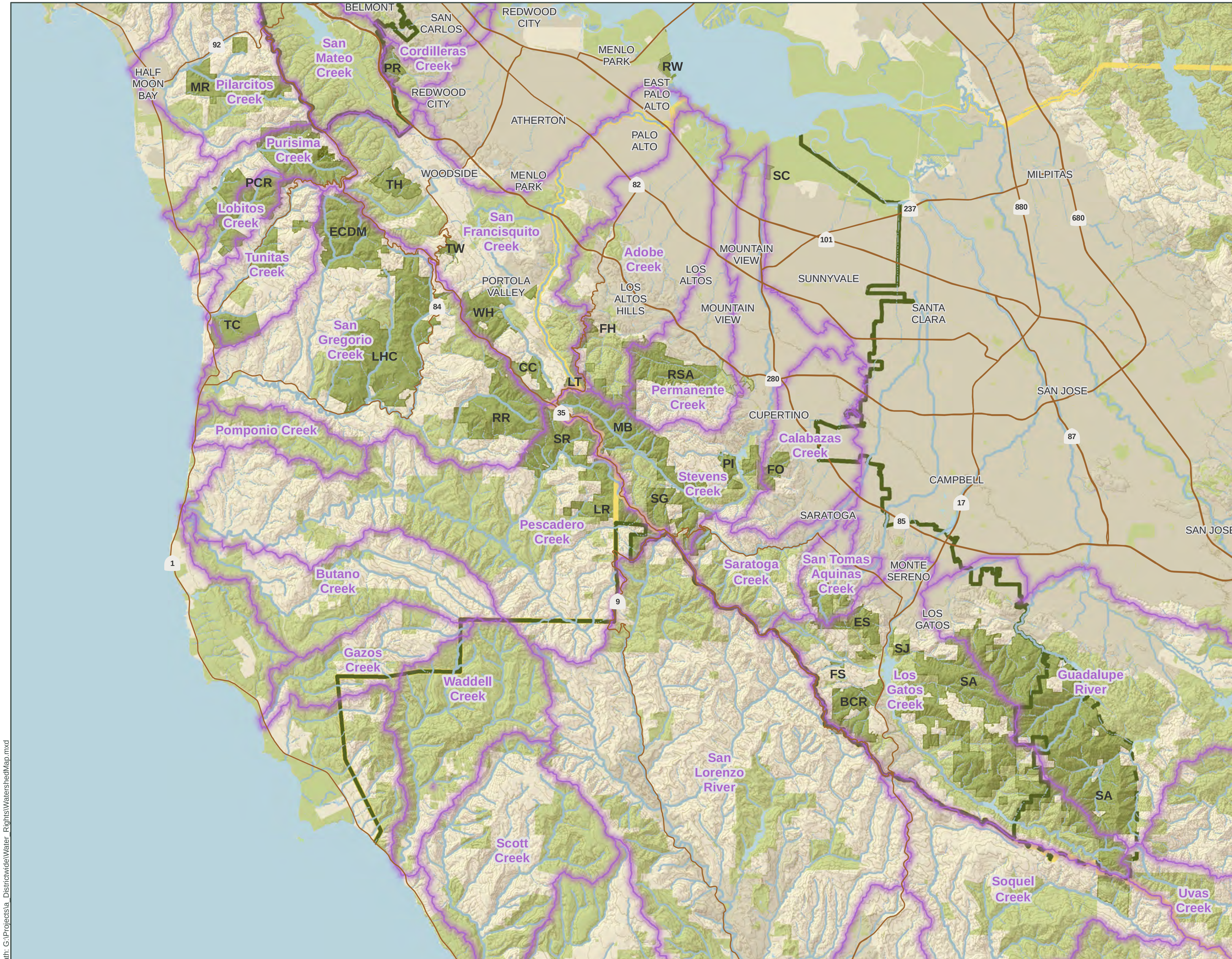

Major Watersheds Attachment 1

Midpeninsula Regional Open Space District

A. Hébert

April 2017

Miles 0 2 4

- Watershed Boundary
- Streams
- MROSD Preserves
- Other Protected Lands and Conservation Easements
- District Boundary
- County Boundary
- Highways

Path: G:\Projects\a_Districtwide\Water_Rights\WatershedMap.mxd

Firm Name:

	Yes/No	Yes/No	Yes/No	Project Name
Task	**Interested?**	**Self Perform?**	**Sub-contract?**	**Project Example**
Water Quality Sampling				
Suspended Sediment and Bedload Sampling				
Turbidity Monitoring				
Title 22 Analysis				
V* Pool Sediment Surveys				
Stream Gage Installation and Monitoring				
Rain Gage installation and monitoring				
Stage-Sediment rating curves				
Fish Bypass Assessments				
Large woody debris design				
Water Availability Analysis in support of water rights appropriation applications				
Well Pump Testing and analysis				
Hydrogeologic assessments to locate new wells				
Specification, installing, and monitoring of water meters				
Water demand estimation and modeling				
Bathymetric Pond Surveys				

Firm Name:

Task	Interested?	Self Perform?	Sub-contract?	Project Example
Pond Volume Measurement				
Pond staff plate installation and maintenance				
Pond Water Source analysis: delineating sheetflow, groundwater, and stream water contributions				
Small Dam Failure and Inundation Studies				
Pond volume estimate models based on precipitation and evaporation for water rights reporting				
Wetland delineations				
Jurisdictional delineation for California Department of Fish & Wildlife, Army Corps of Engineers				
Permit: 1600 permits,				
Permit: 401/other water quality certificates				
Permit: Army Corps Permits				
Sediment Source Inventories				
Hydrology and Hydraulic Calculations in support of culvert, bridge, road, and parking lot design				
Peer review of the above				
CEQA Expertise in Hydrology				
Access to scientific and academic resources to inform District projects and policies				
Geologic and geotechnical expertise in support of the above projects				
Civil engineering in support of the above projects				
Biological and ecological expertise in support of the above projects				

Midpeninsula Regional Open Space District

AGREEMENT FOR PROFESSIONAL SERVICES
BETWEEN THE MIDPENINSULA REGIONAL OPEN SPACE DISTRICT
AND [CONSULTANT'S NAME] **FOR** _[PROJECT NAME]_

THIS AGREEMENT is by and between _______________ ("Consultant") and the Midpeninsula Regional Open Space District, a public body of the State of California ("District"). Consultant and District agree:

1. **Services.** Consultant shall provide the Services set forth in Exhibit A, attached hereto and incorporated herein.

2. **Compensation.** Notwithstanding the expenditure by Consultant of time and materials in excess of said Maximum compensation amount, Consultant agrees to perform all of the Scope of Services herein required of Consultant for $_________ including all materials and other reimbursable amounts ("Maximum Compensation"). Consultant shall submit invoices on a monthly basis. All bills submitted by Consultant shall contain sufficient information to determine whether the amount deemed due and payable is accurate. Bills shall include a brief description of services performed, the date services were performed, the number of hours spent and by whom, a brief description of any costs incurred and the Consultant's signature.

3. **Term.** This Agreement commences on full execution hereof and terminates on _______ unless otherwise extended or terminated pursuant to the provisions hereof. Consultant agrees to diligently prosecute the services to be provided under this Agreement to completion and in accordance with any schedules specified herein. In the performance of this Agreement, time is of the essence. Time extensions for delays beyond the Consultant's control, other than delays caused by the District, shall be requested in writing to the District's Contract Administrator prior to the expiration of the specified completion date.

4. **Assignment and Subcontracting.** A substantial inducement to District for entering into this Agreement is the professional reputation and competence of Consultant. Neither this Agreement nor any interest herein may be assigned or subcontracted by Consultant without the prior written approval of District. It is expressly understood and agreed by both parties that Consultant is an independent contractor and not an employee of the District.

5. **Insurance.** Consultant, at its own cost and expense, shall carry, maintain for the duration of the Agreement, and provide proof thereof, acceptable to the District, the insurance coverages specified in Exhibit B, "District Insurance Requirements," attached hereto and incorporated herein by reference. Consultant shall demonstrate proof of required insurance coverage prior to the commencement of services required under this Agreement, by delivery of Certificates of Insurance to District.

6. **Indemnification.** Consultant shall indemnify, defend, and hold District, its directors, officers, employees, agents, and volunteers harmless from and against any and all liability, claims, suits, actions, damages, and causes of action arising out of, pertaining or relating to the negligence, recklessness or willful misconduct of Consultant, its employees, subcontractors, or agents, or on account of the performance or character of the Services, except for any such claim arising out of the sole negligence or willful misconduct of the District, its officers, employees, agents, or volunteers. It is understood that the duty of Consultant to indemnify and hold harmless includes the duty to defend as set forth in section 2778 of the California Civil Code. Notwithstanding the foregoing, for any design professional services, the duty to defend and indemnify District shall be limited to that allowed pursuant to California Civil Code section 2782.8. Acceptance of insurance certificates and endorsements required under this Agreement does not relieve Consultant from liability under this indemnification and hold harmless clause. This indemnification and hold harmless clause shall apply whether or not such insurance policies shall have been determined to be applicable to any of such damages or claims for damages.

7. **Termination and Abandonment.** This Agreement may be cancelled at any time by District for its convenience upon written notice to Consultant. In the event of such termination, Consultant shall be entitled to pro-rated compensation for authorized Services performed prior to the effective date of termination provided however that District may condition payment of such compensation upon Consultant's delivery to District of any or all materials described herein. In the event the Consultant ceases performing services under this Agreement or otherwise abandons the project prior to completing all of the Services described in this Agreement, Consultant shall, without delay, deliver to District all materials and records prepared or obtained in the performance of this Agreement. Consultant shall be paid for the reasonable value of the authorized Services performed up to the time of Consultant's cessation or abandonment, less a deduction for any damages or additional expenses which District incurs as a result of such cessation or abandonment.

8. **Ownership of Materials.** All documents, materials, and records of a finished nature, including but not limited to final plans, specifications, video or audio tapes, photographs, computer data, software, reports, maps, electronic files and films, and any final revisions, prepared or obtained in the performance of this Agreement, shall be delivered to and become the property of District and are assumed to be public records within the meaning of the California Public Records Act unless expressly deemed otherwise by District. All documents and materials of a preliminary nature, including but not limited to notes, sketches, preliminary plans, computations and other data, and any other material referenced in this Section, prepared or obtained in the performance of this Agreement, shall be made available, upon request, to District at no additional charge and without restriction or limitation on their use. Upon District's request, Consultant shall execute appropriate documents to assign to the District the copyright or trademark to work created pursuant to this Agreement. Consultant shall return all District property in Consultant's control or possession immediately upon termination.

9. **Compliance with Laws.** In the performance of this Agreement, Consultant shall abide by and conform to any and all applicable laws of the United States and the State of California, and all ordinances, regulations, and policies of the District. Consultant warrants that all work done under this Agreement will be in compliance with all applicable safety rules, laws, statutes, and practices, including but not limited to Cal/OSHA regulations. If a license or registration of any kind is required of Consultant, its employees, agents, or subcontractors by law, Consultant warrants that such license has been obtained, is valid and in good standing, and Consultant shall keep it in effect at all times during the term of this Agreement, and that any applicable bond shall be posted in accordance with all applicable laws and regulations.

10. **Conflict of Interest.** Consultant warrants and covenants that Consultant presently has no interest in, nor shall any interest be hereinafter acquired in, any matter which will render the services required under the provisions of this Agreement a violation of any applicable state, local, or federal law. In the event that any conflict of interest should nevertheless hereinafter arise, Consultant shall promptly notify District of the existence of such conflict of interest so that the District may determine whether to terminate this Agreement. Consultant further warrants its compliance with the Political Reform Act (Government Code § 81000 et seq.) respecting this Agreement.

11. **Whole Agreement and Amendments.** This Agreement constitutes the entire understanding and Agreement of the parties and integrates all of the terms and conditions mentioned herein or incidental hereto and supersedes all negotiations or any previous written or oral Agreements between the parties with respect to all or any part of the subject matter hereof. The parties intend not to create rights in, or to grant remedies to, any third party as a beneficiary of this Agreement or of any duty, covenant, obligation, or undertaking established herein. This Agreement may be amended only by a written document, executed by both Consultant and District's General Manager, and approved as to form by the District's General Counsel. Such document shall expressly state that it is intended by the parties to amend certain terms and conditions of this

Agreement. The waiver by either party of a breach by the other of any provision of this Agreement shall not constitute a continuing waiver or a waiver of any subsequent breach of either the same or a different provision of this Agreement. Multiple copies of this Agreement may be executed but the parties agree that the Agreement on file in the office of District's District Clerk is the version of the Agreement that shall take precedence should any differences exist among counterparts of the document. This Agreement and all matters relating to it shall be governed by the laws of the State of California.

12. **Capacity of Parties.** Each signatory and party hereto warrants and represents to the other party that it has all legal authority and capacity and direction from its principal to enter into this Agreement and that all necessary actions have been taken so as to enable it to enter into this Agreement.

13. **Severability.** Should any part of this Agreement be declared by a final decision by a court or tribunal of competent jurisdiction to be unconstitutional, invalid, or beyond the authority of either party to enter into or carry out, such decision shall not affect the validity of the remainder of this Agreement, which shall continue in full force and effect, provided that the remainder of this Agreement, absent the unexcised portion, can be reasonably interpreted to give effect to the intentions of the parties.

14. **Notice.** Any notice required or desired to be given under this Agreement shall be in writing and shall be personally served or, in lieu of personal service, may be given by (i) depositing such notice in the United States mail, registered or certified, return receipt requested, postage prepaid, addressed to a party at its address set forth in Exhibit A; (ii) transmitting such notice by means of Federal Express or similar overnight commercial courier ("Courier"), postage paid and addressed to the other at its street address set forth below; (iii) transmitting the same by facsimile, in which case notice shall be deemed delivered upon confirmation of receipt by the sending facsimile machine's acknowledgment of such with date and time printout; or (iv) by personal delivery. Any notice given by Courier shall be deemed given on the date shown on the receipt for acceptance or rejection of the notice. Either party may, by written notice, change the address to which notices addressed to it shall thereafter be sent.

15. **Miscellaneous.**

a. Except to the extent that it provides a part of the definition of the term used herein, the captions used in this Agreement are for convenience only and shall not be considered in the construction of interpretation of any provision hereof, nor taken as a correct or complete segregation of the several units of materials and labor.
b. Capitalized terms refer to the definition provide with its first usage in the Agreement.
c. When the context of this Agreement requires, the neuter gender includes the masculine, the feminine, a partnership or corporation, trust or joint venture, and the singular includes the plural.
d. The terms "shall", "will", "must" and "agree" are mandatory. The term "may" is permissive.
e. The waiver by either party of a breach by the other of any provision of this Agreement shall not constitute a continuing waiver or a waiver of any subsequent breach of either the same or a different provision of this Agreement.
f. When a party is required to do something by this Agreement, it shall do so at its sole cost and expense without right to reimbursement from the other party unless specific provision is made otherwise.
g. Where any party is obligated not to perform any act, such party is also obligated to restrain any others within its control from performing such act, including its agents, invitees, contractors, subcontractors and employees.

IN WITNESS WHEREOF, Consultant and District execute this Agreement.

MIDPENINSULA REGIONAL OPEN SPACE DISTRICT
330 Distel Circle
Los Altos, CA 94022-1404
By:________________________
Name
Title

Date:___________________________

Attest:__________________________
Jennifer Woodworth
District Clerk

Approved as to form:
____
Sheryl Schaffner
General Counsel

CONSULTANT
Name
Address

By:_______________________________________
Name_____________________
Title_____________________

Date:_____________________________________

Federal Employer ID Number: _______________

License Number: ___________________________

Expiration Date: ___________________________

Attachments:
Exhibit A Scope of Services
Exhibit B District Insurance Provisions

EXHIBIT A
Scope of services and compensation
[PROJECT NAME]

1. **Scope of Services:**

2. **Compensation** [Select a compensation option a through e below, and delete the remaining compensation options]

(a) ( ) **Single Fixed Fee Agreement**. For performance of all of the Scope of Services by Consultant as herein required, District shall pay a single fixed fee in the amounts, and at the times or milestones, set forth below:

[Contract Fee(s) : $________________________]

(b) ( ) **Phased Fixed Fee Agreement.** For the performance of each phase or portion of the Scope of Services by Consultant as separately identified below, District shall pay the fixed fee associated with each phase of Services, in the amounts and at the times or milestones set forth. Consultant shall not commence Services under any Phase, and shall not be entitled to the compensation for a Phase, unless District shall have issued a notice to proceed to Consultant as to said Phase.

Phase 1	$ _______________
Phase 2	$ _______________

(c) ( ) **Hourly Rate Arrangement** For performance of the Scope of Services by Consultant as herein required, District shall pay Consultant for the productive hours of time spent by Consultant in the performance of said Services, at the rates or amounts set forth in the Rate Schedule below according to the following terms and conditions:

(d) ( ) **Not to exceed Limitation on Time and Materials Arrangement**: Notwithstanding the expenditure by Consultant of time and materials in excess of said Maximum compensation amount, Consultant agrees that consultant will perform all of the Scope of Services herein required of Consultant for _______ including all Materials, and other reimbursable ("Maximum Compensation").

(e) ( ) **Limitation without Further Authorization on Time and Materials Arrangement**. At such time as Consultant shall have incurred time and materials equal to ________________ ("Authorization Limit"), Consultant shall not be entitled to any additional compensation without further authorization issued in writing and approved by the District. Nothing herein shall preclude Consultant from providing additional Services at consultant's own cost and expense.

RATE SCHEDULE

Category of Consultant	Name	Hourly Rate

3. Consultant's Expenses

( ) The compensation to be paid to Consultant set out in Section 2 includes all incidental expenses incurred by Consultant in performing services required by this Agreement.

( ) District shall pay consultant for the reasonable and necessary cost of the following incidental expenses incurred by consultant in providing the services required herein: document reproduction, postage, printing, mileage, telephone, authorized travel expenses.

( ) Consultant's expenses shall not exceed ___________.

4. Contract Administrators

District: [enter name of staff here]

Consultant: [enter consultant's name here]

5. Permitted Subconsultants, if any:

EXHIBIT B
INSURANCE REQUIREMENTS

Before beginning any of the services or work called for by any term of this Agreement, Consultant, at its own cost and expense, shall carry, maintain for the duration of the Agreement, and provide proof thereof that is acceptable to the District, the insurance specified herein.

Insurance Requirements.

- Statutory Worker's Compensation Insurance and Employer's Liability Insurance coverage: $1,000,000
- Commercial General Liability Insurance: $1,000,000 (Minimum), $2,000,000 Aggregate
- Business Automobile Liability Insurance-with coverage evidencing "any auto" and with limits of at least $1,000,000 per occurrence.
- Errors and Omissions Insurance (or Professional Liability): $1,000,000

Workers' Compensation. Statutory Workers' Compensation Insurance and Employer's Liability Insurance for any and all persons employed directly or indirectly by Consultant shall be provided if required under the California Labor Code.

Commercial General and Automobile Liability. Consultant, at Consultant's own cost and expense, shall maintain Commercial General and Business Automobile Liability insurance for the period covered by this Agreement in an amount not less than the amount set forth in this Exhibit B, combined single limit coverage for risks associated with the work contemplated by this Agreement. If a Commercial General Liability Insurance or an Automobile Liability form or other form with a general aggregate limit is used, either the general aggregate limit shall apply separately to the work to be performed under this Agreement or the general aggregate limit shall be at least twice the required occurrence limit. Such coverage shall include but shall not be limited to, protection against claims arising from bodily and personal injury, including death resulting there from, and damage to property resulting from activities contemplated under this Agreement, including the use of hired, owned and non-owned automobiles. Coverage shall be at least as broad as the latest edition of the Insurance Services Office Commercial General Liability occurrence form CG 0001 and Insurance Services Office Automobile Liability form CA 0001 (ed. 12/90) Code 1 (any auto). No endorsement shall be attached limiting the coverage.

a. A policy endorsement must be delivered to District demonstrating that District, its officers, employees, agents, and volunteers are to be covered as insured as respects each of the following: liability arising out of activities performed by or on behalf of Consultant, including the insured's general supervision of Consultant; products and completed operations of Consultant; premises owned, occupied or used by Consultant; or automobiles owned, leased, hired, or borrowed by Consultant. The coverage shall contain no special limitations on the scope of protection afforded to District, its officers, employees, agents, or volunteers.
b. The insurance shall cover on an occurrence or an accident basis, and not on a claims made basis.
c. An endorsement must state that coverage is primary insurance and that no other insurance affected by the District will be called upon to contribute to a loss under the coverage.
d. Any failure of Consultant to comply with reporting provisions of the policy shall not affect coverage provided to District and its officers, employees, agents, and volunteers.
e. Insurance is to be placed with California-admitted insurers.

Professional Liability. Where Consultant is a licensed professional, Consultant, at Consultant's own cost and expense, shall maintain for the period covered by this Agreement professional liability insurance for licensed professionals performing work pursuant to this Agreement in an amount set forth in this Exhibit B covering the licensed professionals' errors and omissions, as follows:

a. The policy must contain a cross liability or severability of interest clause.

b. The following provisions shall apply if the professional liability coverages are written on a claims made form:

1) The retroactive date of the policy must be shown and must be before the date of the Agreement.

Insurance must be maintained and evidence of insurance must be provided for at least five years after completion of the Agreement or the work.

If coverage is canceled or not renewed and it is not replaced with another claim made policy form with a retroactive date that precedes the date of this Agreement, Consultant must provide extended reporting coverage for a minimum of five years after completion of the Agreement or the work. The District shall have the right to exercise at the Consultant's cost, any extended reporting provisions of the policy should the Consultant cancel or not renew the coverage.

A copy of the claim reporting requirements must be submitted to the District prior to the commencement of any work under this Agreement.

Deductibles and Self-Insured Retentions. Consultant shall disclose the self-insured retentions and deductibles before beginning any of the services or work called for by any term of this Agreement. Any self-insured retention or deductible is subject to approval of District. During the period covered by this Agreement, upon express written authorization of District Legal Counsel, Consultant may increase such deductibles or self-insured retentions with respect to District, its officers, employees, agents, and volunteers. The District Legal Counsel may condition approval of an increase in deductible or self-insured retention levels upon a requirement that Consultant procure a bond guaranteeing payment of losses and related investigations, claim administration, and defense expenses that is satisfactory in all respects to each of them.

Notice of Reduction in Coverage. In the event that any coverage required under the Agreement is reduced, limited, or materially affected in any other manner, Consultant shall provide written notice to District at Consultant's earliest possible opportunity and in no case later than five days after Consultant is notified of the change in coverage.

Remedies. In addition to any other remedies District may have if Consultant fails to provide or maintain any insurance policies or policy endorsements to the extent and within the time herein required, District may, at its sole option:

Obtain such insurance and deduct and retain the amount of the premiums for such insurance from any sums due under the Agreement;

Order Consultant to stop work under this Agreement or withhold any payment which becomes due to Consultant hereunder, or both stop work and withhold any payment, until Consultant demonstrates compliance with the requirements hereof;

Terminate this Agreement.

Exercise of any of the above remedies, however, is an alternative to other remedies District may have and is not the exclusive remedy for Consultant's failure to maintain insurance or secure appropriate endorsements.

Creek Sedimentation in Response to Watershed Improvements, 2004 to 2006 El Corte de Madera Creek Open Space Preserve, San Mateo County, California

Report prepared for:
Midpeninsula Regional Open Space District

Prepared by:
John Gartner
Jonathan Owens
Scott Brown
Barry Hecht

Balance Hydrologics, Inc.

August 2007

A report prepared for:

Midpeninsula Regional Open Space District
330 Distel Circle
Los Altos, California 94022
(650) 691-1200
Attention: Meredith Manning

Creek Sedimentation in Response to Watershed Improvements, 2004 to 2006, El Corte de Madera Creek Open Space Preserve, San Mateo County, California

Balance Project Assignment 204020

by

John Gartner
Hydrologist / Geomorphologist

Scott Brown
Geologist

Jonathan Owens
Hydrologist

Barry Hecht
Principal, CEG 1245, CHg 50

PROFESSIONAL GEOLOGIST
BARRY HECHT
No. 1245
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

REGISTERED GEOLOGIST
BARRY HECHT
NO. 50
CERTIFIED HYDROGEOLOGIST
STATE OF CALIFORNIA

841 Folger Avenue
Berkeley, California 94710-2800
(510) 704-1000
office@balancehydro.com

August 9, 2007

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APPENDICES

1. SUMMARY

This report focuses on the 2nd and 3rd year of monitoring sedimentation in pools using the V* technique. It is one component of a larger body of work examining stream sediment in the El Corte de Madera Creek Open Space Preserve (ECDM Preserve). Concurrent monitoring of stream flow and sediment transport will be presented in a forthcoming report for water year 2007[1].

The 2,821-acre (4.4 square-miles) ECDM Preserve is the headwaters of a tributary to the larger San Gregorio watershed, home to federally-listed threatened coho salmon (Oncorhynchus kisutch) and steelhead trout (Oncorhynchus mykiss). San Gregorio Creek is currently listed under the Clean Water Act 303(d) List as impaired by sediment (SWRCB, 2003). The ECDM Preserve has a substantial legacy of historic timber harvest, from the 1860s to the 1980s. It was purchased shortly after the last cycle of timber harvests, and is currently managed by the Midpeninsula Regional Open Space District ('MROSD', or 'District') for multiple-use recreation on over 28 miles of roads and trails.

Starting in 2004, Balance Hydrologics Inc. ('Balance') and MROSD staff have followed three main tracks of field studies to quantify sediment production, storage and discharge in the ECDM Preserve: 1) an inventory and quantification of the amount of sediment being delivered to the creek channels from large sediment sources such as landslides, debris flows, bank failures, and gullies; 2) pool sedimentation measurements (V*)[2] which calculated the percent of pool volume filled by sediment; and 3) recording continuous flow and sediment discharge observations on El Corte de Madera Creek during water years 2006 and 2007. District staff have assisted with field data collection, quality assurance and analysis in each of these efforts,

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[1] Most hydrologic investigations occur for a period defined as the water year, which begins October 1 and ends on September 30 of the named year. For example, water year 2007 (WY2007), begins October 1, 2006 and concludes on September 30, 2007.

[2] V* (pronounced "V-star") is a method developed by geomorphologists (Lisle, 1991; Lisle and Hilton, 1993) frequently applied to evaluate sedimentation of pools. It is most effectively used in streams with large contrast between bed material and the fine sediment that fills pools (Lisle, 1999). The streams in ECDM tend to have cobbles or small boulders as the dominant bed material, and they are filled with fine to medium sand. We believe V* is suitable for many purposes at ECDM. The V* method tends to be applied especially to those pools supporting salmonids (c.f., Flossi and others, 2004). Although barriers preclude steelhead from reaching and using the ECDM pools, V* remains a useful and suitable metric in El Corte de Madera Creek for monitoring bed sedimentation in pools.

especially the latter two. Balance has taken the lead in the technical direction of the studies as well as data analysis and reporting.

Based on the initial (or "baseline") monitoring in these three tracks of study, sediment conditions in the ECDM Preserve are within the moderately-sedimented range compared to other similar-sized watersheds in the northern Santa Cruz Mountains. The baseline studies also indicated that trail improvements have the capacity to improve sediment conditions in ECDM Preserve, because trails appear to contribute sediment to the creeks that can be mitigated, and overall sediment conditions are not so high that trail improvements would be inconsequential nor so low that changes are unnecessary or imperceptible (see Section 2.1).

We believe that pool sedimentation is a sensitive and informative metric for use in the long-term monitoring program, and is well suited to the geology and stream-sediment conditions at the site. We selected 17 pools in ECDM Preserve and established baseline pool sedimentation conditions using the V* technique. For comparison or 'control' for practices at the ECDM Preserve, we identified and measured six pools within a paired watershed in the adjacent La Honda Creek Open Space Preserve (La Honda Preserve).

The District has now measured pool sedimentation in the same pools in 2004, 2005 and 2006 using the V* method. In combination with the streamflow and sediment discharge gaging, the V* results will enable District staff to assess the effectiveness of the comprehensive Watershed Protection Program recently adopted and implemented by the District.

1.1 Summary of Conclusions

The results of this study report on pool sedimentation conditions for years two and three of a multi-year study, and compare to baseline measurements conducted in 2004. Balance has developed the following conclusions:

1. In the La Honda Preserve (control site), average pool sedimentation increased consistently from 2004 to 2005 to 2006 (average V* values were 0.37, 0.44, and 0.55 respectively). We believe this is due to weather patterns, where above-average rainfall and large storms flushed sediment from the hillsopes into the creek channels. There was considerable variability from pool to pool (see Section 5).

2. In the ECDM Preserve (treatment site), average pool sedimentation increased from 2004 to 2005 but remained at about the same level from 2005 to 2006 (average V* values were 0.35, 0.49, 0.48 respectively). The increase and then leveling of pool sedimentation in the ECDM Preserve may be due to the District's sediment control programs. The increase between year one and two is likely due to increases due to weather patterns *plus* increases due to the disturbance from recent trail improvements. It appears that trail improvements may have begun to have a net benefit in the winter of 2006, when pool sedimentation did not increase in the treatment site but did increase in the control site (see Section 5).

3. We have confidence that the average V* numbers are indicative of general watershed conditions and are a useful metric for evaluating watershed-scale improvements undertaken by the MROSD, especially in concert with the initial sediment source inventory and ongoing stream gaging. This confidence comes from several factors, such as the relatively large number of pools measured and the review of the data for quality assurance and quality control (see Sections 5.3 and 5.5).

4. We recommend continuing V* measurements in 2007 for several reasons. The V* measurements appear to be an effective metric of pool sedimentation and general watershed conditions. Monitoring watershed conditions serves a MROSD goal of land stewardship, and the project team is now efficient with this sampling and analysis. The dry conditions in 2007 permit us to evaluate the watershed response to a dramatically different set of conditions than the previous years, as well as resolve issues of consistency in interpretations of scoured residual pool geometry (see Section 6.0).

2. INTRODUCTION

The overarching goal of this study is to design and implement a long-term monitoring program of stream sediment in the ECDM Preserve, with particular attention to measuring the effectiveness of sediment-reduction measures implemented under the District's new Watershed Protection Program. In 2004, the District adopted a Watershed Protection Program[3] to prioritize and implement sediment reduction measures.

The ECDM Preserve is a focus for this study because human activities and natural processes within the Preserve produce sediment which may be washed into the downstream creek system and impair salmonid fish habitat. Anadromous fish cannot use the streams of the ECDM Preserve because fish-passage barriers downstream of the property prevent upstream migration. El Corte de Madera Creek drains the ECDM Preserve and is a tributary within the larger San Gregorio watershed, home to coho salmon (Oncorhynchus kisutch) and steelhead trout (Oncorhynchus mykiss). These species are federally listed as threatened along this segment of the central California coast. San Gregorio Creek is currently listed under the Clean Water Act 303(d) List as impaired by sediment (SWRCB, 2003); therefore any sediment-producing activities are management concerns and may be subject to special scrutiny.

The ECDM Preserve has many sources of sediment. The preserve is owned and actively managed by the District for multiple-use recreation with over 28 miles of roads and trails in current use. Hiking, mountain biking, equestrian, and occasional ranger vehicle traffic on roads and trails requires continued maintenance and management, especially because most of the actively-used roads were constructed for timber harvests and were not designed or constructed for long-term, year-round use. The Watershed Protection Program aims to reduce sediment delivery to creeks from current and recently-used roads and trails by grading and/or narrowing roads, repairing culverts and water bars, and closing or reducing traffic on troublesome sections. Historical timber-harvest practices and associated road construction have altered hillside and creekside morphology, which increased sediment delivery to streams. The legacy may still contribute to increased sediment conditions today. In addition, the steep topography, high rainfall, and geology make the area prone to landsliding and debris flows, especially in wet years (Wagner and Nelson, 1961).

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[3] The Watershed Protection Program as adopted by the Board of Directors on January 21, 2004, Midpeninsula Regional Open Space District

This report describes Balance's study design and documents the second and third year and findings of the pool-sedimentation monitoring plan, and compare them to those of the initial study year. The study is designed to establish current conditions and track changes in bed sedimentation, and (combined with stream gaging and sediment-transport monitoring conducted in water year 2006, 2007 and perhaps the future) it provides the basis for assessing the effects of the District's new management practices on sediment and physical salmonid habitat within, and downstream from the ECDM Preserve.

2.1 Prior Studies

To aid in the planning and implementation of the Watershed Protection Plan, the MROSD commissioned an independent geologist/consultant, Tim Best, Certified Engineering Geologist (CEG), to inventory and report on the roads and trails in the ECDM Preserve. Best's report (published in November 2002) serves to identify individual sources of road erosion and create a prioritized prescription to reduce long-term sediment production from roads and trails within the ECDM Preserve.

Balance has produced two previous reports on sediment sources, transport and storage in the Preserve (see Appendix I for Overall Study Approach). The main conclusions of these previous studies are 1) our inventory of sediment sources suggests that landslides supply the large majority of sediment to the creeks, 2) sediment sources, transport and storage are in a moderate range for the region 3) the District's watershed improvements have the potential to reduce measurably the sediment contributions to the lower San Gregorio watershed, and 4) the La Honda Preserve is a suitable control for V* measurements in the ECDM Preserve. Findings from the sediment inventory and first year of V* monitoring are presented in the report Initial Findings of Sediment Source Survey and Creek Sedimentation, El Corte de Madera Creek Open Space Preserve (Owens and others, 2006). The findings from the first year of streamflow and sediment transport monitoring are reported in Streamflow and Sediment Monitoring, El Corte de Madera Creek, Water Year 2006, El Corte de Madera Open Space Preserve (Gartner and others, 2006).

3. SITE DESCRIPTION

3.1 Historic Land Use

The ECDM Preserve has a history of timber harvest dating from the 1860's (Stranger, 1967) until as recently as the 1980's. During our investigations, we observed numerous legacies of the timber-harvest era that serve to increase or accelerate sediment delivery to the creeks. Most significant were ubiquitous former skid trails, most of which have now become revegetated. Many former skid trails and roads (even revegetated ones) continue to be sources of stream sediment. Repairing all of these, however, is unadvised—the disturbance from the repairs would cause a substantial short-term increase in erosion that is hard to justify for the long-term improvement. A more detailed description of historic land use is included in the Balance's sediment inventory report (Owens and others, 2006).

3.2 Hydrology, Precipitation and Sediment Delivery

ECDM Preserve contains the headwaters of El Corte de Madera Creek, Lawrence Creek and a number of tributaries, the largest of which is informally referred to as "Methuselah Creek" in this report. Together, these tributaries are within a 4.4 square-mile sub-watershed in the Preserve that contributes to the 51.6 square-mile San Gregorio watershed.[4] The La Honda Preserve contains the upper reaches of La Honda Creek, Harrington Creek, and several unnamed tributaries that drain to La Honda Creek. All of these tributaries are also within the San Gregorio watershed (Figures 1, 2 and 5).

Average annual rainfall for the watershed ranges from 36 to 40 inches, depending on elevation (Saah and Nahn, 1989), and supports perennial flow in the mainstem channels during a normal rainfall year. Fog drip and mist can contribute a small, but measurable, component of flow to the stream system year-round.

Rainfall intensity and total rainfall can vary greatly from year to year, and therefore, sediment delivery to the channels will vary accordingly. The precipitation history of the watershed is

[4] The 4.4 square-mile subwatershed is measured upstream from the point where El Corte de Madera Creek exits the preserve on it southern boundary. The total watershed area of San Gregorio Creek (51.6 square miles) is slightly larger than the 50.9 square miles listed for the USGS gage number 11162570, which is about one mile upstream from the ocean.

important particularly in the interpretation of pool sedimentation, flood terraces and landslides. During water years with very large storms, such as 1956, 1982, and 1998, many landslides and bank failures occurred, which added large amounts of sediment to the network of creeks within the El Corte de Madera Creek, La Honda Creek, and nearby watersheds (e.g. Ellen and Wieczorek, 1988, Wieczorek and others, 1988, Godt, 1999, Owens and others, 2001). Water year 1983 was also very wet, but the intensity of storms was not as great. Compared to water year 1982, water year 1983 had smaller storms, lower peak flows and fewer landslides.

3.3 Geology

The majority of the ECDM and La Honda Preserve watersheds are underlain by Butano sandstone, designated as "Tb" (Brabb and Pampeyan, 1972, Brabb and others, 1998) in Figure 2. The sandstone weathers and erodes as large boulders, cobbles and sand in the creeks (Hecht and Rusmore, 1973). A portion of the uppermost mainstem of El Corte de Madera Creek is underlain by Vaqueros sandstone (designated "Tvq") and Lambert shale ("Tla"), which tend to weather to fine-grained sand, silt and clay. Although not shown on the geologic map, dikes and sills of mainly basaltic composition occur throughout all three rock types. These intrusive rocks are coeval (of the same age) with Mindego basalts, which outcrop immediately downstream of the preserve. Collectively, they are an important part of the stream framework, constituting about 6 to 8 percent of the cobbles and pebbles on the bed of El Corte de Madera Creek downstream from the confluence with Lawrence Creek, where we assessed their prevalence. These intrusive, more resistant units may affect stream gradients. They can inhibit downcutting by the stream, sometimes creating cascades at the resistant outcrops and lower-gradient reaches upstream.

Most of the pebbles, cobbles, and boulders on the beds of the ECDM Preserve streams originate from the Butano formation; the sand and silt which constitutes the fine sediment filling the pools (and runs, glides, and riffles as well) have their sources in all three formations (Tb, Tvq, Tla) with the recognizable orange-tinged, poorly-sorted and often-angular sands originating in the Butano unit being obviously dominant. All three rock types generate soils with erosion hazards designated as 'high' and 'extreme' by the Natural Resources Conservation Service (Wagner and Nelson, 1961). Hecht and Rusmore (1973) note that the Butano formation is the most common source of pool-filling sands in the central Santa Cruz Mountains. Additional information relevant to the erodibility of formations in the El Corte de Madera and Harrington Creek watersheds is available in Best (2003).

Because the beds of pools at the ECDM Preserve are typically formed of cobbles and gravels originating mainly from the Butano formation, and the pools are filled with sand originating mainly from the same formation, it is possible to use the V* monitoring method based on pools, which tends to be a sensitive and accurate measure of bed sedimentation. Contrasts between the bed and the sediment filling the pools are generally easily recognized, and the V* measurements are generally reproducible. Additionally, the pool-filling sediment is intrinsically habitat-impairing, occupying space in pools that might otherwise provide habitat for various aquatic organisms.[5] In section 4, we will describe a standard measure of pool sedimentation, known as 'V*' ("V-star"), which can be used as a metric for both the amount of bed sedimentation and habitat loss in the ECDM Preserve pools.

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5 Although steelhead cannot reach ECDM, other aquatic biota do live in the pools at the Preserve. V* and other measurements of pool sedimentation may also be used by others elsewhere in El Corte de Madera Creek or other San Gregorio watershed streams to quantify aquatic habitat values in pools used by anadromous salmonids further downstream.

4. POOL SEDIMENTATION METHODS (MEASURED AS V*)

4.1 V* Measurements

For the past three years, Balance and District staff have used the V* technique to quantify pool sedimentation across El Corte de Madera Creek watershed and in the upper La Honda Creek watershed (in La Honda Preserve). The V* technique uses a repeatable grid-based pattern of depth measurements from which is calculated the decimal fraction of pool that is filled with fine sediment (Hilton and Lisle, 1993). For example, a V* value of 0.63 means that about 63% of the potential pool volume is filled with fine sediment. A V* value of 0.63 is not inherently good or bad, nor do changes in *one* pool from year to year indicate "improving" or "deteriorating" conditions. However, sampling a large number of pools over several years can be used as an index of general trends in pool sedimentation and storage of sediment in the creeks. The first-year data should be considered baseline data; subsequent years of repeated measurements may be used to assess broad-scale changes in the watershed.

Inherent in the technique is the ability to differentiate fine sediment that may be filling a pool from the coarser sediment that forms the shape of the pool. Generally, in El Corte de Madera Creek and its tributaries, the fine sediment is sand and small gravel, while the coarse sediment is cobbles and boulders; this bimodal dichotomy makes the differentiation between pool filling material and pool forming material fairly clear. The V* technique is most suited for this type of bed material (Lisle, 1999; Roques and Angelo, 2004). Figure 4 illustrates sampling patterns and terminology for the V* technique, in cross-section and plan view.

4.2 V* Pool Selection

After observing and mapping more than 100 pools over 7.3 miles of streams, Balance staff identified pools that met conditions appropriate for conducting the V* measurements (Figure 5). From these "appropriate" pools, Balance and MROSD staff selected 17 pools in the ECDM Preserve and 6 pools in the La Honda Preserve. According to the authors of the technique, most user bias can be eliminated or minimized from measurements, especially with a sample size of greater than 10 pools (Hilton and Lisle, 1993).

The main criterion for pools chosen for V* was seemingly-stable pool morphology; we avoided choosing pools that were formed by small-sized sediment (gravel or sand) likely to wash away with moderate floods, or by woody debris that can decay and thereby greatly alter the pool size and shape over time. Secondary factors for pool selection included appropriately broad distribution and coverage throughout the two preserves. We selected pools in a distributed manner in sections of the ECDM Preserve that we thought would best represent the various reaches of the mainstem creek and its tributaries. Some consideration was also given to ease of access to the V* pools, to allow for streamlining of repeat measurements in subsequent monitoring years.

4.3 Adding New V* Pools at a Future Date

There are several reasons that the District may wish to add more V* pools at a later date. If a large disturbance happens to one of the pools (such as downed tree or a nearby landslide), then that pool may no longer be representative of general stream conditions. The District might also want to add pools to a tributary section where we did not perform any V* measurements, in order to evaluate a particular portion of a preserve. In either of these cases, new pools could be added; although the results would not be fully comparable the first year, those new pools would be resampled the following year, and changes in sedimentation could then be evaluated.

4.4 Using the La Honda Creek Open Space Preserve as a "Control" Site

To isolate the effect of conservation measures proposed in the District's Watershed Protection Plan to inhibit sedimentation, Balance incorporated a "control" watershed into the V* study. This provides a comparison between the "treatment" watershed (the ECDM Preserve that has numerous trail recreational uses and conservation efforts) and the control watershed (the northern half of the La Honda Creek Preserve, where trail uses are likely to be limited to hiking and where no large trail improvements are planned). Given these differences, both preserves are suitable for use as a paired watershed assessment because they have the following similar watershed characteristics:

- Annual rainfall (36 to 40 inches),
- Geology (Butano sandstone, with subordinate Vaqueros sandstone and Lambert shale formations), and related soils
- Vegetation (Redwood, mixed conifer, and mixed deciduous),
- Elevation and steepness (1025 feet to 2390 feet above mean sea level),
- Ownership and management by Midpeninsula Regional Open Space District
- A legacy of historical timber-harvest operations and associated road construction.

We expect year-to-year changes in sedimentation due to natural variation in rainfall and other influences upon sedimentation. By evaluating changes at the two preserves, we aim to differentiate changes in sedimentation that are due to winter precipitation patterns from changes due to conservation measures.

The validity of the La Honda Preserve as a control site may need to be qualified as the Master Plan for this preserve is adopted and implemented, or if unusual sediment sources are identified during the plan-development process. If significant land use changes occur in the La Honda Creek Preserve, then its usefulness as a control site may be diminished.

4.5 Data Collection

Pool sedimentation was measured during September and October 2004, July, August and September 2005, and August and September 2006 by Balance and District staff. One small rainstorm occurred before the final day of sampling in 2004, but we do not think that it greatly affected the results.

4.6 V* Weighting

A group of V* values can be weighted by the "scoured residual-pool volume," effectively giving larger pools greater effect on the average and median. This option can be used to account for the concept that a greater volume of sediment is stored in a large pool than in a small pool if the two pools have the same V* value. Applying this weighting makes sense along a relatively uniform reach of creek or river. We think that it makes less sense for a network of tributary and mainstem creeks, because the weighting system would then weight the mainstem pools more than tributary pools (simply because the mainstem is wider than the tributaries).

The pool locations that we selected already give more importance to the downstream reaches in El Corte de Madera Creek, because we have more measured pools in the larger creeks. We think that weighting the V* values by scoured residual-pool volume would *overweight* the pools in the mainstem of the creek.

4.7 Data Quality Assurance and Quality Control

Balance Hydrologics performed all of the V* data entry and calculations for the 2004 surveys. For the 2005 and 2006 surveys the data entry and calculations were conducted by various members of the MROSD staff, with a thorough review of the data entry. Balance was asked, however, to review the spreadsheet calculations and formulas, checking that the spreadsheet was being used correctly.

To avoid making a detailed check of every spreadsheet, we instead entered the raw data for one-third of the 2006 pools into a new spreadsheet template for which the internal formulas had been carefully checked. The volume and V* numbers were then compared with the spreadsheets provided by MROSD, and where differences were noted the original sheets where inspected for formula errors and incorrect data placement. Through this process we identified several systematic formula and data placement errors that occurred on several spreadsheets[6]. Other spreadsheets for 2005 and 2006 were reviewed for these systematic errors and corrected, where present. We also found that one of the systematic errors was present in several of the 2004 spreadsheets and those spreadsheets were revised. Therefore, the 2004 values in Table 1 supersede those presented in Owens and others (2006) and previous summary tables submitted to MROSD.

In addition to the spreadsheet review above, we ran each spreadsheet through two data filters to identify common data entry problems—high values due to errant keystrokes and data points where the depth of water is larger than the depth of water plus sediment. None of the first error types and only a few of the second were identified, none of which resulted in a significant change in pool volume or V* value.

[6] The complexity of the calculations and the variability in the number of data points and cross sections requires that the format of the V* analysis spreadsheet be somewhat flexible. Because of this, some formula and cell reference errors can occur when data entry staff are unfamiliar with the spreadsheet and the supporting calculations. In this case, most of the errors were the result of inexperience in working with this rather complex spreadsheet.

5. V* POOL SEDIMENTATION RESULTS AND DISCUSSION

5.1 V* Results

The V* results are shown in Table 1, and Figures 6 and 7. The mean for the 17 measured pools in the ECDM Preserve was 0.35, 0.49, and 0.48 in the summers of 2004, 2005, and 2006, respectively. In the La Honda Creek Preserve, the mean for the six pools was 0.37, 0.44, and 0.55 in the summers of 2004, 2005, and 2006. The medians and standard deviations are shown in Table 1 for each year in both preserves. In both preserves in most years, the mean V* value is close to the median, and there is a roughly normal distribution without outliers. In 2006 at the ECDM Preserve, the mean is higher than the median (0.48 compared to 0.40, respectively). This is in part because one pool, the "Long Skinny Pool," had an especially high V* value that skewed the distribution.

5.2 Precipitation, Flow and Sediment Transport in Previous Years

Precipitation varied greatly over the three years of the project. At the rain gage operated by MROSD staff, precipitation was approximately 34.5, 50.0 and 63.6 inches in water years 2004, 2005, and 2006. The peak flows for these three water years had approximately 2.6-, 1.7-, and 19.5-year recurrence intervals at a stream gage with a 77-year record operated by the USGS in an adjacent watershed to the east (USGS gage 11164500, San Francisquito Creek at Stanford University)[7].

During water year 2006, our flow and sediment gaging in El Corte de Madera Creek recorded numerous storms with flows sufficient to transport silt, sand and gravel. Boulders up to two feet in diameter were moved short distances in at least one event, the peak flow on December 31, 2005, based on repeat photographs. Evidently, this storm had the potential to re-shape the scoured residual pool geometry in the lower regions of the watershed, although the pools in this area did not show significant changes in their scoured residual volume (Table 1). In contrast, water year 2007 produced only a few storms that generated sediment-transporting flows due to the relatively dry conditions; sediment that was transported by these relatively small flows included the smaller clays, silt, sand and gravel.

[7] The stream gage operated by Balance on El Corte de Madera Creek does not have a long enough record to calculate flow recurrence intervals. Peak flow at the El Corte de Madera station was 550 cubic feet per second (cfs) in water year 2006.

5.3 Data Validity

In our review for data quality assurance and quality control, we found that the data seem to be valid and free of systematic sampling and computation errors. In most cases, the scoured residual pool sizes were reasonably constant from year to year. We feel that persisting errors in data collection, entry and computation (if any) are sufficiently small and offset by the relatively large sample size, which diminishes the effect of these errors.

In a few pools, however, the scoured residual pool geometry was not consistent from year to year. An assumption in the V* method is that the underlying pool structure is composed of either bedrock or boulders/cobbles that will not move except in the most extreme events. The V* method, therefore, is expected to measure the amount of fine sediment that fills this relatively stable scoured residual pool. Some variation in scoured residual pool volume is to be expected due to the randomness of the survey, especially if the pool shape is highly irregular, but the volume should remain relatively constant from year to year.

As a minor point, the scoured residual pool boundary is difficult to discern for some of the pools within the El Corte de Madera Creek and La Honda Creek watersheds. On the whole we do not expect that these few pools greatly affected the analysis and conclusions (see section 5.3, regarding the benefit of a large sample size). Sand deposits along the edge of the pool grade into soft, fine-grained bank deposits (colluvium). The measured scoured residual pool therefore gets deeper toward the bank, without a well-defined edge. In the field, the surveyor is sometimes required to make a judgment call about the boundary between the scoured residual pool and stream bank or hillslope. We noted in our review of the data from the past several years that there may be some variability in the way pools were being surveyed, because it appears that some survey teams measured further into the deposited or bank material than others. This results in a higher scoured residual pool volume, and is the likely reason that the volume changes so drastically for the 'Long Skinny', 'New Bridge', and 'Above Property Line' pools, among others. .

5.4 Comparison of ECDM Preserve to La Honda Creek Preserve

The primary difference between the ECDM and La Honda Preserve datasets is that the mean V* values increased significantly from 2004 to 2005 but not significantly from 2005 to 2006 at the ECDM Preserve (treatment site), while the mean V* values increased slightly each year at La Honda Preserve (control site). The increase from 2004 to 2005 at the ECDM Preserve was greater than the increase at the La Honda Preserve in the same time period. When comparing median values (which diminishes the effect of outliers such as the "Long Skinny Pool" in 2006), pool sedimentation initially increased, then *decreased* slightly in the ECDM Preserve, while it increased in each successive year for the La Honda Preserve.

We interpret that the wet conditions in the winters of 2005 and 2006 tended to increase sedimentation at the control site, likely due to high volumes of sediment being washed from the hillslopes and debris flow scars into the creek channels. In drier years without large storm events, presumably the hillslopes do not contribute as much sediment to the stream channels, and storm flows tend to flush sediment out of the pools at an overall greater rate than new sediment is flushed into the creek channels and pools.

In the ECDM Preserve, we believe that the increase in pool sedimentation from 2004 to 2005 is a combination of sediment being flushed from the hillslopes independent of the trail improvements *plus* sediment from the recently improved trails. It is common and expected to have an increase in sediment production, or sediment pulse, immediately following disturbances such as the trail improvement. Freshly disturbed bare dirt is easily prone to erosion before new vegetation takes root and before the material becomes compacted. It may be that in the third year, when pool sedimentation did not increase, the trail improvements may have become stabilized and were functioning as planned; that is, they seemed to be reducing sediment delivery to the creeks.

5.5 Importance of Unmeasured Variables and Large Sample Size

There are many other variables that were not measured in this study that affect the timing and amount of stream sedimentation. For example, we did not re-inventory landslides after the summer of 2004 (although we did observe several new landslides). We also did not measure the connectivity between sediment on the roads and sediment in the streams, nor the speed that a pulse of sediment travels through this system, either from a discreet landslide or from the trail improvements in general. It is conceivable that these other variables could combine to create the conditions that were measured in 2004, 2005 and 2006, independent of the trail improvements.

However, we do have a relatively large sample size, especially in the ECDM Preserve. This tends to diminish the effect of a few pools with stochastic disturbances, for example a new landslide that could increase sediment delivery or a new logjam just upstream that could sequester sediment. With a sample size of 17 pools, we believe we are measuring the general conditions in the ECDM preserve.

5.6 Comparison of V* Values among Tributaries

The V* results shown on Figure 6 do not show a clear pattern based on tributary location, nor contributing area. For example, some pools with small contributing areas have a steady increase in pool sedimentation, while others increase then decrease from 2004 to 2006, and others change little between years. This lack of a consistent trend, even for adjacent pools, highlights that there are multiple factors affecting pool sedimentation. It underscores that it is important to examine overall watershed trends and not emphasize the conditions at one or two pools.

5.7 Expectations of Future Stream Conditions

The main value and purpose of the V* measurements is year-to-year comparisons of the pools (Lisle and Hilton, 1993). We might expect that V* values in the ECDM and La Honda Preserves will decrease or stay the same in 2007 due to the recent weather patterns. The lack of large storms in the winter of 2007 inhibited sediment contributions from the hillslopes into the creeks. Only a few small storms generated flows high enough to transport sediment at the stream gage. However, it may be the storm flows were so slight that they were unable to flush sediment from pools.

Implementation of the Watershed Protection Program will continue to occur at least through 2010. A significant portion of construction is scheduled to occur during the next several years, during which time there may be a successively increasing supply of sediment to the creeks; however, this sediment pulse is expected to decline following completion of the construction portion of the Watershed Protection Program.

Given the short time since some of the initial watershed improvements took place, there may still be an increase in sediment delivery from the construction, albeit diminished from that recorded in 2005. Results of this V* study should be applied recognizing that: a) sediment delivery from the road and trail system is likely to be less than that from landslides and bank failures in most years, b) considerable year-to-year variability (noise) may be expected in the data (sediment delivery rates are much higher during very wet years), c) V* data are typically most usefully applied at the watershed scale, because individual pools may be affected by individual factors, d) construction schedules will change from year to year, resulting in varying amounts of disturbance, and e) there may be some lag time before the effects of watershed-protection measures can be quantified.

6. RECOMMENDATIONS

Even though water year 2007 had few storms large enough to transport sediment in the creek, we recommend continuing with V* measurements in 2007 for the following reasons:

1. V* measurements are proving to be an effective tool for measuring year-to-year changes in channel sedimentation, which is a primary concern for MROSD and its monitoring of the efficacy of the trail improvements.

2. The light rainfall this year provides a dramatically different set of conditions compared to water years 2006 and 2005, allowing interpretation of creek sedimentation in response to a year with below average rainfall. We hypothesize that creek sedimentation has not changed much in 2007, but there are theoretical arguments for either a slight increase or a slight decrease.

3. V* measurements in 2007 will shed light on the repeatability of this technique, especially for specific pools. Some pools did not have consistent scoured residual pool geometry from 2004 to 2006. Since there were no major storms this year likely to have changed the pool geometry, the data from 2007 may show that some pools are not good for V* and should be removed from the analyses.

4. Continued monitoring serves the MROSD goal of stewardship. It shows commitment to land management and opens the door for outside funding to continue the work.

5. In 2004, V* values were lower than each of the subsequent years. It would be more satisfying and conclusive to continue monitoring to see whether V* values return to or fall below the values from 2004 (baseline conditions prior to road and trail improvements).

We recognize that there is a valid argument to suspend V* measurements following this dry year, when large changes are not expected, and then resume V* measurements following the next wet or relatively wet winter. We supply this counter argument with the caveat that it is much harder to resume monitoring after a hiatus than it is to continue monitoring uninterrupted, especially given the increased efficiency that this team has achieved. It might be noted that in another major study, our client chose to continue with annual monitoring despite our recommendations to concentrate monitoring only during normal and wet years. They are more than satisfied with their decision, and we now concur with their approach.[8]

[8] Reference contact: Gregory Andrew, Sr. Fisheries Biologist, Marin Municipal Water District.

7. ACKNOWLEDGEMENTS

We would like to acknowledge the assistance from the MROSD staff and rangers who helped with the data collection, entry, and calculations as well the careful review of this report.

8. LIMITATIONS

Analyses and information included in this report are intended for use at the watershed scale and for the planning and long-term monitoring purposes described above. Analyses of channels and other water bodies, rocks, earth properties, topography and/or environmental processes are generalized to be useful at the scale of a watershed, both spatially and temporally. Information and interpretations presented in this report should not be applied to specific projects or sites without the expressed written permission of the authors, nor should they be used beyond the particular area to which we have applied them. Estimates of sediment originating from mass wasting, slope sources and/or roads and trails are developed solely for the purpose of providing context for planning the monitoring program; these should not be taken, for the roads in particular, as the long-term yields from individual sediment sources.

Balance Hydrologics, Inc. should be consulted prior to applying the contents of this report to evaluating upland sediment sources, any out-of-stream locations, or any in-stream locations not specifically cited in this report. Results are limited to information needed to plan a long-term monitoring program. In particular, information developed in this report is not intended for use in design of structures, or specific slope or road repairs.

Readers who have additional pertinent information, who observed changed conditions, or who may note material errors should contact us with their findings at the earliest possible date, so that timely changes may be made.

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TABLES

Table 1. V* values and pool geometry: El Corte de Madera Creek Open Space Preserve and La Honda Creek Open Space Preserve, San Mateo County, California.

Creek Reach[1]	Pool No.[2]	Pool Name	Residual Pool Volume[3]			Scoured Residual Pool Length[4]			Scoured Residual Pool Volume[5]			Average Scoured Residual Pool Depth[6]			V*[7]		
			(cubic feet)			*(feet)*			*(cubic feet)*			*(feet)*					
			2004	*2005*	*2006*	*2004*	*2005*	*2006*	*2004*	*2005*	*2006*	*2004*	*2005*	*2006*	*2004*	*2005*	*2006*
El Corte de Madera Creek Open Space Preserve (treatment)																	
El Corte de Madera Creek (upper)																	
	1	Long Skinny Pool	30	20	28	25	25	29	108	166	310	0.7	1.1	1.6	0.72	0.88	0.91
	2	Rusty Rod Pool	51	34	41	12	11	12	65	58	54	1.0	0.8	1.0	0.22	0.41	0.23
		reach average													*0.47*	*0.65*	*0.57*
Methuselah Tributary																	
	1	Dusk Pool	27	21	13	8	8	5	37	29	18	0.7	0.5	0.6	0.26	0.28	0.27
	2	Lower Dusk Pool	21	38	3	8	8	4	26	49	13	0.4	0.7	0.4	0.17	0.24	0.75
	3	Log Bank Pool	9	17	12	15	15	10	23	34	23	0.3	0.4	0.4	0.61	0.50	0.50
		reach average													*0.35*	*0.34*	*0.51*
El Corte de Madera Creek (middle)																	
	3	Between Logjams Pool	26	26	52	11	11	11	33	46	64	0.4	0.6	0.6	0.24	0.44	0.20
	4	Moss Rock Pool	52	13	51	15	14	14	74	40	74	0.7	0.4	0.7	0.29	0.68	0.28
		reach average													*0.26*	*0.56*	*0.24*
Lawrence Creek																	
	1	Twisted Twin Redwood Pool	88	109	58	12	12	11	122	154	147	0.3	0.9	1.2	0.27	0.29	0.60
	2	Waterfall Pool	18	31	26	12	9	14	31	46	42	0.9	0.6	0.4	0.42	0.33	0.39
	3	Lawrence Bridge (u/s)	39	30	15	23	14	16	57	59	41	0.4	0.5	0.4	0.31	0.50	0.64
	4	Lawrence Bridge (d/s)	90	97	118	21	23	24	107	134	194	0.8	0.8	0.7	0.16	0.28	0.39
	5	Long Pool	463	363	456	83	78	76	771	913	953	0.9	1.1	1.0	0.40	0.60	0.52
		reach average													*0.31*	*0.40*	*0.51*
El Corte de Madera Creek (lower)																	
	5	Iron Artifact Pool	162	118	216	53	52	52	304	231	356	0.4	0.4	0.5	0.47	0.49	0.39
	6	New Bridge Pool (Virginal Mill)	221	153	260	32	30	32	397	352	626	0.9	0.8	1.3	0.44	0.56	0.58
	7	Virginia Mill Bridge (d/s)	135	102	156	44	35	33	196	322	668	0.5	0.8	1.6	0.31	0.68	0.77
	8	Instruction Pool	371	251	415	60	62	60	575	538	692	0.6	0.6	0.7	0.36	0.53	0.40
	9	Above Property Line Pool	431	355	818	43	39	53	680	832	1320	1.1	1.3	1.5	0.37	0.57	0.38
		reach average													*0.39*	*0.57*	*0.50*
		mean (all pools)	**131**	**105**	**161**	**28**	**26**	**27**	**212**	**235**	**329**	**0.65**	**0.72**	**0.85**	**0.35**	**0.49**	**0.48**
		median (all pools)	**52**	**38**	**52**	**21**	**15**	**16**	**107**	**134**	**147**	**0.70**	**0.73**	**0.71**	**0.31**	**0.50**	**0.40**
		standard deviation (all pools)	**151**	**115**	**220**	**22**	**21**	**21**	**246**	**278**	**389**	**0.26**	**0.27**	**0.44**	**0.15**	**0.17**	**0.20**
La Honda Creek Open Space Preserve (control)																	
La Honda Creek																	
	1	Triple Redwood Pool	48	36	4	22	21	17	81	68	58	0.6	0.7	0.7	0.41	0.47	0.93
	2	Cracked Rock Pool	26	25	33	15	11	13	42	48	53	0.7	0.5	0.5	0.37	0.47	0.37
	3	Fir Bridge Pool	28	25	26	26	23	23	43	46	86	0.4	0.4	0.8	0.34	0.45	0.70
	4	Charred Wood Pool	30	35	24	18	21	20	42	61	69	0.5	0.5	0.4	0.29	0.43	0.65
		reach average													*0.35*	*0.46*	*0.66*
"Big Tree" Tributary																	
	5	Fallen-Fir Rocky-Gorge Pool	14	15	23	10	10	9	22	24	35	0.4	0.4	0.7	0.36	0.38	0.33
	6	Hanging Stump Pool	36	38	60	12	12	12	65	70	90	1.2	1.3	1.6	0.44	0.46	0.33
		reach average													*0.38*	*0.43*	*0.44*
		mean (all pools)	**30**	**29**	**29**	**17**	**16**	**16**	**49**	**53**	**65**	**0.62**	**0.64**	**0.75**	**0.37**	**0.44**	**0.55**
		median (all pools)	**29**	**30**	**25**	**16**	**16**	**15**	**42**	**55**	**64**	**0.54**	**0.53**	**0.66**	**0.36**	**0.46**	**0.51**
		standard deviation (all pools)	**11**	**9**	**18**	**6**	**6**	**5**	**21**	**17**	**21**	**0.31**	**0.36**	**0.42**	**0.05**	**0.03**	**0.25**

Notes:

1 Pools are listed in downstream order. Tributary pools are listed based on where that tributary joins El Corte de Madera Creek. (For example, Methuselah Tributary joins El Corte de Madera Creek between 'Rusty Rod Pool' and 'Between Logjams Pool'.)

2 Pools are numbered from upstream to downstream within a given watershed or tributary. Note that for El Corte de Madera Creek mainstem, numbering is continuous from the upper reach through the lower reach.

3 'Residual pool volume' refers to the volume of the scoured residual pool that is filled only with water. (The 'Scoured residual pool' minus the volume of sediment.)

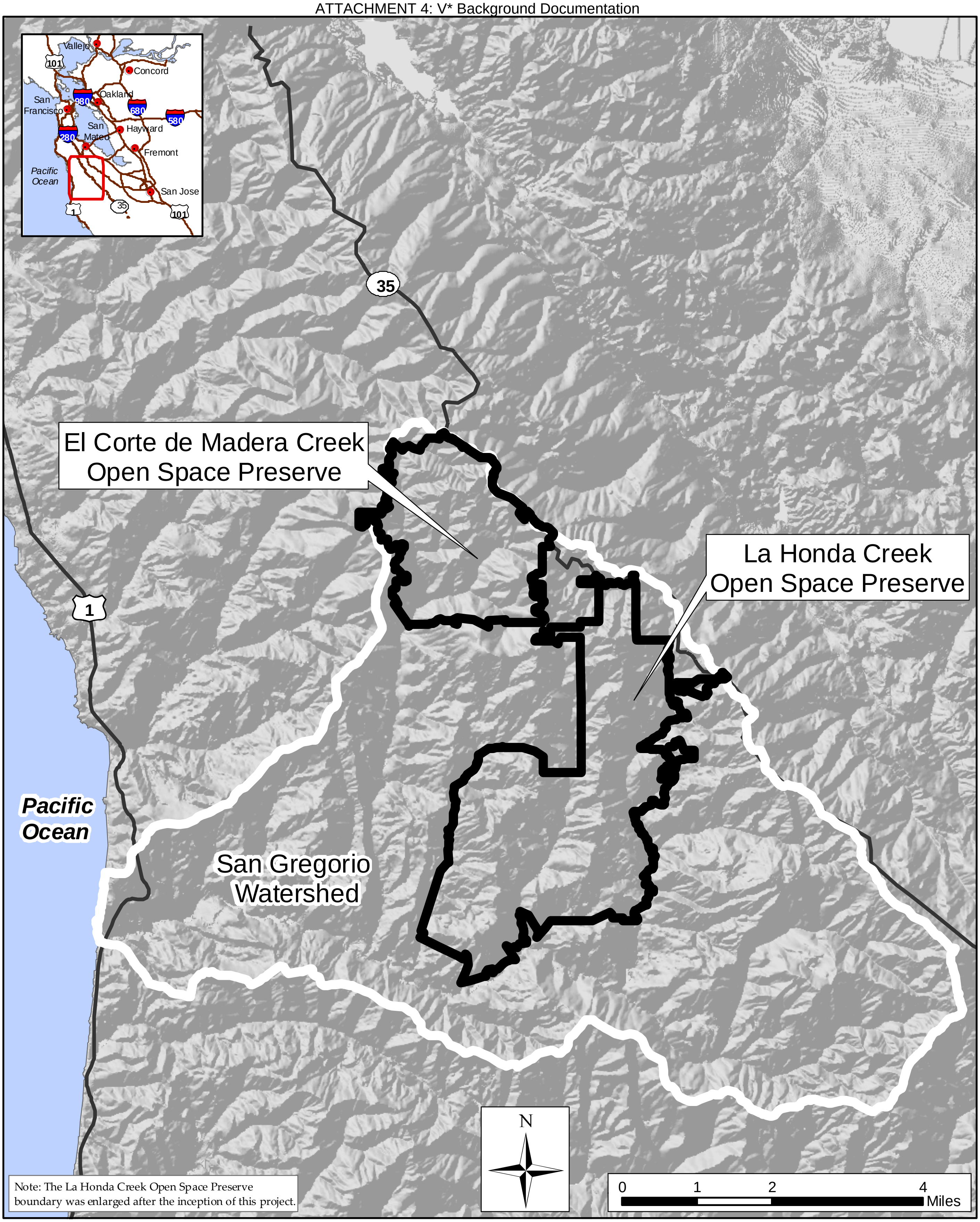
4 'Scoured residual pool length' is assumed to be the length of the surveyed pool. Variations of less than a few feet are likely the result of differences in surveyor's designations of the pool boundaries. Large changes in pool length could be due to the encroachment of the riffle from upstream, or erosion of the riffle crest.

5 'Scoured residual pool volume' represents the total volume of the pool if all the fine sediment were removed. In theory, the scoured residual pool volume should remain the same from year to year. Large changes in scoured residual pool volume could indicate an influx or scour of coarse material, or may indicate a difference in surveyor designations (whether or not areas of soft bank material were included, for example).

6 'Average scoured residual pool depth' was calculated by dividing the scoured residual pool volume by the scoured residual pool surface area.

7 V represents the proportion of the scoured residual pool that is filled with fine sediment (volume of residual fines divided by scoured residual pool volume).*

FIGURES



Balance Hydrologics, Inc.

Figure 1. Location of El Corte de Madera Creek and La Honda Creek Open Space Preserves, San Mateo County, California

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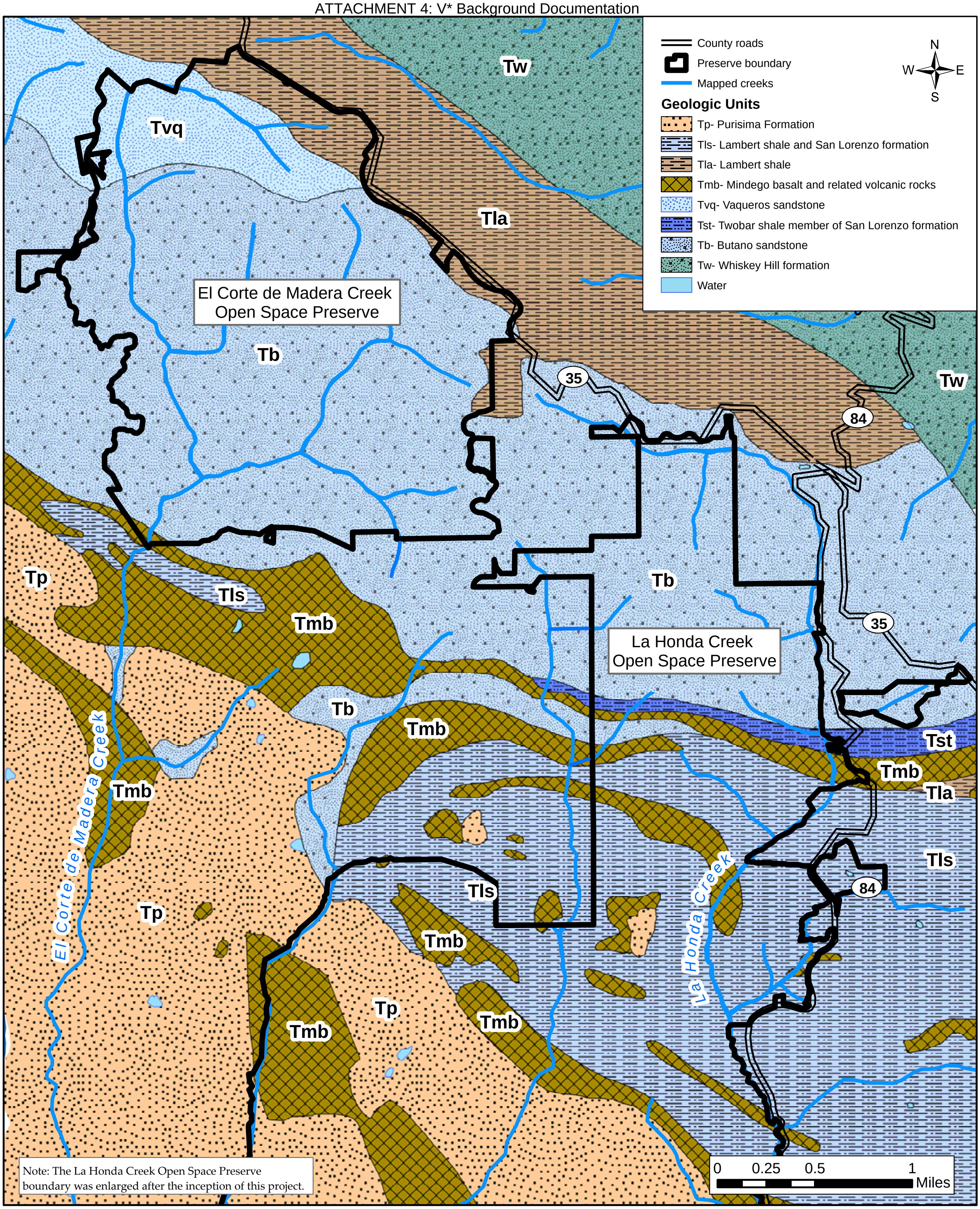

Source: Brabb, E. E., Graymer, R.W., Jones, D.L., 1998, Geology of the onshore part of Santa Mateo County, California: A digital database, U.S. Geological Survey OF-98-137.

Balance Hydrologics, Inc.

Figure 2. Bedrock geology map of the El Corte de Madera Creek and La Honda Creek Open Space Preserves, San Mateo County, California

Butano sandstone (Tb) is the dominant bedrock in the ECDM Preserve, so we compared these to pools in the La Honda Preserve underlain by the same formation. Isolated unmapped outcrops of Mindego basalts are found throughout the Tla and Tvq units

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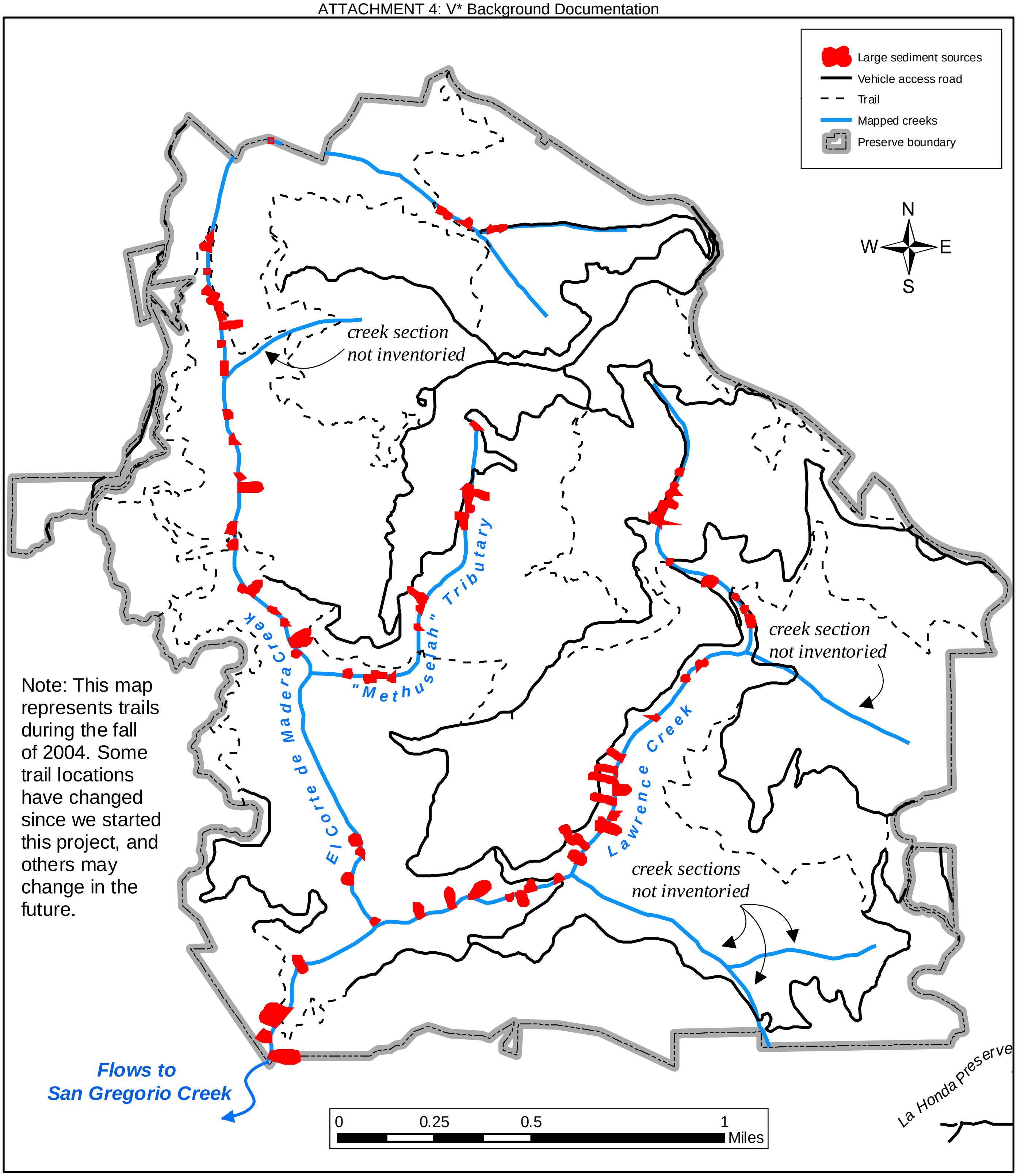


Note: This map represents trails during the fall of 2004. Some trail locations have changed since we started this project, and others may change in the future.

Balance Hydrologics, Inc.

Figure 3. Inventoried large sediment source locations, MROSD's El Corte de Madera Creek Open Space Preserve, San Mateo County, California

Large sediment sources (>15-27 yd^3) were inventoried along the entire length of El Corte de Madera Creek, Lawrence Creek, and the Methuselah Tributary within the Preserve. Other unnamed tributaries were not mapped. Owens and others (2006) estimated that approximately 80 % of sediment entering the creeks is derived from landslides and bank failures and about 20 % could be from roads and trails.

W:\Projects\204020\204020_V-star_06rpt_sed_sources (Fig3).mxd

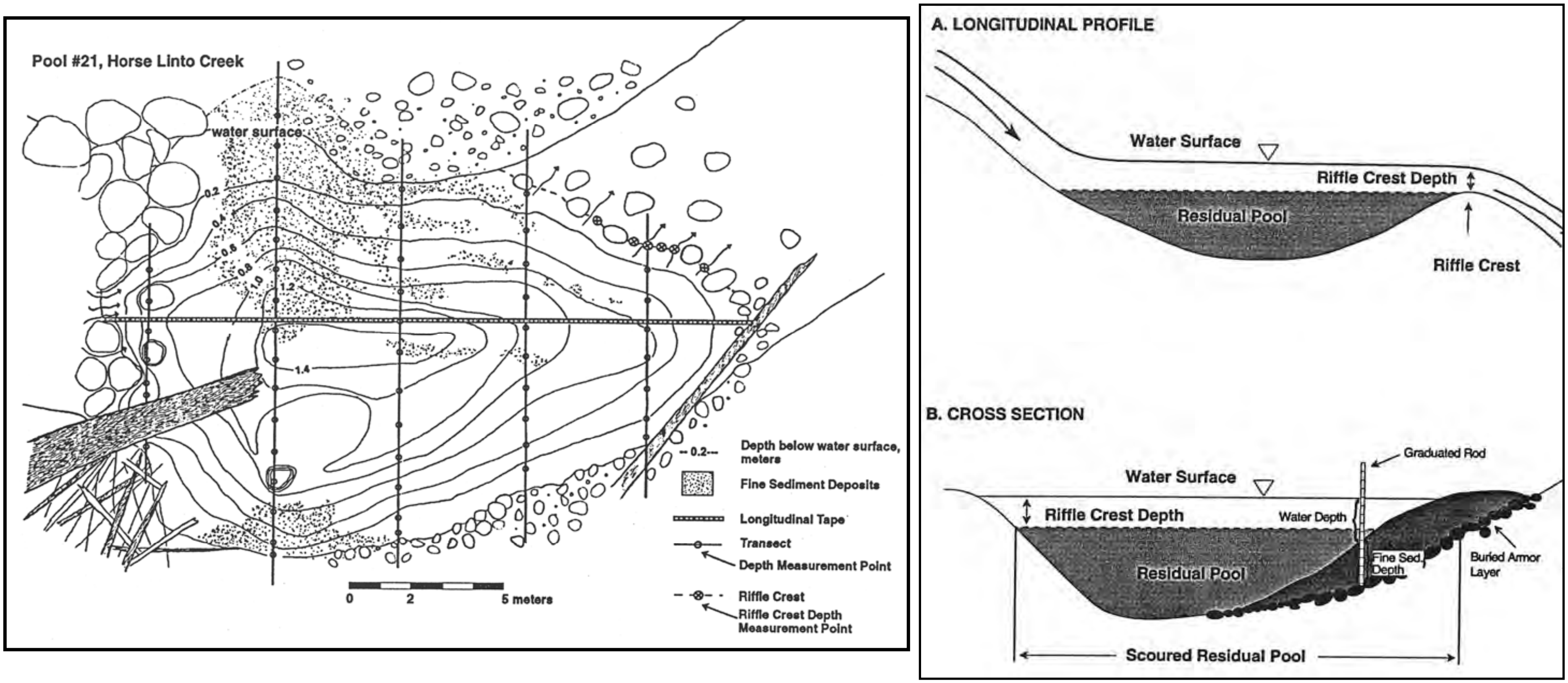
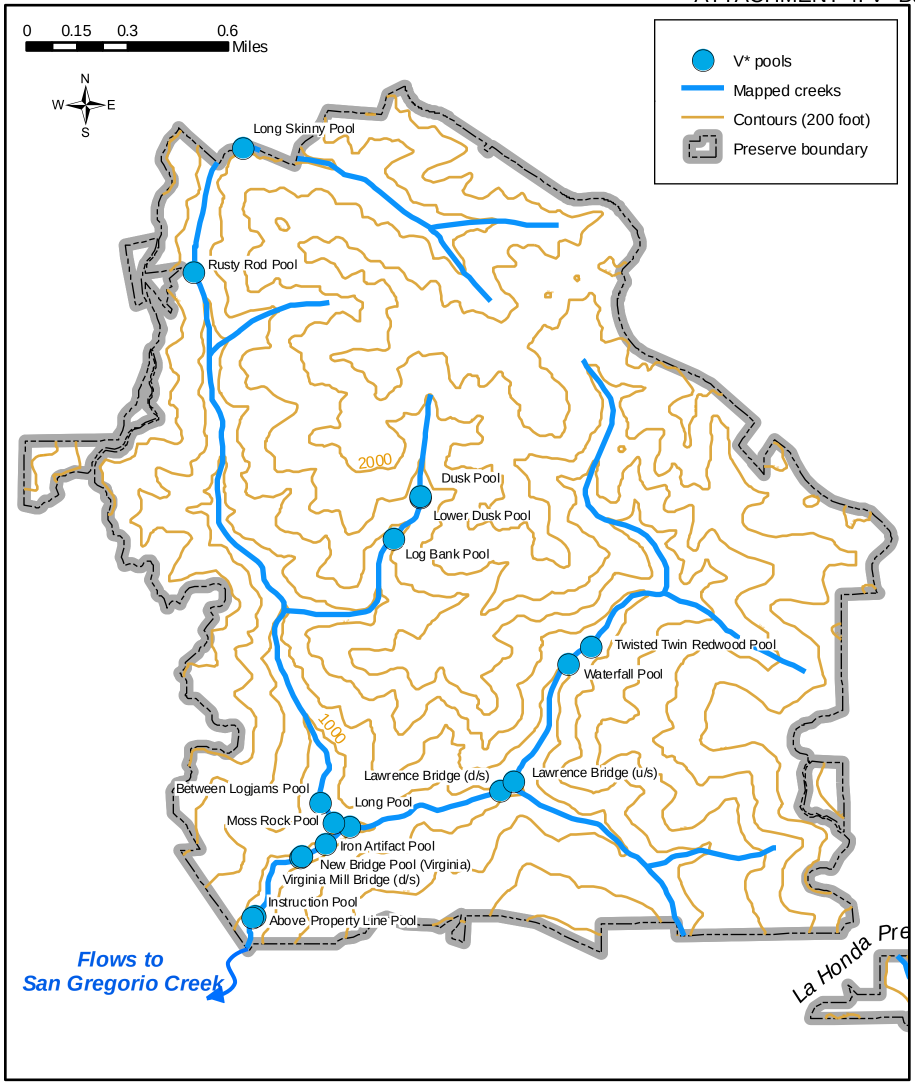
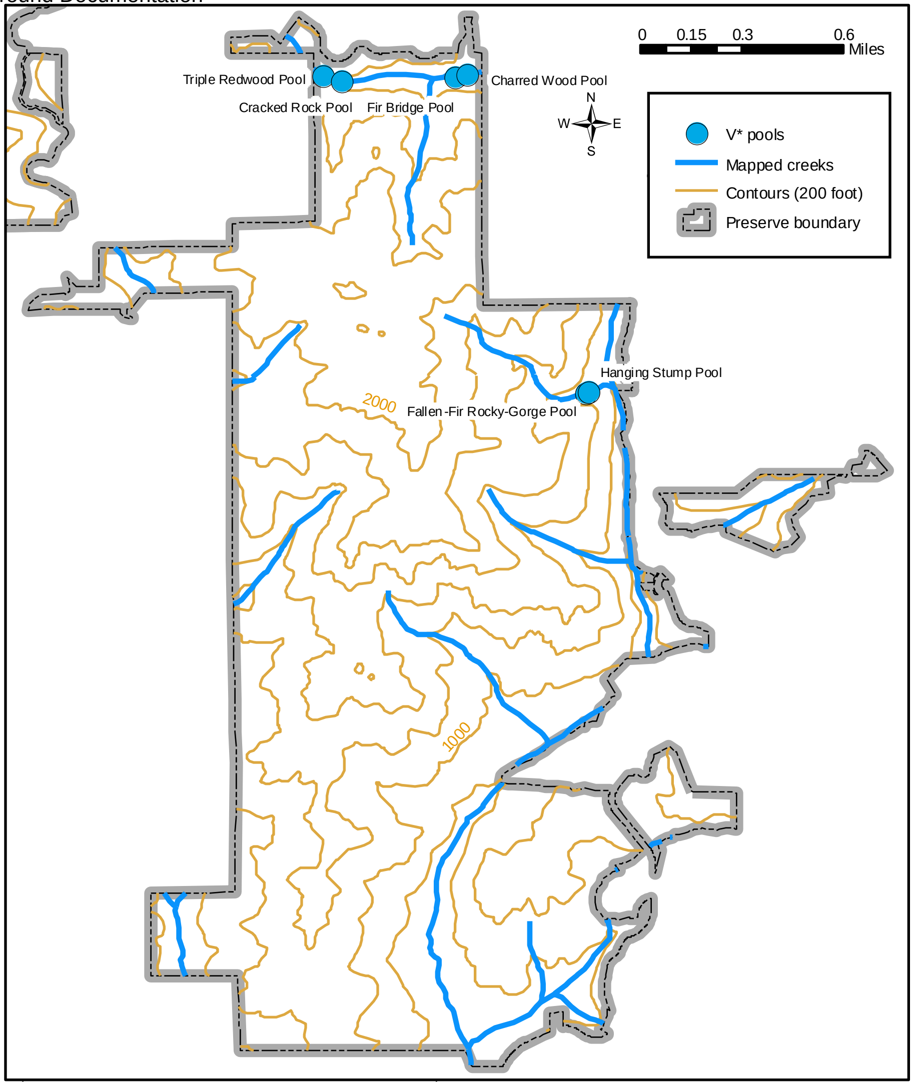


Figure 4. **V* method for evaluating stream pool sedimentation.** Plan view and cross-sectional views of a pool with metrics and measurements locations used for the V-star technique. Figures from Hilton and Lisle, 1993.





Note: The La Honda Creek Open Space Preserve boundary was enlarged after the inception of this project and is larger than shown here.

Balance Hydrologics, Inc.

Figure 5. V* pool locations, El Corte de Madera Creek and La Honda Creek Open Space Preserves San Mateo County, California. Balance and MROSD staff made detailed measurements at 23 pools within the Preserves (17 pools in El Corte de Madera Preserve, 6 pools in La Honda Preserve). These pools were chosen from over 130 pools encountered on our stream walks

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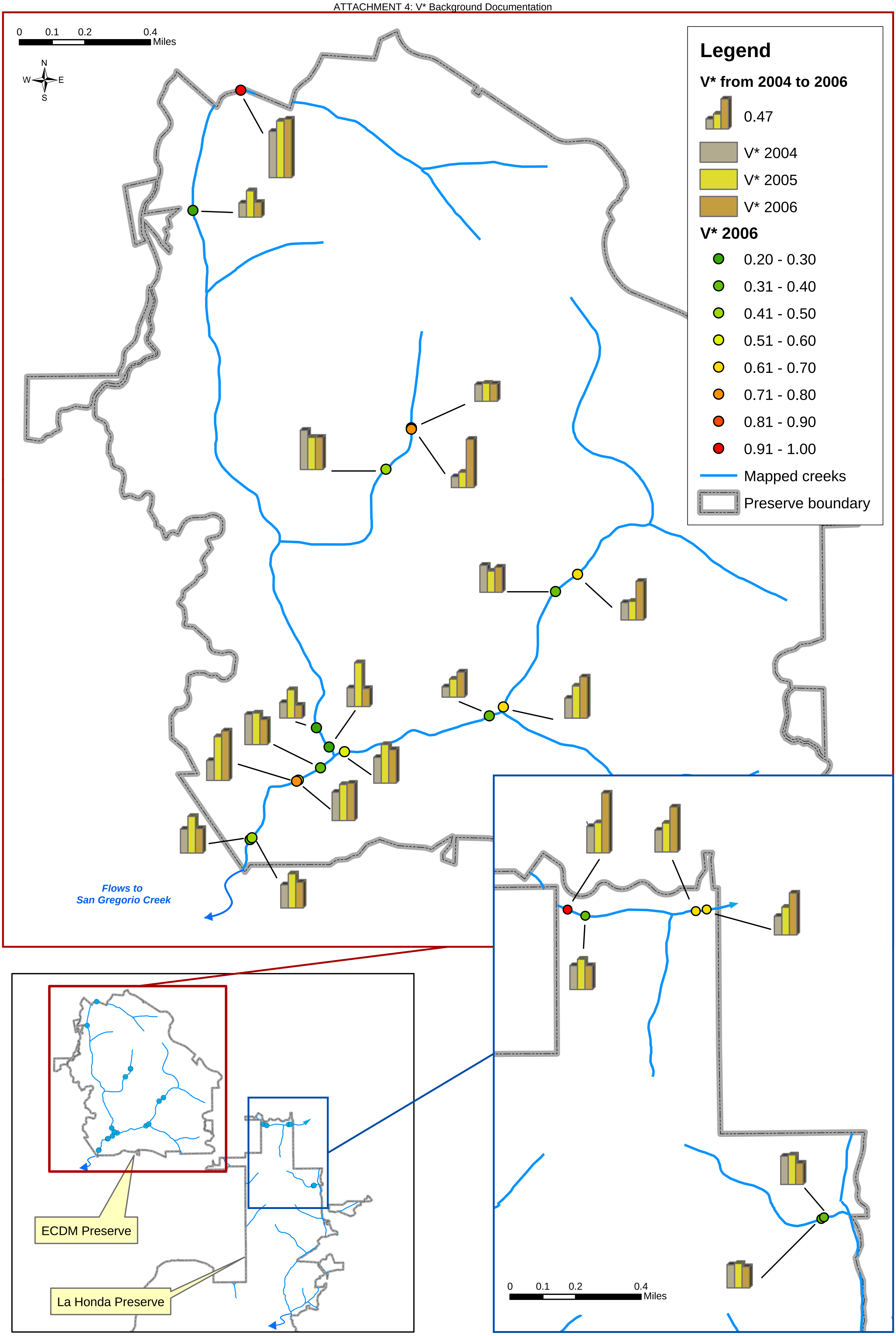

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Figure 6. V* pool measurements, water year 2004 to 2006, ECDM and La Honda Preserves San Mateo County, California. Balance and MROSD staff made detailed measurements at 23 pools within the Preserves (17 pools in El Corte de Madera Preserve, 6 pools in La Honda Preserve).

W:\Projects\204020\204020_Vstar_06_rpt_graph map(Fig 6).mxd

preliminary and subject to revision

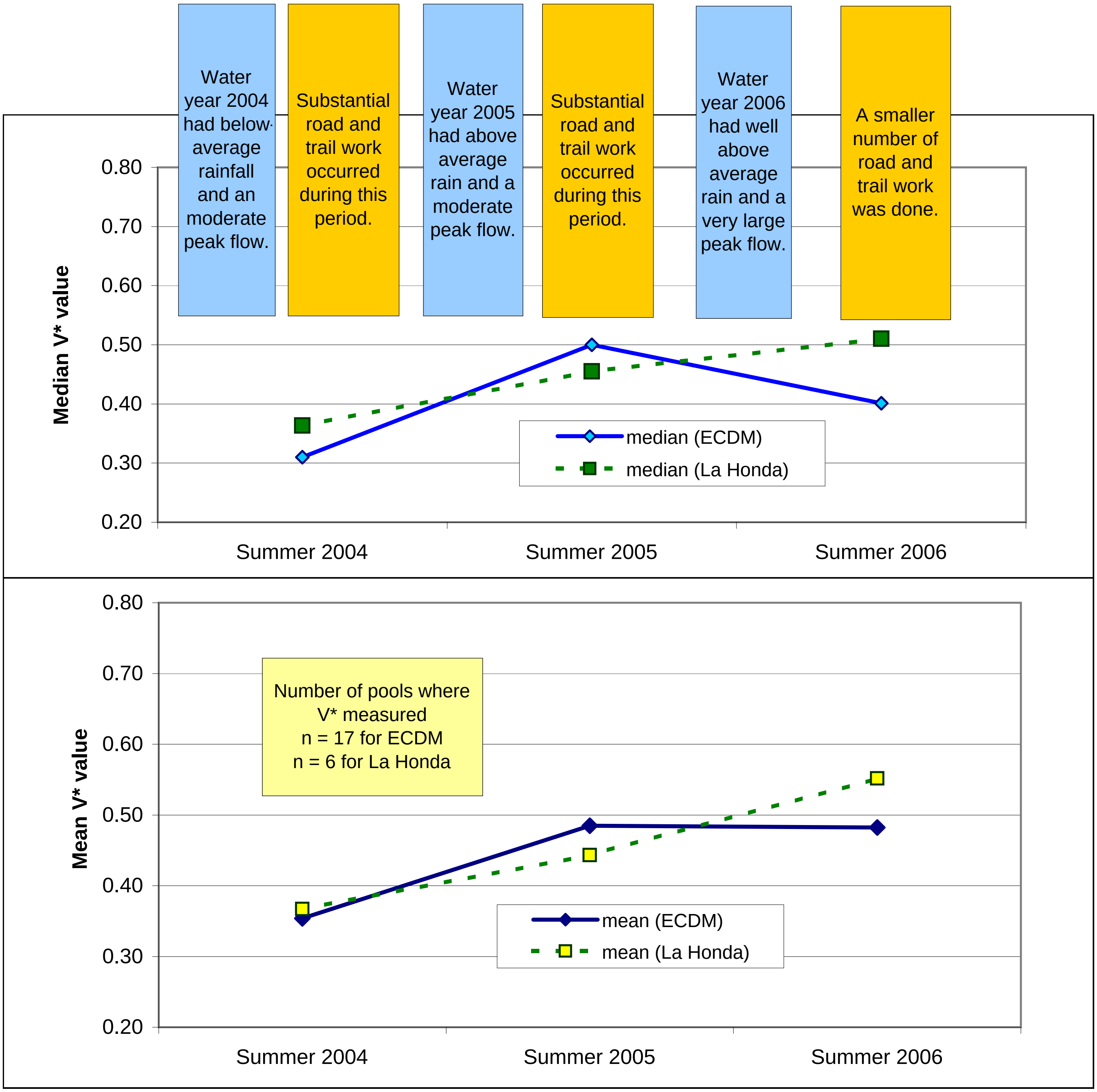

Figure 7. Short-term trend of V* values, El Corte de Madera Creek and La Honda Creek Open Space Preserves, 2004 to 2006. V* values for the control site (La Honda) increased between each sampling, which is probably due to several, large winter storms. V* values for the treatment site (ECDM) increased more than La Honda in 2005, but decreased slightly in 2006. The trend at ECDM should be a combination of the winter weather patterns and the steps being taken to improve road and trail drainage.

APPENDICES

APPENDIX A

Overall Sediment Study Approach: Sediment Sources, Transport and Storage

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Overall Sediment Study Approach: Sediment Sources, Transport And Storage

Balance planned an investigation for the MROSD using three main approaches to assessing stream sediment:

1. *Storage:* The first approach was designed to establish a baseline and then track changes in pool sedimentation following road and trail upgrades and other conservation efforts. The northern half of the La Honda Creek Preserve serves as the control watershed for the ECDM Preserve, which is considered the treatment watershed.

   Balance and MROSD staff measured sediment depth and water depth in multiple pools within the creeks and tributaries. Sediment in pools is measured using the standard V* method, as defined by USDA Forest Service research hydrologists (c.f., Lisle and Hilton, 1993). We trained District scientists, and they have made measurements and helped reduce these data. See Owens and others (2006) for first year results and conclusions.

2. *Sources:* The second approach was designed to identify the processes and spatial distribution of sediment delivered directly to the creek system. It is also intended to quantify the volume of sediment being contributed to the creeks such that road- and trail-related sediment contributions might be placed in context.

   Balance staff inventoried large sediment sources near the channel, generally within the inner gorge, that were delivering sediment directly to the creek. The inventory included landslides, debris flows, bank failures, and gullies, plus selected other features. (Not discussed in this report, see Owens and others, 2006).

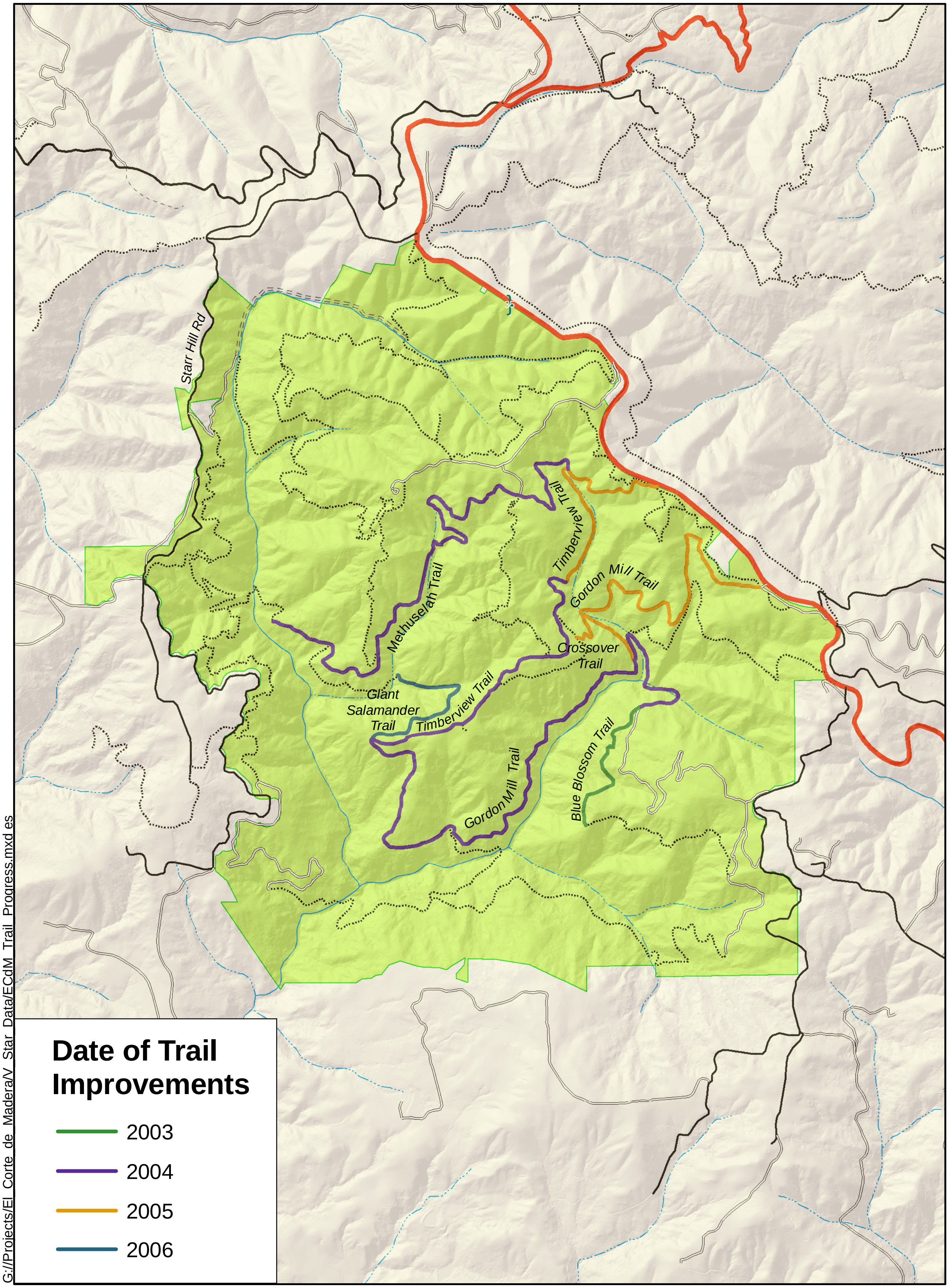
3. *Transport*: The third approach is intended to better understand the effect of sediment load contributed from headwaters in ECDM Preserve on the larger San Gregorio watershed and its spawning habitat.

   Balance and MROSD staff installed a stream gage on El Corte de Madera Creek near the downstream boundary of the ECDM Preserve. A stream gage and sediment sampling program is used to calculate a continuous record of stream flow and sediment discharge for water year 2006 forward. Both the records of flow and of sediment transport can be used as baselines from which future changes can be quantified. A formal daily stream record is a welcome byproduct of this effort that has widespread planning and habitat improvement applications.

APPENDIX B

Watershed Protection Program Trail Improvements, El Corte De Madera Creek Open Space Preserve, Prepared by Mid-Peninsula Regional Open Space District.

Watershed Protection Program Trail Improvements
El Corte de Madera Open Space Preserve



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Produced by Midpeninsula Regional Open Space District, August 2007

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Streamflow and Sediment Monitoring, El Corte de Madera Creek, Water Year 2008 El Corte de Madera Creek Open Space Preserve, San Mateo County, California

Report prepared for:
Midpeninsula Regional Open Space District

Prepared by:
John Gartner
Jonathan Owens
Barry Hecht

Balance Hydrologics, Inc.

February 2009

A report prepared for:

Midpeninsula Regional Open Space District
330 Distel Circle
Los Altos, California 94022
(650) 691-1200
Attention: Meredith Manning

Streamflow and Sediment Monitoring, El Corte de Madera Creek, Water Year 2008, El Corte de Madera Creek Open Space Preserve, San Mateo County, California

by

John Gartner
Hydrologist / Geomorphologist

Jonathan Owens
Hydrologist

Barry Hecht
Principal, CEG 1245, CHg 50

PROFESSIONAL GEOLOGIST
BARRY HECHT
No. 1245
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

REGISTERED GEOLOGIST
BARRY HECHT
NO. 50
CERTIFIED HYDROGEOLOGIST
STATE OF CALIFORNIA

Balance Hydrologics, Inc.®
800 Bancroft Way, Suite 101
Berkeley, California 94710-7227
(510) 704-1000
office@balancehydro.com

February 25, 2008

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1. PROJECT SUMMARY

1.1 Background and Objectives

Beginning in water year 2006[1], Balance Hydrologics ('Balance') has gaged streamflow and sediment discharge in El Corte de Madera (ECDM) Creek at the Virginia Mill Trail, near the downstream property boundary of the El Corte de Madera Creek Open Space Preserve ('Preserve'), which is managed by the Midpeninsula Regional Open Space District (MROSD). The Preserve is located in the headwaters of El Corte de Madera Creek, part of the San Gregorio Creek watershed, and the waters downstream provide spawning habitat for coho salmon (*Oncorhynchus kisutch*) and steelhead (*Oncorhynchus mykiss*), species federally-listed as endangered and threatened, respectively. Although a barrier to upstream migration prevents these anadromous fish from spawning within the Preserve, it is possible that sediment from the Preserve might adversely affect habitat downstream. High rates of sediment production and transport are possible within the Preserve due to local geology and a legacy of redwood logging and logging-road construction, existing uses, and natural physiography. Downstream, San Gregorio Creek is currently listed under the Clean Water Act 303(d) List as impaired by sediment (SWRCB, 2003).

This gaging effort is part of a larger endeavor to quantify, mitigate, and monitor sediment production, storage and transport within the Preserve encompassing a three-component approach considering

- Sediment sources,
- Sediment storage in the channel, and
- Sediment discharge from the Preserve.

Recent and ongoing work has assessed sediment sources to streams such as landslides, bank failures, and trails (Owens and others, 2006), and changes in sediment storage within stream pools using the V*[2] technique (Gartner and others, 2007; Owens and others, 2006).

---

[1] Most hydrologic and geomorphic monitoring occurs for a period defined as a water year, which begins October 1 and ends on September 30 of the named year. For example, water year 2008 (WY2008), begins October 1, 2007 and concludes on September 30, 2008.

[2] The V* (pronounced "V-star") technique calculates the percent of a pool filled by finer sediment than forms the bed of a stream (Hilton and Lisle, 1993).

Concurrently, MROSD has been implementing a wide-ranging Watershed Protection Plan that aims to reduce erosion and subsequent delivery of fine sediments to the aquatic system through trail improvements, among other goals (Best, 2002; Freeman, 2004).

A primary goal of the sediment gaging effort during water years 2006, 2007 and 2008 is to quantify baseline and changes in transport (or ”sediment discharge”) of suspended load and bedload sediment at the watershed scale in El Corte de Madera Creek. Quantifying sediment discharge provides:

- A direct measurement of sediment discharge, the constituent for which the watershed has been listed, and an index which complements indices of sediment sources and storage measured in other studies within the Preserve;
- Comparison of sediment yield in the Preserve with other regional streams;
- A watershed-scale baseline against which recent and future changes may be compared, enabling assessment of sediment reduction from trail improvements and other short- and long-term management actions in the Preserve.

The present study builds upon the foundation of previous reports. In this report, we examine stream flow and sediment transport during water year 2008, a year with two moderately large storms but with below average rainfall. Ongoing watershed improvements to roads and trails occurred during the preceding dry season, so monitoring sediment is still important to measure sediment conditions that may change due to the road and trail improvements.

1.1.1 Previous reports

We initially measured sediment discharge during water year 2006 (Gartner and others, 2006), very shortly after the onset of MROSD’s ongoing watershed improvements (Freeman, 2004) During water year 2006, rainfall in the watershed, and in several nearby catchments, was about 160 percent of the long-term average, and included an event with mid-range recurrence (5- to 20-year) on December 31, 2005.

Data collected in water year 2007 built upon our understanding of watershed sediment transport dynamics, especially in a dry year. Rainfall was at about 80 % of long-term average precipitation, no large storms occurred when the watershed soils were fully saturated, and there were no large flow events to transport abundant sediment (Gartner and others, 2008).

Balance's initial reports on sediment sources and baseline creek sedimentation (Owens and others, 2006; Gartner and others, 2007) contains more information on the overall study design, regulatory background, MROSD Watershed Protection Plan improvements, and site characteristics.

Sediment gaging has other important applications in addressing the MROSD mission to preserve, protect and provide for enjoyment of a greenbelt system in the region. The sediment study, with its associated record of stream flow and other physical conditions, allows MROSD to contribute to and set standards for watershed management at the larger scale, enable basic research, and possibly provide educational opportunities for visitors.

1.2 Summary of Conclusions

Our water year 2008 study yields the following preliminary conclusions:

1. Total suspended and bedload sediment transported past the ECDM stream gaging station was approximately 236 tons, or about 50 tons per square mile. This volume is much less than transported during water year 2006 (approximately 5,600 tons, or about 1200 tons per square mile), but greater than that during water year 2007 (approximately 57 tons, or about 12 tons per square mile). At other gages in the region, sediment discharge during WY2008 showed similar patterns compared to previous water years (see Sections 5.5, 5.6, 5.7).

2. During water year 2008, total precipitation was 31.7 inches (approximately 81 percent of long-term average precipitation), the peak flow was likely approximately a 2.5-year storm, and there were only a few flow events capable of transporting sediment. Total flow for this year was about 130 percent of water year 2007 and 20 percent of water year 2006 (see sections 5, 6).

3. We are using comparison of sediment-rating curves in the first (baseline) year with rating curves in future years to monitor MROSD's performance in attaining the preserve management objectives. The sediment-rating curves measured during water year 2008 were deemed consistent with the previous year's data. This means the amount of sediment entrained at a given flow did not appear to be higher or lower than during water years 2006 and 2007 (see Sections 5.5, 6.2).

4. Rainfall conditions during water year 2008, with three moderate storms and no very large storms were favorable to establishment of the watershed improvements. These types of conditions tend to allow areas of recent work to vegetate, compact and stabilize before being tested by subsequent large storms (see Section 6.1).

5. Flow monitoring will continue during water year 2009, but sediment monitoring will be discontinued. The decision to sample pools regularly measured for V* ("V-star") should

be reassessed at the end of the rainy season of water year 2009. V* measurements were not collected in summer 2007 or 2008 (see Sections 6.3).

2. HYDROLOGIC SETTING

El Corte de Madera Creek is located in the headwaters of the western slopes of the Santa Cruz Mountains of central coastal California and drains to San Gregorio Creek before flowing into the Pacific Ocean. The stream gage is located about 100 feet upstream of the bridge on the Virginia Mill Trail, near the downstream boundary of the Preserve (Figure 1), at the coordinates 37°22'58" N, 122°19'39" W (NAD83). The watershed above the gage is about 4.74 square miles with limits corresponding roughly (although not exactly) with the boundary of the Preserve, which encompasses 4.4 square miles. The watershed upstream of the gage ranges in elevation from 700 to 2417 feet above sea level.

The gaged watershed is underlain by deformed and uplifted Tertiary sedimentary rocks of the Butano and Vaqueros formations, primarily sandstones. These sediments of early-Tertiary age are intruded by occasional dikes and sills of the Miocene Mindego basalt (c.f., Brabb and Pampeyan, 1972). The sandstones weather and erode in many ways, appearing as large boulders, cobbles, and sand in the creeks, but typically yielding a low proportion of gravel (Hecht and Rushmore, 1973). Landslides and other forms of mass wasting are common (Ellen and Wieczorek, 1988; Godt, 1999; Owens and others, 2006). Vegetation varies with aspect and timber-harvest history; it is predominantly redwood, tan oak, and Douglas fir, with small areas of grasslands and shrub species.

Mean annual precipitation varies with elevation and is thought to range from 32 to 40 inches from the lower to higher elevation areas in the watershed[3] (Rantz, 1971; Saah and Nahn, 1989). About 85 percent of the total annual rainfall occurs during the wet season, which typically spans the months of November through March. Fog is common throughout the year; fog-drip is ecologically significant and can contribute a measurable component to the total precipitation along ridges and in other certain areas.

Land use within the watershed is predominantly rural parklands, with a few rural homes and a two-lane state highway within the gaged watershed outside of the park boundary. The watershed has a history of extensive logging in the late 1800’s to early 1900’s (Stranger, 1967) with intermittent timber harvests on what is now MROSD’s ECDM Preserve in the mid-1900’s

[3] Rainfall averages 38 to 40 inches per year at the MROSD-operated gages, which are located at a relatively high elevation in the Preserve.

through the mid-1980's of varying extents and intensities. The area that is now the Preserve was also used as a motorcycle recreation area in the mid-1980's (Grench, 1985).

3. STATION INSTRUMENTATION AND MAINTENANCE

The stream gage on El Corte de Madera Creek at the Virginia Mill Trail station is equipped with Type C staff plates and two Druck pressure transducers connected to a Campbell Scientific CR10X datalogger. The datalogger records current and maximum water depth every 15 minutes. Pressure transducers were tested and calibrated by Balance staff prior to installation. Calibration of water depth to stream stage[4] is performed by recording water levels and the height of any previous high-water marks as read against the staff plate during each visit. The direct field observations are then compared with the electronic record and used to calibrate the record.

In addition to routine monthly visits, Balance and MROSD staff made high-flow measurements of streamflow and sediment transport during storms throughout the winter months. When manual flow and stage measurements were made, Balance staff also measured the specific conductance and water temperature of the stream, recorded the level of recent high-water marks, downloaded the dataloggers, inspected the instruments, and replaced datalogger batteries and desiccant as needed. Measurements of sediment transport were not made on visits when we could observe that suspended- and bedload-sediment transport was negligible, such as during base flows (usually less than 6 cfs at this station).

MROSD operates a rain gage within the Preserve at the location shown in Figure 1. A tipping bucket gage was operational throughout water year 2008, and a manual-reading rain gage was visited daily by MROSD rangers during the study period. The daily rainfall record is shown in Figure 2.

[4] Stage is the elevation of the water surface at the gage relative to an arbitrary datum (staff plate). Subtracting the reading at the base of the staff plate from measurement at the current water levels allows an answer to question, "How deep is the water?".

4. CREATING A RECORD OF FLOW AND SEDIMENT DISCHARGE

4.1 Flow Record

Based on staff plate readings of stream stage and flow measurements during our periodic site visits, we created a stage-to-discharge relationship (“stage-discharge rating curve”) shown in Figure 6. The stage record from the datalogger was then converted to a flow record (Figure 3) using the rating curve. Small stage shifts, which are changes in the rating curve usually caused by leaf and debris jams or by scour or deposition along the stream channel, were applied to the record of flow. For quality control, the unit flow[5] record was compared with unit flow records of similar, nearby gaged watersheds (Figure 4). The flow record for water year 2008 is plotted with flow records from water years 2006 and 2007 in Figure 5.

We utilized streamflow equipment appropriate for the conditions encountered in the field, following standard hydrographic practice. Station observers’ logs are provided in Table 1, summarizing the measurements made and conditions encountered. Our methods include both hand-held, low-flow (pygmy) and high-flow (Price Type-AA) bucket-wheel current meters. In this relatively dry year, we did not encounter high-flow conditions that prevented safe wading or required standard float measurements.

4.2 Sediment Record

4.2.1 Bedload versus suspended sediment

Following convention, we distinguish two types of sediment in transport, each measured during storms using specific samplers and methods. ***Bedload sediment*** is supported by the bed of the stream; it rolls or ‘saltates’ along the bed, commonly within the lowermost 3 inches of the water column. Movement can be either continuous or intermittent, but is generally much slower than the mean velocity of the stream. In El Corte de Madera Creek, bedload consists primarily of medium and coarse sands and very fine gravels, with occasional cobbles or boulders during the highest flows. ***Suspended sediment*** is finer material supported by the turbulence of the water. It is transported at a velocity approaching the mean velocity of flow. The size of sediment that can travel in suspended mode will generally increase as streamflow and velocity increase. In El Corte de Madera Creek, as elsewhere in the Santa Cruz Mountains, suspended load is primarily fine sands, silts and clays. Different standard samplers are used

[5] Unit flow is the actual flow divided by the watershed area.

for the two modes of transport. ***Total sediment discharge*** is the sum of bedload-sediment and suspended-sediment discharge.

4.2.2 Methods of sediment measurements and calculations

Standard methods and equipment reviewed by the Federal Interagency Sedimentation Project (FISP) were used to make measurements and calculations of sediment transport (Edwards and Glysson, 1999). Bedload and suspended sediment were measured using Helley-Smith and DH-48 or DH-81 hand-held samplers. Bedload samples were processed at Balance Hydrologics and suspended load samples were processed by Soil Control Lab, Watsonville, California. These samples were direct measurements of sediment being transported at the time. The measured results were plotted compared to concurrent streamflow to develop instantaneous sediment-discharge rating curves (see Figure 7). Sediment discharge, or sediment yield, calculations were based on applying instantaneous sediment-discharge rating curves to the flow data for each 15-minute unit, computing both bedload- and suspended-sediment discharge for each 15-minute interval. Daily sediment discharge was then calculated by totaling sediment discharge summed from the 96 daily, 15-minute intervals.

4.2.3 Unit sediment discharge

To compare sediment transport amongst stations in different watersheds, total annual sediment discharge (in tons per year) was divided by the watershed area (in our case, square miles) to calculate the unit sediment discharge, also known as sediment yield per unit watershed area.

5. FINDINGS: HYDROLOGIC AND SEDIMENT SUMMARY

5.1 Precipitation Conditions

Water year 2008 was a relatively dry year with both peak flows and total flow volumes being below average. This water year had 83 to 87 % of average rainfall at most long-term monitoring stations from coastal areas of North San Francisco Bay to Santa Cruz (California Data Exchange Center, 2008). Rainfall measured at the MROSD-operated rain gage along the eastern boundary of the Preserve totaled 31.7 inches from October 1, 2008 to September 30, 2008 (Figure 2). At this location, the two widely-used mean annual rainfall maps for the region (Rantz, 1971; Saah and Nahn, 1989) estimate a mean annual rainfall of 38 to 40 inches. Thus rainfall at the rain-gage location was about 81 % of average rainfall.

5.2 Peak Flows

The water year 2008 pattern of rainfall produced only a few flows capable of transporting sediment during this water year. The peak flow of 155 cfs occurred on January 4, 2008, and another peak flow of 148 cfs occurred on January 25, 2008 (Figure 3). At a nearby stream gaging station with a long period of record,[6] we estimate that the water year 2008 peak flow corresponds to an approximate 2.5-year recurrence interval (or 41 percent exceedance probability).

5.3 Sediment Transport, Water Year 2008

5.3.1 Sediment-discharge totals

Total sediment transported past the ECDM station during water year 2008 was estimated at approximately 236 tons; about 19 percent was bedload and 81 percent suspended load (see Form 2), based on the measured flow hydrograph and sediment-discharge rating curve. Form 2 shows that at lower flows, such as in June, sediment transport was negligible.

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[6] San Francisquito Creek at Stanford Golf Course (USGS ID# 11164500) has a 67-year record. At this USGS gage, the peak flow of water year 2008 was approximately 1,850 cfs during the storm on January 25, 2008, with a 2.5-year recurrence interval. This storm produced the second highest flow at the ECDM station, but the magnitude was very close to the highest flow. The USGS data are provisional because the final data were not released by the time of this report.

The unit sediment discharge was about 50 tons per square mile per year, based on a drainage area of 4.74 square miles.

Our sediment total does not include dissolved sediment, which is generally not considered an important factor in bed conditions or spawning habitat in this region. Measurements of specific conductance collected during water years 2006 through 2008 allow estimation of a baseline of total dissolved solids for these years, if deemed needed at a later date.

5.3.2 Geomorphic changes to the channel

For the purposes of gaging technique, the location of pools, riffles, and cobble and sand bars did not change greatly in the vicinity of the gage. The flow measurements taken in the spring suggest there may have been approximately 0.1 to 0.2 feet of bed lowering at the gaging station; however our visual observations indicate that channel scour was not consistent through the reach and could be due to very localized conditions, such as a single boulder shifting during a storm. While surveys (including V* measurements) may show deposition and / or scour in pools and other changes in stream channel geometry at riffles and bars due to sediment movement, the major segmental bedforms (such as bars, pools, and riffles) did not change sufficiently to affect the stage-discharge rating curve, although minor 'shifts' were applied, consistent with standard practice. There were no great changes in the location of woody debris that influenced flows or bed conditions at the gaging station. Photographs from photo points and visual observations of the channel following large storms were documented over the water year.

5.4 Comparison of ECDM Sediment Discharge to nearby Streams

Total sediment "exported" from the watershed at the ECDM station was similar to or less than transport observed at nearby stations. Table 3 and Figure 8 compare the sediment discharge per watershed area from ECDM and other sediment gaging stations in the central Santa Cruz Mountains during water year 2008. Figure 9 shows the location of the other watersheds. The computed values at ECDM are in the same range as those reported for Bear Creek in Woodside. Corte Madera Creek and Los Trancos Creek in Portola Valley have sediment yields much greater than the other creeks shown here. Corte Madera Creek is generally regarded as a creek with elevated sediment yields relative to Bear Creek and Los Trancos Creek (c.f., Balance Hydrologics, 1996, which attributes at least part of the difference to the underlying geologic units). In each of the watersheds, there is disturbance from historic logging and associated logging road construction, development and/or water diversions. This pattern of comparative sediment yield in water year 2008 is similar to the pattern in water years 2006 and 2007.

The percentage of suspended sediment versus bedload sediment in ECDM was also similar to other nearby streams (Table 3).

5.5 Comparison with Previous Years

Sediment yield at El Corte de Madera Creek was much lower during water year 2008 than water year 2006, but higher than water year 2007 (Tables 3, 4). Most of this variability is due to the amount of rainfall and streamflow that occurred during those years (Figure 5). Water year 2008 was close to the median value of sediment transport at other gages operated by Balance in the region, with records covering 9 to 11 years. Water year 2007 sediment transport was the lowest over the same period. Although there are just three years of monitoring at this station, we assume that the pattern at El Corte de Madera Creek from year to year is approximately similar to the pattern at these regional stations. The variability in the sediment transport shown in Table 3 underscores an important characteristic of sediment transport; it can differ greatly from year to year and from one watershed to the next.

6. INTERPRETATION AND DISCUSSION

A comprehensive sediment study investigates sediment sources, sediment transport and sediment storage—the three components of a watershed sediment budget. Balance and MROSD staff have previously inventoried sediment sources along stream banks at ECDM Creek Open Space Preserve and measured storage in stream pools at both ECDM and La Honda Creek Open Space Preserves (Owens and others, 2006; Gartner and others, 2007). With the ongoing gaging of sediment transport, this study design provides quantitative indices of each of the 3 components affecting sediment yield and clarifies its relationship to bed-habitat conditions at downstream locations.[7]

6.1 Implications of Water Year 2008

The rain pattern in water year 2008 may have been fortuitous in minimizing erosion at the recent watershed improvements by allowing them to vegetate, compact and stabilize before being tested by large storms. Soil disruption is a necessary part of these improvements. Appropriate measures are taken to compact, vegetate, and / or generally control sediment in areas of recent work, and long-term sediment reduction is likely. However, these areas can be more vulnerable to some surface erosion initially. The lighter rains in water year 2008 (and 2007) favored ongoing stabilization of the disturbed areas before possible large storm events to come.

6.2 Change in Sediment Transport and Assessment of Management Objectives

One of the primary questions of this study is to investigate if and how much watershed improvements will be reducing sedimentation in the preserve and downstream. The work conducted during the past several years establishes a very strong baseline against which future changes in sediment delivery to downstream channels from the MROSD lands can be evaluated over the long term using both the sediment-rating curves and yield data.

The sediment rating curves quantify the amount of sediment transport for a given flow. If more sediment is transported at a certain flow, then the rating curve shifts ‘upwards’, as indicated in Figure 7. In contrast, if less sediment is transported at a certain flow, then the

[7] Although technically feasible, it is cost-prohibitive to conduct a long-term, complete sediment budget that quantifies *all* types of sediment sources, storage and transport.

rating curve shifts 'down'. Two years ago, we were fortunate to have wet conditions in water year 2006; with numerous high flows, it was an excellent year to establish the sediment rating curve over a wide range of flows (Figure 7). We have predicted in previous work that the sediment rating curves may be slightly elevated in the first few years following watershed improvements because the work necessarily disturbs the soil. In future years we expect the rating curves to shift downward – adjusting for large storms, wildfires or other episodic events -- and this would be one indication that the watershed improvements are meeting a goal to reduce sedimentation.

In environments that are not "sediment starved[8]," a downward shift in the sediment rating curve generally indicates that the watershed-enhancement measures are working, such that less sediment is being delivered to the streams. Less sediment delivery and lower sediment yields generally mean that (a) bed conditions used by anadromous fish and other aquatic biota are more favorable, (b) less sediment is in transport to impair fish incubation or feeding, and (c) less sediment is transported into the lagoon or other important reaches where it can reduce habitat value. If in future years the rating curves shown in Figure 7 move downward – i.e., less sediment being transported by a given streamflow -- it means that habitat conditions within and downstream from the Preserve are likely improving. Therefore, the ECDM sediment-rating curves are useful tools not only for computing sediment discharge, but also as a means of assessing changes in stream habitat quality, notably (in this case) for salmonids – such as steelhead, resident trout or coho salmon – all other factors being equal (Hecht and Owens, 2006).

Over the shorter term, we cannot say whether improvements have already changed sediment yields to downstream channels because an insufficient number of sediment-transporting flows occurred during 2008.[9] We tentatively conclude that the sediment measurements made in water years 2007 and 2008 do not indicate a shift in the rating curves that were established in water year 2006. All of the suspended sediment measurements for water year 2007 and 2008 plot on or near the water year 2006 suspended-sediment rating curve (although there is typical scatter in the data). The bedload measurements plot both above and below the water year 2007 bedload rating curve, but there are not enough new data points to justify moving the curve. It

[8] Stream reaches downstream of dams or blockages often have a paucity of sediment, which can adversely affect aquatic habitat.
[9] In the sort term, the expected decrease in erosion control associated with the restoration work is expected to be offset in whole or part by the disturbance associated with MROSD's improvement plan. Detecting short-term changes were not envisioned as an expected result of this study.

is common to have more scatter in bedload data than in suspended sediment data. During normal or dry conditions, high flows do not occur, therefore sediment transport at the high flows (under which virtually all sediment is transported in steep mountain streams) may not be sampled. This is balanced by the knowledge that only a moderate amount of total sediment for the year was transported, an amount not likely to affect downstream bed conditions.

6.3 Ongoing and Future Work

Flow gaging will continue in water year 2009. V* measurements were not conducted in the summer of 2007 or 2008, in part because of the low sediment transport in the previous winters. We recommend evaluating if V* measurements should be taken in summer 2009 depending on flow and sediment transport conditions in the forthcoming months.

Watershed improvements continued in summer 2007 and 2008 and have been concluded, so additional disturbance is not scheduled to continue in summer 2009.

7. ACKNOWLEDGMENTS

We would like to acknowledge MROSD staff and rangers, especially Matt Baldzikowski, Meredith Manning, Kirk Lenington, and Steve Cotterel for their assistance in the field and office with this gaging effort. In addition to the authors, Balance staff members Travis Baggett, Tim Bartholomaus, Brian Hastings, and Gustavo Porras helped with field measurements and assisted in report preparation.

8. LIMITATIONS

This report was prepared in general accordance with the accepted standard of practice in Northern California at the time the investigations were performed. No other warranty is made or implied.

Analyses and information included in this report are intended for use at the watershed scale and for the planning and long-term monitoring purposes described above. Analyses of channels and other water bodies, rocks, earth properties, topography and / or environmental processes are generalized to be useful at the scale of a watershed, both spatially and temporally. Information and interpretations presented in this report should not be applied to specific projects or sites without the expressed written permission of the authors, nor should they be used beyond the particular area to which we have applied them. Estimates of sediment originating from mass wasting, slope sources and / or roads and trails are developed solely for better understanding of the processes generating sediment in this particular watershed and for the overall ecological description of El Corte de Madera Creek. These estimates provide context for planning the monitoring program; these should not be taken, for the roads in particular, as the long-term yields from individual sediment sources.

Balance Hydrologics, Inc. should be consulted prior to applying the contents of this report to evaluating upland sediment sources, any out-of-stream locations, or any in-stream locations not specifically cited in this report. Results are limited to information needed to plan a long-term monitoring program designed primarily to assess the effectiveness of MROSD's watershed enhancement program. In particular, information developed in this report is not intended for use in design of structures, or specific slope or road repairs.

Readers are asked to contact us if they have additional relevant information and can propose revisions or modified descriptions of conditions, such that the best data can be applied at the earliest date possible.

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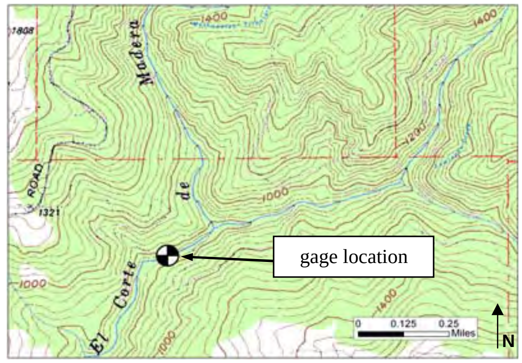
FORMS

Water Year:	**2008**
Stream:	El Corte de Madera Creek
Station:	at Virginia Mill Trail
County:	San Mateo County, CA

Form 1. Annual Hydrologic Record, Water Year 2008

Map



Station Location / Watershed Descriptors

Latitude 37°22'58" N, Longitude 122°19'39" W. Gage is located on north bank, approximately 100 feet upstream of bridge on Virginia Mill Trail. Current land use includes forested open space and a few rural homes. Drainage area above the gage is 4.74 squre miles.

Mean Daily Flow (MDQ)

MDQ for WY 2008 is 2.1 cfs
MDQ for WY 2007 was 1.6 cfs. MDQ for WY 2006 was 11 cfs.

Peak Flows

Date	Time (24-hr)	Gage Ht. (feet)	Discharge (cfs)	Date	Time (24-hr)	Gage Ht. (feet)	Discharge (cfs)
1/4/08	**14:45**	**6.97**	**155**	1/31/08	23:30	6.05	36
1/5/08	16:15	5.90	21	2/3/08	2:30	6.61	90.5
1/25/08	22:45	6.89	148	2/24/08	20:15	5.80	20.1
1/27/08	23:15	5.93	28				

Peak for Period of Record (Oct. 2005 to Sept. 2008): 550 cfs on 12/31/05.

Period of Record

Staff plate and water-level recorder installed 9/29/05.
Gaging sponsored by the Midpeninsula Regional Open Space District.

WY 2008 Daily Mean Flow (cubic feet per second)

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT
1	0.13	0.24	0.18	0.58	27.55	7.20	0.90	0.46	0.42	0.27	0.12	0.07
2	0.13	0.24	0.19	0.56	23.56	5.76	0.93	0.45	0.42	0.25	0.14	0.07
3	0.12	0.24	0.23	0.87	52.28	4.99	1.03	0.52	0.42	0.28	0.13	0.08
4	0.12	0.24	0.53	34.45	23.70	4.44	0.79	0.50	0.43	0.27	0.12	0.08
5	0.11	0.23	0.45	13.74	16.34	4.09	0.80	0.49	0.40	0.25	0.11	0.09
6	0.12	0.22	0.43	9.75	13.54	3.59	0.80	0.55	0.39	0.25	0.12	0.09
7	0.10	0.22	1.23	5.89	10.71	3.49	0.72	0.50	0.34	0.24	0.12	0.09
8	0.11	0.24	0.63	4.46	9.40	3.19	0.69	0.51	0.36	0.26	0.12	0.07
9	0.11	0.25	0.46	4.72	8.27	3.03	0.76	0.50	0.42	0.26	0.11	0.07
10	1.11	0.37	0.41	4.54	7.15	3.12	0.69	0.48	0.40	0.25	0.11	0.08
11	0.28	1.04	0.37	4.07	6.45	2.88	0.68	0.50	0.41	0.21	0.12	0.07
12	0.68	0.32	0.31	3.46	5.78	2.48	0.68	0.45	0.42	0.21	0.12	0.07
13	0.57	0.29	0.30	3.15	4.83	3.06	0.66	0.48	0.41	0.21	0.12	0.07
14	0.29	0.29	0.29	2.63	3.71	2.63	0.54	0.52	0.36	0.21	0.11	0.07
15	0.33	0.27	0.30	2.15	3.13	2.19	0.56	0.52	0.32	0.20	0.11	0.06
16	0.46	0.25	0.33	1.75	2.74	1.83	0.59	0.43	0.28	0.20	0.11	0.06
17	0.37	0.23	0.90	1.43	2.60	1.70	0.69	0.40	0.29	0.19	0.11	0.06
18	0.31	0.24	2.72	1.28	2.63	1.71	0.66	0.40	0.33	0.17	0.11	0.06
19	0.36	0.24	1.44	1.19	3.13	1.80	0.57	0.38	0.35	0.16	0.12	0.05
20	0.47	0.22	5.02	1.16	4.05	1.54	0.48	0.39	0.34	0.15	0.13	0.06
21	0.30	0.21	1.69	1.39	3.26	1.37	0.44	0.37	0.31	0.16	0.14	0.07
22	0.28	0.21	0.88	1.49	6.39	1.39	0.45	0.39	0.24	0.17	0.12	0.06
23	0.28	0.20	0.70	1.68	6.79	1.27	0.85	0.41	0.21	0.17	0.11	0.06
24	0.29	0.20	0.68	1.96	13.46	1.24	0.53	0.40	0.23	0.14	0.11	0.06
25	0.26	0.21	0.51	32.94	16.85	1.38	0.48	0.41	0.22	0.14	0.11	0.05
26	0.23	0.20	0.47	44.44	14.02	1.14	0.47	0.41	0.24	0.15	0.09	0.06
27	0.22	0.21	0.38	23.35	12.01	0.99	0.46	0.41	0.28	0.16	0.10	0.07
28	0.22	0.20	0.48	22.91	10.10	0.94	0.40	0.39	0.27	0.15	0.10	0.06
29	0.24	0.20	0.59	17.04	8.69	1.39	0.43	0.39	0.26	0.17	0.09	0.05
30	0.24	0.17	0.65	15.12		1.05	0.43	0.40	0.26	0.16	0.08	0.05
31	0.24		0.54	17.28		0.89		0.41		0.13	0.06	
MEAN	0.29	0.26	0.78	9.08	11.14	2.51	0.64	0.44	0.33	0.20	0.11	0.07
MAX. DAY	1.11	1.04	5.02	44.44	52.28	7.20	1.03	0.55	0.43	0.28	0.14	0.09
MIN. DAY	0.10	0.17	0.18	0.56	2.60	0.89	0.40	0.37	0.21	0.13	0.06	0.05
cfs days	9.10	7.89	24.26	281.44	323.10	77.76	19.19	13.79	10.02	6.20	3.46	2.02
ac-ft	18.04	15.64	48.11	558.24	640.86	154.24	38.06	27.35	19.87	12.30	6.86	4.00

Monitor's Comments

1. Continuous water-level record for all days.
2. Multiple stage shifts were applied to the rating equation. Stage shifts adjust for local scour and fill in addition to water-level changes due to algae growth, or leaf and debris jams.
3. Daily values with more than 2 to 3 significant figures result from electronic calculations. No additional precision is implied.

Water Year: 2008		
Mean daily flow	**2.1**	(cfs)
Max. daily flow	**52**	(cfs)
Min. daily flow	**0.05**	(cfs)
Annual total	**778**	(cfs-days)
Annual total	**1544**	(ac-ft)

Balance Hydrologics, Inc. 800 Bancroft Way, Suite 101, Berkeley, CA 94710-2227 (510) 704-1000; fax: (510) 704-1001
www.balancehydro.com

Water Year:	**2008**
Stream:	El Corte de Madera Creek
Station:	at Virginia Mill Trail
County:	San Mateo County, CA

Form 2. Annual Sediment-Discharge Record, Water Year 2008

Daily Suspended-Sediment Discharge *(tons)*

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	
1	0.0	0.0	0.0	0.0	7.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	
2	0.0	0.0	0.0	0.0	6.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	
3	0.0	0.0	0.0	0.0	34.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	
4	0.0	0.0	0.0	29.5	5.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
5	0.0	0.0	0.0	1.7	2.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
6	0.0	0.0	0.0	0.8	1.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
7	0.0	0.0	0.0	0.3	0.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
8	0.0	0.0	0.0	0.1	0.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
9	0.0	0.0	0.0	0.2	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
10	0.0	0.0	0.0	0.1	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
11	0.0	0.0	0.0	0.1	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
12	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
13	0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
14	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
15	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
18	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
19	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
20	0.0	0.0	0.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
21	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
22	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
23	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
24	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
25	0.0	0.0	0.0	38.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
26	0.0	0.0	0.0	27.8	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
27	0.0	0.0	0.0	5.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
28	0.0	0.0	0.0	5.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
29	0.0	0.0	0.0	2.6	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
30	0.0	0.0	0.0	2.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	**Qss**
31	0.0		0.0	3.3		0.0		0.0		0.0	0.0		**Annual**
TOTAL	0	0	0	117	71	2	0	0	0	0	0	0	**190**
Max.day	0	0	0	38	35	0	0	0	0	0	0	0	38

Daily Bedload-Sediment Discharge *(tons)*

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	
1	0.0	0.0	0.0	0.0	1.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
2	0.0	0.0	0.0	0.0	1.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
3	0.0	0.0	0.0	0.0	8.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
4	0.0	0.0	0.0	7.1	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
5	0.0	0.0	0.0	0.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
6	0.0	0.0	0.0	0.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
7	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
8	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
9	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
10	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
11	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
12	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
20	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
22	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
23	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
24	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
25	0.0	0.0	0.0	9.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
26	0.0	0.0	0.0	6.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
27	0.0	0.0	0.0	1.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
28	0.0	0.0	0.0	1.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
29	0.0	0.0	0.0	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
30	0.0	0.0	0.0	0.5		0.0	0.0	0.0	0.0	0.0	0.0	0.0	**Qbed**
31	0.0		0.0	0.8		0.0		0.0		0.0	0.0		**Annual**
TOTAL	0	0	0	28	17	0	0	0	0	0	0	0	**46**
Max.day	0	0	0	9	8	0	0	0	0	0	0	0	9

Daily values are based on calculations of sediment discharge at 15-minute intervals.
Daily values with more than 2 to 3 significant figures result from electronic calculations. No additional precision is implied.

Total annual sediment discharge (suspended- plus bedload-sediment discharge)		
WY 2008:	**236**	***tons***

Balance Hydrologics, Inc. 800 Bancroft Way, Suite 101, Berkeley, CA 94710-2227 (510) 704-1000; fax: (510) 704-1001
www.balancehydro.com

TABLES

preliminary and subject to revision

Table 1. Station observer log: El Corte de Madera Creek at Virginia Mill Trail, water year 2008

Site Conditions				Streamflow				Water Quality Observations				High-Water Marks		Remarks
Date/Time (mm/dd/yr)	Observer(s)	Stage (staff plate) (feet)	Hydrograph (R/F/S/B)	Measured Discharge (cfs)	Estimated Discharge (cfs)	Instrument Used (AA/PY)	Estimated Accuracy (e/g/f/p)	Water Temperature (°C)	Specific Conductance at field temp. (µmhos/cm)	Specific Conductance at 25C (at 25 °C)	Additional sampling? (pH, etc.)	Estimated stage at staff plate (feet)	Inferred dates? (mm/dd/yr)	
9/28/07 10:45	mb	4.74	B	0.1	…	PY	f	…	…	…	…	…	…	Foggy and cool; 2 dead 9-10 cm resident trout; other trout and many newts observed alive in pools; oil sheen at margin of 1 pool; some rain last week; small leaf dam at gage
11/28/07 11:15	mb	4.80	B	0.2	…	PY	g	…	…	…	…	…	…	cool, breezy
1/8/08 13:00	mm, bkh	5.41	R	4.8	4	PY	g, f	7.6	259	389	Qss	7.0, 6.6	1/4, 1/6/08	light to moderate rain; water only slightly turbid; no bedload movement; sand bars have been overtopped and deposited
1/23/08 11:00	mb, sc	5.23	F, B	1.7	…	PY	f	…	…	…	…	…	…	some pools appear scoured of sand (following Jan. 4 high flow); clean gravels at pool tail
1/25/08 17:45	jg, tcb	6.25	R	54	…	AA	f	8.2	139	203	Qss, Qbed	…	…	water turbid, visibility ~0.5 inches; rain all day
2/3/08 8:35	tcb, gp	6.40	F	51	…	AA	f	9.0	152	218	Qss, Qbed	6.6	2/2/2008	rain last night
3/9/08 16:30	tcb	5.21	B	…	…	…	…	…	…	…	…	…	…	water very clear
3/20/08 13:10	tjb	5.12	B	1.5	1.2	PY	g	8.2	296	434	…	7.0	1/4/08	mid-channel debris jams at seasonal HWM (7.0'); no signs of boulders having moved during high flows
5/13/08 10:45	mb	4.90	B	0.5	…	PY	f	…	…	…	…	…	…	fine silt dusting on bottom of pools, pool tail gravels fairly clean, about 50% embedded
8/1/08 12:15	mb	4.67	B	0.1	…	PY	f	…	…	…	…	…	…	two 40 mm young-of-year trout and one 80 mm resident trout observed
10/2/08 12:20	mb	4.57	B	0.06	…	PY	p	…	…	…	…	…	…	flow very low; 5 young-of-the-year resident trout and 1, 1+ in 2 pools above

Observer Key: Balance- bkh= Brian Hastings; jg = John Gartner; gp = Gustavo Porras; tjb = Travis Baggett; tcb = Tim Bartholomaus; MROSD- mm = Meredith Manning; mb = Matt Baldzikowski; sc = Steve Cotterel

Stage: Water level observed at staff plate

Hydrograph: Describes stream stage as rising (R), falling (F), steady (S), baseflow (B), or uncertain (U).

Instrument: If measured, typically made using a standard (AA) or pygmy (PY) bucket-wheel ("Price-type") current meter. If estimated, from rating curve (R) or visual (vis. est.).

Estimated measurement accuracy: Excellent (e) = +/- 2%; Good (g) = +/- 5%; Fair (f) = +/- 8%; Poor (p) = +/- > 8%

High-water mark (HWM): Measured or estimated at location of the staff plate

Specific conductance: Measured in µS/cm in field; then adjusted to 25 °C by equation (1.8813774452 - [0.050433063928 * field temp] + [0.00058561144042 * field temp^2]) * field specific conductance

Additional sampling: Qbed = Bedload, Qss = Suspended sediment

preliminary and subject to revision

Table 2. Sediment-discharge measurements: El Corte de Madera Creek at Virginia Mill Trail, water year 2008

Site Conditions					Bedload Sampling Details						Sediment Transport			
Sample Date and Time	Observer(s)	Gage Height	Streamflow Discharge	Stream Condition	Active Bed Width	Sampler Width	No. of Verts.	Time/Vert.	Total Time	Sample Dry Weight	Bedload-Sediment Discharge Rate	Bedload-Sediment Discharge Rate	Suspended-Sediment Concentration	Suspended-Sediment Discharge Rate
		(feet)	(cfs)	R,F,B,U	(feet)	(feet)		(sec)	(sec)	(gm)	(lb/sec)	(tons/day)	(mg/l)	(tons/day)
1/8/08 13:20	bkh, mm	5.40	3.9	F, R	…	…	…	…	…	…	…	…	6.8	0.1
1/25/08 16:55	jg, tcb	6.20	43	R	…	…	…	…	…	…	…	…	346.1	40.1
1/25/08 17:10	jg, tcb	6.24	47	R	12	0.25	2	120	240	528	0.233	9.8	…	…
1/25/08 18:00	jg, tcb	6.32	56	R	…	…	…	…	…	…	…	…	363.8	54.8
2/3/08 8:45	gp, tcb	6.29	56	F	12	0.25	6	30	180	212	0.124	5.2	58.7	8.8
2/3/08 10:00	gp, tcb	6.28	53	F	11	0.25	5	30	150	64	0.041	1.7	40.8	5.8

Notes:

Observer Key: Balance- bkh= Brian Hastings; jg = John Gartner; tcb = Tim Bartholomaus; gp = Gustavo Porras; MROSD- mm = Meredith Manning

Streamflow discharge is the measured or estimated instantaneous flow when sediment was sampled, and usually differs from the mean flow for the day.

Stream Condition: R = rising, F = falling, B = baseflow, U = uncertain

Values for sediment discharge having more than two to three digits displayed are the result of calculations; increased precision is not implied.

Active Bed Width: The width thought by the field observer to be transporting significant amounts of bedload

Sampler Width and Type: 0.25 = 3-inch Helley Smith; 0.50 = 6-inch Helley Smith

Bedload Discharge (lbs/sec) = [active bed width (ft) * sample dry weight (gm) * 0.002205 (lbs)]/ [sampler width (ft) * sampling time (sec)]

Bedload Discharge (tons/day) = [active bed width (ft) * sample dry weight (gm) * 86,400 (sec)]/ [sampler width (ft) * sampling time (sec) * 907,200 (gm)]

Table 3. Unit sediment-discharge calculations and comparisons:
Bear, Los Trancos, Corte Madera, and El Corte de Madera Creeks, San Mateo County, CA

Water Year	Total Flow	Drainage area	Suspended Sediment	Bedload Sediment	Total sediment	Unit sediment discharge
	(ac-ft)	*(sq.mi.)*	*(tons)*	*(tons)*	*(tons)*	*(tons/sq. mi.)*
Bear Creek at Sand Hill Road						
2000	6,120	11.7	12,365	997	13,361	1,142
2001	2,379	11.7	443	62	505	43
2002	3,214	11.7	843	118	961	82
2003	4,965	11.7	11,258	762	12,020	1,027
2004	4,260	11.7	5,624	555	6,179	528
2005	8,113	11.7	2,460	98	2,559	219
2006	13,181	11.7	14,128	565	14,693	1,256
2007	1,269	11.7	133	5	138	12
2008	2,629	11.7	1,184	47	**1,231**	**105**
Los Trancos Creek at Arastradero Road						
1998	6,444	5.3	3,398	5,418	8,816	1,673
1999	2,507	5.3	2,639	1,135	3,774	716
2000	2,084	5.3	754	1,202	1,956	371
2001	881	5.3	119	200	318	60
2002	1,066	5.3	410	158	568	108
2003	1,870	5.3	3,109	991	4,101	778
2004	1,106	5.3	1,136	472	1,608	305
2005	2,382	5.3	683	455	1,139	216
2006	4,808	5.3	7,314	3,339	10,653	2,021
2007	384	5.3	48	8	56	11
2008	1,426	5.3	3,005	721	**3,726**	**707**
Corte Madera Creek at Westridge Drive						
1998	11,346	6.0	148,912	43,251	192,163	32,027
1999	3,869	6.0	8,113	7,106	15,219	2,537
2000	4,733	6.0	40,174	17,007	57,181	9,530
2001	1,561	6.0	1,011	391	1,402	234
2002	1,694	6.0	3,661	1,482	5,143	857
2003	2,678	6.0	13,239	8,771	22,010	3,668
2004	1,798	6.0	8,068	4,385	12,453	2,076
2005	3,465	6.0	2,417	514	2,931	489
2006	6,813	6.0	22,574	8,507	31,081	5,180
2007	941	6.0	333	58	391	65
2008	1,868	6.0	5,709	2,116	**7,825**	**1,304**
El Corte de Madera Creek at Virginia Mill Trail						
2006	7,665	4.7	4,546	1,091	5,637	1,189
2007	1,169	4.7	46	11	57	12
2008	1,544	4.7	190	46	**236**	**50**

Notes:

Bear, Los Trancos and El Corte de Madera Creeks have similar unit sediment yield. Corte Madera (in Portola Valley, CA) typically has a significantly higher sediment yield, in part due to different geology.

Values displaying more than 2 significant figures result from electronic calculations, and do not indicate increased accuracy or precision.

Additional years are shown for Bear, Los Trancos and Corte Madera Creeks to show the context of wetter, higher-sediment-yield years.

Total flow is included to show the pattern of wet, average, and dry years.

Table 4. Hydrologic summary for period of record,
El Corte de Madera Creek at Virginia Mill Trail

Water Year	Annual Flow: Mean Annual Flow	Annual Flow: Maximum Daily Flow	Annual Flow: Minimum Daily Flow	Annual Flow: Total Flow Volume	Sediment Discharge: Suspended Sediment	Sediment Discharge: percent suspended	Sediment Discharge: Bedload Sediment	Sediment Discharge: percent bedload	Peak Flow: Peak Flow	Peak Flow: Peak Stage	Peak Flow: Date Time
	(cfs)	*(cfs)*	*(cfs)*	*(ac-ft)*	*(tons)*	*(%)*	*(tons)*	*(%)*	*(cfs)*	*(ft)*	*(24-hr)*
2006	10.6	321	0.17	7,665	4,546	81%	1,091	19%	550	8.54	12/31/2005 6:30
2007	1.6	32	0.10	1,170	46	81%	11	19%	56	6.40	2/10/2007 0:15
2008	2.1	52	0.05	1,544	190	81%	46	19%	155	6.97	1/4/2008 14:45

Notes:

The period of record for this station is Oct. 2005 to Sept. 2008. Flow monitoring is continuing during water year 2009.

This period of record contains a relatively wet and a relatively dry year, based on nearby gages with longer periods of record.

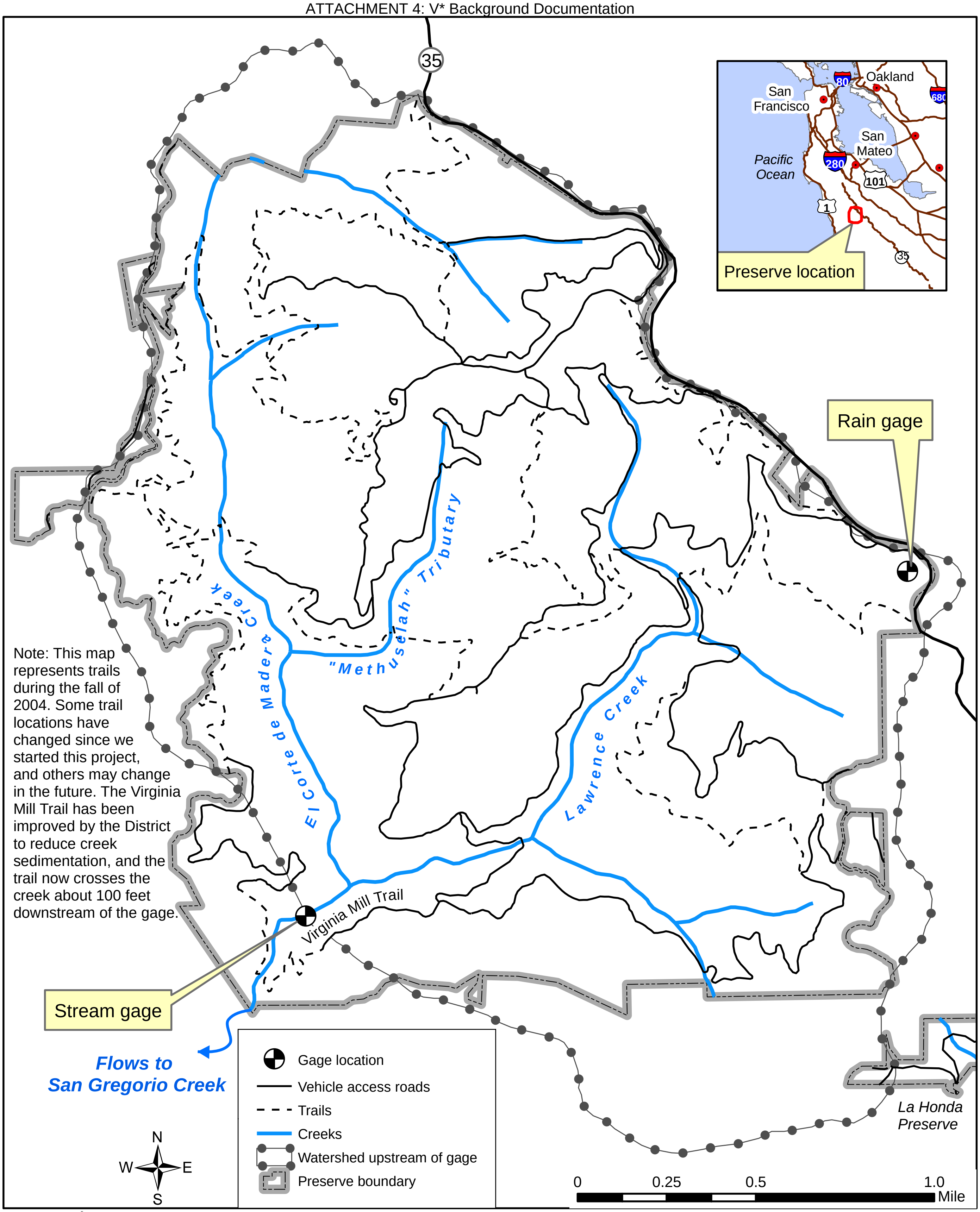
A "water year" ends on Sept. 30 of the named year. For example, water year 2007 starts Oct. 1, 2006, and ends Sept. 30, 2007.

Stage is the staff plate reading; the staff plate is set at an arbitrary datum and does not represent the absolute depth of water in the creek.

Daily flow values are based on flow calculated at 15-minute intervals. Sediment-discharge values are totalled from calculations at 15-minute intervals.

Values displaying more than 2 or 3 significant figures are the result of electronic calculations; no additional precision is implied.

FIGURES



Data source for streams, boundary, trails and road locations: MROSD, 2004

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Figure 1. Gage location and contributing watershed, El Corte de Madera Creek Open Space Preserve, San Mateo County, California

The watershed (4.74 square miles) above the gage coincides roughly with the Preserve boundary.

204020_gage_location (Fig1).mxd

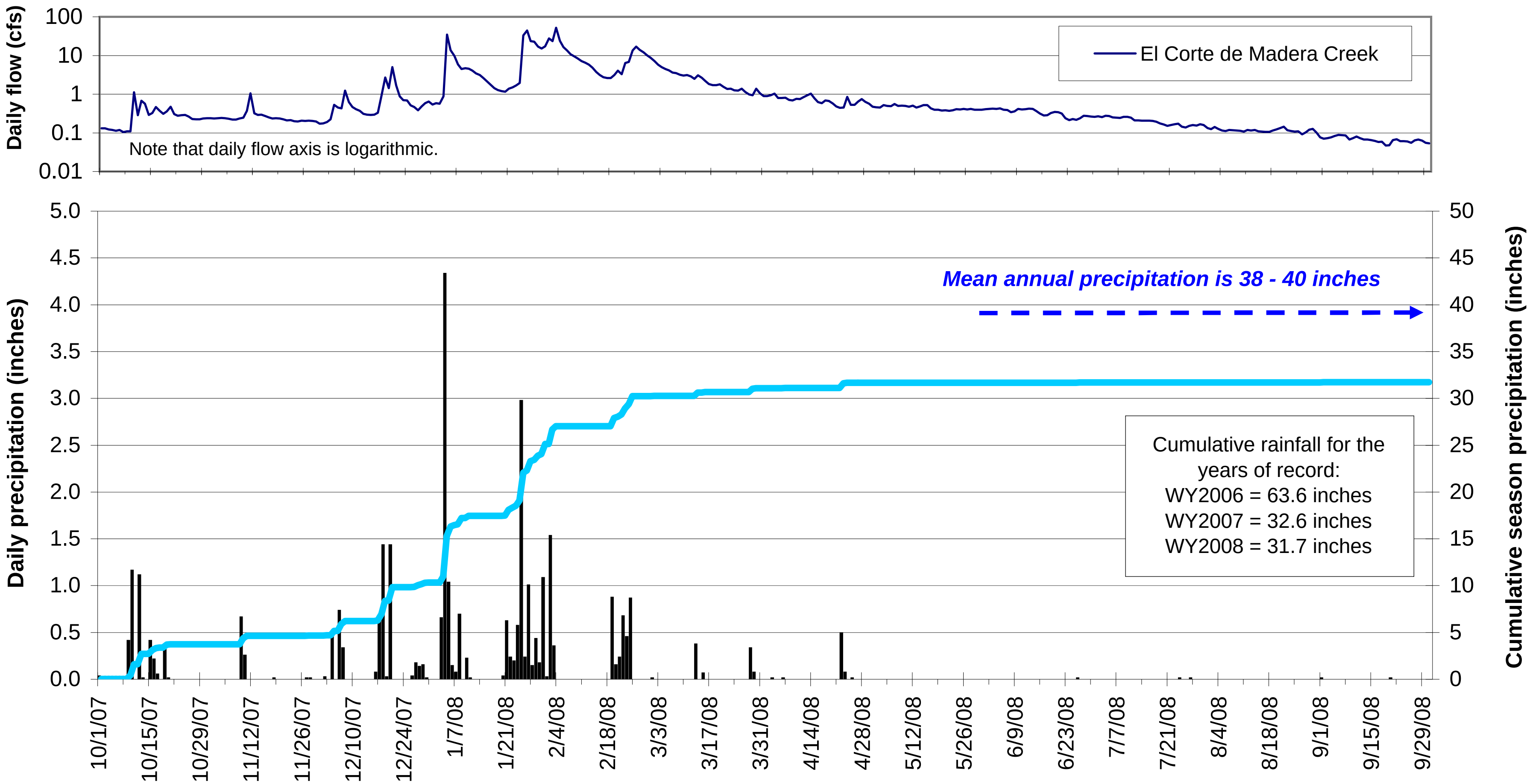

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Figure 2. Daily and cumulative precipitation, El Corte de Madera Open Space Preserve, water year 2008. Rainfall data is from an automated tipping-bucket rain gauge operated by MROSD. Total precipitation was about 80 to 90% of normal at this and other nearby stations. The higest daily precipitation was 4.33 inches on January 4, 2008.

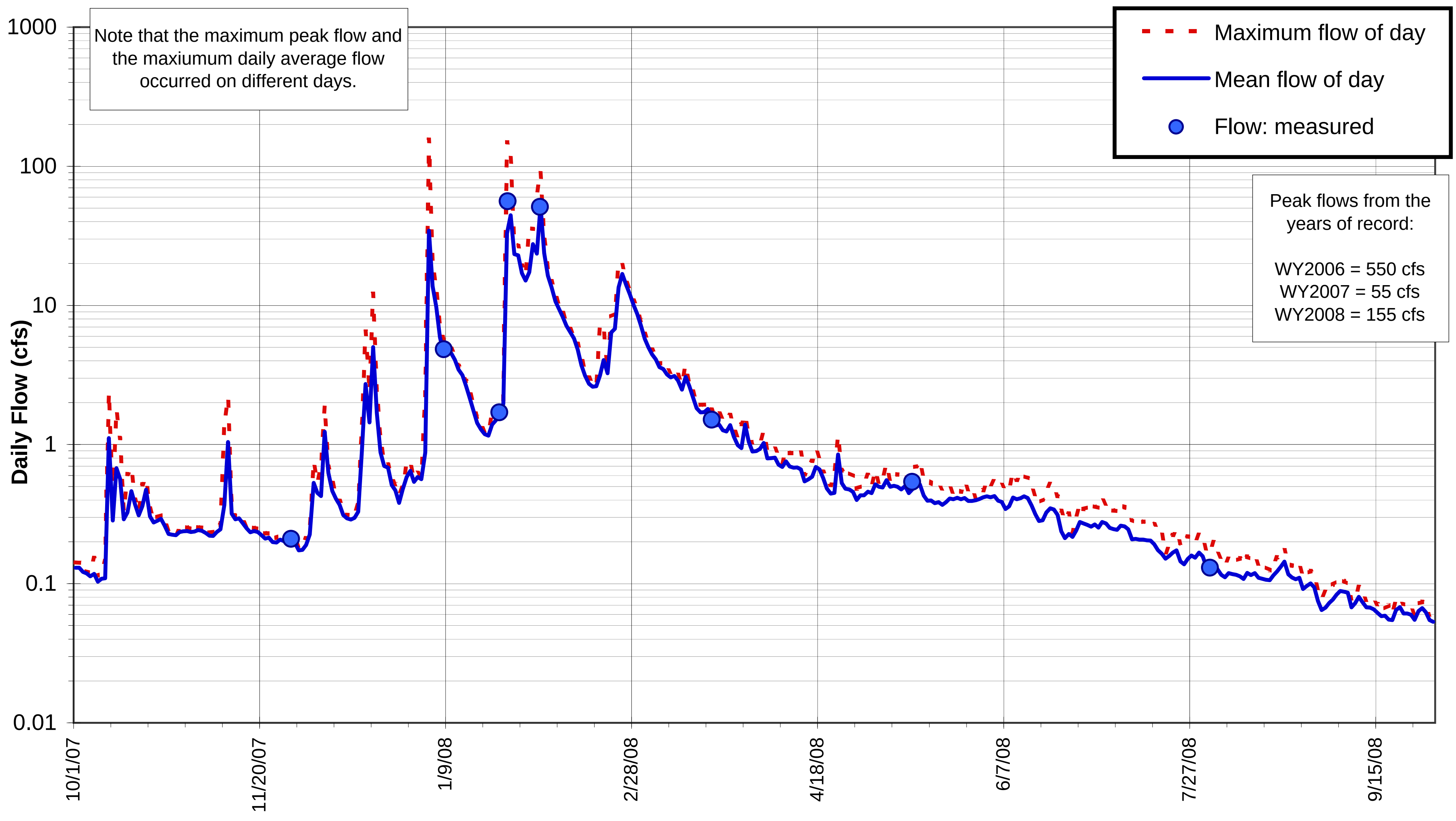

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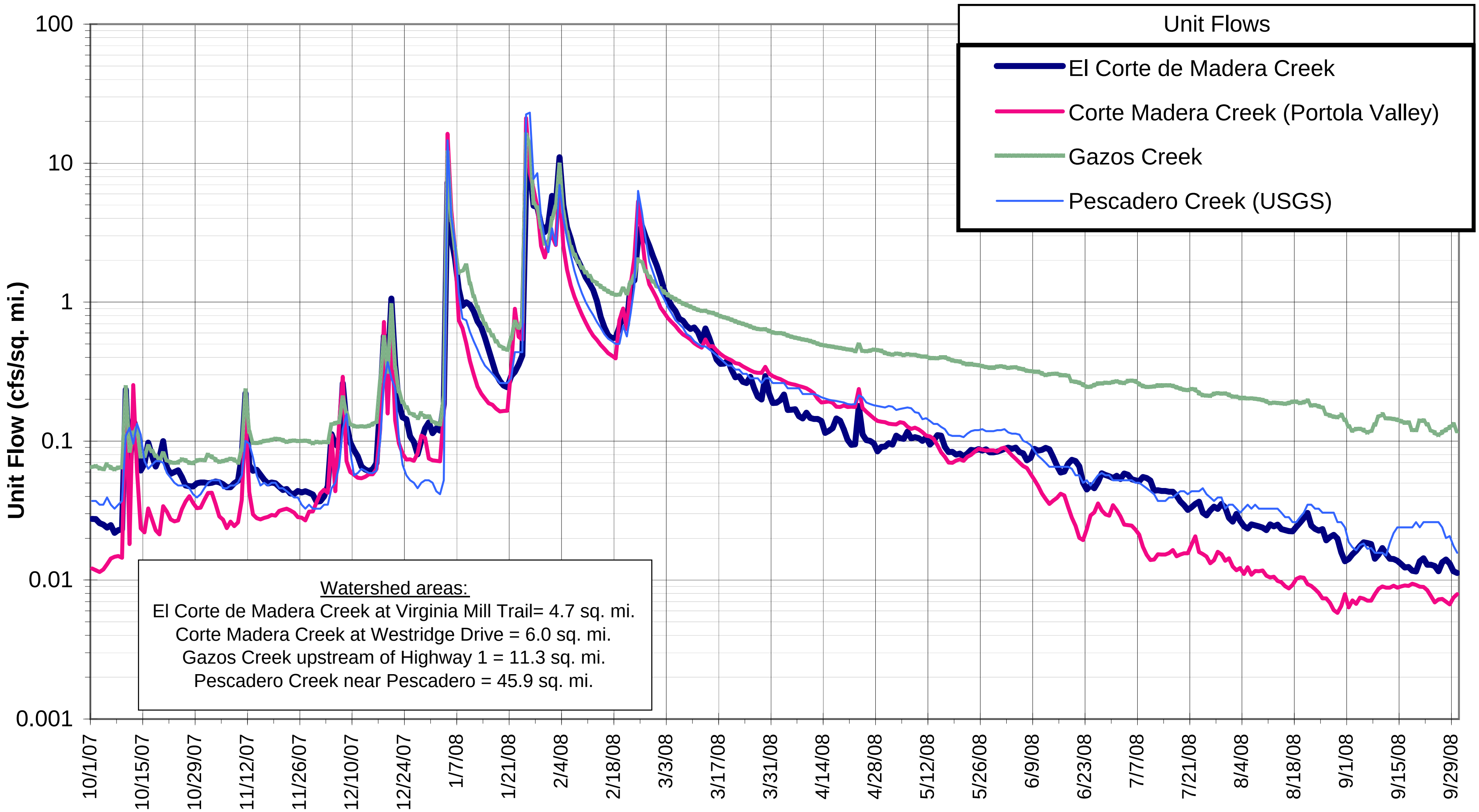
Figure 3. Daily flow hydrograph: El Corte de Madera Creek at Virginia Mill Trail, water year 2008. The peak flow occurred on January 4, 2008 and was approximately 155 cfs. Another large flow occurred January 25, 2008 (148 cfs). Despite the two moderately large peak flows, the total rainfall and flow for the year were below normal.



Note that the flow axis is logarithmic.

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Figure 4. Unit flow hydrographs: El Corte de Madera Creek compared to nearby creeks, water year 2008. "Unit" flow is normalized by watershed area. This plot compares flow among minimally-regulated stations. Comparable timing and magnitude of peaks provides quality control and assurance for the flow record.

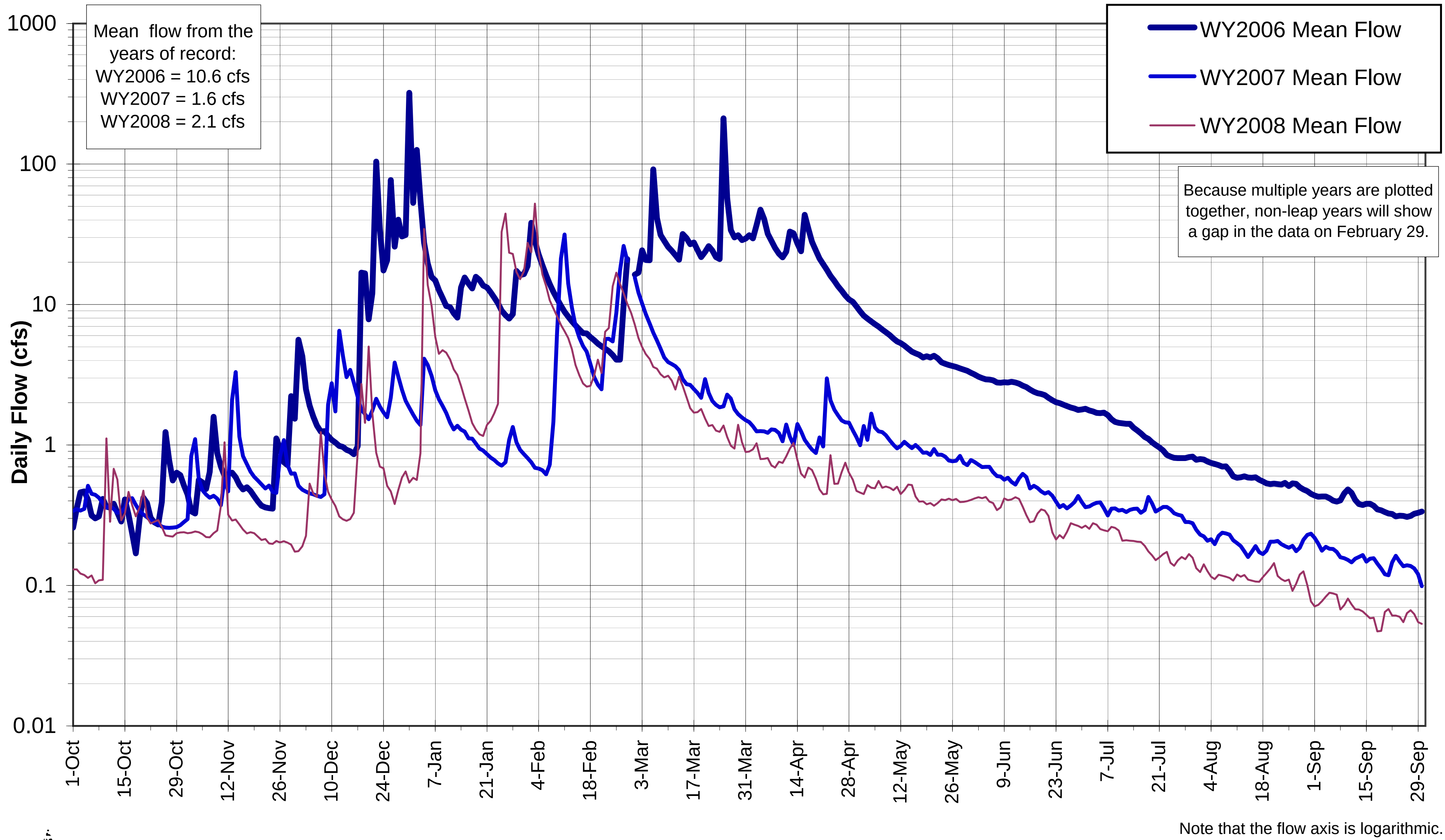

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Figure 5. Comparison of previous years' hydrographs: El Corte de Madera Creek at Virginia Mill Trail. Water year 2006 was significantly wetter than normal at all regional locations. Water years 2007 and 2008 had below-average rainfall; the difference in their summer baseflow may indicate the amount of multi-year storage of ground water that supplies summer baseflow.

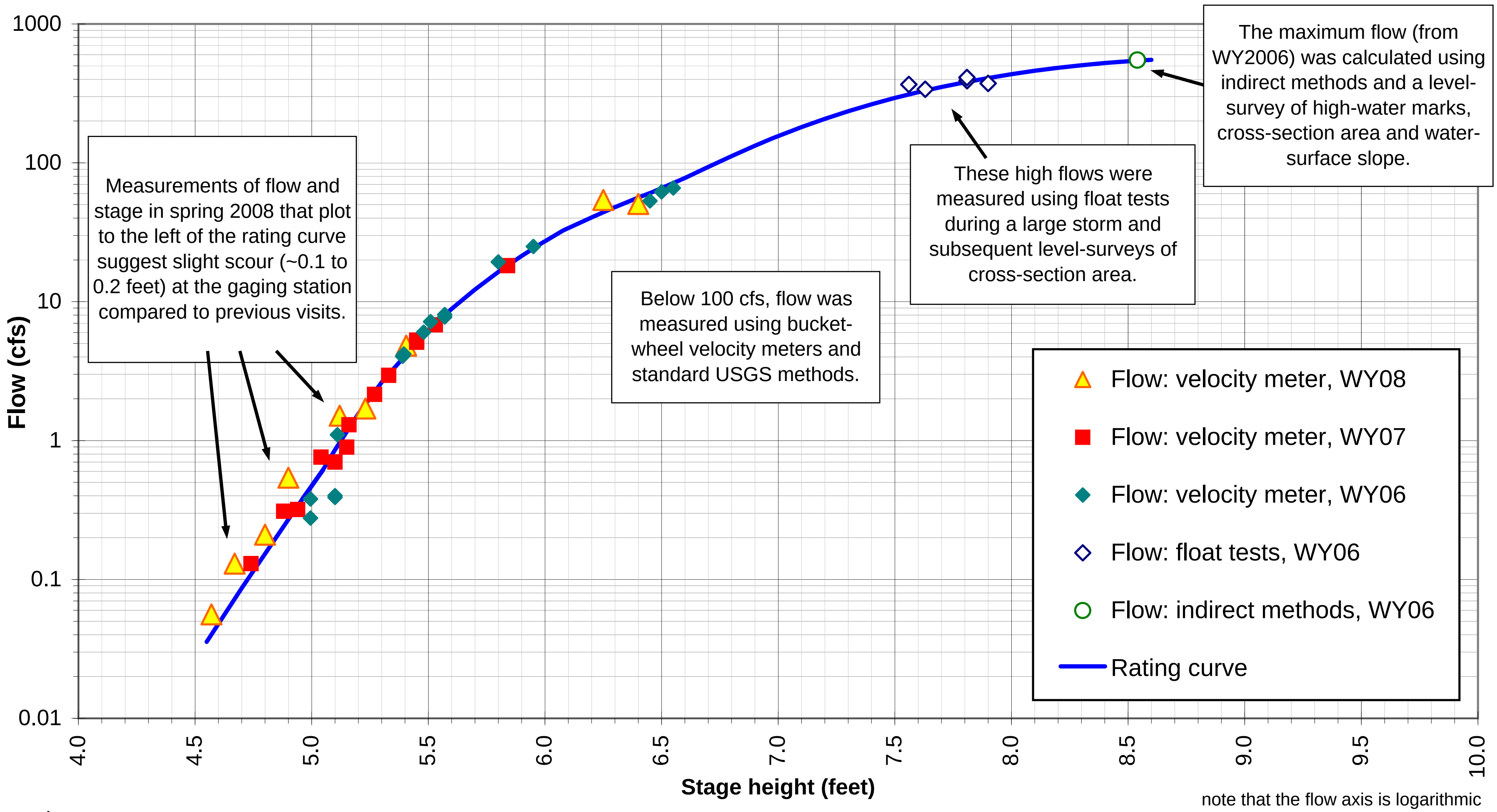

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Figure 6. Flow measurements and stage-discharge rating curve, El Corte de Madera Creek at Virginia Mill Trail. The rating curve relates flow to stage height and is used to calculate flow from the datalogger record of water depth (stage) at the gaging station. Stage height is the water-surface elevation relative to a fixed but arbitrary elevation datum. The rating curve can be shifted to account for deposition and scour; changes to the stream bed have not been large in this relatively stable reach.

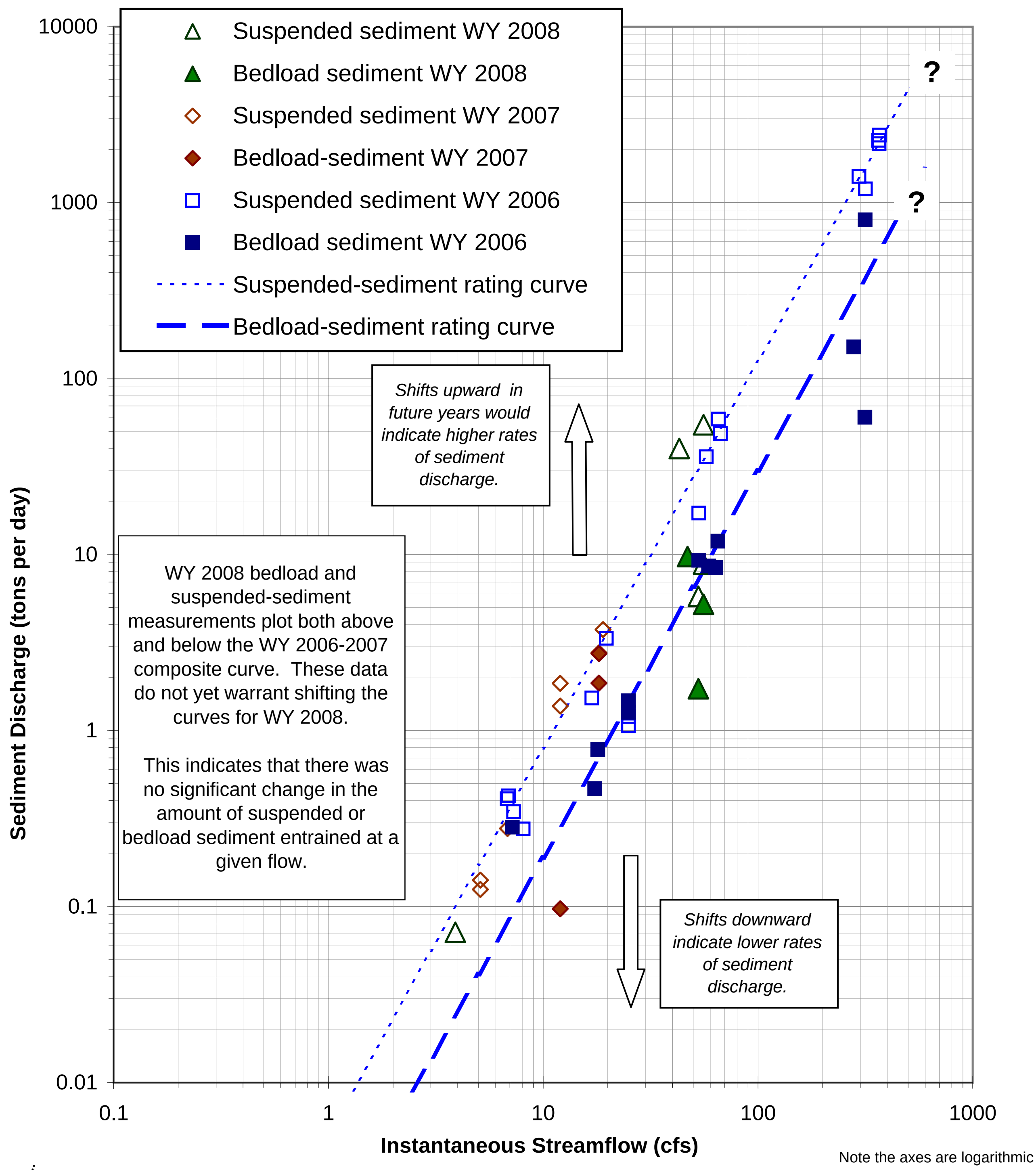

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Figure 7. Sediment-discharge measurements and rating curve, El Corte de Madera Creek at Virginia Mill Trail. Suspended-sediment discharge is higher than bedload discharge at a given flow; this is typical for most creeks in the region. The measured sediment data show a similar relationship to streamflow as during previous years.

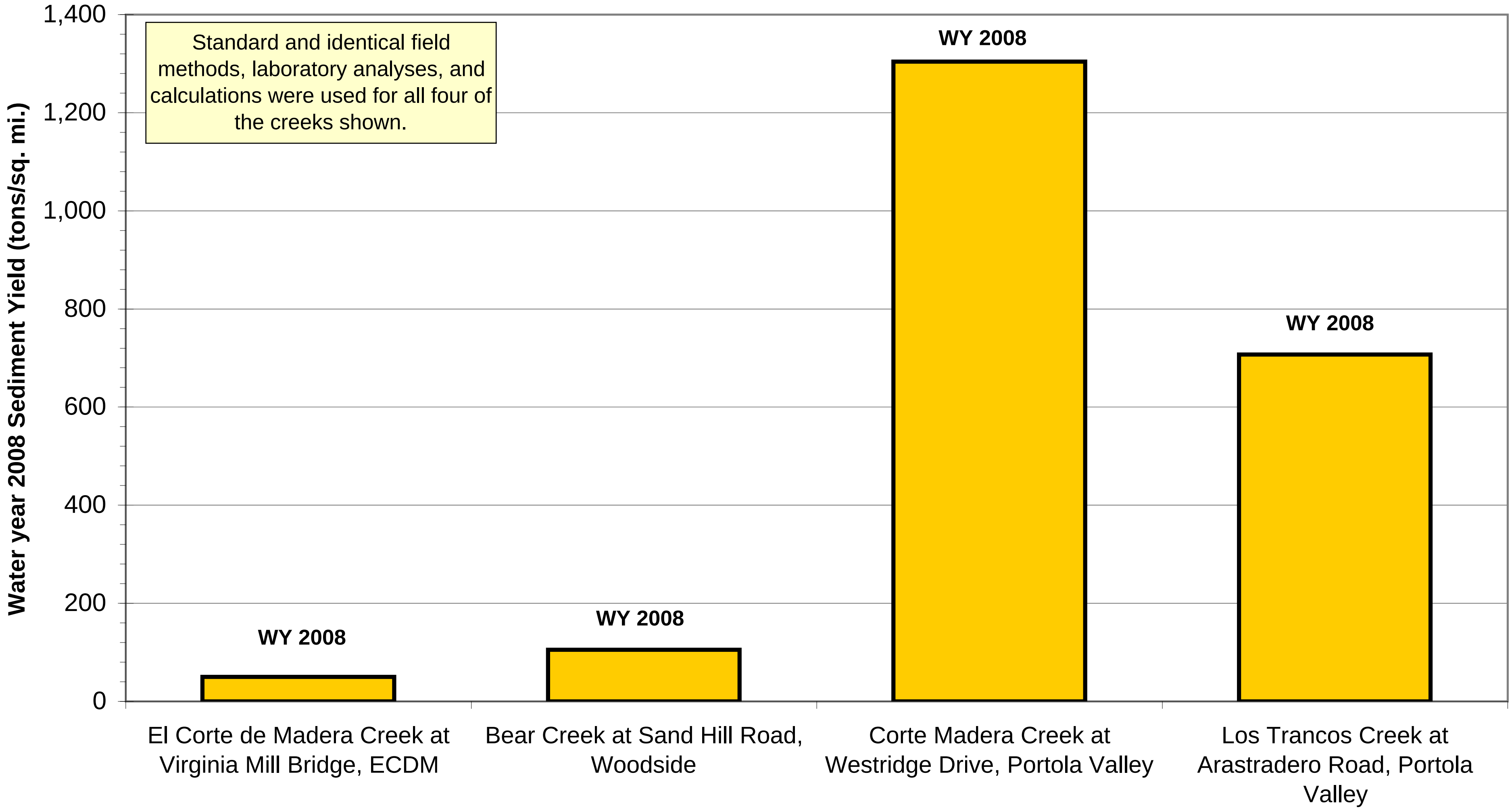

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Figure 8. Comparison of unit sediment yield from several nearby watersheds. Based on sediment gaging during water year 2008, sediment yield from El Corte de Madera Creek Open Space Preserve (ECDM) appears lower than other local watersheds. These comparison data are from watersheds where Balance Hydrologics is carrying out continuing sediment studies. Bedload sediment and suspended sediment are added together to calculate total sediment yield.

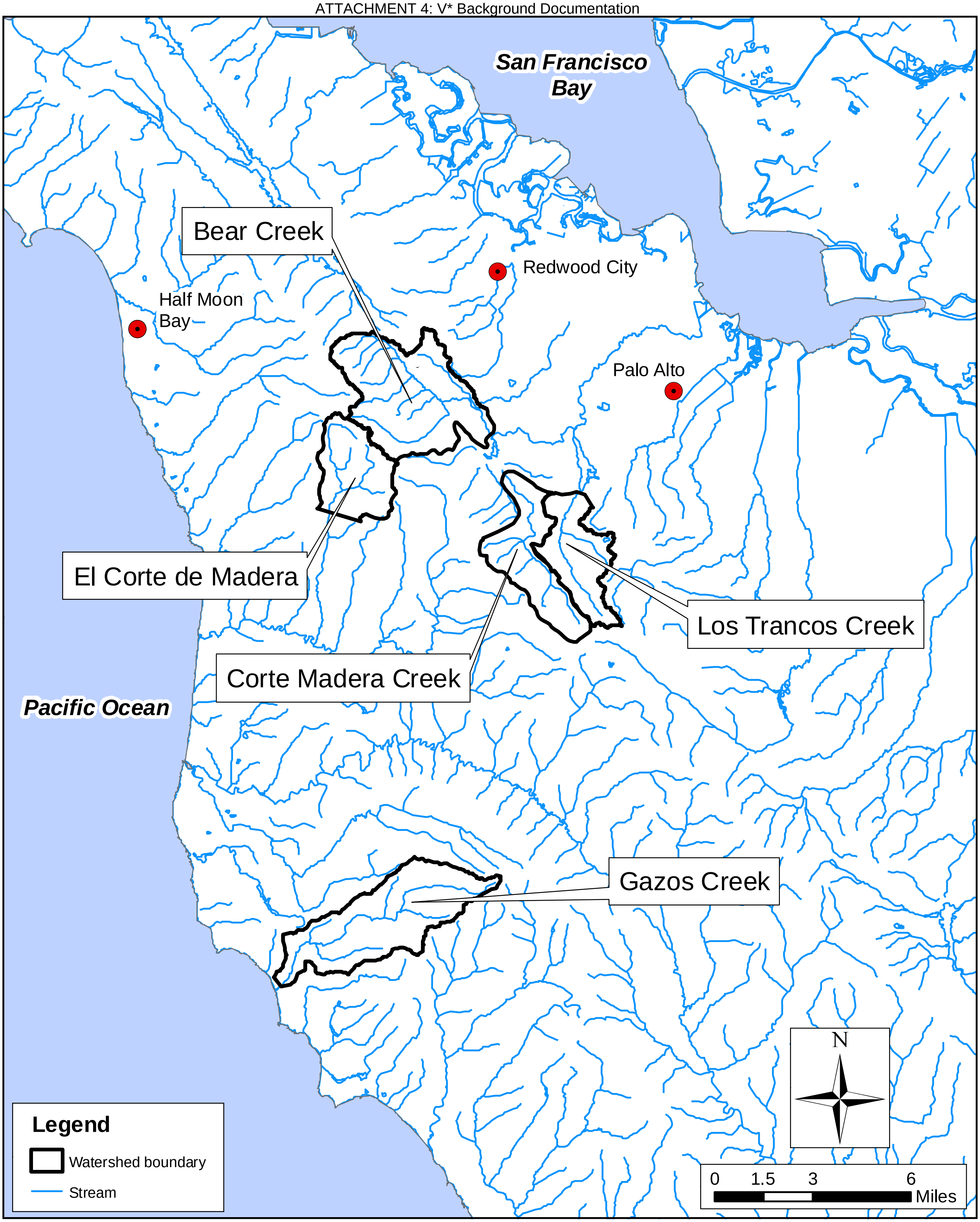

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Figure 9. Location map of local montane watersheds with measured flow and sediment-discharge data, northern Santa Cruz Mountains

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