City of Santa Rosa Offset Credit Proposal
for Pepperwood Preserve BMPs

Credit Proposal Summary

Selected Project:
Treatment of 34 eroding or potentially eroding stream crossing sites and 2.3 miles of gravel roads by implementing best management practices (BMPs) at the Pepperwood Preserve.

Discharge Location in the Laguna:
Mark West Creek discharging into the Laguna de Santa Rosa approximately 2.5 miles upstream of the Trenton-Healsburg Road Crossing.

Credit Generating Practices:
BMP Type #1: Repair 26 stream crossings, reducing an estimated 864 cubic yards of future sediment delivery
BMP Type #2: Stabilize 8 additional other stream crossing sites, reducing an estimated 29 cubic yards of anticipated future site-specific load delivery
BMP Type #3: Repair 2.3 miles of road surfaces and/or ditches currently draining to stream channels, either directly or through gullies, reducing an estimated 2,249 cubic yards of decadal erosion

Margin of Safety Factors:

- Bioavailability of total nitrogen (TN) and total phosphorus (TP) in stream bank and road materials compared to wastewater treatment plant (WWTP) effluent (discounts TN and TP credits by 15% and 49%, respectively)
- Conservative soil density conversion factor to convert cubic yards of soil to tons of soil

Calculated Credits and Credit Life for Proposed BMPs:

Proposed Crediting Options	Annual Credits (lbs TP+TN/yr)	Proposed BMP Eligibility Period
BMP Type #1: Currently eroding stream crossings (26)	2,186	4 years
BMP Type #2: Other sites[1] (8) (Future potential erosion sites)	88	4 years
BMP Type #3: Currently eroding road surface/ditches (2.3 miles)	9,993	30 years

[1] The term "other sites" is used in PWA, 2008 to describe a list of corrective actions to protect crossings from future potential erosion.

Pepperwood Preserve Project Synopsis:

A detailed site assessment of Pepperwood Preserve was completed by Pacific Watershed Associates Inc. (PWA)[2] in 2008. A detailed description of the proposed BMPs can be found in this report (see Attachment A). PWA conducted a follow-up inspection in 2012 on behalf of the Sotoyome Resource Conservation District (RCD), which is included as Attachment B. Kieser & Associates, LLC (K&A) used data collected by PWA to determine the total phosphorus (TP) and total nitrogen (TN) offset credits generated by the BMP projects proposed by PWA and outlined herein. The BMP sites represent voluntary initiatives at the Preserve as there are currently no regulatory controls addressing nutrient loading from these sites. The City of Santa Rosa (City) proposes to fund these voluntary practices to obtain nutrient credits as part of the Nutrient Offset Program under Resolution R1-2008-0061. The City would apply reductions at the Preserve as offsets toward its compliance with regulatory requirements for annual wastewater treatment plant (WWTP) discharges to the Laguna.

Voluntary land management practices that are not otherwise required by regulation, ordinance or policy can be considered eligible for generating nutrient reduction offsets. Such offsets, when described as pounds of phosphorus and nitrogen reduced per year from land management practices (and accounting for various margins of safety and pollutant equivalence), are referred to as credits. Final crediting details are provided in this formal crediting proposal. Relevant information regarding verification and annual reporting is also provided. BMP installations likely would occur in 2013, subsequent to North Coast Regional Water Quality Control Board Executive Officer approval of these proposed project site BMPs.

The erosion sites at Pepperwood Preserve are road and ditch systems that are hydrologically connected to the stream channels discharging to Mark West Creek and eventually the Laguna de Santa Rosa. These systems are either threatened to erode, or actually eroding as the result of poor stream crossing designs, the presence of springs, and/or inadequate storm flow drainage facilities. Figure 1 illustrates the type of sites being addressed.

Figure 1. Example of an eroding bank of a headwater stream in the Pepperwood Preserve (left) and poorly designed stream culvert systems (right).

[2] PWA. 2008. Pepperwood Preserve/Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County California. PWA Report No. 08081301, March 2008. (See Attachment A.)

Introduction

This document describes the Pepperwood Preserve Nutrient Offset Project (Project) and is proposed for consideration by the North Coast Regional Water Quality Control Board (RWQCB or Board) as a basis for project approval under the Santa Rosa Nutrient Offset Program adopted by the Board with Resolution R1-2008-0061. This proposal is organized according to the Nutrient Offset Program information requirements identified in Attachment 1 to Resolution R1-2008-0061. This resolution, approving the Santa Rosa Nutrient Offset Program, generally defines conditions for credit-generating BMP project eligibility and credit life. This formal proposal complies with those conditions and relies on previous discussions with the RWQCB.

Relevant information is provided in the following sections of this City of Santa Rosa offset project proposal:

- Project location
- Description of TN & TP Reduction Practices
- Quantity of N and P Removed/Expected Life of Crediting Practices
- Monitoring and Reporting Plan
- Description of Anticipated CEQA Documentation

Project Location

The Pepperwood Preserve is located in the watershed of Mark West Creek, approximately 10 miles northeast of Santa Rosa, California. The BMP projects are contained within the Pepperwood Preserve, a 3,117-acre nature preserve owned by the Pepperwood Foundation. The preserve is situated in the headwaters of Mark West Creek in the lower portions of the Laguna de Santa Rosa basin.

Description of TN & TP Reduction Practices

An agreement between the Sotoyome RCD and the Pepperwood Preserve will be used to coordinate corrective activities to reduce and prevent erosion. For the purposes of the agreement, the relevant project site contacts are Ms. Valerie Minton and Mr. Andy Casarez at the RCD and Mr. Michael Gillogly, Manager of the Pepperwood Preserve. The agreement will include implementation of the recommended PWA report BMPs (from 2008) and two additional sites added by PWA after a 2012 re-inspection, as well as conducting appropriate operation and maintenance. Appropriate practices for roads will include either upgrading and managing the road and its drainage facilities to accommodate the 100-year peak storm flow, or decommissioning the road. Both options address the hydrologic connections of the eroding surfaces to prevent and minimize future sediment contributions to the stream channels. These sediment loads not only add phosphorus and nitrogen to the receiving stream, but also diminish salmonid habitat and increase stream temperature. The recommended BMPs from the PWA assessments are listed in Table 1. [Note: multiple treatments apply to some sites].

Table 1. Recommended erosion control and erosion prevention treatments, Pepperwood Preserve/Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, California (adapted from PWA, 2008).

Treatment type		No.	Comments
Site specific treatments	Critical dip	7	Install to prevent stream diversions (site #1, 5, 7, 11, 12, 35, 36).
	Culvert (clean)	2	Clean inlet/interior of stream crossing or ditch relief culvert (site #13, 34).
	Culvert (install)	3	Install a culvert at an unculverted fill (site #1, 37, 38).
	Culvert (replace)	7	Replace undersized or damaged culvert (site #3, 5, 6, 6.1, 6.2, 7, 11).
	Decommission stream crossing	3	Decommission stream crossings by removing all road fill material from the stream channel (site #24, 25, 26)
	Rock (armor)	1	Add 5 yd^3 of rock armor on an outboard stream crossing fillslope.
	Soil excavation	16	At 16 sites, excavate and remove a total of 702 yd^3 of sediment, primarily at fillslopes and stream crossings.
	Wet crossing	10	Install 1 ford crossing and 9 armored fill crossings using 145 yd^3 of riprap and rock armor.
Road treatments	Cross road drain	5	Install to improve road drainage.
	Ditch (clean or cut)	4	At 4 locations, clean or cut ditch for a total of 620 ft.
	Ditch relief culvert (install or replace)	17	Install or replace ditch relief culverts to improve road surface drainage.
	Ditch relief culvert downspout	1	Install to prevent erosion at DRC outlets.
	Outslope road and remove ditch	13	At 13 locations, outslope road and remove ditch for a total of 4,455 ft of road to improve road surface drainage.
	Outslope road and retain ditch	5	At 5 locations, outslope road and retain ditch for a total of 2,767 ft of road to improve road surface drainage.
	Road rock (for road surfaces)	26	At 26 locations, use a total of 745 yd^3 of road rock to rock the road surface at 5 stream culvert installations, 8 DRC installations, 4 rolling dips, 2,225 ft of outslope and remove ditch, 2,042 ft of outslope and retain ditch, and 2 other site-specific locations.
	Rolling dip	55	Install to improve road drainage.

Proposed Credit Eligibility and Credit Life Considerations

The City is proposing application of the eligibility and credit life as outlined in Table 2. For actively eroding stream crossings and other future projected erosion sites, a four-year credit life is proposed. The eight stream crossing corrections cited for imminent failure are categorized into bins: High, High Moderate, Moderate, Moderate Low and Low (see Attachment A) based on their potential for failure. As these designations represent future erosion potential, the associated sediment loading predictions are equally divided over four years after BMP implementation for the purposes of proposed credits. A 30-year life of credit is proposed for actively eroding road surfaces and associated ditches. The PWA site assessment indicates 2,249 cubic yards of sediment are contributed every decade from un-surfaced roads and cutbank contributions. The City will enter into a long-term, legally binding agreement with the Pepperwood Preserve (or Sotoyome RCD that will in turn, contract with the Preserve) that will assign the roles and responsibilities of the parties involved to correct or protect erosion sites and maintain BMPs. Implementation, operation and maintenance of appropriate storm flow management practices are proposed as eligible credit generation practices throughout the agreement period.

The proposed nutrient offset credits are provided in Table 2. The table format follows the PWA results for the Pepperwood Preserve/Upper Mark West Creek Erosion Inventory and Assessment. Crediting details are provided in the following sections.

Table 2. Proposed credits (combined pounds of TP + TN) calculated for stream crossings, other sites, and road surfaces and ditches.

Proposed Crediting Option	BMP Elements	Annual TP Credits in lbs/yr (% of combined total)	Annual TN Credits in lbs/yr (% of combined total)	Annual Combined Credits (lbs TP+TN/yr)	Proposed BMP Eligibility Period
Stream Crossing Sites (actively eroding)	Culverts, dips, swales, de-commission	178 (8%)	2,008 (92%)	2,186	Short-term (4 years)
Other Sites (with future potential for erosion)*		7 (8%)	81 (92%)	88	Short-term (4 years)
Road Surfaces and Ditches (actively eroding)	Drains, culverts, road rock, dips	341 (3%)	9,652 (97%)	9,993	Long-term (30 years)

Note: Annual credits include discount for bioavailability and location factor.
*The term "other sites" is used in PWA, 2008 to describe a list of corrective actions to protect crossings from future potential erosion.

Quantity of N and P Removed/Expected Life of Crediting Practices

Pepperwood proposed crediting options and associated credit calculations are presented in this section. Attachments to this proposal provide supporting information for credit calculations based on soil erosion values reported by PWA. These illustrate various considerations for the Pepperwood Preserve using site-specific soil nutrient measurements (Attachment C) and empirical calculations (Attachment D).

As summarized in Table 1, site-specific treatments for actively eroding stream crossings and other potentially eroding sites would be implemented to prevent further and/or future soil erosion. Treatments include installing critical dips to prevent stream diversions; cleaning, installing or replacing culverts at stream crossings; decommissioning crossings; installing rock armor to prevent erosion; soil excavation at fillslopes and crossings; wet crossings with rock armor; road drains; relief culverts; culvert downspouts; outslopes; and rolling dips. Details of each site are included in Appendix C of the PWA 2008 Report included herein as Attachment A.

PWA surveyed and inspected these sites in 2008 and again in 2012 to estimate the potential annual soil loss at each site. K&A used the total soil loss estimated by these PWA assessments as the basis for credit calculations. These reported losses include:

- Actively eroding stream crossings (26) = 864 cubic yards per year
- Future potential sediment loading sites (8) = 29 cubic yards per year
- Actively eroding road surfaces and ditches (2.3 miles) = 2,249 cubic yards per year

The empirical calculations K&A applied to derive nutrient loading included a soil density value to convert cubic yards of soil to tons of soil (Attachment D). General soil classifications for the Preserve were obtained through the USDA's web soil survey online tool[3]. Soils generally consisted of a mix of sands, hummocks and fine silts. An average soil dry density by soil class was selected from the Michigan Pollutants Controlled Calculation and Documentation for Section 319 Watersheds Training Manual[4]. This manual is used broadly in EPA Region 5 (the Midwest) and can be applied to all soils, including those in California. A soil density of 0.037 tons/ft^3 was selected for stream crossings; 0.045 tons/ ft^3 for "other sites" (future potential erosion sites); and 0.055 tons/ft^3 for road surfaces/ditches. These were selected from a range of 0.011-0.055 tons/ft^3 for organic to sand/loamy sands, respectively. Site-specific sampling data collected by Sotoyome RCD from stream crossings at the preserve were analyzed for TN and TP concentration (as mass per dry weight). Laboratory results from Environmental Testing Services are included in Attachment C. Mean concentration values were applied to the tons of soil loss per year. High concentration outliers were removed for calculating these mean values making load estimates conservative (lower) than if all soil nutrient data were used (see Attachment D). The average soil value for TN was 2.7 lbs/ton for stream crossings and other sites and 3.4 lbs/ton for road surfaces and ditches. The average value for TP was 0.4 lbs/ton for stream crossings and other sites and 0.2 for road surfaces and ditches. These calculations yielded TN and TP load reductions in pounds per year (see Attachment D) for each site.

Site-specific credit calculations therefore consider:

- PWA estimated soil loss (cubic yards)
- Soil density by type
- Mean soil nutrient concentrations (from on-site sampling data)

[3] See http://www. http://websoilsurvey.nrcs.usda.gov.
[4] Michigan Department of Environmental Quality (1999). Pollutants Controlled Calculation and Documentation for Section 319 Watersheds Training Manual. Water Division, Nonpoint Source Unit. Lansing, Michigan.

The Nutrient Offset program Resolution requires credit calculation methods to consider a Margin of Safety (item 9 on page 2):

> "... To account for any uncertainties in granting reduction credits, all projects proposals must include an appropriate Margin of Safety (MOS), which can be described numerically, or by spatial and temporal aspects of a given proposal. ..."

To account for appropriate considerations for a Margin of Safety for the Pepperwood Preserve, conservative assumptions were used for volume estimates and mean soil nutrient concentrations. The sediment load estimates are also for particulate nutrient loading only and based on the PWA sediment volume estimates. These result in conservative (lower) estimates of actual loading for the 26 eroding stream crossings and the 2.3 miles of roads, but not necessarily for future potentially eroding sites. Because the soil nutrient content is the basis for the nutrient credit, soluble nutrient fractions are not considered in the calculation even though these will also be reduced when road and ditch runoff are diverted to the adjacent lands for dispersion and infiltration instead of being channelized and concentrated in ditch runoff to the streams. These structural practices for roads will use rolling dips as well as insloping and outsloping of the road to increase dispersion.

As identified in the Resolution, nutrient bioavailability must also be considered for credits. These factors for phosphorus and nitrogen were applied as follows:

- Bioavailability Factors:
    - TP = 51%
    - TN = 85%

These are based on a comparison of bioavailability of nutrients from wastewater versus soil erosion components[5].

No spatial discount factors to address overland attenuation were applied for calculating credits because all erosion sites are directly connected to streams.

No watershed location factors were applied to credits despite Mark West Creek's downstream discharge location in relation to low-flow pools in the Laguna de Santa Rosa. This was considered reasonable given that Delta Pond (the City's discharge location) is also downstream of these pools. The City also wishes to qualitatively recognize the ancillary biological and physical improvement value of these voluntarily implemented BMPs for critical salmonid habitat restoration and protection.

[5] Barr, 2004. Detailed Assessment of Phosphorus Sources to Minnesota Watersheds. Prepared by Barr Engineering for the Minnesota Pollution Control Agency. Available at: http://www.pca.state.mn.us/index.php/download-document.html?gid=3958 .

Monitoring and Reporting Plans

This section outlines the proposed monitoring and reporting plan that the City will follow if this proposal is approved the Regional Board Executive Officer. Expected agreements between the various parties that will be enlisted to ensure this plan is followed are also identified herein.

Monitoring and Reporting

The City will require all BMPs implemented for offset credits to be maintained to specific engineering designs produced by a licensed professional engineer to ensure nutrient reductions and water quality benefits continue throughout the life of the crediting period (either short-term or long-term). This will be accomplished through annual site inspections to verify the proper operation and maintenance of each BMP. Similar to other environmental trading programs in the nation, the following verification protocols are proposed for the City:

- Annual site visit to inspect and confirm operation and maintenance of BMP prior to the appropriate season of expected operation (as applicable)
    - RCD or other authorized agent will visit the BMP site
    - Agent will inspect all components of the BMP and surrounding area to ensure proper function/operation (using final engineering specifications)
    - Agent will document BMP operation and maintenance through forms and photographs
    - Any deficiencies must be noted on the inspection documentation
    - All site inspection documentation must be submitted to the City within a set period following inspection
- Deficiencies
    - All deficiencies will be reported to the land owner immediately after the City receives the inspection documentation
    - These must be appropriately corrected to previously specified conditions within 15 days of discovery, or within 30 days if an alternative improvement is necessary to avoid future failures (the Regional Board will be notified of this latter condition where applicable)
    - Agent must complete a second site visit to verify all deficiencies have been corrected
- Verification letter stating the BMP passed the annual inspection will be included in the City's annual report to RWQCB
- Verification letters for all BMPs will be forwarded to the RWQCB as proof that offset credits are being maintained

Agreements for Implementation

The City anticipates entering into several agreements to fully implement, verify and monitor the proposed BMP projects at Pepperwood Preserve, once RWQCB approval is obtained. The City will rely on written agreements for the following activities:

- Project implementation oversight
- Engineering
- Construction
- Long-term maintenance
- Annual site inspections

The City will likely enter into an agreement with the Sotoyome RCD to oversee implementation of the BMPs and provide annual BMP verification. For implementation, this will involve the RCD contracting directly with an engineer to design the BMPs and a separate contractor for BMP construction. The City will enter into a long-term agreement with Pepperwood Preserve to maintain the BMPs and ensure continued nutrient reductions and water quality benefits for the life of the crediting period.

Description of Anticipated CEQA Documentation

Final engineering design of the BMPs will provide further information on what permits may be necessary to implement the proposed projects. The Sotoyome RCD anticipates the need for permits from following entities: Department of Fish and Game (Section 1600 Permit); Regional Water Board (401 Water Quality Certification); US Army Corps of Engineers (Section 404 Permit); and Sonoma County Grading Permit (Exemption). The RCD will be responsible for obtaining all permits related to the BMP projects. If permits are required, the RCD will submit CEQA documentation as appropriate to ensure proper practices are used for excavation and work within a waterway to assure no significant, negative impact to the environment.

Section 15168(c)(2) of the CEQA Guidelines provides that "If the agency finds that pursuant to Section 15162, no new effects could occur or no new mitigation measures would be required, the agency can approve the activity as being within the scope of the project covered by the program EIR, and no new environmental document would be required." The Discharge Compliance Project (DCP) EIR evaluated an Enhanced Nutrient Removal (ENR) component at a program-level. The EIR Project Description for the ENR component specifically includes manure management at up to eight dairies and agricultural land management in the Laguna Watershed. The Pepperwood Preserve Nutrient Removal Project is entirely consistent with the Project Description for the ENR component in the DCP EIR. Further, the City has evaluated whether the Pepperwood Preserve Nutrient Removal Project would have new effects that are greater than those identified in the DCP EIR and that, pursuant to Section 15162 of the CEQA Guidelines, would be new significant impacts or significant impacts of a substantially more severe nature. The evaluation found no new significant impacts or significant impacts of a substantially more severe nature beyond those impacts already identified for the ENR component in the DCP EIR. And, therefore, the Pepperwood Preserve Nutrient Removal Project is adequately evaluated by the program-level review in the DCP EIR, and no subsequent environmental document is required.

ATTACHMENT A

Pacific Watershed Associates 2008 Soil Erosion Assessment Report

Pepperwood Preserve/
Upper Mark West Creek
Erosion Inventory and Assessment
Sonoma County, California

PWA Report No. 08081301
March 2008

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CONTENTS

FIGURES

TABLES

APPENDICES

1 EXECUTIVE SUMMARY

The Pepperwood Preserve/Upper Mark West Erosion Inventory and Assessment area is located in the watershed of Mark West Creek, a tributary of the lower Russian River, approximately 10 miles northeast of Santa Rosa, California. The project area is contained within the Pepperwood Preserve, a 3,117-acre nature preserve owned by the Pepperwood Foundation.

Erosion and sediment delivery from rural roads is a recognized environmental threat to the lower Russian River system, which is an important habitat for anadromous fish, including coho salmon. In 2007, the Sotoyome Resource Conservation District (SRCD) received grant funding from the National Fish and Wildlife Foundation and the Sonoma County Water Agency to conduct a watershed assessment and generate a restoration plan for the area of the upper Mark West Creek watershed located within the Pepperwood Preserve. SRCD contracted Pacific Watershed Associates (PWA) to conduct an erosion assessment and develop a prioritized plan-of-action for cost-effective erosion prevention and control for the 6.5 mi of road system within the project area. This involved a complete field inventory of existing and potential road-related erosion and sediment delivery sites, data entry, analyses and quality control, and recommendations for erosion control and prevention.

PWA identified a total of 40 sites with the potential to deliver nearly 850 yd^3 of sediment to streams in the project area if left untreated. In addition, field crews measured approximately 2.6 miles of road surfaces and/or ditches (representing over 40% of the total inventoried road mileage) currently draining to stream channels, either directly or via gullies. From these hydrologically connected road segments, we estimate that over 2,200 yd^3 of sediment could be delivered to stream channels within the project area over the next decade if no efforts are made to change road drainage patterns. We recommend that 32 of the identified sites and their associated road segments be treated for erosion control and prevention. PWA estimates that the total cost for implementing the recommended erosion control-and-prevention treatments for the entire Pepperwood Preserve/Upper Mark West Erosion Inventory and Assessment area will be $186,177.

The expected benefit of completing the erosion control and prevention planning work outlined in this report lies in the reduction of long term sediment delivery to the Mark West Creek in the lower Russian River system. With this prioritized plan of action, cooperative watershed stakeholders (i.e., SRCD, Pepperwood Foundation) can advance efforts to obtain funding and implement the erosion remediation for the Pepperwood Preserve/Upper Mark West Erosion Inventory and Assessment area. We assert that the erosion control-and-prevention treatments recommended in this assessment, if implemented and employed in combination with protective land use practices, will significantly improve and protect water quality and salmonid habitat in these watersheds.

2 CERTIFICATION AND LIMITATIONS

This report, entitled Pepperwood Preserve/Upper Mark West Creek Erosion Inventory and Assessment, was prepared by or under the direction of a licensed professional geologist at Pacific Watershed Associates Inc. (PWA), and all information herein is based on data and information collected by PWA staff. Sediment-source inventory and analysis for the project, as well as erosion control treatment prescriptions, were similarly conducted by or under the responsible charge of a California licensed professional geologist at PWA.

The interpretations and conclusions presented in this report are based on a study of inherently limited scope. Observations are qualitative, or semi-quantitative, and confined to surface expressions of limited extent and artificial exposures of subsurface materials. Interpretations of problematic geologic and geomorphic features (such as unstable hillslopes) and erosion processes are based on the information available at the time of the study and on the nature and distribution of existing features.

The conclusions and recommendations contained in this report are professional opinions derived in accordance with current standards of professional practice, and are valid as of the submittal date. No other warranty, expressed or implied, is made. PWA is not responsible for changes in the conditions of the property with the passage of time, whether due to natural processes or to the works of man, or changing conditions on adjacent areas. Furthermore, to be consistent with existing conditions, information contained in the report should be re-evaluated after a period of no more than three years, and it is the responsibility of the landowner to ensure that all recommendations in the report are reviewed and implemented according to the conditions existing at the time of construction. Finally, PWA is not responsible for changes in applicable or appropriate standards beyond our control, such as those arising from changes in legislation or the broadening of knowledge, which may invalidate any of our findings.

Prepared by:

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Pacific Watershed Associates

3 INTRODUCTION

One of the most important elements of long-term restoration and maintenance of both water quality and fish habitat is the reduction of future impacts from upland erosion and sediment delivery. Sediment delivery to stream channels from roads and road networks has been extensively documented, and is recognized as a significant impediment to the health of salmonid habitat (Harr and Nichols, 1993; Flosi et al., 1998). Unlike many watershed improvement and restoration activities, erosion prevention and "storm-proofing" of rural, ranch, and forest road systems has an immediate benefit to the streams and aquatic habitat of a watershed (Pacific Watershed Associates, 1994; Weaver and Hagans, 1999; Weaver et al., 2006). It helps ensure that the biological productivity of the watershed's streams is minimally impacted by future road-related erosion, and that future storm runoff can cleanse the streams of accumulated coarse and fine sediment, rather than depositing additional sediment from managed areas.

The Pepperwood Preserve is located in the Mayacamas Mountains approximately 25 miles from the Pacific coast, and 10 miles northeast of the city of Santa Rosa. The preserve comprises 3,117 acres, of which 1,138 acres in the southern portion of Pepperwood Preserve property are within the upper Mark West Creek watershed. The remaining acreage of Pepperwood Preserve drains to Franz Creek, a separate tributary of the Russian River. The Pepperwood Preserve/Upper Mark West Erosion Inventory and Assessment area lies in the upland area of Mark West Creek upstream of its confluence with Porter Creek.

Mark West Creek is a tributary of the Russian River, draining a basin of approximately 55 sq mi in central and eastern Sonoma County. Mark West Creek joins the Laguna de Santa Rosa near the town of Forestville before draining into the Russian River (Figure 1). The creek is a fourth-order stream, with 27 miles of mapped blue line stream on the USGS Mark West Springs 7.5-minute quadrangle (1998). Mark West Creek contains two species of anadromous salmonids: steelhead trout (*Oncorhynchus mykiss*) and coho salmon (*Oncorhynchus kisutch*) (CDFG, 2000).

The purpose of the Pepperwood Preserve/Upper Mark West Erosion Inventory and Assessment is to identify and quantify road-related erosion and sediment delivery to streams, and present a prioritized plan-of-action for cost-effective erosion prevention and erosion control for the road system. This assessment represents a critical first step in reducing road-related erosion in the Pepperwood Preserve and upper Mark West Creek areas, and includes a prioritized list of erosion control and erosion prevention treatments that not only considers the need to prevent future sediment delivery to streams in the area, but also to maintain transportation routes for management of the preserve. We assert that the erosion treatments recommended in this assessment, if implemented and employed in combination with protective land use practices, will significantly improve and protect water quality and salmonid habitat in the Mark West Creek watershed.

BLANK SHEET-PLACE HOLDER FOR FIGURE 1

4 FIELD DESCRIPTION OF THE ASSESSMENT AREA

4.1 Climate and Terrain

The climate of the upper Mark West Creek watershed is temperate, characterized by hot, dry summers and cool, wet winters. It is not unusual for the area to reach over 100° Fahrenheit in the summer months or for temperatures to drop below freezing in the dark valley bottoms during winter. Annual precipitation at the nearest monitoring station in Santa Rosa averages 31 in, with most of the precipitation delivered during winter months. Precipitation is likely a good deal higher in the project area due to greater elevation.

The geology of the watershed is composed of the Coastal Belt Franciscan Complex, Glen Ellen Formation, and Sonoma volcanics. The Coastal Belt Fransiscan Complex consisits of undifferentiated and erodible mélange, with large blocks of varying lithology. These blocks form much of the rolling hill topography in the project area. The Glen Ellen Formation is highly erodible due to the unconsolidated nature of the fluvial and lacustrine sediments comprising it (McLaughlin and others, 2004). It can be seen in the southwest project area along streamside roads.

The Pepperwood project area lies in the headwaters of the Mark West Creek watershed, just below the drainage divide with the Napa River watershed. Elevations range from approximately 650 ft to 1,500 ft (USGS, 1998). The terrain of the area mostly consists of moderately steep slopes and rolling hills, although slopes are somewhat steeper in the canyons of the streams that drain toward the west and southwest.

The vegetation of the project area is dominated by mixed forest and vast meadows. The forests consist of oak, bay and madrone on the upper and south-facing slopes, with redwood, fir and maple on the north-facing slopes and valley bottoms.

4.2 The Pepperwood Preserve Road Network

The Pepperwood Preserve road network consists of roughly 6.5 mi of maintained and unmaintained roads used to access the property for maintenance, research, and educational enrichment. The roads traverse a variety of settings, from low-gradient streamside areas, to mid-slope locations to ridgetops. Access to the Pepperwood Preserve is via a locked gate off Franz Valley Road (Figures 1-3).

Bechtel House Road, the primary maintained access road, is surfaced with coarse aggregate base and surface rock, has culverted drainage structures at most stream crossings, and is drained through the use of infrequent ditch relief culverts and minor outsloping. The remaining roads in the watershed are maintained for seasonal use or are unmaintained (without rock surfacing). In general, roads on or near the ridgetops are in good condition, while streamside roads in the lower areas of the property have undersized culverts, and permanent road drainage features are either inadequate or non-existent. Along some unmaintained road segments, excessive lengths of inboard ditch drain directly into stream crossings and hydrologically-connected ditch relief culverts. As a result, fine sediment from road runoff, ditch incision, and cutbank ravel is being delivered directly into the watershed's streams.

5 SEDIMENT SOURCES

Sources of erosion and sediment delivery in the Pepperwood Preserve/Upper Mark West Creek Assessment area are divided into two categories: (1) sediment from specific treatment sites, and (2) sediment from the surfaces of road segments of varying lengths—and their associated cutbanks and inboard ditches—that are hydrologically connected[1] to streams.

5.1 Site-Specific Erosion Sources

5.1.1 Stream crossings

A *stream crossing* is a ford or structure on a road (such as a culvert or bridge) installed across a stream or watercourse (USDA Forest Service, 2000). When they erode, sediment delivery from stream crossings is always assumed to be 100%, because any sediment eroded is delivered directly to the stream. The size of the stream affects the rate of sediment movement, but any sediment delivered to small ephemeral streams will eventually be transported to downstream fish-bearing stream channels.

Common features of stream crossings that lead to erosion problems include (1) fill crossings without culverts, (2) crossings with undersized culverts, (3) crossings with culverts susceptible to being plugged, (4) crossings with logs or debris buried in the fill intended to convey streamflow (i.e., *Humboldt crossings*), (5) crossings with a potential for stream diversion, and (6) crossings that have currently diverted streams.

A *fill crossing* is a stream crossing without a culvert to carry the flow through the road prism. At such sites, stream flow either crosses the road and flows over the fillslope, or is diverted down the road via the inboard ditch. Most fill crossings are located at small Class II or III streams that only have flow during larger runoff events. *Armored fill crossings* and *ford crossings* are similarly designed to be functional, unculverted stream crossings. A properly constructed armored fill crossing is based on a site-specific design, using a mix of riprap-sized rock to minimize erosion while allowing the stream to flow across the road prism. A ford crossing may use rock armor to stabilize the roadway, but the road is built essentially on the natural stream channel, and fill is not used.

Humboldt crossings are constructed from logs or woody debris, usually laid parallel to flow, which are then covered with fill. Humboldt crossings are susceptible to plugging, gullying, and

1 *Hydrologically connected* describes sites or road segments from which eroding sediment is delivered to stream channels (Furniss et al., 2000).

washout during storm flows (Weaver et al., 2006). Older Humboldt log crossing structures beneath more recently installed culverts are often found in rural northern California road networks.

Large volumes of erosion may occur at stream crossings when culverts are too small for the drainage area and storm flows exceed culvert capacity, or when culverts become plugged by sediment and debris. In these instances, flood runoff will spill across the road, allowing erosion of the stream crossing fill and development of a *washout crossing*. Washout crossings will remain highly problematic as the stream banks continue to erode to a natural grade.

Serious erosion problems may occur at a stream crossing that has a high *diversion potential*, which means that flow is diverted down the road, either on the roadbed or in the ditch, instead of spilling over the fill and back into the same stream channel. In this case, the roadbed, hillslope, and/or stream channel that receive the diverted flow may become deeply gullied or destabilized. As road and hillslope gullies enlarge over time, they will deliver increasingly greater quantities of sediment to stream channels (Hagans et al., 1986), and streamflow diverted onto steep, unstable slopes may trigger hillslope landslides.

To be considered adequately sized, culverts at stream crossings must be able to convey a 100-year peak storm flow[2] as well as sediment and organic debris in transport during high flows (Weaver et al., 2006). Undersized culverts do not have the capacity to convey stream flow during periods of heavy rainfall, and are susceptible to plugging by sediment and debris. Some stream crossing culverts in the project area are substandard, i.e., are not large enough to convey a 100-year flow, or are installed at too low a gradient through the stream crossing fill to prevent plugging. Improper culvert installations such as these were once common because they required shorter lengths of pipe to convey flow through the road, and were therefore used to minimize construction costs. However, in the long run these cost-cutting measures prove detrimental to erosion control and maintenance costs because the culvert discharges water onto unconsolidated road fill, rather than into the pre-existing stream channel, which results in pronounced erosion of the outboard, downstream fill face.

5.1.2 “Other” sources

Other sources of sediment delivery may include: (1) ditch relief culverts, (2) discharge points for road surface, cutbank, and ditch erosion, (3) point source springs, (4) sites of bank erosion, (5) swales, (6) channel scour; (7) non-road-related upslope gullies.

A *ditch relief culvert* (DRC) is a plastic, metal, or concrete pipe installed beneath the road surface to convey flow from an inside road ditch to an area beyond the outer edge of the road fill. When properly spaced, DRCs limit the quantity of water available to cause erosion at any single location, allowing flow to disperse and reducing the likelihood of gullies forming at their outlets.

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[2] The *100-year peak storm flow* for a location is the discharge that has a 1% probability of occurring at that location during any given year.

It is sometimes necessary to install downspouts or rock armor at DRC outlets to further disperse energy and prevent erosion.

Unpaved road surfaces, and their associated cutbanks and inboard ditches, are major sources for erosion and delivery of fine sediment to stream channels. Road surface, cutbank, and ditch erosion is termed "chronic" because it occurs throughout the year, during both wet and dry weather, and may include one or more of the following processes: (1) mechanical pulverizing and wearing down of road surfaces by vehicular traffic; (2) erosion of unpaved road surfaces by rainsplash and runoff during periods of wet weather; (3) erosion of inboard ditches by runoff during wet weather; and (4) erosion of cutbanks by dry ravel, rainfall, slope failures, and brushing/grading practices. *Discharge points for road surface, cutbank, and ditch erosion* are locations where sediment-laden flow from poorly drained road/cutbank/ditch segments exits the roadway to be delivered into the stream system. Discharge points are often in the form of roadside gullies or water bars, but on some low gradient or streamside roads may simply be low spots where concentrated flow exits the road and is delivered directly into a stream without gully formation.

Point source springs refer to sites where spring flow is entering the roadbed and causing erosion. Flow from multiple springs may become concentrated along a road with inadequate drainage structures, creating roadside gullies or fillslope failures. *Swales* are channel-like depressions that only carry minor flow during periods of extreme rainfall. *Bank erosion* sites refer to locations of streambank erosion caused or exacerbated by emplacement of a road. *Non-road-related upslope gullies* are sites of focused runoff channeled from upslope areas during high discharge.

5.2 Evaluation of Hydrologically Connected Road Segments

PWA measures the lengths of hydrologically connected road segments adjacent to sediment delivery sites, such as on either side of a stream crossing, ditch relief culvert, or discharge point, to derive an estimate for total potential sediment delivery from connected road surfaces in the project area (e.g., Tables 1, 2). In addition, because the adjacent hydrologically connected road segments contribute to the overall erosion and sediment delivery problem at a site, PWA considers the treatment site and adjacent road segments as a unit when estimating future sediment delivery and developing treatment prescriptions for that location (e.g., Tables 4, 5).

6 FIELD TECHNIQUES AND DATA COLLECTION

The Pepperwood Preserve/Upper Mark West Erosion Inventory and Assessment consists of three distinct elements: (1) an analysis of aerial photographs to document the road network; (2) a complete field inventory of all current and potential road-related erosion sources along 6.5-mi of road; and (3) the development of a prioritized plan-of-action for cost-effective erosion control and erosion prevention treatments in the watershed.

In the first phase of the Pepperwood Preserve/Upper Mark West Erosion Inventory and Assessment, PWA analyzed orthophoto imagery from the USDA Aerial Photography Field Office and the Pepperwood Preserve location map (2003) to document all roads within the project area. To define a road, we looked for traces on the imagery that ended in a terminal landing, and took apparent road grade and width into consideration when determining whether each trace was a road or a trail. Narrow traces, as well as those running up steep slopes, were considered to be trails and not mapped. Using these data, and GIS base maps produced by PWA, we developed composite maps that accurately depict the location and morphology of roads in the project area. These served as our reference maps for documenting the locations of inventoried erosion and sediment delivery sites and road segments in the field. Following field investigations, we made any necessary modifications to the road layer for the development of the final maps.

For the second phase of the project, PWA conducted a field inventory of roads in the project area to identify all existing and potential road-related erosion sites. Erosion sites, as defined in this assessment, include locations where there is direct evidence that current or future erosion or mass wasting, caused by or related to the road network, may deliver sediment to a stream channel. Sites of past erosion were not inventoried unless we determined that there was a potential for additional future sediment delivery. Furthermore, as the purpose of the inventory was to identify erosion sites with the potential to adversely impact fish-bearing streams, we excluded any erosion site that did not show evidence for delivering sediment to a stream channel, regardless of its evident potential for future erosion. All roads (including both maintained and unmaintained routes) were walked and inspected by trained personnel, and all existing and potential erosion sites were identified. PWA completed all aspects of the inventory, and field locations and treatment prescriptions were reviewed by a PWA licensed professional geologist.

Inventoried sites for this assessment primarily consist of stream crossings, gullies below ditch relief culverts, and various discharge points (e.g., roadside gullies, berm breaks) for uncontrolled road surface and/or inboard ditch runoff. For each site identified as a potential erosion source, PWA staff plotted its location on a GIS-generated base map, and recorded a series of field observations including (1) detailed site description, (2) nature and magnitude of existing and potential erosion problems, (3) likelihood of erosion, (4) length of hydrologically connected road surface associated with the site, and (5) treatments needed for prevention or elimination of future sediment delivery. The data collected for each site also includes an evaluation of treatment immediacy, based on the potential or likelihood of sediment delivery from the site to stream channels in the watershed, and the level of urgency for addressing erosion problems at that location. Stream crossing sites were additionally evaluated for potential fish barrier problems.

For each existing or possible problem site in the project area, PWA field staff evaluated the potential for erosion and sediment delivery, and collected field measurements (width, depth, and length of the potential erosion area) to derive sediment volume. In addition, field crews measured the lengths of hydrologically connected road (either individual road surface sites or segments of road adjacent to other sites) to derive estimates for sediment delivery, on a decadal basis, using the empirical formula: (measured length) x (25 ft average width, including cutbanks) x (0.2 ft average lowering of the road per decade). For most stream crossings, PWA field crews used tape and clinometer surveying techniques to develop longitudinal profiles and cross sections, and compile the data necessary to calculate road fill and potential sediment delivery volumes with the STREAM computer program. This program, developed for PWA, provides accurate and reproducible estimates of: (1) the potential volume of erosion at a stream crossing, whether over time, or during any possible catastrophic, storm-generated washouts; (2) excavation volumes associated with culvert installation, culvert replacement, or complete decommissioning of a stream crossing; and (3) backfill volumes associated culvert installation or replacement.

Stream crossing culverts are sized to convey the 100-year peak storm flow as well as sediment and organic debris in transport. For channels with cross sectional areas greater than 3 ft x 1 ft[3], PWA calculates minimum sizes for new or replacement culverts using one of the following methods:

(a) for drainage areas less than 80 acres, the Rational Method (Dunne and Leopold, 1978), which is an analytical approach based on rainfall intensity and watershed characteristics;
(b) for drainage areas larger than 80 acres , the empirical equations of the USGS Magnitude and Frequency Method (Wannanan and Crippen, 1977).

In the final phase of the project, PWA personnel analyzed the inventory results to develop cost-effective erosion control and erosion prevention prescriptions, as well as a prioritized plan-of-action for the project area. Using field observations, data analyses, and information from the landowner about realistic needs for future road usage, PWA staff assigned a treatment designation of either “upgrade” or “decommission” for each treatment site[4]. These designations are intended to provide the landowner with prescriptions and estimated costs for storm-proofing treatment sites and hydrologically connected road segments, and are our best recommendations for the most efficient and cost-effective methods to accomplish this goal.

7 GENERAL CONSIDERATIONS FOR STORM-PROOFING ROADS

Forest and rural roads may be storm-proofed by one of two methods: upgrading or decommissioning (Pacific Watershed Associates, 1994; Weaver and Hagans, 1999; Weaver et al., 2006). Upgraded roads are kept open, and are inspected and maintained. Their drainage facilities and fills are designed or treated to accommodate the 100-year peak storm flow. Conversely, properly decommissioned roads are closed and no longer require maintenance. Whether through upgrading or decommissioning, the goal of storm-proofing is to make the road as “hydrologically invisible” as possible, that is, to reduce or prevent future sediment delivery from the road to the local stream system. Heavy equipment techniques for storm-proofing roads,

[3]For stream channels with cross sectional areas of 3 ft^2 or smaller, PWA follows the recommendations outlined in the California Department Fish and Game *Salmonid Habitat Stream Restoration Manual* and defaults to a minimum culvert size of 24”.
[4] Road upgrading and decommissioning is discussed in further detail in Section 7 and Appendix A.

as well as the characteristics and benefits of a properly designed storm-proofed road, are described in Appendix A.

7.1 Road Upgrading

Road upgrading involves a variety of treatments used to make a road more resilient to large storms and flood flows. The most important of these include upgrading stream crossings (especially culvert upsizing to accommodate the 100-year peak storm flow and debris in transport, and correct or prevent stream diversion); removing unstable sidecast and fill materials from steep slopes; and applying road drainage techniques (e.g., installing ditch relief culverts, removing berms, constructing rolling dips, insloping or outsloping the road) to improve dispersion of surface runoff (appendix A). Road upgrading usually also includes adding road rock or riprap as needed to fortify roads and crossings.

7.2 Road Decommissioning

In essence, decommissioning is “reverse road construction”, although complete topographic obliteration of the roadbed is not usually required to achieve cost-effective erosion prevention. In most cases, serious erosion problems are confined to a few, isolated locations along a road (perhaps 10% to 20% of the full road network to be decommissioned) where stream crossings need to be excavated, unstable sidecast on the downslope side of a road or landing needs to be removed before failure, or the road crosses unstable terrain and the entire road prism must be removed. But typically, lengths of road beyond the extent of individual treatment sites usually require simpler, permanent improvements to surface drainage, such as surface decompaction, additional road drains, and/or partial outsloping. As with road upgrading, the heavy equipment techniques used in road decommissioning (appendix A) have been extensively field tested, and are widely accepted (Weaver and Sonnevil, 1984; Weaver and others, 1987, 2006; Harr and Nichols, 1993; Pacific Watershed Associates, 1994).

8 DETERMINING TREATMENT IMMEDIACY AND COST-EFFECTIVENESS

This assessment is intended to provide guidance for long-range transportation planning and prioritization of erosion control and erosion prevention treatments, for the ultimate goal of protecting and improving fish habitat in the assessment area. Treatment prescriptions follow guidelines described in the *Handbook for Forest and Ranch Roads* (Pacific Watershed Associates, 1994), as well as Part X of the California Department of Fish and Game *Salmonid Habitat Stream Restoration Manual* (Weaver et al., 2006).

Identifying *treatment immediacy* is an integral part of an assessment used to prioritize sites prior to implementation. Treatment immediacy is a professional evaluation of how important it is to quickly perform erosion control or erosion prevention work. It is defined as “high,” “moderate,” or “low,” and represents the urgency of treating the site before it erodes or fails. An evaluation of treatment immediacy is based on the following criteria: (1) *erosion potential*, or whether there is a low, moderate, or high likelihood for future erosion at a site; (2) *sediment delivery*, which is an estimate of the sediment volume projected to be eroded from a site and delivered to a nearby stream; and (3) the value or sensitivity of downstream resources being protected. Generally, sites that are likely to erode or fail in a normal winter, and are expected to deliver significant quantities of sediment to a stream channel, are rated as having high treatment immediacy.

The *erosion potential* of a site is a professional evaluation of the likelihood that erosion will occur during a future storm, based on local site conditions and field observations. It is a subjective probability estimate, expressed as “low,” “moderate,” or “high,” and not an estimate of how much erosion is likely to occur. The volume of sediment projected to erode and reach stream channels is described by *sediment delivery*, which plays a significant role in determining the treatment immediacy for a site. The larger the volume of potential future sediment delivery to a stream, the more important it becomes to closely evaluate the need for treatment.

From this assessment, treatment immediacy and *cost-effectiveness* may be analyzed, along with the client’s transportation needs, to prioritize treatment sites or locations for implementation. *Cost-effectiveness* is not only a necessary consideration for environmental protection and restoration projects for which funding may be limited, but is also an accepted and well-documented tool for prioritizing potential treatment sites in an area (Weaver and Sonnevil, 1984; Weaver and Hagans, 1999). A quantitative estimate for cost-effectiveness is determined by dividing the cost of accessing and treating a site by the volume of sediment prevented from being delivered to local stream channels. The resulting value, or *sediment savings*, provides a comparison of cost-effectiveness among sites, and an average for the entire project area. For example, if the cost to develop access and treat an eroding stream crossing is projected to be \$5000, and the treatment will potentially prevent 500 yd^3 of sediment from reaching the stream channel, the predicted cost-effectiveness for that site would be \$5000/500yd^3, or \$10/yd^3.

PWA further evaluates cost-effectiveness for an entire assessment area by organizing sites into logistical groups based on similar requirements for heavy equipment and materials, and addressing these as a unit to minimize expenses. Furthermore, although sites and road segments with the lowest immediacy ratings are placed last on the list for treatment, PWA recommends that project managers look for opportunities to conveniently treat these sites once the project is underway, as opportunities to cost-effectively treat low-immediacy sites often arise when heavy equipment is already located nearby to perform maintenance or restoration at higher-immediacy sites.

9 RESULTS

The following is a summary of results for the entire Pepperwood Preserve/Upper Mark West Erosion Inventory and Assessment area. Comments and results for each site in the assessment are provided in Appendix C.

9.1 Summary of Field Data

PWA inventoried 6.5 mi of road, and identified a total of 40 sites and 2.6 mi of hydrologically connected road surfaces with the potential to deliver sediment to streams in the Pepperwood Preserve/Upper Mark West Erosion Inventory and Assessment area (table 1). We recommend that 32 sites and 2.3 mi of road be treated for erosion control and erosion prevention.

Table 1. Inventory results and treatment recommendations for sediment delivery sites and hydrologically connected road segments, Pepperwood Preserve/Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, California.

Sources of sediment delivery	Sediment delivery sites		Hydrologically connected roads adjacent to sites		Total roads surveyed (mi)
	Inventoried (#)	Recommended for treatment (#)	Inventoried (mi)	Recommended for treatment (mi)	
Stream crossing	30	24	1.9	1.6	-
Other[a]	10	8	0.7	0.7	-
Total	**40**	**32**	**2.6**	**2.3**	**6.5**

[a]*Other* sources of sediment delivery include: ditch relief culverts; discharge points for road surface drainage, and point source springs.

PWA recommends treatment for 24 stream crossings in the Pepperwood Preserve/Upper Mark West Erosion Inventory and Assessment area, which account for 75% of all treatment sites (figure 2; table 1). Inventoried stream crossing sites include 8 crossings with culverts, 12 fill crossings, and 4 wet crossings. We project that approximately 816 yd^3 of future road-related sediment delivery will originate from stream crossings if they are left untreated, which is approximately 26% of total future sediment delivery for the Pepperwood Preserve/Upper Mark West Erosion Inventory and Assessment area (table 2). Furthermore, of the 30 inventoried stream crossings, 20 have the potential to divert in the future and 11 streams are currently diverted. Of the 8 existing culverts at stream crossings, 4 have a moderate or high potential to become plugged by sediment and debris (figure 2, 3; table 3).

Table 2. Estimated future sediment delivery for sites and road surfaces recommended for treatment, Pepperwood Preserve/Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, California.

Sources of sediment delivery	Estimated future sediment delivery (yd^3)	Percent of total
Stream crossings	816	26%
Other sites[a]	29	1%
Hydrologically connected road and cutbank surfaces adjacent to other sediment delivery sites[b]	2,249	73%
Total	**3,094**	**100%**

[a]*Other* sources of sediment delivery include: ditch relief culverts; discharge points for road surface, and point source springs.
[b]Decadal sediment delivery for unsurfaced roads, assuming a 25 ft wide road surface and cutbank contributing area, and 0.2 ft lowering of road and retreat of cutbank surfaces per decade.

Table 3. Erosion problems at stream crossings, Pepperwood Preserve/Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, California.

Stream crossing problem	# Inventoried	% of total[a]
Stream crossings with diversion potential	20	67%
Stream crossings currently diverted	11	37%
Crossings with culverts likely to plug[b]	4	13%
Crossings with culverts that are currently undersized[c]	5	17%

[a]From Table 1, total stream crossings inventoried = 30.
[b]Culvert plug potential is moderate to high.
[c]Culverts in stream channels larger than 3 ft x 1 ft that are too small to convey the calculated 100-year peak storm flow.

Eight (8) of the treatment sites (25%) are classified as “other” sites, which include ditch relief culverts, point-source springs, and miscellaneous discharge points for surface flow from segments of hydrologically connected road (figure 2; table 1). “Other” sites account for 29 yd^3 of future site-specific sediment delivery in the project area, or 1% of the total (table 2). However, although these sites represent relatively low total sediment yield, they are potential conduits for future sediment delivery from hydrologically connected road surfaces and inboard ditches, and should be carefully considered for erosion control treatments.

PWA field crews measured approximately 2.6 mi of road surfaces and/or ditches (representing over 40% of the total inventoried road mileage) currently draining to stream channels, either directly or via gullies (figure 2; table 1). From these hydrologically connected road segments, we

Table 4. Evaluation of treatment immediacy for sediment delivery sites (and adjacent hydrologically connected road reaches) in the Pepperwood Preserve/Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, California.

Treatment immediacy	Upgrade		Decommission		Number of treatment sites by type[b]	Estimated future sediment delivery[c] (yd^3)	Percent of total
	# sites	Road length[a] (mi)	# sites	Road length[a] (mi)			
High	0	0	0	0.0	0	0	0%
High-moderate	2	0.14	1	0.0	3 stream crossings	355	11%
Subtotal	**2**	**0.14**	**1**	**0.0**		**355**	**11%**
Moderate	7	0.43	2	0.09	8 stream crossings, 1 other	777	25%
Moderate-low	4	0.08	0	0.0	2 stream crossings, 2 other	149	5%
Subtotal	**11**	**0.51**	**2**	**0.09**		**926**	**30%**
Low	16	1.57	0	0.0	11 stream crossings, 5 other	1,813	59%
Total	**29**	**2.22**	**3**	**0.09**	**24 stream crossings, 8 other**	**3,094**	**100%**

[a]*Road length* refers to hydrologically connected road reaches adjacent to recommended treatment sites.
[b]*Other* sediment source treatment sites include: ditch relief culverts, discharge points for road surface, and point source springs.
[c]*Estimated future sediment delivery* is total delivery from treatment sites and any adjacent hydrologically connected road reaches.

estimate that approximately 2,249 yd^3 of sediment could be delivered to stream channels within the Pepperwood Preserve/Upper Mark West Erosion Inventory and Assessment area over the next decade if no efforts are made to change road drainage patterns (table 2).

Of the 32 inventoried sites that we recommend for treatment, we designate 3 with priority ratings of high-moderate (figure 3; table 4). The potential sediment delivery for these 3 sites is approximately 355 yd^3, which equates to nearly 11% of the expected sediment savings for the Pepperwood Preserve/Upper Mark West Erosion Inventory and Assessment area. We assign moderate or moderate-low priorities to 13 sites, which accounts for approximately 926 yd^3, or nearly 30% of the expected sediment savings. Finally, we assign a low priority to 16 sites, which accounts for approximately 1,813 yd^3, or nearly 59% of the expected future sediment delivery.

9.2 Recommended Treatments

The following is a summary of recommended treatments for the entire Pepperwood Preserve/Upper Mark West Erosion Inventory and Assessment area; complete details for treatment prescriptions are provided in the electronic database. Typical drawings of all recommended treatments are provided in Appendix B, and a summary of recommended treatments for each site is provided in Appendix C.

9.2.1 Site-specific and road drainage treatment recommendations

PWA recommends 16 different types of erosion control and erosion prevention treatments for the project area, which we generally subdivide into 2 categories: site-specific treatments and road drainage treatments (table 5). These prescriptions include both upgrading and decommissioning measures. Site-specific treatments include the following stream crossing treatments: (1) installing 3 culverts at currently unculverted stream crossings; (2) replacing 5 undersized or damaged culverts; (3) constructing 10 wet crossings; (4) decommissioning 3 stream crossings; (5) constructing a total of 7 critical dips to prevent diversions at streams with diversion potential; and (6) removal of 702 yds^3 from 16 different sites. Other miscellaneous treatments (table 5) are detailed in the electronic database.

To curtail road surface erosion, we recommend: (1) constructing 55 rolling dips; (2) constructing 5 cross road drains; (3) cleaning or cutting a new ditch at 4 locations for a total of 620 ft to drain flow primarily from springy cutbanks to ditch relief culverts; and (4) installing or replacing 17 ditch relief culverts at selected locations, and at intervals appropriate for the steepness of the road. We recommend 1 downspout be installed on specific ditch relief culvert location to prevent erosion at the culvert outlet. Further we recommend changing road shapes to better disperse road drainage along various lengths of road at a total of 18 locations. At 13 of these locations, currently flat or insloped roads will be reconfigured to an outsloped shape. In addition, we recommend using approximately 745 yd^3 of road rock to fortify road surfaces and prevent surface erosion following treatment of at 26 locations, both by adding material on currently rocked roads, and by placing new material at locations that currently have native road surfaces.

9.2.2 Note on sites not recommended for treatment

Of the 40 inventoried sites, 8 were not recommended for treatment. The majority of these sites are in the southwest part of the project area along Rogers Canyon Road (Figure 3). These sites were not recommended for treatment because their potential for sediment delivery burden is minimal. Most of this road segment has minimal road fill and a vegetated native surface. The road traverses into and out of the floodplain, lying primarily on fluvially deposited sediments. The remaining 2 sites are stream crossings that are not recommended for treatment because they were judged to have no risk of future sediment delivery.

Table 5. Recommended erosion control and erosion prevention treatments, Pepperwood Preserve/Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, California.

Treatment type		No.	Comments
Site specific treatments	Critical dip	7	Install to prevent stream diversions (site #1, 5, 7, 11, 12, 35, 36).
	Culvert (clean)	2	Clean the inlet or interior of a stream crossing or ditch relief culvert (site #13, 34).
	Culvert (install)	3	Install a culvert at an unculverted fill (site #1, 37, 38).
	Culvert (replace)	5	Replace an undersized or damaged culvert (site #3, 5, 6, 7, 11).
	Decommission stream crossing	3	Decommission stream crossings by removing all road fill material from the stream channel (site #24, 25, 26)
	Rock (armor)	1	At 1 site, add a total of 5 yd^3 of rock armor on an outboard stream crossing fillslope.
	Soil excavation	16	At 16 sites, excavate and remove a total of 702 yd^3 of sediment, primarily at fillslopes and stream crossings.
	Wet crossing	10	Install 1 ford crossing and 9 armored fill crossings using 145 yd^3 of riprap and rock armor.
Road treatments	Cross road drain	5	Install to improve road drainage.
	Ditch (clean or cut)	4	At 4 locations, clean or cut ditch for a total of 620 ft.
	Ditch relief culvert (install or replace)	17	Install or replace ditch relief culverts to improve road surface drainage.
	Ditch relief culvert downspout	1	Install to prevent erosion at DRC outlets.
	Outslope road and remove ditch	13	At 13 locations, outslope road and remove ditch for a total of 4,455 ft of road to improve road surface drainage.
	Outslope road and retain ditch	5	At 5 locations, outslope road and retain ditch for a total of 2,767 ft of road to improve road surface drainage.
	Road rock (for road surfaces)	26	At 26 locations, use a total of 745 yd^3 of road rock to rock the road surface at 5 stream culvert installations, 8 DRC installations, 4 rolling dips, 2,225 ft of outslope and remove ditch, 2,042 ft of outslope and retain ditch, and 2 other site-specific locations.
	Rolling dip	55	Install to improve road drainage.

9.3 Heavy Equipment and Labor Requirements

Equipment needs for erosion control treatments in the assessment area are detailed in the project database and summarized, based on treatment immediacy, in table 6. Most treatments require the use of heavy equipment, e.g., excavator, bulldozer, grader, and water truck. Some hand labor is required at sites needing downspouts, new culverts or culvert repairs, or for applying seed and mulch to ground disturbed during construction. Equipment needs are reported as equipment times, in hours, to treat all sites and road segments. These estimates only include the time needed for the actual treatment work, and do not include activities categorized as logistics, such as travel time between work sites, or the time needed for work conferences at each site. Work hours tallied under logistics are added to the hours needed for the actual treatment work to determine total equipment costs (e.g., table 7).

Table 6. Estimated heavy equipment and labor requirements based on treatment immediacy, Pepperwood Preserve/Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, California.

Treatment immediacy	# of sites	Excavated volume[a] (yd^3)	Excavator (hr)	Bulldozer (hr)	Dump truck (hr)	Water truck (hr)	Labor (hr)
High or high-moderate	3	501	21	26	10	5	14
Moderate or moderate-low	8	549	42	59	0	14	22
Low	9	347	73	89	0	31	53
Total	**20**	**1,397**	**136**	**174**	**10**	**50**	**89**

Note: Equipment and labor times do not include hours necessary for opening roads, traveling between sites, and spreading straw and mulch.
[a]Excavated volume includes material permanently removed and stored, as well as material excavated and reused for backfilling upgraded stream crossings.

PWA estimates that erosion control and erosion prevention remediation in the Pepperwood Preserve/Upper Mark West Erosion Inventory and Assessment area will require 136 hr of excavator time and 174 hr of bulldozer time (table 6). An excavator and bulldozer will not be needed at all treatment sites, and some treatment sites will require one but not the other. Dump truck operators will require 10 hr to transport excavated spoil material to disposal sites and import necessary fill for rebuilding fillslopes. Approximately 50 hr of water truck time will be needed for applying water to dry soils during road-drainage treatment implementation, and for backfilling excavations at stream crossings and ditch relief culverts. Finally, approximately 89 hours of labor time will be required for various tasks, including culvert installation or replacement. Construction activities such as opening roads, staging materials at work sites, traveling between sites, final grading, and spreading road rock, straw, and mulch require equipment and labor hours in addition to those listed above and in table 6. These additional needs are described in detail in table 7.

9.4 Estimated Costs

The estimated total cost to implement the recommended erosion control and erosion prevention treatments for the Pepperwood Preserve/Upper Mark West Erosion Inventory and Assessment area is $186,177 (Table 7). Approximately $54,000, or 29% of the total, is for the purchase of rock and culvert materials. A total of $30,400 is projected for detailed project planning, on-site equipment operator instruction and supervision, establishing effectiveness monitoring measures, and post-project analysis and reporting. There will also be necessary expenses for the use of lowboy trucks to haul construction equipment to and from the work area.

The costs in table 7 are based on a number of assumptions and estimates, and many of these are included as footnotes to the table. The costs provided are assumed reasonable if work is performed by outside contractors, and there is no added overhead for contract administration and pre- and post-project surveying.

Most of the treatments listed in this plan are not complex or difficult for equipment operators with experience in road upgrading and decommissioning operations on forestlands. The use of inexperienced operators or the wrong combination of heavy equipment would require additional technical oversight and supervision in the field, as well as an escalation of the costs to implement the work. To help insure success of the project, it is imperative that the project coordinator be on-site full time at the beginning of the project and intermittently after equipment operations have begun.

10 CONCLUSIONS

This assessment is a comprehensive inventory of road-related erosion and sediment delivery to streams in the Pepperwood Preserve/Upper Mark West Creek Assessment project area. It provides field data to identify and quantify existing and potential future sources of erosion and sediment along roads totaling 6.5 mi in length in the upper Mark West Creek watershed.

The expected benefit of completing the erosion control and erosion prevention treatments recommended in this report lies in the reduction of long-term sediment delivery to Mark West Creek, which is a tributary to the Russian River, an important river for salmonid production in northern California. The assessment includes a prioritized plan of action for cost-effective erosion prevention and erosion control, which, when implemented and employed in combination with protective land-use practices, may be expected to significantly contribute to the long-term improvement of water quality and salmonid habitat in these watersheds. With this prioritized plan of action, entities interested in the sustainability of the watersheds and preservation of salmonid habitat (e.g., Mark West Creek) can advance efforts to obtain funding required to implement road-related erosion remediation for the Pepperwood Preserve/Upper Mark West Creek Assessment project area.

Table 7. Estimated equipment times and costs to implement erosion control and erosion prevention treatments, Pepperwood Preserve/Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, California.

Cost category[a]		Cost rate[b] ($/hr)	Estimated Project Times			Total estimated costs[e] ($)
			Treatment[c] (hr)	Logistics[d] (hr)	Total (hr)	
Move in, move out[f]	Excavator	110	12	--	12	1,320
	Bulldozer	110	12	--	12	1,320
	Roller	110	12		12	1,320
	Water truck	110	12	--	12	1,320
	Truck/trailer	80	4		4	320
Road opening	Excavator	185	5	--	5	925
	Bulldozer	185	5	--	5	825
Heavy equipment for site-specific treatments[g]	Excavator	185	94	28	122	22,570
	Bulldozer	165	70	21	91	15,015
	Dump truck	110	13	4	17	1,870
	Roller	125	4	1	5	625
	Water truck	100	20	6	26	2,600
	Truck/trailer	80	25	8	33	2,640
Heavy equipment for road drainage treatments	Excavator	185	54	16	70	12,950
	Bulldozer	165	104	31	135	22,275
	Roller	125	14	4	18	2,250
	Water truck	100	30	9	39	3,900
Laborers[h]		50	112	34	146	7,300
Rock costs (includes trucking for 1105 yd^3 of road rock and 145 yd^3 of riprap)						26,707
Culvert materials costs (500' of 18", 170' of 24", 70' of 30", 60' of 36", 50' of 48", and 60' of 60", including costs for couplers and elbows)						27,407
Mulch, seed, and planting materials for 0.43 acres of disturbed ground[i]						318
Supervision, coordination, layout, and reporting[j]						30,400
Total Estimated Costs: $186,177 **Potential sediment savings: 3,094 yd^3** **Overall project cost-effectiveness: $60.17 spent per cubic yard of sediment saved**						

(Continued on next page.)

Table 7—continued.

[a]Costs excluded from the list are for (1) tools and miscellaneous materials, and (2) variable administration and contracting expenses.

[b]Heavy equipment costs include operator and fuel. Costs listed are estimates for favorable local private sector equipment rental and labor rates.

[c]Treatment times refer to equipment hours expended explicitly for erosion control and erosion prevention work at all project sites and roads.

[d]Logistics times for heavy equipment (30%) include all equipment hours expended for opening access to sites on maintained and abandoned roads, travel time for equipment to move from site to site, and conference times with equipment operators to convey treatment prescriptions and strategies. Logistic times for laborers (30%) include estimated daily travel time to project area.

[e]Total estimated project costs for equipment rental and labor are based on private sector rates at prevailing wage. Materials costs are subject to change.

[f]Move in and move out times are based on 2 hauls each (1 to move in and 1 to move out) at 6 hr/ trip for excavator, bulldozer, roller and water truck, as well as a single 4-hr round trip for truck and trailer.

[g]An additional 3 hr of excavator and dump truck time are added for importing fill for stream crossing backfills, and 16 hr of truck and trailer time are added for delivering straw to sites. A total of 9 hr of excavator and truck and trailer time are added for distributing culverts.

[h]This includes 16 hr of labor for delivering straw to sites and 7 hr for spreading straw mulch and seeding.

[i]Seed costs are based on 16 lb of native seed per acre at $9.75/lb. Straw needs are 23 bales per acre at $6.95/bale. Labor time for straw mulching and seeding is 7 hr.

[j]Supervision time includes detailed layout (flagging, etc) prior to equipment arrival, training of equipment operators, supervision during equipment operations, supervision of labor work, and post-project documentation and reporting.

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Appendix A

Overview of storm-proofing roads
(road upgrading and decommissioning)

Overview of storm-proofing roads (road upgrading and decommissioning)

Forest and rural roads may be storm-proofed by one of two methods: upgrading or decommissioning (Pacific Watershed Associates, 1994; Weaver and Hagans, 1999; Weaver et al., 2006). Upgraded roads are kept open, and are inspected and maintained. Their drainage facilities and fills are designed or treated to accommodate the 100-year peak storm flow[5]. Conversely, properly decommissioned roads are closed and no longer require maintenance. Whether through upgrading or decommissioning, the goal of storm-proofing is to make the road as "hydrologically invisible" as possible, that is, to reduce or prevent future sediment delivery to the local stream system. A well-designed storm-proofed road includes specific characteristics (Table A1), all proven to contribute to long-term improvement and preservation of watershed hydrology and aquatic habitat.

Road upgrading

In general, road upgrading consists of improving the function of stream crossings, excavating unstable or potentially unstable fillslopes, and implementing treatments to disperse road surface runoff. In addition to many minor treatment techniques, road upgrading may include the following major construction techniques:

1. Installing rolling dips. Rolling dips are installed on low- to moderate-gradient hydrologically connected[6] roads to disperse surface runoff and discharge it onto native hillslope below the road. Rolling dips extend from the inboard edge to the outboard edge of a road, and are constructed at intervals as needed to control erosion (typically 100, 150, or 200 ft). They are effective in reducing year-round ("chronic") sediment delivery from road surfaces, and are designed to be easily drivable and not impede vehicular traffic.

3. Road shaping. Road shaping changes the existing geometry or orientation of the road surface, and is accomplished through *insloping* (sloping the road toward the cutbank), *outsloping* (sloping the road toward the outside edge), or *crowning* (creating a high point down the center axis of the road so that it slopes equally inward and outward). Like rolling dips, road shaping is used to prevent uncontrolled delivery of road surface runoff by dispersing it into the inside ditch or onto the hillslope below the road. This is also effective in preventing the formation of gullies at the edge of the road, and localized slope instability below the road.

3. Installing ditch relief culverts. A ditch relief culvert is a drainage structure (usually an 18 in. pipe) installed across a road prism to move water and sediment from the inboard ditch so that it can be dispersed on native hillslope beneath the road. Ditch relief culverts are used to drain ditch flow on roads that are too steep for rolling dips or outsloping, as well as at sites with excessive flow from springs or seepage from cutbanks.

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5 The *100-year peak storm flow* for a location is the discharge that has a 1% probability of occurring at that location during any given year.

6 *Hydrologically connected* describes sites or road segments from which eroding sediment is delivered to stream channels (Furniss et al., 2000).

Table A1. Characteristics of storm-proofed roads (*from* Weaver et al., 2006).

Storm-proofed stream crossings

- All stream crossings have a drainage structure designed for the 100-year peak storm flow (with debris).
- Stream crossings have no diversion potential (functional critical dips are in place).
- Stream crossing inlets have low plug potential (trash barriers installed).
- Stream crossing outlets are protected from erosion (extended beyond the base of fill; dissipated with rock armor).
- Culvert inlet, outlet, and bottom are open and in sound condition.
- Undersized culverts in deep fills (greater than backhoe reach) have emergency overflow culvert.
- Bridges have stable, non-eroding abutments and do not significantly restrict 100-year flood flow.
- Fills are stable (unstable fills are removed or stabilized).
- Road surfaces and ditches are "hydrologically disconnected" from streams and stream crossing culverts.
- Class I stream crossings meet CDFG and NMFS fish passage criteria (Taylor and Love, 2003).

Storm-proofed fills

- Unstable and potentially unstable road and landing fills are excavated or structurally stabilized.
- Excavated spoil is placed in locations where it will not enter a stream.
- Excavated spoil is placed where it will not cause a slope failure or landslide.

Road surface drainage

- Road surfaces and ditches are "hydrologically disconnected" from streams and stream crossing culverts.
- Ditches are drained frequently by functional rolling dips or ditch relief culverts.
- Outflow from ditch relief culverts does not discharge to streams.
- Gullies (including those below ditch relief culverts) are dewatered to the extent possible.
- Ditches do not discharge (through culverts or rolling dips) onto active or potential landslides.
- Decommissioned roads have permanent drainage and do not rely on ditches.
- Fine sediment contributions from roads, cutbanks, and ditches are minimized by utilizing seasonal closures and implementing a variety of surface drainage techniques including berm removal, road surface shaping (outsloping, insloping, or crowning), road surface decompaction, and installing rolling dips, ditch relief culverts, waterbars, and/or cross-road drains to disperse road surface runoff and reduce or eliminate sediment delivery to the stream.

4. Excavating unstable fillslope. The fillslope, the sloping part of the road between its outboard edge and the natural ground surface below, may fail or show signs of potential failure. As a preventative measure, unstable fillslope sediment is excavated and relocated to a permanent, stable spoil depository site.

5. Upgrading stream crossings. Techniques used to remediate road related erosion at a stream crossing are dependent on the size of the stream channel, and specific physical characteristics at the crossing site. Class I and large stream crossings may require a bridge, or, if their banks are small or low gradient, a ford crossing may be suitable, particularly if seasonal use is anticipated. A common approach to upgrading moderate sized Class II and III crossings is to construct a culverted fill crossing capable of withstanding the 100-year flood flow. Techniques for upgrading small stream crossings include:

5.1 Installing or replacing culverts. A culvert capable of withstanding the 100-year storm flow, including expected sediment and debris, is installed or replaced in the fill crossing. Culverts on non fish-bearing streams are placed at the base of fill, in line and on grade with the natural stream channel upstream and downstream of the crossing site. Backfill material, free of woody debris, is compacted in 0.5-1.0 ft thick lifts until 1/3 of the diameter of the culvert has been covered. At sites where fillslopes are steeper than 2:1, or where eddying currents might erode fill on either side of the inlet, rock armor is applied as needed.

5.2. Installing an armored fill. Armored fills are installed on smaller stream crossings with relatively small fill volume, but where debris torrents are common, channel gradients are steep, or inspection and maintenance of a culverted crossing is impossible. The roadbed is heavily rocked, and a keyway in the outboard fillslope is excavated and backfilled with interlocking rock armor of sufficient size to resist transport by stream flow. Armored fill crossings are constructed with a dip in the axis of the crossing to prevent diversion of the stream flow, and focus the flow over the part of the fill that is most densely armored.

5.3 Installing secondary structures. A variety of secondary structures may be used to increase the function of small stream crossings by allowing uninterrupted stream flow, decreasing flooding, and controlling erosion. Where a culvert has been improperly installed too high in the fill, a *downspout* may be added to its outlet to release the flow close to the ground surface, rather than letting it cascade from the height of the culvert. *Rock armor* may be used to buttress steep fillslopes, as well as to prevent erosion of inboard or outboard fillslopes by eddying currents. A *trash rack* placed in the channel above a culvert inlet will trap debris and reduce plugging. To prevent stream diversion should the culvert become plugged or its capacity exceeded, a *critical dip* (essentially a rolling dip constructed in line with the stream channel) may be installed to ensure that stream flow will be directed across the road and back into the natural channel. Finally, an *overflow culvert* may be a necessary addition at a culverted crossing where, because of site conditions, plugging or capacity exceedence of the primary culvert is anticipated.

Road decommissioning

The procedures for decommissioning roads using heavy equipment are widely accepted and described in further detail elsewhere (Weaver and Sonnevil, 1984; Weaver et al., 1987, 2006; Harr and Nichols, 1993; Pacific Watershed Associates, 1994). In essence, road decommissioning is “reverse road construction,” and, to an extent, reversion to natural landscape, although topographic obliteration of the entire roadbed is not usually required to achieve cost-effective erosion prevention. Serious erosion problems are typically confined to a few, isolated locations along a road, often as little as 10% to 20% of the full road network to be decommissioned. Examples of serious erosion problems might include stream crossings that need to be excavated, unstable sidecast on the downslope side of a road or landing that must be removed before it fails, or a section of road that must be entirely removed where it crosses unstable terrain. Commonly, stretches of road beyond the extent of individual treatment sites only require relatively simple, permanent improvements to surface drainage, such as surface decompaction, construction of cross-road drains, and/or partial outsloping. In increasing order of complexity, road decommissioning may include the following techniques:

*1. Road ripping or decompactio*n. Road ripping is a technique in which the surface of a road or landing is disaggregated or "decompacted" to a depth of at least 18 in. using mechanical rippers. This action reduces or eliminates surface runoff and usually enhances revegetation.

2. Installing cross-road drains. Cross-road drains (also called “deep waterbars”) are large ditches or trenches excavated across a road or landing surface to provide drainage and prevent runoff from traveling along, or pooling on, the former road bed. They are typically installed at 50, 75, 100 or 200 ft intervals, or as necessary at springs and seeps. In some locations (e.g., streamside zones), partial outsloping may be used instead of cross-road drain construction.

3. In-place stream crossing excavation (IPRX). IPRX is a decommissioning treatment used for roads or landings that are built across stream channels. The fill (including the culvert or Humboldt log crossing) is completely excavated and the original streambed and side slopes are exhumed. Excavated spoil is stored at nearby, stable locations where it will not erode. In some cases, this may necessarily be as far as several hundred feet from the crossing. An IPRX typically involves more than simply removing a culvert, as the underlying and adjacent fill material must also be removed and stabilized. As a final measure, the sides of the channel may be cut back to slopes of 2:1, and mulched and seeded for erosion control.

4. Exported stream crossing excavation (ERX). ERX is a decommissioning treatment in which stream crossing fill material is excavated and the spoil is hauled off-site for storage (the act of moving spoil material off-site is called “endhauling”). This procedure is necessary when large, stable storage areas are not available at or near the excavation site. It is most efficient to use dump trucks to endhaul the spoil material.

5. In-place outsloping (IPOS). IPOS (also called "pulling the sidecast") calls for excavation of unstable or potentially unstable sidecast material along the outside edge of a road prism or landing, and placement of the spoil on the roadbed against the corresponding, adjacent cutbank or within several hundred feet of the site. As a further decommissioning measure, the spoil material is placed against the cutbank to block access to the road.

6. Export outsloping (EOS). EOS is a technique comparable to IPOS, except that spoil material is moved off-site to a permanent, stable storage location. EOS is required when it is not possible to place spoil material against the cutbank, e.g., where the road prism is narrow or where there are springs along the cutbank. EOS usually requires dump trucks to endhaul the spoil material. This technique is used for both decommissioning and upgrading roads, but as the roadbed is partially or completely removed, EOS is more commonly used for decommissioning.

Appendix B

Schematic diagrams (typical drawings) of recommended treatments

Appendix C

Summary of Field Inventory Site Data

Summary of Field Inventory Site Data, Pepperwood Preserve / Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, CA

Site #	Problem	Comment on Problem	Erosion Potential	Left ditch/ road length (ft)	Right ditch/ road length (ft)	Future sediment delivery (yds3)	Treatment Immediacy	Comment on treatment
1	Stream crossing	Stream initiates 300' above the road. It is currently diverted to the right and drains across the road through a ditch relief culvert (site 2). During peak flow the stream appears to flow over the road surface. Bechtel House Road is well maintained and near the ridge top.	L	242	0	10	L	1. Excavate from TOP to BOT, install a 24" x 60' culvert at channel grade and in the natural stream axis. 2. Outslope left road approach for 100'. 3. Define channel for 20' above TOP. 4. Construct a critical dip along right hingeline.
2	Spring	A 12" ditch relief culvert drains 165' of right road and 115' of left road surface and springy ditch as well as a spring located beneath a Bay tree on the inboard side of the road. The road appears to have been built through a swale with stream initiation occurring below. It is likely the stream detailed in site 1 has diverted to this location in the past. Inlet and outlet as well as fill prism appear armored. The pipe appears worn and should be bigger.	L	115	165		L	1. Replace existing culvert pipe with 18" x 20' ditch relief culvert- set inlet and outlet at current locations and utilize existing in-place armor if possible. 2. Install 1 rolling dip to the right. 3. Outslope road/fill ditch 165' right. 4. Clean/cut ditch 115' left to site 1.
3	Stream crossing	An ephemeral stream in a swale setting with a defined channel above the inboard road. Below the outboard fill the stream meanders through a grassy meadow for 90' to a break in slope and channel becomes clearly defined again. The current pipe is set too high in the fill and water is ponding at inlet before it can pass through.	L	33	40	12	L	1. Excavate from TOP to BOT. 2. Install an 18" x 40' culvert at channel grade and in the natural stream axis. 3. Spoil locally.
4	Stream crossing	Low flow ephemeral stream with clearly defined channel above TOP. Stream goes subsurface shortly below crossing into the hummocky, grassy natural hillslope. Surface flow connects during peak events.	L	300	60	4	L	1. Construct an armored fill crossing: Create a broad dip, excavate a keyway 7'w (avg.) x 9'h x 2'd, place 5 cubic yards of 0.5-1.5' rock armor. 2. Outslope 300' of left road. 3. Construct 2 rolling dips along left approach.

Summary of Field Inventory Site Data, Pepperwood Preserve / Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, CA								
5	Stream crossing	A class II flows through a 48" culvert, which is set high in the fill with a 4' drop at the outlet to creek level, though this area is well armored. The pipe appears plenty big but is rusting and short. Diversion potential to the left. The IBF and OBF fully armored and may be difficult to get pipe lower due to channel bedrock.	ML	0	90	55	ML	1. Excavate channel from TOP to BOT and replace culvert at grade, 48" x 50'. 2. Install a critical dip on left hingeline. 3. Outslope 90' of right approach.
6	Stream crossing	Large stream with a lot of potential power. Above inlet there is a depositional area created from a Bay tree growing in the channel. Stream appears to erode the right bank and deposits sediment on the left bank; appears to be flowing into the inlet okay for now. JH 3/12/08- The outboard fill face is vertical and failing. Pipe should be replaced and set deeper. Rebuild fill at 2:1. May need to remove Bay cluster downstream of crossing on left bank. Culvert seems to be adequately sized.	M	170	2533	127	L	1. Excavate from TOP to BOT. 2. Replace culvert with 60" x 60' and rebuild fill face at 2:1. 3. Outslope left approach 170' and construct 1 rolling dip. 4. Outslope right approach 1400' on road to Turtle Pond. 5. Retain outslope and ditch adjacent to DRCs. 6. Install 17 rolling dips to right.
7	Stream crossing	A 12" CMP, undersized and high in the fill, drains 542' of left road length and a small 2 x 1/2 class 3 stream. The outlet is shotgunned and much of the outboard fill has already eroded (approximately 6'w x 3'd x 22'l). Two ditch relief culverts are present along the 542' left approach. This whole area appears to be very springy.	M	542	0	30	HM	1. Excavate TOP to BOT, replace existing culvert pipe with a 24" x 60' pipe at channel grade oriented in the natural stream axis. 2. Install critical dip along right hingeline. 3. Install 2 18" x 30' ditch relief culverts along left road approach. 4. Outslope road/keep ditch 542' left. 5. Install 4 rolling dips along left road approach to drain road surface only (do not connect to ditch).
8	Spring	Five separate ditch relief culverts drain a springy hillside along a streamside road. The ditch relief culverts are fairly new and in good working condition and deliver to the stream via a gently sloping grassy hillside. All have minor erosion gullies below the outlets.	L	1500	20		L	1. Install 4 additional 18" x 40' ditch relief culverts. 2. Outslope 1500' of left road approach.

Summary of Field Inventory Site Data, Pepperwood Preserve / Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, CA

9	Ditch relief culvert	An 18" ditch relief culvert drains 50' of left approach, including a small stream (detailed in site 10) and a springy hillslope. The outlet shotguns, though the pipe is either rusted through or separated and water is piping out through the fill. The outboard fill face is heavily brush covered, making for difficult assessment of the outlet, though the scour hole below the outlet is 17'd and 3-6' across. Treatment of site 10 will likely cut much of the flow to this site.	HM	50	0	15	ML	1. Replace pipe with 18" x 30' ditch relief culvert and attach an 18" x 10' downspout.
10	Stream crossing	The hillside above road is hummocky and vegetated with grasses. Stream initiates ~100' above in low crenulation on hillside. The concentrated stream flow is diverted to right at the road and travels down road surface and in ditch to site #9.	ML	65	0	69	L	1. Construct an armored fill crossing: Create a broad dip, excavate keyway 5'x44', place 20 yds3 of 0.5-1.5' rock. 2. Outslope 50' of the left approach.
11	Stream crossing	A 3x1 class III stream in a springy grassland setting drains through a 24" CMP set high in the fill. Aggraded sediment is present below the future outlet, possibly building up on a stump or rock. Pipe can outlet at xs3 location, and channel grade established by excavating from the turn to the BOT. 3/12/08 JG- Unknown mechanism retaining downstream sediment. Have equipment remove vinca to see what it is, then decide whether to excavate. Outlet pipe at trees on rock.	M	160	0	36	M	1. Excavate from the TOP to the BOT and install a 24" x 50' culvert. Place outlet at xs3 location, ~38' upstream from the BOT. 2. Install critical dip on the right hingeline. 3. Install 1 rolling dip to the left. 4. Outslope and cut ditch 160' to left. 5. Install 1-18" x 40' DRC along left approach. 6. Spoil locally.

Summary of Field Inventory Site Data, Pepperwood Preserve / Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, CA								
12	Stream crossing	This stream channel is the remnant morphology of the drainage dammed to create Turtle Pond. This now likely acts as on overflow channel and intercepts some hillside surface flow. Very little road if any exists where channel crosses the road an down channel crosses the road an down channel is visible on the outboard road side, suggesting historic flows have diverted left and dispersed on the broad natural low gradient bench across which the road is built. Treatments are for diversion protection of the road.	M	0	640		M	1. Create a broad, large critical dip. 2. Outslope and fill ditch 640' to the right. 3. Install 4 rolling dips along right approach.
13	Ditch relief culvert	The DRC drains 425' of left road into headwall of a class III stream. The inlet is 30% plugged with coarse gravels and leaf litter from crumbling hillside and road. DRC also drains the hillside.	L	425	0		L	1. Construct 3 rolling dips on left approach. 2. Outslope and keep ditch for 100' to left of DRC. 3. Clean the DRC at the inlet.
14	Road surface	Condensed road drainage, a very springy cutbank/hillside, and possibly a diverted flows from the stream detailed in site #12, contribute flows to a series of 3 OBF streamlet/gully features which deliver to a swale and ultimately a crack. Currently road drainage condenses in those features and should be dispersed. FE based on possible enlargement of all 3 gully features.	M	325	0	14	M	1. Outslope/cut ditch 325' of left approach. 2. Install 2 rolling dips to drain road surface only. 3. Install 2 18" x 30' DRCs.
15	Road surface	A discharge point of the road drainage along a grassed over seasonal road through a swale above stream initiation.	ML	0	185		ML	1. Outslope and fill ditch for 185' to the right. 2. Modify existing waterbars by replacing with 2 rolling dips.
16	Stream crossing	This portion of road has little to no road fill and surface is fully vegetated with grass. The road here is near the base of a wide valley and during large storm events is likely to be under water. A small berm on the left is built to prevent diversion but is not sufficient. Some of the stream flow diverts to left for 120' and then saturates into road surface. No past erosion visible.	L	0	315		L	1. Enhance ford crossing with broad dip. 2. Outslope right approach. 3. Construct 2 rolling dips on right.

Summary of Field Inventory Site Data, Pepperwood Preserve / Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, CA

18	Stream crossing	Low use seasonal road width with fill crossing. The stream travels across vegetated road surface with minor erosion and travels down the OBF via gully. The gully will continue to migrate into road fill. Surrounding hillsides are very springy but vegetated native road (plus intermittent outslope) reduce future erosion. 3/12/08 JG-Low use seasonal road, fully grassed over. Treatment should be light.	ML	0	420	10	L	1. Construct an armored fill crossing: Create a broad dip, excavate keyway 7' wide x 26' long, and place 15 yds3 of 0.5-1.5 of rock. 2. Construct 3 rolling dips on right. 3. Spoil locally.
19	Stream crossing	A steep 3x1 class III stream crosses Goodman road in partially washed out fill crossing. 375' of right road contributes to crossing. Road is low use grassed over seasonal route. 3/12/08 JG-No outslope. Road is outsloped with wet cutbanks, but well vegetated with minimal use. Rolling dips only.	M	0	375	16	M	1. Construct an armored fill crossing: Create a broad dip, excavate keyway 11' wide x 27' long, and place 25 yds3 of 0.5-1.5 of rock.2. Construct 3 rolling dips on right.3. Spoil locally.
20	Stream crossing	The stream is downcutting through the steep, poorly consolidated hillside and depositing large gravels eroding out of bedrock onto the road surface. Small, low power stream with diversion potential. 3/12/08 JG-Rolling dips only on well vegetated road. Rolling dips only on well vegetated road. Road is outsloped already.	L	0	345	11	L	1. Construct an armored fill crossing: Create a broad dip, excavate keyway 7' wide x 30' long, and place 15 yds3 of 0.5-1.5 of rock. 2. Construct 2 rolling dips on right. 3. Spoil locally.
21	Stream crossing	A small fill crossing along Goodman road. The 2x0.5 class III diverts left a short way before exiting roadbed. Short right approach.	ML	0	75	5	ML	1. Construct an armored fill crossing: Create a broad dip, excavate keyway 7' wide x 25' long, and place 15 yds3 of 0.5-1.5 of rock. 2. Spoil locally.
22	Stream crossing	Small stream erodes through poorly unconsolidated slump block and diverts into IBD. May be remnant swale below road. The road here is less than 100' away from main channel.	L	0	145	15	L	1. Construct an armored fill crossing: Create a broad dip, excavate keyway 7' wide x 29' long, and place 15 yds3 of 0.5-1.5 of rock. 2. Clean and cut ditch for 100' on right. 3. Rock right approach 100'x12'.

Summary of Field Inventory Site Data, Pepperwood Preserve / Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, CA								
23	Ditch	Currently the stream detailed in site #22 diverts into the IBD, which travels next to the road for ~100' before fanning out above the creek. Treatment at site @@ will cut off the majority of flows to this site and very little will be gained by trying to dewater the ditch of cut bank flow. Sediment will deposit on flood plain and enter stream during high flows.	L	0	100			No treat.
24	Stream crossing	A large class I? stream is culverted under the road in 2 48" side by side cmps that are armored with Gabion structures at the inlet and outlet. Preserve manager informed us this crossing is scheduled for decommission this summer. All Pepperwood owned road past this crossing is abandoned and unused, and will be assessed for decommission.	HM	150	115	72	M	1. Excavate from the TOP to the BOT, remove pipes and armor, and lay back sideslopes 2:1. 2. Store spoils locally. 3. Construct 3 cross road drains.
25	Stream crossing	Natural channel is filled with large cobbles. The ephemeral stream plus downslope processes transport sediment and has enough power to erode crossing. The road is built on top of unconsolidated terrace and/or debris flow deposits. A significant amount of the crossing is washed out, leaving a 7' headcut near the center of the road. The headcut will continue to migrate overtime. The road approaches show low surface erosion. They are covered with grasses and oak litter and some small pines.	HM	0	0	158	HM	1. Decommission crossing: Excavate from the TOP to the BOT with a 4' channel width, and lay back sideslopes 2:1. 2. Endhaul spoils to left.
26	Stream crossing	A flashy 2x1 class III has partially washed this fill crossing on an abandoned unused walk road. A large amount of the road has eroded, possibly as a result of eddying and undercutting during high flows from the main creek.	M	190	0	24	M	1. Decommission crossing: Excavate from the TOP to the BOT with a 4' channel width, and lay back sideslopes 2:1. 2. Spoil Locally. 3. Install 2 cross road drains to left.

Summary of Field Inventory Site Data, Pepperwood Preserve / Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, CA								
27	Stream crossing	A pulled crossing on the main channel through the canyon- may be upper Mark West Creek and a fish crossing, though no fish were seen during survey and stream likely dries out during summer. Remaining side slopes are stabilized by abundant roots and small trees are growing on the road surface.	L	25	375	0		No treat
28	Stream crossing	A small, flashy 2 x 0.5 class 3 stream diverts down the left road. Flows appear to settle on road surface and infiltrate the coarse channel rock used as road bed material prior to entering main creek. It is possible a gully may eventually develop if left untreated. 3/12/08 JG- Stream is in a depositional environment. No future. No treat.	L	0	15	0		No treat
29	Road surface	Stream crossing detailed in site #28 diverts left and mainly saturates into road surface at the break in slope. During high flows it may deliver to the main creek via a gully at this site. Both road approaches and the gully and minimal future erosion is likely to occur. Right approach is possibly a flood plain of the main creek and the left is built above the creek and partially outsloped.	L	160	145	0		No treat
30	Stream crossing	Small, steep channel diffuses through duff and fill flows over headcut above washed out road. The road is gone through the crossing due to channel scour from main creek. Stream is undercutting headcut and will continue to migrate upstream but future erosion is minimal. To the right and left of this site the main channel is scouring through the road.	ML	0	60	0		No treat

Summary of Field Inventory Site Data, Pepperwood Preserve / Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, CA								
31	Stream crossing	A small ephemeral stream, which has been heavily altered upslope by skids, combines with abundant natural spring flow on the hillside to create a soggy road bed and possibly rilling to minor gullying during large precipitation events. Not a lot of road fill here though dipping the road surface will help reduce diversion and associated impacts to the road surface. The channel appears to have been diverted upstream of the crossing by a neighbors skid road (outside of the property). Road is unused, vegetated, and is to be decommissioned.	L	80	0	0	L	No treat
32	Stream crossing	A ford crossing on a fairly small class 2 stream with stable, low gradient approaches along a low use, grassed over seasonal road which appears to have little or no road fill. No treat as is; if road use resumes/increases, install 2 broad, gradual, low-gradient dips would benefit the left road approach.	L	475	60			No treat
33	Stream crossing	This crossing acts as a conduit for flows from a near origin stream in a broad, grassy swale. The road approaches are grassed over and appear to have little or no fill. The culvert is placed askew of the natural stream axis and a scour hole is visible near the outlet. Large rocks have been placed at the inlet and aggraded gravels are collecting. During high flows the stream appears to wash over the stream bank through a grassy hillside, across the road and down the outboard fill face. The outboard fill face is nearly vertical with bare soil/fill. 3/12/08 JG- Low gradient, vegetated approaches in grassland. No treatment on approaches.	L	230	100	15	L	1. Dip road by 2' through oblique crossing 2. Construct an armored fill crossing using 25 yds3 of .5-1.5 ' rock. Make crossing extra wide to accommodate oblique stream angle 3. Spoil locally.

Summary of Field Inventory Site Data, Pepperwood Preserve / Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, CA								
34	Other	A large, very broad swale concentrates water into IBD and across road through a DRC. The ditch is shallow, rocky, and grassy. During high flows water may overflow and erode through fill. The road approaches are grassy and right road has no road fill. The road approaches are grassy and right road has no road fill. Overflow of turtle pond may come this direction.	L	0	550		L	1. Clean ditch from inlet up to 80'. 2. Construct a critical dip. 3. Clean inlet. 4. Outslope 100' of right approach from crossing.
35	Stream crossing	A small class III 2x0.5 crosses the road through a possible armored fill. 550' of the right road also contributes. Crossing looks good but needs diversion protection and road approaches could benefit from outsloping and rolling dips.	ML	0	550	1	M	1. Construct a critical dip. 2. Outslope 550' of right approach. 3. Install 4 rolling dips along right approach.
36	Stream crossing	Small crossing on low use road. Minimal fill on road approaches and area is vegetated. The crossing is rocked and dipped slightly. The OBF looks stable.	L	380	0	4	L	1. Outslope 180' of left road and construct 1 rolling dip. 2. Outslope remaining 200' and construct 1 rolling dip. 3 Enhance dip though crossing. 4. Place 5 yds3 of 0.5-1.5' rock in dip.
37	Stream crossing	A flashy stream with armored fill crossing which has fallen across the crossing obscuring some details and making accurate profile and cross section problematic. This will have to be removed before treatment. Lots of LWD in channel upstream from road.	M	120	40	106	M	1. Excavate from the TOP to the BOT and install a 30" x 70' long culvert at base of fill in natural stream axis. 2. Install 1 rolling dip to the left. 3. Outslope 120' of left road. 4. Spoil locally.
38	Stream crossing	Large crossing >75% washed out with a foot bridge. Sideslopes are nearly vertical and mostly bare. Good candidate for decommissioning, but land manager would like to keep road open. Stream down to channel grade through crossing. Collapsing sideslopes are largest concern.	M	130	45	34	HM	1. Excavate from the TOP to the BOT and install a 36" x 60' long culvert at base of fill in natural stream axis.3. Install 1 rolling dip to the left.4. Outslope 130' of left road.

Summary of Field Inventory Site Data, Pepperwood Preserve / Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, CA

39	Stream crossing	A low gradient ephemeral 1x0.5' stream appears to have diverted resulting in an outboard fill gully 30' right. Flow appears to have jumped the channel 15' up from the crossing and has incised above the cutbank into the hill and now dumps onto the road surface.	M	65	0	2	M	1. Install and armored fill crossing by dipping out the road surface, excavating a keyway 4.5'w x 22'l x 2'd and placing 10 cubic yards of 0.5-1.5' rock armor in keyway. 2. Transition/establish channel for 20' above TOP. 3. Use spoils to build up right road to act as further diversion deterrent.
40	Road surface	Discharge point at low spot in the road. During high precipitation events site 38 may divert to this location. A diversion gully runs through the road surface and into the inboard road due to insloping. Road is grassed over. Past erosion gully down outboard fill face to creek (3'w x 1'd x 20'l).	L	145	0		L	1. Outslope left approach 145'. 2. Install 1 rolling dip along left approach.
41	Stream crossing	This is the last site on Skovie Road. There is no road fill present at the crossing, and approaches are diffuse, vegetated and rocky. Stream is currently dry.	L	40	30	0		No treat.

ATTACHMENT B

Pacific Watershed Associates 2012 Memorandum

PACIFIC WATERSHED ASSOCIATES INC.

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Ph 707-773-1385 • Fax 707-773-1451
www.pacificwatershed.com

May 25, 2012

Andy Casarez
Sotoyome Resource Conservation District
P.O. Box 11526
Santa Rosa, CA 95406

Re: Summary of adjusted costs based on re-evaluation of site conditions and 2012 implementation costs to execute erosion control and sediment reduction measures at Pepperwood Preserve (Contract #SRNO-002).

Dear Andy:

At your request, Pacific Watershed Associates (PWA) has prepared an adjusted cost table with a brief summary of current site conditions and 2012 implementation costs estimated to execute erosion control and sediment reduction measures recommended in the *Pepperwood Preserve/Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, California* (PWA Report #08081301, March 2008).

On 16 May 2012, PWA staff conducted an onsite field review of the project area and existing plans to confirm original recommendations from the 2008 assessment. Some adjustments were made to the treatment prescriptions based on current conditions on the property and two additional sites were identified and recommended for treatment (Table 1, Map 1). PWA staff adjusted the overall estimated project costs and sediment saving estimates for the 34 sites recommended for treatment as well as associated hydrologically connected road required to perform the recommended erosion control measures (Table 2). The cost estimate is based on current prevailing wage equipment rates and materials quotes from local providers.

We understand that construction is intended to begin this season. However, based on funding, permitting, scheduling qualified equipment operators and technical oversight; construction might require two seasons. If two seasons are needed to complete construction, an estimated $12,000-$15,000 of additional costs should be added to the 2012 adjusted cost estimate (Table 2). Additional charges required for a second construction season include: equipment re-mobilization; additional special species surveys, permit extensions, and agency field reviews; pre-construction layout, field meetings, and coordination; and construction materials coordination and delivery charges.

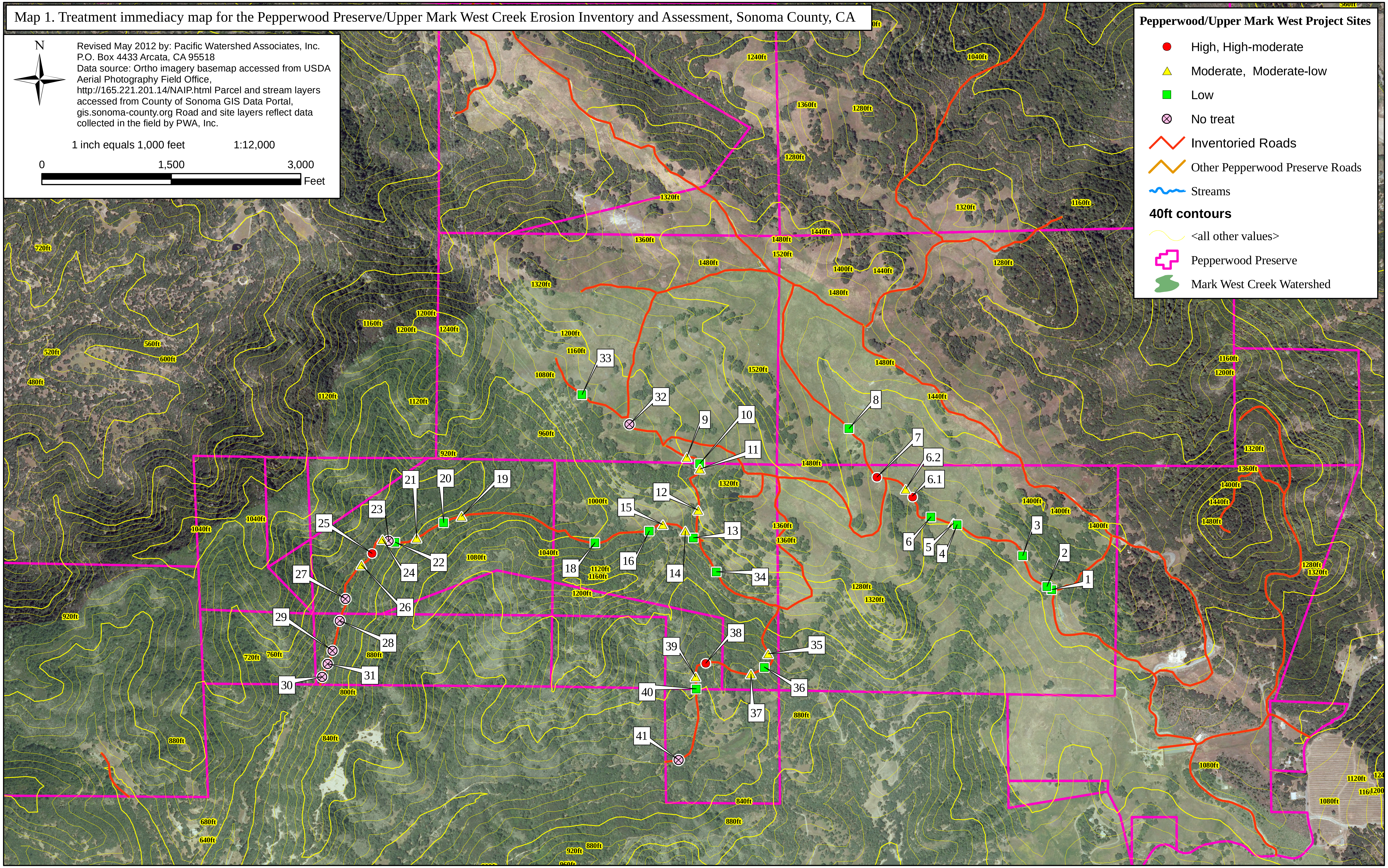
Table 1. Summary data table for additional inventoried sites in 2012, Pepperwood Preserve/Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, CA						
Site #	**Problem**	**Comment on problem**	**Erosion potential**	**Future delivery (yds^3)**	**Treatment immediacy**	**Comment on treatment**
6.1	Stream crossing	Ephemeral stream crossing with undersized 9 inch culvert, located down the road from site 7, up from site 6. The undersized culvert is set high in the fill so that flows cannot enter into it and stream diverts for approximately 275 feet down the ditch and off the road creating a gully which eventually delivers to the stream below site 6. Future erosion estimate is based on ditch expansion. Connected road length is already attributed to site 6 (along with road drainage treatment recommendations from 2008).	HM	30	HM	1. Excavate from TOP to BOT, replace existing culvert with a 24" x 30' pipe set at the base of fill and in the natural stream axis. Upon re-build, raise the road bed 2' to protect pipe and narrow tread to 10' width to accommodate 30' pipe length with 2:1 fillslopes. 2. Excavate the sediment lobe above the pipe inlet to define the channel; establish a 4' channel width with 2:1 sideslopes. 3. Construct a critical dip along the right hingeline (use spoils from crossing excavation).
6.2	Stream crossing	New 30" diameter culvert installed near channel grade and in line with stream channel. Small drop at the outlet with armor for energy dissipation. Hummocky hillslope above. Connected road length is already attributed to site 6 (along with road drainage treatment recommendations from 2008).	L	18	ML	1. Construct a critical dip along the right hingeline.

Table 2. Estimated equipment times and costs to implement erosion control-and-prevention treatments, Pepperwood Preserve/Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, California. **Adjusted in 2012**

Cost category[1]		Cost rate[2] ($/hr)	Estimated Project Times			Total estimated costs[5] ($)
			Treatment[3] (hr)	Logistics[4] (hr)	Total (hr)	
Move in, move out[6]	Excavator	115	12	--	12	1,380
	Bulldozer	115	12	--	12	1,380
	Roller	115	12	--	12	1,380
	Water truck	115	12	--	12	1,380
	Truck/trailer	90	4	--	4	360
Road Opening	Excavator	195	5	--	5	975
	Bulldozer	165	5	--	5	825
Heavy equipment for site-specific treatments[7]	Excavator	195	101	30	131	25,545
	Bulldozer	165	75	23	98	16,170
	Dump truck	125	19	6	25	3,125
	Roller	145	145	11	3	2,030
	Water truck	115	46	14	60	6,900
	Truck/trailer	90	28	8	36	3,240
Heavy equipment for road drainage treatments	Excavator	195	63	19	82	15,990
	Bulldozer	165	109	33	142	23,430
	Roller	145	65	20	85	12,325
	Water truck	115	43	13	56	11,130
Laborers[8]		70	122	37	159	11,130
Rock costs (includes trucking for 1,095 yd^3 of road rock and 165 yd^3 of riprap)						31,974
Culvert materials costs (570’ of 18”, 240’ of 24”, 60’ of 36”, 50’ of 48”, 60’ of 60”, including costs for couplers and elbows)						29,793
Mulch, seed, and planting materials for 0.75 acres of disturbed ground[9]						600
Layout, coordination, supervision, and reporting[10]						38,415
Contract administration, permitting, CEQA[11]						50,104
Total Estimated Costs: $284,891						

(Continued on next page.)

[1]Costs excluded from the list are for (1) tools and miscellaneous materials, (2) variable administration and contracting expenses, and (3) repaving upgraded roads.
[2]Heavy equipment costs include operator and fuel. Costs listed are estimates for favorable local private sector equipment rental and labor rates.
[3]Treatment times refer to equipment hours expended explicitly for erosion control-and-prevention work at all project sites and roads.
[4]Logistics times for heavy equipment (30%) include all equipment hours expended for opening access to sites on maintained and abandoned roads, travel time for equipment to move from site to site, and conference times with equipment operators to convey treatment prescriptions and strategies. Logistic times for laborers (30%) include estimated daily travel time to project area.
[5]Total estimated project costs for equipment rental and labor are based on private sector rates at prevailing wage and updated materials costs from 2012. All costs are subject to change. In addition, all costs assume 1 construction season only. If two seasons are required, additional costs will be incurred.
[6] Move in and one to move out times are based on 2 hauls each (1 to move in and 1 to move out) at 6 hours per trip, for excavator, bulldozer, water truck, truck/trailer and roller to move into the Pepperwood Preserve, and an additional 5 hours each for the excavator and bulldozer to move in between work sites and open access to sites.
[7]An additional 3 hr of dump truck time are added for importing fill for stream crossing backfills, and 18 hr of truck/trailer time are added for delivering straw to sites. A total of 10 hr of excavator and truck/trailer time are added for distributing culverts to sites.
[8]An additional 18 hr of labor time are added for delivering straw to sites and 8 hr for spreading straw mulch and seeding.
[9]Seed costs are based on 26 lb of native seed per acre at $11.50/lb. Straw needs are 37 bales per acre at $6.75/bale.
[10]Supervision time includes detailed layout (flagging, etc) prior to equipment arrival; field review with the client and representatives from partner organizations, funders and/or permitting agencies; training of equipment operators, materials coordination, supervision during equipment operations, supervision of labor work, and post-project documentation and reporting.
[11]This time includes; contract administration; preparation of permits and CEQA documents, permit and CEQA fees, field visits with permitting agencies, subcontractors and clients; onsite review during construction to ensure adherence to CEQA mitigation; documentation and reporting; 10% overhead.


Map 1. Treatment immediacy map for the Pepperwood Preserve/Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, CA
N
Revised May 2012 by: Pacific Watershed Associates, Inc.
P.O. Box 4433 Arcata, CA 95518
Data source: Ortho imagery basemap accessed from USDA Aerial Photography Field Office, http://165.221.201.14/NAIP.html Parcel and stream layers accessed from County of Sonoma GIS Data Portal, gis.sonoma-county.org Road and site layers reflect data collected in the field by PWA, Inc.
1 inch equals 1,000 feet
1:12,000
0
1,500
3,000
Feet
Pepperwood/Upper Mark West Project Sites
High, High-moderate
Moderate, Moderate-low
Low
No treat
Inventoried Roads
Other Pepperwood Preserve Roads
Streams
40ft contours
<all other values>
Pepperwood Preserve
Mark West Creek Watershed

ATTACHMENT C

ETS Laboratory Results

ETS

Environmental Technical Services

975 Transport Way, Suite 2
Petaluma, CA 94954
(707) 778-9605/FAX 778-9612
e-mail: entech@pacbell.net

-Soil, Water & Air Testing & Monitoring
-Analytical Labs
-Technical Support

Serving people and the environment so that both benefit.

CLIENT: Sotoyome Resource Conservation District, 201 Concourse Blvd., Santa Rosa, CA
ATTN: Valerie Minton
SITE: Pepperwood, Mark West Springs, Santa rosa, California

DATE COLLECTED	DATE RECEIVED	DATE of COMPLETION	ANALYST(S)	SUPERVISOR	LAB DIRECTOR
unk	4/19/2012	5/1/2012	D. Salinas S. Santos	D. Jacobson	G.S. Conrad,PhD

LAB SAMPLE NUMBER	SAMPLE ID	SOURCE &/or TYPE of SOIL/SEDIMENT	Soil pH - log [H+]	SOLUBLE SALTS mS/cm	AMMONIA-N NH4-N ppm	NITRATE-N NO3-N ppm	PHOSPHOROUS PO4-P ppm	POTASSIUM K PPM
04866-1	PPWD	Site #5						
04866-2	PPWD	Site #7						
04866-3	PPWD	Site #12						
04866-4	PPWD	Site #14						
04866-5	PPWD	Site #19						
04866-6	PPWD	Site #21						
04866-7	PPWD	Site #24						
04866-8	PPWD	Site #25						
04866-9	PPWD	Site #26						
04866-10	PPWD	Site #35						
04866-11	PPWD	Site #37						
04866-12	PPWD	Site #38						
04866-13	PPWD	Site #39						

LAB SAMPLE NUMBER	SAMPLE ID	SOURCE of WATER	CALCIUM Ca ppm	MAGNESIUM Mg ppm	PERCENT ORGANIC MATTER	TOTAL NITROGEN Ntot ppm	TOTAL PHOSPHOROUS Ptot ppm	TOTAL POTASSIUM Ktot ppm
04866-1	PPWD	Site #5				1,522	300	
04866-2	PPWD	Site #7				1,479	312	
04866-3	PPWD	Site #12				2,044	310	
04866-4	PPWD	Site #14				1,702	118	
04866-5	PPWD	Site #19				675	181	
04866-6	PPWD	Site #21				744	185	
04866-7	PPWD	Site #24				1,285	240	
04866-8	PPWD	Site #25				794	191	
04866-9	PPWD	Site #26				949	188	
04866-10	PPWD	Site #35				14,572	228	
04866-11	PPWD	Site #37				6,802	201	
04866-12	PPWD	Site #38				945	124	
04866-13	PPWD	Site #39				2,458	245	

COMMENTS

Total nitrogens are consistent with moderate to low organic content soils in all but two cases. Levels are mostly in the range of 600-2500 ppm with one at <7,000 and another at >14,500 ppm! These latter two are consistent with obvious organic matter content of soil from Sites #35 & # 37; the former appears to have more OM than the latter, while the latter seems to have more than the other sites in this set. All of the Ptot results are at fairly low levels being only in the range of approximately 120-310 ppm. There is no obvious correlation with apparent organic content as there is with nitrogen levels. But the Ptot results may correlate with other factors that might be identified in the field such as with soil type and/or with other properties. It might be expected that mineral nutrient levels (NO_3, NH_3, PO_4-P, etc.) in #35 & #37 soils coud be significantly greater than in all of the other soils.

\\\ NOTES: Test methods follow Methods of Soil Analysis, © 1982, and/or UC Davis as in Plant, Soil and Water Test Methods for the Western Region © 1994, and/or other appropriate university or commercial methods: Ammonia-N and Nitrate-N by aqueous extraction with Nesslerization detection and Cd detection, respectively; Potassium & Sodium by NH4-Acetate extraction and AAS detection; Soil pH by ISE probe on 2:1; Salinity on aequeous ext/ECe meter; OM by wet oxidation (KCr2O4/H2SO4); Ntot - combustion; Ptot - perchlorate dig.

ATTACHMENT D

Credit Calculation Data and Table

Pepperwood Preserve Sampling Results

Analyzed by Environmental Techinical Services (May 1, 2012)

Sampled by Soyotome RCD (April 17, 2012)

			TN ppm	Parent Material lbs/ton[1]	TP ppm	Parent Material lbs/ton
Stream crossing	Site #5		1,522	3.0	300	0.6
Stream crossing	Site #7		1,479	3.0	312	0.6
Stream crossing	Site #12		2,044	4.1	310	0.6
Road surface	Site #14		1,702	3.4	118	0.2
Stream crossing	Site #19		675	1.4	181	0.4
Stream crossing	Site #21		744	1.5	185	0.4
Stream crossing	Site #24		1,285	2.6	240	0.5
Stream crossing	Site #25		794	1.6	191	0.4
Stream crossing	Site #26		949	1.9	188	0.4
Stream crossing	Site #35	*	14,572	29.1	228	0.5
Stream crossing	Site #37	*	6,802	13.6	201	0.4
Stream crossing	Site #38		945	1.9	124	0.2
Stream crossing	Site #39		2,458	4.9	245	0.5
			Mean	5.5	Mean	0.4
			Median	3.0	Median	0.4
			(Remove values of concern)			
			Mean	2.7		
			Median	2.6		

Notes:

Highlighted sites were high in organic matter. However, phosphorus values do not show a similar increase.

The highlighted values are atypical and not applied in the credit equations.

[1] 500 ppm = 1 lb/ton of soil

Site Type	PWA Erosion Measurement (cubic yards)	Dry Density (tons/cubic ft)	Total Sediment Reduction (tons)	Total Nitrogen Reduction (lbs) with Bioavailability (85%)[1]	Total Phosphorus Reduction (lbs) with Bioavailability (51%)[2]	TN & TP Combined Credits/Year	BMP Eligible Life	Total Credits (per year)	Total Credit for Project
Stream crossings	864	0.0375	874.8	2007.7	178.5	2,186	4-years	547	2,186
				92%	8%	100%			
Other (springs, upslope gullies and streambanks)	29	0.045	35.2	80.9	7.2	88	4-years	22	88
				92%	8%	100%			
Road surfaces/ditches	2249	0.055	3339.8	9651.9	340.7	9,993	30-years	9,993	299,777
				97%	3%	100%			
								Total Credits	302,051

Percentages reflect ratio of TN and TP in a combined credit

[1]Total Sediment Reduction (tons)*Nutrient Content*Bioavailability

Where Nutrient Content = 2.7 lbs/ton for stream crossings & other and 3.4 lbs/ton for road surfaces/ditches

[2]Total Sediment Reduction (tons)*Nutrient Content*Bioavailability

Where Nutrient Content = 0.4 lbs/ton for stream crossings & other and 0.2 lbs/ton for road surfaces/ditches

To: Lynn Small, Deputy Director
Environmental Compliance
City of Santa Rosa, CA

Date: July 17, 2012

From: James A. Klang, PE, K&A
Mark S. Kieser, K&A

cc: Dave Smith, Merritt Smith Consulting

RE: Pepperwood Preserve Summary of Best Management Practice Reduction Estimation Methods for City of Santa Rosa Offset Credits

This Kieser & Associates, LLC (K&A) memorandum provides information on the calculations used to determine the offset credits from the City of Santa Rosa Offset credit proposal for Pepperwood Preserve BMPs. The City of Santa Rosa submitted a June 28, 2012 proposal for nutrient offset credits associated with future installation of erosion control practices and restoration at the Preserve. These were submitted as part of their commitment to a no net discharge requirement under the Nutrient Offset Program established by the North Coast Regional Water Quality Control Board. In general, these calculations use estimated sediment loads and soil nutrient concentrations from current sites of erosion or threatened sites of erosion at the Pepperwood Preserve. Soil erosion methods come directly from Pacific Watershed Associates (PWA) site documentation for the Pepperwood Preserve.

Calculation Description

A simple calculation methodology using site-specific soil nutrient concentration data was selected because of the readily available erosion volume estimates provided by PWA. The PWA methods for estimating soil erosion involved an analysis of aerial imagery to document the road network, and extensive field inventories of current and potential road-related sources of erosion (PWA, 2008). K&A obtained site-specific soil nutrient concentration data from the Soyotome Resource Conservation District (RCD).

Soil Erosion Volume Estimation

The methods used by PWA are summarized from their 2008 Report No. 08081301 to the Soyotome RCD (PWA, 2008). PWA analyzed orthophoto imagery from USDA Aerial Photography Field Office to document all roads within the project area. PWA developed a composite map using GIS to depict the locations of inventoried erosion and sediment delivery sites and road segments. The map was used as a reference for on-site field inventories.

PWA completed field inventories of all roads in the project area to identify existing and potential future erosion sites. Erosion sites were defined as locations where direct evidence of current or future erosion or mass wasting, caused by or related to the road network, may deliver sediment to a stream channel. Sites where PWA determined there was no potential for future erosion were not included. Their report noted that the purpose of the study was to evaluate erosion impacts on fish-bearing streams, and thus sites that had no evidence of impacting the stream channel were excluded.

Their 2008 report describes their site assessments as an inventory of stream crossings, gullies below ditch relief culverts, and various other discharge points (e.g., roadside gullies and berm breaks) for uncontrolled sites of erosion (PWA, 2008). PWA recorded a description of the site, nature/magnitude of connected road surface, likelihood of erosion, length of hydrologically connected road surface, and necessary treatment(s). For sites that showed existing problems, they measured the width, depth and length of the potential erosion area to derive a sediment volume. The final recommendation was restoration for 32 of 40 sites that were inventoried. In 2012, PWA conducted a follow-up site assessment to update project costs. In this updated report, PWA recommended restoration at two additional stream crossing sites. (See Attachments A and B of the June 28, 2012 City of Santa Rosa Pepperwood Preserve Credit Proposal for the full PWA reports from 2008 and 2012, respectively.)

PWA (2008) further described their empirical methods on page 9 of their original report. The methodology explains how the lengths of hydrologically connected roads were measured and how an empirical estimate of sediment delivery (cubic feet) is derived. The PWA equation description is presented as Equation 1:

$$SD = L * 25 * 0.2 \quad \textbf{(EQ. 1)}$$

Where:

SD= Sediment Delivery (cubic feet)
L = Measured Length
25 = 25 ft average width, including cutbanks, per decade
0.2 = 0.2 ft average lowering of road per decade

To predict sediment delivery at stream crossings, PWA used tape and clinometer surveying techniques to record measurements and develop longitudinal profiles and cross sections of the sites. Data were then compiled to calculate road fill and potential sediment delivery with the STREAM computer program (see the 2008 PWA report in Attachment A of the Pepperwood Preserve Credit Proposal). Table 2 in the 2008 PWA report presented the sediment delivery results for the 32 recommended restoration and protection sites in cubic yards of sediment delivered to a stream. The total predicted sediment delivery for these sites was 3,094 cubic yards (PWA, 2008). Table 1 in the PWA, 2012 report estimates an additional 48 cubic yards of sediment delivery from the two additional sites.

K&A combined the delivered sediment values from PWA's 2008 and 2012 reports and used 3,142 cubic yards of sediment in the offset credit calculations. (Note: To remain consistent, the City's Pepperwood Preserve Credit Proposal used the same terms as the PWA reports where erosion sites were divided into three categories: 1) stream crossings, 2) road surfaces/ditches, and 3) other sites. "Other sites" refers to any other sources of sediments identified in PWA's assessment, including ditch relief culverts, discharge points for road surfaces, and springs).

Nutrient Loading Calculations

K&A used the combined PWA estimated volume of delivered sediment as a first step to quantify nutrient loading. It is assumed that with appropriate restoration or protection, the sediment erosion losses from these locations will cease. Thus, estimated sediment delivery can be equated to sediment reduced, which can then be equated with nutrient load reduction. As such, the cubic yards of sediment delivered (as estimated by PWA) are first converted into a mass equivalent of tons of sediment reduced. Second, tons of sediment reduced are equated to pounds of nutrient reduced (using measured soil nutrient concentrations from erosions sites in the Pepperwood Preserve).

The calculation steps for determining nutrient load reductions are described by Equations 2 and 3. Equation 2 calculates tons of total sediment reduction to the stream by multiplying cubic yards of delivered sediment by the dry density of soil (in tons/cubic foot) and an appropriate unit conversion value.

TSR = EM * DD * 27 (**EQ. 2**)

Where:

TSR = Total Sediment Reduction (tons)
EM = Erosion Measurement (cubic yards) [reported by PWA]
DD = Dry Density (tons/ft^3)
27 = Conversion Factor (ft^3/cubic yard)

K&A used the Michigan Department of Environmental Quality's, "Pollutants Controlled Documentation for Section 319 Watersheds Training Manual" (MDEQ, 1999) for assigning dry density soil weight values to soil types encountered at Pepperwood sites. K&A selected a dry density value of 0.0375 tons/ft^3 for stream crossings corresponding to clay loam, 0.055 tons/ft^3 for road surfaces/ditches corresponding to sands/loamy sands, and 0.045 tons/ft^3 for other sites corresponding to loams/sandy clay loams/sandy clay. The range of dry densities for all soil types is provided in Table 1. K&A selected a dry density weight corresponding to sand for sites associated with roads and ditches because road surfaces are commonly improved by using borrow material hauled in from offsite that results in a mix of soils rich in sands and gravels. According to USDA's Web Soil Survey[1], the sediment at Pepperwood Preserve consists of sands, hummocks, and silts. Therefore, K&A selected lower dry density values for stream crossings and other sites consisting of silts and clays.

Next, Equation 3 was used to calculate the total load reduction of a particular nutrient (TN and TP). The equation is applied separately for TN and TP.

[1] See: http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm.

LR = TSR * NC * BIO (**EQ. 3**)

Where:

LR = Nutrient Load Reduction (lbs TN or lbs TP)
TSR = Total Sediment Reduction (tons)
NC = Nutrient Concentration (lbs/ton)
BIO = Bioavailability Factor (dimensionless)

Equation 3 requires the total sediment reduction volume from Equation 2, the nutrient concentration, and a bioavailability factor. For nutrient concentrations, K&A used TN and TP data reported by Environmental Technical Services (in ppm). (See the laboratory analytical results in Attachment C of the City of Santa Rosa Pepperwood Preserve Credit Proposal.) Nutrient concentrations in ppm were converted by K&A to pounds per ton using a conversion factor of 500 ppm = 1 lb/ton. This reflects one pound of nutrient per ton of soil equaling 500 (ppm of nutrient) times 2,000 (lbs/ton) divided by 1,000,000 parts in a ton. K&A calculated separate TN and TP average concentrations (in lbs/ton) for soil samples collected from road surfaces/ditches versus stream crossings. This is due to the above noted assumption that road surfaces generally consist of imported sands and gravels while stream crossings and other sites would be more representative of native soils. These differences are especially important for phosphorus that has an affinity for charged particles (e.g., clays). Thus, clay commonly has higher concentrations of phosphorus than silts and sands due to ionic bonding potential.

Two elevated TN concentrations identified by the lab as high in organic content were also removed when calculating the average concentration for TN. This resulted in a 40 percent lower average TN value for stream crossings and other sites. For TN, K&A used a nutrient concentration of 2.7 lbs TN/ton for stream crossings and other sites, and 3.4 lbs TN/ton for road surfaces/ditches. K&A used a nutrient concentration of 0.4 lbs TP/ton for stream crossings and other sites and 0.2 lbs TP/ton for road surfaces/ditches.

It is worth noting that these average concentrations used results from soil samples collected in April 2012. In addition to removing data with elevated TN values, the timing of the soil sample collection introduces another conservative assumption into this credit estimation process. The organic content of the soils will be richest at the end of a growing season. During the winter, natural decay processes occur releasing some nutrients from plant matter that have accumulated in the soils. The wet season rains and related runoff also typically occur before April, further reducing the organic content in soils. Therefore, the TN and TP concentrations measured in April are considered conservative because samples likely reflect a lower organic content than what would be delivered to the stream during the wet season. This, in effect, lowers nutrient load estimates and reduces the number of credits to be claimed by proposed BMPs. In addition, the reduction estimate from this credit equation accounts for only the sediment-attached nutrients. Many types of BMPs proposed for implementation in the Preserve will reduce soluble nutrient loading as well. For instance, rolling dips redirect road surface runoff into adjacent fields before channel erosion can occur. This redirection of runoff allows for infiltration and plant uptake of nutrients and water in addition to the prevention of road surface erosion. Other BMPs that reduce the soluble nutrient loading include swales and insloping or outsloping of roads. These soluble losses are not included in calculations providing an additional margin of safety for offset crediting.

Following the requirements of the Nutrient Offset Program, K&A applied a bioavailability factor to the total load reductions expected from the Pepperwood Preserve BMP projects. A bioavailability factor takes into account the extent to which a particular nutrient is biologically available in the water environment based on the source of the nutrient. This factor is generally based on the differences in bioavailability of a nutrient discharged from two different sources in a watershed. For this offset program, the two types of discharges are treated wastewater from the City of Santa Rosa's Laguna Treatment Plant and the nonpoint source discharge from soil erosion in Pepperwood Preserve. The bioavailability factors applied here by K&A include a factor of 85% for TN and 51% for TP. Refer to Attachment A for a detailed description of the data sources and calculations used to derive the bioavailability factors applied in Equation 3.

References:

Michigan Department of Environmental Quality (MDEQ), 1999. Pollutants Controlled Calculation and Documentation for Section 319 Watersheds Training Manual. Water Division Nonpoint Source Unit, Revised June 1999. http://www.michigan.gov/documents/deq/deq-wb-nps-POLCNTRL_250921_7.pdf. Accessed July 6, 2012.

Pacific Watershed Associates, Inc. (PWA), 2008. Pepperwood Preserve/Upper Mark West Creek Erosion Inventory and Assessment, Sonoma County, California. Prepared for Soyotome Resource Conservation District, March 2008.

Pacific Watershed Associates, Inc. (PWA), 2012. Summary of Adjusted Costs Based on Re-Evaluation of Site Conditions and 2012 Implementation Costs to Execute Control and Sediment Reduction Measures at Pepperwood Preserve. Prepared for Sotoyome Resource Conservation District under Control #SRNO-002, May 2012.

Table 1. Dry Density Soil Weights (Source: MDEQ, 1999).

SOIL TEXTURAL CLASS	DRY DENSITY (Tons/Ft^3)
Sands, loamy sands	.055
Sandy loam	.0525
Fine sandy loam	.05
Loams, sandy clay loams, sandy clay	.045
Silt loam	.0425
Silty clay loam, silty clay	.04
Clay loam	.0375
Clay	.035
Organic	.011

Attachment A

Santa Rosa Nutrient Offset Program Bioavailability Review

To: Lynn Small, City of Santa Rosa
Control Board

Date: July 3, 2012

From: James A. Klang, PE, K&A

cc: Dave Smith, Merritt Smith

RE: Santa Rosa Nutrient Offset Program Bioavailability Review

Addressing Nutrient Bioavailability in Offsets

This memorandum provides a brief review of published literature and selected water quality trading programs, analyzing various approaches for addressing nutrient (phosphorus and nitrogen) bioavailability between sources. This background information forms the basis for recommended bioavailability factors included in equations for calculating Santa Rosa nutrient offset credits. For water quality offsets, discount factors are often applied to nutrient load reductions to ensure that the environmental outcome from the offset is equivalent to the protection that would be achieved under conventional methods of additional wastewater treatment. Such factors are used in crediting proposals to account for bioavailability equivalence in the Santa Rosa Nutrient Offset Program for loading between non-point sources and the City's treated wastewater discharge.

Phosphorus:

The State of Minnesota addressed phosphorus bioavailability issues in the Statement of Needs and Reasonableness (SONAR) document written to support Water Quality Trading rule promulgation[1]. The Minnesota Pollution Control Agency (MPCA) based this document on a study entitled, "Detailed Assessment of Phosphorus Sources to Minnesota Watersheds" (Barr, 2004). An appendix to the 2004 study compiles phosphorus bioavailability by source. The table from this appendix is reproduced below as Table 1.

The literature reviewed for this memo most commonly determined bioavailability using a one-month period after release to a water environment. Applying the results of these bioavailability studies to longer time periods (as would be the case in the Laguna de Santa Rosa setting), provides a conservatively low range. The nutrients in the Laguna setting have substantially more time to undergo chemical and biological changes. To address bioavailability, a coefficient can be calculated that reflects the bioavailability of the different phosphorus forms discharged by each source.

[1]MPCA. 2010. A Scientifically Defensible Process for the Exchange of Pollutant Credits under Minnesota's Proposed Water Quality Trading Rules. Accessed July 3, 2012, available at: http://kieser-associates.com/uploaded/MPCA_Defensible_Processs_Exchange_Credits_072809.pdf

K&A used Table 1 to calculate recommended equivalence factors that incorporate phosphorus bioavailability considerations for the Laguna de Santa Rosa. An equivalence factor accounts for differences in phosphorus bioavailability from each type of source. For point source domestic wastewater treatment plants (WWTPs) using agricultural nonpoint source offsets (without presence of manure), the recommended equivalence factor is 58/85.5 (or 0.68). When working on agricultural sites that are seeking to improve manure management, this factor becomes 80/85.5 (or 0.94).

Table 1. Estimates of phosphorus bioavailability fractions for specific source categories (from Barr, 2004).

Phosphorus Sources		Fraction of PP that is Bioavailable (Range)	Fraction of PP that is Bioavailable (Most Likely)	Fraction of DP that is Bioavailable (Most Likely)	Fraction of TP that is Particulate (Most Likely)	Estimate of TP that is Bioavailable (Most Likely)
Publicly Owned WWTP for domestic use (effluent)		**0.6 - 0.8**	**0.7**	**1.0**	**0.5**	**0.855**
Privately Owned WWTP for domestic use (effluent)		**0.6 -0.9**	**0.8**	**1.0**	**0.3**	**0.94**
Commercial/Industrial WWTPs (effluent)		**0.2 - 0.8**	**0.6**	**1.0**	**0.3**	**0.88**
Agricultural Runoff						
	Manure Management	**0.5 -0.7**	**0.6**	**1.0**	**0.5**	**0.8**
	Cropland Runoff	**0.2 - 0.7**	**0.4**	**1.0**	**0.7**	**0.58**
Urban Runoff						
	Turfed Surfaces	**0.2 - 0.7**	**0.4**	**1.0**	**0.7**	**0.58**
	Impervious Surfaces	**0.10 - 0.5**	**0.2**	**1.0**	**0.5**	**0.6**
Forested Land		**0.2 - 0.8**	**0.3**	**1.0**	**0.8**	**0.44**
Roadway and Sidewalk Deicing Chemicals						
	salt	**0.2 - 0.8**	**0.6**	**1.0**	**0.2**	**0.92**
	sand	**0.1 - 0.3**	**0.2**	**1.0**	**0.8**	**0.36**
Stream Bank Erosion		**0.1 - 0.5**	**0.3**	**1.0**	**0.8**	**0.44**

Nitrogen:

Total nitrogen (TN) consists of dissolved and particulate nitrogen. Dissolved nitrogen can be further subdivided into inorganic and organic forms. Organic forms of particulate nitrogen also can be present. The dissolved inorganic nitrogen (DIN) forms (NO_2, NO_3 and NH_4^+) are commonly assumed to be 100 percent bioavailable (Berman, 1999). However, independent study findings regarding the bioavailability of organic nitrogen, dissolved organic nitrogen (DON) and particulate organic nitrogen (PON) suggest that the bioavailability of these forms might vary widely. The predictability of this range in bioavailability also might vary substantially, in part due to results based on algal bioassays (Seitzinger, 2002). DON in freshwater riverine systems was historically thought to be available only for bacterial uptake, rather than direct algal uptake. Research indicates that humic systems release more DON during summer periods than previously thought. Up to 20 percent of the DON can be photo-ammoniafied (Bushaw, 1996; Dagg, 2003).

The Laguna de Santa Rosa nitrogen loading affecting the low flow dissolved oxygen conditions, is likely in the forms of DON and PON that remain in the system for longer periods of time (e.g., when disconnected summer pools develop). These longer time periods likely expose the DON and PON to photochemical breakdown, zooplankton grazing and bacterial uptake resulting in NH_4-N or NO_3 release. Therefore, non-point source DIN is assumed to be 100 percent bioavailable (as discussed above) while DON and PON collectively are conservatively estimated at 20 percent bioavailable during the summer period for various Ag non-point sources. This is conservative because it does not include bacterial and zooplankton uptake. In the Laguna de Santa Rosa setting, the application of nitrogen bioavailability might be further complicated by limited laboratory or bioassay testing methods, which can use three-week incubation periods (Urgun-Demirtas *et al.*, 2008; Berman, *et al*. 1999). The use of this lab analysis is considered conservative due to the longer time periods and numerous chemical and biological activities that occur when the low flow polls trap nitrogen beyond the three-week timeframe of the lab tests.

Total Nitrogen to Dissolved Organic Nitrogen Ratios in Non-point Source Dominated Streams

Research indicates a broad range of ratios comparing stream TN to DON in non-point source dominated streams. Seitzinger (2004) conducted a literature review that suggested a range from 10 to 80 percent. Assessing the cropping and pasture runoff results from the Laguna de Santa Rosa TMDL source monitoring program, the 34-sample mean concentration was 2.6 mg/l TN. The dataset did not provide flow estimates. Therefore, a flow-weighted mean could not be generated. The mean concentration of the 34 samples of the total DIN fraction (NO_3- and NH_4-N) was 2.0 mg/l DIN.

A comparison of the two concentration means indicates approximately 76 percent of the total nitrogen is DIN. This can be roughly confirmed by solving for the DON fraction independently for each sampling event (TN - DIN = DON + PON) and then averaging the estimated percent of organic nitrogen results. The average organic nitrogen percentage of total nitrogen plus the 76 percent DIN fraction should be approximately 100 percent (not taking into account difficulties regarding sampling variability). The result of this calculation indicates approximately 29 percent of the total nitrogen is in the form of organic nitrogen. The 76 percent plus 29 percent is a reasonable indicator that these assumptions are within an acceptable range for the Laguna de Santa Rosa setting. Therefore, using a 75 percent bioavailable fraction as DIN and 25 percent as organic nitrogen form in non-point source runoff was deemed reasonable for nitrogen offset credits.

After combining the stream fractions of inorganic and organic nitrogen (and bioavailability of each), the TN bioavailability of crop and pasture sources can be estimated as follows: DIN bioavailability (75 percent times 100 percent bioavailable) plus organic nitrogen bioavailability (25 percent times 20 percent bioavailable) equals 80 percent total nitrogen bioavailability. This estimate is used in Ag settings with high organic content as a conservative estimate. However, as previously mentioned, in settings where there is a substantial presence of particulate organic nitrogen, the estimate is unreasonably low because it is based on three week lab analysis methods. In settings where the credit estimation method is dominated by PON, a higher bioavailability factor will be used.

The bioavailability of WWTP nitrogen also must be determined. Assessing the same forms of nitrogen (e.g., particulate and dissolved, further subdivided into inorganic and organic) the inorganic fractions are assumed to be 100 percent bioavailable. Literature indicates that secondary effluent WWTPs that denitrify have DON percentages around 10 percent of the TN discharged (Pehlivanoglu, 2004). However, advanced treatment with low total nitrogen levels (below 3 mg/l) increases the fraction of DON to 40-50 percent of TN (Chandran, 2010). Therefore, an analysis of the Laguna WWTP pond storage system sampling was performed. The results provided in Table 2 indicated that average concentrations were:

Table 2. Average nitrogen concentrations from Delta Pond samples (City of Santa Rosa, Delta Pond monitoring results, 2006-2010).

Nutrient Form	Concentration (mg/l)	Number of Samples
Nitrate Nitrogen	8.19	20 samples
Organic Nitrogen	1.34	24 samples
Ammonia nitrogen	0.48	14 samples
Total Nitrogen	9.8	Sum of nitrate, organic and ammonia samples (same day) from Delta Pond

These values indicate that approximately 89 percent of the discharged pond effluent was DIN (assumed to be 100 percent bioavailable). A conservative assumption for the Santa Rosa offset program would be to use a 50 percent bioavailable fraction of DON, assuming algal uptake is enhanced by bacteria (Pehlivanoglu, 2004). Therefore, the contributing DON bioavailable fraction is assumed to be 5.5 percent of the total nitrogen loading. The estimated wastewater bioavailable fraction result is 94.5 percent. The nitrogen bioavailability discount factor for cropping and pasture land offsets is determined by 0.8 non-point source bioavailability/0.945 WWTP bioavailability, or a discount factor of 0.85 times the credited loading reduction.

References:

Barr Engineering Company, 2004. Detailed Assessment of Phosphorus Sources to Minnesota Watersheds. Supporting Technical Memorandum: Assessment of Bioavailable Fractions of Phosphorus and Annual Phosphorus Discharge for Each Major Basin memo. Available on line at: http://www.pca.state.mn.us/index.php/viewdocument.html?gid=3987

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