Upper Rancheria Creek
Preliminary Bio-geomorphic Assessment

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Background and Plan Purpose

The Upper Rancheria Creek Preliminary Bio-geomorphic Assessment (the Plan) has the following objectives:

- to provide an overview of the features and processes within the Upper Rancheria watershed
- to compile existing information about the watershed
- to gather preliminary biological and geomorphic data about the watershed
- to identify management recommendations based on existing data
- to identify additional data gathering and assessment needs to support refined management recommendations
- to recommend demonstration projects that may be adopted by other landowners in the watershed

Background information about the Navarro and Rancheria watersheds was gathered from a variety of sources, and provides the context for more detailed assessment. New data were derived via remote sensing, as well as several field visits by West Coast Watershed, Dr. Joan Florsheim and Pacific Watershed Associates during January-March 2007. The Rancheria project GIS was developed to assess and illustrate features at the landscape scale. Data were compiled from a number of sources including USGS digital elevation data, roads and Calveg vegetation data from the CDF Watershed Assessment Program; timber harvest data from the CDF Northern Region Forest Practice program; fish passage barrier data from the CalFish program; hydrology from CDFG; 2004 ortho-corrected aerial imagery from the USDA National Agriculture Imagery Program; and Galbreath data developed by the Sonoma State University Geographic Information Center.

The Plan broadly addresses watershed processes and management issues for the entire Upper Rancheria watershed, while detailed data gathering and specific management recommendations focus on Sonoma State University's Galbreath Preserve. The Galbreath Preserve was selected as an area of focus because it is a representative land area within the watershed, and due to its status as a long-term research station – an area that will serve as a testing ground for various demonstration projects that can be deployed throughout the watershed once they are reviewed by landowners and scientifically vetted. An assessment of the geomorphic processes of the Galbreath Preserve was developed by Dr. Joan Florsheim, and includes recommendations for management activities and further study (Appendix A. Upper Rancheria Creek Baseline Fluvial Geomorphology: Reconnaissance Assessment). Detailed road surveys of the Galbreath Preserve were performed by Pacific Watershed Associates, and include implementation recommendations that will reduce the input of deleterious sediments to aquatic environments (Appendix B. Draft Summary Report SSU Galbreath Preserve Road Drainage Improvements, Mendocino County, California). West Coast Watershed performed aerial photo interpretation and mapping, evaluated both upslope and stream corridor areas within the Galbreath Preserve, and made a series of management recommendations based upon this preliminary assessment. A summary of recommendations by all three consultants are included in the main text of the Plan.

Rancheria Creek/Navarro Watershed

Physical and biotic setting

The Navarro River watershed is the largest and most diverse basin in the Mendocino Coast Hydrologic Unit (CDFG 2004). It encompasses approximately 315 square miles – slightly more than 200,000 acres – and flows northwest through the coastal range to the Pacific Ocean (Map A Navarro River Watershed Hillshade Map). The Navarro watershed is subdivided into five subbasins: Mainstem Navarro River, North Fork Navarro River, Indian Creek, Anderson Creek, and Rancheria Creek and includes the towns of Boonville, Philo, and Navarro. The Rancheria creek sub-basin comprises 59,262 acres (29.3% of the Navarro watershed), and the Galbreath Preserve comprises 3,865 acres (6.5% of Rancheria, 1.9% of Navarro). CalWater delineates the Lower and Upper Rancheria watersheds as the confluence of an unnamed creek that runs through the Diamond D Ranch.

Hydrology

The Navarro River watershed receives about 40 inches of precipitation in the form of rain yearly with about 60% falling during winter months, from mid-December through the end of March (NCRWQCB 2000). Recent alluvium, stream channel, and terrace deposits provide groundwater recharge to surface streams and supply wells and springs. The Franciscan formation contributes only minor amounts of groundwater. Since 1951, a USGS stream flow gage has been maintained about nine miles upstream of the mouth of the Navarro. Flows dry up in tributaries during summer months, with the only surface water present derived from springs. Only the mainstem Navarro River, North Fork Navarro River, and lower reaches of Anderson, Rancheria, and Indian Creeks contain year-round surface water. Anthropogenic activity exacerbates these dry conditions - wells lower water tables, reducing groundwater available for recharge, which, along with surface water diversions, contributes to higher stream temperatures and reduces instream habitat (Reference this statement—I think RWQB did a report using Tetratech as a consultant).

Geology

The Navarro River watershed contains the highly erodible Franciscan mélange and alluvial fill, as well as the Coastal Belt of the Franciscan Assemblage, which is more stable and resistant to erosion. Alluvial fill occurs in Anderson Valley and low-lying areas of major tributaries and Franciscan melange is associated with middle and upper Rancheria Creek. Most of the rest of the watershed contains soil derived from the Coastal Belt of the Franciscan Assemblage. Estimates of sediment contributions from various portions of the watershed are provided in (Entrix, Inc. 1998) with relatively high erosion rates similar to other watersheds in the north coast region. Whereas large volumes of sediment delivered to aquatic zones is considered deleterious due to potential impacts salmonid habitat by decreasing oxygen availability for developing eggs and fry emergence, in contrast coarse sediment delivered to channels is required to maintain riffle-pool structure. Sediment production rates decreased during the 1980s and '90s from historic highs during the 1950s through '70s due to changes in harvest practices and improved construction and maintenance of active logging roads (Entrix, Inc. 1998).

The Rancheria subbasin experienced channel aggradation and widening from tractor logging during the 1950s and '60s (Entrix, Inc. 1998). Although much of the rest of the

Navarro River watershed is beginning to recover from logging activities. As of 10 years ago, in upper and middle Rancheria Creek, aggradation and widening persisted, however—trends in the last decade have not been documented. Understanding rates and mechanisms of recovery are important in attempts to restore aquatic habitat for salmonids.

Instream Habitat

Throughout the watershed, riparian forest is not well established, presumably due to a variety of historic land use practices. The lack of riparian forest in the watershed coupled with the instream large woody debris (LWD) removal program encouraged by CDFG in the 1950s through the 1970s has resulted in a dearth of LWD, which negatively impacts salmonid habitat. Without adequate levels of LWD, instream habitat lacks pool frequency, depth, and complexity. In most surveyed streams in the watershed, there is low pool frequency and an excess of fast water habitat. These conditions are deleterious to both adult and juvenile salmonids. Lack of resting places may lead to adult mortality before spawning and lack of cover may lead to increased adult predation. Likewise, it can be difficult for juveniles to shelter during high flow events and they may be swept away.

Vegetation and Terrestrial Habitat

Vegetation types in the watershed roughly follow soil type. Franciscan melange derived soils support grassland, the Franciscan Coastal Belt derived soils support grass-scrub or forested vegetation, and valley fill supports mixed forest (Entrix, Inc. 1998). Habitat types that occur in the Navarro watershed include redwood forest (42%), montane hardwood (24%), annual grassland (14%), Douglas-fir forest (9%), and montane hardwood conifer (6%) (Map B. Navarro River Watershed Vegetation Type) (CDF and USFS 2005). In the Rancheria Creek subbasin, terrain follows the same pattern. In the upper basin, the terrain is Franciscan mélange and the habitat type is composed mainly of grassland and forest. The terrain of the lower Rancheria Creek sub-basin is Franciscan Coastal Belt forested with predominantly redwood forest. Franciscan Coastal Belt grass-scrub terrain predominantly occurs in the mid and upper basin. In the Rancheria subbasin, vegetation distribution and cover is also similar to the entire watershed: redwood forest (37%), montane hardwood (30%), annual grassland (17%), and Douglas-fir forest (6%)(CDF and USFS 2005). Redwood and Douglas-fir forest are more abundant in the lower reaches of the subbasin while montane hardwood occurs more frequently in the upper reaches.

Redwood forest is a composite name for a variety of conifer species growing in the coastal zone and is usually a mixture of several tree species, including redwood, Sitka spruce, grand fir, red alder, and Douglas-fir. Near the coast and in flood plains, redwood is the dominant tree species with Douglas-fir becoming dominant further inland and higher in the watershed where tanoak and madrone are its primary associates. Redwood forest and Douglas-fir forest are the most productive timber forests (County of Mendocino 2003). Montane hardwood habitat typically consists of an evergreen hardwood tree layer, a patchy shrub layer, and sparse herbaceous cover. Canyon oak is the usual dominant on steep slopes, replaced by huckleberry oak at higher elevations and pines at still higher elevations. Associates include tanoak, Pacific madrone, Douglas-fir, and California black oak. Annual grassland habitat is open and composed primarily of annual plant species; non-native forage grasses are usually dominant. Douglas-fir forest is characterized by a high, irregular overstory of Douglas-fir with a lower overstory of densely packed sclerophyllous broad leaved evergreen trees such as tanoak and madrone (Mayer and Laudenslayer 1998).

Detailed vegetation surveys were performed at the Galbreath Preserve between 2005-2007 by Sonoma State University researchers, and document a diversity of plant species that are likely to be found in the larger Rancheria watershed (Appendix C – Plant Species of Galbreath Preserve).

Wildlife

According to the California Wildlife Habitat Relationships System (CDFG and CIWTG 2005), 309 species of terrestrial wildlife potentially inhabit the Rancheria Creek subbasin. Eighteen species of amphibians are predicted to occur. These species include California giant salamander (*Dicamptodon ensatus*), southern torrent salamander (*Rhyacotriton vareigatus*), ensatina (*Ensatina eschscholtzi*), tailed frog (*Ascaphus truei*), California red-legged frog (*Rana aurora draytonii*), and the invasive bullfrog (*Rana catesbeiana*). The California red-legged frog is listed as threatened under the federal Endangered Species Act. Although specific habitat requirements vary, all of the amphibians predicted to occur in the Rancheria Creek subbasin require a cool, moist environment close to or within rocky streams, pools, or springs and most prefer coniferous forest habitat (CDFG and CIWTG 2005). Twenty species of reptiles are predicted to be present including sagebrush lizard (*Sceloporus graciosus*), southern and northern alligator lizard (*Elgaria* sp.), rubber boa (*Charina bottae*), gopher snake (*Pituophis cateniter*), Western rattlesnake (*Crotalis viridis*) and Calfornia mountain kingsnake (*Lampropeltis zonata*)(CDFG and CIWTG 2005). The reptiles generally inhabit drier upland habitat and are likely to be found in montane hardwood forest and grassland.

Seventy-six mammal species are predicted to occur in the Rancheria subbasin including several rodents, bats, and squirrels, American beaver (*Castor canadensis*), ringtail (*Bassariscus astutus*), American marten (*Martes americana*), fisher (*Martes pennanti*), weasels, American badger (*Taxidea taxus*), western spotted skunk (*Spilogale gracilis*), striped skunk (*Mephitis mephitis*), mountain lion (*Puma concolor*), bobcat (*Lynx rufus*), mule deer (*Odocoileus hemionus*), and elk (*Cervus elaphus*). Non-native species predicted to occur in the subbasin are wild pig (*Sus scrota*), fallow deer (*Dama dama*), red fox (*Vulpes vulpes*), and Virginia opossum (*Didelsphis virginiana*)

Two-hundred nineteen bird species are likely to occur in the Navarro watershed at least part of the year, including pelagic birds, wading birds, ducks and other water birds, raptors and other birds of prey, ground nesters, owls, and passerines. The species likely to occur in the Rancheria Creek subbasin is a subset of this list and likely does not include birds that remain along the coast, although occasional vagrants may be spotted. The federally endangered Brown Pelican is predicted to occur in the watershed and the federally threatened Marbled Murrelet and Northern Spotted Owl may also be found (CDFG 2005). The Marbled Murrelet (*Brachyramphus marmoratus*; MAMU) and Northern Spotted Owl (*Strix occidentalis caurina*; NSO) are of special concern because they are closely associated with old-growth and mature redwood forest, which has been heavily impacted by timber harvest since the late 1800s.

Coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Oncorhynchus kisutch*) occur in Navarro River watershed and the Rancheria sub-basin creeks and streams. Specific information about anadromous fish is provided below, in the section entitled Management Considerations . Coho are listed as threatened under ESA (Central California Coast Evolutionarily Significant Unit, 1996) and steelhead are also listed as threatened (Northern California Evolutionary Significant Unit, 2000) (CDFG 2006). Salmonids possess a specialized life cycle that includes both fresh and salt water stages. They hatch from eggs buried in cobble in freshwater streams, rear in pools and other relatively slow flowing freshwater habitat, and migrate to the ocean as adults, returning to spawn in their natal streams. While in freshwater habitat, salmonids have very specific requirements with respect to temperature, gravel quality, and instream complexity that vary by species. Steelhead tend to be more tolerant of a broader range of environmental factors than coho, which is reflected in their greater presence in watersheds where coho were once more plentiful, but where anthropogenic activity has changed conditions. Specific freshwater habitat requirements and the condition of the Navarro watershed and Rancheria Creek subbasin with respect to those requirements is discussed below (see Natural Resources Management Issues).

On-the-ground wildlife surveys (as opposed to WHR predictive models) were performed at Galbreath Preserve by Sonoma State University researchers between 2004-2007, and document 32 mammal species, 90 bird species, 11 amphibian species and 7 Reptile species (Appendix D – Vertebrate Species at Galbreath Preserve)

Land Use

Like much of the rest of the North Coast of California, the first large scale industry in the Navarro River watershed was timber harvest. Timber harvest began in the mid nineteenth century and re-harvest of the mainstem Navarro River subbasin occurred during the 1930s through '50s. By the 1870s, sheep and cattle ranching had begun (NCRWQCB 2000). Present day land use in the Navarro watershed is 70% forestry, 25% ranching, and 5% row crops, orchards and vineyards, with a small percent rural residential development (US EPA 2000) (Map C. Rancheria Creek Watershed Timber Harvest Plan (THP). Within the Rancheria Creek subbasin, major land uses include sheep and cattle ranching, timber harvest, and open space and rural residential homes, with only a few locations in field and row crops (NCRWQCB 2000). Between 1984 and 1996, the number of new vineyards drastically increased in the upper subbasin and numbers continue to rise.

Timber harvest, roads, agricultural practices, grazing management, grading, and other land disturbances contribute to high levels of sedimentation in the Navarro River watershed. Land use in the lower Rancheria Creek basin consists of ranching, logging, open space, and rural residential development. For the most part, the forested Franciscan Coastal Belt terrain in the lower portion of Rancheria Creek subbasin contains the highest density of roads due to timber harvest activities. In the upper Rancheria Creek basin few roads exist – ranching and open space are the primary land uses. Highway 128, which connects Cloverdale to the Mendocino Coast, is a major feature in the upper basin.

The Galbreath Wildlands Preserve is located in the upper Rancheria Creek subbasin. It encompasses 3,760 acres and was donated to Sonoma State University by the estate of Fred Burckhalter Galbreath to honor his memory. The stated mission of the preserve is to "promote environmental education and research, as well as the effective stewardship of this diverse landscape (SSU 2005)." Rancheria Creek and several seasonal tributaries flow north through the preserve.

Management Issues

Management Issues – Navarro Watershed and Rancheria Sub-basin

Water Quality

In the early 1960s, most of the water quality in the Navarro basin and its tributaries had experienced intense degradation from recent timber harvest activities. By the time CDFG conducted surveys in 1996, many of the streams had at least partially recovered; however, historic impacts and current land use practices continue to impair water quality in the Rancheria watershed. Water quality in the Navarro River watershed is impacted by sediment and temperature. The river is on the 303(d) list of impaired waterbodies in California; potential sources of the impairment include: agriculture, agricultural return flows, resource extraction, flow regulation/modification, water diversions, habitat modification, removal of riparian vegetation, streambank modification or destabilization, and drainage or filling of wetlands (NCRWQCB 2006). The US EPA (2000) has prepared Total Maximum Daily Load guidelines (TMDLs) for sediment and temperature in the Navarro River watershed. Load allocations are presented in Table 1.

Table 1. TMDL Targets for the Navarro River Watershed (TMDL NCRWQCB)

Indicator	Target
% fines ≤ 0.85 mm	14%
% fines ≤ 6.4 mm	30%
Residual Pool depth	No less than 2 feet deep for first and second order channels and 3 feet deep for third order and greater channels
V* Lower Order Streams	15%
V* Higher-Order Streams	15%
Stream length in pools	40%
Thalweg variability	Increasing trend
Stream crossings with diversion potential	< 1% of all stream crossings
Stream crossings with high risk of failure	1%
Stream crossing failures	Decreasing trend

Hydrologic connectivity	10% The hydrologic connectivity data from 40 miles of roads collected by PWA showed hydrologic connectivity is 56%
Road related landslides	Decreasing trend
Aquatic insect production	Improving trend
Backwater pools	Increasing trend

The beneficial use most sensitive to sediment impacts in the Navarro River watershed is the cold water fishery; by protecting the cold water fishery, all other beneficial uses sensitive to sedimentation are expected to be protected. The most pervasive and widespread sediment problem in the Navarro River watershed is fine sediment deposition that accumulates in pools and riffles. Estimates of sedimentation associated with various erosion mechanisms are summarized in (NCRWQCB (2000) and US EPA (2000). These studies noted that sediment sources in Rancheria Creek include bank erosion, shallow landslides, gullies, and deep seated landslides. All of these sources are natural phenomena that may be accelerated by human activities. However, before public funding is provided to reduce sediment inputs—the temporal frequency and spatial distribution of sediment sources such as landslides, gully, and bank erosion should be documented (as is already the case for road surveys - Appendix B by Pacific Watershed Associates). Such work is necessary in order to understand the geomorphic watershed context of erosion and sedimentation processes (e.g. what is essential for the natural evolution of a watershed), to aid in prioritization of restoration projects, and most importantly, to ensure that short-term sediment control projects do not have detrimental effects on long-term watershed restoration. Moreover, some processes, such as deep-seated landslides are not likely to be arrested by human interventions unless substantial engineering projects are implemented.

Cool stream temperatures (<59 °F) are essential for salmonid population recovery. Extreme diurnal temperature fluctuations – as much as 15 °F – have been observed in many streams in the Navarro River Watershed (Entrix 1998). Diurnal fluctuations this extreme can be harmful to juvenile salmonds, which do not have enough time to acclimate to such drastic changes. These conditions may continue to limit salmonid recovery until management activities are undertaken to improve water temperature conditions.

Rancheria Creek is a large inland waterway with a mostly open canopy. Because inland air temperatures are higher than coastal temperatures, stream temperatures in Rancheria Creek are higher than temperatures in the lower elevation areas of the watershed. Thirteen temperature collection sites that were monitored from 1995 through 1999 exhibited results ranging from poor/unsuitable to good temperature conditions. Maximum Weekly Average Temperature (MWAT) was less than 63 °F at two of the thirteen sites each year, but exceeded 66 °F at seven sites and exceeded 71 °F at three sites. Temperature ranges varied from 2° to 10° and hourly temperatures regularly exceed 66 °F at three sites and regularly exceeded 75 °F at three sites (NCRWQCB 2000).

High water temperatures in the Rancheria Creek basin are exacerbated by water diversions. Studies conducted during the mid '90s show that summer flows in Rancheria Creek can be significantly reduced by agricultural pumping (Entrix 2000). In upper Rancheria Creek, water temperatures are not suitable for coho and only marginal for steelhead during most of the summer. Much of the upper mainstem reach goes dry during summer, with only isolated pools remaining. Beasley, Yale, and Adams Creek have suitable temperatures for steelhead and possibly coho, but the gradient at Beasley Creek, which has a 3-4% slope, is much steeper than streams typically frequented by coho, which prefer slopes < 2%. The lower reach of Rancheria Creek is also marginal for steelhead and unsuitable for coho with respect to temperature. However, Dago Creek, Cold Springs Creek, Horse Creek, Minnie Creek, Camp Creek, and Ham Canyon have suitable temperatures for steelhead and potentially coho. The lower reach contains some surface flow during summer as do most of the larger tributaries. However, small tributaries such as Beasley Creek have only subsurface flow near the confluence with Rancheria Creek.

Salmonid Recovery

Historically, the Upper Rancheria Creek basin produced, but did not support, year round populations of juvenile coho and juvenile steelhead; however, no coho of any age class have been documented in the upper subbasin since the late 1980s. This section of the creek typically goes dry during the summer, however juvenile coho and steelhead were collected during the late '40s, early '50s, and early '70s while moving to more permanent habitat downstream. Juvenile coho were last collected during a survey in the late '80s and have not been documented in the subbasin since. In 2000 – 2002 in the Navarro watershed, coho were present in Marsh Gulch, Murray Gulch, Flume Gulch, Flynn Creek, and the North Branch North Fork Navarro River. The North Fork Navarro River has been identified as a key coho population "to maintain or improve" by CDFG.

Coho and steelhead have a slightly competitive relationship due to similar habitat requirements; high juvenile coho biomass density is correlated with relatively low juvenile steelhead biomass density. Steelhead are more tolerant of changes to stream conditions caused by land use activities. Juvenile steelhead are able to rear in both relatively fast water habitat and pool habitat, while coho require pools. Steelhead can tolerate warmer temperatures than coho. Coho enter streams in the Navarro watershed during late fall through mid-winter and steelhead begin entering in early winter and continue through spring. This may affect coho redd survival, which can be scoured out with winter storms. Many steelhead spawn after much of the danger from winter storms has passed, resulting in greater opportunity for egg, alevin, and fry survival.

The primary limiting factors for salmonids in the Rancheria Creek subbasin are high stream temperatures, excessive fine sediment, and a lack of instream habitat and shelter. Temperature influences growth and feeding rates, metabolism, development of embryos and juveniles, timing of life history events, and food availability. When food is scarce, high stream temperatures become extremely important since fish metabolize faster in warmer water and need more food than they do when temperatures are cooler. Optimal temperatures for coho are <59 °F and for steelhead are <63 °F ; marginal temperatures are between 59 and 63 °F for coho, between 64 and 66 °F for steelhead and poor habitat is > 63 °F for coho and > 66 °F for steelhead (US EPA 2000). Temperatures high enough to be lethal to salmonids have been documented at many of the temperature monitoring locations throughout the watershed. Temperatures tend to be lowest in smaller tributaries with riparian cover, highest on the mainstems of Anderson, Indian, and Rancheria Creeks and the Navarro River, in part due to the width of these channels.

Excessive fine sediment can adversely affect ability to spawn, embryo respiration, fish passage, and the availability of food items, whereas, coarse sediment is needed to construct riffle-pool morphology. Excess fine sediment in the water reduces aquatic insect production, which decreases food available for fish. Although still a factor limiting salmonid success, particle size of potential spawning gravels collected in 1989 shows less fine sediments in Rancheria Creek than in the North Fork and Mainstem Navarro Assessment Areas (NCRWQCB 2000). Field reconnaissance conducted as part of the current studying Rancheria Creek noted that there appeared to be a deficit of fine sediment on bars—that is needed to facilitate vegetation establishment. Sedimentation may influence stream temperature by decreasing profile depth and filling in pools. Similarly, the loss of large woody debris in the aquatic system may contribute to the decrease in pool depth and generally raise temperatures. Habitat data from all sub-watersheds indicates that lack of pool frequency may be a limiting factor for rearing in the Navarro watershed; pool frequency is about one-quarter to one-half of the historical frequency. Lack of pool frequency is associated with a lack of large woody debris (LWD), due in part to historic timber harvest practices and in part to the CDFG program in the 1950s that encouraged instream LWD removal because it was thought to impede fish passage and interfere with instream habitat.

Fish passage upstream to spawning habitat is often impacted by both natural and anthropogenic barriers. When natural, these large debris accumulations (LDAs) usually provide only a partial barrier and are transitory, breaking down within a few seasons. When anthropogenic, however, barriers can severely limit salmonid success. In the Rancheria Creek subbasin, there is one LDA on a small tributary to Rancheria Creek and a dam in the lower middle subbasin which serves as a temporal barrier (Map D. Rancheria Creek Watershed Fish Passage Barriers). In the upper watershed, there are about twenty road crossings – mostly on Rancheria Creek – which pose complete barriers to fish passage. In addition, there are about a dozen diversions in the upper subbasin which have not been evaluated for barrier status (CalFish 2006). Prior to upstream restoration project implementation, evaluation of these barriers should be conducted.

During the 1960s, CDFG surveyed the entire length of Rancheria Creek and most of its major tributaries. All reaches of the sub-basin except the upper reaches of Camp Creek were severely degraded due to recent logging operations; roads and landings were reported in the stream channel (NCRWQCB 2000). Since that time, streams have partially recovered – in 1996 CDFG surveys in Dago, Ham Canyon, Horse, South Fork Dago, and Rancheria Creeks documented riffles, runs, and pools, although at smaller than optimal percentages (NCRWQCB 2000). In 1998, steelhead were observed in all Rancheria Creek sub-watershed waterways surveyed, but no coho were found. Many steelhead young-of-year were observed – approximately 30 per pool (Entrix 1998).

In 1998, salmonid habitat conditions on Bear Wallow and Beasley Creeks in the Rancheria Creek subbasin were rated poor to fair depending on the life cycle stage under consideration. Both creeks had an average maximum pool depth of only 1.5 feet; optimal pool depth is at least 2 ft in 1st and 2nd order channels and greater than 3 ft in 3rd and higher order channels. Bear Wallow has a 5.5% slope and Beasley has a 3-4% slope. In the entire watershed, coho were only present in streams with gradients less than 2% and steelhead were present in streams with gradients less than 8% (Entrix 1998). Stream gradient is likely a limiting factor for coho in both creeks. In terms of canopy cover, both creeks are adequate. Bear Wallow Creek has high to moderate cover except where land slides have occurred and Beasley Creek had cover greater than 65% which was composed mostly of deciduous trees and hardwoods.

Streams draining the north slopes of upper Rancheria Creek including Maple, Shearing, and Beebe Creeks are located in Franciscan melange-grassland terrain, with relatively small, steep subbasins, and limited LWD input. These streams are not suitable for coho habitat and likely only provide marginal steelhead habitat. Lower Rancheria Creek tributaries on the southwest side of the basin located within forested Franciscan Coastal Belt terrain include Dago, Cold Springs, Minnie, Horse Camp, and Beasley Creeks. It is probable that these streams provide suitable stream temperatures and potential for LWD recruitment to enhance and expand salmonid habitat.

Adams and Yale Creek, which are located in the upper watershed, historically provided habitat for only steelhead. There is recent evidence of coho only in Dago Creek in the Lower Rancheria Creek subbasin. Although Cold Springs, Minnie, and Camp Creeks were not field checked, they are thought to be similar to Dago Creek (Entrix 1998).

Invasive plant species

The Navarro River watershed contains over 1000 species of plants in natural habitats. Of these, about 20% are non-native (Montgomery, undated). Many non-native plants naturalize without causing perceptible harm to the system; however, some non-native plants possess both the potential to disrupt the structure and function of native ecosystems and the ability to rapidly expand their range and population size in their new habitat. These plants may pose a serious threat to native plant and animal communities by out-competing native vegetation, altering fire regimes, interrupting successional processes, consuming a disproportionate amount of groundwater, or otherwise interfering with ecosystem processes. Additionally, invasive non-native plants have socioeconomic costs associated with prevention, control, and mitigation, as well as indirect costs associated with impacts to ecological services.

Fifteen non-native invasive plants that have the potential to negatively impact the Navarro River watershed were identified by local natural resource organizations. These plants and some of their characteristics are presented in Table 2.

Table 2. Non-native Invasive Plant Management

Common Name	Scientific Name	Reproduction	Habitat Preference	Control Methods
Tree-of-heaven	*Ailanthus altissima*	Seed, stump and root sprouts	Disturbed areas, prefers dry	Manual, mechanical, chemical

			soil	
Giant reed	*Arundo donax*	Rhizomes	Well-drained soils with abundant moisture	Manual, mechanical, chemical, grazing
Yellow starthistle	*Centaurea solstitialis*	Seed	Open grasslands with deep well-drained soils	Mechanical, grazing, burning, biological, chemical
Poison hemlock	*Conium maculatum*	Seed	Wet soils	Manual, mechanical, chemical
Jubata grass	*Cortaderia jubata*	Seed, fragmented tillers	Disturbed coastal areas, estuaries, grasslands, wetlands	Manual, mechanical, chemical
Scotch broom	*Cytisus scoparius*	Seed, resprouts	Disturbed areas, grassland, shrubland, and open canopy forest	Manual, mechanical, burning, chemical
English ivy	*Hedera helix*	Seeds, tillers	Open forests	Manual, mechanical, burning, chemical (on young plants)
Klamathweed	*Hypericum perforatum*	Seeds, rhizomes	Grasslands, open forest, disturbed areas	Manual, mechanical, biological
Pennyroyal	*Mentha pulegium*	Seed, stolons	Moist meadows, marshes, ditches, disturbed sites	Chemical
Himalayan blackberry	*Rubus discolor*	Seeds, clonal	Disturbed sites, moist	Manual, mechanical,

			areas	chemical, burning
Sheep sorrel	*Rumex acetosella*	Seeds, root resprouts	Grasslands, disturbed areas	Manual, mechanical, chemical
Tansy ragwort	*Senecio jacobaea*	Seeds, root resprouts	Disturbed areas, stream banks, grasslands, open forests	
Milk thistle	*Silybum marianum*	Seeds	Disturbed sites with fertile soil	Manual, mechanical, chemical
Common spring vetch	*Vicia sativa*	Seeds	Disturbed sites	Manual, mechanical, chemical
Periwinkle	*Vinca major*	Rhizomes	Moist shaded areas, riparian banks	Manual, mechanical, herbicide

Non-native Animal Species
The presence of non-native animal species can alter plant and animal species composition, disrupt ecosystem processes, and influence geomorphic regimes such as sediment transport. Wild turkey (*Meleagris gallopavo*), wild pig (*Sus scrofa*), Virginia opossum (*Didelphis virginiana*), feral cat (*Felis catus*), and bullfrog (*Rana catesbiana*), are important non-native animal species that are likely to occur in the Rancheria Creek subwatershed.

Turkeys are considered a valuable upland game bird by CDFG. They prefer open woodland habitat and have an omnivorous diet, consisting of other bird eggs, acorns, seeds, small insects, wild berries, and small reptiles. During foraging, they cause soil disturbance and they may outcompete other wildlife seeking similar food or habitat. Wild pigs occur in nearly every habitat type in California, although they prefer woodland, chaparral, grasslands, and wetlands. They are omnivorous, consuming herbs in spring, mast and fruit during summer and fall, and roots, tubers, and invertebrates year-round. Wild pigs are considered a potential competitor for food with deer, bear, rodents, raccoons, and waterfowl. While rooting, they can change species composition and successional patterns and alter nutrient cycling. Additionally, they can hamper the regeneration of woody species by consuming acorns and seedlings and increase sedimentation in streams by rooting and wallowing. Virginia opossum occur in a wide range of habitats but are most common in urban and suburban settings. They may compete for food and shelter with other mammals such as skunk, fox, weasels, and ringtail. Feral cats compete with and prey upon wildlife species. When fed, feral cats have a fitness advantage over native wildlife, which must forage for itself. Bullfrogs are highly aquatic, requiring permanent water for larval development. They are opportunistic feeders that out-compete and prey upon many native amphibians. They have a wide diet of both aquatic and terrestrial prey including invertebrates, fish, salamanders, frogs, tadpoles, toads, snakes, turtles, birds, and mice (CDFG and CIWTG 2005).

Management Issues – Galbreath Preserve

The Galbreath Preserve is representative of many of the landscapes in the Upper Rancheria and Navarro watersheds – an area of relatively steep, low order headwater streams and their influencing processes, as well as representative historic land use practices related to logging and grazing. It is therefore an appropriate research and demonstration area for management and science-based ecological restoration, and may serve as an area where watershed landowners can review management practices for adoption on their own properties.

Current land uses are limited to research, road maintenance and the placement of bathroom facilities. There is no current grazing or timber harvest taking place on the Preserve. Sonoma State University is committed to using the Preserve as a long-term research station and is in the process of developing a management plan, with graduate students, professors and volunteers available to evaluate and monitor management activities. Additionally, SSU is interested in collaboration with natural resources agencies and NGOs to further mutual conservation goals.

Following is a list of natural resource management issues that require action on the Preserve. Recommendations for management actions are included in the next section, below.

Fences
There are numerous internal and boundary fences on the Galbreath Preserve – a legacy of cattle grazing (see Photo Figure 1). These fences are predominantly multi-strand barbed wire, and are in various states of disrepair. These fences may interrupt the natural range of movement for some terrestrial species. Additionally, fences of this type have been demonstrated to injure wildlife when they are caught in the strands. Finally, the fences disrupt the visual aesthetic of the Preserve – which is dedicated to wildland conservation and education. There is an incomplete understanding of the linear extent of fencing on the Preserve, as well as boundary fencing between the Preserve and other properties.

Logging Debris/Slash Piles
There are several large debris piles on the Preserve that are comprised of large trees and slash (see photo figure 2). These are presumably remnants of a logging operation. These piles pose a fire hazard to the surrounding forest, and are aesthetically inconsistent with the Preserve's mission of wildland conservation.

Invasive Plants and Animals
Numerous invasive plants and animals are predicted to exist, or have been documented via surveys, in the Navarro/Rancheria watershed and on the Preserve. As stated above,

invasive flora and fauna have profoundly negative impacts on watersheds and ecosystems, and may be one of the most significant threats to conservation and restoration success. Although floristic surveys for presence/absence of plant species have been completed on the Preserve, no systematic surveys or mapping of invasive exotic plants have been completed. In order to effectively control invasive plants, a spatially explicit database of their locations and population size is needed. This lack of data inhibits the development of a logical, science-based approach to invasive species management.

Sudden Oak Death

Sudden Oak Death (SOD) has been documented on the Preserve, and some locations have been mapped. Dr. Hall Cushman (Galbreath Preserve Manager and Biology Professor at Sonoma State University) is a leader in SOD research in California, and is engaged in ongoing evaluations regarding the pathogen and its impacts. Substantial data gaps remain regarding the extent of the pathogen on the Preserve and the surrounding watershed.

Road Related Sediment

Road related sediments are a non-point source pollutant detrimental to aquatic environments. Many of the current and abandoned roads and trails on the Preserve are contributing sediment to in-stream environments. A preliminary assessment of the roads on the Preserve was performed by Pacific Watershed Associates (see Appendix B). However, many roads and trails have yet to be assessed.

Historic grazing

Galbreath Preserve was grazed by cattle and sheep during the 18-20th centuries, with the potential effects of this grazing including soil disturbance and the presence of large numbers of invasive exotic species in the rangeland environments on the Preserve. There are inadequate data regarding the history of grazing on the Preserve and in the larger watershed, and no detailed assessments of the impacts have been performed.

Historic logging

The Preserve has a history of timber harvest. There has not been a detailed, spatially explicit assessment of the history of logging on the Preserve.

Riparian Corridors

The riparian corridors on the Preserve appear to be responding to various historic and current land uses – including grazing, logging and road development. Floodplains are mostly devoid of riparian habitat and are predominantly populated by exotic herbaceous species. Bank height in general appears typical of alluvial gravel bed rivers—with the exception of where the River has eroded into an older alluvial terrace deposit, where bank heights appear to exceed 25 feet (see Photo figure 3). Pool formation, due to large woody debris (LWD), associated with bedrock outcrops, or in alluvial reaches is evident, yet there are no data regarding the frequency of pools formed by LWD.

General Data Gaps

There are numerous data gaps on the Preserve in addition to those outlined above. Many of these data gaps are applicable to the larger Rancheria and Navarro watersheds, and include a lack of stream gages, a lack of high quality current aerial photography, detailed information regarding landslide potential, and the lack of a comprehensive GIS database for the Navarro or Rancheria watersheds. The development of a GIS database would allow for analysis of multiple management factors at various temporal and spatial scales, and would support long term monitoring and change detection in response to management activities.

<u>General Recommendations – Navarro Watershed and Rancheria SubBasin</u>

Public agency and watershed group recommendations for enhancement of the Rancheria Creek watershed focus on remediating historic land use impacts and ameliorating or removing current land use impacts to improve water quality and contribute to salmonid recovery (See Appendix E – Priority Management Recommendations). High priority recommendations include implementation of sediment reduction projects, water conservation, instream habitat restoration, and riparian restoration.

The Navarro River Watershed Plan (Entrix 1998) prioritized streams for fisheries restoration and conservation based on the following attributes: a) restoration feasibility; b) restoration efforts likely to be successful; c) restoration would result in near-term (5 years) habitat improvement; and d) restoration efforts would be likely to benefit first coho salmon, then steelhead and general water quality. Prioritized streams are located mainly in forested Coastal Belt terrain and in the western part of the watershed, where stream temperatures are low. In the Rancheria Creek Basin, prioritized streams are: Adams Creek and Yale Creek subbasins (for steelhead management only), Dago, Cold Springs, Minnie, Horse, Camp Creeks, and lower mainstem Rancheria Creek subbasins. Because of the acquisition of the Galbreath Preserve by Sonoma State University—the entire Upper Rancheria should also be considered as a priority area. Sediment reduction projects should be considered within a geomorphic context at the watershed scale. Projects that directly address anthropogenic disturbances, such as inadequate logging road crossings or eroding road surfaces that are easily addressed and that have rapid and measurable impacts should be prioritized. Projects that inhibit natural functions such as bank erosion that are part of river evolution, and that may preclude later restoration of bio-geomorphic process through use of hard structures should be avoided.

The Navarro Watershed Restoration Plan contains recommended land management practices (RLMPs) to assist landowners in identifying and remediating environmental problems associated with current and historic land management practices. Not all RLMPs are applicable to every situation, and should be based on, and evaluated in the context of, specific site conditions. The RLMPs were to be implemented on a voluntary basis with all landowners encouraged to participate. Detailed descriptions of recommended land management practices are provided in Section 6 of the Navarro Watershed Restoration Plan (Entrix 1998). The land management practices proposed in this work a decade ago should be re-evaluated based on results of a review of projects implemented to date. An important component of watershed restoration is to document effectiveness, and long-term impacts associated with projects that have been implemented. Before new projects are constructed—we recommend that each project is evaluated with respect to its goals and objectives, pre-and post-project monitoring, analysis of changes since implementation. Interpretation of results of such studies will help ensure that projects are effective and beneficial.

Based on the preliminary assessments performed by West Coast Watershed, Dr. Joan Florsheim, and Pacific Watershed Associates include the following:

- Expand the road assessment to the entire Rancheria watershed (Galbreath Preserve comprises 3,865 acres or 6.5% of Rancheria and 1.9% of Navarro).
- Document sediment erosion and deposition trends in the past decade at the watershed scale.
- Initiate geomorphic surveys at the reach scale that may provide detailed baseline characteristics needed prior to implementation of restoration activities and a quantitative reference for future monitoring.
- Initiate bio-geomorphic surveys at the site scale in order to understand interactions required for effective restoration.
- Develop a GIS database for the entire Navarro watershed that includes key physical and biotic features and socio-economic data. This database would be useful for analysis of conservation and restoration opportunities, for project planning and implementation, and for monitoring conservation management activities over time.
- Re-establish stream gages in the Rancheria and Navarro – ideally at the locations of historic USGS gages
- Obtain high quality LiDAR coverage for the Navarro watershed
- Perform a detailed analysis of fish passage barriers throughout the Navarro watershed and Rancheria subbasin, and develop a prioritized removal plan

Specific Recommendations – Galbreath Preserve

Fences
All non-essential fences – both internal and boundary fences – should be removed from the Galbreath Preserve and the materials recycled on-site or off-site. If labor resources are limited, the wire and metal posts should be removed, and the wooden posts left in place. Boundary fence removal will require the agreement and cooperation of adjacent landowners.

Logging Debris and Slash Piles
The logs in the debris piles may be useful for augmenting pool formation and habitat in aquatic areas where LWD is limited. Once a riparian corridor assessment has been completed (see below) to determine pool frequency associated with LWD recruitment, a management recommendation may be the placement of large logs in stream to enhance pool formation and in-stream habitat values. The largest logs in the debris piles may be of sufficient size for this approach. The slash and smaller debris in the piles may be separated and spread into smaller piles throughout the Preserve as habitat for small mammals, insects and birds. This work can be accomplished with equipment, and/or by hand in areas where equipment will cause excess disturbance.

Invasive Plants and Animals
A map-based assessment of invasive plants should be conducted on the Preserve, using methods outlined in the *Invasive Species Assessment Protocol* (NatureServe 2004) and a spatially explicit prioritization framework for management and control should be developed. Invasive animals should be documented, a species-specific control plan should be developed, and those with the greatest potential impact on threatened or endangered plant or animal species (such as salmonids) should be priorities for control.

Grazing and Rangeland Impacts
An assessment of historic grazing patterns should be developed, to determine the degree to which current vegetation patterns are natural or the result of grazing-related disturbance, and to help inform management decisions regarding native plant revegetation and/or natural regeneration. An evaluation of grazing as a management tool for invasive plant control and enhancement of floristic diversity should be undertaken.

Logging History/Forest Evaluation
A GIS-based assessment of the actual logging history of the Preserve (ie, not just THP data) as well as an assessment of forest health will help to inform forest management decisions.

Road Related Sediment
Road-related sediment recommendations are included in Appendix B. Next steps include an expansion of the road assessment to those roads not covered in PWA's preliminary assessment (including trails, old logging roads, etc) as well as the larger Rancheria watershed.

Data Gaps
A stream gage(s) should be established for the Preserve. High quality, current aerial photography should be obtained. A change detection analysis should be performed that evaluates landscape-scale changes (based on historic aerial photos and maps). GIS data for the Preserve should be developed in a manner consistent with the larger watershed databases, and with established state and federal protocols. LiDAR data should be acquired as a new baseline data set to help understand factors that influence the Galbreath Preserve.

Bio-Geomorphology
A series of bio-geomorphic management and research sites should be established (see Map E and Photo figure 4) that will allow for a multi-year investigation of the riparian corridors along Rancheria Creek, and upslope processes affecting these areas. Following are recommendations to aid in understanding the relationship between geomorphic features and ecology.

Channel morphology. The channel contains areas of complex structure—large woody debris, multiple channels, bars, vegetation, topographic variation and bedrock that benefit habitat. Baseline morphologic surveys of Rancheria Creek to document morphology and trends include:

- LiDAR survey of the channel and adjacent hillslopes to provide a high resolution topographic base map including bars, floodplains, and the terrace;

- augment LiDAR survey with total station topographic survey of channel bed unless water penetrating LiDAR is used;
- longitudinal profile surveys of channel bed to assess character of riffles, pools, and to quantify channel deposition and scour;
- topographic survey of the channel cross section surveys to integrate physical character of channel with biological attributes (habitat composition, structure, successional stage, LWD potential, etc);
- establish a flow discharge and sediment transport gaging station to provide baseline data to understand aquatic ecology, geomorphic changes and climate change;
- establish a rain gage to correlate channel changes to various storm events.

Pools. Whereas some pools are a component of riffle-pool sequences, many pools are associated with obstructions such as tree roots or bedrock. Riparian trees are present alongside the main low flow channel Tree roots protruding into the channel increase roughness and scour pools locally, fallen branches and woody debris trapped by the live vegetation creates complex pool-bar habitat.

- Investigate the relationship between riparian vegetation and adjacent channel pool morphology.
- Document and monitor changes in the spatial distribution and depths of pools.

Bars. Bars exist adjacent to the low flow channel at a lower elevation than the floodplain. Small patches of fine sediment are present over coarse sediment downstream of trees or other roughness elements.

- Investigate the interaction of vegetation establishment and gravel deposition on channel bars to help understand the mechanisms of bar formation and stability.
- Document bar morphology, spatial distribution, and monitor changes in bar volume and sediment size in relation to riparian vegetation.

Floodplains. The presence of floodplains appears dependent on valley width—with limited floodplain development where the valley is narrow. Floodplains are generally composed of coarse sediment, similar to the channel material. Their surfaces appear relatively level and are vegetated with grass. They contain some woody debris deposition, but few trees. In one location, a coarse cobble levee is about 0.5 m higher than the floodplain further from the channel. Riparian trees are generally present along the floodplain-channel margin. Secondary channels are incised within the floodplains—with fine patches of sand and silt deposited over gravel in topographic low spots.

- Investigate vegetation changes to determine if lack of riparian trees on the floodplain is a result of land use practices such as grazing, if frequent large floods scour any trees that establish on the surface, or if the large sediment size of the floodplain material precludes riparian vegetation establishment.

- Monitor floodplain deposition and erosion processes including sediment accretion during floods and erosion of the floodplain edge as the channel migrates or widens.
- Conduct a photographic time-series to understand the natural dynamics of secondary channel incision and migration.

Bank Erosion. Bank erosion appears to be relatively significant source of sediment of fine material derived from erosion of the inactive terrace. Bank erosion is also active in some areas along floodplain channel margin. Some evidence of recent widening exists, with channels apparently recently cut into adjacent floodplain; recent bank erosion on channel-floodplain margin; and tension cracks along edge of floodplain.

- Document spatial frequency and extent of bank erosion through mapping of various erosion features.
- Monitor rates of change using methods such as erosion pins or ground based lidar.

Hillslope Channel Interactions. In mountain streams, hillslope-channel interactions are important. Small debris slides are present along the edge of the terraces, and on hillslopes adjacent to Rancheria Creek. Inactive terrace is a large deposit of fine sediment—best exposure is downstream of barn where a portion of the terraces is undergoing active erosion.

- Document landslides that contribute sediment to Rancheria Creek and its tributaries using high resolution aerial images. Compare to historical photographic images to aid in understanding sediment supply rates to Rancheria Creek.

Revegetation Research Trials. Plan and implement native plant revegetation trials in selected active channel and floodplain areas to compare natural regeneration with active revegetation. Revegetation plots should be distributed along a cross-sectional gradient in each of the research zones shown on Map E, with revegetation data correlated to geomorphic features (ie, elevation, distance from low-flow channel, sediment characteristics, etc). Corresponding cross-sectional controls should be implemented up and downstream of the revegetation trial zones. Plant selection for the revegetation trials should be based on reference sites up or downstream from the research areas, in areas with similar hydrologic and geomorphic features. Native plants for revegetation should be collected from within the upper Rancheria watershed to ensure that they are genetically appropriate and well-adapted to the site. Baseline assessment and monitoring should evaluate plant survival, growth, reproductive status and influences on physical features and processes (ie, temperature and sediment) over a 5-10 year period.

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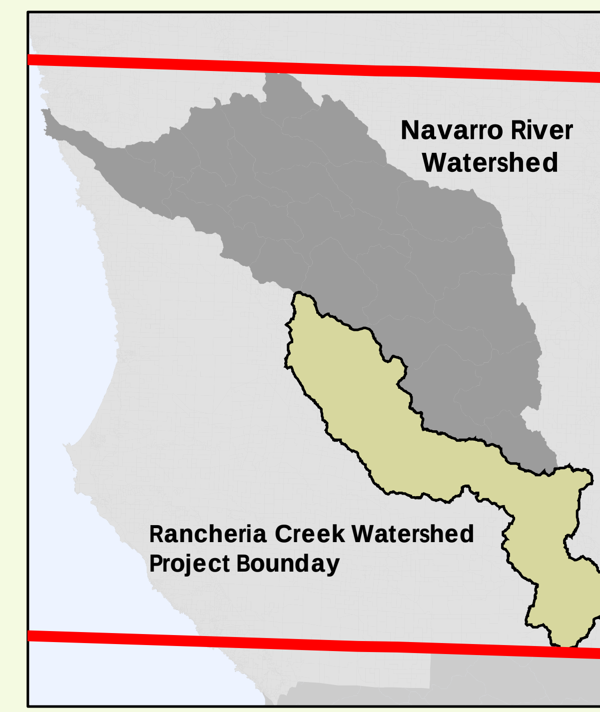
Upper Rancheria Creek

Preliminary Bio-Geomorphic Assessment

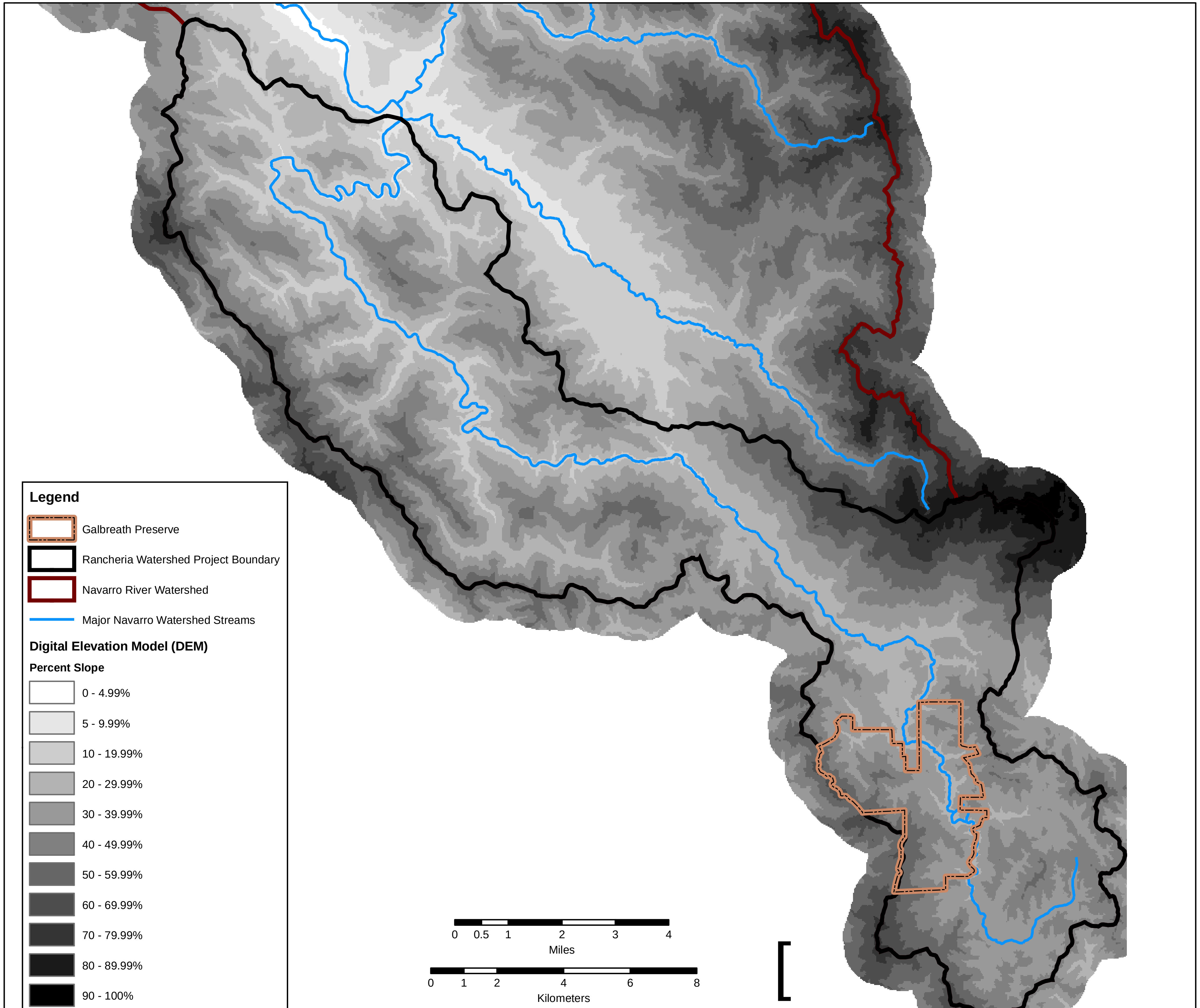
Navarro River Watershed Hillshade Map Map A

Data Souce:

California Interagency Watershed Mapping Committee
CDF, Fire and Resource Assessment Program
Sonoma State University



WEST COAST WATERSHED



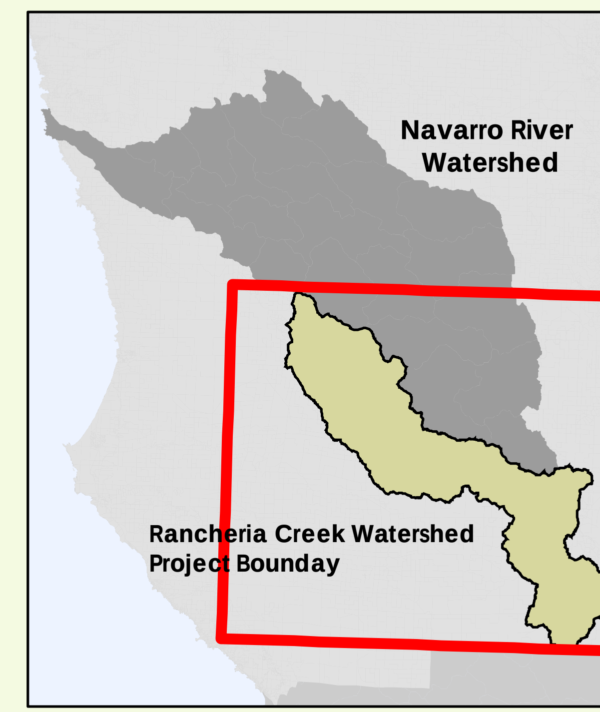
Upper Rancheria Creek

Preliminary Bio-Geomorphic Assessment

Rancheria Creek Watershed Slope Map Figure 2

Data Souce:

California Interagency Watershed Mapping Committee
CDF, Fire and Resource Assessment Program
US Geologic Survey
Sonoma State University



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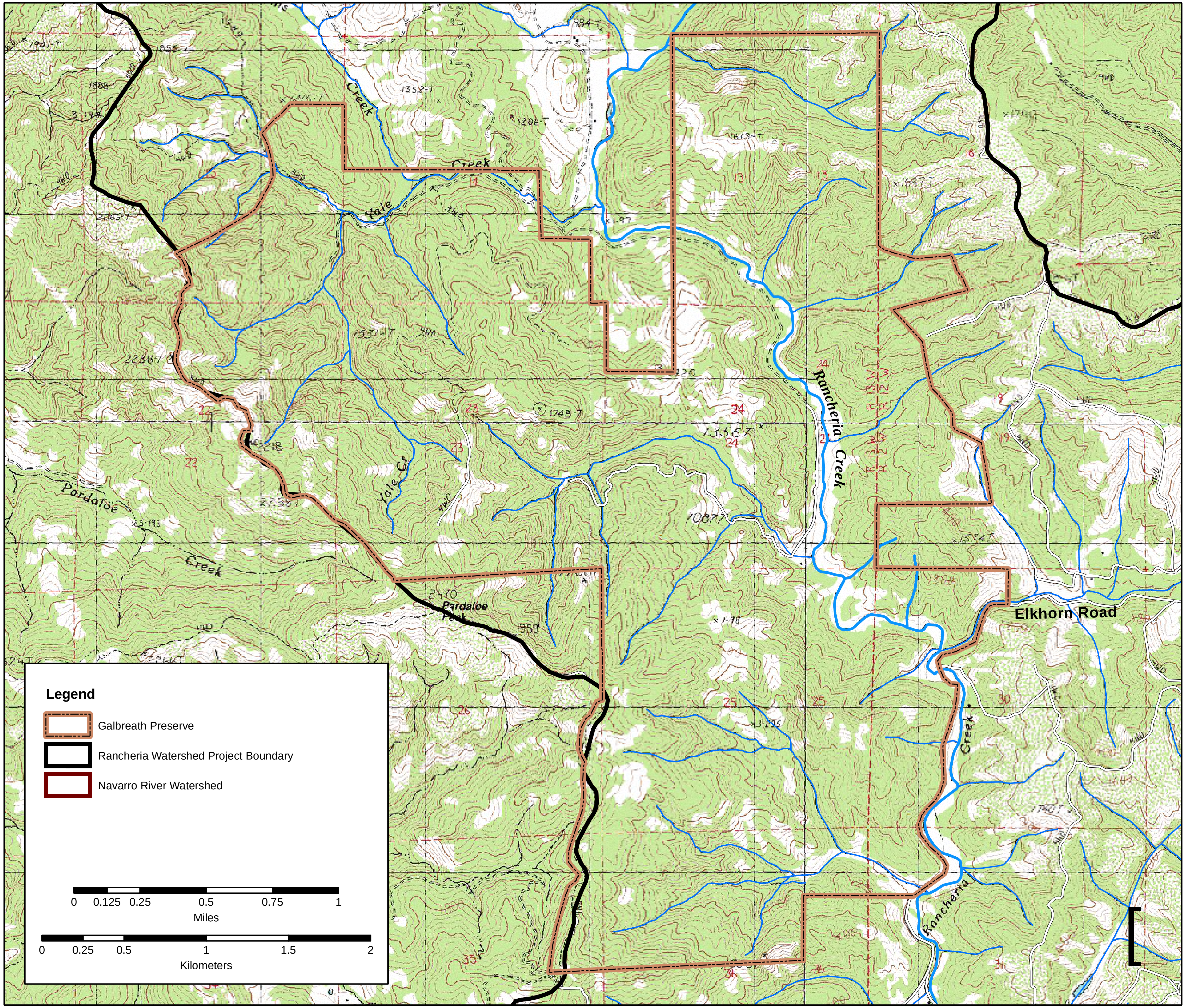


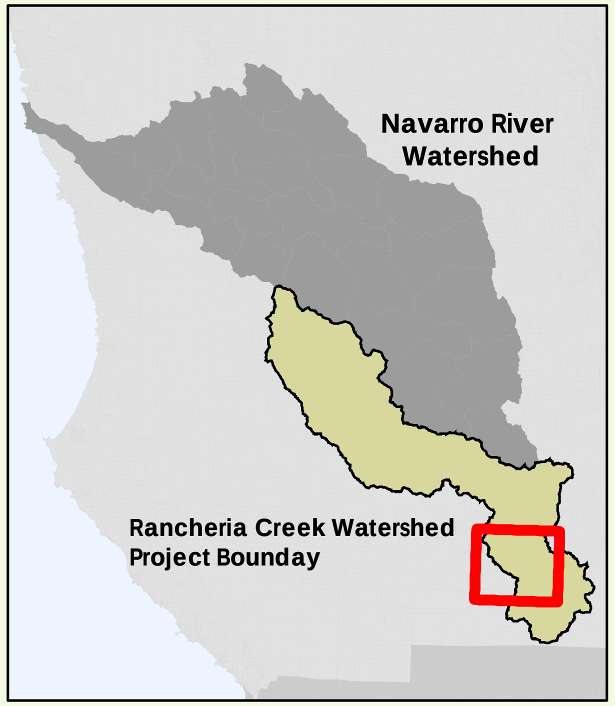
Upper Rancheria Creek

Preliminary
Bio-Geomorphic Assessment

Galbreath Preserve
Topographic Map
Figure 3

Data Souce:

California Interagency Watershed Mapping Committee
CDF, Fire and Resource Assessment Program
USGS Topographic 7.5 minute Quadrangle, Yorkville
Sonoma State University



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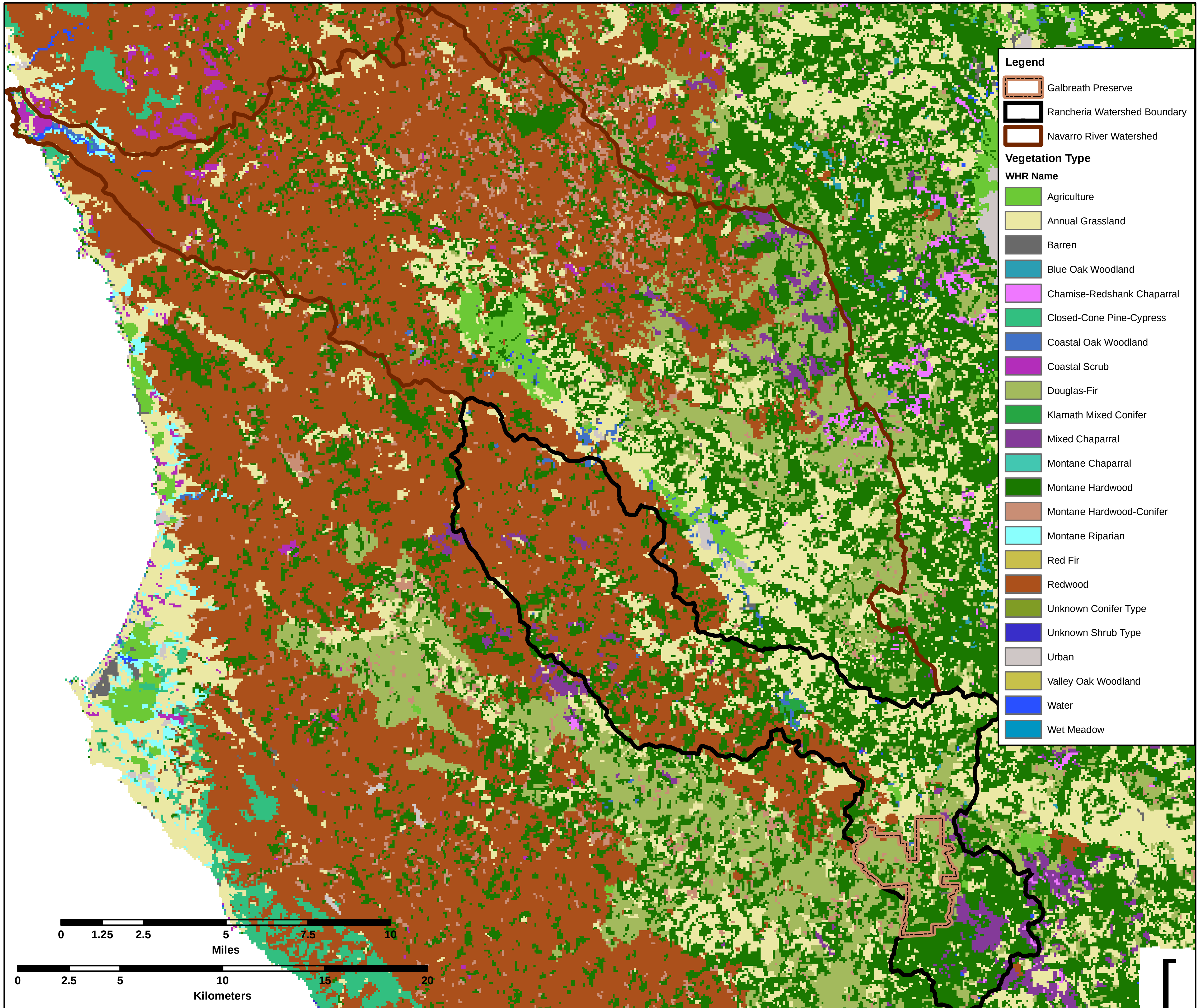


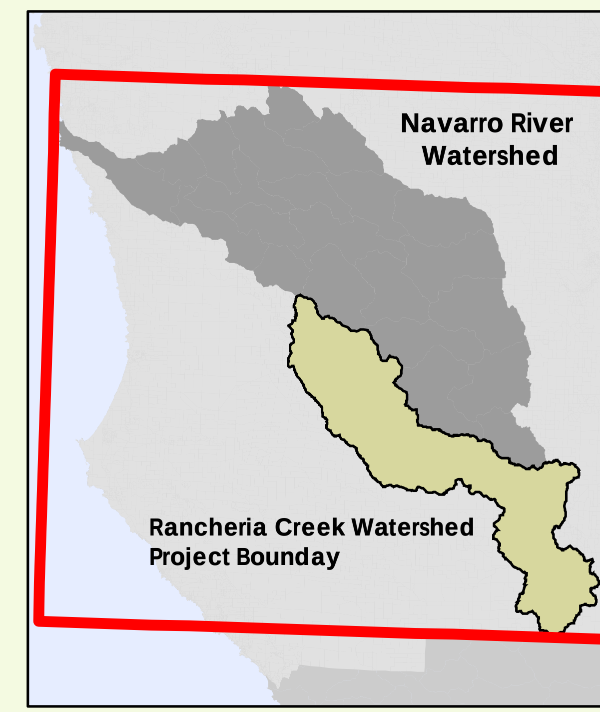
Upper Rancheria Creek

Preliminary Bio-Geomorphic Assessment

Navarro River Watershed Vegetation Type Map B

Data Souce:

California Interagency Watershed Mapping Committee
CDF, Fire and Resource Assessment Program
Sonoma State University



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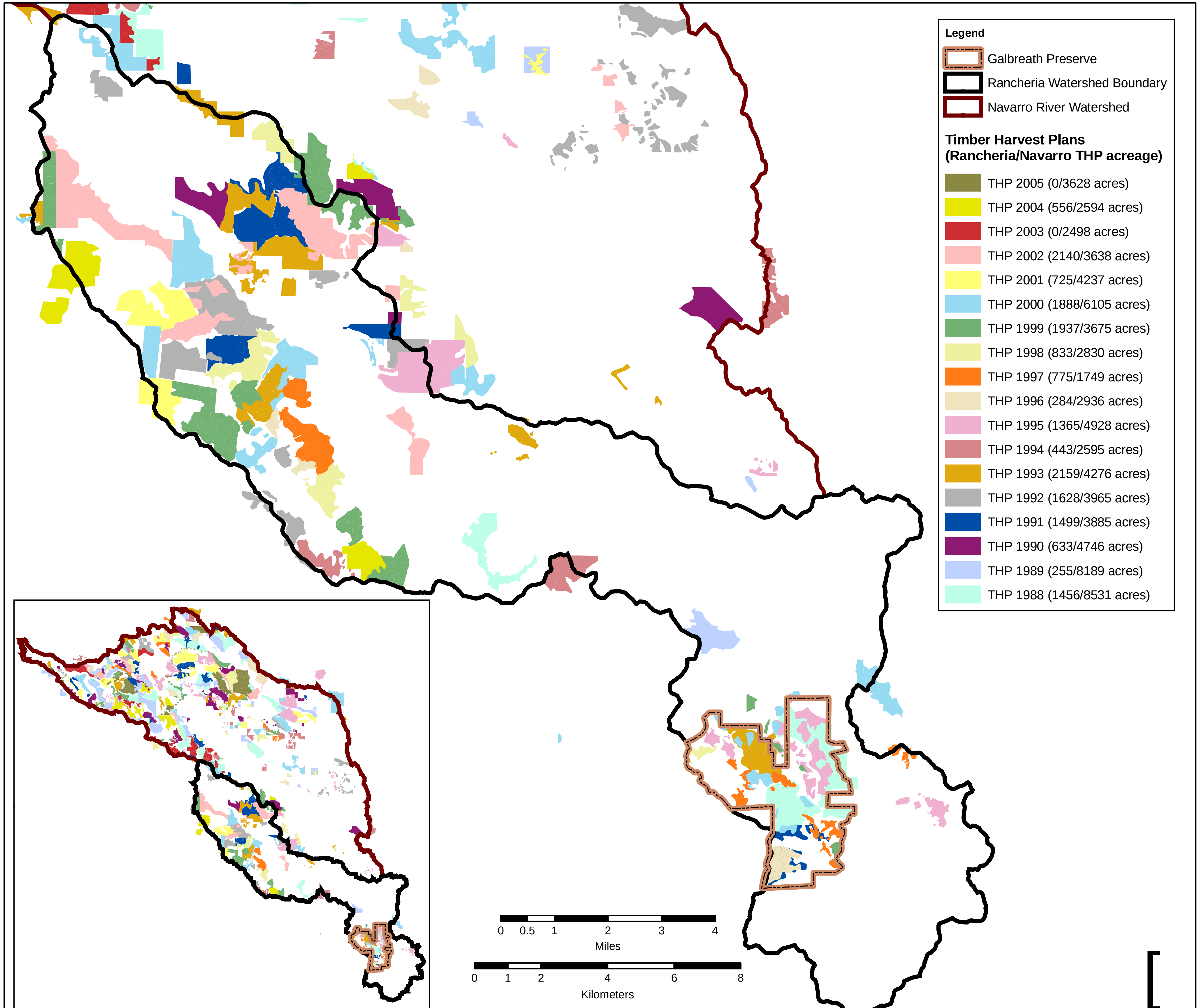


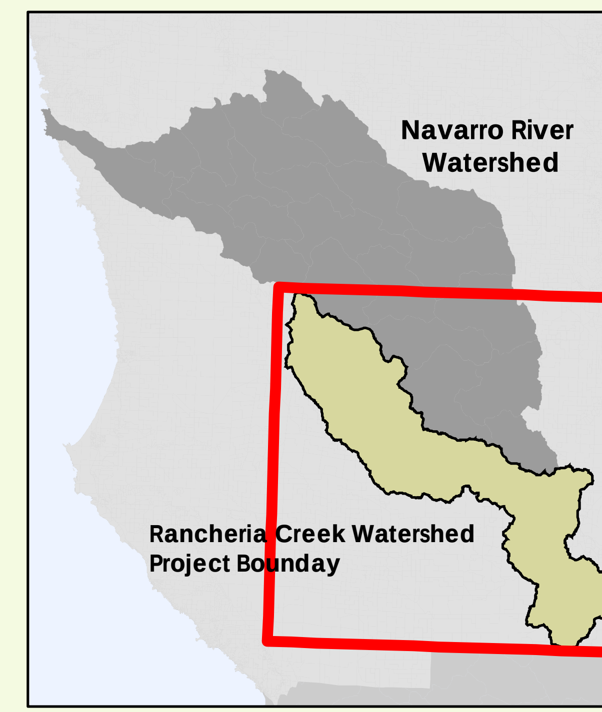
Upper Rancheria Creek

Preliminary
Bio-Geomorphic Assessment

Rancheria Creek Watershed
Timber Harvest Plan (THP)
Map C

Data Souce:

California Interagency Watershed Mapping Committee
CDF, Fire and Resource Assessment Program
Sonoma State University



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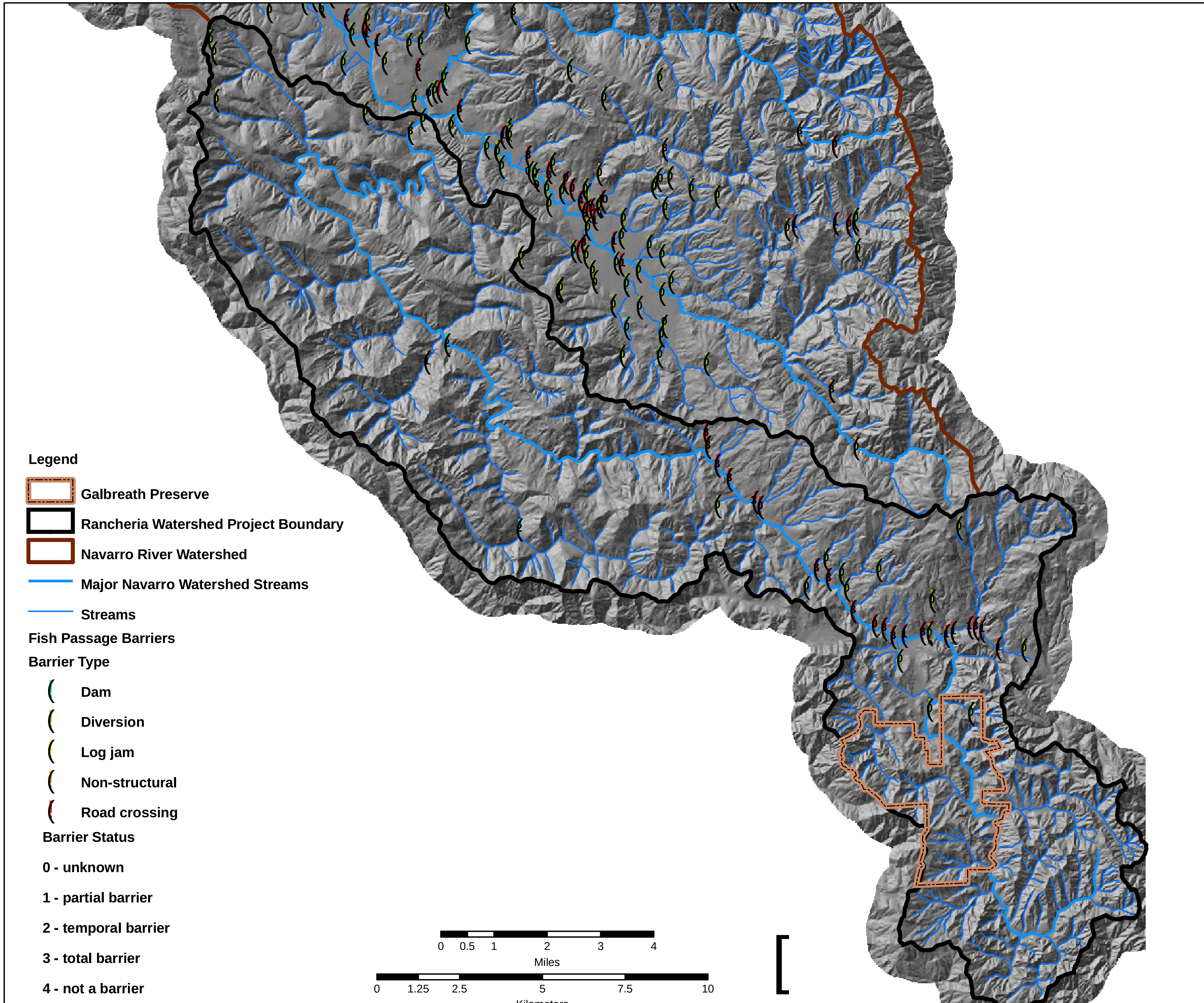


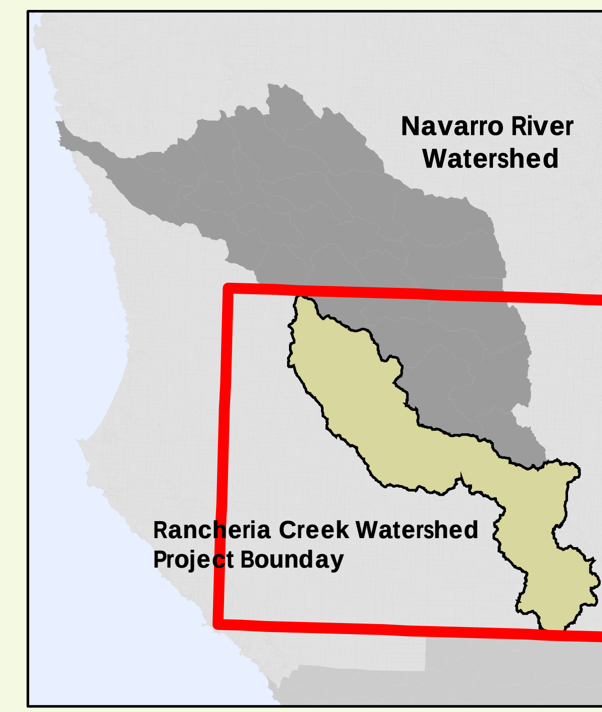
Upper Rancheria Creek

Preliminary
Bio-Geomorphic Assessment

Rancheria Creek Watershed
Fish Passage Barriers
Map D

Data Souce:

California Interagency Watershed Mapping Committee
CalFish, California Fish Passage Assessment Database
Sonoma State University



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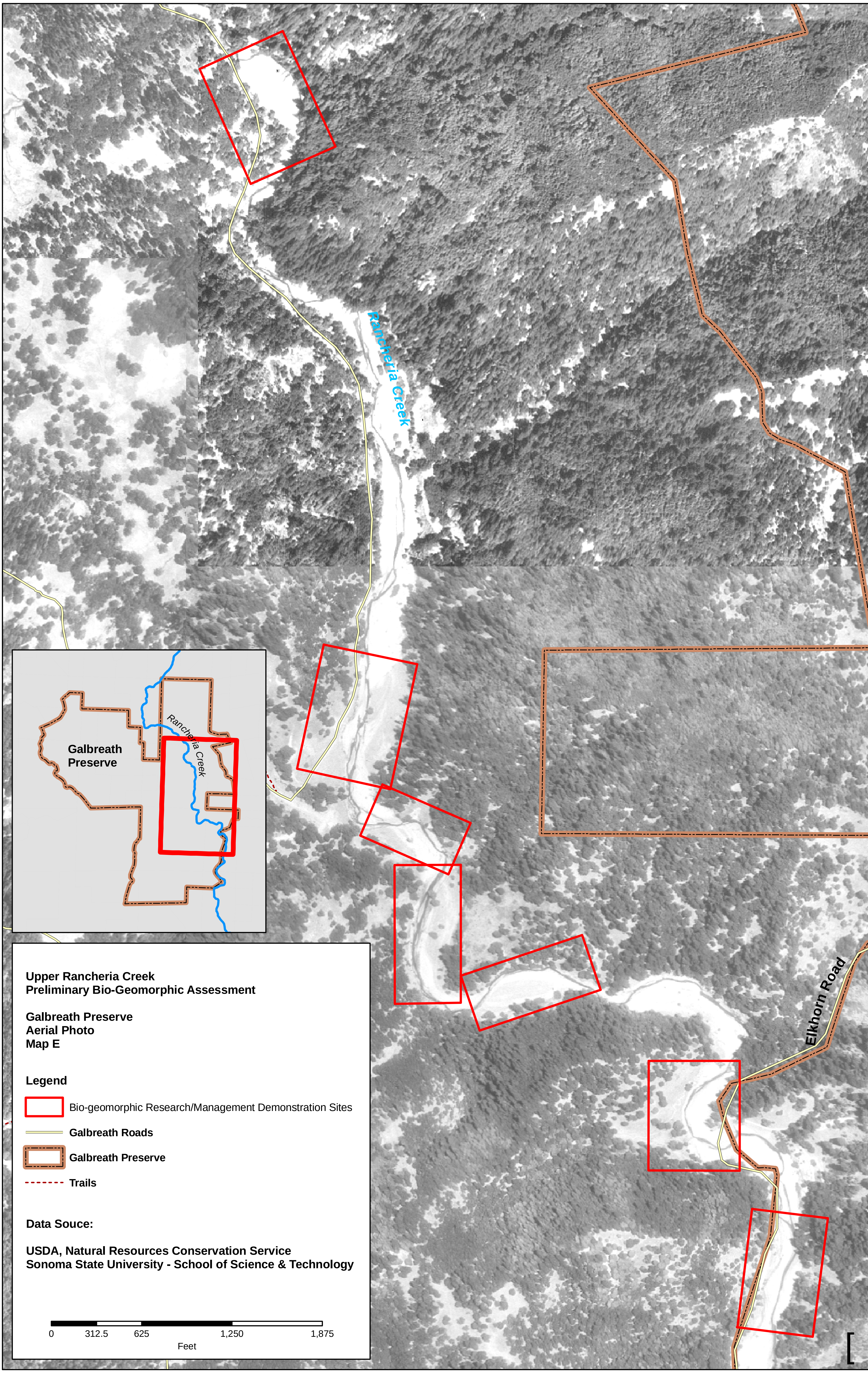
Rancheria Creek
Galbreath Preserve
Rancheria Creek
Elkhorn Road
Upper Rancheria Creek
Preliminary Bio-Geomorphic Assessment
Galbreath Preserve
Aerial Photo
Map E
Legend
Bio-geomorphic Research/Management Demonstration Sites
Galbreath Roads
Galbreath Preserve
Trails
Data Souce:
USDA, Natural Resources Conservation Service
Sonoma State University - School of Science & Technology
0
312.5
625
1,250
1,875
Feet

Photo Figure 1.
Fences on Galbreath Preserve

Photo Figure 2. Logging Debris Piles

Photo Figure 3. Riparian Corridors

Floodplains - limited riparian vegetation

Vertical banks – fine sediments

Photo Figure 4.
Bio-geomorphic Research and Management Demonstration Sites

Appendix A

Upper Rancheria Creek Baseline Fluvial Geomorphology: Reconnaissance Assessment

Dr. Joan Florsheim, UC Davis

Upper Rancheria Creek
Baseline Fluvial Geomorphology: Reconnaissance Assessment

DRAFT

A REPORT PREPARED FOR
MENDOCINO COUNTY RESOURCE CONSERVATION DISTRICT

Prepared by:

Joan Florsheim, Geology Department
University of California, Davis

APRIL 2007

Watershed Context

The Navarro River in Mendocino County, California is a mountainous coastal watershed, with a drainage area of about 785 km^2, enters the Pacific Ocean 32 km south of the town of Mendocino (Figure 1). Four main tributaries form the Navarro River, including: Rancheria Creek, Anderson Creek, Indian Creek, and the North. The confluences of three of these tributaries—Rancheria Creek, Anderson Creek, and Indian Creek—form the Navarro River in the northern portion of the Anderson Valley. Rancheria Creek is the largest of these main tributaries and generally flows from the southeast to northwest in a drainage basin with an area of about 240 km^2 (see Figure 1).

Climate, geology, tectonics, and land uses are the primary factors controlling erosion and sedimentation processes in the Rancheria Creek watershed. Climate in the basin is relatively wet. Rainfall and floods are seasonal, falling primarily between October and May, typical of the wet Mediterranean-type climate of north coastal California. Large storms, floods, and resulting sediment transport processes are episodic. Since the 1950's significant floods have occurred frequently, on a temporal scale of about once a decade (Florsheim et al., 2001).

The entire Navarro basin is underlain by the Franciscan Formation, and is characterized by its distinctive geology; however no detailed geologic maps of the area are available. The dominant rock type in Upper Rancheria Creek includes Cretaceous/Jurassic Franciscan mélange and metamorphic rocks, whereas the dominant rock types present in lower Rancheria Creek includes Tertiary/Cretaceous Franciscan coastal belt sandstone and shale. Quaternary alluvium fills the relatively larger valleys.

The area is tectonically active, and the drainage pattern of Rancheria Creek is governed by the structural control imposed by tectonics and geology. Regional uplift rates are relatively high, averaging between 0.6 to 1.5 m/ka (Muhs et al., 1987; Merritts and Vincent, 1989). The northeast portions of the Rancheria Creek watershed contain the highest slopes in the basin (Figure 2). Figure 2a illustrates the distribution of slope classes in the Galbreath Preserve relative to Rancheria Creek. Upper Rancheria Creek and the Galbreath Preserve contain relatively moderate slopes compared to the steeper portion of the basin along the northeast and southwest divides, and the lower gradient downstream reaches of Rancheria creek that flows through wider valleys. The drainage network present of the Upper Rancheria watershed is contained within three main subbasins: Upper Rancheria, Double Diamond, and Yale-Adams as illustrated in Figure 3. Numerous small tributaries to these systems are unnamed creeks draining steep slopes.

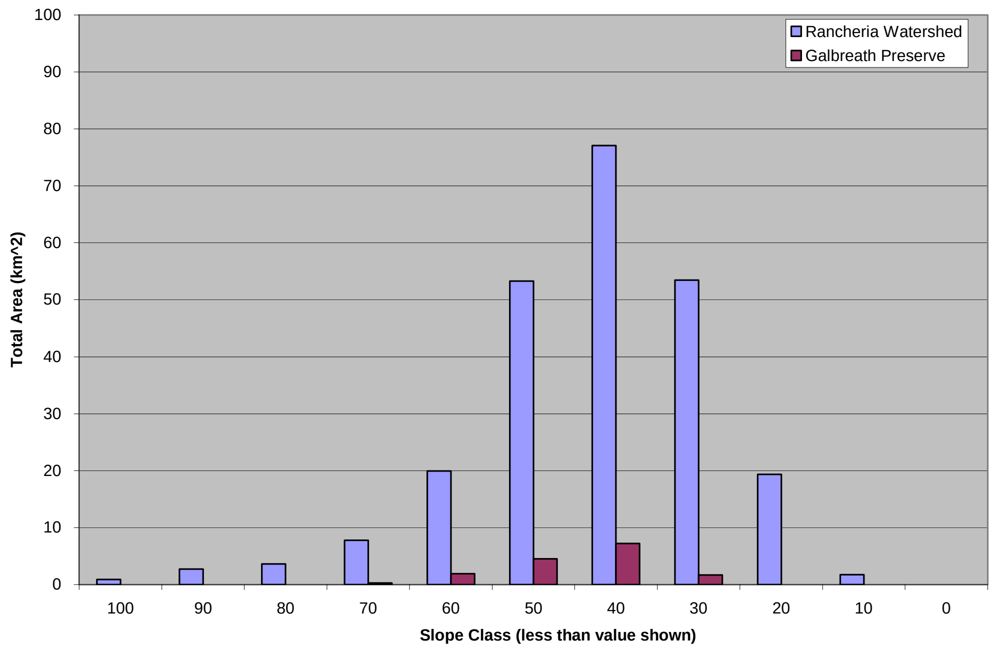

Figure 2a. Distribution of Slope Classes in Galbreath Preserve Relative to the Rancheria Creek Watershed.

Faults apparent throughout the watershed follow the regional northwest-south east tectonic trend of California, and Rancheria Creek flows alternately through structurally formed broad alluvial valleys and relatively narrow canyons. A "shutter ridge" moving along one side of a fault appears to have blocked the valley that separates the Rancheria Creek from the Anderson Creek drainage basin, sending Rancheria Creek away from the Robinson Creek headwaters, in a somewhat circuitous route to its confluence with Anderson Creek further downstream. Figure 4 shows that within the diversity of soils associated with the Franciscan rocks, geologic structures influence the spatial distribution of geomorphic processes. For example, where Highway 128 follows Rancheria Creek, the north side of the valley is underlain by Franciscan mélange prone to large hillside earthflows, whereas the south side is underlain by Coastal Belt Franciscan prone to smaller debris slides.

Landuses influencing Rancheria Creek include grazing, logging, agriculture, rural residential development, road construction, and water diversions. Highway 128 influences Rancheria Creek and the downstream segment of Beebe Creek for about 12 km. Small stock ponds dam the upstream reaches of some tributaries. The Navarro River is currently listed by the State Water Resources Control Board (2000) as having impaired water quality due to sediment and temperature, in accordance with Section 303 (d) of the federal Clean Water Act. Both factors influence coho and steelhead habitat.

Timber harvest plans (THPs) digitized for the period between 1988-2000 illustrates the pervasiveness of planned logging activities within several distinct clusters (Figure 5) within the Rancheria Creek Watershed. The Galbreath Preserve is one of the clusters with the majority of the area planned for logging during that period. (Entrix et al., 1998) shows moderate logging road density the area around Galbreath Preserve, whereas there is high density in the northernmost forested portion of the Rancheria basin. This legacy of logging within the watershed, with potential abandoned logging roads and associated landings provides a potential source of sediment to downstream aquatic environments.

Geomorphic Processes Active at the Galbreath Preserve

In steep areas such as is present in the Galbreath Preserve, natural hillslope processes include shallow debris slides, debris flows, earthflows, and gullies—similar to processes present areas with similar geology in the Navarro basin mapped by Manson (1984). Such processes all contribute to the relatively high sediment supply of the Navarro basin. Data from RWQCB (2000) suggest that natural geomorphic processes in the Rancheria Creek basin account for about 25% of the sediment yield from the Navarro River watershed. The influence of logging roads on sediment production is currently being addressed by PWA in a separate part of this study.

Figure 6 illustrates stream order in upper Rancheria Creek. Stream order is a useful indicator of channel processes and functions—with the smallest first order channels influenced by landslides and debris flows and the highest order channels dominated by fluvial processes. Figure 6 suggests that the main stem of Rancheria Creek is a fifth order stream within the Preserve. The tool is limited by the methods used to generate the stream order classification system—here a 1:24,000 scale topographic map was used as the base map. Thus, finer resolution images such as lidar combined with detailed field mapping can show smaller streams than was possible with the data used here. Despite this limitation, the stream order map illustrates that the majority of channels present in the Galbreath Preserve are headwater streams of the Yale-Adams and Upper Rancheria Creek tributaries. Attributes of mountain rivers are described in Wohl (2000) as relatively steep streams with high spatial complexity, where bedrock and coarse clasts such as cobbles and boulders are common. She notes the potential for extraordinary high sediment yields over a period of a few years following wildfire or timber harvest.

Within the Galbreath Preserve, numerous low order headwater channels are present. Although many are unnamed, such streams are significant because they form the linkage between stream channel networks and the surrounding land. Low order channels typically are important source areas for sediment, water, large woody debris, and nutrients. Headwater streams play a role in water supply and quality, sediment supply, and biodiversity. In these small channels, landslides, debris flows, and fluvial flood flows occur episodically—creating diverse aquatic habitat and riparian wetlands.

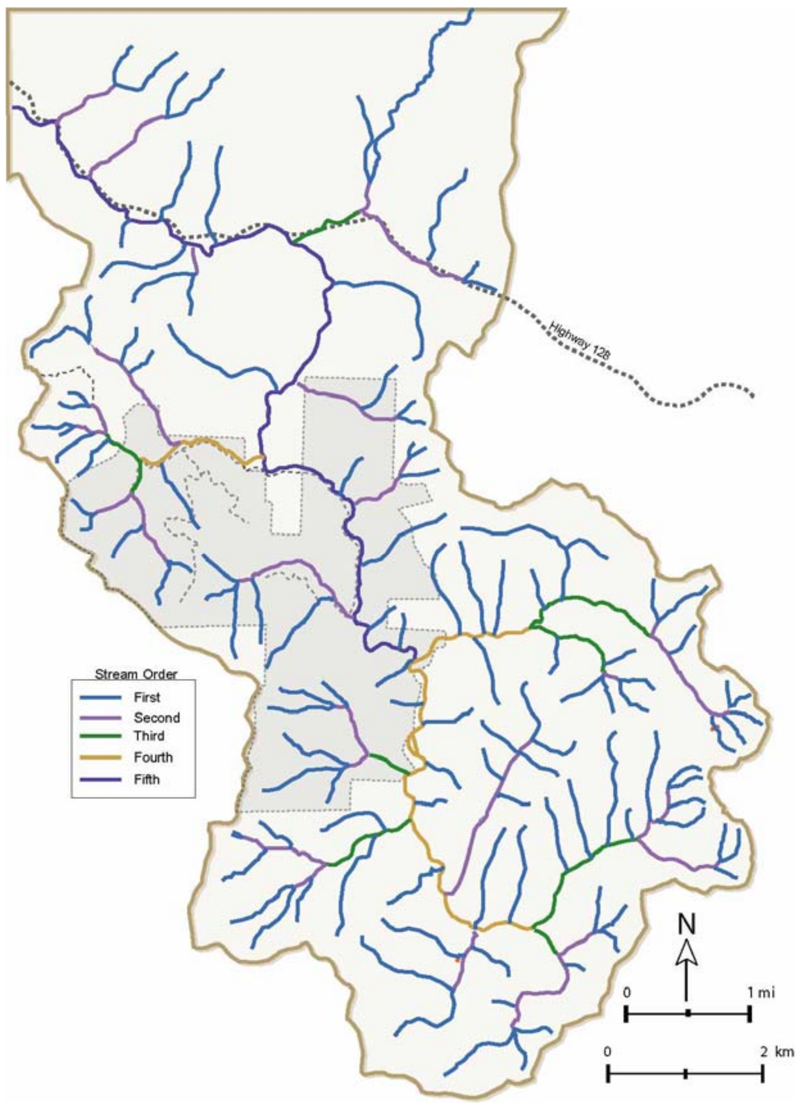

Figure 6. Preliminary Stream Order Map of Upper Rancheria Creek.

Rancheria Creek Fluvial Geomorphology: Field Reconnaissance

A field reconnaissance of Rancheria Creek was conducted in the reach upstream of the barn within the Galbreath Preserve. In this reach, the main stem of Rancheria Creek is a gravel-cobble bed stream, with an inactive terrace, an active floodplain, bars, and some riffle-pool habitat. Observations of morphologic characteristics and geomorphic and vegetation interactions can lead to further research investigations. The following reflects field observations and discussion made in the field with Karen Gaffney and is the basis for an integrated approach for reach scale geomorphic analyses and long-term monitoring:

Channel morphology. The channel contains areas of complex structure—large woody debris, multiple channels, bars, vegetation, topographic variation and bedrock that benefit habitat. Baseline morphologic surveys of Rancheria Creek to document morphology and trends include:

- lidar survey of the channel and adjacent hillslopes to provide a high resolution topographic base map including bars, floodplains, and the terrace;
- augment lidar survey with total station topographic survey of channel bed unless water penetrating lidar is used;
- longitudinal profile surveys of channel bed to assess character of riffles, pools, and to quantify channel deposition and scour;
- topographic survey of the channel cross section surveys to integrate physical character of channel with biological attributes;
- establish a flow discharge and sediment transport gaging station to provide baseline data to understand aquatic ecology, geomorphic changes and climate change;
- establish a rain gage to help related channel changes to various storm events.

Pools. Whereas some pools are a component of riffle-pool sequences, many pools are associated with obstructions such as tree roots or bedrock. Riparian trees are present alongside the main low flow channel Tree roots protruding into the channel increase roughness and scour pools locally, fallen branches and woody debris trapped by the live vegetation creates complex pool-bar habitat.

- Investigate the relationship between riparian vegetation and adjacent channel pool morphology.
- Document and monitor changes in the spatial distribution and depths of pools.

Bars. Bars exist adjacent to the low flow channel at a lower elevation than the floodplain. Small patches of fine sediment are present over coarse sediment downstream of trees or other roughness elements.

- Investigate the interaction of vegetation establishment and gravel deposition on channel bars to help understand the mechanisms of bar formation and stability.
- Document bar morphology, spatial distribution, and monitor changes in bar volume and sediment size in relation to riparian vegetation.

Floodplains. The presence of floodplains appears dependent on valley width—with limited floodplain development where the valley is narrow. Floodplains are generally composed of coarse sediment, similar to the channel material. Their surfaces appear relatively level and are vegetated with grass. They contain some woody debris deposition, but few trees. In one location, a coarse cobble levee is about 0.5 m higher than the floodplain further from the channel. Riparian trees are generally present along the floodplain-channel margin. Secondary channels are incised within the floodplains—with fine patches of sand and silt deposited over gravel in topographic low spots.

- Investigate vegetation changes to determine if lack of riparian trees on floodplain is a result of land use practices such as grazing, if frequent large floods scour any trees that establish on the surface, or if the large sediment size of the floodplain material precludes riparian vegetation establishment.
- Monitor floodplain deposition and erosion processes including sediment accretion during floods and erosion of the floodplain edge as the channel migrates or widens.
- Conduct a photographic time-series to understand the natural dynamics of secondary channel incision and migration.

Bank Erosion. Bank erosion appears to be relatively significant source of sediment of fine material derived from erosion of the inactive terrace. Bank erosion is also active in some areas along floodplain channel margin. Some evidence of recent widening exists, with channels apparently recently cut into adjacent floodplain; recent bank erosion on channel-floodplain margin; and tension cracks along edge of floodplain.

- Document spatial frequency and extent of bank erosion through mapping of various erosion features.
- Monitor rates of change using methods such as erosion pins or ground based lidar.

Hillslope Channel Interactions. In mountain streams, hillslope-channel interactions are important. Small debris slides are present along the edge of the terraces, and on hillslopes adjacent to Rancheria Creek. Inactive terrace is a large deposit of fine sediment—best exposure is downstream of barn where a portion of the terraces is undergoing active erosion.

- Document landslides that contribute sediment to Rancheria Creek and its tributaries using high resolution aerial images. Compare to historical photographic images to aid in understanding sediment supply rates to Rancheria Creek.

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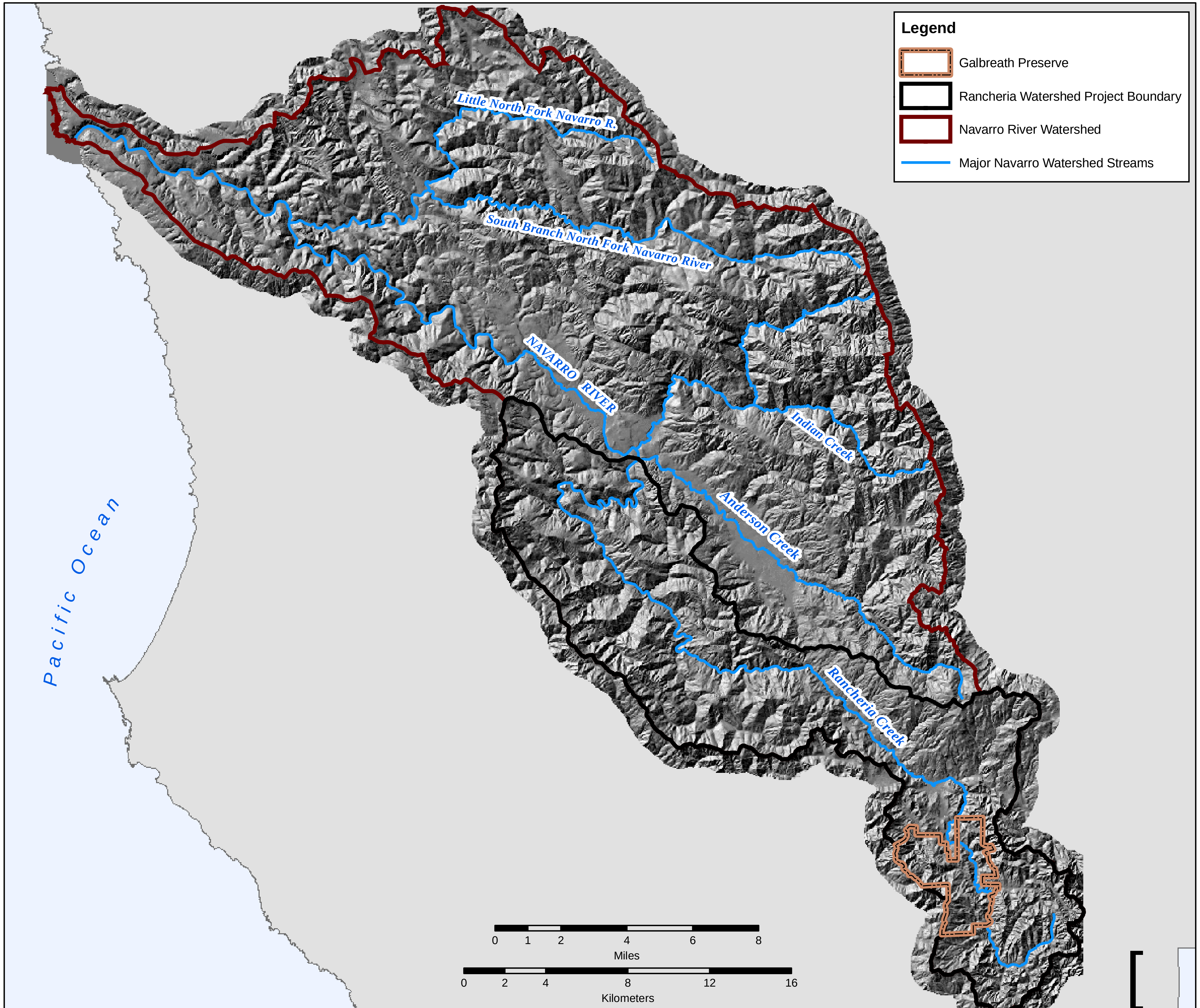


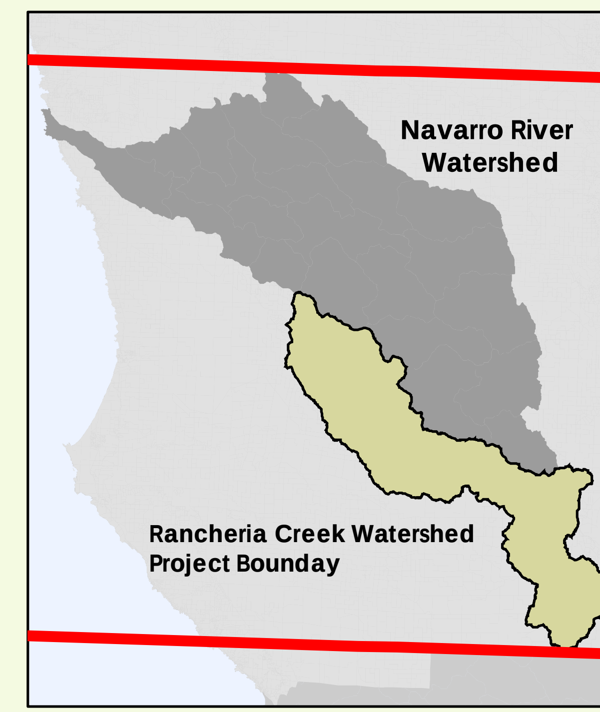
Upper Rancheria Creek

Preliminary
Bio-Geomorphic Assessment

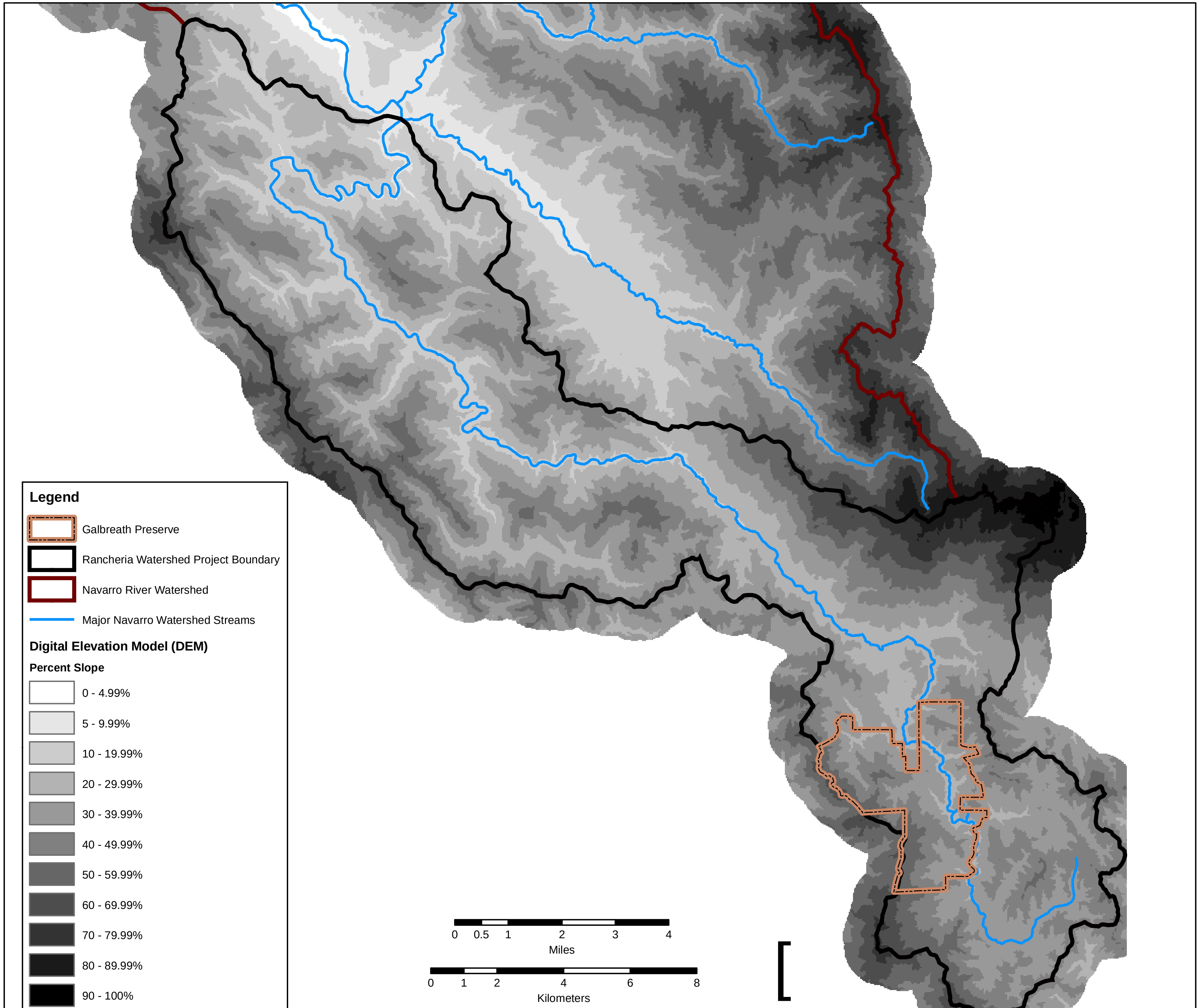
Navarro River Watershed
Hillshade Map
Figure 1

Data Souce:

California Interagency Watershed Mapping Committee
CDF, Fire and Resource Assessment Program
Sonoma State University



WEST COAST WATERSHED



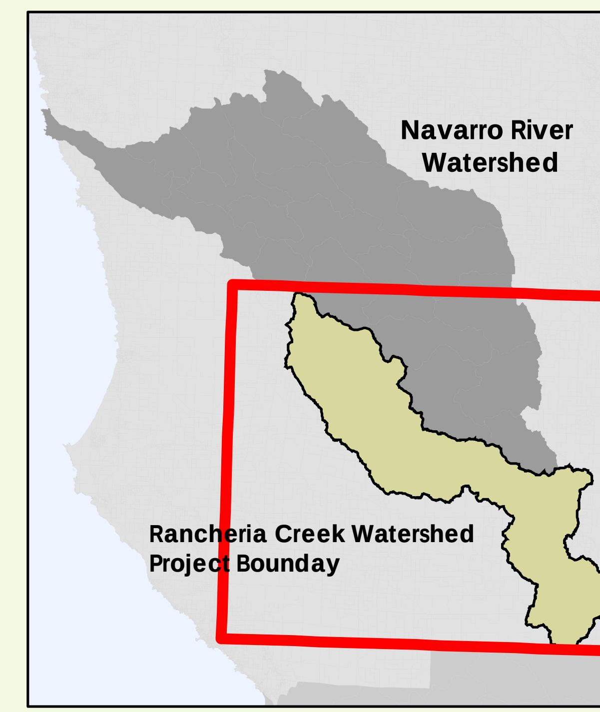
Upper Rancheria Creek

Preliminary
Bio-Geomorphic Assessment

Rancheria Creek Watershed
Slope Map
Figure 2

Data Souce:

California Interagency Watershed Mapping Committee
CDF, Fire and Resource Assessment Program
US Geologic Survey
Sonoma State University



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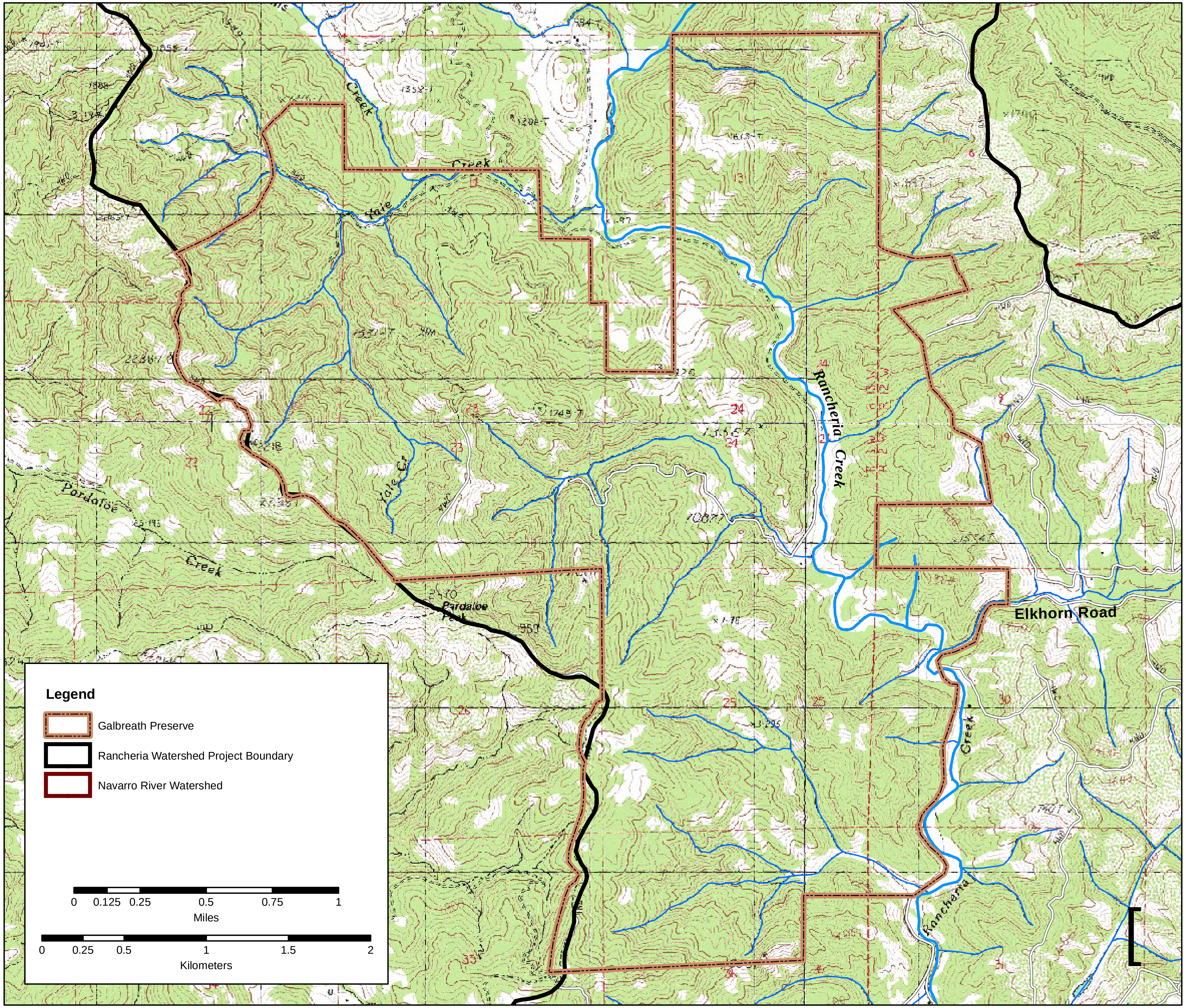


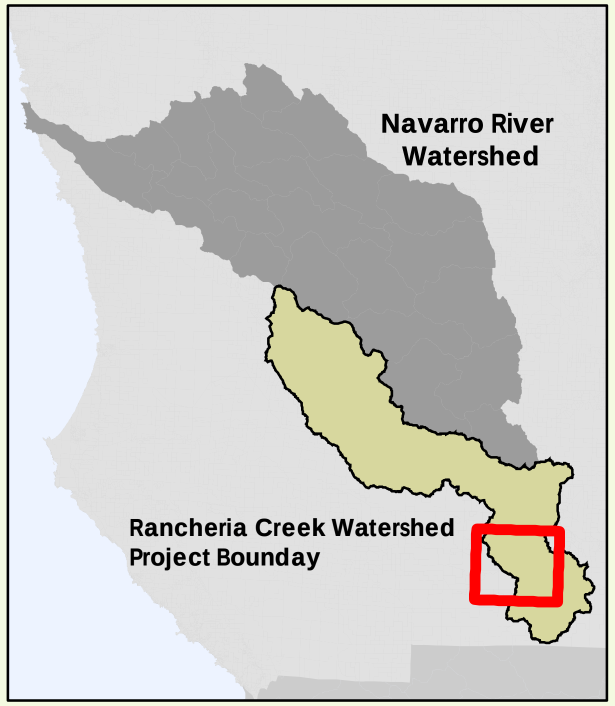
Upper Rancheria Creek

Preliminary Bio-Geomorphic Assessment

Galbreath Preserve Topographic Map Figure 3

Data Souce:

California Interagency Watershed Mapping Committee
CDF, Fire and Resource Assessment Program
USGS Topographic 7.5 minute Quadrangle, Yorkville
Sonoma State University

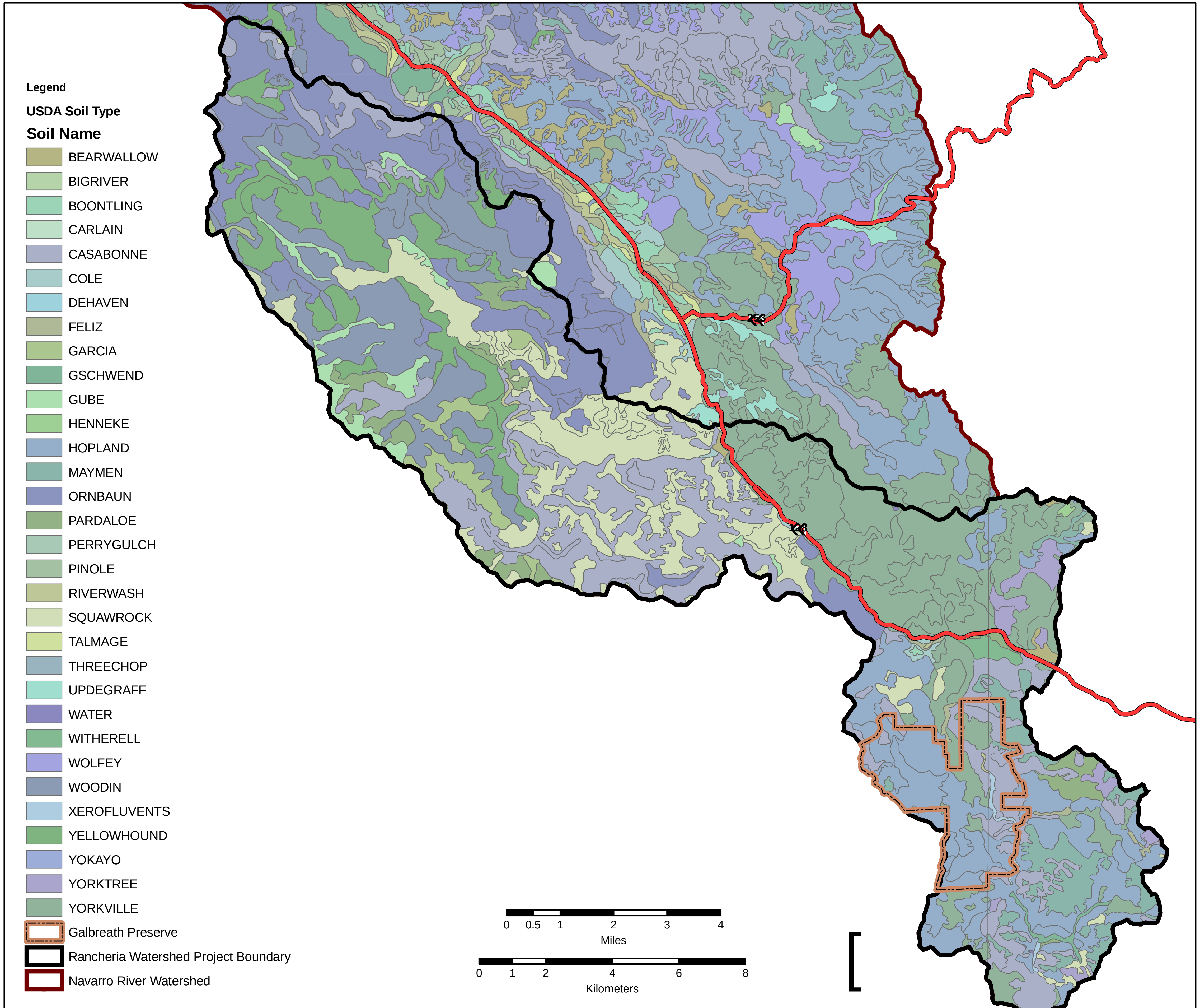


WEST COAST WATERSHED

Upper Rancheria Creek

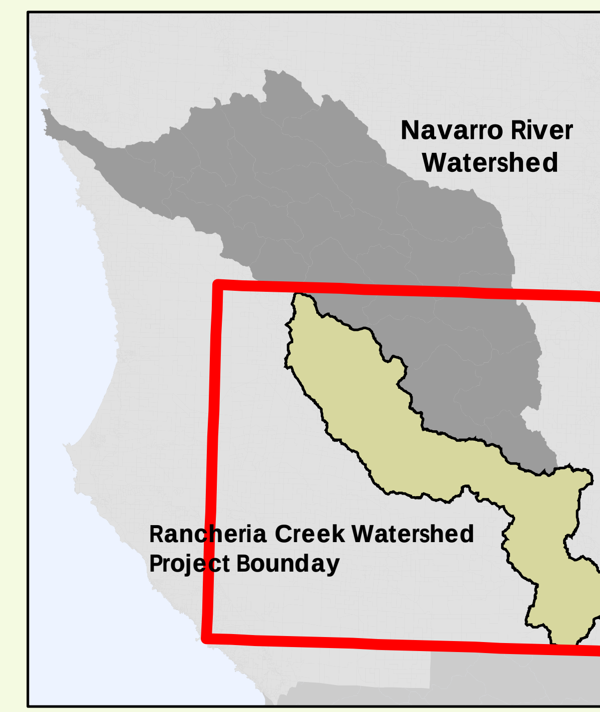
Preliminary
Bio-Geomorphic Assessment

Rancheria Creek Watershed
Soils
Figure 4



Data Souce:

California Interagency Watershed Mapping Committee
USDA Soil Survey Geographic (SSURGO) Database
Sonoma State University



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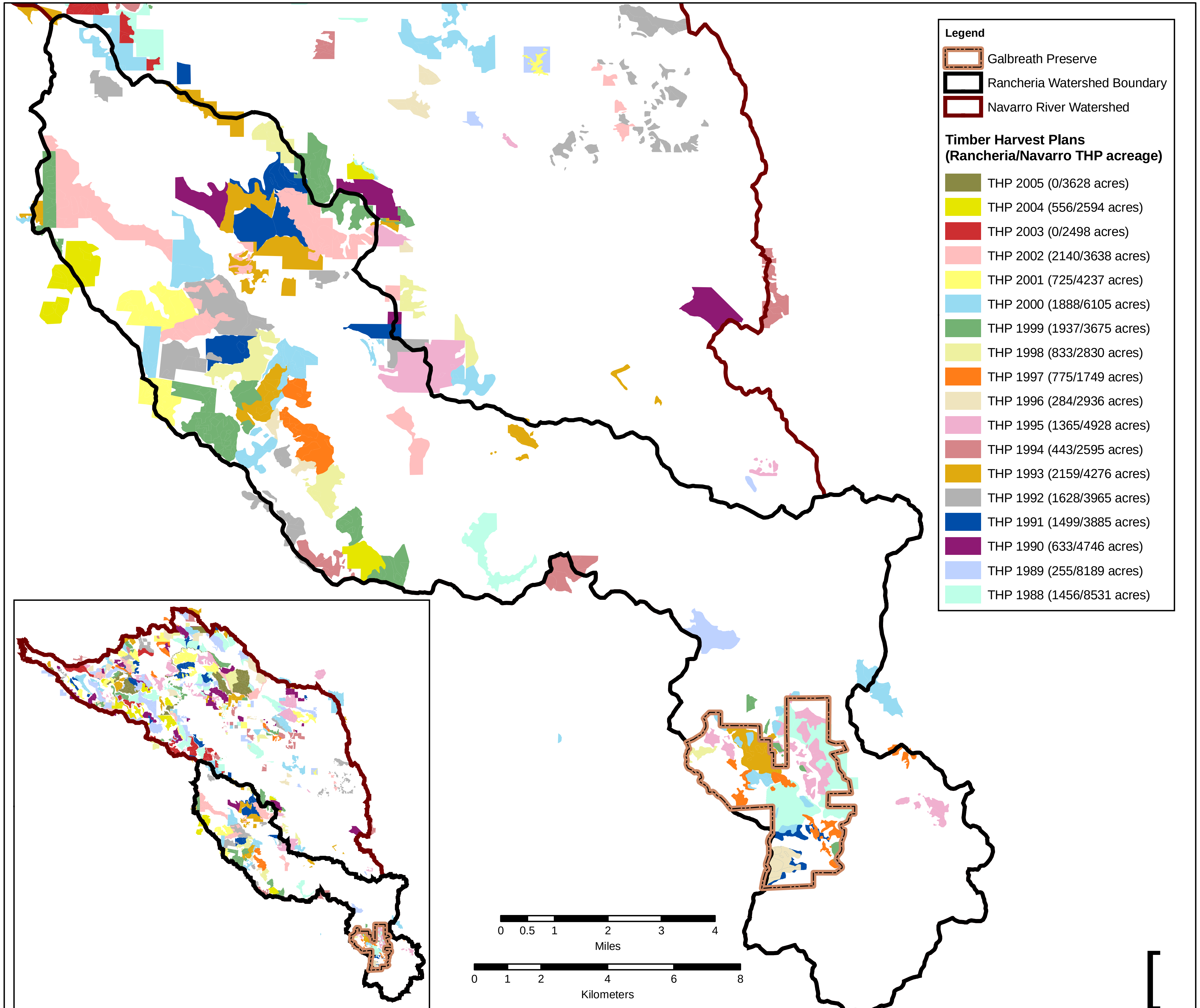


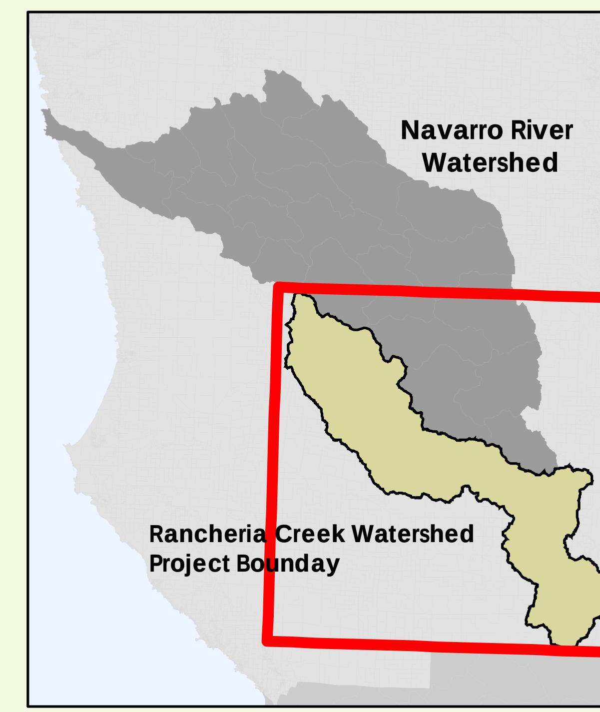
Upper Rancheria Creek

Preliminary
Bio-Geomorphic Assessment

Rancheria Creek Watershed
Timber Harvest Plan (THP)
Figure 5

Data Souce:

California Interagency Watershed Mapping Committee
CDF, Fire and Resource Assessment Program
Sonoma State University



WEST COAST WATERSHED

Appendix B

Draft Summary Report
SSU Galbreath Preserve Road Drainage Improvements
Mendocino County, California

Pacific Watershed Associates

Draft Summary Report
SSU Galbreath Preserve
Road Drainage Improvements,
Mendocino County, California

PWA Report No. 07076701
March 2007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Appendix C. Schematic diagrams ("typical drawings") of erosion control-and-prevention treatments.
Appendix D. Field inventoried road-related site information.

1 EXECUTIVE SUMMARY

The Fred B. Galbreath Wildlands Preserve is located in Mendocino County approximately 15 miles south of Booneville, California. The 5.7 mi^2 wildlands preserve is owned and managed by Sonoma State University (SSU) for the purposes of environmental research and education. Upper Rancheria Creek flows through the eastern half of the wildlands preserve and drains directly to the Navarro River, an important anadromous river.

Erosion and sediment delivery from forest roads is a recognized environmental threat to the Navarro River system, which is an important habitat for anadromous salmonids, including Coho salmon and steelhead trout. In March 2007, Pacific Watershed Associates (PWA) was contracted by Mendocino County Resource Conservation District (MCRCD) to evaluate drainage patterns and on-going erosion and sediment delivery occurring on the SSU Galbreath property in the vicinity of the Mendocino County maintained Elkhorn Road and bridge crossing. Specifically, PWA proposed to conduct a watershed assessment and generate a prioritized erosion control and erosion prevention plan intended to eliminate, to the degree possible, on-going erosion and sediment delivery to fish streams of Upper Rancheria Creek.

Using field inventories and data analysis, PWA identified a total of 92 sites with the potential to deliver over 11,000 yd^3 of sediment to streams in the Galbreath Wildlands Preserve (GWP) if left untreated. We recommend that 90 of these sites and road segments be treated for erosion control and/or erosion prevention. Similarly, field crews measured approximately 8.2 miles of road surfaces and/or ditches (representing over 63% 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 8,000 yd^3 of sediment could be delivered to stream channels within the GWP over the next decade if no efforts are made to change road drainage patterns. Our estimate of total costs for implementing the recommended erosion control-and-prevention treatments for the entire GWP is $495,837.

The expected benefit of completing the road drainage improvements outlined in this report lies in the reduction of long term sediment delivery to Upper Rancheria Creek, a major tributary to the Navarro River. With this prioritized plan of action, SSU can advance efforts to obtain funding and implement the erosion remediation for the Galbreath Wildlands Preserve. 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

The report entitled "**SSU Galbreath Preserve Road Drainage Improvements, Sonoma County, California**" was prepared by or under the direction of a licensed professional geologist at Pacific Watershed Associates (PWA), and all information therein is based on data and information collected under the supervision of 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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Associate Geologist
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 (Hagans and Weaver, 1987; Harr and Nichols, 1993; Flosie 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, 1996; 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 Fred B. Galbreath Wildlands Preserve (GWP) is located in southern Mendocino County approximately 17 miles inland from the Pacific Ocean and nearly 15 miles south of Booneville, CA (Figure 1). The GWP is owned and maintained by Sonoma State University (SSU) for the purposes of environmental education and research. The GWP was donated to SSU from the family of Fred B. Galbreath in 2004. Previous to 2004, the Galbreath family managed the land for sheep ranching, timber harvest, and recreation. Upper Rancheria Creek, a major tributary to the Navarro River, flows northward through the eastern portion of the preserve. The Navarro River, is an important anadromous river to the California North Coast, supporting Coho salmon and steelhead trout.

At the request of J. Hall Cushman, Director, GWP, the Mendocino County Resource Conservation District (MCRCD) directed Pacific Watershed Associates (PWA) in March 2007 to evaluate drainage patterns and on-going erosion and sediment delivery occurring on the SSU Galbreath property. The purpose of the Galbreath Road Drainage Improvements Project is to evaluate the current drainage patterns in the GWP, 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 control for the road system. This project represents a critical first step in reducing road-related erosion to Upper Rancheria Creek and its tributaries. In developing this plan, PWA designated all targeted road segments and erosion-source sites on inventoried roads for upgrading depending on the risk of erosion and sediment delivery to streams. Furthermore, we developed a prioritized list of erosion treatments that considered both the need to prevent future sediment delivery to streams, as well as maintain transportation routes for educational and recreational access in the area. We assert that the erosion control-and-prevention treatments recommended in this report, if implemented and employed in combination with protective land use practices, will significantly improve and protect water quality and salmonid habitat in the Upper Rancheria Creek watershed.

3.1 Climate, Terrain, and Local Geology

The climate of the Upper Rancheria Creek watershed and the GWP is temperate, characterized by hot, dry summers and moderately wet, stormy winters. Annual precipitation averages 42 in., based on data from the monitoring station in Yorkville, California, with most of the precipitation delivered during the winter months. Forest fires are a high risk during the dry summers, and during the rainy winters, surface and fluvial erosion, streambank erosion and mass wasting are exacerbated. Elevations in the 5.7 mi^2 wildlands preserve range from 900 feet to 2,200 feet.

The geology underlying the majority (92%) of the Galbreath Wildlands Preserve is composed of sheared and potentially unstable rocks of the Tertiary/Cretaceous Coastal Belt Franciscan Complex (Entrix et al., 1998). The northern edge (8%) of the preserve is underlain by Cretaceous/Jurassic Franciscan mélange. Vegetation types in the preserve consist primarily of conifer forests and mixed conifer and hardwood forests, with smaller areas of annual grasslands. Prior to SSU acquiring the wildlands preserve, the land was managed for sheep ranching and timber harvesting. According to California Department of Forestry's Fire and Resource Assessment Program (FRAP), approximately 47% (2.6 mi^2) of the GWP was harvested using selective harvest methods between 1988 and 2000.

3.2 The SSU Galbreath Preserve Road System

The GWP contains a total 13.1 mi of primary roads, all of which are maintained and primarily native surface roads. Short sections of road within the GWP are rocked mainly at recent stream crossing culvert installations and ditch relief culvert installations, and at bridge locations. Numerous roads within the project area have small berms along their outboard edges or are slightly insloped, preventing road drainage. Drainage structures, where present, are infrequently spaced along the road alignment. Finally, stream crossings commonly have long road reaches draining to them, delivering fine sediment from road-surface erosion, ditch incision, and cutbank raveling directly into the numerous, smaller watercourses throughout the GWP.

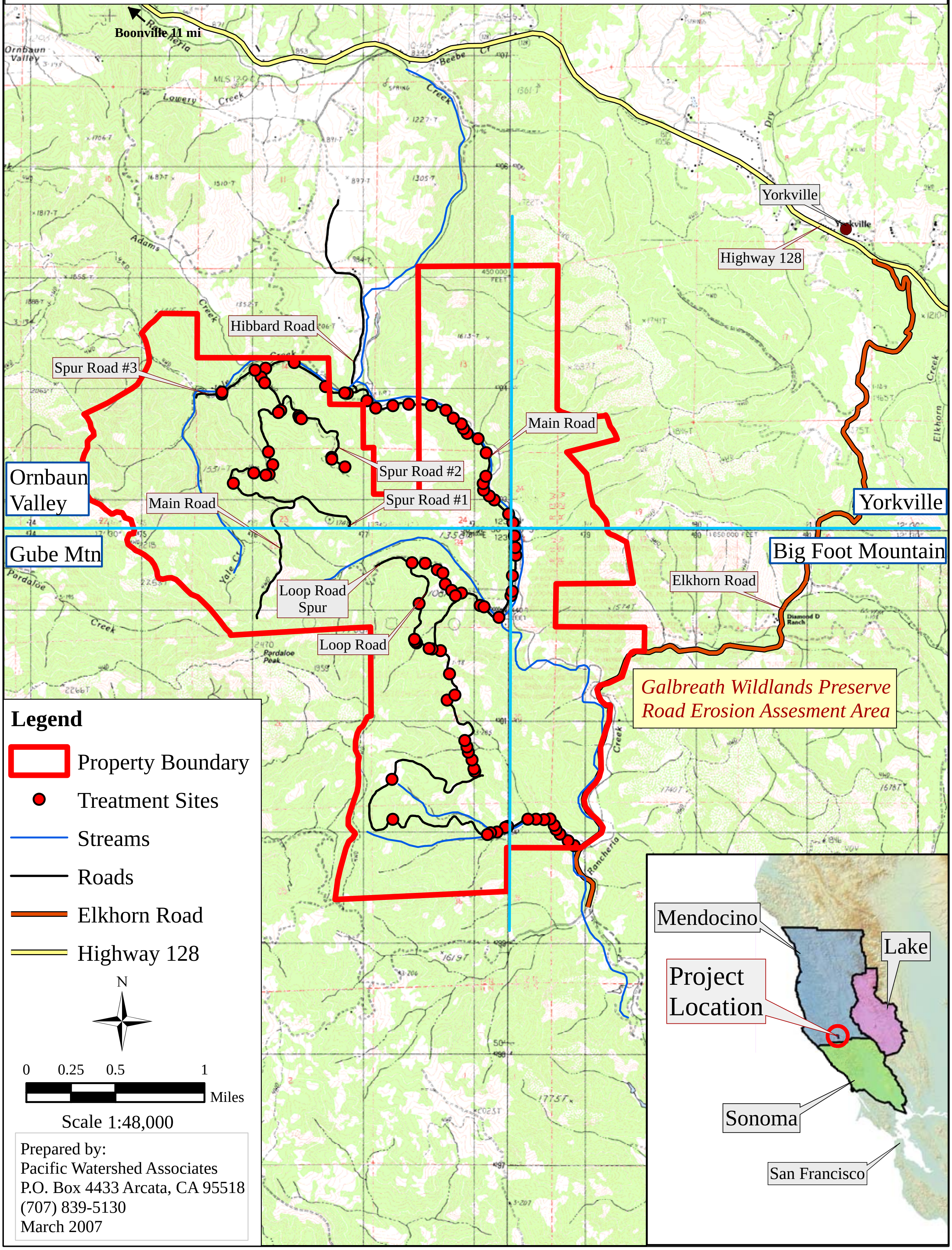
The GWP primary road system consists of the Main Road totaling approximately 9.0 miles and runs north-south through the center and into the western portion of the preserve (Figure 1). Approximately 4.1 miles of spur roads extend from the Main Road, including Main Spur Road #1, Main Spur Road #2, Main Spur Road #3, Loop Road, and Loop Road Spur. All of the roads within the preserve are drivable with the exception of the Main Spur Road #2 which is accessible by quad or walking.

In addition to the primary road system, we estimate there are up to 8 miles of secondary, mostly abandoned and overgrown, former road beds throughout the property. Several of these are currently designated as foot trails throughout the GWP.

4 FIELD TECHNIQUES AND DATA COLLECTION

The GWP project involved a complete field inventory of all current, and future, road-related erosion sites and sediment sources along the 13.1 miles of primary roads; and the development

Figure 1. Location map. Galbreath Wildlands Preserve Road Drainage Improvements Project, Mendocino County, California. Ornbaun Valley, Yorkville, Gube Mtn, Big Foot Mtn 7.5' Quadrangle maps.



of a prioritized plan-of-action for cost-effective erosion-control and erosion-prevention treatments in the watershed. The approximately 8 miles of abandoned roads will be inventoried at a latter date.

Erosion sites, as defined in this assessment, include locations where there is direct evidence that future erosion or mass wasting will deliver sediment to a stream channel. Sites of past erosion were not inventoried unless we determined that there was potential for additional future sediment delivery. Similarly, sites of future erosion that were not expected to deliver sediment to a stream channel were identified but were not included in the assessment.

To complete the field inventory, all roads were walked and inspected by trained personnel, and all existing and potential erosion sites were identified. Inventoried sites for this assessment primarily consist of stream crossings, potential and existing landslides related to the road system, gullies below ditch relief culverts, and long sections of uncontrolled road-surface and ditch runoff that currently discharge to the stream system. For each identified existing or potential erosion source, we completed a database form (Appendix A) and plotted the site location on a field base map (Figure 2). Information on each field data form includes: (1) site location, (2) nature and magnitude of existing and potential erosion problems, (3) the likelihood of erosion or slope failure, (4) length of hydrologically connected road surface, and (5) recommended treatments to eliminate erosion at the site or minimize its risk as a future source of sediment delivery.

PWA personnel estimated the erosion potential (and potential for sediment delivery) for each problem site or potential problem site, and the approximate volume of sediment expected to be eroded and delivered to streams. These estimates provide quantitative assessments of how much sediment could be eroded and delivered in the future if no erosion-control or erosion-prevention work is performed. In a number of locations, especially at stream diversion sites, the actual sediment loss could easily exceed our field estimates. All sites were assigned a treatment priority, based on their potential or likelihood to deliver sediment to stream channels in the watershed, and based on the cost-effectiveness of the proposed treatment. Also, during the assessment stream crossing sites were evaluated for potential fish barrier problems.

Fieldwork also included collecting survey data at most stream crossings using standard tape and clinometer techniques. These data were used to develop longitudinal profiles and cross sections for the stream crossings, and calculate sediment volume using the STREAM computer program. The survey data for these locations allow for quantitative, accurate, and reproducible estimates of: (1) future erosion volumes, which reflects the consequences of a possible storm-generated washout at the stream crossing; or (2) upgrading volumes, which estimates excavation requirements to complete a variety of road-upgrading and erosion-prevention treatments (i.e., culvert installation, culvert replacement, complete excavation, etc.).

Where new or replacement stream crossing culverts were being recommended for installation, the culverts were sized using two different methods to predict the 24 hour, 100-year recurrence interval discharge. The culvert sizing calculations occurred at all stream crossings where the field estimated channel dimensions were greater than three foot by one foot in cross sectional area.[1] The two methods were: (1) **either** the Rational Method (Dunne and Leopold, 1978), an analytical approach based on rainfall intensity and watershed characteristics for drainage areas less than 80 acres, **or** for drainage areas larger than 80 acres, the empirical equations of the USGS Magnitude and Frequency Method (Wannanan and Crippen 1977), and (2) the Hasty Method, a field determination of predicted peak flow based on estimating flood flow channel dimensions.

For the final phase of the GWP project, data analysis occurred when all the inventory information had been collected, properly entered in the database, and checked for completeness. The use of a relational database allows for rapid data analysis. Data searches were performed to isolate the nature, frequency and magnitude of a host of problems and treatments. Specific searches included analyses of the frequency and volume of potential sediment delivery associated with each sediment source (landsliding, fluvial erosion and surface erosion), the frequency of undersized culverts, stream crossings with a diversion potential, etc. Data tables developed for the Phase 3 summary report contain information regarding: (1) the number of sites recommended for treatment, (2) erosion potential, (3) treatment immediacy (priority), (4) sediment savings, (5) recommended treatments, (6) excavation volumes, (7) estimated heavy equipment and labor hours, and (7) costs.

5 SEDIMENT SOURCES

Sources of erosion in the GWP 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—that are hydrologically connected to the treatment sites (Figure 2; Table 1).

5.1 Types of Treatment Sites

5.1.1 Stream crossings

A *stream crossing* is a ford or structure on a road (such as a raised road prism or bridge) installed across a stream or watercourse (USDA Forest Service, 2000). In the GWP, stream crossings are the most common type of treatment site (Figure 2; Table 1). The rate of sediment delivery from stream crossings is always assumed to be 100%, because any sediment eroded is delivered directly to a stream channel. Furthermore, any sediment delivered to small ephemeral streams will eventually be transported to downstream fish-bearing stream channels.

[1] In catchments with small drainage area, as reflected by steep, mountain stream channels with small, 3 ft^2 cross sectional areas, hydrologists, geologists and engineers have no accurate methods for sizing culverts. Consequently, PWA treatment prescriptions default to a minimum size of a 24" culvert at these smaller stream channels with 3 ft^2 or smaller cross sectional areas. This size will not only accommodate the 24 hour, 100-year recurrence interval discharge, but also lowers the risk of the culvert inlet plugging with debris and sediment.

Common problems that cause erosion at stream crossings include: (1) crossings without culverts, (2) crossings with undersized culverts, (3) crossings with culverts that are likely to plug frequently, (4) crossings with logs or debris buried in the fill intended to convey stream flow (i.e., *Humboldt crossings*), (5) crossings with a potential to be diverted, and (6) crossings that are currently diverted.

A *fill crossing* is an example of 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 Class III streams that only have flow during larger runoff events.

Table 1. Frequency of sites with future episodic road-related erosion and sediment delivery, by problem type, and associated hydrologically connected road length, SSU Galbreath Wildlands Preserve, Mendocino County, California.

Site Type	Treatment sites		Hydrologically connected road reaches to treatment sites[1]		Total roads surveyed (mi)
	Inventoried (#)	Recommended for treatment (#)	Inventoried (mi)	Recommended for treatment (mi)	
Stream crossings	57	57	3.87	3.87	-
Landslides	2	2	0.03	0.03	-
Ditch relief culverts	20	18	3.23	3.17	
"Other" sites[2]	13	13	1.13	1.13	-
Total	**92**	**90**	**8.26**	**8.2**	**13.1**

[1]*Hydrologically connected road reaches adjacent to treatment sites* are lengths of road that are eroding and delivering sediment to those sites.
[2]*Other sites* include point-source springs, and hydrologically connected road segments not adjacent to treatment sites.

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 onto or across the road, eroding the stream-crossing fill. Alternately, the stream crossing may have a *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 receives the diverted flow may become deeply gullied or destabilized.

These hillslope gullies can become quite large and capable of delivering significantly greater quantities of sediment to stream channels (Hagans et al., 1986). Diverted stream flow discharged onto steep, unstable slopes can also trigger large hillslope landslides.

Stream crossing culverts must be able to convey a 100-year storm flow, as well as sediment in transport during high flows to be considered adequately sized (Pacific Watershed Associates, 1994). Undersized culverts do not have the capacity to convey stream flow during periods of heavy rainfall, and are more likely to become plugged by sediment and debris. Because the majority of roads in the GWP were constructed more than 20 years ago, many stream crossing culverts 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 cut costs. However, in the long run these cost-cutting measures are detrimental to water quality and increase periodic maintenance costs because the culvert discharges water onto unconsolidated road fill, rather than into the pre-existing stream channel, which exacerbates erosion of the outboard, downstream fill face.

5.1.2 Landslides

Potential landslide problems in the GWP exist along roads where sidecast material from earlier road construction has become unstable (Figure 2; Table 1). During field inventories, PWA personnel identified tension cracks or scarps showing vertical displacement, corrective re-growth on trees (i.e. pistol butt trees), and perched, hummocky fill as indicating slope instability. Correcting or preventing potential road-fill landslides is relatively straight forward, generally requiring excavation of unstable road fill and sidecast materials, and disposing of the excavated material in a stable location.

5.1.3 Ditch relief culverts

Ditch relief culverts (DRCs) are drainage structures that move water from an inside road ditch to areas beyond the outer edge of the road fill. This results in flow from the inside ditch, which may include both runoff from the road surface and shallow subsurface flow intercepted by the cutbank, being relocated beyond the road (Pacific Watershed Associates, 1994).
When properly spaced, DRCs limit the quantity of water available to cause erosion at any single location, allowing flow to infiltrate back into the ground and reducing the likelihood of gullies forming at their outlets (Optimally, a DRC will discharge water onto a stable native hillslope). But when culvert spacing is too wide (i.e. where a single culvert drains too great a length of road and ditch), erosion below DRC outlets becomes more likely. Another practice that leads to the development of gully erosion at DRCs includes improperly installing culverts, particularly when a culvert is *shotgunned*, which means it is perched high in the road fill without a proper downspout to the ground below (USDA Forest Service, 2000). Many DRCs in the GWP are installed in this manner.

DRC-related gullies have the potential to deliver sediment to stream channels through two mechanisms: (1) gullies may progressively increase in size (i.e., increase their cross-sectional area) as excessive road runoff flows through them, and (2) existing gullies may act as a conduits for delivery of fine sediment produced by physical wear on the road surface. The delivery of roadbed-derived fine sediment is recognized as a problematic issue associated with DRCs, since it occurs on a chronic, annual basis.

5.1.4 "Other" sites

"Other" sites in the GWP include point-source springs and individual hydrologically connected road segments (Figure 2; Table 1). *Point-source springs* are sites where springs with significant flow enter the roadbed. The delivery point is usually located at a water bar or gully adjacent to a stream channel. *Individual hydrologically connected road segments* are areas of chronic, accumulated runoff and uncontrolled flow from long sections of un-drained road surface and/or inboard ditch. They are termed *hydrologically connected* because they are sources of sediment delivery to streams, but are not adjacent to, or associated with, other treatments sites (e.g., stream crossings). As with point-source springs, the delivery point is usually located at a water bar or gully adjacent to a stream channel.

5.2 Road and Cutbank Surfaces

Unpaved road surfaces, and their associated cutbanks, may also be major sources for the production and delivery of fine sediment to stream channels. This is the result of: (1) mechanical pulverizing and wearing down of road surfaces by vehicular traffic; (2) erosion of the road surface on unpaved roads by rain splash and runoff during periods of wet weather; (3) erosion of the inboard ditch by runoff during wet weather; and (4) erosion of the cutbank by dry ravel, rainfall, slope failures, and brushing/grading practices. Sediment production associated with *hydrologically connected* road reaches occurs annually, both during wet and dry winters as well as during dry summer months, and hence is referred to as chronic erosion.

For each treatment site in an assessment, PWA determines the lengths of the adjacent *hydrologically connected* road segments, i.e., the sections of road also contributing sediment to that site (Table 1). In developing treatment recommendations, we base our estimates for future sediment delivery on the total sediment volume for the treatment site *plus* sediment from the road segments connected to that site (Table 2). Furthermore, all recommendations to address erosion problems at treatment sites includes remediation of adjacent hydrologically connected road segments.

6 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). Upgraded roads are kept open and are inspected and maintained. Their drainage facilities and fills are designed or treated to accommodate or withstand the 100-year storm. In contrast, properly decommissioned roads are closed and no longer require maintenance.

Table 2. Estimated future sediment delivery for sites and road surfaces recommended for treatment, SSU Galbreath Wildlands Preserve, Mendocino County, California.

Sediment sources	Estimated future sediment delivery (yd^3)
Stream crossings	2,450
Landslides	241
Ditch relief culverts	208
"Other" sites[1]	97
Road surfaces with chronic erosion[2]	8,018
Total	**11,014**

[1] *Other sites* include ditch-relief culverts, point-source springs, and hydrologically connected road segments not adjacent to treatment sites.
[2]For unsurfaced roads, assuming a 25-ft-wide road surface and cutbank contributing area, and 0.2 ft lowering of road and cutbank surfaces per decade.

Good land stewardship requires that if roads are going to be used, they must be designed to minimize erosion and maintained in good condition. If no longer needed, they must be properly decommissioned, not simply abandoned. The outdated practice of abandoning roads, either by installing barriers to traffic (logs, tank traps, or gates) or simply letting them naturally revegetate, is environmentally unacceptable. Abandoned roads typically continue to fail, and may contribute to erosion problems for decades.

The goal of storm proofing is to make the road as hydrologically invisible as is possible, that is, to disconnect the road from the stream system and thereby preserve aquatic habitat. Characteristics and benefits of storm-proofed roads, whether through upgrading or decommissioning, are listed in Appendix B.

6.1 Road Upgrading

All 13.1 miles of inventoried roads associated with this assessment have been recommended for road upgrading. Relatively straightforward erosion prevention treatments can be applied to upgrade road systems to prevent fine sediment from entering stream channels. These treatments generally involve dispersing road runoff and disconnecting road surface and ditch drainage from the natural stream channel network. For stream crossings either without culverts or with undersized culverts, preventive treatments may include installing or replacing undersized culverts with culverts designed for the 100-year storm flow. Culverts should be installed level with the natural channel gradient to maximize the sediment transport efficiency of the pipe, and ensure that the culvert outlet will discharge on the natural channel bed below the base of the road fill. Based on the specific conditions at each site, other prescribed treatments may include: (1) constructing critical dips at stream crossings to prevent stream diversions, and rolling dips along stretches of road to control excessive surface runoff; (2) installing additional DRCs to reduce concentrated road-surface runoff; (3) installing downspouts to prevent outlet erosion; and (4) armoring the downstream fill face of a crossing to minimize or prevent future erosion. Schematic typical drawings of upgrading treatments prescribed in this assessment are provided in Appendix C.

7 BASIS FOR TREATMENT RECOMMENDATIONS

This assessment is intended to provide guidance for long-range transportation planning, as well as identify and prioritize erosion prevention and erosion-control remediation with the ultimate goal of protecting and improving water quality and fish habitat throughout the Navarro River watershed. Prioritizing treatment sites is an integral part of an assessment because it is the most effective way to address a large and diverse number of erosion issues in a single assessment area. PWA prioritizes treatment sites based on the following criteria: (1) *erosion potential*, i.e., whether there is a low, moderate, or high likelihood for future erosion at a site; (2) *sediment delivery*, i.e., whether the volume of sediment that may be delivered from a site to a stream is projected to be small or large; (3) *treatment immediacy*, i.e., whether the urgency for treating a site is perceived to be low or high; (4) *cost-effectiveness of accessing a site*, which includes an evaluation of how difficult it may be to deliver heavy construction equipment to a site; and (5) *cost-effectiveness of completing recommended treatments*, which includes consideration of the *logistics*, or organization and setup needed to complete the remediation.

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 *sediment delivery*, or volume of sediment expected to enter stream channels from future erosion, plays a significant role in determining the treatment priority for a site. The larger the potential future sediment delivery volume to a stream, the more important it becomes to closely evaluate the need for treatment. This criterion is closely related to *treatment immediacy*, which is a professional evaluation of the urgency for erosion control or erosion-prevention work to address the threat of sediment delivery to waterways.

The final 2 criteria involve *cost-effectiveness*, which 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). 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. 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 \$10/yd^3 (i.e., \$5000/500yd^3). PWA further evaluates cost-effectiveness for an entire assessment area by organizing sites into logistical groups, taking into consideration different treatment sites that may need the same kinds of erosion remediation, and addressing these as a unit to save expenses.

In summary, PWA assigns treatment-priority ratings to sites or groups of sites based on the combined evaluation of 5 criteria that consider different aspects of remediating erosion problems. Higher priority ratings apply when erosion potential, sediment delivery, treatment immediacy, and cost effectiveness are all moderate or high, with lower priority ratings correspondingly based on lower ratings for the combination of these criteria. Although sites and road segments with the lowest priority ratings are placed last on the list for treatment, PWA recommends that these sites be reconsidered once the project is underway, as cost-effective opportunities to treat low-priority sites often arise when heavy equipment is already located nearby to perform maintenance or restoration at higher-priority sites.

8 RESULTS

PWA formulated basic treatment priorities and prescriptions for this assessment concurrent with the identification, description, and mapping of potential sources of road-related sediment delivery. All recommended treatments conform to guidelines described in the *Handbook for Forest and Ranch Roads* (Pacific Watershed Associates, 1994), as well as Part IX and X of the California Department of Fish and Game *Salmonid Habitat Stream Restoration Manual* (Taylor and Love, 2003; Weaver et al., 2006).

PWA field crews inventoried 13.1 miles of roads, and identified a total of 92 sites and 8.26 mi of hydrologically connected road surfaces as having the potential to deliver sediment to streams in the GWP (Figure 2; Table 1). We recommend that 90 of these sites and the hydrologically connected road segments be treated for erosion control and prevention. Roads were classified as maintenance reaches along the remaining 4.84 miles of inventoried roads. Some road bed erosion was occurring along these maintenance reaches, but no sediment delivery was observed. Consequently, no treatments have been recommended for these road reaches. However, road drainage improvements recommended at the 90 inventoried sediment delivery sites can also be applied to improve drainage along these maintenance reaches in the future. In addition, we have recommended re-routing the road alignment for approximately 800 ft at 2 locations to avoid perennial ponds and springs along the road.

Fifty seven (63%) of the sites recommended for treatment in the GWP are stream crossings (Figure 2; Table 1). Inventoried stream crossing sites include (1) 45 crossings with culverts, (2) 5 bridges, and (3) 7 fill crossings. We project that approximately 2,450 yd^3 of future road-related sediment delivery will originate from stream crossings if they are left untreated, which is approximately 22% of total future sediment delivery for the GWP (Table 2). Furthermore, of the 57 stream crossings, 33 have the potential to divert in the future and 5 streams are currently diverted. Of existing culverts at stream crossings, 29 have a moderate or high potential to become plugged by sediment and debris (Table 3).

Two (2%) of the treatment sites in the GWP are classified as potential road fill landslides (Tables 1, 2; Figure 2). We project that approximately 240 yd^3 of future road-related sediment delivery will originate from road fill landslides if they are left untreated, which is approximately 2% of total future sediment delivery for the GWP.

Table 3. Erosion-related problems at stream crossings, SSU Galbreath Wildlands Preserve, Mendocino County, California.

Stream-crossing problem[1]	**# Inventoried**
Stream crossings with diversion potential	33
Stream crossings currently diverted	5
Culverts likely to plug[2]	29
Total	**67**

[1] Some inventoried sites may have a diversion potential, be currently diverted and have a moderate to high plug potential.
[2]Culvert plug potential rating = moderate or high.

Eighteen (20%) of the sites recommended for treatment in the GWP are classified as ditch relief culverts (Tables 1, 2; Figure 2). Approximately 210 yd^3, or nearly 2% of the total sediment delivery to streams is expected from these sites if left untreated.

Thirteen (14%) of the treatment sites are classified as “other” sites, which include point-source springs and segments of hydrologically connected road reaches that are not draining to other treatment sites (Figure 2; Table 1). “Other” sites account for nearly 100 yd^3 of future site-specific sediment delivery in the GWP, or less than 1% of the total sediment delivery (Table 2). However, we emphasize that, although these sites represent relatively low total sediment delivery, they are potential conduits for future sediment delivery from hydrologically connected road surfaces and should be carefully considered for erosion-control treatments.

PWA field crews measured approximately 8.2 miles of road surfaces and/or ditches (representing over 63% of the total inventoried road mileage) currently draining to stream channels, either directly or via gullies (Table 1). From these hydrologically connected road segments, we estimate that approximately 8,020 yd^3 of sediment could be delivered to stream channels within the GWP over the next decade if no efforts are made to change road drainage patterns (Table 2). This volume of material represents 73% of the predicted future sediment delivery from the inventoried GWP roads.

Of the 90 inventoried sites that we recommend for treatment, we designate 16 with priority ratings of high or high-moderate (Figure 3; Table 4). The potential sediment delivery for these 16 sites is approximately 2,160 yd^3, which equates to nearly 20% of the expected sediment savings for the GWP. We assign moderate or moderate-low priorities to 57 sites, which accounts for approximately 6,650 yd^3, or nearly 60% of the expected sediment savings. Finally, we assign a low priority to 17 sites, which accounts for approximately 2,200 yd^3, or nearly 20% of the expected future sediment delivery.

Table 4. Treatment priorities for all inventoried sediment sources in the SSU Galbreath Wildlands Preserve, Mendocino County, California

Treatment priority	Upgrade sites (#)	Number, types and *(site ID numbers)* of treatment sites	Estimated future sediment delivery (yd^3)[1]
High	6	5 stream crossings *(Site no: 18, 33, 35, 36, 77),* 1 ditch relief culvert *(Site no: 1)*	420
High Moderate	10	8 stream crossings *(Site no: 3, 19, 22, 29, 44, 69, 83, 93),* 2 ditch relief culverts *(Site no: 26, 71)*	1,740
		Subtotal for high + high-moderate:	*2,160*
Moderate	29	19 stream crossings *(Site no: 3, 4, 11, 21, 34, 38, 40, 42, 53, 57, 64, 65, 66, 67, 73, 79, 81, 86, 88),* 2 landslides *(Site no: 49, 80),* 5 ditch relief culverts *(Site no: 17, 37, 43, 63, 89),* 3 other *(Site no: 27, 82, 90)*	3,874
Moderate Low	28	18 stream crossings *(Site no: 6, 9, 10, 12, 23, 48, 52, 54, 68, 70, 72, 74, 75, 76, 78, 87, 91, 92),* 6 ditch relief culverts *(Site no: 24, 30, 32, 50, 60, 61),* 4 other *(Site no: 16, 20, 62, 84)*	2,777
		Subtotal for moderate + moderate-low:	*6,651*
Low	17	7 stream crossings *(Site no: 2, 8, 31, 47, 56, 58, 59),* 4 ditch relief culverts *(Site no: 14, 45, 46, 55),* 6 other *(Site no: 13, 15, 25, 39, 41, 51)*	2,203
Total	**90**	**57 stream crossings *(Site no:2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 18, 19, 21, 22, 23, 29, 31, 33, 34, 35, 36, 38, 40, 42, 44, 47, 48, 52, 53, 54, 56, 57, 58, 59, 64, 65, 66, 67, 68, 69, 70, 72, 73, 74, 75, 76, 77, 78, 79, 81, 83, 86, 87, 88, 91, 92, 93),* 2 landslides *(Site no: 49, 80),* 18 ditch relief culverts *(Site no: 1, 14, 17, 24, 26, 30, 32, 37, 43, 45, 46, 50, 55, 60, 61, 63, 71, 89),* 13 other *(Site no: 13, 15, 16, 20, 25, 27, 39, 41, 51, 62, 82, 84, 90)***	**11,014**

[1]Future sediment delivery is the total of sediment from treatment sites and from the adjacent road segments hydrologically connected to those sites.

8.1 Recommended Treatments

The following is a summary of recommended treatments for the GWP; complete details for treatment prescriptions are provided in the project electronic database and in Appendix D. PWA recommends 18 different types of erosion-control and erosion-prevention treatments for the GWP, which we generally subdivide into 2 categories: site-specific treatments and road treatments (Table 5). These prescriptions include only upgrading measures; no roads were recommended for permanent closure in the GWP.

Table 5. Recommended treatments for all inventoried sites and road surfaces in the SSU Galbreath Wildlands Preserve, Mendocino County, California.

Treatment type		No.	Comments
Site specific treatments	Culvert (install)	2	Install a culvert at an unculverted fill. *(Site no: 40, 69)*
	Culvert (replace)	32	Replace an undersized or damaged culvert. *(Site no: 3, 4, 6, 11, 18, 21, 22, 29, 34, 35, 36, 38, 42, 44, 47, 48, 54, 64, 65, 67, 68, 70, 76, 77, 78, 79, 81, 82, 83, 86, 88, 93)*
	Wet crossing	7	Install 7 armored fill crossings using 105 yd^3 of riprap and armor. *(Site no:19, 23, 33, 58, 72, 73, 74)*
	Bridge	2	Install 2 bridges at Class I streams. *(Site no: 5, 9)*
	Trash rack	13	Install at culvert inlets to prevent plugging**.** *(Site no: 3, 22, 29, 34, 44, 47, 48, 59, 66, 68, 75, 78, 83)*
	Critical dip	29	Install to prevent stream diversions. *(Site no: 2, 3, 6, 10, 11, 18, 21, 29, 34, 36, 38, 40, 44, 48, 52, 53, 54, 57, 64, 65, 66, 67, 69, 76, 77, 78, 79, 91, 92)*
	Soil excavation	32	At 32 sites, excavate and remove a total of 2,492 yd^3 of sediment, primarily at fillslopes and stream crossings. *(Site no: 3, 5, 6, 9, 11, 17, 18, 19, 23, 29, 33, 34, 36, 40, 42, 44, 49, 57, 58, 64, 67, 68, 72, 73, 74, 77, 80, 81, 82, 83, 86, 90)*
	Rock (armor)	10	At 10 sites, add a total of 112 yd^3 of rock armor on inboard and outboard stream-crossing fillslopes, ditches, headcuts, and stream banks. *(Site no: 13, 22, 23, 27, 34, 38, 44, 70, 84, 89)*
	Downspout	6	Install to prevent erosion at culvert outlets. *(Site no: 24, 30, 37, 57, 66, 90)*
Road treatments	Berm (remove)	2	At 2 sites, remove a total of 380 ft of berm to improve road-surface drainage.
	Cross road drain	1	Install to improve road drainage.
	Ditch (clean or cut)	8	At 8 sites, clean or cut ditch for a total of 1,230 ft.
	Outslope road and remove ditch	18	At 18 sites, outslope road and remove ditch for a total of 10,013 ft of road to improve road-surface drainage.
	Outslope road and retain ditch	29	At 29 sites, outslope road and retain ditch for a total of 12,007 ft of road to improve road-surface drainage.
	Rolling dip	197	Install to improve road drainage.
	Ditch relief culvert (install or replace)	41	Install or replace ditch relief culverts to improve road surface drainage.
	Rock (road surfaces)	195	At 195 sites, use a total of 4,782 yd^3 of road rock to rock the road surface at 34 stream culvert installations, 7 armored fill crossings, 8 critical dips, 18 DRC installations, 81 rolling dips, 10,1013 ft of outslope and remove ditch, 12,007 ft of outslope and retain ditch

Site-specific treatments include the following stream crossing treatments: (1) constructing a total of 29 critical dips to prevent diversions at streams with diversion potential; (2) installing 2 culverts at currently un-culverted stream crossings (3) replacing 32 undersized or damaged culverts, (4) constructing 7 wet crossings (armored fill crossings), and 5) installing 2 bridges at Class I streams. We recommend 6 downspouts be installed on culverts at specific stream crossing and ditch relief culvert locations to prevent erosion at culvert outlets.

As an erosion prevention measure, we recommend adding approximately 112 yd^3 of mixed and clean riprap-sized rock to armor stream crossing fillslopes and ditch headcuts at 10 sites. To reduce road-surface erosion, we recommend: (1) removing a total of approximately 380 ft of outboard road berm, (2) constructing 197 rolling dips, (3) outsloping approximately 22,020 ft of hydrologically connected road, and (4) installing or replacing 41 ditch relief culverts at selected locations, and at intervals appropriate for the steepness of the road. In addition, we recommend using approximately 4,780 yd^3 of 1”-2” pit-run, road rock to fortify road surfaces and prevent surface erosion following treatment at 195 locations that currently have native road surfaces.

8.2 Heavy Equipment and Labor Requirements

Equipment needs for erosion-control treatments in the assessment area are detailed in the project electronic database and summarized, based on priority level, 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 include only 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.

Table 6. Estimated heavy equipment and labor requirements for treatment sites based on priority, SSU Galbreath Wildlands Preserve, Mendocino County, California.[1]

Treatment Priority	# of sites	Excavated Volume (yd^3)	Excavator (hr)	Bulldozer (hr)	Water truck (hr)	Grader (hr)	Labor (hr)
High or High-Moderate	16	1,618	109	130	24	8	89
Moderate or Low-Moderate	57	2,982	221	350	79	40	205
Low	17	162	34	69	21	15	32
Total	**90**	**4,762**	**364**	**549**	**124**	**63**	**326**

[1] Equipment and labor times do not include hours necessary for opening roads, traveling between sites, and emplacing straw and mulch.

PWA estimates that erosion control-and-prevention treatments in the GWP will require 364 hours of excavator time and 549 hours 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. Approximately 124 hours 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. Approximately 63 hours of grader time is required for road drainage treatments including outsloping, cleaning ditches and berm removal. Finally, approximately 326 hours of labor time will be required for various tasks, including culvert installation or replacement. Construction activities such as staging materials at work sites, final grading, spreading road rock, and mulching 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.

8.3 Estimated Costs

Estimated total cost to implement the recommended erosion control-and-prevention treatments for the GWP is $495,837 (Table 7). Approximately $215,935, or 44% of the total, is for the purchase of rock and culvert materials. A total of $55,800 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. The costs for the recommended bridge installations have not been included in the final estimate due to the unknown costs of survey and engineering fees, as well as the purchase and installation costs of the required bridges.

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 forest lands. 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.

9 CONCLUSIONS

This assessment is a comprehensive inventory of road-related erosion and sediment delivery to streams in the SSU Galbreath Wildlands Preserve, Mendocino County, California. It provides field data to identify and quantify on-going, and possible future, sources of sediment and erosion from the 13.1 miles of inventoried roads in the GWP.

Table 7. Estimated equipment times and costs to implement erosion control-and-prevention work in the SSU Galbreath Wildlands Preserve, Mendocino County, California.

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	110	4	--	4	440
	Bulldozer	110	4	--	4	440
	Grader	110	4	---	4	440
	Water Truck	90	4	---	4	360
	Truck/Trailer	50	4	---	4	200
Heavy equipment for site-specific treatments[7]	Excavator	135	266	80	346	46,710
	Bulldozer	100	249	75	324	32,400
	Water Truck	90	33	10	43	3,870
	Truck/trailer	50	38	12	50	2,500
Heavy equipment for road drainage treatments[8]	Excavator	135	123	37	160	21,600
	Bulldozer	100	300	90	390	39,000
	Water Truck	90	120	36	156	14,040
	Grader	100	92	28	120	12,000
Laborers[9]		50	367	111	478	23,900
Rock costs (includes trucking for 4,782 yd^3 of road rock and 217 yd^3 of riprap)						124,967
Culvert materials costs (20' of 12", 20' of 15", 1,650' of 18", 890' of 24", 180' of 30", 100' of 36", 90' of 42", 180' of 48", 50' of 60", and 60' of 72", including costs for couplers and elbows)						90,968
Bridge costs: Purchase 60' and 30' flat car bridges.						25,000
Mulch, seed, and planting materials for 1.75 acres of disturbed ground[10]						1,202
Layout, coordination, supervision, and reporting[11]						55,800
Total Estimated Costs: $495,837						
Potential sediment savings: 11,014 yd^3						

(Continued on next page.)

Table 7 Notes

[1]Costs for tools and miscellaneous materials have not been included in this table. Costs for administration and contracting are variable and have not been included.

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

[3] Treatment times include all equipment hours expended on excavations and work directly associated with erosion prevention and erosion control at all the sites and road reaches.

[4] Logistics time for heavy equipment (30%) includes all equipment hours expended for brushing work sites on maintained and abandoned roads, travel time for equipment from site-to-site, and conference times with equipment operators at each site to discuss treatment prescriptions and strategies. Logistics time for laborers (30%) includes estimated daily travel time to project area.

[5] Total estimated project costs listed are averages based on private sector equipment rental and labor rates.

[6] Lowboy hauling for tractor and excavator: 4 hours round trip to the SSU Galbreath Wildlands Preserve. Costs assume 2 hauls for 1 set of equipment (1 to move in and 1 to move out) for 1 field season.

[7]A total of 25 hr of truck and trailer time are added for delivering culverts and 13 hr for delivering straw to sites.

[8]An additional 29 hr of water truck time and 29 hr of grader time are added for final grading and spreading road rock.

[9]An additional 41 hr of labor time are added for spreading straw mulch and seeding. This includes 13 hr of labor for initial delivery of straw to sites.

[10] Seed costs equal $9.75/pound for native seed. Seed costs based on 35# of native seed per acre. Straw costs include 50 bales required per acre at $6.95 per bale. Sixteen hours of labor are required per acre of straw mulching.

[11] Technical oversight includes the following: detailed layout and flagging of project sites and treatment prescriptions; development of equipment and treatment logs for equipment operators; on-site review with equipment operators of proposed work activities for each site; technical oversight, and QA/QC of heavy equipment and labor activities for the duration of the operations; pre- and post-project documentation and monitoring (establishing selected photo points and surveys); review and analysis of equipment logs and volume data reported by operator; develop draft and final implementation report once work is completed. Direct costs for technical oversight include personnel time (including benefits), lodging and per diem (where needed), field supplies and materials, all printing and reporting expenses, and mileage costs. Costs do not include indirect overhead expenses.

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 Upper Rancheria Creek, which is a major tributary to the Navarro 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., SSU, MCRCD) can advance efforts to obtain funding required to implement road-related erosion remediation for the SSU Galbreath Preserve.

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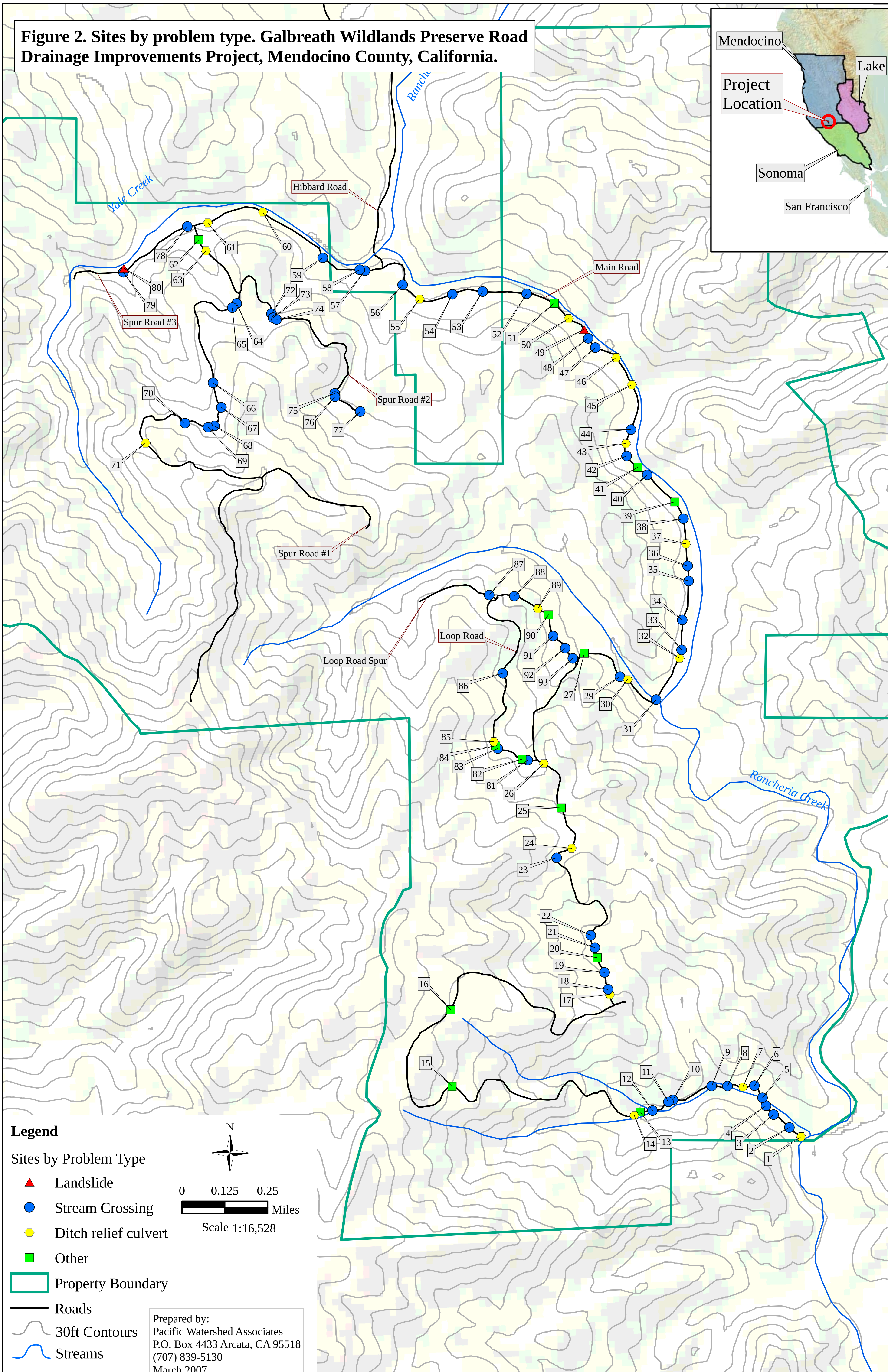
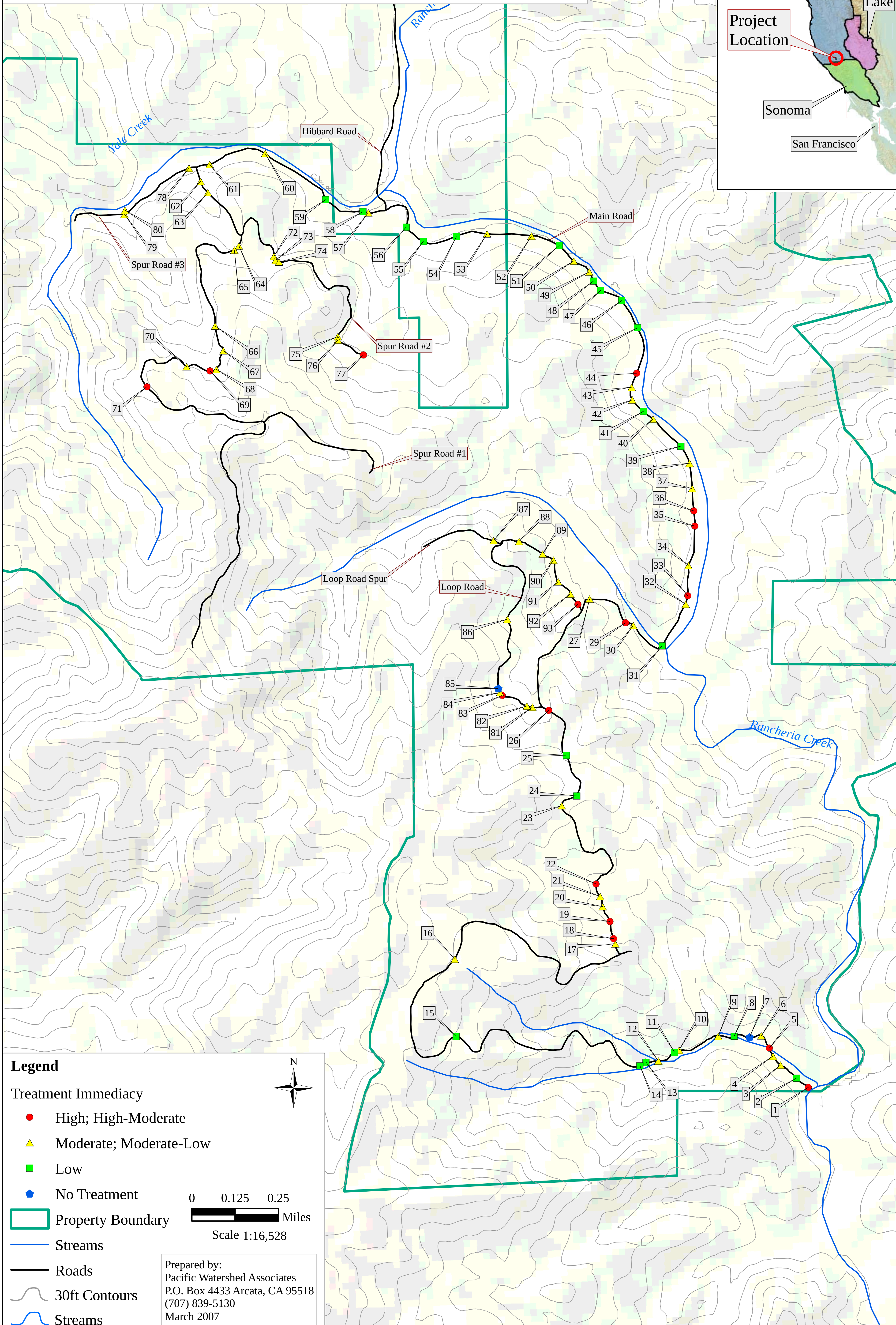


Figure 2. Sites by problem type. Galbreath Wildlands Preserve Road Drainage Improvements Project, Mendocino County, California.

Figure 3. Sites by treatment immediacy. Galbreath Wildlands Preserve Road Drainage Improvements Project, Mendocino County, California.



Appendix A.

Field Database Form

for the Road Drainage Improvements Project, SSU Galbreath Wildlands Preserve, Mendocino County, California.

CHECK **SSU GALBREATH PRESERVE *PWA* ROAD INVENTORY DATA FORM** (3/07 version) Front______ Back_______

GENERAL	Site No:_______	Watershed:	Subwatershed:		Sketch (Y)			
	Photo:_________	Road :	Mileage:____________	Landowner:				
	Inspectors:_______	Date:______	Year Built:____	Surface - rocked, native, paved, chip seal (R, N, P, C):________				
	Maintained	Abandoned	Decomissioned	Road use (Year round, Seasonal, No recent use (>5 yrs))	Driveable, quad, walk (D,Q,W):_______			
PROBLEM	Stream xing	Landslide	Roadbed (bed, ditch, cut)	DR-CMP	Spring	Channel scour	Bank erosion	Other
	Road related? (Y, N)	Geomorphic Association: SS, IG, ST, SW, HD, BIS, Other						
ROAD/ DITCH INFO	Left road/ditch length (ft):	Right road/ditch length (ft):	Left rd grade%:	Right rd grade%:				
LANDSLIDE	Road fill	Landing fill	Cutbank slide	Hillslope debris slide (>50% original ground)	Deep seated, slow	Past failure	Potential failure	
	Slope shape: (convergent, divergent, planar, hummocky)	Natural slope %:____________	Distance from toe to stream (ft):_______					
STREAM	CMP	Bridge	Humboldt	Fill	Ford	Armored Fill	Pulled xing	% pulled:______
	CMP diam (in):	Culvert type (P, S, A, C)	Inlet (O, C, P, R)	Outlet (O, C, P, R)	Interior (O, C, P, R)	Separated (Y)	Check CMP size (Y)	
	Plug potential (H, M, L)	Headwall (in)_____	CMP slope % _____	Rust/silt line (in):____	CMP appears undersized (Y, M, N):____			
	Stream class (1, 2, 3)	Sed trans (H,M,L)	Ch grade (%)_____	Ch width (ft): _______	Ch depth (ft):_______			
	Diversion Pot?(Y, N):	Currently diverted? (Y, N):	Past diversion? (Y, N):	Fish barrier? (Y, N):				
EROSION	E.P. (H, M, L):	Potential for extreme erosion? (Y):	Volume of extreme erosion (yds^3): <500, 500-1000, 1-2K, 2-5K, >5K					
Past Erosion..	Is the stream crossing washed out? __________%	Past stream crossing erosion (yds^3):						
Future Erosion..	Total Future Erosion (yds^3):	Future delivery %:	Total Future Yield (yds^3):					
	Future width (ft):	Future depth (ft):	Future length (ft):					
TREATMENT	Treat (Y N)	Immed. (H, M, L)	Complexity (H, M, L)	Upgrade	Decommission	Maintenance		
	Excavate soil	Critical dip	Trash Rack	Install bridge	Other treatment? (Y)	Mulch (ft^2):		
	Wet crossing (ford or armored fill)	armored fill hgt (ft)__	armored fill/ford width (ft) __	Armor size range (ft):	Armor vol (yds^3) :			
	Install culvert	Replace culvert	CMP diameter (in) _____	CMP length (ft) _______	Couplers(#)___	Clean CMP	Repair CMP	
	Install flared inlet	Flared inlet diam (in):	X-ing Downspout diam (in):____	X-ing D.S. length (ft) ______	Couplers (#)_______			
	Armor Ditch / headcut	Armor fill face (in out)	Armor area (ft^2) :	Armor size range (ft) :	Armor vol (yds^3) :			
	Install DR-CMP (#) ___	*Replace DR-CMP (#) ___*	*DR-CMP diam (in):*	*Total DR-CMP length (ft):*	*Couplers (#) _______*			
	Number of DR-CMP downspouts needed_______	DR-CMP downspout diam______	Total DR-CMP downspout length _______	Couplers (#) ____				
	Outslope & Remove ditch (ft) ________	*Outslope & Retain ditch (ft) ______*	*Inslope road (ft) ____________*					
	Rolling dip (#) ___	*Remove berm (ft) _________*	*Berm width (ft):*	*Berm depth (ft):*	Engineered fill			
	Clean or cut ditch length (ft) _________	*Remove ditch (ft) __________*	*Cross rd drains(#)_____*					
Road Opening (To this site from last site)	*Vegetation: Brush Small trees Large trees*	*Landslides inhibiting access: Cutbank Road fill*	*Other road opening obstacles:*	*No road opening costs*				

COMMENT ON PROBLEM:(i.e. What is causing the erosion? How active is the erosion? Where is the erosion currently occurring or where could it potentially occur?)

Appendix B.

Characteristics of Storm-Proofed Roads

for the Road Drainage Improvements Project,
SSU Galbreath Wildlands Preserve,
Mendocino County, California.

Characteristics of Storm-proofed Roads

Storm-proofed stream crossings

- All stream crossings have a drainage structure designed for the 100-year flow (with debris).
- Stream crossings have no diversion potential (functional critical dips are in place).
- Stream crossing inlets have low plug potential (trash barriers & graded drainage).
- Protect stream crossing outlets from erosion (extended, transported or dissipated).
- 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 “disconnected” from streams and stream crossing culverts.
- Class I stream crossings meet DFG and NMFS fish passage criteria (Part IX).

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 “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 installing a variety of surface drainage techniques including berm removal, road surface shaping (outsloping, insloping or crowning), rolling dips, ditch relief culverts, water bars and other measures to disperse road surface runoff and reduce or eliminate sediment delivery to the stream

Appendix C.

Schematic Diagrams ("Typical Drawings") of Erosion Control and Erosion Prevention Treatments

for the Road Drainage Improvements Project, SSU Galbreath Wildlands Preserve, Mendocino County, California.

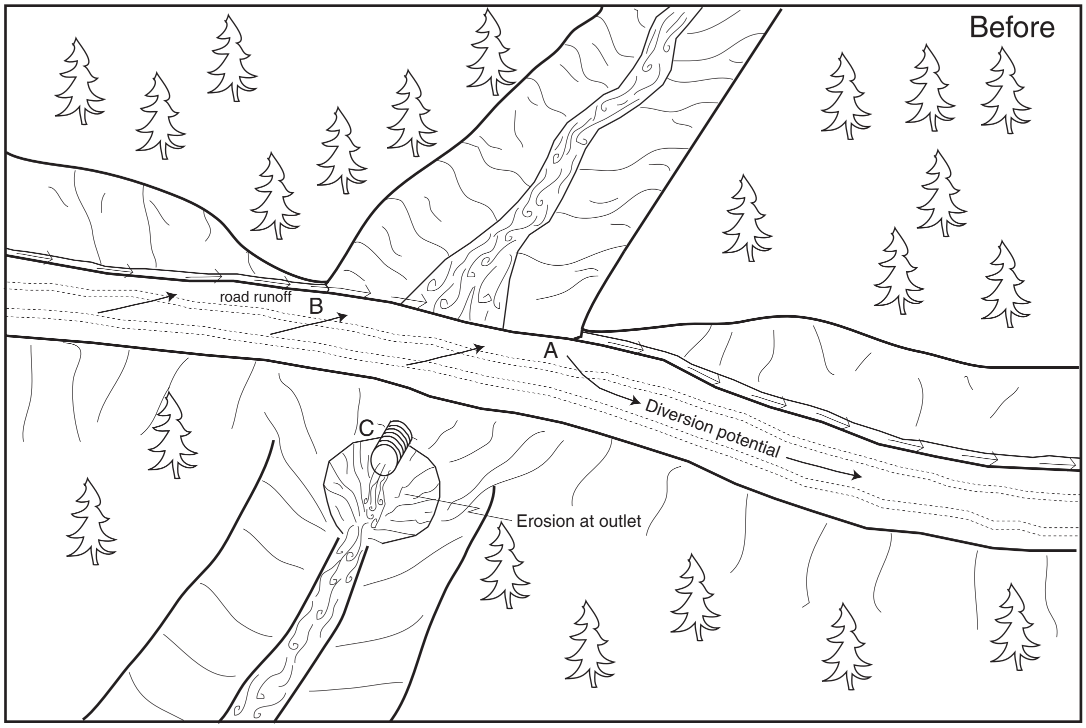
Typical Schematic
Components of an upgraded stream crossing

Common problems

A - Diversion potential

B - Road surface and ditch drains to stream

C - Undersized culvert high in fill with outlet erosion

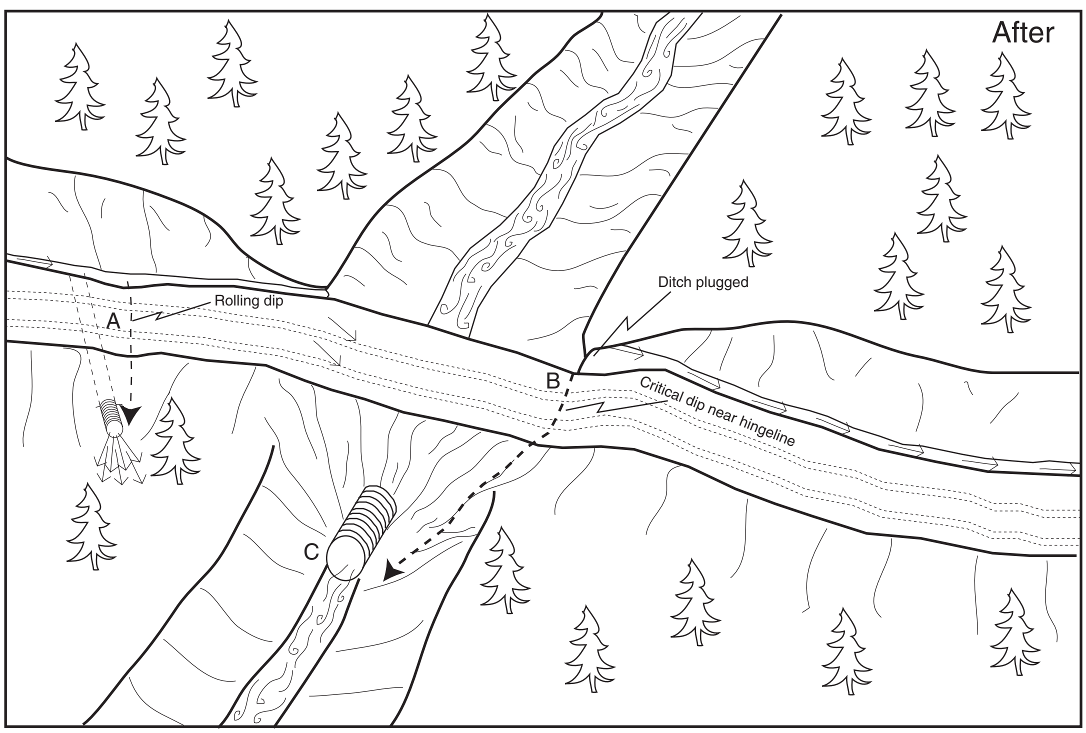


General Standards

A - Road surface and ditch "disconnected" from stream

B - No diversion potential

C - 100 year culvert set at base of fill



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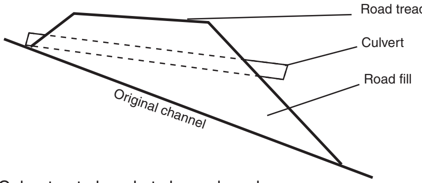
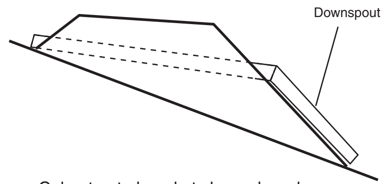
Typical design of non-fish bearing culverted stream crossings

Existing



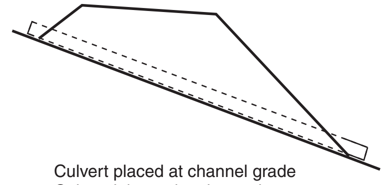
Culvert not placed at channel grade
Culvert outlet does not extend past base of road fill

Upgraded



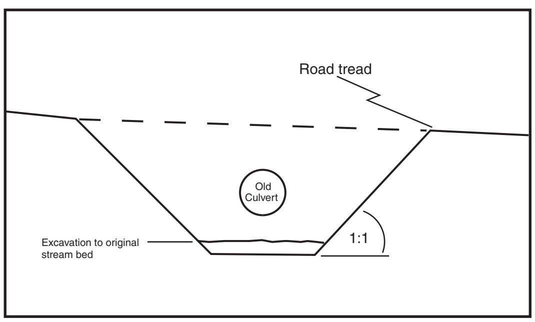
Culvert not placed at channel grade
Downspout added to extend outlet past road fill

Upgraded (preferred design option)

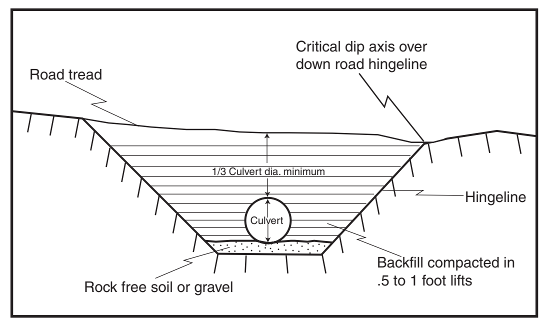


Culvert placed at channel grade
Culvert inlet and outlet resting on or partially in the original stream bed

Excavation in preparation for upgrading culverted stream crossing



Upgraded stream crossing culvert installation



Typical installation of non-fish bearing culverted stream crossings

Road upgrading tasks typically include upgrading stream crossings by installing larger culverts and inlet protection (trash barriers) to prevent plugging. Culvert sizing for the 100 year flood flow should be determined by both field observation and calculations using a procedure such as the Rational Formula.

Stream crossing culvert installation

1) Culverts shall be aligned with natural stream channels to ensure proper function, prevent bank erosion and debris plugging problems.
2) Culverts shall be placed at the base of the fill and at the grade of the original streambed or downspouted past the base of the fill.
3) Culverts shall be set slightly below the original stream grade so that the water drops several inches as it enters the pipe.
4) Culvert beds shall be composed of rock free soil or gravel, evenly distributed under the length of the pipe.
5) To allow for sagging after burial, a camber shall be between 1.5 to 3 inches per 10 feet culvert pipe length.
6) Backfill material shall be free of rocks, limbs or other debris that could dent or puncture the pipe or allow water to seep around pipe.
7) One end of the culvert pipe shall be covered then the other end. Once the ends have been secured, the center will be covered.
8) Backfill material shall be tamped and compacted throughout the entire process.
 -Base and side wall material will be compacted before the pipe is placed in its bed.
 -Backfill compacting will be done in 0.5- 1 ft lifts until 1/3 of the diameter of the culvert has been covered. A gas powered tamper can be used for this work.
9) Inlets and outlets shall be armored with rock or mulched and seeded with grass as needed.
10) Trash protectors shall be installed just upstream from the culvert where there is a hazard of floating debris plugging the culvert.
11) Layers of fill will be pushed over the crossing until the final, design road grade is achieved, at a minimum of 1/3 to 1/2 the culvert diameter.

Erosion control measures for culvert replacement

Both mechanical and vegetative measures will be employed to minimize accelerated erosion from stream crossing and ditch relief culvert upgrading. Erosion control measures that are implemented will be evaluated on a site by site basis. Erosion control measures that may be employed include but are not limited to:
1) Minimizing soil exposure by limiting excavation areas and heavy equipment disturbance.
2) Installing filter windrows of slash at the base of the road fill to minimize the movement of eroded soil to downslope areas and stream channels.
3) Retaining rooted trees and shrubs at the base of the fill as "anchor" for the fill and filter windrows.
4) Bare slopes created by construction operations will be protected until vegetation can stabilize the surface. Surface erosion on exposed cuts and fills will be minimized by mulching, seeding, planting, compacting, armoring and/or benching prior to the first fall rains.
5) Extra or unusable soil will be stored in long term spoils disposal locations that are not limited by factors such as excessive moisture, steep slopes greater than 10%, archeology potential or proximity to a watercoarse.
6) On running streams water will be pumped or diverted past the crossing and into the down stream channel during the construction process.
7) Straw bales and/or silt fencing will be employed where neccessary to control runoff within the construction zone.

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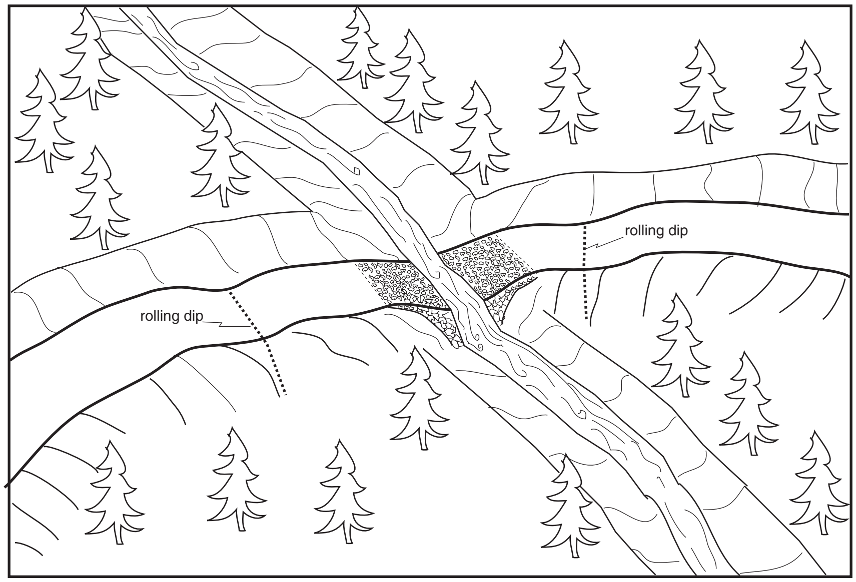
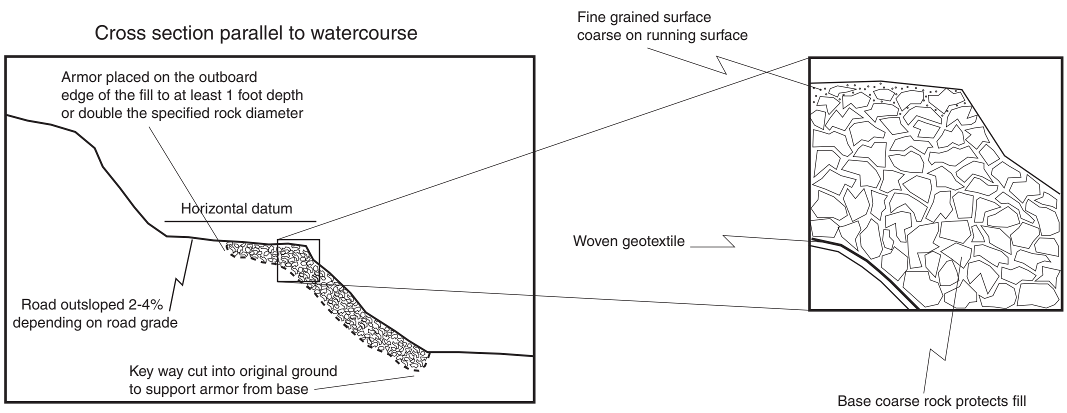
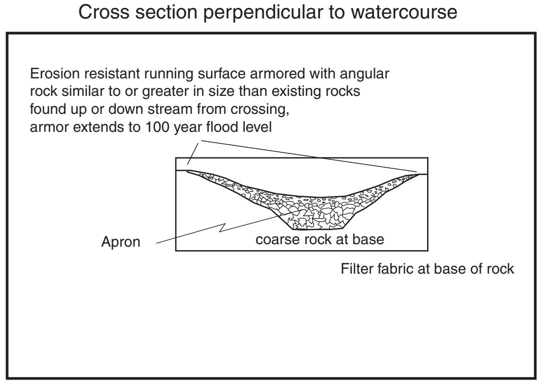
Typical armored fill crossing installation



Cross section parallel to watercourse



Cross section perpendicular to watercourse



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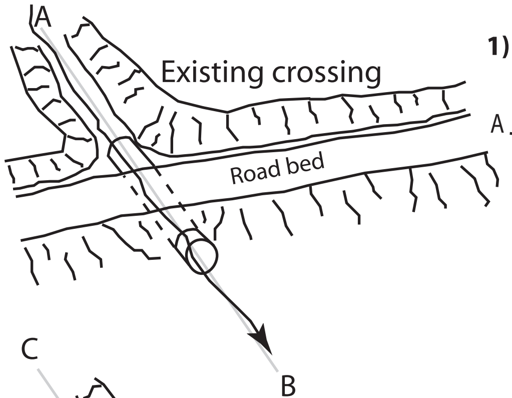
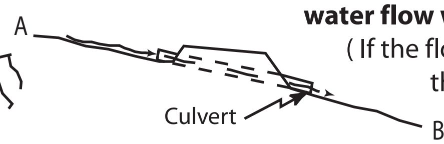
10 steps to building an armored fill stream crossing



Building an armored fill

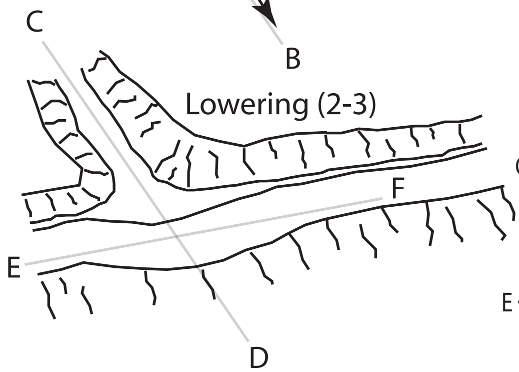
1) The two most important concepts to understand when constructing an armored fill are:

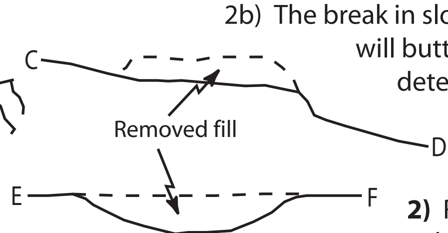
A) **The rock must be placed in a "U" shape across the channel so that the water flow will always stay confined within the armored area.** (If the flow gets around the rock armoring it will quickly gully through the remaining road fill. Proper shaping of the remaining road fill and good armor placement will reduce the likelihood of crossing failure.)



B) **The largest rocks must be used to butresss the rest of the rock armor in two locations:** 1b) The base of the armored fill where the road fill meets the natural channel. (This will buttress the armor placed on the outboard road fill face and reduce the likelihood of it washing downslope.)

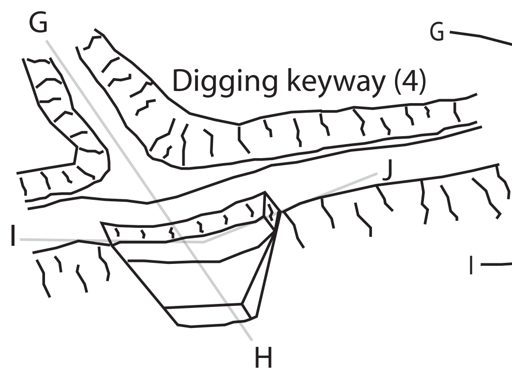
2b) The break in slope from the road tread to the outer fill face. (This will buttress the fill placed on the outer road tread and will determine the "base level" of the creek as it crosses the road surface.)

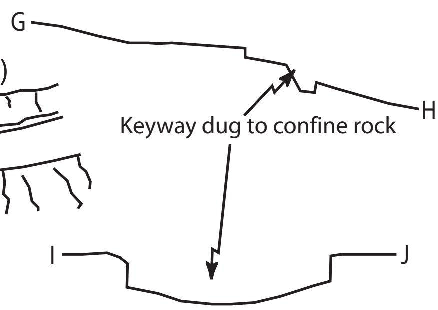




2) Remove any existing drainage facilities including culverts and humboldt logs.

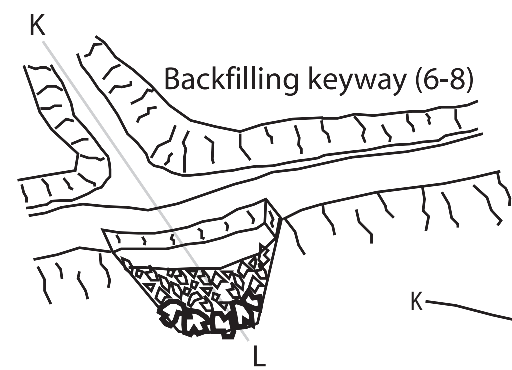
3) Costruct a dip centered at the crossing that is large enough to accomodate the 100 yr. flow event and prevents diversion. (C-D, E-F)

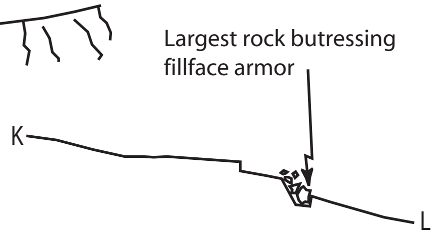




4) Dig a keyway (to place the rock in) that extends from the outer 1/3 of the road tread down the outboard road fill to where the outboard fill meets the natural channel, up to 3' into channel bed depending on site specific specifications. (G-H, I-J)

5) (Optional) Install geofabric within keyway to support rock in wet areas and to prevent winnowing of the crossing at low flows.

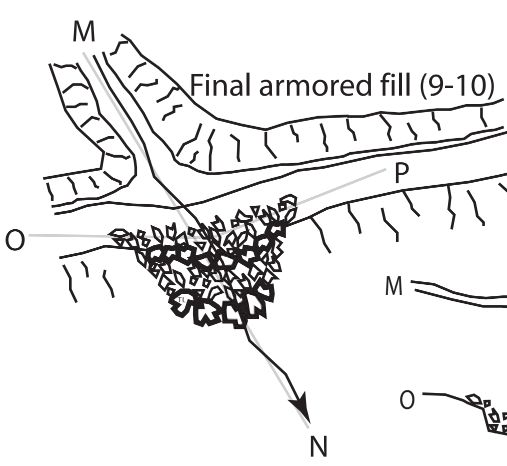


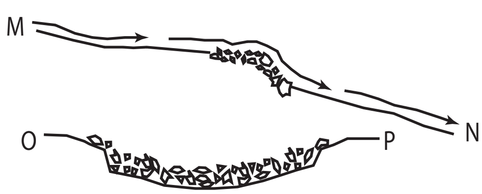


6) Put aside the largest rock armoring to create 2 buttresses in the next step. (K-L)

7) Use the largest rock available (as described in the treatment specifications at the site) to create a buttress at the base of the fill, (this should have a "U" shape to it and it will define the outlet of the aromored fill.)

8) Backfill the fillface with remaining rock armor making sure the final armored area has a "U" shape that will accomodate the largest expected flow. (K-L)



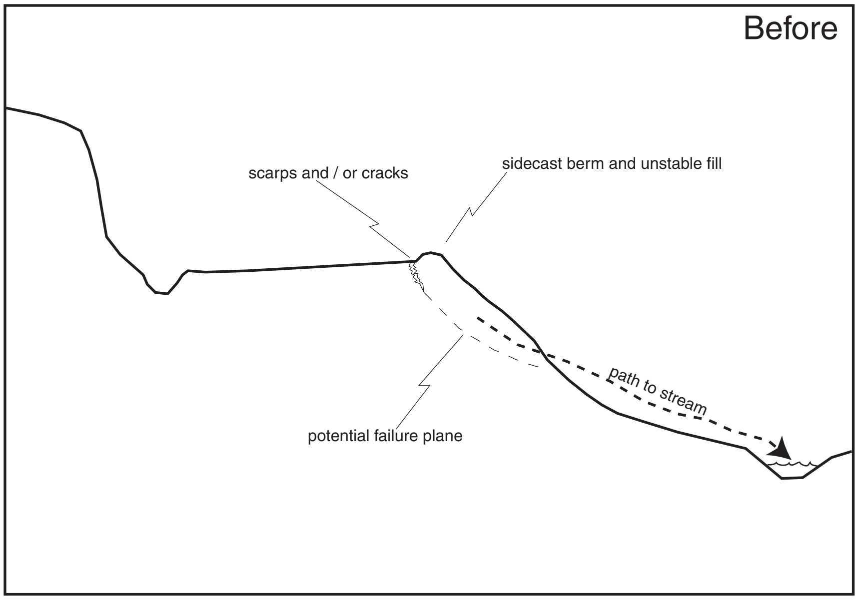


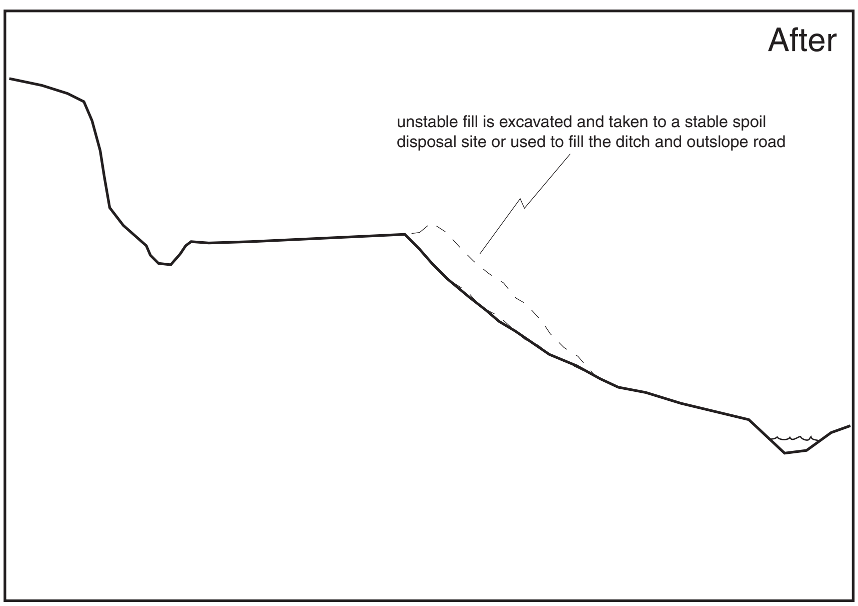
9) Install a second buttress at the break in slope between the outboard road and the outboard fill face, (this should define the base level of the stream and determine how deep the stream will backfill after construction.) (M-N)

10) Back fill the rest of the keyway with the unsorted rock armor making sure the final armored area has a "U" shape that will accomodate the largest expected flow (O-P)

Pacific Watershed Associates (2005)

Excavating unstable fill slope on maintained road





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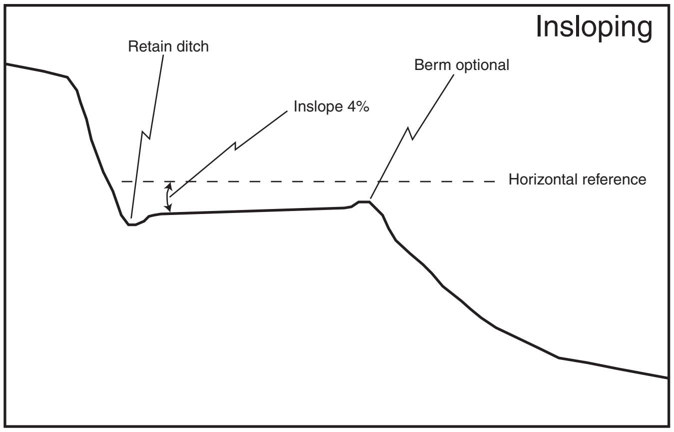
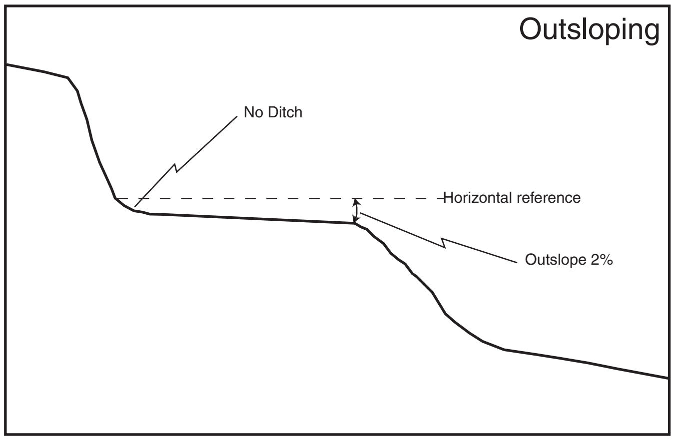
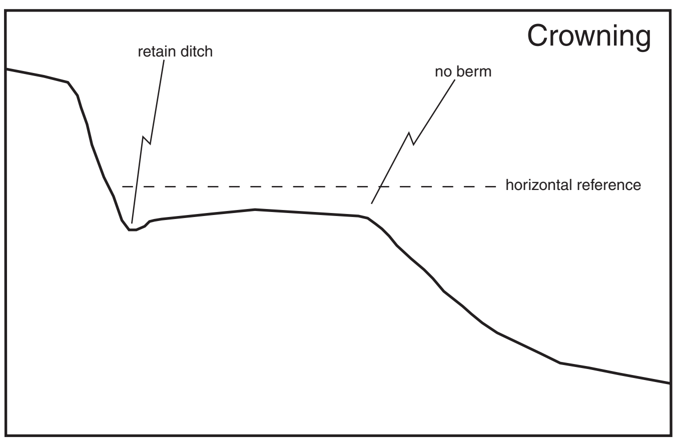
Using road shape to control road runoff







Outsloping pitch for roads up to 8% grade		
Road grade	Outslope pitch for unsurfaced roads	Outslope pitch for surfaced roads
4%, or less	3/8" per foot	1/2" per foot
5%	1/2" per foot	5/8" per foot
6%	5/8" per foot	3/4" per foot
7%	3/4" per foot	7/8" per foot
8%, or more	1" per foot	1 1/4" per foot

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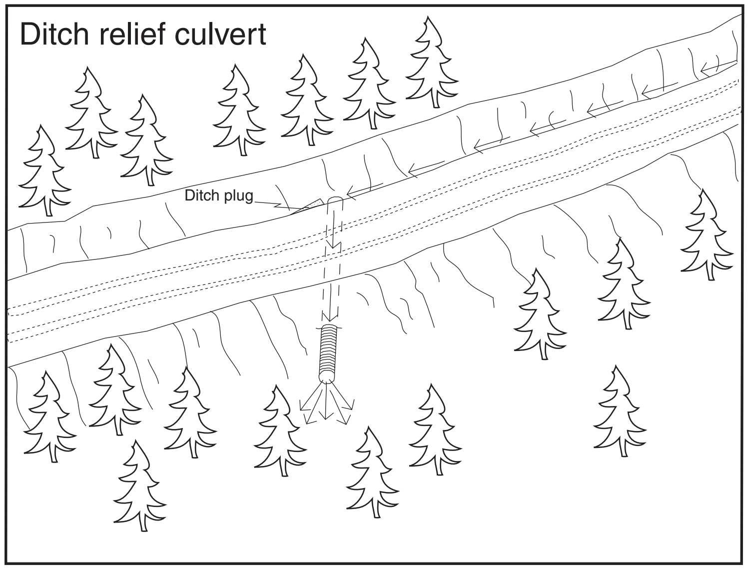
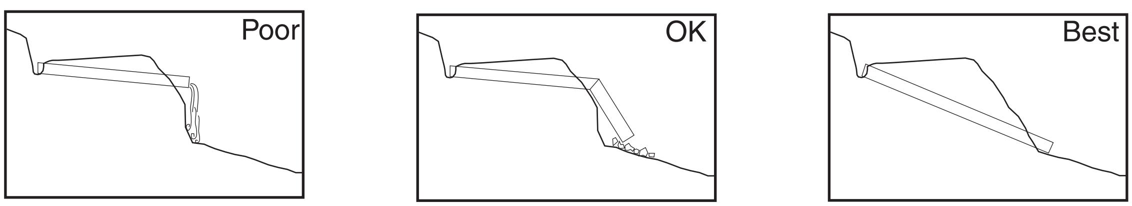
Typical ditch relief culvert installation



Cross sections of typical installations



Ditch relief culvert installation

1) The same basic steps followed for stream crossing installation shall be employed.
2) Culverts shall be installed at a 30 degree angle to the ditch to lessen the chance of inlet erosion and plugging.
3) Culverts shall be seated on the natural slope or at a minimum depth of 5 feet at the outside edge of the road, whichever is less.
4) At a minimum culverts shall be installed at a slope of 2 to 4 percent steeper than the approaching ditch grade, or at least 5 inches every 10 feet.
5) Backfill shall be compacted from the bed to a depth of 1 foot or 1/3 of the culvert diameter, whichever is greater, over the top of the culvert.
6) Culvert outlets shall extend beyond the base of the road fill (or a flume downspout will be used).Culverts will be seated on the natural slope or at a depth of 5 feet at the outside edge of the road, whichever is less.

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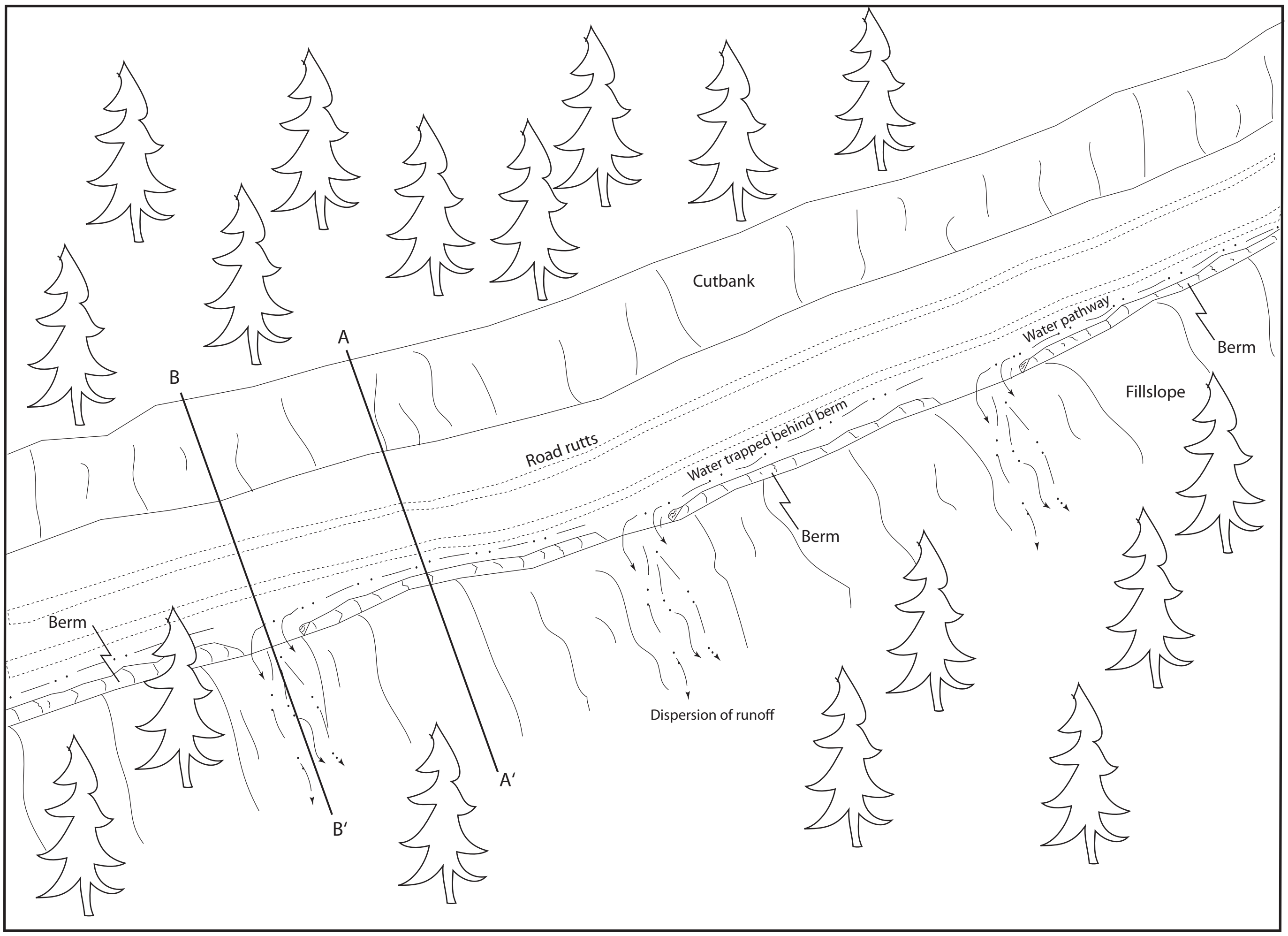
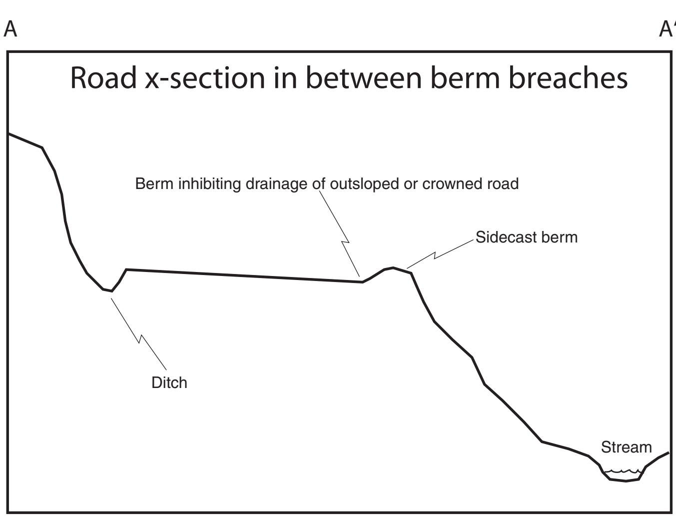
Removing outboard berms on maintained roads

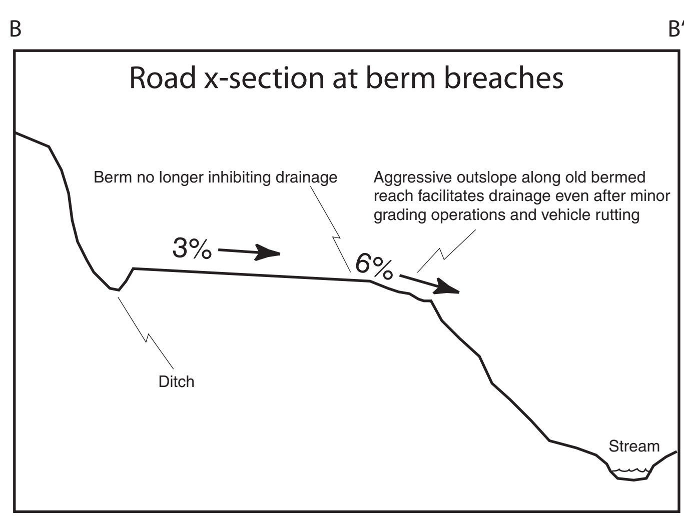
Either by sidecast or excavation methods

1) On gentle road segments berms can be removed continuously (see B-B′)
2) On steep road segments, where safety is a concern, the berm can be frequently breached (see A-A′ & B-B′)

Berm Breaches should be spaced every 30 to 100 feet to provide adequate drainage of the road system while maintaining a semi-continuous berm for safety reasons







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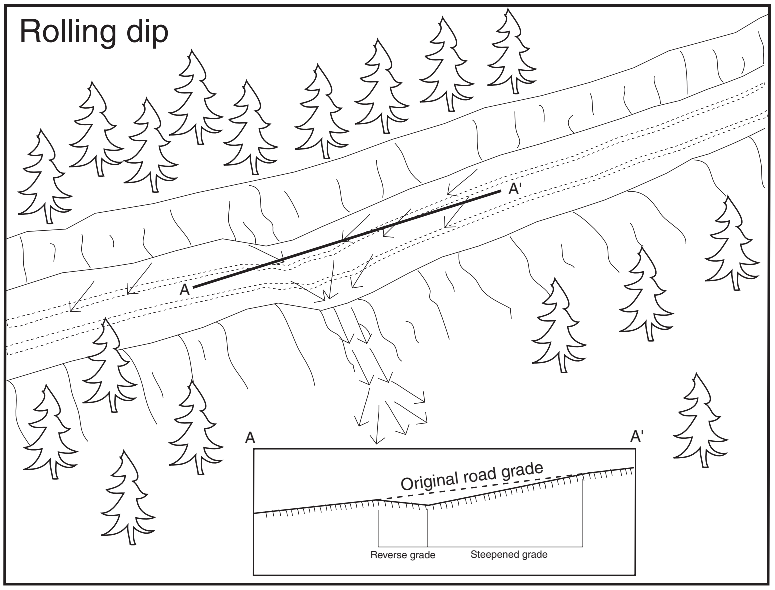
Road surface drainage by rolling dips



Rolling dip installation:
1) Rolling dips will be installed in the road bed as needed to drain the road surface.
2) Rolling dips will be sloped either into the ditch or to the outside of the road edge as required to properly drain the road.
3) Rolling dips are usually built at 30-45 degree angles to the road alignment with cross grade of at least 1 percent greater than the grade of the road.
4) Excavation for the dips will be done with a medium size bulldozer or similar equipment.
5) Excavation of the dips will begin 50 to 100 feet up-road from where the axis of the dip is planned per guidelines established in the rolling dip dimensions table.
6) Material will be progressively excavated from the road bed, steepening the grade until the axis is reached.
7) The depth of the dip will be determined by the grade of the road (see table).
8) On the down-road side of the rolling dip axis a grade change will be installed to prevent the runoff from continuing down the road (see figure).
9) The rise in grade will be carried for about 10 to 20 feet then it will fall to the original slope.
10) The transition from axis to bottom, through rising grade to falling grade will be in a road-distance of at least 15 to 30 feet.

Table of rolling dip dimensions

Road grade	Upslope approach (distance from up-road start of rolling dip to trough) (ft)	Reverse grade (Distance from trough to crest)	Depth below average road grade at discharge end of trough. (ft)	Depth below average road grade at upslope end of trough. (ft)
<6	55	15-20	0.9	0.3
8	65	15-20	1.0	0.2
10	75	15-20	1.1	.01
12	85	20-25	1.2	.01
>12	100	20-25	1.3	.01

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Appendix D.

Field Inventoried Road-Related Site Information

for the Road Drainage Improvements Project, SSU Galbreath Wildlands Preserve, Mendocino County, California.

General information for inventoried road-related erosion sites, SSU Galbreath Wildlands Preserve, Mendocino County, California

Site #	Problem	Comment on Problem	Erosion Potential	Left ditch/road length (ft)	Right ditch/road length (ft)	Future Yield (yds3)	Treatment Immediacy	Comment on treatment
1	Ditch relief culvert	Newly installed ditch relief culvert at beginning of road (intersection with 'Elkhorn Rd'). Both inlet and outlet are 50% plugged with sediments. Majority of left rod length has been freshly rocked. Inboard ditch looks to be actively incising to adjust to flows, hence the future erosion volume. Ditch relief culvert also receives an estimated 500ft of road contribution from 'Elkhorn Rd'. Beyond outlet of culvert fillslope looks well armored with 2-3' rock. Outlet of culvert is about 10ft above Camp Creek.	HM	360	0	13	H	1) Replace existing ditch relief culvert with an 18" by 20' long culvert. 2) Install two 18" by 40' long ditch relief culverts up left road. 3) Outslope and retain ditch up left road for 360'. 4) Install 1 rolling dip up left road to drain road surface only.
2	Stream crossing	Stream is small and currently dry. Culvert placed well in fill with rock armor below outlet. Crossing has diversion potential.	L	170	0	45	L	1) Install a critical dip along right hinge line. 2) Outslope and retain ditch for 170ft up left road. 3) Install one 18" by 40' long ditch relief culvert up left road. 4) Install 1 rolling dip to drain road surface only.
3	Stream crossing	An undersized culvert has been recently installed at a flashy stream. There is evidence that a large wad of sediment came down the channel last year and plugged this pipe. Pipe is set high in fill and most of the flow in the stream now goes subsurface 18ft above inlet. Diversion potential to the left. A rotting 2ft diameter log lies in fill at BOT.	M	0	145	66	M	1) Excavate crossing from TOP to BOT to replace culvert with a 24" by 50' long culvert placed in at channel grade. 2) Install a single post trash rack 24" above inlet. 3) Install a critical dip.

General information for inventoried road-related erosion sites, SSU Galbreath Wildlands Preserve, Mendocino County, California								
Site #	**Problem**	**Comment on Problem**	**Erosion Potential**	**Left ditch/road length (ft)**	**Right ditch/road length (ft)**	**Future Yield (yds3)**	**Treatment Immediacy**	**Comment on treatment**
4	Stream crossing	Class lll stream currently dry. Large amount of sediment has deposited in ditch to the right of the inlet. Site could be an on going maintenance issue. Because of shallow grade of pipe, sediments are aggrading above inlet.	ML	120	144	9	M	1) Replace culvert with a 24" by 20' long culvert set in at channel grade. 2) Cut/clean ditch up right road for 140ft. 3) Cut/clean ditch up left road for 45ft.
5	Stream crossing	A short bridge and right road fill are constricting flow on Camp Creek. Bridge is 20' long and stream looks to be actively under cutting fill abutments (future erosion). About 60ft of right road looks to be occupying active channel. Up stream fillslope of rod is currently armored with 3ft rock, which looks to be keeping current flows from eroding road. But at higher flows steam has the potential to over top the road, hence the 'potential for extreme erosion' call.	HM	195	100	16	HM	1) Remove existing bridge. 2) Remove right road fill that is occupying creek channel (35x4x60) back to madrone tree on right bank. 3) Spoil locally. 4) Install a 60ft long bridge and establish thalweg of stream (and center of new bridge) where fir tree is on outboard edge of right road. Use existing 3ft rock armor along inboard right road for bridge abutments.
6	Stream crossing	Site has minor diversion potential to the left. Plug potential due to culvert being under sized, not from wood transport. A skid road captures flow from upslope, with no erosion. This tributary meets Camp Creek 75ft below outlet.	M	0	60	33	ML	1) Excavate crossing from TOP to BOT to replace culvert with a 24" by 50' long culvert placed in at channel grade. 2) Install a critical dip along left hinge line.

General information for inventoried road-related erosion sites, SSU Galbreath Wildlands Preserve, Mendocino County, California

Site #	Problem	Comment on Problem	Erosion Potential	Left ditch/road length (ft)	Right ditch/road length (ft)	Future Yield (yds3)	Treatment Immediacy	Comment on treatment
7	Ditch relief culvert	A 12" ditch relief culvert has recently been installed to drain 80ft of left road and 200ft of right road. Pipe outlets onto flood plane of Camp Creek. Six inch cobbles have been placed around inlet and outlet. A 2' wide by 15' long channel runs to flood plain below. Road has been recently rocked and is slightly crowned.	L	80	200	0		No Treat.
8	Stream crossing	Steel bridge is 35ft long by 10ft wide and is 6ft above stream. Three foot diameter log abutments. Unlike site#5 position of thalweg looks fairly constant. Abutments look stable. Future erosion is fill slopes under bridge.	ML	15	190	17	L	1) Outslope right road for 190ft. 2) Install 1 Rolling Dip up right road.
9	Stream crossing	Twelve foot long bridge looks to be constricting stream flow. Stream is actively eroding right fill slope under bridge. Right bank above bridge may be old roadbed (not inventoried). If right abutment was armored, bridge might be stable enough to leave in place. Right road has been recently rocked with 3 newly installed ditch relief culverts that do not deliver.	M	600	0	14	ML	1) Remove bridge. 2) Establish a 15 foot wide channel and lay back both fill slopes to 2:1. 3) Armor lower 1/4 with 15cy of 3' rock armor. Some rock may be available form site#5. 4) Install a 30' long bridge. 5) Outslope right road for 600' and retain ditch. 6) Install 3 rolling dips to drain road surface only.

General information for inventoried road-related erosion sites, SSU Galbreath Wildlands Preserve, Mendocino County, California

Site #	Problem	Comment on Problem	Erosion Potential	Left ditch/road length (ft)	Right ditch/road length (ft)	Future Yield (yds3)	Treatment Immediacy	Comment on treatment
10	Stream crossing	Stream flows out of a narrow canyon 130' above road and enters a broad low gradient valley. Flow goes subsurface and creates a large juncus field, rooted extensively by pigs. Flow from this very wet field separates into two sections, the less active flow runs to the right and into this well installed pipe. The larger flow volume travels to site#11. Flow has very little force here.	L	0	60	43	ML	Install a critical dip to the left.
11	Stream crossing	Small stream has incised 6" wide by 6" deep through tractored ground 20' up stream from inlet. Stream bed fans out to 10' wide with sands and colonized by juncus.	M	45	0	12	M	1) Replace culvert with a 24" by 50' long culvert set in at channel grade. Install a critical dip along right hinge line.
12	Stream crossing	Older smooth walled steel culvert. Culvert looks to be at base of fill and at channel grade. Inlet looks to be too close to the left bank. Inboard fill of right road (that is in active channel) is well armored with 3' rock. Channel is sinuous above inlet. Both inlet and outlet are also well armored with 3' rock. Left rod inboard ditch looks stable until it drops into crossing (above armor) where it has head cut slightly.	L	210	312	134	ML	1) Install 1 Rolling Dip up left road. 2) Install 1 Rolling dip up right road.
13	Road surface	Inboard ditch up left road has incised from road drainage. Earth flow from above also contributing to ditch. Past gullies off of right bank are evident.	L	140	0	6	L	1) Install 1 Rolling Dip up left road to drain road surface only. 2) Rock outboard fill face with 5cy of 6" rock.

General information for inventoried road-related erosion sites, SSU Galbreath Wildlands Preserve, Mendocino County, California

Site #	Problem	Comment on Problem	Erosion Potential	Left ditch/road length (ft)	Right ditch/road length (ft)	Future Yield (yds3)	Treatment Immediacy	Comment on treatment
14	Ditch relief culvert	Ditch relief culvert drains ditch and cutbank. Newly installed and inboard ditch is active adjusting but should stabilize soon. Culvert delivers to Camp Creek but much of the material deposits on flat below outlet before reaching creek. Right road length has 3 non delivering ditch relief culverts. Majority of right road is outsloped.	L	0	4270	1	L	1) Install 14 rolling dips up right road.
15	Road surface	Gully enlargement is future erosion for this site. Flow exits road into a swale below road. Swale doesn't look to have carried much flow this year.	L	0	682	2	L	1) Outlsope right road for 680ft. 2) Install 4 rolling dips up right road.
16	Road surface	Off road drain at low point in road delivers road sediments to a class lll stream. Ditch down to stream is presently flowing due to emergent spring flow 25ft down hill form outboard road. This spring flow most likely promotes road sediment transport to stream.	ML	50	410	1	ML	Install 2 rolling dips up right road.
17	Ditch relief culvert	A small 12" steel pipe has been installed in small wet swale below a pool. Pipe does not receive overflow from pool but rather seepage through small dam keeping pool in place. Pipe is short and set high in fill. A 3x3x35 ft gully runs down outboard fill. A 45x2x25ft fill failure has been created to the right and exacerbated by road drainage and the culvert gully. Roughly 20% of the future erosion from this site delivers to the stream at site#18 below.	HM	0	2040	84	M	1) Replace existing culvert with an 18" by 40' long culvert, set deep enough that pipe is at base of fill. 2) Excavate unstable fill to the right of culvert at outboard edge, 45x2x25ft. 3) Spoil locally. 4) Install 10 rolling dips up road to the right.

General information for inventoried road-related erosion sites, SSU Galbreath Wildlands Preserve, Mendocino County, California

Site #	Problem	Comment on Problem	Erosion Potential	Left ditch/road length (ft)	Right ditch/road length (ft)	Future Yield (yds3)	Treatment Immediacy	Comment on treatment
18	Stream crossing	Forty feet up stream form inlet stream flow goes subsurface. Two 12" culverts parallel to each other. One is crushed and non functional. Remaining culvert is 20% plugged. Culverts are placed high in fill and shot gunned 4ft.	HM	0	93	39	H	1) Replace existing culverts with a 24" by 50' long culvert place in at base of fill and at channel grade. 2) Install a critical dip along left hinge line. 3) Outlsope 93ft of right road.
19	Stream crossing	Small stream crossing is diverted left down inboard ditch for 240ft to site#20. Old channel exists below fill. Old diversion gully to the right. Whole area is in disrupted drainage pattern and some large firs are tipped below road.	M	0	115	8	HM	1) Install an armored fill crossing using 15cy of 1-2' rock.
20	Spring	Springy flowing left ditch. Right ditch receives diverted stream flow from site#19. Culvert inlet is 20% plugged. Culvert carries flow to top of a class lll stream below road. Flow has developed a small gully down outboard fill, gully looks stable. Majority of flow to this site will be cut off when site#19 is treated. Springy area to the left looks to be part of an earth flow.	ML	150	213		ML	Replace existing culvert with an 18" by 30' long culvert.

General information for inventoried road-related erosion sites, SSU Galbreath Wildlands Preserve, Mendocino County, California								
Site #	Problem	Comment on Problem	Erosion Potential	Left ditch/road length (ft)	Right ditch/road length (ft)	Future Yield (yds3)	Treatment Immediacy	Comment on treatment
21	Stream crossing	Large class ll stream with smaller 2x1 stream that confluences form right. Smaller stream to right is subsurface for 75' and re-emerges 25' from larger stream confluence. Large past failure on left bank of larger stream. Tow 24" culverts placed high in fill. One is completely crushed at outlet. Partial road failure deposits directly below. Inlet is armored and currently flow is only entering one culvert. Outlet of functioning culvert is shotgunned 4', however large boulders and rocks are preventing incision.	ML	0	124	71	M	1) Replace existing culvert with a 48" by 60' long culvert set in at channel grade. 2) Install a critical dip on left hinge line. 3) Outslope 124' of right road. 4) Install 1 rolling Dip.
22	Stream crossing	A 7x2 class ll stream flows through three 18" culverts aligned side by side horizontally across channel. Pipe inlets have been damaged by repeated cleanings. A residual sediment deposit above inlets shows that pipes have likely plugged in recent past. Outboard fill has begun to fail due to long left road contribution and potential culvert overflow. A small spring enters inboard ditch 100' to the left. There is no good place to drain it across road there so leaving it in ditch to this site is likely best option.	HM	1915	125	123	HM	1) Excavate existing culverts and replace with a48" by 60' long culvert set at channel grade. 2) Armor small head-cut from left inboard ditch with 1cy of 6" minus rip rap. 3) Install 7 Rolling Dips to left road. 4) Install four 18" by 40' ditch relief culverts up left road. 5) Install an "I" beam or galvanized post trash rack.
23	Stream crossing	Wet swale develops into a class lll about 30ft above inlet. Springy left ditch also contributes flow. Outlet of culvert carries flow on to a flat for 20' before flow drops down a 5ft head-cut into a more defined stream valley.	L	115	0	8	ML	1) Install an armored fill crossing at site with 10cy of rock. 2) Use 2cy of rock to armor head-cut 20ft beyond outboard road.

General information for inventoried road-related erosion sites, SSU Galbreath Wildlands Preserve, Mendocino County, California

Site #	Problem	Comment on Problem	Erosion Potential	Left ditch/road length (ft)	Right ditch/road length (ft)	Future Yield (yds3)	Treatment Immediacy	Comment on treatment
24	Ditch relief culvert	Culvert has a 3ft drop to a scour pool plus 10' by 0.5'by 0.5' rill below that. Distance then to stream is 100' through lumpy open actively creeping meadow. Flow is both dispersed across slope and channelized in multiple rills to stream.	ML	300	185	2	ML	1) Install a 12" by 20' downspout to outlet. 2) Outslope left road for 300'. 3) Install 2 rolling dips. 4) Outslope 185ft of right road.
25	Spring	Springy swale drained by a 15" newly installed culvert. Road has recently been rocked. Upper portion of right road is insloped with a newly installed ditch relief culvert (non delivering). Gully below outlet of culvert at site looks stable.	L	30	390		L	1) Outslope road and keep ditch for 390 ft up right road. 2) Install 1 rolling dip to drain road surface only.
26	Ditch relief culvert	Two newly installed ditch relief culverts deliver to a class ll stream via two gullies across grassland hillside. Road has been recently rocked. Inboard ditch has recently been cut and is currently adjusting to flows and has plugged 50% of the inlet of both culverts. Gully below outlet is 4x2x40ft and actively enlarging.	HM	730	0	40	HM	1) Outlsope road and retain ditch for 345'. 2) Install 2 Rolling Dips to drain road surface only.
27	Road surface	2100ft of road drainage delivers to class ll stream at various locations along road length, see sketch. Future erosion is based upon these gullies enlarging.	ML	2100	0	65	M	1) Outslope 2100ft of left road. 2) Install 3 ditch relief culverts, each an 18" by 40' long, at various springy sections. 3) Install 14 rolling dips up left road.

General information for inventoried road-related erosion sites, SSU Galbreath Wildlands Preserve, Mendocino County, California

Site #	Problem	Comment on Problem	Erosion Potential	Left ditch/road length (ft)	Right ditch/road length (ft)	Future Yield (yds3)	Treatment Immediacy	Comment on treatment
29	Stream crossing	Culvert is shotgunned and placed high in fill. A 4' drop exists below outlet. A small amount of water is traveling through fill, likely through rusted culvert. The short pipe has eroded a large hole in outboard fill. Banks are up to 5' tall and actively collapsing into stream. Sediments and organics are piled up behind a 2 post trash rack. Posts are being bent towards inlet and won't function much longer.	HM	800	0	64	HM	1) Replace existing culvert with a 36" by 50' long culvert placed in at channel grade. 2) Install a critical dip along right hinge line. 3) Install 3 rolling dips up left road. 4) Install an "I" beam or galvanized post trash rack 36" above inlet.
30	Ditch relief culvert	Newly installed 15" ditch relief culvert. No ditch has been cut to inlet of culvert. Springy cutbank flow is rilling inboard road. Pipe is a little short and has been placed in older existing gully. Outboard fill above outlet has failed. Some due to road runoff and some due to short culvert. Flow gullies down fillslope to old roadbed below, where majority of sediments deposit. Bedrock exists below outlet of culvert.	ML	200	0	1	ML	1) Cut inboard ditch from site# 29 to inlet of culvert. 2) Install a 20ft long full round downspout to outlet of culvert.
31	Stream crossing	Newly installed 40' long steel bridge. Bottom of bridge is 8ft above stream. About 30' of road on either side of bridge has been recently rocked. Last 100' of right road is on natural flat.	L	30	500		L	Install 2 rolling dips up right road.
32	Ditch relief culvert	Two hundred and ninety feet of right springy ditch drains to a 30% plugged 6" culvert. Outlet has gulled outboard fill for 25ft to Rancheria creek. Gully looks stable. Road bed above pipe is wet from springy cutbank.	ML	0	290		ML	1) Install 2 rolling dips up right road to drain road surface only. 2) Install an 18" by 30' ditch relief culvert up right road. 3) Replace existing culvert with an 18" by 30' culvert.

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Site #	**Problem**	**Comment on Problem**	**Erosion Potential**	**Left ditch/road length (ft)**	**Right ditch/road length (ft)**	**Future Yield (yds3)**	**Treatment Immediacy**	**Comment on treatment**
33	Stream crossing	Small stream flows down a hummocky hillside to road. Flow travels across road and is actively eroding the outboard fill in a 2x3x12ft gully. This will continue to migrate through fill . The road here is on top of the left bank of Rancheria Creek. The creek flow has begun to erode this bank along a 150ft wide stretch. The banks are 5-10ft high and actively eroding into the flood plain. Only high flows are reaching this spot.	H	290	110	11	H	1) Pull back unstable fill 150x3.5x7ft. And lay back 2:1. 2) Spoil locally. 3) Move road bed up slope for 290ft of it's length to get it out of the way of Rancheria Creek and outslope this new section of road. 4) Install an Armored fill crossing with 15cy of 1-2ft rock. 5) Install 1 Rolling dip to the left.
34	Stream crossing	Inlet is 50% plugged by highly mobile sediment load carried by stream. Most material is sourced in first 20-50ft above inlet, where stream is incising (2x2) across flat and through failed cutbank. Scalloped fillslope is from past failure at top and 1/2 round steel downspout is effective for it's 10ft length. Erosion is active below downspout with a 6ft drop then a 3x2x20ft active gully with vertical sides and delivers directly to Rancheria Creek.	M	0	80	77	M	1) Replace existing culvert with a 24" by 60' long culvert set in at channel grade. Use perched on left hinge line of outboard fill as back fill. 2) Install a critical dip along left hinge line. 3) Armor lower 3/4 of outboard fill with 1-2' rock armor. 4) Install a trash rack 24" up from inlet.
35	Stream crossing	Class lll stream with no flow at present time. 30" culvert is separated in the middle. A 1'x1' hole is in the road above separation. Culvert is high in fill and outlet has an elbow directing flow to the left. With elbow pointing flow to left bank it is most likely that erosion of bank will continue.	M	0	0	55	H	1) Replace existing culvert with a 30" by 60' long culvert place in at channel grade. 2) Dip road through crossing.

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Site #	Problem	Comment on Problem	Erosion Potential	Left ditch/road length (ft)	Right ditch/road length (ft)	Future Yield (yds3)	Treatment Immediacy	Comment on treatment
36	Stream crossing	Stream flows down a broad low gradient canyon and into two culverts. A newer 15" culvert to the left and an older rusted crushed 12" culvert to the right. Both culverts are shotgunned and are very high in the fill. As a result outlet flow has eroded a 5'x5'x25' gully into outboard fill. A small berm built around the inlets has long since eroded so the stream has diverted to the right over 5" head wall. Diversion flow has gone down a short skid 120' to the right and created a 6'x4'x30' gully before it drops onto Rancheria Creek.	H	15	0	32	H	1) Replace existing culverts with a 24" by 40' long culvert placed in at channel grade. 2) Install a critical dip along right hinge line.
37	Ditch relief culvert	50% plugged ditch relief culvert. Culvert receives 330' of left road/ditch as well as flow from a springy swale about 200' up left road. Beyond outlet of culvert, flow has developed a 10' deep gully that is roughly 8ft wide. Cutting off spring flow and putting a culvert in deeper into fill should prevent future head-cutting of this gully. Future erosion is gully lying back to outlet of culvert.	HM	330	0	6	M	1) Replace existing ditch relief culvert with an 18" by 40' culvert placed lower into fill. 2) Install a new ditch relief culvert 200' up left road. 3) Install a 20' full round downspout to outlet of culvert. 4) Outslope road and retain ditch for 330' up left road. 5) Install 2 rolling dips up left road.

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Site #	Problem	Comment on Problem	Erosion Potential	Left ditch/road length (ft)	Right ditch/road length (ft)	Future Yield (yds3)	Treatment Immediacy	Comment on treatment
38	Stream crossing	Erosion potential is because of diversion potential, plug potential, and erosion occurring at outlet of culvert. Two post trash rack at inlet is effective. Outboard fill is gullied out, which is 25% of the whole crossing volume. Outlet is very high in fill and gully is 5'x4'x40' on average. Culvert is bent and broken on top 3/4 down it's length and rusted at outlet.	HM	180	0	143	M	1) Excavate from TOP to BOT. Replace existing culvert with a 24" by 70' long culvert placed at channel grade. 2) Rock outboard fillslope (30 cu yds). 3) Install a critical dip along right hinge line.
39	Spring	Ditch relief culvert drains both left and right road reaches, including a spring 90' to the left of inlet. Flow from culvert diverts down skid road. Large incision through skid all the way to Rancheria creek. Most of the flow creating this gully is from the spring and will be cut off with treatment.	L	200	252	6	L	1) Outslope 200' of left road and retain inboard ditch. 2) Install an 18" by 40' ditch relief culvert at spring. 3) Replace existing culvert with a 18" by 40' long culvert. 4) Outslope 252' of right road and retain inboard ditch. 5) Install 1 rolling dip up right road to drain road surface only.
40	Stream crossing	Small stream hits inboard ditch of road and diverts 90' to the left. Flow then enters a 12" culvert. Outlet is well armored. Basin around inlet is virtually full of sediments. Only a two post trash rack is stopping inlet from plugging.	M	0	300	22	M	1) Install a 24" by 50' culvert at point where steam intersects inboard ditch. 2) Install a critical dip along left hinge line. 3) Install 2 rolling dips up right road. 4) Install a single post trash rack 24" up from inlet.
41	Road surface	Low point in road. Small grassed over off road drain drains both road reaches. Road bed is on a terrace, so it would be difficult to outslope. Road is about 40 horizontal feet from Rancheria Creek.	L	110	175		L	1) Install 2 rolling dips up right road reach.

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Site #	**Problem**	**Comment on Problem**	**Erosion Potential**	**Left ditch/road length (ft)**	**Right ditch/road length (ft)**	**Future Yield (yds3)**	**Treatment Immediacy**	**Comment on treatment**
42	Stream crossing	Steep boulder-filled stream channel above inlet. Crossing on natural terrace. A two post trash rack is currently keeping sediments from plugging inlet rocks in channel above terrace are mossy. Beyond outlet a 35' long 3' wide channel has been cut across terrace to facilitate flow to Rancheria Creek. Banks are near vertical but are mossy and look stable.	L	0	0	13	M	1) Excavating existing culvert to replace current culvert with a 30" by 40' long culvert, set in at channel grade. 2) Pull back vertical banks (below outlet) to 2:1. 3) Install a single post trash rack 30" above inlet. *If 30" culvert will not fit, would landowner object to an Armored Fill crossing?
43	Ditch relief culvert	Plugged inlet of a ditch relief culvert and outlet is crushed. There is a small puddle at outlet and flow coming from road drainage. Armor at outlet has slumped crushing outlet.	L	380	125	3	M	1) Replace culvert with a 18" by 20' culvert. 2) Clean ditch 15' on either of side of new culvert. 3) Outslope 380' of left road and retain ditch. 4) Install 2 rolling dips up left road. 5) Outslope 125' of right road and retain ditch.
44	Stream crossing	A rowdy 7x1 class ll comes out of a large broad canyon out onto a hummocky and grassy hillslope. The stream is transporting a high volume of 4"-6" rock. Pipe is set extremely high in fill with only 1"-2" of fill over culvert. 20' of 1/2 round downspout takes flow to channel below. Stream has diverted 30' to right in past and caused a 25'x3'x25' gully/slide.	HM	30	0	108	HM	1) Replace existing culvert with a 36" by 50' long culvert set in at channel grade. 2) Armor lower 1/4 of outboard fill with 5cy of 1-2' rock. 3) Install a critical dip along right hinge line.

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Site #	**Problem**	**Comment on Problem**	**Erosion Potential**	**Left ditch/road length (ft)**	**Right ditch/road length (ft)**	**Future Yield (yds3)**	**Treatment Immediacy**	**Comment on treatment**
45	Ditch relief culvert	Ditch relief culvert at low point in road. Outlet of culvert drains on to flood plain that probably only experiences flow during very large storm events.	L	275	650		L	1) Replace culvert with a 18" by 20' culvert. 2) Clean ditch around new inlet. 3) Outlsope 380' of left road and retain ditch. 4) Install 2 rolling dips up left road. 5) Outslope 125' of right road and retain ditch. 6) Install one 18" by 40' ditch relief culvert up right road. 7) Install 2 rolling dips up right road.
46	Ditch relief culvert	Ditch relief culvert is 80% plugged at the inlet. Culvert receives 215' of springy right ditch. Flow travels form outlet down stabilized gully to Rancheria Creek.	L	115	215		L	1) Outslope right road for 215' and retain ditch. 2) Install 1 rolling dip up right road. 3) Outslope left road for 115' and retain ditch. 4) Replace existing ditch relief culvert with an 18"by 30' culvert.
47	Stream crossing	Large class ll stream with two streams joining above inlet. Stream to the left is completely dry at this time.	L	150	235	147	L	1) Excavate existing culvert and install a 48" by 60' long culvert set in at channel grade. 2) Outslope and retain ditch for 235' up right road. 3) Outslope and retain ditch for 150' up left road. 4) Install a single an "I" beam or galvanized steel pole trash rack 48" above inlet. 5) Install 1 rolling dip up left road.

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Site #	Problem	Comment on Problem	Erosion Potential	Left ditch/road length (ft)	Right ditch/road length (ft)	Future Yield (yds3)	Treatment Immediacy	Comment on treatment
48	Stream crossing	Non flowing stream. Inlet is has 2 post trash rack and is 1/4 plugged. Not a lot of wood in channel. Rancheria Creek is at base of outboard fill. Multiple fill failures due to natural stream bank erosion. Left road run-off is also spilling over outboard fill here. Culvert set high in fill and at shallow grade.	ML	125	0	34	ML	1) Replace existing culvert with a 24" by 40' long culvert set in at channel grade. 2) Install a critical dip along right hinge line. 3) Install a single post trash rack 24" above inlet. 4) Outlsope 120' of left road and retain ditch.
49	Landslide	A 45'x3'x45' slide is slowly flowing downward as its toe is eaten away by Rancheria Creek. 6" to 1' scarps exist across 40' of the outboard road. This failure is not necessarily road related. About 40' above the road is 4' tall head-scarp of the slide. Slide is being saturated by multiple springs 160' above road.	M	150	0	27	M	1) Use excavator to remove upper portion of slide below road (45'x2'x25') 2) Spoil locally. 3) Maintain inboard ditch for 80' across slide are to site#48. 4) Install 1 rolling dip just to the left of the slide to drain road and short ditch.
50	Ditch relief culvert	Low spot in road. Both left and right road reaches, hillslopes, and cutbanks are springy. Majority of flow is coming from springy area 100' to the left of the site. Inlet has a two post trash rack. Culvert is short but outlet is well armored.	L	445	400		ML	1) Outslope right road for 400' and retain ditch. 2) Install 2 rolling dips up right road. 3) Install two 18" by 40' ditch relief culverts up right road. 4) Outslope left road for 345' and retain ditch. 5) Install 2 rolling dips up left road. 6) Install two 18" by 40' ditch relief culverts up left road. 7) Replace existing ditch relief culvert with a 18" by 30' culvert.

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Site #	Problem	Comment on Problem	Erosion Potential	Left ditch/road length (ft)	Right ditch/road length (ft)	Future Yield (yds3)	Treatment Immediacy	Comment on treatment
51	Road surface	Left road run off drains off outboard road here. Large gully down outboard fill and then fans out and then at creek another gully (10'x4'x10) that delivers to Rancheria Creek. Treating left road should cut off flow to this gully.	L	282	0	3	L	1) Install two 18" by 40' long ditch relief culverts up left road. 2) Outslope left road for 280' and retain ditch. 3) Install 2 rolling dips up left road.
52	Stream crossing	Recently installed culvert. Inlet and outlet are well armored. A two post trash rack exists above inlet. Slight diversion potential to the right.	ML	350	0		ML	1) Install a critical dip along right hinge line. 2) Outslope 350' of left road and retain ditch. 3) Install one 18" by 40' long ditch relief culvert. 4) Install 2 rolling dips up left road.
53	Stream crossing	Currently not on SSU property. Newly installed culvert with a two post trash rack at inlet. Pipe is shallow relative to channel grade, but area below outlet is well armored. Minimal channel morphology above inlet. Further down channel (well beyond road influence) stream has created a very large gully across a flat area. Doesn't look to be old road bed.	L	0	230		M	1) Install a critical dip along left hinge line. 2) Outslope right road for 100' and retain ditch. 3) Install one 18" by 40' long ditch relief culvert up right road. 4) Install 1 rolling dip up right road.
54	Stream crossing	Crossing receives excessive ditch flow form right road reach through grassland setting. Culvert has a two post trash rack. Flow from outlet drops 1' onto rocks. Large gully extends for 90' to Rancheria Creek, but gully is not road related.	ML	0	560	15	ML	1) Excavate existing culvert and install a 30" by 30' long culvert set in at channel grade. 2) Install a critical dip along left hinge line. 3) Install three 18" by 40' long ditch relief culverts up right road. 4) Install a single trash rack 30" above inlet. 5) Install 3 rolling dips up right road. 6) Outslope and retain ditch for 560' up right road.

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Site #	Problem	Comment on Problem	Erosion Potential	Left ditch/road length (ft)	Right ditch/road length (ft)	Future Yield (yds3)	Treatment Immediacy	Comment on treatment
55	Ditch relief culvert	Ditch relief culvert outlets on to flat area above Rancheria Creek. Culvert is at low point in road. Inlet has a three post trash rack above it. Gully below outlet looks stable.	L	290	360	2	L	1) Outlsope left road for 290' and retain ditch. 2) Install 2 rolling dips up left road. 3) Outslope right road for 360' and retain ditch. 4) Install 2 rolling dips up right road.
56	Stream crossing	Forty foot long steel bridge placed on top of older failing wooden bridge. Bridge is about 18' above stream. Log abutments look stable. Stream banks are about 18' high and near vertical both above and below crossing.	L	0	150		L	Install 1 rolling dip up right road.
57	Stream crossing	Near source stream emerges from hillslope 200' above inlet. Culvert occasionally receives diverted flow form site#58. Culvert outlets onto 5' flat with almost a reverse grade and is contributing to the outlet being 25% plugged. Below this flat Yale Creek is actively eroding this bank for about 200'. Moving the road further up slope should be considered as this erosion continues.	HM	6	0	89	M	1) Install a critical dip along right hinge line. 2) Excavate 10cy of unstable fill material below outlet. 3) Install a 10' long full round downspout to outlet.

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58	Stream crossing	No real road fill here. Road travels across natural depositional area from streams above. Outboard edge of alluvial terrace is actively being eroded by Yale Creek. Stream at site has completely buried culvert. Stream now diverts to the left and fans out under redwood and bay forest. Some flow crosses road and has gullied down to where culvert used to outlet. About 20' down from outlet is an overturned cut fir tree with its root wad in Yale Creek. Low treat immediacy because no road fill here.	L	345	115	28	L	1) Install an armored fill crossing here using 15cy of 1-2' rock. 2) Install 2 rolling dips up left road.
59	Stream crossing	Low point of road is 12' to the right of center line of crossing. Gravels are actively being transported down channel. Woody material in channel is being transported as well. Culvert looks well sized. Both the inlet and outlet are well armored. Channel below outlet has 6' vertical banks.	L	40	30	19	L	Install a single post trash rack 30" above inlet.
60	Ditch relief culvert	Ditch relief culvert is 50% plugged. Below outlet slope has incised 3-5' in sections.	L	530	0		ML	1) Replace culvert with a 18" by 30' culvert. 2) Outlsope and cut ditch for 530' up left road. 3) Install 3 rolling dips up left road. Dip out road at culvert.
61	Ditch relief culvert	Ditch relief culvert drains 360' of road and 60' of broad landing. A 1'x0.5'x200' gully runs to Yale Creek. Culvert inlet is 50% plugged. Culvert also receives flow from an off road drain above.	M	400	0	4	ML	1) Replace existing culvert with an 18" by 20' long culvert. 2) Install 1 rolling dip up left road.

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62	Road surface	Water bar on lower section on road delivers sediments to class lll stream. Portion of water bar on road is almost completely filled in with road sediments. About 50ft of upper left road has been freshly rocked.	ML	300	0	1	ML	1) Outslope left road and remove berm for 300'. 2) Install 2 rolling dips up left road.
63	Ditch relief culvert	Ditch relief culvert drains 1300' of main road and 690' of spur 2 road. Culvert is newly installed and portion of the road has been recently rocked. Left road reach has off road drains that are not functioning. Road length above rocked section is already starting to rill. 400' of left road is thru-cut. Future erosion is based upon 3 off road drains gullies that deliver to stream, as well as outlet of culvert.	M	1990	0	5	M	1) Outslope left road for 900' beyond thru-cut. 2) Install 7 rolling dips up left road. 3) Install 3 rolling dips up spur road.
64	Stream crossing	Small mossy class lll drained by a 12" culvert. Flow travels from outlet down armored fillslope to abandoned road prism below. Once flow hits this road it diverts to the right on a gradual grade for about 250' before re-entering its natural channel. Diversion rill/gully is relatively shallow and looks benign.	M	180	0	12	M	1) Replace culvert with a 24" by 30' long culvert. 2) Use excavator to channelize flow from outlet down to the right of burnt stump below abandoned road. 3) Install a critical dip along right hinge line. 4) Outslope left road for 180'.

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65	Stream crossing	Undersized culvert receives flow from a 2x1 class ll stream. Culvert is short and set high in fill. Fill around inlet has been rocked. Road drainage from left road exits road above outlet. Top of the pipe is 39% crushed, where exposed through road surface. Site also receives flow form a springy swale 125' to the left.	M	1950	0	13	M	1) Replace culvert with a 24" by 40' culvert installed in at channel grade. 2) Install a critical dip on right hinge line. 3) Install an 18" by 40' long culvert up left road an springy swale. 4) Establish inboard ditch just above inlet of Ditch relief culvert. 5) Outslope left road for 1900'. 6) Install 10 rolling dips up left road. 7) Excavate a channel below outlet of culvert at site to channelize flow across abandoned road.
66	Stream crossing	Skidded stream channel above inlet. Very little channel morphology above inlet, yet presently flowing (12hrs since last rain). Culvert is set shallow relative to channel grade but outlet has a 10' 1/2 round downspout. Left road reach is moderately rilled.	L	440	0		M	1) Install a single post trash rack 24" above inlet. 2) Install a 20' full round downspout to outlet. 3) Install a critical dip along right hinge line. 4) Install 3 Rolling dips up left road. 5) Outslope left road for 440'.
67	Stream crossing	Very small class lll stream. Even after yesterday's rain storm, the steam has hardly moved any of the duff or leafy matter. Flow pools 30' above inlet and then trickles down into culvert. Culvert is a 15" steel at inlet and an 18" plastic at outlet.	M	180	0	31	M	1) Replace existing culvert with an 18" by 50' long culvert at channel grade. 2) Install a critical dip along right hinge line. 3) Install 1 rolling dip up left road.

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68	Stream crossing	Channel looks slightly aggraded above inlet for about 50'. This is mostly due to deposited sediments coming down off road drain to the left (see sketch). Right bank from TOP flag to inlet is natural hillslope. Both inboard and outboard fill slopes around culvert are neatly armored with hand placed 6" minus rock. Outlet has a half round downspout. From downspout steam cascades down naturally armored fill for 20' to BOT. Left road contribution is a thru-cut.	ML	108	100	154	ML	1) Excavate existing culvert and install a 30" by 50' long culvert set in at channel grade. 2) Install a single trash rack 30" above inlet.
69	Stream crossing	A 2x1 class lll stream through hummocky terrain to road. Stream flow then diverts to right and splits into two sections. One half of the flow runs down inboard ditch for 125' to an off road drain where enters steam at site# 68. Ditch is active and a 1'x0.5'x100' gully may result. The other half of the flow crosses road and enters a broad landing. Flow exits landing in a 2'x3'x200' gully. An old road bed exits landing below true stream channel and should be addressed when putting flow back into channel.	HM	340	0	20	HM	1) Install a 24" by 50' long culvert at channel grade. Align culvert to the left of the landing. 2) Install a critical dip along right hinge line. 3) Cut ditch for 40' to the left from inlet. 4) Dip out old road bed below crossing. 5) Outslope 300' of left road. 6) Install 2 rolling dips up left road.

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70	Stream crossing	Stream above is very small with very little drainage area. Slope is very well armored and limited to one 2'x2'1' spot on left bank.	L	924	75	33	ML	1) Excavate existing culvert and install a 24" by 50' long culvert set in at channel grade. 2) Armor lower 3/4 of outboard fill with 15cy of 1-2' rock. 3) Outslope 924' of left road and install 6 rolling dips.
71	Ditch relief culvert	Newly installed (used) metal ditch relief culvert. Left road has been recently rocked and insloped which is the majority of the problem. Ditch relief culvert outlets onto abandoned road which it is actively eroding (2x1x60). Inboard ditch is actively incising and is included in the future erosion volume. Road/ ditch sediments can be seen for 100' down a class lll steam channel.	HM	1190	130	47	HM	1) Outslope left road and remove ditch for 1190'. 2) Install 11 rolling dips up left road.
72	Stream crossing	Small fill crossing on left hinge line of large older stable depositional feature with multiple flowing springs and another defined stream channel on its right hinge line. This steam is being kept in its natural center line by a berm to its right. Area is densely forested with redwoods. Left road length is well water barred.	L	470	10	33	ML	1) Install an armored fill crossing using 15cy of 1-2' rock armor. 2) Outslope left road for 470'. 3) Install 3 rolling dips up left road.

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73	Stream crossing	A near source stream flows down a very broad low gradient swale. The area above road has been heavily disturbed by logging which left a hummocky and tractored landscape. This site is the combination of two small steam flows that divert at the inboard road to site# 74, 30' to the right. During high flows the flow makes it to outboard fill and is causing a gully. Presently flow is diverting to site#74.	ML	15	0	6	M	Install an armored fill crossing at site using 20cy of 1-2' rock.
74	Stream crossing	Small stream on right hingeline of broad depositional feature. Site # 72 defines left hinge line of feature. Multiple springs between both streams. Some fill has been removed out of crossing, but stream is still gullying down outboard fill (2x0.5x11). Right road is well water barred.	ML	30	597	19	ML	Install an armored fill crossing at site using 15cy of 1-2' rock. 2) Outslope right road for 597' and install 4 rolling dips.
75	Stream crossing	A 5x1 and a 2x1 streams confluence 30' above inlet. Culvert outlet is 5' to the left of natural channel. A 10' long 1/2 round downspout at outlet runs onto a 10' long piece of sheet metal to channel below. Downspouts are functioning. A 2.5 diameter stump holding up stream bank prevents the installation of a 36" full round downspout. Left ditch carries 60' of spring flow to inlet and ditch looks stable.	L	600	50	123	ML	1) Install a "I" beam or galvanized steep pole 36" above inlet of culvert. 2) Outslope 600' of left road and install 3 rolling dips.

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Site #	Problem	Comment on Problem	Erosion Potential	Left ditch/road length (ft)	Right ditch/road length (ft)	Future Yield (yds3)	Treatment Immediacy	Comment on treatment
76	Stream crossing	Culverted crossing in mixed conifer bay forest. Culvert is high in fill. Outlet has a partially functioning downspout made out of metal roofing metal. Both left and right road lengths are well water barred.	ML	100	0	48	ML	1) Excavate crossing from TOP to BOT to replace culvert with a 24" by 50' long culvert placed in at channel grade. 2) Install a critical dip along right hinge line.
77	Stream crossing	There is an old diversion gully at outboard fill to right of crossing. Old Humboldt logs sticking out of fill at outboard fill. Stream flow enters an area below the road that looks like a tractored earth flow. Stream drops a vertical 10' below outlet and then goes beneath a collapse lobe of material with a fir tree growing out of it. Stream then enters a large 20'x15'x100' long gully thru hummocky deposit. This is not a man made gully.	H	95	0	92	H	1) Excavate crossing from TOP to BOT to replace culvert with a 24" by 50' long culvert placed in at channel grade. Remove Humboldt logs and remove lobe of material that fir tree is growing out of. 2) Install a critical dip along right hinge line. 3) Install a single post trash rack 24" above inlet.
78	Stream crossing	Newly installed 30" culvert 20' long. Looks to be at base of fill. Crossing is to the left of a landing and about 170' from intersection with main road. Stream has diverted in the past, about 100' to the left at low point in the road. Spring road lengths contributing to old diversion gully have left outboard fill near vertical. As a maintenance site this area could use about 15cy of rock armor to support outboard fill.	L	0	168	26	ML	1) Excavate crossing to replace culvert with a 42" by 40' long culvert placed in at channel grade. 2) Install a critical dip along left hinge line. 3) Install a "I" beam or galvanized post trash rack 42" above inlet. * Would an Armored fill work for Landowner?

General information for inventoried road-related erosion sites, SSU Galbreath Wildlands Preserve, Mendocino County, California								
Site #	**Problem**	**Comment on Problem**	**Erosion Potential**	**Left ditch/road length (ft)**	**Right ditch/road length (ft)**	**Future Yield (yds3)**	**Treatment Immediacy**	**Comment on treatment**
79	Stream crossing	Channel is carved through an old landing to culvert inlet. Culvert is in good shape. Inboard and outboard fill are armored with 2-3' rip rap. There is diversion potential to the right. Right bank below outlet is vertical and raveling (site#80). If culvert is sized well, treat road drainage.	ML	230	0	75	M	1) Excavate crossing to replace culvert with a 60" by 50' long culvert placed in at channel grade. 2) Install a critical dip along right hinge line. 3) Install 2 rolling dips to right.
80	Landslide	Old landing adjacent to right bank of stream just beyond outboard fill of site#79. Stream is actively scouring landing fill, leaving fill slope nearly vertical for 80'. Fill slope is about 12' high. No signs of cracking further back from vertical area. Future erosion is based upon assumption that landing fill will lay back to a 1:1 slope.	HM	0	0	214	M	1) Excavate landing fill along right bank of steam from START to END flags, 80'x12'x24', laying slope back to 2:1. 2) Spoil locally.
81	Stream crossing	Newly installed 18" culvert on a class ll stream. Culvert also receives road drainage form Main Road above. Culvert does not seem to have over topped yet, but easily could.	ML	100	225	12	M	1) Replace existing culvert with a 24' by 30' long culvert place in at channel grade.

General information for inventoried road-related erosion sites, SSU Galbreath Wildlands Preserve, Mendocino County, California

Site #	Problem	Comment on Problem	Erosion Potential	Left ditch/road length (ft)	Right ditch/road length (ft)	Future Yield (yds3)	Treatment Immediacy	Comment on treatment
82	Gully	Significant gully/diverted flow coming down hill to a 12" newly installed culvert. I followed the gully up slope for a couple thousand feet, and could not find from where diverted stream flow was coming. Currently flow is diverted above road for about 40' into what looks like or could be a sediment basin. Flow crosses road via 12" culvert. Road bed is saturated and has juncus growing on it. Where culvert is presently looks to be best place to carry flow. Future erosion is road fill only. Gully above road looks relatively stable with mossy slope and rocky bottom. * Need to find where diverted flow is coming from.	ML	195	50	4	M	1) Replace culvert with a 24" by 30' long culvert. 2) Excavate depositional area above inlet (35x2x15) and create a sediment catchment basin inboard of road. 3) Spoil locally. 4) Outslope left road for 195'. 5) Install 1 rolling dip up left road.
83	Stream crossing	Newly installed single walled plastic 18" culvert. Stream is currently diverted into an older gully. Gully looks relatively stable with naturally rocky bottom and somewhat mossy vertical banks. Gully depth varies form 5' to 12' and is about 20' wide. Glow is diverted into gully for about 130' and then enters natural stream channel. Future erosion for this site is road fill only. Right road approach is springy.	M	0	322	49	HM	1) Install a 42" by 50' long culvert with outlet 40' to the left of present outlet to put stream in natural channel. 2) Outlsope first 172' of right road from site and fill ditch. 3) Install 1 rolling dip. 4) Outslope remaining 150' and retain ditch. 5) Install a 18" by 30' long ditch relief culvert. Critical dip will be taken care of at site#84.

General information for inventoried road-related erosion sites, SSU Galbreath Wildlands Preserve, Mendocino County, California

Site #	Problem	Comment on Problem	Erosion Potential	Left ditch/road length (ft)	Right ditch/road length (ft)	Future Yield (yds3)	Treatment Immediacy	Comment on treatment
84	Spring	Very small steam is being diverted from its natural course by an old road bed 150' up slope from 'Loop' road. The small stream flows into the stream of site#83 with little consequence. Down here, some subsurface flows emerge on to the road through the small cutbank and in the roadbed. The result is a wet road bed and a 2x2x8 gully at the outboard fill.	ML	65	45		ML	1) Dip road so water from entire spring area drains efficiently to outboard fill gully point. 2) Install 3cy of 1-2' rock armor at outboard fill. 3) Rock road bed through dip.
85	Ditch relief culvert	A 12" ditch relief culvert receives flow from a very active spring which emerges 12' above roadbed. Pipe is installed well with armor placed at outlet and inlet. A functioning ditch has been cut for 20' to the right to capture spring flow.	L	0	20			No Treat.
86	Stream crossing	Newly installed single walled 18" culvert. Culvert is set high in fill. Outlet is well armored. Outlet may be on top of old Humboldt logs. Majority of right road is outsloped with some shallow water bars.	L	0	930	27	M	1) Excavate crossing from TOP to BOT to replace culvert with a 24" by 40' long culvert set in at channel grade. 2) Install a critical dip on left hinge line. 3) Outslope and remove ditch for first 300' up right road, from site. 4) Install 6 rolling dips.
87	Stream crossing	Small stream in springy area flows through a newly installed culvert. Fill at inlet and outlet has been well armored.	ML	400	120		ML	1) Install 1 rolling dip up right road. 2) Install 2 rolling dips up left road.

General information for inventoried road-related erosion sites, SSU Galbreath Wildlands Preserve, Mendocino County, California

Site #	Problem	Comment on Problem	Erosion Potential	Left ditch/road length (ft)	Right ditch/road length (ft)	Future Yield (yds3)	Treatment Immediacy	Comment on treatment
88	Stream crossing	Newly installed 20' long single walled culvert. Flow comes out of cutbank in broad swale at various places, with one flowing channel 60' to the left of culvert. Culvert has been placed within center of swale to capture all spring flow. Inboard ditch looks stable. If culvert were moved to where stream enters road, it would not capture all spring flow and most likely incise through fill and hillside below road to create a channel to present channel.	L	1215	120		M	1) Replace existing culvert with a 24" by 30' long culvert. 2) Install 8 rolling dips up left road. 3) Some outsloping may be needed.
89	Ditch relief culvert	Recently installed ditch relief culvert drains a small spring and 528' of road. The last 200' is across a rocky cutbank and a ditch has been cut along the base of it. The ditch has been plugged in three places by small slides. Newly installed culvert and ditch most likely caused these slides. The deepest part of the failure is just over the culvert. Left road is well outsloped.	L	530	0		M	1) Install 4 rolling dips up left road. 2) Clean ditch for 200ft. 3) Use 6cy of 1' rock to buttress failing fill over culvert outlet.

General information for inventoried road-related erosion sites, SSU Galbreath Wildlands Preserve, Mendocino County, California

Site #	Problem	Comment on Problem	Erosion Potential	Left ditch/road length (ft)	Right ditch/road length (ft)	Future Yield (yds3)	Treatment Immediacy	Comment on treatment
90	Spring	Two springs deliver to this culvert. Spring 115' up left road, part of its flow delivers to inlet and part of the flow continues down right road for 90' then exits road via a small gully. This gully looks to settle out on grassy hillside below. Pipe is placed just below second spring. Outlet has a 1/2 round downspout that becomes a plugged full round downspout. Outboard fill is actively failing around outlet and downspout. Thirty five feet of inboard ditch just above inlet has been filled in by slumping grassy toe. There is a hole in the top of the culvert and that is why it is called to be replaced.	M	154	0	9	M	1) Replace culvert at site with a 18" by 30' culvert with a 30' downspout. 2) Excavate failing fill around outlet of culvert. 3) Install an 18" by 40' long culvert at upper spring. 4) Install 1 rolling dip up left road. 5) Cut inboard ditch around toe of grassy slide without disturbing slide.
91	Stream crossing	Near source stream flows through an over sized culvert. Culvert is shallow relative to channel grade. A 10' 18" 1/2 round downspout is attached to the outlet and if functioning well. A 4'x3'x35' gully has appeared to left in outboard fill. Most likely subsurface flow erodes material from underneath.	ML	270	0	33	ML	1) Install a critical dip along right hinge line. 2) Install 2 rolling dips up left road. 3) Outslope left road and keep ditch for 270'.
92	Stream crossing	Rocky stream channel above and below culvert. Culvert looks to be placed on bedrock. Bottom of culvert is covered with 6" of angular gravels. Springy class lll contacts inboard ditch about 50' to the left of the crossing. Left road is springy for first 100' form site. Slight diversion potential to the right.	ML	315	0	34	ML	1) Install a critical dip along right hinge line. 2) Cut ditch for 100' up left road from inlet to keep springy hillside and spring flow in ditch. 3) Install a rolling dip up left road.

General information for inventoried road-related erosion sites, SSU Galbreath Wildlands Preserve, Mendocino County, California

Site #	Problem	Comment on Problem	Erosion Potential	Left ditch/road length (ft)	Right ditch/road length (ft)	Future Yield (yds3)	Treatment Immediacy	Comment on treatment
93	Stream crossing	A rusty 54" arch culvert forms the first half of the culvert and the lower half is a 42" culvert. Arch culvert is old and rusted. 42" culvert is being crushed at outlet by 3' rip-rap.	HM	175	45	115	HM	1) Replace existing culvert with a 72" by 60' long culvert set in at channel grade. Use excavator to define flow away form right bank below outlet, away from road fill.

APPENDIX C – PLANT SPECIES AT GALBREATH PRESERVE
Documented by Sonoma State University Researchers
2006

Preliminary Plant List
Galbreath Wildlands Preserve

* denotes non-native taxon

Anthocerotaceae
Phaeoceros sp.

Conocephalaceae
Conocephalum conicum

Vascular Plants

Sphenophyta
Equisetaceae
Equisetum telmateia ssp. braunii

Lycophyta

Selaginellaceae
Selaginella wallacei

Pterophyta

Blechnaceae
Woodwardia fimbriata

Dennstaedtiaceae
Pteridium aquilinum var. pubescens

Dryopteridaceae
Athyrium filix-femina
Cystopteris fragilis
Dryopteris expansa
Polystichum californicum
Polystichum munitum

Polypodiaceae
Polypodium californicum
P. glycyrrhiza

Pteridaceae
Adiantum jordanii
Cheilanthes covillei
Pellaea andromedifolia

Pentagramma triangularis

Coniferophyta

Pinaceae
Pseudotsuga menziesii

Taxodiaceae
Sequoia sempervirens

Anthophyta

DICOTYLEDONES

Aceraceae
Acer macrophyllum

Anacardiaceae
Toxicodendron diversilobum

Apiaceae
Anthriscus caucalis*
Lomatium utriculatum
Osmorhiza chilensis
Perideridia sp.
Sanicula crassicaulis
Torilis arvensis*
Yabea microcarpa

Araliaceae
Aralia californica

Asteraceae
Achyrachaena mollis
Adenocaulon bicolor
Agoseris grandiflora
Agoseris heterophylla
Artemisia douglasiana
Carduus pycnocephalus*
Centaurea solstitialis*
Cirsium vulgare*
Filago californica
Filago gallica*
Gnaphalium canescens
Hesperevax acaulis var. acaulis

Hieracium albiflorum
Hypochaeris glabra*
Hypochaeris radicata*
Lasthenia californica
Madia madioides
Micropus californicus
Microseris bigelovii
Psilocarphus tenellus var. tenellus
Soliva sessilis*
Sonchus oleraceus*
Taraxacum officinale*
Tolpis barbata*

Betulaceae
Alnus rhombifolia
Corylus cornuta var. californica

Boraginaceae
Amsinckia menziesii
Plagiobothrys bracteatus
Plagiobothrys nothofulvus
Cynoglossum grande

Brassicaceae
Brassica nigra*
Cardamine californica
Cardamine oligosperma
Lepidium latipes var. latipes
Thysanocarpus curvipes var. curvipes

Calycanthaceae
Calycanthus occidentalis

Campanulaceae
Githopsis specularioides

Caprifoliaceae
Lonicera hispidula var. vacillans
Sambucus mexicana
Symphoricarpos albus var. laevigatus
Symphoricarpos mollis

Caryophyllaceae
Cerastium fontanum ssp. vulgare*
Cerastium glomeratum*

Petrorhagia dubia*
Silene californica
Spergularia rubra*
Stellaria media*
Stellaria pallida*

Chenopodiaceae
Chenopodium album

Convolvulaceae
Calystegia purpurata ssp. purpurata

Crassulaceae
Crassula connata
Crassula tillaea*
Sedum spathulifolium

Cucurbitaceae
Marah sp.

Ericaceae
Arbutus menziesii
Arctostaphylos manzanita

Euphorbiaceae
Eremocarpus setigerus

Fabaceae
Astragalus gambelianus
Cytisus scoparius*
Lathyrus vestitus
Lotus humistratus
Lotus micranthus
Lotus purshianus
Lotus scoparius
Lotus wrangelianus
Lupinus bicolor
Lupinus nanus
Thermopsis macrophyllum
Trifolium albopurpureum var. dichotomum
Trifolium barbigerum var. barbigerum
Trifolium bifidum var. decipiens
Trifolium ciliolatum
Trifolium depauperatum var. depauperatum
Trifolium dubium*

Trifolium fucatum
Trifolium gracilentum
Trifolium hirtum*
Trifolium microcephalum
Trifolium microdon
Trifolium obtusiflorum (? not flowering)
Trifolium oliganthum
Trifolium subterraneum*
Trifolium variegatum
Trifolium willdenovii
Vicia americana
Vicia hirsuta*
Vicia sativa var. sativa*

Fagaceae
Lithocarpus densiflora
Quercus agrifolia
Quercus chrysolepis
Quercus douglasii
Quercus garryana
Quercus kelloggii
Quercus lobata
Quercus wislizenii

Geraniaceae
Erodium botrys*
Erodium cicutarium*
Geranium dissectum*
Geranium molle*

Grossulariaceae
Ribes roezlii var. cruentum

Hippocastanaceae
Aesculus californica

Hydrophyllaceae
Nemophila heterophylla
N. menziesii var. menziesii
N. menziesii var. atomaria
N. pedunculata

Hypericaceae
Hypericum perforatum

Lamiaceae
Mentha pulegium*
Stachys ajugoides var. rigida
Stachys chamissonis

Lauraceae
Umbellularia californica

Limnanthaceae
Limnanthes douglasii ssp. nivea

Oleaceae
Fraxinus latifolia

Onagraceae
Epilobium minutum
Clarkia sp.

Papaveraceae
Eschscholzia californica

Philadelphaceae
Whipplea modesta

Plantaginaceae
Plantago coronopus*
Plantago erecta
Plantago lanceolata*

Polemoniaceae
Collomia heterophylla
Gilia tricolor
Linanthus androsaceus
Linanthus bicolor
Linanthus latisectus
Navarretia sp.

Polygalaceae
Polygala californica

Polygonaceae
Polygonum amphibium
Rumex acetosella*
Rumex crispus*

Portulacaceae
Calandrinia ciliata
Claytonia perfoliata

Primulaceae
Anagallis arvensis*
Dodecatheon hendersonii
Trientalis latifolia

Ranunculaceae
Aquilegia formosa
Delphinium nudicaule
Ranunculus californicus
Ranunculus occidentalis
Ranunculus lobbii

Rhamnaceae
Ceanothus incanus
Ceanothus integerrimus

Rosaceae
Aphanes occidentalis
Fragaria vesca
Heteromeles arbutifolia
Holodiscus discolor
Rosa gymnocarpa
Rubus leucodermis

Rubiaceae
Galium aparine
Galium californicum
Galium parisiense*

Salicaceae
Salix lasiolepis

Saxifragaceae
Heuchera micrantha
Lithophragma affine
L. parviflorum var. parviflorum

Scrophulariaceae
Castilleja attenuata
Collinsia sparsiflora var. arvensis
Mimulus guttatus

Mimulus tricolor
Parentucellia viscosa*
Tonella tenella
Triphysaria pusilla
Triphysaria versicolor ssp. faucibarbata
Verbascum blattaria*
Verbascum thapsus*
Veronica anagallis-aquatica*

Solanaceae
Solanum xanti

Urticaceae
Urtica dioica

Valerianaceae
Plectritis brachystemon
Plectritis congesta

Viscaceae
Phoradendron villosum

Vitaceae
Vitis californica

MONOCOTYLEDONES

Cyperaceae
Carex deweyana ssp. leptopoda
Carex globosa
Carex nudata
Carex pachystachya
Cyperus eragrostis

Iridaceae
Iris fernaldii
Iris macrosiphon
Iris purdyi
Sisyrinchium bellum

Juncaceae
Juncus bufonius
Juncus effusus
Juncus patens
Luzula comosa

Liliaceae
Calochortus amabilis
Calochortus tolmiei
Chlorogalum pomeridianum
Dichelostemma capitatum
Disporum hookeri
Fritillaria affinis

Orchidaceae
Goodyera oblongifolia

Poaceae
Aira caryophyllea*
Avena barbata*
Briza maxima*
Briza minor*
Bromus carinatus var. carinatus
Bromus diandrus*
Bromus hordeaceus*
Bromus laevipes
Cynosurus echinatus*
Dactylis glomerata*
Danthonia californica

APPENDIX D – VERTEBRATE SPECIES AT GALBREATH PRESERVE
Documented by Sonoma State University Researchers
2006

Vertebrates of the Galbreath Wildlands Preserve

Mammals

Family	Common Name	Scientific Name
DIDELPHIDAE	Common opossum	*Didelphis virginiana*
SORCIDAE	Trowbridge shrew	*Sorex trowbridgii*
TALPIDAE	Shrew mole	*Neurotrichus gibbsii*
	Coast mole	*Scapanus orarius*
VESPERTILIONIIDAE	Red bat	*Lasiurus borealis*
	Hoary bat	*Lasiurus cinereus*
	Townsend's big-eared bat	*Plecotus townsendii*
	Big brown bat	*Eptesicus fuscus*
	Yuma myotis	*Myotis yumanensis*
	California myotis	*Myotis californicus*
LEPORIDAE	Black-tailed jackrabbit	*Lepus californicus*
HETEROMYDAE	California kangaroo rat	*Dipodomys californicus*
GEOMYDAE	Botta's pocket gopher	*Thomomys bottae*
SCIURIDAE	Western gray squirrel	*Sciurus griseus*
	Sonoma chipmunk	*Tamias sonomae*
	California ground squirrel	*Spermophilus beecheyi*
MURIDAE	Deer mouse	*Peromyscus maniculatus*
	Pinyon mouse	*Peromyscus truei*
	Western harvest mouse	*Reithrodontomys megalotis*
	Dusky-footed woodrat	*Neotoma fuscipes*
	Red tree vole	*Aborimus longicaudus*
	California vole	*Microtus californicus*
	Red-backed vole	*Clethrionomys rutilus*
CANIDAE	Coyote	*Canis latrans*
	Gray fox	*Urocyon cinereoargenteus*
URSIDAE	Black bear	*Ursus americanus*
PROCYONIDAE	Raccoon	*Procyon lotor*
MUSTELIDAE	Striped skunk	*Mephitis mephitis*
	Bobcat	*Lynx rufus*
FELIDAE	Mountain lion	*Felis concolor*
SUIDAE	Feral pig/ Wild boar	*Sus scrofa*
CERVIDAE	Black-tailed deer	*Odocoileus hemionus*

Vertebrates of the Galbreath Wildlands Preserve

Birds

Order	Common Names	Scientific Name
ANSERIFORMES	Mallard	*Anas platyrhynchos*
	Wood Duck	*Aix sponsa*
	Common Merganser	*Mergus merganser*
FALCONIFORMES	Turkey Vulture	*Cathartes aura*
	Osprey	*Pandion haliaetus*
	Bald Eagle	*Haliaeetus leucocephalus*
	Cooper's Hawk	*Accipiter cooperii*
	Sharp-shinned Hawk	*Accipiter striatus*
	Red-tailed Hawk	*Buteo jamaicensis*
	Red-shouldered Hawk	*Buteo lineatus*
	Golden Eagle	*Aquila chrysaetos*
	American Kestrel	*Falco sparverius*
GALLIFORMES	Blue Grouse	*Dendragapus obscura (obscurus?)*
	Wild Turkey	*Meleagris gallopavo*
	California Quail	*Callipepla californica*
	Mountain Quail	*Oreortyx pictus*
CHARADRIIFORMES	Killdeer	*Charadrius vociferus*
COLUMBIFORMES	Band-tailed Pigeon	*Columba fasciata*
	Mourning Dove	*Zenaida macroura*
STRIGIFORMES	Barn Owl	*Tyto alba*
	Great Horned Owl	*Bubo virginianus*
	Northern Pygmy-Owl	*Glaucidium gnoma*
	Western Screech-Owl	*Otus kennicottii*
	Northern Saw-whet Owl	*Aegolius acadicus*
APODIFORMES	Anna's Hummingbird	*Calypte anna*
	Allen's Hummingbird	*Selasphorus sasin*
CORACIIFORMES	Belted Kingfisher	*Ceryle alcyon*
PICIFORMES	Acorn Woodpecker	*Melanerpes formicivorus*
	Nuttal's Woodpecker	*Picoides nuttallii*
	Hairy Woodpecker	*Picoides villosus*
	Downy Woodpecker	*Picoides pubescens*
	Northern Flicker	*Colaptes auratus*
	Red-breasted Sapsucker	*Sphyrapicus ruber*
	Pileated Woodpecker	*Dryocopus pileatus*
PASSIFORMES	Black Phoebe	*Sayornis nigricans*
	Cassin's Vireo	*Vireo cassinii*
	Pacific-slope Flycatcher	*Empidonax difficilis*
	Ash-throated Flycatcher	*Myiarchus cinerascens*
	Hutton's Vireo	*Vireo huttoni*
	Warbling Vireo	*Vireo gilvus*
	Steller's Jay	*Cyanocitta stelleri*
	Western Scrub Jay	*Aphelocoma californica*
	American Crow	*Corrus brachyrhynchos*
	Common Raven	*Corrus corax*
	Violet-green Swallow	*Tachycineta thalassina*
	Barn Swallow	*Hirundo rustica*
	Northern Rough-winged Swallow	*Stelgidopteryx serripennis*

PASSIFORMES	Chestnut-backed Chickadee	*Poecile rufescens*
	Oak Titmouse	*Baeolophus inornatus*
	Bushtit	*Psaltriparus minimus*
	Red-breasted Nuthatch	*Sitta canadensis*
	White-breasted Nuthatch	*Sitta carolinensis*
	Brown Creeper	*Certhia americana*
	House Wren	*Troglodytes aedon*
	Winter Wren	*Troglodytes troglodytes*
	Bewick's Wren	*Thryomanes bewickii*
	Golden-crowned Kinglet	*Regulus satrapa*
	Ruby-crowned Kinglet	*Regulus calendula*
	European Starling	*Sturnus vulgaris*
	Western Bluebird	*Sialia mexicana*
	Hermit Thrush	*Catharus guttatus*
	Swainson's Thrush	*Catharus ustulatus*
	American Robin	*Turdus migratorius*
	Varied Thrush	*Ixoreus naevius*
	Orange-crowned Warbler	*Vermivora celata*
	Yellow-rumped Warbler	*Dendroica coronata*
	Black-throated Gray Warbler	*Dendroica negrescens*
	Wilson's Warbler	*Wilsonia pusilla*
	Western Tanager	*Piranga ludoviciana*
	Spotted Towhee	*Pipilo maculates*
	California Towhee	*Pipilo crissalis*
	Lark Sparrow	*Chondestes grammacus*
	Savannah Sparrow	*Passerculus sandwichensis*
	Rufous-crowned Sparrow	*Aimophila ruficeps*
	White-crowned Sparrow	*Zonotrichia leucophrys*
	Golden-crowned Sparrow	*Zonotrichia atricapilla*
	Song Sparrow	*Melospiza melodia*
	Fox Sparrow	*Passerella iliaca*
	Dark-eyed Junco	*Junco hyemalis*
	Black-headed Grosbeak	*Pheucticus melanochephalus*
	Red-winged Blackbird	*Agelaius phoeniceus*
	Brewer's Blackbird	*Euphagus cyanocephalus*
	Western Meadowlark	*Sturnella neglecta*
	Purple Finch	*Carpodacus purpureus*
	House Finch	*Carpodacus mexicanus*
	Pine Siskin	*Carduelis pinus*
	Lesser Goldfinch	*Carduelis psaltria*
	American Goldfinch	*Carduelis tristas*
	Evening Grosbeak	*Coccothraustes vespertinus*
	Cedar Waxwing	*Bombycilla cedrorum*

Vertebrates of the Galbreath Wildlands Preserve

Amphibians

Family	Common Name	Scientific Name
SALAMANDRIDAE	Rough-skinned Newt	*Taricha granulose*
	California Newt	*Taricha torosa*
	Red-bellied Newt	*Taricha rivularis*
PLETHODONTIDAE	Ensatina	*Ensantina eschscholtzii*
	CA Slender Salamander	*Batrachoseps attenuatus*
	Black Salamander	*Aneides flavipunctatus*
BUFONIDAE	Western Toad	*Bufo boreas*
HYLIDAE	Pacific Treefrog	*Hyla regilla (Pseudacris regilla)*
RANIDAE	Foothill Yellow-legged Frog	*Rana boylii*
	Red-legged Frog (Northern?)	*Rana aurora*
	Bullfrog	*Rana catesbeiana*

Reptiles

Family Name	Common Name	Scientific name
EMYDIDAE	Western Pond Turtle	*Clemmys marmorata*
	Red-eared Slider	*Trachemys scripta*
CROTAPHYTIDAE	Western Fence Lizard	*Sceloporus occidentalis*
ANGUIDAE	Northern Alligator Lizard	*Gerrhonotus coeruleus (Elgaria coerulea?)*
	Sharp-tailed Snake	*Contia tenuis*
COLUBRIDAE	Western Terrestrial Garter Snake	*Thamnophis elegans*
VIPERIDAE	Western Rattlesnake	*Crotalus viridis*

APPENDIX E – PRIORITY MANAGEMENT RECOMMENDATIONS
RANCHERIA & NAVARRO WATERSHEDS

Source Document	Source Agency	Recommendation Description	Location
Assessment			
Steelhead Trout Management Tasks. 2007.	CDFG	Conduct periodic aerial or ground reconnaissance surveys to locate habitat disturbances and potential fish migration barriers. Prompt corrective action should be pursued.	North Coast
Steelhead Trout Management Tasks. 2007.	CDFG	Encourage research/monitoring that encompasses full steelhead life history. This research is necessary to determine instream versus ocean survival which will help establish relationships between adults and subsequent juvenile production.	North Coast
Steelhead Trout Management Tasks. 2007.	CDFG	Conduct periodic inventories of adult summer steelhead populations by snorkel surveys or by operating fish counting weirs on selected summer steelhead streams.	North Coast
Steelhead Trout Management Tasks. 2007.	CDFG	Continue population surveys that have an established baseline and are providing information useful in assessing steelhead status and/or trends. Baseline data can be used to identify restoration needs or to evaluate restoration effects.	North Coast
Navarro River Total Maximum Daily Loads for Temperature and Sediment. 2000.		Monitoring for water quality implementation. State and landowners should work together to fully implement the implementation and monitoring measures.	Navarro
Navarro River Total Maximum Daily Loads for Temperature and Sediment. 2000.		Focused, coordinated monitoring that examines flow and temperature patterns in areas with diversions to reduce the uncertainty regarding the spatial extent of temperature problem from flow.	Navarro
Navarro River Watershed Technical Support Document for the Total Maximum Daily Load for Sediment and	NCRWQCB	Sediment loading capacity estimate should be reevaluated during TMDL revisions using an approach that takes sediment storage and long-term sediment transport capacity into consideration.	Navarro

Technical Support Document for the Total Maximum Daily Load for Temperature. 2000.			
Navarro River Watershed Technical Support Document for the Total Maximum Daily Load for Sediment and Technical Support Document for the Total Maximum Daily Load for Temperature. 2000.	NCRWQCB	Vegetative Surveys of Upper Rancheria Creek watershed.	Rancheria
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Information on temperatures, streamflow, and habitat conditions were insufficient in the Alder Creek and German Creek sub-basins in lower Rancheria Creek and several unnamed tributaries in upper Rancheria Creek above the Beebe Creek confluence. Additional surveys should be performed in these areas to identify their appropriateness for management and restoration as steelhead streams.	Rancheria
Salmonid Recovery			
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Use hatchery fish – coho - to repopulate lower Rancheria Creek, lower Indian Creek, and Mill Creek after habitat improvements have been completed.	Navarro
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Coho a higher restoration priority than steelhead given greater distribution and abundance of steelhead.	Navarro

Recovery Strategy for California Coho Salmon. 2004		The North Fork Navarro River has been identified as a "key population to maintain or improve" by the CDFG.	Navarro
Planning			
Recovery Strategy for California Coho Salmon. 2004.	CDFG	Investigate stream nutrient enrichment and cycling needs for coho salmon.	Navarro
Instream Restoration			
Recovery Strategy for California Coho Salmon. 2004.	CDFG	Pay particular attention to Implementing actions regarding LWD and shade that are suggested at the HU level.	Navarro
Recovery Strategy for California Coho Salmon. 2004.	CDFG	Implement comprehensive, subbasin-wide erosion control and LWD installation for Flynn, Dutch Henry, John Smith, Minnie, Horse Camp and German creeks such as is being implemented on Little North Fork.	Navarro
Recovery Strategy for California Coho Salmon. 2004.	CDFG	Coordinate LWD placement in streams with logging operations and road upgrades to maximize size, quality, and efficiency of effort.	Navarro
Steelhead Trout Management Tasks	CDFG	Implement stream restoration and upslope sediment source treaments in Adams Creek, Yale Creek, Con Creeek, and Soda Creek basins to benefit steelhead.	Navarro
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Introduction of LWD to increase high flow refuge habitatand improve low flow cover. Sediment reduction to improve aquatic insect production, improve rearing habitat.	Bear Wallow Creek
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Improved substrate conditions in riffle habitat to increase aquatic insect production and increased LWD loading to provide more pools and greater cover in pools to improve rearing habitat.	Beasley Creek
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy,	Increase pool habitat and habitat complexity by the addition of LWD on Dago and Horse Creeks. Encourage canopy closure using re-vegetation techniques and forest protection. Other	Dago, Horse Creeks, potentially

	The Anderson Valley Land Trust	creeks likely to contain similar habitat conditions are Cold Springs, Minnie, and Camp Creeks.	Cold Springs, Minnie, and Camp Creeks.
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Broad objectives for the Navarro basin are to increase the frequency and depth of pool habitat; decrease summer stream temperatures; and reduce accelerated sediment production.	Navarro
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Increase LWD recruitment; install in-stream habitat structures	Navarro
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Increasing pools in the short-term can be accomplished through introduction of LWD or by the construction of in-stream structures like boulder or log deflectors and weirs.	Navarro
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Reduction of stream temperatures can be accomplished through increasing canopy cover, increase baseflows by using water conservation management practices, development of off-stream storage and reducing groundwater extraction in locations where groundwater flows toward the stream channel.	Navarro
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Lower Rancheria Creek is located mostly in the forested Coastal Belt geologic terrain and is a high priority for projects to increase LWD recruitment and install instream habitat structure.	Lower Rancheria Creek
Riparian Restoration , Enhancement, and Protection			
Recovery Strategy for California Coho Salmon. 2004.	CDFG	Where necessary and with willing landowners, protect riparian vegetation buffer zones through conservation planning, acquisition, and easements.	Navarro

Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Along and upstream of Highway 128 - not well suited for in channel restoration because it is low-gradient and wide, storing a lot of sediment in the channel.	Rancheria Creek
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Efforts to restore fish habitat or conduct revegetation efforts to reduce water temperatures may be most effective in medium to small-sized tributaries. Efforts to restore habitat and improve fish production are also likely to be most cost-effective in streams that already provide fair to good habitat conditions.	Navarro
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	All of these sub-basins are recommended for restoration.	Dago, Cold Springs, Minne, Horse, Camp, and Beasley Creeks
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Establish and protect seral old-growth riparian forests for LWD recruitment, streambank stability, increased canopy cover.	Navarro
Navarro Watershed Restoration Plan. 1998.		Increase riparian shading	Navarro
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Consider potential for upstream and downstream impacts that could result from project implementation. Always ensure that a project is developed with respect to specific site conditions – soil depth and erodibility, dominant erosion type, bank height and slope.	Navarro
Sediment Reduction			
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley	Existing haul roads located on recently active or ancient deep-seated slides within the inner gorge should be closed, deconstructed, and relocated.	Navarro

	Land Trust		
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Restoration treatments to reduce gully erosion are likely to be an effective means to substantially reduce sediment delivery to channels.	Navarro
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Excess amount of sediment stored in reaches of the mainstem Navarro, Rancheria and Anderson Creeks must be addressed to enable salmonid recovery	Navarro
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Restoration efforts should focus on developing programs to reduce sedimentation from bank erosion, shallow landsliding, and gullying.	Navarro
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Gully remediation measures; reduce road-related erosion; streambank stabilization measures	Navarro
Socioeconomic			
Recovery Strategy for California Coho Salmon. 2004.	CDFG	Prioritize enforcement of pertinent laws concerning illegal and unpermitted dams and diversions.	Navarro
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Funding should be made available to landowners for road relocation, closure, drainage improvement, and other sediment reduction measures to reduce the sediment contribution from deep-seated landslides.	Rancheria
Land Use			
Recovery Strategy for California Coho Salmon. 2004.	CDFG	Conserve water by providing land-owners education, incentives, and technical assistance.	Navarro

Recovery Strategy for California Coho Salmon. 2004.	CDFG	Provide technical assistance and incentives to Navarro River landowners for developing and implementing sediment reduction plans to meet the requirements of the CWA TMDL.	Navarro
Recovery Strategy for California Coho Salmon. 2004.	CDFG	Where restricting winter access to unpaved roads is not feasible, encourage measures such as rocking to prevent sediment from reaching coho salmon streams.	Navarro
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Actions should be considered to support continuation of ranching as a land-use and to assist ranchers in reducing erosion from grazing activities. New road developments or other land-uses such as housing, orchards, and vineyards, should be discouraged to prevent future accelerated sediment production in the Melange terrain."	Upper Rancheria Creek
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Encourage landowners to reduce or eliminate logging within riparian corridors, along steep-walled inner gorge areas, and near sensitive hillslope features	Navarro
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Promoting voluntary land-use practices, such as protecting riparian corridors by establishing buffer strips, is a cost-effective means for reducing stream-side sediment production over the long term. Such land-use practices would allow, over the long-term, opportunities for conifers to establish in streamside areas, eventually providing greater stream canopy closure in many of the small and medium size tributaries, and a source of large woody debris recruitment to channels."	Navarro
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Road improvements in lower Rancheria Creek basin, where density is high would reduce sediment delivery to waterways.	Navarro
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy,	Implicit in all goals for restoration is the recognition of rights and responsibilities of private landowners.	Navarro

	The Anderson Valley Land Trust		
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Implement recommended land management practices (RLMPs – see Table 3).	Navarro
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	In the Lower subbasin, the reduction of road related sediment is a high priority.	Lower Rancheria subbasin
Navarro Watershed Restoration Plan. 1998.	Mendocino County Water Agency, The Coastal Conservancy, The Anderson Valley Land Trust	Longer rotation, selective harvest, preservation of riparian buffer zones, identification of no-harvest zones in areas with the most susceptibility to mass wasting failures, and proper design, installation, placement and maintenance of roads are recommended management practices for reducing the impacts of timber harvest.	Navarro