Midpeninsula Regional Open Space District

R-22-17
Meeting 22-04
February 9, 2022

AGENDA ITEM 8

AGENDA ITEM

Award of Contract with Vollmar Natural Land Consulting for the Preparation of Habitat Restoration Plans for the Irish Ridge Area of Purisima Creek Redwoods Open Space Preserve

GENERAL MANAGER'S RECOMMENDATIONS

1. Authorize the General Manager to enter into a contract with Vollmar Natural Lands Consulting to provide ecological surveys, analysis, planning, and permitting assistance for land restoration work at Purisima Creek Redwoods Open Space Preserve for a base contract amount of $160,820.

2. Authorize a 10% contingency of $16,082 to cover unforeseen complexities or additional biological survey needs, bringing the total contract to a not-to-exceed amount of $176,902.

SUMMARY

The Natural Resources Department has identified the Irish Ridge area of Purisima Creek Redwoods Open Space Preserve as a high priority site for land restoration and by CalFire as a high priority site for improved fire safety. This report provides an overview of natural resource restoration options as well as informational gaps that need to be addressed to meet stewardship objectives. The General Manager recommends awarding a contract to Vollmar Natural Lands Consulting (Vollmar) of Berkeley, CA, for a not-to-exceed base amount of $160,820 to secure ecological services for restoring and maximizing the long-term natural resource values within the Irish Ridge area of Purisima Creek Redwoods Open Space Preserve. A 10% contingency of $16,082 is also requested to address unforeseen complexities or additional biological surveys, for a total not-to-exceed contract amount of $176,902. There are sufficient funds in the project budget to cover the recommended action through the end of the fiscal year. Funds for FY23 will be proposed as part of the annual budget and action plan process.

BACKGROUND

The Midpeninsula Regional Open Space District (District) purchased the first Purisima Creek Redwoods Open Space Preserve property in 1982 and has since incorporated additional properties, growing the Preserve to its current size of 4,711 acres. The trees at Purisima Creek Redwoods are predominantly second-growth redwoods of uneven age, with trees varying between 50 and 100 years old. The original redwood forest was logged in the late 1800s and early 1900s. The largest redwoods were approximately 1,000 years old when they were cut, with diameters between 10 and 20 feet.

Several large stands of non-native/non-local, invasive tree species have been identified in the Preserve and are presumed to have been actively planted in the Irish Ridge area before District ownership (Attachment 1: Project Location Map). These non-native trees were likely planted as a potential lumber crop; however, as is the case with many planted trees in the San Mateo coastal area, the trees proved to produce poor quality wood for lumber production due to twisted, uneven growth. The non-native/non-local trees at Irish Ridge have since grown into a dense overstory and now exclude many native species (including the rare Kings Mountain manzanita), provide poor quality habitat for rare species (e.g., federally and state listed marbled murrelet), increase the fire risk, and continue to invade surrounding areas, further displacing native species and degrading habitats.

The site has been identified by the Natural Resources Department as a high priority area to restore to more natural conditions, and by CalFire as a high priority to improve fire safety in the area.

DISCUSSION

Project Design Objectives and Requirements
The planned restoration work at Irish Ridge has three objectives: (1) protect and restore the natural resources, (2) increase climate change resiliency by increasing carbon sequestration through native forest restoration, and (3) reduce wildfire risk and improve the Irish Ridge Trail as a potential evacuation route per discussions with CalFire (the site is listed as a priority in the District's Wildland Fire Resiliency Program).

Strategies to meet the objectives include:

- Preventing or reducing/mitigating human-caused impacts, including erosion, invasion of non-native species, disruption of the natural water flow, degradation of water quality, trampling of vegetation, and displacement of wildlife;
- Protecting and restoring rare, endangered, special status species and sensitive habitats;
- Restoring the area as a composite resource, rather than as a separate and isolated area;
- Prioritizing ecosystem function, resilience, and ecological diversity focused on multiple species benefits;
- Accounting for climate change impacts to natural resources; and
- Increasing public knowledge, understanding, and appreciation of the natural and cultural resources of the preserves, and support for their conservation.

On November 18, 2020, the Board of Directors (Board) authorized the General Manager to enter into contract with Applied Technology & Science (ATS) for restoration feasibility studies of the Irish Ridge property (R-20-134, Minutes). ATS has since completed the Irish Ridge Restoration Feasibility Study (Attachment 2) and the Biomass Disposition Alternatives White Paper (Attachment 3).

The feasibility study completed by ATS focused on large, dense stands of non-native and/or non-local trees in the southwest corner of the Preserve (Unit 1: approximately 14 acres). A second potential restoration area has since been discovered by field staff during trail scoping for the Purisima-to-the-Sea Trail project (Unit 2: approximately 10 acres). This area is 2,000 feet west of where the Purisima-to-the-Sea Trail is expected to be located. Both of these areas were likely a mix of habitat types, including redwood forest, scrub, and grassland habitats prior to logging and habitat conversion resulting from the planting of non-native/non-local timber tree. The restoration goal for these areas is to restore a mix of native habitats, prioritizing redwood forest habitat due to its natural fire resiliency and carbon sequestration benefits. The table below describes the status and fire ecology of the non-native/non-local species recommended for treatment.

Common Name	Scientific Name	Status	Fire Ecology
Blackwood acacia	*Acacia melanoxylon*	Invasive, not native	Tolerant
Eucalyptus	*Eucalyptus sp.*	Invasive, not native	Tolerant
Knobcone pine	*Pinus attenuata*	Non-local, native	Obligate
Obligate – fire is required to complete its life cycle. Tolerant - withstands a degree of burning and continue growing. Fire germinates seeds. Highly flammable.			

Knobcone pines are considered a non-local species and were specifically planted in this location as a potential timber crop. The trees are of unknown origin. The nearest natural stand is over 20 miles to the south in Butano State Park. Knobcone pines are an obligate fire species; the species is dependent upon stand-replacing crown fire for reproduction.

Pathogen
A recent local study identified the presence of two fungal species associated with significant Bay Area-wide acacia mortality, including on San Francisco Public Utilities Commission (SFPUC) watershed lands. During a May 2021 inventory of Irish Ridge, the mortality and decline of acacia trees was estimated to be around 30%. The cause of this mortality remains undetermined; however, there is the potential for these fungal pathogens to also occur at this site. The mortality of non-local, native knobcone pines growing in the Irish Ridge property is approximately 50%, and significant amounts of leaking sap was observed on live trees.

Biomass Disposal
One of the largest obstacles to the restoration of these forest habitats is the large quantity of biomass that will be generated from the non-native tree removal. The recommended biomass disposal method for this site utilizes an air curtain burner. An air curtain burner blows high velocity air (curtain) into the upper portion of a combustion chamber, entrapping particulates (smoke) to significantly reduce air emissions and its affects to nearby sensitive individuals/receptors. This is especially important on cold, calm days, when smoke can become trapped close to the ground by a layer of warm air acting as a lid over a layer of cooler air (also known as an inversion layer). Inversions prevent the air below from rising, which causes pollutants to build up. Air curtain burners generate lower greenhouse gas emissions compared to that of trucking the material to an offsite disposal facility and avoid generating truck traffic disturbances to nearby residents. In addition, the proposed biomass disposal methodology eliminates the risk of spreading plant pathogens to other locations and reduces wood waste by 98% to 99%. See the U.S. Forest Service website for more information: https://www.fs.fed.us/eng/pubs/html/02511317/02511317.htm.

With the completion of Phase I – Feasibility Study, the District is now ready to proceed with Phase II – Preparation of the Habitat Restoration Plans.

Consultant Scope of Work Under the Recommended Contract for Phase II
The consultant scope of work to inform and develop the Irish Ridge Habitat Restoration Plan with the inclusion of Unit 2 and the known presence of two fungal pathogens includes:

- **Soil Sampling**: including horizons, texture, pH, and nutrient levels up to 24 inches below the surface;
- **Plant Litter Sampling**[1]: Representative sampling of accumulated plant litter depth;
- **Geomorphic Analysis**: Parameters will include, but not be limited to, slope, aspect, and solar radiation as developed from LiDAR data;
- **Reconnaissance-level biological surveys within Unit 2** to identify additional high-priority invasive weeds and native botanical resources; and
- **Identification of outlying invasive tree seedlings and saplings**.

These investigations will refine the revegetation objectives, define the desired future conditions, and inform the selection of appropriate reference sites.

The Restoration Feasibility Study references the Kings Mountain manzanita habitat suitability study and notes that there is potential habitat for this species within Irish Ridge. To recommend the best locations for reestablishing this particular manzanita species, the consultant will need to integrate field soil data with geomorphic and plant community modeling. This analysis and modeling will provide a solid understanding of when and how to incorporate these rare plants as part of the larger restoration project and provide a baseline for future monitoring and tracking to understand the level of success for their reintroduction into historic habitat areas.

Consultant Selection
On September 9, 2020, staff issued a RFQP for all phases of the project (Phase I – Feasibility Study, and Phase II – Preparation of Habitat Restoration Plans) by posting on the District's website and BidSync and emailing eleven firms with pertinent experience. A virtual pre-proposal conference was held on September 8, 2020 and attended by ten firms. The District received collaborative proposals from three separate teams by the October 9, 2020, deadline:

Lead Firm	Location	Phase I Proposed Fees	Phase II Proposed Fees	Total Proposed Fees
ATS	San Francisco, CA	$34,785*	$57,230	$92,015
Vollmar	Berkeley, CA	$34,840	$111,960*	$146,800
GPA Consulting	El Segundo, CA	$54,980	$82,830	$146,921
*Original proposed amount for each phase; these amounts were revised after additional scope was included during negotiations.				

After careful review of all proposals, staff interviewed the top two firms, ATS and Vollmar, deeming ATS as the most qualified and best suited for the project at a fair and reasonable price. ATS has since completed Phase I composed of the Irish Ridge Restoration Feasibility Study (Attachment 2) and the Biomass Disposition Alternatives White Paper (Attachment 3). As of completion of the feasibility study and white paper report, ATS has undergone numerous personnel changes, causing District staff to reevaluate how to proceed with Phase II.

Given new project complexities related to the identification of pathogens and the addition of Unit 2, as well as the personnel changes at ATS, District staff recommends contracting with Vollmar to complete Phase II. Vollmar was also deemed to be a highly qualified firm during the original

[1] Litter may have altered the soil chemistry by adding allelotoxins or excessive nutrients (these tree species have allelopathic effects on other plants, and blackwood acacia is also a nitrogen-fixer in the legume family). The litter sampling will inform the potential need to remove accumulated litter.

solicitation and can perform the scope of work at a fair and reasonable price. Since their founding in 1996, Vollmar has completed more than 350 projects ranging from small site assessments to large-scale conservation, mitigation, research, and development projects. They possess expertise in the following key areas:

- Rare Plant and Wildlife Surveys, Habitat Assessments, and Species Restoration
- Formal Wetland Delineation and Sensitive Habitat Mapping
- Vegetation Ecology, Classification, and Mapping
- Regional Conservation Planning and Development Studies
- Conservation Land Management and Monitoring, and Invasive Species Control
- Wetland, Riparian, and Upland Habitat Restoration
- Biological Constraints Analysis, Impact Assessment, and Permitting
- Advanced GIS Analysis, Remote Sensing, and Cartography

The General Manager therefore recommends authorizing a contract with Vollmar, based on the qualifications of their key personnel and expertise in restoration and land stewardship.

FISCAL IMPACT

The FY22 adopted budget includes $80,000 for the Irish Ridge Restoration project #80072. There are sufficient funds in the project budget to cover the recommended action and expenditures through the end of the fiscal year. Funds for FY23 will be proposed as part of the upcoming budget and action plan process at which time the total project budget will be adjusted to reflect the new cost estimates.

Irish Ridge Restoration #80072	**Prior Year Actuals**	**FY22 Adopted**	**FY23 Projected**	**FY24 Projected**	**Estimated Future Years**	**TOTAL**
Total Budget:	**$0**	**$80,000**	**$230,000**	**$245,000**	**$245,000**	**$800,000**
Spent-to-Date (as of 01/12/22):	$0	$0	$0	$0	$0	**$0**
Encumbrances:	$0	$0	$0	$0	$0	**$0**
Vollmar Natural Land Consulting Contract:	$0	($80,000)	($80,820)	$0	$0	**($160,820)**
10% Contingency:	$0	$0	($16,082)	$0	$0	**($16,082)**
Budget Remaining (Proposed):	**$0**	**$0**	**$133,098**	**$245,000**	**$245,000**	**$623,098***
*The total project cost will be revised once the FY23 budget is approved in June 2022.						

Cost Estimate for Future Restoration Work

The preliminary engineer's estimate for restoration ranges from $795,000 to $1,420,000 (encompasses over 3 years of removal operations and 5 years of plant establishment) and includes tree removal, soil and erosion management, disposal costs, planting and seeding, three years of plant establishment, monitoring, and reporting. The cost range is attributed to the disposal method used for non-native species. The estimated cost includes the restoration of both the original, non-native acacia site and human-planted plantations of Eucalyptus and non-local knobcone pine. The restoration work was not identified as a project under Measure AA and thus would require general funds to complete. Preliminary analysis by both the Natural Resources and Grants staff and early discussions with some granting agencies show that this restoration project would be competitive for a grant due to its three objectives: voluntary restoration, climate change/improved carbon sequestration, and wildfire resiliency.

The recommended action is not funded by Measure AA.

BOARD AND COMMITTEE REVIEW

On November 18, 2020, the Board of Directors authorized the General Manager to enter into contract with ATS to conduct the Irish Ridge restoration feasibility studies (R-20-134, Minutes).

PUBLIC NOTICE

Public notice was provided as required by the Brown Act. Adjoining neighbors near the project site have been notified.

CEQA COMPLIANCE

Award of a contract is not a project subject to the California Environmental Quality Act. Additionally, the proposed ecological surveys to be provided by the District's consultant are categorically exempt from the California Environmental Quality Act (CEQA) under Article 19, Sections 15306:

> Section 15306 exempts basic data collection, research, experimental management, and resource evaluation activities which do not result in a serious or major disturbance to an environmental resource. These may be strictly for information gathering purposes, or as part of a study leading to an action which a public agency has not yet approved, adopted, or funded.

A requirement of the consultant's work is to produce a habitat restoration plan comprised of actions that have already been fully evaluated in existing District CEQA documents, when feasible. These existing CEQA documents include the Wildland Fire Resiliency Program EIR, the Integrated Pest Management Program EIR, and the San Mateo Coastal Annexation EIR. The District will determine if additional CEQA review is required once the habitat restoration plan is prepared.

NEXT STEPS

Following Board approval, the General Manager will execute a contract with Vollmar.

Attachments

1. Location Map
2. Irish Ridge Restoration Feasibility Study
3. Biomass Disposition Alternatives White Paper

Responsible Department Head:
Kirk Lenington, Natural Resources

Prepared by:
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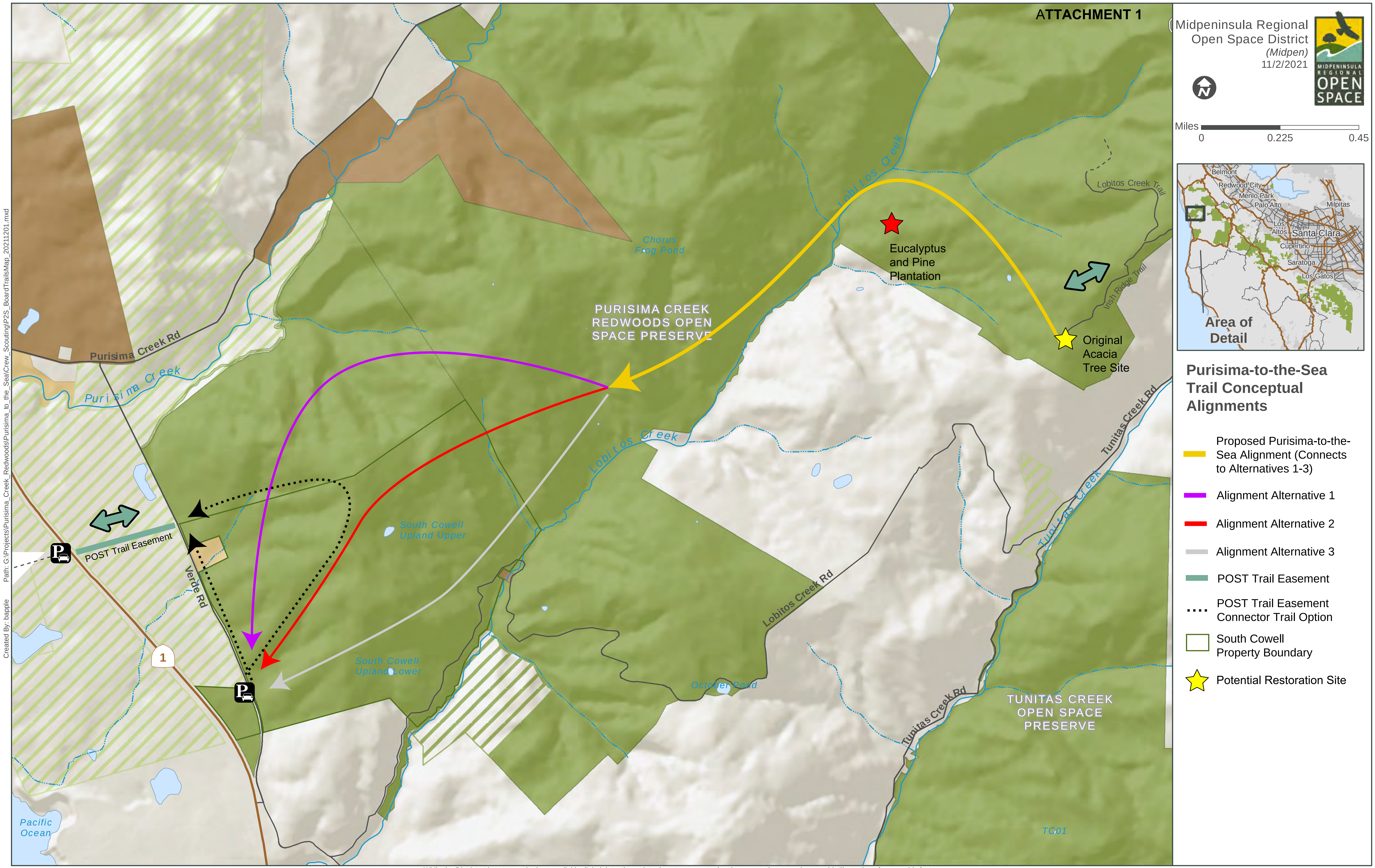
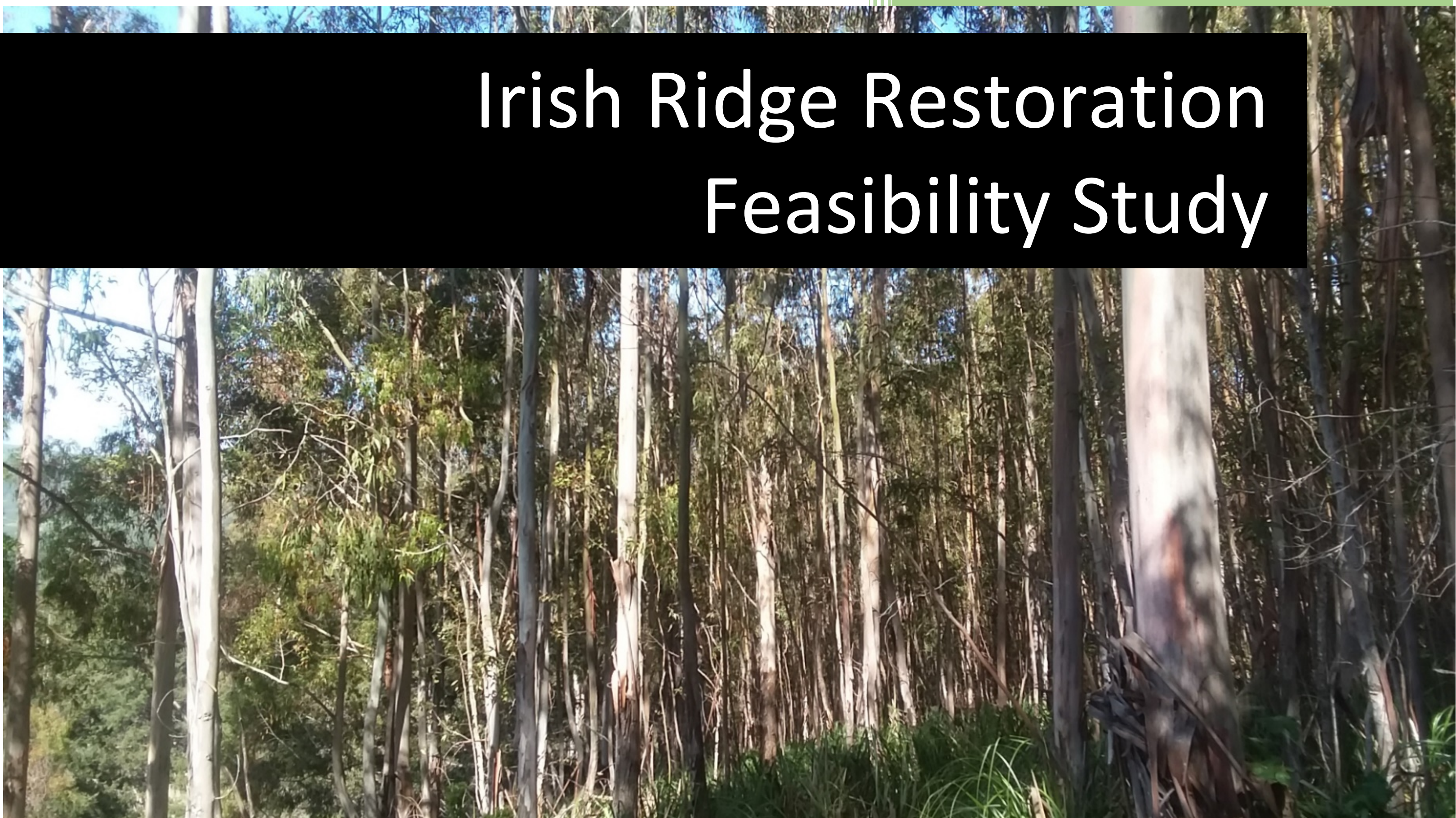
Graphics prepared by:
Bryan Apple, Capital Projects Field Manager, Land & Facilities



While the District strives to use the best available digital data, these data do not represent a legal survey and are merely a graphic illustration of geographic features.

ATTACHMENT 2

Irish Ridge Restoration Feasibility Study



Prepared For: Midpeninsula Regional Open Space District

Prepared By: Applied Technology & Science

August 2021

Contents

Introduction

This document provides a feasibility assessment for the removal of approximately 24 acres of non-native/out of range tree species in the Irish Ridge Area of the Midpeninsula Reginal Open Space District's (District) Purisima Creek Redwoods Open Space Preserve (OSP) in San Mateo County (Figure 1).

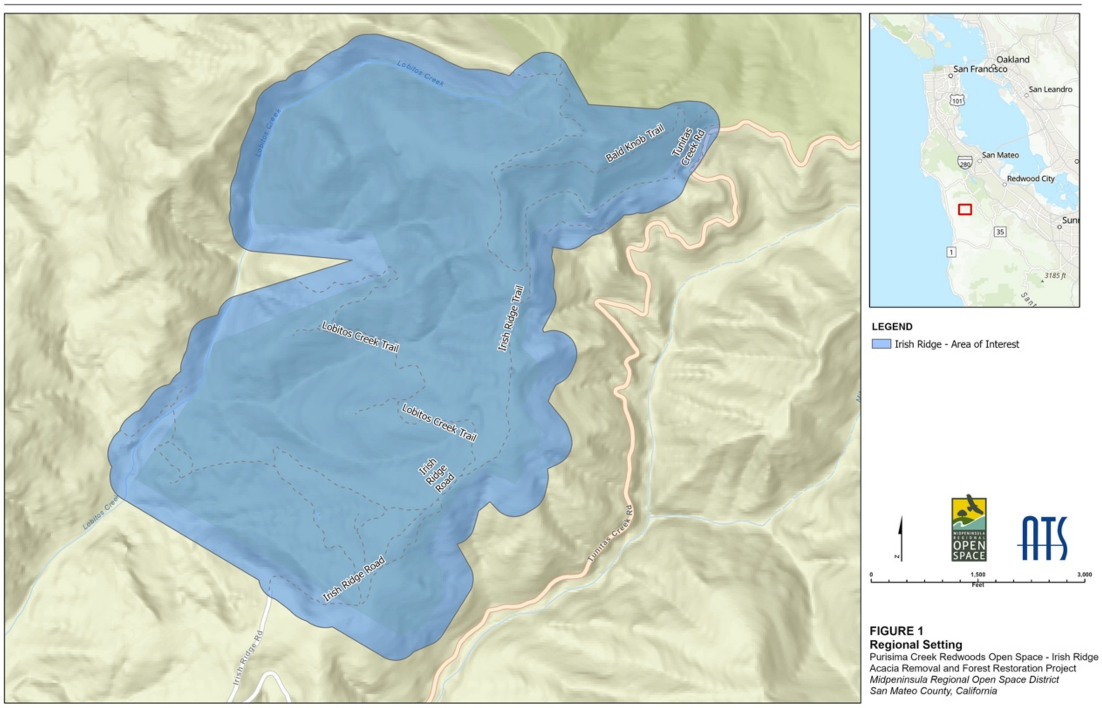


Figure 1. Map of project location

Goals and Objectives

The District's mission 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 policies include resources management to ensure proper care of the lands which they manage consistent with ecological values and public safety. As part of those policies, the District protects and restores the natural diversity and integrity of its resources for their value to the environment, and the public, and provides for the use of the preserves consistent with resource protection. Measure AA was passed in 2014 to improve access to hiking and biking opportunities; protect and preserve redwood forests, natural open spaces, the scenic beauty of our region and coastline, and critical wildlife habitat; restore creeks to protect water quality; and reduce forest fire risk.

Consistent with the intent of the District's mission and Measure AA:

Goal: Restore the landscape to ecologically functioning native plant communities with the removal of non-native trees and reduce fuel and fire risk, from approximately 24 acres within the Purisima Creek Redwood OSP.

Objectives:

- Remove an estimated 14,250 non-native blackwood acacia (*Acacia melanoxylon*), eucalyptus (*Eucalyptus* spp.), and a non-local population of knobcone pine (*Pinus attenuata*) trees.
- Reduce fuel and fire risk by removing dead and dying trees, overly dense stands of non-native trees, and ladder fuels.
- Prevent the spread of non-native species such as French broom (*Genista monspessulana*) and jubata grass (*Cortaderia jubata*).
- Reestablish an appropriate, biologically-diverse native plant community based on current and future site conditions of the treatment areas.
- Incorporate wildfire resiliency and climate change adaptation in the restoration and revegetation design.
- Establish new populations of Kings Mountain manzanita (*Arctostaphylos regismontana*).
- Incorporate public outreach and education about ecological restoration and invasive species management.

Treatment Units

This feasibility study is focused on large, dense stands of non-native and/or non-local trees in the southwest corner of the preserve in the Irish Ridge Area. In May 2021, a 24-acre timber cruise (i.e., a forest survey to locate and estimate the quantity of timber on a given area according to species, size, quality, possible products or other characteristics) was designed as an efficient means to obtain information regarding existing invasive blackwood acacia and eucalyptus trees, with a focus on structure, health and regeneration, and aspects of removal operations. Details on the inventory methods are provided in Attachment A. The inventory identified two treatment units. Unit 1 includes approximately 14 acres dominated by blackwood acacia, and Unit 2 includes approximately 10 acres dominated by eucalyptus and knobcone pine (Figure 2). Descriptions of these units are provided below, and representative photographs are provided in Attachment B.

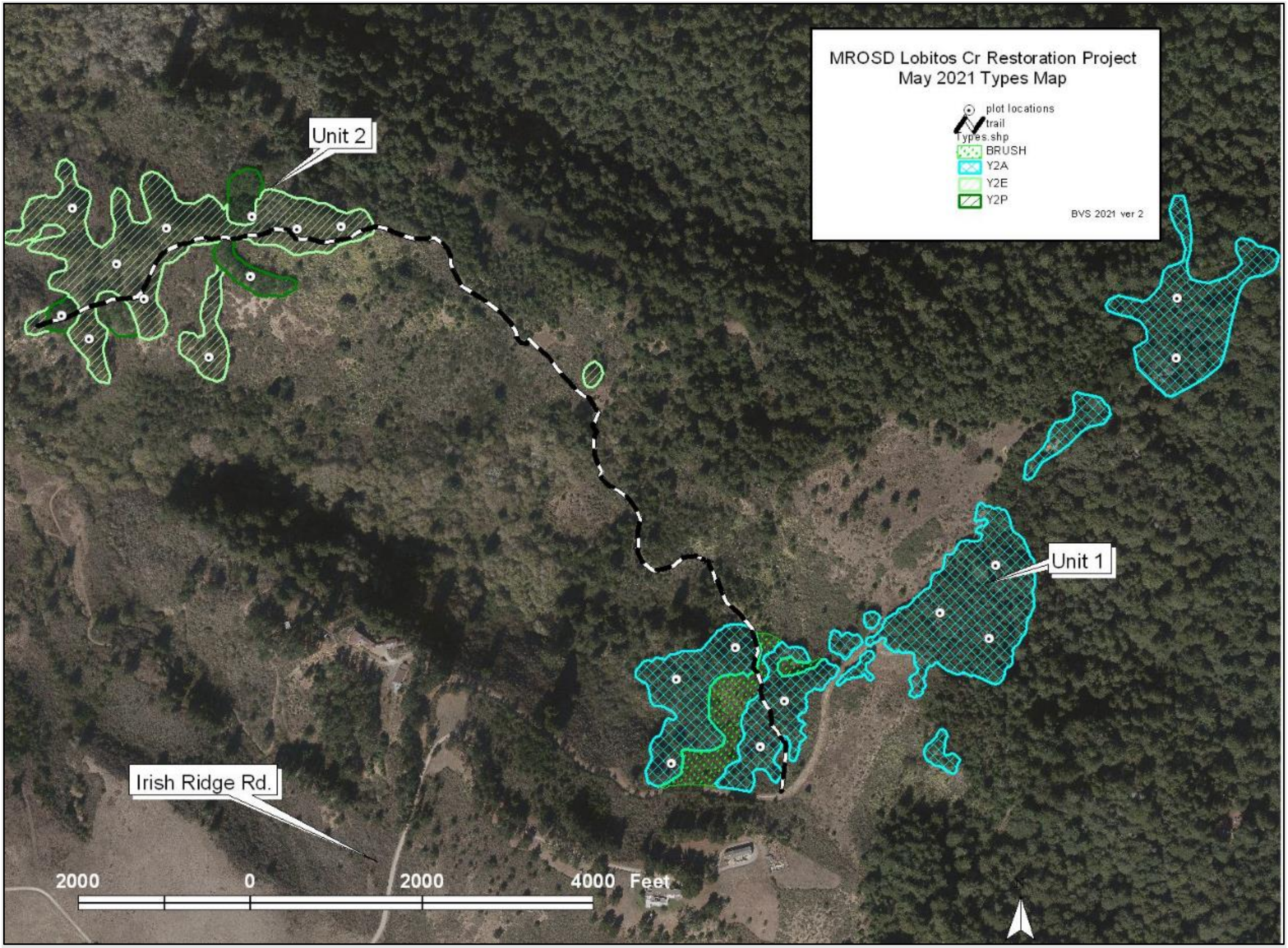


Figure 2. Treatment Units

Unit 1 – Acacia

Unit 1 contains an estimated 9,000 blackwood acacia trees and 5,429.4 cubic yards of biomass. Most of the trees (90%) are less than 12 inches in diameter at breast height (DBH; Table 1). Low densities of coast live oak (*Quercus agrifolia*) and California buckeye (*Aesculus californica*) trees are also present in this unit. Several small coast redwoods (*Sequoia sempervirens*) are present on the northwest edge of the unit where blackwood acacia are also present, but this is atypical of the unit, and coast redwood is not present throughout the sample area. An old skid trail is present below the main road. This old road provides good access for equipment.

Table 1. Unit 1 - Acacia Trees

DBH Class (Inches)	Number of Trees	Avg. Height (Feet)	Volume (Cubic Yards)
2	2380	20	38.5
4	4060	30	393.7
6	560	50	203.6
8	280	50	181.0
10	840	60	1018.1
12	224	70	456.1
14	266	70	737.2
16	140	80	579.2
18	126	90	742.2
20	84	90	610.9
22	14	80	109.5
24	14	80	130.3
30+	14	90	229.1
Total	**9,002**		**5,429.4**

Unit 2 – Eucalyptus – Pine

This unit includes both eucalyptus and knobcone pine, but the species are generally not intermixed and appear to have been planted in even age stands. Based on preliminary identification, the eucalyptus appears to be a mixture of Manna gum (*Eucalyptus* cf. *viminalis*) and red gum (*Eucalyptus* cf. *camaldulensis*) with a total of 4,089 trees and an estimated 3,501.5 cubic yards of biomass (Table 2). Most of the eucalyptus trees (85%) are less than 12 inches in DBH. Eucalyptus health is generally good, with mortality and decline typical for the species. A total of 1,158 knobcone pine trees are included in this unit, where 90% of trees are between 10 and 16 inches in DBH. Knobcone pine are native to California and are endemic to the Santa Cruz mountains near Davenport, but they are not naturally occurring in the Irish Ridge area and appear to have been planted in this location. The total estimated biomass for this unit is 1,156.1 cubic yards (Table 3). Mortality of knobcone pine in the unit is around 50%, and significant amounts of sap exudate was observed on live trees. The pine areas also have a large amount of dead wood debris in the understory that could act as ladder fuels, posing a high fire hazard in this area. The high mortality of the knobcone pines is concerning, but the immediate cause for the high mortality was not determined. There is also a small plantation (possibly olive trees [cf. *Olea europaea*]) to the east of the unit that was not included in the sampling. Access to this unit would follow an existing trail/old road that has a generally gentle grade (never exceeding 10%). There is one small slip-out along the old roadway, but the route can be easily realigned.

Table 2. Unit 2 – Eucalyptus Trees

DBH Class (Inches)	Number of Trees	Avg. Height (Feet)	Thousands of Cubic Feet (Gross)
2	1,333	10	10.8
4	711	10	23.0
6	533	30	116.3
8	533	40	275.6
10	356	40	287.7
12	90	40	104.7
14	107	50	211.8
16	124	60	384.7
18	98	60	384.8
20	53	60	257.0
22	62	70	424.3
24	53	70	431.7
30+	36	90	589.0
Total	**4,089**		3,501.5

Table 3. Unit 2 – Knobcone Pine Trees

DBH Class (Inches)	Number of Trees	Avg. Height (Feet)	Thousands of Cubic Feet (Gross)
2	0	0	0.0
4	100	20	6.5
6	0	0	0.0
8	0	0	0.0
10	778	40	628.6
12	97	40	112.9
14	89	40	141.0
16	76	50	196.5
18	18	60	70.7
20	0	0	0.0
22	0	0	0.0
24	0	0	0.0
30+	0	0	0.0
Total	**1,158**		1,156.1

Desired Outcomes and Reference Sites

The desired outcome is to restore the treatment units to California Department of Fish and Wildlife (CDFW) defined natural communities. Depending on site specific locations, desired habitat types, three primary natural communities and one special-status species community type have been identified:

Coastal Redwood Forest and Woodland Alliance

This community is characterized by coast redwood as the dominant or co-dominant tree species. Associated trees include madrone (*Arbutus menziesii*), Douglas fir (*Pseudotsuga menziesii*), California tanbark oak (*Notholithocarpus densiflorus*), California bay (*Umbellularia californica*), coast live oak, California buckeye, and giant chinquapin (*Chrysolepis chrysophylla*).

Forest communities in the vicinity of the treatment units include some areas where coast redwood is the sole dominant tree with a sparse understory, but other areas are more of a mixed forest community with species such as Douglas fir, California tanbark oak and other species co-dominant.

Further refinement for desired outcomes down to Redwood associations would be developed due Phase II.

Kings Mountain Manzanita (Special-status species community type)

Kings Mountain Manzanita (*Arctostaphylos regismontana*), a California Rare Plant Rank 1B.2 species with populations endemic both to the Santa Cruz Mountains in San Mateo and northern Santa Cruz Counties, can be found within three to five miles generally east of the treatment units but is not present in the treatment area. Nomad Ecology (Principal Investigator: Heath

Bartosh) has been working with the District and the California Native Plant Society to evaluate propagation of Kings Mountain Manzanita into other areas of the Santa Cruz Mountains where there are suitable environmental conditions. Select areas may be suitable for the introduction of Kings Mountain Manzanita as part of replanting and restoration following treatment.

California Coastal Scrub Macrogroup

Some areas adjacent to the treatment units are coastal scrub with coyote brush (*Baccharis pilularis*) as the sole dominant shrub species. While diversity is low in the surrounding areas, some of the other common native species found in this community include California sagebrush (*Artemisia californica*), blue-blossom (*Ceanothus thyrsiflorus*), California hazelnut (*Corylus cornuta*), bush monkey flower (*Diplacus aurantiacus*), buckwheat (*Eriogonum fasciculatum*), coffee berry (*Frangula californica*), bush lupine (*Lupinus arboreus*), and California blackberry (*Rubus ursinus*). Even when plant biodiversity is low at the reference site, it may be beneficial to cultivate more biodiverse restored plant communities, due to the many benefits that plant biodiversity can provide to insect pollinators, birds, and other wildlife.

Nassella spp. - Melica spp. Herbaceous Alliance

This native grassland community is characterized by one or more native perennial grasses such as purple needlegrass (*Stipa pulchra*) and/or onion grass (*Melica californica*; *Melica torreyana*) along with native forbs such as soap root (*Chlorogalum pomeridianum*), California poppy (*Eschscholzia californica*) Mariposa lily (*Calochortus* spp.), farewell to spring (*Clarkia* spp.), Common sandaster (*Corethrogyne filaginifolia*), and blue-eyed grass (*Sisyrinchium bellum*).

Biomass Disposal

Due to large quantities of material, there are two primary options for biomass disposal: offsite transport and disposal or onsite disposal.

Offsite Transport and Disposal

Disposal of woody biomass would involve trucking the material from the treatment units to an offsite facility, such as: a composting facility, a recycling facility, a bioenergy plant, or a landfill. Biomass may be removed as logs, or the material may be chipped and then hauled offsite for disposal. All offsite disposal options will require the use of haul trucks to travel to and from the site (depending on the size of the haul truck, this could be 30 or more trips to haul away the biomass). In addition to the cost of transport, additional cost will be required for traffic control along Lobitos Creek Road. This option will also have a greater impact on neighboring properties and residents in the area due to increased truck traffic and temporary one-way road closures. In addition, off-site disposal methods will result in a higher carbon footprint resulting from trucking materials from the site to a disposal facility as compared to more local disposal options.

Offsite disposal options are briefly discussed in the following sections.

Compost

The volume of material is such that onsite composting is not a realistic option for disposal of all of the biomass that would result from the tree removal. The Recyclery at Newby Island, located in Milpitas (approximately 50 miles from the site) accepts clean wood waste including logs less than two feet in diameter for a cost of $38/ton. Nearly all trees estimated to be removed (14,131 out of 14,249) are less than 2 feet in diameter. The Ox Mountain landfill in Half Moon Bay is another offsite disposal option that operates three small volume green waste chipping and grinding operations. These are not open to the public. The District could consult with the landfill to explore further the option of composting over 3,000 cubic yards of woody debris, but this may exceed the limit for "small volume."

Ox Mountain Sanitary Landfill
12310 San Mateo Rd (Hwy 92),
Half Moon Bay, CA 94019
(13.5 miles from the treatment areas)

The Recyclery at Newby Island
1601 Dixon Landing Road
Milpitas, California 95035
(48.5 miles from the treatment areas)

Green Waste Recycling

Material accepted for recycling includes logs, shrub/brush, branches, log rounds and wood chips.

- Cost for general/mixed green waste: $25 per cubic yard for mixed small material (chips, branches, brush). Assuming biomass is chipped and hauled to this location for disposal, cost is estimated to be around $75,000 – $80,000 for disposal.
- Logs & rounds: $40 per cubic yard for loads containing logs or log rounds under 24" diameter. If biomass is transported as logs, cost is estimated to be around $125,000.

Green Waste Recycle Yard
2550 Garden Tract Rd
Richmond CA 94801
(60 Miles from the treatment areas)

Biomass Energy

This option would involve offsite transport of logs or wood chips to a biomass-fuel power plant. There are currently no operating plants in the San Francisco Bay Area and biomass would need to be trucked to the Central Valley 100 miles away. Under this option, the District would require a formal service agreement with the facility that would include the amount of material, as well as a specified schedule for delivery to the plant.

While bioenergy facilities do impact air quality, the facilities produce significantly less emissions than openly burning wood and slash piles, and they are subject to regulation by the local air pollution control districts. However, transporting the treatment units to the facilities ranges 200 to 250 miles roundtrip per truckload, resulting in additional greenhouse gas emissions and potentially higher costs.

An advantage to this method is the facilities usually pay a small amount for the material, typically between $7 and $20 per ton depending on the material and demand, amounting to an estimated $7,500 to $21,000; however, this benefit may be outweighed by the higher transport and hauling costs.

DTE Stockton
2526 West Washington Street
Stockton, CA 95203
(approximately 100 miles from the treatment area)

This is a 45-megawatt biomass-fueled energy generating facility that utilizes 320,000 tons of woody biomass a year. Sources of biomass include wood chips, urban wood waste, logs from forest thinning, tree/orchard trimmings, and agricultural waste such as nut shells and fruit pits.

Woodland Biomass Power, Ltd.
1786 East Kentucky Avenue,
Woodland, CA 95776
(approximately 120 miles from the treatment area)

This is a 25-megawatt biomass-fueled energy generating facility that utilizes 260,000 tons of woody biomass a year from wood chips, urban wood waste, logs from forest thinning, tree/orchard trimmings, and agricultural waste.

Landfill

The Ox Mountain Sanitary Land Fill is a Class III Municipal Solid Waste Landfill which accepts all types of solid waste and woody biomass. This option provides no environmental benefit and has the highest direct costs (not including transportation and GHG emission costs, at a minimum cost of $200 per ton, with the total cost of landfill disposal ranging between $220,000 to $650,000.

Ox Mountain Sanitary Landfill
12310 San Mateo Rd (Hwy 92),
Half Moon Bay, CA 94019
(13.5 miles from the treatment area)

Onsite Disposal

One option for onsite disposal is the use of an air curtain burner. Under this option, the burn unit can be delivered to the site and can remain in place for the duration of the tree removal project, thereby eliminating the need for transportation costs, disposal fees, and one-way traffic controls. The use of an air curtain burner would also result in lower GHG emissions than trucking material to an offsite disposal facility and would eliminate the risk of spreading plant pathogens. The air curtain burner also reduces wood waste by 98 to 99%. The residual material may be converted to biochar to be used as a soil amendment or converted to ash. Biochar can be used as a soil amendment in Midpen restoration projects, or it can be sold or donated to other organizations for use in conserved, landscaped, or agricultural settings. A roll-off burn box can consume 2-5 tons of wood waste per hour. With a total volume of wood up to 10,000 cubic yards (27,000 cubic feet at 50 lbs per cubic foot translates to 675 tons), the burn box might need to run continuously for up to 350 hours. The project would need to receive approval from the Bay Area Air Quality Management District and review whether a curtain burner can operate at this site in the summer or fall, since the site is difficult to access in winter and spring.

Purchase prices range from $100,000 to $180,000 for a roll-off type box depending on size and capacity. Rental costs are estimated to be between $5000 - $10,000 per month.

Chipping and Grinding

Chipping and grinding can be used to convert the wood waste into mulch or wood chips, but this process does not eliminate the waste. The estimated amount of biomass resulting from tree removal is approximately 10,000 cubic yards of material. Large stockpiles of mulch or wood chips can pose a fire hazard due to the potential for spontaneous-combustion and may also be considered unsightly.

Open Pile Burning

Open pile burning can be a cost-effective method for disposal of wood waste, but it also has several drawbacks, including the impacts to air quality and carbon emissions due to smoke (black carbon). Open pile burning also requires machines or workers to monitor the burn to mitigate wildfire risks. Moreover, reducing the waste to ashes often takes a significant amount of time. Wood and slash piles may also be considered visually unappealing, and this method is also subject to additional regulation and permitting as compared to the previously described methods.

Plant Pathogens

A recent study by Matteo Garbelotto for the San Francisco Public Utilities Commission (SFPUC) and the U.S. Forest Service Pacific Southwest Research Station found that two fungal species, *Diaporthe foeniculina* and *Dothiorella viticola,* are associated with acacia dieback that is causing significant mortality in acacia trees around the Bay Area, including sites on the SFPUC Peninsula watershed (Attachment C). During the May 2021 inventory, the mortality and decline of Acacia trees in Unit 1 was estimated to be around 30%. The cause of this mortality remains undetermined and requires additional investigation; however, there is certainly the potential for these fungal pathogens to occur on site. It is recommended that the District coordinate with SFPUC and the U.S. Forest Service Pacific Southwest Research Station to further evaluate the risk of pathogens in the treatment area as well as prevention measures to limit any further spread during the treatment operations. Management/mitigation recommendations in that report should be considered the most current based on the state of knowledge.

Invasive Plants

In addition to the nonnative trees in the treatment units, two invasive plants, French broom and jubata grass, are common and widespread in the area. Disturbance associated with the tree removal, as well as the removal of canopy cover, creates ideal conditions for the rapid spread of both species.

French broom is more common in and around the blackwood acacia unit (Unit 1), with many small shrubs present in the open areas along the perimeter of the treatment unit as well as scattered individuals and sprouting seedlings throughout the treatment area. French broom was much less common in the eucalyptus area. Jubata grass is very dense and widespread along the trail/former road to the eucalyptus-pine area (Unit 2), as well as along the hillslopes around the unit. In some areas, jubata grass is even dense in the understory of the eucalyptus trees. Jubata grass is also present in and around Unit 1, but not as dense or widespread as in Unit 2.

Management, containment, and control of these and other invasive plants will be an important factor in the successful treatment and restoration of native ecosystem processes in this area. To the extent possible, treatment of these and other invasive species should be completed prior to the tree removal activities. Follow-up monitoring and management will also be necessary to ensure successful ecological restoration.

Special Status Species

The marbled murrelet (*Brachyramphus marmoratus*) is a federally listed threatened and state listed endangered species. In 1994, an active nest was found in the Purisima Creek Redwood OSP approximately two miles northeast of the treatment units, along Purisima Creek near Soda Gulch. Several large coast redwood trees in and around Unit 1 are considered potential nesting habitat for marbled murrelet. Given the presence of suitable habitat, consultation with the U.S. Fish and Wildlife Service and CDFW will likely be required. Performing a full, protocol level survey can likely be avoided as long as a habitat assessment is performed, and work is conducted outside of nesting season (Sept. 15 to Oct. 30, or until the year's first rains).

Bats

Townsend's big-eared bat (*Corynorhinus townsendii*), a CDFW species of special concern, has been reported within five miles of the treatment areas. Suitable habitat for western red bat (*Lasirurs blossevillii*), a state species of special concern, exists within one mile of the project site in riparian drainages. Non-special status species bats may also utilize habitat within the restoration area for roosting. Leila Harris, a PhD student and bat ecologist at U.C. Davis, affirms that the treatment areas provide habitat for bat species and recommends conducting acoustic surveys to better understand the species present in the area, in addition to a more detailed habitat assessment. Depending on the findings of these additional surveys, detailed bat surveys may be required for some or all of the treatment area to check for roosting bats prior to tree removal. The project may also allow for a long-term pre- and post- restoration bat diversity and habitat use study. Appropriately designed acoustic monitoring within the project site may be able to capture any changes in species composition and/or habitat use (number of individual fly overs) within the area.

Other Special-Status Species

Several other special status-status animals have been reported within five miles of the treatment units, including California red-legged frog, San Francisco garter snake, San Francisco dusky-footed woodrat, mountain lion, American badger, and grasshopper sparrow.

California Red-Legged Frog

There are reported occurrences of California red-legged frog (CRLF; *Rana draytonii*) less than a half mile west and south of treatment Unit 2 along Lobitos Creek and its tributaries. There is also a small pond just north of gate PC07 directly adjacent to Unit 1. According to the District's data in Atlas, the pond is a 0.12-acre waterbody overgrown with willows. The treatment areas are considered to be upland dispersal habitat for this species.

San Francisco Garter Snake

Aquatic habitats, including small ponds and streams in the vicinity of the treatment units, provide suitable habitat for the San Francisco garter snake (*Thamnophis sirtalis tetrataenia*). The wooded area with the treatment units provides upland dispersal habitat for this species. Accordingly, avoidance measures from for this species should be included for this project.

San Francisco Dusky-Footed Woodrats

During the initial surveys, several San Francisco dusky-footed woodrat (*Neotoma fuscipes annectens*) nests were observed in and around the treatment areas. Prior to tree removal, a qualified biologist shall live trap all woodrat nests that cannot be avoided to determine if the nest is in use. Trapping activities should occur prior to April and after mid-July each year to prevent impacts to woodrats rearing young or young woodrats. If a nest is found to be unoccupied or not in use for 3 full days (2 nights of trapping), then it may be removed. The nest shall be relocated or a pile of replacement sticks shall be placed outside of the development footprint for future colonization or re-use.

Once trapped, nests shall be torn down and rebuilt surrounding a log based structure, an inverted wooden planter, or similar structure having at least one entrance and exit hole that is slightly buried into the ground to anchor.

Mountain Lion

Mountain lions (*Puma concolor*) are known to occur within the project area. Include avoidance measures from Bear Creek Redwoods Project Specific Analysis.

American badger

American badgers (*Taxidea taxus*) are known to occur in the project area. The removal of invasive trees and creation of open forest, shrubland and grassland habitats would be beneficial for this species.

Grasshopper Sparrow

The removal of invasive trees and creation of open grassland areas with limited shrub cover would be beneficial for the grasshopper sparrow (*Ammodramus savannarum*).

Cultural Resources

What appears to be an old homesite was observed on the east ridge in the vicinity of Unit 2. Additional cultural resources investigations may be needed in this area.

CEQA/Permit Analysis

California Coastal Commission – Coastal Development Permit

Consulting forester McGuire was involved on a previous POST project (El Granada), which removed non-native eucalyptus trees for a fuel break within the coastal zone (CZ). The District was required to obtain a Coastal Development Permit (CDP) from the California Coastal Commission (CCC) for that work. As some portions of the proposed treatment area fall within the CZ, it is possible a coastal development permit would be required in this instance as well. This remains unclear at this time due to numerous salvage projects in the CZ following the 2021 CZU Complex fire and a range of responses from the CCC in this regard.

Wildland Fire Resiliency Program Environmental Impact Report (EIR)

The simplest permitting option is to use the District's existing Wildland Fire Resiliency Program EIR, which allows up to 20 acres of Eucalyptus and Acacia removal each year. The proposed project is ~24 acres.

CAL FIRE – Timber Harvest Plan (THP)

If the Wildland Fire Resiliency Program EIR is used, a THP will most likely not be required by Cal Fire. In the event that Cal Fire does require a permit to be obtained, there are three possible filing options:

1) Fire Hazard Exemption: this is expected to cost around $5,000 to prepare. There is no guarantee that an exemption would be granted, and this approach may be opposed or limited by other regulatory agencies- primarily the CCC.
2) Modified THP (MTHP): while not as extensive as a full THP, this can be an onerous process and includes risk as a public review document would also be subject to CCC input. An MTHP is expected to cost between $40,000 and $50,000 to develop.
3) Regular THP: this option would be more robust and stand up to public review and agency comment. It typically requires 1-3 years to develop and be approved. Like the MTHP, the permit is valid for 5 yrs with the option to extend an additional two years if justified. Cost estimates range from $60,000 - $100,000 to complete (i.e, obtain the permit and licensed forester supervision of operations per the Forest Practice Rules).

Given the expense of options 2 and 3 , the District may want to consider additional treatment areas to maintain some flexibility. Areas included in a THP can be removed if operations are not initiated. Option 1 is the preferred permit path if Cal Fire and the CCC would consider the District's EIR sufficient. Based on our experience and discussions with Cal Fire, this matter will require continued discussions with these agencies.

U.S. Fish and Wildlife Service and California Department of Fish and Wildlife

There is suitable nesting habitat for the marbled murrelet and CRLF in or near the treatment areas. At a minimum, mitigation measures to avoid impacts to listed species will need to be developed, potentially including a protocol for marbled murrelet surveys, nesting season work restrictions, presence of an agency-approved biological monitor during treatment activities, or other measures as needed. Removal of invasive trees and habitat restoration could include measures to aid in the recovery of CRLF. Existing marbled murrelet avoidance measure from the District's existing Section 10 recovery permit could be used for this project; therefore, a USFWS permit is not likely to be needed for this project.

For any work involving the planting and establishment of new populations of Kings Mountain manzanita, a CDFW Scientific, Educational, or Management Permit for work will be required.

State Water Quality Control Board – Storm Water Pollution Protection Plan (SWPPP)

An SWPPP would not be need if the project is required to prepare a THP because all the CEQA mitigations and analysis required to protect "the State's waters" include an Erosion Control Plan to be developed and included in Section II of the plan. If the project does not require a THP, then an SWPPP would need to be developed and submitted for approval.

Community Outreach and Research Opportunities

The tree removal and subsequent revegetation efforts discussed in this document provide many opportunities to engage students and the public in citizen science and academic research projects, and it creates ample opportunities to recruit volunteers from the public and promote environmental education. Graduate and undergraduate students at local universities could be invited to study the effects of tree removal and revegetation on wildlife, soil, hydrology, and the colonization patterns of invasive species. Community members could contribute to the project by helping to manually remove invasive species at certain subsites, they could collaborate with students on data collection, or they could perform long-term ecological monitoring. School groups could visit the site to learn about the impacts of invasive plant species. Active engagement with local universities, schools, and community groups will be needed to achieve these extended benefits of this project.

Engineers Estimate

Biomass Disposal Projected Costs				
Task	**On -Site Biomass Disposal (Air Curtain Burner)**	**Off -Site Biomass Disposal (Biomass Recycling)**	**Off -Site Biomass Disposal (Bio Energy)**	**Off -Site Biomass Disposal (Landfill)**
Tree Removal/Soil &Erosion Management	$425,000	$425,000	$425,000	$425,000
Haul Cost[1]	$0	$15,000	$30,000	$5,000
Disposal Cost	$100,000 – $200,000[2]	$75,000 – $125,000	$0	$220,000 – $650,000
Restoration/Planting/Seeding	$300,000	$300,000	$300,000	$300,000
3 Year Plant Establishment[3]	$40,000	$40,000	$40,000	$40,000
Total Estimate	**$865,000 – $965,000**	**$855,000 – $905,000**	**$795,000**	**$990,000 – $1,420,000**

Notes:

[1] Haul cost includes estimated trucking cost to offsite disposal areas.

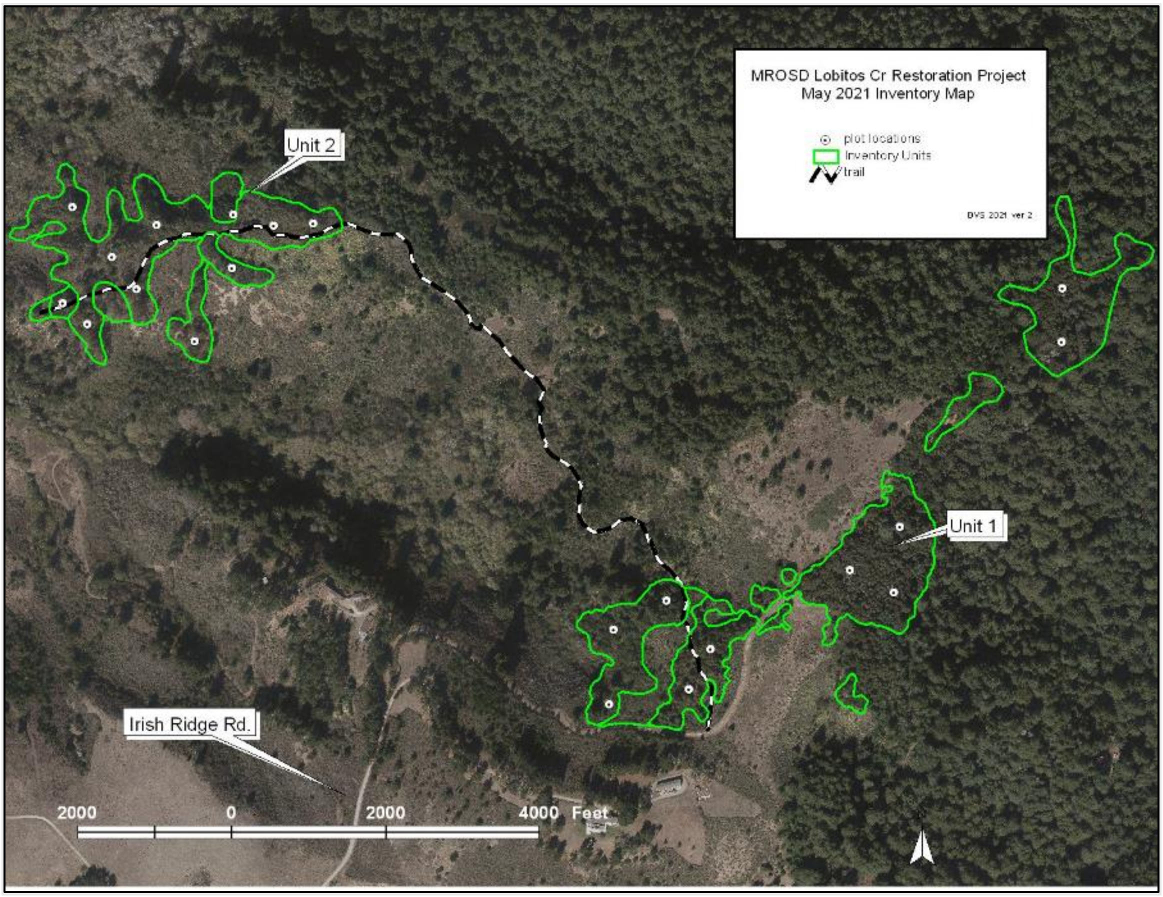
[2] Estimate based on purchase price rather than rental of an air curtain burner unit (renting a unit would likely lower cost) additional cost would be for two-person crew to operate the burner.

[3] Includes: monitoring, plant replacement, and reporting.

Attachment A – Tree Inventory Methods

The 24-acre subject area was divided into two units: (1) An acacia-dominated area approximately 14 acres on both sides of an existing trail/road; (2) to the west, a eucalyptus- and knobcone pine-dominated area of approximately 10 acres accessible via a trail from Unit 1. 21 slope-corrected, 1/10 acre fixed-radius plots, with 1/100-acre nested subplots are to be randomly installed and measured. Plot locations are shown in Figure A1.

Figure A1. Inventory Map



Locating the Plot Center:

A-priori plot locations were loaded into Global Positioning System (GPS) units and were then navigated to in the field. Paper maps showing nominal plot locations on orthophotos and topo maps were also carried. Once in the approximate location, the GPS unit was used to record the location of the plot center. Plot centers were monumented with pink flagging and inscribed with plot ID, date, and the cruiser’s initials.

<u>Information Collected at Each Plot</u>

Plot No.: The plot number loaded in the GPS data.

Slope: Average slope in %, e.g., 65%

Aspect: Compass aspect, e.g., NE or S

Position: ridge/side hill, flat, bench, etc.

Comments: Note Recent Disturbance:

E – "Major active anthropogenic erosion feature, such as crossing failure, diverted stream, gully, etc."

S – "SOD present".

O – "Other" - includes brief description

In addition, anything of significance observed in the plot or while walking between plots was recorded, including: landslides, archaeological resources, trail/roads/landings, trail grade, stream crossings, operational issues, wet areas and stream classes, presence of old growth, old growth stumps, large woody debris, non-native species (e.g., French broom, jubata grass), sensitive plants (including King's Mountain manzanita [*Arctostaphylos regismontana*], Western leatherwood [*Dirca occidentalis*], California bottlebrush grass [*Elymus californicus*], and Choris's popcorn-flower [*Plagiobothrys chorisianus* var. *chorisianus*]), understory condition (describe dominant species, dead and down), and sensitive fauna (nests/whitewash, etc.).

<u>Tree measurements</u>**:**

Trees were measured and recorded in a *generally* clockwise manner starting from true north, but tree sequence was not always perfectly circular due to onsite factors. The subplot was measured first at each location.

<u>1/100 acre subplot:</u>

- 11.8-foot plot radius: A plot rope or tape planted on or at the plot center was used by the cruiser to establish "in" and "out" trees while adjusting for slope per Table A1.
- All trees with DBH **<u>>=1" and <11.0</u>**" (2-10" classes) were measured using a Biltmore stick or tape/caliper as needed. Any significant regeneration was noted if present (<1" DBH) by species. The DBH size class was the median of that class. For example, the 8" DBH class includes trees >=7" and <9".
- Total height (TH) to the nearest foot on all trees (including snags) was measured using a clinometer and logger's tape or plot rope.

1/10 acre major plot:

- 37.9-foot plot radius: A plot rope or tape fixed at the plot center was used to establish “in” and “out” trees, while adjusting for slope per Table A1.
- All trees with DBH **>11.1”** (12”+ classes) were measured using a Biltmore stick or tape/caliper as needed.
- Total height (TH) to the nearest foot was measured using a clinometer and logger’s tape or plot rope.

Table A1 Plot Diameter Slope Corrections:

slope	1/100 ac	1/10 ac
0	11.8	37.2
10	11.8	37.5
20	12.0	37.9
30	12.3	38.9
40	12.7	40.1
50	13.2	41.6
60	13.7	43.4
70	14.4	45.5
80	15.1	47.7
90	15.8	50.1
100	16.7	52.7

Additional Information Collected:

- Comments on tree health, types of defects, and any diseases.
- Any observed habitat features such as presence of goose pen (basal hollow), large branches or wolfy growth habit, broken tops, reiterated trunks, etc.

Attachment B – Site Photographs

Blackwood Acacia Trees in Unit 1

Eucalyptus Trees in Unit 2

Eucalyptus Trees in Unit 2

Knobcone Pine trees in Unit 2

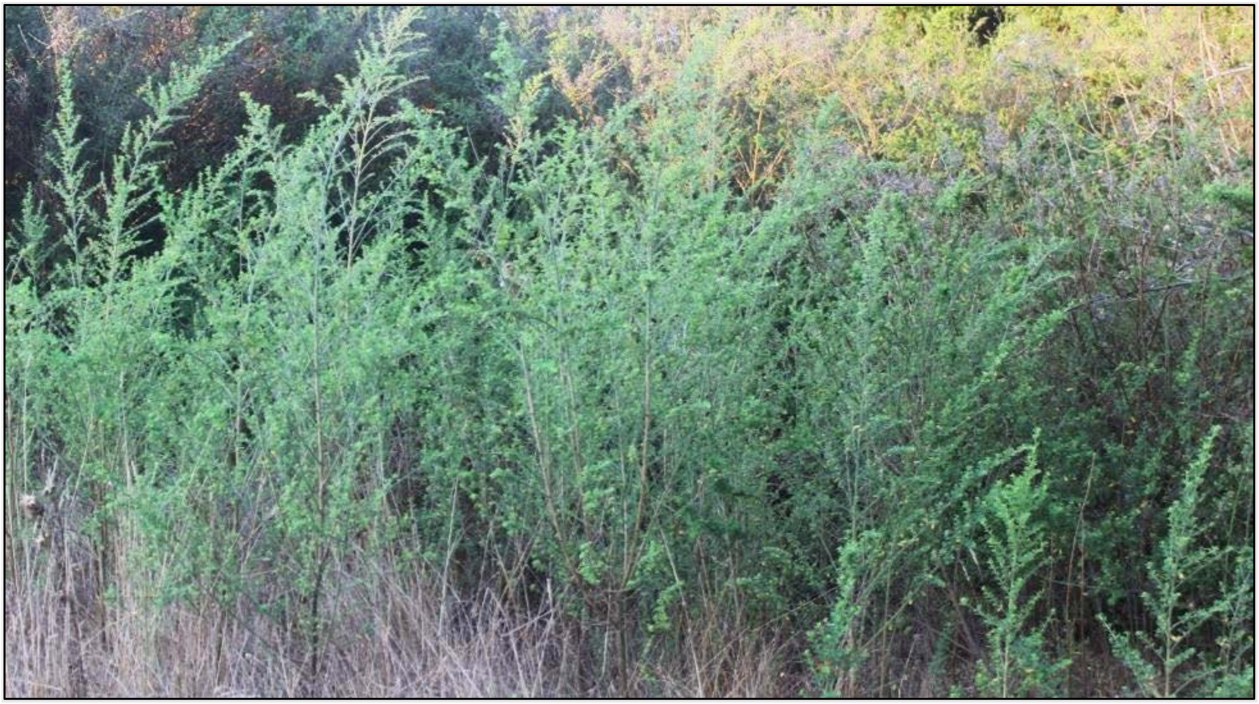
Knobcone Pine Unit 2

Woody debris in understory of Unit 2

Native Redwood Stand north of Unit 1

Mixed forest community in the vicinity of the treatment units

Shrub community characterized by coyote brush south of Unit 1



French broom around the perimeter of Unit 1

Extensive and dense jubata grass on slopes in below access trail and around Unit 2

Large redwood in the vicinity of Unit 1 that provides suitable habitat for Marbled Murrelet

Woodrat nest

Air Curtain Burner in Operation

Attachment C – Acacia Pathogen Report

Investigating the causes of widespread *Acacia* spp. mortality in the San Francisco Bay Area.

A report written in February and March 2021 by Matteo Garbelotto, PI
Department of ESPM, U.C. Berkeley

for

Susan Frankel, Plant Pathologist
U.S. Forest Service, Pacific Southwest Research Station

and

Mia Ingolia, Biologist,
San Francisco Public Utility Commission (SFPUC)

Introduction

In October 2020, many reports of dying Acacia were circulated, primarily *Acacia melanoxylon* (blackwood Acacia) in Oakland, Pt. Richmond, Crockett and other Bay Area locations. The observed Acacia die-off was highly unusual: groups or even entire stands of trees appeared to die-off rather rapidly, showing bright, burnt-orange crowns. Upon examination, Acacia of all conditions could be found in the vicinity of the dying trees, some green, others yellowing, some with dead branches. What appeared to be older dead Acacia were also present.
The SFPUC reported dying Acacia in the Trousdale area, near Burlingame, (San Mateo Co.) in an area scheduled for restoration in February 2021. The SPFUC is concerned that if a new, invasive pathogen was determined to be the cause of this die-off the project could be delayed, or the pathogen could spread to other species that will be planted in the area.

Goals

In order to enable management of this new tree disease concern we set out to determine its cause by answering the following questions.

Are there one or more infectious agents responsible for the reported Acacia mortality? Is it possible the same agents may also be causing mortality of other species, particularly blue gums, *Eucalyptus globolus*? Are these agents native or exotic? Whether native or non-native, can we identify or suggest their origin? Are the agents primary, aggressive pathogens, or are they pathogens thriving on plants stressed by environmental conditions? Is it possible that multiple types of organisms may be accelerating the mortality rate of plants? Could this be just the effect of abiotic stresses or are biotic agents involved? If biotic causes are identified, can we make management recommendations based on the biology of the microbes involved?

Materials and methods

Although mortality of several tree species has been reported, we focused on two Acacia species, given they do appear to be the trees experiencing the most severe and geographically widespread symptoms. Focusing on one host increases our chances of identifying agents involved in the mortality. The main focus of the study was blackwood acacia, but occasionally silver wattle (*Acacia dealbata*) was also sampled.

The project was conducted in San Mateo, Alameda and Contra Costa Counties, with lab analysis done in Alameda County at the UC Berkeley Laboratory of Forest Pathology and Mycology. A total of 5 sites (Leona Heights, Montclair, Dimond Canyon, Carquinez strait, SFPUC) in 4 distinct locations were sampled. Eight trees per location were sampled in locations 1-3, while six trees were sampled in Location 4 (Dimond Canyon).

Samples were collected from Acacia at various stages of decline, but not yet dead, for the identification of associated fungi. Trees were evaluated for the presence of cankers or any other symptoms of ill health. Stems, twigs, roots were evaluated for the presence of pathogens by directly plating out symptomatic tissue onto several types of media (MEA, acidified PDA, Fusarium specific medium, Leptographium medium, Phytophthora PARP medium) and on washed carrot disks. Tissue containing both necrotic and healthy portions was the main focus of our sampling effort. Each sample was plated on all media and on carrots in duplicate, with one replicate bleached in 10% bleach for 30 seconds and washed for a minute in sterile water and one sample plated without surface sterilizations. All samples were collected well inside the plant tissue to minimize surface microbial contamination.

Besides sampling and direct plating of symptomatic tissue, declining trees were also tested for the presence of *Phytophthora* by baiting the soil collected near them with three different baits, namely pears, oregano stems and "Cunningham's white" rhododendron leaves. In brief, soil was dried at room temperature before being rewetted and placed at 8-10 C for 48 hours to stimulate sporangia production. Water was then added so that the soil would be submerged by one inch of water and the three baits were placed in each bag, ensuring they were only partially submerged. Baits were inspected at 3, 7 and 10 days, and any visible lesion was plated on PARP. Molecular and microscopic evaluations of any recovered fungi were made to identify the species and assess its risk to trees and shrubs. Molecular identification was based on ITS sequence and, for groups of fungi of interest, the EF-alpha and the Histone 3 loci were additionally sequenced to obtain a more precise species ID.

Koch's postulates will be conducted to prove pathogenicity of fungi that were found repeatedly in multiple trees and/or locations. Koch's postulate will be completed by inoculating the most frequently isolated fungi on healthy potted seedlings. On March 15th 2021, we inoculated healthy trees in the SFPUC study site **using only local fungal isolates**. These trees, potentially stressed, may better allow us to infer the role played by the fungi isolated from them. A total of 12 small trees were wound inoculated using agar plugs colonized by putative pathogens, while four were mock-inoculated and will serve as controls (see below for details). We will take down the experiment in 6 – 8 weeks.

Cultures' identifications were done at the genus level using morphology and at the species level by using the DNA sequence of the barcode locus ITS for a select number of isolates. ITS sequences were used in two different ways to identify number and name of species involved: 1- Intrageneric or closely related genera sequences for fungi identified in multiple locations were aligned on Geneious and NJ trees were built using such alignments. The number of clades (branches) was used to indicate the number of species or operational taxonomic units (OTUs). 2- Sequences from each clade were compared to sequences deposited in GenBank using the BLAST function, to obtain a putative species ID. For each clade/OUT. When necessary EF-alpha or Histone 3 sequences were also BLASTed against the public database to confirm species ID.

Results

1- A total of 81 soil or tree samples were collected and/or analyzed during the study (See Table 1 for details).

Table 1. List of samples obtained and examined by culturing.

ADP#	date sampled	Site	tree	Sample Type	Spp
1				from Igor Lacan	na
2				from Igor Lacan	Na
3				from Igor Lacan	Na
4				from Igor Lacan	Na
5	12/8/20	1	1	long stem canker	silver wattle

6	12/8/20	1	1	soil	silver wattle
7	12/8/20	1	1	root flare	silver wattle
8	12/8/20	1	2	rootlets for agdia	silver wattle
9	12/8/20	1	2	root piece healthy green	silver wattle
10	12/8/20	1	2	stem above canker	silver wattle
11	12/8/20	1	2	stem below canker	silver wattle
12	12/8/20	1	2	soil	silver wattle
13	12/8/20	1	3	roots	silver wattle
14	12/8/20	1	3	stem above canker	silver wattle
15	12/8/20	1	3	stem below canker	silver wattle
16	12/8/20	1	3	soil	silver wattle
17	12/8/20	1	4	stem	black acacia
18	12/8/20	1	4	rootlets	black acacia
19	12/8/20	1	4	soil	black acacia
20	12/8/20	1	5	roots	black acacia
21	12/8/20	1	5	stem above canker	black acacia
22	12/8/20	1	5	stem below canker	black acacia
23	12/8/20	1	5	soil	black acacia
24	12/8/20	1	5	leaves with dieback	black acacia
25	12/8/20	1	6	root collar, bark	black acacia
26	12/8/20	1	6	stem below canker 5'	black acacia
27	12/8/20	1	6	stem below canker 3'	black acacia

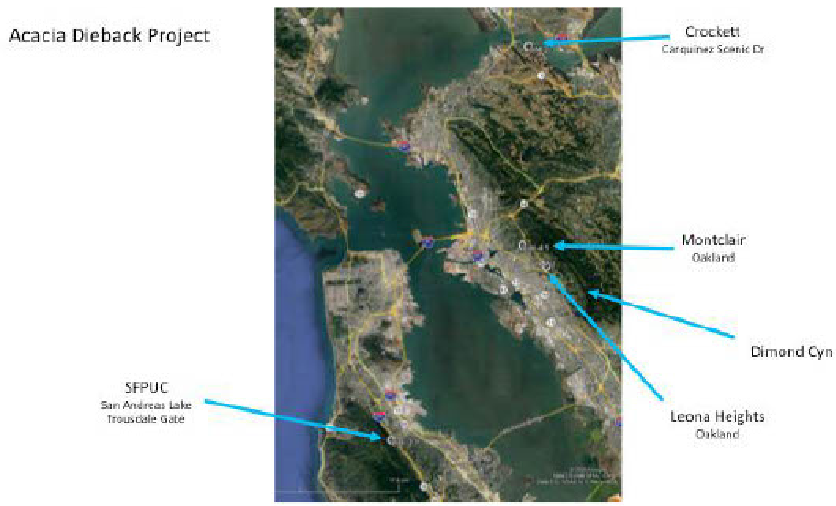
28	12/8/20	1	6	under soil	black acacia
29	12/8/20	1	6	soil	black acacia
30	12/8/20	1	7	stem canker	black acacia
31	12/8/20	1	7	stem canker	black acacia
32	12/8/20	1	7	soil	black acacia
33	12/8/20	1	8	stem canker	black acacia
34	12/8/20	1	8	stem canker	black acacia
35	12/8/20	1	8	stem canker	black acacia
36	12/8/20	1	8	soil	black acacia
37	12/10/20	2	1	soil	black acacia
38	12/10/20	2	1	branch	black acacia
39	12/10/20	2	2	soil	black acacia
-	-	2	2	stem	out of order. It is ADP#50
40	12/10/20	2	3	soil	black acacia
41	12/10/20	2	3	stem	black acacia
42	12/10/20	2	4	soil	black acacia
43	12/10/20	2	4	side branch 1 & 2	black acacia
44	12/10/20	2	5	soil	black acacia
45	12/10/20	2	6	soil	black acacia
46	12/10/20	2	6	stem	black acacia
47	12/10/20	2	7	soil	black acacia
48	12/10/20	2	7	root collar	black acacia

49	12/10/20	2	8	soil	black acacia
50	12/10/20	2	2	stem	black acacia
51	12/14/20	3	1	soil	black acacia
52	12/14/20	3	1	root collar	black acacia
53	12/14/20	3	2	soil	black acacia
54	12/14/20	3	2	root collar nr surface	black acacia
55	12/14/20	3	2	root collar deeper in	black acacia
56	12/14/20	3	3	soil	black acacia
57	12/14/20	3	3	root collar stain	black acacia
58	12/14/20	3	4	soil	black acacia
59	12/14/20	3	4	root collar	black acacia
60	12/14/20	3	5	soil	black acacia
61	12/14/20	3	5	small side root	black acacia
62	12/14/20	3	6	soil	black acacia
63	12/14/20	3	6	side root	black acacia
64	12/14/20	3	6	root collar	black acacia
65	12/14/20	3	7	soil	black acacia
66	12/14/20	3	7	root	black acacia
67	12/14/20	3	8	soil	black acacia
68	12/14/20	3	8	side root	black acacia
69	1/13/21	4	1	root collar/base of tree	Bay
70	1/13/21	4	1	soil	Bay

71	1/13/21	4	1	branch	Bay
72	1/13/21	4	2	branch canker	Black acacia
73	1/13/21	4	2	soil	Black acacia
74	1/13/21	4	2	branch #2	Black acacia
75	1/13/21	4	3	base	Black acacia
76	1/13/21	4	3	soil	Black acacia
77	1/13/21	4	4	side root	Black acacia
78	1/13/21	4	4	soil	Black acacia
79	1/13/21	4	5	branch	Black acacia
80	1/13/21	4	5	soil	Black acacia
81	1/13/21	4	6	branch	Black acacia
82	1/13/21	4	6	soil	Black acacia

Sites:
1= Leona Heights and Montclair (Alameda Co.)
2= Carquinez (Contra Costa Co.)
3= SFPUC (San Mateo Co.)
4= Dimond Canyon (Alameda Co.)

Figure 1. Location of study sites. Note that location here is approximate, the exact location of all samples trees and all sampling locations is provided in a KMZ file below.



Figures 2 and 3. Trees dead and declining, found at the sampling sites and close ups of necrotic tree tissue.

Figure 2

Acacia Dieback Project

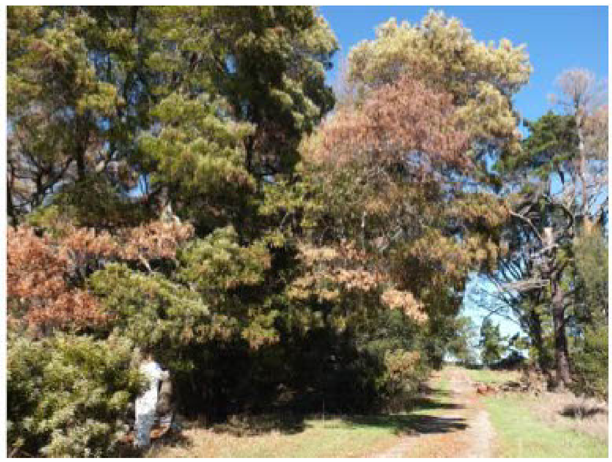


Figure 3

Acacia Dieback Project

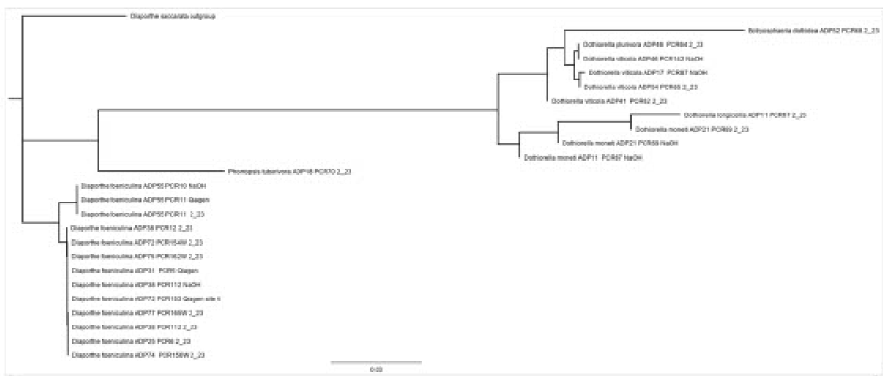
2- Approximately 200 cultures were obtained. Half of them based on the expertise of the laboratory and common knowledge were discarded as being either environmental contaminants or ubiquitous fungi with no known pathogenic action on plants. A total of 99 remaining cultures were then identified at the genus (45) and species (54) levels. Note that these 99 cultures do contain some duplicates obtained from the same sample, either by using different media or by using DNA extraction techniques.

3- **Only two groups of fungi, ecologically similar, were identified at all sites**, providing an important clue on the possible causation of the observed mortality in Acacia. The groups identified in all sites can be referred to as comprising a large number of endophytic fungi, that is fungi belonging to the genus *Botryosphaeria sensu lato* and to *Diaporthe*. The genus *Botryosphaeria sensu lato*, although still in use, is known to actually comprise multiple genera, and is currently split in 6+ genera based on the morphology of the conidia (asexual fungal spores) and on DNA sequence phylogenetic placement. On acacias in the study sites, we identified two species of *Dothiorella* and one species of *Diaporthe* (possibly split into two lineages/subspecies/OTUs). In the KMZ file available at the following URL:

https://drive.google.com/file/d/1dBkvQN4OwuwZDVmBo6Xe1iDq917hA1BA/view?usp=sharing

by zooming in it is possible to visualize results for each individual tree. All trees fit in one of four categories: negative (no fungi isolated and not visible on the map); *Diaporthe/Dothiorella* isolated from them; *Umbelopisis* isolated from them; only contaminants or fungi of uncertain effect isolated. A closer look shows some very important patterns: 1) trees are infected either by *Diaporthe* or by *Dothiorella* (only one tree has both); 2) *Fusarium* spp. and *Mortierella* spp. are isolated **only** from trees infected by *Diaporthe* or *Dothiorella (a Fusarium,* probably soilborne was isolated only once from a tree without *Diaporthe or Dothiorella*; 3) There are several trees infected by *Diaporthe* and *Dothiorella* that are not infected by *Fusarium, Mortierella* or *Umbelopsis.* This more detailed analysis confirms the primary role played by *Diaporthe* and *Dothiorella* in causing mortality, even if possibly on trees predisposed to infection by other factors (see below). It also appears that the two may be partitioning their respective niches, given that their co-occurrence on the same tree seems rare. The role of *Umbelopsis* remains questionable and there is absolutely no literature on the ecology and lifestyle (pathogenic vs. saprobic, endophytic or mycorrhizal) of this genus of zygomycetes. However, *Umbelopsis* was only found in the SFPUC site, suggesting it does not have a generalized role in the reported *Acacia* spp. mortality.

Figure 4. Neighbor Joining tree showing the presence of two OTUs on acacia for *Dothiorella* and one for *Diaporthe*, with the possible presence of a *Diaporthe* variant, maybe at the subspecific level or maybe a very closely related species. *Diaporthe saccarata* (sequence from GenBank) was used as an outgroup. A single *Botryosphaerya dothidea* was also identified and is of limited interested as well as a single *Phomopsis tuberivora*. Histone 3 sequences confirmed the identity of the entire *D. viticola* clade, while EF-alpha confirmed the identity of the entire *D. foeniculina* clade, including the variants. See Table 2 for species information.



Given the consistent presence of *Dothiorella* or *Diaporthe* in association with all studied tree mortality, we conclude these fungi play a significant role in the observed decline and death of acacias. However, it should be noted that the biology of both these fungi is "mixed". They all start as endophytes, without any obvious effect of tree health, they often become pathogens-some relatively aggressive- in conjunction with the onset of predisposing factors stressing trees (drought, limitation in resources due to high stand density, old age) and then survive as saprobes on the wood of the trees they killed. Some aspects of the biology of these fungi deserve attention: 1- Infection is positively correlated with abundant rainfall: thus, we expect that the record-breaking rainfall of 2017 resulted in widespread infection by these fungi; 2- The endophytic phase can last from 1 to 30+ years, meaning that disease development is almost never immediate: even in the presence of stress we expect a minimum of a 2-year lag between infection and disease expression: timing of the observed disease development is consistent with this timeline; 3- Disease is density dependent, so we expect to see more mortality where plants are in thick clusters and monospecific stands, rather than in isolated trees: this has clear management implications ; 4- Sporulation is positively correlated with amount of dead and decaying matter: this has obvious implications for management.

Figure 5. Late stage (left) and early stage (right) of "wedge" shaped wood staining associated with *Dothiorella* infection in our study match the symptoms reported in the literature.

4- Are these *Botryosphaeria* and *Diaporthe* species native or exotic and where do they come from?

We have uncovered both native and introduced pathogens in this study. Given the complex taxonomy of the species involved, comprising many groups of multiple closely related species, this question is difficult to answer. *Diaporthe foeniculina* and *Dothiorella viticola* have a global distribution and have been reported from California multiple times, suggesting they are either native or naturalized in California. What we are observing here is most likely a host jump, given that both species are known as generalists. The host jump may have occurred in the course of several years and may have happened either directly from hosts already known in California or through an intermediate host. In either case, it is likely to have been favored by the high density of hosts (this is a simple statistical inference: the greater the pool of hosts the more likely they will be eventually infected) combined with prolonged wet conditions in 2017, followed by generalized stress conditions including high stand density/basal area as plants are growing and self-propagating, drought (2019 and 2020 both were below average for precipitation levels), smoke

(?). One notable exception is that of *Dothiorella moneti/santali:* these are highly host specific pathogens **only reported from *Acacia* spp. in Australia**. This fungus most likely arrived hitchhiking on acacia stock imported from that continent. At this point we only found it in Leona Heights, but further sequencing will indicate whether it may be present in other sites. Whether abundant or rare, **we can already state this specific pathogen to be exotic and from Australia. This is the first report of this species outside Australia.**

Table 2 below reports what we know about the three species identified in this study in terms of host and geographic range. Beware that these reports may be inaccurate due to the complex taxonomy.

Table 2. Various information about two *Dothiorella* and *Diaporthe* species isolated in 2020/2021 from declining and dying acacias in the SF Bay Area.

Species	Reported in California	California hosts	Where else reported	Hosts outside California	Confidence in Species ID
Dothiorella moneti/ santali	No	Na	Australia	*Acacia rostrellifera, Santalum*	Medium
Dothiorella viticola	Yes	*Vitis vinicola, Citrus sinensis*	South Africa, Australia, China, Tunisia	*Vitis, Podocarpus, Prunus, Juglans, Citrus, Vachellia*	High
*Diaporthe foeniculina** **maybe includes two very closely related species*	Yes	*Citrus latifolia, Citrus limon, Salix sp., Vitis vinifera*	Southern Europe, Germany, Serbia South Africa, Uruguay, New Zealand	*Citrus, Cupressus, Diospyrus, Foeniculum Ficus, Fuchsia, Glycine, Hemerocallis, Juglans, Lumaria, Malus, Melilotus, Microcitrus, Paraserianthes, Persea, Pyrus, Prunus, Rhus, Ribes, Rosa, Salix, Vaccinum,*	Medium/High

				Vicia, Vitis, Wisteria	

5- Are there other fungi involved in Acacia mortality? *Diaporthe foeniculina* and *Dothiorella viticola* are both present in all four sites. Both are reported as causing wood cankers on their hosts, consistent with the symptoms observed. In individual sites, we do find other fungi, taxonomically and ecologically unrelated to *Dothiorella* and *Diaporthe,* that may further accelerate tree decline. One interesting finding is that of zygomycetes found in association with necrotic roots; the interest stems from the fact these fungi are considered as being either beneficial vescicular arbuscular mycorrhizae (VAMs) or competitors of soilborne pathogens. These were found in all sites, but the OTU in each site was different. These additional fungi may in part explain the variety of symptoms observed in the cambium and xylem of branches, stems and roots of declining trees. There is a single report of *Mortierella elongata* being a pathogen of Avocado, possibly supporting this hypothesis.

The important things to note is that these fungi:

a)- Are site-specific and not widespread
b)- Have a complex taxonomy, with some taxa being reported as pathogens and others not. Is it possible that these organisms, usually beneficial may be secondary pathogens on trees with disease caused by *Diaporthe* and *Dothiorella* ?
c) With the exception of *Umbelopsis* at a single site, they are only isolated from trees infected by *Diaporthe* or *Dothiorella*: this is a pattern in agreement with a secondary role of these organisms capable of infecting trees attacked by other pathogens. On the contrary, as stated in section 3 above, *Diaporthe* or *Dothiorella* can be isolated from trees that did not yield and of these "secondary" pathogens.

Below, is a list of the fungi that may additionally contribute to tree decline. I am interested in performing Koch's postulate using *Fusarium solani, Fusarium sarcochroum, Mortierella elongata* and *Umbelopsis ramanniana.*

Table 3. Fungi that may further accelerate acacia decline

Species	Plant part affected	Symptoms	Present in California	Host(s)	Reported as pathogen	ID confidence
Fusarium oxysporum	Rootlets	n/a	Yes	Many	Yes	Low
Fusarium solani	Stem	Canker	Yes	Many	Yes	Low
Fusarium sarcochrum	Stem	Canker	No	Many	Yes	Low
Mortierella elongata	Roots/ Soil	Roots?	Yes?	Many	Once on Avocado	High

Mortierella hialina	Roots	Endophyte	?	Many	Beneficial	High
Umbelopsis ramanniana	Roots and root collar	Staining	Yes?	Tanoak, conifers	? Xylem colonization	High

6- Where other fungi isolated in the four study sites? Yes, a large number of fungi was isolated. Not including common contaminants, we isolated yeasts, entomophagic fungi, mycoparasitic fungi, saprobes, etc. Many are interesting, and may represent first reports for California, but are not likely to be involved in acacia mortality, hence they are not discussed here.

The complete list of fungi isolated is presented in Table 4, below.

Site	Tree	Tree	Sample Origin	B or U	Bait	Seq Results	ID by seq or morph
3	4	Black Acacia	Root collar	Bleached		Absidia heterospora	Sequence
2	7	Black Acacia	Root collar	Unbleached		Absidia pararepens	Sequence
3	2	Black Acacia	Root collar near surface	Unbleached		Absidia pararepens	Sequence
1	4	Black Acacia	Stem	Bleached		Arthrinium kogelbergense	Sequence
1	2	Silver Wattle	Stem below canker	Unbleached		Aureobasidium pullulans	Sequence
1	2	Silver Wattle	Stem below canker	Unbleached		Aureobasidium pullulans	Sequence
1	3	Silver Wattle	Below stem canker	Bleached		Aureobasidium pullulans	Sequence
4	1	Bay laurel	Bay tree root collar base	Bleached		Cladosporium puyae	Sequence
1	1	Black Acacia	Root flare	Bleached		Clonostachys rosea/Hypomyce	Sequence
1	1	Black Acacia	Root flare	Bleached		Clonostachys solani	Sequence
1	1	Black Acacia	Root flare	Bleached		Clonostachys solani	Sequence
1	8	Black Acacia	Stem canker	Bleached		Clonostachys sp./rosea	Sequence
2	2	Black Acacia	Soil		pear	Cordyceps confragosa	Sequence
2	2	Black Acacia	Soil		pear	Cordyceps confragosa	Sequence
2	7	Black Acacia	Root collar	Bleached		Cylindrodendrum hubeiense/N	Sequence
1	7	Black Acacia	Stem canker 5' AGL	Unbleached		Diaporthe foeniculina	Sequence
3	2	Black Acacia	Root collar deep	Bleached		Diaporthe foeniculina	Sequence
3	2	Black Acacia	Root collar deep	Bleached		Diaporthe foeniculina	Sequence
2	1	Black Acacia	Branch	Unbleached		Diaporthe foeniculina	Sequence
4	2	Black Acacia	Branch canker	Unbleached		Diaporthe foeniculina	Sequence
1	5	Black Acacia	Stem above canker	Bleached		Dothiorella moneti	Sequence
1	2	Silver Wattle	Stem below canker	Unbleached		Dothiorella moneti/Botryosphae	Sequence
2	6	Black Acacia	Stem	Unbleached		Dothiorella viticola	Sequence
2	6	Black Acacia	Stem	Unbleached		Dothiorella viticola/Botryosphae	Sequence
1	4	Black Acacia	Stem	Unbleached		Dothiorella viticola/Spencermar	Sequence
1	6	Black Acacia	Stem below canker (oute	Unbleached		Epicoccum italicum	Sequence
3	2	Black Acacia	Root collar near surface	Unbleached		Epicoccum italicum	Sequence
1	1	Black Acacia	Long stem canker	Unbleached		Epicoccum nigrum	Sequence
4	3	Black Acacia	Base of tree	Unbleached		Epicoccum nigrum	Sequence
1	8	Black Acacia	Stem canker	Unbleached		Fusarium lateritium	Sequence
1	4	Black Acacia	Rootlets	Unbleached		Fusarium oxysporum	Sequence
1	4	Black Acacia	Rootlets	Unbleached		Fusarium oxysporum	Sequence
1	4	Black Acacia	Rootlets	Unbleached		Fusarium oxysporum	Sequence
1	7	Black Acacia	Stem canker 5' AGL	Bleached		Fusarium sarcochroum	Sequence
1	7	Black Acacia	Stem canker 5' AGL	Bleached		Fusarium sarcochroum	Sequence
1	7	Black Acacia	Stem canker 5' AGL	Bleached		Fusarium sarcochroum	Sequence
1	6	Black Acacia	Stem below canker (oute	Bleached		Fusarium solani	Sequence
1	6	Black Acacia	Stem below canker (oute	Bleached		Fusarium solani	Sequence
3	3	Black Acacia	Root collar stain	Bleached		Geomyces sp./Geomyces pann	Sequence
1	1	Black Acacia	Soil		pear	Malassezia Globosa	Sequence
1	7	Black Acacia	Soil		pear	Mortierella elongata	Sequence
1	7	Black Acacia	Soil		pear	Mortierella elongata	Sequence
1	7	Black Acacia	Soil		pear	Mortierella elongata	Sequence
1	7	Black Acacia	Soil		pear	Mortierella elongata	Sequence
1	6	Black Acacia	Stem below canker (oute	Unbleached		Mortierella hyalina	Sequence
1	6	Black Acacia	Stem below canker (oute	Unbleached		Mortierella hyalina	Sequence
1	6	Black Acacia	Stem below canker (oute	Unbleached		Mortierella hyalina	Sequence
1	6	Black Acacia	Stem below canker (oute	Unbleached		Mortierella sp./ hyalina	Sequence
1	8	Black Acacia	Soil		oregano	Mortierella sp./Mortierella elong	Sequence
3	3	Black Acacia	Root collar stain	Unbleached		Umbelopsis ramanniana	Sequence
3	3	Black Acacia	Root collar stain	Unbleached		Umbelopsis ramanniana	Sequence
4	2	Black Acacia	Branch	Bleached		Verrucoconiothyrium sp./Conio	Sequence
4	5	Black Acacia	Branch	Unbleached		Verrucoconiothyrium sp./Conio	Sequence
3	7	Black Acacia	Root	Unbleached		Verrucoconiothyrium sp/Coniot	Sequence
1	6	Black Acacia	Root collar bark whitish r	Bleached		Diaporthe	Morphology
1	8	Black Acacia	Stem canker	Bleached		Diaporthe	Morphology
3	2	Black Acacia	Root collar near surface	Unbleached		Diaporthe	Morphology
3	2	Black Acacia	Root collar near surface	Unbleached		Diaporthe	Morphology
2	1	Black Acacia	Branch	Bleached		Diaporthe	Morphology
2	1	Black Acacia	Branch	Bleached		Diaporthe	Morphology
2	1	Black Acacia	Branch	Unbleached		Diaporthe	Morphology
1	7	Black Acacia	Stem canker 3' AGL	Bleached		Verrucoconiothyrium sp./Cor	Morphology
3	7	Black Acacia	Root	Bleached		Verrucoconiothyrium sp./Cor	Morphology
1	6	Black Acacia	Stem below canker (oute	Unbleached		Verrucoconiothyrium sp./Cor	Morphology
2	6	Black Acacia	Stem	Unbleached		Geomyces	Morphology
1	7	Black Acacia	Stem canker 5' AGL	Bleached		Geomyces	Morphology
1	2	Silver Wattle	Root piece healthy and g	Unbleached		Geomyces	Morphology
1	8	Black Acacia	Stem canker	Bleached		Fusarium	Morphology
1	7	Black Acacia	Stem canker 3' AGL	Unbleached		Fusarium	Morphology
3	2	Black Acacia	Root collar near surface	Bleached		Fusarium	Morphology
3	4	Black Acacia	Root collar	Bleached		Umbelopsis	Morphology
3	5	Black Acacia	Small side root	Unbleached		Umbelopsis	Morphology
3	5	Black Acacia	Small side root	Bleached		Umbelopsis	Morphology
1	6	Black Acacia	Root rhizomorphs	Bleached		Absidia	Morphology
3	8	Black Acacia	Side root	Unbleached		Absidia	Morphology
1	3	Silver Wattle	Roots	Bleached		Absidia	Morphology
1	3	Silver Wattle	Roots	Bleached		Absidia	Morphology
1	5	Black Acacia	Roots	Unbleached		Absidia	Morphology
1	5	Black Acacia	Roots	Unbleached		Absidia	Morphology
1	6	Black Acacia	Root collar bark whitish r	Unbleached		Absidia	Morphology
2	3	Black Acacia	Stem	Bleached		Dothiorella	Morphology
2	3	Black Acacia	Stem	Unbleached		Dothiorella	Morphology
2	6	Black Acacia	Stem	Bleached		Dothiorella	Morphology
3	2	Black Acacia	Root collar near surface	Unbleached		Dothiorella	Morphology
3	1	Black Acacia	Root collar	Unbleached		Dothiorella	Morphology
1	4	Black Acacia	Rootlets	Unbleached		Dothiorella	Morphology
3	1	Black Acacia	Root collar	Bleached		Dothiorella	Morphology
1	6	Black Acacia	Root rhizomorphs	Unbleached		Mortierella	Morphology
3	8	Black Acacia	Side root	Unbleached		Arthrinium	Morphology
1	1	Black Acacia	Root flare	Bleached		Arthrinium	Morphology
1	5	Black Acacia	Leaves with dieback			Verrucoconiothyrium sp./Cor	Morphology
1	5	Black Acacia	Leaves with dieback	Unbleached		Verrucoconiothyrium sp./Cor	Morphology
1	2	Silver Wattle	Root piece healthy and g	Bleached		Absidia	Morphology
1	5	Black Acacia	Roots	Unbleached		Dothiorella	Morphology
3	6	Black Acacia	Side root	Bleached		Aureobasidium	Morphology
1	2	Silver Wattle	Root piece healthy and g	Bleached		Absidia	Morphology
1	6	Black Acacia	Root rhizomorphs	Bleached		Arthrinium	Morphology
1	8	Black Acacia	Stem canker	Unbleached		Diaporthe	Morphology
3	8	Black Acacia	Side root	Bleached		Fusarium	Morphology

Table 4. Complete list of fungi isolated and identified in this study.

7- Conclusions and management recommendations.

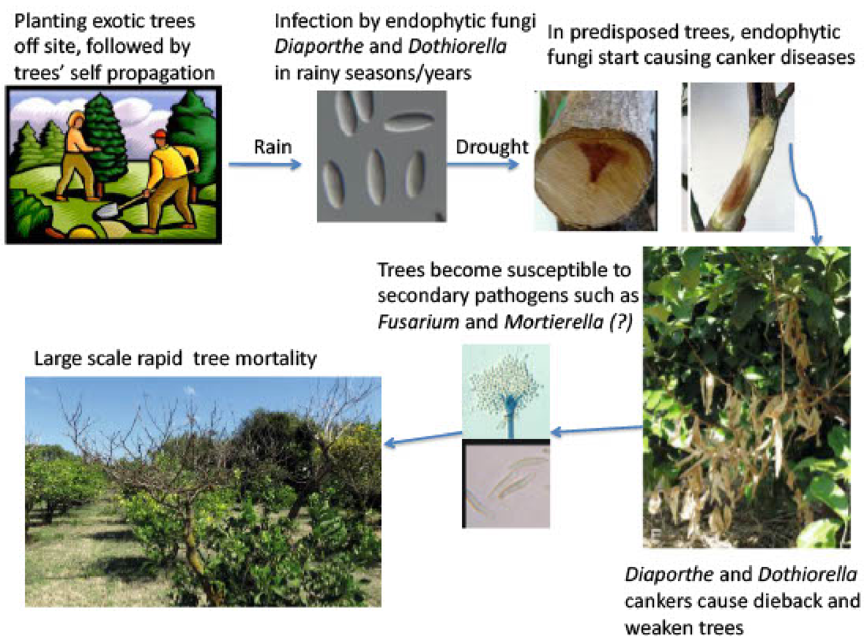
The only fungi consistently associated with *Acacia* spp. mortality in 5 sites across four locations and three California Counties were *Diaporthe* and *Dothiorella*. ***Diaporthe foeniculina* and *Dothiorella viticola* were present in all sites and the disease they cause is the putative major cause of the observed mortality. Thus, we can state that Diaporthe/Dothiorella canker is an emergent disease in acacias around the SF Bay Area.** Both *Diaporthe* and *Dothiorella* fungi are most likely directly involved in causing the observed large-scale mortality. These fungi are interesting because of their mixed biology: they normally initiate their relationship with the host as endophytes, they then shift to a pathogenic life-style and finally survive and sporulate as saprobes on the dead matter generated by the tree mortality they are responsible for. Although this mixed life-style has confused scientists for a long time, it is becoming increasingly accepted that identifying them as secondary pathogens would be incorrect. Secondary pathogens in fact are more properly defined as pathogens that infect a host already infected by a primary pathogen. Many Botryosphaerias and Diaporthes can be defined as pathogens, capable of causing lethal disease ***when*** hosts experience a specific predisposing physiological status. Note that this status may be: a)-unlinked to infection by primary pathogens, and, b)- caused by different reasons (limiting growing conditions in overdense stands, drought, abiotic factors, changes in soil pH and nutrients). One specific advantage these fungi have is that they are already present in their hosts as endophytes, hence, with the onset of the predisposing factors, they can rapidly cause disease, generating large scale outbreaks in a short period of time. When outbreaks are generated by infectious agents yet to infect their hosts, normally the time necessary to produce large outbreaks will be not only significantly longer, given that the infection process will take time and disease will initially manifest in scattered small clusters of mortality, due to the likelihood of escape by plants due to genetic variability (in natural populations) or microclimate variability (in invasive host populations characterized by a narrow genetic diversity). **The take home message is that some of these Botryiosphaerias and Diaporthes can be aggressive pathogens, when the right conditions arise**, while secondary pathogens will always depend on primary infections by other pathogens. Even if we include in the secondary category pathogens that will infect plants stressed by abiotic factors, it is presumed those pathogens will infect their hosts after they are predisposed. In this case, the pathogens in question have already infected their hosts when they were healthy, thanks to their ability of living within plants as endophytes.

Conversely and hypothetically, some of the soilborne zygomycetes here isolated may become secondary pathogens on trees infected by *Diaporthe/Botryosphaeria*, further accelerating mortality. This is just a hypothesis that although in need of substantial further work to be supported, is not in disagreement with our observations and isolation results.

Although infection occurs as part of the initial endophytic process, there is good evidence that infection rates are greatly increased in the presence of abundant rainfall. In our study, the rains of 2017 would have resulted in high infection rates. Only exceptionally do these fungi cause disease in the short term, due to the fact they mostly establish themselves as endophytes. A one to two-year lag between infection and disease is probably a minimum requirement, but in some cases the lag may last decades. If we assume infection occurred in 2017 and in wet years prior to 2017, then, mortality in 2020 matches the expectations of this scenario. It is also likely that 2017 resulted in the pervasive infection of a large percentage of individuals. We suggest that mortality is observed where infection was high in 2017, coupled with predisposing factors occurring post 2017. Certainly drought may be a major predisposing factor, but let's remember that water availability will depend on other factors as well, in particular, aspect (south and southwestern slope being more likely to dry out), frequency and abundance of coastal fog (less fog will increase evapotranspiration), soil compaction (compacted soil will absorb and retain less water), soil texture (sandier soils will retain less water; clay hardpans will prevent roots from reaching deep water during dry period), and plant density and size/age (denser stand will require more water, or in the case of equal density, stands with larger trees mat require more water), finally the effects of chemical changes in soil and leaves caused by smoke are largely unknown. It appears that these acacias are native to mesic environments in their native Australia, not a good match for the Mediterranean climate of the SF Bay Area.

Both acacias studied here are exotic and invasive, meaning they will naturally reproduce and increase rapidly their population size, without necessarily enlarging their genetic pool. Most individuals may thus be equally susceptible to predisposing factors and infection by these fungi. We believe both *Dothiorella viticola* and *Diaporthe foeniculina* to be native or long residents of California and that they may have crossed over from other hosts. The case *Dothiorella moneti/santali* is very interesting as it may have arrived from Australia as an endophyte of acacias. These two species in fact are reported exclusively from acacia

Figure 6. Proposed cycle showing the various interacting factors leading to rapid tree mortality: off-site planting of exotic invasive trees; trees propagate unchecked through self-seeding or clonal propagation; host jumps of native or naturalized fungi starts as number of invasive trees increases and is facilitated by rainfall; high rainfall leads to massive infection by such fungi that are initially endophytes; predisposing factors leading to water/resources deficiency turn endophytes into pathogens; pathogens weaken trees and become primary mortality agents; trees eventually become susceptible to secondary pathogens, multiple diseases foster quicker mortality.



What can we recommend and why?

These recommendations and the priority ratings are based on knowledge from agricultural systems. Although the biology of the pathogens here involved justifies such recommendations, their applicability in non-agricultural systems needs to be carefully evaluated through a case-by-case cost-benefit analysis. We also do not know whether the affected stands will regenerate through resprouting, a phenomenon that may compound the severity of the issue and require different prescriptions.

1- High priority: Reduce stress by thinning considerably remaining Acacia populations. Thinning has to be done in non –rainy periods, mid Summer to mid Fall to avoid further infection associated with disturbances during thinning operations. Thinning can be done by cutting down whole trees, but also by trimming down the size of the canopy of remaining trees: these trees will require less water once their canopy is downsized.

Caveat: Due to self-propagation issues through resprouting or intensive seeding, thinning of thickets may require complex actions involving stems' removal and herbicide treatment, with uncertain outcomes. Trimming of individual high value trees, instead, may be easier to achieve and a valuable option with minimum undesirable side effects.

2- **Medium priority (only because may be hard to implement)**: Preserve only Acacia stands that are in more mesic sites (fertile deep, non sandy soils, and North or East facing slopes, good precipitation records). When possible (socially and financially), replace Acacia stands with other species, native and non-invasive, when acacias are growing in shallow or sandy soils, sites with Southern of Western Exposure, or sites that locally (because of shadow effects or mesoclimatic reasons) receive lower levels of precipitation. **These completely off-site stands will serve as a source of inoculum that may infect other hosts**: as climate changes due to global effects, native hosts may also become susceptible to disease caused by *Dothiorella* and *Diaporthe*, hence we want to minimize the sources of inoculum to avoid a domino effect. We believe that *Eucalyptus* may probably be undergoing the same types of disease due to cross-host infection by these fungi, so we already have a record of this expansion of host ranges happening in California.

3- **Medium priority (because of uncertain efficacy):** As symptoms begin to appear, prune and discard dead branches, making sure to cut at least a foot away the dead portions of the trees. This should reduce inoculum, although it is unclear whether trimmed trees will develop disease on other branches. Trimming trees will also decrease the water deficit, thus slowing down disease progression. This prescription should be preferably implemented in dry season.

Caveat: Although applicable in agricultural settings, this is a labor intensive and costly action with uncertain outcomes in self-generated Acacia stands.

4- Very high priority: Inoculum is produced with great abundance on dead matter resulting from tree mortality. As the host range of these fungi is broad, inoculum can infect not only acacias, but also other hosts, even native plants. Remove all dead trees and woody debris under dead and declining trees. Dispose of debris by burning, composting or by burying in a landfill (these are aerial fungi and should not fare well underground). This operation is essential, and if possible, it needs to be done before each rainy season. For 2021, it may be too late for this prescription, but for areas with abundant tree mortality I recommend delaying any operation to be done in early 2021 to later on in the year, in order to allow for this sanitation removal to occur. Any restoration done without prior removal of woody debris and dead trees may later on be compromised.

Caveat: This may be a disease-mitigating action that needs to be repeated as further dry years occur. The importance of this operation is supported by the possibility that even native trees may become massively infected due to the amount of inoculum generated by dying and dead acacias. Because of ongoing climate change, even native plant species may soon become predisposed to infection by these fungi. Although they may already be occasionally infected by these fungi, the large amount of inoculum available may lead to large scale infection events that are quantitatively different from the ones that may have been locally occurring.
Chipped wood remains infectious and hence cannot be left on site.
Please note that this is not a "all or nothing" recommendation, meaning that any level of woody debris removal will be better than no removal at all: of course, the more dead and dying woody substrate is removed, the more effective the prescription. We do not yet know the correlation between removal amount and level of efficacy.

5- High priority: Sanitize all tools and equipment used both when collecting dead matter and to prune or cut down infected trees. Sanitation will require cleaning the tools from any organic/woody debris followed by the use of chemical treatments using alcohol, bleach, or Lysol. Refer to direction for sanitation of tools by other infectious fungal diseases.

Caveat: These fungi are not currently regulated, however they are infectious and so all precautions should be taken to limit further infection. If operating in the dry season, risk of infection propagation through infected tools and machinery will be minimal.

Future work

Koch's postulate on blackwood acacia potted saplings (4 per treatments) using the following fungi will be performed soon. Potted plants have already been ordered

Diaporthe foeniculina SFPUC strain
Dothiorella moneti Leona Heioghts strain
Dothiorella viticola SFPUC strain

Mortierella elongata
Umbelopsis ramanniana
Control

Note that while positive results will be informative, negative results may be solely due to our inability to reproduce in potted plants the right type of stress that leads to infection.

As of March 15th 2021, plants have been inoculated in the SFPUC. This will allow us to investigate whether disease may occur only when stress is present. We will only use fungi isolated from the SFPUC, and 4 small trees per treatment will be used. Treatments are listed below.

Fungus	Origin	No. trees
Diaporthe foeniculina	SFPUC	4
Dothiorella viticola	SFPUC	4
Umbelopsis ramanniana	SFPUC	4
Controls		4
Total number of trees		16

Results of Acacia inoculations studies should be available by the Summer of 2021. Additional work is required to determine the cause of decline and mortality in other tree species, including *Eucalyptus globulus*.

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Pathogen Study

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ATTACHMENT 3

Biomass Disposition Alternatives

Prepared For: Midpeninsula Regional Open Space District

Prepared By: Applied Technology & Science

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Contents

Introduction

This document reviews the advantages and disadvantages of an array of plant biomass disposal methods associated with multiple vegetation management strategies, including fuel reduction, invasive species management, and trail maintenance. The document was prepared by A-T-S biologists Russell Huddleston, Silas Ellison, and Roger Stephens. This paper considers a variety of methods for biomass disposal, including mulching, lop and scatter, pile burns, brush piles, girdling, trucking off-site to bioenergy power plants or compost yards, air curtain burners, and other local reuses. The costs and benefits for each method are analyzed in terms of greenhouse gas (GHG) emissions, air quality impacts (volatile organic compounds (VOC) and particulate matter (PM)), biodiversity impacts, fire hazards, pathogen spread, cost, staff labor, the safety of staff and visitors, impacts to wildlife habitats, and visual impacts. The appropriate disposal method will often depend on site conditions such as accessibility, public access, and the amount of material requiring disposal. The methods addressed in this document are intended to cover a range of conditions and disposal options.

Biomass disposal methods

In this section, we examine the advantages and disadvantages of various methods for biomass disposal, relying on evidence from the most recent scientific literature. Methods considered include mulching, lop and scatter, pile burns, brush piles, girdling, trucking off-site to bioenergy power plants or compost yards, air curtain burners, and other local reuses. Table 1 (at the end of the text) provides a summary of the advantages and disadvantages of each method.

Mulching and Mastication

Mulching is an increasingly popular method for biomass disposal due to several advantages over other disposal methods (Frame, 2011). In this technique, woody debris is chipped or chopped using a masticator and spread over the ground near the biomass source. Because the biomass is not transported off-site, there are no transportation-related costs or GHG emissions associated with off-site transport, although the chipping and spreading equipment does produce a small quantity of GHGs. Additionally, mulching poses no safety risk for visitors, creates minimal adverse air quality impacts, poses minimal safety risks for staff and equipment operators, and creates minimal visual impacts for park visitors. Chippers can produce some particulate pollution in the form of dust, but this can be reduced by chipping material soon after it is cut, or by adding water to the chipper along with woody debris. The labor and equipment costs are also quite low relative to other methods since the main tasks associated with mulching are chipping and spreading the woody debris. Mulching or other on-site disposal methods are highly recommended when the plant material is suspected to be infected with sudden oak death (SOD; causal agent: *Phytophthora ramorum*) or other plant pathogens, since transporting plant material off-site may result in the spread of the pathogen to uninfected areas (Alexander & Swain, 2010). This method is most applicable for sites with low to moderate amounts of biomass consisting mostly of woody shrubs and small trees (maximum 8 inches in diameter).

The use of a tractor-mounted masticator may be an effective method for small trees and shrubs along roads, trails, and other areas. However, these methods may result in more unsightly vegetation for periods following the mastication and typically leave more coarse woody debris than chipping methods, which can result in a longer burn time and slower decomposition rate. Use of a trailer-mounted masticator near roads or trails may also require public access control while work is being performed.

Depending on the equipment used, the mulch can be considered a quick-burning 1-hour fuel, or a larger particle 10-hour fuel (Frame, 2011). While mulching does increase the fuel load of the forest floor, it also reduces the probability of a fire spreading from the forest floor to the canopy, since mulch on the forest floor is less likely to act as a fuel ladder than dense understory vegetation. When mulch is applied at a low to moderate thickness (typically < 3 inches) mulching does not suppress understory vegetation development or decrease plant species richness, although it is sometimes associated with the introduction of new non-native plant species (likely due to the significant habitat disturbance and the difficulty of perfectly decontaminating masticators and associated equipment). Mulch thickness of greater than 3 inches can lead to decreased availability of soil nitrogen and corresponding suppression of understory vegetation development (Frame, 2011). However, if rare annual plants are present at the biomass removal site, a thick layer of mulch is likely to suppress germination. To minimize negative impacts to soils on site, mulch should be spread evenly across the biomass removal site and work should be conducted in the dry season (Abbas et al., 2011). If the plant material being spread produces allelopathic chemicals (especially *Eucalyptus* sp., but also including native trees like *Umbellularia californica* and non-native herbaceous plants like *Conium maculatum* and *Elymus caput-medusae*), mulching may change local soil chemistry or negatively impact living plants. Additionally, since the masticator needs to be transported to the biomass removal site, it may not be well suited to remote or difficult-to-access sites.

Lop and scatter

Lop and scatter, in which woody debris is chopped into smaller pieces and spread throughout the biomass removal site, is one of the most common treatments in commercial forestry settings. It shares several of the same advantages as mulching: there are no costs or GHG emissions related to the off-site transportation of debris, no air quality impacts or safety risk for visitors, a minimal safety risk for equipment operators, minimal visual impacts, and low cost of labor and equipment. In addition, scattered woody debris with a diameter greater than or equal to 2.5cm is known to offer substantial benefit as habitat for a variety of wildlife species (Abbas et al., 2011); however, the recent widespread tree mortality caused by the rapid spread of SOD has led to an unusually high abundance of woody debris in many Bay Area forest habitats, so the placement of additional woody debris may have only a marginal benefit to wildlife. This method also requires less heavy equipment than mulching and is, therefore, better suited for remote sites or those difficult to access. Similar to mulching, the power tools and machinery used to chop and scatter the woody debris do produce a limited quantity of GHGs, in addition to volatile organic compounds (VOCs) that may adversely impact local air quality. However, logs decompose more slowly than the smaller wood chips produced by a masticator, and therefore carbon dioxide is released more slowly from logs when compared to mulch (Nowak et al., 2002). If the plant material produces allelopathic chemicals (e.g., *Eucalyptus sp., Conium maculatum*, etc.), this method may impact soil and living plants at the site, although the impacts are likely to be less than mulching due to slower decomposition rates. Similarly to mulching, lop and scatter will increase the fuel load of the forest floor but reduce the canopy density fire risk (Frame, 2011). Scattering logs locally can also prevent the spread of plant diseases like SOD to uninfected sites; if small logs are placed near roads, they may be gathered for unauthorized use as firewood and transported off-site (Alexander & Swain, 2010). Therefore, lop and scatter is better suited for areas that are not immediately adjacent to roads. This method is best used for relatively small, localized areas with low amounts of biomass.

Brush piles

Brush piles retain several of the advantages and disadvantages of lop and scatter, with the potential for the creation of high-quality wildlife habitat and with any impacts from allelopathic chemicals or seeds from non-native species concentrated into a smaller area. Here, we use the term “brush piles” to refer to debris that is piled and allowed to decompose naturally; debris piles that are intentionally burned are considered later in the text and are referred to as “pile burns”. Again, there are no off-site transportation-related costs, no air quality impacts or safety risks for visitors, minimal safety risks for equipment operators, and low labor and equipment costs. This method results in minimal GHG emissions, primarily from power tools and machinery and some slow release from wood decomposition. Like lop and scatter, brush piles are well-suited to remote areas since less heavy equipment is required. Brush piles may provide superior habitat for wildlife compared to lop and scatter, as evidence shows that large brush piles are utilized by a wide variety of birds and small mammals, although branches with a small diameter appear to provide better quality habitat than large logs (Gorenzel et al., 1995). Brush piles do create local concentrations of increased fuel load and may lead to localized higher intensity burns in the event of a wildfire. They can also be very effective ladder fuels, increasing the chance that a brush fire on the forest floor will reach forest canopy height. The impacts of allelopathic chemicals and seeds from non-native plants may be reduced compared to lop and scatter or mulching since the debris is concentrated in a smaller number of discrete piles. If brush piles are located near roads or trails, some members of the public may consider them to be visually unappealing. This method is best suited for sites with relatively low amounts of biomass.

Girdling and leaving snag in place

Girdling trees (removing the living inner bark tissue in a ring around the tree) and leaving them in place is the fastest and cheapest options available for biomass disposal, with the lowest carbon and GHG impacts of any method considered here; however, increased fuel loads, safety hazards, and visual impacts are significant disadvantages. Like the other on-site disposal methods considered so far, there are no off-site transportation-related costs or GHG emissions, and very minimal CO_2, VOC, and PM emissions. Labor and equipment costs are lower than all other methods. Because very little equipment is needed, this method is very well suited to sites that are remote or difficult to access, and there are minimal GHG, COV, and PM emissions associated with equipment use. Snags also provide important habitat for wildlife such as cavity-nesting birds (Eklund et al., 2009). Evidence suggests that girdling may decrease soil respiration underneath the girdled trees, potentially reducing the local rate of carbon released into the atmosphere (Chen et al., 2010). The release of nutrients into the soil is also typically slower than for treatments such as mulching, which accelerate the decomposition of woody debris. However, over time, standing dead trees pose a safety hazard in well-traveled areas. Numerous dry, girdled snags can significantly increase the fuel load in an area, potentially leading to higher intensity fires; however, fire risk can vary significantly between sites based on the number, density, and position of snags, and site conditions, such as slope, aspect, wind, etc. Snags may represent increasing safety risks to visitors over time due to increasing fire and deadfall risk, especially if they are located near roads or trails, and some may consider high densities of snags to be visually unappealing. These methods should only be used for carefully selected trees.

Pile burns

Since pile burns are an on-site biomass disposal method, they involve no transportation-related costs or transportation-related GHG emissions, and there is no risk of spreading plant pathogens to uninfected areas. Burning immediately kills most pathogens the biomass may contain, and it is especially effective for fungal and oomycete pathogens, including *P. ramorum* (Sosnowski et al., 2009). There are minimal long-term visual impacts, and less labor and equipment are required than for some other methods such as mulching.

All fires produce smoke, and the amount of smoke that will be produced is dependent on the moisture of the wood burning. To minimize smoke, Midpeninsula Regional Open Space District (MROSD) should allow the piles to dry out or "cure" for approximately 18 months. Weather conditions may also affect the amount of smoke produced. Impacts from pile burning smoke are short term and less intense than that of a wildfire.

Additionally, while very unlikely, the possibility of fire escaping a pile burn would pose a safety risk to staff, visitors, and nearby infrastructure. Careful planning is required to avoid this unlikely scenario. Best management practices outlined in the Midpen Wildland Fire Resiliency Program are important tools to minimize the risks of fire escaping a pile burn.

Seasonal timing, weather conditions, and air quality can limit when burning may occur and some piles may remain in place for several months, resulting in short-term visual impacts in publicly accessible areas. Climate change, which has led to many years with longer, hotter dry seasons, has already caused the window of time in which pile burns are possible and safe to shorten, and these trends are predicted to become even more severe in the future. Because of the temporary nature of the debris piles, this method can be used to dispose of low to moderate amounts of biomass, depending on site conditions.

Air curtain burners

Air curtain burners (also called Air Curtain Incinerators, or Fireboxes) are structures with specialized air filters in which controlled burns can be conducted. Compared to pile burns, air curtain burners significantly reduce wood smoke GHG emissions, as well as negative impacts on local air quality from particulate pollution. In a 2007 review paper published by the U.S. Environmental Protection Agency, PM emissions were found to be approximately 2 orders of magnitude lower in air curtain burners than open pile burns (0.05g PM/kg fuel for air curtain burners vs. 10g/kg for open burns; Miller & Lemieux, 2007). Similarly, CO emissions were reduced by approximately 2 orders of magnitude when burns were performed in an air curtain burner. The process can be used to incinerate the woody material or create biochar. Biochar is a kind of charcoal produced by burning biomass in a low-oxygen environment. Biochar has been touted as a product for improving soil quality by increasing soil structure complexity and reducing acidity, restoring degraded soils, improving agricultural productivity, and helping soils retain water, as well as a means of sequestering carbon. However, recent studies have shown that the use of biochar can alter the composition and biomass of soil communities, hindering plant growth and causing broader ecosystem impacts (Nash et al., 2021).

Like the other local biomass disposal methods, there are no off-site transportation-related costs or GHG emissions, and like pile burns, there are no long-term visual impacts. However, the air curtain machinery has a much higher cost than other disposal methods. Air curtain burners significantly reduce GHG emissions compared to open pile burning. Because air curtain burners are large structures and need to be transported to sites, they may not be well suited to remote sites. However, once in place, large quantities of material can be treated. Purchase prices range from $100,000 to $200,000 depending on the size and amount of material handled (2-13 tons per hour; the maximum quantity of material that can be processed per hour is determined by the size of the air curtain burner). The advantage of this method is that any amount of material can be treated, although it is more efficient to collect enough material in advance to operate the machinery continuously for a short period, rather than starting and stopping over a period of weeks. In some situations, it may be necessary to temporarily stockpile biomass from several small sites until enough material has been amassed to spend a day burning the material. Due to the size of the machinery required, air curtain burners are most easily transported to and operated in locations near roads and trails, and therefore can temporarily impact public access to those areas. Because this method allows for the continuous on-site disposal of materials, it can be advantageous for larger sites with greater amounts of biomass.

Other local reuses for both chips and logs

Woody plant debris may also be transported off-site and used for a variety of purposes on MROSD land or within the local community. For instance, wood chips may be used for trails or parking areas, as well as in playgrounds and parks. Logs may be used in erosion control structures, road barriers, etc, or they may be delivered to MROSD employees to be used to help heat poorly insulated homes. These local reuse strategies may be advantageous because they have limited impact on the biomass removal site: little debris is left behind after the biomass is removed, minimizing visual impacts and the potential impacts of allelopathic chemicals. There are no also local air quality impacts or safety risks for visitors. On the other hand, the potential for pathogen spread outside the removal site is greatly increased, including *Phytophthora* sp. and the recently detected pistachio canker, *Leptosillia pistaciae* (California Department of Food and Agriculture, 2020). While this method focuses on local reuse, the cost and GHG emissions associated with transportation increase proportionally with the distance of the reuse site from the removal site. The safety risks for equipment operators are small, roughly equivalent to the risks for the corresponding on-site reuse strategy (primarily risks from masticators, chain saws, etc.). Given that large vehicles are needed to transport the biomass off-site for local reuse, these strategies are best suited for sites close to an access road. Likewise, due to the limited potential for on-site use, this method is generally best for sites with smaller amounts of biomass.

Composting on-site

Similar to local reuse methods such as mulch and erosion control, composting has the advantage of potentially reduced impacts at the biomass removal site, but the disadvantages of increased costs, GHG emissions, and potential for pathogen spread. Again, this strategy creates no visual impacts, air quality impacts, a safety risk for visitors, and only minimal safety risk for staff and equipment operators. The compost created by several invasive trees common in the Bay Area is a viable alternative to more traditional soil amendments in horticultural settings. A 2015 study found that *Acacia longifolia* and *A. melanoxylon* compost had favorable physical properties, roughly comparable to native peat moss and pine bark treatments, after just 146 days (Brito et al., 2015). Another study found that the bark of *A. melanoxylon* had a high lignin content and high mineral element concentrations, suggesting that it may be appropriate for horticultural uses such as organic substrate formulation (Chemetova et al., 2020). Composting has also been shown to be effective at eliminating fungal and fungus-like pathogens, including *P. ramorum*, provided that temperature and duration are sufficiently high (Alexander & Swain, 2010). In a 2009 study, 33 of 38 fungal pathogens examined were reduced to levels below detection limits when exposed to peak composting temperatures of 64–70°C for 21 days (Sosnowski et al., 2009). However, untreated biomass has the potential to spread pathogens to new areas during transit or before being composted (Shelly et al., 2006). GHG emissions are also associated with both transportation of the debris (if MROSD compost facilities are not located directly in the biomass removal site), and the rapid decomposition of wood in a high-temperature compost pile. Allelopathic chemical impacts are reduced in the biomass removal site, but the presence of allelopathic chemicals limits the potential for beneficial reuse of the compost. The cost of transportation is also higher, and the efficiency of this strategy decreases with the increasing distance of the biomass removal site from the nearest road. As this method requires long-term storage of materials in piles, this method is best suited for limited amounts of biomass.

Trucking off-site to other compost

The advantages and disadvantages for composting at another off-site facility are largely the same as those for composting at a MROSD site, except that the distance between the biomass removal sites and the compost facility are likely to be greater. Therefore, the transportation costs in terms of both GHG emissions and trucking fees are likely to be higher, and labor costs are likely to be higher as well. There is also a higher chance of unintentionally introducing pathogens to previously uninfected areas during transit, although proper precautions taken when preparing the biomass for transit can mitigate these risks. The advantage of this option is it allows for the removal of a higher amount of material than would likely be possible using on-site methods.

Trucking off-site to a bioenergy power plant (waste-to-energy)

In 2020, a total of 87 operating biomass power plants (including 14 located in the nine Bay Area counties) accounted for 2.95% of California's in-state electricity generation portfolio. Trucking biomass off-site to a bioenergy power plant shares some of the same advantages and disadvantages of the other off-site strategies discussed so far: minimal visual impacts and no safety risks for visitors on-site, and minimal safety risk for staff and equipment operators are advantages; increased cost and GHG emissions associated with transportation and increased risk of pathogen spread during transit are disadvantages. Bioenergy power plants have the advantages of generating electricity and creating biomass ash as a byproduct. When biomass ash reacts with carbon dioxide, it can be mineralized and used in cement and construction products, hence reducing the reliance on raw resource extraction (Tripathi et al., 2019); however, this advantage is contingent on the strength of the demand for such construction products in the region of the bioenergy power plant. On the other hand, the conversion of biomass to energy results in substantial GHG emissions and negative local impacts on air quality due to wood smoke. Several bioenergy plants in the Bay Area are located in or near low-income, minority communities (e.g., the Hunter's Point neighborhood of San Francisco, East Palo Alto, and other bayside communities); therefore, the negative impacts on local air quality caused by bioenergy plants may exacerbate health inequalities, among other environmental justice concerns. Recent studies suggest that the negative impacts of bioenergy power plants outweigh the advantages of the energy and products produced (Morris, 2017). Bioenergy power plants can reduce the amount of methane gas and particulate matter produced relative to pile burns (Jones et al., 2010). However, a 2011 study found that burning biomass in a bioenergy power plant did not significantly mitigate the environmental impacts of burning the biomass on-site and that the costs of transporting the biomass to a bioenergy power plant were high relative to on-site pile burns (Springsteen et al., 2011). For these reasons, other techniques for biomass disposal are generally preferred over bioenergy power plants. Like the other off-site disposal options, this strategy is better suited for sites located close to access roads. To be cost-effective, this method would require moderate to large amounts of biomass and disposal may be subject to variable supply and demand of the bioenergy facility.

Trucking off-site to landfill

Trucking biomass off-site to a landfill for disposal is similar to other off-site disposal options in terms of the advantages: there are minimal visual impacts, safety risks for visitors on-site, and minimal safety risks for operators. However, this option provides no environmental benefits and has an increased cost associated with transportation, disposal, and GHG emissions. This option is recommended only for moderate to large amounts of biomass for which there are no other feasible disposal options available.

Table 1. Summary of Biomass Disposal Options

Disposal Method	GHG Emissions[1]	Air Quality Impacts	Visual Impacts	Potential Pathogen Spread	Wildfire Risk/ Hazards	Transport Cost	Labor Costs	Equipment Cost	Use in Remote Locations	Amount of Material
Mulching/Mastication	Minimal	None	Low	Localized	Minimal	None	Low	Low	Yes	Low - Moderate
Lop and Scatter	Minimal	None	Low	Localized	Minimal	None	Low	Low	Yes	Low
Brush Piles	Minimal	None	Low	Localized	Minimal	None	Low	Low	Yes	Low
Tree Girdling	Minimal	None	Moderate	None	High	None	Low	Low	Yes	Low
Pile Burns	Minimal	High	Moderate	None	Moderate[2]	None	Low	Low	Yes	Low - Moderate
Air Curtain Burner	Low	Low	None	None	Low	None	Moderate	High[3]	No	Low - High
Other Local Reuses	Minimal	None	None	High	None	Low	Low	Low	No	Low
Local Composting	Minimal	None	None	Low	None	Low	Low	Low	No	Low
Trucking off-site for Compost	Moderate to High	None	None	Low	None	Moderate - High	Moderate - High[4]	Moderate - High[4]	No	Moderate – High
Trucking off-site to Bioenergy Power Plant (Waste-to-Energy)	Moderate to High	Moderate	None	Low	None	Moderate – High	Moderate – High[4]	Moderate – High[4]	No	Moderate - High
Trucking off-site to Landfill	Moderate to High	Moderate	None	Low	None	High[5]	Moderate – High[4]	Moderate – High[4]	No	Moderate - High

Notes:

[1] Green House Gas (GHG) emissions are associated with the burning of fossil fuels; use of power tools and equipment considered to have minimal impacts; moderate to high impacts are associated with off-site trucking for the removal of biomass.

[2] Pile burns pose a higher risk for potential wildfires, but this risk can be mitigated by seasonal timing and other factors.

[3] This method would require the lease or purchase of equipment, but an initial investment could reduce costs over time.

[4] Methods that require off-site transport will require expenses associated with additional drivers and trucks to haul materials.

[5] This method is likely to have additional costs associated with disposal in addition to transportation costs

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