded animals (CDPR, 2000).

DEET is formulated as a microencapsulated, pressurized spray, or an aerosol; as impregnated materials such as towelettes; and as a ready-to-use solution, such as a non-aerosolized pump spray, liquid, cream, lotion, or foam (EPA, 2012b). DEET concentrations in such products range from 5.0% to 98.25%. DEET also has industrial uses as a resin solvent and as a surface plasticizer (EPA, 2012b).

5.1.2 Exposure Considerations

DEET is directly applied to the human body and clothing being worn (EPA, 2012b). Therefore, dermal exposure is expected to be the primary exposure route; however, inhalation exposure is possible with aerosolized DEET products whereas oral exposure is possible via hand-to-mouth if hands are not washed following use (EPA, 2024b). DEET is not registered for agricultural, non-agricultural, or greenhouse applications, or any home, residential, or indoor applications in which it is applied to surfaces other than the human body. The EPA Health Effects Division (HED) recommends to not spray DEET in enclosed areas, to not apply DEET to the eyes and mouth, to not apply DEET to the hands of young children, to not spray DEET directly on the face, and to wash treated skin with soap and water after returning indoors (EPA, 2024b).

Midpen's annual application of DEET is estimated at 200 cans (6 oz. each). The method of application is noted as spot spray. The exact formulation to be used is not specified.

5.1.3 Human Toxicity and Risk Assessment

5.1.3.1 Acute and Short-term Toxicity

According to EPA (2024b), DEET was classified as Category III for oral and dermal toxicity and Category IV for inhalation toxicity. The oral LD₅₀ values ranged from 1000 to 3664 mg/kg, the dermal LD₅₀ values were 4280-5000 mg/kg, and the inhalation LC₅₀ values were 2.02-5.95 mg/L (

Table 23). As for sublethal effects, in an acute neurotoxicity study in rats, decreased vertical activity was observed one hour after dosing, which was considered adverse; however, the dose was not specified. At higher doses, piloerection, increased vocalization, decreased horizontal and vertical activity, and increased response time to heat were observed; however, recovery occurred within 24 hours of exposure (EPA, 2024b).



Table 23. *Acute Toxicity of DEET*

Species (Sex)	Toxicity Threshold	Dose/Concentration	EPA Category
Rat (M/F)	Oral LD ₅₀	2170-3664 mg/kg	Low Toxicity (III)
Rat (M)	Oral LD ₅₀	3664 mg/kg	Low Toxicity (III)
Rat (M)	Oral LD ₅₀	1944 mg/kg	Low Toxicity (III)
Rat (F)	Oral LD ₅₀	1000-2000 mg/kg	Low Toxicity (III)
Rat (castrated M)	Oral LD ₅₀	1892 mg/kg	Low Toxicity (III)
Rat (M/F)	Dermal LD ₅₀	5000 mg/kg	Low Toxicity (III)
Rabbit (unspecified)	Dermal LD ₅₀	4280 mg/kg	Low Toxicity (III)
Rat (unspecified)	Inhalation LC ₅₀	5.95 mg/L	Very Low Toxicity (IV)
Rat (M/F)	Inhalation LC ₅₀	2.02 mg/L	Very Low Toxicity (IV)
Source: EPA (2024b)			

5.1.3.2 Subchronic and Chronic Toxicity

Based on subchronic and chronic toxicity studies on DEET reviewed by EPA, minor effects were observed at high doses, and it was noted that chronic exposure was not expected (EPA, 1998a). According to EPA (2024b), decreased body weight and decreased body weight gain were noted in several subchronic and chronic toxicity studies on DEET in rats, mice, hamsters, and dogs. NOELs ranging from 61 to 100 mg/kg, LOELs ranging from 100 to 400 mg/kg, and a NOAEC of ≤ 3000 ppm were reported (Table 24). Additional effects included increased liver weights in DEET-exposed rats and mice without accompanying microscopic lesions. In male rats, DEET induced $\alpha 2\mu$ -globulin kidney lesions; however, these effects are not considered to be relevant to human health. In a combined chronic oral toxicity and carcinogenicity study, decreased body weight, decreased food consumption, and

increased cholesterol were observed in female rats. In another chronic oral toxicity study, decreased body weight, decreased body weight gain, and decreased food consumption were observed in male and female mice. In dogs, body weight loss and decreased organ weights in a feeding study were attributed to food avoidance. Ptyalism was observed in male and female dogs administered DEET in capsules. Further, abnormal head movement, decreased body weight, and decreased food consumption were noted in dogs. Additionally, decreased testes and epididymides weights were observed without corroborating gross or histopathological changes, but were not observed at the same dose in the chronic study. In a 90-day dermal study, systemic effects, including $\alpha 2\mu$ -globulin nephropathy, were observed among male rats, and local site of application effects included acanthosis and hyperkeratosis (EPA, 2024b).

Table 24. *Subchronic and Chronic Toxicity of DEET*

Guideline No.	Species	Route	Duration	Doses/Concentrations	Findings	Toxicity Thresholds
870.3100	Rat	Oral	Subchronic	0, 100, 500, 1000, 2000, or 4000 mg/kg/day	Increased liver weights in males and increased incidence of renal lesions (granular casts, inflammation, regeneration, and hyaline droplets in males)	• NOEL = Not available • LOEL = 100 mg/kg/day
870.3100	Mouse	Oral	Subchronic	0, 300, 1000, 3000, 6000, or 10,000 mg/kg/day	Increased liver weights in females	• NOEL = Not available • LOEL = 300 mg/kg/day
870.3100	Hamster	Oral	Subchronic	0, 61/61, 304/305, 611/636, or 940/939 mg/kg/day (M/F)	Decreased food consumption and body weight	• NOEL = 61/61 mg/kg/day • LOEL = 304/305 mg/kg/day
870.1500	Dog	Oral	Subchronic	0, 50, 100, 200, or 400 mg/kg/day	Not available	Not available
870.1500	Dog	Oral	Subchronic	0, 300, 1000, 3000, or 6000/4500/3000 ppm	Not available	NOEC ≤ 3000 ppm
870.3200	Rat	Dermal	Subchronic	0, 100, 300, or 1000 mg/kg/day	Increased incidence of acanthosis and hyperkeratosis at application sites and increased incidence of renal lesions (granular casts, inflammation, tubular regeneration, and hyaline droplets)	• NOEL = Not available • LOEL = 100 mg/kg/day



Guideline No.	Species	Route	Duration	Doses/Concentrations	Findings	Toxicity Thresholds
870.4300	Rat	Oral	Chronic	0/0, 10/30, 30/100, 100/400 mg/kg/day (M/F)	Decreased body weight, food consumption, and increased cholesterol in females	NOEL = 100 mg/kg/day LOEL = 400 mg/kg/day
870.4100	Dog	Oral	Chronic	0, 30, 100, 400 mg/kg/day	Ptyalism and tremors and decreased food intake, body weight, and cholesterol	• NOEL = 100 mg/kg/day • LOEL = 400 mg/kg/day

Source: EPA (2024b)

5.1.3.3 Carcinogenicity and Genotoxicity

Based on the information reviewed by EPA, there was no evidence that DEET was carcinogenic or genotoxic (EPA, 2024b). There was no evidence that DEET was carcinogenic in a combined chronic toxicity and carcinogenicity study in which male rats were administered 0, 10, 30, or 100 mg/kg/day DEET and female rats were administered 0, 30, 100, or 400 mg/kg/day DEET. Similarly, there was no evidence of carcinogenicity in a carcinogenicity study in mice administered 0, 250, 500, or 1000 mg/kg/day DEET. Thus, EPA classified DEET as Group D (i.e., Not Classifiable as to Human Carcinogenicity) (EPA, 2024b).

Regarding genotoxicity, the Agency noted that, based on lack of evidence for mutagenicity in an Ames test in *S. typhimurium*, there was low mutagenicity concern for DEET (EPA, 2024b). Further, no induction of chromosomal aberrations was observed in Chinese hamster ovary cells treated with DEET at an unspecified concentration. There was also no evidence of unscheduled DNA synthesis in rat hepatocytes exposed to DEET at an unspecified concentration (EPA, 2024b).

5.1.3.4 Developmental and Reproductive Toxicity

EPA did not consider DEET to pose developmental or reproductive risks to humans at exposure levels expected from labeled use. According to EPA (2024b), there was no evidence of increased susceptibility of developing or young animals following *in utero* and/or pre-/post-natal exposure to DEET. In a two-generation reproduction study performed according to OPPTS Guideline 870.3800, rats were administered DEET in food at concentrations of 0, 500, 2000, or 5000 ppm. A parental NOEC was not established; however, the parental LOEC was determined to be 500 ppm on the basis of kidney effects, including mottling, inflammation, hyaline droplets, granular cast formation, and tubular regeneration. The reproductive and offspring NOECs were 5000 ppm (or approximately 250 mg/kg/day), the highest concentration tested (EPA, 2024b).

In a developmental toxicity study in rats performed according to OPPTS Guideline 870.3700, dams were administered DEET at doses of 0, 125, 250, or 750 mg/kg/day (EPA, 2024b). The maternal NOEL was reported to be 250 mg/kg/day, whereas a maternal LOEL of 750 mg/kg/day was established based on clinical signs, including hypoactivity, ataxia, foot splay, perinatal encrustation, and perioral wetness, as well as reduced body weight gain and food consumption, increased mortality, and increased liver weight. Regarding developmental effects, a NOEL of 250 mg/kg/day was reported, whereas a LOEL of 750 mg/kg/day was determined based on decreased fetal body weight (EPA, 2024b).

In a developmental study in rabbits, does were administered DEET at doses of 0, 30, 100, or 325 mg/kg/day (EPA, 2024b). The maternal and developmental NOELs were estimated as 325 mg/kg/day, the highest dose tested (EPA, 2024b).

5.1.3.5 Endocrine Disruption

DEET was included in the initial list of chemicals subject to Tier 1 screening under EDSP, and, as of the latest update, DEET was not among the chemicals for which EPA recommended Tier 2 testing (EPA, 2025). Tier 2 testing is required if Tier 1 results indicated significant endocrine bioactivity. This suggests that EPA did not find sufficient evidence of DEET endocrine disruption potential to warrant further testing.

According to the California Department of Pesticides Regulation (CDPR), possible endocrine-related effects were observed in several animal studies on DEET (CDPR, 2000). In one study, urethral plugs of coagulating gland and seminal vesicle secretions were noted in male rats. Further, abnormal sperm morphology was observed in male rats in two studies, and increased testicular weights were noted in male rats in several studies. In some hamster and dog studies, decreases in testicular weight were noted. In the same hamster study, testicular tubular degeneration and small epididymides with luminal cellular debris were observed. Regarding endocrine-related effects in females, uterine hyperplasia was observed in one study in dogs. According to CDPR, there were insufficient data to



determine the exact mechanism of these possible endocrine-related effects (CDPR, 2000).

5.1.3.6 Sensitization and Irritation

According to EPA (2024b), DEET was classified as Category III for eye irritation and Category IV for dermal irritation. Additionally, DEET was not considered to be a skin sensitizer. No studies on respiratory sensitization potential of DEET were identified. Additional details regarding the sensitization and irritation potential of DEET are summarized in **Table 25**.

Table 25. Irritation and Sensitization Potential of DEET

Species	Test Type	Findings
Rabbit	Eye irritation	Eye irritation and corneal opacity cleared by day seven and three, respectively
Rabbit	Eye irritation	Moderately irritating
Rabbit	Skin irritation	Minimal irritation cleared by day seven
Rabbit	Skin irritation	Slightly irritating
Guinea pig	Dermal sensitization	Not a skin sensitizer
Guinea pig	Dermal sensitization	Not a skin sensitizer (Buehler method)
<i>Source: EPA (2024b)</i>		

5.1.3.7 Neurotoxicity

According to EPA (2024b), the possible neurotoxic effects noted in rat studies were not robust enough to provide an adequate basis for risk assessment. In an acute neurotoxicity study in rats, decreased vertical activity was observed one hour after dosing, which was considered adverse; however, the dose was not specified. At higher doses, piloerection, increased vocalization, decreased horizontal and vertical activity, and increased response time to heat were observed; however, recovery was noted within twenty-four hours. In a multi-generation study in rats, adverse neurotoxic effects, including increased motor activity, were observed in the highest dose group of 225 mg/kg/day in the F₂ generation offspring; however, this increased horizontal activity was transient and was significant only at the first measurement period, was not accompanied by any clinical signs or histopathological changes, and was an effect that was small in magnitude. In the previously mentioned subchronic oral study in dogs, abnormal head movements, ptialism, and tremors were noted only at the highest dose tested (400 mg/kg/day). Further, some signs of neurotoxicity were observed in a developmental rat study, but only at the highest dose of 750 mg/kg/day (EPA, 2024b).

According to EPA (2007), reported human effects in case reports include neurological effects (seizures, encephalopathy, tremor slurred speech, coma, and, rarely, death) in children and adults, which typically occurred following ingestion of DEET or dermal applications not consistent with label directions. It was estimated that the incidence of seizures following DEET exposure was low (one per 100 million users). The Agency concluded that, in many cases, data were insufficient to define DEET as the cause of the reported effects (EPA, 2007).

5.1.3.8 Immunotoxicity

According to EPA (2024b), immunotoxicity studies were not relevant based on the available DEET hazard and exposure information.

5.1.4 Ecological Toxicity and Risk Assessment

5.1.4.1 Plants

According to EPA (2012b), there were no potential direct or indirect effects to terrestrial and semi-aquatic plants (monocots and dicots) or aquatic vascular or nonvascular plants from the currently registered uses of DEET. No toxicity data were available for vascular and non-vascular aquatic or terrestrial plants. The Agency also noted that DEET exposure to plants was expected to be inconsequential based on labeled use patterns (EPA, 2012b).

5.1.4.2 Bees (and/or Other Insects)

According to EPA (2012b), there were no potential direct or indirect effects on terrestrial invertebrates from the currently registered uses of DEET. DEET may bind to the olfactory receptors of insects, which interferes with the normal feeding response (EPA, 2024b). DEET was noted to be a “true repellent”, meaning that some insects intensely dislike the smell of the chemical (EPA, 2024b). According to EPA (2012b), no toxicity data were available for honeybees or non-target insects; however, one study assessed DEET toxicity in copra mites (*T. putrescentiae*) and an LD₅₀ of 13.9 µg/cm² was reported.

5.1.4.3 Amphibians and Reptiles

According to EPA (2012b), toxicity tests in amphibians or reptiles were not required. The Agency noted that birds can be used as surrogates for terrestrial-phase amphibians and reptiles, whereas freshwater fish can be used as surrogates for aquatic-phase amphibians. As detailed in sections below, DEET was classified as “Slightly toxic” to birds and



fish, suggesting that it would be “Slightly toxic” to amphibians and reptiles.

5.1.4.4 Birds

According to EPA (1998a), DEET was classified as “Slightly toxic” to birds. EPA also concluded that there were no potential direct or indirect effects to birds from the currently registered uses of DEET (EPA, 2012b). It was noted that DEET was slightly toxic to birds, such that an LD₅₀ of 1375 mg/kg was reported for DEET in an acute oral toxicity study in bobwhite quail (*C. virginianus*). No dietary or chronic toxicity data were available for birds (EPA, 2012b).

5.1.4.5 Mammals

According to EPA (1998a), DEET was classified as “Practically nontoxic” to mammals. EPA also concluded that there were no potential direct or indirect effects to mammals from the currently registered uses of DEET (EPA, 2012b). It was noted that DEET was considered practically nontoxic to mammals, such that a NOAEC of 500 ppm and a LOAEC of 2000 ppm were reported for DEET in a two-generation study in rats. Decreased body weight in female pups was noted, but no effects on survival, growth, or reproduction were identified in parental animals (EPA, 2012b).

5.1.4.6 Fish (and/or Other Aquatic Organisms)

According to EPA (1998a), DEET was classified as “Slightly toxic” to fish. It was also concluded that there were no potential direct or indirect effects to freshwater fish or marine/estuarine fish and invertebrates from the currently registered uses of DEET (EPA, 2012b). It was noted that DEET was slightly toxic to fish and aquatic invertebrates, such that the reported LC₅₀ values were 235 mg/L (*G. affinis*), >100 mg/L (*G. fasciatus*), 71.25 mg/L (*O. mykiss*), and 110 mg/L (*P. promelas*) (EPA, 2012b).

5.1.5 Environmental Fate Assessment

According to EPA (2012b), DEET is expected to be moderately mobile in the soil column. DEET has a half-life measured in days to weeks, indicating that it is expected to degrade at a moderate to rapid rate. The amount of DEET that is retained in the air is subject to rapid photo-oxidation by hydroxy radical-mediated degradation with a half-life between 10 and 15 hours. DEET also has a low bioaccumulation potential (EPA, 2012b).

5.1.6 Conclusions and Recommendations

Based on the information reviewed, no risks to human or environmental health were identified for DEET. With user education on proper application and advice to wash treated skin, this pesticide can be added to Midpen’s list of approved pesticides, as long as its use is consistent with the most recent EPA-stamped label(s)

(<https://ordspub.epa.gov/ords/pesticides/f?p=113:5:.....>).



5.2 Picaridin

Formulations: Various

Typical Target Pests: Insect repellent

Application: Annual application ~200 cans (5 oz. each) via spot spray. Pesticide applied to human body and/or clothing, shoes, and headwear.

Human Toxicity: *Acute and Short-term Toxicity:*

Category III (oral and dermal toxicity). Category IV (inhalation toxicity); *Subchronic and Chronic Toxicity:* No treatment-related effects up to the highest dose; *Carcinogenicity and Genotoxicity:* No evidence; *DART:* No evidence; *Endocrine disruption:* No evidence; *Sensitization and irritation:* Category III (eye). Category IV (skin). Not a skin sensitizer; *Neurotoxicity:* No evidence; *Immunotoxicity:* Studies not required.

Ecological Toxicity: *Plants:* Exposure expected to be inconsequential; *Bees (and/or other Insects):* No potential direct or indirect effects. Significant exposure not expected; *Amphibians and Reptiles:* Practically nontoxic; *Birds:* Practically nontoxic. Significant exposure not expected; *Mammals:* Practically nontoxic; *Fish (and/or other Aquatic Organisms):* Practically nontoxic.

Environmental Fate: Very low environmental concentrations. Not expected to persist or accumulate significantly in the environment.

Conclusions and Recommendations: No risks in humans or ecological receptors expected from labeled use. Picaridin can be added to Midpen's list of approved pesticides.

5.2.1 Background

Picaridin (CAS # 119515-38-7), also known as 2-(hydroxyethyl)-1-piperidinecarboxylic acid 1-methylpropyl ester or hydroxyethyl isobutyl piperidine carboxylate, is an active ingredient in broad-spectrum insect and tick repellents that are used on the human body (i.e., skin and hair) and clothing, shoes, and headwear (EPA, 2014e, 2014f). It is also applied to horses as an insect repellent (EPA, 2014f). Specifically, it is used to repel biting flies, mosquitoes, chiggers, ticks, and fleas. Although the exact mode of action of picaridin has not yet been elucidated, it has been suggested that the direct detection of picaridin by olfactory receptor neurons in the antenna of mosquitos may prevent host recognition. According to some research, mosquito response to picaridin varies by individual organism and species; for example, repellency was decreased in individual mosquitos lacking maxillary bulbs. Additionally, *A. stephensi* mosquitos have demonstrated the ability to sense picaridin while maintaining the ability to recognize hosts with other organs (EPA, 2014f).

Picaridin is usually formulated as a pressurized spray or aerosol, impregnated materials such as towelettes or roll-ons, or as a ready-to-use solution, including non-aerosol pump sprays, liquids, creams, lotions, or foams (EPA, 2014f). The concentrations of picaridin in end-use products range from 5% to 20%, and most products recommend an application frequency of one to three times per day (EPA, 2014e, 2014f).

5.2.2 Exposure Considerations

Picaridin is applied directly to the human body and clothes being worn (EPA, 2014f). Therefore, dermal exposure is expected to be the primary exposure route; however, inhalation exposure is possible with aerosolized picaridin products, and oral exposure is possible via hand-to-mouth if hands are not washed after application (EPA, 2014e). Picaridin is not registered for an agricultural, non-agricultural, greenhouse, home, residential, or indoor applications (EPA, 2014f). Dietary exposure is not expected as there are no registered food uses (EPA, 2014e). Picaridin is not known to be a byproduct of any industrial manufacturing or refining processes and there are no registered uses of picaridin that could result in occupational exposure (EPA, 2014e, 2014f). The EPA Health Effects Division (HED) does not provide any recommendations with regard to use or labelling (EPA, 2014e). However, general use directions on registered labels include the following: avoid application of excessive amounts or frequent applications; use enough repellent to cover exposed skin; do not use under clothing; do not apply over cuts, wounds, irritated, or sunburned skin; do not allow children to handle the product and do not apply to children's hands; do not apply directly to face, near eyes, or mouth; and wash treated skin with soap and water after returning indoors and wash treated clothing before wearing again (EPA, 2014e).

Midpen's annual application of picaridin is estimated at 200 cans (5 oz. each). The method of application is noted as spot spray. The exact formulation to be used is not specified.

5.2.3 Human Toxicity and Risk Assessment

5.2.3.1 Acute and Short-term Toxicity

According to EPA (2005), picaridin was classified as Category III for oral and dermal toxicity and Category IV for inhalation toxicity. Four studies were identified that assessed acute toxicity potential of picaridin (EPA, 2014e). In an oral study in rats with 2% Cremophor EL, the LD₅₀ values were 4743 and 2236 mg/kg in male and female rats, respectively. In a dermal study in rats, the LD₅₀ was > 2000 mg/kg, the highest dose tested. In this acute dermal study,



acute neurotoxicity was also assessed, and no evidence of neurotoxicity was observed up to the highest dose tested of 2000 mg/kg/day. Finally, in an inhalation study in rats, LC₅₀ of > 4.364 mg/L and NOAEC of 4.364 mg/L were reported on the basis of slight body weight anomalies (EPA, 2014e).

5.2.3.2 Subchronic and Chronic Toxicity

In most studies assessing the toxicity potential of picaridin included in the EPA's assessment, no treatment-related effects were observed up to the highest doses tested (EPA, 2014e). It was noted that kidney effects, including increased kidney weight, slight hyaline degeneration, increased incidence of foci of tubular regeneration, chronic kidney inflammation, and protein droplet nephropathy, were observed in oral and dermal studies in rats at picaridin doses of ≥ 500 mg/kg/day. Per EPA, these kidney effects were consistent with nephrotoxicity due to accumulation of $\alpha 2\mu$ globulin ($\alpha 2\mu$ -g). To confirm that exposure to picaridin was related to $\alpha 2\mu$ -g accumulation, pathology slides and droplet staining were also assessed. Droplets were negative with Periodic Acid Schiff (PAS) stain and positive with Mallory's Heidenhain (MH) stain, consistent with what was observed for $\alpha 2\mu$ -g hyaline droplets. It was noted that $\alpha 2\mu$ -g is a male rat-specific protein, indicating that renal effects were unlikely to occur in species not producing $\alpha 2\mu$ -g or a very closely-related protein $\alpha 2\mu$ -g. Therefore, EPA did not consider kidney effects appropriate for picaridin risk assessment. In the same chronic toxicity study, a decrease in body weight was noted in the highest-dose group (1000 mg/kg/day) following oral exposure for five weeks but no progression of toxicity was observed across the remainder of the study period of 14 weeks. Additionally, EPA summarized a 14-day oral range finding study in which rats were administered picaridin at doses of 0, 90, 141, 183, or 1731 mg/kg/day in males and 0, 109, 163, 202, or 1826 mg/kg/day in females; the NOAEL values of 1731 and 1826 mg/kg/day were reported in males and females, respectively (EPA, 2014e).

5.2.3.3 Carcinogenicity and Genotoxicity

According to EPA (2014e), picaridin was classified as not likely to be carcinogenic to humans via the dermal route. In dermal carcinogenicity studies in rats and mice, no treatment-related increase in tumors were observed up to doses of 200 mg/kg/day (EPA, 2014e).

According to EPA (2014e), there was no mutagenic concern for picaridin. Picaridin was negative for mutagenicity in most studies assessed by EPA, including in *S. typhimurium*, Chinese hamster V79 cells, rat hepatocytes, and murine cells. In one study, picaridin was clastogenic in Chinese hamster ovarian (CHO) cells in the absence of metabolic activation; however, in another study in CHO cells, picaridin

was clastogenic with metabolic activation and equivocal in the absence of metabolic activation (EPA, 2014e).

5.2.3.4 Developmental and Reproductive Toxicity

According to EPA (2014e), there was no evidence of quantitative or qualitative susceptibility observed in dermal developmental and reproductive toxicity studies on picaridin. In studies assessing the developmental and reproductive toxicity potential of picaridin in rats and rabbits, no maternal or fetal/offspring effects were observed up to the highest doses tested of 400 and 200 mg/kg/day, respectively (EPA, 2014e).

5.2.3.5 Endocrine Disruption

According to EPA (2005), there was no evidence that picaridin was an endocrine disruptor. The Agency did not identify any endocrine-related effects in animal studies and did not require further testing under EDSP. Picaridin was not classified as an endocrine disruptor and did not appear on the Endocrine Society's list of chemicals with known endocrine-disrupting activity or on the ECHA Endocrine Disruptor Assessment List (ECHA, 2025a; Endocrine Society, 2025).

5.2.3.6 Sensitization and Irritation

According to EPA (2014e), picaridin was not a skin sensitizer because no sensitizing reactions were observed in guinea pig Buehler tests of 20% alcoholic and cream formations of picaridin. Regarding irritation, picaridin was moderately irritating to the eye (i.e., Category III) and not irritating to the skin (i.e., Category IV) based on studies in rabbits (EPA, 2014e).

5.2.3.7 Neurotoxicity

According to EPA (2014e), there was no evidence that picaridin was a neurotoxicant. In dermal acute and subchronic neurotoxicity studies, no evidence of neurotoxicity was observed in picaridin-exposed rats at doses as high as 2000 mg/kg/day (EPA, 2014e).

5.2.3.8 Immunotoxicity

According to EPA (2014e), immunotoxicity studies were not required for picaridin based on the available picaridin hazard and exposure information and using a weight of evidence approach.



5.2.4 Ecological Toxicity and Risk Assessment

5.2.4.1 Plants

No toxicity data were available for vascular aquatic plants or terrestrial plants; however, according to EPA (2014f), exposure of terrestrial plants to picaridin was expected to be inconsequential based on the labeled use patterns.

5.2.4.2 Bees (and/or Other Insects)

According to EPA (2014f), there were no potential direct or indirect effects on terrestrial invertebrates from the currently registered uses of picaridin. No toxicity data were available for bees or non-target insects. Due to the repellent action of picaridin on insects, it was likely that many terrestrial invertebrates would not be exposed for long periods of time; therefore, significant exposure was not expected (EPA, 2014f).

5.2.4.3 Amphibians and Reptiles

According to EPA (2014f), there were no potential direct or indirect effects on terrestrial-phase amphibians and reptiles or aquatic-phase amphibians from the currently registered uses of picaridin. The Agency noted that birds can be used as surrogates for reptiles and terrestrial-phase amphibians as reptiles, whereas freshwater fish can be used as surrogates for aquatic-phase amphibians (EPA, 2014f). As detailed in sections below, picaridin was classified as “Practically nontoxic” to birds and fish, suggesting that it would be “Practically nontoxic” to amphibians and reptiles.

5.2.4.4 Birds

According to EPA (2014f), picaridin was “Practically nontoxic” to birds. It was noted that the subacute avian dietary LC₅₀ was > 5000 ppm. No data regarding avian oral toxicity or avian reproductive toxicity were available. Additionally, the Agency noted that no significant exposure was expected for terrestrial organisms based on current use patterns of picaridin (EPA, 2014f).

5.2.4.5 Mammals

According to EPA (2014f), picaridin was slightly toxic to mammals on the basis of acute oral exposure with LD₅₀ values ranging from 2236 to 4743 mg/kg. However, based on **Table 4**, picaridin should be classified as “Practically nontoxic” because the LD₅₀ values were > 2000 mg/kg. The Agency also noted that in a 14-week feeding study, decreased body weights were observed in picaridin-exposed male and female rats, and that kidney effects,

including increased weight and nephropathy, occurred in males, resulting in a LOAEL of 1033 mg/kg/day. No developmental toxicity was observed up to doses of 400 mg/kg/day in laboratory rats (EPA, 2014f).

5.2.4.6 Fish (and/or Other Aquatic Organisms)

According to EPA (2014f), picaridin was “Practically nontoxic” to fish and aquatic freshwater invertebrates. Picaridin 96-hour LC₅₀ in rainbow trout (*O. mykiss*) was 183 mg/L, whereas the EC₅₀ values were >103 mg/L (water flea *D. magna*) and 97 mg/L (*S. subpiscatus*). Although some toxicity was observed in algae, these effects occurred at concentrations 1000-times above the expected exposure levels (EPA, 2014f).

5.2.5 Environmental Fate Assessment

Picaridin is expected remain dissolved in water given its water solubility of 196 mg/L, and it is not expected to volatilize under moist conditions based on its Henry’s Law Constant of 3.0×10^{-11} atm-m²/mol (EPA, 2014f). Under dry conditions, picaridin is moderately volatile given its vapor pressure value of 4.40×10^{-4} torr; however, picaridin volatilization is not expected to occur to a great extent. After picaridin is washed off from treated skin or clothing, it is expected to remain in the water column to a certain extent. Although picaridin has a logK_{ow} of 4.94, which suggests that it is lipophilic and may bioconcentrate, picaridin has a small bioconcentration factor of 23.05 L/kg. Further, picaridin’s environmental concentrations are expected to be very low. Therefore, picaridin bioaccumulation is not expected to be prevalent. Additionally, there is evidence that picaridin may degrade in the environment to picaridin carboxylic acid from wastewater treatment monitoring data, although picaridin is generally stable for up to 30 days (EPA, 2014f).

5.2.6 Conclusions and Recommendations

Based on the information reviewed, no risks to human or environmental health were identified for picaridin. With user education on proper application and advice to wash treated skin, this pesticide can be added to Midpen’s list of approved pesticides, as long as its use is consistent with the most recent EPA-stamped label(s) (<https://ordspub.epa.gov/ords/pesticides/f?p=113:5:.....>).



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APPENDIX B2

Regulatory and Literature Review of Approved Pesticides in 2019 Program Addendum and 2014 Program (2025)

Regulatory and Literature Review of Pesticides

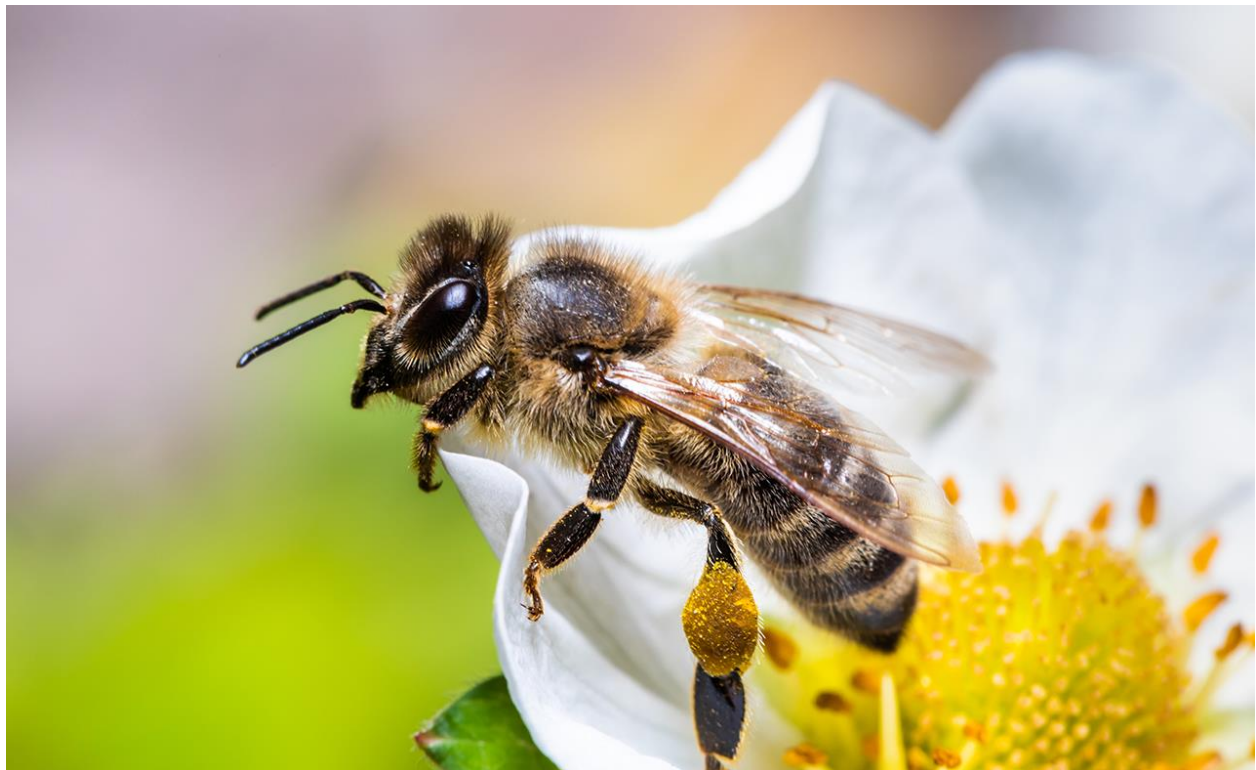
This report documents findings and recommendations following the review of available Midpeninsula Regional Open Space District reports, U.S. Environmental Protection Agency reports, and peer-reviewed literature relevant to the approved pesticides to determine whether there are any changes to the general toxicological findings of effects on humans, wildlife, and plants that were used as the basis for the environmental assessments conducted by Midpen in 2014 and 2019.

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Panorama Environmental, Inc.

Date:
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Prepared by:
Stantec Consulting Services Inc.

Project/File:
Regulatory and Literature Review of
Pesticides



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Executive Summary

Stantec was asked to assist with the environmental compliance review under the California Environmental Quality Act (CEQA) for Midpeninsula Regional Open Space District's (Midpen) 10-year update to their Integrated Pest Management Program (IPMP). To this end, Stantec reviewed the available Midpen pesticide use reports, U.S. Environmental Protection Agency (EPA) reports, and peer-reviewed literature relevant to the approved pesticides to determine whether there are any changes to the general toxicological findings of effects on humans, wildlife, and plants that were used as the basis for the environmental assessments conducted in 2014 and 2019. Based on the materials reviewed, it was determined that the general toxicological findings of effects on humans, wildlife, and plants that were used as the basis for the environmental assessments conducted in 2014 and 2019 remain accurate. It is noteworthy that, among the pesticides reviewed in this report, glyphosate safety remains a topic of scientific debate, with a substantial number of peer-reviewed articles published in 2021-2025 and a new assessment by EPA anticipated in 2026. Although Midpen's use of glyphosate was not anticipated to pose risks, it would be important to continue educational engagement with Midpen personnel applying glyphosate to ensure that it is used per label and with appropriate personal protective equipment.



Acronyms / Abbreviations

Acronym / Abbreviation	Full Name
ASD	Autism spectrum disorder
AHS	Agricultural Health Study
AMPA	Aminomethylphosphonic acid
BE	Biological Evaluation
BEE	Butoxyethyl ester
CEQA	California Environmental Quality Act
EDSP	Endocrine Disruptor Screening Program
EWG	Environmental Working Group
EPA	U.S. Environmental Protection Agency
IARC	International Agency for Research on Cancer
IC ₂₅	25% Inhibition concentration
ID	Interim Registration Review Decision
IPA	Isopropylamine
IPM	Integrate Pest Management
IPMP	Integrated Pest Management Program
K	Potassium
LC ₅₀	Median lethal concentration
LD ₅₀	Median lethal dose
LOC	Level of concern
MEA	Monoethanolamine
Midpen	Midpeninsula Regional Open Space District
MM	Multiple myeloma
NHL	Non-Hodgkin lymphoma
NOAEC	No-observed-adverse-effect concentration
NOAEL	No-observed-adverse-effect level
NPIC	National Pesticide Information Center
POAE	Polyethoxylated tallow amine
PPE	Personal protective equipment
TEA	Triethylamine
TIPA	Triisopropylammonium



1 Overview

Stantec was asked to assist with a review of pesticides used by Midpeninsula Regional Open Space District (Midpen) under their Integrated Pest Management Program (IPMP) to support environmental compliance review under the California Environmental Quality Act (CEQA) for the IPMP update (**Table 1**). The original IPMP Guidance Manual was adopted by the Board of Directors in 2014, with the intention to revise and update the Program every 10 years. The IPMP Guidance Manual is underway to be updated.

Midpen's currently approved list of pesticides was reviewed in light of the IPMP 10-year update. The purpose of the review was to determine whether any new information has emerged regarding toxicological effects on humans, plants, or wildlife that would alter the conclusions of the environmental assessments completed in 2014 and 2019 to support the IPMP update (Midpen 2014; Midpen 2019b). Specifically, Stantec:

- Reviewed Midpen reports provided by Panorama that summarized peer-reviewed articles published from 2015 to 2020.
- Identified and reviewed reports released by the U.S. Environmental Protection Agency (EPA) since 2014.
- Identified and reviewed peer-reviewed articles published in 2021-2025. The articles' abstracts were reviewed to determine if endpoints of interest were addressed. Articles not addressing the endpoints of interest were considered to be not relevant.

The findings and recommendations are outlined in **Sections 2-5**.

Table 1. Pesticides Reviewed in this Report

Active Ingredient	Product Formulations (Manufacturer)
Glyphosate IPA	Roundup Custom (Monsanto)
Glyphosate K	Roundup ProMax (Monsanto)
Aminopyralid TIPA	Milestone (Dow AgroSciences)
Clopyralid MEA	Transline (Dow AgroSciences)
Imazapyr IPA	Polaris (Nufarm), Stalker (BASF)
Clethodim	Envoy Plus (Valent)
Triclopyr BEE	Garlon 4 Ultra (Dow AgroSciences)
Triclopyr TEA	Capstone (Dow AgroSciences)
Phosphite K salts, mono-/di-	Agri-Fos (AgBio)
Cholecalciferol	Cholecalciferol baits
Prallethrin	PT Wasp-Freeze II (BASF)
Indoxacarb	Advion Gel Baits (DuPont)
S-Hydroprene	Gentrol Point Source (Wellmark International)
Fipronil	Maxforce Bait Stations (Bayer)
Sodium tetraborate decahydrate (borax)	Prescription Treatment Baits (BASF), Terro Ant Killer II (Terro)
Diatomaceous earth	Diatomaceous earth



2 Herbicides

2.1 Glyphosate IPA and Glyphosate K

Glyphosate isopropylamine (IPA) salt [Roundup Custom (Monsanto)] and glyphosate potassium (K) salt [Roundup ProMax (Monsanto)] were included on the Midpen approved list of pesticides. According to [Appendix A](#) of Midpen (2014), (1) in humans, glyphosate toxicity was considered to be low, such that there was no evidence of carcinogenicity, neurotoxicity, or immunotoxicity, whereas skin and eye irritation was noted as “possible”, and reproductive toxicity were reported to occur at “very high doses” and (2) in ecological receptors, technical grade glyphosate was practically nontoxic to birds, fish, and aquatic invertebrates, whereas the surfactant polyethoxylated tallow amine (POAE) used in some glyphosate formulations was reported to cause toxicity to amphibians. According to [Appendix 1](#) of Midpen (2019b), glyphosate IPA was classified as “moderately toxic to aquatic-phase amphibians and practically nontoxic to terrestrial-phase amphibians” whereas glyphosate K was classified as “at most, moderately toxic to aquatic-phase amphibians and practically nontoxic to terrestrial-phase amphibians”.

Additional information on glyphosate toxicity was available since the 2014 and 2019 assessments by Midpen. Stantec reviewed the additional information as outlined below.

2.1.1 Toxicity in Humans

2.1.1.1 Midpen Reports

According to Midpen (2018b), studies on glyphosate had “conflicting and complicated results and various shortcomings: most are limited by sample size, confounding factors, a lack of a dose response, or unrealistic exposure levels”. In some animal studies, the effects occurred at low or intermediate doses but not at higher doses, whereas in other animal studies, the adverse effects occurred at doses exceeding environmentally relevant concentrations. It was also noted that in 2015, the International Agency for Research on Cancer (IARC) classified glyphosate as “probably carcinogenic to humans” and that an overarching factor in this decision was a handful of studies that found a positive association between occupational exposure to glyphosate and non-Hodgkin lymphoma (NHL) and several animal studies demonstrating the mechanistic potential for this link. On the other hand, other studies found no links between glyphosate and cancer. The most extensive study on occupational glyphosate and cancer risks was the Agricultural Health Study (AHS) that included 55,000 farmers, of which 45,000 were exposed to glyphosate with varying frequency and intensity. The authors concluded that there was no strong evidence that glyphosate use increased the risk of solid tumors or lymphoid malignancies, including non-Hodgkin's lymphoma; however, some preliminary evidence, albeit not statistically significant, of a possible association between myeloid leukemia and glyphosate use was noted when considering only the subset of participants that used glyphosate on average 38 days/year for 8 years. Further, the report noted that animal and human studies were evaluated by regulatory agencies in the U.S., Canada, Japan, Australia, and the European Union, as well as the Joint Meeting on Pesticide Residues of the United Nations and World Health Organization and based on the studies reviewed, the agencies determined that glyphosate was not likely to be carcinogenic. Another study, however, reported 33% higher odds of premature Parkinson's mortality in residents near glyphosate-treated agricultural land.



In Midpen (2018a), it was noted that glyphosate had very low (Category IV) acute toxicity in mammals through the oral and dermal routes and low toxicity via inhalation. It was also noted that glyphosate may lead to acute eye (temporary corneal opacity or irritation; Category III) or dermal (mild or slight irritation; Category IV) irritation and that glyphosate was not a skin sensitizer. Further, no reproductive or developmental toxicity was observed at doses up to and including the limit dose of 1,000 mg/kg/day and there was no evidence that glyphosate causes neurotoxicity, immunotoxicity, or endocrine disruption. Regarding carcinogenicity, it was noted that contrary to IARC's conclusions that glyphosate is "probably carcinogenic to humans", many regulatory and scientific agencies around the world concluded that glyphosate was not likely to be of carcinogenic risk to humans.

According to Midpen (2019a), conflicting conclusions on glyphosate carcinogenicity potential stemmed from different methodologies used as well as potential influence of industry (e.g., Monsanto). The report noted the aforementioned AHS study as well as two 2019 epidemiological studies, one of which found a 41% increase in NHL risk in the highest exposure group but was criticized for cherry picking and lack of dose-response relationship, whereas the other study found no association between glyphosate exposure and NHL. Regarding other health effects, it was noted that studies found no strong evidence linking glyphosate exposure to kidney disease, autism, or neurotoxicity. Lastly, studies on exposure biomonitoring indicated that glyphosate was detected in urine samples of general population and farmers; however, the exposures were below the maximum acceptable daily intake levels.

In Midpen (2020), it was noted that epidemiological studies found no strong evidence linking glyphosate exposure to increased risk of NHL or multiple myeloma (MM). As for other health effects, a positive association between glyphosate use and serum creatinine (i.e., kidney health biomarker) was noted in a study in farmers; however, glyphosate blood concentrations were not assessed, and causality was unclear. In another study, autism spectrum disorder (ASD)-like behaviors, biochemicals changes, and altered gut microbiota were observed in offspring of mice exposed to glyphosate during pregnancy; however, the authors noted that the effects occurred at doses "exceptionally unlikely" in humans. Lastly, several biomonitoring studies indicated that even high-exposure scenarios resulted in glyphosate levels well below regulatory concern thresholds.

As for recommendations, no changes to Midpen Integrate Pest Management (IPM) practices were proposed in the reports. It was recommended that applicators avoid skin contact and inhalation, wash hands and clothing, and continue using personal protective equipment (PPE) to minimize exposure even though exposure in wildland applicators was significantly lower than in farmers. It was also recommended to stay informed by consulting resources such as the National Pesticide Information Center (NPIC).

2.1.1.2 EPA Reports

According to EPA (2017b), glyphosate was a mild eye irritant, slight skin irritant, and was not a dermal sensitizer. It exhibited low toxicity across species, durations, life stages, and routes of exposure, such that in most studies, adverse effects occurred at doses at or above the limit dose (i.e., 1000 mg/kg/day). In acceptable chronic toxicity/carcinogenicity studies reviewed by EPA, the observed effects included decreased body weights and minor indicators of toxicity to the eyes, liver, and kidney. No effects were observed in route-specific dermal and inhalation studies. There was no evidence of glyphosate neurotoxicity, immunotoxicity, or endocrine disruption. Further, glyphosate showed no evidence of increased susceptibility in offspring following *in utero* exposures in rats or rabbits. In rats, maternal and developmental toxicity occurred at or above the limit dose. In rabbits, maternal toxicity manifested primarily



as clinical signs (diarrhea, few/soft feces) and developmental toxicity (decreased fetal weight) occurred only at high doses.

In EPA (2019a), the agency assessed glyphosate non-cancer and cancer risks in humans. It was concluded that:

- Glyphosate was not likely to be carcinogenic to humans based on a weight of evidence from animal, genotoxicity, and epidemiological studies.
- Acute and chronic dietary risks were not of concern, including in young children.
- Glyphosate did not bioaccumulate in breast milk since no glyphosate or its metabolites were detected in human breast milk samples.
- No risks were anticipated in homeowners who mix and apply products containing glyphosate.
- Residential post-application risks were not anticipated.
- Non-occupational bystander spray drift risks were not of concern.
- Chronic aggregate risks from exposure via food, water, and residential exposures were not of concern.
- Occupational risks were not of concern.
- Glyphosate was not an endocrine disruptor since no endocrine-related effects were identified.

Similar conclusions on lack of human health concerns due to glyphosate exposure were noted in EPA (2020c), reaffirming that glyphosate did not pose significant health risks to humans when used according to label directions, that there was no evidence of carcinogenicity, endocrine disruption, or other systemic toxicity was found, and that exposure scenarios (dietary, residential, occupational) were below levels of concern.

According to EPA (2020b), the agency found no human health risks of concern when the glyphosate-containing product was used according to the pesticide label. It was noted that the agency's findings were consistent with the conclusions of EPA's previous assessments as well as science reviews conducted by several international expert panels and regulatory authorities with the exception of IARC, which classified glyphosate as "probably carcinogenic" in 2015. It was indicated that EPA reviewed hundreds of thousands of public comments and approximately 200 unique scientific submissions and that no new evidence was identified that would change the agency's human health risk assessment conclusions on glyphosate (EPA, 2020b) (EPA 2020b).

In 2022, the U.S. Court of Appeals for the Ninth Circuit vacated the human health portion of the EPA's 2020 Interim Registration Review Decision (ID) for glyphosate [i.e., EPA (2020a)] (EPA, 2022b). EPA plans to: (1) revisit and clarify its evaluation of glyphosate's carcinogenic potential, (2) respond to the 2018 Environmental Working Group (EWG) petition requesting lower tolerance levels for glyphosate in oats and label changes to prohibit preharvest use, (3) make a determination under the Endocrine Disruptor Screening Program (EDSP), and (4) issue a final registration review decision by 2026.

As of May 9, 2025, EPA's website notes that the agency found no risks of concern to human health when glyphosate was used in accordance with label. It was noted that there was no indication that glyphosate was an endocrine disruptor or that children were more sensitive to glyphosate and that there was no evidence that glyphosate causes cancer in humans (EPA, 2025a).

2.1.1.3 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 8, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string "*(glyphosate) and (human) and (health or toxicity or toxicology)*" resulted in 649 articles



published in 2021-2025, which included 73 review articles. Given the multitude of articles, only the review articles were screened for relevance, and 28 review articles were determined to be relevant. As summarized in **Table 2**, glyphosate exposure in humans was thought to be linked to or associated with various adverse effects. Several articles also noted that dietary exposure to glyphosate was common in the general population.

Table 2. *Key Review Articles on Glyphosate Toxicity in Humans Published in 2021-2025*

PMID	DOI	Title	Main conclusion
40873538	10.1007/s43188-025-00294-z	Pre and postnatal exposure to glyphosate-based herbicides and potential neurodevelopmental outcomes: a systematic review of animal and epidemiological studies	There is emerging evidence suggesting that exposure to glyphosate-based herbicides (GBHs) during prenatal and postnatal periods may be associated with adverse neurodevelopmental outcomes in both humans and animal models
40650243	10.3390/ijms26136468	Soil to Synapse: Molecular Insights into the Neurotoxicity of Common Gardening Chemicals in Alzheimer's and Parkinson's Disease	Glyphosate may contribute to neurodegenerative diseases through oxidative stress and mitochondrial dysfunction
40617553	10.1016/j.fct.2025.115621	Scoping review of the relationship between glyphosate-based herbicide exposures and autism spectrum disorder	Evidence suggests a potential link between glyphosate exposure and increased risk of autism spectrum disorder
40462441	10.1002/ps.8901	Measured exposures to glyphosate in applicators and the general population: an updated review of the scientific literature since 2020	Glyphosate exposure is measurable in both occupational and general populations, with biomonitoring studies showing widespread presence
40418353	10.1007/s00204-025-04076-2	Toxicological concerns regarding glyphosate, its formulations, and co-formulants as environmental pollutants: a review of published studies from 2010 to 2025	Glyphosate formulations pose toxicological risks due to active ingredients and co-formulants, necessitating stricter regulation
39359637	10.3389/ftox.2024.1474792	Overview of human health effects related to glyphosate exposure	Glyphosate exposure is linked to various health effects including endocrine disruption, reproductive toxicity, and potential carcinogenicity
39200696	10.3390/ijerph21081087	Potential Role of Glyphosate, Glyphosate-Based Herbicides, and AMPA in Breast Cancer Development: A Review of Human and Human Cell-Based Studies	Glyphosate and its metabolite AMPA may contribute to breast cancer development through endocrine disruption and genotoxicity
38311300	10.1016/j.etap.2024.104381	Neurotoxicity of glyphosate: Focus on molecular mechanisms probably associated with alterations in cognition and behavior	Glyphosate may impair cognitive function and behavior through molecular pathways involving oxidative stress and neurotransmitter disruption
37890382	10.1016/j.jhazmat.2023.132814	Biomonitoring of glyphosate and aminomethylphosphonic acid: Current insights and future perspectives	Biomonitoring reveals consistent detection of glyphosate and its metabolite AMPA, indicating environmental and dietary exposure
37776469	10.1007/s10653-023-01763-w	Glyphosate uses, adverse effects and alternatives: focus on the current scenario in Brazil	Glyphosate use in Brazil is widespread, with documented adverse effects and emerging alternatives for safer use
37604359	10.1016/j.etap.2023.104252	Effects of glyphosate-based herbicides and glyphosate exposure on sex hormones and the reproductive system: From epidemiological evidence to mechanistic insights	Glyphosate disrupts sex hormone balance and reproductive function in both males and females
37598951	10.1016/j.chemosphere.2023.139810	GLYPHOSATE IMPACT on human health and the environment: Sustainable alternatives to replace it in Mexico	Glyphosate poses health and environmental risks; sustainable alternatives are needed for safer agricultural practices
37396986	10.59249/FKW55176	Epigenetic Inheritance and Transgenerational Environmental Justice	Glyphosate may cause heritable epigenetic changes, raising concerns about



Regulatory and Literature Review of Pesticides

2 Herbicides

PMID	DOI	Title	Main conclusion
			environmental justice and long-term health impacts
37209985	10.1016/j.envres.2023.116201	Occurrence and exposure assessment of glyphosate in the environment and its impact on human beings	Environmental presence of glyphosate contributes to human exposure through food, water, and air, raising health concerns
37054847	10.1016/j.chemosphere.2023.138676	Hazardous impacts of glyphosate on human and environment health: Occurrence and detection in food	Glyphosate residues in food are a significant route of exposure, with potential health risks including endocrine and reproductive effects
36548622	10.3390/toxics10120789	Exposure Levels of Pyrethroids, Chlorpyrifos and Glyphosate in EU-An Overview of Human Biomonitoring Studies Published since 2000	Human biomonitoring studies show glyphosate exposure is prevalent across Europe, with implications for health risk assessments
35868581	10.1016/j.envres.2022.113933	Effects of glyphosate and glyphosate-based herbicides like Roundup™ on the mammalian nervous system: A review	Glyphosate exposure affects the mammalian nervous system, potentially leading to neurotoxicity and behavioral changes
35736929	10.3390/toxics10060321	Glyphosate, Roundup and the Failures of Regulatory Assessment	Regulatory assessments have underestimated glyphosate's risks, highlighting gaps in safety evaluations
34831302	10.3390/cells10113079	Review: Mechanisms of Glyphosate and Glyphosate-Based Herbicides Action in Female and Male Fertility in Humans and Animal Models	Glyphosate impairs fertility through hormonal disruption and oxidative stress mechanisms
34830483	10.3390/ijms222212606	Pleiotropic Outcomes of Glyphosate Exposure: From Organ Damage to Effects on Inflammation, Cancer, Reproduction and Development	Glyphosate exposure leads to multiple adverse outcomes including inflammation, cancer, and reproductive toxicity
34829065	10.3390/foods10112785	Glyphosate Use, Toxicity and Occurrence in Food	Glyphosate is widely used and frequently detected in food, raising concerns about chronic exposure and health outcomes
34416252	10.1016/j.envres.2021.111902	The relationship between pesticide exposure during critical neurodevelopment and autism spectrum disorder: A narrative review	Pesticide exposure, including glyphosate, during critical developmental periods may increase the risk of autism
34305812	10.3389/fendo.2021.672532	Glyphosate Herbicide: Reproductive Outcomes and Multigenerational Effects	Glyphosate exposure affects reproductive health and may cause transgenerational effects
34246717	10.1016/j.tox.2021.152851	Glyphosate-based herbicides: Evidence of immune-endocrine alteration	Glyphosate alters immune and endocrine functions, contributing to systemic health effects
34093442	10.3389/fendo.2021.671991	Epigenetic Changes Associated With Exposure to Glyphosate-Based Herbicides in Mammals	Glyphosate exposure induces epigenetic changes that may affect gene expression and health across generations
34052177	10.1016/j.clml.2021.04.009	A Review and Update with Perspective of Evidence that the Herbicide Glyphosate (Roundup) is a Cause of Non-Hodgkin Lymphoma	Glyphosate exposure is associated with increased risk of Non-Hodgkin Lymphoma, supported by epidemiological evidence
33790858	10.3389/fendo.2021.627210	Controversies on Endocrine and Reproductive Effects of Glyphosate and Glyphosate-Based Herbicides: A Mini-Review	There is growing evidence of glyphosate's endocrine and reproductive toxicity, though some findings remain debated
33131751	10.1016/j.chemosphere.2020.128619	Glyphosate and the key characteristics of an endocrine disruptor: A review	Glyphosate exhibits characteristics of an endocrine disruptor, affecting hormone regulation and reproductive health



2.1.2 Toxicity in Wildlife

2.1.2.1 Midpen Reports

According to Midpen (2018b), available studies in amphibians indicated that the reported median lethal concentration (LC₅₀) values for glyphosate were typically higher than the environmental concentrations and that at environmentally relevant concentrations, glyphosate was not acutely toxic to amphibians. It was noted that some studies reported sublethal effects (e.g., changes in development and stress physiology, DNA damage); however, these effects were inconsistent and occurred at higher concentrations that were not environmentally relevant. Further, there was little evidence that glyphosate, when used as directed in natural areas, caused population-level declines in amphibians. Importantly, it was noted that the risk of not controlling invasive plants could be greater for amphibian populations. In fish, glyphosate was reported to be less toxic than in amphibians with LC₅₀ values much higher than environmental concentrations and sublethal effects rarely observed at environmentally relevant concentrations. Further, in most studies, glyphosate was less toxic to aquatic invertebrates than to fish or amphibians, with effects reported only at concentrations exceeding environmental concentrations. In terrestrial organisms, limited studies suggested that glyphosate was not acutely toxic to reptiles at environmental concentrations with adverse effects (e.g., DNA damage, physiological changes) occurring at high doses. In birds and mammals, no studies were identified. In honeybees, glyphosate exposure was shown to alter the gut microbiome and increase susceptibility to certain pathogens, but most studies found no effects on bee survival, development, or behavior at realistic exposure levels. Effects on butterflies (e.g., monarchs) were associated with habitat loss from herbicide use rather than direct toxicity. Lastly, in earthworms, some studies reported reduced survival and reproduction at high concentrations, with minimal or no effects observed at environmentally relevant concentrations. It was concluded that, when used according to best management practices and at recommended rates, glyphosate posed minimal risk to wildlife and that ecological benefits of controlling invasive species with glyphosate generally outweighed the potential risks to wildlife.

In Midpen (2018a), it was noted that available studies indicated low acute toxicity via oral and dermal exposures with median lethal dose (LD₅₀) values exceeding 5000 mg/kg/day and no reproductive or developmental effects in rats at doses up to 1000 mg/kg/day glyphosate. In birds, no significant adverse effects were reported at environmentally relevant doses. In amphibians and fish, it was noted that acute glyphosate exposure was not expected to cause unacceptable risks. Lastly, no risk was anticipated in honeybees at application rates of less than 1.92 and 5.7 lb a.e./A in larvae and adults, respectively. It was concluded that, when applied according to label directions and best management practices, glyphosate was not expected to pose significant risks to wildlife in Midpen.

According to Midpen (2019a), studies indicated that glyphosate was not lethal to amphibians at environmentally relevant concentrations and that sublethal effects occurred only at concentrations much higher than environmentally relevant. In fish, studies indicated no mortality at realistic glyphosate concentrations, whereas sublethal effects, observed in some studies, did not translate into population-level effects (e.g., oxidative stress) or had unclear implications (e.g., swimming behavior). In aquatic invertebrates, no changes in abundance or diversity were found in field studies; however, some laboratory studies reported oxidative stress and reproductive effects at high concentrations. In reptiles, one study reported no skeletal abnormalities in turtle embryos after chronic glyphosate exposure. In birds, a laboratory study showed reduced hatch rates and organ enlargement when glyphosate was injected into eggs, but this exposure route was not environmentally relevant, whereas a field study found no effects on nest or fledgling survival following glyphosate use. In mammals, glyphosate exposure did not affect gut bacteria in cows and there was no evidence of glyphosate-induced resistance or toxicity in rumen simulation studies. In bees,



glyphosate exposure did not affect survival, development, or stress responses; however, some studies found changes in gut microbiota without impact on health or behavior. It was concluded that there was no compelling evidence that glyphosate posed significant risks to wildlife when used in natural areas at recommended rates and that, compared to the ecological harm caused by invasive species, the judicious use of glyphosate remained a low-risk and effective management tool.

In Midpen (2020), it was noted that studies in livestock (i.e., cows, pigs, lambs) showed no major effects of glyphosate exposure on gut microbiota or blood cells, whereas reproductive effects, increased oxidative stress, and altered gene expression were noted at high doses in some species. In birds, chicken embryos injected with glyphosate showed altered liver and intestinal enzyme activity and increased liver weight, whereas in Japanese quail exposed to glyphosate for 52 weeks, no effects were observed on reproduction or body mass, minor changes occurred in gut microbiota and liver enzymes, and there was no evidence of developmental effects in offspring. In reptiles, changes in white blood cell types and antibody levels were noted in lizard embryos; however, the exposure method of egg spraying was unlikely to be environmentally relevant. In honeybees, glyphosate exposure showed reduced survival and increased food consumption, decreased royal jelly production, altered gut microbiota, increased susceptibility to pathogens, minor effects on sleep and larval development, whereas in mason bees, no changes in survival or feeding behavior were noted following glyphosate exposure. Further, field studies in bees showed minimal impacts at environmentally relevant concentrations. In aquatic species, glyphosate exposure caused sublethal effects (e.g., reduced mobility, growth, and malformations) in amphibians but mortality was generally low (<15%) even at high concentrations. Further, some species displayed an avoidance behavior toward glyphosate-contaminated areas. Field studies in amphibians confirmed reduced mobility but not always reduced survival. In fish, glyphosate exposure altered enzyme activity, hormone levels, and immune responses, and induced behavioral changes; however, no consistent evidence of mortality was noted at environmentally relevant concentrations and effects were dependent upon temperature, pH, and duration of exposure. In aquatic invertebrates, glyphosate exposure was reported to affect molting hormones, immune function, and development, and sex-dependent responses were observed in some species; however, no mortality was observed in most studies. It was concluded that lethal effects of glyphosate in wildlife were rare at environmentally relevant concentrations, whereas sublethal effects were common but often minimal or reversible. Importantly, it was noted that, considering the application methods and judicious use of glyphosate by Midpen, glyphosate was not expected to pose serious threats to wildlife.

2.1.2.2 EPA Reports

According to EPA (2015b), glyphosate was practically nontoxic to birds ($LD_{50} > 2,000$ mg/kg) and chronic studies in bobwhite quail and mallard duck indicated no effects on reproduction up to 830 mg/kg-diet with some studies reporting reduced body weight at high doses. Glyphosate-containing formulations were reported to be slightly more toxic than technical glyphosate, but risk was low at typical field exposures. In mammals, glyphosate was practically nontoxic ($LD_{50} > 4,800$ mg/kg-bw in rats) and chronic studies generally indicated no-observed-adverse-effect level (NOAEL) values of > 400 mg/kg for reproduction and development. It was noted that some glyphosate formulations with POEA could pose a greater risk to small mammals at high application rates. In terrestrial invertebrates, acute oral and contact LD_{50} values of > 100 µg/bee (low toxicity) were noted in honeybees and no significant effects on colony survival or larval weight were observed at field-relevant exposures. In other invertebrates (e.g., earthworms, mites, wasps), generally no effects were reported. It was noted that some surfactants (e.g., POEA) were more toxic to invertebrates than technical glyphosate. Regarding aquatic species, glyphosate was slightly to practically nontoxic to freshwater and estuarine/marine fish and amphibians in acute exposures (LC_{50} values typically



>10 mg/L) and chronic studies (e.g., fathead minnow, leopard frog) showed no effects at highest concentrations tested (up to 25.7 mg/L for fish). Formulated products (especially those with POEA) were reported to be more toxic than technical glyphosate, with some acute LC₅₀ values for fish and amphibians as low as 1–2 mg/L. It was noted that amphibians and fish showed similar sensitivity to glyphosate, but some field/mesocosm studies reported increased mortality and developmental effects at environmentally relevant concentrations, especially with formulations containing POEA. In aquatic invertebrates, glyphosate was slightly toxic to freshwater invertebrates [median effective concentration (EC₅₀) values of ~128 mg/L in *Daphnia magna* and ~53 mg/L in midge]; however, formulations with POEA were more toxic with EC₅₀ values as low as 1-5 mg/L. Chronic studies in aquatic invertebrates reported no-observed-adverse-effect concentration (NOAEC) values of >9 mg/L for technical glyphosate, but lower for some formulations.

According to EPA (2017b), glyphosate was considered to have low toxicity in wildlife under typical use conditions, with limited bioaccumulation and low risk for terrestrial and aquatic organisms at environmentally relevant concentrations. It was noted that no significant endocrine, reproductive, or developmental effects were observed at environmentally relevant concentrations.

According to EPA (2018b), glyphosate was generally considered to have low toxicity in aquatic and terrestrial animals. However, formulations containing surfactants (especially POEA) were noted to be more toxic in aquatic organisms.

According to EPA (2019a), glyphosate acute toxicity was low in mammals, birds, reptiles, terrestrial-phase amphibians, and terrestrial invertebrates. It was noted that some risk exceedances in mammals and birds were noted for some uses. It was also noted that in honeybees, no adverse effects were observed at field-relevant application rates. In aquatic species, glyphosate toxicity was considered to be low in fish, aquatic invertebrates, and aquatic-phase amphibians. It was also noted that in terrestrial and aquatic species, glyphosate formulations were more toxic than technical glyphosate.

In 2021, EPA released the Biological Evaluation (BE) that evaluated glyphosate risks to all federally listed endangered and threatened species (<https://www.epa.gov/endangered-species/final-national-level-listed-species-biological-evaluation-glyphosate>) (EPA, 2021b). It was noted that birds, mammals, and terrestrial invertebrates were less sensitive to glyphosate, such that limited sublethal effects were reported at environmentally relevant concentrations. Aquatic organisms were more sensitive to glyphosate, especially to formulations containing POEA. It was also noted that, based on conservative exposure modeling and sensitive toxicity endpoints, glyphosate was likely to adversely affect 93% of listed species and 96% of critical habitats; most of these determinations were for plants, aquatic invertebrates, and fish, reflecting their higher sensitivity.

In 2022, EPA withdrew its Interim Registration Review Decision (ID) on glyphosate after a court found procedural and substantive issues (EPA, 2022b). EPA plans to complete a comprehensive final review by 2026.

2.1.2.3 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(glyphosate) and (wildlife or bird or mammal or reptile or bee or invertebrate or amphibian) and (toxicity or toxicology)” resulted in 617 articles published in 2021-2025, which included 51 review articles. Given the multitude of articles, only the review articles were screened for relevance, and 10 review articles were determined to be relevant. As summarized in **Table 3**, the articles indicated that adverse effects in wildlife could occur upon exposure to glyphosate.



Table 3. *Key Review Articles on Glyphosate Toxicity in Wildlife Published in 2021-2025*

PMID	DOI	Title	Main conclusion
40899327	10.1080/01480545.2025.2553870	Glyphosate in the Iberian Peninsula: Evaluating risks to Iberian wildlife	Reports on oxidative stress, liver and kidney damage, endocrine disruption in reptiles, and genotoxicity in fish due to glyphosate exposure
40710996	10.3390/toxics13070551	Glyphosate-Based Herbicides and Their Potential Impact on the Microbiota of Social Bees	Glyphosate alters gut microbiota in honeybees and bumblebees, affecting digestion, immunity, and disease resistance; surfactants in formulations may worsen effects
38735490	10.1016/j.chemosphere.2024.142320	Was the massive increase in use of teratogenic agrichemicals in western states (USA) associated with declines in wild ruminant populations between 1994 and 2013?	Links increased use of teratogenic agrichemicals, including glyphosate, to reproductive abnormalities and population declines in wild ruminants in western USA
37776469	10.1007/s10653-023-01763-w	Glyphosate uses, adverse effects and alternatives: focus on the current scenario in Brazil	Documents increased glyphosate use in Brazil, its adverse effects on health and environment, and challenges in replacing it with safer alternatives
37756105	10.3390/vetsci10090583	Could Exposure to Glyphosate Pose a Risk to the Survival of Wild Animals? A Case Study on the Field Lizard Podarcis siculus	Glyphosate exposure in field lizards causes liver and gonadal damage, endocrine disruption, and reproductive health risks, validating the species as a model for toxicity studies
37459948	10.1016/j.envres.2023.116678	Glyphosate and environmental toxicity with "One Health" approach, a review	Highlights glyphosate's environmental toxicity across ecosystems using a One Health approach; emphasizes impacts on plants, microbes, and wildlife
36789524	10.1002/jez.2688	Role of herbicides in the decline of butterfly population and diversity	Herbicides, including glyphosate, reduce butterfly diversity by eliminating host plants and disrupting habitats, contributing to population declines
35809430	10.1016/j.aquatox.2022.106232	Effects of glyphosate on cladocera: A synthetic review	Synthesizes studies showing acute and sublethal toxicity of glyphosate to cladocera, affecting survival, reproduction, and population recovery
34971799	10.1016/j.etap.2021.103792	Effects of glyphosate exposure on honeybees	Glyphosate exposure disrupts honeybee immunity and gut microbiota, reducing antimicrobial peptide expression and inhibiting melanization, increasing disease susceptibility
34129918	10.1016/j.cbpc.2021.109103	Reproductive toxicity due to herbicide exposure in freshwater organisms	Reviews reproductive toxicity of herbicides in freshwater organisms, showing bioaccumulation and endocrine disruption leading to population declines

2.1.3 Toxicity in Plants

2.1.3.1 Midpen Reports

According to Midpen (2018b), when applied carefully, glyphosate exposure to non-target plants was minimal; however, incidental exposure of non-target plants could occur, and the damage extent was dependent upon the plant species and exposure amount. It was noted that recent studies showed that seeds of different plant species vary in their sensitivity to glyphosate, with higher concentrations delaying germination, though such levels were rarely encountered in the field. Further, glyphosate and its breakdown product, aminomethylphosphonic acid (AMPA), could disrupt plant physiology by inhibiting antioxidant



enzymes and reducing photosynthesis, but these effects were generally observed at concentrations higher than those used in natural lands management. Studies also showed indicated that glyphosate residues were typically undetectable in edible wild plants. Although glyphosate could have some minor, context-dependent effects on beneficial soil fungi, these did not appear to have significant long-term consequences for plant health or ecosystem function. It was concluded that, when used appropriately, glyphosate posed low risk to non-target plants, and its ecological benefits in invasive species control generally outweighed the potential for unintended plant toxicity.

In Midpen (2018a), it was noted that glyphosate could affect non-target plants through drift or incidental contact, such impacts were generally minimal and depended on plant sensitivity and exposure levels. Glyphosate and its breakdown product, AMPA, were reported to interfere with plant physiological processes like photosynthesis and antioxidant activity, but such effects typically occurred at concentrations higher than those used in field applications. Further, studies showed that glyphosate residues in edible wild plants were usually undetectable or well below harmful levels and that glyphosate did not bioaccumulate in plant tissues. It was concluded that glyphosate posed a low toxicity risk to plants when applied responsibly, and its benefits in invasive plant management outweighed potential ecological concerns.

According to Midpen (2019a), glyphosate use in natural areas, especially when applied with precision tools like backpack sprayers, resulted in minimal environmental spillover compared to agricultural applications. It was noted that studies showed that low concentrations of glyphosate generally did not affect non-target plant growth, while higher concentrations (above 11 g/ha) could reduce biomass and inhibit development. Glyphosate residues could persist in perennial plant roots and later translocate to shoots and fruits, though field studies found no detectable residues in soil after application. In some studies, reduced germination rates and smaller plant sizes were observed in glyphosate-treated soils, but these effects were not consistently replicated in field conditions. It was concluded that glyphosate posed minimal risk to non-target plants when used appropriately, and its ecological benefits in invasive species control outweighed potential impacts.

In Midpen (2020), it was noted that glyphosate was reported to negatively impact native plant species even at low concentrations (i.e., 1-5% of the recommended field rate), causing reductions in leaf length, flowering height, flower number, and pollinator visitation. These effects were observed across multiple species and could potentially disrupt plant reproduction and ecosystem interactions. In some studies, glyphosate exhibited hormetic effects, such that very low doses stimulated growth and fecundity in certain weeds. Further, compared to organic herbicides, glyphosate was equally effective in controlling invasive woody vines and did not significantly affect soil nematodes or moss and fern spores. It was noted that Midpen's targeted application methods (e.g., backpack sprayers) helped minimize non-target exposure, unlike agricultural practices that often resulted in herbicide spillover. It was concluded that although glyphosate was effective and relatively safe when used appropriately, its potential to alter plant growth and reproductive traits at low doses underscored the importance of careful application timing and site selection to protect native biodiversity.

2.1.3.2 EPA Reports

According to EPA (2015b), terrestrial plants were highly sensitive to glyphosate via spray drift or direct exposure with 25% inhibition concentration (IC_{25}) values as low as 0.074 lb ae/A. Regarding aquatic plants, glyphosate EC_{50} values in vascular and non-vascular plants were ~12 and ~11-13 mg/L, respectively, and some formulations were more toxic than technical glyphosate.



According to EPA (2018b), terrestrial plants were sensitive to glyphosate, and non-target plant impacts were a primary ecological concern. It was noted that loss of flowering plants due to glyphosate use could reduce pollinator habitat and resources.

According to (EPA, 2019a), non-target terrestrial plants, especially dicots, were sensitive to glyphosate spray drift. In aquatic plants, glyphosate risks were generally low.

In 2021, EPA released the Biological Evaluation (BE) that evaluated glyphosate risks to all federally listed endangered and threatened species (<https://www.epa.gov/endangered-species/final-national-level-listed-species-biological-evaluation-glyphosate>) (EPA, 2021b). It was noted that plants (especially dicots) were the most sensitive ecological receptor to glyphosate exposure. It was also noted that, based on conservative exposure modeling and sensitive toxicity endpoints, glyphosate was likely to adversely affect 93% of listed species and 96% of critical habitats; most of these determinations were for plants, aquatic invertebrates, and fish, reflecting their higher sensitivity.

In 2022, EPA withdrew its ID on glyphosate after a court found procedural and substantive issues (EPA, 2022b). EPA plans to complete a comprehensive final review by 2026.

2.1.3.3 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(glyphosate) and (plant) and (toxicity or toxicology)” resulted in 231 articles published in 2021-2025, which included 22 review articles. Given the multitude of articles, only the review articles were screened for relevance, and nine review articles were determined to be relevant. As summarized in **Table 4**, the articles indicated that adverse effects in plants could occur upon exposure to glyphosate and that glyphosate could adversely affect soil microbiome as well as soil and water matrices, leading to effects in plants.

Table 4. Key Review Articles on Glyphosate Toxicity in Plants Published in 2021-2025

PMID	DOI	Title	Main conclusion
40485833	10.3389/fmicb.2025.1570235	Glyphosate-microbial interactions: metagenomic insights and future directions.	Glyphosate alters microbial communities, which may indirectly affect plant health and resistance to stress.
40136459	10.3390/cimb47030205	Adaptations of the Genus Bradyrhizobium to Selected Elements, Heavy Metals and Pesticides Present in the Soil Environment.	Bradyrhizobium species adapt to glyphosate exposure, influencing plant-microbe interactions and soil fertility.
37994831	10.1080/15226514.2023.2282720	Glyphosate in the environment: interactions and fate in complex soil and water settings, and (phyto) remediation strategies.	Glyphosate interacts with soil and water matrices, affecting its mobility and persistence; phytoremediation strategies are promising for mitigating its impact on plants.
37269314	10.1007/s00294-023-01272-4	Yeast of Eden: microbial resistance to glyphosate from a yeast perspective.	Microbial resistance to glyphosate, including in yeast, may influence glyphosate degradation and its persistence in plant environments.
37030406	10.1016/j.envres.2023.115811	Recent trends in pesticides in crops: A critical review of the duality of risks-benefits and the Brazilian legislation issue.	Glyphosate use in crops presents both benefits and risks; regulatory frameworks must balance productivity with environmental and plant health concerns.
35478266	10.1007/s11274-022-03281-w	Microbiomes and glyphosate biodegradation in edaphic and aquatic environments: recent issues and trends.	Plant-associated microbiomes play a key role in glyphosate degradation; understanding these interactions is crucial for managing plant health and toxicity.



PMID	DOI	Title	Main conclusion
35221840	10.17179/excli2021-4478	The effects of low-toxic herbicide Roundup and glyphosate on mitochondria.	Glyphosate and Roundup disrupt mitochondrial function, indicating potential cellular toxicity in plant systems.
34830483	10.3390/ijms22212606	Pleiotropic Outcomes of Glyphosate Exposure: From Organ Damage to Effects on Inflammation, Cancer, Reproduction and Development.	Glyphosate exposure can lead to organ damage and developmental effects in plants, highlighting the need for cautious use.
33932185	10.1007/398_2020_55	Evolution of Glyphosate-Resistant Weeds.	Glyphosate resistance in weeds is evolving rapidly, necessitating integrated weed management strategies to sustain crop productivity.

2.1.4 Conclusions and Recommendations

Midpen uses glyphosate IPA (Roundup Custom by Monsanto) and glyphosate K (Roundup ProMax by Monsanto) for nonselective post-emergent broad-spectrum weed control. Based on the additional information reviewed, there were no changes to the general toxicological findings of glyphosate effects on humans, wildlife, or plants that were used as the basis for the environmental assessments conducted in 2014 and 2019. However, science on glyphosate is evolving as evidenced by a myriad of new publications. Further, EPA noted that a new risk assessment for glyphosate will be released in 2026, and there is the possibility that the agency's position on glyphosate will change. Stantec recommends no changes to current application practices by Midpen under the current IPMP; however, it is advisable to re-evaluate glyphosate risks upon release of the new EPA assessment. Further, Midpen may consider additional educational opportunities for the personnel applying glyphosate to ensure that harm reduction practices (e.g., use of personal protective equipment) are well understood and followed. This includes careful review of the latest EPA-stamped labels for glyphosate IPA (https://labelsds.com/images/user_uploads/Roundup%20Custom%20Label%2010-1-20.pdf) and glyphosate K (<https://onthegreeninc.com/wp-content/uploads/2025/09/Roundup-Pro-Max-Label.pdf>).

2.2 Aminopyralid TIPA

Aminopyralid triisopropylammonium (TIPA) salt [Milestone (Dow AgroSciences)] was included on the Midpen approved list of pesticides. According to [Appendix A](#) of Midpen (2014), (1) in humans, aminopyralid toxicity was considered to be low, such that there was no evidence of carcinogenicity, neurotoxicity, immunotoxicity, or reproductive/developmental toxicity, and (2) in ecological receptors, aminopyralid was practically nontoxic to birds, fish, aquatic invertebrates, amphibians, and honeybees. According to [Appendix 1](#) of Midpen (2019b), aminopyralid TIPA was classified as "slightly toxic to aquatic-phase amphibians and practically nontoxic to terrestrial-phase amphibians".

Additional information on aminopyralid toxicity was available since the 2014 and 2019 assessments by Midpen. Stantec reviewed the additional information as outlined below.



2.2.1 Toxicity in Humans

2.2.1.1 Midpen and EPA Reports

According to Midpen (2018b), only one relevant peer-reviewed study was identified that reported that aminopyralid was not a skin sensitizer, whereas no new studies on carcinogenicity, neurotoxicity, immunotoxicity, or developmental toxicity were published between 2015 and 2018. The report also cited EPA (2005), which documented low toxicity potential of aminopyralid in humans. No new studies on aminopyralid toxicity in humans found in 2019 or 2020 (Midpen, 2019a, 2020).

According to EPA (2020d), aminopyralid had low acute toxicity potential via oral, dermal, or inhalation routes (Category IV) and was not an eye irritant in its TIPA salt form (Category IV). It was also noted that there was no evidence that aminopyralid was neurotoxic, immunotoxic, or a reproductive/development toxicant. Further, aminopyralid was not genotoxic and was classified as “not likely to be carcinogenic to humans”. Lastly, aminopyralid was not a concern in residential or occupational application settings and no human health risks of concern were identified for current uses (EPA, 2020c). Similar conclusions were noted in EPA (2021a). As of September 23, 2025, EPA’s website noted that there were no human health risks of concern for any registered uses of aminopyralid (EPA, 2025b).

2.2.1.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 9, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(aminopyralid) and (human) and (health or toxicity or toxicology)” resulted in zero articles published in 2021-2025.

2.2.2 Toxicity in Wildlife

2.2.2.1 Midpen and EPA Reports

According to Midpen (2018b), no new animal studies on aminopyralid toxicity were published between 2015 and 2018. One study was identified that reported no effects on microbial diversity or community. In another study, aminopyralid was not detected in honey samples near oilseed crops. It was noted that despite the lack of recent studies on wildlife toxicity, the existing evidence and regulatory assessments indicated minimal risk when aminopyralid was used as directed and its rapid degradation and low environmental persistence further reduced the likelihood of adverse effects on wildlife. No new studies on aminopyralid toxicity in wildlife were identified in 2019 or 2020 (Midpen, 2019a, 2020).

According to DOI (2015), aminopyralid showed little to no acute or chronic toxicity to mammals with oral and dermal LD₅₀ values in rats reported at >1090 and >5000 mg/kg, respectively. Chronic dietary studies in rats and dogs found no adverse effects at realistic exposure levels and no significant reproductive or developmental effects were observed. In birds, aminopyralid was of low acute toxicity, such that studies in Bobwhite quail and mallard ducks showed no toxic effects, and long-term studies found no reproductive toxicity. In honeybees, acute toxicity tests showed LD₅₀ values of >100 µg/bee (dermal) and >120 µg/bee (oral), indicating low risk. In fish and aquatic invertebrates, aminopyralid was practically nontoxic with no significant effects observed at environmentally relevant concentrations in chronic studies. In amphibians, glyphosate was practically nontoxic in leopard frog larvae with no mortality or sublethal effects observed at 95.2 mg/L glyphosate. Similar conclusions on aminopyralid toxicity in wildlife were noted in EPA (2020e) and EPA (2021a).



2.2.2.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(aminopyralid) and (wildlife or bird or mammal or reptile or bee or invertebrate or amphibian) and (toxicity or toxicology)” resulted in zero articles published in 2021-2025.

2.2.3 Toxicity in Plants

2.2.3.1 Midpen and EPA Reports

According to Midpen (2018b), some studies showed temporary reductions in native forb cover and species richness; however, these effects were generally transitory. No new studies on aminopyralid toxicity in non-target plants were identified in 2019 and one study was identified that found aminopyralid to be an effective herbicide against an invasive plant species (Midpen, 2019a). Similarly, no new studies on aminopyralid toxicity in non-target plants were identified in 2020 and three studies were identified that found aminopyralid to be an effective herbicide against invasive plant species (Midpen, 2020).

According to DOI (2015), aminopyralid was highly selective for broadleaf (dicot) plants. It was noted that direct spray or off-site drift could cause significant injury or mortality to non-target broadleaf plants, including rare and endangered species and that monocots were less sensitive than dicots. Further, some aquatic plants (e.g., duckweed) were sensitive at high concentrations, which were not environmentally relevant. Similar conclusions on aminopyralid toxicity in plants were noted in EPA (2020e) and EPA (2021a).

2.2.3.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(aminopyralid) and (plant) and (toxicity or toxicology)” resulted in zero articles published in 2021-2025.

2.2.4 Conclusions and Recommendations

Midpen uses aminopyralid TIPA (Milestone by Dow AgroSciences) for nonselective post-emergent broad-spectrum weed control. Based on the additional information reviewed, there were no changes to the general toxicological findings of aminopyralid effects on humans, wildlife, or plants that were used as the basis for the environmental assessments conducted in 2014 and 2019. Thus, Stantec recommends no changes to current application practices by Midpen under the current IPMP as long as they are consistent with the latest EPA-stamped label for aminopyralid TIPA (https://www3.epa.gov/pesticides/chem_search/ppls/AR170002-20220421.pdf).

2.3 Clopyralid MEA

Clopyralid monoethanolamine (MEA) salt [Transline (Dow AgroSciences)] was included on the Midpen approved list of pesticides. According to [Appendix A](#) of Midpen (2014), (1) in humans, clopyralid toxicity was generally considered to be low, such that neurotoxicity was reported in acute studies, whereas there was no evidence of immunotoxicity, reproductive/developmental toxicity, or carcinogenicity albeit technical grade clopyralid was noted to contain low levels of hexachlorobenzene classified as a potential human carcinogen by U.S. EPA, and (2) in ecological receptors, clopyralid was practically nontoxic to birds, fish,



aquatic invertebrates, and honeybees. According to [Appendix 1](#) of (Midpen, 2019b), clopyralid MEA was classified as “practically nontoxic to aquatic-phase amphibians and slightly toxic to terrestrial-phase amphibians”.

Additional information on clopyralid toxicity was available since the 2014 and 2019 assessments by Midpen. Stantec reviewed the additional information as outlined below.

2.3.1 Toxicity in Humans

2.3.1.1 Midpen and EPA Reports

No new studies on clopyralid toxicity in humans were identified in the 2015-2018 period (Midpen, 2018b) or in 2019 (Midpen, 2019a). According to Midpen (2020), one study was identified that reported no association between clopyralid exposure and prostate cancer among pesticide applicators.

According to EPA (2020a), there was no evidence of acute or chronic toxicity, carcinogenicity, neurotoxicity, reproductive toxicity, dermal toxicity, or endocrine disruption in humans at expected exposure levels; however, clopyralid acid was a severe eye irritant. It was concluded that clopyralid did not pose significant systemic toxicity risks to humans under current use patterns. The main health concern was eye irritation, which could be managed by a 48-hour restricted entry interval and protective equipment requirement. Further, dietary, residential, and occupational risks were not of concern.

2.3.1.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 9, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(clopyralid) and (human) and (health or toxicity or toxicology)” resulted in two articles published in 2021-2025. Upon screening, these articles were not considered to be relevant.

2.3.2 Toxicity in Wildlife

2.3.2.1 Midpen and EPA Reports

According to Midpen (2018b), three studies were published between 2015 and 2018 on clopyralid toxicity in wildlife. One study indicated that, at environmentally relevant concentrations, clopyralid was not toxic to western fence lizards. Two studies noted no effects of clopyralid on community composition of soil bacteria (Midpen, 2018b). No new studies on clopyralid toxicity in wildlife were identified in 2019 (Midpen, 2019a) or in 2020 (Midpen, 2020).

According to EPA (2020a), no acute or chronic risk concerns were anticipated in birds, reptiles, terrestrial-phase amphibians, or honeybees at labeled clopyralid application rates. In mammals, no acute risk was anticipated; however, at high doses, a chronic risk concern was possible, but it was noted that it could be mitigated by drift management. In aquatic invertebrates, fish, and aquatic-phase amphibians, no risks of concern were anticipated at environmentally relevant concentrations.

2.3.2.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(clopyralid) and (wildlife or bird or mammal or reptile or bee or invertebrate or amphibian)



and (toxicity or toxicology)” resulted in three articles published in 2021-2025. Upon screening, these articles were not considered to be relevant.

2.3.3 Toxicity in Plants

2.3.3.1 Midpen and EPA Reports

No new studies on clopyralid toxicity in non-target plants were published in the 2015-2018 period (Midpen, 2018b). No new studies on clopyralid toxicity in non-target plants were identified in 2019; however, two studies were noted that compared clopyralid efficacy to other herbicides (Midpen, 2019a). Similarly, no new studies on clopyralid toxicity in non-target plants were identified in 2020; however, one study was noted that evaluated clopyralid efficacy (Midpen, 2020).

According to EPA (2020a), the main ecological concern of clopyralid application was for non-target terrestrial plants, especially due to spray drift and compost contamination, which could cause significant damage even at low concentrations. It was noted that regulatory actions focusing on drift management, compost stewardship, and label advisories could help to mitigate these risks.

2.3.3.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(*clopyralid*) and (*plant*) and (*toxicity or toxicology*)” resulted in five articles published in 2021-2025. Upon screening, these articles were not considered to be relevant.

2.3.4 Conclusions and Recommendations

Midpen uses clopyralid MEA (Transline by Dow AgroSciences) for selective broadleaf weed control. Based on the additional information reviewed, there were no changes to the general toxicological findings of clopyralid effects on humans, wildlife, or plants that were used as the basis for the environmental assessments conducted in 2014 and 2019. It was noted that the main concern for clopyralid is for non-target terrestrial plants due to spray drift and compost contamination. Thus, Stantec recommends no changes to current application practices by Midpen under the current IPMP as long as they are consistent with the latest EPA-stamped label for clopyralid MEA (https://www3.epa.gov/pesticides/chem_search/ppls/062719-00259-20150423.pdf).

2.4 Imazapyr IPA

Imazapyr IPA salt [Polaris (Nufarm) and Stalker (BASF)] was included on the Midpen approved list of pesticides. According to [Appendix A](#) of Midpen (2014), (1) in humans, imazapyr toxicity was considered to be low, such that there was no evidence of carcinogenicity, neurotoxicity, immunotoxicity, or reproductive/developmental toxicity, and (2) in ecological receptors, imazapyr was practically nontoxic to birds, fish, aquatic invertebrates, and honeybees. According to [Appendix 1](#) of Midpen (2019b), imazapyr IPA was classified as “practically nontoxic to aquatic-phase amphibians and practically nontoxic to terrestrial-phase amphibians”.

Additional information on imazapyr toxicity is available since the 2014 and 2019 assessments by Midpen. Stantec reviewed the additional information as outlined below.



2.4.1 Toxicity in Humans

2.4.1.1 Midpen and EPA Reports

No new studies on imazapyr toxicity in humans were identified in the 2015-2018 period (Midpen, 2018b), in 2019 (Midpen, 2019a), or in 2020 (Midpen, 2020).

According to EPA (2015a), no adverse effects of imazapyr were identified in the reviewed studies, and no additional data or risk mitigation measures were required. It was noted that imazapyr did not pose risks of toxicological concern to humans via dietary, residential, or occupational exposure. The agency indicated that endocrine disruptor screening was ongoing, but no concerns were identified as of the 2015 interim decision.

2.4.1.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 9, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(imazapyr) and (human) and (health or toxicity or toxicology)” resulted in one article published in 2021-2025. Upon screening, this article was not considered to be relevant.

2.4.2 Toxicity in Wildlife

2.4.2.1 Midpen and EPA Reports

According to Midpen (2018b), two studies were identified between 2015 and 2018 on imazapyr toxicity in wildlife. One study noted that imazapyr LC₅₀ values in the African clawed frog were 36, 32.8, and 173.5 mg/L in embryos, premetamorphic larvae, and prometamorphic larvae, respectively; however, these concentrations were much higher than environmental concentrations. Another study indicated that a herbicide formulation containing imazapyr and imazapic caused stress in fish but the overall health was minimally affected by 96 hours of exposure; it was possible to separate the effects of imazapyr and imazapic (Midpen, 2018b). No new studies on imazapyr toxicity in wildlife were identified in 2019 (Midpen, 2019a) or in 2020 (Midpen, 2020).

According to EPA (2015a), imazapyr did not pose risks to terrestrial or aquatic animals (i.e., birds, mammals, fish, amphibians, and invertebrates) at labeled application rates. The agency noted that no new data or mitigation measures for wildlife were required in this interim decision.

2.4.2.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(imazapyr) and (wildlife or bird or mammal or reptile or bee or invertebrate or amphibian) and (toxicity or toxicology)” resulted in three articles published in 2021-2025. Upon screening, two articles were considered to be relevant. Babalola et al. (2021) reported that imazapyr (Arsenal formulation) had low acute toxicity potential and did not inhibit growth in frog embryos; however, teratogenic effects were observed in imazapyr-exposed frog embryos, albeit at high concentrations. Mallick et al. (2023) reviewed the role of herbicides in the decline of butterfly population and diversity. The authors concluded that imazapyr (and other herbicides) contributed to butterfly population decline by reducing plant diversity and habitat quality, rather than through direct acute toxicity to butterflies. The loss of host and nectar plants was the main driver of reduced butterfly abundance and diversity in treated areas.



2.4.3 Toxicity in Plants

2.4.3.1 Midpen and EPA Reports

According to Midpen (2018b), one study was identified between 2015 and 2018 on imazapyr toxicity in non-target plants. The study noted that imazapyr reduced the biomass of non-target aquatic forbs (Midpen, 2018b). No new studies on imazapyr toxicity in non-target plants were identified in 2019; however, several studies were identified that compared imazapyr efficacy to other herbicides (Midpen, 2019a). Similarly, no new studies on imazapyr toxicity in non-target plants were identified in 2020; however, several studies were identified that evaluated imazapyr efficacy (Midpen, 2020).

According to EPA (2015a), imazapyr posed risk to non-target terrestrial plants (especially via drift or non-crop uses); however, these risks could be mitigated by label requirements. It was also noted that risks in aquatic plants were expected, as these are target species.

2.4.3.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(imazapyr) and (plant) and (toxicity or toxicology)” resulted in three articles published in 2021-2025. Upon screening, these articles were considered to be relevant. Mallick et al. (2023) reviewed the role of herbicides in the decline of butterfly population and diversity. The authors concluded that imazapyr (and other herbicides) contributed to butterfly population decline by reducing plant diversity and habitat quality, rather than through direct acute toxicity to butterflies. The loss of host and nectar plants was the main driver of reduced butterfly abundance and diversity in treated areas. de Moura-Silva et al. (2025) reported that imazapyr (Kifix formulation) caused significant phytotoxic effects in *P. crassipes*, especially by inhibiting the development of new tissues and triggering physiological and biochemical disturbances in mature tissues. In a study by Liu et al. (2025), exposure of *S. alterniflora* to imazapyr acid resulted in initial activation of photoprotective mechanisms but ultimately leading to photosynthetic system damage; inhibition of root growth and development was also noted. It was indicated that the effects were mediated by disruption of key metabolic and biosynthetic pathways, leading to impaired growth and survival.

2.4.4 Conclusions and Recommendations

Midpen uses imazapyr IPA (Polaris bu Nufarm; Stalker by BASF) for nonselective pre- and post-emergent broad-spectrum weed control. Based on the additional information reviewed, there were no changes to the general toxicological findings of imazapyr effects on humans, wildlife, or plants that were used as the basis for the environmental assessments conducted in 2014 and 2019. It was noted that imazapyr’s main concern is for non-target terrestrial plants (especially via drift or non-crop uses), which, in turn, could adversely impact butterfly habitats. Thus, Stantec recommends no changes to current application practices by Midpen under the current IPMP, as long as they are consistent with the latest EPA-stamped label for imazapyr IPA (https://www3.epa.gov/pesticides/chem_search/ppls/000228-00570-20240625.pdf and https://www3.epa.gov/pesticides/chem_search/ppls/000241-00398-20110428.pdf).

2.5 Clethodim

Clethodim [Envoy Plus (Valent)] was included on the Midpen approved list of pesticides. According to [Appendix A](#) of Midpen (2014), (1) in humans, clethodim toxicity was considered to be low, such that there



was no evidence of carcinogenicity, neurotoxicity, immunotoxicity, or reproductive/developmental toxicity, and (2) in ecological receptors, clethodim was slightly toxic to birds, fish, and aquatic invertebrates, and practically nontoxic to honeybees. According to [Appendix 1](#) of Midpen (2019b), clethodim was classified as “slightly toxic to aquatic-phase amphibians and practically nontoxic to terrestrial-phase amphibians”.

Additional information on clethodim toxicity was available since the 2014 and 2019 assessments by Midpen. Stantec reviewed the additional information as outlined below.

2.5.1 Toxicity in Humans

2.5.1.1 Midpen and EPA Reports

No new studies on clethodim toxicity in humans were identified in the 2015-2018 period (Midpen, 2018b) or in 2019 (Midpen, 2019a). According to Midpen (2020), one epidemiological study was identified that reported no association between clethodim use and prostate cancer.

According to EPA (2017a), no adverse effects of clethodim were identified in the reviewed studies, and no additional data or risk mitigation measures were required. It was noted that clethodim did not pose risks of toxicological concern to humans via dietary, residential, or occupational exposure. The agency indicated that endocrine disruptor screening was ongoing, but no concerns were identified as of the 2017 interim decision.

2.5.1.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 9, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(clethodim) and (human) and (health or toxicity or toxicology)” resulted in four articles published in 2021-2025. Upon screening, these articles were not considered to be relevant. However, one of the articles identified during the search for peer-reviewed articles for wildlife (see section below) could be applicable to human health. Specifically, Dcunha et al. (2023) reported that oral exposures to technical clethodim or clethodim-based formulation resulted in adverse effects on reproductive measures in male mice via an endocrine disrupting function; however, the effects typically occurred in one or both of the highest dose groups of 100 and 200 mg/kg and occasionally in the 50 mg/kg group; these doses are unlikely to be relevant for human exposure.

2.5.2 Toxicity in Wildlife

2.5.2.1 Midpen and EPA Reports

According to Midpen (2018b), one study was identified between 2015 and 2018 on clethodim toxicity in wildlife. The study noted that clethodim effects on butterfly caterpillar survival were inconclusive and that clethodim exposure resulted in higher concentrations of aucubin (a defense compound) in the caterpillars (Midpen, 2018a). According to Midpen (2019a), one study was identified on clethodim toxicity in wildlife, according to which chronic exposure to high doses of clethodim was reported to cause lethal and sublethal effects in zebrafish larvae. According to Midpen (2020), one study was identified reporting that clethodim exposure affected growth and toxin production in two species of cyanobacteria.

According to EPA (2017a), clethodim posed low risk to wildlife. Chronic risks to mammals, fish, and aquatic-phase amphibians were considered low based on real-world application rates, whereas in birds and



terrestrial invertebrates, clethodim was practically nontoxic. The agency noted that it required ongoing monitoring and could require additional pollinator data in future reviews.

2.5.2.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(*clethodim*) and (*wildlife or bird or mammal or reptile or bee or invertebrate or amphibian*) and (*toxicity or toxicology*)” resulted in four articles published in 2021-2025. Upon screening, one article was considered to be relevant. Dcunha et al. (2023) reported that oral exposures to technical clethodim or clethodim-based formulation resulted in adverse effects on reproductive measures in male mice via an endocrine disrupting function. However, the effects typically occurred in one or both of the highest dose groups of 100 and 200 mg/kg and occasionally in the 50 mg/kg group; these doses are unlikely to be environmentally relevant.

2.5.3 Toxicity in Plants

2.5.3.1 Midpen and EPA Reports

According to Midpen (2018b), one study was identified between 2015 and 2018 on clethodim toxicity in non-target plants. The study indicated that, in common camas, clethodim exposure reduced leaf length and increased flower and seed production but did not affect seed viability or palatability to herbivores; it was concluded that clethodim was not detrimental to common camas (Midpen, 2018b). No new studies on clethodim toxicity in plants were identified in 2019 (Midpen, 2019a). According to Midpen (2020), one study was identified reporting that clethodim exposure increased pollen sterility and meiotic abnormalities in pea plants.

According to EPA (2017c), clethodim was highly selective for monocot plants, especially grasses in the Poaceae family, and posed a risk to non-target monocots primarily via spray drift; however, dicots were not affected at labeled application rates. It was noted that the agency implemented label changes to mitigate off-target risks, including application rate limits and spray drift reduction measures.

2.5.3.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(*clethodim*) and (*plant*) and (*toxicity or toxicology*)” resulted in four articles published in 2021-2025. Upon screening, two articles were considered to be relevant. Santos et al. (2023) evaluated clethodim toxicity in model plant *A. cepa*; it was noted that clethodim demonstrated phytotoxicity, inhibiting germination and root growth, increased frequency of micronuclei, and affected activities of catalase and ascorbate peroxidase. Fernandes Júnior et al. (2025) compared hemp sensitivity to clethodim and three other herbicides; it was reported that, in contrast to atrazine, fomesafen, and nicosulfuron, clethodim did not cause significant injuries to hemp plant during the evaluation period.

2.5.4 Conclusions and Recommendations

Midpen uses clethodim (Envoy Plus by Valent) for selective post-emergent grass weed control. Based on the additional information reviewed, there were no changes to the general toxicological findings of clethodim effects on humans, wildlife, or plants that were used as the basis for the environmental



assessments conducted in 2014 and 2019. It was noted that clethodim posed a risk to non-target monocots primarily via spray drift; the agency implemented label changes to mitigate such risks. Thus, Stantec recommends no changes to current application practices by Midpen under the current IPMP as long as they are consistent with the latest EPA-stamped label for clethodim

(https://www3.epa.gov/pesticides/chem_search/ppls/059639-00078-20240507.pdf).

2.6 Triclopyr BEE and Triclopyr TEA

Triclopyr butoxyethyl ester (BEE) [Garlon 4 Ultra (Dow AgroSciences)] and triclopyr triethylamine (TEA) salt [Capstone (Dow AgroSciences)] were included on the Midpen approved list of pesticides. Triclopyr was not evaluated in [Appendix A](#) of Midpen (2014). According to [Exhibit A](#) of Midpen (2019b), the toxicity of triclopyr BEE and triclopyr TEA in humans was considered to be low, such that both pesticides were classified as Category III for oral and dermal routes and Category IV for inhalation route. Potential for carcinogenicity, neurotoxicity, immunotoxicity, or reproductive/developmental toxicity of triclopyr was not specified. According to [Appendix 1](#) of Midpen (2019b), triclopyr BEE was classified as highly toxic to freshwater fish, moderately toxic to aquatic-phase amphibians and freshwater aquatic invertebrates, slightly toxic to birds and mammals, and practically nontoxic to bees; triclopyr BEE toxicity in terrestrial-phase amphibians and reptiles was considered to be similar to that in birds. Triclopyr TEA was classified as practically nontoxic aquatic-phase and terrestrial-phase amphibians, aquatic invertebrates, freshwater fish, birds, mammals, and bees; triclopyr TEA toxicity in terrestrial-phase amphibians and reptiles was considered to be similar to that in birds (EPA, 2019a).

Additional information on triclopyr toxicity was available since the 2014 and 2019 assessments by Midpen. Stantec reviewed the additional information as outlined below.

2.6.1 Toxicity in Humans

2.6.1.1 Midpen and EPA Reports

No new studies on triclopyr toxicity in humans were identified in the 2015-2018 period (Midpen, 2018b). However, it was noted that a 2016 study reported no detectable levels of triclopyr in urine samples of children playing on an athletic field sprayed with a herbicide containing triclopyr. It was also noted that a 2018 study reported that 93-94% of triclopyr was excreted in urine within 24 hours of exposure, indicating rapid elimination. Further, it was stated that as of 2018, EPA did not classify triclopyr for carcinogenicity due to insufficient number of studies. A 2015 study reporting DNA damage in European eels exposed to triclopyr was also mentioned; however, its relevance to human health was unclear (Midpen, 2018a). No new studies on triclopyr toxicity in humans were identified in 2019 (Midpen, 2019a). According to Midpen (2020), one study was identified that reported no association of triclopyr exposure and prostate cancer risk among pesticide applicators.

According to EPA (2020i), triclopyr did not pose significant dietary, residential, or aggregate risks to humans when used according to label directions. It was noted that occupational risk was only of concern for mixers/loaders in aerial forestry applications, necessitating use of respirators to mitigate risks. The agency indicated that there was no evidence of significant human toxicity or epidemiological associations with adverse health outcomes.



2.6.1.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 9, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(triclopyr) and (human) and (health or toxicity or toxicology)” resulted in nine articles published in 2021-2025. Upon screening, two articles were considered to be relevant. Y. Li et al. (2022) assessed urinary pesticide concentrations in New Zealand school-aged children and concluded that New Zealand children had relatively high exposures to chlorpyrifos/triclopyr and pyrethroids and suggested that the factors associated with exposure included age, season, area of residence, diet, in-home pest control, and pets. Harmon O'Driscoll et al. (2024) modeled pesticide transport to drinking water sources via runoff; it was noted that herbicides triclopyr and 2-methyl-4-chlorophenoxyacetic acid occurred in the greatest concentrations in surface water but posed little risk to human health under current application patterns and climatic conditions.

2.6.2 Toxicity in Wildlife

2.6.2.1 Midpen and EPA Reports

Several studies were noted in Midpen (2018b) that evaluated triclopyr toxicity in wildlife. One study noted an LD₅₀ of 550 µg/g triclopyr in western fence lizards; the LD₅₀ was higher than environmentally relevant triclopyr concentrations. Two studies reported that triclopyr did not increase mortality in red-legged or northern leopard frog tadpoles; however, body mass was reduced by 16-24% in exposed leopard frog tadpoles, whereas in red-legged frog tadpoles, lethargy and a one-day delay in metamorphosis were noted with no long-term effects on behavior or body condition. Two studies were conducted in fish, such that one study reported increased DNA damage in European eels exposed to triclopyr or its commercial formulation and another study noted increased mortality, delayed hatching, and developmental abnormalities in zebrafish embryos exposed to >400 µg/L triclopyr. Lastly, two studies noted that triclopyr at high doses or after repeated application could affect soil bacterial community structure, whereas fungal diversity and community composition was not affected by triclopyr. It was concluded the triclopyr poses low acute toxicity to most wildlife at environmentally relevant concentrations (Midpen, 2018b). No new studies on triclopyr toxicity in wildlife were identified in 2019 (Midpen, 2019a). According to Midpen (2020), one study was identified, reporting that application of 0.3% triclopyr to palm flowers resulted in a 63% mortality in the pollinating weevil.

According to EPA (2020i), triclopyr posed chronic risks to mammals, birds, and pollinators at higher application rates, whereas risks to aquatic organisms were generally low except at the highest aquatic weed control rates. The agency noted that it required additional studies and label changes to mitigate risks. The latest EPA-stamped labels for triclopyr BEE and triclopyr TEA were available as of 2023 and 2025, respectively. For both products, the labels include information on environmental hazard, use directions, and use restrictions (https://www3.epa.gov/pesticides/chem_search/ppls/HI120001-20220513.pdf and https://www3.epa.gov/pesticides/chem_search/ppls/089442-00051-20231024.pdf).

2.6.2.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(triclopyr) and (wildlife or bird or mammal or reptile or bee or invertebrate or amphibian) and (toxicity or toxicology)” resulted in 13 articles published in 2021-2025. Upon screening, six articles were considered to be relevant. Curtis and Bidart (2021) assessed triclopyr toxicity in frog tadpoles and



concluded that, at environmentally relevant concentrations, triclopyr had minimal direct effects on tadpole growth. Voinorosky and Stewart (2021) quantified triclopyr drift and foliage concentrations after two field application methods; the authors concluded that triclopyr dissipation was rapid in boreal rights-of-way, but chronic exposure risk to large herbivores (like moose) could be a concern and that application method mattered (basal bark method minimized off-target risk whereas foliar application increased foliage residues). Barlow et al. (2022a) reported that triclopyr acid and its variants were not specifically toxic to the rabbit embryo and fetus, such that post-implantation loss only occurred at maternally toxic doses and there was no evidence of developmental toxicity at non-maternally toxic doses. The study indicated that triclopyr and its major variants did not pose a specific developmental risk to rabbits at environmentally relevant exposure levels. Barlow et al. (2022b) conducted a two-generation study in rats and reported that developmental toxicity was only observed at maternally toxic doses, indicating that triclopyr and its variants were not reproductive or developmental toxicants. Voinorosky et al. (2022) investigated indirect effects of triclopyr on habitat quality in boreal rights-of-way, focusing on soil processes and invertebrate responses; the authors concluded that field application rates of triclopyr were not expected to impair habitat quality or ecosystem services in boreal ecoregions and suggested that responsible use of triclopyr at recommended application rates was unlikely to disrupt key soil processes or harm soil invertebrate populations. Mallick et al. (2023) herbicides, including triclopyr, could contribute to the decline of butterfly population and diversity by reducing plant diversity and habitat quality.

2.6.3 Toxicity in Plants

2.6.3.1 Midpen and EPA Reports

According to Midpen (2018b), some non-target plants were highly sensitive to triclopyr with extensive damage or mortality observed even at low doses; however, it was noted that triclopyr persistence in the environment was low, such that triclopyr degraded rapidly in forage grass and bound strongly to soil. No new studies on triclopyr toxicity in plants were identified in 2019 (Midpen, 2019a). No new studies on triclopyr toxicity in plants were identified in 2020; however, two studies were noted that evaluated triclopyr efficacy (Midpen, 2020).

According to EPA (2020i), triclopyr posed significant risks to non-target terrestrial and aquatic plants, especially from spray drift and compost contamination. The agency noted that it required additional studies and label changes to mitigate risks. The latest EPA-stamped labels for triclopyr BEE and triclopyr TEA were available as of 2023 and 2025, respectively. For both products, the labels include information on environmental hazard, use directions, and use restrictions

(https://www3.epa.gov/pesticides/chem_search/ppls/HI120001-20220513.pdf and https://www3.epa.gov/pesticides/chem_search/ppls/089442-00051-20231024.pdf).

2.6.3.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(triclopyr) and (plant) and (toxicity or toxicology)” resulted in zero articles published in 2021-2025.



2.6.4 Conclusions and Recommendations

Midpen uses triclopyr BEE (Garlon 4 Ultra by Dow AgroSciences) and triclopyr TEA (Capstone by Dow AgroSciences) for selective post-emergent woody plant broadleaf weed, and tree control. Based on the additional information reviewed, there were no changes to the general toxicological findings of triclopyr effects on humans, wildlife, or plants that were used as the basis for the environmental assessments conducted in 2014 and 2019. While the EPA identified potential risks to mammals, birds, and pollinators at high application rates and non-target terrestrial and aquatic plants from spray drift and compost contamination in their 2020 assessment, they modified the label following their assessment. Thus, Stantec recommends no changes to current application practices by Midpen under the current IPMP, as long as they are consistent with the latest EPA-stamped labels for triclopyr BEE and triclopyr TEA (https://www3.epa.gov/pesticides/chem_search/ppls/H1120001-20220513.pdf and https://www3.epa.gov/pesticides/chem_search/ppls/089442-00051-20231024.pdf).



3 Fungicide

3.1 Phosphite K Salts, Mono-/Di-

Phosphite K salts, mono-/di- (a.k.a., potassium salts of phosphoric acid) [Agri-Fos (AgBio)] were included on the Midpen approved list of pesticides. According to [Appendix A](#) of Midpen (2014), (1) in humans, phosphite K salts toxicity was considered to be low, such that there was no evidence of carcinogenicity, neurotoxicity, immunotoxicity, or reproductive/developmental toxicity, and (2) in ecological receptors, phosphite K salts were practically nontoxic to birds, fish, and aquatic invertebrates, and toxic to bees. Importantly, it was noted that phosphite K salts were designed to be applied directly to the bark of forest trees, thereby decreasing its potential to impact non-target species (Midpen, 2014). According to [Appendix 1](#) of Midpen (2019b), phosphite K salts were classified as “practically nontoxic to aquatic-phase amphibians and, at most, slightly toxic to terrestrial-phase amphibians”.

Additional information on phosphite K salts toxicity was available since the 2014 and 2019 assessments by Midpen. Stantec reviewed the additional information as outlined below.

3.1.1 Toxicity in Humans

3.1.1.1 Midpen and EPA Reports

No new studies on phosphite K toxicity in humans were identified in the 2015-2018 period (Midpen, 2018b), in 2019 (Midpen, 2019a), or in 2020 (Midpen, 2020).

According to EPA (2019b), phosphite K (phosphorous acid and its salts) had low toxicity to humans when used as labeled. It was noted that no significant risks were expected for the general population, workers, or consumers and that no additional data or risk mitigation measures were required at the time of the report

3.1.1.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 9, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(phosphite) and (human) and (health or toxicity or toxicology)” resulted in 16 articles published in 2021-2025. Upon screening, these articles were not considered to be relevant.

3.1.2 Toxicity in Wildlife

3.1.2.1 Midpen and EPA Reports

No new studies on phosphite K toxicity in wildlife were identified in the 2015-2018 period (Midpen, 2018b), in 2019 (Midpen, 2019a), or in 2020 (Midpen, 2020).

According to EPA (2019b), phosphite K (phosphorous acid and its salts) was considered practically nontoxic to wildlife (birds, mammals, and insects). It was noted that phosphite K was slightly toxic to freshwater invertebrates but was not expected to pose a risk due to its rapid breakdown and use restrictions. The agency also noted that no additional ecological risk mitigation measures were required.



3.1.2.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(phosphite) and (wildlife or bird or mammal or reptile or bee or invertebrate or amphibian) and (toxicity or toxicology)” resulted in six articles published in 2021-2025. Upon screening, these articles were not considered to be relevant.

3.1.3 Toxicity in Plants

3.1.3.1 Midpen and EPA Reports

No new studies on phosphite K toxicity in plants were identified in the 2015-2018 period (Midpen, 2018b), in 2019 (Midpen, 2019a), or in 2020 (Midpen, 2020).

According to EPA (2019), phosphite K (phosphorous acid and its salts) was considered practically nontoxic to non-target plants. The agency also noted that no additional ecological risk mitigation measures were required.

3.1.3.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(phosphite) and (plant) and (toxicity or toxicology)” resulted in 15 articles published in 2021-2025. Upon screening, three articles were considered to be relevant. Z. Li et al. (2022) reported that seedling growth and photosynthesis in alfalfa were inhibited in the presence of phosphite. Wang et al. (2022) noted that exposure to phosphite resulted in significant reductions in leaf length, root length, relative growth rate, and photosynthetic pigments in *V. natans*, suggesting potential phytotoxicity of phosphite to aquatic plants, especially at higher concentrations or prolonged exposure. Koyukan et al. (2025) reported that phosphite treatment in maize mitigated the adverse effects of boron toxicity, characterized by improved antioxidant defense system, reduced reactive oxygen species accumulation, and enhanced photosynthetic efficiency.

3.1.4 Conclusions and Recommendations

Midpen uses Phosphite K Salts, mono-/di- (Agri-Fos by AgBio) for prevention of sudden oak death. Based on the additional information reviewed, there were no changes to the general toxicological findings of phosphite K effects on humans, wildlife, or plants that were used as the basis for the environmental assessments conducted in 2014 and 2019. Although a couple of peer-reviewed articles suggested that phosphite could be phytotoxic, these findings are not applicable to Midpen’s phosphite K application to bark. Thus, Stantec recommends no changes to current application practices by Midpen under the current IPMP as long as they are consistent with the latest EPA-stamped label for phosphite K (https://www3.epa.gov/pesticides/chem_search/ppls/071962-00001-20201218.pdf).



4 Rodenticide

4.1 Cholecalciferol

Cholecalciferol (Cholecalciferol baits) was included on the Midpen approved list of pesticides. According to [Appendix A](#) of Midpen (2014), cholecalciferol was considered to have high acute toxicity in humans. It was noted that consumption of “large doses” of cholecalciferol led to increased absorption of calcium from intestines, resulting in vomiting, lethargy, muscle weakness, renal tubular necrosis, gastrointestinal stasis, gastric acid secretion, and decreased responsiveness of skeletal muscles and neural tissues. It was also noted that cholecalciferol metabolites stimulated phosphorous transfer from bone to plasma. Potential carcinogenicity, neurotoxicity, immunotoxicity, or reproductive/developmental toxicity of cholecalciferol was not specified. Regarding ecological receptors, cholecalciferol was moderately toxic to birds and generally toxic to rodents with one ingestion. Cholecalciferol toxicity to other ecological receptors was not specified (Midpen, 2014). According to [Appendix 1](#) of Midpen (2019b), cholecalciferol was classified as “at most, slightly toxic to terrestrial-phase amphibians”, whereas no classification was possible for aquatic-phase amphibians. Importantly, it was noted that cholecalciferol was applied inside Midpen buildings using bait stations (Midpen, 2014, 2019b), suggesting that toxicity to non-target organisms and humans was unlikely.

Additional information on cholecalciferol toxicity was available since the 2014 and 2019 assessments by Midpen. Stantec reviewed the additional information as outlined below.

4.1.1 Toxicity in Humans

4.1.1.1 Midpen and EPA Reports

No new studies on cholecalciferol toxicity in humans were identified in the 2015-2018 period (Midpen, 2018b), in 2019 (Midpen, 2019a), or in 2020 (Midpen, 2020).

According to EPA (2022a), cholecalciferol was acutely toxic at high doses (causing hypercalcemia), but risk to humans was minimized by current regulatory controls. It was noted that incidents of human poisoning were rare and generally minor, whereas severe cases were extremely uncommon and often not directly attributable to cholecalciferol rodenticide products. The agency noted that risk mitigation measures (packaging, bait station requirements, personal protective equipment, and labeling) were considered effective in reducing human health risks.

4.1.1.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 9, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(cholecalciferol) and (human) and (health or toxicity or toxicology)” resulted in 1233 articles published in 2021-2025. However, the articles were not reviewed for relevance given that the application method of cholecalciferol indicated low potential for exposure or risk in humans and non-target organisms.



4.1.2 Toxicity in Wildlife

4.1.2.1 Midpen and EPA Reports

No new studies on cholecalciferol toxicity in wildlife were published in the 2015-2018 period (Midpen, 2018b), in 2019 (Midpen, 2019a), or in 2020 (Midpen, 2020).

According to EPA (2022a), cholecalciferol posed a high acute risk to non-target mammals if they accessed baits, but risk to birds, reptiles, amphibians, and invertebrates was low. It was noted that secondary poisoning risk was low for both mammals and birds due to the mode of action and use patterns. The agency also noted that cholecalciferol exposure incidents in wildlife were rare, but EPA proposed continued mitigation (e.g., bait station use, carcass collection, reporting) to further reduce risk.

In December of 2023, the EPA released a draft BE to determine whether 11 active rodenticide ingredients, including cholecalciferol, may affect any listed species or their critical habitats (EPA, 2023). The EPA evaluated the effects of the 11 rodenticides on 1,784 listed species and 904 designated critical habitats in the U.S. and its territories. For 88% of listed species and 95% of their critical habitats, these rodenticides were found to have no effect. One to 8 percent of listed species and 4% of their critical habitats, dependent on chemical and application type, were likely to be adversely affected. Cholecalciferol was determined likely to adversely affect 20 species of listed mammals, the majority of which do not occur on Midpen lands. Additionally, exposure to non-target birds and mammals is expected to be minimal when cholecalciferol is used according to label instructions (EPA, 2023).

In November of 2024, the EPA released its final BE and included several mitigation measures meant to serve as the EPA's Rodenticide Strategy (EPA, 2024). The EPA initiated formal consultation with the U.S. Fish and Wildlife Service in November of 2024.

4.1.2.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string *“(cholecalciferol) and (wildlife or bird or mammal or reptile or bee or invertebrate or amphibian) and (toxicity or toxicology)”* resulted in 189 articles published in 2021-2025. However, the articles were not reviewed for relevance given that the application method of cholecalciferol indicated unlikely exposure or risk in non-target organisms.

4.1.3 Toxicity in Plants

4.1.3.1 Midpen and EPA Reports

No new studies on cholecalciferol toxicity in plants were published in the 2015-2018 period (Midpen, 2018b), in 2019 (Midpen, 2019a), or in 2020 (Midpen, 2020).

According to EPA (2022a), plant toxicity data were not required or assessed for cholecalciferol due to the use pattern and low likelihood of exposure.

4.1.3.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string *“(cholecalciferol) and (plant) and (toxicity or toxicology)”* resulted in four articles published



in 2021-2025. However, the articles were not reviewed for relevance given that the application method of cholecalciferol indicated unlikely toxicity in humans and non-target organisms.

4.1.4 Conclusions and Recommendations

Midpen uses cholecalciferol baits for rodent pest control (e.g., rats, mice). Based on the additional information reviewed, there were no changes to the general toxicological findings of cholecalciferol effects on humans, wildlife, or plants that were used as the basis for the environmental assessments conducted in 2014 and 2019. Thus, Stantec recommends no changes to current application practices by Midpen under the current IPMP.



5 Insecticides

5.1 Prallethrin

Prallethrin [PT Wasp-Freeze II (BASF)] was included on the Midpen approved list of pesticides. Prallethrin was not evaluated in [Appendix A](#) of Midpen (2014). According to [Exhibit A](#) of Midpen (2019b), prallethrin toxicity in humans was considered to be moderate (Category II) via oral and inhalation routes and very low (Category IV) via dermal route. Potential for carcinogenicity, neurotoxicity, immunotoxicity, or reproductive/developmental toxicity of triclopyr was not specified. According to [Appendix 1](#) of Midpen (2019b), prallethrin was classified as very highly toxic to aquatic invertebrates and freshwater fish, highly toxic to bees, moderately toxic to mammals, and “at most” slightly toxic to birds; prallethrin toxicity to aquatic-phase amphibians was considered to be similar to that in freshwater fish, whereas prallethrin toxicity to terrestrial-phase amphibians and reptiles was considered to be similar to that in birds. Importantly, it was noted that prallethrin use was limited to around buildings and along trails in recreational parks, indicating low potential for risk (Midpen, 2019b).

Additional information on prallethrin toxicity was available since the 2014 and 2019 assessments by Midpen. Stantec reviewed the additional information as outlined below.

5.1.1 Toxicity in Humans

5.1.1.1 Midpen and EPA Reports

According to Midpen (2018b), only one study was identified between 2015 and 2018 on prallethrin toxicity in humans. The study reported that prallethrin could cause inflammation in the respiratory system following inhalation and suggested that adequate ventilation should be required when using indoor insecticide (Midpen, 2018b). No new studies on prallethrin toxicity in humans were identified in 2019 (Midpen, 2019a) or in 2020 (Midpen, 2020).

According to EPA (2020h), prallethrin did not pose significant dietary, residential, or aggregate risks to humans when used according to label directions. It was noted that occupational risk was only of concern for certain application scenarios (e.g., mixing, loading, applying liquid solutions), but such risks could be mitigated by personal protective equipment and restriction of application methods. The agency also noted that there was no evidence of significant human toxicity or epidemiological associations with adverse health outcomes and that no further human health data needs were identified by EPA.

5.1.1.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 8, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(prallethrin) and (human) and (health or toxicity or toxicology)” resulted in 10 articles published in 2021-2025. Upon screening, these articles were not considered to be relevant.



5.1.2 Toxicity in Wildlife

5.1.2.1 Midpen and EPA Reports

According to Midpen (2018b), two studies were identified between 2015 and 2018 on prallethrin toxicity in wildlife. One study reported that prallethrin applications in a suburban setting had no effect on honeybee mortality, colony health, or production of detoxification enzymes. The other study noted that honeybee mortality was 2% or less when prallethrin was applied at various distances from a truck-mounted ultra-low-volume sprayer (Midpen, 2018b). No new studies on prallethrin toxicity in wildlife were identified in 2019 (Midpen, 2019a) or in 2020 (Midpen, 2020).

According to EPA (2020h), no major risks of prallethrin were identified for birds, mammals, reptiles, or amphibians; however, ecological risks to aquatic invertebrates and fish were noted, especially from urban runoff, down-the-drain disposal, and wide-area mosquito control. In pollinators, prallethrin risks were possible but not fully characterized, requiring additional data. The agency noted that mitigation measures (e.g., label changes, buffer zones, application restrictions) were needed to reduce environmental exposure and risk. The latest EPA-stamped labels for prallethrin-containing products included environmental hazard warnings and directions for proper use (([US EPA, Pesticide Product Label, TC 303,10/08/2024](#); [US EPA, Pesticide Product Label, MGK Formula 3172,09/11/2025](#), and https://www3.epa.gov/pesticides/chem_search/ppls/089459-00130-20220502.pdf).

5.1.2.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(prallethrin) and (wildlife or bird or mammal or reptile or bee or invertebrate or amphibian) and (toxicity or toxicology)” resulted in six articles published in 2021-2025. Upon screening, three articles were considered to be relevant. In a study by Tamagno et al. (2022), prallethrin exposure affected markers of neurotoxicity in *C. elegans*. In two other studies by the same group, prallethrin exposure in zebrafish elicited enzymatic antioxidant responses in different tissues and resulted in behavioral and cholinergic changes in different brain regions (Tamagno, Alves, Pompermaier, Amaral, et al., 2023; Tamagno, Alves, Pompermaier, Veneral, et al., 2023).

5.1.3 Toxicity in Plants

5.1.3.1 Midpen and EPA Reports

No new studies on prallethrin toxicity in plants were identified in the 2015-2018 period (Midpen, 2018b), in 2019 (Midpen, 2019a), or in 2020 (Midpen, 2020).

According to EPA (2020h), prallethrin was not identified as a phytotoxicant and no risks to plants were highlighted or assessed.

5.1.3.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(prallethrin) and (plant) and (toxicity or toxicology)” resulted in one article published in 2021-2025. Upon screening, this article was not considered to be relevant.



5.1.4 Conclusions and Recommendations

Midpen uses prallethrin (PT Wasp-Freeze II by BASF) for wasp and hornet control. Based on the additional information reviewed, there were no changes to the general toxicological findings of prallethrin effects on humans, wildlife, or plants that were used as the basis for the environmental assessments conducted in 2014 and 2019. Though the EPA identified potential risks to ecological species in their 2020 assessment, they subsequently updated their label. Thus, Stantec recommends no changes to current application practices by Midpen under the current IPMP as long as they are consistent with the latest EPA-stamped label (https://www3.epa.gov/pesticides/chem_search/ppls/000499-00540-20241008.pdf).

5.2 Indoxacarb

Indoxacarb [Advion Gel Baits (DuPont)] was included on the Midpen approved list of pesticides. According to [Appendix A](#) of Midpen (2014), (1) in humans, indoxacarb toxicity was considered to be low, such that there was no evidence of carcinogenicity, neurotoxicity, immunotoxicity, or reproductive/developmental toxicity, whereas eye irritation was noted as “possible”, and (2) in ecological receptors, indoxacarb was moderately toxic to birds and moderately to highly toxic to fish and aquatic invertebrates. According to [Appendix 1](#) of Midpen (2019b), indoxacarb was classified as “highly toxic to aquatic-phase amphibians and moderately toxic to terrestrial-phase amphibians”. Importantly, it was noted that indoxacarb was used in the form of gel baits to treat cockroach infestations in or around buildings (Midpen, 2014, 2019b), indicating low risk potential to non-target organisms.

Additional information on indoxacarb toxicity was available since the 2014 and 2019 assessments by Midpen. Stantec reviewed the additional information as outlined below.

5.2.1 Toxicity in Humans

5.2.1.1 Midpen and EPA Reports

No new studies on indoxacarb toxicity in humans were identified in the 2015-2018 period (Midpen, 2018b), in 2019 (Midpen, 2019a), or in 2020 (Midpen, 2020).

According to EPA (2018a), indoxacarb did not show evidence of carcinogenicity in either the rat or mouse studies, nor was there any evidence of mutagenicity; therefore, a cancer risk assessment was not conducted. It was noted that no risks of concern were identified for dietary, residential, aggregate, or occupational post-application exposures, and a quantitative bystander spray drift assessment for indoxacarb was not required based on the application rate. It was also noted that all occupational handler inhalation risk estimates for registered uses of indoxacarb were not of concern, except for mixing/loading formulations for aerial application to high acreage field crops.

5.2.1.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 8, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(indoxacarb) and (human) and (health or toxicity or toxicology)” resulted in 20 articles published in 2021-2025. Upon screening, six articles were considered to be relevant. Patel et al. (2024) documented a case report in which methemoglobinemia was observed in a patient with symptoms of cyanosis and low oxygen saturation due to indoxacarb ingestion; it was noted that the patient was



successfully treated with methylene blue. Hassanen et al. (2025) exposed rats to indoxacarb via epicutaneous and intranasal exposures. It was noted that signs of neurotoxicity and oxidative stress as well as histopathological changes were observed in brain and lungs; thus, the authors concluded that epicutaneous and intranasal exposure to indoxacarb could pose neurotoxic and respiratory risks relevant for occupational safety. The remaining four articles evaluated indoxacarb exposure via consumption of fruits and vegetables and indicated that no significant risk to consumers was anticipated (Kazar Soydan et al., 2021; Łozowicka et al., 2025; Odabas et al., 2024; Reddy et al., 2025).

5.2.2 Toxicity in Wildlife

5.2.2.1 Midpen and EPA Reports

No new studies on indoxacarb toxicity in wildlife were identified in the 2015-2018 period (Midpen, 2018b) or in 2019 (Midpen, 2019a)). It was noted that indoxacarb baits were generally placed strategically indoors; thus, the potential for exposure in non-target organisms was negligible (EPA, 2018b; Midpen, 2018b, 2019a). According to Midpen (2020), two studies evaluated indoxacarb effects in non-target animals; however, these studies considered extensive indoxacarb use in agricultural and forestry applications that were not relevant to Midpen.

According to EPA (2018a), there were potential ecological risks of concern from the registered uses of indoxacarb. It was noted that risk assessment in birds showed exceedances of acute level of concern (LOC), but not chronic LOC in agricultural settings. In mammals, exceedances of chronic LOC, but not acute LOC, were noted in agricultural settings. For risk assessment in honeybees, the agency considered a variety of exposure types; however, a high level of uncertainty was noted for some exposure routes due to lack of information and no conclusion could be reached. In aquatic invertebrates, exceedances of chronic LOC, but not acute LOC, were noted in water column invertebrates and benthic invertebrates. In fish and aquatic invertebrates, no acute or chronic risks of concern were noted.

5.2.2.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(indoxacarb) and (wildlife or bird or mammal or reptile or bee or invertebrate or amphibian) and (toxicity or toxicology)” resulted in 63 articles published in 2021-2025. Upon screening, nine articles were considered to be relevant. As summarized in **Table 5**, the articles indicated that adverse effects in wildlife could occur upon exposure to indoxacarb.

Table 5. Key Articles on Indoxacarb Toxicity in Wildlife Published in 2021-2025

PMID	DOI	Title	Main conclusion
40378186	10.1093/etojnl/vgaf131	Acute toxicity of cyprodinil, glyphosate isopropylamine salt, and indoxacarb pesticides in narrow-clawed crayfish, <i>Pontastacus leptodactylus</i> (Eschscholtz, 1823)	Indoxacarb exposure in crayfish led to oxidative damage and severe hepatopancreas histopathology, indicating significant toxicity
39959498	10.1016/j.heliyon.2025.e42241	Beneficial arthropods threatened by synthetic agricultural pesticides around the southeast slopes of Mount Cameroon	Synthetic pesticides including indoxacarb pose threats to beneficial arthropods, highlighting ecological risks
38801905	10.1016/j.chemosphere.2024.142387	Toxic effects of commercial grade indoxacarb and endosulfan on <i>Gammarus kischineffensis</i> (Schellenberg, 1937) (Crustacea: Amphipoda)	Indoxacarb and endosulfan caused toxic effects in <i>G. kischineffensis</i> , demonstrating risks to aquatic invertebrates



PMID	DOI	Title	Main conclusion
36508809	10.1016/j.econ.2022.114400	Sublethal effects of an indoxacarb enantiomer insecticide on <i>Plutella xylostella</i> caterpillar and <i>Chrysoperla sinica</i> predator	Sublethal exposure to indoxacarb enantiomers affected development and reproduction in <i>P. xylostella</i> and <i>C. sinica</i>
35164134	10.3390/molecules27030870	Comprehensive Detoxification Mechanism Assessment of Red Imported Fire Ant (<i>Solenopsis invicta</i>) against Indoxacarb	Transcriptomic analysis revealed upregulation of detoxification genes in <i>S. invicta</i> exposed to indoxacarb, indicating adaptive responses
34997483	10.1007/s11356-021-17988-0	Indoxacarb effects on non-target predator, <i>Podisus distinctus</i> (Hemiptera: Pentatomidae)	Indoxacarb caused high mortality and behavioral changes in <i>P. distinctus</i> , suggesting incompatibility with this predator in pest management
34608487	10.1093/jeet/toab176	Lethal and Sublethal Toxicity of Pesticides Used in Fruit Growing on the Parasitoid <i>Diachasmimorpha longicaudata</i> (Hymenoptera: Braconidae): Implications for Integrated Fruit Fly Management	Indoxacarb exhibited lethal and sublethal toxicity to <i>D. longicaudata</i> , impacting parasitoid viability in fruit fly management
34571423	10.1016/j.econ.2021.112812	Compatibility of six reduced-risk insecticides with <i>Orius strigicollis</i> (Heteroptera: Anthrenidae) predators for controlling Thrips hawaiiensis (Thysanoptera: Thripidae) pests	Indoxacarb was evaluated for compatibility with <i>O. strigicollis</i> ; results suggest moderate safety for this predator in pest control
33179745	10.1093/jeet/toaa260	Acute and Chronic Toxicity of Indoxacarb in Two Populations of <i>Plutella xylostella</i> (Lepidoptera: Plutellidae)	Indoxacarb showed acute and chronic toxicity in <i>P. xylostella</i> , with reduced survival and fecundity, relevant for resistance management

5.2.3 Toxicity in Plants

5.2.3.1 Midpen and Reports

No new studies on indoxacarb toxicity in plants were identified in the 2015-2018 period (Midpen, 2018b), in 2019 (Midpen, 2019b), or in 2020 (Midpen, 2020).

According to EPA (2018a), no risks of concern were noted in terrestrial or aquatic plants.

5.2.3.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(indoxacarb) and (plant) and (toxicity or toxicology)” resulted in 47 articles published in 2021-2025. Upon screening, these articles were not considered to be relevant.

5.2.4 Conclusions and Recommendations

Midpen uses indoxacarb (Advion Gel Baits by DuPont) for structural pest control (e.g., ants, cockroaches). Based on the additional information reviewed, there were no changes to the general toxicological findings of indoxacarb effects on humans, wildlife, or plants that were used as the basis for the environmental assessments conducted in 2014 and 2019. Although several new articles on indoxacarb toxicity were available, the findings of adverse are highly unlikely to be applicable to Midpen’s indoxacarb use in gel baits in and around buildings. Thus, Stantec recommends no changes to current application practices by Midpen as long as they are consistent with the latest EPA-stamped label for indoxacarb (https://www3.epa.gov/pesticides/chem_search/ppls/000100-01484-20240725.pdf).



5.3 S-Hydroprene

s-Hydroprene [Gentrol Point Source (Wellmark International)] was included on the Midpen approved list of pesticides. According to [Appendix A](#) of Midpen (2014), (1) in humans, hydroprene toxicity was considered to be low, such that it did not pose acute dietary risk, there was no evidence of carcinogenicity, neurotoxicity, or immunotoxicity, and developmental toxicity in animal studies occurred at high doses, and (2) in ecological receptors, hydroprene was practically nontoxic to fish, aquatic invertebrates, and adult honeybees (some toxicity to larval honeybees). According to [Appendix 1](#) of Midpen (2019b), s-hydroprene was classified as “practically nontoxic to aquatic-phase amphibians and terrestrial-phase amphibians”. Importantly, it was noted that s-hydroprene was used in the form of baits to treat cockroach infestations in or around buildings (Midpen, 2014, 2019b), indicating low risk potential to non-target organisms.

Additional information on s-hydroprene toxicity was available since the 2014 and 2019 assessments by Midpen. Stantec reviewed the additional information as outlined below.

5.3.1 Toxicity in Humans

5.3.1.1 Midpen and EPA Reports

No new studies on s-hydroprene toxicity in humans were identified in the 2015-2018 period (Midpen, 2018b), in 2019 (Midpen, 2019a), or in 2020 (Midpen, 2020).

According to EPA (2021c), the toxicological database was considered complete for characterizing hazard and assessing risk from hydroprene, and no additional studies were anticipated to be needed for registration review. It was noted that the available toxicology data were sufficient to demonstrate that there were no foreseeable human health hazards likely to arise from the use of hydroprene when applied according to the registered product labels.

5.3.1.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 8, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(hydroprene) and (human) and (health or toxicity or toxicology)” resulted in zero articles published in 2021-2025.

5.3.2 Toxicity in Wildlife

5.3.2.1 Midpen and EPA Reports

No new studies on s-hydroprene toxicity in wildlife were identified in the 2015-2018 period (Midpen, 2018b), in 2019 (Midpen, 2019a), or in 2020 (Midpen, 2020).

According to EPA (2021c), the agency waived all non-target and environmental fate data requirements for hydroprene due to the lack of exposure based on their use patterns. It was also noted that given the lack of exposure, the agency determined that adverse effects in bees or other non-target insects were unlikely to occur.



5.3.2.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(hydroprene) and (wildlife or bird or mammal or reptile or bee or invertebrate or amphibian) and (toxicity or toxicology)” resulted in zero articles published in 2021-2025.

5.3.3 Toxicity in Plants

5.3.3.1 Midpen and EPA Reports

No new studies on s-hydroprene toxicity in plants were identified in the 2015-2018 period (Midpen, 2018b), in 2019 (Midpen, 2019a), or in 2020 (Midpen, 2020).

According to EPA (2021c), the agency waived all non-target and environmental fate data requirements for hydroprene due to the lack of exposure based on their use patterns.

5.3.3.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(hydroprene) and (plant) and (toxicity or toxicology)” resulted in zero articles published in 2021-2025.

5.3.4 Conclusions and Recommendations

Midpen uses s-hydroprene (Gentrol Point Source by Wellmark International) for pest control (e.g., cockroaches, beetles, moths). Based on the additional information reviewed, there were no changes to the general toxicological findings of s-hydroprene effects on humans, wildlife, or plants that were used as the basis for the environmental assessments conducted in 2014 and 2019. Thus, Stantec recommends no changes to current application practices by Midpen under the current IPMP as long as they are consistent with the latest EPA-stamped label for s-hydroprene (https://www3.epa.gov/pesticides/chem_search/ppls/002724-00469-20250307.pdf).

5.4 Fipronil

Fipronil [Maxforce Bait Stations (Bayer)] was included on the Midpen approved list of pesticides. According to [Appendix A](#) of Midpen (2014), (1) in humans, fipronil toxicity was considered to be moderate, such that there was no evidence of neurotoxicity or immunotoxicity but it was classified as a possible human carcinogen, and (2) in ecological receptors, fipronil was highly toxic to fish, aquatic invertebrates, bees, and some bird species. According to [Appendix 1](#) of Midpen (2019b), fipronil was classified as “highly toxic to aquatic-phase amphibians and terrestrial-phase amphibians”. Importantly, it was noted that fipronil was used in the form of baits to treat ant infestations in or around buildings (Midpen, 2014, 2019b), indicating low risk potential to non-target organisms.

Additional information on fipronil toxicity was available since the 2014 and 2019 assessments by Midpen. Stantec reviewed the additional information as outlined below.



5.4.1 Toxicity in Humans

5.4.1.1 Midpen and Reports

According to Midpen (2018b), several studies were published between 2015 and 2018 that evaluated exposure and health risks of fipronil. In one study, fipronil and its metabolite fipronil sulfone did not affect estrogenic processes; however, fipronil sulfone affected thyroid hormone activity. In another study, exposure and health effects of fipronil were investigated in rice farmers; it was noted that fipronil in personal air samples was detected at a concentration of 462.5 ng/m³, which was lower than the concentration thought to be associated with lifetime cancer risk. In a 2018 study, fipronil was detected at concentrations ranging from 4.8 to 90 ng/g on wrist bands worn by 10 out of 13 participants; it was noted that four of the participants used pet care products containing fipronil, and higher cumulative fipronil concentrations were noted in participants who smoked or were on vegetable-rich diets. Two mechanistic studies were also identified, such that one study noted that exposure to fipronil affected expression of 269 out of 56,384 genes in the liver and another study indicated that fipronil induced structural changes in SH-SY5Y cells and shortened neurite outgrowth projections. Lastly, it was noted that EPA classified fipronil as a possible human carcinogen. Thus, fipronil was considered to be moderately toxic to humans, with possible carcinogenic and neurotoxic effects. No new studies on fipronil toxicity in humans were identified in 2019 (Midpen, 2019a). According to Midpen (2020), one study was identified that found a correlation between fipronil metabolite in maternal hair and increased birth length; however, this was not considered to be evidence of toxicity or causation given the small samples size and lack of data showing direct effects of fipronil on birth measurements.

According to EPA (2020g), exposure to fipronil could cause neurotoxicity, thyroid disruption, and hepatotoxicity in humans. Further, fipronil was classified as a possible human carcinogen (Group C) based on increased thyroid tumors in rats. It was noted that fipronil risks of concern were identified for chronic dietary exposure (especially infants/children) and long-term residential exposure (children exposed to treated pets). However, the agency indicated that most acute and short-term exposures were not of concern under current use patterns and use of personal protective equipment and that most reported human incidents were mild and resolved quickly.

5.4.1.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 8, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(fipronil) and (human) and (health or toxicity or toxicology)” resulted in 122 articles published in 2021-2025. Upon screening, nine articles were considered to be relevant. As summarized in **Table 6**, the articles documented instances of fipronil exposure in workers and general population and in some cases the exposures were associated with health risks.

Table 6. Key Articles on Fipronil Toxicity in Humans Published in 2021-2025

PMID	DOI	Title	Main conclusion
40595883	10.1038/s41598-025-04295-8	Neurological and organ health risks associated with pesticide mixture exposure in banana farm workers in Moungo Division, Cameroon	Occupational exposure to fipronil and other pesticides may contribute to systemic health effects
40137540	10.3390/toxics13030213	Serum Concentrations of Fipronil and Metabolites in Japanese Pregnant Women: Relationship with Thyroid Hormone Levels	Fipronil exposure may disrupt thyroid function during pregnancy, indicating potential endocrine toxicity



PMID	DOI	Title	Main conclusion
39002332	10.1016/j.envint.2024.108881	Exposure to pesticides, persistent and non - persistent pollutants in French 3.5-year-old children: Findings from comprehensive hair analysis in the ELFE national birth cohort	Early-life exposure to pesticides may affect development; calls for stricter exposure controls
37624182	10.3390/toxics1080677	Bayesian-Based Probabilistic Risk Assessment of Fipronil in Food: A Case Study in Taiwan	Probabilistic risk assessment supports low risk under current exposure levels; useful for regulatory decisions
35534087	10.1111/1750-3841.16161	Quantitative exposure assessment and risk characterization for fipronil residues in laying hen eggs	Residue levels may pose risks depending on consumption patterns; monitoring is essential
35357189	10.1021/acs.jaf.c.2c00824	Occurrence of Phenylpyrazole and Diamide Insecticides in Lactating Women and Their Health Risks for Infants	Infants may be exposed to fipronil through lactation; potential developmental risks warrant further study
35356410	10.46234/ccdcw2022.046	Exposure to Fipronil Insecticide in the Sixth Total Diet Study - China, 2016-2019	Dietary intake of fipronil is within acceptable limits for most populations but requires continued surveillance
34971309	10.1021/acs.jaf.c.1c05694	Human Exposure of Fipronil Insecticide and the Associated Health Risk	Exposure levels may pose health risks, especially in vulnerable populations; calls for improved monitoring
33964773	10.1016/j.scitotenv.2021.147342	Insecticide fipronil and its transformation products in human blood and urine: Assessment of human exposure in general population of China	Widespread exposure confirmed; highlights need for regulatory oversight and public health evaluation

5.4.2 Toxicity in Wildlife

5.4.2.1 Midpen and EPA Reports

According to Midpen (2018b), several studies were published between 2015 and 2018 that evaluated fipronil toxicity in wildlife. In amphibians, fipronil and fipronil sulfone could be absorbed through skin from soil or overspray. It was noted that exposure to high fipronil concentrations was not lethal to tadpoles after seven days, but some biochemical markers of oxidative stress were affected. It was also noted that the degree of toxicity could be influenced by soil organic matter content, with lower organic matter leading to higher tissue concentrations in toads. In bees, fipronil was highly toxic following oral and contact exposures with LD₅₀ values in the low µg/bee range. It was also noted that fipronil could impair bee motor function, reduce sperm count and quality of drones, and cause abnormal development of wings and antennae. In other insects, fipronil was reported to reduce feeding activity in dragonflies and was toxic to damselfly nymphs. In fish, fipronil was reported to cause increased mortality, delayed hatching, and developmental abnormalities in zebrafish embryos as well as DNA damage in European eel. In birds, fipronil exposure was reported to reduce food consumption, body weights, and reproductive performance. Thus, fipronil was considered to be highly toxic to wildlife. According to Midpen (2019a), 13 studies were identified that evaluated fipronil toxicity in wildlife following intensive use in agricultural and residential settings; these studies were not considered to be relevant to Midpen's fipronil use scenario (Midpen, 2019a). Similarly, according to Midpen (2020), 16 studies were identified that evaluated fipronil toxicity in non-target organisms; however, these studies considered fipronil use in agricultural, veterinary, or residential settings, and were not relevant to Midpen's fipronil use scenario (Midpen, 2020).

According to EPA (2020f), fipronil posed significant risks to aquatic invertebrates, pollinators, birds, and mammals under current labeled uses, especially for broadcast and perimeter applications. It was noted that mitigation measures and additional data (especially for pollinators) were needed to address these risks. The



agency indicated that the environmental persistence and toxicity of fipronil degradants contributed to the long-term ecological risks.

5.4.2.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(fipronil) and (wildlife or bird or mammal or reptile or bee or invertebrate or amphibian) and (toxicity or toxicology)” resulted in 224 articles published in 2021-2025. Upon screening, six articles were considered to be relevant. As summarized in **Table 7**, the articles highlighted the potential for adverse effects of fipronil in wildlife, especially in pollinators.

Table 7. Key Articles on Fipronil Toxicity in Wildlife Published in 2021-2025

PMID	DOI	Title	Main conclusion
40517215	10.1007/s10646-025-02904-w	Behavioral impairments in Africanized <i>Apis mellifera</i> exposed to lethal and sublethal doses of acetamiprid, fipronil, and thiamethoxam	Fipronil causes behavioral impairments in bees even at sublethal doses, posing ecological risks
40058743	10.1016/j.etap.2025.104671	Mitigating pesticide risk on bee pollinators and angiosperm biodiversity in the Ndop wetlands: A conservation approach	Conservation strategies are needed to mitigate pesticide risks to pollinators and biodiversity
39874362	10.1371/journal.pone.0315915	Fipronil in sub-lethal doses leads to immunotoxicological effects in broiler birds	Fipronil poses immunotoxic risks to poultry even at low doses, warranting careful use
39317251	10.1016/j.scitotenv.2024.176334	Hazardous fipronil insecticide effects on aquatic animals' health: Historical review and trends	Fipronil is hazardous to aquatic wildlife and its use should be regulated to prevent ecological harm
39153725	10.1016/j.etap.2024.104536	Impact of environmental concentrations of fipronil on DNA integrity and brain structure of <i>Bombus atratus</i> bumblebees	Fipronil exposure compromises bee health and may contribute to pollinator decline
37532359	10.1016/j.pestb.p.2023.105505	Biochemical alterations in cotton leafworm, <i>Spodoptera littoralis</i> (Boisd.) related to emamectin benzoate and fipronil compared to their joint action	Fipronil persistence in fish tissues indicates potential long-term ecological risks in aquatic environments

5.4.3 Toxicity in Plants

5.4.3.1 Midpen and EPA Reports

No new studies on fipronil toxicity in plants were identified in the 2015-2018 period (Midpen, 2018b), in 2019 (Midpen, 2019a), or in 2020 (Midpen, 2020).

According to EPA (2020f), fipronil was not phytotoxic at labeled use rates. It was noted that no significant risks to terrestrial or aquatic plants were anticipated from fipronil or its major degradants under current use patterns.

5.4.3.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(fipronil) and (plant) and (toxicity or toxicology)” resulted in 75 articles published in 2021-2025. Upon screening, 10 articles were considered to be relevant. As summarized in **Table 8**, the articles indicated that fipronil could pose risks to plants.



Table 8. Key Articles on Fipronil Toxicity in Plants Published in 2021-2025

PMID	DOI	Title	Main conclusion
40841036	10.1016/j.jes.2025.02.005	Impact of irrigation with fipronil-contaminated waters on zucchini plants and their main insect pest, <i>Aphis gossypii</i>	Fipronil exposure through irrigation poses risks to crop health and pest dynamics, highlighting the need for careful water management
40244833	10.1093/etojnl/vgaf104	Field application doses of fipronil and 2,4-D and toxic effects on non-target soil organisms: a microcosm-level approach	Even recommended application rates can harm soil biodiversity, suggesting the need for ecological risk reassessment
40216582	10.1093/etojnl/vgaf095	Effects of pyraclostrobin and fipronil on spore germination of three species of arbuscular mycorrhizal fungi in subtropical soil	Fipronil may disrupt plant nutrient uptake and soil health by impairing mycorrhizal fungi
39627469	10.1007/s11274-024-04203-8	Short-term responses of identified soil beneficial-bacteria to the insecticide fipronil: toxicological impacts	Fipronil can impair soil microbial functions essential for plant health and nutrient cycling
39477588	10.1016/j.pestb.2024.106135	Phyto-toxicological effect of fipronil to plant seedlings: Assessing germination attributes, root-tip morphology, oxidative stress, and cellular respiration indices	Fipronil exhibits phytotoxic effects that compromise early plant development and cellular health
37146771	10.1016/j.chemosphere.2023.138850	Repeated applications of fipronil, propyzamide and flutriafol affect soil microbial functions and community composition: A laboratory-to-field assessment	Chronic pesticide use can degrade soil ecosystem services, affecting long-term plant productivity
36799483	10.1080/03601234.2023.2178789	Phytotoxicity of 2,4-D and fipronil mixtures to three green manure species	Combined pesticide applications may exacerbate toxicity in cover crops, impacting soil fertility management
35138446	10.1007/s00244-022-00914-x	Irrigation with Water Contaminated by Sugarcane Pesticides and Vinasse Can Inhibit Seed Germination and Crops Initial Growth	Agricultural runoff containing fipronil can impair crop establishment, necessitating better waste management practices
33396142	10.1016/j.ecoenv.2020.111622	Assessing single effects of sugarcane pesticides fipronil and 2,4-D on plants and soil organisms	Single pesticide exposures can harm both plants and soil biota, emphasizing the need for integrated toxicity assessments
29105037	10.1007/s11356-017-0394-3	An update of the Worldwide Integrated Assessment (WIA) on systemic insecticides. Part 1: new molecules, metabolism, fate, and transport	Fipronil's persistence and mobility raise concerns for non-target plant exposure and ecosystem contamination
40841036	10.1016/j.jes.2025.02.005	Impact of irrigation with fipronil-contaminated waters on zucchini plants and their main insect pest, <i>Aphis gossypii</i>	Fipronil exposure through irrigation poses risks to crop health and pest dynamics, highlighting the need for careful water management

5.4.4 Conclusions and Recommendations

Midpen uses fipronil (Maxforce Bait Stations by Bayer) for ant control. Based on the additional information reviewed, there were no changes to the general toxicological findings of fipronil effects on humans, wildlife, or plants that were used as the basis for the environmental assessments conducted in 2014 and 2019. It was noted that fipronil posed significant risks to aquatic invertebrates, pollinators, birds, and mammals under current labeled uses, especially for broadcast and perimeter applications. However, the current fipronil use in baits placed in and around buildings by Midpen is unlikely to pose ecological risks. Thus, Stantec recommends no changes to current application practices by Midpen under the current IPMP as long as they are consistent with the latest EPA-stamped label for fipronil (https://www3.epa.gov/pesticides/chem_search/ppls/000432-01256-20210228.pdf).



5.5 Sodium Tetraborate Decahydrate (Borax)

Sodium tetraborate decahydrate (borax) [Prescription Treatment Baits (BASF) and Terro Ant Killer II (Terro)] was included on the Midpen approved list of pesticides. According to [Appendix A](#) of Midpen (2014), (1) in humans, borax toxicity was considered to be low, such that there was no evidence of carcinogenicity, neurotoxicity, immunotoxicity, or reproductive/developmental toxicity, whereas eye irritation was noted as “possible”, and (2) in ecological receptors, borax was practically nontoxic to slightly toxic to birds, fish, and aquatic invertebrates, and “relatively nontoxic to beneficial insects”. According to [Appendix 1](#) of Midpen (2019b), borax was classified as “practically nontoxic to aquatic-phase amphibians and terrestrial-phase amphibians”.

Additional information on borax toxicity was available since the 2014 and 2019 assessments by Midpen. Stantec reviewed the additional information as outlined below.

5.5.1 Toxicity in Humans

5.5.1.1 Midpen and EPA Reports

No new studies on sodium tetraborate decahydrate toxicity in humans were identified in the 2015-2018 period (Midpen, 2018b), in 2019 (Midpen, 2019a), or in 2020 (Midpen, 2020).

No EPA reports assessing borax or sodium tetraborate decahydrate toxicity in humans were released between 2015 and 2025.

5.5.1.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 8, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(borax or sodium tetraborate decahydrate) and (human) and (health or toxicity or toxicology)” resulted in 40 articles published in 2021-2025. Upon screening, one article was considered to be relevant. Hadrup et al. (2021) reviewed toxicity of borax, boric acid, and boron-containing compounds. The authors noted that inhalation toxicity data were sparse, but one animal study showed reduced fetal weight after inhalation of cellulose that had a boric acid content of 20%. Skin exposure to boric acid was reported to be fatal in some cases, and the range of toxicity effects included abdominal as well as local dermal effects. Fatalities from boric acid also occurred after oral ingestion, and the endpoints in animals were weight loss and reproductive toxicity. Concerning genotoxicity studies, the available data suggested that boron-containing compounds were not genotoxic, and there was no evidence of the carcinogenicity of boric acid in a 2-year study in mice.

5.5.2 Toxicity in Wildlife

5.5.2.1 Midpen and EPA Reports

No new studies on sodium tetraborate decahydrate toxicity in wildlife were identified in the 2015-2018 period (Midpen, 2018b), in 2019 (Midpen, 2019a), or in 2020 (Midpen, 2020).

No EPA reports assessing borax or sodium tetraborate decahydrate toxicity in wildlife were released between 2015 and 2025.



5.5.2.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(borax or sodium tetraborate decahydrate) and (wildlife or bird or mammal or reptile or bee or invertebrate or amphibian) and (toxicity or toxicology)” resulted in 18 articles published in 2021-2025. Upon screening, these articles were not considered to be relevant.

5.5.3 Toxicity in Plants

5.5.3.1 Midpen and EPA Reports

No new studies on sodium tetraborate decahydrate toxicity in plants were identified in the 2015-2018 period (Midpen, 2018b), in 2019 (Midpen, 2019a), or in 2020 (Midpen, 2020).

No EPA reports assessing borax or sodium tetraborate decahydrate toxicity in plants were released between 2015 and 2025.

5.5.3.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(borax or sodium tetraborate decahydrate) and (plant) and (toxicity or toxicology)” resulted in five articles published in 2021-2025. Upon screening, these articles were not considered to be relevant.

5.5.4 Conclusions and Recommendations

Midpen uses borax (Prescription Treatment Baits by BASF; Terro Ant Killer II by Terro) for ant control. Based on the additional information reviewed, there were no changes to the general toxicological findings of borax effects on humans, wildlife, or plants that were used as the basis for the environmental assessments conducted in 2014 and 2019. Thus, Stantec recommends no changes to current application practices by Midpen under the current IPMP as long as they are consistent with the latest EPA-stamped label for Borax (https://www3.epa.gov/pesticides/chem_search/ppls/073605-00009-20161004.pdf) and (https://www3.epa.gov/pesticides/chem_search/ppls/000149-00008-20240410.pdf).

5.6 Diatomaceous Earth

Diatomaceous earth was included on the Midpen approved list of pesticides. According to [Appendix A](#) of Midpen (2014), (1) in humans, diatomaceous earth toxicity was considered to be low, such that there was no evidence of carcinogenicity, neurotoxicity, immunotoxicity, or reproductive/developmental toxicity, whereas skin and eye irritation was noted as “possible”, and (2) in ecological receptors, there was no evidence of toxicity to wildlife. According to [Appendix 1](#) of Midpen (2019b), diatomaceous earth was classified as “practically nontoxic to terrestrial-phase amphibians” and that exposure to diatomaceous earth was unlikely in aquatic-phase amphibians given its use.

Additional information on diatomaceous earth toxicity was available since the 2014 and 2019 assessments by Midpen. Stantec reviewed the additional information as outlined below.



5.6.1 Toxicity in Humans

5.6.1.1 Midpen and EPA Reports

No new studies on diatomaceous earth toxicity in humans were identified in the 2015-2018 period (Midpen, 2018b), in 2019 (Midpen, 2019a), or in 2020 (Midpen, 2020).

No EPA reports assessing diatomaceous earth toxicity in humans were released between 2015 and 2025.

5.6.1.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 8, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(*diatomaceous earth*) and (*human*) and (*health or toxicity or toxicology*)” resulted in 25 articles published in 2021-2025. Upon screening, none of these articles evaluated toxicity of diatomaceous earth in humans; however, several articles described diatomaceous earth as “inert”, “safe” and eco-friendly”, or as a “natural” insecticide with no toxicity on mammals including humans (Ogreten et al., 2025; Romei & Schilman, 2024; Zeni et al., 2021).

5.6.2 Toxicity in Wildlife

5.6.2.1 Midpen and EPA Reports

No new studies on diatomaceous earth toxicity in wildlife were identified in the 2015-2018 period (Midpen, 2018b), in 2019 (Midpen, 2019a), or in 2020 (Midpen, 2020).

No EPA reports assessing diatomaceous earth toxicity in wildlife were released between 2015 and 2025.

5.6.2.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(*diatomaceous earth*) and (*wildlife or bird or mammal or reptile or bee or invertebrate or amphibian*) and (*toxicity or toxicology*)” resulted in 14 articles published in 2021-2025. Upon screening, none of these articles evaluated diatomaceous earth toxicity in wildlife; however, several articles described diatomaceous earth as “inert”, a “safe and effective alternative to chemical acaricides”, a promising, environmentally friendly control of triatomines, or a “natural” insecticide with no toxicity on mammals (Dong et al., 2025; Romei & Schilman, 2024; Vargas-Abasolo et al., 2024; Zeni et al., 2021).

5.6.3 Toxicity in Plants

5.6.3.1 Midpen and EPA Reports

No new studies on diatomaceous earth toxicity in plants were identified in the 2015-2018 period (Midpen, 2018b), in 2019 (Midpen, 2019a), or in 2020 (Midpen, 2020).

No EPA reports assessing diatomaceous earth toxicity in plants were released between 2015 and 2025.



5.6.3.2 Peer-reviewed Articles (2021-2025)

Stantec conducted a literature search on September 10, 2025 using AbstractSifter v7 (Adkins et al., 2022). The search string “(*diatomaceous earth*) and (*plant*) and (*toxicity or toxicology*)” resulted in six articles published in 2021-2025. The review articles were screened for relevance. Upon screening, these articles were not considered to be relevant.

5.6.4 Conclusions and Recommendations

Midpen uses diatomaceous earth for structural pest control (e.g., ants, cockroaches). Based on the additional information reviewed, there were no changes to the general toxicological findings of diatomaceous earth effects on humans, wildlife, or plants that were used as the basis for the environmental assessments conducted in 2014 and 2019. Thus, Stantec recommends no changes to current application practices by Midpen under the current IPMP.



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APPENDIX B3

Screening-Level Ecological Risk Assessment for the New Pesticides in the 2019 Program Addendum (2019)

Midpeninsula Regional Open Space
Integrated Pest Management Program

Pesticide 2019 Literature Review and Annotated Bibliography



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1.1 Introduction

The information provided in this report is a synthesis of findings published in 2019 that describe the effects of pesticides used by MROSD on non-target organisms, and their persistence in the environment as well as their efficacy at controlling invasive species.

1.2 Literature Review and Evaluation Process

I performed a comprehensive literature review of all the scientific papers published in 2019 on the 18 active ingredients included in the MROSD Integrated Pest Management Plan (Environmental Assessment). All papers included in the review were peer reviewed and published in reputable journals and indexed in Web of Science. I completed a literature search for each of the 18 pesticides in Web of Science that included the pesticide name as the sole search term and refined each search to include only papers published in 2019. The titles and abstracts of all papers returned by the query were read. If the topic of the paper included human health risks, acute or chronic impacts to non-target organisms (i.e. plants, animals, bacteria, or fungi), pesticide effectiveness, or persistence in the environment, then the papers were reviewed and described in an annotated bibliography (Appendix 1). All study findings described in the report and the annotated bibliography are supported by appropriate statistical analyses unless otherwise stated.

2.0 HERBICIDES

2.1 GLYPHOSATE

2.1.1 Human Exposure and Health Risks

Described in this review are epidemiological studies that evaluate human health risks associated with glyphosate use. These studies compare disease prevalence in groups with different levels of glyphosate exposure. Not included in this review are mechanistic in vitro studies on human cell lines or studies on rats and mice that evaluated physiological pathways whereby glyphosate could result in disease. Although these studies can offer important insights into how pesticides could cause disease they are beyond the scope of this report. These types of studies typically do not use glyphosate concentrations that are relevant to exposure levels experienced by herbicide applicators or the general public and cannot address the effects of long-term and repeated exposure. Richardson et al (2019) published a review paper that describes the state of knowledge regarding these potential pathways.

There is a great deal of controversy over the carcinogenic risks of glyphosate. The International Agency for Research on Cancer (IARC) is a World Health Organizations (WHO) program that uses a panel of experts to evaluate the evidence for carcinogenicity of chemicals. Experts that contribute to IARC chemical risk evaluations, published in IARC Monographs, volunteer a minimum of two weeks to review scientific literature prior to an 8-day panel meeting in Lyon, France. The WHO vets each expert panelist to ensure that they do not have conflicts of interest and the panelists are well aware of the possible implications of their classifications. In 2015, IARC classified glyphosate as “probably carcinogenic to humans”. IARC’s intent is to classify potential hazards and ask “can it cause cancer under any circumstance”. The IARC classification system is not intended to provide risk assessment, which is done by regulatory agencies such as the U.S. Environmental Protection Agency (EPA). Risk assessment further incorporates expected levels of exposure. In 2017, in opposition with IARC classification, the EPA, a regulatory agency, classified glyphosate as “not likely to be carcinogenic to humans”. However, since the IARC classification there has been a flurry of lawsuits claiming that people who occupationally apply glyphosate at high rates and frequency are at a higher risk than the population on average of getting non-Hodgkin’s lymphoma.

IARC's decision to classify glyphosate as a "probable human carcinogen" was in part due to the discovery that Monsanto (now owned by Bayer) was caught interfering with the scientific literature by ghost-writing papers and reviewing research papers to manipulate messaging prior to being submitted for peer review. These conflicts of interest have tainted the scientific literature and contributed to the difficulty of interpreting the evidence published in the scientific literature. Interpretation of conflicting results is very challenging with this body of literature partly because it is difficult to sort out the conflicting interests and biases of the researchers. At this point, there is no consensus in the scientific literature on the relationship between glyphosate exposure and cancer risk. The most important and informative study to date informing human health risks associated with glyphosate-based herbicides is the Agricultural Health Study. This long-term cohort study includes over 50,000 pesticide applicators in the US, where approximately 80% of the participants have been exposed to glyphosate. In this study 575 out of 50,000 have or have had non-Hodgkin's lymphoma. Two studies were published in 2019 that evaluated non-Hodgkin's lymphoma risk associated with glyphosate exposure (Zhang et al. 2019 and Leon et al. 2019). Both of these studies re-evaluated the Agricultural Health Study (AHS) cohort data that was presented in Andreotti et al (2018). In brief, Andreotti et al found that glyphosate applicators were not at a higher risk of getting non-Hodgkin's lymphoma. In 2019, Zhang et al. published a metanalysis that combined the large Agricultural Health Study with 4 smaller case control studies and re-evaluated the risk associated with high exposure to glyphosate and non-Hodgkin's lymphoma. They concluded that that risk of non-Hodgkin's lymphoma is 41% higher if you are in the highest glyphosate exposure group. One major difference between the Andreotti et al 2018 analysis and the Zhang et al 2019 analysis is that Zhang et al teased out just the people that had had the highest duration and intensity of exposure. Though the Zhang et al finding appears alarming, using just the highest exposure group is a somewhat misleading approach. Using only the highest exposure group is evidence of cherry-picking, hunting for an effect, rather than *observing* without bias. Generally, it is preferable to look for patterns between exposure level and disease prevalence, so that you can determine if increased exposure results in increased risk. Zhang et al found that applicators with 5, 10, or 15 years of exposure had lower rates of NHL compared to the general population. Agricultural workers who were using

glyphosate for over 20 years also had access to chlordane, parathion, and several other now banned chemicals and chemical resistant gloves were less frequently used. Because there was no accounting for these covariates it is impossible to disentangle the effects of glyphosate from these other chemicals. It is difficult to say what explains the difference between 15 years of exposure (lower risk) and 20 years of exposure (higher risk). If glyphosate was capable of increasing non-Hodgkin's lymphoma risk, we should see a dose-dependent relationship among the 500 cases of non-Hodgkin's lymphoma in the cohort. No such relationship was found. Applicators in the bottom quartile for exposure had the same risk ratio as applicators in the top quartile. This lack of a relationship between exposure intensity suggests that glyphosate is not likely associated with non-Hodgkin's lymphoma. That said, some MROSD herbicide applicators might be in the situation where they will have 20 years of exposure to glyphosate in their career. Given the difficulty of determining if there are health risks associated with 20 years of cumulative exposure applicators should be taking steps from day one, to minimize exposure by using adequate PPE.

In a study that was funded in part by IARC, Leon et al (2019) used data from 3 large cohort studies in the US, France, and Norway to generate relative risk ratios (AKA odds ratios) in order to provide further insights into the relationship between non-Hodgkin's lymphoma and pesticide use by agricultural workers. The data from the US was from the Agricultural Health Study (AHS) that was analyzed by Andreotti et al (2018) and Zhang et al (2019). Leon et al corroborates some of the findings of Andreotti et al (2018), that is, overall, they found no association between non-Hodgkin's lymphoma and occupational exposure to glyphosate. Leon et al further evaluated risk associated with specific subtypes of non-Hodgkin's lymphoma and concluded that there was an elevated risk of diverse large B-cell lymphoma with a relative risk ratio of 1.36 (CI= 1-1.85). However, the relative risk overlaps 1 and is therefore difficult to interpret and requires more data before conclusions should be drawn. There are some important differences between the Leon et al study and the Andreotti et al study. Leon et al treated glyphosate exposure as a binary (ever exposed vs. never exposed) variable and essentially asked "does ever being exposed to glyphosate increase your risk of non-Hodgkin's lymphoma?", whereas Andreotti et al evaluated extent of exposure and related that to cancer

risk (as described above). The authors decision to use glyphosate exposure as a binary variable rather than consider exposure levels make it less informative. This study also included the cases that could not recall the frequency of glyphosate exposure, whereas the Andreotti et al study did not include the cases where frequency of exposure could not be recalled. A strength of the Leon et al study is that it includes a few additional years of data from the Agricultural Health cohort study and includes data from other studies in other countries. Andreotti et al (2018) used a more nuanced, robust, and informative approach than either of the two cohort studies published in 2019 (Leon et al. 2019, Zhang et al. 2019) or that related lifetime exposure to disease risk.

Whether you err on the side of caution and assume that glyphosate is a “probable human carcinogen” or you find that the evidence is insufficient to demonstrate carcinogenicity when exposure levels are included in risk assessments, it is important to consider the major differences between the frequency and rates of application that agricultural workers experience and rates and frequency that MROSD and other wildland weed workers experience. The accumulative exposure to glyphosate is dramatically different between agricultural and wildland weed workers. All of the studies to date only consider cancer risk associated with agricultural glyphosate use. The pesticide application techniques are vastly different. It is also relevant to consider that the safety measures and PPE used by pesticide applicators today are more protective than what was practiced decades ago.

Although, glyphosate is thought to be poorly absorbed through the skin (Wester et al. 1991), to date, there is little data in how much glyphosate enters the body following contact. A literature review by Gillezeau et al (2019) compared urine glyphosate concentrations of occupational glyphosate users to the concentrations found in the general population. On average urinary concentrations of glyphosate in people occupationally exposed varied from 0.26 to 73.5 µg/L and 0.16 to 7.6 µg/L. in the general public. The large variability among individuals and across studies could be due to a number of factors including methodological study approaches, time between exposure and urine test, difference in kidney health and metabolisms, amount of PPE used, and intensity of glyphosate exposure. Since these important and confounding variables

could not be accounted for in this review it is difficult to say whether or not, or how much more glyphosate enters the bodies of occupational users versus the general public. In a review paper, Solomon et al. (2019) reported that 0.7-5.4% of glyphosate the contacts an applicators skin or clothing could be absorbed and that these concentrations do not exceed acceptable daily intake levels considered safe by regulatory agencies such as the US-EPA. In a letter to the editor, Perry et al. (2019) analyzed frozen urine samples that were initially collected from from United States farmers in 1997 and 1998 and found that 39% of the samples from farmers that used glyphosate had detectable levels of glyphosate (mean concentration 4.04 µg/kg; range:1.3–12 µg/kg) and that 0 samples had detectable glyphosate among the non-glyphosate applicator samples. The concentrations of glyphosate in urine that Perry et al reported were consistent with levels reported in the occupational biomonitoring studies reviewed by Gillezeau et al. 2019. Detecting glyphosate in these 20-year-old samples demonstrates that glyphosate exposures among farmers was prior to the widespread planting of genetically engineered glyphosate tolerant crops first approved in 1996.

Smpokou et al (2019) used a case control study approach to evaluate relationship between pesticide exposure in sugar cane farmers and Mesoamerican Nephropathy (kidney disease). They measured glyphosate (and other pesticides) in urine samples from 350 men and women between the ages of 18-30 years old, without self-reported kidney disease risk factors. Smpokou conducted kidney function tests over two years and correlated these measures with pesticide concentrations in urine and found no difference in glyphosate concentrations in urine between the people with declining kidney function and those with stable kidney function. In the majority of urine samples (68% and 70%) glyphosate concentrations were below the limit of detection (0.1 ng/mL). In a similar study, Trasande et al (2019) evaluated the relationship between low levels of glyphosate exposure and kidney (renal) disease. They measured concentrations of glyphosate in urine, as well as 3 biomarkers for kidney function in children. They identified glyphosate in urine in 11% of the children that had been exposed to glyphosate. They found no association between glyphosate and kidney function biomarkers. Together these studies suggest that glyphosate exposure poses minimal risk to kidney health.

von Ehrenstein et al (2019) used a case control study to evaluate risk associated with early developmental exposure to 11 pesticides, including glyphosate, and autism prevalence in California's Central Valley. They used data from California Department of Developmental Service (DDS) to identify the cases of Autism Disorder, the most severe autism spectrum diagnosis. They randomly selected controls from birth records in the region and used a 10:1 control to case ratio. The authors determined exposure based on data from California Pesticide Use Reports. They used GIS to estimate whether pregnant moms and infants were within 2000 or 2500 m from where glyphosate was applied in an agricultural context. Exposure was 'ever exposed' compared to 'never exposed'. Odds ratios and 95% confidence intervals were calculated and used to determine risk. The authors concluded that the risk of autism disorder was associated with prenatal exposure to glyphosate (odds ratio 1.16, 95% confidence interval 1.06 to 1.27). However, to understand if glyphosate, per se, is associated with autism the study would ideally identify and evaluate cases that were exposed to glyphosate and not the other 10 agricultural chemicals in this study. That can be difficult to impossible to do because rarely (if ever) do farmers use only 1 pesticide. When the authors attempted to consider the other chemicals in the analysis the relationship between glyphosate exposure during pregnancy and autism was lost, but was maintained for exposure during the 1st year of life. The authors also found that the association of autism prevalence was greater when the radius around homes was extended from 2 to 2.5Km, but do not examine what the associations were for a smaller radius (e.g. 1km). Exposure should presumably be greater, not smaller, when the distance between homes and where the glyphosate is applied. Another notable issue with this study is that many important factors are likely to differ between cases and controls. For example, the test group differs from the control group by not only having increased pesticide exposure, but by all the demographic differences that distinguish urban populations from agricultural ones. It is also suspect that the authors find similar autism risks associated with all 11 pesticides they evaluated (both herbicides and insecticides) even though these pesticides vary drastically in chemical structure and mode of actions. The only commonality is that all of the pesticides are used agriculturally. The methodological flaws in this study are in many ways unavoidable, but

they also limit ability to draw the conclusion that autism is associated with glyphosate exposure.

Solomon (2019) is an update on a previous review published in 2016 and describes the range of glyphosate concentrations found in the environment. Solomon et al puts these concentrations in the context of exposure risks to the general public, domesticated animals, pets, and most importantly glyphosate applicators. In all cases, measured and estimated glyphosate exposures experienced by humans and animals were less than reference doses that are considered safe. Solomon concludes that realistic glyphosate concentrations found in the environment do not pose any substantial risk to people.

I recommend that MROSD pesticide applicators receive yearly up to date information regarding health risks associated with glyphosate. The National Pesticide Information Center (NPIC) provides excellent informational videos and fact sheets that are updated regularly with pertinent information as it becomes available. Kaci Buhl the Director of NPIC has an informative video on YouTube (<https://youtu.be/xEQVpKm921w>) and fact sheet (<http://npic.orst.edu/factsheets/glyphogen.html>).

2.1.2 Non-target Effects

Here I describe studies published in 2019 that evaluated the effects of glyphosate on non-target organisms including: animals, microbes, and non-target plants. When examining the risks of pesticides on non-target organisms, it is important to evaluate the range of ecologically relevant concentrations. The amount of glyphosate encountered by non-target organisms depends upon the application rate, the frequency of applications, the size of the area being treated, whether the applications are direct or indirect, and the degradation rate of the chemical in the environment.

2.1.2.1 Amphibians

There were six papers published in 2019 that evaluated the effects of glyphosate on amphibian mortality, development, physiology, reproduction, and behavior. Each of these studies are described in the annotated bibliography (Appendix 1). None of the studies published in 2019 evaluated amphibian taxa present in the general vicinity of MROSD's jurisdiction. Four studies published in 2019 assessed the effect of environmentally relevant concentrations of glyphosate on amphibian mortality and none of these studies found a relationship between glyphosate and amphibian toxicity. Amphibian toxicity testing is not typically required for ecological risk assessments because it has been demonstrated that fish have comparable sensitivities. Daam et al (2019) compiled toxicity values for fish and amphibians from the US-EPA ECOTOX database and compared tropical and non-tropical species and found that amphibians were less sensitive than fish to glyphosate toxicity and that the standard fish test species rainbow trout (*Oncorhynchus mykiss*) was more sensitive than the most sensitive amphibian test species.

In aquatic environments the maximum concentration of glyphosate found in lakes, ponds, and wetlands was 0.301 mg/L and 0.427 mg/L in ditches and drains (Battaglin et al. 2014). In this review I consider these concentrations as worst-case glyphosate exposure scenarios. In 2019, no studies reported environmentally relevant concentrations of glyphosate to cause amphibian mortality. All four of the studies that did evaluate acute toxicity of glyphosate-based herbicides reported LC50 values that were more than a magnitude higher than environmentally relevant concentrations (Babalola et al. 2019, Carvalho et al. 2019, Daam et al. 2019, Lajmanovich et al. 2019).

While not lethal to amphibians, sublethal impacts of glyphosate-based herbicides on growth, and development, behavior, physiology, and DNA damage could have important consequences for amphibian populations. At very high concentrations, the glyphosate formulations Roundup and Kilo max caused tadpole growth reductions, however these herbicides cannot technically be classified as growth inhibitors because the concentrations used in this study greatly exceeded relevant concentrations (Babalola et al. 2019). In amphibians, corticosterone regulates metamorphosis induction. Gulf coast toad (*Incilius nebulifer*) tadpoles exposed to

glyphosate did not elicit a hormone (corticosterone) response, alter tail morphology, or change behavior in response to the predator cues (Gabor et al. 2019). In contrast, Wilkens et al (2019) found that bullfrog corticosterone production was reduced following exposure to a glyphosate-based herbicide that contained 234 µg of glyphosate/L. Exposure to a herbicide that contained 234 µg glyphosate/L for seven days had no effect on bullfrog tadpoles (*Rana catesbeiana*) nutritional condition, plasma protein, glucose, uric acid, or 3 out of the 4 biomarkers used to assess oxidative stress, but the herbicide did increase triglycerides and cholesterol (Wilkens et al 2019). DNA damage occurred in toad tadpoles (*Rhinella arenarum*) exposed to 5 % and 10% of the 96-hour LC50 concentration of a glyphosate-based herbicide (Carvalho et al. 2019). However, it is important to consider that even the low concentration of 5% of 78.18 mg/L used in this study exceeds glyphosate concentrations realistically found in the environment by several orders of magnitude. In a separate study, Lajmanovich et al. (2019) found that following 22 days of exposure to 1.25 mg/L of Roundup DNA damage was not induced. Collectively these studies provide undisputable evidence that environmentally relevant concentrations of glyphosate are not lethal amphibians. In some cases, the studies that evaluated sub lethal effects of glyphosate produced contradictory results. This suggests that more research is needed to better understand how field applications of glyphosate impact amphibian physiology and growth and whether or not these sublethal effects result in population level impacts (i.e. influence birth or death rates).

2.1.2.2a Terrestrial Invertebrates

Invertebrates play dominant roles in nearly all terrestrial ecosystems. Invertebrates provide crucial ecosystem services such as pollination, herbivory, decomposition, and nutrient cycling. Invertebrates are an essential part of the diet of many organisms. Insect abundance and diversity are declining globally and it is important to understand what role, if any, glyphosate application is playing in this decline. In 2019, 7 studies were published that examined the effects of glyphosate on the health, behavior and food web dynamics of terrestrial invertebrates (Crone et al 2019, Galin et al 2019, Hanger et al 2019, Marqus et al 2019, Niedobova et al 2019, Pochron et al 2019, Talyn et al 2019).

Crone et al. (2019) found that Western monarch butterfly (*Danaus plexippus plexippus*) abundance was negatively correlated with coastal development, glyphosate use, neonicotinoid use, breeding season temperature and breeding season drought. Trends in statewide glyphosate use and coastal development are so highly correlated ($r = 0.91$) that they were effectively substitutable in the models. This collinearity makes teasing apart the effects of development and glyphosate use impossible. The authors concluded that more experimental research is needed to understand the relationship between glyphosate use and monarch abundance.

Fruit flies (*Drosophila melanogaster*) fed glyphosate at the manufacturers recommended rate (2.8 mg/ml) had reduced fertility and lifespan (Galin et al. 2019). In another study, Talyn et al. (2019) found that there was no difference in life span or reproductive behavior of fruit flies that were fed organic corn, non-GMO corn, GMO Roundup resistant corn, and GMO Roundup resistant corn that had been sprayed with Roundup. They also determined that the Roundup LC_{50} for male fruit flies was 7.1 and 11.4 g/L for females and that the concentrations of glyphosate residues that they detected in the glyphosate treated corn was seven orders of magnitude lower than the LC_{50} for male fruit flies. Hagner et al (2019) hypothesized that in northern latitudes the potential effects of glyphosate-based herbicides on non-target soil organisms could be larger than at lower latitudes because of the shorter growing season. With decreased time to degrade glyphosate, the herbicide could potentially have stronger impacts on soil organisms. They compared the effects of 3 management approaches to treating weeds and found that killing plants by hoeing had much larger effects on soil fauna than glyphosate did. The effects of glyphosate were minor and transient and no glyphosate remains were found in the soil at the end of the experiment. This is the kind of study that is really helpful to land managers trying to understand the impacts of herbicide use relative to other potential management actions. Survival of Colorado potato beetle (*Leptinotarsa decemlineata*) larval was not affected by a glyphosate-based herbicide (Roundup), but did inhibit the *Ldace1* gene expression which encodes AChE activity and increased the activity of a biomarker associated with oxidative stress, suggesting that glyphosate increased oxidative stress (Margus et al 2019).

There was one study published in 2019 that described the non-target effects of glyphosate on spider behavior. Niedobova et al 2109 determined that Roundup by itself had no effect on predatory activity of wolf spiders (*Pardosa spp.*).

Studies have found conflicting results regarding the effects of glyphosate-based herbicides on earthworms. There was only one study published in 2019 that evaluated glyphosate impacts on earthworms. Pochron et al. (2019) evaluated how initial earthworm body size and soil temperature influence the effect of Roundup on earthworm growth and survival. They found that in hot soil, large worms exposed to Roundup grew larger than large worms not exposed to Roundup, but that growth of large worms in cold soil was not affected by Roundup. The growth of small worms was not affected by Roundup in either hot or cold soil. This study provides further evidence the relationship between earthworms and glyphosate are highly context dependent.

Collectively the studies published in 2019 suggest that the impacts of glyphosate on terrestrial invertebrates is nuanced and context dependent. For example, fruit flies that were fed glyphosate directly had shorter lifespans and reduced fertility, but that fruit flies that were exposed to plants sprayed with glyphosate were not affected by the herbicide. Earthworms exposed to glyphosate in hot soils had increased growth, whereas in cool soil the glyphosate had no impact on the worms. Glyphosate did not affect predatory behavior of wolf spiders by itself, but did reduce predatory behavior when it was mixed with a surfactant. Glyphosate use on invasive plants in wildlands may have some negative effects on invertebrates, however invasive plants may also impact terrestrial invertebrate abundance and diversity.

2.1.2.2b Bees

Pollinator decline has spurred research on the effects of glyphosate on pollinator health, particularly honeybee health. Since MROSD does not use aircraft or large equipment approaches to apply herbicide and instead uses primarily hand-held backpack sprayers and other methods that allow applicators to place herbicide precisely on target plants, it is highly

unlikely that bees (or other flying insects) will encounter herbicide spray directly. However, bees and other pollinators could be exposed to glyphosate by foraging on treated plants and feeding on nectar or pollen that contains pesticide traces. Bees can then transport contaminated pollen and nectar into hives and expose the brood. There were four papers published in 2019 that evaluated the non-target effects of glyphosate-based herbicides on bees. All four studies found that the herbicides did not have any adverse direct or indirect effects on bee survival following acute or chronic exposure (Blot et al. 2019, Decio et al. 2019, Ulziibayar and Jung 2019). The glyphosate concentrations used in these studies exceeded environmentally relevant concentrations. Ulziibayar and Jung (2019) applied a glyphosate-based herbicide to a native bee at twice the manufacturers recommended rate and it had no effect on bee survival.

Blot et al. (2019) found that fifteen days of chronic glyphosate (or AMPA) exposure did not influence honey bee survival, food consumption, or parasite infection. Glyphosate, but not AMPA, decreased the abundance of two of the dominant taxa in honey bee guts and increased the abundance of *Lactobacillus* spp. Findings from this study are consistent with Motta et al. (2018) and provides compelling evidence that the gut microbiome of honeybees is influenced by glyphosate, but that it is seemingly inconsequential to bee survival. It is well understood that neonicotinoids have detrimental impacts on honeybee health and viability. Decio et al (2019) evaluated whether the combined effects of a neonicotinoid (thiametoxam) and glyphosate were worse than the effects of the neonicotinoid alone. They injected worker bees with the neonicotinoid with and without added glyphosate and measured bee survival and several splicing patterns associated with important genes (*x box*, *elav*, and *dscam*) involved in responding to stress. Neither honeybee survival or gene-splicing patterns were affected by the addition of glyphosate. It should be noted that glyphosate concentrations injected into the honey bees was the highest water-soluble concentration possible (23mM) and it was administered at this rate twice over a 48-hour period. Tome et al. (2019) exposed honeybees to a glyphosate-based herbicide during the entire larval feeding period with an artificial diet containing glyphosate at worse-case environmental concentrations previously recorded in

pollen or wax obtained from managed honey bee colonies. Glyphosate had no effect on larvae survival, pupae survival, development time, body mass or hypopharyngeal or antenna morphology. Adult honey bees did not up or down regulate any of the 8 measured detoxification genes. Bee larva downregulated one of the 8 genes.

None of the studies published in 2019 found any evidence that glyphosate has negative impacts in bee survival, development, stress, morphology, or nutrition.

2.1.2.3 Aquatic Invertebrates

Aquatic invertebrates could potentially be more vulnerable to pesticides than terrestrial invertebrates since pesticides can collect and concentrate in waterways. In 2019, only four studies were published that evaluated non-target effects of glyphosate on aquatic invertebrates (Canosa et al. 2019, de Melo et al. 2109, Marineau et al. 2019, Pala et al. 2019). Marinaeu et al (2019) found no difference in invertebrate abundance or diversity in the San Joaquin River Delta pre and one-month post glyphosate applications used to control water hyacinth. The authors conclude that current glyphosate treatments used to control water hyacinth poses minimal risk to aquatic invertebrates. de Melo et al (2019) found that gene expression and the production of a hormone involved in crustacean molting were unaffected by glyphosate in female shrimp, but that the male shrimp upregulated the molting genes after 7 hours of exposure to an intermediate glyphosate concentration, but not at higher or lower concentrations. The lack of a dose response pattern in males makes it difficult to infer implications, but suggests that negative result is spurious. One of the studies published in 2019 found that glyphosate can inhibit the nervous system and cause oxidative stress to *Gammarus pulex*, a freshwater amphipod (Pala et al. 2019), and another study found that the estuarine crab (*Neohelice granulata*) exposed to pure glyposate and a Roundup formulation for 30 days had reduced size and less muscle protein, and that Roundup, but not pure glyphosate, reduced spem count and inhibited the secreation of hormone from the the androgenic glad (Canosa et al 2019).

Together the studies published in 2019 provide further evidence that glyphosate can have sublethal non-target effects on aquatic invertebrates. Based on these findings, glyphosate applications near waterways should be used cautiously and sparingly. As always, land managers must carefully weigh the potential costs to invertebrates against the known benefits of using glyphosate for invasive weed management. More studies that compare the impacts of herbicides to other management options are desperately needed to properly understand how wildland applications of glyphosate impact invertebrates and other non-target organisms. Until such studies exist, land managers are forced to extrapolate from laboratory or mesocosm studies with complex findings and questionable relevance to their specific application.

2.1.2.4 Reptiles

In 2019, only one paper was published concerning impacts of glyphosate on reptiles. Lus Hirano et al (2019) studied the effects of chronic exposure to 65 and 6500 ug/L of glyphosate on the bones and cartilage of turtle (*Podocnemis unifilis*) embryos and found that chronic glyphosate had no influence on the frequency or severity of bone or cartilage malformations or other skeletal abnormalities.

2.1.2.5 Birds

Two studies were published in 2019 that considered the non-target effects of glyphosate on birds. Fathi et al (2019) demonstrated that injecting eggs with glyphosate at a rate of 10 mg/Kg reduced the proportion of eggs that hatched by 66% and that the livers and kidney were enlarged in surviving chicks. This paper is not particularly relevant to wildland weed managers because it is not clear that bird chicks inside eggs would have any exposure to glyphosate in an invasive species control context. Rivers et al. (2019) used a large-scale field experiment to test how nest and post-fledging survival of white-crowned sparrows (*Zonotrichia leucophrys*) were influenced by herbicide intensity within managed conifer plantations across 2 breeding seasons. They found no evidence that either daily nest survival or post fledgling survival were influenced by light, moderate, or intensive use of glyphosate applied to forestry plantations. This paper has direct utility for land managers because it measured herbicide impacts following realistic

concentrations in natural settings and because the researchers measured vital rates that ultimately contribute to population level persistence.

2.1.2.6 Soil Microbes

The effect of glyphosate on soil microbial communities can depend upon on many different factors including the concentration and formulation of glyphosate, soil pH, organic matter content, and exposure time (Nguyen et al. 2016, Nguyen et al. 2018). Soil microbes can be exposed to glyphosate residues if spray is not intercepted by target plants or if rain rinses it off plants. Because MROSD does not apply glyphosate with large equipment or by aerial spray, and instead uses backpack sprayers and other methods that apply the herbicide directly onto the target plants it is very unlikely that glyphosate will be applied directly onto the soil. Since herbicides are not used when rain is forecasted at MROSD, it is unlikely to be rinsed from plants into the soil.

In 2019, four papers were published that evaluated the effects of glyphosate on soil microbial communities. Bruckner et al (2019) grew white clover (*Trifolium repens*) in pots with arbuscular mycorrhizal fungi. The clovers were sprayed with glyphosate and after two weeks microbial respiration increased by 30%, and there was a small shift in microbial community composition, with a decrease in the abundance of bacteria, and no effect on the abundance of mycorrhizal fungi. Unfortunately, this experiment did not include a treatment where the plants were killed by cutting without Roundup. It is not possible to distinguish between the effects of Roundup per se and plant/root death. We can however conclude from this study that glyphosate did not have any negative effects on mycorrhizal fungi. Farthing et al. (2019) compared the effects of different Bermuda grass (*Cynodon dactylon*) removal in grassland restoration projects. They determined that repeated glyphosate applications did not affect the species richness or diversity of the soil microbial communities. In another study, Gu et al. (2019) found that controlling weeds with Roundup reduced the total biomass of soil bacteria, fungi, and actinomycetes more than tilling or the untreated control treatments. Suleman et al. (2019) compared the abundance of 7 polar membrane lipids found in soil spiked with glyphosate. The

lipids are proxies for microbial diversity. They found that of the 7 lipids identified in the soils, glyphosate applied at the maximum rate (1.25 kg/ha) decreased the concentration of 2 lipids, increased the concentration of 1 lipid, had no effect of 4 lipids. The lipid that was found in the highest abundance in the soil following the herbicide application was associated with fungi. It is unclear from these studies how shifts in the abundance and diversity soil microbes influences soil processes (e.g. decomposition rates, fertility, etc) or aboveground plant dynamics.

2.1.3 MANAGEMENT IMPLICATIONS

There is a rich body of literature dating back over 60 years that provides ample evidence that invasive species reduce biodiversity and alter ecosystem processes (Elton 1958, Richardson and Pysek 2008). Public agencies, such as MROSD are tasked with protecting biodiversity and preserving ecosystem integrity and the management of invasive species is a critical part of this responsibility. Controlling invasive species is extremely challenging and often times removal efforts are ineffective (Kettenring and Adams 2011). Controlling plants with herbicide is generally more effective than other approaches (Kettenring and Adams 2011). Given that there is far more information available on the non-target risks associated with glyphosate than any other herbicide, and that the risks appear to be quite minimal, using glyphosate over other herbicides is the safest option.

In agriculture, the intensity and frequency of glyphosate far exceeds its use in natural areas. In agriculture settings, pesticides, including glyphosate-based herbicides, can be applied to the same area, multiple times a year, and with mechanical equipment that cannot discriminate between target and non-target surfaces. These applications methods can result in a significant amount of spillover into the environment. Herbicide application techniques used by MROSD apply chemicals directly onto target plants and largely avoid spillover into the environment thus avoiding impacts to the non-target species that occur in these areas.

To date, the evidence clearly demonstrates that glyphosate is both highly effective at controlling invasive plants and that even the worst case environmentally relevant concentrations are not lethal to most animals that could inadvertently be exposed to the herbicide. Almost all of the studies published in 2019 that evaluated sublethal effects of glyphosate dosed animals with concentrations that far exceed what organisms are likely to encounter in even the worst-case scenarios that could occur in field situations. The numerous studies summarized in the MROSD reports suggest that sublethal impacts can sometimes occur. The non-lethal effect of glyphosate published in 2019 include changes to growth and development rates, behavior, and physiology. However, none of the studies further demonstrated that these sub-lethal effects resulted in population level consequences. These studies also do not evaluate how the sub-lethal effects recover over time following glyphosate exposure. Upon evaluation of the studies published in 2019 that evaluated non-target impacts of glyphosate, I see no compelling evidence that the use of glyphosate in natural areas poses substantial risk to the viability of non-target organisms. To date research suggests that the presence and spread of invasive species pose far greater risk to the conservation of biodiversity in natural areas than judicious use of glyphosate.

2.2 IMAZAPYR

No studies were published in 2019 that describe human health risks or the environmental fate of imazapyr. Two studies described non-target effects of imazapyr use on soil microbial processes and non-target plants (McCaskill et al. 2019 and Rohal et al. 2019). McCaskill et al. (2019) compared the effects of imazapyr (applied at a rate of .21 kg/ha) on soil nitrogen mineralization, soil microbial biomass, and the survival and growth of long leaf pine. Imazapyr was the only treatment that improved long leaf pine growth following a single application. One application of imazapyr increased nitrogen mineralization rates, and ammonification, but had no effect on microbial biomass. In another study, Rohal et al. (2019) expected native plant recovery to be less successful following imazapyr applications used to control phragmites than glyphosate applications because imazapyr has a longer half life than glyphosate and is purported to be able to persist longer in the soil. Contrary to their predictions, imazapyr did not

restrict native plant recruit more than glyphosate. The authors speculate that this may be because the persistence of imazapyr in the anerobic soil conditions associated with wetlands is lower than in aerobicoic soil. There were five studies published in 2019 that describe the efficacy of imazapyr use to control invasive plants (Annen et al. 2019, Berrill and Howe 2019, Goodall and Braack 2019, Murray et al. 2019, Rohal et al. 2019) and are described in the annotated bibliography (Appendix1).

2.3 AMINOPYRALID

No studies were published in 2019 that describe human health risks, ecological effects, or the environmental fate of aminopyralid. One study was published in 2019 that describes the efficacy of aminopyralid use to control an invasive plant (Dias et al 2019) and is described in the annotated bibliography (Appendix1) .

2.4 CLOPYRALID

MacDonald et al. 2019 used a myriad of restoration approaches to increase cover of native forbs and grass in an area dominated by *Centaurea stoebe* (spotted knapweed). To remove *C. stoebe* prior to seeding with native forbs MacDonald et al sprayed the sites with 1) clopyralid or 2) glyphosate, or 3) mowed the sites. They found that clopyralid treated plots, and mowed plots had fewer native species than plots that were treatend with glyphosate.

2.5 TRICLOPYR

No studies were published in 2019 that describe human health risks or ecological effects of triclopyr. Only one study evaluated the environmental fate triclopyr in the environment. There were 4 studies published in 2019 that described triclopyr efficacy (Appendix 1).

To understand how agricultural applications of pesticides, including triclopyr, persit in estuaries Rodrigues et al. (2019) sampled surface water and sediments within an estuary in Portugal before and after the pesticides were applied to crops. Triclopyr was not found in concentrations

that exceed the European Union's acceptable limits in either the water or sediment samples. The authors conclude that the agricultural pesticides used in the region, including tricolpyr pose minimal risk to aquatic organism that occur in the studied estuary.

2.6 CLETHODIUM

3.0 ADJUVANTS/SURFACTANTS: Alcohol ethoxylate, Alkylphenol ethoxylate, Lecithin, and Canola oil: ethyl & methyl esters

No studies were published in 2019 that describe human health risks, ecological effects, or the environmental fate of the adjuvants and surfactants used by MROSD.

4.0 FUNGICIDE

4.1 PHOSPHITE K

No studies were published in 2019 that describe human health risks, ecological effects, or the environmental fate of the fungicide Phosphite K.

5.0 INSECTICIDES

5.1 DIATOMACEOUS EARTH

No studies were published in 2019 that describe human health risks, ecological effects, or the environmental fate of the diatomaceous earth used as an insecticide.

5.2 D-TRANS ALLETHRIN

No studies were published in 2019 that describe human health risks, ecological effects, or the environmental fate of the D-trans allethrin used as an insecticide.

5.3 FIPRONIL

Fipronil is a broad-spectrum phenylpyrazole insecticide that blocks gamma-amino butyric acid (GABA) receptors in the central nervous system of insects, leading to hyper-excitation and

death. At MROSD fipronil is the active ingredient in Maxforce bait stations to control Argentine ants. MROSD only uses fipronil indoors, so exposure risks to non-target plants and animals is negligible. The research findings summarized in this report include studies that evaluate risk and best practices associated with bait station applications of fipronil. Fipronil bait stations are secure pesticide reservoirs that are placed where termites, roaches, or ants occur in or around structures. Currently PPE is not required during bait station application of fipronil. The potential handler and post-application exposure scenarios are minimal because of the low vapor pressure of fipronil, small treatment areas, and low application rates.

5.3.1 Human Exposure and Health Risks

In 2019, one study evaluated human exposure risk associated with fipronil. Harley et al. (2019) assessed weekly pesticide exposure in 14-16 year old latina girls that live in the Salinas Valley, an agricultural region of California. The study participants wore silicon wrist bands for a week that were analyzed for pesticide concentrations. Fipronil was detected on 87% of the wrist bands and was the most frequently detected pesticide. In California, fipronil is not used in agriculture and is only used for treating termites, roaches, and ants in and around buildings, or to treat fleas and ticks on dogs and cats. The authors do not address what pathway the study participants were exposed to fipronil, but did find that living within 100 m of active agricultural fields, having carpeting in the home, and having an exterminator treat the home in the past six months were associated with higher odds of detecting certain pesticides.

No papers were published in 2019 that described the human health risks of fipronil.

5.3.2 Non-Target Effects

Pandit et al. (2019) used a microarray and qPCR approach to evaluate the effects of fipronil on the transcriptome profile associated with the lungs of mice that were fed 1/10th and 1/20th of the LC50 for 90 days. They concluded that these concentrations of fipronil can alter the transcriptome profile of lungs and potentially cause damage through the production of cytokines

that cause lung inflammation. Seydi et al. (2019) found that fipronil increased mitochondrial oxidative stress (increased production of ROS and LPO, mitochondrial swelling, and cytochrome C release) following apoptosis signaling. These impacts on mitochondria likely have hazardous effects on heart tissues. Testa et al. (2019) compared the amount fipronil in dust within homes with and without pets. They found that fipronil dust contamination in the presence of pets was far higher than in homes without pets. The amount of fipronil found in homes with and without pets never exceeded the concentrations considered hazardous by the US (EPA) or EU(ECHA) regulatory agencies. These papers are not directly relevant to MROSD because they do not assess the effects of fipronil bait stations used in and near to structures.

5.3.3 Environmental Fate

In 2019, 13 studies were published that evaluate effects of fipronil on non-target animals and X studies that describe the persistence and fate of fipronil in the environment. However, all of these studies evaluated intensive use of fipronil in agricultural and residential applications. None of these studies describe the fate of fipronil entering or persisting in the environment through the use of indoor bait traps and are therefore not described here.

5.4 INDOXACARB

Indoxacarb is the active ingredient in Avion gel bait traps used to control cockroaches and ants indoors. It blocks sodium channels and impairs the nervous system and causes paralysis and then death.

5.4.1 Human Health Risks

In 2019, one study evaluated human exposure risk associated with indoor use of indoxacarb bait traps. Wang et al (2019) measured residues of indoxocarb on kithchen and bedrooms floors of 69 low income apartments in New Jersey that used Advion indoxacarb bait traps and insect sticky traps to treat german cockroaches. In each apartment 18 g of gel bait (with 0.6% indoxacarb) was applied every two weeks for as long as cockroaches were still present. Twelve months following the onset of the study indoxacarb was detectable in only 2 out of 69 apartments.

No papers were published in 2019 that described the human health risks of indoxacarb.

5.4.2 Non-Target Effects

Like fipronil, indoxacarb bait traps are only used by MROSD to control ants or cockroaches inside buildings. The Advion bait traps used by MROSD contain 0.5 g of a formulation that contains 0.6% of the insecticide and they are generally placed strategically >10 feet apart, so the potential for exposure of non-target organisms is negligible. No studies were published in 2019 that evaluated the effects of indoxacarb on non-target organisms when indoxacarb is used in bait traps to control indoor pests. The European Food Safety Authority published a risk assessment that concluded that indoxacarb when used to control pests in corn crops posed high risk to small herbivorous after a single application and to earthworm eating mammals following repeated applications. They also concluded that adult honeybees and bumble bees are at high risk of being poisoned if indoxacarb is applied to the crops prior to or during the flowering period, but not if applied after the flower period (Vernis et al. 2019).

5.5 PHENOTHRIN

No studies published in 2019 described the human health risks, ecological effects, or the environmental fate of phenothrin.

5.6 PRALLETHRIN

No studies published in 2019 described the human health risks, ecological effects, or the environmental fate of prallethrin.

5.7 S-HYDROPRENE

No studies published in 2019 described the human health risks, ecological effects, or the environmental fate of S-Hydroprene.

5.8 SODIUM TETRABORATE DECAHYDRATE

No studies were published in 2019 that describe human health risks, ecological effects, or the environmental fate of sodium tetraborate decahydrate.

6.0 RODENTICIDES

6.1 CHOLECALCIFEROL

No studies were published in 2019 that describe human health risks, ecological effects, or the environmental fate of cholecalciferol when it is used as a rodenticide.

Table 1: Summary of non-target effects of glyphosate published in 2019

Organism	Findings published in 2019	Reference
AMPHIBIANS		
<i>Frog (Xenopus laevis)</i>	The LC50 value of Roundup original for frog embryos exceeded concentrations found in some aquatic environments following treatment of aquatic plants. LC50 values of Kilo max and Enviro glyphosate did not exceed these environmental concentrations.	<i>Babalola et al. 2019</i>
<i>Toad (Anura bufonidae)</i>	The DNA of toad tadpoles that were exposed to 5% and 10% of the 96-hour LC50 concentration of glyphosate had altered DNA migration across an electrophoresis gel. DNA migration was a proxy for DNA damage. Even the low concentration of 5% of 78.18 mg/L used in this study exceeds glyphosate concentrations realistically found in the environment.	<i>Carvalho et al. 2019</i>
	Amphibians were less sensitive than fish to glyphosate toxicity and that the standard fish test species rainbow trout (<i>Oncorhynchus mykiss</i>) was more sensitive than the most sensitive amphibian test species.	<i>Daam et al. 2019</i>
<i>Gulf coast toad (Incilius nebulifer)</i>	Roundup did not elicit a hormone (corticosterone) response, alter tail morphology, or change behavior in response to the predator cues of Gulf Coast toad tadpoles.	<i>Gabor et al. 2019</i>
<i>American toad (Rhinella arenarum)</i>	Chronic exposure to Roundup did not affect Acetylcholinesterase (AChE), CbE, and GST activity in American toad tadpoles while acute exposure to 10 mg/L of Roundup increased AChE activity. Roundup had no effect on thyroid hormone levels in either the acute or chronic study. Roundup did not induce DNA damage or alter red blood cells.	<i>Lajmanovich et al. 2019</i>
<i>Bullfrog (Rana catesbeiana)</i>	A glyphosate-based herbicide had no effect on nutritional condition, plasma protein, glucose, or uric acid levels in bullfrog tadpoles. Triglycerides and cholesterol increased following herbicide exposure. In amphibians, corticosterone regulates the metamorphosis induction. Following exposure to glyphosate bullfrog corticosterone production was reduced. Four biomarkers were used to assess oxidative stress (SOD, CAT, TABRS and GST). Of these, only GST was affected by glyphosate.	<i>Wilkins et al. 2019</i>
FISH		
<i>Cnesterodon decemmaculatus</i>	Glyphosate had no effect on fish mortality. AChE was inhibited by exposure to 1 and 10 mg/l of glyphosate in all 4 seasons.	<i>Bernal-Rey et al. 2019</i>
<i>Cnesterodon decemmaculatus</i>	A glyphosate-based herbicide applied at rate of 0.2 and 2 mg/L for 42-days had no effect on genotoxicity or liver histology	<i>Bonifacio et al. 2019</i>
<i>Zebrafish</i>	Glyphosate had no effect on the time it took zebrafish to move into the top part of the tank, the frequency of crossing the tank,	<i>Chaulet et al. 2019</i>

Organism	Findings published in 2019	Reference
	or the total distance traveled, but it did cause the fish to rotate more frequently and to spend more time at the top of the tank. Implications from this study are that fish could be more vulnerable to predators if they are spending more time nearer to the surface.	
<i>Amur sleeper fish</i> (<i>Perccottus glenii</i>)	30-days of exposure to 2 ug/L Roundup reduced amolytic activity and water soluble protein content, but had no effect on body size, maltase, or AchE activity in Amur sleeper fish.	<i>Golovanova et al. 2019</i>
<i>Rainbow trout</i> (<i>Oncorhynchus mykiss</i>)	28 days of exposure to 1/5 or 1/10 of the LC50 concentration of Roundup decreased cerebral AChE activity and liver catalase activities.	<i>Meshkini et al. 2019</i>
	Physiological response of fish species to a glyphosate-based herbicide are different in lab and field conditoins and the physiological response of the fish varied between species. The findings collectively suggest that interpretation of lab studies may not be indicidive of risk in real world exposure sceanrios.	<i>Samanta et al. 2019</i>
REPTILES		
<i>Turtle</i> (<i>Podocnemis unifilis</i>)	Neither 65 and 6500 ug/L of glyphosate influenced the presence or severity of bone or catildege malofmations or any other skeletal abnormalities.	<i>Lus Hirano et al. 2019</i>
BIRDS		
<i>White-crowned Sparrow</i> (<i>Zonotrichia leucophrys</i>)	No evidence that either daily nest survival or post-fledging survival were influenced by herbicide application intensity.	<i>Rivers et al. 2019</i>
MAMMALS		
<i>Cow</i>	Even the highest concentrations glyphosate (10 mg/L) had no effect on the abundance of either <i>E. coli</i> or <i>Salmonella</i> in cow guts.	<i>Bote et al. 2019</i>
TERRESTRIAL INVERTABRATES		
<i>Honey bee</i> (<i>Apis mellifera</i>)	Neither glyphosate or AMPA had any effect on honey bee survival, food consumption, or <i>Nosema ceranae</i> parasite infection. Glyphosate, but not AMPA, decreased the abundance	<i>Blot et al. 2019</i>

Organism	Findings published in 2019	Reference
	of two of the dominant taxa in honey bee guts and increased the abundance of <i>Lactobacillus</i> spp.	
<i>Honey bee</i> (<i>Apis mellifera</i>)	Neither honey bee survival or gene-splicing patterns were affected by glyphosate injections. It should be noted that glyphosate concentrations injected into the honey bees was the highest water-soluble concentration possible (23mM) and it was administered at this rate twice over a 48-hour period.	<i>Decio et al. 2019</i>
<i>Honey bee</i> (<i>Apis mellifera</i>)	Glyphosate had no effect on larvae survival, pupae survival, development time, body mass or hypopharyngeal or antenna morphology. Adult honey bees did not up or down regulate any of the 8 measured detoxification genes. Bee larva downregulated one of the 8 genes	<i>Tome et al. 2019</i>
<i>Bee</i> (<i>Melipona scutellaris</i>)	Exposure to topically and orally applied glyphosate at half, twice, or the recommended dose, had no impact on bee survival.	<i>Uliziibayer and Jung 2019</i>
<i>Fruit fly</i> (<i>Drosophila melanogaster</i>)	The highest concentration (2.8 mg/ml) of glyphosate tested reduced the lifespan of male flies and the number of pupae and imago in the progeny, while the concentrations of 0.028 and 0.28 mg/ml produced no adverse effects. It should be notes that the highest concentration used in this study was the manufacturers recommended concentration for use in the environment.	<i>Galín et al. 2019</i>
	Removing invasive plants by hoeing had much larger effects on soil fauna than glyphosate did. The effects of glyphosate were minor and transient and no glyphosate remains were found in the soil at the end of the experiment.	<i>Hagner et al. 2019</i>
<i>Pardosa spider</i> (<i>Pardosa</i> spp.)	Roundup had no effect on spider behavior	<i>Niedobova et al. 2019</i>
<i>Earthworm</i> (<i>Eisenia fetida</i>)	In hot soil, large worms exposed to Roundup grew larger than large worm controls, but that growth of large worms in cold soil was not affected by Roundup. The growth of small worms was not affected by Roundup in either hot or cold soil. Worms in cold soil that were exposed to Roundup had lower survival than controls, but Roundup had no effect in hot soil.	<i>Pochron et al. 2019</i>
<i>Fruit flies</i> (<i>Drosophila melanogaster</i>)	There was no difference in life span or reproductive behavior of fruit flies that were fed organic corn, non-GMO corn, GMO Roundup resistant corn, and GMO Roundup resistant corn that was sprayed with Roundup. The concentrations of glyphosate residues that they detected in the glyphosate treated corn was seven orders of magnitude lower than the LC ₅₀ for male fruit flies.	<i>Talyn et al. 2019</i>

Organism	Findings published in 2019	Reference
AQUATIC INVERTEBRATES		
<i>Estuarine crab (Neohelice granulata)</i>	Exposed to Roundup and pure glyphosate for 30 days resulted in smaller crabs compared to a control group. These crabs had less muscle protein. Roundup, but not pure glyphosate, reduced sperm count and inhibited the secretion of hormone from the the androgenic gland.	<i>Canosa et al. 2019</i>
<i>Shrimp (Macrobrachium potiuna)</i>	Male shrimp upregulated EcR genes after 7 hours of exposure to the 0.65 mg/L dose, but not the higher or lower herbicide concentrations. The lack of a dose response pattern makes it difficult to infer implications. Expression of the EcR gene in females was unaffected by glyphosate following 7 and 14 days of exposure. Vt transcription was upregulated in males following 14 days of glyphosate exposure of the intermediate concentration, but not with lower or higher herbicide concentrations. There was no effect of glyphosate-herbicide exposure on Vg expression of female shrimp. MIH also increased following 7-day glyphosate exposure for the intermediate concentration, but not the higher concentration, and not following 14-days of exposure.	<i>De Melo et al. 2019</i>
	There was no difference in invertebrate abundance or diversity pre and one-month post glyphosate applications.	<i>Marinaeu et al. 2019</i>
<i>Amphipod (Gammarus pulex)</i>	AChE activity in the freshwater amphipod was inhibited by 23% to 53% and oxidative stress increased when exposed to 10-40 ug/L of a glyphosate-based herbicide.	<i>Pala et al. 2019</i>
SOIL MICROBES	Glyphosate was applied to the plants and after two weeks microbial respiration increased by 30%. Glyphosate had a small effect on microbial community composition, decreased bacteria, and had no effect on mycorrhizal fungi. It is not possible to distinguish between the effects of Roundup per se and root death. Glyphosate and AMPA were detected in soil leachate, even though it had only been applied to the plants. This suggests that glyphosate entered the soil via the plants.	<i>Bruckner et al. 2019</i>
	Repeated glyphosate treatments had no effect on soil bacteria or archaea species richness or diversity.	<i>Farthing et al. 2019</i>
	Glyphosate applied at the maximum rate (1.25 kg/ha) decreased the concentration of 2 lipids, increased the concentration of 1 lipid, and had no effect of 4 of the lipids. The lipid that was found in the highest abundance in the soils is associated with fungi and algae and it decreased by a 10% as a result of the glyphosate addition.	<i>Suleman et al. 2019</i>

Organism	Findings published in 2019	Reference
AQUATIC MICROORGANISMS	Following s glyphosate addition to brackish water microbial cell counts initially increased and the then decreased as the glyphosate was consumed by the microbes. After 71 days glyphosate was reduced by 99%. Glyphosate temporality increased the diversity and richness of the plankton and did not influence the diversity or richness of the biofilm.	<i>Janssen et al. 2019</i>
	At extremely high concentrations glyphosate inhibited growth of 2 plankton species and increased growth of the other. At environmentally relevant concentrations glyphosate had no effect on phytoplankton or cyanobacteria growth. Of the 3 herbicides tested, glyphosate was the least toxic.	<i>Lam et al. 2019</i>
PLANTS	Low concentrations glyphosate had no effect on the growth of a non-target plant (<i>Urochloa decumbens</i>), but that high glyphosate concentrations (>11 g/ha) decreased plant growth.	<i>de Moraes et al. 2019</i>
	Glyphosate reduced native plant biomass by 64-100%. Season of application did not influence the extent that the herbicides reduced native plant biomass.	<i>Enloe et al. 2019</i>
	Crop yield was unaffected by glyphosate or Roundup applications. In the greenhouse, oats germinated faster in the control soil than in the herbicide treated soils. Oat plants in the Roundup treated soil were smaller than plants in the untreated soil, but not the glyphosate soil. In the field, oats started out larger in the control, but by the end of the study were the same size in the control and herbicide treated soils. No traces of glyphosate or AMPA were detected in the greenhouse soils.	<i>Helander et al. 2019</i>
	Glyphosate were stored in root structures of perennial plants during dormancy periods and moved up to shoot and fruit portions in years following applications in some species	<i>Wood et al. 2019</i>

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1.0 HERBICIDES**1.1 GLYPHOSATE****HUMAN HEALTH**

Crump, K. 2019. The Potential Effects of Recall Bias and Selection Bias on the Epidemiological Evidence for the Carcinogenicity of Glyphosate. Risk Analysis.

Crump (2019) evaluated the possibility of bias intrinsic to the calculation of odds ratios and relative risk metrics that were reported in the 5 case control studies that have been conducted to assess cancer risk associated with glyphosate. Crump argues that the studies are at risk of recall bias and that two of these studies (Eriksson et al. 2008 and Hardell et al. 2002) are also at risk of selection bias. Crump further argues that these types of biases can make glyphosate appear carcinogenic even if it is not. In case control studies the evidence of glyphosate exposure relies on self reporting from the case and the control subjects. In theory this could result in recall bias because the “cases” are more likely to “search their memories” more carefully to recall exposure scenarios whereas the “controls” may not be as motivated and fastidious at recalling exposure as those with the disease. Selection bias could also be a problem because cases that do not claim exposure to glyphosate will be more likely than similarly unexposed controls to claim exposure to other pesticides. Thus, cases that claim no exposure to glyphosate will be more likely to be excluded from the analysis than controls who claim no glyphosate exposure.

Gao, H., J. Chen, F. Ding, X. Chou, X. Zhang, Y. Wan, J. Hu, and Q. Wu. 2019. Activation of the N-methyl-d-aspartate receptor is involved in glyphosate-induced renal proximal tubule cell apoptosis. Journal of Applied Toxicology 39:1096-1107.

Gao et al. (2019) used a cell culture model and an animal exposure model to evaluate 2 possible pathways that glyphosate could contribute to kidney disease. They investigated the influences of glyphosate on renal proximal tubule cells and the role that N-methyl-D-aspartate receptor (NMDAR) has in the kidney's response to glyphosate exposure. They treated a human renal proximal tubule cell line with glyphosate for 24 hours at concentrations of 0, 20, 40 and 60 μM . In short, glyphosate reduced cell viability and induced apoptosis and oxidative stress in a dose-dependent manner. The mechanism appears to be in part due to the expression of NMDAR1, as well as intracellular Ca^{2+} , and reactive oxygen levels, increased after glyphosate treatment. Blocking NMDAR attenuated glyphosate-induced upregulation of Ca^{2+} and ROS levels as well as apoptosis. Inhibition of Ca^{2+} reduced glyphosate-induced reactive oxygen and apoptosis, and inhibition of ROS alleviated glyphosate-induced apoptosis. In mice exposed to 400 mg/kg glyphosate, the urine low molecular weight protein levels started to increase from day 7. Upregulation of apoptosis and NMDAR1 expression in renal proximal tubule epithelium and an imbalance of oxidant and antioxidative products were observed. These results strongly suggest

that activation of the NMDAR1 pathway, together with its downstream Ca^{2+} and oxidative stress, is involved in glyphosate-induced renal proximal tubule apoptosis.

Gillezeau C, van Gerwen M, Shaffer RM, Rana I, Zhang L, Sheppard L *et al.*, The evidence of human exposure to glyphosate: a review. *Environ Health* 18:2 (2019).

A literature review by Gillezeau et al. (2019) compared urine glyphosate concentrations of occupational glyphosate users to the concentrations found in the general population. On average urinary concentrations of glyphosate in people occupationally exposed varied from 0.26 to 73.5 $\mu\text{g/L}$ and 0.16 to 7.6 $\mu\text{g/L}$ in the general public. The large variability among individuals and across studies could be due to a number of factors including methodological study approaches, time between exposure and urine test, difference in kidney health and metabolisms, amount of PPE used, and intensity of glyphosate exposure. Since these important and confounding variables could not be accounted for in this review it is difficult to say whether or not, or how much more glyphosate enters the bodies of occupational users versus the general public.

Hao, Y., Y. Zhang, H. Ni, J. Gao, Y. Yang, W. Xu, and L. Tao. 2019. Evaluation of the cytotoxic effects of glyphosate herbicides in human liver, lung, and nerve. *Journal of Environmental Science and Health Part B-Pesticides Food Contaminants and Agricultural Wastes* 54:737-744.

In this review paper Hao et al. (2019) examined the toxicity of glyphosate alone and glyphosate-based herbicides on liver, lung, and nerve tissues. The studies included in this review measured in vitro toxicity on human cell lines. They conclude that the toxic effects of glyphosate-based herbicides are primarily due to the use of formulants and that glyphosate salts alone are relatively safe.

Leon, M. E., L. H. Schinasi, P. Lebailly, L. E. B. Freeman, K.-C. Nordby, G. Ferro, A. Monnereau, M. Brouwer, S. Tual, I. Baldi, K. Kjaerheim, J. N. Hofmann, P. Kristensen, S. Koutros, K. Straif, H. Kromhout, and J. Schuz. 2019. Pesticide use and risk of non-Hodgkin lymphoid malignancies in agricultural cohorts from France, Norway and the USA: a pooled analysis from the AGRICOH consortium. *International Journal of Epidemiology* 48:1519-1535.

In this important paper, Leon et al. (2019) pooled cohort data from 3 large studies in the USA, France, and Norway to generate relative risk ratios in order to provide further insights into the relationship between non-Hodgkin's lymphoma and pesticide use by agricultural workers. This study was funded in part by the International Agency for Research on Cancer (IARC). Relative risk values greater than 1 with confidence intervals that do not overlap with 1 indicate that there is an association between non-Hodgkin's lymphoma and glyphosate. Overall, Leon et al did not find an association between having ever been exposed to glyphosate occupationally and risk of non-Hodgkin's lymphoma, that is the relative risk ratio was 0.95 (+/- 0.77.1.18). They further evaluated risk associated with specific subtypes of non-Hodgkin's lymphoma and concluded that there was an elevated risk of diverse large B-cell lymphoma with a relative risk ratio of 1.36 (+/- 1.1-1.85). However, the relative risk overlaps 1, barely, and is therefore difficult

to interpret and requires more data before strong conclusions should be drawn. This is a big study and corroborates some of the findings of Andreotti et al. 2018, that it, overall there is no association between non-Hodgkin's lymphoma and glyphosate exposure. Some of the data in this study is the same data as in the Andreotti et al 2018 study, but with some major differences. Here Leon et al use the data to compare risk between ever exposed and never exposed and Andreotti et al evaluated extent of exposure and related that to risk. The Leon et al 2019 study also included the cases that could not recall the frequency of glyphosate exposure, whereas the Andreotti et al 2018 analysis did not include these cases. The Leon et al analysis also included a few additional years of data.

Martinez, A., and A. J. Al-Ahmad. 2019. Effects of glyphosate and aminomethylphosphonic acid on an isogenic model of the human blood-brain barrier. *Toxicology Letters* 304:39-49.

Martinez et al. (2019) investigated the effect of acute exposure to concentrations ranging from 0.1 μM to 1000 μM of glyphosate on the blood-brain barrier. The short hand description of the methods described in this paper are beyond my capabilities to understand. In short, Martinez et al all used an in vitro approach to manipulate pluripotent stem cells to evaluate how oral exposure to glyphosate, AMPA, and glycine influenced factors that could lead to blood brain barrier permeability. Although not statistically significant the authors found an increase in blood brain barrier permeability at very high (100 and 1000 μM) concentrations. They further concluded that glyphosate may increase blood brain permeability by the disrupting tight junctions. The authors did not address how realistic glyphosate exposure levels could influence blood brain barrier permeability.

Mendler, A., F. Geier, S.-B. Haange, A. Pierzchalski, J. L. Krause, I. Nijenhuis, J. Froment, N. Jehmlich, U. Berger, G. Ackermann, U. Rolle-Kampczyk, M. von Bergen, and G. Herberth. 2020. Mucosal-associated invariant T-Cell (MAIT) activation is altered by chlorpyrifos- and glyphosate-treated commensal gut bacteria. *Journal of Immunotoxicology* 17:10-20.

Mendler et al. (2019) investigated the effects of glyphosate on the ability for the 3 common bacteria species found in the human guts to produce vitamins (folate (b2) and riboflavin (B9)) and mucosal-associated invariant T-cells (MAIT). Gut microbiota are an important source of vitamins and humans cannot synthesize folate and riboflavin. MAIT cells produce pro-inflammatory cytokines and proteins. They found that when exposed to glyphosate, 2 out of the 3 bacteria species had increased production of MAIT, but that vitamin production was not influenced by glyphosate.

Perry, M. J., D. Mandrioli, F. Belpoggi, F. Manservigi, S. Panzacchi, and C. Irwin. 2019. Historical evidence of glyphosate exposure from a US agricultural cohort. *Environmental Health* 18.

In a letter to the editor, Perry et al (2019) reported data from a repository of frozen urine samples collected from United States farmers in 1997–98 in response to the recent review by Gillezeau et al (2019) published in *Environmental Health*. Of 18 glyphosate applicator samples

tested, 39% showed detectable levels of glyphosate (mean concentration 4.04 µg/kg; range:1.3–12) compared to 0% detections among 17 non-glyphosate applicator samples (p-value < 0.01). Concentrations of glyphosate were consistent with levels reported in the prior occupational biomonitoring studies reviewed by Gillezeau et al. Accurately detecting glyphosate in this small sample of Wisconsin farmers demonstrates that glyphosate exposures among farmers were occurring 20 years ago, which was prior to the widespread planting of genetically engineered glyphosate tolerant crops first approved in 1996.

Richardson, J. R., V. Fitsanakis, R. H. S. Westerink, and A. G. Kanthasamy. 2019. Neurotoxicity of pesticides. *Acta Neuropathologica* 138:343-362.

Richardson et al. (2019) reviewed the literature and synthesized the studies that have evaluated the relationship between glyphosate (or the commercial formulations) exposure and neurotoxicity. The authors state that “While some research suggests that glyphosate inhibits AChE, the IC₅₀ in human serum was calculated to be 714 mM, which is much higher than blood concentrations associated with indirect exposures (< 0.05 mM) or acute poisoning (0.05–5.0 mM). As such, this seems unlikely to be a mechanism of neurotoxicity. In terms of neuropathology, dopaminergic and γ-aminobutyric acidergic neurons preferentially undergo neurodegeneration in *C. elegans* treated with commercial glyphosate formulations at concentrations used by pesticide applicators. This neuro degeneration was attributed to mitochondrial inhibition and increased oxidative stress. Other studies demonstrate that zebrafish exposed to glyphosate formulations show abnormal brain development which may be attributable to glutamate excitotoxicity observed in developing rats exposed to glyphosate. More recently, rats treated with a commercial formulation showed increased anxiety and depression that correlated with changes in gut microbiota number and diversity. Since many bacteria also rely on the shikimic acid pathway to produce cyclic amino acids, inhibition of this pathway by glyphosate is hypothesized to decrease tryptophan catabolism. This decrease is potentially important since tryptophan is the precursor for serotonin, which plays an important role in both anxiety and depression. Taken together, these recent studies strongly support further research into the potential neurotoxic effects of glyphosate-based herbicides.”

Smpokou, E.-T., M. Gonzalez-Quiroz, C. Martins, P. Alvito, J. Le Blond, J. Glaser, A. Aragon, C. Wesseling, D. Nitsch, N. Pearce, J. Norman, C. H. Lindh, J. Morton, and B. Caplin. 2019. Environmental exposures in young adults with declining kidney function in a population at risk of Mesoamerican nephropathy. *Occupational and Environmental Medicine* 76:920-926.

Smpokou et al. (2019) used a case control study approach to evaluate relationship between pesticide exposure in sugar cane farmers and Mesoamerican Nephropathy (kidney disease). They measured glyphosate (and other pesticides) in urine samples from 350 men and women between the ages of 18-30 years old, without self-reported kidney disease risk factors. Smpokou conducted kidney function tests over two years and correlated these measures with pesticide concentrations in urine. There was no difference in glyphosate concentrations in urine between the people with declining kidney function and those with stable kidney function. OTA

and CIT were below the limit of detection. Glyphosate urinary concentrations were below the limit of detection (0.1 ng/mL) for the majority of the samples.

Solomon, K. R. 2019. Estimated exposure to glyphosate in humans via environmental, occupational, and dietary pathways: an updated review of the scientific literature. Pest Management Science.

Solomon (2019) is an update on a previous review published in 2016. This is a useful paper to read if you are trying to understand the range of glyphosate concentrations found in the environment and assess exposure risks to the general public, domesticated animals, pets, and most importantly glyphosate applicators. The levels reported in the literature are summarized here are also put into risk context. In all cases, measured and estimated systemic exposures to glyphosate in humans and animals were less than the acceptable daily intakes and the reference doses. Solomon concludes that realistic glyphosate concentrations found in the environment pose minimal risk to people

Szezanowski, F., C. Kleinschnitz, and M. Stettner. 2019. Glyphosate-based herbicide: a risk factor for demyelinating conditions of the peripheral nervous system? Neural Regeneration Research 14:2079-2080.

Szezanowski et al (2019) compared the effects of pure glyphosate and the glyphosate-based formulation Roundup LB plus on myelination and demyelination of neurites that would be associated with the peripheral nervous system. Glyphosate was added to culture medium before and after 10 days of myelination induction. Szezanowski et al found that glyphosate did not impact the neurons even at the highest concentrations. Glyphosate did not interfere with myelination or cause demyelination. However, there was a dose dependent effect of the Roundup LB Plus formulation on both myelination and demyelination and this appeared to be due to impairment of myelin rather than the integrity of the neurons. They conclude that the undisclosed additives in Roundup or likely driving these results.

Trasande, L., S. I. Aldana, H. Trachtman, K. Kannan, D. Morrison, D. A. Christakis, K. Whitlock, M. J. Messito, R. S. Gross, R. Karthikraj, and S. Sathyanarayana. 2020. Glyphosate exposures and kidney injury biomarkers in infants and young children. Environmental Pollution 256.

Trasande et al. (2019) evaluated the relationship between low levels of glyphosate exposure and kidney (renal) disease. They measured concentrations of glyphosate in urine, as well as 3 biomarkers for kidney function in children. They identified glyphosate in urine in 11% of the children that had been exposed to glyphosate. They found no association between glyphosate and kidney function biomarkers.

von Ehrenstein, O. S., C. Ling, X. Cui, M. Cockburn, A. S. Park, F. Yu, J. Wu, and B. Ritz. 2019. Prenatal and infant exposure to ambient pesticides and autism spectrum disorder in children: population based case-control study. Bmj-British Medical Journal 364.

Von Ehrenstein et al. (2019) used a case control study to evaluate risk associated with early developmental exposure to 11 pesticides, including glyphosate, and autism prevalence in California's Central Valley. They used data from California Department of Developmental Service (DDS) to identify the cases of Autism Disorder, the most severe autism spectrum diagnosis. They randomly selected controls from birth records in the region and used a 10:1 control to case ratio. The authors determined exposure based on data from California Pesticide Use Reports. They used GIS to estimate whether pregnant moms and infants were within 2000 or 2500 m from where the pesticides were applied in an agricultural context. Exposure was 'ever exposed' compared to 'never exposed' to the chemicals. Odds ratios and 95% confidence intervals were calculated and used to determine risk. If an odds ratio is greater than one and the confidence interval does not overlap 1 then risk is supported. If the odds ratio is 1 or below then no risk is assumed. The authors concluded that the risk of autism disorder was associated with prenatal exposure to glyphosate (odds ratio 1.16, 95% confidence interval 1.06 to 1.27). However, to understand if glyphosate, per se, is associated with autism the study would ideally identify and evaluate cases that were exposed to glyphosate and not the other 10 chemicals in this study. That can be difficult to impossible to do because rarely are farmers only using 1 pesticide. When the authors attempted to consider the other chemicals statistically the relationship between glyphosate exposure during pregnancy and autism was lost, but was maintained for exposure during the 1st year of life. The authors also found that the association of autism prevalence was greater when the radius around homes was extended from 2 to 2.5Km, but do not examine what the associations were for a smaller radius (e.g. 1km). Exposure should presumably be greater when the distance between homes and where the glyphosate is smaller. Another notable issue with this study is that many important factors are likely to differ between cases and controls. For example, the test group differs from the control group by not only having increased pesticide exposure, but by all the demographic and lifestyle differences that distinguish urban populations from agricultural ones. It is also suspect that the authors find similar risks associated with all the pesticides they evaluated (both herbicides and insecticides) even though these pesticides vary in chemical structure and mode of actions. The methodological flaws in this study are in many ways unavoidable, but they also limit ability to conclusively associate autism with glyphosate exposure.

Zhang, L., I. Rana, R. M. Shaffer, E. Taioli, and L. Sheppard. 2019. Exposure to glyphosate-based herbicides and risk for non-Hodgkin lymphoma: A meta-analysis and supporting evidence. *Mutation Research-Reviews in Mutation Research* 781:186-206.

Zhang et al. (2019) conducted a meta-analysis approach that combined 5 case control studies and the large cohort study to re-evaluate the risk associated with high exposure to glyphosate and non-Hodgkins lymphoma. The analysis teased out just the subjects that had had the highest duration of exposure and the highest intensity of exposure. They found that that risk of non-Hodgkins lymphoma is 41% higher if you are in the highest glyphosate exposure group. Though the Zhang et al finding appears alarming, using just the highest exposure group is a somewhat misleading approach and is evidence of cherry-picking, hunting for an effect, rather than *observing* without bias. Generally, a more robust approach is to look for patterns between

exposure level and disease prevalence, so that you can determine if increased exposure results in increased risk.

NON-TARGET IMPACTS

AMPHIBIANS

Babalola, O. O., J. C. Truter, and J. H. van Wyk. 2019. Mortality, teratogenicity and growth inhibition of three glyphosate formulations using Frog Embryo Teratogenesis Assay-Xenopus. Journal of Applied Toxicology 39:1257-1266.

Babalola et al. (2019) studied the effects of 3 formulations of glyphosate (Roundup original, Kilo max, and Enviro Glyphosate) on frog (*Xenopus laevis*) embryo survival, growth, and malformations. The LC50 of Roundup was 1.05 mg/L, Kilo max was 207 mg/L and Enviro glyphosate was 466 mg/L. Glyphosate concentrations found in aquatic environments following applications on aquatic plants can be as high as 1.43 mg/L. This suggests that Roundup original should not be used in aquatic environments where frog embryos are present. The other two glyphosate formulations are not toxic to the frog embryos. These findings suggests that something other than glyphosate in Roundup may have contributed to the embryo mortality rate. Although Roundup and Kilo max both caused tadpole growth reductions at very high concentrations, they cannot be classified as growth inhibitor. In order to be considered a growth inhibitor, embryo growth would have had to be suppressed at lower concentrations.

Carvalho, W. F., C. R. de Arcaute, J. M. Perez-Iglesias, M. R. R. Laborde, S. Soloneski, and M. L. Larramendy. 2019. DNA damage exerted by mixtures of commercial formulations of glyphosate and imazethapyr herbicides in *Rhinella arenarum* (Anura, Bufonidae) tadpoles. Ecotoxicology 28:367-377.

Carvalho et al.(2019) evaluated the toxicity of Credit, a glyphosate-based herbicide, and Pivot, an imazethapyr-based herbicide on bullfrog (*Anura bufonidae*) tadpoles. The 96-hour LC50 values were 78.18 mg/L and 0.99 mg/L for the glyphosate-based herbicide, and the imazethapyr based herbicide, respectively. Glyphosate was far less toxic than imazethapyr. Toad tadpoles were exposed to 5% and 10% of the 96-hour LC50 concentration of each chemical alone and in combination and changes in DNA migration across a gel (electrophoresis) was measured as a proxy for DNA damage. Both chemicals at both the 5% and 10% of the 96-hour LC50 values altered DNA migration across an electrophoresis gel. It is important to note that even the low concentration of 5% of 78.18 mg/L used in this study exceeds glyphosate concentrations realistically found in the environment.

Carvalho, W. F., C. R. de Arcaute, J. M. Perez-Iglesias, M. R. R. Laborde, S. Soloneski, and M. L. Larramendy. 2019a. DNA damage exerted by mixtures of commercial formulations of glyphosate and imazethapyr herbicides in *Rhinella arenarum* (Anura, Bufonidae) tadpoles. Ecotoxicology 28:367-377.

Carvalho et al. (2019) evaluated the genotoxicity of Credit, a glyphosate based herbicide used in Argentina. DNA damage (erythrocyte damage) was observed after the fish were exposed to 5% and 10% of Credit's 96-hour LC50. However, this paper is missing some important information. The authors do not describe how the fish were exposed to the herbicide or what the 96-hour LC50 is so it is difficult to evaluate the results because it is unclear if concentrations are relevant to concentrations observed in the environment.

Daam, M. A., M. F. Moutinho, E. L. G. Espindola, and L. Schiesari. 2019. Lethal toxicity of the herbicides acetochlor, ametryn, glyphosate and metribuzin to tropical frog larvae. *Ecotoxicology* 28:707-715.

Daam et al. (2019) evaluated the acute toxicity of glyphosate to tadpoles of two tropical frog species (*Physalaemus cuvieri* and *Hypsiboas pardalis*). The calculated 96-hour LC50 values for *P. cuvieri* and *H. pardalis* were 115 and 106 mg/L. They also compiled toxicity values for fish and amphibians from the US-EPA ECOTOX database and compared tropical and non-tropical species and found that amphibians were less sensitive than fish to glyphosate toxicity and that the standard fish test species rainbow trout (*Oncorhynchus mykiss*) was more sensitive than the most sensitive amphibian test species.

Gabor, C. R., H. R. Perkins, A. T. Heitmann, Z. R. Forsburg, and A. S. Aspbury. 2019. Roundup (TM) With Corticosterone Functions as an Infodisruptor to Antipredator Response in Tadpoles. *Frontiers in Ecology and Evolution* 7.

Gabor et al. (2019) exposed tadpoles to glyphosate and exogenous corticosterone to evaluate how these chemical interactions influence the behavior, morphology and stress hormone response of Gulf coast toad (*Incilius nebulifer*) tadpoles. Roundup alone did not elicit a hormone (corticosterone) response, alter tail morphology, or change behavior in response to the predator cues. The combined effects of exogenous corticosterone and glyphosate did increase activity following exposure to predator cues.

Lajmanovich, R. C., P. M. Peltzer, A. M. Attademo, C. S. Martinuzzi, M. F. Simoniello, C. L. Colussi, A. P. Cuzziol Boccioni, and M. Sigrist. 2019. First evaluation of novel potential synergistic effects of glyphosate and arsenic mixture on *Rhinella arenarum* (Anura: Bufonidae) tadpoles. *Heliyon* 5

Lajmanovich et al. (2019) evaluated the acute (48-hour) and chronic (22-day) exposure toxicity of a glyphosate-based herbicide alone and in combination with arsenic on common South American toad (*Rhinella arenarum*) tadpoles. Acetylcholinesterase (AChE), Carboxylesterase enzyme (CbE), and Glutathione S-transferase (GST) enzyme activity, thyroid hormones (triiodothyronine; T3 and thyroxine; T4) and DNA damage were examined following 48 hours of exposure 10 mg/L of the glyphosate-based herbicide or 22 days of exposure to 1.25 mg/L of the herbicide. The LC50 values at 48 h were 45.95 mg/L for Roundup, and 30.31 mg/L for Roundup + arsenic. AChE is a neural enzyme that catalyzes the hydrolysis of the neurotransmitter acetylcholine in the nervous system of animals. Chronic exposure to Roundup

did not affect AChE activity alone or when mixed with arsenic. Acute exposure to 10 mg/L of Roundup increased AChE activity of *R. arenarum* tadpoles. The CbE enzyme plays an important role in detoxification. CbE activity increased following 48-h exposure to the Roundup but was not affected by chronic exposure to Roundup. GST is part of the first line of cellular defense, and is present in the cytosol of cells involved in the transport and elimination of reactive compounds in aquatic organisms. GST activity increased after 48-hour exposure to Roundup, arsenic, and the mixture of both. However, chronic exposure to Roundup alone or mixed with arsenic did not affect GST activity. Thyroid hormones are essential for tadpole metamorphosis. Roundup alone had no effect on thyroid hormone levels in either the acute or chronic study. Roundup did not induce DNA damage or alter red blood cells.

Wilkens, A. L. L., A. A. N. Valgas, and G. T. Oliveira. 2019. Effects of ecologically relevant concentrations of Boral (R) 500 SC, Glifosato (R) Biocarb, and a blend of both herbicides on markers of metabolism, stress, and nutritional condition factors in bullfrog tadpoles. Environmental Science and Pollution Research 26:23242-23256.

This study compared the effects of a glyphosate-based herbicide (Glifosato) and a sulfentrazone-based herbicide (Boral) on Bullfrog (*Rana catesbeiana*) tadpole metabolism, oxidative stress, and nutritional condition following 7 days of exposure of each herbicide alone or as a mixture. The glyphosate concentration used in this study was 234 µg/L. The glyphosate-based herbicide applied alone had no effect on nutritional condition. Triglycerides and cholesterol increased following glyphosate exposure. Plasma protein, glucose, and uric acid were not affected by glyphosate. In amphibians, corticosterone regulates the metamorphosis induction. Following exposure to glyphosate bullfrog corticosterone production was reduced. Four biomarkers were used to assess oxidative stress (SOD, CAT, TABRS and GST). Of these, only GST was affected by glyphosate.

FISH

Bernal-Rey, D. L., C. G. Cantera, M. dos Santos Afonso, and R. J. Menendez-Helman. 2020. Seasonal variations in the dose-response relationship of acetylcholinesterase activity in freshwater fish exposed to chlorpyrifos and glyphosate. Ecotoxicology and Environmental Safety 187.

The effect of glyphosate exposure on survival and AChE activity in *Cnesterodon decemmaculatus* fish was compared across seasons. Glyphosate had no effect on fish mortality. AChE was inhibited by exposure to 1 and 10 mg/l of glyphosate in all 4 seasons (winter, spring, summer, and fall).

Fabian Bonifacio, A., and A. Cecilia Hued. 2019. Single and joint effects of chronic exposure to chlorpyrifos and glyphosate based pesticides on structural biomarkers in *Cnesterodon decemmaculatus*. Chemosphere 236.

Bonifacio et al. (2019) measured nuclear abnormalities and liver abnormalities in of *Cnesterodon decemmaculatus* fish that experienced 42-days of exposure to 0.2 and 2 mg/L of Roundup Max. Alterations to liver tissues are particularly relevant due to the liver's role in detoxification of environmental pollutants. The glyphosate-based herbicide had no effect on genotoxicity or liver histology.

Chaulet, F. d. C., H. H. de Alcantara Barcellos, D. Fior, A. Pompermaier, G. Koakoski, J. G. Santos da Rosa, M. Fagundes, and L. J. Gil Barcellos. 2019. Glyphosate- and Fipronil-Based Agrochemicals and Their Mixtures Change Zebrafish Behavior. Archives of Environmental Contamination and Toxicology 77:443-451.

Chaulet et al. (2019) studied how glyphosate influences the behavior of zebrafish. They measured how much time zebrafish spend in the top and bottom of the tank, how long it takes to travel from the bottom to the top, total distance traveled, and the amount of rotating, and crossing. They found that glyphosate had no effect on the time it took to move into the top part of the tank, the frequency of crossing the tank, or the total distance traveled, but it did cause the fish to rotate more frequently and to spend more time at the top of the tank and less time at the bottom. Implications from this study are that fish could be more vulnerable to predators if spending more time nearer to the surface.

Golovanova, I. L., V. K. Golovanov, G. M. Chuiko, V. A. Podgornaya, and A. I. Aminov. 2019. Effects of Roundup Herbicide at Low Concentration and of Thermal Stress on Physiological and Biochemical Parameters in Amur Sleeper *Perccottus glenii* Dybowski Juveniles. Inland Water Biology 12:462-469.

Golovanova et al. evaluated the effect of 30-day exposure to 2 ug/L of Roundup on body size, intestinal enzyme activity (maltase and amolytic activity), water solubel protein content, and AChE activity in Amur sleeper fish (*Perccottus glenii*). Roundup reduced amolytic activity and water soluble protein content, but had no effect on body size, maltase or AchE activity.

Meshkini, S., M. Rahimi-Arnaei, and A. A. Tafi. 2019. The acute and chronic effect of Roundup herbicide on histopathology and enzymatic antioxidant system of *Oncorhynchus mykiss*. International Journal of Environmental Science and Technology 16:6847-6856.

Meshkini et al. (2019) assessed the effects of 28 days of Roundup exposure on rainbow trout (*Oncorhynchus mykiss*) by measuring biochemical factors (AChE and liver catalase) and histopathological studies (gills, liver, and kidney tissues). Fish were exposed for 28 days to either 1/5 or 1/10 of the LC50 concentration of Roundup and compared to a control group. Cerebral acetylcholinesterase (AChE) and liver catalase activities decreased following glyphosate exposure at both concentrations. No statistical analyses were used to evaluate structural abnormalities in gill, kidney, or liver tissues and can therefore not be interpreted.

Samanta, P., S. Pal, A. K. Mukherjees, T. Senapati, J. Jung, and A. R. Ghosh. 2019. Assessment of adverse impacts of glyphosate-based herbicide, Excel Mera 71 by integrating multi-level biomarker responses in fishes. International Journal of Environmental Science and Technology 16:6291-6300.

This is a large study that evaluated several biomarkers in 3 different fish species exposed to glyphosate in lab and field conditions. Samanta et al. (2019) found that often times lab conditions resulted on different outcomes than in the field and the physiological response of the fish to the glyphosate-based herbicide varied between species. The findings collectively suggest that interpretation of lab studies may not be indicative of risk in real world exposure scenarios.

REPTILES

Luz Hirano, L. Q., L. d. S. Alves, L. T. Menezes-Reis, J. d. S. Mendonca, K. Simoes, A. L. Quagliatto Santos, and L. G. Vieira. 2019. Effects of egg exposure to atrazine and/or glyphosate on bone development in *Podocnemis unifilis* (Testudines, Podocnemididae). Ecotoxicology and Environmental Safety 182.

Luz Hirano et al. (2019) studied the 30 and 50 day exposure effects of 65 and 6500 µg/L of glyphosate on bone and cartilage malformations of turtle (*Podocnemis unifilis*) embryos. Glyphosate did not influence the presence or severity of bone or cartilage malformations or other skeletal abnormalities.

BEEES

Blot, N., L. Veillat, R. Rouze, and H. Delatte. 2019. Glyphosate, but not its metabolite AMPA, alters the honeybee gut microbiota. Plos One 14.

Blot et al. (2019) evaluated the effect of 15 days of chronic glyphosate or AMPA exposure on the relative abundance of the dominant taxa in honeybee gut microbiota. They further evaluated how chronic exposure of glyphosate and AMPA influenced parasite infection on honeybees. Glyphosate, but not AMPA, decreased the abundance of two of the dominant taxa in honeybee guts and increased the abundance of *Lactobacillus* spp. Neither glyphosate or AMPA had any effect on honey bee survival, food consumption, or *Nosema ceranae* parasite infection. Findings from this study are consistent with Motta et al. (2018) and provides compelling evidence that the gut microbiome of honeybees is influenced by glyphosate, but that it is seemingly inconsequential to honeybee survival.

Decio, P., P. Ustaoglu, T. C. Roat, O. Malaspina, J.-M. Devaud, R. Stoger, and M. Soller. 2019. Acute thiamethoxam toxicity in honeybees is not enhanced by common fungicide and herbicide and lacks stress-induced changes in mRNA splicing. Scientific Reports 9.

It is well understood that neonicotinoids have detrimental impacts on honeybee health and viability. Decio et al. (2019) evaluated whether the combined effects of a neonicotinoid (thiametoxam) and glyphosate were worse than the effects of the neonicotinoid alone. They injected worker bees with the neonicotinoid with and without added glyphosate and measured bee survival and several splicing patterns associated with important genes (x box, elav, and dscam) that are involved in responding to stress. Neither honey bee survival or gene-splicing patterns were affected by the addition of glyphosate. It should be noted that glyphosate concentrations injected into the honey bees was the highest water-soluble concentration possible (23mM) and it was administered at this rate twice over a 48-hour period.

Farina, W. M., M. S. Balbuena, L. T. Herbert, C. Mengoni Gonalons, and D. E. Vazquez. 2019. Effects of the Herbicide Glyphosate on Honey Bee Sensory and Cognitive Abilities: Individual Impairments with Implications for the Hive. *Insects* 10.

This is a review paper that describes earlier studies that evaluated the effects of glyphosate on foraging behavior of honeybees.

Tome, H. V. V., D. R. Schmehl, A. E. Wedde, R. S. M. Godoy, S. V. Ravaiano, R. N. C. Guedes, G. F. Martins, and J. D. Ellis. 2020. Frequently encountered pesticides can cause multiple disorders in developing worker honey bees. *Environmental Pollution* 256.

Honey bee larvae were fed an artificial diet that contained glyphosate for six days. They glyphosate concentrations used in this study were the worse-case environmental concentrations previously recorded in pollen or wax from managed honey bee colonies. Glyphosate had no effect on larvae survival, pupae survival, development time, body mass or hypopharyngeal or antenna morphology. Adult honey bees did not up or down regulate any of the 8 measured detoxification genes. Bee larva downregulated one of the 8 genes.

Ulziibayar, D., and C. Jung. 2019. Comparison of Acute Toxicity of Different Groups of Pesticides to Honey Bee Workers (*Apis Mellifera* L.). *Journal of Apiculture* 34:305-313.

To understand how glyphosate impacts the survival of a native bee (*Melipona scutellaris*) in Brazil, Ulziibayer and Jung (2019) exposed bees topically and orally to 1/2 the manufactures recommended dose, the manufactures recommended dose, and 2x the manufactures recommended dose. None of these applications impacted bee survival.

TERRESTRIAL INVERTEBRATES

Crone, E. E., E. M. Pelton, L. M. Brown, C. C. Thomas, and C. B. Schultz. 2019. Why are monarch butterflies declining in the West? Understanding the importance of multiple correlated drivers. *Ecological Applications* 29.

Crone et al. (2019) used two separate modeling approaches to evaluate how factors associated with climate and land use change are contributing to western monarch butterfly abundance.

Monarch abundance was negatively correlated with coastal development, glyphosate use, neonicotinoid use, breeding season temperature and breeding season drought. Trends in statewide glyphosate use and coastal development are so highly correlated ($r = 0.91$) that teasing apart the effects of development and glyphosate use is impossible. The authors conclude that more experimental research is needed to understand the relationship between glyphosate use and Monarch abundance.

Galin, R. R., I. F. Akhtyamova, and E. I. Pastukhova. 2019. Effect of Herbicide Glyphosate on *Drosophila melanogaster* Fertility and Lifespan. *Bulletin of Experimental Biology and Medicine* 167:663-666.

Galin et al. (2019) fed fruit flies (*Drosophila melanogaster*) 0.028, 0.28, or 2.8 mg/ml of glyphosate to evaluate the effects of the herbicide on fruit fly fertility and lifespan. The highest concentration (2.8 mg/ml) of glyphosate tested reduced the lifespan of male flies and the number of pupae and imago in the progeny, while the concentrations of 0.028 and 0.28 mg/ml produced no adverse effects. It should be noted that the highest concentration used in this study was the manufacturers recommended concentration for use in the environment.

Hagner, M., J. Mikola, I. Saloniemi, K. Saikkonen, and M. Helander. 2019. Effects of a glyphosate-based herbicide on soil animal trophic groups and associated ecosystem functioning in a northern agricultural field. *Scientific Reports* 9.

Hagner et al. (2019) hypothesized that in northern latitudes the potential effects of glyphosate-based herbicides on non-target soil organisms could be larger than at lower latitudes because of the shorter growing season. With decreased time to degrade glyphosate, the herbicide could potentially have stronger impacts on soil organisms. They compared the effects of controlling weeds by hoeing, and hoeing + Roundup, to an untreated control. They found that killing plants by hoeing had much larger effects on soil fauna than glyphosate did. The effects of glyphosate were minor and transient and no glyphosate remains were found in the soil at the end of the experiment.

Margus, A., M. Rainio, and L. Lindstrom. 2019. Can Indirect Herbicide Exposure Modify the Response of the Colorado Potato Beetle to an Organophosphate Insecticide? *Journal of Economic Entomology* 112:2316-2323.

Margus et al. (2019) studied the interacting effects of glyphosate and an insecticide (azinphos-methyl) on Colorado potato beetle (*Leptinotarsa decemlineata*) larval survival and biomarkers associated with stress. Beetle larvae were exposed to potato plants that were grown in soil that had been treated with Roundup and to control plants (grown in soil not treated with Roundup). Beetle larval survival was not affected by Roundup and the Roundup did not influence how the insecticide affected the beetle (i.e. no interaction effect). Glyphosate inhibited the Ldace1 gene expression which encodes AChE activity and increased the activity of a biomarker that is associated with oxidative stress.

Niedobova, J., M. Skalsky, J. Ourednickova, R. Michalko, and A. Bartoskova. 2019. Synergistic effects of glyphosate formulation herbicide and tank-mixing adjuvants on *Pardosa* spiders. *Environmental Pollution* 249:338-344.

This study compared the effects of Roundup alone, to Roundup mixed with the surfactants agrovital or wetcit, and the surfactants alone on *Pardosa* spider predator behavior. Pure surfactants as well as herbicide-and-surfactants tank mixes decreased the predatory activity of *Pardosa* spiders. Roundup by itself had no effect on spider behavior.

Pochron, S., M. Choudhury, R. Gomez, S. Hussaini, K. Illuzzi, M. Mann, M. Mezic, J. Nikakis, and C. Tucker. 2019. Temperature and body mass drive earthworm (*Eisenia fetida*) sensitivity to a popular glyphosate-based herbicide. *Applied Soil Ecology* 139:32-39.

Numerous studies have found conflicting results regarding the effects of glyphosate-based herbicides on earthworms. Pochron et al. (2019) evaluated how initial earthworm body size and soil temperature influence the effect of Roundup on earthworm growth and survival. They found that in hot soil, large worms exposed to Roundup grew larger than large worms not exposed to Roundup (controls), but that growth of large worms in cold soil was not affected by Roundup. The growth of small worms was not affected by Roundup in either hot or cold soil. Worms in cold soil that were exposed to Roundup had lower survival than controls, but the Roundup had no effect in hot soil.

Talyn, B., R. Lemon, M. Badoella, D. Melchiorre, M. Villalobos, R. Elias, K. Muller, M. Santos, and E. Melchiorre. 2019. Roundup (R), but Not Roundup-Ready (R) Corn, Increases Mortality of *Drosophila melanogaster*. *Toxics* 7.

Talyn et al. (2019) found that there was no difference in life span or reproductive behavior of fruit flies, *Drosophila melanogaster*, that were fed organic corn, non-GMO corn, GMO Roundup resistant corn, and GMO Roundup resistant corn that was sprayed with Roundup. They also determined that the Roundup LC₅₀ for male fruit flies was 7.1 and 11.4 g/L for females. The concentrations of glyphosate residues that they detected in the glyphosate treated corn was seven orders of magnitude lower than the LC₅₀ for male fruit flies.

AQUATIC INVERTEBRATES

Canosa, I. S., M. Zanitti, N. Lonne, D. A. Medesani, L. S. Lopez Greco, and E. M. Rodriguez. 2019. Imbalances in the male reproductive function of the estuarine crab *Neohelice granulata*, caused by glyphosate. *Ecotoxicology and Environmental Safety* 182.

Canosa et al. (2019) evaluated the effects of pure glyphosate and Roundup Ultramax on body weight, muscle protein, sperm number and sperm viability of the estuarine crab (*Neohelice granulata*) following 30 days of exposure to the herbicides. The crabs exposed to the herbicides were smaller compared to the control group and had less muscle protein. Roundup, but not

pure glyphosate, reduced sperm count and inhibited the secretion of hormone from the the androgenic gland.

de Melo, M. S., E. M. Nazari, C. Joaquim-Justo, Y. M. Rauh Muller, and E. Gismondi. 2019. Effects of low glyphosate-based herbicide concentrations on endocrine-related gene expression in the decapoda *Macrobrachium potiuna*. *Environmental Science and Pollution Research* 26:21535-21545.

De Melo et al. (2019) studied the effects of chronic (7 and 14 day) exposure to a glyphosate-based herbicide on the expression of genes that are involved in molting and reproduction of crustaceans. They measured the relative transcript expression levels of the ecdysteroid receptor (EcR), the molt-inhibiting hormone (MIH), and the vitellogenin (Vg) genes. Male shrimp upregulated EcR genes after 7 hours of exposure to the 0.65 mg/L dose, but not the higher or lower herbicide concentrations. The lack of a dose response pattern makes it difficult to infer implications. Expression of the EcR gene in females was unaffected by glyphosate following 7 and 14 days of exposure. Vt transcription was upregulated in males following 14 days of glyphosate exposure of the intermediate concentration, but not with lower or higher herbicide concentrations. There was no effect of glyphosate-herbicide exposure on Vg expression of female shrimp. MIH also increased following 7-day glyphosate exposure for the intermediate concentration, but not the higher concentration, and not following 14-days of exposure.

Marineau, E. D., M. J. Perryman, S. P. Lawler, R. K. Hartman, and P. D. Pratt. 2019. Management of Invasive Water Hyacinth as Both a Nuisance Weed and Invertebrate Habitat. *San Francisco Estuary & Watershed Science* 17:4-4.

Marinaeu et al. (2019) studied the effects of glyphosate applications used to control water hyacinth in the San Joaquin River Delta on invertebrate abundance and diversity. There was no difference in invertebrate abundance or diversity in pre and one-month post glyphosate applications. The authors concluded that current glyphosate use to control water hyacinth poses minimal risk to aquatic invertebrates.

Pala, A. 2019. The effect of a glyphosate-based herbicide on acetylcholinesterase (AChE) activity, oxidative stress, and antioxidant status in freshwater amphipod: *Gammarus pulex* (Crustacean). *Environmental Science and Pollution Research* 26:36869-36877.

Pala et al. (2019) evaluated the toxic and sub lethal effects of glyphosate on *Gammarus pulex*, a freshwater amphipod. They measured acetylcholinesterase (AChE) enzyme inhibition in the nervous system, and looked for depletion of antioxidants and the accumulation of reactive oxygen species to determine if the organisms experienced oxidative stress following glyphosate exposure. The AChE is an important enzyme used as a biomarker in biomonitoring studies related to the exposure of pesticides and glyphosate is classified as a non-AChE

inhibitor to animals. Pala et al (2019) found that the AChE activity in the freshwater amphipod *Gammarus pulex* was inhibited by 23 to 53% when exposed to 10-40 ug/L of a glyphosate containing herbicide. They also found that the herbicide caused an increase in oxidative stress.

BIRDS

Fathi, M. A., E. Abdelghani, D. Shen, X. Ren, P. Dai, Z. Li, Q. Tang, Y. Li, and C. Li. 2019. Effect of in ovo glyphosate injection on embryonic development, serum biochemistry, antioxidant status and histopathological changes in newly hatched chicks. Journal of Animal Physiology and Animal Nutrition 103:1776-1784.

This study aimed to characterize the impacts of Roundup and pure glyphosate (10 mg/Kg egg) on hatchability, blood parameters, and liver and kidney function after being injected with the herbicides. Roundup reduced the proportion of chicks that hatched by 66%. There was no difference in yolk sac weights or the weight of most of the organs. Glyphosate and Roundup increased liver and kidney mass. In the liver neither GSH or SOD were affected by Roundup or pure glyphosate. Liver MDA increased with both glyphosate and Roundup relative to the controls. In the kidney, GSH was also unaffected by glyphosate and Roundup. Glyphosate and Roundup caused the liver SOD to decreased by the same amount. Glyphosate increased liver MDA while Roundup had no effect on MDA . Glyphosate decreased SOD activity, but Roundup had no effect. Glyphosate and Roundup decreased CAT activity to the same extent.

Rivers, J. W., J. Verschuyt, C. J. Schwarz, A. J. Kroll, and M. G. Bett. 2019. No evidence of a demographic response to experimental herbicide treatments by the White-crowned Sparrow, an early successional forest songbird. Condor 121.

Rivers et al. (2019) used a large-scale experiment to test how nest and post-fledging survival were influenced by herbicide intensity within managed conifer plantations across 2 breeding seasons. They herbicide treatments that were light, moderate, and intensive, and no-spray control. Rivers et al evaluated the reproductive response of the White-crowned Sparrow (*Zonotrichia leucophrys*), a declining songbird in managed forest landscapes of the Pacific Northwest following the herbicide treatments. They found no evidence that either daily nest survival or post-fledging survival were influenced by herbicide application intensity. They also found that vegetative cover at nest sites did not differ across herbicide treatments.

MAMMALS

Bote, K., J. Poeppe, S. Riede, G. Breves, and U. Roesler. 2019. Effect of a Glyphosate-Containing Herbicide on Escherichia coli and Salmonella Ser. Typhimurium in an In Vitro Rumen Simulation System. European Journal of Microbiology and Immunology 9:94-99.

Bote et al. (2019) used an in vitro fermentation study approach to evaluate if glyphosate contaminated food can increase pathogenic bacteria (*E. coli* and *Salmonella*) associated with livestock. Considering that the pathway that is inhibited by glyphosate in plants, is also found in

bacteria, it is conceivable that glyphosate may alter bacterial communities in the guts of animals. However, Bote et al found that at even the highest concentrations glyphosate (10 mg/L) had no effect on the abundance of either *E. coli* or *Salmonella*, and had did not prompt any resistance to glyphosate or to antibiotics.

SOIL MICROBES

Bruckner, A., A. Schmerbauch, L. Ruess, F. Heigl, and J. Zaller. 2019. Foliar Roundup application has minor effects on the compositional and functional diversity of soil microorganisms in a short-term greenhouse experiment. *Ecotoxicology and Environmental Safety* 174:506-513.

White clover (*Trifolium repens*) was grown in pots with earthworms and arbuscular mycorrhizal fungi. Glyphosate was applied to the plants and after two weeks microbial respiration was increased by 30%. Glyphosate had a small effect on microbial community composition, decreased bacteria, and had no effect on mycorrhizal fungi. Unfortunately, the experiment did not include a treatment where the plants were killed by cutting without Roundup. It is not possible to distinguish between the effects of Roundup per se and root death. Glyphosate and AMPA were detected in soil leachate, even though it had only been applied to the plants. This suggests that glyphosate entered the soil via the plants.

Farthing, T. S., J. P. Muir, and J. A. Brady. 2020. Three Bermudagrass-suppression techniques have little effect on soil-nutrient availability and microbial communities 200 days after application. *Applied Soil Ecology* 145.

Farthing et al. (2019) evaluated how different treatments used to remove Bermuda grass (*Cynodon dactylon*) influenced soil microbial communities. They compared repeated glyphosate treatments, and repeated mechanical treatments to each other and to a control. They found that the herbicide treatments had no effect on soil bacteria or archaea species richness or diversity.

Suleman, M., B. J. Keely, S. Liaqat, and W. Ali. 2020. Assessment of the impact of pesticides on the soil microbial community using intact polar membrane lipids as biomarkers. *Journal of Animal and Plant Sciences* 30:192-204.

Suleman et al. (2019) compared the abundance of 7 polar membrane lipids found in soil spiked with different pesticides, including glyphosate. The lipids are proxies for microbial diversity. They found that of the 7 lipids identified in the soils, glyphosate applied at the maximum rate (1.25 kg/ha) decreased the concentration of 2 lipids, increased the concentration of 1 lipid, and had no effect of 4 of the lipids. The lipid that was found in the highest abundance in the soils is associated with fungi and algae and it decreased by a 10% as a result of the glyphosate addition. It is unclear from this study how changes in the abundance of these lipids influences soil processes such as decomposition rates.

AQUATIC MICROORGANISMS

Janssen, R., W. Skeff, J. Werner, M. A. Wirth, B. Kreikemeyer, D. Schulz-Bull, and M. Labrenz. 2019. A Glyphosate Pulse to Brackish Long-Term Microcosms Has a Greater Impact on the Microbial Diversity and Abundance of Planktonic Than of Biofilm Assemblages. *Frontiers in Marine Science* 6

Janssen et al. (2019) evaluated how glyphosate applied to brackish water influenced microbial community diversity and composition (plankton and biofilm forming bacteria). They further evaluated the persistence of glyphosate in the water following application. The bacteria that make up the biofilm can use the phosphorus in glyphosate as a food source. Following the glyphosate addition microbial cell counts initially increased and then decreased as the glyphosate was consumed by the microbes. After 71 days the glyphosate was reduced by 99%. Glyphosate temporality increased the diversity and richness of the plankton and did not influence the diversity or richness of the biofilm.

Lam, C. H., T. Kurobe, P. W. Lehman, M. Berg, B. G. Hammock, M. E. Stillway, P. K. Pandey, and S. J. Teh. 2020. Toxicity of herbicides to cyanobacteria and phytoplankton species of the San Francisco Estuary and Sacramento-San Joaquin River Delta, California, USA. *Journal of Environmental Science and Health Part a-Toxic/Hazardous Substances & Environmental Engineering* 55:107-118.

Lam et al. (2019) evaluated the effect of aquatic herbicides, including glyphosate, on the growth of phytoplankton and cyanobacteria that occur in the San Francisco Bay Delta. Of the 3 herbicides tested, glyphosate was the least toxic. At extremely high concentrations (7×10^4 ug/L) glyphosate inhibited growth of 2 plankton species, but increased growth of the other. At environmentally relevant concentrations glyphosate had no effect on phytoplankton or cyanobacteria growth.

PLANTS

de Moraes, C. P., I. P. F. S. de Brito, L. Tropaldi, C. A. Carbonari, and E. D. Velini. 2019. Hormetic effect of glyphosate on *Urochloa decumbens* plants. *Journal of Environmental Science and Health Part B-Pesticides Food Contaminants and Agricultural Wastes*.

de Moraes et al. (2019) used greenhouse experiments to evaluate how a non-target plant, *Urochloa decumbens*, responded to different concentrations of glyphosate. They found that at low concentrations glyphosate had no effect on plant growth, but that high concentrations (>11 g/ha) glyphosate decreased plant growth.

Enloe, S. F., K. H. Quincy, M. D. Netherland, and D. K. Lauer. 2020. Evaluation of fluazifop-P-butyl for para grass and torpedograss control in aquatic and wetland sites. *Journal of Aquatic Plant Management* 58:36-40.

Enloe and Netherland planted native aquatic plants along with the torpedo grass (*Panicum repens*) into a mesocosm experiment and applied glyphosate and imazapyr to evaluate how the herbicides influenced the native species. They further evaluated if the impacts on native plants varied in the spring and fall. Both glyphosate and imazapyr reduced native plant biomass by 64-100%. Season of application did not influence the extent that the herbicides reduced native plant biomass. The authors do not explain whether the herbicide was intentionally applied onto the native plants or if it was only applied to the invader. The herbicide reduced mycorrhizal biomass relative to a control, but had the same effect as the other removal treatments.

Helander, M., A. Pauna, K. Saikkonen, and I. Saloniemi. 2019. Glyphosate residues in soil affect crop plant germination and growth. Scientific Reports 9.

Helander et al. (2019) used a greenhouse and a field experiment to evaluate how Roundup and pure glyphosate effect seed germination and growth of four crop plants. In the greenhouse, soils were treated with Roundup or glyphosate and after 14 days the crop plants were planted into the treated soils. In the field, Helander et al treated soils in agricultural fields with Roundup and planted crops 3 weeks later. Fava bean seed germination was not affected by the herbicide treatments in the greenhouse experiment, but the seeds germinated faster in the untreated controls. The plants grown in the control soils were larger than in the Roundup treated soils, Crop yield was unaffected by the herbicides. In the greenhouse, oats germinated faster in the control soil than in the herbicide treated soils. Oat plants in the Roundup treated soil were smaller than in plants in the untreated control soil, but not the glyphosate soil. In the field, the oats were damaged by geese herbivory, but the lack of a significant treatment x herbivory damage interaction term suggests that geese did not prefer one soil treatment over the others. In the field, oats started out larger in the control, but by the end of the study were the same size in the control and herbicide treated soils. No traces of glyphosate or AMPA were detected in the greenhouse soils.

Wood, L. J. 2019. The presence of glyphosate in forest plants with different life strategies one year after application. Canadian Journal of Forest Research 49:586-594.

Wood (2019) measured glyphosate in the roots, shoots, and fruits of native traditional-use plants with different life strategies (i.e. herbaceous, woody). Perennial herbaceous and woody plants were collected one year after forestry-based applications of glyphosate. Glyphosate residues were found one-year after application. The highest and most consistent levels of glyphosate and AMPA were found in herbaceous perennial root tissues, but shoot tissues and fruit were also shown to contain glyphosate in some species. Findings from this study indicate that glyphosate can be stored in root structures of perennial plants during dormancy periods and move up to shoot and fruit portions in years following applications in some species.

ENVIRONMENTAL FATE

Muskus, A. M., M. Krauss, A. Miltner, U. Hamer, and K. M. Nowak. 2019. Effect of temperature, pH and total organic carbon variations on microbial turnover of (13)CA(3)(15)N-glyphosate in agricultural soil. *Science of the Total Environment* 658:697-707.

The degradation of glyphosate in soil may vary with different environmental conditions. Muskus et al. (2019) evaluated the effects of soil temperature, total organic carbon, and soil pH on the rate of microbial conversion of glyphosate to CO₂. Higher temperature and total organic carbon content increased microbial conversion of glyphosate to CO₂. The influence of the soil pH or total organic carbon treatment on the extent of glyphosate mineralization was more discernible at lower temperatures. This study highlights how the rate of glyphosate degradation depends upon many factors including temperature, soil pH, and soil carbon content.

Gu, X., Y. Cen, L. Guo, C. Li, H. Yuan, Z. Xu, and G. Jiang. 2019. Responses of weed community, soil nutrients, and microbes to different weed management practices in a fallow field in Northern China. *PeerJ* 7.

Gu et al. (2019) evaluated how different invasive species management treatments influence invader seed banks, soil nutrients, and soil microbial biomass. They compared the effects of physical removal treatments (tilling) with Roundup treatments. The physical removal treatment reduced weed seeds by 34%, while the herbicide treatment did not reduce weed seeds. Roundup treatments had smaller effects on total microbial biomass than the physical treatments.

1.2 IMAZAPYR

No studies were published in 2019 that describe human health risks or the environmental fate of imazapyr.

NON-TARGET IMPACTS

McCaskill, G. L., S. Jose, and A. V. Ogram. 2019. Low-dose Herbicide Effects on Tree Establishment and Soil Nitrogen Biogeochemistry within Pine Savannas. *Soil Science Society of America Journal* 83:S153-S160.

McCaskill et al. (2019) compared the effects of imazapyr (applied at a rate of 0.21 kg/ha) on soil nitrogen mineralization, soil microbial biomass, and the survival and growth of long leaf pine. Imazapyr was the only treatment to significantly improve growth over the control in a single application. The herbicide increased N mineralization rates, and ammonification. Microbial biomass was not affected by a single imazapyr application.

EFFICACY

Annen, C. A., J. A. Bland, A. J. Budyak, and C. D. Knief. 2019. Effects of Selectively-targeted Imazapyr Applications on *Typha angustifolia* in a Species-rich Wetland (Wisconsin). *Ecological Restoration* 37:3-4.

In this simple and well written short format paper Annen et al. (2019) evaluated multiple approaches to manage narrow leaved cattail (*Typha angustifolia*) in areas where it does not grow in a monoculture. They compared imazapyr and mowing treatments to an untreated control. The applied imazapyr twice and after 2 years the herbicide plots had more plant diversity than the control, but purple loosestrife (*Lythrium salicaria*) increased in abundance following *Typha* control.

Berrill, J.-P., and R. Howe. 2019. Multiaged redwood responds well to partial harvest and herbicide treatments. *Canadian Journal of Forest Research* 49:1425-1433.

Berrill and Howe (2019) studied coast redwood growth following imazapyr herbicide treatments used to remove tan oak competition. Removal of tan oak with the herbicide increased redwood radial growth in 23% of the redwood trees measured, while 67% of the untreated control trees had a reduction in basal area. The ratio 8 years post treatment to 8 years pre treatment was 59% higher basal area in herbicide only pots, and 108% higher when herbicide was combined with selective harvests of redwoods than untreated control plots

Goodall, J., and M. Braack. 2019. Screening herbicides for the control of the wetland invader, *Sambucus nigra* L., in South Africa. *African Journal of Aquatic Science* 44:295-299.

Goodall and Braack et al (2019) tested the efficacy of 5 different herbicides used to treat *Sambucus nigra*. Two of the 9 herbicides in the study were triclopyr and imazapyr. Applied to cut stumps both imazapyr and triclopyr at the lowest recommended application rate resulted in greater than 80% mortality.

Murray, L., B. J. Schutte, C. Sutherland, L. Beck, A. Ganguli, and E. Lehnhoff. 2019. Integrating conventional management methods with biological control for enhanced *Tamarix* management. *Invasive Plant Science and Management* 12:176-185.

Murray et al. (2019) studied how *Tamarix* responds to foliar imazapyr applications in the presence of the *Tamarix* leaf beetle biocontrol agent. They found that at the standard application rate (3.6 g/L) of imazapyr improved *Tamarix* control when applied in conjunction with the presence of the biocontrol.

Rohal, C. B., C. Cranney, E. L. G. Hazelton, and K. M. Kettenring. 2019. Invasive *Phragmites australis* management outcomes and native plant recovery are context dependent. *Ecology and Evolution* 9:13835-13849.

Rohal et al. (2019) compared different management treatments to control *Phragmites*. They compared the efficacy of glyphosate and imazapyr on controlling the invader and on native

plant recovery. They found the glyphosate and imazapyr worked equally well at controlling phragmites and that fall applications were more effective than summer applications. They expected native plant recruitment to be lower following imazapyr applications compared to glyphosate, because imazapyr has a longer half life and is purported to be able to persist in the soil. Contrary to their predictions, imazapyr did not restrict native plant recruit more than glyphosate. The authors speculate that this may be because the persistence of imazapyr in the anerobic soil conditions associated with wetlands is lower than in aerobicoic soil.

1.3 AMINOPYRALID

No studies were published in 2019 that describe human health risks, ecological effects, or the environmental fate of aminopyralid.

EFFICACY

Dias, J. L. C. S., G. E. Duarte, W. L. Colombo, and B. A. Sellers. 2019. Cadillo (*Urena lobata*) control with POST herbicides. *Weed Technology* 33:387-392.

Dias et al. (2019) compared the efficacy of 7 different herbicides for control of *Urena lobata* (cadillo) in cattle pastures. Triclopyr and aminopyralid were the only two herbicides that were tested that are relevant to MROSD. They found that both of these herbicides resulted in >90% target plant mortality.

1.4 CLOPYRALID

No studies were published in 2019 that describe human health risks or the environmental fate of clopyralid.

NON-TARGET EFFECTS

MacDonald, N. W., K. M. Dykstra, and L. M. Martin. 2019. Restoration of native-dominated plant communities on a *Centaurea stoebe*-infested site. *Applied Vegetation Science* 22:300-316.

MacDonald et al. (2019) used a myriad of restoration approaches to increase cover of native forbs and grass in an area dominated by *Centaurea stoebe* (spotted knapweed). To remove *C. stoebe* prior to seeding with native forbs MacDonald et al sprayed study sites with either clopyralid or glyphosate, or mowed them. They found that clopyralid treated plots, and mowed plots had fewer native species than polts that were treatend with glyphosate.

EFFICACY

Farooq, M. H., Q. U. Zaman, N. S. Boyd, and S. N. White. 2019. Evaluation of broadcast and spot herbicide applications for narrowleaf goldenrod *Euthamia graminifolia* (L.) Nutt. management in lowbush blueberry. *Weed Technology* 33:739-747.

Farooq et al. (2019) compared the efficacy of spraying goldenrod that occurs in blueberry crops with a number of different herbicides including glyphosate (7.24 g/L), clopyralid (0.08 g/L) and triclopyr (1.68 g/L). They compared fall and summer spot treatments and found that summer applications of either herbicide reduced shoot density, but that only glyphosate reduced shoot density in the fall.

1.5 TRICLOPYR

ENVIRONMENTAL FATE

Rodrigues, E. T., M. F. Alpendurada, A. Guimaraes, R. Avo, B. Ferreira, and M. A. Pardal. 2019. The environmental condition of an estuarine ecosystem disturbed by pesticides. *Environmental Science and Pollution Research* 26:24075-24087.

To understand how agricultural applications of pesticides, including triclopyr, persist in estuaries Rodrigues et al (2019) sampled surface water and sediments within an estuary in Portugal before and after the pesticides were applied to crops. Triclopyr was not found in concentrations that exceed the EU's acceptable limits in either the water or sediment samples. The authors conclude that the agricultural pesticides used in the region pose minimal risk to aquatic organisms that occur in the studied estuary.

EFFICACY

Frey, M., and J. P. Schmit. 2019. Controlling Italian Arum (*Arum italicum*). *Natural Areas Journal* 39:372-377.

Frey et al. (2019) tested the effectiveness of several different herbicide formulations on controlling Italian arum (*Arum italicum*) with several herbicide formulations. Triclopyr was one of the herbicides evaluated. They found that Triclopyr was ineffective at controlling the invader and that after 1 year there was no difference in arum abundance in the triclopyr and control plots.

Gibson, D. J., L. A. Shupert, and X. Liu. 2019. Do No Harm: Efficacy of a Single Herbicide Application to Control an Invasive Shrub While Minimizing Collateral Damage to Native Species. *Plants-Basel* 8.

Gibson et al. (2019) suggests that collateral damage to non-target plants following invasive species control should be considered following restoration actions. They assessed the efficacy of

various tricolyp formulations on controlling *Lespedeza cuneate* and evaluated how the treatments influenced the plant community. Tricolpyr reduced the abundance of the invader following initial application, but that it had regained dominance within 3 years. Native species initially declined in abundance following the herbicide treatments but recovered to pretreatment abundances

Marble, S. C., and A. Chandler. 2019. Control of skunk-vine (*Paederia foetida* L.) with preemergence and postemergence herbicides in central Florida during the winter season. *Invasive Plant Science and Management* 12:51-59.

Marble et al. (2019) used greenhouse and field experiments to compare the efficacy of several different herbicides on controlling skunk vine (*Paederia foetida*). Aminopyralid, triclopyr, and glyphosate were among the herbicides that were evaluated. All three of these herbicides were equally effective at controlling the skunk vine in this experiment.

Prince, C. M., K. H. Quincy, S. F. Enloe, J. Possley, and J. Leary. 2019. Cut-stem treatments using graminicides for burmameed (*Neyraudia reynaudiana*) invasions in Pine Rocklands, South Florida, USA. *Invasive Plant Science and Management* 12:236-241.

Prince et al. (2019) compared the efficacy of several herbicides and application approaches on Burmameed (*Neyraudia reynaudiana*) plants grown in the greenhouse and the field. They found that triclopyr and glyphosate applied either immediately after stump cutting or applied a year later were equally effective and that glyphosate and triclopyr provide high level control in the greenhouse study, but were relatively ineffective in the field. Under field conditions the two herbicides provided less than 30% control irrespective of whether the herbicides were applied to cut stumps immediately following cutting or the following year after resprouting occurred.

1.6 CLETHODIM

NON-TARGET EFFECTS

Xiong, G., L. Zou, Y. Deng, Y. Meng, X. Liao, and H. Lu. 2019. Clethodim exposure induces developmental immunotoxicity and neurobehavioral dysfunction in zebrafish embryos. *Fish & Shellfish Immunology* 86:549-558.

Xiong et al. (2019) examined the effects of clethodim on the development, immune toxicity, cell death (apoptosis), and locomotion on zebrafish larvae. The larvae were exposed to 10, 50, 100, 300 or 500 µg/L of clethodim. All doses reduced larval survival, and doses > 50 µg/L reduced larval size and heart rate. Cell death and oxidative stress increased in a dose dependent fashion. Together these findings provide evidence that chronic exposure to high doses of clethodim can result in lethal and sublethal effects on zebrafish larvae.

ENVIRONMENTAL FATE

Anastassiadou, M., A. Brancato, L. C. Cabrera, L. Ferreira, L. Greco, S. Jarrah, A. Kazocina, R. Leuschner, J. O. Magrans, I. Miron, R. Pedersen, M. Raczky, H. Reich, S. Ruocco, A. Sacchi, M. Santos, A. Stanek, J. Tarazona, A. Theobald, A. Verani, and E. F. S. European Food Safety Authority. 2019. Review of the existing maximum residue levels for clethodim according to Article 12 of Regulation (EC) No 396/2005. *Efsa Journal* 17.

Anastassiadou et al. (2019) is a review conducted by the European Food Safety Authority that attempted to determine what the maximum residue concentration for clethodim should be in for processed commodities, rotational crops, and livestock. They were unable to identify a maximum residue level because of a paucity of data regarding risk. They did conclude that there is potential for clethodim to have a genotoxic effect, but that more studies are needed to understand if relevant concentrations pose risks to non-target organisms.

EFFICACY

Cassol, M., M. D. Mattiuzzi, A. J. P. Albrecht, L. P. Albrecht, L. C. Baccin, and C. N. Z. Souza. 2019. Efficiency Of Isolated And Associated Herbicides To Control Glyphosate-Resistant Sourgrass. *Planta Daninha* 37.

Cassol et al. (2019) compared the effectiveness of different herbicide applications to control perennial sourgrass (*Digitaria insularis*). Two of the treatments included clethodim alone and glyphosate + clethodim. Clethodim and clethodim + glyphosate initially removed 90% of the sourgrass cover, but after 35 days the plants were resprouting.

2.0 ADJUVENTS/SURFACTANTS:

Alcohol ethoxylate, Alkylphenol ethoxylate, Lecithin, Canola oil: ethyl & methyl esters

No studies were published in 2019 that describe human health risks, ecological effects, or the environmental fate of the adjuvants and surfactants used by MROSD.

3.0 FUNGICIDES

No studies were published in 2019 that describe human health risks, ecological effects, or the environmental fate of the fungicides used by MROSD.

4.0 INSECTICIDES

4.1 DIATOMACEOUS EARTH

No studies were published in 2019 that describe human health risks, ecological effects, or the environmental fate of diatomaceous earth.

4.2 D-TRANS ALLETHRIN

No studies were published in 2019 that describe human health risks, ecological effects, or the environmental fate of *D-trans allethrin*.

4.3 FIPRONIL

Harley, K. G., K. L. Parra, J. Camacho, A. Bradman, J. E. S. Nolan, C. Lessard, K. A. Anderson, C. M. Poutasse, R. P. Scott, G. Lazaro, E. Cardoso, D. Gallardo, and R. B. Gunier. 2019. Determinants of pesticide concentrations in silicone wristbands worn by Latina adolescent girls in a California farmworker community: The COSECHA youth participatory action study. *Science of the Total Environment* 652:1022-1029.

Harley et al. (2019) assessed weekly pesticide exposure in 14-16 year old latina girls that live in the Salinas Valley, an agricultural region of California. The study participants wore silicon wristbands for a week that were analyzed for pesticide concentrations. Fipronil was detected on 87% of the wrist bands and was the most frequently detected pesticide. In California, fipronil is not used in agriculture and is only used for treating termites, roaches, and ants in and around buildings, or to treat fleas and ticks on dogs and cats. The authors do not address what pathway the study participants were exposed to fipronil, but did find that living within 100 m of active agricultural fields, having carpeting in the home, and having an exterminator treat the home in the past six months were associated with higher odds of detecting certain pesticides.

Pandit, A. A., R. K. Gandham, C. S. Mukhopadhyay, R. Verma, and R. S. Sethi. 2019. Transcriptome analysis reveals the role of the PCP pathway in fipronil and endotoxin-induced lung damage. *Respiratory Research* 20.

Pandit et al. (2019) used a microarray and qPCR approach to evaluate the effects of fipronil on the transcriptome profile associated with the lungs of mice that were fed 1/10th and 1/20th of the LC50 for 90 days. They concluded that these concentrations of fipronil can alter the transcriptome profile of lungs and potentially cause damage through the production of cytokines that cause lung inflammation.

Seydi, E., L. Mehrpouya, H. Sadeghi, S. Rahimi, and J. Pourahmad. 2019. Toxicity of fipronil on rat heart mitochondria. *Toxin Reviews*.

Seydi et al. (2019) studied the effects of in vitro fipronil exposure on rat heart mitochondria function. They found that fipronil increases mitochondrial oxidative stress (increased production of ROS and LPO, mitochondrial swelling, and cytochrome C release) following apoptosis signaling. These impacts on mitochondria likely have hazardous effects on heart tissues.

Testa, C., S. Salis, N. Rubattu, P. Roncada, R. Miniero, and G. Brambilla. 2019. Occurrence of Fipronil in residential house dust in the presence and absence of pets: a hint for a

comprehensive toxicological assessment. Journal of Environmental Science and Health Part B-Pesticides Food Contaminants and Agricultural Wastes 54:441-448.

Testa et al. (2019) compared the amount of fipronil in dust within homes with and without pets. They found that fipronil dust contamination in the presence of pets was far higher than in homes without pets. The amount of fipronil found in homes with and without pets never exceeded the concentrations considered hazardous by the US (EPA) or EU (ECHA) regulatory agencies. This paper is not directly useful to MROSD because it does not account for the presence or absence of fipronil bait stations in homes, but nevertheless, it is reassuring that even in homes with pets concentrations of fipronil are considered safe.

4.5 INDOXACARB

Wang, C., A. Eiden, R. Cooper, C. Zha, D. Wang, and E. Reilly. 2019a. Changes in Indoor Insecticide Residue Levels after Adopting an Integrated Pest Management Program to Control German Cockroach Infestations in an Apartment Building. Insects 10.

Wang et al. (2019) measured residues of indoxacarb on kitchen and bedroom floors of 69 low income apartments in New Jersey that used Advion indoxacarb bait traps and insect sticky traps to treat German cockroaches. In each apartment 18 g of gel bait (with 0.6% indoxacarb) was applied every two weeks for as long as cockroaches were still present. Twelve months following the onset of the study indoxacarb was detectable in only 2 out of 69 apartments.

Vernis, L., H. Zorn, B. Glandorf, L. Herman, J. Aguilera, M. Andryszkiewicz, Y. Liu, A. Chesson, and Efsa. 2019. Updated peer review concerning the risk to mammals and bees for the active substance indoxacarb. Efsa Journal 17.

The European Food and Safety Authority completed a risk assessment for the use of indoxacarb to control pest in corn crops on small herbivorous and earthworm eating mammals, honeybees, and bumble bees. The committee concluded that the use of indoxacarb in corn crops poses high risk for secondary poisoning of small herbivorous mammals following a single application, and to earthworm eating mammals following repeated applications. They also concluded that indoxacarb adult honeybees and bumble bees risk have a high risk of being poisoned if the indoxacarb is applied before or during the flowering period, but not if applied after flowering.

4.6 PHENOTHRIN

No studies published in 2019 described the human health risks, ecological effects, or the environmental fate of phenothrin.

4.7 PRALLETHRIN

No studies published in 2019 described the human health risks, ecological effects, or the environmental fate of prallethrin.

4.8 S-HYDROPRENE

No studies published in 2019 described the human health risks, ecological effects, or the environmental fate of S-Hydroprene.

4.9 SODIUM TETRABORATEDECAHYDRATE

No studies were published in 2019 that describe human health risks, ecological effects, or the environmental fate of sodium tetraborate decahydrate.

5.0 RODENTICIDE**5.1 CHOLECALIFEROL**

No studies were published in 2019 that describe human health risks, ecological effects, or the environmental fate of cholecalciferol when it is used as a rodenticide.

APPENDIX B4

Pesticide Technical Background Information for Pesticides in 2014 Program (2014)

Pesticide Technical Background Information



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1 Introduction

The Midpeninsula Regional Open Space District (District) undertakes weed and vector management activities to control noxious and invasive weeds and mobile vectors such as mosquitoes, wasps, hornets, Argentine ants, cockroaches, rats, mice, and certain wildlife (e.g., skunks, raccoons, opossum) that are a nuisance or risk to human and ecological health on District lands.

Because of the importance of providing needed weed and vector control without causing undue adverse impacts to human and ecological health, the District intends to implement a modified Integrated Pest Management (IPM) Program that embodies the use of the most effective, least toxic, suite of treatment options.

IPM is an adaptive strategy developed and utilized to manage insect, weed, and pathogen pest species in production agriculture and urban landscaping environments. Using modified, but similar, IPM strategies to manage wild lands is a relatively new approach and has only been undertaken by a small number of land management agencies. The District intends to evaluate, recommend, and implement weed and vector management in an effective and least toxic manner using currently available and defensible new pest control approaches. The District intends to become a leader in this new application of IPM philosophy and implementation for District wild lands.

While this cutting edge approach to land management can provide safer, more effective approaches to controlling unwanted vegetative and pest vectors, it is essential to understand the physical and chemical characteristics, relative toxicity, and possible adverse impacts to non-target receptors (i.e., humans, domestic pets, non-target wildlife and vegetation) of any pesticides that may be used. The technical background presented in this appendix will provide the necessary information for each pesticide considered for use in the District's IPM to provide the following results when chemical methods are necessary to meet a pest control objective:

- > Providing the most effective treatment of unwanted vectors while achieving the most appropriate and least toxic safe application techniques.
- > Reducing the potential for human and non-target animal exposure to chemicals.
- > Reducing the potential adverse impacts to humans, animals and non-target vegetation.
- > Reducing the potential for human and non-target animal discomfort or injury from applications and from exposure to non-vegetative vectors.

This technical background appendix addresses these objectives for the pesticides being considered to support the IPM approach for the District. In order to comprehensively evaluate the potential safety of the selected pesticides, each candidate chemical (active ingredient or product) is reviewed and evaluated for its reported fate and transport in the environment (summarized for quick reference in Table 1.1) and toxicity to humans and non-target wildlife and vegetation (summarized in tables at the end beginning of each pesticide category section). The evaluations are grouped by the general categories of herbicide, fungicide, rodenticide, insecticide, and several chemicals incorporated as additives (surfactants and "inert" ingredients).

Table 1-1 Summary of Pesticides under Consideration for use by the District

The tables below provide a general overview of the characteristics of each of the pesticides used or being considered by the district. Each category in the table is supplemented in greater detail in tables included in sections four and five. This table is intended for a “quick look” evaluation of the potential effects and toxicity to humans, wildlife, and some physiochemical characteristics of each.

Herbicides- General term for Pesticides developed specifically to target unwanted vegetation

Product and Manufacturer	Mode of Action	Purpose	Toxicity Rank-Humans	Toxicology Non-Target and Wildlife	Solubility and Half Life water	Persistence and Half-life soils	Food Web Issues?	Safe to Children?	MSDS Flags and Cautions
Glyphosate – <i>Roundup Custom, Roundup ProMax</i> (Monsanto)	Amino acid synthesis inhibitor	Nonselective post-emergent broad-spectrum weed control	Low- No evidence of carcinogenicity, neurotoxicity, immunotoxicity. Possible reproductive toxicity very large doses	Practically non-toxic to birds and aquatic invertebrates Surfactants may have toxicity to amphibians	High water solubility	Moderate Persistence Binds to soil Strong soil adsorption Binds to soils and sediment	Since <i>glyphosate</i> does not bioaccumulate in fish or other animals it is not likely to have impacts on the ecological <i>food chain</i>	Very low toxicity to children unless direct consumption of large amounts of chemical.	Practically non-toxic. No known health hazard.
Aminopyralid <i>Milestone</i> Dow Agro	Auxin growth hormone mimic	post-emergent broad-spectrum weed control	Low toxicity to humans. No evidence of carcinogenicity, neurotoxicity, immunotoxicity, or reproductive or developmental toxicity	Practically non-toxic to birds, fish, aquatic invertebrates, amphibians, and honey bees.	Non-persistent in water and soil. Breaks down rapidly in water. Half life is about 0.6 days due to photolysis.	Very low persistence with aerobic half life of avg 103 days.	Due to its low persistence and rapid excretion in animals it is not likely to impact food chain uptake.	Very low toxicity to children unless direct consumption of large amounts of chemical.	Practically non-toxic. No real health hazard.
Clopyralid <i>Transline</i> Dow Agro	Auxin growth hormone mimic	Selective broadleaf weed control	Low toxicity. Neurotoxicity caused by acute poisoning. No evidence of carcinogenicity, immunotoxicity, or reproductive or developmental toxicity	Practically non-toxic to birds, fish, aquatic invertebrate and honey bees	Degrades rapidly in water. Half-life @ 9-22 days	Low likelihood of leaching to ground water. Binds to soils. Half life @40 days.	Very little potential for bioaccumulation or food web impact.	Very low toxicity to children unless direct consumption of large amounts of chemical.	Practically non-toxic. No real health hazard.

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Imazapyr <i>Polaris</i> (Nufarm) <i>Stalker</i> (BASF)	Amino acid synthesis inhibitor	Nonselective pre-and post-emergent broad-spectrum weed control	Low toxicity. No evidence of carcinogenicity, neurotoxicity, immunotoxicity, or reproductive or developmental toxicity	Practically non-toxic to birds, fish, aquatic invertebrates and honey bees	Soluble in water and degraded quickly via photolysis. ½ life @3-8 days.	Moderate potential for soil leaching to groundwater. Moderate soil adsorption.	Rapidly excreted and little potential for bioaccumulation or food web impact.	Very low toxicity to children unless direct consumption of large amounts of chemical.	Practically non-toxic. No real health hazard
Clethodim <i>Envoy Plus</i> (Valent)	Fatty acid synthesis inhibitor	Selective post-emergent grass weed control	Low toxicity. No evidence of carcinogenicity, neurotoxicity, immunotoxicity, or reproductive or developmental toxicity	Slightly toxic to birds, fish, and aquatic invertebrates, practically non-toxic to honey bees	Insoluble in water. ½ life in water @128 days	Short half-life in soil, and unlikely to leach in ground water. ½ life in soil @1-2 days. @128days in sediment.	No apparent uptake via food web issues. Approved for applications to edible food crops.	Very low toxicity to children unless direct consumption of large amounts of chemical.	Practically non-toxic. No real health hazard

1.1 Review and Evaluation Process

Data encompassing the available acute and chronic toxicity of the various active ingredients to numerous mammalian, avian, fish, aquatic invertebrate, and non-target insect species are included herein. In many cases, manufacturers do not include or disclose the proprietary additional ingredients in a product. The product approved for use is tested as the label indicates. Acute data are derived from experiments in which the target organisms are exposed to a single dose/concentration of a compound, and the endpoint, usually survival, is measured 48 or 96 hours post-exposure. Chronic data are derived from experiments in which the experimental organisms are exposed to multiple doses of a compound over an extended period of time, ranging from weeks to months depending on the organism and endpoint of interest (e.g., development, reproduction, carcinogenicity).

1.1.1 Calculations, Uncertainty, Conservatism, and Extrapolations in Toxicity Data

The toxicity of a pesticide (i.e., herbicides, rodenticides, fungicides, and insecticides) is determined by the documented adverse laboratory and field effects to target and non-target organisms that occur after an exposure to that compound. Thus, the key to potential adverse (toxic) effects is the nature of the exposure to the compound, which is based on the specific amount of the compound that reaches an organism's target tissues (i.e., the dose). Several other factors are involved in an exposure, such as the duration of time over which the dose is received, the target tissue or physiological function affected, and the sensitivity of the organism of interest to the compound.

The toxicity of pesticides are generally measured in controlled laboratory or field studies in which the test organisms are exposed to contaminated food or doses of a test substance at several concentrations. Most regulatory studies are designed to evaluate toxic responses based on tiered increases of dose and to determine at what dose the onset of an adverse physiological or behavioral effect occurs. Toxicity studies commonly evaluate the Lethal Dose or LC₅₀, the

dose/concentration that causes mortality in 50% of the test population and the: no observed adverse effect level NOAEL); or the lowest concentration that causes a measured adverse effect (LOAEL). Many toxicity tests, laboratory organisms are not provided alternative food sources, and as a result, these laboratory tests are not particularly representative of realistic exposures in the environment. Furthermore, effects in laboratory species many not adequately represent effects in environmentally relevant species due to genetic, physiological, and behavioral differences. For many pesticides, the suite of tests required for approval of a compound includes other types of exposure, such as dermal, inhalation, and dietary. All of these laboratory data are combined to develop the pesticide product label recommendations and restrictions, incorporating several "safety" factors to provide acceptable use of each product. As a result of the extensive use of safety factors, surrogate test species, and unrealistic exposures to the laboratory animals, the pesticide data available for evaluation of potential adverse impacts for these compounds are subject to uncertainty and conservatism in actual potential effects.

Numerous biological, chemical, and physical parameters that are not apparent in laboratory tests affect the behavior of a compound in the environment and its potential toxicity. The chemistry, and particularly the fate and transport of a compound, must be considered to estimate likely potential exposure. The fate and transport of a compound is determined by the physical and chemical properties of the compound itself and the environment into which it is released. Thus, the following characteristics of a compound are considered when estimating potential adverse effects: 1) its half-life in various environmental media (e.g., sediment, water, air), including its photolytic half-life; 2) lipid and water solubility; 3) adsorption to sediments and plants; and 4) volatilization. Environmental factors that affect fate and transport processes include temperature, rainfall, wind, sunlight, water turbidity, and water and soil acidity (pH). Each of these parameters can markedly influence the potential exposure to a pesticide by modifying its characteristics in the environmental media.

A certain level of exposure to a compound is necessary for potential toxic effects to occur, but an exposure does not, in itself, imply that adverse effects will occur. The potential toxicity of a pesticide can be reduced or mitigated by limiting or modifying the conditions of potential exposure to ensure that resulting doses are less than an amount that may result in adverse effects. The important characteristics of a pesticide are considered before and during any pesticide application by the District, which employs numerous best management practices (BMPs) to minimize the potential for unwanted adverse impacts to non-target species. The culmination of all this information, and its relation to the specific application considered, provides a proven foundation for assuring the most effective, yet relatively safe, use of pesticides when treatment is determined to be needed.

1.1.2 Toxicity Designations

The results of laboratory tests are reported as the highest dose that does not cause any adverse effects (No Observed Adverse Effects) and the dose where adverse effects first appear (Lowest Observed Adverse Effects, LOAEL) and the dose that results in mortality to 50% mortality (LC₅₀).

Figure 1.

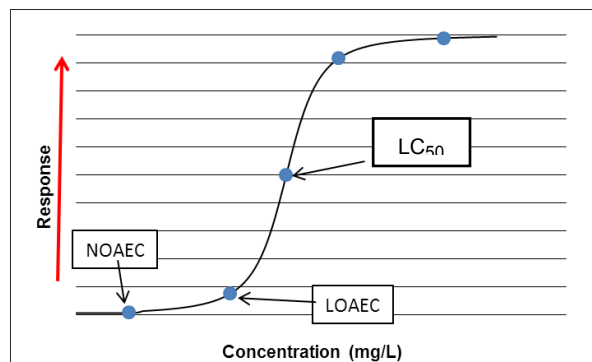


Figure 1. Relative doses reported in laboratory toxicity studies. (Generalized Sigmoidal Concentration-Curve).

1.1.3 Evaluation of Potential Human Health Impact

The information provided for each of the selected pesticides supports a defense of very low risk or “no significant adverse effects (NSAE)” on

humans. Assessments include information about the ingredients reported in the Material Safety Data Sheet (MSDS), pesticide registration documents, and peer-reviewed scientific literature. Review of the pesticide formulations, label recommendations, and application procedures is used to evaluate their potential likelihood for exposure, toxicity, and bioaccumulation. For each pesticide evaluated, information herein includes the physiochemical characteristics of the product, including absorption, metabolism, and elimination, and any other specific reported evidence of acute and chronic effects including reproductive, developmental, or carcinogenic effects.

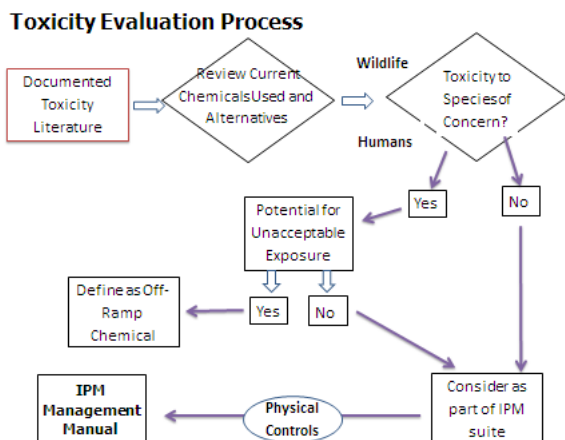
1.1.4 Evaluation of Potential Ecological Impact

Successful application of the IPM approach depends on defensible assessment of the hazards for each of the current reported application scenarios and an evaluation of the possible impacts to representative non-target wildlife (avian, aquatic vertebrate and invertebrate, amphibian, and bee species) and vegetation. This evaluation includes information relevant to the ultimate environmental fate and transport of active and certain “inert” ingredients (when available) as well as review and evaluation of the current toxicity literature (available field and laboratory studies) relevant to non-target ecological receptors impacts and the potential for increased exposure due to food web uptake and accumulation in higher trophic level animals or in vegetation (bioconcentration, bioaccumulation, or biomagnification).

The following use, efficacy, environmental fate and transport, water pollution potential, and toxicity information of the chemicals of interest for the District’s IPM is based on available, documented, and validated government and peer-reviewed experiments and reports.

1.1.5 Ranking of Pesticide Toxicity

Pesticides are evaluated using documented toxicity and adverse effects to humans and animals (Figure 3) and sorted to develop the most effective, yet safe pesticides for use in specific application scenarios.



in IPM applications.

After determination of the toxicity of each pesticide of interest using the process in Figure 3, the toxicity information is used to rank each pesticide according to its potential to cause adverse effects in non-target organisms. The four levels (1-4) of relative toxicity (USEPA) for each general category of species is included in Table 1.2 below.

Each of the pesticides included in this review have been evaluated by USEPA and state agencies and the toxicity results are included in the several tables associated with each category of pesticide. Each pesticide has been ranked for target and non-target toxicity, potential bioaccumulation, food web transfer, and several physio/chemical characteristics, including half-life, solubility, and other parameters that may affect total exposure over time.

1.1.6 Toxicity Interactions and Alterations.

The toxicity of a pesticide is dependent on the concentration of active ingredients and the timing and duration of the exposure. The length of time that a pesticide persists after application is measured as its $\frac{1}{2}$ life in water and/or soil. Although many earlier pesticides, primarily organochlorines like DDT and other highly toxic chemicals were shown to persist in media for months and even years. However, the current pesticides available for pest control have substantially shorter $\frac{1}{2}$ lives and often remain for only a few days. However, when treating to impact a critical pest life stage, it may be

necessary to use a more toxic product that does not last long in the environment. However, for the less toxic pesticides it is often best to utilize separate but successive applications to cover the pest's likely activity cycle.

Pesticide applications are based on two general chemical and physical properties of the pesticide intended for use in the control of specific pests. Efficacy (relative toxicity to the pest) and the persistence of the product in the treated area are evaluated and considered to provide the most effective treatment scenarios resulting in the least unwanted side effects.

Pesticide toxicity in laboratory tests is not always translated to the laboratory effects in actual use scenarios because laboratory tests generally utilize unrealistic exposures to an active ingredient without any possible alternative sources or exposures.

In some cases, it is preferable to use several very low application doses over time to make sure the target pests are adequately controlled. This increases the likelihood that the pesticide will be effective and any side effects (non-target effects) will be alleviated or minimized.

For those applications where it is critical to significantly eradicate a specific life stage, larger doses may be used with very specific focus rather than widespread applications.

In both of these application scenarios, care is taken using documented Best Management Practices and experienced applicators to select the appropriate timing and doses to achieve control of unwanted pest vectors.

Experienced and trained pesticide applicators, using the proper choice and doses of target-specific chemicals, can provide effective pest control with minimal to no unwanted side effects or impacts to non-target species or the environment.

Table 1.2. USEPA Categories Used to Rank Pesticide Toxicity

Route of Exposure	I: High Toxicity	II: Moderate Toxicity	III: Low Toxicity	IV: Very Low Toxicity
Acute Oral LD50	≤50 mg/kg	50-500 mg/kg	500 – 5000 mg/kg	>5000 mg/kg
Acute Dermal LD50	≤200 mg/kg	200 – 2000 mg/kg	2000 – 5000 mg/kg	>5000 mg/kg
Acute Inhalation LC50	≤0.05 mg/L	0.05 - 0.5 mg/L	0.5 - 2 mg/L	>2 mg/L
Primary Eye Irritation	Corrosive (irreversible destruction of ocular tissue) or corneal involvement or irritation persisting for more than 21 days	Corneal involvement or irritation clearing in 8-21 days	Corneal involvement or irritation clearing in 7 days or less	Minimal effects clearing in less than 24 h
Primary Skin Irritation	Corrosive (tissue destruction into the dermis and/or scarring)	Severe irritation at 72 h (severe erythema or edema)	Moderate irritation at 72 h (moderate erythema)	Mild or slight irritation (no irritation or slight erythema)

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2 Herbicides

Table 2-1 Human Toxicity Summary of Herbicide Active Ingredients

Active Ingredient	Mammalian Oral LD50 (mg/kg) ^A	Mammalian Dermal LD50 (mg/kg) ^B	Mammalian Inhalation LC50 (mg/L) ^A	USEPA Toxicity Rating	Carcinogenic	Reproductive or Developmentally Toxic	Neurotoxic	Immunotoxic	Endocrine Disruption
Glyphosate	>4,320 (technical); ≥5,000 (salts)	≥2,000 (tech); ≥5,000 (salts)	≥4.43 (tech); >1.3 (salts)	Oral, dermal, inhalation (III)	No	No	No	No	In human cell lines at very high doses
Aminopyralid	>5,000	>5,000	>5.79	Oral, dermal, inhalation (IV)	No	No	No	No	No
Clopyralid	>5,000	>5,000	>3.0	Oral, dermal, inhalation (III)	No (may contain hexachlorobenzene – potential human carcinogen)	No	Yes	No	No
Imazapyr	>5,000	>2,000	>1.3	Oral, dermal, inhalation (IV)	No	No	No	No	No
Clethodim	>5,000	>5,000	>3.9	Oral, dermal, inhalation (IV)	No (Envoy contains naphthalene – potential human carcinogen)	No	No	No	NA

Table 2-2 Ecotoxicity Summary of Herbicide Active Ingredients

Active Ingredient	Mammalian Oral LD50 (mg/kg) ^A	Mammalian Dermal LD50 (mg/kg) ^B	Mammalian Inhalation LC50 (mg/L) ^A	Avian LD50 (mg/kg) ^C	Fish LC50 (mg/L) ^D	Aquatic Invert EC50 (mg/L) ^E	Honeybee LD50 (µg/bee)	Other Receptors
Glyphosate	>4,320 (technical); ≥5,000 (salts)	≥2,000 (tech); ≥5,000 (salts)	≥4.43 (tech); >1.3 (salts)	>2,000	140 (tech); 1.3 to >1,000 (salts)	55 to 780	>100	Frog LC50 >17.9 mg/L; 1-yr dog NOAEL = 500 mg/kg/day
Aminopyralid	>5,000	>5,000	>5.79	>2,250	>100	>98.6	Contact >100; Oral >117	Northern leopard frog 96-h LC50 > 95.2 mg/L
Clopyralid	>5,000	>5,000	>3.0	>1,645	103-125	225	>100	Dog NOAEL = 100 mg/kg/day
Imazapyr	>5,000	>2,000	>1.3	>2,150	>100	>1,000	>100	1-yr dog NOAEL = 250 mg/kg/day
Clethodim	>5,000	>5,000	>3.9	>2,000	67-120	>120	>100	NA

A. Unless otherwise specified, values are for rats.

B. Unless otherwise specified, values are for rabbits.

C. Unless otherwise specified, values are for mallard duck or bobwhite quail.

D. Unless otherwise specified, values are for rainbow trout or bluegill sunfish.

E. Values are for Daphnia or similar species.

2.1 Glyphosate

GLYPHOSATE

Formulations: Roundup ProMax; Roundup Custom (previously Aquamaster)

- > Human Toxicity: Low toxicity. Skin and eye irritation possible. No evidence of carcinogenicity, neurotoxicity, immunotoxicity, or toxicity. Reproductive toxicity at very high doses.
- > Ecological Toxicity: Technical grade is practically non-toxic to birds, fish and aquatic invertebrates. POAE surfactant used in some formulations causes toxicity to amphibians.
- > Water Pollution Potential: Moderate persistence in the environment. High water solubility, but strongly adsorbs to soil. Sometimes found in surface and ground water in locations of high use.
- > Other Considerations: Glyphosate resistance has been documented in areas of high use.

2.1.1 Basic Use Information

- > Products: *Roundup ProMax*, *Roundup Custom* (previously *Aquamaster*)
- > Typical target pests: Grasses, Brush, Vines, Thistles, unwanted woody plants, Spurges
- > Application rates:

General Weed Management: Grasses, Brush, Vines, Thistles

Material	Rate per 100 gal	Rate per gal (handheld)	Volume/acre
Adjust buffer	½ - 4 pints	To be used if water has pH >7	
Roundup ProMax*	0.4 – 1.5 gal	0.5 – 2 oz.	Spot spray – variable rate
Dye (as necessary)	0.25 gal (1 qt)	0.25 oz.	

*Do not exceed maximum use rate of 7 quarts (8 lbs acid) of product per acre per year.

Cut Stump: *Acacia*, *Baccharis*, *Cytisus*, *Eucalyptus*, *Genista*, *Ilex*, *Spartium*

Material	Rate per 100 gal	Rate per gal (handheld)	Volume/acre
Roundup ProMax*	50 gal	64 oz.	Cut stump variable rate
Dye (as necessary)	1 qt	0.25 oz.	

*Do not exceed maximum rate of 7 quarts (8 lbs acid) per acre per year – especially when treating dense stands of cut stumps.

Sponge/Wick: Grasses, Brush, Vines, Thistles

Material	Rate per 100 gal	Rate per gal (handheld)	Volume/acre
Roundup ProMax*	25-50 gal	32-64 oz.	Wiper/Sponge variable rate
Dye (as necessary)	1 qt	0.25 oz.	

*Do not exceed maximum rate of 7 quarts (8 lbs acid) per acre per year – especially when treating dense stands of vegetation.

Waxy Leaves: Spurges – *Euphorbia oblongata* and Vines

Material	Rate per 100 gal	Rate per gal (handheld)	Volume/acre
Roundup Custom	1.5 gal	2 oz.	Spot spray – variable rate
Liberate NIS	2 qt.	0.6 oz.	
Dye (as necessary)	0.25 gal (1 qt)	0.3 oz.	

*Do not exceed maximum use rate of 8 quarts (8 lbs. acid) of this product per acre per year.

Glyphosate [N-(phosphonomethyl)glycine] is a nonselective, post-emergent, and systemic herbicide registered for use in agricultural and nonagricultural areas. It is applied to a variety of food crops and agricultural drainage, sewage, and irrigation systems. There are several formulations of glyphosate, including an acid, monoammonium salt, diammonium salt, isopropylamine salt, potassium salt, sodium salt, and trimethylsulfonium or trimesium salt. It is highly effective for the control of weeds and invasive species. Glyphosate is a plant growth regulator that functions by targeting the plant-specific shikimic acid pathway, inhibiting the synthesis of the enzyme 5-enolpyruvylshikimic acid-3-phosphate synthase, leading to reductions in aromatic amino acids necessary for plant protein synthesis and growth (Miller et al., 2010). Glyphosate is not effective on submerged or mostly submerged foliage and therefore is only applied to control emergent foliage (Schuette, 1998; Siemerling, 2005).

2.1.2 Exposure Considerations

Glyphosate is a broad spectrum, non-selective herbicide used by the District as the active ingredient in Roundup ProMax and Roundup Custom (previously named Aquamaster) to control invasive weeds including grasses, brush, vines, and thistles via foliar sprays or direct wipe/sponge onto the weeds. Both are used only in specific instances where other pest control methods such as hand pulling or mowing of weeds are not safe or effective options. These spray techniques involve highly localized and focused applications applied to specific, delineated areas with an emphasis on care and control of overspray or off-spray. They are applied at low pressure (30-70 psi) by hand held wands or guns only when wind is between 2-7 mph to reduce drift and never when there is a 40% or greater forecast of rain within 24 h of a planned application. The low and high rate foliar applications of both formulations are 0.5% v/v and 1.5% v/v, respectively, and the low and high rate wipe/sponge treatment rates are 25 and 50% v/v, respectively. Both formulations are also used for treatment of unwanted woody shrubs and trees. To reduce run-off and non-target exposure, they are applied (25% v/v) directly onto the inside

(avoiding the exterior bark) of a woody stem/stump immediately following stump cutting and under the same restrictions as those for foliar applications using approved and BMP spray techniques.

Application sites are prohibited within defined critical habitats for the red-legged frog. For other rare plant and wildlife species, Applications may occur in certain conditions. A qualified biologist that can identify all rare plant and wildlife species present within the application area will supervise all applications of the pesticide to ensure non-target specie are not effected. Application is also restricted around water and wetlands. A buffer of at least 15 ft or greater from aquatic systems is typically implemented during Roundup ProMax use, as it contains the surfactant POAE. Roundup Custom does not contain this surfactant and is approved for use in/near aquatic systems. It is used in conjunction with the nonionic soybean-based surfactant Liberate NIS (discussed in sections 6.2 and 6.3).

2.1.3 Human Toxicity

The shikimic acid pathway is specific to plants and some microorganisms; therefore, glyphosate has very low acute toxicity to mammals. The USEPA classifies glyphosate as Category III for oral and dermal toxicity. The oral LD50 for technical grade glyphosate for rats is >4,320 mg/kg; the oral LD50 for the isopropylamine salt in rats is ≥5,000 mg/kg; and the oral LD50 for the ammonium salt in rats is 4,613 mg/kg (USEPA, 1993b). The dermal LD50 for technical grade glyphosate in rabbits is ≥2,000 mg/kg (USEPA, 1993b), and the dermal LD50 for rabbits is ≥5,000 mg/kg for both salts (Miller et al., 2010). The LC50 for technical grade glyphosate in rats is ≥4.43 mg/L based on a 4-hr, nose-only inhalation study (USEPA, 1993b); the 4-hr LC50 for rats exposed to the isopropylamine salt is >1.3 mg/L air; and the LC50 for rats exposed to the ammonium salt is >1.9 mg/L in a whole-body exposure (Miller et al., 2010).

No chronic adverse effects were observed in beagles exposed to daily doses of 500 mg/kg for one year. Glyphosate has not been shown to be carcinogenic or mutagenic (USEPA, 1993b). The USEPA has classified glyphosate in Group E –

evidence of non-carcinogenicity in humans. Developmental LOAELs range from 1,500-3,500 mg/kg/day in rats. Neither glyphosate nor its major metabolite aminomethylphosphonic acid (AMPA) bioaccumulate in animal tissue. Glyphosate is poorly biotransformed in rats and is excreted mostly unchanged in the feces and urine; 97.5% of the administered dose was excreted in the urine and feces of rats (Williams et al., 2000). The USEPA's Office of Pesticide Programs Reference Dose (RfD) Peer Review Committee has recommended that the RfD for glyphosate be established at 2 mg/kg/day.

Despite the documented scientific research used to evaluate the toxicity to dozens of species required by USEPA to register pesticides, public concern about the toxicity to mammals have been raised about the long-term safety of glyphosate. Only extremely high doses, far beyond any potential exposure that would be seen in actual application have been associated with adverse effects to mammalian systems. In one study, forced ingestion of high doses of glyphosate was shown to alter the respiratory and hepatic systems of rats and caused damage to reproductive functions and fetal development (Clair et al., 2012). In another study, male rats fed a diet containing 25,000 and 50,000 mg/kg (unrealistically high doses of up to 25% of their total body weight) of 99% pure glyphosate for 13 weeks had significant reductions in sperm concentrations. Female rats in the 50,000 mg/kg group had slightly longer estrus cycles than the control group (Chan and Mahler, 1992). Each of these studies elicited toxic effects only after unrealistically high doses of glyphosate

2.1.4 Ecological Toxicity

In toxicological studies, Glyphosate is practically nontoxic to birds. The oral LD50 for bobwhite quail is >2,000 mg/kg, and the 8-day sub-acute dietary LC50 is >4,640 ppm for mallard ducks and bobwhite quail. Glyphosate is also practically nontoxic to freshwater fish, and it is not expected to bioaccumulate. The 48-h LC50 for technical grade glyphosate is 140 mg/L for bluegill sunfish, 140 mg/L for rainbow trout, and 97 mg/L for fathead minnow (USEPA, 1993b). Formulations of the isopropylamine salt range from practically non-toxic to moderately toxic to fish (96-h LC50s

range from 1.3 to >1,000 mg/L for various formulations). Technical grade glyphosate is practically nontoxic to slightly toxic to freshwater invertebrates with 48-hr LC50s ranging from 55 to 780 mg/L, and the isopropylamine salt ranges from practically non-toxic to moderately toxic. The 96-h LC50 for technical grade glyphosate is >17.9 mg a.e./L (the highest dose tested) in green frog (Howe et al., 2004). However, based on surrogate species information (primarily avian), USEPA has made a "may affect" or "likely to adversely affect" determination for the endangered California Red-legged Frog following chronic exposure to glyphosate at application rates of 3.84-7.5 lb a.e./acre and above (certain crops, forestry, areas with impervious surfaces and rights of way) (USEPA, 2008b). It is listed as "may affect but is not likely to adversely affect" endangered and threatened salmonids (Patterson, 2004). Glyphosate is practically nontoxic to honey bees. The acute oral and contact LD50 is >100 µg/bee (USEPA, 1993b).

Polyethoxylated tallowamine (POEA) is a surfactant used in some glyphosate formulations, including some Roundup mixtures. Several studies have indicated that the toxicity observed in tadpoles of various frog species exposed to different Roundup mixtures is due to this surfactant and not glyphosate itself; calculated LC50s for certain Roundup mixtures are an order of magnitude or more lower than technical glyphosate or formulations that do not contain POEA (Howe et al., 2004; Mann and Bidwell, 1999; Relyea, 2005). POEA has also been shown to be highly toxic to aquatic invertebrates and fish, and glyphosate formulations containing POEA are also more toxic than those without the surfactant (Brausch and Smith, 2007; Giesy et al., 2000). Roundup Custom, which is approved for use near and in water sources, is a formulation of glyphosate dissolved in water and does not contain POEA.

2.1.5 Physical Properties/Environmental Fate and Transport

The vapor pressure of glyphosate is very low, making it nonvolatile. It tends to partition to water rather than air. It is highly water-soluble. Glyphosate dissipates from surface water by

partitioning into sediment. It is stable to hydrolysis and photodegradation in water and soil, and it is degraded primarily by microbial degradation in both water and sediment (Barrett and McBride, 2005; Newton et al., 1994). The major metabolite of glyphosate is AMPA. Degradation of AMPA is generally slower than that of glyphosate because AMPA likely adsorbs more strongly to soil particles and because it may be less likely to permeate the cell walls or membranes of soil organisms (Schuette, 1998). AMPA exhibits similar or less toxicity than the original parent glyphosate (Borggaard and Gimsing, 2008).

In soil, glyphosate is resistant to chemical degradation, is stable to sunlight, is relatively non-leaching, and has a low tendency to runoff (except as adsorbed to colloidal matter and sediment). It is relatively immobile in most soil environments and does not move vertically below the 6 inch soil layer. Glyphosate's primary route of decomposition in the environment is through

microbial degradation in soil ($t_{1/2}$ = 8-25 days). The herbicide is inactivated and biodegraded by soil microbes at rates of degradation related to microbial activity in the soil and factors that affect this activity. The biological degradation process is carried out under both aerobic and anaerobic conditions (Schuette, 1998; USEPA, 1993b).

2.1.6 Water Pollution Potential

Glyphosate is very soluble in water; however, due to its strong soil adsorptive characteristics, limited amounts of glyphosate have been found in surface water as a result of runoff (Borggaard and Gimsing, 2008; Vereecken, 2005). Glyphosate has been detected in surface waters in areas of very high Roundup use, such as the Midwest, but at levels lower than the California drinking water standard for the compound (<0.7 mg/L). Glyphosate dissipates quickly in ponds and streams to below detection limit in 3-14 days (Schuette, 1998).

2.2 **Aminopyralid**

AMINOPYRALID

Formulations: Milestone

- > Human Toxicity: Low toxicity. No evidence of carcinogenicity, neurotoxicity, immunotoxicity, or reproductive/developmental toxicity.
- > Ecological Toxicity: Practically non-toxic to birds, fish, aquatic invertebrates, amphibians, and honey bees.
- > Water Pollution Potential: Likely to be non-persistent in the environment. Highly photolabile in water.

2.2.1 Basic Use Information

- > Products: *Milestone*
- > Typical target pests: Thistles; Sweet Pea; Cape ivy.
- > Application rates:

Material	Rate per acre	Rate per 1000 sq. ft	Volume/acre
Milestone*	3-7 oz.	Lo: 2 ml or 0.07 fl. oz. Hi: 4.8 ml or 0.16 fl. oz.	Variable - Applicator responsible to calibrate equipment for proper application rate
Liberate NIS	Variable per acre (0.5% v/v)	Variable	
Dye (as necessary)	Variable	Variable	

* Do not exceed maximum rate of 7 oz. (0.11 lb acid) of product per acre during a single growing season or 14 oz. (0.22 lb acid) per acre where no more than 50% of the acre is treated by spot spraying.

Aminopyralid (4-amino-3,6-dichloropyridine-2-carboxylic acid) is a pyridine carboxylic acid herbicide that provides systemic post-emergence broad-spectrum control of a number of noxious and invasive annual, biennial, and perennial weeds, as well as agronomic broadleaf weeds (USEPA, 2005). Aminopyralid is an auxin growth hormone mimic, affecting cell wall plasticity and nucleic acid metabolism. It has been classified as a low risk herbicide, meaning that USEPA has concluded that the use of aminopyralid as a replacement for other herbicides will decrease the risk to some non-target species (Syracuse Environmental Research Associates, 2007). Its manufacturer, Dow AgroSciences, indicates that aminopyralid is intended as an alternative to picloram, 2,4-D, dicamba, monosodium methanearsonate (MSMA), and metsulfuron methyl (Jachetta et al., 2004; Syracuse Environmental Research Associates, 2007).

2.2.2 Exposure Considerations

Aminopyralid, the active ingredient in Milestone, is used to control invasive broadleaf weeds including thistles, and sweet pea. It is selective for broadleaf plants and does not harm grasses if used after germination. It is not used when wind speeds are greater than 7 mph or when the chance of rain is 40% or greater within 24 h of the planned application. Milestone is used at a rate of 3 oz/acre for pre-emergent applications in winter and early spring and at 5 oz/acre for post-emergent applications. A special high rate of 14 oz/acre is used for spot treatment of cape ivy vines in riparian zone tree canopies during winter. It is used in conjunction with the nonionic surfactant Liberate NIS (discussed in sections 6.2 and 6.3).

Application sites are not within defined critical habitats for the red-legged frog; however, a qualified biologist that can identify all rare plant and wildlife species present within the application area will supervise all applications of the pesticide. It is not to be applied directly to water, and it is used only with a 15 ft or greater buffer between aquatic systems and application sites.

2.2.3 Human Toxicity

Due to the relative newness of aminopyralid, the only acute toxicity studies for the compound are those that were conducted as part of the initial USEPA registration process. Based on these studies, the USEPA has classified aminopyralid as having low acute oral, dermal, and inhalation toxicity (all Category IV). The oral and dermal LC50s for Milestone in rats are both >5,000 mg/kg, and the inhalation LC50 is >5.79 mg/L (USEPA, 2005). Chronic rat neurotoxicity studies and two generation reproductive studies have indicated NOAELs >1,000 mg/kg/day for both endpoints (USEPA, 2005).

The mechanism of toxicity to mammals has not yet been well-characterized. The most typical response of rats to aminopyralid appears to be cecal enlargement after prolonged oral exposure; however, the toxicological significance of this response is unclear (Syracuse Environmental Research Associates, 2007). Aminopyralid is rapidly excreted after exposure, likely by the well-characterized active transport mechanism via the kidneys seen after ingestion of similar herbicides such as picloram. Aminopyralid has not been shown to cause cancer, neurotoxicity, immunotoxicity, teratogenesis, reproductive effects, genotoxicity or mutagenicity in laboratory studies (Dow AgroSciences, 2006; Syracuse Environmental Research Associates, 2007). Due to its low toxicity, an acute RfD for aminopyralid is not required by the USEPA. The chronic RfD for aminopyralid is 0.5 mg/kg bw/day.

2.2.4 Ecological Toxicity

Aminopyralid is practically non-toxic to birds, fish, aquatic invertebrates, amphibians, and honey bees on an acute basis (Dow AgroSciences, 2006; USEPA, 2005). The acute LD50 for bobwhite quail is >2,250 mg/kg, and the dietary 5-day LC50s in bobwhite quail and mallard duck are >5,556 mg/kg diet and >5496 mg/kg diet, respectively. The 96-h LC50s for rainbow trout and bluegill sunfish are >100 mg/L, and the 96-h LC50 for sheepshead minnow is >120 mg/L. The log KOW is <3 and thus aminopyralid is not expected to bioaccumulate in fish tissues. The 48-h LC50 in *Daphnia magna* is >98.6 mg/L; the 48-h EC50 for

Eastern oyster is >89 mg/L; and the 96-h LC50 for mysid is >100 mg/L. A single acute toxicity study has been performed for amphibians, and there was no indication that aminopyralid was toxic to northern leopard frog tadpoles (LC50 >95.2 mg/L) (Henry et al., 2003; Syracuse Environmental Research Associates, 2007). Aminopyralid is also practically non-toxic to honey bees with acute contact and oral LD50s of >100 µg/bee and >117 µg/bee, respectively. There are no known acute or chronic risks to non-target endangered or non-endangered fish, birds, wild mammals, terrestrial and aquatic invertebrates, algae, or aquatic plants (USEPA, 2005).

2.2.5 Physical Properties/Environmental Fate and Transport

Aminopyralid is essentially nonvolatile. In aquatic systems, it is highly photolabile. It is stable to direct hydrolysis, stable in anaerobic sediment-

water systems, and weakly sorbs to soil. It is likely to be non-persistent and relatively immobile in the field with minimal leaching below the 15 to 30 cm soil depth. Under aerobic conditions, degradation results in the production of CO₂, ammonia, and non-extractable residues (USEPA, 2005). Aminopyralid is labile to photolysis at the soil surface but this process occurs at a much slower rate than it does in water ($t_{1/2}$ = 72 days in soil vs. 0.6 days in water).

2.2.6 Water Pollution Potential

Aminopyralid is quickly degraded via photolysis in aquatic systems ($t_{1/2}$ = 0.6 days), while degradation in the absence of photolysis occurs under aerobic conditions at a much slower rate ($t_{1/2}$ = 462-990 days). It has a low potential for groundwater contamination.

2.3 Clopyralid

CLOPYRALID

Formulations: Transline

- > Human Toxicity: Generally low toxicity. Neurotoxicity caused by acute poisoning. No evidence of carcinogenicity, immunotoxicity, or reproductive/developmental toxicity.
- > Ecological Toxicity: Practically non-toxic to birds, fish, aquatic invertebrates, and honey bees.
- > Water Pollution Potential: Degraded rapidly in water. Low potential for leaching.
- > Other Considerations: Very stable in compost piles, and thus is no longer used for lawn and garden applications in California and Washington.

2.3.1 Basic Use Information

- > Products: *Transline*
- > Typical target pests: Thistles; Clover
- > Application rates:

Material	Low volume/acre	High volume/acre
Transline	10 oz. – winter rate on seedlings and pre-emergent plants	20 oz.- spring rate on basal rosettes, bolt stage

Clopyralid is a selective herbicide used for broadleaf noxious weed control. It is structurally similar to aminopyralid, which has an extra amino group, and it is also an auxin hormone mimic,

causing abnormal growth that impairs proper nutrient transport throughout the plant. It is highly selective for terrestrial plants and appears to be relatively non-toxic to aquatic plants (Syracuse Environmental Research Associates, 2004).

2.3.2 Exposure Considerations

Clopyralid is the active ingredient in Transline. It is used to control broadleaf weeds such as thistle and clover. Similar to aminopyralid, it is selective for broadleaf plants and is not harmful to grasses when use post seed germination: however, it appears to be even more selective and effective than aminopyralid on post-emergent plants. It is applied at 10 oz/acre in the winter to pre-emergent invasive weeds and seedlings and at 20 oz/acre in the spring during the bolt (flowering) stage of unwanted plants. It is not used when wind speeds are greater than 7 mph or when the chance of rain is 40% or greater within 24 h of the planned application. It is used only with a 15 ft or greater buffer between aquatic systems and application sites.

2.3.3 Human Toxicity

Clopyralid is listed as a Category III compound for oral, dermal, and inhalation toxicity. The oral and dermal mammalian LD50s are both >5,000 mg/kg, and the mammalian inhalation LC50 is >1.3 mg/L. It is not metabolized extensively; 79-96% of parent clopyralid is excreted in rat urine ($t_{1/2} = 3$ h) (Syracuse Environmental Research Associates, 2004). The NOEL in dogs is 100 mg/kg/day. Clinical signs of acute clopyralid poisoning include neurotoxicity, manifested as ataxia, tremors, convulsions, and weakness. Chronic studies in rats, mice, and dogs have noted general decreases in body weight and increases in liver and kidney weight, which are commonly observed in chronic toxicity studies and can indicate either an adaptive or toxic response. The USEPA OPP has established an acute RfD of 0.75 mg/kg/day and a chronic RfD of 0.15 mg/kg/day for clopyralid. The USEPA classifies clopyralid as a Group E human carcinogen (no evidence of carcinogenicity) because chronic studies in rats, mice, and dogs have shown no indication of carcinogenicity. However, technical grade clopyralid contains low levels of hexachlorobenzene (<2.5 ppm), which is classified as a potential human carcinogen (Syracuse Environmental Research Associates, 2004).

2.3.4 Ecological Toxicity

Clopyralid is practically non-toxic to slightly toxic to birds. The oral LD50 in mallard duck is >1,645 mg/kg. The dietary LC50 for both pure clopyralid and the monoethanolamine salt of clopyralid is >4,460 ppm in both bobwhite quail and mallard duck. Clopyralid is also practically non-toxic to fish and aquatic invertebrates. The 96-h LC50 in bluegill is 125 mg/L, and the LC50 in rainbow trout is 103 mg/L for technical grade clopyralid. The monoethanolamine salts are even less toxic to fish, with LC50s ranging from 700-1,645 mg a.e./L. There is no indication that clopyralid bioaccumulates in fish. The LC50 in Daphnia is 225 mg/L. In a chronic Daphnia reproduction study, the NOAEL was found to be 23.1 mg a.e./L (Syracuse Environmental Research Associates, 2004). Clopyralid is also practically non-toxic to honey bees; the contact LD50 is >100 µg/bee. Clopyralid residues are highly toxic to non-target broadleaf plants.

2.3.5 Physical Properties/Environmental Fate and Transport

Clopyralid is relatively nonvolatile and highly water soluble. It is stable to both hydrolysis and photolysis in aqueous systems but is degraded rapidly. It is degraded in soil primarily through microbial activity ($t_{1/2} = 40$ days), and carbon dioxide is the major breakdown product (USDOE). It is very stable under anaerobic conditions. It is mobile and does not bind tightly to soil. Clopyralid is very stable in compost piles, and thus is no longer used for lawn and garden applications in California and Washington (California Department of Pesticide Regulation, 2004).

2.3.6 Water Pollution Potential

Clopyralid is very water soluble and is also degraded rapidly in water ($t_{1/2} = 9$ -22 days). Various monitoring studies have determined that the potential for leaching is very low due to its rapid degradation; only 0.1-0.6% of applied clopyralid was lost through leaching in various studies (Marin Municipal Water District Vegetation Management Plan, 2010; Syracuse Environmental Research Associates, 2004).

2.4 Imazapyr

IMAZAPYR

Formulations: Polaris, Stalker

- > Human Toxicity: Low toxicity. No evidence of carcinogenicity, neurotoxicity, immunotoxicity, or reproductive/developmental toxicity.
- > Ecological Toxicity: Practically non-toxic to birds, fish, aquatic invertebrates, and honey bees.
- > Water Pollution Potential: Soluble in water and degraded quickly via photolysis. Moderate potential for leaching into groundwater.
- > Other Considerations: Can be applied in areas where glyphosate is ineffective or not approved for use.

2.4.1 Basic Use Information

- > Products: *Polaris, Stalker*
- > Typical target pests: Grasses, Scotch broom.

Material	Low rate foliar	High rate foliar	Cut stump	Volume/acre
Polaris	0.5% v/v - spot treatment of annual wetland, non-crop weeds	1.5 – 5% v/v spot and low volume treatment of perennial wetland, non-crop weeds	10 % v/v	Variable

Material	Cut stump	Volume/acre
Stalker	10 -12 % v/v	Variable

Imazapyr is a systemic, nonselective, pre- and post-emergent herbicide used for the control of a broad range of terrestrial and aquatic weeds. It controls plant growth by preventing the synthesis of branched-chain amino acids. Imazapyr is applied either as an acid or as the isopropylamine salt and is approved for use on grasses, commercial and residential sites, and water bodies.

2.4.2 Exposure Considerations

Imazapyr is a broad-spectrum, non-selective herbicide that is used to control unwanted grasses, woody plants, and riparian plants. It is effective on both pre- and post-emergent (before and after sprouting) plants and can be used when glyphosate treatment is not efficacious or when multiple growth stages of a plant are present in the same location. It is the active ingredient in Stalker and Polaris commercial formulations.

Polaris is used in low volume applications or spot treatments of perennial weeds at 1.5-5% v/v and a low foliar rate of 0.5% v/v for spot treatments of annual wetland and non-crop weeds. It is not used when wind speeds are greater than 7 mph or when the chance of rain is 40% or greater within 24 h of the planned application. Imazapyr is approved for use in and near aquatic systems. However, if suitable habitat for any endangered species is found, and if imazapyr use has the potential to affect the species, coordination with the California Department of Fish and Game, the U.S. Fish and Wildlife Service, and/or National Marine Fisheries shall occur before weed treatment activities may be conducted within this buffer or activities shall be canceled in this area. It is efficacious against aquatic plants when most of the plant is not submerged and can be used in lieu of glyphosate in aquatic systems. Polaris and

Stalker are both used as treatments on stumps immediately following tree cutting at 10% v/v.

2.4.3 Human Toxicity

Imazapyr exhibits low acute toxicity to mammals via oral (Category IV), dermal (Category III), and inhalation (Category II) exposure. The oral LD50 for rats is >5,000 mg/kg; dermal LD50 for rabbits is >2,000 mg/kg; and the inhalation LC50 for rats is >1.3 mg/L. The formulations used by the District are Category III for oral, dermal, and inhalation toxicity. Imazapyr is classified as a Group E chemical, with no evidence of carcinogenicity, and is not mutagenic (USDOE-Bonneville Power Administration, 2000). A NOAEL of 250 mg/kg/day (the highest dose tested) was identified in a one-year dog feeding study, indicating that imazapyr has very low chronic toxicity to mammals. The USEPA has determined that the risk to humans of dietary and incidental exposure is below the level of concern (USEPA, 2006).

2.4.4 Ecological Toxicity

Imazapyr is practically nontoxic to birds, fish, Daphnia, and honey bees. The oral LD50 is >2,150 mg/kg for mallard duck and bobwhite quail. The 96-hr LC50 is >100 mg/L for rainbow trout and bluegill sunfish, and the 48-hr LC50 for Daphnia magna is >1,000 mg/L. The LD50 for honey bees is >100 µg/bee (USDOE-Bonneville Power Administration, 2000). Imazapyr is not expected to bioaccumulate in aquatic organisms because it exists as an anion at typical environmental pH (USEPA, 2006). Although

there are no risks of concern to terrestrial birds, mammals, bees or aquatic invertebrates and fish, imazapyr does pose an ecological risk to non-target terrestrial and aquatic vascular plants, which can be reduced by applications that minimize spray drift and limitations on spraying near certain water bodies (USEPA, 2006).

2.4.5 Physical Properties/Environmental Fate and Transport

Imazapyr is an ionic, organic acid that is nonvolatile and is both moderately persistent and mobile in soil. Commercial formulations contain either imazapyr acid or the imazapyr isopropylamine salt, both of which are dissolved in a water solution. Imazapyr is mainly in ionic form at typical environmental pH levels, and the behavior of the acid and salt forms are similar. Upon direct application, or indirect release into surface water, imazapyr is degraded by photolysis, with a half-life of approximately 3 to 5 days in surface water. It is essentially stable to hydrolysis, aerobic and anaerobic soil degradation, and aerobic and anaerobic aquatic metabolism. In soil, it is degraded primarily by microbial activity, and has a moderate soil adsorption coefficient.

2.4.6 Water Pollution Potential

Imazapyr is soluble in water and is quickly degraded by photolysis ($t_{1/2}$ = 3-8 days). There is moderate potential for leaching into groundwater (USDOE-Bonneville Power Administration, 2000)

2.5 Clethodim

CLETHODIM

Formulations: Envoy Plus

- > Human Toxicity: Low toxicity. No evidence of carcinogenicity, neurotoxicity, immunotoxicity, or reproductive/developmental toxicity.
- > Ecological Toxicity: Slightly toxic to birds, fish, and aquatic invertebrates. Practically non-toxic to honey bees.
- > Water Pollution Potential: Insoluble in water. Very short half-life in soil, and unlikely to leach in ground water.
- > Other Considerations: Envoy contains small amounts of naphthalene, which is listed as a Group 2B (possibly carcinogenic) compound by the USEPA and a carcinogen under California Proposition 65.

2.5.1 **Basic Use Information**

- > Products: *Envoy Plus*
- > Typical target pests: Annual and perennial grasses.
- > Application rates:

Material	Low volume/acre	High volume/acre
Envoy Plus	16 oz. – early/mid season annual grasses – spot and broadcast in non-crop areas	32 oz. – early/mid season annual grasses – spot and broadcast in non-crop areas

Clethodim is a selective, post-emergence herbicide used for the control of annual and perennial grass weeds. It functions by inhibiting fatty acid synthesis in plants.

2.5.2 **Exposure Considerations**

Clethodim is the active ingredient in Envoy Plus and is highly selective for post-emergent grass control. It is not toxic to broadleaf or pre-emergent plants, and it is therefore highly effective in controlling invasive grasses that grow within broadleaf habitats and in eradicating annual unwanted grasses from perennial grasslands. It is used in early to mid season spot and broadcast applications at a high rate of 32 oz/acre on perennial grasses and a low rate of 16 oz/acre on annual grasses.

2.5.3 **Human Toxicity**

Clethodim is listed as Category IV for oral, dermal, and inhalation toxicity. The mammalian oral and dermal LD50s are both >5,000 mg/kg, and the acute inhalation LC50 is >3.9 mg/L. It is a Category III eye irritant and skin irritant and is a dermal sensitizer (USEPA, 1995). Chronic toxicity has been shown to increase liver weights and anemia in rats. There is no evidence of reproductive toxicity or carcinogenicity for pure clethodim. However, Envoy contains small amounts of naphthalene, which is listed as a Group 2B (possibly carcinogenic) compound by the USEPA and a carcinogen under California Proposition 65 (Valent, 2006).

2.5.4 **Ecological Toxicity**

Clethodim is reported as practically nontoxic to slightly toxic to birds; the bobwhite quail LD50 is >2,000 mg/kg. In longer term reproductive studies, the NOAEL in quail was found to be 300 ppm while in mallard ducks it is 1,000 ppm. Clethodim is slightly toxic to fish and aquatic invertebrates. The 96-h LC50 of Envoy Plus in bluegill is 120 mg/L; the 96-h LC50 in rainbow trout is 67 mg/L; and the 48-h LC50 in Daphnia is >120 mg/L. It does not bioaccumulate in fish. Clethodim is practically non-toxic to honey bees (LD50 >100 µg/bee) (USEPA, 1990b, 1995).

2.5.5 **Physical Properties/Environmental Fate and Transport**

Clethodim is relatively nonvolatile. In soil, it is non-persistent, mobile, and weakly binds to soil particles. It is broken down in soil through primarily aerobic processes ($t_{1/2}$ = 1-2.6 days). Its degradation under anaerobic conditions is slow in both water ($t_{1/2}$ = 128 days) and sediment ($t_{1/2}$ = 214 days).

2.5.6 **Water Pollution Potential**

Clethodim is not soluble in water. Because it has a very short half-life in soil (1-3 days), it is unlikely to leach into and contaminate ground water sources (USEPA, 1990a).

3 Fungicide

Table 3-1 Human Toxicity Summary of Fungicide Active Ingredient

Active Ingredient	Mammalian Oral LD50 (mg/kg) ^A	Mammalian Dermal LD50 (mg/kg) ^B	Mammalian Inhalation LC50 (mg/L) ^A	USEPA Toxicity Rating	Carcinogenic	Reproductive or Developmental Toxicity	Neurotoxic	Immunotoxic	Endocrine Disruption
Potassium salts of phosphorus acid	>5,000	>5,000	> 2.06	Oral and dermal (III), inhalation (IV)	No	NA	NA	NA	NA

Table 3-2 Ecotoxicity Summary of Fungicide Active Ingredients

Active Ingredient	Mammalian Oral LD50 (mg/kg) ^A	Mammalian Dermal LD50 (mg/kg) ^B	Mammalian Inhalation LC50 (mg/L) ^A	Avian LD50 (mg/kg) ^C	Fish LC50 (mg/L) ^D	Aquatic Invert EC50 (mg/L) ^E	Honeybee LD50 (µg/bee)	Other Receptors
Potassium salts of phosphorus acid	>5,000	>5,000	> 2.06	>1,060	>544.6	>544.6	>13.3	NA

A. Unless otherwise specified, values are for rats.

B. Unless otherwise specified, values are for rabbits.

C. Unless otherwise specified, values are for mallard duck or bobwhite quail.

D. Unless otherwise specified, values are for rainbow trout or bluegill sunfish.

E. Values are for Daphnia or similar species.

3.1 Potassium salts of phosphorus acid

POTASSIUM SALTS OF PHOSPHORUS ACID

Formulations: Agri-Fos

- > Human Toxicity: Low toxicity. No evidence of carcinogenicity, neurotoxicity, immunotoxicity, or reproductive/developmental toxicity.
- > Ecological Toxicity: Practically non-toxic to birds, fish, and freshwater invertebrates. Toxic to bees.
- > Water Pollution Potential: High water solubility, but unlikely to contaminate water due to use practices.
- > Other Considerations: Formulation is used via injection or directed spray in targeted applications, reducing exposure and risk to non-target species.

3.1.1 Basic Use Information

- > Products: *Agri-Fos*
- > Typical target pests: *Phytophthora ramorum*, cause of sudden oak death
- > Application rates:

Material	Basal bark treatment
Agri-Fos	49 % v/v

Potassium salts of phosphorus acid are the active ingredient of Agri-Fos, a fungicide that is used to help prevent infection, or increase infection resistance by the oomycete plant pathogen *Phytophthora ramorum*, which causes sudden oak death. The fungicide functions by inhibiting oxidative phosphorylation in the fungus, and some evidence suggests that phosphorous acid has the indirect effect of stimulating the plants natural defense response against pathogens. Agri-Fos is applied via injection in the oak bark or by a localized spray onto the bark. When applied by spray, it is used with the organosilicone surfactant Pentra-bark.

3.1.2 Exposure Considerations

Potassium salts of phosphorus acid are the active ingredient in the fungicide Agri-Fos, which is used to prevent sudden oak death. It is applied directly to the bark of forest trees at a 49% v/v application rate. The surfactant Pentra-bark is used with Agri-Fos to increase the uptake of the fungicide by the tree, thereby increasing its

efficacy and decreasing its potential to impact non-target species. The basal bark application method also decreases the potential for drift, deposition in water, and exposure to non-targets because the fungicide is sprayed directly onto the bark and quickly taken up by the tree.

3.1.3 Human Toxicity

Potassium salts of phosphorus acid are Category III for oral and dermal toxicity and Category IV for inhalation (USEPA, 1998). The mammalian oral and dermal LD50s are both >5,000 mg/kg, and the inhalation LC50 is >2.06 mg/L. Potassium salts are Category III eye irritants. They are not dermal sensitizers. There is no evidence of genotoxicity. Further, because there are no food uses associated with these compounds, dietary risk is minimal (Health Canada, 2012).

3.1.4 Ecological Toxicity

Potassium salts of phosphorus acid are practically non-toxic to birds, fish, and freshwater invertebrates. The acute LD50 in bobwhite quail

is >1,060 mg/kg, and the 8-day dietary LC50 in mallard ducks is >5,000 ppm (734.2 mg a.i./kg bw/day). For rainbow trout and *Daphnia magna*, the LC50 is >544.6 mg/L. These compounds are highly water soluble and are not expected to bioaccumulate in fish. The LD50 for honey bees is >13.3 µg a.i./bee (Health Canada, 2012).

3.1.5 Physical Properties/Environmental Fate and Transport

Little information regarding the environmental fate and transport of potassium salts of phosphorus acid or Agri-Fos exist. They will produce phosphite ions when in contact with

water, and these phosphite ions can be directly taken up by plant roots, slowly transform to phosphate, or bind with other substances in the soil. Microbial transformation in soil is likely to be very slow.

3.1.6 Water Pollution Potential

Potassium salts are very water soluble. Due to the directed application of Agri-Fos, introduction into the water or soil environment is unlikely, and thus, the water pollution potential of this compound is negligible (USEPA, 1998).

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4 Rodenticides

Table 4-1 Human Toxicity Summary of Rodenticide Active Ingredient

Active Ingredient	Mammalian Oral LD50 (mg/kg) ^A	Mammalian Dermal LD50 (mg/kg) ^B	Mammalian Inhalation LC50 (mg/L) ^A	USEPA Toxicity Rating	Carcinogenic	Reproductive or Developmental Toxicity	Neurotoxic	Immunotoxic	Endocrine Disruption
Cholecalciferol	43.6	2,000	NA	NA	No	No	No	No	No

Table 4-2 Ecotoxicity Summary of Rodenticide Active Ingredient

Active Ingredient	Mammalian Oral LD50 (mg/kg) ^A	Mammalian Dermal LD50 (mg/kg) ^B	Mammalian Inhalation LC50 (mg/L) ^A	Avian LD50 (mg/kg) ^C	Fish LC50 (mg/L) ^D	Aquatic Invert EC50 (mg/L) ^E	Honeybee LD50 (µg/bee)	Other Receptors
Cholecalciferol	43.6	2,000	NA	2,000	NA	NA	NA	Dog oral LD50 = 88 mg/kg

A. Unless otherwise specified, values are for rats.

B. Unless otherwise specified, values are for rabbits.

C. Unless otherwise specified, values are for mallard duck or bobwhite quail.

D. Unless otherwise specified, values are for rainbow trout or bluegill sunfish.

E. Values are for Daphnia or similar species.

4.1 Cholecalciferol

CHOLECALCIFEROL

Formulations: NA

- > Human Toxicity: High acute toxicity to mammals.
- > Ecological Toxicity: Moderate toxicity to avian species. Lower risk of secondary poisoning to non-target birds.. Generally toxic to rodents with one ingestion.
- > Water Pollution Potential: Unlikely to enter aquatic systems due to use of tamper-resistant bait stations.
- > Other Considerations: Use of anchored tamper-resistant bait stations minimizes risk to non-target wildlife, domestic pets, or children.

4.1.1 Basic Use Information

- > Products: *Cholecalciferol (Vitamin D₃) Quintox, Rampage, Hypekill*
- > Typical target pests: Rats, mice
- > Application rates:

Material	Rate
Cholecalciferol	0.075% in bait

Cholecalciferol is used to control Norway rats (*Rattus norvegicus*), roof rats (*Rattus rattus*), and several species of mice, including house mice (*Mus musculus*), and field mice (*Peromyscus spp.*) in and around homes, industrial buildings, and similar man-made structures. Formulation types include pellets and blocks. Cholecalciferol is a sterol (vitamin D₃) and its ingestion results in hypercalcemia from mobilization of calcium from bone matrix into blood plasma leading to metastatic calcification of soft tissues (USEPA, 2011).

4.1.2 Exposure Considerations

Cholecalciferol is the active ingredient (commonly 0.075%) of rodent baits and is applied using tamper-resistant bait stations. The use of bait stations offers protection to non-target organisms, particularly birds, because loose pellets are not available to other animals that might attempt to consume the bait. These bait stations are designed to stop access to the bait by other animals and small children. They are anchored at treatment locations (e.g., by wires or stakes) to ensure that they cannot be dragged

away by non-target wildlife, domestic pets, or children. Bait placements must be inside or within 50 or 100 feet of buildings (distance dependent upon particular product formulation). The amount of bait used in each bait station varies depending upon the target pest.

4.1.3 Human Toxicity

Cholecalciferol is acutely toxic to target rodents. The oral LD₅₀ for cholecalciferol is 42.5 for mice, 43.6 mg/kg for rats, and 88 mg ai/kg for dogs (Marshall, 1984). However, subsequent studies have indicated that the dog LD₅₀ may be much lower (USEPA, 2004). In rats and mice fed 0.075% cholecalciferol, 100% mortality occurred within 3 to 6 days and was found to be efficacious in warfarin-resistant rats. The dermal LD₅₀ of the finished bait product (0.075% cholecalciferol) is 2,000 mg/kg for rabbits (Marshall, 1984).

The parent compound and metabolites are fat soluble and stored in adipose tissue. Enterohepatic recirculation of cholecalciferol and metabolites occurs. After a massive intake of

cholecalciferol, excess calcifediol is produced in the liver. Because of their high lipid solubility, cholecalciferol and its metabolites are eliminated from the body very slowly (primarily through bile and feces). Two mechanisms occur with consumption of large doses of cholecalciferol. First, more calcium is absorbed from the intestines. Second, cholecalciferol metabolites stimulate phosphorus transfer from bone to plasma. The increased plasma calcium concentrations result in vomiting, lethargy, and muscle weakness. Specific organ effects include acute renal tubular necrosis, gastrointestinal stasis, gastric acid secretion, decreased skeletal muscle responsiveness, and decreased neural tissue responsiveness. The increase in plasma calcium causes soft tissue mineralization resulting in loss of functionality of kidneys, cardiac muscle, etc. (Morrow, 2001).

4.1.4 Ecological Toxicity

Cholecalciferol is considered of lower hazard to avian species compared to other rodenticides. The oral LD50 for mallard ducks >2,000 mg/kg (30% a.i.), equating to >600 mg/kg, and the mallard and northern bobwhite dietary LC50 are 1190 and 528 ppm, respectively (Marshall, 1984; USEPA, 2004). The USEPA has made an effects determination of “may affect, and likely to adversely affect” for the endangered salt marsh

harvest mouse based on risk of consuming the compound via bait blocks (USEPA, 2011). In the only secondary avian toxicity study available for cholecalciferol, two turkey vultures and one red-tailed hawk were offered rats or mice fed for 1-day with 0.075% a.i. bait, and no adverse effects were observed in the birds (Marsh and Koehler, 1991). When cholecalciferol-poisoned prey were offered to dogs and cats for five days, no death occurred in either species and while some signs of toxicosis were observed in the dogs, these symptoms were reversible after exposure and all animals recovered (Eason et al., 2000).

4.1.5 Physical Properties/Environmental Fate and Transport

No environmental fate and transport data for cholecalciferol have been submitted to USEPA. Based on physical/chemical properties of the compound, it is expected to be nonvolatile, essentially insoluble in water, and immobile in soil (USEPA, 2011). Information on biotic and abiotic degradation is not available.

4.1.6 Water Pollution Potential

Because cholecalciferol is used in tamper-resistant bait stations, it is unlikely to enter aquatic environments via runoff or spray drift. Thus, the water pollution potential of cholecalciferol is negligible.

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5 Insecticides

Table 5-1 Human Toxicity Summary of Insecticide Active Ingredients

Active Ingredient	Mammalian Oral LD50 (mg/kg) ^A	Mammalian Dermal LD50 (mg/kg) ^B	Mammalian Inhalation LC50 (mg/L) ^A	USEPA Toxicity Rating	Carcinogenic	Reproductive or Developmental Toxicity	Neurotoxic	Immunotoxic	Endocrine Disruption
<i>d-trans</i> allethrin	860	11,332	NA	NA	No	No	Yes	No	No
Phenothrin	>5,000	>2,000	>2.1	Oral and inhalation (IV), dermal (III)	No	No	Yes	No	No
Indoxacarb	<1,000	>5,000 (rat)	>5.5	Oral (II), dermal and inhalation (IV)	No	No	No	No	No
Hydroprene	>5,000	>5,000	>5.2	Oral (IV), dermal and inhalation (III)	Not enough data to classify	No	No	NA	NA
Fipronil	97	>2,000 (rat); 354 (rabbit)	0.390 – 0.682	Oral and inhalation (II), dermal (III)	Possible human carcinogen	Yes (reproductive)	Yes	NA	NA
Sodium tetraborate decahydrate (borax)	>5,000 (Prescription ant bait)	>5,000 (Prescription ant bait)	>0.16 (boric acid)	Oral and dermal (III)	No	Yes, at high doses (reproductive)	NA	NA	NA
Diatomaceous earth	>5,000	>2,000	> 0.859	Oral (IV), dermal (III), inhalation (II)	NA	NA	NA	NA	NA

Table 5-2 Ecotoxicity Summary of Insecticide Active Ingredients

Active Ingredient	Mammalian Oral LD50 (mg/kg) ^A	Mammalian Dermal LD50 (mg/kg) ^B	Mammalian Inhalation LC50 (mg/L) ^A	Avian LD50 (mg/kg) ^C	Fish LC50 (mg/L) ^D	Aquatic Invert EC50 (mg/L) ^E	Honeybee LD50 (µg/bee)	Other Receptors
<i>d-trans</i> allethrin	860	11,332	NA	>5,620 (8-day dietary)	0.0094 (coho salmon) to 0.027 (channel catfish)	NA	Contact – 3.4; Oral – 4.6 to 9.1	2-yr Dog dietary NOEL = 50 mg/kg/day
Phenothrin	>5,000	>2,000	>2.1	>5,000 (dietary)	0.0158 to 0.0942 (inland silverside)	0.000025 (mysid) - .0044	NA, likely toxic	NA
Indoxacarb	<1,000	>5,000 (rat)	>5.5	98	0.65	0.0542 (mysid) – 2.94	Contact - 0.18; Oral - practically non-toxic	90-d Dog LOAEL = 19 mg/kg/day
Hydroprene	>5,000	>5,000	>5.2	NA	>100	NA	Adult - 1000; larval - 0.1	3-month rat LOAEL = 250 mg/kg/day
Fipronil	97	>2,000 (rat); 354 (rabbit)	0.390 – 0.682	11.3; 31 (pheasant)	0.083 to 0.246	0.020 (LOAEL)	Highly toxic	NA
Sodium tetraborate decahydrate (borax)	>5,000 (Prescription ant bait)	>5,000 (Prescription ant bait)	>0.16 (boric acid)	>2,510 (boric acid)	41; 12,000 (mosquito fish)	133 (boron)	100 (boron)	Frog LC50 = 414 to 529 mg borax/L
Diatomaceous earth	>5,000	>2,000	> 0.859	Practically nontoxic	Practically nontoxic	Practically nontoxic	NA	NA

A. Unless otherwise specified, values are for rats.

B. Unless otherwise specified, values are for rabbits.

C. Unless otherwise specified, values are for mallard duck or bobwhite quail.

D. Unless otherwise specified, values are for rainbow trout or bluegill sunfish.

E. Values are for Daphnia or similar species.

5.1 D-trans allethrin

D-TRANS ALLETHRIN

Formulations: Wasp-Freeze

- > Human Toxicity: Low toxicity. Dermal and eye irritation possible. Neurotoxicity caused by acute poisoning. No evidence of carcinogenicity, immunotoxicity, or reproductive/developmental toxicity.
- > Ecological Toxicity: Practically non-toxic to birds. Highly toxic to fish and aquatic invertebrates.
- > Water Pollution Potential: Rapidly degraded in the environment and not likely to leach into groundwater.
- > Other Considerations: Not used in/near aquatic systems due to high fish and aquatic invertebrate toxicity.

5.1.1 Basic Use Information

- > Products: *Wasp-Freeze*
- > Typical target pests: Wasps
- > Application rates:

Material	Formulation	Rate
Wasp-Freeze	0.10% a.i.	One 17.5 oz ready to use spray can/wasp nest

Allethrins are first generation or Type I synthetic pyrethroids that contain three asymmetric carbons and, thus, eight potential isomers; however, four isomers are present in the greatest concentrations in product formulations. One of the stereoisomers, d trans of the d isomer (d-trans allethrin), is recognized as being the most insecticidally active and toxicologically important, and it is the active ingredient (along with phenothrin, discussed below) in Wasp-freeze. Pyrethroids bind to neuronal voltage-gated sodium channels, preventing them from closing; this persistent activation of the channels then leads to paralysis.

5.1.2 Exposure Considerations

D-trans allethrin and phenothrin (discussed below) are the active ingredients in Wasp-Freeze. Each compound is approximately 0.1% of the pesticide formulation. Wasp-freeze is a ready-to-use formulation in a 17.5 oz spray can. The pesticide is applied by hand directly onto the nests of unwanted wasps, hornets, or bees.

Because pyrethroids are highly toxic to fish, Wasp-Freeze is not applied to water; the District maintains a 15 ft or great buffer between aquatic systems and application areas. It is not used when wind speeds are greater than 7 mph or when the chance of rain is 40% or greater within 24 h of the planned application.

5.1.3 Human Toxicity

The toxicity of allethrin varies with the amounts of different isomers present. The LD50 of d-trans allethrin in rats is 860 mg/kg, and the dermal LD50 in rabbits is 11,332 mg/kg. Dermal exposure results in itching, burning, tingling, and numbness. Large doses by any route can cause physical symptoms such as nausea, vomiting, diarrhea, tremors, convulsions, and coma. A chronic dosage of 50 mg/kg/day for two years produced no detectable effect in dogs. Allethrins are not known to cause reproductive, teratogenic, mutagenic, carcinogenic, or endocrine disrupting effects in mammals (EXTOXNET, 1993; World Health Organization, 2002).

5.1.4 Ecological Toxicity

D-trans allethrin is practically nontoxic to birds, but it is highly toxic to fish and invertebrates. The 8-day acute dietary LC50 in bobwhite quails and mallards is >5,620 ppm. The LC50 for fish ranges from 9.4 (coho salmon) to 27 µg/L (channel catfish). The bioaccumulation potential of allethrin is unknown. The LD50 of allethrin to honey bees is 3.4 µg/bee via contact and 4.6-9.1 µg/bee via ingestion (World Health Organization, 2002).

5.1.5 Physical Properties/Environmental Fate and Transport

Allethrins were the first pyrethroids developed, and they are incredibly photolabile (USEPA,

2009). The photolysis half-life is 8-19 hours (WHO, 1989; World Health Organization, 2002). It is stable to hydrolysis at a neutral pH ($t_{1/2}$ = 500 days) but not at pH 9 ($t_{1/2}$ = 4.3 days) (World Health Organization, 2002).

5.1.6 Water Pollution Potential

D-trans allethrin is not soluble in water and is expected to adhere moderately to soil containing organic matter. It rapidly degrades in the environment and is not expected to leach into and contaminate ground water.

5.2 Phenothrin

PHENOTHRIN

Formulations: Wasp-Freeze

- > Human Toxicity: Low toxicity. Dermal and eye irritation possible. Neurotoxicity caused by acute poisoning. No evidence of carcinogenicity, immunotoxicity, or reproductive/developmental toxicity.
- > Ecological Toxicity: Practically non-toxic to birds. Highly toxic to fish and aquatic invertebrates.
- > Water Pollution Potential: Rapidly degraded in the environment and not likely to leach into groundwater.
- > Other Considerations: Not used in/near aquatic systems due to high fish and aquatic invertebrate toxicity.

5.2.1 Basic Use Information

- > Products: *Wasp-Freeze*
- > Typical target pests: Wasps
- > Application rates:

Material	Formulation	Rate
Wasp-Freeze	0.10% a.i.	One 17.5 oz ready to use spray can/wasp nest

Phenothrin is a first generation, or Type I, pyrethroid that is the active ingredient (along with d-trans allethrin, discussed above) in Wasp-freeze. It has been registered by the EPA since 1976. It functions in the same manner as d-trans allethrin, causing a persistent opening of neuronal sodium channels, leading to paralysis and death.

5.2.2 Exposure Considerations

Phenothrin and d-trans allethrin (discussed above) are the active ingredients in Wasp-Freeze. Each compound is approximately 0.1% of the pesticide formulation. Wasp-freeze is a ready-to-use formulation in a 17.5 oz spray can. The pesticide is applied by hand directly onto the nests of unwanted wasps, hornets, or bees. Because pyrethroids are highly toxic to fish, Wasp-Freeze is not applied to water; the District maintains a 15 ft or great buffer between aquatic systems and application areas. It is not used when wind speeds are greater than 7 mph or when the chance of rain is 40% or greater within 24 h of the planned application.

5.2.3 Human Toxicity

Phenothrin exhibits low acute toxicity by oral (Category IV), dermal (Category III), and inhalation (Category IV) exposure routes, and it is a mild eye irritant (Category III). The rat oral LC50 is >5,000 mg/kg; the dermal LC50 is >2,000 mg/kg; and the inhalation LC50 is >2.1 mg/L (USEPA, 2008a).

Neurotoxic effects were observed in developmental toxicity studies but not observed in other acute, chronic, and subchronic toxicity studies done in rats and dogs up to the highest dose of 20,000 mg/kg/day. In rats, decreased parental weight gain and decreased weight gain during lactation of pups was observed in animals exposed to 150 mg/kg/day for up to 6 months (USEPA, 2008a).

5.2.4 Ecological Toxicity

Phenothrin is practically nontoxic to avian species. The LC50 for avian dietary toxicity is above 5,000 ppm (USEPA, 2008a). Phenothrin is highly toxic to freshwater, estuarine, and marine

fish. LC50s range from 15.8 - 18.3 µg/L for freshwater fish and from 38.3 - 94.2 µg/L for estuarine and marine fish. The chronic NOAEL in fish is 1.1 µg/L. It is also very highly toxic to freshwater invertebrates. The EC50 for freshwater invertebrates is 4.4 µg/L. The lowest LC50 for phenothrin is 0.025 µg/L, based on a 96-h mysid test (SWRCB, 2012). Chronic data for phenothrin show adverse reproductive effects for freshwater invertebrates at a NOAEL of 0.47 µg/L. Estuarine invertebrates are even more sensitive than freshwater invertebrates, with an EC50 of 0.025 µg/L. Chronic effects to estuarine and marine invertebrates are expected based on the chronic reproductive toxicity to freshwater invertebrates and the acute effects to estuarine and marine invertebrates (USEPA, 2008a). Exposure to phenothrin in terrestrial non-target listed or non-listed species mammals is not expected to result in acute or chronic risks.

5.2.5 Physical Properties/Environmental Fate and Transport

Phenothrin has a relatively high affinity for binding to soils, moderate persistence in surface soils, and low water solubility. The major routes of dissipation in the environment are photolysis in water ($t_{1/2}$ = 6.5 days) and aerobic metabolism ($t_{1/2}$ = 36 days in aquatic environments and 18.6-25.8 days in soil). Phenothrin is moderately persistent under aerobic conditions and is persistent under anaerobic conditions (USEPA, 2008a).

5.2.6 Water Pollution Potential

Phenothrin is likely to remain immobile in soil. It has low leaching potential and is unlikely to cause groundwater contamination (USEPA, 2008a). Phenothrin has a high affinity for sediments or suspended solids in the water column and thus may persist if applied to aquatic systems.

5.3 Indoxacarb

INDOXACARB

Formulations: Advion gel baits

- > Human Toxicity: Low toxicity. Eye irritation possible. No evidence of neurotoxicity, carcinogenicity, immunotoxicity, or reproductive/developmental toxicity.
- > Ecological Toxicity: Moderately toxic to birds. Moderately to highly toxic to fish and aquatic invertebrates.
- > Water Pollution Potential: Rapidly degraded in the environment and not likely to leach into groundwater.
- > Other Considerations: Designated as a low risk pesticide. Potential for exposure to non-target species is very low due to use of the pesticide in contained bait stations.

5.3.1 Basic Use Information

- > Products: *Advion gel baits*
- > Typical target pests: Cockroaches, ants.
- > Application rates:

Material	Formulation	Low rate	High rate
Advion gel baits	0.60% a.i	0.5 g bait/10 linear feet	0.5 g bait/2 linear feet

Indoxacarb is proposed for use on structural pests such as ants and cockroaches. It possesses both larvicidal and ovicidal activity. It functions by blocking sodium channels, leading to impaired nerve function, paralysis, and ultimately death of lepidopteran pests (California Department of Pesticide Regulation, 2006; USEPA, 2000). It must be metabolized to elicit its toxicity. Indoxacarb is considered an organophosphate replacement (USEPA, 2000). Formulations often contain indoxacarb and its R-enantiomer.

5.3.2 Exposure Considerations

Indoxacarb is the active ingredient of Advion gel bait, which is applied indoors to cracks and crevices, along and inside access points to treat cockroach infestations. The baits contain 0.6% indoxacarb. For heavy cockroach infestations, 0.5 g bait/2 linear feet is applied, and for lighter infestations, 0.5 g bait/10 linear feet is used. These baits are not used near aquatic systems

(>15 ft buffer) or where surface water may be present.

5.3.3 Human Toxicity

Indoxacarb is classified as a Category II oral toxicant; the rat acute oral LD50 is <1,000 mg/kg, with large variation in toxicity between male and female rats (843 and 179 mg/kg, respectively). It is a Category IV dermal and inhalation toxicant; the rat dermal LD50 is >5,000 mg/kg and the inhalation LC50 is >5.5 mg/L. It is a moderate eye irritant (Category III). In a 90-day oral toxicity study in dogs, the LOAEL was determined to be 19 mg/kg/day based on impacts to various blood parameters. There is no evidence that indoxacarb is carcinogenic or mutagenic (California Department of Pesticide Regulation, 2006; USEPA, 2000).

5.3.4 Ecological Toxicity

Indoxacarb is moderately toxic to birds. The LD50 in bobwhite quail is 98 mg/kg, and the

subacute 5-day LC50 in bobwhite quail is 808 mg/kg in the diet. It is moderately to very acutely toxic to freshwater, estuarine, and marine fish. The LC50s for rainbow trout, carp, and channel catfish are 0.65, 1.02, and 0.29 mg/L, respectively. It is moderately to very highly acutely toxic to freshwater, estuarine, and marine invertebrates. The acute LC50s in *Daphnia carinata* and *Daphnia magna* are 2.94 and 0.60 mg/L, respectively. The LC50 in Eastern oyster is 0.203 mg/L, and the LC50 in mysid shrimp is 0.0542 mg/L. Chronic toxicities range from 0.003 to 0.25 mg/L for fish and invertebrates (California Department of Pesticide Regulation, 2006). Indoxacarb is practically non-toxic to honey bees by dietary intake but is highly toxic by contact (LD50 = 0.18 µg/bee).

5.3.5 Physical Properties/Environmental Fate and Transport

Indoxacarb is relatively non-volatile and has a low vapor pressure. In water, it is degraded primarily via photolysis, and to a lesser extent, hydrolysis (the hydrolysis half-life is about ten times longer than the photolysis half-life of three days). It is stable to photolysis in soil. It is immobile in soil and is also moderately persistent under both aerobic and anaerobic conditions (California Department of Pesticide Regulation, 2006).

5.3.6 Water Pollution Potential

Indoxacarb is degraded quickly in water. The water pollution potential of this active ingredient is negligible as it is used in contained bait stations.

5.4 Hydroprene

HYDROPRENE

Formulations: Gentrol Point source baits

- > Human Toxicity: Low toxicity; does not pose acute dietary risk. No evidence of neurotoxicity, carcinogenicity, immunotoxicity. May be developmentally toxic at very high doses.
- > Ecological Toxicity: Practically non-toxic to fish, aquatic invertebrates, and adult honey bees. Some toxicity to larval honey bees.
- > Water Pollution Potential: Used indoors, so groundwater contamination is unlikely.
- > Other Considerations: Only used in directed applications in response to cockroach infestations indoors.

5.4.1 Basic Use Information

- > Products: *Gentrol Point source baits*
- > Typical target pests: Cockroaches, beetles, moths.
- > Application rates:

Material	Formulation	Low rate	High rate
Gentrol Point source baits	91% a.i.	1 bait/75 sq. ft.	2 baits/75 sq. ft.

Hydroprene is an insect growth regulator that functions by mimicking insect juvenile hormones.

It is used against cockroaches, beetles, and moths. It is not applied to plants.

5.4.2 Exposure Considerations

Hydroprene is the active ingredient in Gentrol Point source bait, which is used to control cockroaches. The bait stations contain 91% hydroprene. To treat heavy infestations, two bait stations per 75 sq. ft are used, and to treat light infestations, one bait station per 75 sq. ft is used. These bait stations are permitted for use indoors only, so exposure to wildlife in their natural habitat is highly unlikely.

5.4.3 Human Toxicity

Hydroprene is listed as a Category IV oral toxicant and Category III for dermal and inhalation routes of exposure. Based on the available acute toxicity data, the USEPA has determined the hydroprene does not pose any acute dietary risks. The mammalian oral and dermal LD50s are both >5,000 mg/kg, and the inhalation LC50 is >5.2 mg/L. The USEPA has determined that the parental toxicity LOAEL is 7,500 ppm for the rat reproductive toxicity study based on parental weight gain reductions (Federal Register, 1997). The NOEL for pup development was 1,500 ppm. In a three-month feeding study in rats, the LOAEL based on vacuolated ovarian luteal cells in females was 250 mg/kg/day. There is no evidence for

genotoxicity or mutagenicity. It is classified as a Group D compound – not classifiable as to human carcinogenicity. Based on chronic rat studies, the Rfd for hydroprene is 0.1 mg/kg/day (Federal Register, 1997).

5.4.4 Ecological Toxicity

There are no data available regarding the toxicity of hydroprene to birds. It is practically non-toxic to fish, with LC50s >100 mg/L. It is practically non-toxic to adult honey bees by oral and contact routes (LD50 >1,000 µg/bee); however, it is highly toxic to larval honey bees (LD50 = 0.1 µg/bee) (Federal Register, 1997).

5.4.5 Physical Properties/Environmental Fate and Transport

There is a paucity of data regarding the environmental fate and transport of hydroprene because it is only used indoors. Hydroprene is insoluble in water, and it is rapidly degraded in soil ($t_{1/2}$ = days) (National Pesticide Information Center, 2001).

5.4.6 Water Pollution Potential

Because hydroprene is only used indoors, the EPA does not anticipate any contamination of drinking water.

5.5 Fipronil

FIPRONIL

Formulations: Maxforce bait stations

- > Human Toxicity: Moderate toxicity. No evidence of neurotoxicity or immunotoxicity. Possible human carcinogen.
- > Ecological Toxicity: Highly toxic to fish, aquatic invertebrates, bees, and some bird species.
- > Water Pollution Potential: Degrades rapidly in water and unlikely to leach from soil.
- > Other Considerations: Bait stations are used in response to ant infestations indoors so risk to non-target species is low.

5.5.1 Basic Use Information

- > Products: *Maxforce bait stations*
- > Typical target pests: Argentine ants
- > Application rates:

Material	Formulation	Low rate	High rate
Maxforce bait stations	0.01% a.i.	3 baits/room	6 baits/room

Fipronil is a non-systemic insecticide registered for use to control ants, beetles, cockroaches, fleas, mole crickets, ticks, termites, and other insects in a variety of agricultural and residential uses. It functions by blocking GABA-gated chloride channels in the central nervous systems of pests.

5.5.2 Exposure Considerations

Fipronil, the active ingredient in Maxforce bait stations, is used to control Argentine ants. The bait stations contain 0.01% fipronil. The bait stations are restricted to placement indoors at rates of 3 or 6 baits per room, respectively. Fipronil baits are not used outside and the District does not employ spray applications, so exposure to wildlife is highly unlikely.

5.5.3 Human Toxicity

Fipronil exhibits moderate acute toxicity (Category II) by the oral and inhalation routes in rats. The oral LD50 in rats is 97 mg/kg. The acute oral LD50 of fipronil-desulfinyl in rats is 15 and 18 mg/kg for females and males, respectively. The

4-h inhalation LC50 ranges from 0.390 to 0.682 mg/L in rats. By the dermal route, it is of moderate toxicity in rabbits and low toxicity (Category III) in rats. The dermal LD50 is 354 mg/kg in rabbits and >2,000 mg/kg in rats. It is relatively non-irritating to the skin (Category IV) and eye (Category III) of rabbits and is not a dermal sensitizer. In a one-year chronic rat feeding study, responses included reduced feeding and food conversion efficiency, reduced body weight gain, seizures and seizure-related death, changes in thyroid hormones, increased mass of the liver and thyroid, and kidney effects. It is not mutagenic. However, fipronil has been classified as a Group C, possible human carcinogen, based on increases in thyroid follicular cell tumors in both sexes of the rat. Fipronil does not cause these tumors in mice. Based on chronic rat studies, the chronic Rfd for humans is 0.0002 mg/kg/day (USEPA, 1996).

5.5.4 Ecological Toxicity

Fipronil is highly toxic to some birds. The LD50 in bobwhite quail is 11.3 mg/kg and in pheasants is

31 mg/kg. The five-day dietary LC50 in bobwhite quail is 49 mg/kg in feed. However, it is practically non-toxic to mallard ducks with no documented acute (LC50 >5,000 mg/kg in 8-day dietary study), sub-acute, or chronic effects. It is highly to very highly toxic to marine and freshwater fish. The 96-h LC50 is 0.246 mg/L for rainbow trout, 0.083 mg/L for bluegill sunfish, and 0.130 mg/L for sheepshead minnow. Fipronil-sulfone is three-six times more toxic than the parent compound in fish, and fipronil has been shown to bioconcentrate in fish. Fipronil is highly toxic to freshwater invertebrates. In *Daphnia*, the 48-h LC50 = 248 µg/L. The LOAEL in *Daphnia* is 20 µg/L, and fipronil-sulfone and fipronil-desulfinyl are almost seven and two times more toxic, respectively, than parent fipronil. It is highly toxic to honey bees by contact and ingestion when it is applied to plants (USEPA, 1996).

5.5.5 Physical Properties/Environmental Fate and Transport

Fipronil is nonvolatile. It degrades rapidly in water under UV light. The primary photodegradate is fipronil-desulfinyl. Under aerobic conditions in soil, it is subjected to microbial degradation, which results in the production of fipronil-sulfone (USEPA, 1996). It can also be hydrolyzed to form fipronil-amide. These degradates are persistent and immobile in soil (National Pesticide Information Center).

5.5.6 Water Pollution Potential

Fipronil degrades rapidly in water under UV light ($t_{1/2}$ = 3 days). It is not likely to leach from soil into ground or surface water. The fipronil-containing bait stations used by the are used indoors, and thus the water pollution potential is negligible.

5.6 Sodium tetraborate decahydrate (borax)

SODIUM TETRABORATE DECAHYDRATE (BORAX)

Formulations: Prescription Treatment and Terro Ant Killer II

- > Human Toxicity: Low toxicity. Eye irritation possible. No evidence of neurotoxicity, carcinogenicity, immunotoxicity, or reproductive/developmental toxicity.
- > Ecological Toxicity: Practically nontoxic to slightly toxic birds, fish, and aquatic invertebrates, and it is relatively nontoxic to beneficial insects
- > Water Pollution Potential: Naturally present in water.
- > Other Considerations: Used in targeted response to ant infestations.

5.6.1 Basic Use Information

- > Products: *Prescription Treatment* and *Terro Ant Killer II*
- > Typical target pests: Argentine ants
- > Application rates:

Material	Prescription Formulation	Terro Ant Killer Formulation
Borax	1.3% a.i.	5.4% a.i.

Sodium tetraborate decahydrate, also known as borax, was first registered for use as a pesticide by the USEPA in 1948. It is the active ingredient in Prescription Treatment and Terro Ant Killer II. It functions by disrupting the water balance of insects. The USEPA has determined that, because boric acid and its sodium salts are of low toxicity and occur naturally, they should be exempted from the requirement of a tolerance (maximum residue limit) for raw agricultural commodities (USEPA, 1993a). Additionally, relatively small amounts of borax and boric acid are used for pesticide purposes. Because of its minimal usage and low potential toxicity, very little experimental data exist for borax.

5.6.2 Exposure Considerations

Borax is the active ingredient in Prescription Treatment and Terro Ant Killer II baits. Prescription Treatment ant baits contain 1.3% borax and are approved for use both indoors and outdoors. Terro Ant Killer II liquid contains 5.4% borax and can be used indoors and outside near buildings. These products are not used within 15 ft of aquatic systems.

5.6.3 Human Toxicity

Borax is listed as a Category III compound for oral and dermal toxicity and skin irritation. For Prescription ant bait, the rat oral LD50 is >5,000 mg/kg, and the rabbit dermal LD50 is >5,000 mg/kg (BASF, 2009). Terro liquid ant bait has a similar lack of toxicity to mammals: the rat acute oral LD50 is >5,000 mg/kg and the rabbit acute dermal LD50 is > 2,000 mg/kg (Senoret Chemical Company, 2009). It is listed as a Category I eye

irritant. The USEPA has classified boric acid as a Group E carcinogen, indicating that there is evidence of noncarcinogenicity to humans (USEPA, 1993a).

5.6.4 Ecological Toxicity

Technical boric acid and borax are reported to be practically nontoxic to slightly toxic birds, fish, and aquatic invertebrates, and it is relatively nontoxic to beneficial insects (USEPA, 1993a). The LD50 for boric acid in bobwhite quail is >2,510 mg/kg. Bluegill appear to be the most sensitive fish to borax, with a 24-h LC50 of 41 mg/L, while mosquito fish are the least sensitive (24-h LC50 = 12,000 mg/L). In *Daphnia magna*, 48-h LC50s range from 133-530 mg boron/L when exposed to boric acid or borate salts. LD50 values for frogs and toads range from 414 to 529 mg borax/L (National Pesticide Information Center).

5.6.5 Physical Properties/Environmental Fate and Transport

Due to the fact that significant amounts of boron are naturally present in soil and water, the fate and transport of borax is not well elucidated. Boron salts also occur naturally in low concentrations in most unpolluted waterways. There is no data to show that borates or boric acid are transformed or degraded in the atmosphere through photolysis or hydrolysis.

5.6.6 Water Pollution Potential

Boron is ubiquitous and naturally present in water. The water pollution potential of borax is negligible.

5.7 Diatomaceous earth

DIATOMACEOUS EARTH

Formulations: NA

- > Human Toxicity: Low toxicity. Mild skin and eye irritation possible. No evidence of neurotoxicity, carcinogenicity, immunotoxicity, or reproductive/developmental toxicity.
- > Ecological Toxicity: No evidence of toxicity to wildlife.
- > Water Pollution Potential: Insoluble in water.
- > Other Considerations: This natural compound consists of the fossilized remains of hard shelled algae known as diatoms.

5.7.1 Basic Use Information

- > Products: N/A
- > Typical target pests: All insects
- > Application rates:

Material	Use	Rate
Diatomaceous earth	Fill in crack/voids/interior walls, claimed to be non-toxic insecticide and additive.	Various rates

Diatomaceous earth is a natural compound that also functions through disrupting the water balance of insects. It is practically non-toxic to humans and wildlife, and it is not of environmental concern. The USEPA has identified it as a compound to deregulate due to its lack of toxicity.

5.7.2 Exposure Considerations

Diatomaceous earth applied to cracks, interior walls, voids, and bulk food storage to control unwanted insects. It is used at various rates depending on the target nuisance insect and level of infestation. Because it is not selective, it is used in very directed and specific applications. It is not used within 15 ft of aquatic systems.

5.7.3 Human Toxicity

The LD50 in rats is >5,000 mg/kg (Category IV); the dermal LD50 is >2,000 mg/kg (Category III); and the acute inhalation LD50 is > 0.859 mg/L,

the highest dose tested in the study (USEPA, 1984). Diatomaceous earth may cause mild eye and skin irritation in some people.

5.7.4 Ecological Toxicity

There is no evidence of toxicity to wildlife exposed to diatomaceous earth.

5.7.5 Physical Properties/Environmental Fate and Transport

Diatomaceous earth is insoluble in water.

5.7.6 Water Pollution Potential

The water pollution potential of this active ingredient is negligible.

6 Adjuvants/Surfactants

Table 6-1 Human Toxicity Summary of Adjuvant/Surfactant Active Ingredients

Active Ingredient	Mammalian Oral LD50 (mg/kg) ^A	Mammalian Dermal LD50 (mg/kg) ^B	Mammalian Inhalation LC50 (mg/L) ^A	USEPA Toxicity Rating	Carcinogenic	Reproductive or Developmental Toxicity	Neurotoxic	Immunotoxic	Endocrine Disruption
Modified Vegetable Oil/Methylated Seed Oil	>5,000 (Competitor)	>5,000 (Competitor)	NA	NA	NA	NA	NA	NA	NA
Lecithin	>5,000 (Liberate)	>2,000 (Liberate)	NA	NA	NA	NA	NA	NA	NA
Alcohol Ethoxylates	600 to >10,000	2,000 to >5,000 (rat)	1.5 – 20.7	NA	No	No	NA	NA	NA
Alkylphenol ethoxylate (APE)	low	low	NA	NA	NA	Yes	NA	NA	Yes

Table 6-2 Ecotoxicity Summary of Adjuvant/Surfactant Active Ingredients

Active Ingredient	Mammalian Oral LD50 (mg/kg) ^A	Mammalian Dermal LD50 (mg/kg) ^B	Mammalian Inhalation LC50 (mg/L) ^A	Avian LD50 (mg/kg) ^C	Fish LC50 (mg/L) ^D	Aquatic Invert EC50 (mg/L) ^E	Honeybee LD50 (µg/bee)	Other Receptors
Modified Vegetable Oil/Methylated Seed Oil	>5,000 (Competitor)	>5,000 (Competitor)	NA	NA	95 (Competitor)	>100 (Competitor)	NA	NA
Lecithin	>5,000 (Liberate)	>2,000 (Liberate)	NA	NA	17.6 (Liberate)	9.3 (Liberate)	NA	NA
Alcohol Ethoxylates	600 to >10,000	2,000 to >5,000 (rat)	1.5 – 20.7	NA	0.25 - 100	0.100 – 100	NA	NA
Alkylphenol ethoxylate (APE)	low	low	NA	NA	0.135 (fathead minnow) – 110 (killifish)	0.18 to 1.5	NA	NA

A. Unless otherwise specified, values are for rats.

B. Unless otherwise specified, values are for rabbits.

C. Unless otherwise specified, values are for mallard duck or bobwhite quail.

D. Unless otherwise specified, values are for rainbow trout or bluegill sunfish.

E. Values are for Daphnia or similar species.

6.1 Modified vegetable/seed oil

MODIFIED VEGETABLE/SEED OIL

Formulations: Competitor MSO

- > Human Toxicity: Low toxicity. No evidence of neurotoxicity, carcinogenicity, immunotoxicity, or reproductive/developmental toxicity.
- > Ecological Toxicity: Slightly toxic to fish and practically non-toxic to freshwater invertebrates.
- > Water Pollution Potential: Biodegradable and insoluble in water.
- > Other Considerations: Limited toxicity and fate and transport data are available.

6.1.1 Basic Use Information

- > Products: *Competitor MSO*
- > Application rates:

Material	Surfactant Low Rate	Surfactant High Rate	Diluent Use	Volume/acre
Competitor MSO	0.5% v/v spot, low volume, and broadcast treatments	1% v/v spot and low volume treatments	90% v/v for stump cut treatments	Variable

Modified vegetable seed oil is one of the active ingredients in Competitor MSO. These oils act as adjuvants to decrease surface tension, increase herbicide uptake, and enhance wetting and spreading. They are used in conjunction with and to help the efficacy of aquatic pesticides.

6.1.2 Exposure Considerations

Competitor MSO is used as a surfactant with other active ingredient herbicides at a high foliar rate of 1% v/v for spot and low volume treatments. It is used at a low foliar rate of 0.5% v/v for spot, low volume, and broadcast treatments. It is also used as a diluent (90% v/v) with other herbicides for cut stump treatments. The same BMPs and precautions utilized for active ingredient herbicides are also utilized for this surfactant.

6.1.3 Human Toxicity

Competitor MSO exhibits very low toxicity to mammals. The rat oral and rabbit dermal LD50

are both >5,000 mg/kg. It is minimally irritating to eyes (Competitor MSO MSDS). It is not listed as a carcinogen.

6.1.4 Ecological Toxicity

Competitor MSO is reported to be slightly toxic to fish; the 96-h LC50 in rainbow trout is 95 mg/L. It is practically non-toxic for freshwater invertebrates, with a 48-h EC50 of >100 mg/L for daphnids (Washington State Department of Agriculture, 2009).

6.1.5 Physical Properties/Environmental Fate and Transport

Very little information exists about the environmental fate and transport of these oils.

6.1.6 Water Pollution Potential

According to the product sheet for Competitor MSO, it is biodegradable and is relatively insoluble in water. Thus, the water pollution potential of this compound is low.

6.2 Lecithin

LECITHIN

Formulations: Liberate NIS

- > Human Toxicity: Low toxicity. No evidence of neurotoxicity, carcinogenicity, immunotoxicity, or reproductive/developmental toxicity.
- > Ecological Toxicity: Slightly toxic to fish and moderately toxic to freshwater invertebrates.
- > Water Pollution Potential: Registered for use near/in water and recognized as safe by the USDA.
- > Other Considerations: NA.

6.2.1 Basic Use Information

- > Products: *Liberate NIS*
- > Application rates:

Material	Low Foliar Rate	High Foliar Rate	Volume/acre
Liberate NIS	0.25% v/v spot, low volume, and broadcast treatments	0.5% v/v spot and low volume treatments	Variable

Lecithin is a general term used to describe yellow-brownish fatty substances occurring in animal and plant tissues. It is often derived from soybeans. It is one of the ingredients in Liberate, a nonionic surfactant, which also contains alcohol ethoxylates, discussed below (Washington State Department of Agriculture, 2009). Liberate is an uptake enhancing surfactant that is used in conjunction with other herbicides and pesticides.

6.2.2 Exposure Considerations

Liberate NIS is used as a surfactant with other active ingredient herbicides at a high foliar rate of 0.5% v/v for spot and low volume treatments. It is used at a low foliar rate of 0.25% v/v for spot, low volume, and broadcast treatments. It is commonly used as a surfactant with Roundup Custom. The same BMPs and precautions utilized for active ingredient herbicides are also utilized for this surfactant.

6.2.3 Human Toxicity

Lecithin is metabolized by mammals and is non-toxic when ingested. It is used as a food additive and is recognized as safe by the USFDA. The

acute oral LD50 of Liberate for rats is >5,000 mg/kg, and the acute dermal LD50 in rabbits is >2,000 mg/kg. It is not an eye irritant and not a skin sensitizer. It is not listed as a carcinogen (Liberate MSDS, 2012).

6.2.4 Ecological Toxicity

The 96-h LC50 for Liberate in rainbow trout is 17.6 mg/L (slightly toxic), with a NOAEL of 12.5 mg/L. Liberate is moderately toxic to freshwater invertebrates: the 48-h LC50 for daphnids is 9.3 mg/L, and the NOAEL is 7.5 mg/L (Liberate MSDS, 2012).

6.2.5 Physical Properties/Environmental Fate and Transport

Little is known about the fate of lecithin in the environment (Tu et al., 2001). It is relatively insoluble in water.

6.2.6 Water Pollution Potential

Lecithin is registered for use near/in water, is insoluble in water, and is recognized as safe by the USDA. The water pollution potential of lecithin is negligible.

6.3 Alcohol ethoxylates

ALCOHOL ETHOXYLATES

Formulations: Liberate NIS

- > Human Toxicity: Low toxicity. No evidence of neurotoxicity, carcinogenicity, immunotoxicity, or reproductive/developmental toxicity.
- > Ecological Toxicity: Slightly toxic to fish and moderately toxic to freshwater invertebrates.
- > Water Pollution Potential: Registered for use near/in water and recognized as safe by the USDA.
- > Other Considerations: NA.

6.3.1 Basic Use Information

- > Products: *Liberate NIS*
- > Application rates:

Material	Low Foliar Rate	High Foliar Rate	Volume/acre
Liberate NIS	0.25% v/v spot, low volume, and broadcast treatments	0.5% v/v spot and low volume treatments	Variable

Alcohol ethoxylates are a constituent of Liberate, along with lecithin. They are also commonly used in laundry detergents and household cleaners.

6.3.2 Exposure Considerations

Liberate NIS is used as a surfactant with other active ingredient herbicides at a high foliar rate of 0.5% v/v for spot and low volume treatments. It is used at a low foliar rate of 0.25% v/v for spot, low volume, and broadcast treatments. It is commonly used as a surfactant with Roundup Custom. The same BMPs and precautions utilized for active ingredient herbicides are also utilized for this surfactant.

6.3.3 Human Toxicity

Alcohol ethoxylates exhibit low toxicity to mammals via oral, inhalation, and dermal routes of exposure. Oral LD50 values for rats range from 600 mg/kg to >10,000 mg/kg depending on the structure of the compound. One- to four-hour inhalation LC50 values range from 1.5 to 20.7 mg/L in rats. Acute dermal LD50 values range from 2,000 to >5,000 mg/kg in rats (HERA, 2009). They may be irritating to eyes and skin. There are no data indicating that alcohol

ethoxylates are genotoxic, mutagenic, or carcinogenic. They are also not categorized as reproductive or developmental toxicants. See above section for Liberate toxicity information.

6.3.4 Ecological Toxicity

The toxicity of alcohol ethoxylates differs depending on the branching and number of carbons in the specific compound. No toxicity data are available for birds. The 96-h LC50s in fish vary widely, from 0.25 – 100 mg/L (HERA, 2009). EC50s for invertebrates range from 0.1 to 100 mg/L. See above section for Liberate toxicity information.

6.3.5 Physical Properties/Environmental Fate and Transport

Alcohol ethoxylates are readily biodegradable under aerobic and anaerobic conditions. Total measured removal rates in wastewater treatment plants vary from 99.6 to 99.9%. They have low vapor pressure and are relatively nonvolatile. As they increase in carbon number, their water solubility decreases. They are able to sorb to soils. Hydrolysis in water and photolysis in water or soils is unlikely (HERA, 2009).

6.3.6 Water Pollution Potential

Alcohol ethoxylates are permitted for use in/near aquatic systems and are readily biodegradable.

Therefore, the water pollution potential of these compounds is low.

6.4 Alkylphenol ethoxylates

ALKYLPHENOL ETHOXYLATES

Formulations: Pentra-bark

- > Human Toxicity: Low toxicity. Irritating to skin and eyes. No evidence of neurotoxicity, carcinogenicity, or immunotoxicity. Potential estrogen-mimicking behavior of some congeners.
- > Ecological Toxicity: Toxic to fish and aquatic invertebrates.
- > Water Pollution Potential: Persistent in sediment and stable to photolysis and hydrolysis.
- > Other Considerations: Formulation is used via injection or directed spray in targeted applications, reducing exposure and risk to non-target species.

6.4.1 Basic Use Information

- > Products: Pentra-bark
- > Application rates:

Material	Basal bark treatment	Volume/acre
Pentra-bark	2.5% v/v oak treatment in forests	Variable

Alkylphenol ethoxylates (APEs) are used as detergents, wetting agents, dispersants, emulsifiers, solubilizers and foaming agents. They are constituents of Pentra-Bark, a nonionic wetting agent, which is used in conjunction with Agri-Fos to prevent sudden oak death. Use of Pentra-Bark with Agri-Fos eliminates the need for aerial applications, reducing exposure to non-target systems.

6.4.2 Exposure Considerations

Alkylphenol ethoxylates are the active ingredients in the surfactant Pentra-bark, which is used with Agri-Fos to increase the uptake of the fungicide by the tree, thereby increasing its efficacy and decreasing its potential to impact non-target species. Pentra-bark is used at a rate of 2.5% v/v. Agri-Fos and Pentra-bark are applied by the basal bark method, which decreases the potential for drift, deposition in water, and exposure to non-targets because the fungicide is sprayed directly onto the bark and quickly taken up by the tree.

6.4.3 Human Toxicity

The toxicity of APEs usually increases as the length of the hydrophobic chain increases. Nonylphenol (NP), a well-studied APE, is of low acute oral and dermal toxicity but is highly irritating and corrosive to the skin and eyes (USEPA, 2010). Concern exists regarding the estrogen-mimicking behaviors of APEs (USEPA, 2010). NP and nonylphenol ethoxylate (NPE) are of particular interest and concern to the public and the EPA. The USEPA (USEPA, 2010) has recently recommended that this suite of chemicals be evaluated further due to their widespread use (past and present), persistence, and possible estrogen-mimicking behavior.

6.4.4 Ecological Toxicity

Toxicity of APEs to aquatic organisms increases with alkyl chain length. The 48-h LC50 for APEs in brown trout is 2.7 mg/L, and the 48-h LC50 in Daphnia is 1.5 mg/L (Argese et al., 1994). NP is bioaccumulative and toxic to aquatic organisms.

NPEs, though less toxic than NP, are also highly toxic to fish, aquatic invertebrates, and aquatic plants (USEPA, 2010). The 96-h LC50 of NP in fathead minnow is 0.135 mg/L (Holcombe et al., 1983), and the 48-h LC50 in *Daphnia* is 0.18 mg/L (Comber et al., 1993).

6.4.5 Physical Properties/Environmental Fate and Transport

Alkylphenol ethoxylates are essentially nonvolatile. They degrade faster in the water column than in sediment. Aerobic conditions further facilitate biotransformation of APE metabolites as compared to anaerobic conditions (Ying et al., 2002). Primary degradation of APEs in the environment generates more persistent shorter chain APEs and alkylphenols (i.e., nonylphenol, octylphenol, and mono- to triethoxylates), some of which may mimic natural

hormones and disrupt endocrine function in wildlife and humans (Ying et al., 2002).

6.4.6 Water Pollution Potential

The solubility of APEs decreases with increasing carbon number. They are stable to photolysis and hydrolysis in water, though labile to biodegradation under aerobic conditions ($t_{1/2}$ = 4-24 days). APEs bind strongly to aquatic particles in river and coastal environments and are persistent in sediments. Due to the basal park application of Pentra-bark, the water pollution of this formulation is negligible.

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8 List of Abbreviations/Acronyms/Definition

a.e.	Acid equivalent-The acidic level of a chemical in solution
a.i.	Active ingredient-The primary chemical in a products that is the toxic chemical of concern.
AMPA	Aminomethylphosphonic acid
APE	Alkylphenol ethoxylate
BMP	Best Management Practice- Documented approaches to conducting field applications that have been demonstrated to minimize any unwanted adverse effects to the environment.
bw	Body weight- The weight of an individual, usually expressed in grams for toxicology rankings to wildlife species impacted or in kilograms for humans.
K _{OW}	Octanol-water partitioning coefficient of an organic compound. A dimensionless concentration ratio whose magnitude expresses the distribution of a compound between equal volumes of n-octanol and water.
LC ₅₀	Median lethal concentration. A statistically derived concentration of a substance that can be expected to cause death in 50% of the test animals when administered by the indicated route (oral, dermal, inhalation). Usually expressed as the amount of substance per amount of solution (e.g., mg/L).
LD ₅₀	Median lethal dose. A statistically derived concentration of a substance that can be expected to cause death in 50% of test animals when administered by the indicated route (oral, dermal, inhalation). Usually expressed as a weight of substance per unit weight of animal (e.g., mg/kg).
LOAEL	Lowest observed adverse effect level. The lowest dose/concentration of a compound that causes a significant predetermined adverse effect in an experimental population.
µg	Micrograms One thousandth of a gram.
µg/g	Micrograms per gram of substance.
mg/kg bw	Milligrams per kilogram of body weight- General metric used for determining dose.
mg/L	Milligrams per liter-
MSDS	Material safety data sheet- Published documentation of all available information about a chemical, including toxicity to humans and wildlife, known hazards and special conditions required for use.
NOAEL	No observed adverse effect level. The highest dose/concentration of a compound that causes no significant predetermined adverse effects in an experimental population.
NSAE	No significant adverse effects
IPM	Integrated Pest Management- An approach to pest management that combines BMPs, use of appropriate application scenarios, and minimal chemical use to achieve desired pest control.
POAE	Polyethoxylated tallowamine

RfD	Reference dose. The RfD is an estimate of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.
t $\frac{1}{2}$	Half-life. The period of time required for the amount of a substance undergoing decay to decrease by half.
USEPA	United States Environmental Protection Agency

Glossary

Table of USEPA Toxicity Categories

Route of Exposure	I: High Toxicity	II: Moderate Toxicity	III: Low Toxicity	IV: Very Low Toxicity
Acute Oral LD50	≤50 mg/kg	50-500 mg/kg	500 – 5000 mg/kg	>5000 mg/kg
Acute Dermal LD50	≤200 mg/kg	200 – 2000 mg/kg	2000 – 5000 mg/kg	>5000 mg/kg
Acute Inhalation LC50	≤0.05 mg/L	0.05 - 0.5 mg/L	0.5 - 2 mg/L	>2 mg/L
Primary Eye Irritation	Corrosive (irreversible destruction of ocular tissue) or corneal involvement or irritation persisting for more than 21 days	Corneal involvement or irritation clearing in 8-21 days	Corneal involvement or irritation clearing in 7 days or less	Minimal effects clearing in less than 24 h
Primary Skin Irritation	Corrosive (tissue destruction into the dermis and/or scarring)	Severe irritation at 72 h (severe erythema or edema)	Moderate irritation at 72 h (moderate erythema)	Mild or slight irritation (no irritation or slight erythema)

Table of Fate and Transport of Active Ingredients Used by the District

Active Ingredient	Air	Water	Soil
Glyphosate	Nonvolatile	> Very soluble > In aquatic systems, sediment appears to be the major sink for glyphosate residue > Broken down by microbial degradation > Stable to hydrolysis and photolysis > $T_{1/2} \approx 8$ days	> Strongly adsorbs to soil particles; remains in top 0-6" of soil > Low tendency to leach or runoff > Resistant to chemical degradation and photolysis > Biodegraded by microbes under aerobic ($t_{1/2} = 1-2$ days) and anaerobic conditions ($t_{1/2} = 8-25$ days)
Aminopyralid	Nonvolatile	> Degraded by photolysis; $t_{1/2} = 0.6$ days > Stable to hydrolysis > Susceptible to degradation under aerobic conditions; $t_{1/2} = 462-990$ days	> Weakly sorbs to soil > Minimal leaching below the 15-30 cm soil depth > Non-persistent > Degraded by photolysis but much more slowly than in water; $t_{1/2} = 72$ days > Susceptible to degradation under aerobic conditions; $t_{1/2} = 31-533$ days
Clopyralid	Relatively nonvolatile	> Very soluble > Degraded rapidly > Stable to hydrolysis and photolysis > $T_{1/2} = 9-22$ days	> Does not bind tightly to soil; mobile > Primarily degraded by microbes > Low leaching potential > Stable in compost > $T_{1/2} = 8-250$ days
Imazapyr	Nonvolatile	> Degraded by photolysis; $t_{1/2} = 3-8$ days > Stable to hydrolysis > Stable to aerobic and anaerobic aquatic metabolism	> Moderately persistent > Mobile > Primarily degraded by microbes; $t_{1/2} = 14-150$ days > Stable to hydrolysis > Stable to aerobic and anaerobic degradation > May leach to groundwater
Clethodim	Nonvolatile	> Very persistent	> Non-persistent; $t_{1/2} = 3$ days > Weakly bound to soil; mobile > Degraded through aerobic processes
Potassium salts of phosphorus acid	na	> Very soluble > Rapidly dissociate to yield hydrogen and phosphite ions	> Microbial transformation is very slow
d-trans allethrin	na	> Insoluble > Degraded rapidly by photolysis; $t_{1/2} < 8$ h > Stable to hydrolysis	> Adheres moderately to soil containing organic matter

Active Ingredient	Air	Water	Soil
Phenothrin	na	> Low water solubility > Stable to hydrolysis > Degraded rapidly by photolysis; $t_{1/2}$ = 6.5 days > Degraded by aerobic metabolism; $t_{1/2}$ = 36 days	> High affinity for binding to soils and moderate persistence in surface soils > Low leaching potential; relatively immobile > Aerobic metabolism $t_{1/2}$ = 18-26 days
Indoxacarb	Nonvolatile	> Degraded primarily via photolysis; $t_{1/2}$ = 3 days > Relatively stable to hydrolysis at pH 5 and 7; $t_{1/2}$ > 30 days > Susceptible to hydrolysis at pH 9; $t_{1/2}$ = 1 day	> Moderately persistent > Immobile > Degraded under aerobic conditions; $t_{1/2}$ = 4-7 days > Stable to photolysis; $t_{1/2}$ = 139 days
Hydroprene	Nonvolatile	> Insoluble	> Rapidly degraded; $t_{1/2}$ $\approx$ 3 days
Fipronil	Nonvolatile	> Degrades rapidly under UV; $t_{1/2}$ = 3 days	> Under aerobic conditions, broken down by microbes > Photodegradation $t_{1/2}$ = 34 days > Low potential for leaching
Sodium tetraborate decahydrate (borax)	Nonvolatile	> Soluble	na
Diatomaceous earth	Nonvolatile	> Insoluble	na
Modified Vegetable Oils and Methylated Seed Oil	na	> Insoluble	na
Lecithin	na	> Insoluble	na
Alcohol Ethoxylates	Nonvolatile	> Solubility decreases with increasing carbon > Rapidly biodegraded under aerobic conditions; $t_{1/2}$ = 4-24 h > Stable to hydrolysis and photolysis	> Rapidly biodegraded under aerobic conditions > Stable to hydrolysis and photolysis
Alkylphenol ethoxylates	Nonvolatile	> Degrades faster in water than in soil; $t_{1/2}$ = 4-24 days > Solubility decreases with increasing carbon	> Bind strongly to particulates and are persistent in sediments > Aerobic conditions facilitate biotransformation; $t_{1/2}$ = 4-320 days

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APPENDIX C

2025 Integrated Pest Management Program Best Management Practices

APPENDIX C: 2025 INTEGRATED PEST MANAGEMENT PROGRAM BEST MANAGEMENT PRACTICES

Best Management Practices

#	BMP	Functional Groups	Responsible Party	Timing
1.	Annual Pesticide Literature Review To inform updates to the Program, the District shall eConduct an annual pesticide literature review of all newly published toxicological, regulatory, and efficacy information relevant to products on the research and court proceedings related to pesticides in the "Approved Pesticide List."	Administrative	IPM Coordinator	Annual planning; Prior to treatment
2.	Glyphosate Use Reduction Where feasible, the District shall reduce the use of glyphosate in its preserves For IPM projects currently utilizing glyphosate as a management tool, the District shall identify suitable sites to implement alternative treatment methods. The District shall seek to replace by replacing glyphosate use with the safest available effective alternative broad-spectrum, post-emergent herbicide with minimal residual soil activity.	Administrative	District staff	Annual planning; Prior to treatment
3.	Pest Control Recommendation All pesticides and adjuvants use shall be implemented used consistently with written Pest Control Recommendations prepared annually by a licensed Pest Control Advisor. The Pest Control Advisor shall ensure that a All pesticide applications are to be performed at the time of year and phenological window for maximum effectiveness, thereby increasing treatment efficacy and reducing the need for follow-up applications, unless constraints limit application at the optimal time. Adjuvants shall be used and applied consistent with the District's Pest Control Recommendations. All appropriate laws and regulations pertaining to the use of pesticides and safety standards for employees and the public, as governed by the U.S. Environmental Protection Agency, the California Department of Pesticide Regulation, and local jurisdictions shall be followed. All applications shall adhere to label directions for application rates and methods, storage, transportation, mixing, and container disposal. All contracted applicators shall be appropriately licensed by the state. District staff shall coordinate with the County Agricultural	Administrative	Licensed pest control advisor	Prior to treatment; During treatment

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	Commissioners, and all required licenses and permits shall be obtained prior to pesticide application.			
4.	Pesticide Label Applicators shall follow all pesticide label requirements and refer to all other relevant IPMP BMPs regarding mandatory measures to protect sensitive resources, and employee and public health during pesticide application. Some herbicides, such as Envoy, Milestone, Transline, and Capstone, contain specific label language restrictions that shall be adhered to, such as those pertaining to when to use in grazed rangelands. All District field crew who perform herbicide treatments shall have specialized experience and training in pesticide safety, IPM principles, and special status species. Grazing Animals – Some herbicides, such as Milestone, Transline, and Capstone contain label language restricting grazing and/or use of compost. Always read and follow label directions.	District staff/ Contractor	Pesticide applicator (qualified District staff/ contractor)	Prior to treatment; During treatment
5.	Pesticide Certification and Supervision Pesticide applicators shall have or work under the direction of a person with a Qualified Applicator License (QAL) or Qualified Applicator Certificate (QAC). As appropriate, the District shall implement QAC certification requirements for additional field staff to enhance field crew training. Contractors and grazing and agricultural tenants may apply approved pesticides after review and approval by the District and under the direction of QAL/QAC field supervisors. After review and approval by the District and under the direction of QAL/QAC, contractors may apply approved fungicides to District preserves for the research and control of Sudden Oak Death (SOD). As needed for the control of mosquitos, cattle grazing rangers may apply District approved bacterial pathogens to water troughs in District preserves. Employees, contractors and tenants may install approved ant and roach bait stations inside buildings in tamper-proof containers without review by a QAL/QAC. Tenants may not use rodenticides; only qualified District staff or District contractors may use approved rodenticides and these should only be used in the event of an urgent human health issue, in a manner consistent with the product label, and in anchored, tamper-proof containers inside buildings. Pesticide applicators must hold or operate under a Qualified Applicator License (QAL) or Qualified Applicator Certificate (QAC). Contractors	District staff/ Contractor	Pesticide applicator (qualified District staff/ contractor)	Prior to treatment

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	and agricultural tenants may apply District-approved pesticides with District approval and QAL/QAC supervision. District-approved rodenticides may only be used by qualified contractors, and only for urgent human health concerns, following label guidelines and placed indoors in anchored, tamper-proof containers. Termiticides must be applied by applicators licensed by the Structural Pest Control Board. Employees, contractors, and tenants may install ant and roach bait stations in tamper-proof containers indoors and approved bacterial agents to water troughs for mosquito control without QAL/QAC supervision.			
6.	Pesticide Storage, Loading, and Mixing All storage, loading, and mixing of pesticides shall be set back at least 300 feet from any aquatic feature, <u>or known locations of special-status species, occupied or suitable special-status species or their habitat</u>, or sensitive natural communities. Applicators shall use an air gap or antisiphon device to prevent backflow while loading <u>pesticides</u>. All mixing and transferring shall occur within a contained area. Any transfer or mixing on the ground shall be within containment pans or over protective tarps and away from drain inlets, culverts, wells, areas with porous or erosion-prone soil, or other features that may allow for runoff.	District staff/ Contractor	Pesticide applicator (qualified District staff/ contractor)	Prior to treatment
7.	Uses of Herbicide Dyes As deemed necessary by the Pest Control Adviser, QAL, or QAC, appropriate, non-toxic colorants or dyes shall be added to the herbicide mixture to determine treated areas and prevent over-spraying, particularly in public areas.	District staff/ Contractor	Pesticide applicator (qualified District staff/ contractor)	Prior to treatment
8.	Notification of Pesticide Application Signs <u>stating "Pesticide Use Notification"</u> shall be posted notifying the public, employees, and contractors of the District's use of pesticides. The sign shall consist of the following information: - product name, signal word, and manufacturer, active ingredient, and EPA registration number; - target pest; - preserve name <u>and/or building</u>; <u>treatment location in preserve</u>, date and time of application;	District staff/ Contractor	District staff/ Contractor	Prior to treatment

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	- for buildings, if vacancy is required and duration; - date which notification sign may be removed; and - contact person with telephone number (typically IPM Coordinator). Signs shall be posted in accordance with the following dependent upon the location and urgency: <i>Outdoor areas of all District-owned preserves and unoccupied buildings:</i> posted at each end of the outdoor treatment area and any intersecting trails 24 hours before the start of treatment until 72 hours after the end of treatment <i>Occupied buildings:</i> - notification will be provided to building occupants (employees, visitors, residents) 24 hours before the start of treatment by email, letters or telephone calls - posted at the entrances to the building 24 hours before the start of treatment until 72 hours after the end of treatment (except for approved insecticidal baits in tamper-proof containers) <i>Urgent application of pesticides to control stinging insects or immediate public safety concern:</i> posted at the treatment area until 72 hours after the end of treatment generally be posted 24 hours before the start of treatment and notification shall remain in place for 72 hours after treatment ceases. In no event shall a sign be in place longer than 14 days without dates being updated. See the IPM Guidance Manual for further details on posting locations, posting for pesticide use in buildings and for exceptions.			
9.	Trail Closures <i>Parking lots, Trails, and Trailheads.</i> Establish a minimum 5-ft no-spray buffer from parking lots and trails unless a temporary 24-hour closure is used to prevent visitor exposure. To reduce potential staff and visitor exposure to pesticides, no-spray trail buffers shall be established at least 5 feet from any trails, trailheads, or parking lots unless a 24-hour trail closure is observed. <i>Building.</i> Buildings shall be closed for the recommended label timeframe (from 24 to 72 hours) when pesticides are used for structural pests (e.g., Vikane). Closures are not required for baiting or perimeter applications.	District staff/ Contractor	District staff/ Contractor	Prior to treatment

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10.	Crew Training to Prevent Spread of Weeds Annual worker environmental awareness training shall be conducted for all treatment field crews (staff and volunteers) and contractor crews, which shall include the following at a minimum:- • All staff, contractors, and volunteers shall be properly trained to prevent spreading Preventing the spread of weeds and pests to other sites. • Special-status species and sensitive natural communities that are known to occur or determined to have the potential to occur on the treatment site by a District--approved biologist. The education training shall be conducted prior to starting work and upon the arrival of any new. The training shall consist of a brief review of life history, field identification, and habitat requirements for each special-status species, their known or probable locations in the vicinity of the treatment site, potential fines for violations, avoidance measures, and necessary actions if special-status species or sensitive natural communities are encountered. • All District field crews who perform herbicide treatments shall have specialized experience and training in pesticide safety, IPM principles, and special--status species. • Identification and protection of sensitive archaeological, paleontological, or historic resources (e.g., projectile points, mortars, midden sites, historic bottles, cans, trash deposits, or structures and structural remnants).	District staff/ Contractor	District staff/ Contractor	Prior to treatment
11.	Pre-Treatment Surveys A District-approved biologist shall survey all selected treatment sites shortly before work to determine site conditions and develop any necessary site-specific measures. Treatment sites are defined as areas where IPM activity, including manual, mechanical, and chemical treatment, is expected to occur. In addition, on a repeating basis, grassland Treatment sites shall be surveyed by a District-approved biologist once every five 5 years and brushy and wooded sites shall be surveyed once every five years. Treatment sites are defined as areas where IPM activity, including manual, mechanical, and chemical treatment, is expected to occur. Brush removal on rangelands will require biological surveys before work is conducted in any year. Site inspections are to determine existing site conditions shall evaluate existing conditions at a given treatment site	District staff/ Contractor	District-approved biologist or other personnel	Prior to treatment

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	including the presence, population size, growth stage, and percent cover of target weeds and pests relative to native plant cover and the presence of special-status species and their habitat, or sensitive natural communities <u>and develop any necessary site-specific measures, such as buffer strips to avoid disturbance of grassland wildlife.</u> <u>Aquatic Areas</u> ~~Shortly before treatment, a~~ <u>During the pre-treatment surveys, a</u> District-approved qualified biologist or other District-approved personnel shall survey the treatment sites to determine whether any aquatic features <u>or water-supply infrastructure</u> are located on site. ~~In addition, on a repeating basis, grassland treatment sites shall be surveyed once every five years and brushy and wooded sites shall be surveyed by a District-approved biologist once every five years. Brush removal on rangelands will require biological surveys before work is conducted in any year. Aquatic features are defined by the presence of wetland indicators and/or a defined bed and bank, and can include as any natural or manmade lake, pond, wetland, river, creek stream, drainage way, ditch, spring, saturated soils, or similar feature that holds water at the time of treatment or typically becomes inundated during winter rains. Water-supply infrastructure includes spring boxes, wells, troughs, tanks, and water-distribution lines, and other infrastructure necessary to divert, store, or convey water, but does not include fully sealed pipes that are aboveground or underground. Treatment sites are defined as areas where IPM activity, including manual, mechanical, and chemical treatment, is expected to occur. If during the survey it is found that aquatic features or water-supply infrastructure are present within 15-30 feet of the proposed treatment area, the District shall either eliminate all treatment activities within 15-30 feet of the aquatic features from the project (i.e. do not implement treatment actions in those areas) or if the District chooses to continue treatment actions in these areas, it shall use pesticides and adjuvants in accordance with label requirements (BMP #4) that are, be labeled for aquatic use and follow the requirements of the mitigation measure for special-status wildlife species and the CDFW Streambed Alteration Agreement all relevant permit requirements (e.g., CDFW Streambed Alteration Agreement), if appropriate.~~ <u>Rare Plants</u>			

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#	BMP	Functional Groups	Responsible Party	Timing
	Shortly before treatment, all selected treatment sites shall be surveyed by District-approved personnel with environmental awareness training (BMP #20) prior to work to determine the potential presence of special-status plants. Rare During the pre-treatment surveys, rare plant surveys shall be conducted by a District-approved biologist during the appropriate season to assess the occurrence, if any. If special-status plants are reported, information such as species and location shall be uploaded into an electronic inventory system and a District-approved biological monitor shall be present to oversee the planned IPM treatment. On a repeating basis, grassland treatment sites shall be surveyed by a District-approved biologist once every five years and brushy and wooded sites shall be surveyed once every five years. Brush removal on rangelands will require biological surveys before work is conducted in any year. Treatment sites are defined as areas where IPM activity, including manual, mechanical, and chemical treatment, is expected to occur. A 30-foot buffer shall be established from special-status plants. No application of herbicides shall be allowed within this buffer. Non-herbicide methods can be used within 30 feet of rare plants but they shall be designed to avoid damage to the rare plants (e.g., pulling). In addition, annual worker environmental awareness training shall be conducted for all treatment field crews and contractors for special-status species and sensitive natural communities determined to have the potential to occur on the treatment site by a District approved biologist. The education training shall be conducted prior to starting work at the treatment site and upon the arrival of any new worker onto sites with the potential for special-status species or sensitive natural communities. The training shall consist of a brief review of life history, field identification, and habitat requirements for each special-status species, their known or probable locations in the vicinity of the treatment site, potential fines for violations, avoidance measures, and necessary actions if special-status species or sensitive natural communities are encountered. Mowing Patterns Where appropriate, equipment modifications, mowing patterns, and buffer strips shall be incorporated into manual treatment methods to avoid disturbance of grassland wildlife.			

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	Nesting Birds For all IPM activities that could result in potential noise and other land disturbances that could affect nesting birds (e.g., tree removal, mowing during nesting season, mastication, brush removal on rangelands), treatment sites shall be surveyed within two weeks prior to initiating activity to evaluate the potential for nesting birds. Tree removal will be limited, whenever feasible, based on the presence or absence of nesting birds. For all other treatments, if birds exhibiting nesting behavior are found within the treatment sites during the bird nesting season: March 15 – August 30 for smaller bird species such as passerines and February 15 – August 30 for raptors, impacts on nesting birds will be avoided by the establishment of appropriate buffers around active nests. The distance of the protective buffers surrounding each active nest site are: 1,000 feet for large raptors such as buteos, 500 feet for small raptors such as accipiters, and 250 feet for passerines. The size of the buffer may be adjusted by a District biologist in consultation with CDFW and USFWS depending on site specific conditions. Monitoring of the nest by a District biologist during and after treatment activities will be required if the activity has potential to adversely affect the nest. These areas can be subsequently treated after a District biologist or designated biological monitor confirms that the young have fully fledged, are no longer being fed by the parents and have left the nest site. For IPM activities that clearly would not have adverse impacts to nesting birds (e.g. treatments in buildings and spot spraying with herbicides), no survey for nesting birds would be required. For IPM activities that may cause noise or land disturbances affecting nesting birds (e.g., tree removal, mowing during nesting season, mastication, brush removal), sites must be surveyed by a District-approved, qualified biologist or biological monitor within 15 days prior to treatment to assess nesting activity. Tree removal shall be limited when feasible based on nest presence. During nesting season (March 15–August 30 for passerines; February 15–August 30 for raptors), if nesting behavior is observed, appropriate buffers shall be established: 1,000 feet for large raptors (e.g., buteos), 500 feet for small raptors (e.g., accipiters), and 250 feet for passerines. However, buffers may be adjusted by a District-approved biologist in coordination with CDFW and USFWS based on a number of factors including site conditions, time of year, and type/duration of disturbance. If treatment is therefore allowed to proceed by CDFW/USFWS, the nest must be			
12.		District staff/ Contractor	District-approved qualified biologist or biological monitor	Prior to treatment

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	monitored by a District-approved biologist to confirm that the treatment activities are not negatively affecting bird behavior. If negative effects are observed, treatment activities shall be paused, or substantially modified to avoid the disturbance in further consultation with CDFW/USFWS, and may resume only after fledglings have fully left the nest. IPM activities unlikely to affect nesting birds (e.g., indoor treatments, spot herbicide spraying) do not require a nesting bird survey.			
13.	Cultural Resources District staff, volunteer crew leaders, and contractors implementing treatment activities shall receive training on the protection of sensitive archaeological, paleontological, or historic resources (e.g., projectile points, bowls, baskets, historic bottles, cans, trash deposits, or structures). In the event volunteers would be working <u>Where work occurs</u> in locations with potential cultural resources, District staff shall provide instruction to protect and report any previously undiscovered cultural artifacts that might be uncovered during hand-digging activities. <u>If highly sensitive sites are known within or near the treatment site (e.g. burials or significant midden sites, which have a high potential for burials), the nature of the site should not be disclosed to volunteers or contractors, except to state that the site is sensitive and must be avoided (or treated only with appropriate methods).</u> If archaeological or paleontological resources are <u>known or</u> encountered on a treatment site and the treatment method consists of physical disturbance of land surfaces (e.g., mowing, brush cutting, pulling, or digging), work shall avoid these areas or shall not commence until the significance of the find can be evaluated by a qualified archeologist. <u>This measure is consistent with federal guidelines 36 CFR 800.13(a), which protects such resources in the event of unanticipated discovery.</u>	District staff/ Contractor	District staff/ Qualified archaeologist	Prior to treatment; During treatment
14.	Pesticide Application Restrictions in California Red-Legged Frog Habitat Application of <u>glyphosate, triclopyr, and chloropicrin pesticides</u> shall be conducted in accordance with the California Red-Legged Frog Injunction (Center For Biological Diversity v. U.S. Environmental Protection Agency (2006) Case No.: 02-1580JSW) in <u>known or critical habitat or specific sections of non-critical</u>	District staff/ Contractor	Pesticide applicator	Planning prior to treatment; During treatment

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	habitat potential for California red-legged frog habitat specifically by <u>complying with all of the following:</u> • <u>only using the amine formulation of triclopyr</u> • not applying specified pesticides within 15 feet of aquatic features (including areas that are <u>intermittent creeks, seeps, and springs</u> ~~wet at time of spraying or areas that are dry at time of spraying but subsequently might be wet during the next winter season~~); • utilizing only <u>localized spot treatment using hand-held devices</u> ~~spot-spraying techniques and equipment~~ by a certified applicator (<u>QAL or QAC</u>) or person working under the direct supervision of a certified applicator; and • not ~~spraying~~ <u>applying</u> during precipitation or if precipitation is forecast to occur within 24 hours before or after the proposed application. Preserves in which these precautions must be undertaken are: <u>Cloverdale Ranch, Coal Creek, El Corte de Madera Creek, La Honda Creek, Miramontes Ridge, Monte Bello, Picchetti Ranch, Purisima Creek Redwoods, Rancho San Antonio, El Corte de Madera, La Honda Creek, Picchetti Ranch, Russian Ridge, Sierra Azul, Skyline Ridge, and Tunitas Creek, Skyline Ridge, Rancho San Antonio, Monte Bello and Coal Creek OSP preserves and Toto Ranch.</u> <u>Alternatively, as applicable and appropriate, application of glyphosate, triclopyr, and chloropicrin shall be conducted in accordance with the most recent incidental take permit issued by the USFWS (Endangered Species Act section 7(a)(2)).</u>			
15.	<u>Fipronil Special-Status Species Buffer Requirements</u>~~Goby-11 Injection~~ <u>In accordance with the 2010 Stipulation Injunction (Center for Biological Diversity v. EPA, Case No. 07-2794-JCS (N.D. Cal.), May 30, 2007), prior to Fipronil pesticide treatment, the following buffer requirements shall be complied with:</u> • <u><i>San Francisco Garter snake</i>: Within Cloverdale Ranch and Russian Ridge OSPs, do not apply Fipronil within 200 feet of fresh-water ponds (including natural or manmade, such as stock ponds), slow moving streams or pools within streams, vernal pools and other ephemeral or permanent water bodies, which typically support inundation during winter rains and hold water for a minimum of 12 weeks in a year of average rainfall.</u>	District staff/ Contractor	Pesticide applicator	Planning prior to treatment; During treatment

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	• <u>Bay checkerspot butterfly</u>: Do not apply Fipronil within 100 feet of the Bay checkerspot butterfly habitat within Pulgas Ridge OSP, Edgewood County Park, and the Midpen-managed portion of the San Francisco Public Utility Company land at Pulgas Ridge. • <u>California clapper rail</u>: Within Ravenswood OSP, do not apply Fipronil within 300 feet of the high water line of salt or brackish water marshes. Also do not apply Fipronil within 200 feet of a cordgrass/pickleweed stand if any part of the stand occurs within 100 feet of the high water line of a salt or brackish water marsh. • <u>Tidewater goby</u>: Within Cloverdale Ranch and Tunitas Creek OSPs, do not apply Fipronil within 100 feet of lagoons, estuaries and backwater marshes that are adjacent to the Pacific Ocean; and freshwater streams up-gradient of and tributary to brackish habitats. • <u>Salt marsh harvest mouse</u>: Within Stevens Creek Shoreline Nature Study Area and Ravenswood OSP, do not apply Fipronil within 300 feet of the high water line of salt or brackish water marshes. Also, do not apply Fipronil within 200 feet of a cordgrass/pickleweed stand if any part of the stand occurs within 100 feet of the high water line of a salt or brackish water marsh. Application of glyphosate and cholecalciferol shall be conducted in accordance with the Goby-11 Injunction (Center for Biological Diversity v. EPA, Case No. 07-2794-JCS (N.D. Cal.), May 30, 2007) in applicable and relevant habitats for those species named in the Injunction that occur within the District. Applicable habitats for each species named in the Injunction are defined in the 2010 court order for the Center for Biological Diversity v. EPA. Because the interim protective measures (i.e., no-use buffer zones adjacent to certain features within certain geographic areas) established in the 2010 order vary depending on the species at issue and the pesticide being used, the USEPA webpage should be consulted: https://www.epa.gov/endangeredspecies/interim-use-limitations-eleven-threatened-or-endangered-species-san-francisco-bay. In addition, District internal special status species mapping resources, buffer zones established on the CNDDB webpage, and an interactive species location map (https://www.epa.gov/endangered-species/san-francisco-bay-area-map-toolidentify-interim-pesticide-use-limitations) should be consulted. The interim use limitations remain in effects until USEPA completes effects determinations for four pesticides named under the 2015 revised settlement agreement for the			

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#	BMP	Functional Groups	Responsible Party	Timing
	Center for Biological Diversity v. EPA. The effects determinations are expected to be completed by 2020.			
16.	San Francisco Dusky-footed Woodrat and Santa Cruz Kangaroo Rat Restrictions All District staff, volunteers or contractors who will implement treatment actions shall receive training from a qualified biologist on the identification of dusky-footed woodrat, Santa Cruz kangaroo rat, and their nests or burrows. Generally, all San Francisco dusky footed woodrat and their nests, and Santa Cruz kangaroo rat and their burrows will shall normally be avoided and left undisturbed by proposed work activities. If a nest site or burrow will be affected, the District will consult with CDFW. Rodenticides and snap traps, and glue boards shall not be used in buildings within 100 feet of active San Francisco dusky-footed woodrat nests or Santa Cruz kangaroo rat burrows; instead rodent control in these areas will shall be limited to non-lethal exclusion and relocation activities, including relocation of nests if approved by CDFW. Tenants will contact the District for assistance in managing rat populations in buildings and under no circumstances will be allowed to use rodenticides.	District staff/ Contractor	Pesticide applicator/ District staff	Planning prior to treatment; During treatment
17.	Operation of Noise-Generating Equipment and Vehicle Operation Restrictions Operation of noise-generating equipment (e.g., chainsaws, wood chippers, brush-cutters, pick-up trucks) shall abide by the time-of-day restrictions established by the applicable local jurisdiction (i.e., City and/or County) if such noise activities would be audible to sensitive receptors (e.g., residential land uses, schools, hospitals, places of worship) located in the applicable local jurisdiction. If the local, applicable jurisdiction does not have a noise ordinance or policy restricting the time-of-day when noise-generating activity can occur, then the noise generating activity shall be limited to two hours after sunrise and two hours before sunset, generally Monday through Friday. Additionally, if noise-generating activity would take place is planned to occur on a site that spans over multiple jurisdictions, then the most stringent noise restriction, as described in this BMP or in a local noise regulation, would apply. For treatment site where marbled murrelet has the potential to nest, identified in the District's 2014 maps (see attachment) if noise-generating activities would occur during its breeding season (March 24 to September 15), the IPM activities would be subject to the noise requirements listed in the most current in the CDFW RMA issued to the	District staff/ Contractor	District staff/ Contractor	During treatment

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	~~District (see attachment)~~All relevant permit requirements applicable to noise restrictions and special-status species will be adhered to (e.g., CDFW Streambed Alteration Agreement), if appropriate. All motorized equipment ~~and vehicles~~ shall be shut down when not in use. Idling of equipment and off-highway vehicles idling ~~will shall~~ be limited to 5 minutes.			
18.	Weather Parameters for Pesticide Applications ~~Application Requirements~~—The following general application parameters shall be employed during herbicide pesticide application: • Application shall cease when weather parameters exceed label specifications, when wind at site of application exceeds 7 miles per hour (MPH), or when precipitation (rain) occurs or is forecasted with greater than a 40 percent probability in the next 24-hour period to prevent loss of efficacy and lessen the potential for pesticides to enter surface water~~;~~ • All restrictions and limitations, including those on irrigation, cultivation, re-entry, etc., as described on the pesticide product label shall be followed for sites treated with pesticides~~;~~ • Spray nozzles shall be configured to produce a relatively large droplet size~~;~~ • Low nozzle pressures (30-70 pounds per square inch [PSI]) shall be observed~~;~~ • Spray nozzles shall be kept within 24 inches of vegetation during spraying~~;~~ • Application equipment shall be calibrated periodically per manufacturer specifications or frequently enough such that equipment is applying pesticides according to label directions~~;~~ • Drift and overspray avoidance measures shall be used to prevent drift in all locations. Particular attention shall be paid to areas where target weeds and pests are in proximity to special-status species or their habitat. Such measures can consist of, but would not be limited to, the use of plastic shields around target weeds and pests and selecting and using appropriate spray nozzles and pressures. Spray areas may also be limited by using application methods such as spot treatments and thin line treatments of one-inch wide or less. Due to the potential presence of temperature inversion layers, no spraying shall be conducted on designated “Spare the Air” days.	District staff/ Contractor	Pesticide applicator	During treatment

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19.	Surface and Groundwater Protection Applicators shall use BMPs regarding the prevention of drift, runoff, erosion, and water quality impairment. All work pesticide application shall be in compliance with the regulations (3 CCR § 6800, Groundwater Protection). ~~When~~ Where possible, plant covers such as landscaping shall be established on bare soil and hillsides to minimize pesticide and sediment runoff. Pesticides without an aquatic label shall not be applied to: 1) permeable soils, soils prone to or with evidence of erosion without containment strategies (e.g., vegetative buffers, sediment barriers); or 2) in areas where aquatic habitats/features are located within 15-30 feet of the application site. In no cases should pesticides be applied to surface water bodies unless in compliance with an existing permit or appropriate permits are obtained.	District staff/ Contractor	Pesticide applicator	During treatment
20.	Pesticide Contamination Prevention ~~Disposal of Pesticide Containers~~ Cleanup of all pesticide and adjuvant containers shall follow the product label and local waste disposal regulations. This generally consists of triple rinsing with clean water at an approved site and adding the rinsate to the batch tank for application. Used containers shall be punctured on the top and bottom to render them unusable, unless said container ~~are is~~ part of a manufacturer's container recycling program, in which case the manufacturer instructions shall be followed. Disposal of non-recyclable containers shall be at legal dumpsites. ~~Cleaning of equipment shall not be cleaned and personnel worker clothes and boots shall occur where runoff would flow into the sanitary sewer for treatment not bathe in a manner that allows contaminated water to directly enter any body of water within the treatment areas or adjacent watersheds.~~	District staff/ Contractor	Pesticide applicator	During treatment
21.	Pathogen Sanitation and Prevention of Contamination All personnel working in infested areas shall take appropriate precautions to not carry or spread ~~weed seed or SOD-associated pathogens~~ outside of the infested area by adhering to the <i>Guidelines for Minimizing Phytophthora Contamination at Midpeninsula Regional Open Space District Preserves</i>. Such precautions will consist of, as necessary based on site conditions, cleaning of soil and plant materials from tools, equipment, shoes, clothing, or vehicles prior to entering or leaving the site.	District staff/ Contractor	District staff/ Contractor	During treatment; Post treatment

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#	BMP	Functional Groups	Responsible Party	Timing
	<u>Maintenance of Facilities-Invasive Species Spread Prevention</u>			
22.	<u>Clothing, footwear, and equipment, including rentals, used during treatments of soil, seeds, vegetative matter, other debris or seed-bearing material, or water (e.g., rivers, streams, creeks, lakes) shall be inspected and cleaned before entering a treatment area or when leaving an area with infestations of invasive plants, noxious weeds, known plant pathogens, or invasive wildlife.</u> District staff shall appropriately maintain facilities where tools, equipment, and vehicles are stored <u>to ensure the area is free from invasive plants.</u> District staff shall ensure that rental equipment and project materials (especially soil, rock, erosion control material, and seed) are free of invasive plant material prior to their use at a worksite. <u>Relevant best practices from the Invasive Species Council of California, University of California Statewide Integrated Pest Management Program, and the California Invasive Plant Council shall also be consulted and implemented, as appropriate.</u>	District staff/ Contractor	District staff/ Contractor	Before Treatment; During treatment; Post treatment
	<u>Erosion Control and Revegetation</u>			
23.	For sites with loose or unstable soils, steep slopes (greater than 30 percent), where a large percentage of the groundcover will be removed, or near aquatic features that could be adversely affected by an influx of sediment, <u>approved, biodegradable erosion-control measures and non-filament-based geotextiles erosion control measures</u> shall be implemented before or after treatment as appropriate. These measures could consist of the application of forest duff or mulches, straw bales, straw wattles, other erosion control material, seeding, or planting of appropriate native plant species to control erosion, restore natural areas, and prevent the spread or reestablishment of weeds. Prior to the start of the winter storm season <u>and during storms, if appropriate,</u> these sites shall be inspected to confirm that erosion control techniques are still effective. <u>When Where possible, applicators-field workers</u> may select vegetation control techniques to maintain sufficient vegetative cover to mitigate erosion.	District staff/ Contractor	District staff/ Contractor	Prior to treatment; Post treatment
	<u>On-site Disposal</u>			
24.	Invasive plant material shall be rendered nonviable <u>when being if</u> retained on site. <u>District staff</u> shall desiccate or decompose plant material until it is nonviable (partially decomposed, very slimy, or brittle). Depending on the type of	District staff/ Contractor	District staff	Post treatment

APPENDIX C: 2025 INTEGRATED PEST MANAGEMENT PROGRAM BEST MANAGEMENT PRACTICES

#	BMP	Functional Groups	Responsible Party	Timing
	plant, disposed plant material can be left out in the open as long as roots are not in contact with moist soil, or can be covered with a tarp to prevent material from blowing or washing away. Suitable on-site disposal areas shall be identified <u>and approved by the District's Natural Resources Department</u> to prevent the spread of weed seeds. <u>District staff shall monitor all sites where invasive plant material is disposed on-site and treat any newly emerged invasive plants.</u>			
25.	Off-site Disposal When transporting invasive plant material off-site for disposal, the plant material shall be contained in enclosed bins, heavy-duty bags, or a securely covered truck bed. All vehicles used to transport invasive plant material <u>for disposal</u> shall be cleaned after each use.	District staff/ Contractor	District staff/ Contractor	Post treatment
26.	Post-Treatment Monitoring District staff shall <u>normally</u> monitor <u>IPM activities treatment sites</u> within <u>two-2</u> months after herbicide treatment <u>(except for routine minor maintenance activities, which can be evaluated immediately after treatment)</u> to determine if the target pest or weeds were effectively controlled with minimum <u>effect</u> impact to the environment and non-target organisms. Future treatment methods in the same season or future years shall be designed to respond to changes in site conditions.	District staff/ Contractor	District Staff	Post treatment

APPENDIX D

Resource Management Policies

RESOURCE MANAGEMENT POLICIES

MIDPENINSULA REGIONAL OPEN SPACE DISTRICT



May 2022

RESOURCE MANAGEMENT POLICIES

MIDPENINSULA REGIONAL OPEN SPACE DISTRICT

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PREFACE

ABOUT THIS DOCUMENT

Document Purpose

This Resource Management Policies (RMPs) document defines the policies and practices used by the Midpeninsula Regional Open Space District (District) to protect and manage **resources** on District lands. The word resources as used in this document includes plants, animals, water, **soil**, terrain, geologic formations, **historic**, scenic, and cultural features. Recreational resources are described in other documents.¹

The purpose of the RMPs is to:

- ◆ Set the framework for the District's resource management program;
- ◆ Provide general guidance for issue-specific and site-specific planning;
- ◆ Provide staff and Board a tool for informed, consistent, and effective resource management decision making;
- ◆ Inform the public of the purpose and intent of the District's resource management program;
- ◆ Provide a basis for evaluating the District's progress in reaching its resource management objectives.

This document does not provide detailed plans for management of individual preserves or resources. Other more specific master plans, site plans, and resource management plans will supplement these policies to further refine and resolve the implementation strategies on a site-specific basis.

The suitability and scope of implementation of a specific RMP can only be effectively determined on a site-specific or issue-specific basis given the

¹ These documents include Use and Management Plans for individual preserves, Trail Use Guidelines and Mitigation Measures, Land Use Regulations and the Visitor's Guide to the Open Space Preserves.

circumstances and conditions to be addresses. The suitability or effectiveness of a RMP may depend on a number of factors. These may include evaluation of potential environmental impacts associated with the RMP, physical or other constraints, availability of funding, and feasibility of implementation. Therefore, the determination of whether and to what extent a RMP is implemented in whole or in part will be made on a site-or issue-specific basis. In some circumstances, deviations from an RMP will represent a more effective resource management approach given applicable factors.

In addition, carrying out and implementing RMPs will be achieved over time, and is subject to funding availability and competing District needs and overall feasibility. Competition for District funds requires balancing the expense of resource management with the cost of continued land acquisition, project planning, and the cost of access and facilities improvements.

Document Organization

The RMPs are organized into chapters by subject and resource category. The chapter format generally consists of a background section and a section containing goals, policies, and implementation measures. The background section provides rationale for the goal and policies that follow. The goal is phrased as a broad, general statement describing the desired state or condition to be achieved. The policies state what steps the District will take in order to attain that goal. Policies are numbered according to chapter with the first letter of each of the first two words of the Chapter title followed by a number (e.g. **VM-1** is **V**egetation **M**anagement Policy **1**).

Each policy includes one or more recommended implementation measures, highlighted by bullets (◆). Implementation measures specify action items the District will strive to carry out to apply the policies to the landscape where feasible. Implementation measures are referenced internally according to bullets. For instance, VM-1: Measure 2 refers to the second bulleted measure under VM-1. Informational sidebars identify current knowledge and practices regarding resource conservation. Key words are noted in **bold** and definitions for each can be found in the Glossary.

The District will apply the RMPs to every day District functions and operations from the planning of new trails and facilities to the evaluation of new

prospective land acquisitions, to routine Preserve maintenance. It will draw upon varied expertise to balance resource needs and public interests. The annual action plan will describe existing and proposed resource management plans and projects, and progress towards resource management goals.

Document Review and Amendment

The RMPs comprise a "living" document that will grow and change regularly, based on new experience and information. It will be reviewed and updated every five to ten years and chapters amended as needed to respond to ever-changing resource conditions (e.g. insect or disease outbreaks, large cataclysmic events, climate change etc.). The staff or Board may decide to amend the document for a significant single purpose at any time.

I. DISTRICT RESOURCE MANAGEMENT PROGRAM

MIDPENINSULA REGIONAL OPEN SPACE DISTRICT

Midpeninsula Regional Open Space District (District) is a public agency that owns and manages 26 **open space** preserves totaling over 59,000 acres of land (as of 2011). Created by a voter initiative in 1972, the District's mission statement is "To acquire and preserve a regional greenbelt of open space land in perpetuity; protect and **restore** the **natural** environment; and provide opportunities for ecologically sensitive public enjoyment and education."

District boundaries enclose an area of 227,900 acres in northern Santa Clara and southern San Mateo counties, and a small portion of Santa Cruz County. The District's Sphere of Influence, or the area within which the District is likely to expand, includes an additional 12,333 acres. Extending from Montara in the north to the Lexington Hills in the south, the District directly serves more than 25 communities having a combined population of over 700,000. Preserves vary in size from 59 acres (Stevens Creek Nature Study Area) to over 17,000 acres (Sierra Azul). Elevations range from sea level in the baylands preserves to 3,486 feet atop Mount Umunhum in the Sierra Azul Range.

The District manages land primarily to preserve a regional greenbelt of open space land. There are few improvements, other than parking areas, some rest rooms, and informational signs. Over 220 miles of public trails invite activities such as hiking, biking, jogging, horseback riding, dog walking, and picnicking limited only as required. The preserves are open to the public every day, free of charge. Because the preserves are "close to home," they serve as popular weekday and weekend recreational destinations.

District lands protect a variety of **habitats** rich in both numbers and variety of plants and animals. The District preserves tidal salt marshes in the east, home to the endangered clapper rail and salt marsh harvest mouse and

used by thousands of migratory birds. The heart of the District straddles the eastern and western flanks of the Santa Cruz Mountains. These lands are covered in a diverse mix of oak **woodland**, grassland, **chaparral**, coastal scrub, and both evergreen and **coniferous forests** that form an impressive scenic backdrop for the densely populated San Francisco Bay Area and Central California Coast. Creeks and streams that run through District lands provide refuge area for endangered coho salmon and threatened steelhead trout. The natural setting of District preserves provides a peaceful refuge for visitors seeking low intensity recreational opportunities away from the pressures of urban life.

PURPOSES OF OPEN SPACE

Open space consists of land and water areas that remain in a natural state and are minimally developed. Open space may include compatible agriculture uses. Open space preserves provide protection in the form of permanent sanctuaries for **native** wildlife and vegetation. These irreplaceable resources are rapidly disappearing as human presence and activity encroach into natural areas. Reasons to preserve open space that are discussed in the District's Master Plan include protecting scenic beauty, public health and safety, natural, cultural and agriculture resources; shaping urban growth; and providing low-intensity outdoor recreation opportunities and environmental education.

NEED FOR RESOURCE MANAGEMENT POLICIES

Resource management at the District includes management of both natural cultural and agricultural resources. Natural resource management generally consists of protecting, restoring, enhancing, and monitoring native vegetation and wildlife, and monitoring and protecting the quality of geo-

logical and hydrological conditions. Cultural resource management consists of identifying and evaluating and protecting archeological sites and **cultural landscapes**.

The District faces many issues, challenges, and choices in management of District land and sensitive resources. Land acquisition is politically, socially, and opportunistically driven, sometimes independent of resource needs. Defining, identifying and communicating resource needs and management objectives provides for more informed decision making, guides property acquisition, and results in better protection of land and sensitive natural and **cultural resources**.

The complex and constantly changing **ecosystems** of District preserves are comprised of a wide variety of interrelated components resources that sometimes have competing needs for preservation. Managers must be able to recognize, distinguish, and decide among competing priorities. Compounding these inherent challenges is the change in open space management needs over time: the amount of land managed by the District continues to grow; employees and board members who function as caretakers change; funding sources come and go; and the public's interests, values, and use patterns differ over both time and place; and visitation continues to increase which can place increased pressure upon natural systems. A well-defined set of policies is essential for the District to maintain consistent and effective resource management despite these changes.

The Basic Policy adopted March 10, 1999 directs the District to:

“follow management policies that ensure proper care of the land, that provide public access appropriate to the nature of the land, and that are consistent with ecological values and public safety.”

Although the Basic Policy implies a direction for managing the land, it does not offer specific guidance as to what constitutes “proper care.” These RMPs are intended to provide that guidance.

MISSION STATEMENT FOR RESOURCE MANAGEMENT

The resource management mission statement defines the purpose toward which the District directs its resource management efforts. The District's resource management program is one of stewardship not only intended to protect resources and to sustain them in perpetuity. The District calls its lands "preserves" rather than "parks," emphasizing the goal of resource preservation. The following overall mission statement reflects the District's commitment to resource management:

Resource Management Mission Statement

The District will protect and restore the diversity and integrity of its resources and ecological processes for their value to the environment and to people, and will provide for the use of the preserves consistent with resource protection.

Overall Resource Management Strategies

The following general strategies summarize how the District will achieve its resource management mission.

Strategy 1	Favor protection of resources when use significantly interferes with resource protection and preservation.
Strategy 2	Provide an effective interdisciplinary program to protect and enhance natural and cultural resources. This program should include planning, interpretation , research, protection, maintenance, and monitoring practices.
Strategy 3	Prevent or minimize human-caused and accelerated impacts, including erosion, invasion by non-native species, disruption of the natural flow of water, degradation of water quality , trampling of vegetation, and displacement of wildlife.
Strategy 4	Protect and restore known rare, endangered, special status species and sensitive habitats , as well as seriously

degraded or deteriorating areas. Give priority to sensitive habitats and consider the relative scarcity of the specific resources involved.

- Strategy 5 Manage open space as a composite resource, rather than as separate and isolated parts. Maintain ecological processes as well as individual species and features. Consider the regional context and cumulative impacts of resource management decisions. Favor long-term goals over short-term benefits.
- Strategy 6 Support low intensity recreational and agricultural use of District lands consistent with resource protection. Consider present and potential use.
- Strategy 7 Balance efforts to protect and restore resources with efforts to acquire and provide public access to lands.
- Strategy 8 Monitor changing conditions and the effectiveness of resource management practices.
- Strategy 9 Increase public knowledge, understanding, and appreciation of the natural and cultural resources of the preserves, and support for their conservation.

PLANNING AND IMPLEMENTATION

The RMPs are to be used to guide the overall planning, budgeting, and decision making processes for individual Preserves and for District-wide programs. Implementation of the policies will be through the Use and Management Plan and Master Plan for each Preserve. The District's Land Acquisition Policies shall reference the RMPs to help guide future land acquisitions. Successful implementation of the Policies will result in informed, consistent, and effective resource management.

II. VEGETATION MANAGEMENT

BACKGROUND

District Plant Communities

The District is located along the western edge of the North American continent on a geologically active peninsula between the Pacific Ocean and San Francisco Bay, which limits migration of plants and animals. This unique location is dominated by the Santa Cruz Mountains which are influenced by a Mediterranean climate comprised of mild wet winters and long hot and dry summers cooled by cyclical coastal fog. Because of this climate regime, the landscape is subject to periodic fire. The San Andreas Fault, one of the world's longest and most active faults, cuts through the eastern side of the Santa Cruz Mountains. Continuing movement along the fault and differing composition of the underlying rocks created many **soil** types and terrain features including steep, narrow canyons, rolling hills, and flat bay lands. The eastern edge of the District is heavily influenced by the urban areas of San Francisco, San Jose and other peninsula cities which result in **natural** lands that are often used as a large “urban backyard” rather than a pristine wilderness. These and other factors have shaped diverse and dynamic **native** plant communities that are precisely adapted to these complex and varied conditions.

A **plant community** is a group of plants growing in an interrelated manner on a particular site. Each community has characteristic dominant and associated species, spacing, and **habitat**.

Native plant communities in District preserves include the following general vegetation types:

- ◆ Salt marsh and brackish marsh
- ◆ Freshwater marsh
- ◆ Redwood **forest**
- ◆ Douglas fir forest
- ◆ Coastal scrub
- ◆ **Chaparral**
- ◆ Mixed evergreen forest
- ◆ **Riparian** forest

- ◆ Native grassland
- ◆ Oak **woodland**

The condition of vegetation affects other **resources** in the preserves. A mixture of natural plant communities gives scenic character to a landscape, and provides the diversity and stability needed to support native wildlife, clean water and reduce erosion. Loss or fragmentation of plant communities reduces their ability to provide the full range of ecological benefits, including maintenance of species diversity, soil and watershed protection, wildlife, and recreational and aesthetic values. It is the main reason why animal species have become endangered or threatened.

Alterations to Vegetation

Continuing effects of past and present land use practices, including **fire suppression**, grazing, logging, **non-native** plant invasion, feral animals, and uses which trample vegetation, threaten the District's native plant communities. Such activities have caused drastic and rapid changes in vegetation. In some areas the alteration is permanent.

Protection of Sensitive Species

A number of plants listed by either federal or State agencies or the California Native Plant Society as rare, threatened, endangered, and of limited distribution have been identified within or near District preserves. Site-specific information is needed for both existing and new properties to protect sensitive species.

Ecological Restoration

Ecological restoration is the process of returning land that has been degraded and disturbed into ecologically functioning habitat. The District often employs the principles of ecological restoration when performing **vegetation management**. Vegetation management is the maintenance, establishment, or **restoration** of target vegetation that meets a preserve's management objectives. The term **revegetation** is used to describe the process of replacing existing vegetation or bare ground on a site with ap-

Ecological restoration is an intentional activity initiated by the District that accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability. Frequently, ecosystems requiring restoration have been degraded, damaged, transformed, or destroyed by direct and indirect human actions.

appropriate plant species. Selecting effective vegetation management strategies requires understanding natural ecological processes at a specific site. It also may involve coordinating with neighbors, as part of the District's "good neighbor" policy. The District applies ecological restoration when it replaces landscaping with native vegetation, stabilizes slopes or restores degraded sites with natural drainage patterns.

Management measures may include actions such as eliminating or restricting activities that destroy vegetation, restoring grasslands and meadows that were formerly maintained by natural processes, conducting prescribed burns, managing **conservation grazing**, and either planting or removing vegetation.

Fire Suppression

Periodic fires were a part of natural ecological processes on lands which now make up the District preserves. As a result, many species evolved with fire adaptations and need periodic fire for renewal. Fire opens forests to new generations of younger trees, purges grassland of invasive shrubs, and stimulates seed germination and shoot growth in chaparral. Without fire, fire-adapted communities are eventually replaced by forest, and plant and animal species are lost. **Fuel** in unburned areas can build up to such a high level that when a wildfire occurs, it can have devastating effects.

Local Native Americans allowed natural fires to burn and also deliberately set fires to clear underbrush and create meadow areas attractive to deer and other animals. Open meadows improved visibility for hunting and encouraged the growth of acorn oaks and other edible plants. Subsequent implementation of fire suppression policies eliminated these benefits, reversing their positive environmental effects.

Impacts of **fire suppression** continue to reduce **biodiversity** in the preserves. Grasslands and oak woodlands are decreasing in area due to invading brush and forest species. **Stands** of coastal scrub and chaparral have aged and are not being renewed. Dense tangles of brush and young trees have largely replaced the park-like understory beneath redwood and Douglas fir forests and mature oak woodlands described by early European explorers.

High Use Areas

High use areas such as those around parking lots, visitor centers, restrooms, and specially surfaced or whole access trails, require more intensive vegetation management than natural areas that make up the bulk of District land.

VEGETATION MANAGEMENT GOALS, POLICIES, AND IMPLEMENTATION MEASURES

Goal VM- Sustain and promote viable and diverse native plant communities characteristic of the region

Policy VM-1 Maintain the diversity of native plant communities. (See WR-7, ES-1, IS-2, and FM-6)

- ◆ Map and describe plant communities; analyze successional trends and formulate site-specific vegetation management goals as part of the Resource Management Plan for a preserve or geographic area.
- ◆ Identify appropriate areas for restoring lost or altered native plant communities and **restore** them to a natural condition. This is often best done by restoring natural processes and controlling invasive plants, rather than by planting.
- ◆ Manage native grassland sites to encourage reestablishment and perpetuation of California native grasses.
- ◆ Manage oak woodland to encourage reestablishment and perpetuation of California native oaks.
- ◆ Control invasive non-native plants. (See Section VI.)

Policy VM-2 Use native species occurring naturally on similar sites in ecological restoration projects.

- ◆ Use seed and cuttings collected from the same geographic area to revegetate or **enhance** degraded areas. One source of native seed is topsoil or mulch taken from adjacent intact habitat and applied thinly.

- ◆ Use fill, mulch, and seed mixtures that are as free as possible of non-native plants in ecological restoration projects. Know where such materials come from. (See GS-2 for possible exception.)
- ◆ Work with nurseries to grow native plants needed for ecological restoration projects.
- ◆ Avoid seeding with rye grass (unless sterile), "Zorro" fescue, Harding grass, or other non-native aggressive plants after fires to control erosion.
- ◆ Use plant material that is biologically and visually appropriate to the surrounding wild landscape and appropriate to the stage of plant community development at the site.
- ◆ Encourage District tenants to use native plants for landscaping to provide natural habitat.

Special status species are species that are state or federally listed as threatened, rare, endangered, species of special concern, candidate species, or those plant species listed by the California Native Plant Society's list 1B and 2.

Policy VM-3 Protect and enhance the habitats and **populations of special status** plant species.

- ◆ Identify the location and condition of special status plants and their habitats as part of the Resource Management Plan for a preserve or geographical area.
- ◆ Conduct surveys for special status plants during the appropriate season before significant site-specific development or any unusual anticipated increase in use. Modify the project or use to avoid impacting such plants.
- ◆ Protect areas with special status species from human activities and other negative impacts such as erosion. Examples of protective measures include trail rerouting, signs, and fencing. (See GS-2)

Policy VM-4 Manage forest diseases, when necessary, to protect native biological diversity and critical **ecosystem functions**.

- ◆ Develop a plan to detect, report, and monitor areas infested by high priority insects and diseases; utilize sanitation and **best management practices (BMPs)** to control the spread of infestations; train staff and educate the public; and support research to guide land management decisions.

- ◆ Prioritize research and management activities to slow the spread of Sudden Oak Death (SOD) and actively pursue partnerships with other public agencies to develop treatment alternatives.

*Sudden Oak Death (SOD) is a prevalent disease of particular concern within District forested lands. SOD has killed over one million native oak and tanoak trees and infests many other forest species in one Oregon and 14 coastal California counties. Hundreds of dead tanoak trees and other symptoms of the SOD pathogen, *Phytophthora ramorum*, are commonly seen on the District's preserves. There currently is no cure for SOD, and as with other extensive forest diseases, a strategy may take decades to develop. The District has adopted a ten-year plan to slow the spread of SOD, collaboratively study impacts on wildland ecology and recreation, and develop a restoration strategy for heavily infested forests.*

III. WILDLIFE MANAGEMENT

As pressures from the expanding human population increase, District preserves become more important as refuges for wildlife. The term **wildlife** as used here includes all animals, from the smallest invertebrates to the largest mammals. Without a sufficient amount of proper **habitat**, an animal cannot survive. As a result, most management of **native** wildlife involves management of habitat conditions and habitat impacts from visitor activities rather than hands-on management of the animals themselves. Protection of habitat is key to protection of wildlife.

BACKGROUND

Animal Habitat Characteristics

Habitat refers to the area where an organism occurs, its **natural** home or "neighborhood." An animal's habitat includes plant communities which provide the shelter, food, and water it needs to live and reproduce. Other aspects of the environment that affect an organism, such as geographic location, climate, and topography, are also part of its habitat.

Animals move from place to place and require a variety of land, both daily and seasonally. Some have precise habitat requirements; others are more flexible. Some species live their entire lives within one vegetation type. Others use several vegetation types in a single day or use different habitats at different stages of their lives. Some animals use one habitat for part of the year and migrate elsewhere for the rest. Ultimately it is important to preserve all these habitats to ensure continued wildlife diversity.

The habitats most important for wildlife are those which offer food, cover, topography, and other parameters essential to survival and reproduction. Examples include springs and seeps, nesting and breeding sites such as standing dead trees, movement and migration corridors, pathways to perennial streams, and foraging areas. Some of these habitats are considered **sensitive**, in that they are vulnerable to disturbance and do not recover easily once disturbed.

The Importance of Riparian, Pond, and Other Wetland Habitats

Certain habitats are intensively used by many kinds of wildlife. **Riparian** (streamside), pond, and other wetland habitat, with their wide variety of plants and readily available water, are perhaps the most important. These habitats provide a drinking source; dense, green foliage for cover and food; shade in which to rest and escape the heat; perennial or seasonal water bodies which are required for breeding by some amphibian and other wildlife species, and protected corridors through dry, open areas. Almost all species of wildlife depend on external sources of water and will often travel long distances to reach it. People are also attracted to water, especially ponds and riparian areas. Excessive human use can cause problems from trampling, **soil** compaction, destruction of vegetation, alteration of water quality and temperature, introduction of pathogens or foreign substances and species, and frequent disturbance of wildlife.

Predators Indicate Habitat Health

The presence of large predators is a strong indicator of a healthy habitat. Large predators are at the top of the food pyramid and depend on the availability of large numbers of smaller animals. The greenbelts of District and neighboring public lands in the Skyline and Sierra Azul areas are large and diverse enough to support such wide-ranging predators as black bear (although no resident black bears are present in the Santa Cruz Mountains presently), mountain lion, coyote, bobcat, fox, badgers, and numerous hawks and owls. The chance to see such animals is a big incentive for many people to visit the preserves.

Results of Habitat Fragmentation

In the last century, population growth, urban expansion, and construction of roads and highways have fragmented habitats and interrupted wildlife movement corridors. Fragmentation has four main consequences for wildlife:

- a. Isolated habitat **patches** may not be large enough to support wildlife that requires a certain size of habitat. Fragmentation may also destroy particular plant species that some animals require for food or cover.
- b. Wide-ranging animals such as the larger predators can be cut off from territories they need for feeding and breeding.
- c. **Non-native** species become more common, displacing natives and thereby also reducing **biodiversity**.
- d. Inbreeding increases when **populations** are cut off from neighboring **populations**. The resulting lack of diversity in the gene pool weakens the species through “inbreeding depression” and reduces the **population's** long-term chance of survival. A single environmental change or disease could then eliminate all members of the local **population**.

WILDLIFE MANAGEMENT GOALS, POLICIES, AND IMPLEMENTATION MEASURES

Goal WM- Maintain and promote healthy and diverse native wildlife populations

Policy WM-1 Understand and maintain the diversity of native wildlife.
(See WR-6 and WR-7)

- ◆ Identify wildlife usage, movement patterns, and habitat features with high value to wildlife.
- ◆ Consider and avoid or minimize impacts on wildlife when planning trails and other facilities.
- ◆ Develop a wildlife data base to record wildlife sightings and guide management decisions.
- ◆ Non-native wildlife release on District lands shall adhere to the policies identified in the Integrated Pest Management chapter (See IPM).

- ◆ The District shall strive to control or remove non native wildlife using management actions identified in the Integrated Pest Management chapter (See IPM).
- ◆ Native wildlife shall not be released onto District land if it is adapted to urban conditions or interaction with human.
- ◆ Native wildlife can be released onto District preserves if the animal has been rehabilitated by an animal rescue center specializing in wildlife, it is disease-free, suitable unoccupied habitat is available, and there is a high likelihood for the animal to adapt and survive in its new surroundings without adversely affecting existing resources at the site. The rehabilitated animal should be marked or banded, if feasible, to allow monitoring of its adaptation.

Policy WM-2 Protect, maintain and **enhance** habitat features that have particular value to native wildlife. (See HC-2: Measure 5, WR-6 and WR-7)

- ◆ Inventory critical and sensitive wildlife habitats and develop management strategies for their protection.
- ◆ Leave brush piles, **snags**, and fallen trees in areas where they do not pose a fire hazard or visual blight, to provide cover and nesting sites for animals, and nursery conditions for forest seedlings.
- ◆ Evaluate the wildlife habitat value associated with human-made structures before altering or removing them and avoid or mitigate any impacts.
- ◆ Repair, modify, and maintain stock ponds as wildlife watering sources and habitat for aquatic and semi aquatic organisms (See WR-3).

Policy WM-3 Protect animal **populations** against the impact of human actions. (See HC-2: Measure 5)

- ◆ Discourage human intrusion into sensitive wildlife habitats by appropriate placement of facilities and trails.
- ◆ Identify and eliminate **barriers** (e.g. remove unnecessary fences, old barbed wire, and other barriers) and provide safe crossings (e.g. protect established wildlife crossings and use wildlife friendly fencing) to

*Examples of wildlife using human-made structures on District lands include the Red barn at La Honda Creek Open Space Preserve which is used by both the Townsend's big-eared bat (*Plecotus townsendii*) and Pallid bat (*Antrozous pallidus*).*

Wildlife movement and safe passage is affected at a regional level by large-scale transportation needs and development including housing, roadways, and commercial development. The District works with Preserve neighbors, municipalities, counties, and regional planning organizations to improve new development projects through the use of wildlife friendly fencing, clustering new development away from sensitive areas, and providing refuge areas for wildlife.

enhance wildlife movement on a regional basis. (See HC-3, HC-4, and GM-2: Measure 1)

- ◆ Consult with responsible wildlife agencies to conserve special status species or to control problem wildlife when human life, property, or other significant natural resources are threatened.
- ◆ Reduce conflicts between wildlife and humans through notification and education, control of human access and, as a last resort, control of wildlife presence or movement.
- ◆ Prohibit hunting or trapping in District preserves except as a management tool or for scientific or educational purposes.
- ◆ Fishing is allowed only in areas declared by the District to be permitted fishing areas, where state laws regulate the taking of game fish.
- ◆ Review and update criteria for designating temporary (e.g., day-use) access areas for domestic animals into District preserves. Incorporate the criteria into District regulations.

Policy WM-4 Protect and enhance the habitats and **populations of special status** animal species.

- ◆ Conduct surveys of special status animals in affected areas before initiating significant development or any substantial increase in use. Give priority to protection of special status species.

IV. INTEGRATED PEST MANAGEMENT

BACKGROUND

Integrated Pest Management

Integrated pest management (IPM) is a process for efficiently managing **pests** while protecting human health and environmental quality. IPM is a long-term, science-based, decision-making system that uses a specific methodology to manage damage from **target pests**. IPM requires monitoring site conditions before, during, and after treatment to determine if objectives are being met and if methods need to be revised. IPM requires that non-chemical methods be considered in addition to chemical methods (i.e., **pesticides**, herbicides, insecticides). If chemical methods are necessary to meet a pest control objective, the potential for harm to the public and workers are carefully considered, as are effects on the environment and **non-target organisms**, and then the least toxic and most effective, efficient, and target-specific method is chosen.

Pesticide is a broad term that includes any material (natural, organic, or synthetic) used to control or prevent pests including herbicides (weed or plant killers), insecticides (insect killers), and rodenticides (rodent killers) as a few examples.

The Problem with Invasive Species

Invasive species are animal or plant species that invade and dominate sufficiently large areas causing a reduction in **biodiversity**. They proliferate in the absence of natural control and interfere with the natural processes that would otherwise occur on **wildlands**. Once established, invasive species can become difficult to manage and they can eliminate native species or otherwise alter the **ecosystem**. This chapter addresses the management of invasive species in order to protect the native species and natural processes of the preserves.

Invasive species can alter ecosystem processes by changing biotic ecosystem characteristics (such as plant community composition, structure, and interactions; trophic relationships; and genetic integrity) and abiotic characteristics and processes (such as fire regimes, erosion, sedimentation, hydrological regimes, nutrient and mineral conditions, and light availability).

Invasive Plants

Invasive plants have greatly altered many of California's natural plant communities. Because they originated elsewhere, many invasive plants are not susceptible to **predation** or diseases of this region. They are extremely adaptable and can thrive in a wide range of conditions. They can grow quickly, reproduce early, produce many long-lasting seeds, and tolerate disturbance. They reduce native biodiversity by gradually crowding out or competing with native plants for water and sun, and by reducing or modifying wildlife **habitat**.

Invasive Animals

*Wild (feral) pigs are an example of an invasive wildlife species with obvious impact on District lands. They have been widespread in the central coast of California since about 1970, reproduce rapidly, dig up meadows and wetlands, and carry diseases that can affect people and livestock. They eat acorns, bulbs, and soil animals, and are difficult to control. Feral pigs were abundant in the South Skyline region in the 1990s. The District has been trapping feral pigs since 2000 and has substantially reduced their **population** and damage from their rooting.*

Ranking second to loss of habitat resulting from human intrusion, invasive animals pose another threat to native wildlife. Escaped domestic animals and other non-native wildlife species can thrive in the favorable climate of the San Francisco peninsula. Once established in a preserve, they compete for valuable **resources** and disturb the sensitive balance of natural **food webs**. Bullfrogs and wild pigs are examples of invasive introduced animals found in District preserves that physically displace or predate upon native plants and wildlife.

Programs to manage pests require long-term commitment. With many invasive plant and animal species, short-term lapses in management activity may negate years of expensive control programs.

INTEGRATED PEST MANAGEMENT GOALS, POLICIES, AND IMPLEMENTATION MEASURES

Goal IPM- Control pests by consistent implementation of IPM principles to protect and restore the natural environment and provide for human safety and enjoyment while visiting and working on District lands.

Policy IPM-1 Develop specific pest management strategies and priorities that address each of the five work categories.

- ◆ Manage pests in buildings to support existing uses, while also protecting human health and surrounding natural resources.
- ◆ Manage pests and potential human interactions in recreational facilities to minimize conflict, ensure visitor safety and enjoyment, and protect the surrounding natural resources.
- ◆ Manage pests in fuel management areas to reduce risk to human life and property, while also protecting natural resources.
- ◆ Manage pests in rangelands and on agricultural properties to support existing uses, while also protecting human health and surrounding natural resources.
- ◆ Manage invasive species in natural areas and set priorities for their control based on the potential risk to sensitive native species and loss of native biodiversity.

Policy IPM-2 Take appropriate actions to prevent the introduction of new pest species to District preserves, especially new invasive plants in natural areas, rangelands, and agricultural properties.

Best management practices for preventing the introduction of invasive species include cleaning equipment before leaving a weedy site, and using seed, plant, forage, fill, erosion-control and other materials that are free of weed seeds.

The California Invasive Plant Council maintains an Invasive Plant Inventory that rates the threat of non-native plant species by evaluating their ecological impacts, invasive potential and ecological distribution. Along with local knowledge, the District uses this list to evaluate the invasive risk of existing and new non-native plants found on District preserves.

Prior to the approval of the use of any new biological control agent, the US and California Departments of Agriculture conduct years of laboratory and field studies to assess the candidate's host specificity and its potential impact on target and nontarget species and environmental safety.

The District coordinates with the San Mateo County and Santa Clara County Weed Management Areas, the California Invasive Plant Council, the California Department of Fish and Game, the California Department of Food and Agriculture, County Agricultural Departments, and the Cooperative Extension Service to stay informed on invasive plants and animals, IPM techniques, and pesticide regulations.

Policy IPM-3 Manage pests using the procedures outlined in the following eight implementation measures.

- ◆ Develop and implement tolerance levels for pests within each of the Work Categories to determine when to undertake pest control.
- ◆ Identify the pest, determine its life cycle and disruptive potential, and identify relevant site conditions prior to implementing a pest control activity. Review pest control objectives for consistency with other site goals and establish tolerance levels that must be exceeded before pest control is undertaken.
- ◆ Choose site-specific strategies and times of treatment that provide the best combination of protecting preserve resources, human health, and non-target organisms and that are efficient and cost effective in controlling the target pest. Whenever feasible, direct the control method narrowly at vulnerable points in the target organism's life cycle to avoid broad impacts.
- ◆ Monitor results and modify control methods over time as site conditions and treatment techniques change and as needed to obtain an effective level of control.
- ◆ Use the least harmful method(s) to control identified pests. Where the use of pesticides is necessary, apply according to the label using all safety precautions and take all measures needed to protect the environment, the health and safety of visitors, employees, neighbors, and the surrounding natural areas including water and soil resources.
- ◆ Plan for repeat treatments as indicated by the pest's regenerative capabilities.
- ◆ Coordinate and cooperate with adjacent landowners, neighbors, and other responsible agencies to control pests and limit secondary effects.
- ◆ If eradication of a pest from a distinct location is not feasible, apply measures to achieve containment, sustained control, slow down a pest's rate of spread, or minimize pest damage.

Policy IPM-4 Monitor pest occurrences and results of control actions and use **adaptive management** to improve results.

MIDPENINSULA REGIONAL OPEN SPACE DISTRICT
RESOURCE MANAGEMENT POLICIES
INTEGRATED PEST MANAGEMENT

Policy IPM-5 Develop and implement an IPM Guidance Manual to standardize pest management and IPM procedures across all District Lands.

V. WATER RESOURCES

BACKGROUND

Water is essential to life on earth and is also one of the most important forces shaping **habitats** and **biodiversity**. District **open space** lands contain a variety of water **resources** that include such diverse habitats as freshwater **wetlands** (including ponds and seasonal wetlands) and **watercourses**, salt water tidal wetlands within San Francisco Bay, and ground-water resources such as springs, seeps, and underground aquifers. These water resources have **natural**, scenic, recreational, scientific, and educational values. In general, this policy will discuss **waters** (sag ponds, artificial impoundments, lakes, and aquifers), watercourses (such as streams and creeks), and wetlands. These terms are discussed further below.

“Waters” is a term that is broadly used to describe all aquatic systems. This policy defines “waters” as areas of standing water, both seasonal and permanent, such as lakes and ponds, as well as underground aquifers. “Watercourse” is a generic term used to define any land feature that conveys concentrated water flow, regardless of whether the water flow is ephemeral, intermittent, or perennial. “Wetlands” are distinguished by the presence of water, either at the surface or within the root zone. Wetlands have unique **soil** conditions that differ from adjacent uplands and support vegetation adapted to wet conditions. Wetlands provide critical ecological functions and habitat for a variety of fish, wildlife, and plant species

Wetlands are lands that are transitional between terrestrial and aquatic systems. The water table is usually at or near the surface, or land is covered by shallow water. Some functions of wetlands include the following: provide habitat for fish and aquatic wildlife, offer foraging habitat or water for terrestrial wildlife and birds, absorb flood waters, reduce erosion, recharge aquifers, cleanse pollutants, provide aesthetic values, support unique plant associations, and provide habitat for many rare species of plants and wildlife. In California, wetlands of all types have been greatly reduced in area from their historic extent and are being rapidly lost or adversely impacted.

Watersheds Within the District

District Preserves are located within 22 major **watersheds** extending from the Pacific Ocean in San Mateo County to the baylands in San Mateo and Santa Clara Counties. Watersheds are land or “basins” within which all precipitation within a given watershed drains to a single body of water, often a creek or stream. Many of the District's lands are located within the headwaters or uppermost sections of these watersheds.

Most preserve watersheds contain steep ridges and deep canyons typical of the Santa Cruz Mountains. Rainfall occurs mostly between November and April with seasonal rainfall totals varying greatly within the District. The greatest rainfall quantities occur along the west facing slopes near the summit of the mountain range where totals can reach 40 to 50 inches per year, however, averages around 20 to 30 inches per year are more typical. In the Santa Cruz Mountains, fog accounts for approximately 10-20 inches of this precipitation, much of which is delivered in the dry summer months. Many smaller creeks and streams are intermittent, reflecting this seasonal distribution of rainfall. Winter flows are higher, especially during and immediately following storms.

The Influence of Water Movement

Water flows in predictable patterns on the surface, through rocks beneath the soil, and in underground water tables. Plants and animals are adapted to specific movement patterns of water, sediment, and nutrients occurring in their area. A significant change in any of these factors may reduce or eliminate original species in favor of those better able to survive in the new conditions. Maintaining and restoring hydrologic patterns is important in maintaining healthy **ecosystems**.

The condition of soil and vegetation influences the rate at which water moves as well as its quality and quantity. Leaf litter acts as mulch that helps absorb and conserve rainwater. Maintaining a continuous cover of live and decomposing vegetation residue is the most successful long-term approach to controlling erosion and maintaining **water quality** and quantity.

Water Management Within The District

As rain falls on District Preserves, it is captured and transported through the ecosystem. These processes create high-quality water for the environment and people. District Preserves also support groundwater recharge that helps sustain summer and fall water availability and mitigate the impact of drought.

Groundwater is water that is held underground in soil or pores and crevices in bedrock

Surface water is found in streams, rivers, ponds, and lakes.

Springs are a type of groundwater that surfaces at a point on the land.

Consumptive use is the amount of water that is used by people, livestock, or crops that is unavailable to the environment after use.

The District is also dependent on water to fulfill its mission. District field offices require water for employees, equipment maintenance, dust control, and fire suppression. The District manages residential properties that are often located in areas without municipal supplies, thus relying on locally, naturally occurring water sources. Grazing operations that manage grasslands for multiple benefits require water in remote areas. Irrigation supports farming that provides local food.

The District manages ponds that support aquatic and terrestrial wildlife. In the semi-arid region of the Santa Cruz Mountains, restoration of stream and **aquatic ecosystems** is a priority for managing ecosystems.

The District relies on a variety of water sources. **Springs** are captured and developed to provide water to people and livestock with the goal of allowing wildlife access to the spring water. Wells capture deeper groundwater sources and require energy to pump the water to the surface. Streamflow can be captured by small impoundments or pumps and diverted to the place it is needed. These waters are often stored to provide water during the dry seasons in tanks or ponds

Water Resource Issues

Wetlands and watercourses on the District's open space lands provide valuable and increasingly scarce habitat for a variety of **native** plant and animal species as well as many **special status** species. Where aquatic habitat is not directly present on District lands, runoff from District lands supports habitats downstream, a connection that should be recognized and preserved. Issues associated with the management of water resources and water quality include erosion and sedimentation, excessive diversion of water for consumptive use, severe erosion following **wildland** fires, agricultural runoff, **pesticides** and fertilizers, septic system

wastewater disposal, stormwater runoff, flooding, drought, climate change, associated sea level rise, and chemical **contamination** from neighboring areas or from former use of preserve lands.

WATER RESOURCES GOALS, POLICIES, AND IMPLEMENTATION MEASURES

Goal WR- Protect and restore natural water courses, wetlands and hydrologic processes

Policy WR-1 Protect surface and ground water from contamination.

- ◆ Inventory existing facilities and uses that affect watercourses, **riparian** areas, and wetlands, and prepare plans for protection or **restoration**, as appropriate.
- ◆ Research and pursue cleanup of likely sources of pollution, such as buried fuel tanks, improperly dumped or stored material, and faulty waste or drainage systems.
- ◆ Utilize self-contained sanitary facilities or place rest rooms where they cannot contaminate water sources.
- ◆ Control activities having a high potential for pollution.
- ◆ Properly decommission abandoned septic systems and avoid water quality impacts when constructing new septic systems. Manage active and abandoned wells to avoid groundwater contamination
- ◆ Regulate the type and intensity of human activity on District lands to protect water quality.
- ◆ Review and comment on offsite land use and water management projects and policies that affect District water resources. Recommend and support measures to maintain natural water quality, channel flow, and sedimentation rates on District lands.

Contamination is man-made waste that has polluted the environment making it unfit or unsafe. Examples on District lands include deteriorated septic systems, underground storage tanks, leaking transformers, and trash and debris.

Restoration and enhancement are terms that are sometimes used interchangeably when discussing habitat improvement projects. Restoration refers to the process of returning land that has been degraded and disturbed into functional habitat. Enhancement refers to the process of altering a habitat to provide specific ecosystem functions that may be missing; typically to provide habitat for endangered species.

Many of the District's properties contain legacy logging and ranching roads that were not designed or constructed for year-round use. These road systems can greatly alter the flow of water across the land, causing erosion and sediment problems due to concentrated runoff from winter rains.

Policy WR-2 Restore, maintain or **enhance** water quality on District lands.

- ◆ Manage vegetation to improve watershed productivity and water quality.
- ◆ Manage agricultural leases and easements to maximize the protection and **enhancement** of riparian areas and water quality.
- ◆ Monitor sediment delivery and transport on District preserves located within watersheds identified as impaired by sediment or supportive of special status animals requiring aquatic habitat.
- ◆ Coordinate with agencies and organizations to establish volunteer-based monitoring programs. Participate in regional watershed management activities.

Policy WR-3 Restore Hydrologic Processes.

- ◆ Incorporate **best management practices (BMPs)** and develop storm-water pollution prevention plans (SWPPP) when required at staging areas.
- ◆ Inventory and assess roads and trails on District lands to identify significant erosion and sediment sources. Prioritize maintenance and road/trail management based on most severe erosion and sediment delivery sites.
- ◆ Manage human activities to control erosion--for example, abandon and where feasible **restore** to a natural condition poorly designed or sited roads to a natural condition, close certain trails to bicycle and equestrian use during the wet season, re-route existing trails to minimize erosion and sediment delivery.
- ◆ Restore hydrologic processes altered by past land uses by 'slowing water, spreading it, and sinking it' through installing erosion control materials and structures, removing culverts and drainage diversions where appropriate, and using improved drainage structures that minimize alteration of hydrology.
- ◆ Minimize soil disturbance during all construction projects.
- ◆ Locate new trails to minimize potential water pollution and stream bank erosion and sediment delivery.

- ◆ Construct trails, roads, staging areas, and buildings so that streams are not permanently diverted nor interrupted, and runoff is not concentrated. Minimize creation of impermeable surfaces.
- ◆ Identify and mitigate significant impacts of altered water flow on plants and animals, including aquatic organisms.

Policy WR-4 Manage Water Consumption to Balance Operational and Environmental Needs.

- ◆ Phase in installation of water meters or other measures to monitor annual consumptive water use.
- ◆ Develop and regularly update BMPs for efficient water use in offices, field operations, residences, grazing, and farming.
- ◆ Evaluate and consider the environmental and operational benefits and tradeoffs of each water source for new projects.
- ◆ Evaluate and consider the construction and operational costs of each water source.
- ◆ Balance operational and consumptive use needs with the goal of maintaining healthy ecological functions.
- ◆ Provide technical assistance to lessees of District lands and owners of lands on which the District has an agricultural easement to secure water rights for the continuation or establishment of viable agriculture consistent with the protection of sensitive habitats (see Coastal Service Plan PA.2).

Two types of surface water use are recognized under California law: appropriative rights and riparian rights.

Appropriative rights require a permit from the State Water Resources Control Board, which grants the right to use water on parcels not adjacent to the watercourse or to store water.

Riparian rights are the rights of any owner of a parcel immediately adjacent to a watercourse to use water.

Policy WR-5 Determine and maintain District water rights and utilization.

- ◆ Identify existing uses of surface water on newly acquired open space lands, as part of the purchase process. Protect appropriative and riparian water rights for appropriate and beneficial existing or possible future uses.
- ◆ Secure water rights for the continuation or establishment of viable agriculture and **conservation grazing** on District land consistent with protection of sensitive habitats.

Policy WR-6 Preserve and enhance fisheries habitats. (See WM policies).

- ◆ Inventory and assess stream reaches accessible to **anadromous** fish to identify impediments to fish passage and opportunities for habitat enhancement.
- ◆ Remove artificial **barriers** to fish passage where removal will enhance spawning and rearing habitats.
- ◆ Enhance spawning and rearing habitats for native fisheries through restoration. Prioritize restoration and enhancement of areas providing habitat to sensitive species.
- ◆ Monitor sensitive fish species **populations** in District waters.
- ◆ Monitor water quality and condition of high priority aquatic habitats associated with District projects containing spawning, breeding, rearing habitat for special status fish, reptile, amphibian, or other aquatic species.
- ◆ Evaluate and consider the environmental benefits and construction/operational costs of off-stream storage facilities to minimize stream diversion and/or allow for the release of water into natural waterways during low flow seasons and implement accordingly.
- ◆ Avoid new direct stream diversion for consumptive uses where economically feasible alternative water sources exist, or the diversion captures the majority of flows, or the aquatic habitat would be substantially impaired. Explore alternate sources for existing in stream diversions.

Few of the ponds in the Santa Cruz Mountains are naturally occurring features. The majority of ponds were created as artificial impoundments that require ongoing management to maintain. Regardless of their origin, ponds provide wildlife access to a scarce resource (water) and greatly increase the diversity of species inhabiting the District's lands.

Policy WR-7 Preserve and enhance ponds and other wetland habitats. (See VM-1 and WM policies).

- ◆ Maintain ponds or other water bodies as wildlife watering sources as appropriate (See WM-2).
- ◆ Inventory and assess ponds and wetlands to identify opportunities for habitat maintenance and enhancement.
- ◆ Monitor sensitive reptile, amphibian, and aquatic organism **populations** dependent on District wetlands.

- ◆ Preserve ponds through maintenance of artificial impoundment structures where ponds provide habitat for sensitive and other wildlife species.

Policy WR-8 Develop seasonal and multi-year drought management strategies for District lands.

- ◆ Evaluate and develop where appropriate wells and springs to create resilient water supplies.
- ◆ Identify and curtail diversions that strain naturally limited water sources, especially those that significantly impact special status species.
- ◆ Evaluate and implement where appropriate additional water storage infrastructure to store water when it is naturally abundant for later use during dry seasons.
- ◆ Evaluate and alter as appropriate water-intensive land management practices during drought conditions to reduce overall District-wide water consumption.

VI. GEOLOGY AND SOILS

BACKGROUND

District lands include a diverse set of dynamic geological **resources characterized by steep slopes**, earthquake faults, landslides, unstable and erosive **soils**, and attractive but fragile rock formations. **Open space** is an appropriate designation for such areas.

Soil – A Valuable and Fragile Resource

Soil is the essential surface layer that predominates in the District Preserves. Soil provides the rooting medium for plants and supplies most of the nutrients they require, whether native or cultivated. As plant communities mature, plant roots, surface debris, and animal remains break down and are incorporated into the soil. Over time, this organic material builds up soil structure and fertility. If depleted or lost, soil takes a long time to regenerate- often longer than a single human generation. This surface layer of the land is readily accessible and easy to disturb and therefore requires the most protection by land managers.

Factors Contributing to Soil Loss

In some areas, District soil erosion has been accelerated by loss of plant cover, disruption of **natural** drainage patterns, landslide activity and/or some types of recreational uses. Some of these are naturally occurring causes, some are natural causes accelerated by human activity. By far the largest amount of soil erosion on District lands is human-caused. Poor placement of roads or trails, shortcutting of trails, poor design, construction or placement of drainage systems, excessive grazing pressure or past cultivation practices, and development of facilities can accelerate natural erosion. These activities can destroy protective plant and mulch cover, exposing soil to wind and water or diverting water from natural drainages. Recovery of soils from such disturbances is slow. Monitoring, preventing, and, where necessary, remedying human-caused erosion are all important parts of the District's **resource management** responsibilities.

GEOLOGY AND SOILS GOALS, POLICIES, AND IMPLEMENTATION MEASURES

Goal GS- Avoid or minimize soil loss and prevent or remediate contamination related to human land use, and protect unique or exceptional geologic features

Policy GS-1 Locate and construct facilities to avoid high-risk areas subject to landslides, liquefaction, faulting, flooding and erosion.

- ◆ Minimize construction of major improvements (examples: buildings, roads, pipelines, and septic tanks) in landslide-prone areas, active fault zones, flood zones, and highly erodible areas.
- ◆ Design trails with respect to natural topography to maintain or **restore** natural drainage patterns as much as possible. Design roads, trails and facilities to minimize disturbance to vegetation and soil.
- ◆ Review available geohazard data for proposed facilities and infrastructure, where **geologic hazards** may be present.

Policy GS-2 Minimize unnatural soil erosion and sedimentation. (See VM-3: Measure 3)

- ◆ Monitor soil erosion and slope failure and identify areas where these processes are accelerated and causing resource damage. Utilize existing information (soil maps, geologic reports etc.) to avoid construction in problem areas and to identify areas with conditions that may impact existing infrastructure.
- ◆ Reduce human-caused erosion by identifying, limiting or eliminating the causative activity, properly locating or relocating facilities, installing drainage or erosion control measures, or revegetating the area. Construct roads and trails to maintain natural drainage patterns.
- ◆ Reconstruct or stabilize and abandon roads and trails that display or have the potential for ongoing erosion problems.
- ◆ Limit agricultural activities, facility development, and trail construction in riparian and other wetland areas to protect them from disturbance.

- ◆ Minimize soil disturbance associated with construction and maintenance operations.
- ◆ Seed to rehabilitate disturbed ground and lessen erosion. Time seeding projects to ensure adequate soil moisture for seed germination. Utilize mulch or other appropriate groundcover to reduce erosion where sediment can be delivered to a **watercourse** or wetland.
- ◆ Utilize **native** plants when possible for projects requiring **revegetation** for long-term erosion control. **Non-native** sterile grass seed may be used to quickly establish ground cover and reduce erosion. In areas of active **livestock** grazing, incorporation of non-invasive pasture grasses may be utilized.
- ◆ Prevent, to the extent possible, the physical removal of naturally occurring soil.

Policy GS-3 Protect unique or exceptional geologic features from human damage.

- ◆ Identify locations and document the condition of unique or exceptional geologic features (example: tafoni sandstone formations, serpentine outcrops, sag ponds).
- ◆ Monitor such features to determine if action is needed to prevent or stop damage.
- ◆ Control access to features requiring protection by informing visitors, placing signs and **barriers**, and enforcing restrictions.
- ◆ Develop security protocols to limit availability and distribution of geographic information for geology and soil resources to protect sites from accidental destruction, looting, and vandalism.

Policy GS-4 Prevent or remediate contaminated soils

- ◆ Prevent the release of hazardous materials into the environment associated with District operations by implementing and following Best Management Practices (BMPs) for spill prevention.
- ◆ Investigate areas where soil contamination may have occurred due to previous land use including: disposal sites, mining areas, or leaks from storage tanks.

- ◆ Remediate areas where contaminants pose a threat to human and ecological health through implementation of recommended treatment options including biodegradation, safe removal of contaminated soils, capping of soils, or other methods as recommended by a remediation professional.
- ◆ Adhere to requirements outlined in soil management plans approved for the preserves.

VII. SCENIC AND AESTHETIC RESOURCES

BACKGROUND

The District recognizes the protection of scenic values as one of the primary benefits of **open space**. The scenic and aesthetic **resources** of District lands provide physical and psychological relief from the stresses and uniformity of urban life. They also contribute to our "sense of place" - our appreciation of the qualities that set this area apart from others and make it feel like home.

District preserves include a variety of **natural** settings and landscapes that form magnificent scenic backdrops to the urbanized peninsula. Local residents and visitors particularly appreciate the interplay of color, pattern, form, and light on the coastal mountains, where rugged topography, hot sun, wind, and fog combine to create dramatic and appealing contrasts in vegetation.

In some cases, preserving a significant scenic or **historic** landscape may involve managing it to actually *prevent* natural succession, for example, without intervention; a shallow pond may gradually fill in and become a meadow or open grassland. Active management through vegetation maintenance or pond deepening not only promotes the scenic and aesthetic value of a wetland setting, but may also be more beneficial to wildlife. However in most instances, restoring or mimicking natural processes can help maintain the appealing visual and biological diversity of **native** communities.

SCENIC AND AESTHETIC RESOURCES GOAL, POLICIES, AND IMPLEMENTATION MEASURES

Goal SA- Preserve lands with natural appearance, diversity, and minimal evidence of human impacts

Policy SA-1 Minimize evidence of human impacts within preserves.

- ◆ Clarify and document appropriate standards for designing and locating trails, parking areas, and buildings.
- ◆ Locate trails to minimize their visibility from a distance.
- ◆ Where feasible, locate telecommunication towers, power lines, water towers, firebreaks, and other infrastructure along margins of roads, next to existing structures or where vegetation and terrain help ease undesirable visual and environmental impacts. Install utility lines underground, if practical.
- ◆ Cluster new facilities near existing development, where possible.
- ◆ Design facilities such as structures, bridges, fencing, benches, and barriers to harmonize with natural landscape features, colors, and materials.
- ◆ Cluster, reduce, and place signs to lessen their visual impact.
- ◆ Rehabilitate areas degraded by human use by restricting access or type(s) of use, rerouting trails and roads, removing unsightly human-made features and **non-native** plants, restoring natural contours, and revegetating with native plants.

Policy SA-2 Maintain significant landscapes or features that were formerly maintained by natural processes.

- ◆ Control encroaching vegetation where it adversely affects significant scenic, historic or **habitat** resources (See **Vegetation Management**, **Cultural Resources**, and **Integrated Pest Management** policies).

District development consists of facilities such as trails, restrooms, parking lots, fencing, offices, and residences. District facilities are designed to blend into the natural surroundings and are located within or adjacent to previously disturbed areas such as placing parking lots along existing roadways, or improving, remodeling, or placing new structures in previously developed areas.

- ◆ Control vegetation to create or maintain important scenic viewpoints and vistas (See Vegetation Management and Integrated Pest Management policies).
- ◆ Require District tenants to maintain landscapes and improvements to acceptable visual standards that do not detract from a visitor's experience or adversely impact wildlife.
- ◆ Allow for habitat changes associated with control of vegetation for fuel-breaks, disc lines, and prescribed burns under the concepts of **ecological resiliency** to reduce larger-scale aesthetic impacts of catastrophic wildfire.

Policy SA-3 Minimize unnatural noise within preserves

- ◆ Prevent or reduce unnatural sounds that adversely impact preserves resources or a visitors' enjoyment of them.

VIII. CULTURAL RESOURCE MANAGEMENT

BACKGROUND

Cultural Resources at the District

The San Francisco Peninsula has had a rich and diverse history, including settlement by **Native** American groups; the Spanish (1776-1821) and Mexican Republican (1821-1848) colonization of the region; the annexation of California by the United States in 1848; and subsequent industrial, agricultural, and residential development. There are remains from each of these periods on District lands, including Native American village sites and bedrock mortars, barns and other ranching features, orchards, wineries, **historic** homes, sawmills, mines, historic roads and trails, and outdoor recreational sites. As time passes, more recent periods of California's history become **historically significant**. As such, some 20th century sites such as World War II and Cold War military sites are now considered historically significant **resources** throughout California. Collectively, these sites, structures, features, and **artifacts** comprise the **cultural resources** of the District.

The District was founded to preserve a regional greenbelt of **open space** land on the San Francisco Peninsula from the rapid suburban development that accelerated in the post-World War II boom in the Bay Area. Although the District's mission is to protect the greenbelt for open space values, **natural** resource protection, and ecologically sensitive recreation, this mission compliments cultural resource preservation goals. The development pressures from which the District protects open space land also threaten its associated **historic** and **prehistoric** structures, cultural landscapes, and **archaeological sites**. The preservation of open space land

Native American groups, such as the Ohlone, have lived on the San Francisco Peninsula for thousands of years. Bedrock mortars and other artifacts from their habitation and use of the landscape can be seen on District lands today.

During the Spanish Colonial and Mexican Republican periods, the San Francisco peninsula was divided into large ranching tracts. District preserves, including Rancho San Antonio, the Rancho de Guadalupe area of Sierra Azul, and La Honda Creek (formerly Rancho San Gregorio), were part of these large land grants.

In the second half of the 19th century, District forests were used for timber harvesting, residences, and outdoor recreation. Grasslands were developed for ranching and agriculture, including vineyards and orchards. Historic roads, such as Old Page Mill Road, connected communities and industries in the growing region.

in the peninsula's greenbelt provides the opportunity for the District to protect and interpret the rural history of the Santa Cruz Mountains and San Francisco Bay for the benefit of present visitors and future generations.

Cultural resources are irreplaceable resources that face substantial threats such as disturbance from construction and maintenance activities, theft, vandalism, and deterioration over time. When the District acquires land with historic structures, the structures often have suffered years of neglect and are at risk of collapse. In these cases, it can be very expensive to **rehabilitate** and maintain these structures, many of which have already lost significant **resource integrity**. It is sometimes necessary to remove dilapidated historic structures due to public safety concerns and the prohibitive expense of **historical rehabilitation**. The District has adopted "Policies Regarding Improvements on District Lands" to provide a public process used to assess and determine whether District structures and improvements are cultural resources, and how they can most appropriately be managed. The District has successfully completed a number of important historic preservation projects, often with assistance from granting agencies and/or public/private partnerships. Cultivating relationships with historic preservation groups, research organizations, and knowledgeable local residents, including Native American groups, will allow the District to pursue new opportunities to preserve cultural resources and protect remnants of the peninsula's heritage for present and future Bay Area residents. The District serves communities of diverse ethnic heritage, who seek a wide variety of experiences in District preserves. To the extent that these practices can be accommodated with minimal impact to the natural and cultural resources, they should be encouraged and accommodated wherever feasible.

Examples of completed historic preservation projects on District lands include the Woodhills Home at Fremont Older, Picchetti Winery, Grant Cabin at Deer Hollow Farm, and the Red Barn at La Honda Creek.

CEQA defines a historical resource as potentially significant if it is at least 50 years old and is determined to be eligible for listing on the California Register of Historic Resources. A unique archaeological site is defined as a site that is at least 100 years old and has the potential to provide useful information about the past. Therefore, as time passes,

Regulatory Context

There are a number of state and federal laws pertaining to cultural resources to which the District must adhere in its operations. The California Environmental Quality Act (CEQA) (Guideline 15064.5, Public Resources Code 21038.2) states that a substantial adverse change to the significance of a historical resource or a unique archaeological resource must be treated as a significant effect on the environment in a project's environmental review. Public Resources Code 5097.9-5097.994 mandates pro-

protocols for protecting Native American graves and human remains, and prohibits unauthorized excavation, destruction, or vandalism to Native American archaeological sites on public land.

Section 106 of the National Historic Preservation Act of 1966 requires consideration of impacts to historic resources on federal lands or projects requiring federal permits. Likewise, any project that requires review under the National Environmental Policy Act of 1969 must consider impacts to cultural resources. The Native American Graves Protection and Repatriation Act of 1990 (NAGPRA) mandates the protection of Native American burial sites on federal lands and the repatriation of human remains and funerary objects to descendent Native American groups. Under NAGPRA, institutions with collections of Native American remains and funerary items must create an inventory and notify lineal descendants as part of the repatriation process.

In compliance with the statutes listed above, the District has included protocols for unexpected discoveries of archaeological sites and human remains as mitigation measures in District projects. An example of a District project specifically identifying protocols for cultural resource protection is the Service Plan and accompanying Environmental Impact Report for expansion of the District's boundaries to include coastal San Mateo County completed in 2003. The Service Plan recognized the unique value of cultural resources in the San Mateo County coastal area and established Cultural Resource Policies to preserve cultural resources in the Coastal Annexation Area. The Policies and Implementation Measures established in this Cultural RMPs are consistent with the Cultural Resource Policies in the Service Plan.

The Cultural RMPs is intended to be consistent with and to supplement the District's "Policies Regarding Improvements on District Lands." The purpose of this policy is to formalize and enhance the District's cultural resource management practices for the long-term stewardship of the District's significant historical and archaeological sites.

Cultural resources are not restricted to historic structures. Many of the landscapes on District preserves are artifacts of historic and prehistoric human activity. These include agricultural landscapes, such as the orchards at Stevens Canyon Ranch; the remnants of logging in the District's redwood forests; ranching landscapes; and the formal estates of August Schilling in Thornewood and, Harry Tevis in Bear Creek Redwoods and Fremont and Cora Older at Fremont Older.

Archaeological sites include prehistoric sites, such as Native American villages and other remnants, and historic sites dating from after European settlement. These can include Spanish Colonial /Mexican sites, and sites dating from after the annexation of California by the United States.

To protect vulnerable archaeological resources, the State Legislature has exempted sensitive archaeological site information from disclosure requirements in the California Public Records Act.

CULTURAL RESOURCE GOALS, POLICIES, AND IMPLEMENTATION MEASURES

Goal CR- Identify, protect, preserve, and interpret cultural resources for the benefit of present and future generations.

Policy CR-1 Maintain an inventory of cultural resources on District preserves.

- ◆ Inventory and assess cultural resources throughout the District, including **prehistoric** and historic archaeological sites, structures, and **cultural landscape** features. The **Cultural Resource Inventory** should include a Geographic Information Systems database; however, access to this inventory must be restricted to District staff and qualified professionals, to the extent allowed by law to protect sites from looting and vandalism.
- ◆ Record cultural resources in the District's Cultural Resource Inventory when purchasing new property and perform research on previous uses of the property. Examples of research activities include performing a records search with the **Northwest Information Center** and consulting historic preservation organizations, previous residents, and descendants to gather local historical information.
- ◆ Complete archaeological site records for known unrecorded sites on District land and file reports with the Northwest Information Center.

Policy CR-2 Address cultural resources in the development of preserve use and management plans.

- ◆ Consult the Cultural Resource Inventory when planning projects that may have an impact on cultural resources in the project area.
- ◆ Conduct appropriate reconnaissance measures, such as research or archaeological survey, early in the planning process for trail construc-

tion, maintenance activities, or other projects that entail ground disturbance in an area of known archaeological sensitivity. Monitor construction activities when appropriate.

- ◆ Locate facilities, such as trails, staging areas, and new structures, to avoid loss or degradation of historically or archaeologically significant resources wherever possible. If not possible to avoid, minimize impacts, for example by: capping site, recording important features and/or artifacts, relocating structures, or **data recovery** excavation.
- ◆ Include stakeholder groups when developing plans for the management of historically or **archaeologically significant** resources. Consult with descendent communities such as Native American and other ethnic groups when developing plans for the management of historically or archaeologically significant resources related to their heritage.
- ◆ Assess the significance, integrity, and feasibility of preservation of historic structures when developing Preserve Use and Management Plans or Master Plans. If a structure is determined to be eligible for the California Register of Historic Resources, assess feasibility of preserving the resource.

Policy CR-3 Protect cultural resources from disturbance to the maximum extent feasible.

- ◆ Wherever possible and appropriate, preserve historical resources and archaeological sites **in situ**.
- ◆ Prohibit looting, vandalism, and unauthorized removal of cultural resources and associated artifacts from District preserves.
- ◆ Implement security measures such as protective fencing and patrolling to reduce vulnerability of the resources due to vandalism and looting.
- ◆ Develop security protocols to limit availability and distribution of geographic information for cultural resources to protect sites from looting and vandalism.
- ◆ Prohibit District sale, purchase, or commercial trade of individual archaeological artifacts.

Looting of archaeological sites for commercial gain poses a threat to sites around the world. Codes of archaeological ethics therefore discourage any activity that commodifies artifacts and encourages their commercial trade.

There are a number of potential sources of grant funding for historic preservation projects. In the past, the District has received grants from the Santa Clara County Historical Heritage Commission and the California Heritage Fund. Listing resources on local, state, or national registers can increase opportunities for grant funding.

Provenience, or the contextual information associated with an artifact or collection, is important for retaining its research potential and relevance for interested communities. A cataloging system is a crucial tool for preserving this information and keeping it linked to objects.

- ◆ Develop and follow guidelines for reporting, protecting and recording archaeological sites and features in the event of unexpected discovery.
- ◆ Provide District staff with basic training to identify and protect cultural resources.
- ◆ Assess existing operations within areas of known archaeological sensitivity to protect and preserve cultural resources.
- ◆ Require that all archaeological investigations or research activities that have the potential to physically significantly impact archaeological resources are carried out by qualified archaeologists, and that a technical report for each project is provided to the District following excavation.

Policy CR-4 Preserve and maintain cultural resources wherever feasible.

- ◆ Actively pursue grant assistance from local, state, federal, and other programs to supplement District funds to implement historic preservation projects for historically and archaeologically significant resources.
- ◆ Seek partnerships with private or non-profit groups to aid in the **restoration**, management, and use of historic structures.
- ◆ Assess the condition, identify needed repairs, and prepare maintenance plans for significant high priority historic structures as funds allow.
- ◆ Assess the eligibility of cultural resources for nomination on local registers, the California Register of Historic Resources, and the National Register of Historic Places. Consider nomination to registers for which a resource is determined eligible.
- ◆ Catalog artifacts associated with sites on District lands to prevent deterioration and to document the site and location where the artifacts were recovered. Consider curating artifacts in danger of deterioration. Maintain a cataloging system to preserve artifacts' contextual information and storage locations. Where appropriate, coordinate with other agencies and organizations to assist in long-term curation of District collections.
- ◆ Develop and follow guidelines and procedures governing loans of artifacts to other agencies and organizations.

Policy CR-5 Provide public access and educational programs to interpret historical and archaeological resources. (See PI-1)

- ◆ Provide controlled public access to historical and archaeological sites where appropriate, considering other public access resource constraints and resource protection.
- ◆ Allow appropriate uses of cultural resources by descendent communities.
- ◆ Seek input from descendent communities, such as Native American and other ethnic groups, when planning public access and educational programs that interpret cultural resources related to their heritage.
- ◆ When developing partnerships for the use and management of historic structures, plan for public access to the structures where appropriate while minimizing impact to the structures and respecting the needs of building occupants.
- ◆ Provide interpretive materials such as signage or brochures for self-guided hikes to inform visitors about the history of District lands and the San Francisco Bay Area. Develop locations to display artifacts for public benefit.
- ◆ Encourage, utilize, and support historical research by docents and volunteers.
- ◆ Provide training opportunities for docents to aid them in the development of docent-led tours of **historic** and archaeological sites and landscapes.
- ◆ Facilitate school field trips of historic and **archaeological sites** and cultivate other opportunities to work with educational groups to interpret cultural resources on District preserves.
- ◆ Support historical and archaeological research conducted by District-approved, qualified cultural resource professionals on District lands.

Public interpretation and access to non-sensitive information about cultural resources on District land is an important part of their preservation, conveying their importance to the general public. The District's cultural resources are a valuable public asset.

MIDPENINSULA REGIONAL OPEN SPACE DISTRICT
RESOURCE MANAGEMENT POLICIES
CULTURAL RESOURCE MANAGEMENT

Policy CR-6 Preserve District institutional history.

- ◆ Preserve documents and artifacts important to the history of the District.

IX. RESEARCH AND COLLECTION OF INFORMATION

BACKGROUND

Achieving the District's **resource management** objectives requires support in the form of basic academic research and applied field studies. This level of research is usually conducted by colleges and universities, by consultants as part of environmental analysis for project proposals, or by environmental and wildlife organizations such as the California Native Plant Society, the Nature Conservancy, or the Audubon Society. Although the District may conduct or sponsor research directly, it will continue to depend on and support outside research to expand its knowledge about the **natural** resources under its care, and to provide the basis for sound planning and management decisions.

RESEARCH AND INFORMATION GOALS, POLICIES, AND IMPLEMENTATION MEASURES

Goal RC- Use and document scientific knowledge of preserve resources and resource management techniques as a basis for management decisions

Policy RC-1 Maintain resource information files for each preserve and resource subject.

- ◆ Systematically gather information and data from appropriate agencies, universities, non-profit organizations, studies, and reports. Integrate spatial data into the District's **GIS database**.
- ◆ Maintain an electronic filing system to facilitate access of spatial data and information by location and resource type.
- ◆ Facilitate the reporting of resource related observational data by field staff and the public and its access by District staff.

- ◆ Respond to public information requests and promote release of non sensitive resource information to better distribute and share District scientific knowledge.
- ◆ Recruit interns and volunteers to help organize and maintain resource information files, in cooperation with the District's volunteer program.

Policy RC-2 Coordinate and cooperate with institutions, agencies, organizations, and individuals conducting resource management or research.

- ◆ Maintain a list of District related potential resource research projects. Encourage research directed to specific sites, District-related issues, or resource management practices.
- ◆ Administer the District's Resource Management Grant Program to fund projects that contribute to resource management projects. Incorporate the District's list of potential projects into the Grant Program.
- ◆ Explore partnerships and foster relationships with educational institutions, scientists, and other land management professionals in order to share information and resources and to develop Memorandums of Understanding or Memorandums of Agreement between the District and other agencies.
- ◆ Sponsor or participate in events and activities such as symposiums, workshops, and conferences that support scientific research and sound resource management practices.
- ◆ Encourage and facilitate currency on resource management techniques, such as **restoration, integrated pest management**, and erosion control.
- ◆ Provide internship support for appropriate research.

Policy RC-3 Undertake original research necessary for planning or management decisions.

- ◆ Carefully research existing information and explore opportunities for cooperative studies to collect additional information.

- ◆ Retain qualified consultants or researchers to conduct studies or collect additional information in a standardized format that can be integrated with the District's GIS database.
- ◆ Encourage and facilitate training of District staff to obtain environmental permits (such as scientific collection or sensitive species handling permits) in order to participate in or conduct needed research and monitoring and to maintain relationships with agency staff.
- ◆ Share significant new information through resource agency contacts and local and regional databases, such as the California Natural Diversity Data Base and Natural Resources Database.

Policy RC-4 Allow collecting, trapping, or other field research activities only in conjunction with legitimate research consistent with the District's management goals.

- ◆ Continue to administer the District's Special Use Permit Program for collection, trapping, archaeological research, or field studies on District lands.
- ◆ Require the researcher to share the information resulting from the studies with the District and other appropriate parties. If appropriate, integrate data into electronic filing system or GIS database.

Policy RC-5 Develop performance measures when designing District projects and collect monitoring data to evaluate project success.

- ◆ Research and utilize existing performance measures from comparable prior projects and partner agencies.
- ◆ Collect and evaluate monitoring data to measure project success and for use in **adaptive management**.
- ◆ Engage in benchmarking opportunities with public, partners, and research institutions through collaborations and the sharing of project data.

X. PUBLIC INTERPRETATION AND ENVIRONMENTAL EDUCATION

BACKGROUND

Communication and **outreach** are key to developing broad public support for acquiring and protecting **open space**. Increasing public knowledge and appreciation of the preserves' **natural** and **cultural resources** will improve support for their conservation. The District needs to inform the public about District treasures, so it will care about protecting them.

The **resource management** program will play a vital role in this effort by providing a greatly improved information base for the public. Studying the current condition of preserve resources and discovering how best to maintain and **restore** them will reveal information that stimulates public interest, makes the preserves more enjoyable places to visit, and inspires respect and a sense of stewardship.

The District's Public Affairs department is charged with communicating this information to the public. For example, staff works closely with local schools, districts, agencies, and other special groups to provide **environmental education** and interpretive programming to students, organizations, and the general public. The Public Affairs department also gets the word out through publications, presentations, and working with the media. The volunteer and docent programs greatly increase public outreach opportunities. The volunteer program provides a means for the public to learn firsthand about stewardship, by participating in District projects. The docent program trains docents to conduct activities on the preserves and interpret District resources. Docents also staff the Daniels Nature Center and lead environmental science-based field trips for students.

Environmental education is typically a curriculum-based approach targeted toward students to attain an ultimate goal (such as environmental stewardship). The District's environmental science-based programming was established in 1996 and serves elementary school students in a field trip experience at the District's Daniel's Nature Center and surrounding Skyline Ridge Preserve. During the program students engage in hands on discovery and learning.

Interpretation is a communication method that reveals meanings, connections, and relationships by firsthand experience, and by illustrative media, such as web pages or signs. The District's interpretive program includes communication and outreach by District staff and docents, as well as through brochures, publications, signage, signboards, exhibits, and other means. Interpretive programs are often the most effective means of stimulating understanding and appreciation of open space, providing information, promoting stewardship of resources, and helping ensure visitor safety.

INTERPRETATION AND EDUCATION GOALS, POLICIES, AND IMPLEMENTATION MEASURES

Goal PI-	Increase public knowledge, understanding, and appreciation of the natural and cultural resources of the preserves, and support for their conservation.

Policy PI-1 Provide interpretive **programming**, facilities, and materials.
 (See CR-5, GM-6 and GM-7)

- ◆ Develop appropriate and timely projects and plans to support natural and cultural resource interpretive opportunities that are guided by recommendations and priorities in the District's **Interpretive Systems Plan (ISP)**,
- ◆ Provide interpretive materials via a wide range of media (web and print based).
- ◆ Continue to operate an interpretive program at the David Daniels Nature Center at Skyline Ridge Open Space Preserve with docents and staff to support its use by the general public and local schools and organizations.

An Interpretive Service Plan (ISP) serves to identify and prioritize the valuable natural and cultural resource "stories" and connections that can be brought forward through enhanced or new interpretive programs or facilities at each location being evaluated.

- ◆ Provide information about the District's mission, resources, management practices, and goals in District signboards, facilities, and publications. Encourage publication of this information in the general media.
- ◆ Provide training for new docents and additional "refresher courses" to continue to help them provide interpretive services.
- ◆ Provide opportunities for the public to learn about natural resources and support resource management activities through the docent and volunteer programs.

Policy PI-2 Provide environmental education programming and outreach.

- ◆ Coordinate and cooperate with local agencies and organizations, particularly schools that would like to use District lands and facilities for **environmental education**, whenever appropriate.
- ◆ Involve school children in District-sponsored environmental projects and educational activities.
- ◆ Provide environmental education programs and materials to schools, groups, and organizations.

Policy PI-3 Provide other public **outreach**.

- ◆ Support and/or participate in special events and programs that foster public knowledge and appreciation of **open space** resources.
- ◆ Participate in multi-agency forums to share information and resources and explore partnership opportunities.
- ◆ Develop and use outreach opportunities to gain public support for resource management goals and policies.
- ◆ Work with the Public Affairs Department to increase public awareness of resource values.

XI. CONSERVATION GRAZING MANAGEMENT

BACKGROUND

The vegetation of the Santa Cruz Mountains is comprised of a rich and diverse assemblage of plant species. This wealth of diversity was most evident within the grassland **ecosystems** that evolved under a variety of disturbance pressures including fire and grazing by large herds of **ungulate animals**, which are now mostly extinct or locally extirpated. The **flora** that emerged has been described as one of the most diverse and species rich ecosystems in the United States

The arrival of early Spanish and Anglo settlers initiated a particularly dramatic change in species composition of California grasslands, primarily as a result of tilling the grasslands for agricultural crop production, reduction of **native** grazing animals and introduction of cattle herds brought over from Europe and let loose on the new rangeland. This introduction of **non-native** plants and animals, coupled with the concurrent suppression of fire on the landscape as the western United States was settled, resulted in the substantial replacement of the native grassland vegetation with a predominately **exotic**, annual flora. The exotic vegetation is often more competitive, productive, and prolific than the native plants within which it coexists, and tends to dominate and replace existing native grasses and wildflowers. Over the last 150 years, coastal grassland areas have also experienced large-scale conversion to agriculture or urban development. The remaining undeveloped grasslands face continued development pressure and are severely impacted by exotic, invasive organisms.

The District's **open space** preserves contain large acreages of grasslands that in many areas have been degraded due to the pressures described above. Management of these grassland habitats is desirable to reduce the risk of wildfire and to maintain viable native plant communities. **Vegetation management** using **livestock conservation grazing** or other **resource management** tools can be a substitute for native grazing animals and recurring fire to achieve the District's objective of preserving, protecting and restoring the **natural** environment.

The greatest diversity within California's coastal grasslands can be seen in the forbs or wildflowers that emerge in the spring following winter rains. Sites with adequate management of non-native vegetation will reward these efforts with bountiful displays of colorful spring wildflowers.

By some estimates, nearly 80 percent of the vegetation cover within California grasslands is exotic vegetation.

District lands currently contain approximately 5300 acres of grassland habitat. The largest contiguous grassland areas are within District lands in western San Mateo County.

Livestock ranching is a small but vital part of the Bay Area's agricultural economy. As with any business that depends on local infrastructure and services, livestock ranching is increasingly threatened with each ranch that goes out of business. Every livestock rancher depends on services and supplies including veterinary care, feed sales and delivery, farm and ranch infrastructure supplies, and livestock transportation services. As land is taken out of ranching, all of these services and supplies are incrementally affected and may cease to operate, increasing the burden for families and businesses that choose to keep ranching.

*Typical fencing used to control livestock movement that the District inherits as part of property acquisitions is **five-strand barbed wire fencing**. The District standard for new/replacement cattle fence construction is wildlife-friendly 5-strand fencing with a smooth bottom wire approximately 16" above the ground unless conditions warrant an alternative fence type. Other fencing types that may be used include four-strand barbed wire for interior fencing, wood rail fencing and temporary electric fencing that can be installed to seasonally restrict livestock to target areas or exclude livestock from sensitive areas. Wildlife-friendly fences enable virtually all wild animals to move through an area without harm and with minimal impediment.*

In 2003, the District completed the Service Plan and accompanying Environmental Impact Report for the San Mateo Coastal Annexation Area expansion of the District's boundaries to include coastal San Mateo County. The Service Plan recognized the unique value of the San Mateo County coastal area and established Agricultural Policies to preserve and encourage viable agricultural use of land. The Policies and Implementation Measures established in this **Conservation Grazing** Management Policy are intended to supplement and complement the Agricultural Policies in the Service Plan. Furthermore, these **Conservation Grazing** Management Policies will be implemented in a manner that is consistent with the Service Plan.

CONSERATION GRAZING MANAGEMENT GOALS, POLICIES, AND IMPLEMENTATION MEASURES

Goal CGM- Where appropriate manage District land with livestock conservation grazing that is protective of natural resources and that is compatible with public access; to maintain and enhance the diversity of native plant and animal communities, manage vegetation fuel for fire protection, help sustain the local agricultural economy, and preserve and foster appreciation for the region's rural agricultural heritage.

Policy CGM-1 Ensure that **conservation grazing** is compatible with and supports wildlife and wildlife habitats.

- ◆ Inventory and assess sensitive habitats to identify areas requiring special management practices. The conservation of these areas will take precedence over other uses and management practices that are determined to have an adverse effect on these **resources**.

- ◆ Prepare site-specific grazing management plans by a certified range-land manager including **best management practices (BMPs)** for pre-serves where **conservation grazing** will be utilized as a resource management tool. The site-specific grazing management plan will be a component of the agricultural production plan developed through the Use and Management Planning process. The Use and Management Planning process provides for public input and Board approval of site-specific grazing management plans.
- ◆ Manage agricultural leases and easements to protect and enhance **riparian** areas and to maximize the protection or **enhancement** of **water quality**. (See WR-4)
- ◆ Per the District's long-standing policy of protecting native predators, continue to prohibit the lethal take of predators in response to livestock depredation.

Policy CGM-2 Provide necessary infrastructure to support and improve grazing management where appropriate.

- ◆ Utilize fencing that allows wildlife movement and fosters habitat connectivity. (See WM-3: Measure 3)
- ◆ Manage access to existing water features and where needed supply supplemental drinking water through stock ponds and water troughs to preserve clean water for livestock, protect water quality, and enhance habitat for wildlife. Provide wildlife escape ramps where necessary.
- ◆ Encourage and assist grazing tenants on District land to provide range improvements to **restore** or conserve **wildland** resources and to enhance range condition.
- ◆ Inventory and assess roads and trails on District lands to identify significant erosion and sediment sources – abandon and where feasible restore to a natural condition poorly designed or sited roads. (See WR-4)

Policy CGM-3 Monitor environmental response to grazing on District lands.

- ◆ Monitor forage utilization and distribution by grazing animals to assure appropriate amounts of **residual dry matter (RDM)** remain on the

*The goals of **conservation grazing** are to maintain and enhance biodiversity by moderating the impacts of exotic grasses, manage fuel loads to reduce risk of catastrophic wildfire, and to help sustain local agricultural heritage*

Residual Dry Matter (RDM) is a measure of the amount of vegetation left on the ground, typically measured at the end of the summer or fall. Appropriate levels of RDM strive to minimize thatch, which can inhibit new plant growth, while maintaining adequate levels of vegetation to prohibit soil erosion.

Fire reduction is a great concern for some landowners. However, cattle are not able to graze all land areas effectively for fire protection purposes, such as steep slopes or slopes partially vegetated with brush. In these instances, goats may be an effective alternative. Goat herds can be rented for a short period of time and can be moved with a goat herder and dog(s) along with portable fence enclosures. Goats and other small livestock must be penned in enclosures at night to protect them from predators.

ground to achieve desired resource management objectives. In the course of RDM monitoring, evaluate and report on wildland fire **fuel** levels that may result in an increased risk of wildland fire (See WF policies).

- ◆ Monitor livestock use levels and **agricultural infrastructure** condition to ensure conformity with lease provisions to contribute to improved management.
- ◆ Monitor wildland conditions with an emphasis on documenting the location, distribution and abundance of native grasses, wildflowers, and other native flora and fauna
- ◆ Monitor water quality in ponds, **wetlands**, and **watercourses** with unrestricted livestock access.
- ◆ Monitor non-native vegetation response to **conservation grazing** with an emphasis on documenting the location, distribution and abundance of **target, invasive species**.
- ◆ Use information collected from monitoring to annually review range-land conditions and response to livestock **conservation grazing**. Use **adaptive resource management decision making framework** within grazing management plans.

Policy CGM-4 Utilize different livestock species to accomplish vegetation management objectives.

- ◆ Research the effective use of cattle, goats, sheep, and horses to manage vegetation on District lands.
- ◆ Utilize appropriate species depending on management needs.

Policy CGM-5 Preserve and foster existing and potential **conservation grazing** operations to help sustain the local agricultural economy.

- ◆ Establish longer term grazing leases to promote financial viability for the operators and efficient land stewardship for the District.
- ◆ Seek grants or other economic support for agricultural infrastructure maintenance and improvements.
- ◆ Ensure site-specific grazing management plans are economically feasible and practical for **conservation grazing** operators.

Policy CGM-6 Provide information to the public about the region's rural agricultural heritage. (See PI-1)

- ◆ Install display boards and give presentations highlighting historical and educational facts about ranching families and industry at appropriate sites.

Policy CGM-7 Provide public access in a manner that minimizes impacts on the **conservation grazing** operation. (See PI-1)

- ◆ **Conservation grazing** operators on District lands or lands under easement to the District shall be consulted when public access is being planned and considered for the property to minimize conflicts between the public and the **conservation grazing** operation.
- ◆ Prepare and distribute a brochure to educate visitors about etiquette for use of open space property with livestock animals.
- ◆ Prepare and distribute a brochure to educate visitors about etiquette for use of open space property with livestock animals.
- ◆ Install signage where appropriate to educate the public about the resource benefits of **conservation grazing** and to educate visitors about approaching animals, closing gates, and other etiquette appropriate for moving through lands with livestock animals.

Policy CGM-8 **Conservation grazing** operations on District lands in San Mateo County will be managed in accordance with the policies established in the Service Plan for the San Mateo Coastal Annexation Area.

- ◆ Consult with appropriate agencies and interest groups, including the San Mateo County Farm Bureau and San Mateo County Agricultural Advisory Committee in the development of site-specific Use and Management plans and agricultural production plan components in the Coastside Protection Area.

Policy CGM-9 Safeguard native plants and wildlife while promoting the economic sustainability of conservation cattle grazing as a **resource management** tool and reducing **predation** of **livestock**.

- ◆ Consider the economic impact of predation in setting lease rates for **conservation grazing** tenants.
- ◆ Provide economic relief for **conservation grazing** tenants who, as required per conditions of a Board of Directors approved lease, are performing **resource management** services and are in good standing with the District, in response to confirmed cattle losses from **predation** to sustain **conservation grazing** as a viable tool for natural **resource management**. Require cattle grazing tenants to document annual livestock losses due to both **predation** and non-predation-related causes.
- ◆ Support and promote scientific research on the effectiveness of wildlife and **livestock protection methods**, and their influence on wildlife behavior, grazing productivity, and livestock health. Periodically review research results and consider findings in future policy development.

XII. FOREST MANAGEMENT

BACKGROUND

As of 2007, District lands encompass approximately 30,000 acres of **forest** and **woodland habitat**. Approximately 11,500 acres consist of redwood and Douglas-fir associated **coniferous forest**, located primarily in the northern Skyline area of the District. These forests are often intermixed with a lesser component of **hardwood**, primarily tanoak, madrone, California bay, black oak, and various live oaks.

The remaining 18,500 acres consist of a variety of hardwood forest and woodlands. These consist of numerous oak species (coast live, canyon live, and Shreve oak, black oak, blue oak, valley oak), madrone, tanoak, California bay, California buckeye, and **riparian** species such as red and white alder, big-leaf maple, various willow species, California sycamore, and box elder.

Forest and woodlands within the District have been subject to significant historic modifications. Portions of the oak forests and woodlands have had a history of **livestock** grazing and **fuel wood** procurement. The effects of these uses are not well documented, but young dense **stands** (primarily live oak species) occur within the preserves in areas of prior disturbance. These young dense stands often occur along forest margins or have regenerated within areas that had been previously cleared. At the other end of the spectrum are beautiful stands of large old majestic oaks. Concerns about the reduction of oak forest and woodland within California often center on their conversion to urbanized uses or commercial agriculture. The primary role for the District is the preservation and protection of these forests and woodlands, particularly considering the heavy urban growth pressures within the San Francisco Bay Area.

Riparian hardwood forests have also been modified in areas by past land use practices. These practices have typically whittled away at the width of the corridors, in places narrowing the corridors to thin strips along the

The term forest applies to habitats dominated by tree species with a continuous or nearly continuous canopy covering substantial portions of the landscape.

Woodlands consist of scattered trees across the landscape intermixed with a significant habitat component of other vegetation types such as grassland.

edges of creeks. When riparian forests are modified in this manner, it is common for the species composition to change to those species that prefer to be near the water (typically willow and alder), while reducing species that typically occupy elevated floodplains such as sycamore.

The proximity of the redwood and Douglas-fir forests in the Santa Cruz Mountains to the urban San Francisco Bay Area and associated ports of trade fostered the development of an early and intense commercial logging industry. Commercial timber harvest and milling activities were well underway beginning in the 1850's within the La Honda Creek, Purisima Creek Redwoods, and El Corte de Madera Creek Open Space Preserve areas. Timber harvest activities have generally altered the forest stands by reducing the size and age of the stands and increasing the density of the young growth. This is clearly evident when viewing the distribution of **old growth** redwood stumps within the forests. A second round of logging that focused on residual (left over) old growth and the second growth that re-sprouted from the late 1800's clear cuts began in the 1950's-1960's. Tractor logging continued within El Corte de Madera Creek and Purisima Creek **watersheds** throughout the 1970's and 1980's, resulting in third and fourth timber harvest entries into much of the areas that are now protected by the open space preserves.

Numerous roads were constructed to facilitate access to early timber (and grazing) operations on the properties now owned by the District. These roads were often constructed in locations, and utilizing methods that were insufficiently protective of **water quality** and aquatic resources. The elimination or conversion of non-**essential roads** and the judicious maintenance of **essential roads** will be necessary to protect water quality and aquatic resources.

Pathogens are a significant threat to the District forests. The most notable pathogen at present is *Phytophthora ramorum* which is responsible for Sudden Oak Death syndrome, commonly known as SOD. A number of oak species are susceptible to death and slow decline from SOD, particularly tanoak, and additional **host** species include many other forest trees and shrubs. SOD has the potential to seriously impact forests within the preserves and the region, presenting a number of social and ecological concerns.

All of the forest **ecosystems** within the District preserves evolved in association with periodic fire. **Fire suppression** activities within the Santa Cruz Mountains, as well as throughout the Western United States, have also had an effect on District forests. The effects of fire suppression typically include an increase in forest density, a build up of forest floor **fuel loads**, and a decrease in herbaceous forest floor plant communities. **Forest management** actions can be undertaken to reduce the severity of fires within the forest ecosystem and watersheds when these fires occur. Prescriptive forest management can achieve conditions suitable for the reintroduction of fire into forest ecosystems, an ecological function that has been largely absent, except under typically severe conditions, for the past sixty years.

The District has preserved large blocks of forest and woodland. The overall extent of District land holdings within the greater Santa Cruz Mountain Bioregion is exceptionally important to regional **biodiversity** and well suited to regional ecosystem management. State, county and local parks, non profit and conservation organization owned properties and numerous conservation easements over both public and private properties, together with the District preserves, provide tremendous opportunities for regional forest preservation and **restoration**.

Active **conifer** forest management on public lands is typically limited to relatively small fuel management projects and controlled burns in old growth stands within some state parks. This limits the majority of these forests to more hands off management, requiring long periods of time where trees compete for food, water, and sunlight. During this time period, which can take hundreds of years, the dominant trees will persist, while the less dominant trees will be crowded out and die. During much of this transitional period, habitat complexity and biodiversity can remain relatively stagnant and simplified. Maintaining most of these protected forests under the same management paradigm has the potential to suppress regional biodiversity.

From a regional perspective, old growth and **late-seral** conifer forests are very limited in distribution. Late-seral forests, or **late-successional** forests, are older forests that begin to develop some characteristics similar to old growth forests. The initial development of late-seral redwood and Douglas-fir forests is generally considered to take place between 80 to 300

Late-seral and old growth forest characteristics typically include: large widely spaced trees, thick bark, large complex branches, large standing snags in various stages of decay, large downed logs on the forest floor, and a closed canopy. This complex structure results in a very wide variety of habitat conditions and results in tremendous biodiversity.

years, and continue to persist for centuries, with the oldest redwoods reaching an age of 1,000 to 2,000 years old. The District preserves have retained a significant “**biological legacy**” of residual (uncut) single old growth trees and small stands of old growth, as well as a substantial older Douglas fir component. These biological legacies are known to harbor significant remaining habitat components that are used by wildlife, from the canopy species such as marbled murrelets down to soil microbes.

The District’s conifer dominated Preserves offer the opportunity to manage **forest conditions** to accelerate late-seral habitat conditions to promote biologically diverse, dynamic forest habitat, increase the extent of this limited habitat, and accelerate the development of forest structure for the benefit of protected species and for improved fire resistance.

FOREST MANAGEMENT GOALS, POLICIES, AND IMPLEMENTATION MEASURES

Goal FM-	Manage District land to retain and promote biologically diverse, dynamic forest conditions; maintain and enhance high quality forest and aquatic habitat; encourage and enhance the development of late-seral conifer forest; provide for visitor experiences within diverse forest habitat; and promote District and regional fire management objectives.

Policy FM-1 Inventory and assess District forest and woodland.

- ◆ Inventory and assess existing District forest conditions. Inventories within hardwood stands should include forest age, structure, health, and an evaluation of regeneration (growth of seedlings and young trees). Inventories within conifer stands should have a particular emphasis on forest age and structural characteristics, identification of biological legacies, and the reconnection and restoration of late-seral habitat. Inventories should also include the identification and assessment of any effects of urbanization on the forests.

- ◆ Identify unique habitat features such as meadows, ponds, or other non-forested communities. Evaluate the need for management to maintain landscape heterogeneity and specialized habitat for non-forest wildlife and vegetation.
- ◆ Inventory District forest wildlife with a particular emphasis on **special status** species, such as the marbled murrelet, spotted owl, Vaux's swift, numerous raptor species, and indicator species such as the pileated woodpecker.
- ◆ Inventory District forest to assess fuel loads and forest structure related to fire. Identify access issues and District and community/regional fire concerns.

Policy FM-2 Ensure that forest management activities are compatible with the protection of special status plant and animal species.

- ◆ Conduct time appropriate surveys for special status species to establish the presence or absence thereof, and identify essential habitat features (nest trees, roosts, sheltering trees, springs, and ponds).
- ◆ Manage forests to expand critical habitat for sensitive species by restoring forest structure and habitat elements utilized by sensitive species to develop and connect suitable habitat.
- ◆ Continue regular consultation with regulatory agencies and experts to develop plans to protect and **enhance** habitat for sensitive species.

Policy FM-3 Ensure that forest management activities are compatible with riparian ecosystem and water resources protection and policies.

- ◆ Protect riparian ecosystems and habitat to maintain **natural** hydrologic process, water quality, and wildlife benefits. Maintain essential riparian functions, and if necessary enhance and restore riparian habitats.
- ◆ Inventory and assess roads and trails on District forestlands to identify significant erosion and sediment sources. Maintain **essential roads** to high standards, and eliminate or reduce to trail width all non-**essential roads**. (See Policies WR-3 and WR-4).

Riparian ecosystems are streamside ecosystems that are extremely important to numerous forest plant and wildlife species. In addition to benefits to wildlife such as fish and amphibians, these ecosystems also play critical roles regarding forest hydrology and water quality. The protection and restoration of Riparian ecosystems is a primary component of Forest Management.

Late-seral redwood and Douglas-fir forests are generally considered to be some of the most fire resistant and resilient type of forest.

Restoration forestry practices may result in timber that would be available for commercial sale. Revenue derived from commercial timber sales conducted in conjunction with restoration activities will be used for resource management activities (such as road upgrade projects, weed abatement projects, and long-term monitoring).

Snags are dead standing trees that are important to a variety of species. As trees age and die, holes created by woodpeckers cavity decay, and broken branches create new habitat niches for a host of bird, bat, small mammal, amphibian, and insect species. Snags and large downed wood are critical components of high quality late-seral forest communities.

- ◆ Discourage forest management activities within riparian areas unless justified and implemented for the specific purpose of restoring degraded riparian habitat.

Policy FM-4 Manage District conifer forests to sustain and encourage the development of late-seral habitat conditions.

- ◆ Prepare Forest Management Plans for **high priority District forests** to establish habitat goals and appropriate management treatments. Utilize restoration ecologists, forest ecologists, Registered Professional Foresters, or other **resource management** professionals to prepare plans, as appropriate.
- ◆ Restore degraded forest habitats to promote the development of late-seral habitat, forest habitat complexity, and to enhance biodiversity, where existing stand conditions and access permit. Utilize state of the art silvicultural (forestry) practices to restore degraded forests.
- ◆ Protect existing residual old growth trees and stands, mature oaks, and most large, older Douglas fir trees. The conservation of these areas will take precedence over other uses and management practices that are determined to have an adverse effect on these resources.
- ◆ Maintain and/or create large **snags** and downed wood for wildlife habitat where not a safety hazard.
- ◆ Foster relationships with educational institutions, forest scientists and forest professionals to inform District forest management decisions based upon sound, current science, and to contribute opportunities for continuing research of late-seral focused management. Seek grant opportunities and partnerships for forest research and monitoring.

Policy FM-5 Provide necessary fire and fuel management practices to protect forest resources and public health and safety. (See WF policies)

- ◆ Maintain **essential roads** for emergency fire access, and forest management activities undertaken to reduce fire hazard.
- ◆ Maintain adequate fire clearance around District structures and facilities. (See WF-3 and WF-1: Measure 5)

- ◆ Encourage neighboring property owners to maintain adequate fire clearance around existing development. Consult with regulatory agencies to encourage that construction of new development maintains fire agency recommended setbacks for fire clearance between new development and District forest and woodland.
- ◆ Evaluate the potential to reduce forest fuel loading through the removal of smaller trees to reduce forest floor fuel buildup and **ladder fuels**.
- ◆ Coordinate with **fire agencies** and local communities to define locations where fire protection infrastructure is desirable and practical.
- ◆ Reintroduce fire as a resource management tool to reduce forest floor fuels and reestablish fire for ecosystem health where stand conditions, access, and public safety permit. Coordinate with other agencies for planning and implementation.
- ◆ Seek grant opportunities and partnerships for fuel management projects and monitoring.

Policy FM-6 Protect forest health from intense wildfire, **pests**, and pathogens with high potential to cause damage.

- ◆ Evaluate potential for forest loss to intense wildfire, pests and pathogens where effective methods are available and justified.
- ◆ Limit the scale of clearings and light-gaps in forests to reduce potential for weed establishment. Where activities occur within the forest edges, weed treatments and monitoring will be a component of the treatment plan.
- ◆ Manage forest diseases when necessary to protect natural biological diversity and critical **ecosystem functions**. Regarding Sudden Oak Death (SOD): detect, report and monitor infested areas; utilize sanitation and **best management practices (BMPs)** to control the spread of the SOD pathogen; train staff and educate the public; and support SOD research to guide land management decisions (See VM-1 and WF policies).

Policy FM-7 Monitor wildlife, water quality, and vegetation response to forest management activities.

Fire hazard reduction is a great concern for some landowners, particularly residential landowners. Fire can also be a significant threat to the environment, particularly water and aquatic resources.

Shaded fuel breaks are an example of a fuel reduction project that the District can undertake. They consist of areas where vegetation is thinned to break up horizontal connectivity, and lower growing "ladder fuels" that can connect ground fire to tree canopy are removed. Enough tall tree canopy is retained to maintain shade to discourage the re-growth of ladder fuels. These often require follow-up maintenance.

- ◆ Conduct pre and post project wildlife and vegetation surveys with emphasis on special status species.
- ◆ Monitor water quality upstream and downstream of forest management activities that have the potential to negatively affect water quality or aquatic resources.
- ◆ Periodically re-inventory forest conditions with a frequency adequate to monitor forest response to management.

Policy FM-8 Provide educational opportunities for the general public and recreational users regarding **forest** ecosystems and management.

- ◆ Place interpretive displays in accessible locations to inform and educate the public about forest ecosystems, and management techniques employed on District lands.
- ◆ Conduct public outreach to inform and gain support for District activities within the local community.
- ◆ Conduct interviews with individuals related to past land use and history of forested Preserves to compile historical details and perspectives on District forest land. Include history into **interpretation** and educational opportunities within the Preserves.

XIII. ECOLOGICAL SUCCESSION

BACKGROUND

Ecological succession is the sequential development of plant and animal communities following disturbance. In a land management context, this natural process can be both positive and negative. For example, the natural recruitment of coyote brush in grassland areas on District lands is reducing the extent of this already-limited **habitat** type and has serious impacts on **native** plants and wildlife. Regrowth of mixed evergreen forest in previously-logged areas is threatening to shade out rare species. Ponds and seasonal **wetlands, which** are slowly filling in with sediment and converting to grassland and areas dominated by broadleaf tree species can become shaded out by coniferous forests. This policy addresses such undesirable habitat type conversions that result from the process of ecological succession.

The directional nature of succession was once thought to result in a stable, stationary species composition (known as the “climax community”) over time. In reality, however, all natural systems are subject to disturbance and limited by seed availability and the process of succession may never reach completion. Early-succession species have specific life history strategies which allow them to take advantage of disturbance. Furthermore, some species, such as knobcone pine, King’s Mountain manzanita, and many grassland plants, are **disturbance-dependent**: they require disturbance to maintain habitat conditions suitable for reproduction and establishment. Both natural and human disturbance drive species composition in **natural** habitats. Past disturbance regimes (either natural or historic and pre-historic land management) can be artificially re-created to maintain desired habitat types. More intensive management may also be necessary as climate change causes large-scale shifts in **plant community** composition and distribution.

Ecological disturbance is the disruption of an ecosystem's structure and function, generally with effects that last for time periods longer than a single growing season for vegetation.

Physical disturbances in our region include fire, windstorm, drought, flood, and earthquake.

Biogenic disturbances include the impacts of herbivorous insects, mammals, disease, and pathogens.

Anthropogenic disturbances include logging, development, agricultural land use conversion, and non-native invasive species introductions.

ECOLOGICAL SUCCESSION GOAL, POLICIES, AND IMPLEMENTATION MEASURES

Goal ES- Use sustainable land management techniques to maintain, restore, or simulate natural disturbance in priority habitats.

As Alpine Pond, Horseshoe Lake, and other District ponds fill with sediment, open water habitat is rapidly transitioning to cattail marsh with little open water. Certain rare amphibians as well as many common wildlife species require open water for key portions of their life cycles.

Unique stands of knobcone pine, a fire-adapted species, in southern Sierra Azul Open Space Preserve will hold seeds in pine cones for up to 30 years waiting for a fire to release them. With the absence of fire, knobcone stands are not being replaced as older mature trees die off and their seeds are not released resulting in an overall decline of the species.

Policy ES-1 Manage historic grassland areas that are threatened by shrub encroachment. (See VM-1)

- ◆ Identify priority grasslands for management, focusing on those with cultural significance and/or a substantial component of native species.
- ◆ Identify the most cost-effective, safe, and least environmentally damaging management technique for shrub removal, including livestock grazing, mechanical removal, and **prescribed fire**.
- ◆ Prepare long-term plans for managed grassland areas to ensure that desired conditions are maintained.
- ◆ Monitor and manage grasslands for **invasive species** and biodiversity to promote use of grasslands by native and special status species

Policy ES-2 Preserve and **enhance** pond habitats and other wetlands.

- ◆ Inventory and assess ponds to identify opportunities for habitat maintenance and/or aesthetic enhancement.
- ◆ Monitor sensitive reptile and amphibian **populations** on District lands.
- ◆ Preserve pond habitats through maintenance of infrastructure such as: pond contours, depth, earthen berms, spillways and inlet and outlet features
- ◆ Remove sediment or invasive vegetation to provide improved habitat for sensitive species.

Policy ES-3 Facilitate regeneration of disturbance-dependent special status, rare, or unique plants.

MIDPENINSULA REGIONAL OPEN SPACE DISTRICT
RESOURCE MANAGEMENT POLICIES
ECOLOGICAL SUCCESSION

- ◆ Research, document, and implement site specific fire prescriptions to improve regeneration of fire adapted and special status vegetation in fire-dependent ecosystems where feasible.
- ◆ Develop and implement an alternative management protocol to encourage seedling establishment of special status and disturbance adapted species in aging stands when regeneration by fire is not feasible.

Nearly all stands of the rare Kings Mountain manzanita on District lands are in danger of being shaded out by Douglas fir and other trees. No regeneration has been observed in these stands.

XIV. HABITAT CONNECTIVITY

BACKGROUND

Habitats are the conditions and locations in which plants and animals live and reproduce, and are a critical component of a naturally functioning **eco-system**. Habitats come in many forms, but are traditionally thought of as the particular communities of plants and animals that together comprise the ideal conditions for one focal species or for a broad assembly of particular plants and animals. District **open space** lands are made up of a wide variety of habitats, including freshwater streams, redwood **forests**, oak **woodlands**, coastal grasslands, **chaparral**, and many others. In areas surrounding District Preserves, one finds many of these same communities. Connections that link otherwise isolated habitats are known as corridors, and effectively extend the range of a species from one location to many locations in accessible areas. **Wildlife corridors** may be extensive contiguous **natural** areas suitable for a wide-ranging organism, a stream with a continuous wide buffer of **riparian** vegetation, or even a tunnel or culvert beneath a highway that allows passage of animals.

Although the Santa Cruz Mountains are geographically separate from the nearby mountain ranges, they share many of the same species, and are interconnected through routes of migration and dispersal. These connections often referred to as “wildlife corridors,” commonly follow watercourses into and out of the foothills and valleys. In the San Francisco Bay region and elsewhere, wildlife corridors are frequently intersected by roads and highways.

The District’s Geographic Setting

The District’s sphere of influence, spanning the San Francisco Peninsula from the Pacific Ocean in San Mateo County to the baylands in San Mateo and Santa Clara Counties, is drawn along both natural and political boundaries. The District encompasses much of the northern portion of the Santa Cruz Mountains, numerous foothills and ridges of that mountain system, and more than 50 miles of coastline, both on the Pacific Ocean and the San Francisco Bay. The Santa Cruz Mountains are a local spur of the Coast Range, and are physically separated from the larger system by the Golden Gate to the north, the Santa Clara Valley to the east and south, and the Pajaro Valley to the south. The closest adjacent mountains and foothills with a similar suite of resident species are the Gabilan Range and the Diablo Range, and it is with these regions that biological exchange is both most likely and most critical.

Habitats in the Santa Cruz Mountains are both connected to and isolated from comparable habitats in nearby areas. This means that interaction between local and neighboring plant and animal **populations** is governed by their need and ability to move across areas that are inhospitable or even hazardous to survival of the **population**. These **barriers** can take many forms, and have differing effects on various species. Furthermore, as humans modify the natural environment, pre-existing boundaries to plant and animal movement can change dramatically. Modified habitat connectivity may result from new roads or houses, changing vegetation, or even from the effects of climatic changes on habitat distribution. Habitat features are just one aspect of a functioning interdependent ecosystem; thus, the permeability of geographic barriers is a complex and ever-changing relationship. It is a function not only of the species' capacity for crossing barriers, but also of the obstacles themselves.

Basic Habitat Ecology

An ecosystem's many habitats form a complex mosaic on the landscape. They may gradually transform from one to another, or change suddenly at a natural or a man made **boundary**. Two or more habitats may coexist or form a relationship, as when a stream, a linear habitat for fish, insects, and riparian plants, flows through an oak woodland, which is found only where specific kinds of soil type, water availability, and weather conditions occur. Habitats may also be partially or completely interrupted, as when a broad river bisects a grassy plain, a highway passes through the redwoods, or a meadow forms in the woods.

Both the relative size and extent of a habitat's connectivity to other habitats are key factors in its ability to support the plants and animals that depend on it, and in the variety of species, or **biodiversity**, it can support. Typically, the most resilient and diverse habitats are large areas connected by corridors along which wide-ranging animals can travel, plants can propagate, genetic interchange can occur, **populations** can move in response to environmental changes and natural disasters, and species at risk can be replenished from other areas. For habitats in the District, migratory and genetic linkage with neighboring mountain ranges, where many of the same plant and animals live and reproduce, is important for overall **population** health. Species living in small, isolated **patches** of habitat are more vulnerable to disease, population pressures, predation, and other

*Preserving contiguous natural habitats is key to preserving biodiversity in a changing world. When a species is reduced to a few isolated **populations** due to fragmentation of its habitat, a natural stressor such as a fire or drought can wipe out a significant portion of the remnant **population**, bringing it closer to extinction. Connected habitats help species respond to changes in their environment.*

stresses. Such isolation can also lead to inbreeding, which compromises genetic diversity and contributes to instability of species **populations**. This need for habitat connectivity is particularly true of wide-ranging animals such as mountain lions, eagles, or salmon, but is also applicable at smaller scales. For example, movement across a small road can be critical for the newt that must locate a valuable food source or find a mate.

To support a viable **population** over the long term, a given species needs an uninterrupted patch of suitable habitat of a particular size. The needed size varies, but always greatly exceeds the range of one individual. This **core** habitat is bordered by **edges** that can fill some of an organism's needs, but do not support stable **populations**. The largest patches have a high proportion of core habitats, but also provide edge zones. Barriers to movement such as roads, homes, or walls cause **habitat fragmentation**, in which multiple smaller edge habitats are formed. Habitat fragmentation can greatly diminish the viability of the ecosystem. As habitats become fragmented, the amount of core habitat decreases while edge habitat increases. This can greatly reduce habitat viability for species with unique requirements such as nesting owls or murrelets, or increase predation by edge-adapted predators such as cats or raccoons.

Types of Movement and Barriers to Movement

Movement of plant and animal species occurs at every scale, from the small matter of crossing a trail to the significant task of climbing a mountain. Furthermore, movement of species can be described not only as locomotion, or movement of individuals, but also as dispersal of eggs, seeds, or larvae. Although the challenges to a single individual can be seen as an effective model for their whole species, habitat networks are more specifically relevant to **populations** than to individuals. Various species use these corridors frequently, seasonally, or only on rare occasions. Again, the large and wide-ranging animals utilize regional scale habitat networks most heavily, while smaller scale networks may occur between one stream and a woodland for frogs or among interconnected grasslands for a **population** of deer.

The District's boundaries encompass many of the remaining undeveloped habitats within the San Francisco Peninsula. The main connection for the plants and animals inhabiting District habitats is through relatively narrow corridors at the southern end of the Santa Cruz Mountain Range and across the Santa Clara Valley. Smaller thoroughfares, residential construction, and some natural features are hindrances to the movement of smaller animals and distribution of plants.

HABITAT CONNECTIVITY GOAL, POLICIES, AND IMPLEMENTATION MEASURES

Goal HC- Protect ecosystem integrity by maximizing habitat connectivity.

Policy HC-1 Identify and include habitat connectivity from a local and regional scale in strategic land acquisition planning.

- ◆ Maximize habitat connectivity for priority plant and wildlife species in new property purchases.
- ◆ Actively participate and coordinate with regional and local land preservation groups and resource agencies to develop strategic goals for protecting or purchasing critical habitat areas and/or movement corridors.
- ◆ Emphasize protection of extensive and interconnected open space habitats.

Policy HC-2 Identify and protect existing habitat networks to prevent further compromise to ecosystem integrity. (See WM-2: Measure3)

- ◆ Evaluate existing facilities and land uses that impact habitat connectivity and riparian corridors and prepare plans for protection or restoration, as appropriate.
- ◆ Identify wildlife movement patterns and high value habitat features and formulate site-specific habitat management goals.
- ◆ Encourage field research activities including collecting, trapping, and tracking in support of studies that can inform District management of natural **resources** and ecosystems.
- ◆ Incorporate construction practices that avoid the creation of unnecessary barriers to habitat connectivity. Where feasible, utilize removable

*Wildlife corridors, or the paths of movement between patches of an animal's distribution, are only one component of an effectively connected habitat. As the science of biogeography and **population** dynamics develops, wildlife corridors have come to mean structures or narrow reserves set aside for crossing highways at pinch points or along established migration routes. Habitat networks are a more resilient and extensive linkage of suitable environments that support dynamic and mobile **populations** of plants and animals.*

fencing, wildlife friendly silt trapping devices, and other design features that allow passage of plants and animals during and after project implementation

- ◆ Evaluate the existing habitat values of human-made structures prior to removal.
- ◆ Strive to connect isolated natural areas through movement corridors to facilitate connection across barrier(s).
- ◆ Identify unique or locally rare habitat types and **target** for protection. Strive to maximize habitat connectivity for locally rare habitats such as serpentine grassland, valley oak woodlands, coastal terrace prairie, etc.

*Early results from the Bay Area Puma Project indicate that Highway 17 may act as barrier to movement within the Santa Cruz Mountains. If mountain lions are not able to actively cross this barrier, it can result in a loss of connectivity leading to an isolated **population** of lions on the San Francisco Peninsula. Over time this isolated **population** may lose genetic diversity and become vulnerable to disease, predation, and other stressors. Multiple agency and landowner cooperation are needed to effectively address this issue.*

Policy HC-3 Collaborate with neighboring land holders and surrounding agencies to support regional efforts to establish and maintain habitat networks. (See WM-2: Measure 3 and WM-3: Measure 3)

- ◆ Advocate for land use plans and policies that preserve the District's biogeographic connectivity with the greater Santa Cruz Mountains and with the neighboring Gabilan and Diablo Ranges.
- ◆ Review and comment on land use decisions that impact habitat connectivity within the District's jurisdiction and bioregion, including construction or modification of roads and proposals for large scale developments.

Policy HC-4 Restore, maintain or enhance local habitat networks formed within or incorporating Preserves and other protected lands. (See WM-2: Measure 3 and WM-3: Measure 3)

- ◆ Review and comment on land use decisions that impact habitats contiguous to those located on District Preserves. Recommend and support measures to maintain connected and undegraded habitats where possible.
- ◆ Protect and restore known habitats of rare, endangered, or special status species, taking into consideration the legal protection, distribution and abundance, and risk to specific resources involved.

- ◆ Designate sensitive habitat areas and, if necessary, limit or exclude public access to these areas for resource protection.
- ◆ Evaluate impacts on wildlife movement and habitat connectivity when planning trails and other facilities.
- ◆ Identify and protect established wildlife crossings to allow movement across existing roads. Where appropriate, modify established crossings to improve habitat features.
- ◆ Collaborate with resource agencies to restore and enhance the habitats of protected and **special status** species known to utilize preserve areas.

Policy HC-5 Preserve and enhance riparian, stream, and other wetland habitat locally and at a **watershed** level to provide important habitat connections. (See WM-2: Measure 3)

- ◆ Inventory and assess stream reaches accessible to **anadromous** fisheries to identify impediments to fish passage and opportunities for habitat **enhancement**. Remove artificial barriers to fish passage where removal would enhance spawning and rearing habitats.
- ◆ Enhance spawning and rearing habitats for **native** fisheries through restoration. Prioritize restoration and enhancement of areas providing habitat to sensitive species.
- ◆ Restore hydrologic processes altered by human activity by installing erosion control materials and structures, and minimizing culverts and drainage diversions where appropriate, and using improved drainage structures that minimize alteration of hydrology.
- ◆ Participate in regional watershed management planning and restoration activities.
- ◆ Identify and remove invasive species in riparian, stream and wetland habitats that act as a barrier to wildlife use

Streams can be thought of as linear habitat corridors, particularly for fish that migrate from land to sea. Anadromous fish, such as steelhead trout, return from the open ocean as adults to freshwater streams to breed. Human activities have greatly altered and degraded many of the streams in the Bay Area primarily through barriers to fish passage, such as road culverts and dams and through degradation of spawning habitats by excessive sedimentation of spawning gravels.

XV. WILDLAND FIRE MANAGEMENT

BACKGROUND

The Mediterranean climate of California's San Francisco Bay Area affords District lands an unparalleled diversity of plants and **habitats**; from red-wood forests on the coast and northern portions of the District to dry **chaparral** habitats and **hardwood** (oak, madrone) dominated forests in the southern end of the District. Given the diversity of rainfall, climate, vegetation, soil and geology, one constant emerges throughout the District (and in fact throughout California); all landscapes have been subject to periodic fires through time. The present and future will be no different.

To understand the role of **wildland** fire on District lands, it is important to understand the past. Native Americans within the area utilized fire as a tool for improving wildlife habitat for grazing animals (deer, elk, rabbits), maintaining productive vegetation communities for food procurement (grasslands, oak **woodlands**), to maintain travel routes, and to manage **pests**. Burning by Native Americans took place for thousands of years, a practice that significantly increased the frequency of fire locally. These practices, in addition to the benefits listed above, greatly reduced much of the **fuel load** on the ground and significantly reduced the severity of fires within these fire managed landscapes.

Many of the vegetation communities on District lands evolved with the occurrence of periodic fire and have acquired unique adaptations to withstand and regenerate after a fire. Without periodic fire, these plant communities build abnormally high and dangerous fuel levels and are susceptible to large scale destructive fire events. Fire is a **natural** occurrence on the landscape; our challenge is to find ways to live safely with fire.

From 1860 through the early 1920's unprecedented alterations took place within the forests of the Santa Cruz Mountains. The ancient "**old growth**" forests were mostly clear-cut and burned. This removed the largest, most fire-resistant trees from the forested landscape. The forest that has grown back typically consists of a much higher density of trees that are more susceptible to fire. This period of time also corresponded to the first wave

of development within the San Francisco Bay Region and ushered in a new paradigm for wildland fire response: immediate suppression.

This has increased the time interval between fires on most land to time periods substantially longer than Native American burning and natural lightning-caused fire. The result is a vegetated landscape that has largely been prevented from burning, and that has accumulated fuel loads and structural characteristics that have not occurred on the landscape for thousands of years, if ever.

The District was formed in response to the observed population growth and development pressure within the San Francisco Bay Region of the late 1900's. This has substantially reduced residential development in some areas, and significantly decreased the level of fire risk by precluding development that would have likely otherwise resulted in additional high risk communities. Nonetheless, there is some residential development (including some on District property) intermixed with District Preserves that deserve consideration.

The **wildland-urban interface (WUI)** refers to areas where residential development, from a few scattered houses to larger subdivisions or communities, exist immediately adjacent to or nearby parks, open space preserves, or other relatively undeveloped "wildlands". Important issues within this interface include **defensible space** around residential structures, emergency vehicle access, and residential fire improvements such as water tanks, fire hydrants, sprinklers, and fire resistant construction techniques.

The District is an active participant in coordinating with various **fire agencies** and community fire planning efforts. District participation in these planning efforts will continue. These include the development of regional fire plans, **Fire Safe Council** meetings, and the preparation of **Community Wildfire Protection Plans (CWPPs)**. The District also coordinates with local fire agencies and other park agencies conducting and participating in **prescribed fire** for **resource management** purposes.

The District, for many years, has undertaken various wildland fire management practices to effectively manage fuel loads and decrease wildland fire risk. Among these, the District annually maintains a series of disc lines (where vegetation is mechanically disked with a tractor to reduce dry fuel along ignition sources such as roads); vegetation is mowed or brushed back from roads and trails; roads, parking areas, and Preserve entrances

The WUI is an area where urban ignition sources such as vehicles, equipment, burn piles, barbeques, chimneys, smoking, fireworks, etc. from adjacent residential properties and public streets pose a threat to Open Space lands. Residential structures can also supply fuel for fire that can cross into open space lands.

are maintained to provide access for District patrol vehicles and other emergency vehicles; and vegetation is cleared from around District structures and residences. Preserve access points are closed when appropriate during periods of high fire risk. The District possesses a number of firefighting apparatus including a water tank truck, and smaller water tanks with hoses outfitted on Ranger vehicles, as well as portable water-pack/spray outfits for individual personnel. Fire training is also provided to District personnel who may be involved in combating wildland fire.

The District has an active **vegetation management** program that has been **targeting** invasive plant species that can be fire hazards, such as eucalyptus and French broom. Active **livestock** grazing is being maintained and has been re-introduced on some Preserves to reduce the fuel loads in the mostly **non-native** grasslands. **Conservation grazing** is being used to encourage the vigor of native grasses and **forbs** that typically produce less fuel (thatch). Given their year-round growth cycle, perennial native grasses maintain moisture later into the dry season, reducing fire hazard. The vegetation management program at the District also utilizes prescribed fire for managing invasive species in addition to fuel load reduction benefits.

The substantial **historic** alterations of the landscape, the history of **fire suppression**, and the numerous jurisdictions involved in wildland fire management and suppression, present challenges in managing wildland fire, but also present many opportunities. Effective wildland fire management actions can be undertaken to reduce the severity of fires within the WUI and within the District's **ecosystems** and **watersheds**, when fires inevitably occur. Additionally, active management can achieve conditions suitable for the reintroduction of fire into many ecosystems, an ecological function that has been absent, except under atypically severe conditions, for most of the past century. Prescribed fire is a powerful tool that not only has ecological benefit, but also significant wildland fire management benefit.

WILDLAND FIRE MANAGEMENT GOAL, POLICIES, AND IMPLEMENTATION MEASURES

Goal WF- Manage District land under the concepts of ecological resiliency to reduce the severity of wildland fire and to reduce the impact of fire suppression activities within District Preserves and adjacent residential areas; manage habitats to support fire as a natural occurrence on the landscape; and promote District and regional fire management objectives.

Policy WF-1 Implement necessary fire and fuel management practices to protect public health and safety, protect natural **resources**, and to reduce the impacts of wildland fire.

- ◆ Prepare wildland fire management plans for District lands that address, at a minimum, public safety, District staff and firefighter safety, District infrastructure including residences and roads, natural resource protection (particularly **special status** species), **cultural resources**, and vegetation management for fire protection and **fire behavior** and hazardous fuels modification.
- ◆ Assess the degree of fire hazard by evaluating the degree of human use and occupancy of the wildland area, the level and ability of public services to respond to fires, and the natural setting of the wildland area.
- ◆ Identify, with input from responsible fire agencies and neighboring public agencies, **essential roads** for wildland fire access. Maintain designated roads for fire access and patrol purposes, and improve with surfacing, additional turnouts and safety zones when necessary and reduce roadside vegetation to a level that allows ease of access for emergency response personnel and equipment, improves public safety in the event of an evacuation, reduces the number of roadside fire starts, allows for quicker response, and ensures the safety of fire suppression personnel. Set a priority to work with neighboring public

agencies, including the California Department of Transportation (Caltrans), county roads departments and local municipalities to standardize clearing widths on each side of roads and driveways.

- ◆ Coordinate with fire agencies and local communities to identify locations where additional fire infrastructure is desirable and practical (e.g. hydrants, water tanks, helicopter zones, safety zones, **fuel breaks**, consistent with the **incident command system (ICS)**). Work cooperatively with these groups to permit as appropriate installation and maintenance of new infrastructure.
- ◆ Work with Cal Fire, other appropriate fire management and regulatory agencies, and tribal entities to develop and carry out plans that use prescribed burns to maintain and restore natural and cultural systems including through the use of traditional ecological knowledge.
- ◆ Maintain adequate fire clearance around District structures and facilities. (See FM-5 and WF-4:Measure 5)
- ◆ Expand fuelbreak systems and identify fuel reduction areas that reduce the fuel mass of flammable vegetation and combustible growth, thereby limiting the intensity of fire and slowing its rate of spread.
- ◆ Require lessees of District land or structures to maintain fire hazard reduction measures as directed.
- ◆ Prohibit activities that have a high risk of sparking fires during periods of **extreme fire hazard**.
- ◆ Close Preserve areas of particular concern during **extreme fire weather**, as appropriate, and increase patrol levels where appropriate.
- ◆ Seek grant opportunities and partnerships for fuel management and monitoring projects.

Policy WF-2 Aggressively support the immediate suppression of all unplanned fires that threaten human life, private property or public safety and develop a response plan that, in the event of wildfire, allows the District to reduce post-fire impacts and initiate habitat restoration.

- ◆ Identify a Resource Advisor as the District contact in the event of an unplanned fire on District lands.
- ◆ Respond to wildland and structure fires on District lands in coordination with responding fire agencies.

- ◆ Prioritize and prepare Preserve specific wildland fire response plans that identify appropriate fire suppression activities for District lands in the event of a wildland fire. Plans should include detailed maps of infrastructure such as roads, fuel breaks, structures, water sources (hydrants, water tanks, ponds), as well as sensitive natural and cultural resources to be avoided during fire suppression activities.
- ◆ Direct bulldozer actions to areas identified in wildland fire response plans to minimize and reduce ground disturbance, erosion, and rehabilitation efforts wherever possible.
- ◆ Develop guidelines for appropriate rehabilitation measures to address erosion, **revegetation**, invasive species, trail and road stability, security, public safety, and natural and cultural resources following fires.
- ◆ Encourage rapid post-fire assessment, when and where appropriate, to determine values at risk within and downstream of the fire perimeter from flooding, debris flows, and excessive surface erosion. Provide preliminary emergency protection measures that can be implemented in a timely manner and help coordinate project implementation with appropriate agencies. (See also GS-2)
- ◆ Assess the effects of pre- and post-fire treatments to refine best management practices and address rapid treatment of fuels in high-priority areas.
- ◆ Consider allowing unplanned ignitions to burn to predesignated areas for resource benefit where there is no clear threat to life, property, or safety and when considering how to prioritize the suppression of multiple ignitions.
- ◆ Encourage and, where appropriate, partner with fire agencies and residential communities so that adequate evacuation routes and vegetation clearance around structures are maintained on adjacent non-District lands. Coordinate with fire agencies and local communities to define locations where community and regional fire protection infrastructure is desirable and practical.

Policy WF-3 Work with adjacent landowners and fire agencies to maintain adequate fire clearance around qualifying structures. (See FM-5 and WF-1: Measure 5)

- ◆ Maintain a permit system that enables adjacent landowners to maintain defensible space clearance surrounding homes and other qualifying structures across property boundaries and onto District land as long as the activity is recommended by the local fire agency and is

Defensible space is the area adjacent to a structure where basic wildfire protection practices are implemented, providing a key point of defense for an approaching wildland fire or area to escape from a structure fire. Cal Fire publishes guidelines for fuel (vegetation) treatments to create a perimeter around buildings and structures in order to maintain minimum conditions for firefighters to defend a property.

consistent with the District's resource management policies, including protection of environmentally sensitive habitat.

- ◆ Implement fire clearance recommendations and defensible space around District-owned structures, as appropriate.
- ◆ Collaborate with and support fire departments and fire scientists in educating landowners, residents, fire safe councils, and business owners to understand that fire prevention is more than defensible space, including why structures ignite, the role embers play in such ignitions, and the importance of fire safe building materials, designs, and retrofits. (See also PI-3)
- ◆ Seek fire agency guidance on understanding trends in fire cause and focus prevention and education efforts to modify human behavior and reduce ignitions.
- ◆ Work with fire agencies and local governments to develop requirements for new development to maintain required fire clearance distance from District land wherever possible.
- ◆ Focus non-prescribed fire fuel management activities in areas adjacent to development, essential facilities and improvements, major egress and emergency routes, essential fuel breaks, and sensitive natural and cultural areas.
- ◆ Investigate alternative funding sources in conjunction with fire agencies and residential communities within the WUI adjacent to District Preserves to fund and implement fire hazard reduction projects.

Policy WF-4 Manage District vegetation communities to reduce the risk of catastrophic fire and to maintain biological diversity and to promote resilience. (See VM-1, FM-6, and CC-4)

- ◆ Prioritize ecosystem function, resilience, and **ecological diversity** focused on multiple species benefits rather than aiming to prevent ecological change or return to past conditions.
- ◆ Evaluate, study, and implement additional land management strategies to promote ecosystem resilience.
- ◆ Promote the **restoration** and development of late-seral forest communities.
- ◆ Evaluate the potential to reduce forest fuel loading in accordance with a Vegetation Management Plan that includes removal of smaller trees to reduce forest floor fuel buildup and **ladder fuels**, development of additional fuelbreaks, and identification of **fuel reduction zones**.

Manage scrub, shrub, and chaparral communities to maintain a mosaic of ages and species within strategic management corridors on roads, on ridgetops, and near residential development or other critical infrastructure to compartmentalize preserves and reduce fuel loads. Manage forest diseases such as Sudden Oak Death (SOD) to improve forest health and resiliency and to reduce fuel loads.

- ◆ Continue to utilize and expand the District's **conservation grazing** program to reduce grassland fuels, brush encroachment, and encourage the vigor of native grass and forb species.
- ◆ Use prescribed fire to address multiple management objectives such as: training opportunities, public safety through fuels reduction, use of traditional ecological knowledge as imparted by Native American tribes, enhancement of native plants and habitats, and improved natural resource response to fire and rangeland resources.

Policy WF-5 Utilize programmatic documentation to increase the pace and scale of fuel treatments, ensuring that they are performed with the appropriate considerations for biological, cultural, and other natural resource constraints and to reduce regulatory hurdles to implementation.

- ◆ Perform fuel management activities under an approved Wildland Fire Resiliency Program that defines vegetation management, prescribed fire, pre-fire plans, and monitoring.
- ◆ Work to streamline or remove regulatory or policy or cost barriers that limit fuels reduction activities through the use of the programmatic documentation and defined mitigation, and CEQA exemptions, where feasible.
- ◆ Coordinate with air quality regulators to enable increased use of prescribed fire and to allow unplanned ignitions to burn to predesignated areas for resource benefit.

Policy WF-6 Conduct prescribed burns to re-introduce fire into native ecosystems and maintain natural ecological processes on District lands.

- ◆ Continue to utilize fire as a resource management tool to reduce fuels and reestablish fire for **resource benefit** where vegetation conditions, access, and public safety permit. Coordinate with other agencies and tribes for planning and implementation. and perform prescribed burns following defined safety processes and protocols.

Sudden Oak Death mortality is also a potential concern within the wildland- urban interface area, as well as within other areas of District Preserves. This concern is currently being studied by researchers in conjunction with District staff. These studies should provide additional insight into the potential fire hazard associated with SOD mortality and propose effective management options.

- ◆ Continue to utilize prescribed fire to reduce and prevent unwanted fire damage resulting from excessive fuel load and altered **plant community** structure and to control invasive species.
- ◆ Conduct prescribed burns in an ecologically sound manner which mimic natural **fire** regimes and/or traditional ecological knowledge practices, and to promote **biodiversity**. Consider how traditional, indigenous fire management for food, fiber, and all forms of subsistence are different management tools and outcomes than defensible space, thinning, and prescribed fire, for example. Document/monitor the impact of traditional fire management on biodiversity, water yield and quality, and ecosystem resiliency.
- ◆ Develop burn units based on science and implement site-specific fire prescriptions to improve regeneration of fire-adapted and special status vegetation and to improve habitat conditions for special status wildlife in fire-dependent ecosystems where feasible (see ES-3).
- ◆ Develop and implement an alternative management protocol to encourage seedling establishment of special status and disturbance-adapted species in aging stands when regeneration by fire is not feasible
- ◆ Conduct public **outreach** to recreational users, adjacent landowners and the general public through mailings, web site postings and press releases related to the benefits of prescribed fire and other fire management activities and inform the public of the District's safety protocols and processes associated with prescribed burns.

Policy WF-7 Foster and maintain interagency fire management partnerships.

- ◆ Annually coordinate with fire management and other resource agencies to discuss pre-fire planning conditions and needs in advance of the fire season ,and also coordinate with tribes regarding feedback on prescribed burning plans and goals.
- ◆ Participate in county **Fire Safe Councils** efforts.
- ◆ Incorporate and include the recommendations of the Community Wild-fire Protection Plans (CWPPs) adopted for San Mateo and Santa Clara Counties into the District's vegetation management practices, as appropriate and where they align with the District's practices.
- ◆ Train with fire agencies and participate in training burns when possible.

- ◆ Complete and distribute to fire agencies up-to-date maps of Preserve infrastructure including existing road network available for wildland fire management, helicopter landing zones, safety zones, evacuation routes, and other pertinent information as the maps become available.

Policy WF-8 Conduct research and monitoring to refine fire management practices.

- ◆ Census and mMap in geographic information systems (GIS) databases forest and fuel conditions, including hazardous fuel areas, treatment areas and zones, tree hazard management zones or areas, and other hazards and update regularly (See also RC-1)
- ◆ Monitor pre-project vegetation, soil, erosion, and **water quality** to establish baseline conditions for post project analysis.
- ◆ Monitor post fire and vegetation management projects to assess the achievement of project objectives and to identify potential impacts to vegetation, soil, erosion, and water quality. Implement **adaptive management** to respond to ecological feedback from monitoring efforts to optimize future fuel treatments and to determine the level of resources necessary to effectively identify, plan, and implement fire management activities. Manage fire breaks to decrease erosion and the spread of invasive plants.
- ◆ Conduct monitoring in a manner consistent with other land management agencies to obtain comparable data. Implement dynamic/interactive mapping and other methods to actively share information with surrounding and partner agencies and jurisdictions and information technology infrastructure allows.
- ◆ Utilize the latest technology to monitor weather and other real-time conditions on the preserves to improve response in the event of wild-fire.
- ◆ Integrate the latest research, techniques, and technology on fire resiliency and risk into the District's forest health and vegetation monitoring, forestry practices, and fuels management practices, as part of the **adaptive management** strategy.
- ◆ Foster relationships with educational institutions, scientists, tribal entities, and other land management professionals to inform District land management decisions based upon sound, current science, and to create opportunities for continuing research. Seek grants and pursue partnerships for research and monitoring.

- ◆ Integrate wildland fire management into District **interpretation** and education programs.
- ◆ Collaborate with local fire departments and safe fire councils to educate adjacent landowners about the need to: maintain defensible space between their properties and parklands; inspect and remove hazard trees; detect and treat diseased plants; and contain spread of disease.
- ◆ Collaborate with the tribes on traditional ecological knowledge practices for prescribed fire.

Policy WF-9 Wildland Fire management actions on District lands in the Coastside Protection Area will be in accordance with the policies established in the Service Plan for the San Mateo Coastal Annexation Area.

- ◆ In consultation with the County of San Mateo Environmental Services Department and fire agencies, determine whether the construction of dry hydrants on specific lands acquired is feasible in order to provide additional remote area water supplies for fire suppression activities
- ◆ Select native plant materials and/or seed mixes utilized at staging areas or along trails for their low maintenance and drought and fire resistant characteristics to minimize additional fuel available to wildland fires to the extent feasible.
- ◆ Where compatible with other trail characteristics, planners shall locate trail alignments and access points to allow trails to also serve as emergency access routes for patrol or emergency medical transport. Where feasible for more remote areas, emergency helicopter landing sites shall be provided.
- ◆ Coordinate with appropriate agencies, such as the County and Cal Fire to formalize mutual aid agreements.
- ◆ Consult with fire agencies in developing site-specific **fuel modification** and management programs for specific lands acquired as part of its Use and Management planning process, in addition to continuing the current District fuel management practices.
- ◆ Prohibit smoking, firearms, fireworks and off-road vehicle use and limit trail use, picnicking, and camping to designated areas.
- ◆ Develop and maintain staging areas and trail heads in accordance with the wildland fire **hazard mitigation** measures established in the Service Plan for the Coastside Protection Area.

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XVI. CLIMATE CHANGE

BACKGROUND

Greenhouse gases, such as carbon dioxide, methane, and nitrous oxide, contribute to the atmospheric warming “greenhouse effect” by absorbing infrared radiation.

Climate change is directly affecting temperatures, precipitation, weather patterns, species ranges, wildfire risk, and sea levels, impacting the District’s ability to meet its resource management goals. Human activities that put excess **greenhouse gases** into the atmosphere, such as burning fossil fuels for transportation and energy generation, are the leading cause of climate change.

Impacts on Natural Systems

According to the National Park Service, the wide range of climate change impacts in the Bay Area include the following:

- ◆ Increase in average annual temperatures of 1.2 degrees Celsius (2.2 degrees Fahrenheit) between 1960 and 2010
- ◆ Northern shifts in winter bird ranges of 0.5 kilometers (0.3 miles) per year between 1975 and 2004
- ◆ Upward shifts in elevation for 12 percent of endemic species and 27 percent of non-native species between the periods of 1895-1970 and 1971-2009
- ◆ Sea level rise of 22 centimeters (9 inches) between 1854 and 2016
- ◆ Decrease in coastal fog by 33 percent between the periods of 1901-1925 and 1951-2008
- ◆ Increase in heavy storms by 25 percent between the periods of 1901-1960 and 1991-2000
- ◆ Human-caused climate change accounted for 10-20% of the 2012-2014 drought
- ◆ Climate was the dominant factor controlling the extent of wildfire burn areas between 1916 and 2003, even during periods of active fire suppression

The Carbon Cycle

The carbon cycle is a natural process by which carbon moves between different stores or reservoirs, such as the atmosphere, oceans, sedimentary rocks, soils, and plant biomass. When burning fossil fuels, humans move a massive amount of carbon from the ground to the atmosphere, putting the carbon cycle out of balance and causing climate change. The two key approaches to solving climate change are 1) to avoid adding any more carbon to the atmospheric store and 2) to move carbon from the atmospheric store to safer stores, such as plant biomass and soils. Humans can avoid adding more carbon to the atmospheric store by reducing greenhouse gas emissions from fossil fuels and preventing the release of carbon in plants and soils. Wildfire poses a considerable threat to the carbon stock of forests and open space areas. Reducing the risks of catastrophic wildfires also helps to maintain existing carbon stores. Humans can facilitate the movement of carbon from the atmosphere into plant biomass and soils, also known as **carbon sequestration**, through land conservation and management. The District has preserved nearly 65,000 acres of open space lands, including redwood forests, which store large amounts of carbon in trees, other vegetation, and soils.

Carbon sequestration is the process by which carbon is removed from the atmosphere and stored elsewhere, such as in plants and soils.

The management of open space lands should include actively addressing and working to increase carbon sequestration while also reducing or mitigating the risk of loss of enormous quantities of existing carbon stock in catastrophic wildfire. Vegetation management should be performed carefully with the goal to reduce the risks of carbon loss through wildfire, while carefully balancing fuel reduction needs with managing the landscape for long-term increases in carbon storage.

CLIMATE CHANGE GOAL, POLICIES, AND IMPLEMENTATION MEASURES

Goal CC-	Reduce agency-generated greenhouse gas emissions, increase carbon sequestration, and promote resilience to climate change impacts

Policy CC-1 Reduce administrative greenhouse gas (GHG) emissions 20% below 2016 baseline by 2022, 40% below 2016 baseline by 2030, and 80% below 2016 baseline by 2050, in line with the State of California's GHG reduction goals.

The State of California set a goal to reduce GHG emissions 40% below 1990 baseline levels by 2030 and 80% by 2050 (AB 32). The District first inventoried GHG emissions in 2016 so that is the baseline for the District's reduction goals.

District GHG emissions are divided into administrative emissions, which come directly from District operations such as vehicles and facilities, and non-administrative emissions, which are related to District activities but the District has less control over. A numerical GHG reduction goal is set only for administrative emissions.

- ◆ Implement Climate Action Plan strategies to reduce or offset administrative GHG emissions from vehicles, equipment, facilities, employee commuting, and tenant residences.
- ◆ Periodically update GHG Inventory and track GHG reduction.
- ◆ Improve GHG Inventory data quality and tracking systems.
- ◆ Consider GHG emissions related to all policies, plans, decisions, and management practices, in addition to other factors.
- ◆ Evaluate the full life-cycle footprint of equipment, services, and supplies, and choose lower impact/responsible services and supplies.
- ◆ Develop sustainability guidelines for facilities, operations, projects, and events.

Policy CC-2 Reduce non-administrative GHG emissions related to District activities, such as visitor transportation and livestock.

- ◆ Implement Climate Action Plan strategies to reduce or offset GHG emissions from visitor transportation to preserves.
- ◆ Implement Climate Action Plan strategies to reduce or offset GHG emissions from livestock, and research additional techniques or technologies.
- ◆ Where agricultural sustainability is not a leading factor, select appropriate livestock species to accomplish vegetation management objectives (See GM-4).

Policy CC-3 Increase **carbon sequestration** in vegetation and soils and minimize carbon release from wildfire.

- ◆ Manage conifer forests to sustain and encourage the development of late-seral habitat conditions (FM-4). Evaluate the potential to reduce forest fuel loading through the removal of smaller trees to reduce fuel buildup and ladder fuels (See FM-5).
- ◆ Manage vegetation communities to reduce the risk of catastrophic fire and to maintain biological diversity (WF-4). Conduct prescribed burns to re-introduce fire into native ecosystems and maintain natural ecological processes on District lands (See WF-5).
- ◆ Evaluate, study, and implement additional land management strategies to increase carbon sequestration in vegetation and soils.
- ◆ Improve data on carbon sequestration in District lands with a goal to pursue and maximize opportunities

- ◆ Evaluate opportunities to create and sell carbon offsets on the California Cap and Trade market or other voluntary offset markets.
- ◆ Consider trade-offs between carbon sequestration losses from fuel load reduction and emissions from prescribed fire to establish **ecological resiliency** in the face of wildfire, given the overwhelming benefits of reduced risks of catastrophic wildland fire on climate change.

Policy CC-4 Prepare for climate change impacts and promote **resilience** for both natural and built environments.

- ◆ Prioritize ecosystem function, resilience, and **ecological diversity** focused on multiple species benefits, rather than aiming to prevent ecological change or return to past conditions.
- ◆ Establish goals for biodiversity and ecosystem structure and function to identify the types of diversity future conditions can support
- ◆ Incorporate climate change impacts on natural resources such as species range and phenology changes into restoration and monitoring activities. Utilize an **adaptive management** framework to adjust resource management methods and priorities as impacts start to occur and climate change knowledge and response options continue to increase (See GM-3).
- ◆ Support ecological functions and ecosystem services that protect the built environment from climate change impacts, such as flooding and increased wildland fire frequency and intensity.
- ◆ Incorporate climate change impacts to infrastructure, such as flooding, drought, and sea level rise, into planning, project design, and other relevant activities.
- ◆ Evaluate, study, and implement additional land management strategies to promote ecosystem resilience.

Resilience is the capacity of natural and human communities to withstand and bounce back from climate stress and hazardous events.

Policy CC-5 Lead by example and support state, regional, and community-scale action on reducing climate change impacts to ecosystem health and biodiversity, and increasing ecosystem resilience.

- ◆ Support and participate in regional climate change initiatives and burgeoning community of practice. Foster partnerships to respond to climate change collaboratively, and seek opportunities to share information with other agencies.

- ◆ Support and influence local and state climate change policies that are protective of ecosystem health and biodiversity. Seek grant opportunities to fund implementation of GHG reduction, carbon sequestration, and natural resource resilience efforts.
- ◆ Increase public awareness of climate change impacts and solutions the District is pursuing through education and outreach. Incorporate climate change into interpretive programming, facilities, and materials (See PI-1).
- ◆ Coordinate and cooperate with institutions, agencies, organizations, and individuals conducting research on climate change and resource management (See RC-2).

XVII. MITIGATION

Mitigation refers to a suite of measures that avoids, minimizes, or effectively eliminates the impact(s) for a given activity on the environment.. Project mitigations may come from a California Environmental Quality Act (CEQA) document, state and federal permits, or from county or local ordinances. This policy applies to mitigations that pertain to natural and cultural resources which may be incorporated into local, state and federal permit approvals. CEQA-related mitigation involving natural and cultural resources are considered elsewhere in District policy - specifically other chapters of the Resources Management Policies, the Basic Policy, and other Board Policies such as 4.09- Factors to Consider for Structures Disposition.

This mitigation policy creates the process by which District staff define and consider the **least environmentally damaging practicable alternative** of a project. Mitigation may result from either an **internal** or District-led project occurring on District-owned lands or an **external** project, which is a project led by another agency. Midpen's role in reviewing external projects' where Midpen may be a **CEQA Responsible Agency** is detailed in the "District Guidelines for Implementation of the California Environmental Quality Act."

BACKGROUND

Impacts to the environment come in many forms but can be broadly characterized as **temporary** and/or **permanent**. Temporary impacts are those which do not result in a durable change or are short-term in nature. Permanent impacts are those that convert habitat or affect resources in a durable fashion.

Impacts can be described as **potential** or **actual**. Potential impacts cannot be ruled out or confirmed definitively until a future assessment is completed or the project is implemented. Some permits require defining the **Area of Potential Effect**, which encompasses a larger area around the actual impact location. **Actual impacts** arise from known and definite impacts to a resource, whether temporary or permanent. CEQA analyzes three types of effects: direct, indirect, and cumulative. **Direct effects** occur at the place and at the same time as the project implementation (e.g., ground disturbance, tree removal, etc.). **Indirect effects** are reasonably foreseeable effects that occur at different times or places (e.g. impacts that

An example of a project having a direct effect may include the removal of select trees or other vegetation to construct new bridge footings within a riparian area resulting in the need for replacement plantings.

An example of a project having an indirect effect may include installation of a new trail that may cause an increase or decrease in preserve visitation.

An example of cumulative impacts using the above examples would be removal of the riparian vegetation compounded with an increase in visitor usage that may together cumulatively affect water quality and/or future wildlife usage at the project site.

occur due to the proposed action but beyond the footprint of a project or activity). **Cumulative effects** are two or more effects that compound together or increase other environmental impacts.

The existing condition or **environment baseline** describes the environmental setting, ecology, and resources prior to a proposed activity. **Temporal loss** is an impact arising from a delay between an impact and **compensatory mitigation**.

While CEQA and permitting agencies have different definitions and frameworks, including the precise use of the term ‘mitigation’, the principles of mitigation are shared. The main difference is that CEQA mitigations are approved, monitored, and reported by the CEQA **lead agency**, which is usually the District in the case of District-led projects. Mitigations required through permitting are ultimately approved by the permitting agencies yet monitored and reported by the lead agency.

MITIGATION GOALS, POLICIES, AND IMPLEMENTATION MEASURES

Goal M-	Avoid and minimize adverse impacts to natural and cultural resources to the maximum feasible extent and use mitigation for all other unavoidable impacts. Couple mitigation with high priority restoration when feasible.

Policy M-1 Review and consider all applicable District Policies, programmatic permits, and CEQA documents to develop the project scope, incorporating the following practices (listed in in order of priority): avoidance, minimization and/or mitigation of potential impacts.

- ◆ Refer to Board Policies, including but not limited to the Basic Policy, and other applicable Resource Management Policy Chapters.
- ◆ Review applicable resource agency programmatic permits and/or programmatic CEQA documents to determine if the project can be covered using existing avoidance, minimization or mitigation measures to reduce the need for compensatory mitigation.

Policy M-2 Identify and evaluate sensitive resources to determine the least impactful project design that meets the project goals and objectives.

- ◆ Develop a brief and inclusive project description.
- ◆ Define the maximum Area of Potential Effect.
- ◆ Survey, identify, and map sensitive ecological and cultural resources within the project area.
- ◆ Analyze how different project alternatives may avoid or impact existing resources.
- ◆ Analyze other activities within the watershed and/or Preserve to understand the net effect of the proposed project.
- ◆ Compare potential impacts against the feasibility, cost, and project goals and objectives (including long term maintenance and monitoring).
- ◆ Document the **basis of design** and why the project is the least environmentally impactful alternative.
- ◆ The basis of design can be informed by the CEQA review process and/or an alternatives analysis conducted during permitting review.

The basis of design integrates engineering, constructability, costs, and environmental considerations to explain the rationale behind the selected project and why other alternatives do not sufficiently meet the project goals.

Policy M-3 Evaluate and incorporate measures that minimize the effects of the project on the sensitive resources.

- ◆ Refine the project description into a sequential narrative and refine the resulting Area of Potential Effect.
- ◆ Conduct further detailed and site-specific surveys of natural and cultural resources as needed to adjust and refine the project design to avoid and minimize project impacts.
- ◆ Define and quantify the temporary, permanent, potential, and actual impacts of the project to the extent feasible.
- ◆ Adjust the project scope, extent, seasonality, duration, or other measures to minimize actual or potential impacts to the resources.

Policy M-4 Develop a compensatory mitigation strategy as a measure of last resort.

- ◆ Review the temporary and permanent impacts.
- ◆ Evaluate onsite mitigation for short-term and long-term cost efficiencies, habitat benefit, physical capacity, and staff resources.
- ◆ Evaluate existing voluntary restoration projects for potential use as mitigation, including vegetation management for resiliency work (e.g., wildland fire, climate change, and/or invasive species removal).
- ◆ If the overall impacts and associated mitigations are substantial, review other voluntary restoration work that the District may plan or conduct in the watershed or Preserve that can mitigate the impacts and/or result in a 'net environmental benefit'.
- ◆ When applying restoration and/or recovery work to compensate for project impacts, select high priority species, habitats, populations, and ecological processes first, preferably in high conservation value areas, including Conservation Management Units, to maximize the regional net environmental benefit.
- ◆ When onsite mitigation is not feasible, evaluate the appropriateness of implementing mitigation work in off-site locations (refer to 'like for like' as described above)
- ◆ Prioritize facilitating or supporting regionally significant restoration projects, as defined by a recovery plan, watershed plan, or other collaborative planning document, when using compensatory mitigation funds.
- ◆ Ensure that baseline mitigation ratios are correctly proportioned by accounting for both the uncertainty inherent in mitigation work and the anticipated probability of success.
- ◆ If no other options are cost effective and feasible, search for partner agencies or conservation organizations that may facilitate third-party mitigation. Consider those that support a Natural Community Conservation Plan, Habitat Conservation Plan, Regional Conservation Investment Strategy or other regional conservation planning.

Policy M-5 Weigh the mitigation, maintenance, monitoring, and reporting costs and impacts alongside the project benefits.

- ◆ After defining a third-party compensatory mitigation strategy, evaluate the sum of all mitigation costs (construction expenses, biological or cultural monitoring, revegetation, compensatory mitigation, and post-construction monitoring).
- ◆ If the overall impacts and associated mitigation costs are substantial, determine whether revisiting the project goal(s) and scope is warranted.
- ◆ Consider a recommendation to alter or withdraw the project.

Policy M-6 When needed, evaluate compensatory mitigation proposed by the District for purchase or implementation on other properties.

- ◆ Confirm if the project is using the least environmentally damaging and feasible alternative.
- ◆ If no feasible option or habitat within District lands is available for which to mitigate for an impact, consider a recommendation to alter or withdraw the project.
- ◆ If after evaluation no feasible alternative or option exists, funding of or implementing off-site mitigation may be considered.

Policy M-7 When third-party compensatory mitigation is proposed by outside parties to the District, evaluate proposals using criteria that aligns with the District's Mission, Goals, and Policies.

- ◆ District analysis of third-party proposals will include a summary of the request, a description of the third-party project ("proposed project"), the required mitigation, and a finding that the project and mitigation will likely result in a long-term benefit to the affected resource.
- ◆ Evaluation criteria of third-party proposals shall include:
 - ***Alignment with District Mission, Policies, and Goals***

- Does the proposed project support the District's mission?
- Does the proposed project provide a public benefit?
- Does the proposed project align with the Basic Policy and Good Neighbor policy?
- Is the project proponent's mission aligned with the District and do they have a track record of environmentally sensitive projects?
- o ***Proximity to District Lands and Regional Context***
 - Is the proposed project located within the District's boundaries or sphere of influence, or within the larger nine-county Bay Area region?
 - Is the proposed project at an appropriate scope and scale for the site and/or region?
 - Will the proposed project directly affect District lands or surrounding ecosystems?
- o ***Public, Partner, and Social Implications***
 - What are the potential impacts and/or benefits to the public and our partners? What are the potential impacts and/or benefits to under-resourced and/or vulnerable communities and to Native American tribes?
 - Is there public support for or opposition to the project and/or to the proposed mitigation?
 - Does the project offer opportunities to strengthen relationships or partner with outside agencies, non-profit organizations, and other groups?
 - Does the project improve or reduce public access opportunities?
- o ***Low-impact Project Design and Appropriate Mitigation***
 - Does the proposed project use the least impactful, practicable alternative and if not, did

the proponent first consider how to avoid and minimize impacts to the greatest feasible extent? Are impacts temporary or permanent? Are the impacts too large to offset?

- What are the sources of funding, conditions imposed, monitoring and oversight requirements, and timeline?
- Are the mitigation funds too small to be useful?
- Is the mitigation project consistent with an existing Preserve Plan, Use and Management Plan and/or an existing CEQA document?
- Will the mitigation project require the District to allocate resources to design, peer review, or monitor the mitigation work?
- Does the District already have a voluntary restoration project in mind or one that requires additional funding that would be a good match?

o ***Ecological Impact vs Value***

- Is the affected species for which mitigation is proposed present at the area of impact or do they only have the potential to occur in the area?
- Does the Area of Potential Effect and the proposed off-site mitigation fall within critical habitat, or is part of a habitat linkage, climate refugia, or another sensitive habitat?
- Does the proposed mitigation:
 - ❖ benefit a sensitive species population, habitat assemblage, and/or multiple species?
 - ❖ facilitate regional restoration priorities and/or recovery of species?
 - ❖ restore or provide ecological system function(s)?
 - ❖ promote long-term health of the ecosystem or provide resource benefits?

- ❖ help meet priority land conservation and management goals?
- ❖ support the goals of a Natural Community Conservation Plan, Habitat Conservation Plan, Regional Conservation Investment Strategy or other regional conservation plan?

Policy M-8 Recommend third-party compensatory mitigation that fulfill District goals and meet District criteria.

- ◆ Evaluation criteria will be used to determine whether to further consider outside proposals for acceptance of mitigation funds and/or mitigation work on District lands.
- ◆ Projects are ranked against the evaluation criteria. Although not all projects will meet every criterion, projects must be able to provide a clear benefit to the District to be considered for acceptance.
- ◆ The value of the outside mitigation funds or proposed mitigation work determines the level of approval authority. External mitigation valued at greater than the General Manager's signing authority requires Board approval.
- ◆ Staff findings and recommendations are forwarded to the approving authority. Recommendations will be based on the (ranked) criteria and the particulars of the proposed project and associated compensatory mitigation. Projects that do not meet minimum criteria, do not provide a clear public benefit, and/or are controversial may be denied.
- ◆ Staff will review and ensure a Mitigation Monitoring and Reporting Plan, or Program is in place before accepting funds or mitigation work.

XVIII. GLOSSARY

Actual impacts - arise from known and definite impacts to a resource, whether temporary or permanent.

Adaptive Management - A systematic process for continually improving management policies and practices by learning from the outcomes of previously employed policies and practices

Advance mitigation - 1) a form of mitigation (compensation) implemented before an impact occurs. 2) a science-based approach to identify mitigation opportunities early in the planning process prior to the design and permitting phases to identify higher-quality mitigation opportunities and/or those that support regional conservation priorities.

Agricultural Infrastructure – Improvements made to a property to support an agricultural operation such as fencing, roads, water supply systems and structures. (Conservation Grazing Management)

Alternatives analysis - 1) the evaluation of the different project choices or actions available to achieve a desired objective. It is an analytical comparison of different factors, including environmental impacts, operational cost, risks, effectiveness etc. 2) A process of completing an alternatives analysis under the Clean Water Act that requires demonstration and determination that the proposed project is the least environmentally damaging practicable alternative. 3) Under the California Environmental Quality Act, when completing an Environmental Impact Report, an alternatives analysis is required and describes a reasonable range of alternatives that could feasibly avoid or lessen any significant environmental impacts while substantially attaining the basic objectives of the Project or Program.

Anadromous – Fish, such as steelhead trout, that return from the open ocean as adults to freshwater streams to breed. (Water Resources, Habitat Connectivity)

Area of Potential Effect (APE) - the larger area surrounding the project activity location that encompasses ancillary features such as staging, access routes, refueling stations and other features that may be affected incidentally.

Archaeological site – A site in which physical evidence of past prehistoric or historic human activity has been preserved. (Cultural Resources)

Artifacts – Objects created by humans or modified by human activity. (Cultural Resources)

Avoidance - to cause no potential impact while undertaking a proposed action. Avoidance involves deliberate and thoughtful planning to evaluate and document the strategies that will be used to prevent impacts to the resources as a result of a proposed activity.

Barrier – An impediment to migration, genetic exchange, dispersal, or other essential movement of an organism. Barriers may be of natural or human-made origin. (Habitat Connectivity)

Basis of design - documents the principles, assumptions, rationale, criteria, and considerations used for the calculations and decisions required during design of a project, system, or other activity.

Best Management Practices (BMPs) – District developed standard practices that identify the preferred manner in which an activity is to be performed in order to be protective of both human health and the environment. (Vegetation Management, Integrated Pest Management, Water Resources, Conservation Grazing Management, Forest Management)

Biodiversity – Describes the natural variety and abundance of plants and animals and the environments in which they live. U.S. Congressional Biodiversity Act, 1990 HR1268, defines biodiversity as “The full range of variety and variability within and among living organisms, and the ecological complexes in which they occur, and encompass ecosystem or community diversity, species diversity and genetic diversity.” (Vegetation Management, Integrated Pest Management, Water Resources, Forest Management, Ecological Succession, Habitat Connectivity, Wildland Fire)

Biological Legacies – The retention of forest components that were originally present within the forest, prior to large scale disturbance such as fire, or timber harvesting. Notable “legacy” components include: large live trees (especially old growth) with mosses and lichen growth within the canopy, hollow cavities, and complex large branch structure; large pieces of

wood on the forest floor; intact forest soil and associated fungi and microbes. These forest components have a profound influence on recovering forest ecosystems and are important considerations for habitat reconnection and restoration. (Forest Management)

Boundary – The area of border between habitat patches or vegetation types; a zone comprised of edges of adjacent ecosystems or land types. (Habitat Connectivity)

Carbon Sequestration – The process by which carbon is removed from the atmosphere and stored elsewhere, such as in plants and soils. (Climate Change)

Chaparral – Shrub and small tree dominated landscapes composed of species with small, thick, evergreen, leathery leaves that often grow dense and tangled. (Vegetation Management, Ecological Succession, Habitat Connectivity, Wildland Fire)

Community Wildfire Protection Plan (CWPP) – The Healthy Forests Restoration Act (HFRA), passed in 2003 by the federal government, established statutory incentives for the US Forest Service (USFS) and the Bureau of Land Management (BLM) to give consideration to the priorities of local communities as they develop and implement forest management and hazardous fuel reduction projects. In order for a community to take full advantage of this federal assistance, a community must first prepare a CWPP. CWPPs may address issues such as wildfire response, hazard mitigation, community preparedness, or structure protection—or all of the above. (Wildland Fire)

Compartmentalize – Using fire management techniques such as installation of shaded fuel breaks, or defensible space surrounding homes to separate a potentially large scale wildland fire into distinct smaller management areas separated by vegetation type, fuel loading, access, or terrain into pre-designated fire management units. (Wildland Fire)

Compensatory mitigation - measures taken to offset the unavoidable impact remaining after avoidance and minimization actions are taken. Com-

pensatory mitigation involves either the restoration, establishment, enhancement and/or preservation of impacted habitats or waters on or off site.

Conifer, Coniferous – Cone bearing trees with needles or scale-like leaves, stay green throughout the year in California. Examples include: coast redwood, Douglas fir, pine trees, and cypresses. Conifers are also referred to as softwood. (Forest Management, Ecological Succession)

Conservation easement – a voluntary, legal agreement that permanently limits uses of the land in order to protect its conservation values. A conservation easement is one option to protect a property for future generations absent of having fee title to that land.

Conservation Grazing – Conservation Grazing is the intentional use of grazing management to meet resource management objectives including protecting and enhancing habitat for native plants and animals that occur in grassland habitat and moderating the negative effects of invasive exotic plants on these species. (Wildland Fire, Conservation Grazing Management, Vegetation Management)

Contamination – Human-made waste that has polluted the environment making it unfit or unsafe. (Water Resources, Geology and Soils)

Core – The portion of an ecosystem or habitat where effects of the surrounding area are limited. (Habitat Connectivity)

Cultural Landscape – A landscape modified by past human activity or otherwise holding historical or prehistoric cultural importance. (Cultural Resources, Public Interpretation, Wildland Fire)

Cultural Resource – A structure, landscape feature, archaeological site, or other artifact of human activity in the past during prehistoric or historic periods. (Cultural Resources)

Cultural Resource Inventory – The District's inventory of cultural resources on District preserves. Information in this inventory may include site locations, descriptions, and photographs, as well as historical information on individual sites and preserves. (Cultural Resources)

Cumulative effects - changes to the environment caused by the combined impact of past, present and future human activities and natural processes. Cumulative effects to the environment are the result of multiple activities whose individual direct (or indirect) impacts may be relatively minor but in combination with others result in significant environmental effects.

Data Recovery – Research and recording techniques such as the excavation of archaeological sites or recording of architectural features prior to site disturbance. Data recovery is a common mitigation measure for projects that may have a substantial adverse impact on a significant cultural resource. (Cultural Resources)

Defensible Space – Defensible space is the area adjacent to a structure where basic wildfire protection practices are implemented, providing a key point of defense for an approaching wildland fire or area to escape from a structure fire. The California Department of Forestry and Fire Protection (Cal Fire) publishes guidelines for fuel (vegetation) treatments to create a perimeter around buildings and structures in order to maintain minimum conditions for firefighters to defend a property. (Wildland Fire)

Direct effects - effects that occur at the place and at the same time as project implementation (e.g., ground disturbance, tree removal etc.)

Direct take - immediate injury or death to one or more individuals of one or more species as a result of project activities.

Disturbance (Ecological Disturbance) – The disruption of an ecosystem's structure and function, generally with effects that last for time periods longer than a single seasonal growing cycle for vegetation. (Wildlife Management, Integrated Pest Management, Water Resources, Geology and Soils, Ecological Succession)

Disturbance-dependent – Species that require disturbance to maintain habitat conditions suitable for reproduction and establishment. (Ecological Succession)

Ecological Diversity - The variety and abundance of species in different habitats and communities.

Ecological Resiliency- the ability of an ecosystem to maintain a dynamic equilibrium of nutrient cycling and biomass production after being subjected to damage caused by an ecological disturbance.

Ecological Restoration - the process of returning land that has been degraded or disturbed into functional habitat and processes to accelerate the recovery of an ecosystem.

Ecological Succession – The sequential development of plant and animal communities following disturbance. (Ecological Succession)

Ecosystem – An area within the natural environment in which physical (abiotic) factors of the environment, such as rocks and soil, function together along with interdependent (biotic) organisms, such as plants and animals, within the same habitat. (Vegetation Management, Integrated Pest Management, Water Resources, Conservation Grazing Management, Forest Management, Ecological Succession, Habitat Connectivity, Wildland Fire)

Ecosystem Function – The interaction(s) or ecological processes that exists between organisms with one another and the physical environment, such as nutrient cycling, disturbance, soil development, water budgeting, and flammability. (Vegetation Management, Water Resources, Forest Management, Wildland Fire)

Edge – The portion of an ecosystem or habitat near its perimeter, where influences of the surroundings prevent development of interior/core-area environmental conditions. (Habitat Connectivity)

Enhancement - the process of altering a habitat to improve one or more specific ecosystem condition(s) and/or function(s).

Enhance – To increase or improve a habitat in value or quality. (Vegetation Management, Wildlife Management, Water Resources, Conservation

Grazing Management, Forest Management, Ecological Succession, Habitat Connectivity)

Environment baseline - the existing condition that describes the environmental setting, ecology, and resources prior to a proposed activity.

Environmental Education – A learning process that increases people's knowledge and awareness about the environment and associated challenges, develops the necessary skills and expertise to address the challenges, and fosters attitudes, motivations, and commitments to make informed decisions and take responsible action. (Public Interpretation)

Essential Roads – These are roads important to community and visitor ingress/egress and emergency access.

Exotic – Species that were not present in the Santa Cruz Mountains region of California prior to the large scale development of the American continent by European humans prior to 1769. (Conservation Grazing Management)

External mitigation - mitigation that results from a project led by another agency involving District-owned lands either for project implementation (such as the flood detention basin at Rancho San Antonio) and/or as a site to implement mitigation required from one of their offsite projects (such as Valley Water mitigation implementation at Hendrys Creek).

Extreme Fire Hazard/Weather – The National Weather Service, operating through cooperative agreement with the State of California, issues Red Flag Warnings during conditions of extreme fire weather. This alert is used by fire agencies to plan staffing levels and preparedness and set public use restrictions (such as campfires or the use of spark producing equipment). (Wildland Fire)

Five-Strand Barbed Wire Fencing – Fencing typically used in ranching operations to confine livestock to established areas, constructed of five evenly spaced rows of barbed wire stretched between posts comprised of wood or metal. (Conservation Grazing Management)

Flora – The plants of a particular region or period. (Conservation Grazing Management)

Fire Agencies – Agencies with jurisdiction to respond to wildland and structure fires on District lands and that may work in cooperation with the District in planning site-specific fuel and wildland fire management practices and in conducting training in fire and fuel management. They can include Cal Fire as well as local, regional, city, county and special district fire agencies. (Wildland Fire, Forest Management)

Fire Behavior – The manner in which a fire reacts to fuel, weather, topography, or fire suppression efforts. (Wildland Fire)

Fire Regime – The characteristic frequency, extent, intensity, severity, and seasonality of fires within an ecosystem. (Wildland Fire)

Fire Safe Councils – The Fire Safe Council is a coalition of public and private organizations with a common, shared interest in reducing losses from wildfires. (Wildland Fire)

Fire Suppression – Human efforts connected with fire-extinguishing operations, such as use of tools, engines, water or aircraft, or installation of fuel breaks, or removal of fuels surrounding homes or other structures. (Vegetation Management, Forest Management, Wildland Fire)

Food Web – The relationships between interconnected plants and animals in an ecosystem pertaining to how each organism gets their food and meets energy requirements. (Integrated Pest Management)

Forbs – A broad-leaved herb other than a grass, especially one growing in a field, prairie, or meadow. (Conservation Grazing Management, Wildland Fire)

Forest – Habitats dominated by tree species with a continuous or nearly continuous canopy covering substantial portions of the landscape. (Vegetation Management, Wildlife Management, Forest Management, Ecological Succession, Wildland Fire)

Forest Conditions – A characterization of forest age, structural complexity (height, spacing, multiple canopy levels), species composition, habitat suitability, biological legacies, fuel loads, diseases or pathogens, regeneration, and level of disturbance. (Forest Management)

Forest Management – The active stewardship of a forest or stand to achieve a desired future condition. (Forest Management)

Formal mitigation banks - areas of potential restoration that consolidate compensatory mitigation of many upcoming projects, thus avoiding temporal loss, and are regulated by the agencies that oversee them.

Fuel – Combustible vegetation including live or dead forbs, shrubs, branches, trees, vines etc. (Vegetation Management, Conservation Grazing Management, Forest Management, Wildland Fire)

Fuel Break – A strip of land on which vegetation has been removed, reduced, thinned, or otherwise modified so that a fire burning into or up to it can be more readily controlled (Wildland Fire)

Fuel Load – The oven-dry weight of fuel per unit area. (Wildland Fire)

Fuel Modification – Breaking up, thinning, reducing, or otherwise modifying continuous fuels to prevent or reduce the spread of a wildfire. (Wildland Fire)

Fuel Reduction Zones - An area in which vegetation, debris, and other types of combustible fuels have been treated, cleared, or reduced to slow the spread of fire, to modify habitat, or for other reasons with the outcome of natural or cultural resources benefit.

Fuel Wood – Woody vegetation or wood products, primarily used as fuel for heating, cooking, or industry. (Forest Management)

GIS (Geographic Information System) – A combined database and mapping system used for the storage, retrieval, and analysis of geographic data. (Integrated Pest Management, Research and Collection)

GIS Database – A database that contains information about the location of real-world features and the characteristics of those features. (Integrated Pest Management, Research and Collection)

Geologic Hazards – Hazards created by fault zones, landslide prone areas, and flood zones. (Geology and Soils)

Greenhouse Gases – Gases such as carbon dioxide, methane, and nitrous oxide that contribute to the atmospheric warming “greenhouse effect” by absorbing infrared radiation. (Climate Change)

Habitat – the combination of living and non-living factors that surround and potentially influence an organism; or species’ typical environment. (Vegetation Management, Wildlife Management, Integrated Pest Management, Water Resources, Scenic and Aesthetic, Conservation Grazing Management, Forest Management, Ecological Succession, Habitat Connectivity, Wildland Fire)

Habitat Conservation Plans (HCP)- a form of permit from USFWS that authorize **incidental take** of federally listed species and establishes a formal mitigation approach, usually at a regional, large scale.

Habitat Fragmentation – the breaking up of a previously continuous habitat (or ecosystem) into spatially separated and smaller pieces. (Wildlife Management, Forest Management)

Hardwood – Broadleaf trees that usually produce flowers that ripen into fruits containing seeds. Local examples include: numerous oak species, madrone, tanoak, willows, and western sycamore. (Forest Management, Wildland Fire)

Hazard Mitigation – action taken to reduce or eliminate long-term risk to people and their property from hazards such as proximity of flammable vegetation, dead or dying tree limbs, or pollution or contamination in close proximity to homes or public facilities. (Wildland Fire)

High Priority District Forests – Forests that have been identified through inventories or other analysis as priority areas for forest management. Priority can be based on different management objectives such as: restoring

degraded habitat, reconnecting late-seral habitat, and/or wildland- urban interface fire concerns. (Forest Management)

Historic – Dating from periods post-dating the use of written historical documents. In the American West, the historic period is generally considered to refer to all periods after European exploration and colonization of the region. (Water Resources, Scenic and Aesthetic, Cultural Resources, Forest Management, Ecological Succession, Wildland Fire)

Historical Rehabilitation – “The act or process of making possible a compatible use for a property through repair, alterations and additions while preserving those portions or features which convey its historical, cultural, or architectural values.” (Definition from *Secretary of the Interior’s Standards for Treatment of Historic Properties*) (Cultural Resources)

Host – A plant or animal that provides sustenance for another organism. (Integrated Pest Management)

Inbreeding Depression – The decrease in growth, survival and fertility of an individual often observed following mating among relatives or self-fertilization (in plants). (Wildlife Management)

Incident Command System (ICS) – a standardized, on-scene, all-hazard incident management concept. ICS allows its users to adopt an integrated organizational structure to match the complexities and demands of single or multiple incidents without being hindered by jurisdictional boundaries. (Wildland Fire)

Indirect effects - are reasonably foreseeable effects that occur at different times or places (e.g. impacts that occur due to the proposed action but beyond the footprint of a project or activity).

Informal mitigation banks - areas of potential restoration that consolidate compensatory mitigation of many upcoming projects, thus avoiding temporal loss, without being regulated as a formal mitigation bank.

In Situ – “In place;” at the site of original deposition or discovery. (Cultural Resources)

Integrated Pest Management (IPM) – A long-term strategy that specifically reviews alternatives and monitors conditions to effectively control a target pest with minimum impact to human health, the environment, and non-target organisms. (Integrated Pest Management)

Internal mitigation - results from either a District-led project occurring on District-owned lands or from a District-led project not on District lands (such as the Highway 17 Wildlife and Regional Trails Project).

Interpretation – A communication method that aims to reveal meanings, connections, and relationships by firsthand experience, and by illustrative media. (Cultural Resources, Public Interpretation, Forest Management, Wildland Fire)

Interpretive Systems Plan (ISP) – An overarching analysis of the interpretive opportunities that exist throughout an agency's parks or preserves. (Public Interpretation)

Invasive Species – animal or plant species that take over sufficiently large areas to reduce biodiversity. (Integrated Pest Management, Conservation Grazing Management, Ecological Succession, Habitat Connectivity, Wildland Fire)

Ladder Fuels – Live or dead vegetation that allows a fire to ascend from low lying vegetation such as forbs and grasses, into the upper or uppermost vegetation such as taller shrubs and trees. Common fuel ladders include tall grasses, shrubs, and tree branches, both living and dead. (Forest Management, Wildland Fire)

Late-Seral – Stage of forest development dominated by large mature trees. Initial age development of this stage for redwood and Douglas-fir forests is generally considered to occur between 80- and 300 years. Trees and forest begin to develop some characteristics associated with old growth including large decadent trees, snags and large down logs. (Forest Management, Wildland Fire)

Late-Successional – Same as late-seral. (Forest Management)

Least environmentally damaging and feasible alternative - a term that comes from the Clean Water Act for a practicable alternative that would have less adverse impact on the aquatic ecosystem than other proposed project alternatives.

Lead Agency - the public agency that has the principal responsibility for carrying out or approving a project. The lead agency will decide whether a project is subject to the California Environmental Quality Act (CEQA) or is categorically exempt, and if subject to CEQA, what level of environmental analysis/document will be required for the project. The lead agency is responsible for preparing the appropriate CEQA document.

Like for like mitigation - meaning impacts to one habitat, species, or function are compensated for with a similar (if not identical) replacement (e.g. if one large oak tree is removed it is replaced with one large oak tree at a suitable site - most likely onsite, but in some instances may be located offsite).

Livestock – The horses, cattle, sheep, and other useful animals kept or raised on a farm or ranch. (Integrated Pest Management, Geology and Soils, Conservation Grazing Management, Forest Management, Ecological Succession, Wildland Fire)

Livestock Protection Methods – Wildlife and livestock conflict mitigation tools that promote the protection and continued conservation of wildlife while safeguarding **conservation grazing** as a management tool (Conservation Grazing Management).

Minimization - modifying the way an activity is to be undertaken in order to reduce the potential or actual impact to a resource. Minimization is the next preferred method to reduce project impacts when a potential impact cannot be completely avoided.

Mitigation - a single or a suite of measures that minimizes, or effectively eliminates the impact(s) of a given activity on the environment. Project mitigations may come from California Environmental Quality Act (CEQA), state and federal permits, or county or local ordinances.

Mitigation (or Conservation) banks - a system where landowners can permanently create certain habitats targeting specific listed species or other regulated features such as wetlands in order to use these features for actions anticipated to occur in the future for which mitigation will be required. Landowners can create banks to offset their own impacts or may sell the mitigation credits to other parties causing impacts in similar ecosystems elsewhere.

Mitigation credits - units of habitat that are preserved or protected (typically measured in area) that may be used, purchased or sold to offset impacts from an action for which mitigation is required.

Mitigation Credit Agreement (MCA) - formal agreement that creates mitigation credits by implementing conservation or habitat enhancement actions identified in a California Department of Fish and Wildlife (CDFW) approved Regional Conservation Investment Strategy. Credits developed under an MCA may be used as compensatory mitigation for impacts under CEQA, the California Endangered Species Act, and the CDFW Lake and Streambed Alteration Program.

Mitigation Monitoring and Reporting Plan or Program (MMRP) - specifies what the mitigation is, the entity responsible for monitoring the program, and when in the process it should be accomplished. The MMRP is designed to ensure compliance with Public Resources Code Section 21081.6 during implementation of mitigation measures which requires the Lead Agency, for each project that is subject to the California Environmental Quality Act (CEQA), to monitor performance of the mitigation measures included in any environmental document to ensure that mitigation does, in fact, take place.

Mitigation ratio - defined as the number or extent of compensatory restoration efforts, relating the scale of impact to a greater scale of restoration.

Native – Those elements of the natural world occurring within an ecosystem prior to disturbance from an outside event. (Vegetation Management, Wildlife Management, Integrated Pest Management, Water Resources, Geology and Soils, Scenic and Aesthetic, Cultural Resources, Research

and Collection, Conservation Grazing Management, Ecological Succession, Habitat Connectivity, Wildland Fire)

Natural – Plant, animal, and microorganism life, native materials, and ecosystem processes that make up the physical world. (Vegetation Management, Wildlife Management, Integrated Pest Management, Water Resources, Geology and Soils, Scenic and Aesthetic, Cultural Resources, Research and Collection, Public Interpretation, Conservation Grazing Management, Forest Management, Ecological Succession, Habitat Connectivity, Wildland Fire)

No-net-loss policy - a principle by which counties, agencies, and governments strive to balance unavoidable habitat, environmental and resource losses with replacement of those items on a project-by-project basis so that further reductions to resources may be prevented.

Non-Native – Species which moved into, or were introduced into, preserve environments as a direct or indirect result of human activities. (Vegetation Management, Wildlife Management, Integrated Pest Management, Geology and Soils, Scenic and Aesthetic, Conservation Grazing Management, Ecological Succession, Wildland Fire)

No project alternative - refers to 1) a project alternative whereby the impacts, costs, and staff resources necessary to implement the project consistent with the project goals outweigh the benefit to the District, resulting in a recommendation to not implement the project. 2) the potential impacts that may result from not undertaking the project (e.g. a culvert continuing to cause erosion without replacement).

Non-Target Organisms – those plants and animals that are not intentionally targeted by a pest management strategy in order to spare benign and often beneficial species. (Integrated Pest Management)

Northwest Information Center – A clearing house for historical and archaeological information associated with the California Historical Resources Information System, which houses historical documents, site reports and other research pertaining to cultural resources in Northwest California. (Cultural Resources)

Old Growth – Stand or residual (uncut) trees in excess of 200 years old, often characterized by very large trees, large plated bark, broken, dead or forked tops, with a prevalence of mosses and lichens on large branches within the canopy. Old growth stands also typically include large snags and large downed logs. (Forest Management, Wildland Fire)

Off-site mitigation - refers to compensatory mitigation distant from the area of impact.

On-site mitigation - refers to working within or immediately adjacent to the Area of Potential Effect to implement the compensatory restoration and is the generally preferred standard for both the District and most permitting agencies.

Open Space – Land and water areas that remain in a natural state and are minimally developed, and may include compatible agriculture uses. (Wildlife Management, Water Resources, Geology and Soils, Scenic and Aesthetic, Cultural Resources, Public Interpretation, Conservation Grazing Management, Forest Management, Ecological Succession, Habitat Connectivity, Wildland Fire)

Outreach – The communication of the District's mission and goals to a wide variety of audiences usually conducted away from the office or preserves. (Integrated Pest Management, Public Interpretation, Forest Management, Wildland Fire)

Patch – A relatively homogenous type of habitat that is spatially separated from other similar habitat and differs from its surroundings. (Habitat Connectivity)

Pathogen – A disease causing organism. (Vegetation Management, Forest Management)

Performance Measure(s) – Parameter(s) used to measure project success tied to project goals and objectives.

Permanent impacts - those impacts that convert habitat or affect resources in a durable fashion.

Pesticides – A broad term used to describe any material (natural, organic, or synthetic) used to control or prevent pests including herbicides (weed or plant killers), insecticides (insect killers), and rodenticides (rodent killers). (Integrated Pest Management)

Pests – Animals or plants that proliferate beyond natural control and interfere with the natural processes which would otherwise occur on open space lands. (Integrated Pest Management, Forest Management, Wildland Fire)

Plant Community – A group of plants growing in an interrelated manner on a particular site. (Vegetation Management, Integrated Pest Management, Ecological Succession, Wildland Fire)

Population – the number of organisms in a particular species that occupy the same geographic region at the same time and are capable of interbreeding (Vegetation Management, Wildlife Management, Water Resources, Habitat Connectivity, Wildland Fire).

Potential impacts - impacts that cannot be ruled out or confirmed definitively until some future assessment is completed or the work is implemented.

Potentially significant impact(s) - based on substantial evidence, a project (or portion of project) is determined to have a significant effect on the environment under CEQA and therefore the environmental impact requires mitigation to reduce the impact to less than significant.

Predation – a biological interaction where a predator (an organism that is hunting or browsing) feeds on its prey (the organism that is hunted or consumed). (Integrated Pest Management, Wildlife Management, Habitat Connectivity)

Prehistoric – Dating from periods of human activity prior to the use of written history. In the American West, prehistory generally refers to all periods before European colonization of the region. (Cultural Resources)

Prescribed Fire – Fire applied to wildland ecosystems under specified fuel and weather conditions to accomplish predetermined resource management objective such as regeneration of sensitive species in a fire-adapted plant community. (Wildland Fire)

Programming – The regularly scheduled organized, topic-specific presentations or other delivery of information, including community outreach, education, interpretation, and docent led activities, or other special events. (Public Interpretation)

Recovery - is the process that *stops the decline* of an endangered or threatened species by removing or reducing threats and ensures the long-term survival of the species. Recovered habitat (natural or restored) has documented use by target and non-target native organisms within a suite of healthy ecosystem functions. Once a target species is recovered, protection under the Endangered Species Act is no longer necessary.

Regional Conservation Investment Strategy - a voluntary, non-regulatory, non-binding conservation assessment that includes information and analyses of important species, ecosystems, protected areas, and habitat linkages at the USDA ecoregion scale and may include more than one ecoregion regional and must be approved by the California Department of Fish and Wildlife.

(Regional) net environmental benefit (net benefit) - the gains in value of environmental services (such as species and/or habitat enhancements) or other ecological properties (ecologic functions such as improved hydrologic connectivity) that are attained by an action minus the value of adverse environmental effects caused by the action that result in an overall improvement or net benefit to the environment at a regional scale.

Residual Dry Matter (RDM) – A measure of the amount of vegetation left on the ground, typically measured at the end of the summer or fall. Appropriate levels of RDM strive to minimize thatch, which can inhibit new plant growth, while maintaining adequate levels of vegetation to prohibit soil erosion. (Conservation Grazing Management)

Resilience – The capacity of natural and human communities to withstand and bounce back from climate stress and hazardous events. (Climate Change)

Resource Integrity – The extent to which character-defining features of a resource or its research potential remain intact. (Cultural Resources)

Resource Management – Management of both natural and cultural resources. Natural resource management generally consists of protecting, restoring, enhancing and monitoring native vegetation and wildlife, and monitoring and protecting the quality of geological and hydrological conditions. Cultural resource management consists of identifying and evaluating archeological sites and cultural landscapes. (Vegetation Management, Geology and Soils, Research and Collection, Public Interpretation, Conservation Grazing Management, Forest Management, Wildland Fire)

Resources – Plants, animals, water, soil, terrain, geologic formations, historic, scenic, and cultural features. (Vegetation Management, Wildlife Management, Integrated Pest Management, Water Resources, Geology and Soils, Scenic and Aesthetic, Cultural Resources, Research and Collection, Public Interpretation, Conservation Grazing Management, Forest Management, Habitat Connectivity, Wildland Fire)

Restoration – The process of returning land that has been degraded and disturbed into functional habitat. (Vegetation Management, Integrated Pest Management, Water Resources, Research and Collection, Forest Management, Wildland Fire)

Restoration action, activity, or project - An action, activity, or project whose primary purpose is to improve habitats and/or waters and has measurable environmental benefits.

Restore – To bring back to or put back into a former or original state. (Vegetation Management, Geology and Soils, Public Interpretation, Conservation Grazing Management, Forest Management, Ecological Succession, Habitat Connectivity, Wildland Fire)

Revegetation – The process of replacing existing vegetation on a site with desired vegetation. (Vegetation Management, Geology and Soils, Wildland Fire)

Riparian – Terrestrial environments adjacent to lakes, streams, springs and estuaries where transported surface and subsurface fresh water provides soil moisture for vegetation. (Wildlife Management, Water Resources, Geology and Soils, Forest Management, Habitat Connectivity)

Significance – A measure of the importance of an archaeological or historical resource. The threshold of significance determines eligibility for state and national registers and whether a cultural resource must be considered in NEPA and CEQA documents related to a project. The criteria detailed in CEQA by which significance (See Appendix A) is determined differ for historic and archaeological resources but include the resource's age, integrity, association with important individuals or trends in local history, and potential to provide important information about the past. (Cultural Resources)

Snag – A standing dead or partially dead tree, important wildlife habitat for woodpeckers and other cavity nesting birds, and small mammals. (Wildlife Management, Forest Management)

Soil – Natural material that covers much of the earth's surface; consisting of rock and mineral particles often mixed with organic matter. (Vegetation Management, Wildlife Management, Integrated Pest Management, Water Resources, Conservation Grazing Management, Forest Management, Habitat Connectivity, Wildland Fire)

Special Status – Species that are state or federally listed as threatened, rare, endangered, species of special concern, candidate species or those plant species listed by the California Native Plant Society. (Vegetation Management, Wildlife Management, Water Resources, Forest Management, Ecological Succession, Habitat Connectivity, Wildland Fire)

Stand – An aggregation of trees occupying a specific area, similar in age, size, arrangement and composition, that is distinguishable from the forest in adjoining areas. (Forest Management)

Target Pests – Plant or animal species that have a negative impact on other organisms or the surrounding environment and are targeted for treatment. (Integrated Pest Management)

Temporary impacts - those which do not result in a durable change or are short-term in nature.

Temporal loss - is an impact arising from a delay between impact and compensatory mitigation.

Third-party mitigation - refers to another entity either causing an impact requiring compensatory mitigation that is facilitated on District lands or facilitating compensatory mitigation outside of District lands on the District's behalf.

Ungulate Animals – Hoofed mammals, including ruminants, such as cattle, goats, and sheep, as well as horses, and donkeys. (Conservation Grazing Management)

Vector – An organism, such as a tick or mosquito, that is able to transport and transmit a pathogen to a host. (Integrated Pest Management)

Vegetation Management – The maintenance, establishment, or restoration of target vegetation that meets a preserve's management objectives. (Vegetation Management, Conservation Grazing Management, Wildland Fire)

Voluntary restoration - restoration undertaken for the sake of the underlying species, habitat, or process that is not a result of a CEQA and/or regulatory required mitigation.

Watercourse – A natural or artificial channel through which water flows. (Water Resources, Geology and Soils, Habitat Connectivity)

Waters – Areas of standing water, seasonal and permanent, such as lakes and ponds, as well as underground aquifers. (Water Resources)

Water Quality – The chemical, physical, and biological characteristics of water. Important issues related to forest management include water temperature, nutrients, and sediment inputs. (Wildlife Management, Water Resources, Conservation Grazing Management, Forest Management, Wildland Fire)

Watershed – A bounded hydrologic system, where all of the precipitation that falls drains into a single water feature, often a creek or stream. (Vegetation Management, Water Resources, Habitat Connectivity)

Wetlands – Areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted to life in saturated soil conditions (hydrophytes). (Wildlife Management, Integrated Pest Management, Geology and Soils, Conservation Grazing Management, Ecological Succession, Habitat Connectivity)

Wildland – Land in a natural uncultivated state that forms habitat for plants and wildlife. (Vegetation Management, Integrated Pest Management, Water Resources, Conservation Grazing Management, Wildland Fire)

Wildland-Urban Interface – The area where structures and other human development meet or intermingle with undeveloped wildland. (Wildland Fire)

Wildlife – A broad term that includes all living animals that have not been domesticated. (Vegetation Management, Integrated Pest Management, Water Resources, Scenic and Aesthetic, Research and Collection, Conservation Grazing Management, Forest Management, Habitat Connectivity, Wildland Fire)

Wildlife Corridors – Avenues along which wide-ranging animals can travel, plants can propagate, genetic interchange can occur, **populations** can move in response to environmental changes and natural disasters, and threatened species can be replenished from other areas. (Habitat Connectivity)

Woodland – A scattering of trees across a landscape intermixed with a significant component of another vegetation community, such as grass or

shrub land. (Vegetation Management, Forest Management, Habitat Connectivity, Wildland Fire)

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APPENDIX A. CEQA CRITERIA

This appendix outlines the CEQA Criteria of Significance for Historic Resources and Archaeological Resources:

HISTORICAL RESOURCES

A historical resource may be considered significant under CEQA if it is listed on the National Register of Historic Places (NRHP), California Register for Historical Resources (CRHR), or a local register (e.g., a town or county register), if it is determined to be eligible for the CRHR by a qualified expert, or if a Lead Agency finds it to be historically significant based on substantial evidence.

A resource is considered eligible for listing on the CRHR if it meets one of the following criteria:

- ◆ Criterion 1: Associated with events that have made a significant contribution to the broad patterns of local or regional history or the cultural heritage of California or the United States.
- ◆ Criterion 2: Associated with the lives of persons important to local, California, or national history.
- ◆ Criterion 3: Embodies the distinctive characteristics of a type, period, region, or method of construction or represents the work of a master or possesses high artistic value.
- ◆ Criterion 4: Has yielded, or has the potential to yield, information important to the prehistory or history of the local area, California, or the nation.

ARCHAEOLOGICAL RESOURCES

In addition to the definition of historical resources above (which can include archaeological sites), the following criteria for unique archaeological resources (California Public Resources Code 21083.2) determine significance under CEQA:

A resource is considered a unique archaeological resource if it meets one of the following criteria:

- ◆ Contains information needed to answer important scientific research questions and that there is a demonstrable public interest in that information.
- ◆ Has a special and particular quality such as being the oldest of its type or the best available example of its type.
- ◆ Is directly associated with a scientifically recognized important prehistoric or historic event or person.

APPENDIX B. PROJECT MANAGEMENT APPROACH

This appendix outlines the Project Management Approach to prevent and/or reduce environmental impacts that may occur with District Projects:

District projects should be managed to prevent and/or reduce environmental impacts through 1) **avoidance**, 2) **minimization**, 3) **internal mitigation** and 4) **purchase of external mitigation credits** (in that order).

AVOIDANCE

The first principle of the policy is **avoidance**, which directs District staff to document potential impacts to the resources and then to consider how to avoid those resources during the planning process. Avoidance is achieved through an analysis of appropriate and practicable alternatives and evaluating the impact footprint. This can mean physically working around a given resource or shifting the timing of the project. At times, a potential impact cannot fully be avoided regardless of how the project is designed or implemented. The same biological and cultural richness that motivated the District to protect and restore the land also creates a sensitive ecological and complex regulatory environment within which to operate. Full avoidance is often more achievable in degraded areas.

MINIMIZATION

If a potential impact cannot be totally avoided, then **minimization** is a way of modifying an activity to reduce the potential or actual impact to a resource. Minimization directs District staff to consider how to alter the project's scope, scale, or duration to lessen a potential or actual impact. Measures include shifting where or when the activities occur, changing the type of equipment to be used, or modifying the project scope or scale. The

Common avoidance measures include conducting activities away from avian nesting locations or deferring implementation until nesting season is over or until young have fledged.

A common example of an unavoidable potential impact is encountering a dispersing adult California red-legged frog in upland habitat. Although the federally threatened frogs are rarely encountered in that ecosystem, the potential for an encounter cannot be eliminated.

A beneficial pond restoration project can minimize potential impacts through careful planning within an inherently sensitive and highly regulated area; complex mitigation measures may include biological monitoring and species relocations may be required.

extent to which an activity or project can be modified to minimize impacts while meeting the project goals varies considerably. Some permits call for an **alternatives analysis** requiring demonstration and determination that the proposed project is the **least environmentally damaging practicable alternative**.

COMPENSATORY MITIGATION

The extent of avoidance and minimization directly affects the scale and cost of **compensatory mitigation**, i.e. measures taken to offset the unavoidable impact(s) remaining after avoidance and minimization actions are taken. Multiple types of mitigation are available to minimize, compensate, and/or restore the environment.

There is inherent uncertainty in whether mitigation will fully replace the functions that are lost from an impact. As a result, mitigation ratios must be increased commensurately with the risk that a one-to-one mitigation ratio will not achieve the designated compensatory goal (e.g. planting two trees to replace the loss of one mature tree hedges against the loss of a replacement tree over time due to drought, competition, etc.). Baseline mitigation ratios account for the uncertainty inherent in all mitigation work to achieve “no net loss” of sensitive community functions even if some (relatively small) portions of the mitigation fail to achieve the desired conditions.

TYPES OF COMPENSATORY MITIGATION

When a potential or actual impact is deemed necessary, unavoidable, and has been minimized to the greatest practical extent by the District, compensatory restoration measures are taken.

Compensatory mitigation involves either the restoration, establishment, enhancement and/or preservation of impacted habitats or waters either onsite, offsite, or a combination of the two. It frequently takes the form of revegetation and plantings.

A frequent form of compensatory mitigation comes from vegetation removal and replanting. New trails and bridges often require select vegetation removal. Compensatory plantings offset these impacts.

Compensatory mitigation concepts include:

- A. **Like for like**, meaning impacts to one habitat, species, or function must be compensated for with a similar if not identical replacement. For example, if a project removes riparian vegetation, planting riparian vegetation will likely be required as mitigation. This is also known as 'In Kind' mitigation. 'Out of Kind' is the direct opposite, where different habitat types are recreated than those impacted.
- B. A **Mitigation ratio** can be defined as the number or extent of compensatory restoration efforts, relating the scale of impact to a greater scale of restoration. Usually 1:1 for low quality habitats or temporary impacts and as high as 10:1 for difficult to replace habitats. For example, removal of a large, mature tree could require planting three to six times as many seedlings.
- C. **On-site mitigation** refers to working within or immediately adjacent to the area of impact to implement the compensatory restoration and is generally preferred by most permitting agencies. This can be the simplest method of compensatory mitigation but may not be feasible if the site is not practical for restoration (e.g. the area is too remote for efficient management, or the site does not have the space for the required restoration).
- D. **Off-site mitigation** refers to compensatory mitigation distant from the area of impact. The general permitting agency preference is to mitigate as close as possible to the area of impact, preferably within the same watershed or Preserve if on-site mitigation is not possible.
- E. **Third-party mitigation** refers to another entity either causing an impact requiring compensatory mitigation that is facilitated on District lands or facilitating compensatory mitigation outside of District lands on the District's behalf. Third-party mitigation is discussed in greater detail below.

Mitigation for impacts to species that do not or are not likely to occur in highly degraded areas result in less efficient use of mitigation funds. In this case, using off-site mitigation can fulfill the permitting and mitigation requirement and result in higher net environmental benefits.

No mitigation banks exist within the District's service boundary except for saltwater wetlands in San Francisco Bay. The Central Valley, by contrast, has many privately held mitigation banks for vernal pools and other species. California has the most mitigation banks in the nation.

The Santa Clara Valley Habitat Plan and Habitat Agency function similarly to a mitigation bank within their defined area.

In-lieu fees are similar to mitigation banks, but rather than transferring the funds soon after to an existing physical habitat, the fee goes towards future restoration activities, typically administered by a government agency.

- F. **Conservation or Mitigation banks** are a system where landowners can permanently create certain habitats targeting specific listed species or other regulated features such as wetlands to anticipate mitigations that may be required in the future or to sell as **credits**. This can be achieved through an informal process (e.g. defining a tree restoration area) or to sell the credits (i.e. units of habitat typically measured in area) created by the mitigation (or conservation) bank through a formal process to other parties who are causing impacts elsewhere in the region. **Informal mitigation banks** are areas of potential restoration that consolidate compensatory mitigation of many upcoming projects, thus avoiding temporal loss, without being regulated as a bank. **Formal mitigation banks** are regulated by the agencies that oversee them.
- G. **Regional Conservation Investment Strategy and Mitigation Credit Agreements** A mitigation credit agreement (MCA) is developed under a California Department of Fish and Wildlife-approved Regional Conservation Investment Strategy (RCIS). The RCIS Program encourages a voluntary, non-regulatory regional planning process to facilitate higher quality conservation outcomes and includes an **advance mitigation** tool.
- H. **No project alternative** refers to a staff recommendation whereby the impacts, costs, and staff resources necessary to implement the project consistent with the project goals outweigh the benefit to the District, resulting in a recommendation to not implement the project or to substantially revise the project goals.

Stanford University has funded trail projects on lands outside of the university, including District lands, through its General Use permit with the County of Santa Clara to mitigate for the loss of public recreation and open space opportunities on Stanford lands resulting from their development.

THIRD-PARTY MITIGATION

Third-party mitigation is complex and nuanced because it can involve impacts to habitats outside of District lands (or potentially the District's sphere of influence). Off-site compensatory mitigation for these impacts may be the only possible or most preferable mitigation approach especially for private landowners or other government agencies who do not

own multiple areas of similar habitat. District lands could benefit from receiving compensatory mitigation from a third party to facilitate additional restoration beyond the current capacity of the District. Third-party mitigation can also come in the form of grant funding, matching funds, or other measures that support District activities to acquire conservation easements and/or fee-title or pursue **voluntary restoration** projects.

Historically, the District has, with a few exceptions, completed its compensatory mitigation within District lands. Defining the circumstances in which off-site, third-party mitigation is preferable requires consideration of the nature of the impacts, the cost of restoration, the benefit of restoration, and other factors. While the primary focus of the RM policies is on District activities and practices, it is also the primary lens through which to evaluate outside parties' activities and policies. The same drivers that may cause the District to involve a third-party in compensatory mitigation can be used to evaluate a request from an outside party to support or conduct mitigation on District lands.

RESTORATION

Site specific mitigation may reduce impacts of a specific action or improve a site-specific condition, but rarely provides regional or ecosystem-wide benefit. However, **ecological restoration** is an intentional activity initiated by the District that accelerates the **recovery** of an ecosystem with respect to its health, integrity, and sustainability and goes above and beyond mitigation or **enhancement** of a localized site. To fulfill the District's mission *to protect and restore the natural environment* and provide regional **net-positive** environmental benefits (producing greater benefits at a landscape scale), the District places strong emphasis on implementing high priority restoration and recovery work focused on specific sensitive habitats, populations, and ecological processes in high conservation value areas.

Whereas mitigation must offset impacts from a project to ensure no net loss of habitats or waters, **a restoration project** has the primary purpose of improving habitats and waters and has measurable environmental benefits. When coupled with a restoration project or component, a compensatory mitigation action may include additional habitat or watershed improve-

***Restoration** encompasses all activities that restore an ecosystem, including those required by a mitigation and **voluntary restoration**, which is implemented solely for the purpose of resource enhancement.*

Opening Mount Umunhum involved both a development project (new site amenities, parking and trails) that required mitigation, as well as a habitat restoration project (recontouring the summit and repopulating with native plants). Installing regulatory-required mitigation plantings within the native plant restoration area reduced the need for additional mitigation planting sites and furthered two parts of the District's mission: natural resource restoration and public enjoyment and education.

ments beyond what are required by permits or CEQA to seek a 'net positive' benefits to the environment. Some of the factors that affect whether restoration actions are feasible or advisable include available physical space, cost, and ecological benefit. High quality restoration and habitat enhancement sites are carefully evaluated and prioritized before selection. As a result, high priority sites may not always be located near or within the footprint of the project that causes the original ground disturbance, and instead may be located elsewhere in areas of high conservation value where restoration would be the most beneficial at regional, watershed, and ecosystem scales to achieve a high net positive environmental benefits.

Restoration projects are frequently located in or adjacent to rich habitats and often require avoidance and minimization measures for incidental impacts and at times compensatory mitigation to complete, even though the project action itself is overall beneficial for the environment (i.e. even a voluntary restoration project can include a mitigation component if a resource will be affected by the restoration work). An important planning strategy is to combine various public access and/or repair projects with habitat restoration projects to allow the District to focus its mitigation work on high-value restoration sites for the highest net-positive environmental return for the time and funding allocated toward the mitigation work.

The District conducts many voluntary restoration projects each year, from small scale invasive plant removal to large scale restoration with heavy equipment. Some of these projects may require mitigation and some may not. A small-scale volunteer activity removing invasive plant species such as French broom by hand may not have any adverse impacts to the environment and may be able to move ahead without mitigation. Larger restoration projects, such as decommissioning an old road, may involve heavy equipment working near a stream and require mitigation to offset incidental impacts. At times, public access or other development projects require compensatory mitigation often in the same areas as voluntary restoration projects.

Conservation Management Units (CMUs) are protected areas designated by the District as areas of high restoration and conservation priority. CMUs are defined in Board Policy 4.01 "Acquisition & Maintenance of District

Lands”, Section E as: “areas within preserves, or possibly entire preserves, which because of certain criteria limiting their use, are planned and subsequently managed primarily for preservation of natural resources and viewshed.” CMUs are frequently the focus of voluntary restoration projects and off-site compensatory mitigation because of their high-quality habitats.

APPENDIX E

IPMP Forms



Midpeninsula Regional Open Space District New Pest Control Recommendation

Submitting Person

Date

Preserve

Location

Species

Common Name

Calflora Record Number

Date Last Assessed

Known Site
Conditions

- ☐ Access Issues
- ☐ Aquatic Areas (within 15 feet)
- ☐ Preserve Boundary (within 100 feet)
- ☐ Steep Slopes (Erosion Potential)
- ☐ T&E Species (within 30 feet)
- ☐ Other

Site History

Proposed Treatment

Year 1			

Work Force	☐ Contractors	Hours	
	☐ Staff	Hours	
	☐ Volunteers	PP days or ARMS Hours	

Year 2			

Work Force	☐ Contractors	Hours	
	☐ Staff	Hours	
	☐ Volunteers	PP days or ARMS Hours	

Year 3			

Work Force	☐ Contractors	Hours	
	☐ Staff	Hours	
	☐ Volunteers	PP days or ARMS Hours	

ENVIRONMENTAL SITE REVIEW FORM

Biologist _____

Date: _____

Preserve _____

Treatment Site _____

Photo Filename _____

GIS Filename _____

Target Species _____

Vegetation Type	Grassland		Brush		Wooded		
	0	0-1	1-5	5-25	25-50	50-75	75-100
% Cover - Target Sp							
Treatment Method	Manual		Mechanical		Chemical		

Sensitive Plant Species

Sensitive Animal
Species

Cultural Resources

Aquatic Features

Erosive Conditions

SOD Symptoms

Specific BMPs or other site conditions needs

Work Performed

Date: _____

Preserve _____

Reporter _____

Treatment Site _____

% Area Treated _____

Target Species _____

Person Hours

$$\frac{\text{Person Hours}}{\text{\# of People}} \times \frac{\text{Project Hours}}{\text{Person-Hours}} =$$

Herbicide Use

Product _____

Method _____

Amount of Concentrate (oz) _____

Post Treatment Survey

Surveyor _____

Photo Filename _____

Date _____

Signs of Herbicide Damage (Target)

Signs of Herbicide Damage (Non-target)

New Environmental Issues

Recommendations for next treatment

Additional Comments

Project ID

Safe	
Human Health	
The proposed method is the safest method for workers at that location.	
There are human occupied facilities nearby (trails, parking lots, buildings, school, etc.).	
Environmental Health	
The pest provides habitat for beneficial species.	
Removal method would cause a seed bank flush or erosion issues.	

Prevents and Controls Most Destructive Pests	
Prevent	
The species is listed as a State or Federal noxious weed.	
The species is listed as a Cal-IPC Alert and/or Cal-IPC or District watch list.	
The species' Cal-IPC rating is ...	
Control	
This is the only population of the species at the preserve.	

Protects Biodiversity	
The removal will ...	
assist in the recovery of a Special Status Species.	
protect a sensitive ecological community (wetlands, serpentine grassland, coastal prairie).	
actively protect against spread of pathogens.	
assist in retaining a bio-diverse community.	
The species is allopathic or can change the soil chemistry.	

Provides for Public Engagement	
The project has significant public interest and/or support.	
The project provides for the participation or education of the public.	

Feasible and Effective	
The project be done with existing staffing and/or funding.	
There is a high level of anticipated outcome (Cost/Benefit)	
The treatment method is considered the most effective.	
The project method will reduce the overall maintenance of the area.	

Comment

APPENDIX F

Early Detection and Rapid Response Protocol

Early Detection / Rapid Response Protocol

INTEGRATED PEST MANAGEMENT PROGRAM



MIDPENINSULA REGIONAL OPEN SPACE DISTRICT

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Introduction

One of the most important aspects of a successful Integrated Pest Management (IPM) program is early detection and rapid response (EDRR). The goal of EDRR is to detect new populations of invasive plants while populations are still small, and eradication is achievable. For some of the most aggressive invasive species, a rapid response to a new infestation is the only way that eradication can be achieved. Treatment of a small initial population can be accomplished with limited resources as compared to the significant investment of time and resources that is required to treat well-established infestations.

The key components of an early detection program are prioritizing areas to be surveyed, performing surveys to identify new populations and inventory existing populations, and rapid response treatments to any significant discoveries.

Preventing the introduction of invasive species is the first line of defense against invasions. However, even the best prevention practices will not stop all invasive species introductions.

Early Detection and Rapid Response (EDRR) programs increase the likelihood that invasions will be addressed successfully while the population size and extent are not beyond that which can be contained and eradicated on both practical and economic scales. According to the 2005 California State Noxious Weed Plan, “early detection

is the single most important element in successful and economical eradication of new weeds before they become permanently established in new localities” (California Department of Food and Agriculture, 2005).

Objectives for the District’s Early Detection / Rapid Response Program are:

1. Identify potential threats in time to control or mitigation measures to be taken;
2. Detect new invasive species in time to allow efficient and safe eradication or control decisions to be made;
3. Respond to invasions effectively to prevent the spread and permanent establishment of invasive species;
4. Educate staff, partners and the public about emerging threats from invasive species, and encourage public participation in the program;
5. Adaptively implement early detection and early response strategies over time.

EDRR Species List

The EDRR Species list is a critical tool for any EDRR program, and must be adaptable and revisited regularly. Maintaining an EDRR list allows the District to easily communicate target species to a wide audience, and be used as a tool for ‘passive’ early detection:

- The search criteria for a CalFlora Saved Search
- The search criteria in iNaturalist for a project

If the list is too long, it becomes too burdensome for the botanists performing the surveys, and decreases the likelihood that non-botanists will be able to learn the species on the list, and will therefore have a decreased ability to make valuable detections in the field.

District preserves stretch across 40 miles of the Santa Cruz Mountains, and as a result, often have different microclimates, veg type, soil type, and even tectonic plates. Because of this, maintaining smaller, more precise EDRR target lists for specific preserves or regions will be beneficial, and can be distributed to ARMS volunteers, docents, and patrol and maintenance staff as appropriate.

EDRR List Updating Process

1. Start off with EDRR plant list from the IPM EIR (Table 10-4, pg 297)
2. Identify candidate species for EDRR list
 - a. Search CalWeedMapper tool by county or WMA to identify candidate species
 - b. Consult with WMA members
 - i. Compile individual agency’s EDRR lists
 - ii. List Priority management species on their land that are not yet present on District preserves
 - iii. WMA Strategic Plan species lists
3. Develop a two-tiered EDRR list
4. Annual review by IPM Coordination team to review and update EDRR list
5. Develop additional EDRR lists by Preserve or by Field Office

Survey Protocol

Protocol development

limited time and funding requires concentration on realistic goals to optimize limited surveying capabilities. Thus, surveys are performed in a style that maximizes survey efforts based on the probability of observing invasive plants and decreasing their potential to spread. Invasive plant occurrence can be assessed by estimating the varying degrees of propagules pressure and resource availability for sites throughout the District. This method should:

- maximize invasive plant observations
- decrease spread of invasive plants (because we will concentrate on dispersal corridors)
- facilitate treatment efforts

An EDRR Program is a formalized monitoring program that utilizes active and passive land surveillance as a method to discover and identify new invasive species or their symptoms before they become widely established. This can be accomplished with 1) active detection, 2) passive detection, and 3) syndromic surveillance as defined by the National Invasive Species Working Group (National Invasive Species Counsel 2003, 2008).

- **Active Detection:** Active detection programs have structure, staffing, and dedicated funding to accomplish land surveillance (landscape-level invasive plant monitoring). Dedicated staff, volunteers, or contractors under a specific set of goals may run these programs. Active detection programs for invasive species often have limited resources so it is important to be focused on high-priority targets, such as high-risk locations, high-value resources, important pathways, and populations and species of concern.
- **Passive Detection:** Passive detection programs have more limited goals and structure that are embedded into existing programs and activities. These programs fortuitously detect invasive species as staff, volunteers, or contractors conduct other activities and may or may not have specific training or funding for the detection of invasive species.
- **Syndromic Surveillance:** Syndromic surveillance uses the analysis of other resource management problems to detect invasive species indirectly through their direct damage or other ecosystem disruption. Detecting the damage associated with invasive species may be the first indication of a new invasion. This is often the case with invasive pathogens and parasites that are difficult to detect.

Survey Area Prioritization

Ranking of Most Likely Pathways of Invasive Species Introductions (Identification of Areas and Activities to Prioritize for Early Detection Monitoring)	
Ranking of vectors' Probability to Import/Distribute Invasive Plants	
1	Heavy equipment from outside District
2	Top soil importation for construction
3	Sand or gravel for road construction
4	Work activities along rights-of-way external to District (e.g., PG&E, CalWater)
5	Work activities of District employees or contractors
6	Grazing lessees/livestock grazing

7	Visitor vehicle traffic
8	Wind
9	Visitors hiking
10	Wildlife
11	Water

New invasive species may arrive in the District through sudden, unpredictable pathways (e.g., boots on a traveler) and more constant, predictable pathways (e.g., roads, trails, and/or horticultural escapees from neighboring properties). District lands are scattered throughout the San Francisco Peninsula, adjacent to urban development, rural private residences and hobby farms, and production agricultural landscapes including rangelands, dairies, commercial nurseries, and row and cereal crops. Each of these lands uses account for some possible introductions of invasive species along preserve borders, roads, trails, and easements. Areas should be prioritized based upon the likelihood for invasive plants to establish. The highest priority areas will be those that receive constant disturbance along with a steady source of vectors. Areas with significant biological resources such as rare plants may be higher priority simply because of the resources at risk.

The most efficient way to prevent routine introductions of invasive species into District lands is to use vigilant patrol and monitoring protocols along District boundaries that interface with urban and agricultural landscapes. Trails, roads, and waterways intersecting District lands are the most likely routes of invasion for new species. Many of these common pathways have been confirmed by previous District mapping and planning work (District 2004). Refer to Chapter 5, IPM Program Implementation, for more information on how the District intends to implement this action during IPM Program implementation.

The District maintains approximately 142 miles of single-track trail, 444 miles of road, and has a geographic border (not including adjacent District parcels) totaling 397 miles. Not all of these trails, roads, and edges have the same potential to introduce new invasive species into District properties. Locations within the District that receive the most intense impacts from disturbance, visitation, utility maintenance, and neighboring land use are the most likely sources for new species introductions. Simple models can be used on a local preserve level to analyze probable pathways for key invasive species the District may expect to encounter. The District can identify routine and sporadic activities that have a high probability of introducing invasive species and also the types of species anticipated.

Vegetation Type

The vegetation type is an important consideration when prioritizing areas for surveys. Habitat types with higher resource availability are most susceptible to invasion as there are often excess resources available (Davis et al. 2000b). Habitat types that are conducive to invasion include: open canopy meadows, riparian areas, and seeps. The extra water availability and more nutrient rich soils present in these locations can be exploited by invasive plants. Vegetation types such as dense canopy red fir forest rarely harbor weed infestations. A dense canopy allows very little sunlight, and thin granitic soils offer few resources. Places where high resource areas converge with disturbance and vector sources- e.g. trails crossing streams, roads through meadows are of particular interest as they are some of the most likely locations for invasive plants to establish.

Disturbance

Many invasive plants are well adapted to colonize freshly disturbed ground. This can be a result of newly available resources or stimulation of the seed bank through scarification. Areas that receive perennial disturbance such as roadsides and parking lots have been observed to have high levels of exotic species richness. All surveys, regardless of habitat should concentrate on patterns of disturbance.

Human Use

Humans are perhaps the most substantial invasive plant vectors. We are not only significant disturbance agents, we also act as vectors that can transport invasive plant propagules on clothing, vehicles, gear etc. (Mack and Lonsdale 2001). The areas with the most notable species present in Yosemite surveys were those areas with heavy human use, particularly immediately surrounding employee housing and facilities.

Existing Infestations and Dispersal Corridors

Invasive plants must disperse from an existing propagule source. While some dispersals will occur over long distances, short-range dispersal by an outside vector such as humans, wildlife, or waterways are far more common. As such, it is important to survey travel corridors that pass through known infestations of invasive plants as they will double as distribution corridors for propagules.

Vectors such as humans and wildlife can transport propagules along roads and trails. Waterways such as streams and rivers can transport propagules downstream along riparian corridors. Wind dispersed species can travel great distances from their existing populations.

Survey Timing

- Surveys will occur from (March-September)
- Each site shall be surveyed two times a year to capture early late season phenology
- Some targeted surveys targeting specific species may be timed during other parts of the year

Survey Return Intervals

Prioritization of Specific Areas for Monitoring Based on Suitability for Invasion and Volume of New Plant Material (Seeds, etc.) likely to be Introduced		
Very high priority		Survey Return Interval
1	Construction/maintenance areas	Annual, up to 3 years
2	Buildings, houses at the urban interface	1-3 years
3	Paved areas (e.g., roads/parking lots/trailheads)	3 years
4	Landscaped areas	3 years
5	Disturbance from human intervention (e.g.,	Annual, up to 3 years
High Priority		
6	Trails (near/far)	3years / 5 years
7	Areas of high visitor use	1-3 years
8	Utilities (e.g., cell towers, powerline corridors)	3 years
9	Pastures/agricultural areas	5 years (annual at Toto)
Medium priority		
10	District offices, structures	2 year

11	Riparian areas	5 years
12	Natural disturbances with no human intervention	Annual, up to 3 years
Low priority		
16	Off-trail wilderness areas	Opportunistically
Source: adapted from Gerlach et al. 2001		

Areas should be categorized, and a survey return interval should be created for each category. Areas with higher exotic species cover or notable discoveries should have a shorter time between surveys. Wilderness or other areas with very low likelihood of weed establishment only need to be surveyed every few years, while some places such as stables and low elevation housing areas should be surveyed annually.

A survey return interval will help plan what the survey needs are for any given year. This process could be automated in a geodatabase by assigning different areas different values and keeping track of surveys. This will increase the integrity of survey regimes by being able to automatically mark what areas need to be surveyed that year.

Passive Early Detection

Calflora Saved Searches

Use CalFlora saved searches and email Alerts for Midpen and WMA EDRR lists.

iNaturalist

Create and monitor an iNaturalist project to receive alerts about new detections of priority species.

Data Management

CalFlora Weed Manager

Invasive Plant Points and Polygons

All data will be stored within the CalFlora Weed Manager database, and will be collected in the field using Android or iOS mobile devices running CalFlora Observer Pro. CalFlora allows for easy sharing of data across organizations and to the public, which is a critical component of a regional early detection strategy.

Survey Entry

Record GPS track logs during surveys and upload to Calflora Survey Entry

Work Session Entry

Track hours for survey time and labor for invasive plant treatment.

Plant Voucher Collection

Voucher specimens should be collected for all invasive species found in the District. At least one specimen of each species shall be deposited into a reference herbarium to serve as a plant identification resource for District staff. New species discovered for the district or the county shall be vouchered and deposited into a local herbarium. Processing botanical specimens can take a considerable amount of time, and time must be budgeted in the winter to process specimens collected in the previous field season.

When to collect a voucher:

- First recorded occurrence of a species in a given area
 - District
 - Preserve
 - County
- Last voucher in the area was collected more than 20 years ago.

Rapid Response

Treating small invasive plant populations before they thoroughly establish and create infestations is of utmost importance, and for some species, is the only way that eradication can be achieved. When plant populations are small and isolated, immediate treatment by the surveyors is ideal. Whether or not the surveyor will treat a population is a judgment call that must be made by the surveyor.

They must consider the time it would take them in addition to the time investment required to reach the population. In the case of a remote infestation in the wilderness that may take a day or more to access, a surveyor taking the time to treat the entire population manually may be more efficient than sending a work crew out at a later date. The phenology of a population when it is discovered is an important consideration because it must be treated before seed dispersal occurs. In cases where a population is flowering or fruiting, the surveyor should try to mitigate seed dispersal through the removal of flowering and fruiting structures. These seeds should be packed out and disposed of, but on prolonged backcountry trips, careful burning is an option.

Training

Providing in-person trainings and education materials for staff, volunteers, and members of the public not directly involved in the EDRR program is a crucial component of an EDRR program. Trainings help raise awareness of the program, target species, and the importance of early detection of invasive species. This will increase the capability of opportunistic early detections. An annual training at a Midpen all-staff meeting or as a brown bag presentation should be provided an available to all staff and volunteers.

Early detection monitoring can be accomplished by staff, volunteers, park patrons, or contractors. The utilization of existing natural resource management and maintenance staff and volunteers provides the best value for the District. With limited training, existing staff resources can be utilized and repurposed for early detection monitoring at minimal additional cost although it will not be a comprehensive effort.

In a world with millions of species, detecting a new arrival can sometimes be a challenge since very few people have adequate training to identify foreign and unfamiliar species. However, there is potential to train staff and volunteers familiar with District habitats to notice and report when species are found that appear unusual or out-of-place. In addition to new invasive species, other resource management targets such as rare plants and animals may also be discovered through this type of observation.

EDRR Identification Guides

Complete Guide

Develop a simple invasive species identification guide for use by laypeople. Include invasive species currently known to occur in District preserves (Table 10-2), as well as “Watch List” species known to occur in the regions

(Table 10-4). The identification guide should include photographs (several life stages), life cycle, and associated habitats. As funding and staffing allow, update this identification guide over time to ensure its usefulness in EDRR efforts. The IPM Coordinator will coordinate regularly with local agencies who track and monitor invasive plants in the region, such as California State Parks, San Mateo and Santa Clara Weed Management Areas.

Cal-IPC EDRR Species ID Cards

Cal-IPC currently maintains over 100 Species ID cards for the purpose of raising awareness about high priority invasive species. The District should assemble a set of these cards from the District's EDRR list, and develop additional cards for any species that have not yet had cards developed. All ID cards that the District develops should be shared back with Cal-IPC so that other land managers and native plant communities throughout the state can benefit

Sets of EDRR Species ID cards should be located in prominent locations throughout the District, including:

- Each field office
- All District vehicles
- AO break rooms
- AO lobby
- Downloadable from the Midpen website
 - Include a flyer with QR code with link to ID cards at trailhead boards with data service

CalFlora Training

Offer an annual training for permanent and seasonal Rangers, Open Space Technicians, volunteers, and contractors.

Volunteer Recognition Events

- Host an iNat / CalFlora mapping demo at VRE event?
- Present awards and shout-outs to active volunteers

Roles

Staff-based approach

EDRR is an ongoing and constant surveillance effort, and is a core function of the IPM program. In order to maximize success, EDRR must be considered a program and not a project, and EDRR surveys and treatment should be performed by District staff. The presence of biologists at each field office will encourage daily interactions between Natural Resources and other divisions, and raise awareness of EDRR and invasive species as a whole.

IPM Coordinator

Continue to perform pre-treatment surveys along District roads and trails, mapping target EDRR species.

EDRR Botanists

The ideal workforce for EDRR surveys is a team of two year-round botanists. EDRR surveys will take up approximately 6 months out of a given year, from approximately March-September. For the remainder of the

year, the botanists could be embedded with the Natural Resource field crews¹, one at each field office. During the crew-portion of the year, the botanist is responsible for recording significant plant observations encountered during the course of their work. Interns could be paired with botanists to assist with surveys and data management.

Field Crews

- Distribute EDRR guide
- CalFlora Training (annual/biannual)
- Attend Annual EDRR training (during pesticide safety and IPMP training?)
- Perform Rapid Response treatments, as needed

Rangers

- Distribute EDRR guide
- CalFlora Training
- Attend Annual EDRR training

Volunteers

- Distribute EDRR guide
- Assign specific sites to ARMS
- Hold special Rapid Response volunteer programs
 - Help raise awareness of EDRR among volunteers
 - Provide a meaningful project that makes a significant difference

Trail Patrol

- Distribute EDRR guide
- Attend annual EDRR training

Docents

- Distribute EDRR guide
- Attend Annual EDRR training

ARMS

The ARMS program is shifting towards an adopt-a-site model, where each volunteer is tasked to re-visit their assigned sites at least 2-3 times per year. This will result in ARMS volunteers developing an intimate familiarity of the plant community at their site, and facilitate the early detection of new invasive species that colonize the area. Even if an ARMS volunteer does not have well-developed plant identification skills, intimate site familiarity will facilitate detection of unknown plants.

Additionally, when newly discovered invasive species are found at a site, the ARMS may be able to treat the infestation.

EDR-ARMS

Develop a new type of volunteer that performs targeted surveys for select early detection species. This is a good option for ARMS or Preserve Partners volunteers who are not physically able to continue manual labor, but want

¹ This is assuming that Natural Resource crews are realized. A botanist embedded on Land & Facilities crews would also be beneficial.

to continue with IPM, and for trail patrol volunteers who have botanical skills or would like to contribute to IPM without pulling weeds.

Contractors

The District should only utilize contractors and consultants for surveys if dedicated staff is unfeasible. Early detection surveys require strong local botany skills, so consultants should have demonstrated knowledge of local flora.

Outreach and Community Education

A critical component of an EDRR component is education of the public on target species. Educating the public allows for a greater likelihood of incidental observations

- Targeted social media-
 - EDRR plant of the month? (during identification period only: e.g. flowering or fruiting)
 - Social media posts to highlight:
 - new species found,
 - regional cooperation
 - rapid response success stories
 - weed prevention tips
- Prevention & EDRR education
 - Series on 1-page tips on prevention
 - Boot cleaning
 - Vehicle cleaning
 - Heavy equipment cleaning
 - Neighbors should pull their weeds
 - Weed prevention screens on neighboring properties (?)
 - PURCHASE 1000 boot brushes and distribute everywhere
 - Set-up a study to collect soil and seeds from boot brushes and bike brushes across the district
- Post EDRR list and photos on website
- Develop BOLO pages for each preserve
- iNaturalist Project

Regional Collaboration

Invasive species readily cross jurisdictional boundaries, and as a result, regional cooperation is imperative to achieve a successful EDRR program. The District is currently a part of several regional coordinating groups, all of which should be utilized to leverage efforts and build upon one another towards shared goals. Other public agencies are in various stages of development of EDRR programs, but it is important that each agency's EDRR program is complimentary to one another. In addition to public agencies, the District must partner with Resource Conservation Districts and County Agricultural Commissioners offices to survey and treat invasive species on private lands.

Regional collaboration with partners should include:

- Data sharing through CalFlora Weed Manager
- Sharing recent invasive species discoveries
- Coordination on cross-boundary surveys and treatments

Weed Management Areas

Weed Management Areas (WMAs) are a formal collaborative structure of public and private entities that facilitate collaborative weed management. Midpen is currently an active member of two Weed Management Areas: San Mateo and Santa Clara. Each WMA holds bi-weekly meetings which are a critical opportunity to share findings and discuss and coordinate treatment strategies. Through California Department of Agriculture (CDFA), who administers WMAs, there are opportunities for grant funding for collaborative invasive plant projects with WMA partners.

Role of WMAs in the District's EDRR Program:

- San Mateo and Santa Clara WMAs:
 - Share recent invasive plant discoveries
 - Coordinate collaborative surveys and treatments
 - Coordinate EDRR watch lists with other agencies
 - Apply for grant funding with WMA partners
- Santa Cruz WMA
 - Attend quarterly Santa Cruz WMA meetings.

Santa Cruz Mountains Stewardship Network

The Santa Cruz Mountains Stewardship Network is an organization that facilitates coordination and collaboration among network agencies. This network is poised to grow in the coming years, and could fill a similar role in interagency

There is a chance that at some point in the future, SCMSN adopts a role similar to

OneTam in Marin County is an excellent example of multiple agencies working together to implement a single survey protocol across boundaries. Individual agencies within the OneTam network are responsible for surveying their own land if they have the capacity to do so. OneTam staff fills in the survey gaps

Resource Conservation Districts

Continue partnership with San Mateo RCD to survey and treat specific target species on private lands near District preserves. Surveys and treatment efforts should bolster EDRR efforts on District lands.