Executive Summary

This technical report follows extensive field surveys of streams and roads in the Forsythe Creek watershed, in addition to reports on hydrology, geology and deep landslide analysis, a sediment source analysis and a summary of limiting factors for fish. It is supported by a 2004 color aerial photograph series; aerial photograph interpretation; an advanced GIS application including the SHALSTAB model for shallow landslide hazard; oral histories and a comprehensive wildlife report. There is now a wealth of information on both the substantial erosion problems in this watershed and the solutions that have been developed to confront them.

Recommendations range from restoration of the streambed gradient and pool/riffle sequence to tree planting, improved grazing management and addressing the causes of upland erosion. Treatments include specific road repair techniques for surveyed sites. Streambank and floodplain enhancements include application of soil bioengineering techniques for stream bank repair to assist recovery of shady riparian corridors.

Acknowledgments

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- California Dept. of Fish & Game funded the project through the MCRCD.
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- All funding was administered by Bioengineering Associates, Inc, responsible for hiring all sub-contractors that participated in the project.
- The Oral History project was a direct contract between Linda Gray and the Coyote Valley Tribe.
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1. Introduction

1A. Description of the Watershed

The Forsythe Creek Watershed is a rural catchment in northern Mendocino County, California. Forsythe Creek joins the mainstem Russian River at the confluence with the West Fork Russian River near Calpella, just north of Ukiah, the largest city in the county. Prior to European settlement, the watershed was vegetated with native grasses and old growth forests of hardwoods and conifer. Forsythe Creek, a headwater stream of the Russian River, has carved a fertile and rugged landscape in a dynamic geologic setting.

The Forsythe watershed covers an area of 48 square miles comprised of grasslands, oak woodlands, redwood forest, Douglas fir forest, mixed conifer hardwoods and chaparral. The watershed includes the largest natural lake in Mendocino County, Leonard Lake; some patches of old growth Douglas fir forest and redwood groves; as well as a few vernal pools, a tiny freshwater marsh and two mineral springs.

Historically, Native American Pomo and Yuki tribes established villages and towns long before Mexican Rancheros established the farthest northern Mexican land grants in coastal California. Mendocino County history is a colorful mosaic of the land, its earliest settlers and the Pomo
people. The Pomo native people called themselves Yokaya, meaning "people of the South or Deep Valley." Europeans changed the spelling to Ukiah.

European and American settlers began arriving from the gold fields in the 1850s. According to Margaret Leland, her great-grandfather started the 1st winery and vineyard in Mendocino County. Margaret’s mother, Blanch Richey, corroborates that, saying that the history of that winery is documented at the Mendocino County Museum at Willits. Other immigrants planted apple and pear orchards in the main Russian River valley at Ukiah. Today, the Forsythe Creek watershed is a visually beautiful and dynamic landscape, and is treasured by the diverse people who live and make their livelihood there.

The landscape provided a rich living for its original inhabitants. The valley's mild, well-watered climate produced extensive and diverse food sources, from rabbit, deer and salmon to many fruits and other foods. Although other tribes were also present in the area, it was the Pomo and Yuki people who occupied the region that we now call Mendocino County.

As one of the northernmost streams flowing into the Russian River, Forsythe Creek is considered a “headwaters” tributary to the Russian River. The Forsythe Creek watershed is approximately 48 square miles, about 30,000 acres, and is the first major tributary to join the West Fork of the Russian River just south of Redwood Valley, about a half mile north of Highway 20 and north of Ukiah.

The tributary streams or sub-watersheds of the Forsythe Creek watershed include Forsythe Creek, Walker Creek, Mill Creek, Jack Smith Creek, Bakers Creek, Eldridge Creek and the short reach called Seward Creek below the confluence of Jack Smith with Eldridge. In all, the watershed includes 177 miles, or 934,560 feet, of GIS-identified stream drainage channels; this includes all channels mapped as blue line streams on the USGS 1:24,000 topographic map.

Maximum elevation at the highest point in the watershed is Eagle Peak at 2699ft (822.6 m), located between Mill and Jack Smith sub-watersheds on private land. The lowest elevation, where the confluence of Forsythe Creek meets the West Fork Russian River, is approximately 665 ft (202.7 m). The maximum elevation change for the watershed is 2034 ft (620 m).

Total mapped road miles (identified by GIS data) in the watershed are 92.1 miles (148.2 km), with 9.4 (15.1 km) of those paved. Mapped unpaved roads total 82.7 miles (133.1 km). However, provisional analysis of unpaved and logging roads based on aerial photo sampling increased the total to an estimated 150 miles (241.4 km). The road survey crew inventoried 94.41 miles of paved and unpaved roads, demonstrating that the road survey was not limited to the mapped roads.

In 2005, as shown in Figure 5 of the Wildlife Habitat Report by Legacy, the population densities in the watershed varied from less than 6 people per square mile (ppsm) in the large area southwest of the Forsythe Creek mainstem (about 65% of the whole) to less than 10 ppsm in the area to the north-east of the creek (about 35% of the whole) and to about 300 ppsm in a relatively small area (about 5%) in the south-east of Forsythe Creek. Primary economic activities in the watershed include forestry, viticulture, pasturage and diverse small holdings including recreation homes. The Coyote Valley Tribe, a member tribe of the Elem Pomo Nation, operates a major casino, Shodakai, and a vineyard at the lower end of Forsythe Creek.
1B. Vision for this Restoration Plan

The vision for this Forsythe Creek Watershed Assessment is a healthy, properly functioning ecological system that supports anadromous fish, other biological life and balanced human uses. A healthy watershed allows physical or geomorphic functions to process naturally, supports Coho salmon, Chinook salmon, steelhead trout, native vegetation and wildlife, and supports its residents’ homes and local economy. The overall purpose of this assessment is to create a prioritized set of site-specific projects with guidelines for restoration and rehabilitation of the Forsythe Creek Watershed.

1C. Project Goals and Objectives

The goal of the assessment is to identify opportunities for conservation and/or restoration (or more accurately rehabilitation) of the watershed.

Specifically, the assessment operated under the following objectives developed by Mendocino Resource Conservation District:

- Determine areas of the watershed that are in need of restoration.
- Take a holistic approach to watershed analysis, including biology (stream channel and upland), geomorphology, non-point source pollution and social aspects (land use, economy and oral history).
- Be defensible. All aspects of analysis shall be grounded in generally accepted protocols and analysis methodologies.
- Involve and engage the residents who will ultimately be responsible for making the watershed healthy.

The primary objective for this project is to produce watershed documents in digital format.

1D. Project organization

This watershed assessment project was conceived and led by Bioengineering Associates Inc. of Laytonville, California, working in collaboration with the Mendocino County Resource Conservation District. Under Bioengineering Associates, the stream survey team carried out all stream surveys. The road surveys were conducted by Ridge to River in collaboration with Bioengineering Associates.

The technical analysis was led by WaterCycle Inc. of Sandy Oregon, Dr. John Gardiner, PE and Dr. Christine Perala. The project GIS was created and managed by Dr. Jan Derksen. The Geology Report was written by Dr. Matt O'Connor, RPG. The Hydrology Report calculations were prepared for WaterCycle by Matt Cox.

The Wildlife Report was written and mapped by Linda Gray of Legacy, the Landscape Connection, Ukiah, CA. Public outreach and meetings were carried out by the Mendocino
1E. Organization of restoration implementation plan (section 6)

The restoration plan is organized in the following sections:

Prescriptions for restoration -
Site-specific recommendations to address identified limiting factors to anadromous fish production. All surveyed sites have been prioritized, based on the STAR system and the PWS protocol, by the cost-effectiveness of the prescription in reducing sediment delivery to the stream. However, the interactive abilities of the GIS allow a researcher with ArcGIS software to further prioritize using a wide variety (and combination) of factors, such as slope stability, proximity of sites to one another, sites requiring specific heavy equipment, etc. Maps created in GIS illustrate the treatment recommendations by location and priority.

Recommended Land Management Practices—landowners are key players in the success of any restoration program. Creating an environment in which ‘willing landowners’ (those who support the objectives of restoring salmon habitat) are encouraged is a vital investment of resources; without this investment, watershed-wide restoration is unlikely to be achieved.

1F. Summary of Fish Presence and Limiting Factors

Forsythe Creek watershed is home to Chinook salmon (*Oncorhynchus tsawytscha*) and steelhead trout (*Oncorhynchus mykiss*). The watershed also supported an historic population of Coho salmon (*Oncorhynchus kisutch*), according to surveys and research by DFG biologist, Weldon Jones (Jones, 2000). Each of these species is listed under the federal Endangered Species Act as “threatened” within the Russian River and its tributaries. Coho salmon, in addition to their federal threatened listing, are listed as “petition endangered” under California’s Endangered Species Act.

Previous research has shown that several fish species were observed in surveys conducted from the 1950s to 1980s (Mendocino County Water Agency, 1997). Species and Limiting Factors in the following five sub-watersheds included:

**Forsythe Creek** – Anadromous species include rainbow/steelhead trout and Chinook salmon. Other fish species include brown trout, roach, suckers, lamprey ammocoetes (Pacific and brook), squawfish, smallmouth bass, largemouth bass, bluegill, green sunfish and threespine sticklebacks. Some residents claim to have seen Coho salmon in the past. Limiting Factors included high summer water temperatures, migration barriers, erosion problems and low streamflows.

**Eldridge Creek** - rainbow/steelhead trout and Chinook salmon. According to Weldon Jones, a DFG fisheries biologist, Coho salmon may have historically been present in the Eldridge Creek watershed. Limiting Factors included high summer water temperatures, migration barriers and low streamflows.
Seward Creek - rainbow/steelhead trout, Chinook salmon, California roach and Sacramento squawfish, with residents claiming to have seen Coho salmon in the past. Limiting Factors included high summer water temperatures and low streamflows.

Mill Creek - rainbow/steelhead trout, Chinook salmon, brown trout, roach, suckers, lamprey ammocoetes, squawfish, smallmouth bass, largemouth bass, bluegill and green sunfish, with residents claiming to have seen Coho salmon in the past. Mill Creek seems to have been of great importance to the Forsythe Creek watershed as a salmonid spawning and nursery area. Limiting Factors included high summer water temperatures, low streamflows, erosion problems and migration barriers.

On March 26, 2004, NRCS staff walked the Lindsey site on Mill Creek to examine a rock outcrop considered to be a barrier to fish passage. The idea had been raised that the rock outcrop could be made passable through technical removal, such as with dynamite. The team included John Bennett, Agricultural Engineer of MCRCD, Ukiah; Julia Grim, Geologist, UC Davis; Marianne Hallet, Civil Engineer, UC Davis; and Tim Walls, Watershed Coordinator, MCRCD. The field survey produced a written conclusion that the rock barrier could not safely or cost-effectively be removed to improve fish passage.

Walker Creek - rainbow/steelhead trout, Chinook salmon, California roach, largemouth bass and bluegill, with residents claiming to have seen Coho salmon in the past. Walker Creek seems to have been of great importance to the Forsythe Creek watershed as a salmonid spawning and nursery area. Limiting Factors included high summer water temperatures, low streamflows, erosion problems and migration barriers.

The Limiting Factors identified by California Department of Fish and Game (CDFG) are largely a result of human activities. The watershed in its “natural condition” had a background rate of sediment delivery to the stream system lower than its present condition. The erosional effects of land use by the Pomo, who inhabited much of Mendocino and northern Sonoma counties, are unknown (MCRCD, 1992), but likely included practices of regular burning of grass in oak savannah areas. Large excavations and earth moving (as for road construction) did not occur in the previous era.

The past century of land use within the Upper Russian River basin has included in-channel gravel extraction and channel straightening, ditching and dyking of streams and wetlands, water abstraction for agricultural irrigation, grazing (including within stream corridors), logging, road construction and culverting of streams, channel obstruction by road crossings at streams, urbanization and dam construction (primarily for water supply).

1G. Context of the restoration plan

Water flows down, away from the headwaters in upper watersheds like Forsythe to estuaries like the one in Jenner, at the mouth of the Russian River. Giving priority to initiating assessment and restoration efforts at the headwaters is therefore desirable, because conditions downstream will be affected by changes or practices implemented upstream. Also, small streams with smaller flood events are relatively easier to enhance than larger channels, as flood events downstream increase in the magnitude of effects. This basic watershed dynamic makes repair goals in small
headwater streams relatively easier to achieve than similar goals in larger, lower-watershed channels.

In the year 2000, the Mendocino County Resource Conservation District (MCRCD) decided to make a substantial commitment to begin restoration efforts in the Russian River watershed. This commitment resulted in hiring a watershed coordinator, Tim Walls, to implement the Board’s restoration objectives. The coordinator’s objectives included the task of organizing a Watershed Advisory Group (WAG) for the Forsythe Creek watershed, an action which took place in June 2001. Tim Walls led the Forsythe Creek WAG effort to involve watershed residents and landowners in potential assessment and restoration activities. The WAG is composed of 5 landowners, 6 agency staff, 3 restoration-business interests, and the Coyote Valley Tribal EPA.

WAG stakeholders have expressed interest in working together to ensure coordination among programs, people and restoration projects. Several of the landowners and the Tribal EPA realized that unless problems in the upper parts of the watershed are recognized and treated, restoration projects in the lower parts of the watershed will be in danger of decreased effectiveness or failure. The Coyote Valley Tribal EPA is important because the Tribe made an initial push for watershed assessment of the entire watershed, and its EPA representatives, Jeff Harris and Mary Corte, have been active, supporting members of the WAG.

The CDFG considers Forsythe Creek to be one of the most important spawning and rearing tributaries in the Upper Russian River Watershed (Coey, 2001). In addition, CDFG’s habitat surveys for all Forsythe Creek sub-watersheds noted seven recommendations, which taken collectively are as follows:

- Monitor and mitigate barriers to fish migration.
- Limit livestock access to the creek and landslide areas.
- Map and identify in-channel and upland sources of sediment and erosion; prioritize them for treatment; and treat them.

The report recommends the following strategies for improving fish habitat in the Forsythe Creek watershed:

a) bioengineered streambank protection projects to re-establish floodplain benches  
b) define the low flow channel  
c) discourage lateral migration  
d) increase canopy cover  
e) decrease bank erosion  
f) add to the riparian canopy to shade creeks  
g) add to stream complexity through large wood recruitment  
h) increase the number of pools in the streams  
i) increase cool water releases from the Ridgewood Dam at Walker Lake, while simultaneously reducing warm water flows over the spillway.

The recommendations outlined in the habitat inventories were meant to enhance habitat for anadromous fish. Because the surveys were completed in 1999, further study was needed to see what changes had taken place and to augment the information in the surveys with a more
comprehensive, multi-disciplinary analysis. At the same time, the surveys recommended that further in-channel and upland sediment and erosion sources be mapped, identified and treated. The concept was that this assessment would map, identify and prioritize sites over the entire watershed and recommend projects that restore the watershed to a more healthy system.

Both CDFG and National Marine Fisheries Service (NMFS) have worked cooperatively in a Coho recovery program that involves raising wild Coho and releasing them in healthy Russian River tributaries that historically supported Coho populations. The objective of this program is to augment wild populations of Coho to the point that they become self-sustaining. Because Forsythe Creek is an historic Coho watershed, assessment and subsequent restoration could work to enhance CDFG’s Coho recovery efforts.

In 1998, the US Environmental Protection Agency listed the Russian River and its tributaries as “impaired” under Section 303d of the Clean Water Act. The listing identifies excess sediment as the primary type of non-point source pollution affecting the river system. Sediment is a concern to anadromous fish habitat since it clogs spawning gravels, fills rearing pools, adversely affects geomorphology and may contain pollutants, such as agricultural chemicals. The Russian River is slated to receive a Total Maximum Daily Load (TMDL) review in 2011 by the North Coast Regional Water Quality Control Board (NCRWQCB).

At the same time, other poor management practices have resulted in the decline of anadromous fish populations in the Russian River and its tributaries, including Forsythe Creek. In “Section 2.1” of the Russian/Bodega Watershed Management Area, the NCRWQCB documented that the decline in the anadromous fishery is due to: dams, loss of habitat, low tributary flows, elevated summer water temperatures and excess sedimentation/siltation (hence the River’s listing in the California Unified Watershed Assessment as a “Category I Priority”).

2. Strategic Approach to Watershed Assessment

2A. Introduction

North Coast Watershed Assessment Program

In 1999, the California Resources Agency and the California Environmental Protection Agency began developing an interagency watershed assessment program for California's North Coast. The purpose of the program is to develop consistent, scientifically credible information to guide landowners, agencies, watershed groups, and other stakeholders in their efforts to improve watershed and fisheries conditions.

The agencies brought together the Department of Fish and Game (DFG), Forestry and Fire Protection (CDF), Conservation's Division of Mines and Geology (DMG), Water Resources (DWR), and the North Coast Water Quality Control Board (NCWQCB) to identify the appropriate role and objectives of a state assessment program. The resulting North Coast Watershed Assessment Program, or NCWAP, is designed to meet four goals:

- Develop baseline information about watershed conditions.
- Guide watershed restoration programs.
- Guide cooperative interagency, non-profit, and private sector approaches to ‘protect the best’ through stewardship, easement, and other incentive programs.
Better implement laws requiring watershed assessments such as Forest Practices, Clean Water and Porter-Cologne Acts, Lake or Streambed Alteration Agreement, and others.

**Benefits of Watershed Assessment to Landowners**

The North Coast Watershed Assessment Program will support watershed protection and planning at the project level in several ways. It will provide information that small landowners could not easily obtain, such as landslide, sediment, and Timber Harvest Plan (THP) maps for all ownerships within a watershed. These products, when used in conjunction with site-specific assessments by the landowner, will improve his or her ability to design projects that mitigate potential watershed impacts and address limiting factors to salmonid recovery. NCWAP also works with interested landowners to demonstrate the use of GIS tools and predictive models for project planning and cumulative effects analysis.

The program includes two DFG positions to identify near-term restoration opportunities and to develop projects with interested landowners. NCWAP results will also be shared with State Water Resources Control Board and DFG grant programs (e.g. Proposition 13, 319 Clean Water Act, SB 271 Fisheries Restoration, and Coastal Salmon Recovery Programs).

Project proposals that reflect NCWAP findings and restoration priorities will have improved chances of getting funded. Assessments can also be used for developing cooperative watershed level salmon recovery plans that benefit multiple landowners.

**NCWAP Assessment Questions**

The North Coast Watershed Assessment Program is designed to answer the following critical questions for each river basin:

1. What are the relationships among land use history, current vegetation conditions and watershed disturbance?
2. What is the spatial and temporal distribution of sediment delivery to streams from different sources and what is the relative importance of each source?
3. What are the effects of stream, spring, and groundwater uses on water quality and quantity?
4. What is the current role of large wood structures in forming fish habitat and determining channel morphology and sediment storage?
5. What are the current salmonid habitat conditions, and how do they compare to desired conditions (life history requirements and Basin Plan objectives)?
6. What are the sizes, distributions, and relative health of salmon populations in the watershed?
7. Do current aquatic community populations and diversity reflect assessed watershed and water quality conditions?

These questions are similar to those guiding other watershed assessment programs. There are already well-established protocols to measure many of the parameters needed for answering these questions. The program will develop a manual of methods that references other published sources. NCWAP will strive to answer assessment questions at scales ranging from the planning watershed up to basin level, as appropriate, but will need to adapt objectives, methods, and level of assessment based on individual basin characteristics, stakeholder input, existing data, and landowner cooperation for fieldwork.
2B. 2004 aerial photograph analysis

At the start of the project, it was discovered that there were no recent aerial photographs of the area. WaterCycle Inc. commissioned a set of stereoscopic-paired, color aerial photographs of the entire Forsythe Creek watershed, at a scale of 1:24,000. The photographs were digitized and ‘rubber-sheeted’ over the existing GIS topographic layer. This approach allowed the resulting GIS digital layer to provide horizontal accuracy of 10 meters.

In non-forested areas, the aerial photographs showed areas of disturbed land that might indicate landslide activity, ephemeral channels, gullies, and rills. These disturbances are particularly visible when photos are viewed as stereoscopic pairs. These features were mapped, and a representative sample was field-checked for accuracy of both area and feature identification.

Excellent detail can be seen using the 2004 aerial in the GIS in digital space by opening layers such as the Digital Elevation Model (called light gray hillshade), the topographic map and the stream layer. The zoom function permits very accurate interpretation of hillslope features at a larger scale than can be achieved by foot on the ground. This method was used to identify features such as gullies below culverts and areas of potential soil disturbance associated with roads, culverts, deep-seated slope instability and other irregular surface textures. A representative sample of surface irregularities was field-checked for accuracy of both extent of surface area and feature identification, with very satisfactory results.

2C. Discussion of Sediment Processes and Sources in the Forsythe Watershed

Initially, the use of a rapid evaluation of sediment budget was intended to direct field survey crews to areas of high instability in the watershed. However, as it turned out, the survey crews were able to survey every mile of stream and road that were available with landowner access; the crews surveyed a total of 94.41 miles of roads and approximately 50 miles of stream channel in the Forsythe Creek watershed. See the Stream Survey Data Report and Road Survey Data Report for detailed descriptions of both the problems and prescriptions outlined by the field survey crews.

2D. Watershed Geology Report and Estimated Background Sediment Yield

Location and Setting

The highest point in the Forsythe Creek watershed is Eagle Peak at 823 m above sea level. Eagle Peak is located on the ridge between Mill Creek and Jack Smith Creek watersheds. Precipitation in the watershed ranges from 45” in the north to 35” in the south (DWR, 1984). Forsythe Creek parallels the strike of northwest-southeast trending Maacama Fault and is approximately 12 miles long. Forsythe Creek reaches the western edge of Redwood Valley about 12 miles north of Ukiah. Highway 101 parallels the lower 7 miles of the stream channel on its east bank.

Bedrock Geology and Faults
The bedrock geology in the vicinity of Forsythe Creek was mapped by Kilbourne (1984) as Franciscan mélange in the upper reaches of Walker Creek. In this area, the Central block Franciscan mélange consists of individual blocks of greywacke, sandstone, mudstone, conglomerate, green stone, chert and serpentinite within a sheared argillaceous matrix. A thin bed of Leggett peridotite outcrops in the upper Walker Creek basin. This suite of rocks is characteristic of the Franciscan Formation, comprised primarily of a variety of sea floor rocks uplifted by tectonic forces, and it bears testament to the high level of tectonic activity in the region in general and the project area in particular.

On the California Division of Mines and Geology 1:250,000 scale map of California (Ukiah Sheet), the Forsythe Creek watershed is traversed by the Talmage Fault (not so-named on this map), which extends from the city of Ukiah in a north-westward direction to just northwest of Willits (DMG, 1960). The fault cuts through the middle portions of Mill Creek and Forsythe Creek watersheds and is mapped as ‘approximately located’. The fault separates undivided Cretaceous marine deposits (i.e. Coastal Belt Franciscan) to the west from Central Belt Franciscan Formation to the east. The lower reaches of the Forsythe Creek watershed are mapped as Plio-Pleistocene non-marine deposits and Quaternary terrace deposits and alluvium. There is a small outcrop of Franciscan volcanic and metavolcanic rocks (map unit KJfv) mapped alongside Highway 101 in the north-east portion of the watershed, and there is another small outcrop in the lower reaches of Mill Creek. Three small Mesozoic ultrabasic intrusive rock outcrops within the Franciscan formation are also mapped in Forsythe Creek near Highway 101.

The Talmage fault (the northern extension of the Maacama Fault as mapped by CDMG, 1985) runs through the eastern portion of the study area, approximately parallel to State Highway 101. The Talmage fault is described as an active (i.e. having ruptured in the Quaternary period), northwest trending, strike slip fault. Creep rates are estimated to be approximately 6 mm per year near Willits (CalTrans 1982). The Talmage fault separates Central Belt Franciscan mélange on the eastern side from Coastal Belt Franciscan complex on the western side. A shear zone has been mapped in the upper Walker Creek area by Kilbourne (1984). The fault is mapped on the 1:750 000 scale fault map of California as a minor pre-Quaternary fault (DMG, 1985); however, this same report notes that slip movement occurs on this fault. More recent maps (Jennings, 1994) describe the Maacama Fault in central Mendocino County as active within Holocene time (the past 10,000 years), with short segments of historical activity (within the past 200 years).

On the 1:62,500 scale map produced by Caldwell (1965, pg 64), the lower portion of Forsythe Creek is underlain by undifferentiated Franciscan and Knoxville (Great Valley Sequence) formations of Cretaceous age. Quaternary alluvium and terrace deposits are present in the river valleys and younger terraces, while freshwater deposits of Pliocene and Pleistocene age are underlying the higher terraces and hills and are exposed along Highway 101 and in the steep-sided canyon of Forsythe Creek. In some places, the continental deposits contain up to 75-100 ft of gravel, with boulders up to 1 ft in diameter in a matrix of silty sand.

Recent alluvium in the watershed is present in the valleys, floodplains and terraces of rivers and streams, and it consists of unconsolidated gravel, sand and silt deposits. Recent alluvium is thickest in the central portions of the major river valleys; in the Russian River valley, it is estimated to be up to 80 ft thick (DWR, 2004). Plio-Pleistocene alluvium (“continental” deposits of Caldwell, 1965) consist of poorly consolidated and poorly sorted deposits of clayey
gravel, sandy gravel, clayey sand, and sandy clay. Moderately indurated deposits of gravel interfinger with large deposits of blue sandy silt and clay (Cardwell, 1965).

**Historic Channel Characteristics**

The channel of Forsythe Creek is described in a memo from Mendocino County dated September 8, 1954, describing fish populations in Forsythe Creek (from KRIS website). The channel was described as a narrow gorge from the falls (presumably located about 1 mile downstream of the present-day Ridgewood Ranch) downstream to the confluence with Mill Creek. The channel was described as being filled with large boulders and rubble. Upstream of the falls the channel was described as very steep with house-sized boulders. Below Mill Creek the channel gradient is reduced. About a mile upstream of the confluence with the Russian River, Forsythe Creek was described as a typical lowland stream with low flow and a wide shallow channel. There were several pools identified in this reach that were shallow and had sand or silt in the bottom.

In a DFG stream survey report (from KRIS website) dated July 1963, the headwater basin of Forsythe Creek was noted to be undergoing down-cutting, which resulted in a steep v-shaped canyon. Soil creep and slope erosion were evident, although minimal. The lower 5 miles of the creek were described as a wide valley with a broad floodplain and channel that was predominantly an area of deposition. The overall gradient of the stream was 79.2 ft/mile (1.5 %), but ranged from 260 ft/mile (5 %) in the canyon areas to 20 ft/mile (0.4 %) in the floodplain areas.

**Geomorphology of Hillslopes**

Kilbourne (1984) also mapped geomorphic features and identified several dormant translational/rotational slides and areas of disrupted ground and amphitheatre slopes. Amphitheater slopes are formed by numerous debris slide events. Only about 2 square miles of the northwestern portion of the watershed was mapped by Kilbourne (1984).

Recent geologic mapping in the Gualala River watershed (conducted by the California Geologic Survey (CGS; formerly California Division of Mines and Geology) for the Northwest California Watershed Assessment Program’s analysis of the Gualala River watershed (Kampt et al. 2002)), provides additional perspective on the extent, scale and complex character of deep-seated rockslides and earthflows (equivalent to the translation/rotational slides of Kilbourne, 1984) that occur in the region. CGS mapping in the Gualala identifies large rock slides and earthflows (Fuller, Haydon et al. 2002) that frequently encompass entire hillslopes and may extend across watershed divides and stream channels. Individual mapped features are commonly on the order of 1 mi² in area. The eastern edge of the Gualala River watershed is traversed by the Toombs Creek fault, which is similar in some respects to the Talmage Fault in the Forsythe Creek watershed. Hence, it is not surprising that similar geomorphic features are present in the Forsythe Creek watershed.

The local extent of deep seated rockslide and earthflow features in the region has also been documented in reconnaissance aerial photo mapping by Mendocino Redwood Company of the Navarro River and Gualala River watersheds. These aerial photo reconnaissance mapping projects were supervised by Dr. Matt O’Connor, who reviewed aerial photos of both watersheds for the purpose of identifying active and dormant rock slides. Hence, the extent of rock slides
and earthflows observed in the Forsythe Creek reconnaissance mapping project is not unusual in the region, although the concentration of features appears to be relatively high in the Forsythe Creek project area.

Reconnaissance Mapping of Rock Slides

Aerial photographs and compilation of the existing data were the primary information sources for this product. One set of aerial photographs (the same set of 2004 color photography used to produce project orthophotos) were interpreted by Matt O'Connor, PhD, PG #6847 using a 3x Topcon mirror stereoscope and table. Aerial photos had a nominal scale of 1:24,000 and covered the entire Forsythe Creek watershed. No field assessment of the mapped landslide-related features was performed. Interpretation focused on slope morphology indicative of rockslide processes (including rockslides, earthflows, and composite slides) in the watershed for the purpose of estimating long-term background erosion rates in the project area. Shallow rapid landslides (debris slides, debris flows, debris torrents) were not evaluated for the purposes of this (geology) report; however, information regarding shallow landsliding can be found on pages 24 and 25 in the hillslope report.

Rockslide features identified through photo-interpretation were compiled on clear acetate overlays atop individual aerial photos and then incorporated into ArcGIS 9.1. Photo-interpretation was guided by, and intended to be consistent with, similar work performed by CGS for NCWAP. In particular, interpretation of the features such as rockslide type (rockslide, earthflow or complex slide; see unit descriptions below), the confidence level of interpretation (definite, probable or questionable), the initial type and subsequent type of each feature, the activity level (active or dormant; see additional description below) is consistent with CGS methods. At this scale of reconnaissance mapping, all features were considered to have thickness > 50 ft (classified as deep by CGS NCWAP mapping procedures), and all slides were adjacent and/or traversed by stream channels, hence, they were assumed to deliver sediment to the stream channel network (see additional discussion below).

The following descriptions for “rock slides” and “earthflows” are reproduced from maps prepared by CGS for the NCWAP Gualala River project. In this study of the Forsythe Creek area, most features were very large and showed morphological evidence of multiple processes. The dominant map unit utilized in this reconnaissance mapping effort was “complex slide”, owing largely to the variety of landslide processes, landslide scale, and activity levels observed during photo-interpretation. In most cases, a substantial portion of the mapped area of complex slides included morphology indicative of earthflow processes. It should be noted that the description of rock slide given below includes components of earthflow, and that boundaries of all units are generally considered indistinct.

Rock Slide. Slope movement with bedrock as its primary source material. This class of failure includes rotational and translational landslides, relatively cohesive slide masses with failure planes that are deep-seated in comparison to those debris slides of similar area and extent. The slide plane is curved in a rotational slide. Movement along a planar joint or bedding surface may be referred to as translational. Complex versions with combinations of rotational heads and translational movement of earthflows downslope are common.
Earthflow. Slow to rapid movement of mostly fine-grained soil with some rocky debris in a semi viscous, highly plastic state. After initial failure, the mass may flow or creep seasonally in response to changes in groundwater level. These types of slope failures often include complexes of nested rotational slides and deeply incised gullies; boundaries are usually indistinct.

Complex Slide. A combination of rock slide and earthflow features extending over a relatively large area with a variety of activity levels with indistinct interval boundaries. Shallow landslide features may occur within these units, and gully erosion may be common. Complex slides include areas of “disrupted ground,” as defined by CGS.

GIS Analyses

Rockslide and earthflow features mapped on photo overlays were digitized by Bill McDavitt using ArcGIS 9.1. Features were visually transferred from the acetate to the screen using a digital backdrop of a geo-positioned, compressed, mosaiced, MrSid image (that is, an orthophoto developed from the 2004 project photography). Each feature was assigned a unique ID when digitizing onscreen. A relationship was established between the unique ID in the attribute table for the shapefile and the spreadsheet named OEI_LS_Inventory developed by Dr. O’Connor during the photo-interpretation process. The rockslide inventory data from photo-interpretation is summarized in Table 1.

Sediment delivery via soil creep processes to the stream channel network was estimated based on an approach used by CGS for the NCWAP Gualala assessment ((Klamt, LeDoux-Bloom et al. 2002) Appendix 2-Geology Report, Appendix C). This approach quantifies the accelerated soil creep process that occurs within rockslides, including both active and dormant features at a watershed scale utilizing GIS. The essential elements of this technique include mapping of rockslides, assessing their level of activity (active or dormant), mapping the full network of stream channels, and application of assumed soil creep rates derived from scientific literature. Soil creep rates are presented as a range of likely values that vary by movement type (rockslide or earthflow) and activity level (active or dormant). In addition, a substantially lower soil creep rate is applied where rockslides are not present.

A model stream channel network was developed from a 10-meter grid Digital Elevation Model (DEM) for the Forsythe Creek watershed to create the stream layer using the ArcHydro toolbar developed by ESRI. The key variable in creating a vector stream layer from the DEM raster is the contributing area needed to define a stream. For this application a value of 750 cells (0.075 km² = 0.029 mi² = 18.5 acres) was used. This value is consistent with typical drainage areas observed in the field at the threshold of channel initiation by O’Connor Environmental in the Coast Range. Once the stream layer was created, the clip tool was used to distribute the streams into six sub-basin areas developed for the project area (Table 2). Next, for each landslide the clip tool was again used to clip each of the streams by sub-basin layer by the three types of landslides: complex slides, earthflows and rockslides. Finally, the summary statistic tool was used to sum the length of stream for each clipped landslide type and sub-basin.
Table 1. Rockslide Photo-interpretation Summary.

<table>
<thead>
<tr>
<th>Type</th>
<th>Number</th>
<th>Initial Type</th>
<th>Confidence</th>
<th>Subsequent Type</th>
<th>Movement Mode</th>
<th>Activity</th>
<th>Delivery</th>
<th>Estimated Thickness</th>
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<td>P</td>
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<td>A/D</td>
<td>Y</td>
<td>Deep</td>
</tr>
<tr>
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<td>Complex</td>
<td>P</td>
<td>Complex</td>
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<td>A/D</td>
<td>Y</td>
<td>Deep</td>
</tr>
<tr>
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</tr>
<tr>
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<td>Complex</td>
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<td>Slide, compound</td>
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<td>A/D</td>
<td>Y</td>
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<td>Earth Flow</td>
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<td>A/D</td>
<td>Y</td>
<td>Deep</td>
</tr>
<tr>
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<td>Rock Slide</td>
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<td>Na</td>
<td>D</td>
<td>Y</td>
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<td>Q</td>
<td>RS</td>
<td>Slide, compound</td>
<td>D</td>
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<tr>
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<td>Rock Slide</td>
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<td>RS</td>
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<tr>
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<td>Rock Slide</td>
<td>Na</td>
<td>D</td>
<td>Y</td>
<td>Deep</td>
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</tbody>
</table>

Table 2. Stream length (m) adjacent and within rockslide features by sub-basin. The category “no intersection” accounts for streams that do not occur within or adjacent to identified rockslide features.

<table>
<thead>
<tr>
<th>Sub-basin</th>
<th>Jack Creek</th>
<th>Mill Creek</th>
<th>Walker Creek</th>
<th>Seward Creek</th>
<th>Mariposa Creek</th>
<th>Redwood Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complex (A/D)</td>
<td>28,271</td>
<td>21,969</td>
<td>56,743</td>
<td>7,751</td>
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<td></td>
</tr>
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<td>Rock Slide (A/D)</td>
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<td>5,644</td>
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<td></td>
</tr>
<tr>
<td>Rock Slide (D)</td>
<td>1,071</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Earth Flow (A/D)</td>
<td>39,088</td>
<td>49,028</td>
<td>52,590</td>
<td>14,579</td>
<td>12,104</td>
<td>17,891</td>
</tr>
<tr>
<td>No intersection</td>
<td>68,664</td>
<td>73,010</td>
<td>114,977</td>
<td>22,330</td>
<td>12,104</td>
<td>17,891</td>
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<tr>
<td>TOTAL</td>
<td>17,891</td>
<td>17,891</td>
<td>17,891</td>
<td>17,891</td>
<td>17,891</td>
<td>17,891</td>
</tr>
</tbody>
</table>
Calculation of Background Sediment Yield

As described above, the data in Table 2 forms the basis for calculating sediment delivery to streams via soil creep processes. The remaining calculations were as follows. First, we assumed that all stream banks were 1 m high (a conservative assumption; average bank heights are probably greater). We further assumed that creep rates would be applied to both stream banks. The creep rates applied are summarized in Table 3. Volumetric creep was converted to mass using an assumed soil density of 1.75 metric tons per cubic meter (1.48 short tons per cubic yard; 100 lbs per cubic foot). The computed values of estimated annual sediment delivery to streams by sub-basin in the project area are shown in Table 4; these values are converted to sediment delivery rate per unit watershed area in Table 5.

Some inaccuracy was introduced owing to the fact that some landslides were mapped and digitized without insuring that all rockslide feature edges overlapped with adjacent stream boundaries. This affects a small portion of total stream length intersected by mapped rockslides and reduces the estimated sediment by a small quantity that is insignificant relative to the accuracy of the overall range of estimates at the sub-basin scale.

Table 3. Soil Creep Rates

<table>
<thead>
<tr>
<th>Initial Type</th>
<th>Activity</th>
<th>CGS Type</th>
<th>Low Range (m/yr per stream bank)</th>
<th>High Range (m/yr per stream bank)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complex</td>
<td>A/D</td>
<td>historically active earthflow</td>
<td>0.13</td>
<td>0.3</td>
</tr>
<tr>
<td>Rock Slide</td>
<td>A/D</td>
<td>historically active rockslide</td>
<td>0.025</td>
<td>0.05</td>
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<tr>
<td>Rock Slide</td>
<td>D</td>
<td>dormant rockslide</td>
<td>0.005</td>
<td>0.01</td>
</tr>
<tr>
<td>Earth Flow</td>
<td>A/D</td>
<td>historically active earthflow</td>
<td>0.13</td>
<td>0.3</td>
</tr>
<tr>
<td>All other stream banks</td>
<td></td>
<td></td>
<td>0.0016</td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Estimated annual sediment delivery by soil creep processes (metric tons).

<table>
<thead>
<tr>
<th></th>
<th>Smith Creek</th>
<th>Mill Creek</th>
<th>Walker Creek</th>
<th>Seward Creek</th>
<th>Mariposa Creek</th>
<th>Redwood Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Range</td>
<td>13,600</td>
<td>10,400</td>
<td>26,200</td>
<td>3,600</td>
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<td>100</td>
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<tr>
<td>High Range</td>
<td>31,000</td>
<td>23,700</td>
<td>60,100</td>
<td>8,200</td>
<td>70</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 5. Estimated annual sediment delivery by soil creep processes (tons/km²).

<table>
<thead>
<tr>
<th></th>
<th>Smith Creek</th>
<th>Mill Creek</th>
<th>Walker Creek</th>
<th>Seward Creek</th>
<th>Mariposa Creek</th>
<th>Redwood Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Range</td>
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<td>360</td>
<td>550</td>
<td>410</td>
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<td>14</td>
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<tr>
<td>High Range</td>
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<td>820</td>
<td>1,270</td>
<td>940</td>
<td>14</td>
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</table>

Table 6. Estimated annual sediment delivery by soil creep processes (short tons/ft²).

<table>
<thead>
<tr>
<th></th>
<th>Smith Creek</th>
<th>Mill Creek</th>
<th>Walker Creek</th>
<th>Seward Creek</th>
<th>Mariposa Creek</th>
<th>Redwood Creek</th>
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</thead>
<tbody>
<tr>
<td>Low Range</td>
<td>1,360</td>
<td>1,030</td>
<td>1,580</td>
<td>1,170</td>
<td>40</td>
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<td>High Range</td>
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<td>3,620</td>
<td>2,660</td>
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</table>
Interpretation and Significance of Sediment Yield Estimates

The estimated sediment yield rates from soil creep are comparable to those computed by CGS for the Gualala River watershed (298 square miles), where the low and high range estimates were 350 to 990 tons per square km per year. Forsythe Creek tributaries (see Table 5) produced a somewhat higher sediment delivery rate than the Gualala, which is likely due to the high concentration of rockslide features in the Forsythe Creek study area. The low sediment delivery estimates for Mariposa and Redwood Creek sub-basins result directly from the absence of rockslide features in those areas. Mariposa Creek (also known as Butterfly Creek) is a small tributary to Redwood Creek, which is a tributary to Eldridge Creek on Greenfield Ranch.

The annual sediment delivery estimate in Table 6 is provided for comparison with sediment yield measurements at Dry Creek in Sonoma County by USGS (Station 114652000). The climate, vegetation, landscape and geology of these areas are generally similar to Forsythe Creek. Dry Creek annual suspended sediment yield ranged from 1,350 to 4,000 short tons per square mile prior to construction of the Lake Sonoma reservoir. This range of values is consistent with values in Table 6, indicating that the estimated sediment delivery rates by soil creep in Forsythe Creek are quite reasonable.

Soils on rockslide features in the Forsythe Creek study area were determined using a GIS analysis to assess the size distribution of sediment entering streams from soil creep in rock slide and earthflow deposits. The soils are typically soil complexes featuring Yorkville, Yorktree, and Witherell soils that have high proportions of sand, silt and clay that can be sustained in suspension and readily transported through the stream system (Howard and Bowmam 1991). Consequently, most of the soil material entering channels via soil creep would be expected to have a relatively short residence time in the channel network. Nevertheless, some coarser sediment (gravel, cobbles, and boulders) is contributed to channels via soil creep from the subsurface of Yorktree and Squawrock soils, and these materials are retained in channels for decades or longer and are components of habitat for salmonids.

Annual sediment input estimates for each sub-basin indicate that all sub-basins have relatively high suspended yield. The fine sediment produced by rockslides is thought to negatively affect salmonid habitat by introducing relatively high concentrations of fine sediment in spawning gravel and by contributing to infilling of pools and other flatwater rearing habitat. Consequently, those areas with lower sediment input rates might be considered to have somewhat greater suitability for watershed restoration projects intended to benefit fish habitat. Based on this assessment, the upper watersheds in both Mill Creek and Jack Smith Creek appear to be subject to lower levels of background erosion.

Limitations

Features were mapped at the same scale as the published map (1:24,000, or 1 inch equals 2000 feet). Further assessment of positional accuracy has not been conducted. The user is cautioned that the data are not suitable as a substitute for site-specific evaluation. Information in this database is not sufficient to serve as a substitute for the geologic and geotechnical site investigations required under Chapters 7.5 and 7.8 of Division 2 of the California Public Resources Code. Site-specific geologic investigations should follow the outline for assessment
of geologic conditions in DOC/CGS Note 45. O’Connor Environmental, Inc. makes no warranties as to the suitability of this product for any purpose other than developing background sediment yield estimates.

References

CalTrans, 1982. Final environmental impact statement, Route 101 in Mendocino County, pm 30.8/36.1 (Forsythe Creek), Report no. FHWA-CA-EIS-80-02-F.


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2E. Forsythe Hillslope Report

Problem Statement

The objective of the Forsythe Hillslope Report is to identify, map, and analyze areas of hillslope instability in the Forsythe watershed. Hillslope stability depends on a variety of factors, including soil type, drainage patterns, vegetation type, aspect, slope, and drainage area. The hillslope report is based on field observations and data collected by the road survey crew, analyses of aerial photos in GIS by Dr. Perala and Dr. O’Connor, and SHALSTAB analysis by Dr. Jan Derksen.

Dominant processes on hillslopes in the Forsythe watershed include deep landsliding, gully formation, road-related erosion processes, shallow landsliding, and soil creep. Most of these processes are aggravated by the loss of native vegetation, including hardwood and conifer forest cover, shrub vegetation and grasslands.

Data from CDFG 1999 stream surveys for Forsythe, Walker, Mill, Jack Smith and Eldridge/Seward creeks all indicate excessive fine sedimentation in stream channels as a dominant Limiting Factor for salmonid recovery in the tributaries of the Forsythe Creek watershed. These fine sediments are contributed to the fluvial system primarily from hillslopes where soil formation processes convert bedrock to finer, particle sized sediments. Upland landowners are concerned about landslides, gully erosion and other landscape instability issues that affect livelihood, travel and other economic concerns.

Methods

Field observation was an important source of information concerning hillslope processes in this study. The Road Survey crew, led by Teri Barber of Ridge to River, made many useful observations on hillslope conditions, such as road ditch relief and down slope gully formation including width, depth and length; local slumping and landslide features; culvert functions or lack thereof; and sediment delivery from slopes to valley floors, especially by route of gullies.

The Forsythe Creek Watershed Assessment uses an approach strongly based on digital data compiled into a GIS format. The base map for all data layers is a 2004 color aerial photograph scaled to 1:24,000 flown in a small plane by Curtis Holmes of American Aerial Photography on 4 March, 2004. The 26 pairs of fine-resolution color photographs were scanned into digital format, then ‘rubber-sheeted’ into the MrSid format by Stewart Geo Technologies. Horizontal accuracy is within 10 meters. This digital photograph layer has been used as the baseline to rectify all other data layers in the GIS project.

Hillslope features, such as gullies and irregular topography indicative of surface disturbance, can be observed by anyone with the project DVD and a computer. Dr. Perala mapped gullies and surface disturbances in the GIS, and then she went into the field to compare mapped features with field observations to determine accuracy of the extent of features mapped in digital space. Her mapped features consistently under-represented the extent of gullies and disturbed soils, confirming that the mapping process was conservative. It was important to the project that our estimates for erosional features did not over-describe the extent of problem areas in the field.
The aerial photographs were analyzed in stereopairs and transferred to digital format for the Geology Report by Dr. Matt O’Connor of O’Connor Environmental Inc. Dr. O’Connor examined and mapped deep seated landslides.

Shallow landslide hazard prediction was conducted using the SHALSTAB model in GIS (see also the discussion by Dr. Jan Derksen, in the Forsythe GIS report). Early iterations appeared to over-predict shallow landslide frequency in forested areas and to under-predict them in grasslands.

Soil characteristics were taken from the Soil Survey of Mendocino County, Eastern Part (USDA NRCS 1991). Within the Forsythe watershed, there are 35 soil types. Some of these types vary only by slope class, as seen in Table 1.

The soils data presented in the Forsythe Project GIS are derived from the National Cooperative Soil Survey. The NCSS field mapping methods and standards were used to produce the soils maps that were digitized for the Soil Survey Geographic (SSURGO) database. SSURGO datasets represent the most detailed level of mapping done by the Natural Resources Conservation Service (NRCS). The mapping scale is typically 1:24000 and the digitizing is done by line segment (vector) format from orthophotoquads. SSURGO spatial data is linked to a tabular relational Map Unit Interpretation Record (MUIR) database that contains soil property and soil interpretation information. SSURGO datasets are available in modified digital line graph (DLG-3) optional format and in Arc Interchange formats. The MUIR tabular datasets and accompanying metadata sets are available as tab delimited ASCII file formats and text files. To the greatest extent possible, the data gathered for this project were put into digital format, to facilitate their use to form a baseline understanding of this watershed, and subsequent re-use in future analyses.

Results and Discussion

Road Survey Observations
In the Forsythe Creek sub-watershed, a slide feature with a seasonal road crossing was detected on the Fetzer property. The landslide in this area originates near the ridge top and extends several hundred feet in elevation to the toe of the slide, which intersects mainstem Forsythe Creek upstream of the Reeves Canyon Bridge. The road crosses the slide on contour near the top, then travels down the face of it and ultimately fords Forsythe Creek and winds up the other side.

Project team members walked this road and observed the stream bank landslide at the toe. The toe of the slide is subject to undercutting by incision and channel migration processes at work on the mainstem Forsythe Creek. When the stream incises and migrates, the toe of the slope is undercut and subjects the slide to further instability, causing the slide to move downhill to fill the void eroded by the stream.

Because this location has both a road and a stream, the landscape was addressed by both the stream crew and the road crew. Road prescriptions alone cannot control slide erosion on the scale of this massive slide, but they could minimize the sediment delivery coming from this slide. The road prescriptions focused on correcting stream diversions at the top and at a ditch relief gully emanating from the down-road segment. We observed that classic stream
development appears to be underway where single thread channels drain down the slide, and that appeared to us as a positive sign.

Observations included exposed boulders in the single thread streams yielding step pool morphology and pools with aquatic organisms including plants, newts, insects, and frogs. Conversely, where multiple-thread channels drain onto the hummocky, unstable slide surface, more locations of erosion were observed with no boulders or aquatic organisms associated. As such, we focused the roadway prescriptions to convey small slide-related watercourse threads upstream of the road into single channels downhill of the road. The prescription for this site included armoring and revegetating the single thread channels so that they can rapidly and safely remove water off of the landslide.

**Watershed Soils**

The dominant soils in the Walker Creek sub-watershed are Ornbaun Zeni; these are moderately deep and deep soils on rolling hills to very steep slopes, well drained loams and very gravelly loams. These are upland soils that typically support forest vegetation types.

In the areas of lower Walker, Seward and Eldridge Creeks, dominant soils are Yorktree-Yorkville- Squawrock; these are moderately deep and deep soils on rolling hills to very steep slopes, well drained loams and moderately well drained loams and cobbly loams. These are upland soils that support oak woodlands and grasslands.

The valley soils of mainstem Forsythe Creek are Pinole, Talmage and Feliz soils. These soils are very deep, nearly level to moderately steep, well drained gravelly loam to sandy loam and sandy clay loam. These soils support much of the agricultural activity found in the Forsythe watershed.

**Table 7. Soil units found in the Forsythe Creek Watershed.**

<table>
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<tr>
<th>Unit #</th>
<th>Soil name</th>
<th>% slope min</th>
<th>% slope max</th>
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<td>30</td>
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<tr>
<td>105</td>
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<td>50</td>
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<td>111</td>
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<td>Feliz loams</td>
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<td>125</td>
<td>Feliz clay loams</td>
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</tbody>
</table>

**Major Hillslope Landform Processes on the Forsythe Watershed**

On the Hillslope Map, there are three types of slope instability predictions. The first are unstable landforms, such as landslides, mapped by Dr. Perala from the 2004 aerial photo GIS layer. Surface textures indicative of active slope movement present in 2004 were identified and shown as isolated black polygons. These polygons do not indicate any specific process, only the presence of actively mobile surficial process. These 292 features are relatively small in area, and they are comprised of gully features associated with culverts, showing headcut features, or directly connected to stream tributaries; landslide features; and 8 large stream bank failures visible from the aerial photo.

The second set of slope instability processes are shallow landslide hazards mapped by Dr. Jan Derksen using SHALSTAB. These were typically found to be located in the steeper terrain of ridgelines and higher elevation crests, where water is concentrated by topographic convergence. These predictions of shallow earth movement are unrelated to the deep, complex landslides shown in Dr. O’Connor’s map. The assumed maximum depth of a shallow landslide is 5 m.

The third process is deep-seated landsliding, which were mapped from aerial photos in stereo pair analysis by Dr. O’Connor. These are dominated by the orange map color as Complex Slide Areas, where boundaries are indistinct and multiple processes are thought to co-occur. This mapping unit assumes a slide depth of 10 m and indicates much larger areas of slope instability than those features mapped directly from the 2004 aerial in GIS.

According to the California Division of Mines and Geology 1:250,000 scale map of California (Ukiah Sheet), the Forsythe Creek watershed is underlain by two major geologic units. To the west, Cretaceous marine deposits (i.e. Coastal Belt Franciscan) dominate a highly heterogeneous matrix, and this unit is shared with watersheds to the west, such as the Navarro. To the eastern side of the watershed, the Central Belt Franciscan Formation extends into central California. These large units feature complex, often unstable rock assemblages that have been mapped in greater detail in other watersheds.

**Shallow landsliding**
In the upper watershed areas of Forsythe, Walker and Eldridge, upper hillslopes exhibit evidence of shallow landslide activity. We know that this process is widespread in the Forsythe Creek...
watershed. From the ground, the observer may have some difficulty distinguishing surficial movement of fine and course sediments from surface disruption caused by a deeper-slide plane. Shallow landslides typically have a lower sediment delivery than deep-seated landslides because of their distribution on the upper slopes of the watershed. Sediments transported from shallow landslides must be delivered near a swale that is connected to the fluvial system in order to be important sources of fine sediments in the stream channel system.

Shallow landslides are less than 5 m in depth. For this study, these were treated in a GIS analysis using SHALSTAB, an analytic model developed by Dietrich et al., 1998. See also the report on the Forsythe project GIS by Dr. Jan Derksen; it describes technical details of the construction of the SHALSTAB model and its extension for local soil and vegetation conditions. High hazard areas are shown in red on the SHALSTAB map layer in the GIS.

The prediction for shallow-landslide hazard distribution resulting from the SHALSTAB model suggests that a much greater area may be subject to shallow failures than is observed either from aerial photo analysis or from field observation. This suggests that the watershed may be more vulnerable to surface disturbances than previously understood, in that the steep slopes of the upper watershed areas may be ‘meta-stable’ (only in repose until a disturbance event triggers instability, which results in movement of the slope on a shallow failure plane).

A GIS map layer was created to show areas predicted by the calibrated SHALSTAB model to have high and very high probability of shallow landslide failure during storm events. This analysis is based on the assumption of a soil mantle with 1m depth. The analysis used the Digital Elevation Model (DEM, also called Light Gray Hillshade) to compute pathways for the concentration of storm flows, ignoring the role of groundwater in slope failure. Therefore, the areas predicted to have high probability of failure are expected to under-report the extent of areas that may actually fail during storm events, especially on disturbed sites. The compounding effects of groundwater seeps and springs are not accounted for, thus sites with high groundwater connectivity will have higher failure rates than can be shown in the SHALSTAB model.

Hillslope areas with greater vegetation cover typically have lower SHALSTAB hazard values. This is because the model is calibrated to allow for the increased shear strength of soils from the presence of woody and fibrous roots. The theoretical model was modified to reflect field observations that more shallow landslides occur in grasslands than in forested areas. This was found to be valid even for hillslope areas where water is concentrated, such as in colluvium hollows that typically fail during storm events. Results of this model, which is correlated with field experience, support the assertion that protection of the tree, shrub, herb and grass cover in topographic hollows should be an important conservation practice in the Forsythe Creek watershed.

The shallow landslide hazard probability maps do not indicate the presence of actual shallow landslides; they portray regions where shallow landslide hazard is likely to be severe. Extensive areas of shallow landslide hazard probability are predicted for steeper areas near ridgelines of upper Walker Creek, upper Forsythe Creek, the north fork of Eldridge Creek and upper Jack Smith Creek. To a lesser extent, some areas are also found in upper Mill Creek.

Deep Landsliding
Deep seated landslides are those greater than 10 m depth, and they are discussed in the Geology Report by Dr. Matt O’Connor. From the Geology layer in GIS, Dr. O’Connor mapped 26 large areas of complex slides, shown as the largest polygons in the Geology data layer. These cover approximately 40% of the total watershed area, primarily in the Forsythe, Walker, lower Mill Creek and Eldridge sub-watersheds. These very large areas of significant landscape instability are a primary driver for watershed sediment production, and these areas offer substantial challenges to ecological enhancement.

Generally, deep landslides deliver large sediment loads in a chronic manner, but the sediment flux increases during storm events. Because the failure plane of a deep slide is 10 m or more below the earth’s surface, these erosion features are difficult to treat. However, stabilization of a slide toe may be possible, at least to reduce the rate at which sediment is delivered to the stream. Such treatments include diverting storm flows away from landslide areas, encouraging recruitment of native plants on the slide surface, and installing vegetated rock walls and/or other soil bioengineering treatments.

Deep-seated landslides may best be treated by eliminating excess water delivery to the feature to the greatest extent possible. Drainage within a landslide can also be improved, for example, by stabilizing and vegetating incising gullies, allowing water to exit the slide without carrying away sediments. Sediment delivery from landslides may be reduced by eliminating grazing and browsing pressure for a few decades; this allows for regeneration of deeply rooted plants, such as shrubs and trees. Landowners may benefit from the cooperation and support of State and local agencies in fencing active landslide areas. We recommend active programs to educate landowners and the public about ways to reduce unneeded soil disturbance in the Forsythe Creek watershed.

It was noted from the GIS Slope Instability map that there are regions with no slide hazard; regions with shallow landslide hazard; regions with complex, deep-seated hazard; and areas with both deep and shallow landslide hazard. These latter zones are areas of the Forsythe Creek Watershed which are particularly well-suited to management under a “No Disturbance” regime. The model does not conclude that areas with no slide hazard mapped will not experience landslides, only that the model was not able to detect factors driving slope instability in these areas.

**Gully formation**

Gullies are distinct, narrow channels formed by the erosive action of running water over soil or soft rock material. Gullies are larger and deeper than rills and typically carry surface water only during and immediately after heavy rain or other precipitation events, or when associated with spring activity. Gullies are usually formed in response to a ditch or stream diversion upslope that directs water flow away from its historic pathway and into new paths not accustomed to receiving the erosive force of water, such as a convex hillslope in a grassland. Unless a topographic feature such as a lake intervenes, gullies will develop until the water and sediment they carry reach the receiving stream channel and the flowing water system; even then, gullies may further deepen and widen during heavy precipitation events or through the headward migration of incision processes.

Gullies are significant sources of fine and coarse-grained sediments, and they typically have a high sediment delivery ratio (the percent of material removed from a hillside gully feature that
reaches the stream channel and aquatic ecosystem). Gullies may be considered ephemeral, as they can form in response to a sudden change in storm water flow and can become relict features when the flow source is diverted elsewhere.

**Soil creep**

Soil creep is the slow, down-slope movement of soil under the influence of gravity. Frost heave, thermal expansion and contraction of the soil surface, and alternate wetting and drying of the soil can cause soil creep.

Soil creep is nearly imperceptible to the naked eye, as it is one of the slowest of all types of mass soil movement. Soil creep generally occurs in the top few meters of the soil. Creep is an important process especially in hilly areas of loam and clay loam soils that have been modified by vegetation removal or destabilized by physical alteration, such as road construction. Soil creep in the Forsythe Creek watershed is discussed in detail in the Geology Report by Dr. Matt O’Connor.

*The role of vegetation in hillslope stormwater processes*

Fundamentally, woody and herbaceous vegetation intercepts rainfall and reduces the intensity of the erosive power of rain splash. Therefore, the loss of trees, shrubs and grasses increases the volume of stormwater delivered to the soil. In a bare, unprotected state, the soils of the Forsythe watershed can easily be destabilized by higher magnitude storms. Because of the character of these soils and the hillslopes on which they form, even small impacts of soil disturbance can have significant effects. Many of the slope instability processes can be moderated through the recruitment of greater native plant cover. Working with the natural hydrologic cycle, much hillslope revegetation can be accomplished cost-effectively using seeding treatments in the autumn and winter. Exclusion of grazing and browsing animals for a few years may also be a cost-effective approach, especially when combined with direct recruitment measures, such as seeding and/or planting.

**2F. Hydrology summary**

Weather systems arriving from the Pacific meet their first resistance in the coastal mountain ranges of California. Moisture laden clouds drop precipitation as they are pushed upward, resulting in a strong orographic precipitation gradient. Forsythe Creek, a tributary of the Russian River is located on the eastern slope of these coastal mountains. The climate is Mediterranean, with cool, wet winters and warm dry summers. The basic hydrologic driving forces in the Forsythe Creek catchment will be considered in the design and implementation of any subsequent rehabilitation and management plans. This report characterizes basic discharge and precipitation patterns using available historical data (see Hydrology Report by Matt Cox in Appendix A).

**2G. Wildlife habitat and migration corridors**

The full LEGACY report is included as an Appendix; the following is a short summary.

The primary purpose of this wildlife assessment is to demonstrate the value of the Forsythe Watershed as part of a potential wildlife linkage between Jackson Demonstration State Forest
(JDSF) on the west side of Mendocino County and the Mendocino National Forest (MNF) on the east side. In order to do that, a series of sixteen GIS maps have been created by the non-profit conservation organization LEGACY – The Landscape Connection to begin an analysis of the watershed. It should be emphasized here that this is just a preliminary assessment and no specific area is depicted across the watershed as a linkage corridor in any of these 16 maps. The location of any such conservation project lies completely under the control of the landowners and it would be presumptuous to suggest otherwise.

A secondary purpose for this wildlife assessment is to create a repository for all currently available biological data. This creates a “snapshot” of the current (2004-2005) biological conditions that can be referred back to from future points in time. Depending on funding availability, new biological information about the watershed may also be added as it becomes available.

Of course, no biological assessment of any watershed in this region would be accurate without mentioning the regrettable loss of the human part of the ecological relationships within the landscape. The cultures of the Yuki and Pomo persisted in the Forsythe Watershed for at least 7000 years and played an important role in keeping this part of the world in balance. There is no question that the current ecological problems that are plaguing this area, as well as all other parts of the globe, are a direct result of our modern culture. Hopefully, we will recognize this fact and work to design wildlife linkage networks along with our ongoing development plans so that future generations will also have healthy wild ecosystems to inspire them.

The Case for a Wildlife Linkage through the Forsythe Watershed

As time passes, areas of conserved habitat become more and more surrounded by human development, and eventually, in effect, become “islands” of habitat, where the native plants and animals are cut off from others of their kind. As any farmer knows, the genetic health of his/her crops and livestock depend upon “out-breeding”. In terms of landscape level genetics for native species, the least expensive and most natural and efficient way to insure out-breeding over time is to provide linkage networks between conserved areas. In this way, native plants and animals are able to naturally migrate over vast areas. Many wildlife species are “shy”, and therefore depend upon well-canopied riparian forest for migration paths that allow them to travel under cover from one area of use to another. Some wide-ranging species migrate frequently over vast areas within one generation. Other less mobile species may require many generations to migrate across the same area. In any case, the ability to migrate is of critical importance to each species’ genetic health.

Mendocino County is still relatively undeveloped. Therefore, establishing wildlife linkages here would be much easier and less expensive than in many other areas of California. Since the majority of land in this county is privately owned, creating linkages requires the cooperation of landowners, either through the process of establishing conservation easements, or by land acquisition from willing sellers. There still exists the opportunity to establish a linkage to the southeast from JDSF, through the Forsythe Watershed, and then northeast to the Sanhedrin Potential Wilderness Area (PWA) of the Mendocino National Forest.

Within the Forsythe Watershed are 1,700 acres of private land that are held in a conservation easement. Landowners of another property are currently in the process of establishing
conservation easements on 4,000 acres (this project is well underway and partially funded). The Bureau of Land Management (BLM) owns and manages 1,270 acres. Combined, these three ownerships, which are already in some form of protection, comprise nearly 25% of the 30,741 acre Forsythe Watershed. Adjacent, on the west side of the watershed, is another 2,200 acre swath of conserved land linking to the 1,300 acre Montgomery Woods State Park and 690 contiguous acres of BLM land. Adjacent on the east side of the watershed is the 4,000 acre Willits Watershed, public land owned by the city of Willits. In total, these parcels in and around the watershed encompass 15,800 acres, which greatly contribute to the possibility of a continuous linkage through this watershed (see Map 15). Existing and pending conservation easements are not shown on any of the maps in this report in order to protect landowner privacy.

Wildlife Recommendations

- Recruitment of trees along stream courses is needed to re-establish riparian canopy. In time, this will accomplish:
  - a) lower stream temperatures,
  - b) allochthonous organic material for the aquatic food web
  - c) stabilization of stream banks, and
  - d) reestablishment of small terrestrial wildlife linkages.
  Efforts have already begun on Ridgewood Ranch and Greenfield Ranch with the planting of trees along sections of Forsythe and Eldridge Creeks.
- Recruitment of oaks is needed in oak woodland areas, e.g. planting acorns along with the use of tree protectors.
- Planting oak trees around both entrances to the Ridgewood tunnel under Hwy 101 would connect the tunnel passage to nearby oak woodlands. Contiguous canopy will likely increase wildlife use of the tunnel for safe highway crossing.
- Encouraging landowners to remove small populations of invasive exotic plants might prevent massive infestations from those sources in the future. Collaboration with Circuit Rider Productions could prove to be useful by drawing on their experience working with landowners on arundo eradication projects, as well as adding known arundo infestation sites to Circuit Rider’s database and maps.
- More biological assessment is needed on some of the larger acreage properties within the watershed to determine which areas need the most protection. This might be achieved through outreach and collaboration with landowners and universities. For example, Michael Barbour and Ayzik Solomeshch of the University of California at Davis recently wrote a grant to fund a grassland study and several Forsythe Watershed landowners wrote letters of support, offering access to their properties if the study is funded.

Acquisition of funding that would enable willing landowners to put some (or all) of their land into Conservation Easements, or to sell their land, with the goal of building a contiguous network of protected land from the west side of the Forsythe Watershed across to the east side.

2H. Oral Histories

The transcripts of Oral Histories interviews, conducted by Linda Gray, are included as an Appendix, although information from some of these interviews has been included where appropriate in this technical report.
3. Watershed Analysis

3A. Introduction

There are four main strategic components to this assessment. The first involved a map-based enquiry on where to carry out relevant field surveys of representative streams and roads. The second strategy applied a Shalstab model specially developed to indicate areas of high probability of landslide or erosion. Taken together, these two strategies provided direction for the third component, field survey. The fourth component, aerial photo interpretation, provided a basis for the sediment source identification. In practice, however, it was found that landowner permission for access controlled where these surveys could take place.

3B. Elements of the Watershed Geomorphic Analysis

Sampling of streams and roads

Since the survey mileage of both stream and road was limited, representative sampling of streams and roads on the quadrangle maps was required. Most of the samples were taken from the blue-line streams and mapped roads. In addition to this categorization, the sampling recognized differences in land cover such as mixed forest (mostly on eastern-facing slopes) and grassland with oak savannah (typically on western-facing slopes). Three categories of topographic elevation were also chosen: 207-429 m, 430-577 m, and 578-1017 m.

The rationale for this sampling regime was to assess relationships between the chosen categories and their contribution as likely sources of sediment, using mapping and theoretical modeling tested by both aerial photograph interpretation and directed field observation. Specific projects were identified from the field observations and to a lesser extent, from the interpretation of aerial photographs. However, “ground-truthing” of the theoretical sampling allowed the identification of areas where worthwhile projects are likely to be found. Sampling was constrained by landowner access agreements (or lack of them), so this factor also contributed to actual stream and road lengths assessed.

3C. GIS Framework for watershed analysis

The report on the GIS Framework is included in Appendix A.

3D. Road Sediment Inventory of the Forsythe Creek Watershed

This is a summary of the full Forsythe Road Report, which is included in Appendix A.

Background

The natural drainage network shaped by each watershed conducts streamflows and surface runoff downhill in unique patterns that evolved over geologic time. Natural drainage patterns and vegetative buffers are often altered unintentionally or to save costs as road construction progresses throughout a watershed. Drainage alteration often begins on steep roads where rainfall and runoff adopt the road as the path of least resistance: down along a steep road and eventually off it. When concentrated runoff does eventually escape the roadway, it will often
gully the receiving hillslope. Undersized culverts can quickly be overwhelmed in storms. Excess waters will be forced around the culvert and onto the road surface. Often this lost water adopts and erodes the roadway course instead of finding its way back into the natural channel below the road. Landslide instability can be also be aggravated by drainage alterations that reapply runoff waters onto them. The extra water lubricates soil particles and brings more weight - both of which decrease a soil’s resistance to gravity, and dormant landslides can become reactivated. Especially where landscapes are dominated by grass-carpeted earthflows, receiving soils are not sufficiently resistant to absorb the changed runoff regime and are readily eroded by it. Sediments eroded from these sources are often delivered to the aquatic ecosystem where they become deleterious to incubating salmon eggs, cloud the water column, and fill aquatic habitats.

**Objective**
The purpose of the Road Sediment Inventory was to identify sources of controllable road-based erosion and to prescribe cost effective erosion control resolutions. The Inventory provides a guide to implement prioritized erosion control measures we have prescribed.

**Methods**
The STAR system of Road Sediment Inventory was developed by Jack Monschke Watershed Management. Four technicians from Bioengineering Associates were trained in road sediment inventory techniques at a series of workshops sponsored by the Mendocino County Resource Conservation District. Working in two person teams, they conducted an inventory of 94.41 miles of road in the Forsythe Creek Watershed during the winters of 2004 and 2005. About 30% of 334 inventoried sites were also reviewed, edited and photographed by Professional Hydrologist Teri Jo Barber.

The winter’s wet season field inventory maximized our ability to observe active roadway drainage of winter rainfall, surface runoff, and stream crossings. STAR Field Forms include a description of drainage context, an estimate of future risked erosion and sedimentation volumes predicted over 50 years, a sketch relating relevant features, and a prescription for site restoration with costs estimated. Road shaping and stream crossing designs that embrace natural drainage patterns for environmental health have been illuminated by Pacific Watershed Associates in their Handbook and Video for Forest and Ranch Roads (Weaver and Hagans, 1994, 2004). The concept they invoke is to construct or reconstruct roads to mimic natural sheet flow hydrology and to conserve natural topographic drainage patterns across all landscapes. Site by site road prescriptions follow general technology and guidelines published by Pacific Watershed Associates.

**Results**
334 sediment source sites were identified on 94.5 miles roads inventoried in the Forsythe Creek Watershed. Overall, the greatest cumulative potential sediment yield risked is from stream crossings with 121,523 cubic yards of potential sediment delivery estimated. At those sites, the crossing has diversion potential or the crossing is undersized for a 100-year storm. Active erosion from stream crossings was mostly in the form of filled crossings that divert streams down the road and off onto native hillslopes, estimated at 24,180 cubic yards. Walker sub watershed was the exception, with the greatest sediment originating from ditch relief issues. On Forsythe Creek especially, where the magnitude of stream crossing erosion was highest (an order of magnitude higher than in Mill Creek), ditch relief and landslide-earthflow issues are active. Many of the gullies and slides had chronic sediment actively and frequently delivering during
winter storms to streams and rivers during our survey. Gullying from ditch relief and diverted stream crossings was the second dominant source of potential erosion with 18,600 cubic yards of sediment delivery estimated within the next 50 years. Active and past gully erosion was estimated at 6,754 cubic yards. 209 of these sites were considered as high priority for restoration because sediments eroded deliver to the stream network and can be controlled by less than $20 per cubic yard of sediment.

Discussion

The goal of restoring natural drainage patterns is to make the road an invisible feature to natural drainage patterns. This is exemplified by shaping the road surface with an Outslope. The inboard side is higher than the outboard side which conveys rainfall off the road as quickly as it falls onto it. Rolling Dips are large shallow swales excavated into the road surface that distribute road runoff much like water bars but as semi permanent features that can be driven over in winter without maintenance. Ditch Relief Culverts intercept the Inboard Ditch and so conveys road runoff and/or springs across the road and off onto the hillslope. The key in effectively utilizing any of these drainage features to control erosion is to install them often enough to quickly distribute runoff to the hillslope in small pulses to prevent surface rilling and gullies on or off the road. When runoff is collected and concentrated into fewer drainage structures, eventual relief of concentrated water becomes an erosive waste product that increases with rainfall intensity. The number of drainage structures relieving surface runoff should increase as road grade steepens to prevent rilling and gullying and to prevent overloading the inboard ditch at high flows. Infrequent relief of surface runoff is the source behind about half of the gullies we inventoried across the Forsythe Creek landscape.

Bridges, Fords, Culverts and Armored Fill Crossings are all structures used to convey streams and rivers through a roadway. All stream crossing structures should be sized to convey gravel bedload and woody organic debris, as well as the water generated in a 100-year storm. Adequate sizing is especially important for culverts because they have a maximum capacity ceiling. Culverts should be installed at the base of the fill and at the natural stream’s orientation to avoid unnecessary bank failure. Smaller streams can be conveyed across a road without a culvert by way of an Armored Fill Crossing. Armored Fill Crossings are less expensive to install and do not require the effort of maintaining open culverts in winter storms. Critical Dips are excavated into the road bed on top of or next to stream crossing culverts or other drainage structure so in the event the structure is overwhelmed, water will find the lower elevation of the dip, flow through it, and get back into stream’s natural channel on the other side of the road (instead of diverting on down the road surface). Fords and armored fill crossings do not require annual maintenance when properly installed, will facilitate seasonal traffic, and will conduct flows, debris, and bedload across road surfaces. Year round daily traffic is better routed over streams using culverts in order to protect downstream water quality from chronic turbidity caused by repeatedly driving through a stream which pumps fine sediments into it.

Roads built in the dry season sometimes completely ignored the smaller streams that don’t flow year round. In the winter when these streams do flow, they adopt and gully the roadway as the path of least resistance. Steep roads with culverts still impart Stream Diversion Potential if/when the culvert fails. Over years on unmaintained roads, on-road gullies grow deep and wide. Massive off road gullies erode when waters finally exit the roadway onto the hillslope. Stream diversions account for ½ of the gullies we encountered in Forsythe Creek Watershed.
Ongoing proactive conservation of road related erosion is best practiced by educated landowners familiar with their road and drainage networks. Attending informative courses like those sponsored by the Mendocino County RCD will inform landowners about how to identify and correct road drainage problems. Active erosion is often coupled with road maintenance problems that become obvious, like surface erosion of the road surface that make the road uncomfortable or dangerous to drive.

### Forsythe Creek Road Miles Inventoried by Sub-Basin

<table>
<thead>
<tr>
<th>Landowner</th>
<th>Sub-basin</th>
<th>Miles Inventoried</th>
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</thead>
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<tr>
<td>Golden Rule Church</td>
<td>Walker, Forsythe</td>
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</tr>
<tr>
<td>Crofoot</td>
<td>Mill Creek</td>
<td>3.98</td>
</tr>
<tr>
<td>Dakin</td>
<td>Mill Creek</td>
<td>9.72</td>
</tr>
<tr>
<td>Buich – Teran</td>
<td>Mill Creek, Jack Smith</td>
<td>5.7</td>
</tr>
<tr>
<td>Ridout</td>
<td>Mill Creek, Forsythe</td>
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<tr>
<td>Lindsey</td>
<td>Mill Creek</td>
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<td>Walker Creek</td>
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</tr>
<tr>
<td>R. Fetzer</td>
<td>Forsythe</td>
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</tr>
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<td>Greenfield Ranch</td>
<td>Jack Smith, Eldridge</td>
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</tr>
<tr>
<td><strong>Total Miles of Road Inventoried</strong></td>
<td></td>
<td><strong>94.41</strong></td>
</tr>
</tbody>
</table>

### 3E. Observations from the Stream Channel Survey Crew

To view stream survey data and all photos and sketches, see Stream Survey Data Report.

**Forsythe Creek**

Based on field observations, six distinct reaches (with specific erosional processes) were identified within the length of mainstem Forsythe Creek. There appears to be a direct correlation between these specified reaches (and their relative erosional processes) and the location of the reach within the longitudinal profile of the creek.

Reach One: between the downstream boundary of Forsythe Creek and its confluence with Mill Creek. Lateral migration and aggradation are dominant in this reach, with large, vertical, eroding banks on the outsides of bends and large gravel bars opposite (see Photo 1). Some sites appeared to be experiencing incision; these sites are in areas where the channel has been confined, such as downstream of the Uva Drive bridge (see Photo 2).
Reach Two: from confluence with Mill Creek upstream to lower boundary of Ridgewood Ranch. The channel in this reach is steep and has large boulders and numerous bedrock outcrops (see Photo 3). Bedrock spans the channel in numerous locations (see Photo 4). The primary erosional features in this reach are landslides that intersect the channel (see Photos 5 and 6).
Reach Three: Forsythe Creek through Ridgewood Ranch to confluence with Walker Creek. Similar to reach one, this is a low gradient channel with aggradation and lateral migration as primary erosional processes. In many locations, channel is migrating into hill slopes.

Reach Four: upstream of confluence with Walker Creek to Ridgewood Ranch bridge, referred to from here upstream as “Little Forsythe” or “LF”. This reach has evidence of past incision, with both banks severely undercut along the entire reach. Many old growth Bay trees are at risk here (see Photo 7). Observations indicate that current processes in this reach include aggradation, as there are many large gravel slugs in the channel (see Photo 8).

Reach Five: from Ridgewood Ranch bridge upstream to mouth of canyon. Aggradation is the primary process here, resulting in lateral migration and erosion on outside bends (see Photo 9).

Reach Six: from mouth of canyon upstream to end of survey. Steep gradient, boulder and bedrock prominent, large landslide as dominant erosional feature (see Photos 10 and 11). This landslide appears to be a primary source of sediments supplied to Little Forsythe.
Walker Creek

Walker Creek has a high number of erosional sites relative to other sub-basins in the watershed. The survey began at Walker dam. Observations indicate that incision was an important process in the Walker Creek sub-basin below the dam. Directly following the dam, the channel is disproportionately wide (relative to downstream); there is a very large gravel bar in the channel that appears to be relatively immobile (shrubs and grasses are established, see Photo 12). Like many reaches downstream, there are tall, vertical cutbanks on both sides of the channel (see Photos 12 and 13). In the lower stretches of Walker Creek, there are many vertical eroding banks contributing fine sediments to the system (see Photo 14). Many riparian trees are at risk, and many trees have already fallen into the channel (see Photo 15).
There is evidence of incision on tributaries to Walker Creek (such as WCTRB and WCT). Active headcuts were recorded (see Photo 16). In general, these channels are deeply entrenched in their downstream reaches, with vertical eroding banks on both sides.

Mill Creek

The lower stretch of Mill Creek is steep, has boulders and bedrock outcrops in the channel, and the primary erosional features are landslides (see Photo 17). The middle section of Mill Creek continues to have bedrock outcrops, although less frequently. Bank erosion is prominent in this reach, and includes both vertical erosion into hill slopes and slumping on instable slopes. Aggradation is not an active process in this reach. The upper reaches are densely forested, while the lower reaches are oak woodland/grassland. In the upper areas, many banks are undercut, although erosion appears to be occurring slowly due to the root strength of the redwoods. In some areas, the channel is entrenched (see Photo 18), whereas other areas show signs of aggradation and subsequent lateral migration (see Photo 19).
Jack Smith Creek

The upper reaches of Jack Smith Creek (Mendocino Redwood Company property) have numerous headcuts, log jams, and little to no bedrock. There is a healthy (although young) canopy over the creek, but still the channel has numerous eroding banks. Past logging has heavily impacted this area (cables and debris in bank material, indicating in-stream road/logging fill, see Photo 20), but it seems the main factor unraveling this creek is the series of headcuts migrating upstream (see Photo 21). It is possible that the headcuts are migrating through logging debris. Hill slopes seem relatively stable due to the dense forest of tanoak, redwood, and Douglas fir.
Eldridge Creek

Eldridge Creek is rocky and relatively steep throughout its length. There is evidence of past incision, including numerous bedrock outcrops, evenly undercut banks, and elevated and isolated clumps of grass (see Photo 22). The primary erosion in Eldridge Creek is due to instable streambanks; the bed appears to be rocky and stable for the most part. There are numerous slumps on the banks of Eldridge Creek (see Photo 23).

Redwood Creek drains into Eldridge, and has also experienced incision, with an active headcut in the upper reach. One Redwood Creek landowner confirmed past incision, saying that the bed level dropped a number of feet in one season. This landowner has installed a number of cross-channel structures in Redwood Creek, which have helped re-build and maintain the bed level. Unfortunately, we have no photos of Redwood Creek. The riparian canopy is healthy in upper Eldridge and Redwood Creeks.

Trailer Park Trib (TPTRB) (east side of 101, Ridgewood Ranch)

TPTRB and its tributaries are subject to various erosional processes, including landsliding, incision, and lateral migration in the lower reaches. The presence of cattle in this sub-basin has an affect on streambank stability, as most channels lack exclusionary fencing. Cattle crossings
are present in the channel, and the survey crew has witnessed cattle in the stream channel. There are many areas with bedrock outcrops, boulders in the channel, and step pool morphology is prevalent. However, the underlying clay mélange seems to sustain a high level of instability, resulting in landsliding and slumping. Some reaches are severely entrenched, and there are many riparian trees at risk. This is a complex area due to the various factors acting on the landscape (Highway 101, the railroad, cattle grazing, and, in the lower reaches (below Hwy 101), concentration of tributaries into TPTRB).

**Baker Creek**

This creek appears to be relatively stable, in general. It lies in a very steep, rocky, shallow soil canyon, and much of the bed consists of boulders and bedrock in the steep upper reaches. Bank erosion here is relatively slow, and except for a couple of small slides, no major at-risk sites were identified. Only one landowner gave access for this survey, so knowledge of Baker Creek is limited to that reach (Golden Vineyards property in the upper watershed).

![Photo 24, typical reach on Baker Creek](image)

**3F. Sediment Source Identification**

Several sources of sediment were identified from the road and stream surveys. In the road assessment process, categories included road fill prism at stream crossing, cut slope ravel and slumping, culvert blockage and failure, storm flow erosion from abandoned roads, gully erosion on hillslopes, and culvert failure during storms. In the stream surveys, categories included: bank erosion from undercutting, channel incision (bed lowering), landslides and gully that directly delivered sediment into streams.

Interpretation of the aerial photographs provided a watershed-wide assessment of apparent sources, except for the more heavily forested western areas. The modified ShalSTAB GIS model identified potential sources of sediment from natural processes. Ground inspection showed that some of these potential sources were already activated. Looking over a longer timescale of slide activation, the model is likely to be found increasingly accurate. Drive-by surveys revealed sediment sources in the forested areas, mostly associated with poorly constructed roads and inappropriate culvert placements. Much of the unnatural processes driving controllable erosion in the watershed are not identifiable through SHALSTAB though they are correctable.
Restoration funds should be focused on these unnatural processes, thereby reversing human-caused erosion with the sedimentation impacts above background levels.

3G. Discussion of results - sediment delivery to the stream system

Processes of morphological change include channel incision, aggradation, lateral migration and local erosion/deposition. Land management practices that affect these processes include in-stream mining (in the Russian River, causing headward migration of bed lowering, continuing into the Forsythe Creek system), installation of culverts, historical timber harvest practices, grazing, and an increase in impermeable surfaces. These practices can increase runoff and the amount of sediment delivered to the creek system.

Incision and the fluvial system

There are many sub-watersheds in the Forsythe Creek system, all with distinct characteristics, management practices, and morphological processes. Therefore, incision in the Forsythe Creek watershed is a complex process that originates from a variety of sources.

The Russian River has a history of in-stream gravel mining that has led to marked downcutting of the riverbed (Florsheim & Goodwin, 1993). In April 2004, field observation of the confluence of Forsythe Creek with the West Fork Russian River showed that the thalweg continued from the Lower Russian River through to Forsythe Creek, leaving the West Fork “hanging” with a bed elevated at the confluence by some 3 feet.

At least three ‘nick points’ of about one foot in head difference were noted in the reach immediately above the confluence. The Hwy 101 bridge and its foundation over Forsythe Creek presents only a partial barrier to headward recession, which can pass through one of the openings; the other openings are sheet-piled at their downstream end to prevent scour between the northern abutment and the bridge supports. Two walking inspections of Forsythe Creek between Uva Drive and Hwy 101 revealed striking evidence of significant recent downcutting. Further inspections of reaches just above Uva Drive also revealed incision, possibly due to local channel confinement.

Without specific engineering field surveys, it is difficult to assess how long this process has been going on and how far upstream it has extended. However, the shear cliff some 100ft high above Hwy 101 bridge on the right bank showed clear signs of recent erosion. In a meeting with Evan Engber and John Bennett (NRCS Engineer), local residents described how erosion at this site began after a gravel mining operation in the vicinity. A local resident just below Uva Drive insisted that the bed of the river had dropped some 5 feet in the period 2002-5. Apart from one anomalous short reach (upstream of the cliff) that seemed stable, it appears that active incision has recently occurred throughout this reach, and that it has possibly extended upstream of the Uva Drive bridge.

Because incision is widely pervasive and is difficult to measure, there are few data on which to base quantitative observations of bed lowering. Yet both the road and stream survey crews observed the signs and symptoms of incision in most places around the watershed, providing direct evidence that incision remains an active set of processes.
At several points in the upstream system, there are barriers inhibiting further headward progression. Some are natural, such as bedrock outcrops, and some are artificial, such as the ford on Mill Creek and the dam at Walker Lake. Many bedrock outcrop locations, not all of which were spanning the channel, were recorded by the Stream Survey team for this report.

We know from the bridge crossing at Hwy 101 that the channel elevation has lowered over recent decades. A note of caution is advisable, however. In a recent workshop, Army Corps of Engineers Hydraulic Engineer, David Derrick, cautioned that cross-sections observed in the vicinity of bridges are not reliable indicators of processes elsewhere in the stream (NOAA Fisheries workshop, Santa Rosa, CA, March 2006). In a soil bioengineering project just upstream of the 101 bridge, large stones placed at the slope toe in 2003-04 moved by fluvial action into the channel. In this reach, the bed level has dropped; it is unclear whether this is a result of headward incision or local pool/riffle migration and channel confinement just upstream. We hypothesize that a primary influence of bed degradation in lower Forsythe Creek is the gravel extraction operations of recent decades, which has removed material in-channel and increased the stream’s ability to transport sediment during higher flows.

It is also possible that incision is originating from upstream. Due to the changes in vegetation and canopy cover, more storm water is now delivered from hillslopes to the stream network than in the past. Roads now concentrate flows that were once dispersed across a hillslope. A culvert acts as a flow concentrator as well, rather like a fire hose, greatly increasing the erosive force of flowing water during storms. The cumulative effect of these changes to the landscape has increased the ability of storm water to dislodge or erode upslope sediment and deliver it downstream. These changes to Forsythe watershed hydrology could be another important source of landscape incision processes.

Walker Lake acts as a sediment sink to trap much of the sediment delivered from the catchment upstream. Only the finest sediment fractions are likely to pass over the spillway when suspended in flood flows. They are likely to be borne some distance downstream, if not completely through the system. Therefore, “hungry water” from Walker Dam may also be contributing to incision processes in the watershed. At previously installed Bioengineering Associates streambank stabilization structures (on the downstream 2300 ft of Walker Creek), point bar material that was used to build slopes against vertical eroded banks has been replenished in full. This demonstrates that sediments are being supplied to Walker Creek, likely from gullies and destabilized tributaries in the upper reaches of the watershed.

Livestock grazing

In the oak woodland and grassland regions of the Forsythe watershed, grazing is an important land use activity. Unless necessary precautions are taken, livestock grazing can have many negative impacts on the landscape. These impacts include increased erosion and instability on streambanks, hill-slopes, and gullies; reduction in recruitment of riparian and upslope vegetation; and soil compaction where population densities are high. Survey crews witnessed cattle walking in streams and gullies and browsing on landslide and streambank vegetation. In general, cattle crossings through streams were related to gullying and erosion on streambanks. In these cases, exclusionary fencing was a primary treatment recommendation. This is not to say that all grazing is inherently negative. Much federal and private research in the US West has
demonstrated that some grazing practices can actually enhance riparian condition (see for ex, Platts, 1984).

**Increasing impermeability**

The major effects of increasing impermeability are an increase in the volume and rate of runoff and a corresponding decrease in the volume and rate of infiltration. The primary impacts on an affected stream system include increased frequency and magnitude of flooding and decreased volume of low flows over a longer period (resulting in summer dry streams). The effects of this change in flow regime could include channel erosion and a greater likelihood that perennial streams become seasonal. Bankside vegetation is more likely to be damaged and exposed banks more easily eroded. Soil bioengineering can successfully stabilize steep banks and enhance stream function because many structures incorporate permeable gravel slopes which are inherently more stable than vertical, exposed, alluvial horizons. Forsythe watershed is, in general, a rural landscape; it does not have a high proportion of impermeable surfaces relative to an urban environment. Yet roads and the impacts of minimal development in the watershed do have an affect on the permeability of the landscape.

**Culverts**

Roads are generally characterized as (relatively) impermeable surfaces that redistribute, drain, and concentrate runoff into roadside ditches. These ditches usually cross the road in culverts, delivering the runoff efficiently downhill. Concentrated runoff erodes gullies and discharges significant volumes of both water and sediment that would not otherwise be delivered to the receiving stream system.

Stream systems swollen by this extra input of water and sediment then have to negotiate the large number of culverts beneath roads downstream. Any constriction in the natural cross-section of a stream in flood, i.e. at bankfull flows or higher, has the effect of increasing the speed of the flow – the so-called ‘fire-hose’ effect that causes extensive downstream erosion. In other cases, the constriction of the natural stream cross-section causes the smaller culvert to store woody debris behind the inlet, which plugs the pipe and sends water onto the road, where its flow is directed by the road gradient. Many small streams in the watershed are diverted in this way, eroding massive gullies into the landscape. There are some spectacular examples of this phenomenon in the Forsythe Creek watershed.

This erosion is generally confined to the local reach, but the increased flows contribute to the general destabilizing of the downstream system’s width, depth and meander pattern. Clear-span bridges allow the annual flood to pass unimpeded and allow storm water to occupy the floodplain. When a road crossing bridge is designed to allow floating wood and other debris to pass beneath, then the crossing will have a minimal impact on stream morphology. This is the reason that bridges are proposed as an effective alternative to culverts and can be cost-effective when longer term economic analysis includes the externalized costs of fluvial system degradation.

Culverts are commonplace in the Forsythe Creek watershed, and are a cause of erosion and source of sediment, usually from the topsoil and subsoil (A- and B-horizons). Culverts can be undercut by the incision process they may have helped to cause; this undercutting is often
accelerated by “rusting out” of the culvert bottom and leakage on the outside, cutting through the fill beneath. Culverts may also fail if they are undersized, as they can become plugged during a winter storm event. Flows transport road fill downstream and the culvert is washed out of place.

3H. Conclusions

Landscape repair objectives and priorities (see also Legacy Report section 2F):

Discussion of the processes degrading ecological processes and fish habitat sets the stage for prioritizing landscape repair objectives. California Dept of Fish & Game provided guidance on their priorities for fish habitat enhancement, which are consistent with the observations and results of the watershed assessment here. The third objective has been moved to first place in the following, since it is the only recommendation that indicates the importance of upland processes; the rest relate to the creek corridor.

1. map and identify in-channel and upland sources of sediment and erosion; prioritize them for treatment; and treat them
2. monitor and mitigate barriers to fish migration
3. limit livestock access to the creek
4. implement bioengineered stream bank protection projects to re-establish floodplain benches
5. define the low flow channel
6. discourage accelerated lateral migration
7. increase canopy cover
8. decrease bank erosion
9. add to the riparian canopy to shade creeks
10. add to stream complexity through large wood recruitment
11. increase the number of pools in the streams
12. increase cool water releases from the Ridgewood Dam at Walker Lake, while simultaneously reducing warm water flows over the spillway

It is important to recognize that the road drainage system is in practical terms an extension of the stream system. Also, land use in the hinterland of the stream/road system is a powerful determinant of the health of the stream corridor. Thus, from the geology and the hillslope reports, together with the oral histories, recommendations are drawn that address the major causes of the degradation of the stream system in terms of morphological integrity for fish and wildlife habitat.

With reference to objective 1 above, the persistent problem of large landslide sediment delivery will not be easy to address, but the following three relatively simple steps to minimize erosion by addressing the causes may be the most cost-effective measures available to the watershed landowners.
1. Re-direct stormwater flows away from landslide areas, if it can be done safely.
2. Use exclusionary fencing to reduce herbivore grazing and browsing pressure on landslide areas and assist regeneration of deeper-rooting plants on these unstable soils.
3. There is much scope for changing grazing practices in the Forsythe Creek watershed to benefit from grazing and browsing animals; for example, it may be possible to control invasive weeds while enhancing recovery of important streamside woody plants, such as willow, alder, and other important plant species (see WallisDeVries 1998; Savory and Butterfield 1999).

Usually associated with road culverts, gullies connect erosion features in the hinterland with the streams. They are one of the most widespread and numerous sources of sediment delivery to the Forsythe stream system. These features were noted and photographed where they could be seen by the survey teams, but only the selected lengths of roads and streams were surveyed in detail.

The sources of gully erosion can be addressed by correcting stream diversion and diffusing distribution of road runoff. On site treatments for gullies include the USFS Heede permeable check dam and the Schiechtl brush layer (Heede 1976; Schiechtl and Stern 1996). Both of these can be very cost-effective to construct. There are several other actions that can be taken in the watershed hinterland to reduce sediment delivery by addressing its causes; they include the following:

**Reforestation**

Restoration of the creek system to rehabilitate salmon habitat will involve planting trees as well as using soil bioengineering techniques to restore banks and provide willow nursery areas for successional riparian tree species. Coppices can often be established within the headlands of meanders and linked together by riparian vegetation without inconvenience to the farmer.

**Reducing impermeability**

Development in the Forsythe Creek watershed is clearly increasing, but the watershed is still at the rural (rather than semi-rural) level except for the lower reaches around Uva Drive. Despite these developments and associated roads, including Highway 101, it is estimated from Maps 5 and 6 of the Wildlife Upland Ecology Report that the total impermeable area (TIA) for the watershed may still be less than 10%. This implies that the stream system is impacted but not so badly that restoration would be prohibitively expensive. Ideally, the impacts associated with increasing impermeability from all future development should be mitigated on site, using source control techniques that mimic the natural systems that have been replaced, enhancing evaporation, transpiration and infiltration of rainfall.

**Stream Corridor Treatments**

Below is a list of the treatments prescribed in the stream survey. See the full Stream Survey Data Report for site-specific problems and treatments.

**Live Willow Brush Mattress:**
This structure is used to protect and revegetate bare, eroding streambanks. It consists of a thick mat of live willow cuttings placed on a sloped streambank and held down with live willow posts

**Live Willow Siltation Baffles:**
Baffles serve a variety of functions in the channel. They can be used to protect eroding streambanks, constrict stream channels and build terraces, trap fine sediments, and dissipate energy. Baffles are used in a series along a length of streambank. They consist of trenches placed roughly perpendicular to flows and filled with live willow. Baffles are keyed into the streambank to avoid back-cutting, and boulders are placed in the baffle to pin down the willow. For further detail, see State of California Resources Agency DFG *California Salmonid Stream Habitat Restoration Manual, 3rd Edition*, 1998, page VII-81.

**Mini Baffles:**
Mini Baffles are similar to Live Willow Siltation Baffles but are smaller, generally used only to protect the toe of an eroding bank, and do not necessarily have boulder protection. (var. Bioengineering Associates, Inc.)

**Live Woven Willow Wall:**
This structure is used to protect vertical eroding banks and bank failures. It is especially useful in situations wherein heavy equipment is not an option or in narrow channels with little room for protruding stabilization structures. The Woven Willow Wall consists of live willow branches woven between live willow posts and backfilled with layers of willow cuttings, gravel, and small rock. For further detail, see State of California Resources Agency DFG *California Salmonid Stream Habitat Restoration Manual, 3rd Edition*, 1998, page VII-78.

**Woven Willow Deflector (Live Groin Deflector):**
The Woven Willow Deflector is used to protect eroding streambanks by deflecting flows away from the bank. It consists of a Live Woven Willow Wall built in a triangular shape with the apex protruding into the channel. The structure is backfilled with willow cuttings and rock. This is an important habitat structure, as it creates a scour pool and provides overhanging vegetation. It is a versatile structure because it does not necessitate heavy equipment. (Schiechtl and Stern 1997)

**Boulder Wing Deflector (BWD):**
The Boulder Wing Deflector is used to protect eroding streambanks by deflecting flows away from the streambank. It also provides crucial Salmonid habitat, as it creates scour pools and escape cover. Boulders are placed in a triangular shape with the tip of the deflector, the point reaching farthest into the channel, being the lowest point on the structure. These structures can be used singly, in a series, or in opposition, depending on the structural goals of specific sites. For further detail, see State of California Resources Agency DFG *California Salmonid Stream Habitat Restoration Manual, 3rd Edition*, 1998, pages VII-35 and VII-66.

**Boulder and Log Deflector (Digger Log):**
The Boulder and Log Deflector acts in the same manner as the BWD—it deflects flows away from eroding streambanks. However, the Boulder and Log Deflector especially enhances pool habitat, escape cover, and channel diversity through its use of large woody debris. A log,

**Boulder Bank Protection (BBP) or Rock Armor:**
Boulders are used to prevent streambank erosion through armoring. They are strategically placed and keyed into a toe trench for maximum stability. Live Willow Sprigging (LWS) is used between boulders to increase stability, enhance riparian vegetation, and slow scour processes. For further detail, see State of California Resources Agency DFG *California Salmonid Stream Habitat Restoration Manual*, 3rd Edition, 1998, page VII-64.

**Cross-Channel Vortex Weir:**
Cross-Channel Vortex Weirs serve two main purposes: maintaining channel grade and digging scour pools. Vortex weirs can be constructed with boulders or logs. They provide important pool habitat and limit channel degradation. Boulders are placed in a “V” shape with the point on the upstream side. Boulders are keyed into streambanks, and are fastened together with cable and epoxy. For further detail, see State of California Resources Agency DFG *California Salmonid Stream Habitat Restoration Manual*, 3rd Edition, 1998, page VII-32.

**Live Willow Cluster Planting:**
There are two varieties of cluster plantings: deep cluster plantings and augered cluster plantings. In both cases, cluster plantings are used to revegetate bare streambanks while minimizing labor and materials. Clusters consist of willow cuttings placed in an excavated hole in the streambank or terrace; deep cluster holes are excavated with heavy equipment and are generally 3 feet deep, whereas augered cluster holes are dug with a hand-held power auger and are generally 2 feet deep and narrow. (NRCS technique)

**Live Willow Brush Pack:**
This technique is used to fill and protect scour holes in streambanks. It consists of layers of willow, gravel, and cobble built into the area of scour; the pack leans toward the bank (rather than into the channel) for stability. Brush packs may also be built with fir branches and other woody materials in place of live willow; these slow scour, catch fine sediments, and can provide a medium for natural seed collection and propagation. (Schiechtl 1980)

**Log Crib with Brush Layers:**
Log Cribs can be used in a variety of situations; they are primarily used to stabilize eroding streambanks and to protect the toe of active slides and slumps, while providing shade canopy and wildlife habitat. Cribs are built log cabin style, with notched logs fitted together and secured with rebar. Cribs have layers of live willow or other fast-rooting riparian species placed between logs and covered with gravel and cobble. Cribs can be constructed in areas where heavy equipment is not an option. For further detail, see State of California Resources Agency DFG *California Salmonid Stream Habitat Restoration Manual*, 3rd Edition, 1998, page VII-68.

**Live Brush Layers:**
Brush layers are generally used to stabilize slumps and landslides, although they can be used on most non-vertical eroding banks. Terraces are excavated by hand or machine on the surface of a slump or slide and are placed parallel to stream direction. Layers of live vegetation are placed in
a mesh formation on the excavated terrace and mostly covered with soil, leaving only branch tips protruding. For further detail, see Schiechtl and Stern, *Ground Bioengineering Techniques*, 1996, page 79.

**Cross-Channel Structures (Grade Control Structures):**
There are many different types of cross-channel structures, but all of them serve a similar purpose: maintaining and building bed level while limiting incision and undercutting of streambanks. Cross-channel structures are often prescribed for gully and upper tributary erosion control. Many of these structures also act as filters that catch fine sediments. Cross-channel structures can be built with local materials, such as branches, duff, and local cobble, or with imported materials, such as fence posts, filter fabric, and quarry rock. For further detail, see State of California Resources Agency DFG *California Salmonid Stream Habitat Restoration Manual*, 3rd Edition, 1998, page VII-90.

**Brush Grid:**
The brush grid is used to protect an eroding bank by building a terrace at the toe. Rows of posts are installed in the affected area and layers of branches (live willow, manzanita, or fir) are criss-crossed between rows and pinned down with cross-ties and hand-sized rock. Brush grids catch fine sediments and provide a growing platform for naturally occurring riparian species. For further detail, see Schiechtl and Stern, *Water Bioengineering Techniques*, 1997, page 105.

**Incision and Channel-spanning Structures**
Construction of channel-spanning structures using large wood and large rock has achieved growing acceptance for being effective replacement for hard engineering in concrete and steel. These bioengineered structures integrate live, flexible stems of locally native willow, alder and dogwood to protect banks associated with the permeable rock and wood structures in-channel. The soil bioengineering approach offers great ecological benefits at economic rates. Working with bank protection at appropriate elevations, permeable channel-spanning structures placed sequentially along the long profile have great potential for raising the bed elevation and stabilizing the bed in an incising stream. Channel-spanning structures made of large wood and rock must be carefully surveyed into the long profile and need to be placed in related sequences rather than as stand-alone structures. For more detail on various cross-channel structures, see the State of California Resources Agency DFG *California Salmonid Stream Habitat Restoration Manual*, 3rd Edition, 1998, Chapter VII.

In areas where the stream is deeply incised, we recognize that restoring original morphology, with connectivity to the floodplain, is not likely to be possible or practical in a single treatment. As the stream may have degraded or incised over a period of decades, restoration prescriptions may have to follow a similar timeline to be successful. This seems particularly true when the relatively transient nature of natural dams is considered. Non-permanent, permeable rock and large wood structures have many ecologically attractive features.

An approach to restoration based on a vision of what is regarded as the original or pristine natural landscape may not be totally acceptable in the present day. This is because of the long-term timeline needed, coupled with fears of the likely effects of socio-economic and political forces on its sustainability. However, such a landscape vision includes recovery of mature trees such as redwood and cottonwood on banks and floodplains, while shorter-lived species such as willow, alder, and dogwood grow alongside riffles and on side bars.
Bars and banks, together with large rocks and large wood, form short to medium term storage units of sediments that can move during floods; they are processed and reworked by floodwaters that reshape the channels and floodplains. Sediments and wood accumulations can collect on the older growth and form new (permeable) natural dams. Over time, they may be buried under fresh sediment deposits and form new riparian land.

Another cause of erosion is the restriction to flow caused by stream culverts. Culverts should be replaced wherever possible by clear-span bridges that allow the creek to run bankfull under the bridge deck. The clearance should be high enough to allow floating debris to pass under the bridge without becoming caught and causing a debris accumulation. Where bridge replacement is not cost-effective, the road above the culvert should include a critical dip to convey the hundred-year flood across the roadway and back into the natural channel.

4. Recommendations for Stream and Watershed Restoration

See Stream Survey Data and Road Survey Data Reports:
A) Stream bank repair projects by sub-watershed
B) Road repair projects by road segment
C) Culvert and gully repair projects by sub-watershed

5. Demonstration Project Designs

See Stream Survey Data and Road Survey Data Reports:
A) Typical bank protection for various types of bank instability.
B) Typical road repair for the 3 most common road failure types
C) Typical culvert replacement strategy
D) Typical gully repair on slopes > 30%, south facing

6. Implementation Plan

6A. Prescriptions for restoration

Site-specific recommendations have been identified in accord with the CDFG manual, to address identified limiting factors to anadromous fish production. All surveyed sites are prioritized by the relative cost-effectiveness of restoration, in terms of the cost per volume of sediment ‘saved’ from the stream system. Maps created in GIS illustrate the treatment recommendations by location, priority and type. Clearly, restoring groups of these sites that share a common access for construction equipment will be considerably more cost-effective than restoring individual sites.

6B. Recommended land management practices

A major step that could be taken by landowners is the revegetation of stream corridors. Methods include not only using bioengineering techniques to stabilize their banks, but also removing grazing pressure by excluding livestock from a margin of at least 100ft from the bank edge. Over time, if left alone, riparian vegetation will re-establish to provide shade and protection for the banks; this will lower water temperatures and reduce sediment inputs to the stream system, thereby addressing two of the major limiting factors for salmonids. Economic uses of stream
corridors for logging and grazing typically result in the loss of natural recruitment of native riparian trees and shrubs. Judicious planting and protection of oaks and other native trees in savannah and floodplain areas will limit soil erosion and provide other ecosystem services. Bare soil should not remain exposed but be seeded, mulched and irrigated as necessary to provide suitable cover.

Invasive exotic plants should be controlled and removed. Weedy plants should be replaced with appropriate native plantings as funding permits. Goats or other browsing animals can be used to keep in check the regrowth of invasive exotics such as Himalayan blackberry. Monitoring should be scheduled to ensure that pernicious weeds, such as Japanese knotweed and arundo, are found and treated before they proliferate.

Development should be limited to minimize building densities and individual “footprints”, and wherever possible, it should protect existing native trees in good health. Trees that have to be cut should be replaced with healthy trees of native species appropriate to the natural landscape. All hard surfaces should be made porous wherever possible, and runoff from development should be managed so that the pre-development hydrology is maintained or restored within the confines of the site.

Roads no longer in use should be decommissioned. Decommissioning in its most cost-effective form includes excavating road fill from all stream crossings, and ripping and revegetating road surfaces. General guidance on road rehabilitation can be found from the US Forest Service, California Department of Fish and Game, Pacific Watershed Associates, and the Mendocino County Resource Conservation District. Local specific guidance can be found from the Mattole Restoration Council (http://www.mattole.org/program_services/Roads/roads.htm), at Redwood National Park, and at Humboldt Redwoods State Park, visit (http://www.humboldtredwoods.org/index.htm), and the Mendocino County Resource Conservation District.

In stream reaches where restoration of the stream bed following incision/erosion is recommended, landowners should be encouraged to cooperate with any neighbors involved to allow access and otherwise assist the work to progress.

Landowners should be discouraged by all legal means to straighten and/or dredge their section of stream, to remove restoration structures and riparian vegetation, and to modify their banks without the necessary permits.

Programs to raise public awareness of the hazards associated with unstable landscapes common in the County could benefit from using public television, print news, billboards, bus stops and the Internet.

6C. Recommendations for further work

One of the most informative projects that could be carried out is a detailed stream survey of selected reaches, such as from Uva Drive to the confluence with the Russian River and from the “falls” of Forsythe Creek upstream to the confluence with Walker Creek. This survey should record the longitudinal profile of the thalweg, with cross-sections (extending 100ft beyond the highest river bank on both sides) at all changes in riverbed slope. The survey information, coupled with
anecdotal information from riparian owners, would further inform the crucial debate about the past and current rates of channel incision. Repeating the survey every five years would help to assess the extent and rates of incision processes. Ideally, the surveys should be repeated in further years to quantify the time and spatial variability of these processes. Additional economic benefits of this information would include more detailed understanding of the rate of landscape change affecting road and bridge infrastructure, and the stability of pipelines and cables that span large areas of landscape.

Incision can be a local or a systemic phenomenon attributable to a number of causes, as discussed above. One of the major issues emerging from this watershed management plan is the need for detailed surveys of reach-scale geomorphic processes of incision and aggradation. These surveys will be critical in terms of predicting future loss of land to erosion and destabilizing of riverbanks, and also in the design of structures such as bridges and pipe crossings. The incision/aggradation surveys should also inform the design of in-stream measures such as bank stabilization using soil bioengineering techniques. Bank stabilization treatments will need the context of the dynamic effects of bed incision to make such treatments cost-effective.

**Theoretical Techniques Needing Further Research**

The restoration of incised streams has been a hotly debated topic in California for several years. Opposition to engineered checkdams as barriers to fish migration has led to other approaches. In Bavaria, regional Water Authorities responded to the problem of incision by replacing outmoded concrete dams with large boulder weirs, some cemented into place and seemingly irregularly placed over 50-100m depending on the longitudinal profile. These ‘macro-roughness elements’ allow fish to migrate upstream but present a sufficiently high roughness to flood flows to have the equivalent (or greater) effect of a concrete weir in terms of energy dissipation.

The sediment load was also purposefully increased by these authorities, who bought land in the headwaters for the purpose of allowing natural bank erosion to take place. Barriers to sediment passage (such as dams that could not be removed) were overcome by regularly excavating accumulated sediment from upstream, trucking it around the obstruction and dumping it in the downstream channel to be progressively eroded away. In California, the acceptability of this strategy by CDFG would need to be examined because of the rock emplacement.

An alternative currently in practice in California is to attempt re-creation of a new channel and floodplain at a new, lower level. Elevation of the lower bank and floodplain is designed to be reconnected to the stream, sometimes at depths of 30ft or more below its pre-design elevation. The goal of this approach is to break the positive feedback mechanism that otherwise continues to deepen the creek with associated bank failures. While theoretically attractive, this approach involves removal of large quantities of bank material and substantial loss of land at substantial cost. In most (if not all) cases, the width of floodplain created is very small compared with the original floodplain. This approach has not yet been tested over many years, so can be considered experimental.

If this approach were to be adopted in the Forsythe Creek watershed, landowners who have already seen dramatic loss of their riparian land would have to be convinced that an approach involving a significant extra loss of land would result in reduced ‘natural’ erosion during floods. This method may leave unaddressed the ongoing processes of channel incision that may yet remain active; therefore, it should include designs to hold or build bed level.
7. Glossary

**Aggradation:** A geologic process where the level of a stream bed is raised by the deposition of sediment. Aggradation occurs when the stream's sediment load exceeds the ability of the stream to transport sediment.

**Allochthonous:** Food material reaching an aquatic community in the form of organic detritus, derived from outside a system, such as leaves of terrestrial plants that fall into a stream.

**Alluvial:** Sediment deposited by flowing water, as in a valley.

**Anadromous:** Fish that migrate upstream to spawn.

**Basin:** A larger unit of watershed, for example the Russian River can be called a basin, where the Forsythe is considered a watershed.

**Bioengineering:** A set of watershed restoration techniques that integrate live woody and/or herbaceous plant materials with rock and logs. These structural engineering methods are used to protect slopes, stream banks and gullies. If constructed correctly, these techniques are robust during flooding, can enhance sedimentation on banks and floodplains (thus protecting water quality), and improve habitat values and aesthetics of streamside property.

**Biotechnical:** See bioengineering.

**Canopy:** The overhead branches and leaves of stream-side vegetation, includes both shrubs and trees.

**Canopy cover:** The vegetation that projects over the stream.

**Coarse sediment:** rock fragments of gravel size or greater.

**Coho:** One of six species of pacific salmon (*Oncorhynchus kisutch*). Also called silver salmon. Spawning males are sometimes called "hookbills".

**Coppice:** A dense growth of bushes; the tendency of certain tree and brush species to produce a large number of shoots when stems are mechanically removed, but the root system left intact.

**Copse:** A dense growth of bushes; English term for a lowland woodland, derived from coppicing.

**Cover:** May refer to *canopy cover*, or to logs and other large woody debris and boulders in streams that provide shade, shelter, and protection from predators for fish.

**Diurnal:** Daily cycle.

**Embeddedness (degree of):** Refers to the thickness of the fine sediment layer that covers or surrounds larger rock particles (gravel, cobbles, or boulders) in a stream bed or floodplain. It is usually measured in classes according to the percentage of coverage of larger particles by fine sediments.

**Endangered:** In danger of becoming extinct.

**Ephemeral stream:** A stream that does not run year round, or that runs only during and soon after rain.

**Fill:** Localized deposition of material on the stream bed by flowing water. Fill is the opposite of *Scour*, as deposition is the opposite of erosion.
**Fine sediment**: Small particles of soil, rock and organic debris; includes clay, silt, and sand sized particles.

**Floodplain**: The area adjoining a river channel constructed by the river in the present climate. The floodplain is occupied by the river overflow at times of high discharge or flood, and is generally a fairly flat ‘topographic surface’. The floodplain is an important ecological feature of the stream, with important habitat values for plants and wildlife.

**Franciscan Assemblage**: A geologic formation typical of the Northern California coast ranges.

**Geomorphology**: The study of contemporary processes that shape the surface of the earth, including geologic processes, erosion and sedimentation, mass wasting and stream flow.

**Gradient**: The general steepness of a slope or streambed.

**Hydrology**: The study of flowing water.

**Incision**: A physical process where the surface of a stream cuts downward into the bed, lowering the bed elevation. This process can move or migrate upstream in “headward recession”, and the process can also travel or migrate downstream.

**Inner gorge**: A deep, steep-sided canyon. Examples of inner gorges in the Forsythe Creek Watershed include the mainstem Forsythe downstream of the Church of the Golden Rule and lower Mill Creek.

**Shallow landslides**: less than 5 m deep.

**Deep-seated landslides**: 10 m deep or greater.

**Large wood or woody debris**: A large piece of relatively stable wood material from a fallen tree, having a diameter greater than 12 inches and a length greater than 6 feet that intrudes into the stream channel. Best examples have branches and roots still connected.

**Limiting factor**: A particular environmental feature that limits the ability of an organism to survive or thrive. Limiting factors for salmon and steelhead may include stream temperature, frequency and quality of pool habitat, streambed sedimentation, and, especially when populations are abnormally low, degree of predation.

**Mélange**: An earth terrain characterized by serpentine or other ultramafic rock and highly erodible soils.

**Order of Magnitude**: A factor of 10 (10X). An order of magnitude sediment budget provides data that are accurate within a factor of 10 of the actual number.

**Reach**: A relatively homogeneous section of a stream having a repetitious sequence of physical characteristics and habitat types; or a specified length of stream (for example, 5 times the average stream width).

**Redd**: A salmon or steelhead nest built by the spawning female in a gravelly streambed.

**Refuge**: For fish, a part of a stream where they can seek protection from life-threatening events, such as very high stream flows.

**Refugia**: A part of a stream that exhibits an extraordinary characteristic necessary for fish to survive, for example, a deep pool where water is colder than the rest of the stream.

**Riffle**: A part of a stream characterized by rapidly flowing, turbulent water.

**Riparian**: Anything connected with or immediately adjacent to the banks of a stream.
**Riparian vegetation:** Vegetation growing on or near the banks of a stream.

**Salmonid:** Salmon and trout.

**Scour:** The localized removal of material from the stream bed by flowing water. Scour is the opposite of **fill**.

**Sediment:** Fragments of soil, rock and organic (derived from vegetation) debris. Coarse sediment is gravel size or larger; fine sediment includes particles the size of clay, silt, and sand.

**Sediment budget:** An accounting of the sources and disposition of sediment at it travels from its point of origin to its eventual exit from a watershed.

**Sediment production:** The rate at which sediment enters stream channels from various sources.

**Side channel:** A stream channel connected to the main channel that is only wetted during high flows.

**Steelhead trout:** One of 6 species of pacific salmon (*Oncorhynchus mykiss*). Genetically identical to rainbow trout.

**Stream order:** The designations (1,2,3, etc.) of the relative position of stream segments in a drainage basin network: the smallest, unbranched, perennial tributaries are designated order 1; the junction of two first-order streams produces a stream segment of order 2; the junction of two second-order streams produces a stream segment of order 3, etc.

**Sub-basin:** A watershed within a larger watershed. Also called tributary basin.

**Substrate:** The mineral and organic material that forms the bed of a stream.

**Threatened:** In danger of becoming **endangered**.

**Watershed:** The land area that drains to a common waterway. May also be called drainage basin or basin.
8. Bibliography


California State Coastal Conservancy, Mendocino County Water Agency.


9. **Appendix A: Data Sources**

*Includes the following:*
Forsythe Creek Hydrology Report
Forsythe GIS Report
Forsythe Wildlife Uplands Ecology Report
Forsythe Hillslope Report
Forsythe Geology Report
Stream Survey Data Report
Road Survey Data Report
Forsythe Road Report