COPELAND CREEK WATERSHED ASSESSMENT

Copeland Creek Alluvial Fan Reach

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I. INTRODUCTION

Copeland Creek is a small tributary in the southeastern corner of the Russian River watershed (see Figure 1). The City of Rohnert Park occupies the downstream half of the drainage where the creek is primarily a straightened flood control channel. Copeland Creek is a tributary of the Laguna de Santa Rosa. The upstream half of the watershed is rural and the creek is a natural channel.

This watershed assessment reviews erosion sources in the watershed, the current and historic condition of the creek channel and watershed, the extent of riparian forest, water quality and temperature conditions, and land uses. The goal of the watershed assessment is to investigate a broad range of current and historic conditions in the watershed and creek and recommend enhancement projects and Best Management Practices (BMPs) to improve water quality and creek habitat conditions.

Interest in Copeland Creek has grown in recent years, especially at Sonoma State University (SSU). A committee formed to review policies and actions towards Copeland Creek on the campus is also known as the Friends of Copeland Creek. In the fall of 2000, the AmeriCorps Vista Project coordinated a meeting with the purpose of discussing the many activities and interests involved in preserving and restoring the natural resources in and around the Copeland Creek watershed. The AmeriCorps Vista Project, a volunteer-directed program housed at SSU, coordinated communication about the restoration of Copeland Creek outside of the University.

This coordination effort included the Friends of Copeland Creek, groups from neighboring watersheds, the Cities of Rohnert Park and Cotati, agencies with jurisdiction in the Copeland Creek watershed including: National Marine Fisheries Service, California Department of Fish and Game, Sotoyome Resource Conservation District (RCD) and Sonoma County Water Agency (SCWA). The group met several times to discuss coordinating efforts in the Copeland Creek and neighboring watersheds that all drain into the Laguna de Santa Rosa. The group eventually named itself the South Laguna Watershed Group (SLaWG) to represent the members' interests in the Laguna de Santa Rosa and its tributaries on the southeast side of the basin. The long-term intent was to have a forum that coordinated communication among all stakeholders in the Laguna de Santa Rosa watershed.

The City of Rohnert Park provided support by supplying a meeting site and a small amount of funding to support a grant writer. Garfield and Associates was contracted to research and develop grant proposals for coordinated efforts. Proposition 13 funds designated for use in County of Sonoma supported the work in this report. The million dollar Proposition 13 allocation for County of Sonoma is administered by the SCWA. The original proposal was developed by Garfield and Associates with input from both the Sotoyome RCD and Laurel Marcus and Associates. While the initial intention of the grant proposal was to provide support for continuation of the SLaWG and complete an assessment of the conditions in the


Copeland Creek Watershed Assessment
Figure 1. Regional Location
Prepared by: Laurel Marcus and Associates
Map Source: Sonoma County Water Agency
N
RUSSIAN RIVER WATERSHED AND TRIBUTARIES
COPELAND CREEK WATERSHED
POTTER VALLEY
CALPELLA
LAKE MENDOCINO
UKIAH
HOPLAND
CLOVERDALE
ASTI
GEYSERVILLE
LAKE SONOMA
HEALDSBURG
WINDSOR
CAZADERO
GUERNEVILLE
RIO NIDO
MIRABEL PARK
FORESTVILLE
MONTE RIO
JENNER
DUNCANS MILLS
SANTA ROSA
SEBASTOPOL
ROHNERT PARK
COTATI
PACIFIC OCEAN

Copeland Creek watershed, the final grant focused only on preparation of a watershed assessment with minimal emphasis on the watershed group and/or public outreach. Initially, the grant was submitted and to be administered by the City of Rohnert Park, with several tasks being subcontracted to the Sotoyome RCD; however, during the time period from submittal to the actual contract agreement, there were several staffing changes, including the SLaWG contractor leaving the area. The Sotoyome RCD took the lead on this agreement.

The Sotoyome RCD established monitoring areas with permission of property owners and carried out a range of monitoring parameters, including water temperature and water quality. Laurel Marcus and Associates completed historic and current mapping of the watershed, collection and analysis of monitoring data, evaluation of watershed and creek conditions and preparation of the watershed assessment and recommendations.

II. ASSESSMENT AND MONITORING METHODS

A number of tasks were completed to collect information, measure and monitor features of the Copeland Creek watershed. A literature and internet search was completed for information on stream flows, rainfall, geology, soils, vegetation, land use and fish and wildlife specific to the Copeland Creek watershed.

Geographic Information System (GIS)

A Geographic Information System (GIS) was created for the Copeland Creek watershed. Digital ortho-photography was acquired from the County of Sonoma. Data layers depicting perennial and seasonal streams, major roads, vegetation, land use and landslide information were imported from the Russian River Watershed GIS, a joint project of National Oceanic and Atmospheric Agency (NOAA) Fisheries and Circuit Rider Productions, Inc. This was a compilation of data from the US Geological Survey (USGS) and the California Department of Forestry. Topography and slope data were generated from ten-meter digital elevation models (DEMs) obtained from the USGS.

A number of additional layers were created through evaluation of the current and historic aerial photographs and field inspection. These layers include:

- Urban areas – 1942, 1961, 1980 and 2000
- Condition of alluvial fan reach – 1942, 1961, 1980 and 2000
- Upper watershed roads – 1942, 1061, 1980 and 2000
- Extent and density of riparian corridor - 2000
- Stream Network
- Location of monitoring and survey sites
- Confined and unconfined channel reaches and creek slope classes of Copeland Creek
- Slopes in excess of 30 percent

These layers were used to analyze and illustrate conditions and features of the watershed and quantify changes and conditions over time.

Monitoring

Monitoring and channel surveying were carried out in a number of locations. Two types of monitoring locations were established – point locations distributed over the creek system for water temperature and water quality monitoring and one study reach.

Channel conditions provide a practical way of assessing watershed conditions. The study reach serves as a location to complete monitoring of changes in channel form to evaluate trends in the creek that affect aquatic habitats. It would be too labor-intensive and difficult to acquire landowner access to monitor changes in the composition and form of the entire length of the creek frequently. Therefore, only short sections of the channel are defined as study reaches and monitored (Harrelson et al 1994, Washington Forest Practice Board 1997).

Copeland Creek was evaluated in detail for potential study reach locations. A stream reach is defined as a segment of channel that demonstrates similar features throughout its length. For the study reach to provide information on changes in sediment levels in the watershed, the stream reach must be a type of channel that readily responds to changes in sediment load. Potential study reaches must be low slope, unconfined creek channels without excessive alteration or significant tributaries in locations where landowners will grant long-term access.

USGS topographic maps of the watershed (Cotati Quadrangle – 1980, Glen Ellen Quadrangle – 1980) were used to evaluate channel slope. Channel slope is a measure of how the channel drops over a horizontal distance. Contour lines on the topographic map are lines of constant elevation; each point along a single contour line has the same elevation. The distance between contour lines was measured along each creek to document the approximate slope of the stream channel. The stream segments were then separated into slope classes of more than 20 percent, 8 to 20 percent, 4 to 8 percent, 2 to 4 percent 1 to 2 percent, 1 percent and less than 1 percent.

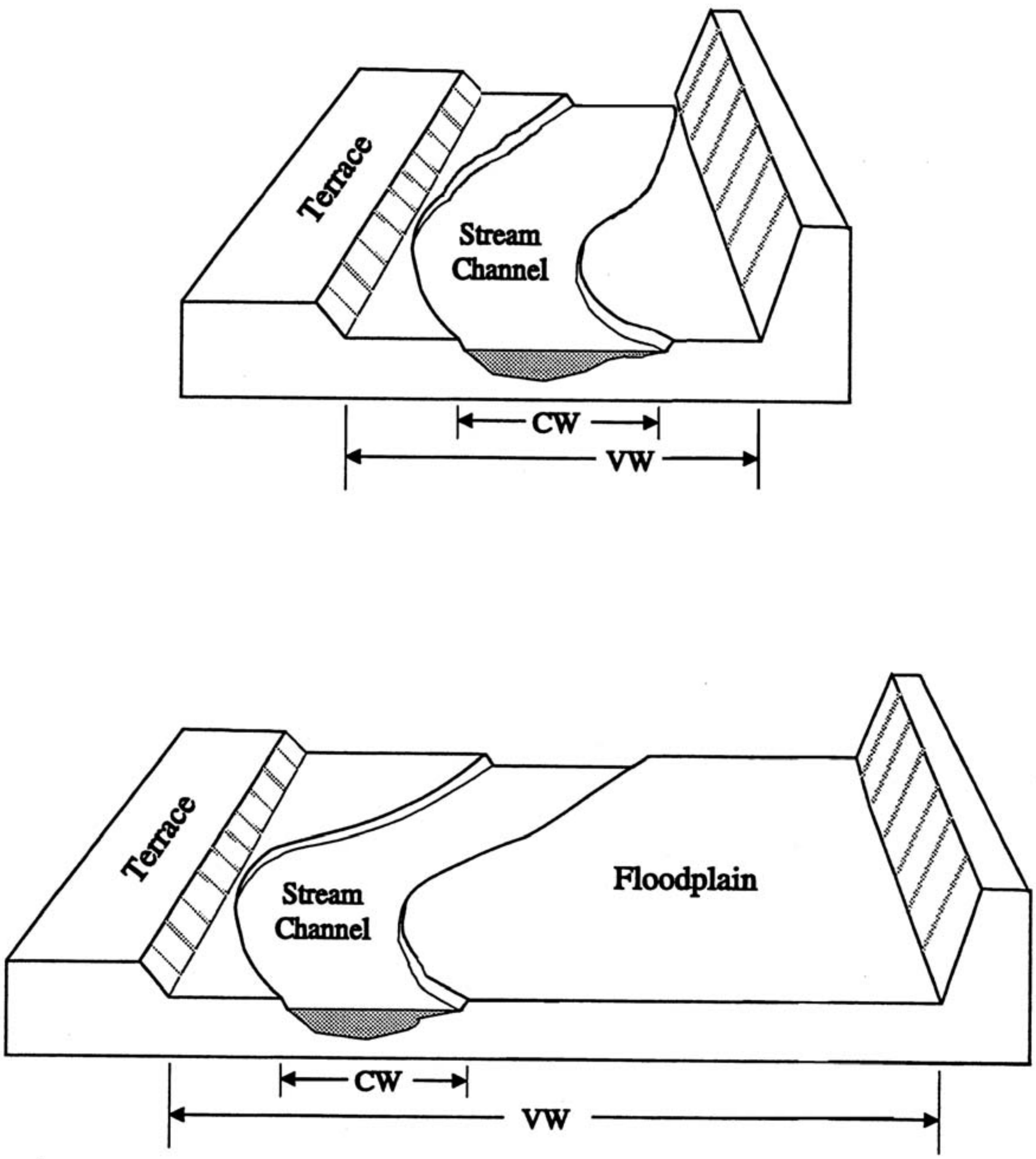
The Copeland Creek channel was also evaluated for confinement. Three types of confinement were used. The creek was indicated as confined if the valley width, including the channel, is less than two channel widths. It is partially confined if the valley width is two to four channel widths. A channel is unconfined if the valley width is greater than four channel widths (see Figure 2). Channel confinement can only be approximated from a topographic map and must be confirmed in the field.

Significant tributaries to Copeland Creek were identified. A tributary is significant if the watershed area of the tributary is greater than or equal to ten percent of the watershed area on the main creek upstream of the tributary. Areas of the creek that are low slope and unconfined, but immediately downstream or upstream of the confluence with a significant tributary are removed from consideration as study reaches.

Following this analysis, the potential study reaches were field checked. The field visit confirmed the analyses and reviewed the level of alteration or disturbance. Highly disturbed channel areas would not accurately reflect watershed conditions, but more likely reflect local disturbance.

After the field check, the number of potential study reaches (PSR) was narrowed down based on their suitability. Landowners along the remaining reaches were identified from assessor parcel maps. Letters and access requests were then mailed out in order to gain permission to access the creek for data collection. One study

Figure 2. Confined and Unconfined Channels. The upper illustration shows a confined channel. The valley width (VW) in the upper illustration is less than twice the channel width (CW). The lower illustration shows an unconfined channel. The valley width, in the lower illustration, is greater than four times the channel width. A terrace is a former floodplain that is too high above the channel to flood.



reach was established.

Creek Conditions

A number of different parameters were monitored in the study reach, including the composition of the channel bed, the level of fine sediment in the cobble/gravel of the stream bed and in pools, the form of the channel, and the amount and type of riparian forest. The study reach was evaluated to determine the bankfull channel width. The bankfull channel was identified using methods described in Leopold and Miller 1964 and Harrelson et al 1994. Detailed surveys were completed in the study reach, including a series of channel cross sections that were monumented and marked in the field with rebar. GPS coordinates were recorded for the locations of each cross section and detailed descriptions completed in field notebooks to allow for identification for future monitoring. The cross sections were surveyed in 2004 to document small topographical changes in the stream bed. A longitudinal profile of the study reach was also surveyed.

Pebble count and embeddedness measurements were completed in the study reach in 2004. A modified-Wolman technique was used (Wolman 1954). These measurements indicate the amount of fine sediment surrounding the gravel and cobble of the streambed. The dominant size of material on the streambed in the study reach was also evaluated.

The V-star protocol (Lisle 1992) is a method for measuring the percentage of fine sediment filling pools and was used in the study reach in 2004.

Riparian plant diversity and density was evaluated. The extent of riparian forest was digitized from 2000 aerial photographs at a 1” = 2000’ scale and was field-checked in both the study reach and as many locations as access allowed. The extent of the riparian forest along the main creek and density of the vegetation was estimated. Species diversity and understory quality, including occurrence of invasive plant species was recorded from field evaluations.

Water Quality and Water Temperature

Water quality and water temperature was monitored in two areas of the creek. Temperature monitoring was completed following the Stream Temperature Protocol of the Forest Science Project, Humboldt State University. Each data logger (Hobo temp H-08, manufactured by Onset Computer Corporation) was calibrated prior to use, in accordance with this protocol, using a NIST traceable thermometer in both a room temperature bath and an ice water bath. All data loggers performed within the manufacturer’s specified accuracy range and protocol requirements.

Deployment of the data loggers was completed in June 2004. The data loggers were placed in the stream at locations representative of summer conditions. In most cases, the data logger was placed at a deep point in the channel to assure submersion as water levels decline over the summer months. Field notes were kept of instrument number, station, flow depth and width, canopy cover and description of conditions. Instruments were downloaded and re-launched using a Hobo shuttle several times during the monitoring period. Field notes on the condition of each station and any changes in instrument location or other features were recorded.

Canopy cover was measured at each station using a spherical densiometer. Four measurements facing opposite directions in a circle were made where the instrument was deployed. The width and depth of the wetted channel at each station was recorded.

Water temperature data, once downloaded into the Hobo shuttle, were transferred into the BoxCar 4.0 program and then Excel program for analysis. Water temperatures at all sites were recorded in 60-minute intervals continuously.

Water quality data were collected on a monthly basis for the June to September period. Dissolved oxygen, temperature, ammonia, nitrate, phosphate and pH were monitored using Chemettes kits and Winkler kits. Water quality data for Copeland Creek were requested from the First Flush program for 2002 and 2003.

III. WATERSHED ASSESSMENT

Description of the Copeland Creek Watershed

Copeland Creek watershed encompasses 5.1 square miles and is long and narrow in shape. This relatively small drainage has its headwaters in the steep Sonoma Mountains. The creek courses over an alluvial fan before reaching flatter topography downstream of Petaluma Hill Road. Through this flat reach, the creek is channelized until it reaches its confluence with the Laguna de Santa Rosa. The main stem of Copeland Creek is 9.1 miles in length. Figure 3 shows roads and bridge locations, urban and rural areas, Copeland Creek and the watershed boundary.

Figure 4 shows the network of creeks in the Copeland Creek watershed and steep slopes in excess of 30 percent. In the Copeland Creek watershed there are numerous ephemeral creeks that only carry water during and immediately after storms. The USGS topographic map indicates Copeland Creek has one unnamed tributary stream that carries water year-round and that Copeland Creek is a year-round creek (indicated in lighter blue on Figure 4). However during 2003 and 2004, neither creek had perennial flow over its entire length.

Geology

Many of the features of the Copeland Creek watershed have evolved over many millions of years of geologic change. Like much of the Russian River watershed, tectonic forces define the features of the Copeland Creek watershed. The coastal ranges of northern California were formed starting 140-100 million years ago and continue to change from the movement of the Pacific Plate beneath the North American Plate. This movement has created the steep and highly erosive mountains of central and northern California. This movement of one plate against the other is visibly defined by the system of faults in the San Andres Fault Zone.

In addition to the uplift of the coastal mountains, land has also been moved laterally along the fault. Over time, portions of southern California's landscape have moved to northern California along the San Andreas Fault. As the coastal ranges have uplifted the area covered by the sea has diminished in certain locations.

The Copeland Creek watershed reflects several distinct geological processes at work – tectonic forces causing mountain building with sinking of the adjacent valley, lateral movement along fault zones, extensive volcanic activity, and erosion processes.

Five to seven million years ago, tectonic movement along the San Andreas Fault system began an era of mountain building in the region of Copeland Creek.

Insert Figure 3. Project Area.

Insert Figure 4. Drainage Network.

About three million years ago, an area of intense volcanic activity developed in eastern Sonoma County/north-western Napa County and stretched to Fairfield, Calistoga and the southern Mayacamas Range. Termed the Sonoma Volcanic field, this area saw massive eruptions of ash and rock over hundreds of square miles. Layers were deposited several thousand feet thick of volcanic rock and ash. During the period that the Sonoma Volcanic field erupted, the faults continued to move and change the landscape. Mountains uplifted along one side of the fault and adjacent lands sank, creating valleys. In the Copeland Creek area, Cotati Valley was formed as the Sonoma Mountains rose. As this valley sank, it filled with water, creating shallow lagoons. With the continued uplift and more rapid erosion from Copeland and other creeks draining the Sonoma Mountains, the lagoons filled with alluvium, forming the Cotati Valley.

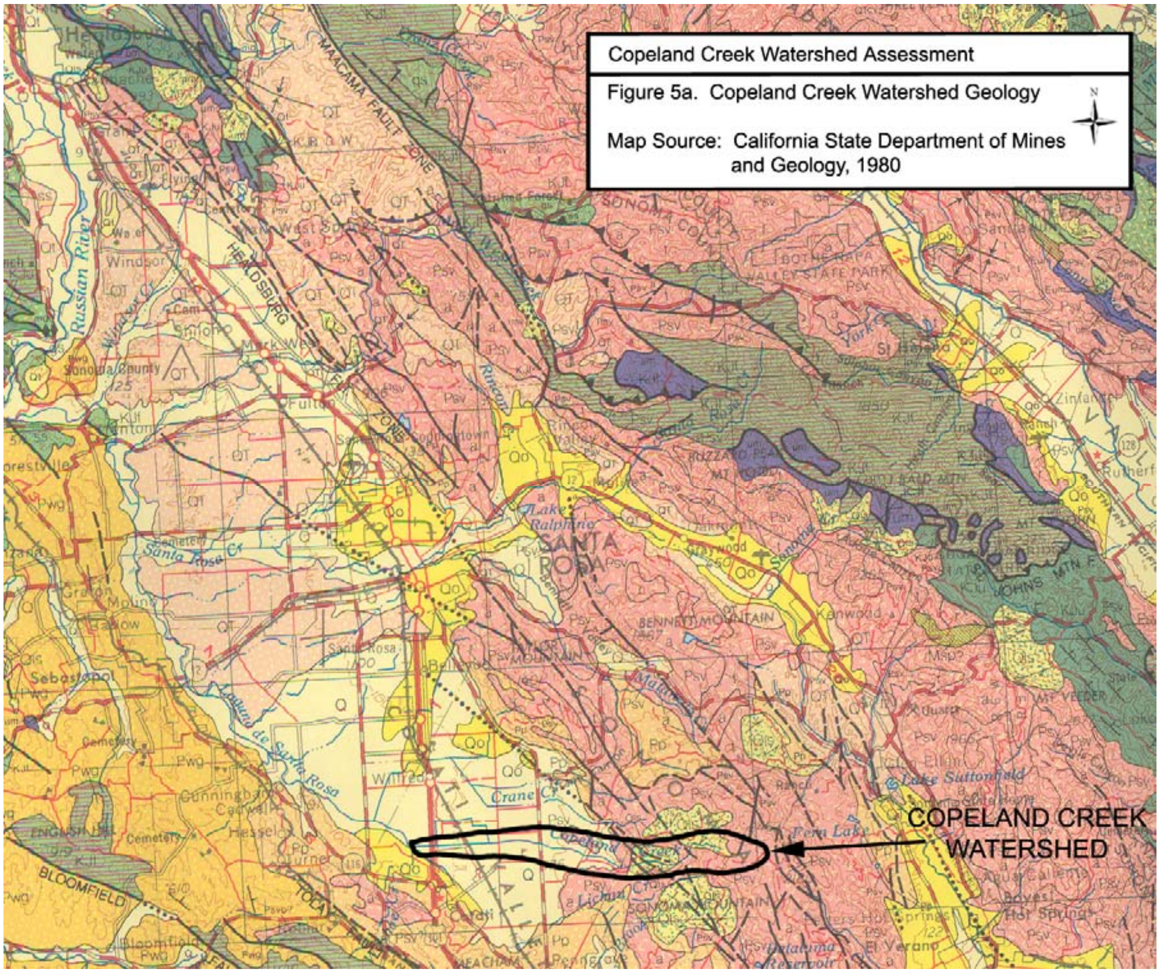
Over the past million years, the area of active volcanism moved to the north to Clear Lake and the Geysers. Further uplift of the Sonoma Mountains resulted in greater incision of streams and erosion of sediment.

From this geologic past, Copeland Creek watershed displays three distinct areas: 1) A steep headwaters area where a network of creeks continues to incise into the Sonoma Volcanic formation, 2) a wide alluvial fan where the creek exits its canyon, depositing bedload and frequently changes its channel location as it moves towards the flat valley, and 3) the most downstream reach where Copeland Creek would naturally meander through the alluvium and wetlands of the Cotati Valley to its confluence with the Laguna de Santa Rosa (see Figures 5a and 5b).

The Rodgers Creek Fault cuts across the Copeland Creek watershed just to the east of the beginning of the alluvial fan reach. There are several creeks with lateral displacement and the fault has been mapped in this vicinity (California Division of Mines and Geology, 1980). In the upper headwaters area of Copeland Creek, another fault crosses through the watershed. Landslides, springs and creeks with lateral displacement are prevalent in the upper watershed.

The basement rock of the Copeland Creek watershed is Franciscan Formation, which dominates the coastal ranges in this region. Franciscan Formation is composed of ancient sea floor sediments that were uplifted and deformed through the subduction process along the fault zone. Franciscan rock is not mapped on the surface of the Copeland Creek drainage (California Division of Mines and Geology, 1980).

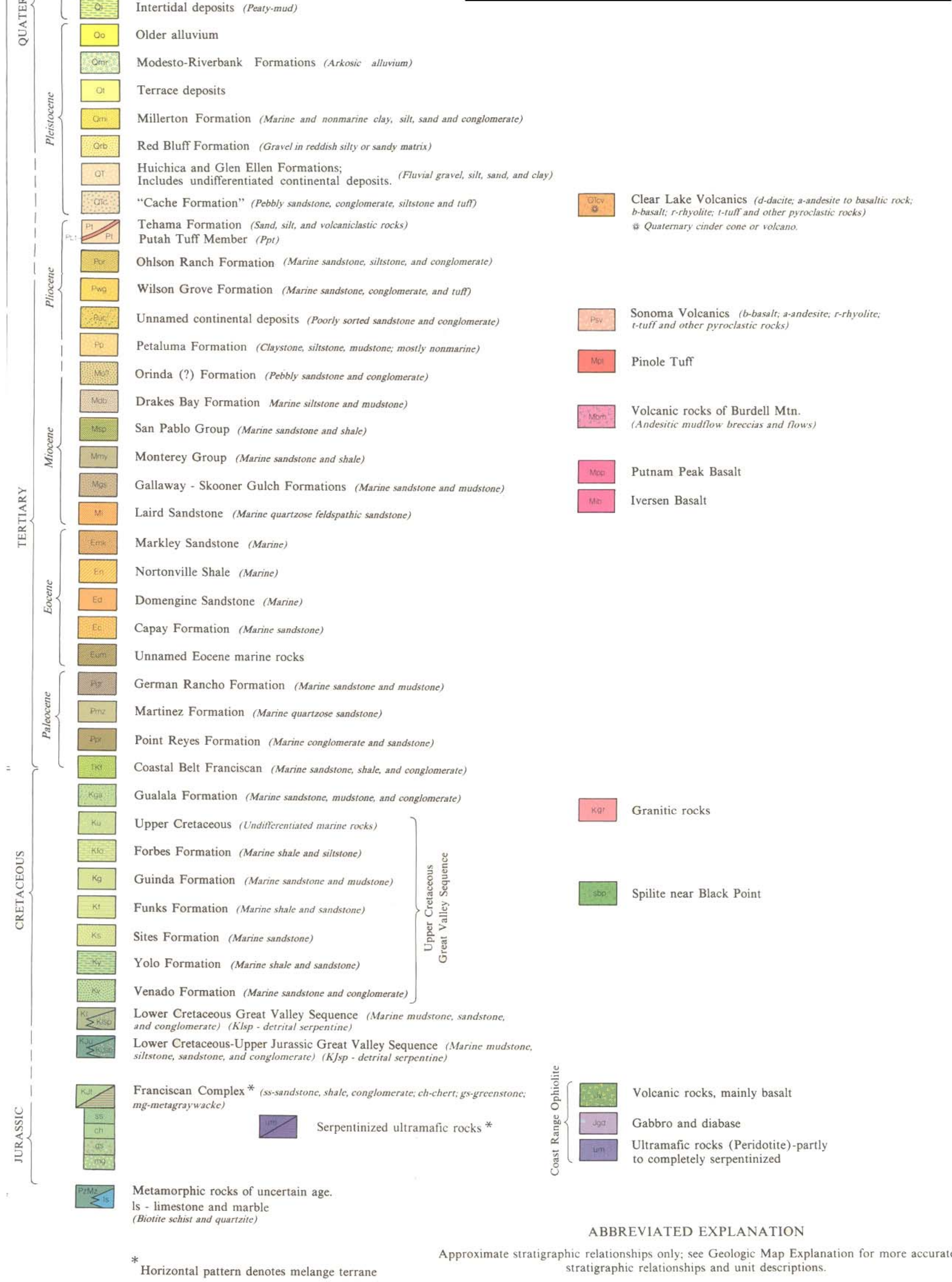
Sonoma Volcanics make up the steep mountainous area of the Copeland Creek watershed. The Sonoma Volcanics Formation was deposited on top of the Franciscan rock approximately three million years ago and consist of a complex series of lava flows, ash and tuff beds. Volcanic eruptions occurred intermittently to create the Sonoma Volcanics as is evidenced by the Petrified Forest, north of Copeland Creek. This forest of redwood and fir grew in soils developed on lava and ash, only to be buried in a subsequent ash flow.


Copeland Creek Watershed Assessment
Figure 5a. Copeland Creek Watershed Geology
Map Source: California State Department of Mines and Geology, 1980
COPELAND CREEK WATERSHED

Copeland Creek Watershed Assessment

Figure 5b. Copeland Creek Watershed Geology

Map Source: California State Department of Mines and Geology, 1980



The Sonoma Volcanic Formation is known for spring activity. Perennial flows in Copeland Creek occur throughout its headwaters area down to the Lichau Road Bridge. Numerous springs are visible on hillsides in small creeks in the watershed and freshwater wetlands occur in a number of locations. The downstream section of the watershed consists of alluvium eroded from the Sonoma Mountains and deposited by creeks during floods.

Landslide deposits and landslide prone lands dominate the upper watershed (see Figure 6). Of the 5.1 square miles of the Copeland Creek drainage, 2.2 square miles are mapped as “mostly landslides.” 1.7 square miles are mapped as “surficial deposits” and 1.06 square miles are mapped as “few landslides.” This large area of landslides is likely the result of movement along the two faults, steep slopes and a high level of spring activity. Locations of obvious erosion and slippage visible on aerial photographs are indicated in Figure 7 and primarily consist of gullies along ephemeral creeks in the landslide prone areas and several major slides and slips. However, all of the area mapped as mostly landslide should be considered as highly erodible (see Figures 8 to 11).

Watershed Vegetation

The Copeland Creek watershed has four primary vegetation types – oak woodland/hardwood forest, annual non-native grassland, seasonal wetland/spring/seep and riparian forest. Figure 12 depicts hardwood forest and annual grassland. Table 1 summarizes the acreage of vegetation types. California bay laurel (*Umbellularia californica)* and coast live oak (*Quercus agrifola*) dominate the hardwood forest with madrone (*Arbutus menziesii*), woodland manzantia (*Actostaphylos manzanita*), Douglas fir (*Pseudotsuga menziesii*), redwood (*Sequoiadendron sempervirens*). Near to the creek or along ephemeral creeks and springs, big leaf maple (*Acer macrophyllum)*, California buckeye (*Aesculus californica*), white alder (*Alnus rhombifolia*), California hazelnut (*Corylus cornuta californica*) red willow (*Salix laevigata*) also occurs.

Table 1. Vegetation types in Copeland Creek Watershed, 2000.

Vegetation Type	Acreage
Hardwood Forest	885.1
Annual Grassland/Rangeland	1635.1
Cropland	94.5

Insert Figure 6. Landslides.

Insert Figure 7. Roads and Erosion Sites.

Figure 8. Unstable Hillsides of Headwaters Reach of Copeland Creek.

Figure 9. Looking East from Alluvial Fan Reach to Headwaters Reach of Copeland Creek.

Figure 10. Wetlands in Hillside of Copeland Creek Indicate Spring Activity.

Figure 11. Hillside with Spring Fed Wetlands and Streams.

Insert Figure 12. Vegetation Map.

The Fairfield Osborn Preserve is located in the northeastern area of the Copeland Creek watershed. The preserve encompasses a variety of vegetation types and landforms, including creek and swale areas, springs and wetlands, and grassland and hardwood forest. Appendix 1 is a plant and animal species list for the Preserve and is representative of the plant species found in the upper Copeland Creek watershed.

Figures 13 and 14 compare the extent of hardwood forest in the upper watershed between 1942 and 2000. For the most part, the extent of the forest has not changed substantially. The understory of the forest, however, may have greater amounts of invasive plant species, such as Himalayan blackberry and blue periwinkle.

The grasslands of the watershed have undergone the greatest degree of change since the European settlement. The Spanish began grazing cattle in this area in the late 1700s. The native perennial bunchgrasses that would have grown in the Copeland Creek watershed do not respond well to intense grazing. Over time, annual European grasses introduced with cattle grazing replaced the perennial natives. These two types of grasses are fundamentally very different. Native perennial grasses are adapted to California's summer drought with dense and deep root systems and summer dormancy. California perennial bunchgrasses form a thick mat on hillsides and provide a high level of soil erosion control. By contrast, the European grasses are annuals that germinate with the first rains, grow quickly, flower, set seed and then die back during the summer drought. The annuals have a less vigorous root system due to their short life cycle. A dense covering of annual grass does no equal the native bunchgrass cover for infiltration and erosional processes. Annual grasses are also adapted to the heavy grazing pressure exerted by livestock operations. The native bunchgrasses were grazed by native animals, but there were few widespread herds of grazing animals in pre-European California than most livestock operations. Finally, bunchgrasses tolerate burning and are able to re-sprout or germinate seed following a fire.

In most grazed grasslands in California, European annual grasses now dominate. Native bunchgrasses have been replanted or have re-colonized lands once grazing is removed or greatly reduced in some areas.

Interspersed in the grasslands are numerous springs and seeps in the hillsides of the upper Copeland Creek watershed (see Figures 10 and 11) The Sonoma Volcanic formation that makes up the upper watershed along with the many landslides and seismicity associated with the Rodger Creek and Healdsburg Faults combine to create the many springs, seeps, wetlands and sag ponds. Willow, cottonwoods and a variety of wetland plants, including rushes (*Juncus* sp.), sedges (*Carex* sp.), nutsedge (*Cyperus* sp.), spike-rush (*Eleocharis* sp.), tules (*Scirpus*) and cattails (*Typha* sp.) are found in the many wetland and spring areas.

Insert Figure 13. Headwaters Reach – 1942.

Insert Figure 14. Headwaters Reach – 2000.

Wetlands were also likely common in the Cotati Valley prior to agricultural reclamation and urbanization. Figure 15 shows a farm road diverting around a wetland on the Copeland Creek floodplain in 1942. Early maps of the area from 1867 indicate the Copeland Creek channel disappearing downstream of the alluvial fan reach into a complex of wetlands in Cotati Valley (Philip Williams and Associates 2004). By 1877, the railroad berm crossed the Cotati Valley ad a straight channel for the creek was created to conduct flow downstream and allow for reclamation of the wetlands.

Land Use

The Copeland Creek watershed has undergone extensive changes since the late 1700s and the arrival of Europeans. California Native Americans lived in the watershed and were known to manage lands by using fire. However, the population of Native Americans was relatively low.

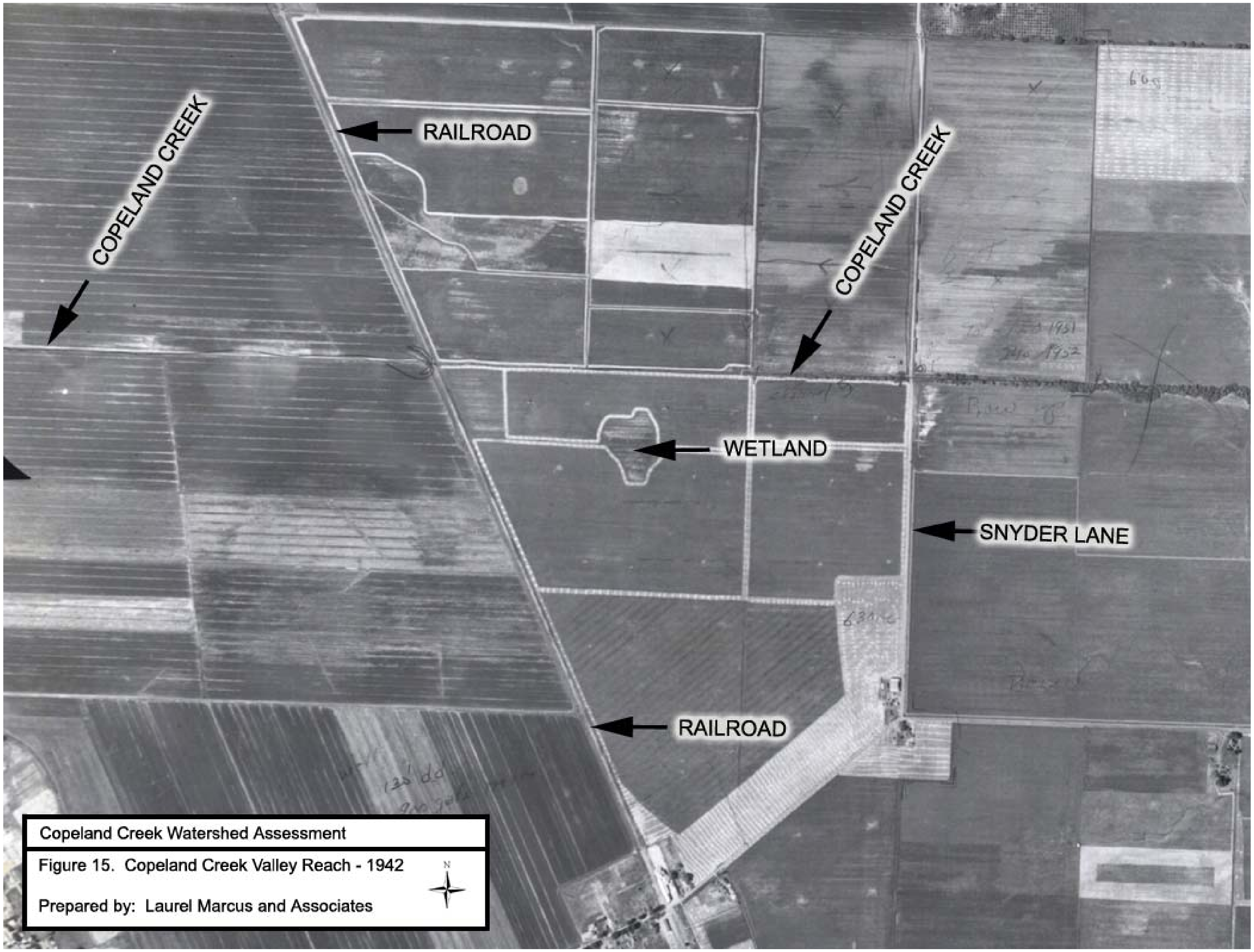
With European settlement, Copeland Creek watershed was included in a land grant to the Carrillo family, who were primarily cattle ranchers. In 1883, after California statehood, the Carrillo holdings were broken up into smaller farms. The Cotati Valley area was reclaimed through ditching and draining of wetlands to wheat farms. It is also likely that most of the large oaks in the valley were harvested around the 1870s and sent by rail to San Francisco as firewood and charcoal. A variety of agricultural operations developed, including dairies, hay and vegetable farms in Cotati Valley and sheep and cattle grazing in the uplands.

Urban Expansion

However, like most of California, agriculture gave way to urbanization. The City of Rohnert Park was incorporated in 1962 and has grown very rapidly from a population of 6,133 in 1970 to 42,236 in 2000 (see Table 2). The City urban limit line encompasses the downstream portion of the Copeland Creek watershed from Petaluma Hill Road to the confluence with the Laguna. Figures 16 to 19 illustrate the expansion of urban areas in the watershed.

Table 2. Urban Areas.

Year	Urban Acreages
1942	17.7
1961	58.9
1980	597
2000	738.8



Copeland Creek Watershed Assessment

Figure 15. Copeland Creek Valley Reach - 1942

Prepared by: Laurel Marcus and Associates

Insert Figure 16. Roads and Urban Residential Areas – 1942.

Insert Figure 17. Roads and Urban Residential Areas – 1961.

Insert Figure 18. Roads and Urban Residential Areas – 1980.

Insert Figure 19. Roads and Urban Residential Areas – 2000.

Flood Control

In the 1960s and 1970s, as part of urban development, Copeland Creek changed from a ditched channel with no vegetation adjacent to agricultural fields (Figures 20 to 23) to an engineered flood control channel with levees and channel maintenance. Early channel maintenance practices likely included removal of accumulated sediment and all vegetation along the bed and banks of the flood control channel. Different areas of Copeland Creek flood control channel have different designations. From the confluence with the Laguna de Santa Rosa to Commerce Blvd., the channel is an engineered channel owned in fee by the SCWA. From Commerce Blvd. Petaluma Hill Road, the channel is an engineered channel with an easement for maintenance. From Petaluma Hill Road to Roberts Road, the channel is designated natural channel with permissive clearing only. Over time, maintenance practices changed to allow for some vegetation on the upper banks of the flood control channel and in some locations, planting of invasive, non-native plant species, such as pampas grass and eucalyptus.

Flood control maintenance practices continue to change as public interest in creek revegetation has increased. According to a 2001 SCWA interim report on channel maintenance:

> *"In the past, food control channels were cleared at least once every five years. Currently, channel cleaning is restricted to an as-needed basis to maintain flood capacity. For example, 100 percent of Copeland Creek was cleared once in 1997, but only 17 percent (2,000 ft.) requires cleaning this year (2001). The frequency of work may change in the future if land use practices or development occur that alters the sediment supply conditions in the sub-basins draining the flood control channels.*
>
> *"One of the largest sediment removal activities was performed in a two and a half mile stretch of Copeland Creek three years ago (1998). About 2,000 feet of channel was maintained in 2000. Sediment input from a large runoff area upstream has resulted in significant sediment loads into this creek (R. Anderson, SCWA, pers. comm., 2000)."*

Unfortunately, no records of the amounts of sediment removed from the flood control channel were kept, so it is not possible to quantify silt deposition in the channel over time (Wendy Gjestland, pers. comm., 2004). After a recent increase in public and resource agency complaints over vegetation removal in Copeland Creek, the SCWA and City of Rohnert Park agreed upon an option to provide partial channel maintenance for two sections of Copeland Creek – Seed Farm Drive to Commerce Blvd. and Country Club Drive to Snyder Lane in 2004 (Sonoma County Water Agency 2004). Under this option the following would be done:

- Remove all trees, bushes, and cattails from stream floor
- Remove all multi-trunk trees, or reduce to single trunk from stream banks
- Trim off lower branches of all single trunk trees from stream banks

Insert Figure 20. Valley Reach – 1942.

Insert Figure 21. Valley Reach – 1961.

Insert Figure 22. Valley Reach – 1980.

Insert Figure 23. Valley Reach – 2000.

- Remove invasive non-native trees and bushes on a case by base basis from streambanks
- Prune single trunk trees so limbs are above top of streambank
- Leave understory vegetation on streambanks
- Revegetate stream slopes with canopy-forming trees where post-maintenance tree spacing is greater than 20 feet on the west or south side, or greater than 40 feet on the north or east side

This maintenance level will provide flood protection for a 40-75 year rainfall event, but not larger events. The maintenance period avoids impacts to birds nesting in trees and is done in compliance with state and federal environmental laws and regulations.

Upland Area

Agricultural and rural residential land uses occur outside of the City of Rohnert Park, to the east of Petaluma Hill Road. Agricultural land uses are primarily vineyard, dairy and cattle grazing. Rural residential uses are depicted in Figure 19. Many rural homesites in the watershed have horses in confined animal areas. Figure 7 shows the expansion of roads and housing in the eastern portion of the watershed and Table 3 summarizes this increase.

Table 3. Length of Roads Upstream of Petaluma Hill Road, Copeland Creek Watershed

Year	Miles of Roads
1942	7.8
1961	11.4
1980	13.1
2000*	17.3
* Only 0.5 miles of 2000 roads are located on slopes in excess of 30%	

Watershed and Stream Processes

For this assessment, creek slope and confinement were determined and information on rainfall, streamflow and floods was collected; the GIS was used to measure and evaluate a variety of features of the existing and historic stream system; a variety of observations on the stream channel were collected during the field work; a study reach was established for channel surveys, v-star and pebble counts/embeddedness measurements and recent monitoring information and reports were collected. No USGS stream flow gaging stations occur on Copeland Creek and no publicly monitored rainfall monitoring stations occur in the watershed.

Background

The network of streams in a watershed moves both water and sediment from hillslopes through streams and out of the watershed. The processes and changes to the stream channel involved in sediment movement and flooding are complex and very dynamic. Additionally, there are different types of stream channels in various areas of the watershed with different sediment and floodwater transport processes. It is the condition of watershed lands that largely create and sustain aquatic and riparian habitats in the creek. There are some general concepts that scientists have developed about stream channels and transport processes that are relevant to watershed assessment and stream habitats.

Stream channels change and adjust during floods to balance out the discharge, or volume of floodwater, with the sediment load. These adjustments include changes in the width and depth of the flow, the velocity or speed of the water, the roughness of the channel (amount of sediment or vegetation in the channel), and the slope of the water surface. These adjustments occur during floods and are largely unobservable until the flood is over and the changes are apparent. In some cases, measurements of various features of the creek or watershed are needed to document changes in the system and can be used as a tool to predict how a certain creek may adjust and change in future floods.

Another important concept of stream morphology is dynamic equilibrium (Leopold 1994). As floods and sediment loads of various sizes are delivered into the stream, the size and shape of the channel adjusts through the processes of erosion and deposition. A large flood may cause great changes to the creek channel and its floodplain, but through subsequent smaller floods and adjustments, these changes are diminished. The creek's size and shape will vary over time within a range of conditions termed dynamic equilibrium (see Figure 24). Because every creek is constantly adjusting its form, improvements to "fix" its form are often short-lived.

A concept particularly applicable to unconfined alluvial channels is the bankfull, or dominant discharge channel. Creek channels tend to be much smaller then the largest flood. This is because the large 100-year frequency flood is relatively uncommon and the small two-year frequency flood is very common. The two-year flood has enough power to scour and deposit sediment in the creek channel and occurs often (Leopold 1994). In general, the two-year flood, also termed the dominant discharge, has the greatest effect on the size of the creek's scour or active channel, also called the bankfull channel (see Figure 25). Adjacent to and slightly above the creek channel is the floodplain where larger floodflows spill out and slow down. The floodplain is an important part of the stream system and is where larger floods are accommodated. It is also the location where streamside or riparian vegetation grows and provides shade to the creek.

Figure 24. Diagram of Dynamic Equilibrium Concept for Streams.

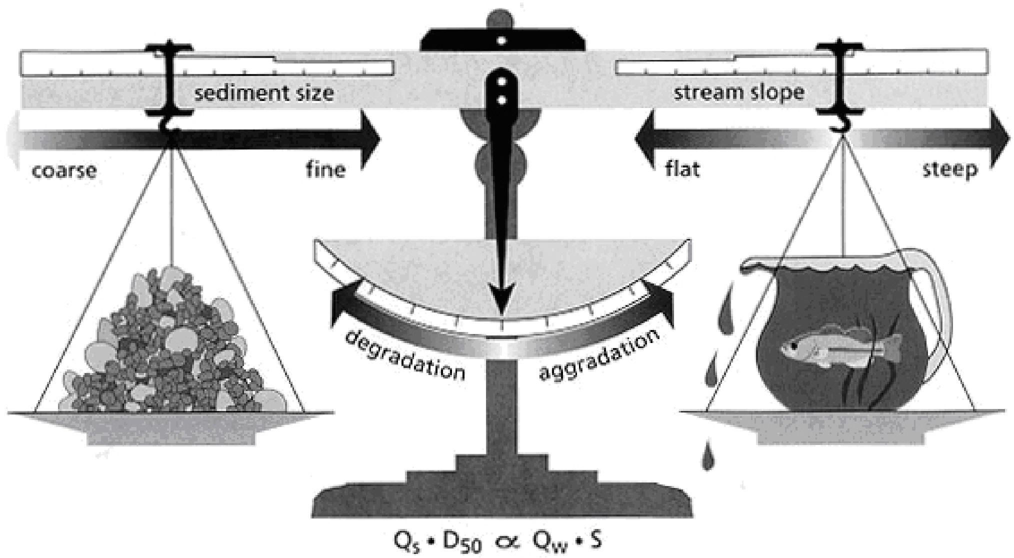
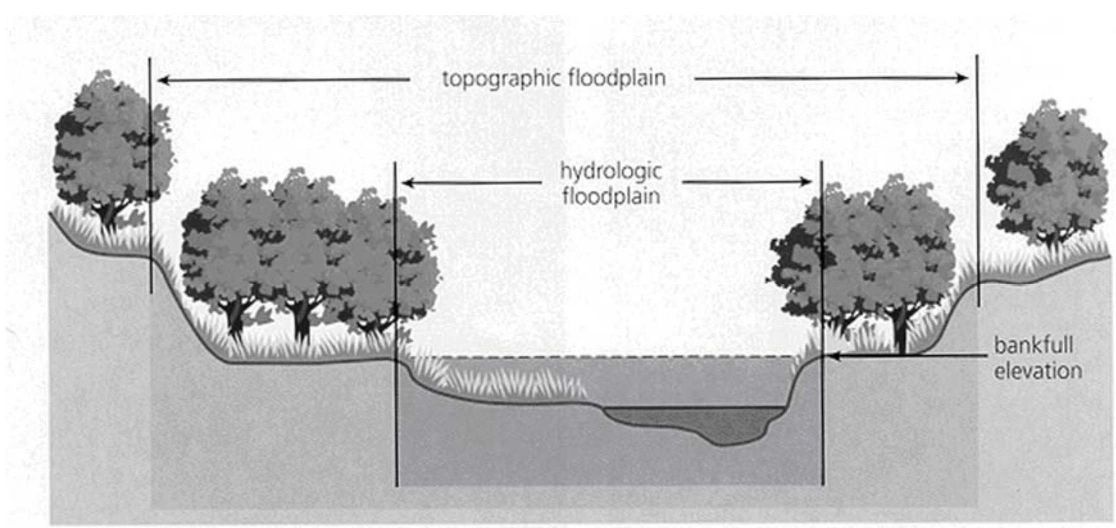


Figure 25. Diagram of Bankfull Channel and Floodplain.



Channel Slope and Confinement

Channel slope was evaluated for Copeland Creek. This is a measure of how much the channel drops over a horizontal distance. Streams with approximately the same slope, respond similarly to changes in flow (discharge) or sediment load. Six slope classes that exhibit distinct channel patterns are listed in Table 4 along with their associated channel pattern. Figure 26 illustrates additional information on the processes associated with these channel patterns, including sediment, deposition and erosion.

Another aspect of the stream system that affects stream processes and aquatic habitats is the level of natural channel confinement.

Unconfined channels are not tightly bound by the walls of a canyon or a bedrock channel bed. Instead, the unconfined channel typically meanders, can change location in a flood and has a floodplain adjacent to the channel. Unconfined channels typically have banks made of alluvial material and have modest bank heights. Unconfined channels are usually low in slope. Unconfined channels can support fish habitats in pools and riffles with riparian forest on their floodplains and banks.

Confined channels typically are dominated by bedrock in the bed and banks. They have little to no floodplain so floodwater does not spread out and slow down, but instead becomes deeper and fast moving. In general, confined channels transport, but do not store sediment, whereas unconfined channels and their floodplains both transport and store sediment. Confined channels may support fish habitats and a limited area of riparian forest along the channel edge. Trees on the slopes of the canyon may serve to shade the confined channel.

Confinement of Copeland Creek was determined from measurement of the topographic maps and channel. Confined channels have a bankfull channel width less than two valley widths and unconfined channels have a valley width of greater than four bankfull channel widths. Channel sections were field-checked to confirm the map determination.

Figure 27 depicts the slope class and confinement of the Copeland Creek channel as determined from the USGS Cotati and Glen Ellen 7.5 minute topographical quadrangles. Channel sections were field-checked to confirm the map determination.

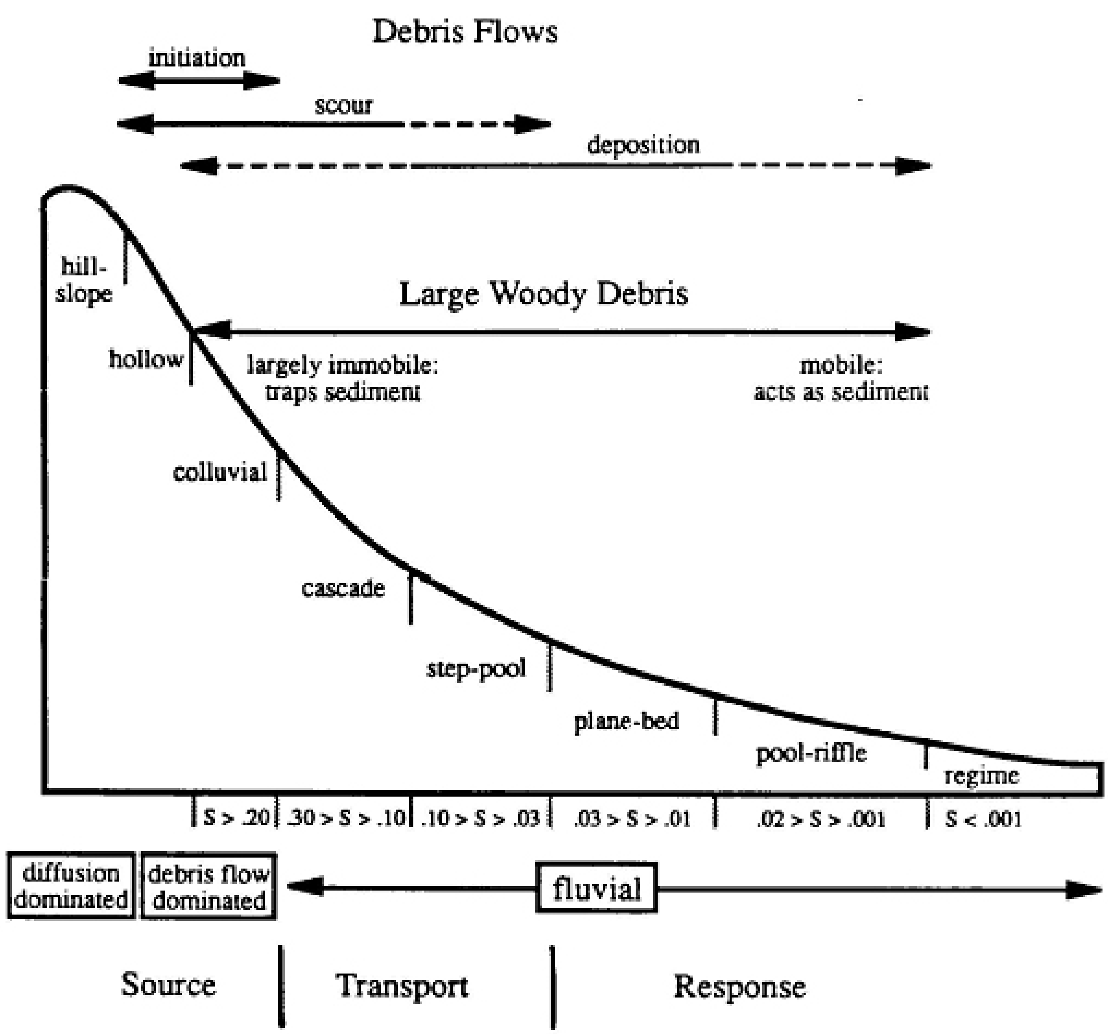
Reaches of Copeland Creek

Based upon a review of channel slope, confinement and geology we have separated Copeland Creek and its watershed into three reaches – headwaters, alluvial fan and valley (see Figure 27).

Table 4. Relationship between Slope Class and Channel Pattern						
Slope Class	<1%	1-2%	2-4%	4-8%	8-20%	>20%
Channel Pattern	Pool-Riffle or Regime	Pool-Riffle Or Plane-Bed	Plane-Bed or Forced Pool-Riffle	Step-Pool	Cascade	Colluvial

From Montgomery and Buffington, 1993

Figure 26. Channel Types. This illustration of an idealized stream shows the general distribution of channel types from the hilltop down through the channel network. From Montgomery and Buffington, 1993.



Insert Figure 27. Channel Slope and Confinement.

Headwaters Reach

The headwaters reach extends upstream from Lichau Road Bridge to the upstream edges of the watershed. Storms tend to release more rainfall over the steep Sonoma Mountains of the headwaters reach than the Cotati Valley area. The Sonoma Mountains are the main area of the watershed where sediment is generated into the stream system through erosion and landslides. The small ephemeral creeks, as well as Copeland Creek in the headwaters area, are all prone to rapid movements of water and sediment.

Copeland Creek is confined upstream of Lichau Road Bridge. The channel slope varies from the 4 to 8 percent class to the 8 to20 percent class. The creek channel is bound in a narrow canyon in most locations. Figures 28 and 29 shows Copeland Creek in the headwaters reach. Copeland Creek in the headwaters reach has large cobbles and boulders, as well as gravel on its channel bed. With the steepness of the hillslopes and ephemeral streams and dominance of landslides, floods in the headwaters reach likely generate large volumes of bedload into Copeland Creek.

Alluvial Fan Reach

This large volume of material is visible just downstream of the confined channel at the Lichau Road Bridge, where Copeland Creek spreads out over an alluvial fan. The alluvial fan reach extends from Lichau Road to just downstream of Petaluma Hill Road and is unconfined, but includes portions of the channel at 2 to 4 percent slope and 1 to 2 percent slope. Figures 30 and 31 shows the deposits of cobble and gravel in the alluvial fan adjacent to the current creek channel. A hand-colored map completed by the California Division of Mines and Geology depicts the alluvial fan of Copeland Creek (see Figure 32).

The alluvial fan reach of Copeland Creek is largely a natural channel, but its processes and management likely affect the downstream valley reach. The alluvial fan reach differs from the valley reach in slope and morphology.

Schumm, Mosley and Weaver (1987) note that

> "An alluvial fan is an accumulation of sediment that has been deposited where a debris-laden stream emerges from the confined valley of an upland area onto the piedmont, where it is free to spread laterally and deposit its load. The ideal form of an alluvial fan is semicircular in plan. Because of their excellent exposure and ease of investigation, alluvial fans in arid and semiarid areas have received the greatest attention in recent scientific literature. However, fans are also common features of more humid regions …."

Alluvial fans are temporary, in the geological sense, sediment storage areas. Because the surface of an alluvial fan is higher than the adjacent valley floor, gravity and flowing water will eventually transport the material stored in the alluvial fan to

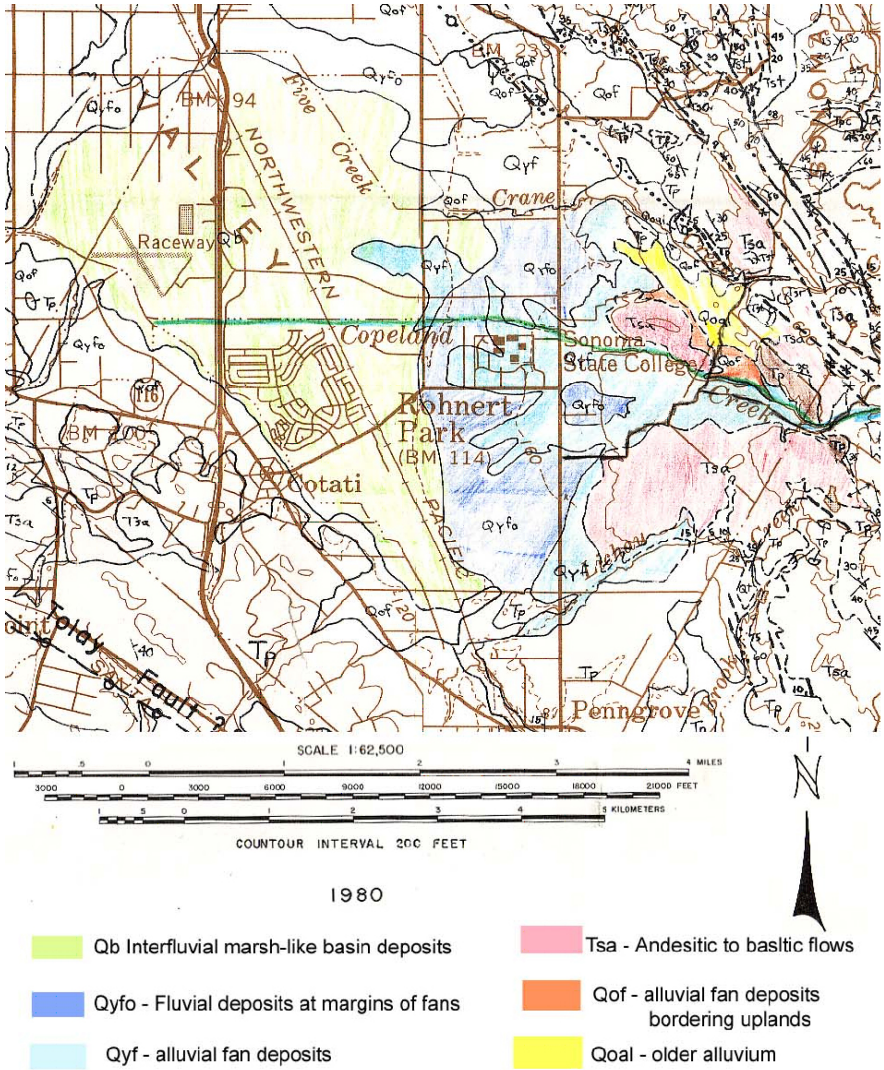
Figure 28. Copeland Creek in Headwaters Reach.

Figure 29. Copeland Creek Headwaters Reach.

Figure 30. Beginning of Alluvial Fan Reach.

Figure 31. Deposits of Cobble and Sand on Copeland Creek Floodplain in Alluvial Fan Reach.

Figure 32. Plate 3b of the Geologic Map from Special Report 120 was Hand-colored to Show the Copeland Creek Alluvial Fan. See legend for complete descriptions of the geologic units.



From: Special Report 120 Plate 3B

Legend for Figure 32. Geologic Map of the Copeland Creek Alluvial Fan.

Qb	Inter-fluvial marsh-like basin deposits; mainly poorly sorted dark clay and silty clay, both rich in organic matter.
Qyfo	Fluvial deposits at the outer edge of alluvial fans (Qyf); forms levees between basin deposits (Qb); characterized by fine, but variable, grain size; composed mainly of fine sand, silt and silty clay.
Qyf	Alluvial fan deposits grading headward to terrace deposits incised in unit Qof; consists of moderately sorted fine sand and silt with gravel becoming more abundant toward fan heads.
Qof	Alluvial fan deposits bordering uplands; heads of fans incised channels partly filled by terrace deposits of younger alluvium (Qb, Qyfo and Qyf); outer margins of fans overlapped by younger alluvial deposits (Qb, Qyfo and Qyf); also includes deposits on stream terraces in narrow canyons cut into uplands; mainly deeply weathered, poorly sorted coarse sand and gravel.
Qoal	Older alluvium; sand, gravel, silt and clay.
Tsa	Andesitic to basaltic lava flows.
From California State Division of Mines and Geology. 1980. Special Report 120.	

the valley floor. The physical processes that control how water and sediment are transported across an alluvial fan are complex.

In an ideal alluvial fan, sediment and water discharge is free to spread out as it leaves the confinement of a mountain canyon and moves out onto the alluvial fan. The flow may separate into multiple channels and produce widespread dispersed deposition over the mid-fan and the apex. The channels tend to bifurcate in the down-fan direction and are called distributaries since they distribute the water and sediment load over the surface of the fan.

Gradually, as deposition on the mid-fan and apex over-steepens the slope of one of the channels, it will incise, forming what is know as a fanhead trench. The fanhead trench tends to capture all of the water and sediment that had been in many distributaries. The presence of a fanhead trench tends to increase the amount of sediment delivered to the toe of the fan. While it is active, a fanhead trench may also migrate laterally. Lateral migration of the channel moves sediment that was previously stored on the fan surface towards the toe of the fan. Movement of the sediment down a fanhead trench eventually causes the trench to fill from the toe of the fan to the head. Backfilling of the fanhead trench in a subsequent flood event results in a return to multiple distributary channels and completes the cycle of alluvial fan channel evolution.

Schumm, Mosley and Weaver (1987) observe that;

> "Fanhead incision causes shifting of the sediment from the apex to downfan areas. It results in the planimetric growth of young fan segments and in the replacement of material lost by surface erosion on older fans. Because it is recognized that apex deposition cannot continue in an uninterrupted fashion for an indefinite periods of time (Lustig, 1974), natural fanhead incision must be integral to any reasonable evolutionary model of alluvial fan growth."

Schumm, Mosley and Weaver conducted experiments on the growth and evolution of alluvial fans using a rain generator and a physical model of a watershed. They note that the growth of the experimental alluvial fan was dominated by repeated fanhead trenching and that the flow conditions at the apex of the fan were important factors in determining the areal extent of flowing water and sediment. Rapid deposition near the apex resulted when numerous streams were spread across the surface of the fan. But, formation of a fanhead trench resulted in lateral fan expansion and aggradation at the toe of the fan. They also note that, even under conditions of constant discharge from the model watershed upstream of the experimental fan,

> "…geomorphic changes on the fan surface were extreme and often dramatically episodic…."

Schumm, Mosley and Weaver (1987) note that Wasson (1977) outlined two types of causes of fanhead trenches.

1. Those which represent fundamental changes in regime that are usually derived from varying external conditions

2. Those which result in the apex incision without operation of external catalysts.

Schumm, Mosley and Weaver (1987) note that Hooke (1967) recognized that the fanhead trenching that are the result of normal alluvial fan processes, which are those that result from Wasson's type 2 causes, are short-term features subject to frequent overbank flooding. Hooke notes that fanhead trenches caused by factors external to the alluvial fan (Wasson's type 1 causes) are so deep that no overbank flooding occurs.

Table 5 is derived from Schumm, Mosley and Weaver's paper and lists the causes of fanhead trenching.

Valley Reach

The valley reach, extending from just downstream of Petaluma Hill Road to the confluence with the Laguna, is also unconfined, but of a lower slope at less than 1 percent. This section of Copeland Creek is channelized and straightened and its bed dominated by sand and silts.

In the valley reach of the Copeland Creek watershed, the stream has a low slope (see Figure 33). This area of the watershed has streams that both store and transport sediment and have a floodplain. Prior to European and American settlement, Copeland Creek likely meandered across the Cotati Valley and overflowed into wetland areas. Stormflows slowed down and spread out. Rather than being dominated by large boulders as in the steep channels, gravel, sand and silts likely dominated the channel. When low-slope streams receive large inputs of sediment, even in undeveloped watersheds, it may take years for transport processes to move it out.

Each of the three reaches has different processes of floodwater and sediment transport and are affected in a particular way by watershed conditions and creek alterations.

Field Monitoring and Analysis

Study Reach Analysis

As part of this assessment, a study reach was established on Copeland Creek upstream of the Roberts Road Bridge in the alluvial fan reach. A series of cross-sections were monumented and surveyed, a pebble count, V-star measurement and an evaluation of the stream was performed.

Table 5. Identified Causes of Fanhead Entrenchment from Schumm, Mosley and Weaver, 1987. Causes 11, 12, and 13 are examples of normal processes that occur on an alluvial fan and do not depend on external agents. Causes 11, 12 and 13 result in transitory fanhead trenches that are subject to frequent overbank flooding. The other causes are external to the alluvial fan and tend to result in a deep channel that does not experience overbank flooding. Note that straightening the Copeland Creek channel near Snyder lane would be equivalent to cause number 14, base level lowering. The storm of 1862 or the storms of the early 1900's may be examples of cause number 9. Movements along the Rogers Creek and Petaluma faults may be examples of cause number 6. Overgrazing may be an example of cause number 10.

Cause of Apex Incision	Selected Reference(s)
1. Climate change towards more arid conditions	Lustig (1965)
2. Deglaciation	Funk (1976), Ryder (1971a), Wasson (1977)
3. Regime change from predominance of mudflows towards more frequent streamflow conditions	Bluck (1964)
4. Regime change resulting in an increased frequency of mudflows	Lustig (1965)
5. Stream capture in the drainage basin resulting in increased discharge to fan	Dzurisin (1975), Eckis (1928)[a]
6. Tectonism (uplift and/or tilting)	Bull (1964b), Hooke (1968b)
7. Decreased load	Eckis (1928)[a], Ryder (1971a)
8. Increase in the frequency of high-magnitude rainfall events with corresponding decrease in frequency of low-magnitude rainfalls	Bull (1964)
9. Extreme event of intense rainfall, runoff	Beaty (1970, 1974), Bull (1964), Denny (1967)
10. Destruction of drainage basin vegetation, resulting in increased surface runoff	Bull (1964), Eckis (1928)[a]
11. Alternation of debris flows and water flows	Hooke, (1967)
12. Erosion of fan surface, headward gully erosion, followed by capture	Denny (1967), Rich (1935)
13. Lateral channel migration to steeper areas on the fan surface	Hooke (1967), Rich (1935)
14. Baselevel lowering (adjacent valley incision)	Drew (1873), Ryder (1971b)
15. Toe trimming (valley stream encroachment)	Drew (1873), Wasson (1977)
16. Basin downwearing over geologic time	Eckis (1928)

[a] Mentioned without elaboration.

Copeland Creek from the Roberts Road Bridge (280-foor contour line) upstream to approximately the 380-foot contour line, a distance of approximately 3,800 feet was evaluated in June 2004. The watershed area above the Roberts Road Bridge is 3.38 square-miles. A study of Fish and Game bankfull widths along with measurements at USGS gaging stations produced an equation that tends to over-estimate the bankfull width based on watershed area (Jackson 1999). That equation is,

Bankfull width = 13.1 * square-root (watershed area)

The above equation produced an estimate of 24 feet for the bankfull width at the Roberts Road Bridge.

Luna Leopold (1994) presents graphs showing the bankfull width, depth and cross sectional area for San Francisco Bay region streams receiving 30 inches of annual rainfall. Approximate values from these graphs for a watershed with an area of 3.38 square-miles are bankfull width equals 25 feet, bankfull depth equals 1.9 feet and bankfull area equals 48 feet. Copeland Creek probably receives more than 30 inches of annual rainfall, but Leopold's estimate of the bankfull width appears to agree with Jackson's estimate. Therefore, it is reasonable to assume that Leopold's

Figure 33. Copeland Creek Valley Reach.

estimates of bankfull depth and cross sectional area are also acceptable for Copeland Creek. Another graph from Leopold gives the bankfull discharge for a 25-foot channel as approximately 150 cubic feet per second (cfs).

Table 6 shows the results from the National Flood Frequency program (USGS) for Copeland Creek at the Roberts Road Bridge. The estimated 2-year discharge is 186 cfs, which agrees well with the estimate for the bankfull discharge from Leopold.

Four observations stood out as we examined Copeland Creek. First, the streambed was covered by cobbles and small boulders (see Figure 34). Second, the width of the active channel was very wide, perhaps about 100 feet from top-of-bank to top-of-bank, which is about four times wider than expected. Third, trees growing below the top-of-bank appear to be no older than about 25-years old. Four, pools were scarce and those that were found were shallow.

The Copeland Creek watershed, upstream of the Roberts Road Bridge is dominated by Sonoma Volcanics and alluvial fan deposits. Most of the cobbles and small boulders observed on the creek walk appeared to be from the Sonoma Volcanics.

A low volume of surface flow was observed near the Roberts Road Bridge in June 2004. As we progressed upstream, surface flow would appear and disappear. A short distance upstream of the 320-foot contour line, by GPS reading, fish were seen in a small pool at the downstream end of a flowing reach. The small fish appeared to behave like juvenile steelhead. The first cross section of the study reach was placed a few feet downstream of this pool at a point where the channel was dry. The end of the study reach was placed about 330 feet upstream at a point where the flow first appeared. A total of four cross sections were surveyed in addition to a longitudinal profile along the low-flow channel. Graphs of the four cross sections, creek profile and the surveyed profile are shown in Figures 35 to 41.

The width of the low-flow channel, at each of the four cross sections, ranged from 24 feet to 40 feet. The width of the low-flow channel approximates Leopold's estimate of the width of the bankfull channel. This suggests that the low-flow channel may actually be the bankfull. The additional 80 to 120 feet of width may have been lost to erosion as the channel adjusted to some type of instability. At this point, it is not clear if the channel instability is ongoing or if the channel has stabilized. It is also not known if the instability was the result of a single intense storm; a relatively rapid adjustment to flood control channelization in the late 1960's; or a gradual response to the change in land use over the last 150 years or so.

Besides widening, the channel appears to have incised about 3 to 4 feet. The estimate for the amount of incision results from assuming that the top of the bank of the low-flow channel is actually the top of the bank of the bankfull-channel. So, the difference in elevation of the top of the low-flow channel compared to the elevation of the top of the outer bank represents the amount of channel incision. The right bank tends to be about one foot lower than the left bank.

Table 6. Output from the National Flood Frequency Program for Copeland Creek at the Roberts Road Bridge.

National Flood Frequency Program	
Version 3.0	
Based on Water-Resources Investigations Report 02-4168	
Equations from database NFFv3.mdb	
Updated by Kries 10/16/2002 at 3:51:06 PM new equation from WRIR 02-4140	
Equations for California developed using English units	
Site:	Copeland Creek, California
Date:	Thursday, July 29, 2004 10:17 AM
Rural Estimate:	Rural 1
Basin Drainage Area:	3.38 mi^2
Region:	North Coast Region
Drainage Area:	3.38 mi^2
Mean Annual Precipitation:	40 inches
Altitude Index:	2.4 thousand feet
Crippen & Bue Region:	17

Flood Peak Discharges, in cubic feet per second.

Estimate	Recurrence Interval (years)	Peak Flow (cfs)
Copeland Creek at Roberts Road	2	186
	5	315
	10	442
	25	609
	50	796
	100	954
	500	1,530
	Maximum	16,900 (for Crippen & Bue region 17)

Figure 34. Copeland Creek in Alluvial Fan Reach in Summer 2004.

Figure 35. Surveying Channel Cross-sections of Copeland Creek Study Reach.

Figure 36. The channel profile was constructed from the USGS topographic map. The study reach is on an alluvial fan.

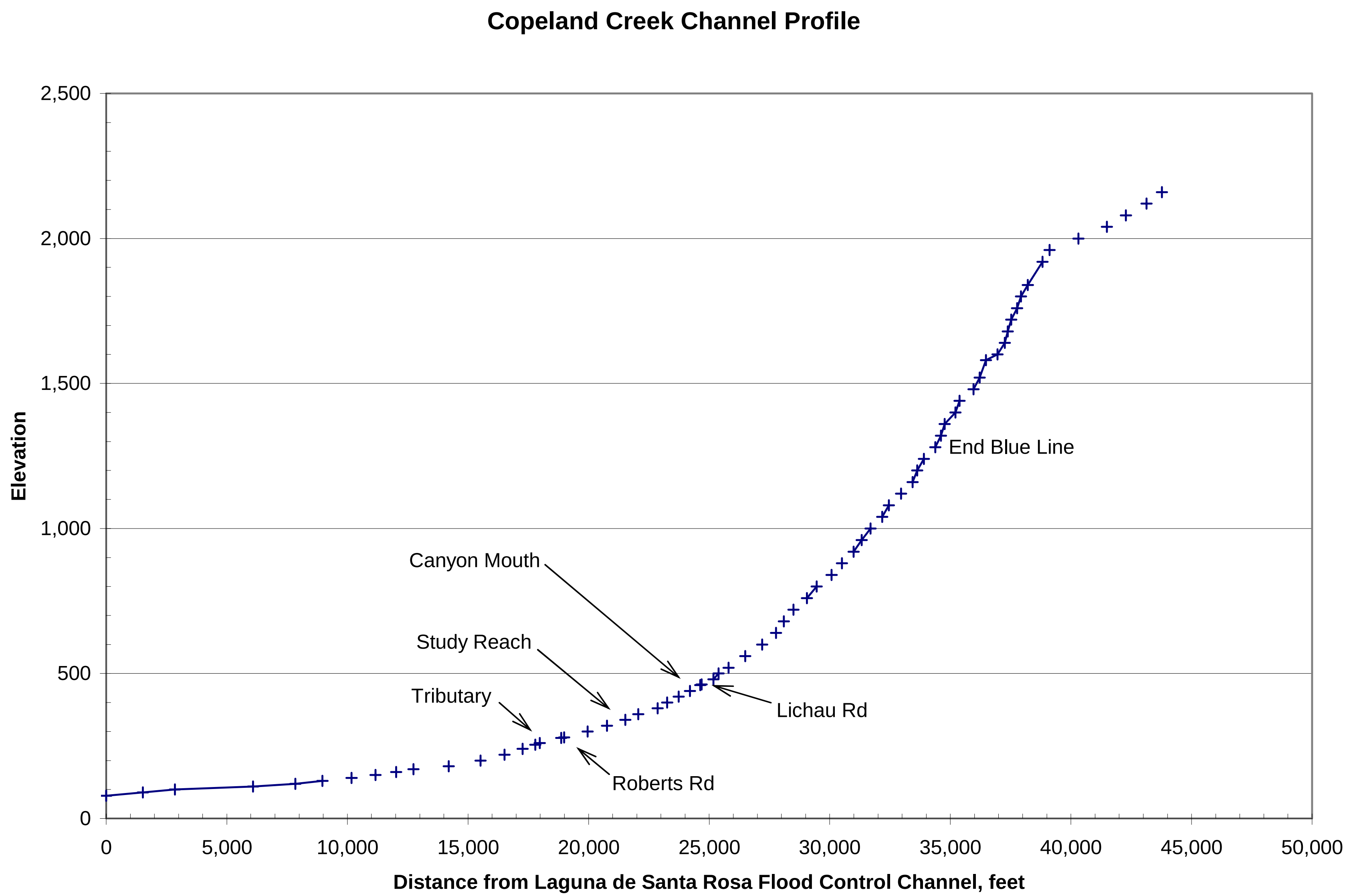


Figure 37. Copeland Creek Longitudinal Profile Constructed from the USGS Topographic Map.

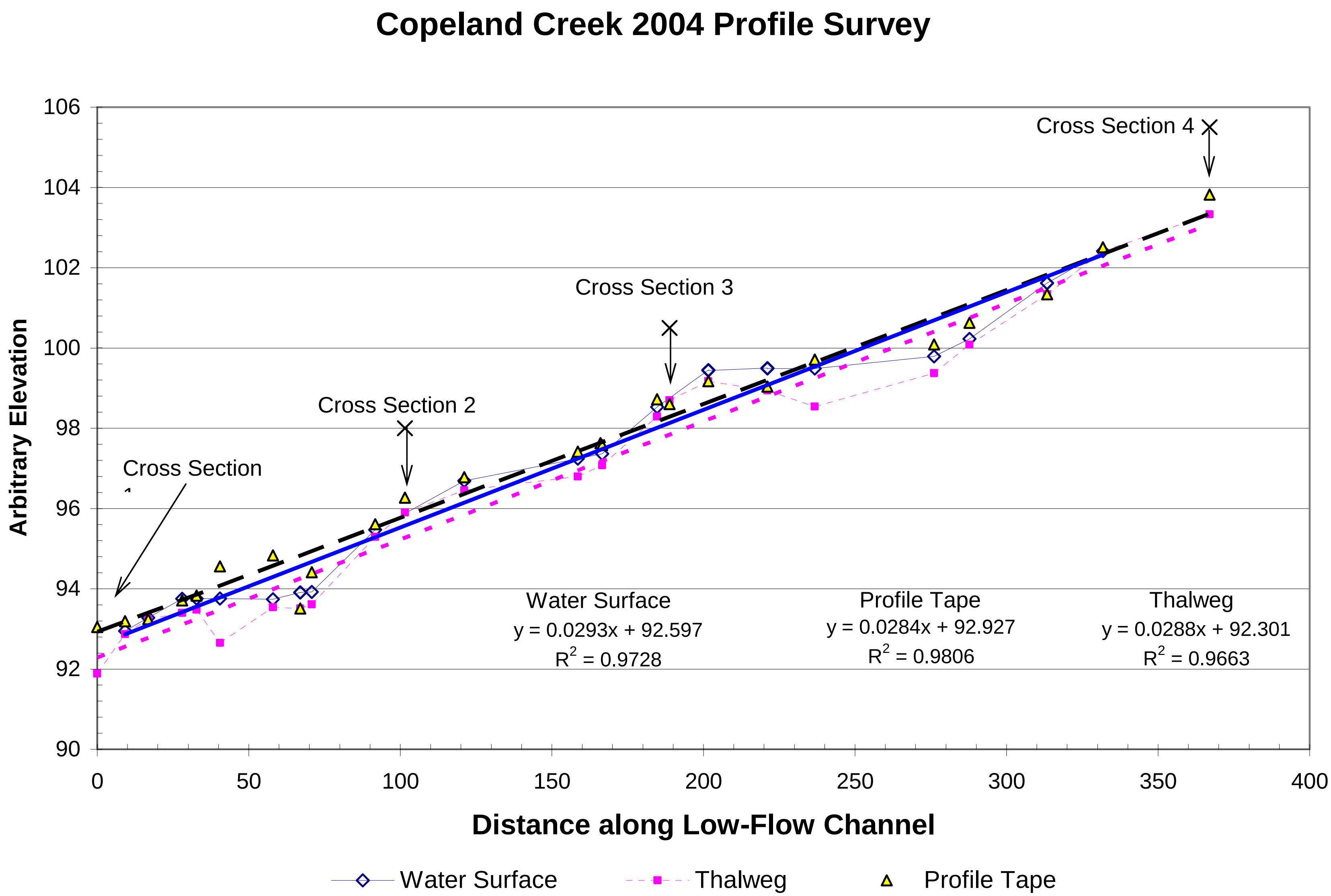


Figure 38. Cross Section 1 at Downstream End of Study Reach. The overflow and low-flow channels join at cross-section 1.

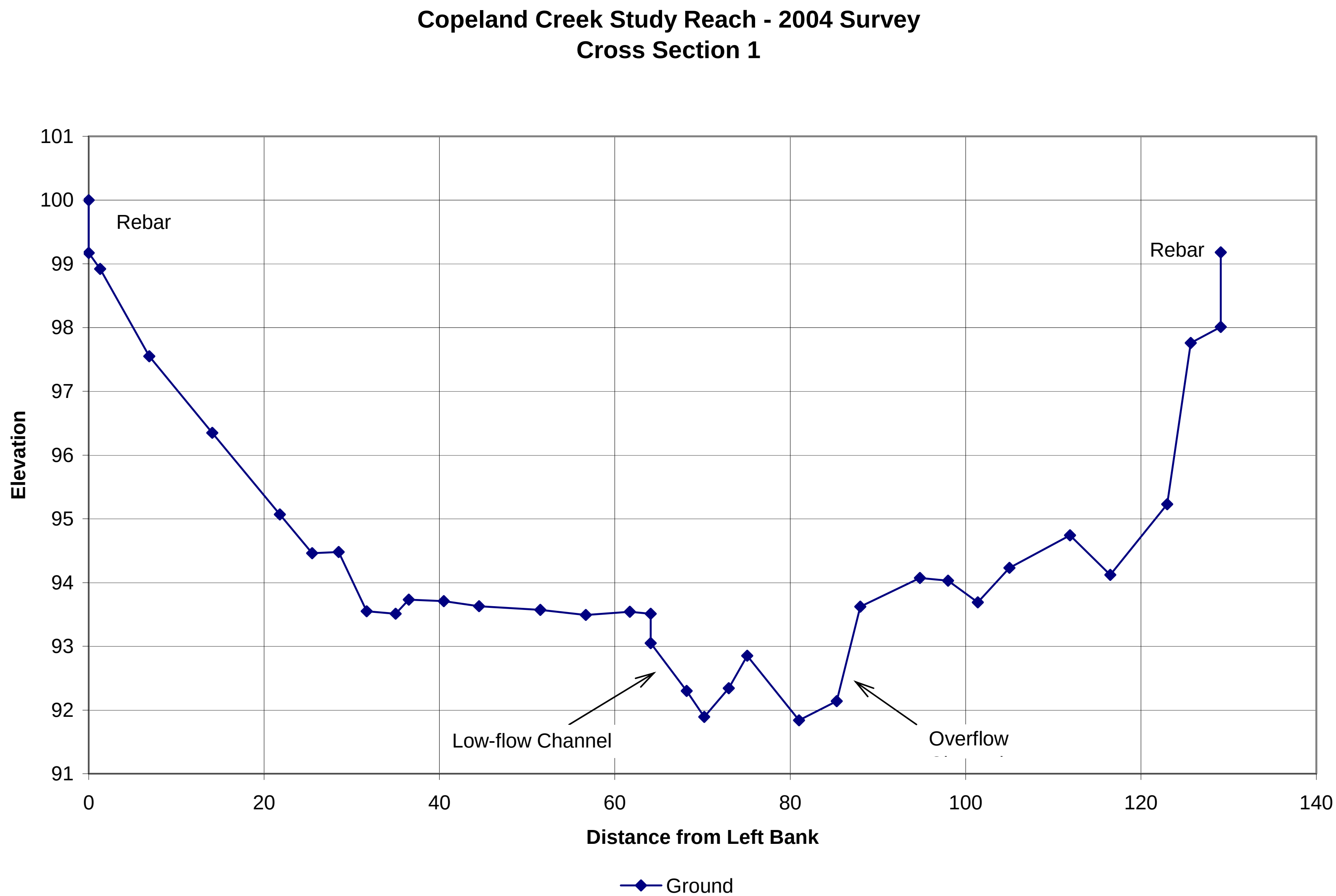


Figure 39. Cross Section 2. The channel is divided into a low-flow channel and an overflow channel, separated by a vegetated bar.

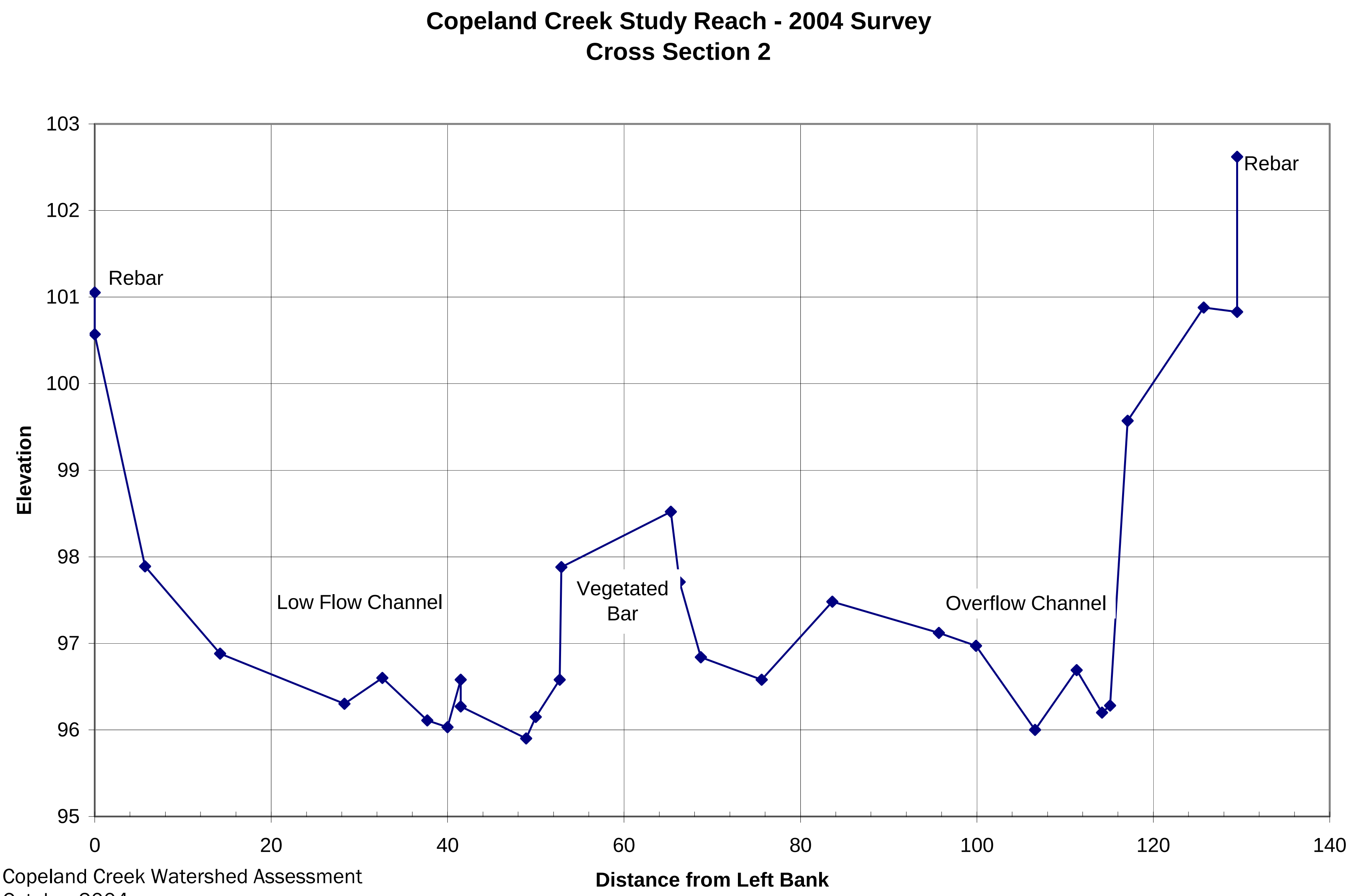


Figure 40. Cross Section 3. The channel begins to divide into a low-flow channel and an overflow channel. Upstream of here, the right half of the channel is densely vegetated with an overflow channel at the base of the right bank.

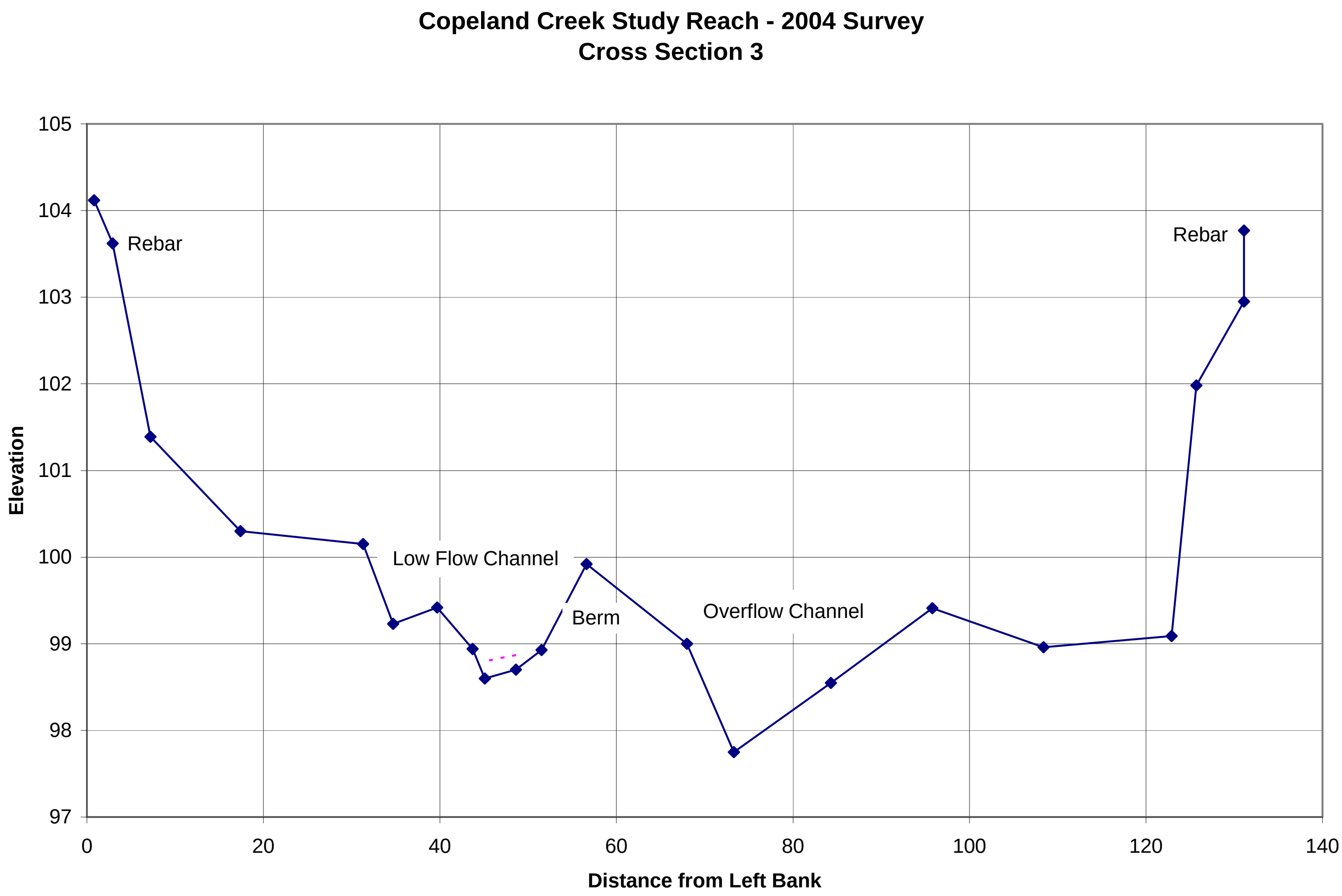
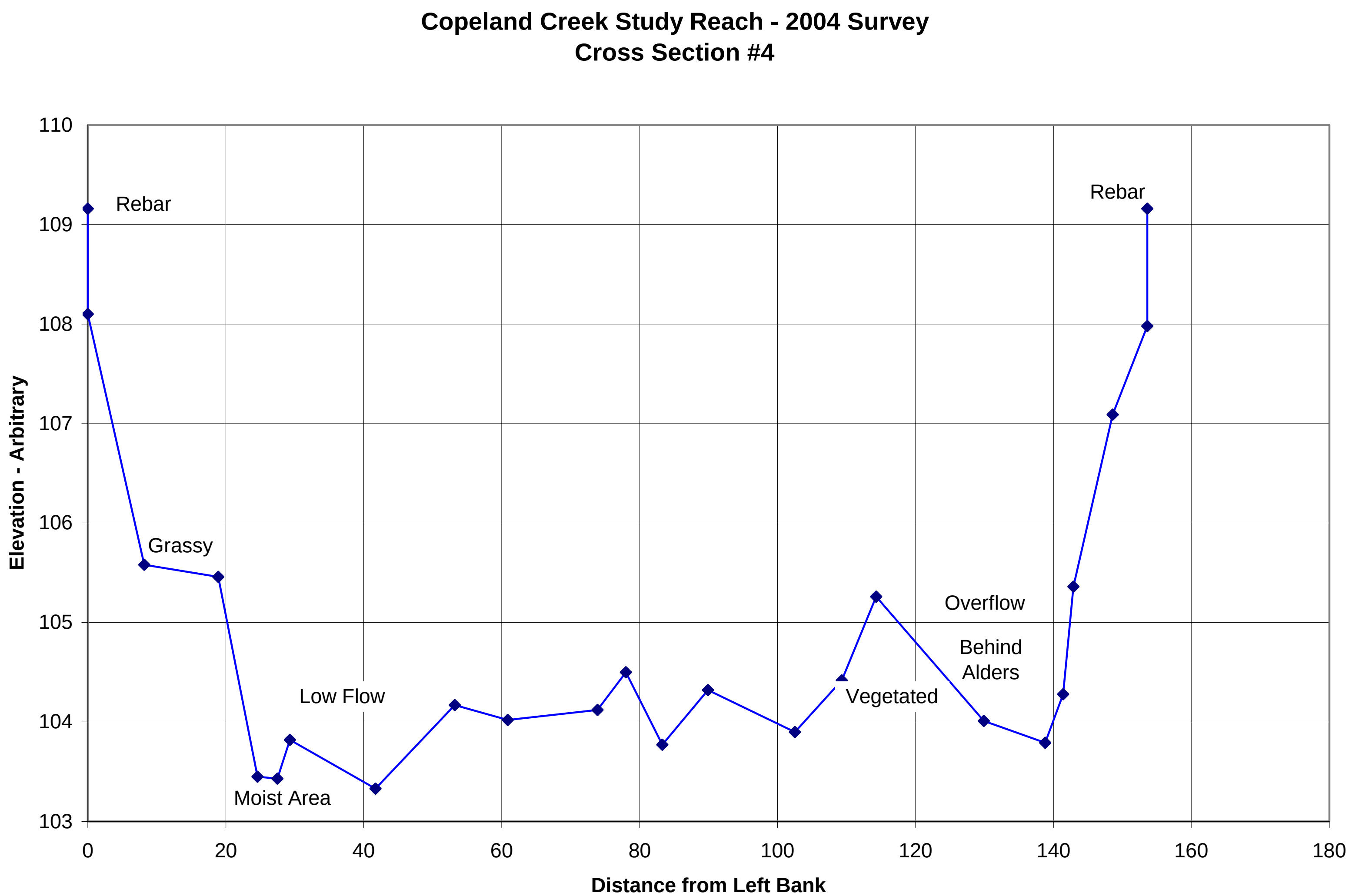


Figure 41. Cross Section 4. An overflow channel at the base of the right bank runs down to cross section 3. Surface flow begins just downstream of the cross section. Stand water was seen about three feet upstream of the cross section near the left bank.



Laurel Collins (2002) studied geomorphic changes in Carriger Creek, which drains the east slope of Sonoma Mountain. Copeland Creek drains the west side of Sonoma Mountain. So, Copeland Creek and Carriger Creek share a common watershed divide on the ridgeline of Sonoma Mountain. Collins found that the channel of Carriger Creek was excessively wide as it crossed the alluvial fan. The alluvium crossed by Carriger Creek also contains a high percentage of cobbles and small boulders. So, it seems that the stream processes discussed in the Collins report are directly applicable to Copeland Creek.

There do appear to be differences in the response of Copeland and Carriger Creeks. The Copeland Creek study reach appears to have experienced greater widening but less incision than the Carriger Creek study reach. The Carriger study reach is significantly larger.

Collins suggests that the numerous large cobbles and small boulders form an armor layer that protects the stream bed of Carriger from erosion. In addition, the banks of Carriger Creek are composed of cobbles and small boulders in a matrix of fine material. The banks of Carriger Creek are more erodible than the streambed, at least at low gradients. As a result, channel instability in Carriger Creek tends to be expressed as widening instead of as incision. This description also fits the situation observed on Copeland Creek. So, Copeland Creek should be expected to widen more than it incises.

The large size of the bed material and weakly consolidated banks of Copeland Creek explain the first two observations of the walk up the creek. The cobble and small boulders on the bed protect it from erosion. The banks contain enough fine material to allow vertical cut faces. However, the stream was noted to be eroding the lower portion of the vertical banks that were inspected. The undercutting will lead to the eventual collapse of the vertical banks. Thus, channel widening has occurred more rapidly than channel incision.

The third observation from the walk, trees growing below the top-of-bank appear to be no older than about 25-years old, can be explained in two ways. One explanation is that a single large event created the excessively wide channel about 25 years ago. An alternative explanation is that the excessively wide channel can contain floods in excess of the 100-year event. The 25-year flood is about 600 cfs and that the 100-year event is about 950 cfs (see Table 6). The width of the overall channel at the bottom of banks is about 100 feet. If a large flood filled the overall channel to an average depth of 2 feet and had an average water velocity of five feet per second, the discharge would be 1,000 cfs. But the banks are at least 4 feet high. Therefore, the excessively wide channel of the Copeland Creek study reach contains its floodplain, even for rare events.

The fourth field observation, infrequent pools, is probably the result of the large size of the bed material, relative to the size of the bankfull discharge. The bed material is effectively protecting the bed from erosion, which implies that the only large rare flood-events can move the cobbles. The relative immobility of the bed prevents the formation of pools.

Table 7 presents a rough estimate of the volume of material that was lost from the Copeland Creek study reach. The calculation was made by assuming that low-flow channel at each cross section is the bankfull channel. The cross sectional area of the overall channel was calculated from the survey data. The cross sectional area of the low-flow channel, up to the top of the outer banks was also calculated. Subtracting the cross sectional area of the low-flow channel from the overall channel gives the cross sectional area of the over-widened portion of the channel.

The volume of material lost from the over-widened channel between consecutive cross sections was calculated as the average area lost from each cross section times the distance between the cross sections. The total volume lost is the sum of the volume lost between the three pairs of adjacent cross sections. This computational procedure is called the *average-end area* method. The cross sectional areas were calculated using WinXSPRO software developed by the US Forest Service.

The Copeland Creek study reach is estimated to have lost a total of 4,325 cubic yards from the over-widening process. The study reach is 367 feet long. Thus an average of 11.78 cubic yards per foot-of-channel-length was eroded from the banks in the study reach. Assuming that the study reach is representative of the 3,800 feet of channel walked on June 8, 2004 produces a loss of 44,779 cubic yards from the bed and banks. The over-widening in Copeland and Carriger Creeks suggest that other creeks that cross the alluvial fan of the Sonoma Mountains may also have experienced over-widening of their channels.

In the study reach, a pebble count was completed in the low flow channel to evaluate bed composition. Coarse gravel to very coarse gravel (16 to 64 mm.) dominated the channel bed and embeddedness of cobble was measured at 32 percent. The V-star value measured in a pool in the study reach was 0.225, indicating a moderate to low supply of fine sediment.

Table 7. Estimate of volume of material lost through excessive widening of Copeland Creek study reach.

Cross Section	XS-1		XS-2		XS-3		XS-4
Profile Location (feet)	0		101.5		188.8		367
Total Area (sq.-ft.)	443		572		408		505
Area of Low Flow (sq.-ft.)	128		247		125		139
Excess Area in Cross Section (sq.-ft.)	315		325		283		366
Distance between Cross Sections (feet)		101.5		84.3		178.2	
Average Excess Area (sq.-ft.)		319.67		303.62		324.44	
Lost Volume between X-Sect, (cubic ft.		32,446		26,506		57,815	
Lost Volume between X-Sect, (cubic yds.)		1,202		982		2,141	

Total Volume Lost from Study Reach =	4,325 cubic yards
Length of Study Reach =	367 feet
Distance walked above bridge =	3,800 feet
Total Volume lost in section of channel that was walked =	44,779 cubic yards

As part of a recent study of sediment sources affecting the Laguna de Santa Rosa, a particle size analysis in several areas of Copeland Creek was completed (Philip Williams and Associates 2001). Samples were taken at the Lichau Road Bridge, downstream where Snyder Lane crosses the flood control channel portion of Copeland Creek, and near the Highway 101 Bridge. Table 8 lists the results of the analysis. Based on this sampling along with other creeks, Copeland Creek was found to be one of the tributaries of the Laguna de Santa Rosa with the coarsest material and greatest percentage of gravel.

There is a dramatic decrease in the percentage of gravel when the toe of the fan (Snyder Lane) is compared to the valley floor site (Highway 101). There is also a marked increase in the percentage of subsurface fines from the toe of the fan to the valley floor. The marked decrease in the percentage of gravel from the toe of the fan to the valley floor is accompanied by a 3 fold decrease in slope.

The sediment transport power on the valley floor (Highway 101 site) is dramatically lower than on the alluvial fan. The loss in sediment transport power is expressed as a loss in competence (i.e. the largest size of bed material that can be transported) and the associated decrease in the size of the subsurface bed material. The loss of sediment transport capacity is caused by the lower channel slope on the valley floor and possibly due to backwater effects from the Laguna de Santa Rosa flood control channel since the channel elevation at the Highway 101 bridge is roughly about 5 feet higher than the channel elevation at the confluence with the Laguna de Santa Rosa flood channel.

Downstream of Snyder lane, fines are becoming part of the bed load whereas on the alluvial fan fines are found only in the wash load and are therefore transported downstream of the alluvial fan during virtually every storm. A small amount of fines may be deposited in the armor layer on the falling limb of the hydrograph.

Table 8. Results of Particle Size Analysis in Copeland Creek, 2004.

Location	Geologic Map Symbol	Slope from Topo Map	Fines (<0.062 mm.) Percent of Sample	Sand (2.0 – 0.062 mm.) Percent of Sample	Gravel (>2.0 mm.) Percent of Sample
Highway 101 Bridge – Valley Floor	Qb – Interfluvial basin deposits	0.002	10%	87%	3%
Snyder Lane Bridge – Toe of Fan	Qyf – Alluvial fan	0.006	0%	36%	64%
Lichau Road Bridge – Head of Fan	Qyf - Alluvial fan	0.036	2%	28%	70%
Subsurface bed material samples by Phillip Williams and Associates.					
Sample size was 20 to 40 pounds, taken below the armor layer.					

Historical Changes: Alluvial Fan Reach

The width of the Copeland Creek meander corridor in the alluvial fan reach between Lichau and Petaluma Hill Roads was evaluated and digitized from a series of aerial photographs dated 1942, 1961, 1980 and 2000 (Figures 42 to 45). The photographs were examined for obvious prior flow lines and channels. Tables 9 and 10 lists the widths as measured at 500 foot intervals and the total acreage. The meander corridor of the unnamed blue-line tributary to Copeland Creek was also measured over time.

The apex of the Copeland Creek alluvial fan is near the Lichau Road Bridge. Along the course of Copeland Creek, the alluvial fan extends downstream to Petaluma Hill Road. A small ephemeral channel lies just to the south of Lichau Road between the 360-foot and 460-foot contour lines. A ridge of low relief about 350 feet wide separates the channel Copeland Creek from the channel of the ephemeral stream to the south. The unnamed ephemeral channel runs along the south flank of the Copeland Creek alluvial fan until it reaches Petaluma Hill Road where it has been turned south to act as a roadside ditch (see Figure 46). Copeland Creek runs along the northern flank of its alluvial fan. Between Roberts Road and Petaluma Hill Road a ridge of Sonoma Volcanic rock has constrained the northward growth of the alluvial fan. An outcrop of Sonoma Volcanic rock also occurs along the southern flank of the alluvial fan near Petaluma Hill Road.

The 1942 photo shows that the Copeland Creek channel was already straightened, from approximately 1,400 feet upstream of Snyder Lane down to the channel of Laguna de Santa Rosa.

The USGS 7.5-minute topographic map was made from 1952 aerial photos. The topographic map does not show any clear evidence of major distributary channels on the Copeland Creek alluvial fan. The topographic map shows that the contour lines that cross Copeland Creek exhibit a strong upstream V-shape, indicating that the surface near the channel tends to be concave which would not tend to promote the formation of distributary channels. The 1942, 1961 and 1980 aerial photos do show evidence of a couple of distributary channels between Roberts Road and Petaluma Hill Road.

Downstream of the Lichau Road Bridge the channel begins to widen and may have multiple threads during moderate to high discharges. The head (apex) of the Copeland Creek alluvial fan is affected by several factors. The following factors could prevent the creation of distributary channels on the alluvial fan upstream of the Roberts Road:

- The low ridge Lichau Road is built on
- Levee adjacent Lichau Road
- Roberts Road and its bridge
- Channel incision

In the vicinity of the Lichau Road Bridge, there are a number of 10- to 12-foot high spoil piles of aggregate excavated from the alluvial fan and sidecast between the creek and Lichau Road. Judging from the size of the vegetation growing on the piles, the material has been there 20 to 40 years and probably date to a large flood event.

Insert Figure 42. Alluvial Fan Reach – 1942.

Insert Figure 43. Alluvial Fan Reach - 1961

Insert Figure 44. Alluvial Fan Reach - 1980

Insert Figure 45. Alluvial Fan Reach - 1950

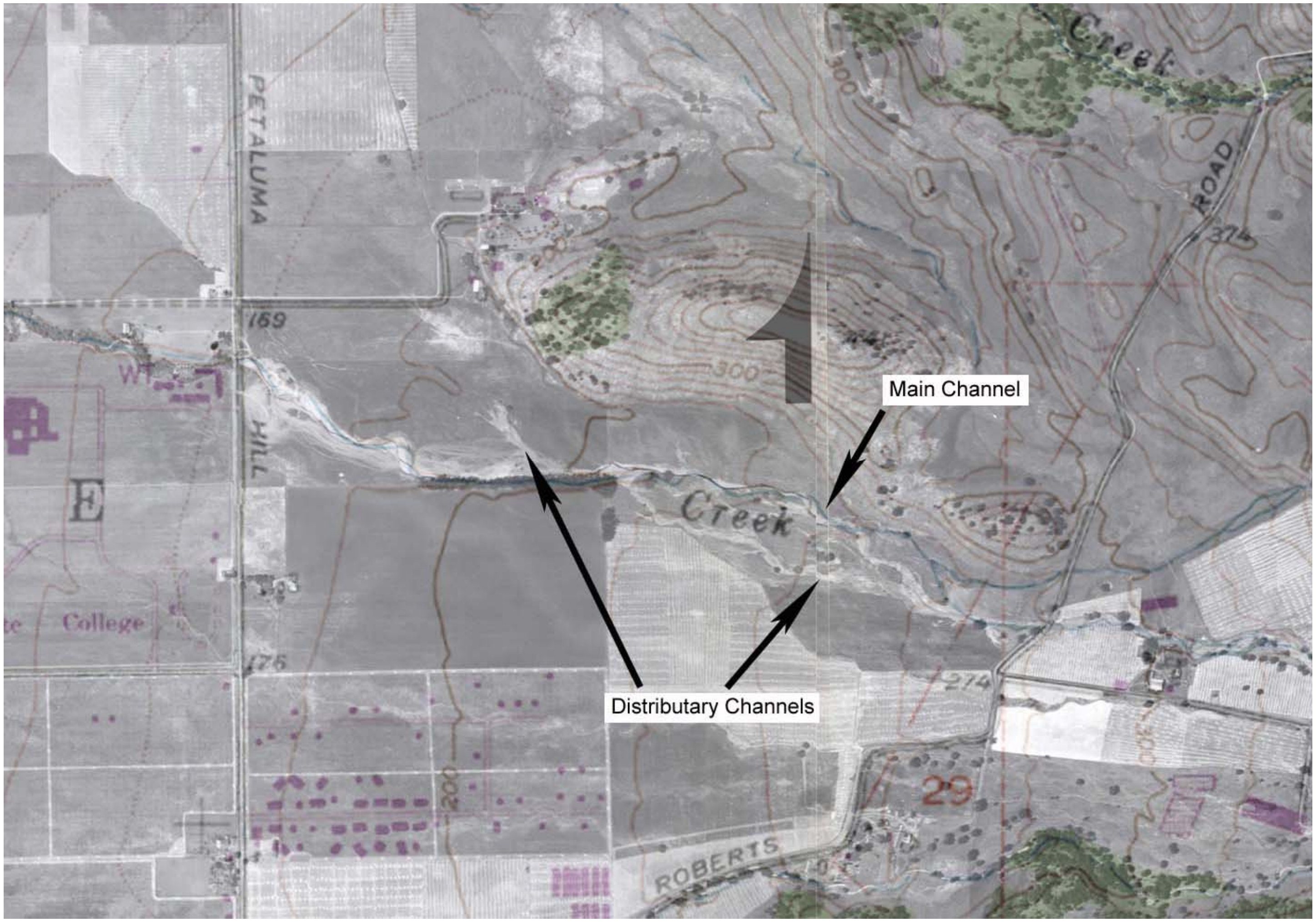
Table 9. Width of Meander Corridor of Copeland Creek from Lichau Road to Petaluma Hill Road, measured at 500 foot intervals.

	Measuring Point (every 500 ft. downstream to upstream)							
Year	1	2	3	4	5	6	7	Total area in acres
1942	159 ft.	62 ft.	221 ft.	72 ft.	80 ft.	112 ft.	72 ft.	87.2
1961	53 ft.	43 ft.	56 ft.	47 ft.	76 ft.	113 ft.	60 ft.	45.8
1980	31 ft.	31 ft.	186 ft.	20 ft.	45 ft.	91 ft.	61 ft.	54.2
2000	40 ft.	25 ft.	51 ft.	11 ft.	43 ft.	130 ft.	20 ft.	35.0

Table 10. Width of Meander Corridor of Copeland Creek Tributary, measured at 500 foot intervals.

	Measuring Point (every 500 ft. downstream to upstream)		
Year	1	2	Total area in acres
1942	40 ft.	48 ft.	7.7
1961	34 ft.	21 ft.	5.4
1980	13 ft.	42 ft.	2.8
2000	6 ft.	4 ft.	1.1

Figure 46. The 1942 Aerial Photo Overlain on the USGS 7.5-minute Topographic Map with 20-foot Contour Intervals. Note the distributary channels downstream of Roberts Road. The distributary channels near Roberts Road may also be described as floodplain channels. The distributary channel that leaves the channel adjacent to the east-west line of trees flows down through the uphill pointing “V” in the 180-foot contour line.



The low ridge, the levee and channel dredging prevent flood waters from Copeland Creek entering the ephemeral channel. Under pre-settlement conditions, the ephemeral channel may have acted as a distributary channel of Copeland Creek. The Roberts Road, which cuts across the top of the fan, also tends to prevent the formation of distributary channels.

The channel incision observed in the study reach extends upstream to near the Lichau Road Bridge. Measurements in the study reach show that it is unlikely that there would be any overbank flow even during the largest floods. According to Hooke (as cited in Schumm, Mosley and Weaver, 1987), trenching which prevents overbank flooding is indicative of a cause that is external to the alluvial fan.

These factors may have effectively shifted the function of the fan head to downstream of the Roberts Road Bridge.

The channel slope decreases in the downstream direction (Figure 47). Thus, the bed material size is also expected to decrease downstream. Once the boulders and cobbles drop out, the channel should be able to fill-in areas of excessive width due to bank erosion from a large flood event. In other words, excessive width is likely to persist in reaches with very large bed material but not in reaches where the dominant bed material can be transported by a bankfull event.

The Roberts Road Bridge over Copeland Creek is shown in Figure 48 and 49. The low clearance of the bridge (see Figure 48) limits the size of the flood that can pass under the bridge with out forming a backwater area upstream. I did not measure the width and height of the opening with a tape measure. But, pacing the width of the opening under the bridge gave a width of approximately 40 feet. Standing near the edge of the water gave a rough distance from the bottom of the bridge to the water surface of about 5 feet. These rough estimates coupled with the flood frequency estimates in Table 6 suggest that a backwater area may develop for floods with a return period greater than about 10-years. The presence of a backwater area during large storm events has allowed the floodplain just upstream of the bridge to be maintained, see Figure 49.

The constriction by the bridge reduces the magnitude of floods with a return period greater than that required to form the upstream backwater area. In other words, the bridge acts as a metering device for the largest floods. Limiting the magnitude of the larger floods also limits the size of the largest bed material that can be transported downstream of the bridge. Limiting the magnitude of the largest floods also limits the power of the largest floods downstream of the bridge, at least until the point where the bridge is over-topped.

The Petaluma Hill Road Bridge may also constrict the passage of large flood events. Field measurements were not made at the Petaluma Hill Road Bridge so the size of the flood that may be constricted by the bridge is unknown.

Figure 47. Slope at Each Contour Line, Calculated Between the Previous and Next Contour Line, Versus the Distance from the Laguna de Santa Rosa Channel. An exponential function was fit to the data using linear regression. The exponential function represents the expected slope. Note that the upstream side of the bridges at Petaluma Hill Road, Roberts Road and Lichau Road all have lower than expected slopes. The survey of the study reach produced a channel slope of 0.029. The slope between adjacent contours in the vicinity of the study reach was 0.03.

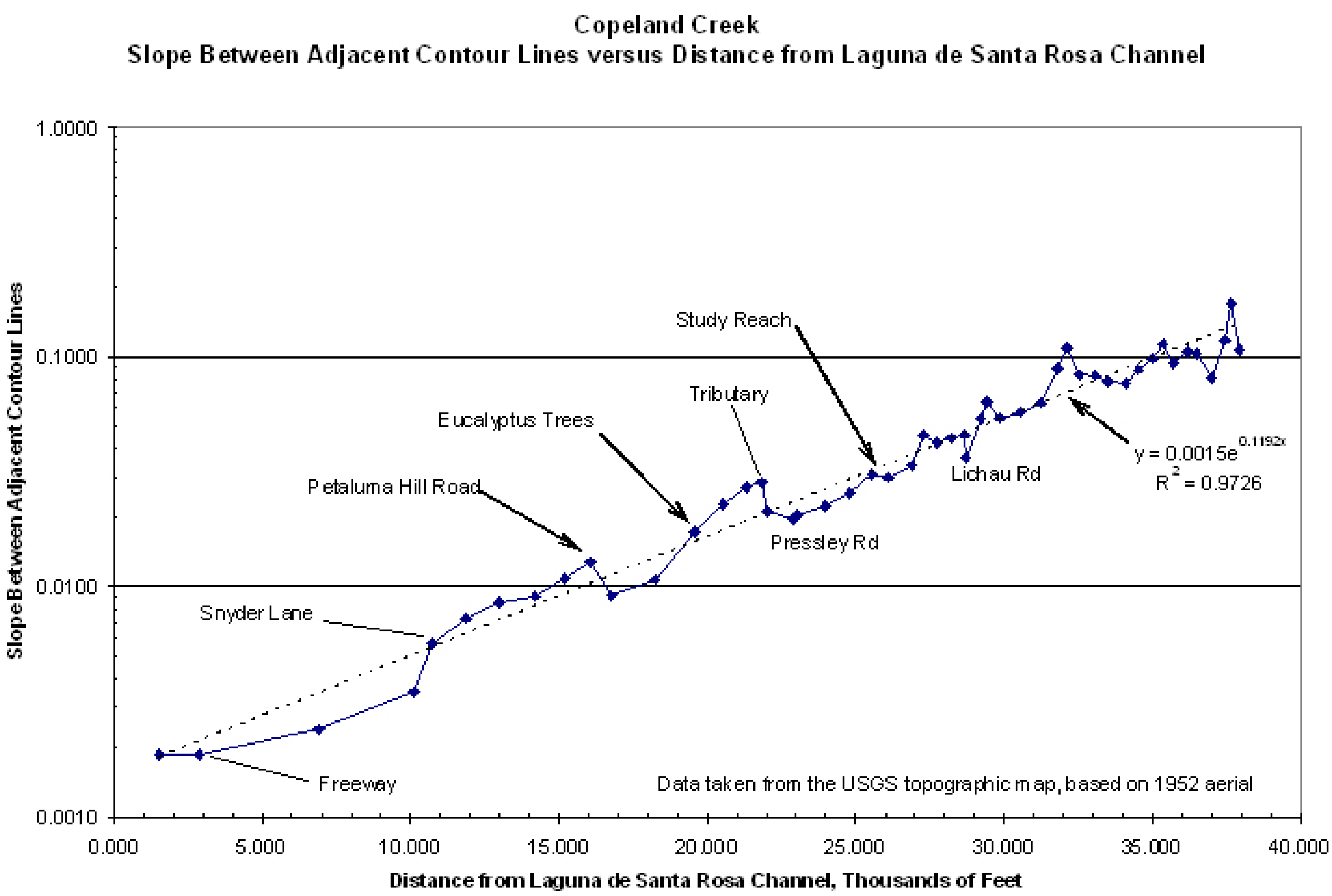


Figure 48. The underside of the Roberts Road Bridge over Copeland Creek Viewed from Upstream. The distance between the bridge abutments is roughly 40 feet and the distance from the water surface to the bottom of the bridge is roughly 5 feet. The bridge may constrict floods with a return period greater than roughly about 10-years.

Figure 49. Looking Downstream at the Roberts Road Bridge over Copeland Creek. The bottom width of the active channel upstream of the bridge is about 20 feet. The bankfull width was not measured but is probably about 30 feet, which is in fair agreement with the predicted bankfull width of 24 feet. Note that a floodplain has developed on the left bank. The bridge constricts floods with a return period greater than about 10-years. The floodplain may have been maintained upstream of the bridge because large catastrophic floods are constricted by the bridge. During a large catastrophic flood, the reach upstream of the bridge would be in a backwater area.

Channel Changes: Alluvial Fan Reach

Figures 42 to 45 demonstrate changes in the alluvial fan reach between 1942 and 2000 and show a wider flow area for the photos taken soon after a flood year than those in relatively low water years. However, overall the width of the active channel of Copeland Creek has not changed dramatically since 1942.

Table 11 is a modification of Schumm, Mosley and Weaver's (1987) table of the identified causes of fanhead trenching expanded to show which factors are external to the Copeland Creek fan and which are internal. Table 11 also shows whether a cause is affecting the Copeland Creek fan and an example of how it is affecting the fan.

Since the channel in the study reach appears wide and deep enough to hold any likely flood without any overbank flooding, the cause of the trenching is probably external to the alluvial fan (Hooke, 1967). Seven potential external causes of fanhead trenching may have affected the Copeland Creek fan. Three of these causes have already occurred on the Copeland Creek fan. These causes are (1) an intense rainfall event as exemplified by the January 1862 event or the December 1955 event; (2) base level lowering caused by channelization of lower Copeland Creek; (3) tectonic activity such as associated with the 1906 earthquake and movement on the Rodgers Creek fault. Therefore, at the present time, it is not possible to say which of the nine factors influencing the Copeland Creek alluvial fan are responsible for the over-widening and incision of the channel in the fanhead.

The large storm of 1861-1862, which affected all of California, may have generated a very large flood event on Copeland Creek which may have had the power to widen the creek in a single catastrophic event. It is unlikely that evidence supporting this speculation will be found.

An alternative hypothesis to a single large storm being the cause of the fanhead trenching is that a series of large storms are responsible for the widening of Copeland Creek. Figure 50 shows the monthly rainfall at the Napa Fire Station from 1905 to 2002. The rainfall has been scaled by the median water-year rainfall (23.41") for the Fire Station.

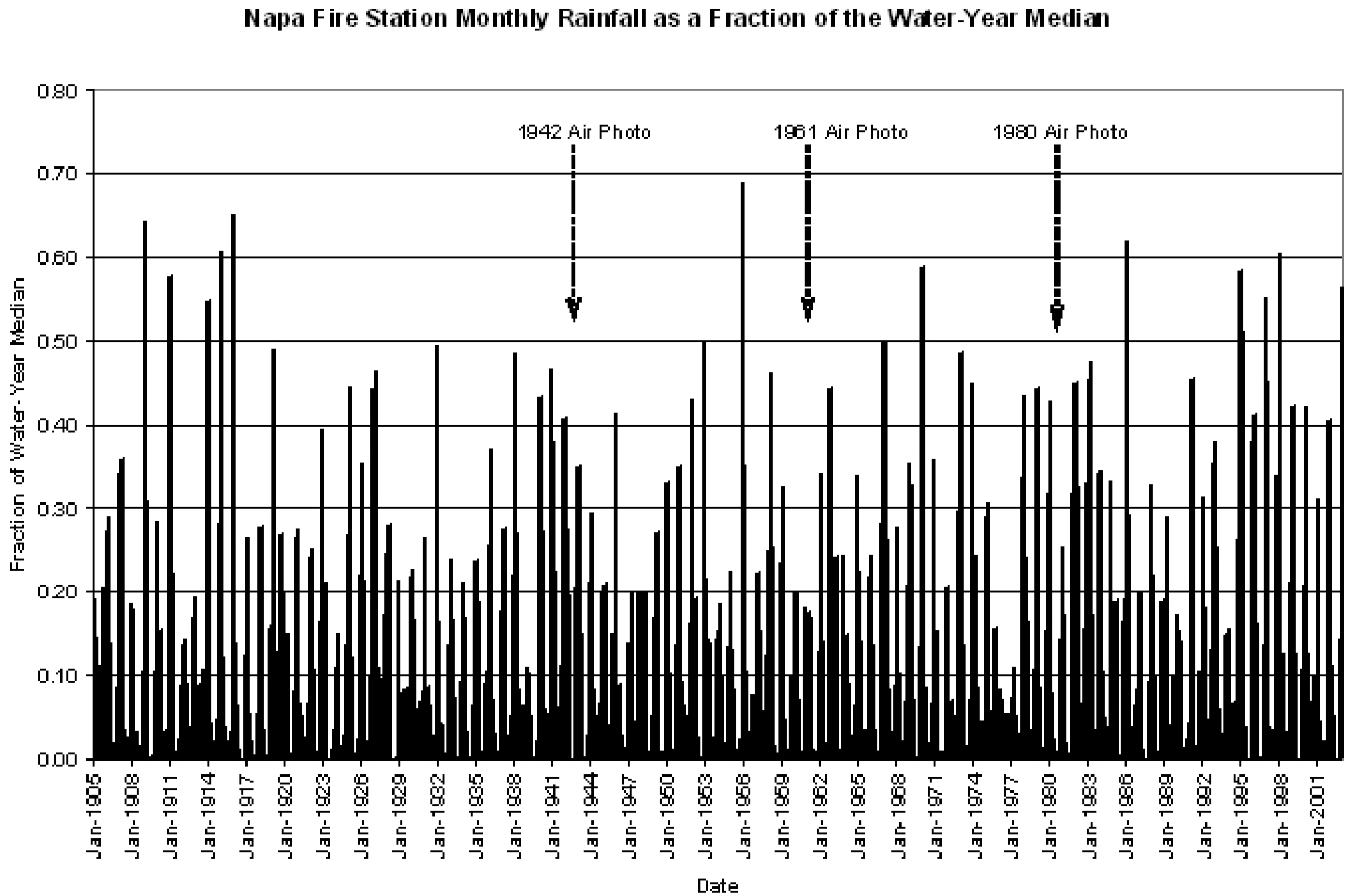
In Figure 50, a monthly rainfall ratio (month/water-year median) of 0.50 represents 11.71" of rainfall. A monthly rainfall ratio of 0.50 indicates that one-half of the total rainfall in a median water-year fell within a single month. Large floods tend to be associated with such high intensity rainfall. It is likely that relatively large floods occurred on Copeland Creek when the rainfall ratio in Figure 50 was greater than 0.50. Figure 50 shows that five out of the 8 years between 1909 and 1916 had rainfall ratios greater than 0.50. These floods may have been responsible for widening Copeland Creek or perhaps they continued the widening process that may have begun in the 1862 event.

The change from pre-settlement conditions to an intensively managed landscape may have exacerbated the effects of a large intense rainstorm. Grazing began in the watershed in the early 1800s. The largest recorded flood in California occurred in January of 1862 following almost four weeks of rainfall. The entire length of the Sacramento and San Joaquin Valleys

Table 11. The table of identified causes of fanhead trenching from Schumm, Mosley and Weaver has been modified to show if a cause is internal or external to alluvial fan processes and whether it is likely affecting the Copeland Creek alluvial fan.

Cause Number	Cause of Apex Incision	Internal (I) or External (E) Process	Influencing Copeland Creek Alluvial Fan?	Example of Process
1	Climate change towards more arid conditions.	E		
2	Deglaciation	E	No	
3	Regime change from predominance of mudflows towards more frequent streamflow conditions	E	No	
4	Regime change resulting in an increased frequency of mudflows.	E	No	
5	Stream capture in the drainage basin resulting in increased discharge.	E	No	
6	Tectonicism (uplift and or tilting).	E	Yes	Rodgers Creek Fault
7	Decreased load.	E	Maybe	Improvement in land management.
8	Increase in the frequency of high magnitude rainfall events with corresponding decrease in low magnitude rainfalls.	E	Maybe	California has experience many long periods (25 - 60 years) of drought over the last few thousand years
9	Extreme event of intense rainfall, runoff.	E	Yes	Flood of January 1862
10	Destruction of drainage basin vegetation resulting in increased surface runoff.	E	Maybe	Grazing on the alluvial fan. Significant change in vegetation in upper watershed has probably not occurred.
11	Alternation of debris flows and water flows.	I	Maybe	Debris flows may have accompanied large intense storms, presence of small boulders in the study reach.
12	Erosion of fan surface, headward gully erosion, followed by capture.	I	Yes	Normal alluvial fan process.
13	Lateral channel migration to steeper areas on the fan surface.	I	Maybe	Normal alluvial fan process.
14	Base level lowering (adjacent valley incision).	E	Yes	Channelization of lower Copeland Creek
15	Toe trimming (valley stream encroachment).	E	No	
16	Basin down-wearing over geologic time.	E	No	Mountains surrounding the basin are uplifting.

Figure 50. Napa Fire Station Monthly Rainfall for 1905 to 2002 as a Fraction of the Water-Year Median Rainfall. The water-year median rainfall for the Napa Fire Station is 23.41". Months with rainfall greater than 0.50 are associated with large flood events. January of 1909, 1911, 1914, 1915 and 1916 all had rainfall in excess of 0.5 of the annual water-year median rainfall. There was also a very large storm in December 1861.



were turned into lakes about 20 miles wide. While no records are available, rainfall amounts in the Copeland Creek watershed were likely very high.

The large size of the bed material in the Copeland Creek study reach is probably only moved by large rare floods or by debris flows associated with intense rainfall. Debris flows may move the larger bed material into the alluvial fan reach from landslide deposits in the headwaters reach. The more frequent floods around bankfull size probably cannot move the large bed material. Therefore, the creek can not re-arrange the bed material during the more frequently occurring flood events. Thus, the over-widened condition tends to persist. So each successive large flood may have contributed to the widening.

Another possible factor in the incision of the creek in the alluvial fan reach is changes made to the valley reach. Straightening the Copeland Creek channel in the valley reach shortened the channel length and resulted in a steeper slope. A steeper channel slope provides more energy to move sediment. The result of increasing the channel slope is identical to lowering the base level. The increased slope caused the sediment transport capacity to increase which resulted in channel incision. The channel incision would have generated a headcut that would have propagated upstream until it encountered a bedrock outcrop or a significant armor layer. It is unlikely that a bedrock outcrop would have been encountered until close to the Lichau Road Bridge since the channel is on an alluvial fan. Thus, it is possible that the incision from straightening the channel in the valley reach affected the alluvial fan reach. Once the incision occurred the banks may have been over-steepened and subsequently collapsed resulting in the over-widening. As mentioned, the large size of the armor layer on the alluvial fan channel may prevent frequent flood events from forming a floodplain in the over-widened reach.

The Rodgers Creek Fault cuts across the Copeland Creek watershed upstream of the Lichau Road Bridge. Even though the Rodgers Creek fault is a right-lateral fault, movements along it may result in some uplift. Uplift near the fault may be sufficient to increase the channel slope and thereby result in incising the fanhead trench. Or, uplift may have increased the likelihood of debris flows reaching the fanhead and setting up conditions for cause 11, alternation of debris and water flows.

Historic Changes: Valley Reach

In the earliest maps of the Cotati Valley (1867), there is no channel for Copeland Creek indicated. Instead, the valley is a complex of wetlands. Wetlands and overflow lands are common downstream of alluvial fans. The fan is highly porous and percolates stormwater. It is also steep enough for the creek to transport most fine sediment to the valley. The valley receives both surface storm flows and subsurface flows, creating a lake/wetland area. The valley area was likely relatively flat. The current Copeland Creek channel was created through the wetlands by at least 1877, probably to move stormflows and drain the area.

Channelization and flood control management is an attempt to keep all stormflows in the Copeland Creek channel and remove the function of the floodplain to spread out and slow down floodwater and deposit fine sediments. The accumulation of sediment, mostly silts and sands, is evident in the flood control channel. As depicted in Figures 20 to 23, Copeland Creek in the 1942 and 1961 photos had little to no vegetation. With the advent of urban development and management of the creek as a flood control channel, a larger riparian corridor is depicted in the 1980 and 2000 photos (see Figures 22 and 23). The valley reach is a modified wetland/lake system, a very different hydrologic system than a creek modified into flood control channel.

Channel Changes: Valley Reach

Although no measurements of sediment deposition exist for the valley reach of Copeland Creek, it is believed that the channel is filling in with fines at a rapid rate and that the upstream creek and rural areas are the cause (Sonoma County Water Agency, 2004, Sonoma State University 2001). There are two types of sediment to consider: 1) fine sediment carried as wash load and; 2) coarse sediment carried as bedload. The actual size range for each type (size) of sediment depends on the energy of the stream. A particle of sand that was carried in the water column in a reach with a high gradient may settle out and become bedload in a low gradient reach.

Table 8 shows that the amount of fines (less than 0.062 mm) in the subsurface area of the creek channel dramatically changes between Snyder Lane and Highway 101. This change is likely due to a decrease in channel slope and the backwater effect from the Laguna de Santa Rosa such that during storms, water-surface slope would probably be less than the channel slope.

There are several likely causes for the sediment filling the flood control channel in the valley reach: 1) low gradient of the flood control channel exacerbated by backwater from the Laguna de Santa Rosa, 2) the alluvial fan reach and 3) fine sediment from watershed erosion.

The creek channel downstream of Snyder Lane has a very low gradient of less than one percent. The low gradient means that Copeland Creek lacks the power to move sediment downstream. The backwater from the Laguna de Santa Rosa may decrease the flood water surface slope to a lower value than the channel slope measured from the topographic map. The backwater area acts like a lake. In other words, the Copeland Creek flood control channel downstream of Snyder Lane is a natural depositional zone.

The underlying problem with sediment deposition in the Copeland Creek flood control channel is the perceived loss of floodwater channel capacity. However, the backwater effect from the Laguna de Santa Rosa will still be present under larger floods even if Copeland Creek is dredged. Therefore, dredging the Copeland Creek flood control channel will not effectively increase its channel capacity if the backwater from the Laguna de Santa Rosa is not addressed. This is a restatement of the fact that channel capacity is the product of cross sectional area and velocity and that velocity depends on the water-surface slope (energy grade).

Significantly reducing the coarse sediment load from the watershed upstream of the alluvial fan may cause fanhead incision, see cause 7 in Table 11. Initiation of fanhead trenching, downstream of Roberts Road, would probably cancel out the benefits of reducing the sediment load from the upper watershed. Reducing the fine sediment load (wash load) from the upper watershed may result in a decrease in deposition below Snyder Lane but the not necessarily increase channel capacity since the backwater from the Laguna de Santa Rosa may still be present.

So, the deposition of sediment in the channelized portion of Copeland Creek may be similar to deltaic deposits in a lake and may not be indicative of an excessive sediment load from the upper watershed.

Copeland Creek on the alluvial fan, between Roberts Road and the start of the channelization upstream of Snyder Lane, maybe in equilibrium, that is, the channel may be adjusted to carry the water and sediment load provided from upstream. The 1942, 1961 and 1980 aerial photos show some modest changes in the plan-form of Copeland Creek but no extreme changes.

Copeland Creek on the alluvial fan, between Roberts Road and the point where it becomes channelized is a meandering alluvial channel with a map slope of 0.02 near Roberts Road to 0.007 where it is channelized just upstream of Snyder Lane. Bank erosion is commonly found on a meandering stream on the outside of bends. In such a stream, bank erosion on the outside of a bend tends to be countered by deposition on the inside of bends. So measuring the amount of bank erosion may overestimate the sediment load reaching Snyder Lane, unless the amount of channel and floodplain deposition is also accounted for.

However during bankfull events or smaller, when the outside of a bend is eroded, the corresponding downstream deposition on the inside of a bend will have a coarser particle-size distribution since the finer material will be transported further downstream or become part of the wash load. During events larger than bankfull, a portion of the fines from upstream bank erosion may be deposited on the floodplain or in distributary channels. In large floods, coarse and fine sediment may be deposited on the surface of the alluvial fan along distributary channels and on channels crossing the floodplain. Both areas of deposition are outside of the main channel.

Riparian Vegetation

The riparian corridor of Copeland Creek was delineated and digitized on aerial photographs from 2000 and field-checked in as many locations as were available (see Figure 51). Table 12 lists the acreage of riparian vegetation along three reaches of Copeland Creek.

Table 12. Acreage of Riparian Corridor Along Copeland Creek.

Reach	Acreage
Headwaters:	
Adjoining creek	54.7
Creek canyon slopes	196.3
Alluvial Fan	38
Valley	38.5

The riparian corridor in the headwaters section of Copeland Creek from the Lichau Road Bridge upstream is very dense with no major breaks in canopy coverage. Only the vegetation immediately adjacent to the confined channel was mapped as riparian; however, the full extent of oak and bay forest on hillsides above and next to the channel was also mapped. This section of the creek is dominated by live oak (*Quercus agrifola*) and California bay laurel (*Umbellularia californica)* with white alder (*Alnus rhombifolia*) and big leaf maple (*Acer macrophyllum*) next to the low-flow channel. Douglas fir (*Pseudotsuga menziesii*) is scattered in the oak and bay forest. Along several ephemeral streams and on hillsides in this reach are springs and wetlands with Fremont cottonwood (*Populus fremontii*), willow (*Salix* spp.), rushes (*Juncus* sp.), chain link fern (*Woodwardia fimbriata*) native blackberry (*Rubus ursinus*), and non-native Himalayan blackberry (*Rubus discolor*).

A review of aerial photographs from 1942, 1961, 1980 and 2000 does not show any significant change in the riparian corridor or vegetation on adjacent hillsides between 1942 and present in the headwaters reach (Figures 13 and 14). Copeland Creek had perennial flow in 2003 and 2004 in the reach upstream of the Lichau Road Bridge.

At the Lichau Road Bridge as the creek makes the transition from confined to unconfined channel, the alluvial fan reach begins, there is a very dense and wide riparian forest made up of California buckeye (*Aesculus californica*), willow (*Salix* spp.), white alder (*Alnus rhombifolia),* big leaf maple (*Acer macrophyllum*), California bay laurel (*Umbellularia californica)* and live oak (*Quercus agrifola*). The understory includes snowberry (*Symphoricarpos rivularis), native blackberry* (*Rubus ursinus*), nettles (*Urtica* sp.) chainlink fern (*Woodwardia fimbriata*), native honeysuckle (*Lonicera hispidula)* non-native Himalayan blackberry (*Rubus discolor*) and a variety of annual grasses.

Most of the rest of the alluvial fan reach has sparse vegetation cover with the largest trees being live oaks (*Quercus agrifola*) scattered along the outside edges of the current channel and in the most upstream area of the reach. There are large areas

Insert Figure 51. Riparian Vegetation.

of creek channels without any vegetation. There are white alder (Alnus rhombifolia), red willow (*Salix laevigata*), sandbar willow (*Salix sessilifolia*), *Psoralea macrostachya* and large amounts of non-native Himalayan blackberry (*Rubus discolor*) growing along the main creek channel. The alders and willow are relatively young, maybe 20 to 25 years old and may represent a period of re-growth following a very major storm. Throughout this reach the creek has multiple channels, very little mature vegetation and only sparse young vegetation (Figures 52 and 53). This reach of Copeland Creek had intermittent flow by July and was largely dry by September 2004.

Figures 42 to 45 show this reach in 1942, 1961, 1980 and 2000 with the creek meander corridor outlined. In the 1942 photograph, there is a scattered corridor of oaks in the area upstream of the Roberts Road crossing and very few oaks in the downstream area. California bay laurel may also have been present. There is no willow, alder or brushy growth on most of the creek. By 1961, there are fewer oaks in the reach and no brushy vegetation in the channel. In the 1980 photograph, the upper portion of the reach looks very similar to the 1961 photograph. The lower portion of the reach in 1980 shows signs of flooding with numerous channels, but does not have an increase in vegetative growth.

Typically, alluvial fans are made of highly porous sand and gravel that quickly percolates runoff downward and out to flatter valley areas. These conditions do not support germination and growth of deciduous riparian plants. It is understandable that evergreen trees, such as live oak and bay laurel would be able to grow in the alluvial fan reach. Grazing in the alluvial fan reach could also have removed most of the deciduous trees prior to the 1942 photo.

The valley reach extends from Petaluma Hill Road to the outlet of Copeland Creek and represents the most altered area of Copeland Creek. Early maps of this reach show extensive wetlands in this area and no well-defined stream channel. As stormflows percolated through the alluvial fan, as well as ran over its surface, downstream areas would have received a large amount of runoff in a short timeframe. Within this wetland area, it is likely there were riparian forests and marshes. As can be seen in the 1942 photograph (Figures 20 to 23), this reach of Copeland Creek was straightened and channelized over 70 years ago and its riparian forest and wetland removed. Comparing the 1942, 1961, 1980 and 2000 photographs, this reach has a larger riparian corridor today than in the 1940s.

In the upstream area of this reach, Copeland Creek is somewhat natural in the SSU area. The creek has a level of sinuosity, and pool and riffle bedforms (see Figures 54 and 55). There are low (5 to 10 feet) levees along the channel on the floodplain. Mature willow dominates the riparian corridor with Himalayan blackberry very abundant in many locations. A number of different native trees have been planted – coast redwood (S*equoiadendron sempervirens*) big leaf maple (*Acer macrophyllum*), live oak (*Quercus agrifola*), Fremont cottonwood (*Populus fremontii*) along with native grasses and understory species (see Figure 56 and 57).

Figure 52. Copeland Creek in Alluvial Fan Reach.

Figure 53. Sparse Vegetation and Large Size Bed Material of Copeland Creek in Alluvial Fan Reach.

Figure 54. Copeland Creek Channel on Sonoma State University Campus.
Note Gravel and Cobble on the Channel Bed.

Figure 55. Copeland Creek Meanders Through Sonoma State University.

Figure 56. Copeland Creek Riparian Corridor on Sonoma State University Campus with New Plantings.

Figure 57. Big Leaf Maple Planted on Edge of Copeland Creek Corridor.

Downstream in the valley reach, Copeland Creek is a flood control channel with no sinuosity or bedforms in the channel and a row of trees and shrubs such as willow, eucalyptus, black locust, weeping willow, Himalayan blackberry and pampas grass along the edge of the channel (Figure 58 to 63). There are herbaceous wetland plants, such as cattails (*Typha latifolia*) and sedges (*Carex* sp.) growing in the channel bottom. The channel appears aggraded with silt and sand and dries up in the summer.

Invasive and ornamental plants are very common along the flood control channel. Invasive Himalayan blackberry is very abundant throughout the riparian corridor. No *Arundo donax* was observed in the field or aerial photographs.

Water Temperature

Background

Water temperature has a large effect on aquatic life and aquatic habitats. In a Mediterranean climate, water temperatures are cold during the rainy months of late fall, winter and early spring. In the hot, dry summer months, water temperatures can increase greatly.

There are a number of factors that affect water temperature – the volume of water flow; the daily hours of sunlight; ambient air temperature; the amount of shade over the water surface, typically called canopy cover; the width and depth of the stream channel and water flow; and the source and temperature of summer water flow – groundwater or reservoir releases.

Most aquatic organisms live in either cold or warm water and are adapted to a particular range of temperatures. Steelhead trout are cold water fish, preferring water below 65ºF. At higher water temperatures of 70-75ºF, there is less dissolved oxygen in the water. While steelhead can withstand temperatures of 70ºF, if exposed to this warmer water for prolonged periods, juvenile fish become lethargic, swim slower and eat less. This behavior reduces the juvenile's ability to survive and makes them more prone to predation. When water temperatures are greater than 70ºF, steelhead need to have a cold water refuge area. This refuge area could be a cold groundwater inflow, or spring, along the bottom or banks of the creek, or a deep shady part of a pool where the fish can cool down in a current of 65-68ºF, or less, water. If a cold water refuge is not available, the warm water may prove lethal to the steelhead. If temperatures exceed 70-75ºF on a regular basis, or for many hours a day, steelhead juveniles will not survive (Barnhart 1986, California Department of Fish and Game 1998).

Another effect of warm water temperatures in a creek is the increase in predatory fish such as pike minnow (*Ptychocheilus grandis*) or introduced green sunfish (*Lepomis cyanellus*) and small-mouthed bass (*Micropterus. dolomieui*). As steelhead

Figure 58. Copeland Creek Flood Control Channel at Snyder Lane Bridge.

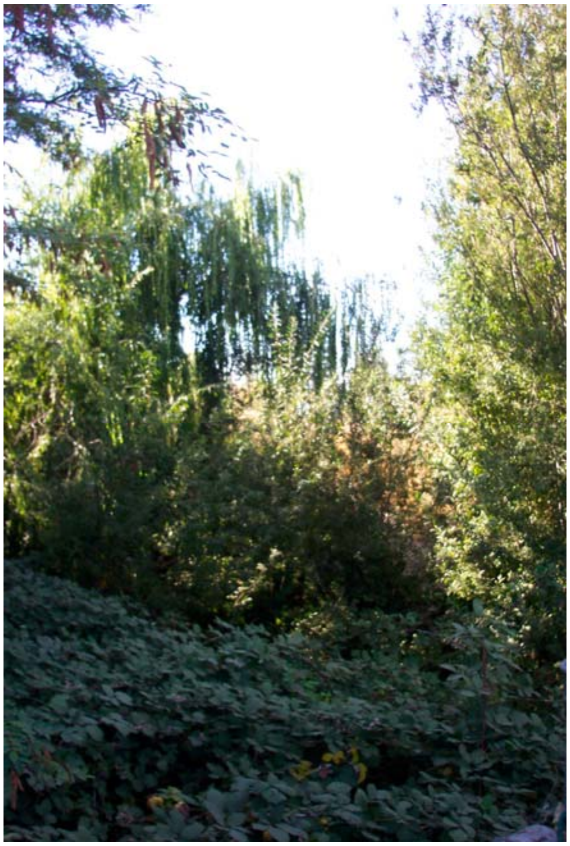
Figure 59. Copeland Creek Flood Control Channel at Country Club Drive.

Figure 60. Country Club Drive Bridge and Copeland Creek Channel with Invasive Non-native Pampass Grass.

Figure 61. Urban Development Fills the Copeland Creek Floodplain, Requiring All Floodflows to be Carried in the Flood Control Channel.

Figure 62. Commerce Blvd. Bridge over Copeland Creek Flood Control Channel.

Figure 63. View of Copeland Creek from Commerce Blvd. Bridge. Note dense Himalayan blackberry in channel.



juveniles become lethargic at higher water temperatures and predatory fish become more numerous, predation can greatly diminish juvenile steelhead numbers.

Monitoring Results

Water temperature was monitored over the June to September 2004 period in two areas of Copeland Creek (Figure 7). Table 13 lists the features of the five water temperature monitoring stations. These two areas of Copeland Creek are very different (Figure 64 and 65). Stations Copeland-45, 50 and 55 are in the headwaters reach (Monitoring Site 1) of the creek in a confined channel with perennial flows and dense evergreen riparian canopy. Stations Copeland-10 and 30 are in the alluvial fan reach (Monitoring Site 2) with intermittent flow and semi-dry conditions and a more open canopy of young riparian trees. Two air temperature stations were also monitored.

The water temperature monitoring data for Copeland Creek was evaluated for several features: the average daily maximum, the average daily minimum and the average daily median temperatures and a seven-day moving average (MA) of both the average daily temperature and the average daily maximum temperature; the daily range in temperature and the number of continuous hours water temperatures exceeded 70ºF (Appendix 2). These analyses give an indication of whether the station location can support steelhead rearing over the summer. The moving averages, along with the three daily averages, give an indication of the overall temperature conditions at the station. If the moving average of the average maximum temperature is in the 68-75ºF or greater range, and the daily range is small, then the water is not cooling sufficiently over the 24-hour period. Finally, the graph of the number of continuous hours water temperatures exceed 70ºF gives an indication of the duration of unsuitable to lethal conditions for steelhead at the station.

Tables 14 and 15 summarize the temperature monitoring data for all the Copeland Creek stations. The upstream stations had consistently cool water temperatures with zero hours of temperatures over 70 degrees F. The data logger at Station 45 dislodged and was floating on the pool surface and temporarily recorded higher temperatures due to air exposure. At the downstream Station 10, water temperatures stayed cool in the 65 to 67 degree F range until the pool dried up in August. At Station 30, the pool was cool, but became very shallow and isolated over the summer.

Water Quality

Background

The quality of the water in a stream is affected by activities in the watershed as well as the natural features of the watershed. There are three broad types of materials

Table 13. Description of Water Temperature Monitoring Stations in the Copeland Creek Watershed.

Station Number	Type of Channel	Deployment Width/Depth (in ft.)	Retrieval Width/ Depth (in ft.)	% Slope of Channel	Average % Canopy Cover	Watershed Drainage Area (in sq. mi.)	Comments
Copeland 10	Unconfined alluvial	5.6/0.9	0/0	2-4%	46%	3.4	In study reach; low level of vegetation in stream overall and at station site. Pool dried up in August.
Copeland 30	Unconfined alluvial	6.6/0.7	3.8/0.6	2-4%	94%	3.4	In study reach; highly shaded pool retained water but became isolated pool in late summer; same as V-star pool site. Data logger floating on pool surface; repositioned into pool.
Copeland 45	Confined	10.4/0.8	9.2/0.5	4-8%	82%	1.3	In Fairfield Osborn Preserve. Continuous flow. Data logger floating on pool surface; repositioned into pool.
Copeland 50	Confined	6.6/1.8	8.6/1.7	4-8%	94%	1.3	In Fairfield Osborn Preserve. Dense forest cover over confined channel. Continuous flow June to September 2004.
Copeland 55	Confined	6.6/1.05	6.4/0.88	4-8%	87%	1.3	In Fairfield Osborn Preserve. Dense forest cover over confined channel. Continuous flow June to September 2004.

Figure 64. Copeland Creek in Headwaters Reach, Near Monitoring Site One, with Canopy of Oak and Bay.

Figure 65. Copeland Creek Near Monitoring Site Two in Direct Sun with Algal Bloom.

Table 14. Copeland Water Temperature Monitoring Summary 2004.

Station*	Year	7-Day Moving Average of Average Daily Temperature	7-Day Moving Average of Average Daily Maximum Temperature	Daily Range	Number of Hours >70ºF (in hours)	Comments
Copeland-10	2004	Jun-Jul: 65-66ºF	Jun-Jul: 66-67ºF	2-3ºF	0	Data logger out of water 7/24-8/9. Placed back in pool 8/10. Pool dry 8/25.
Copeland-30	2004	Jun-Aug: 63-65ºF	Jun-Aug: 66-67ºF	1-4ºF	0	Data logger dislodged and floating on surface in early September; placed deeper into pool.
Copeland-45	2004	58-62ºF	61-69ºF	1-2ºF	0	Data logger dislodged and floating on pool surface 8/2-8/12. Placed back in pool 8/13.
Copeland-50	2004	58-62ºF	59-63ºF	0-2ºF	0	Continuous measurement June-September.
Copeland-55	2004	57-59ºF	58-62ºF	0-2ºF	0	Continuous measurement June-September.
***** All stations are numbered in increasing order from downstream to upstream. Graphs of temperatures are in Appendix 2.						

Table 15. Copeland Air Temperature Monitoring Summary 2004.

Station*	Year	7-Day Moving Average of Average Daily Temperature	7-Day Moving Average of Average Daily Maximum Temperature	Daily Range	Number of Hours >70ºF (in hours)	Comments
Copeland-30a	2004	Jun-Aug: 65-72ºF	Jun-Aug: 80-130ºF	2-60ºF	1-6	Air temperatures at Station 30.
Copeland-45a	2004	58-70ºF	71-87ºF	2-22ºF	1-10	Air temperatures at Station 45.
***** All stations are numbered in increasing order from downstream to upstream.						

found in water. The first one is suspended material such as clay particles, which affect the clarity of the water. Chemicals make up another type of material found in water. The third material is biological organisms such as phytoplankton, single-celled floating algae. In most cases, it is the concentration of chemicals in the water that is of concern.

Water vapor in the sky and rain falling to the ground picks up chemicals from the air. Rain hitting the earth can dissolve chemicals from the land surface and move them into a creek. Rainfall and stormwater will dissolve chemicals from soil and rock as it percolates into and through soil layers. Even in a forest the rainfall will pick up low levels of organic acids from decaying plants on the forest floor. In urban areas, rainfall will pick up oil and grease, heavy metals, pesticides, nutrients and other materials and move them into a creek.

The amount of chemicals in a stream will vary over the time of the year. During winter when rainfall and streamflow levels are high, the large amount of water serves to dilute the concentrations of chemicals in streamflow. However, during the dry months of the year when streamflow is low, any inflow of chemicals is not diluted and can have significant effects on water quality and aquatic life. For example, summertime irrigation of lawns, gardens and agricultural areas can produce chemicals in runoff such as nitrogen and phosphate from fertilizers. These substances serve as nutrients in the aquatic system and are available in very low amounts under natural conditions. These nutrients stimulate algal growth. Algae grow rapidly and form thick mats on the water surface or carpets on the stream bottom. Eventually, as the nutrients are used up, the algae growth diminishes and dies back and bacteria break down the algae. As this process occurs, the bacteria use up much of the oxygen in the water through respiration. This process of algal growth and die-off can result in a reduction of the dissolved oxygen in the stream and have negative effects on steelhead trout and aquatic life (Davis et al 1963, Meehan 1991, Schmitz 1996).

The temperature and pH of the water also changes the effect of some chemicals on the water. For example, ammonia, a form of nitrogen, becomes far more toxic to fish and aquatic organisms under higher temperatures or higher pH. This difference is due to a change in the chemical form of the ammonia from an ionized form (NH_4^+) to the un-ionized form (NH_3) that is far more toxic. Because of these interactions, water quality monitoring tests for a group of chemicals along with temperature and pH.

Certain water quality parameters are monitored to indicate the ambient water quality in a creek (Stednick 1991, North Coast Regional Water Quality Control Board 1998).

These include:

<u>Water temperature</u> – unlike the continuous monitoring of water temperature using the data loggers, this measurement is of the water temperature when the other parameters are measured. A non-mercury thermometer is placed in the stream for at

least three minutes at the same location where the other parameters will be sampled and read immediately after removal from the water.

pH – is the measurement of hydrogen ions and hydroxyl ions defining the acid or base level of the water. The pH scale runs from 0 (highly acidic) to 14 (highly basic) with 7.0 as neutral. The scale is logarithmic, meaning that a small change in numbers, from 7.0 to 5.0 represents an increase in hydrogen ion of one-hundred times. pH is largely influenced by soil and hydrology, but is also affected by land uses.

Most aquatic organisms are adapted to a small range of pH and cannot tolerate changes. pH levels influence the availability of nutrients and their effects on aquatic life. For example, at acidic pH levels, heavy metals that are typically bound to clay particles, release into the water, become available to aquatic organisms and can concentrate through the food chain.

Dissolved oxygen (DO) - is the oxygen content of water. Steelhead trout require relatively high levels of DO as do many aquatic insect larvae. Carp, catfish and snails are examples of aquatic organisms adapted to low levels of DO. DO enters the water from the atmosphere through turbulence as water flows over riffles and cascades in the stream. DO levels vary with water temperature; higher temperatures reduce dissolved oxygen levels. As described previously, unnaturally high nutrient levels that induce algal blooms can decrease DO through the respiration of bacteria breaking down the algae.

Similarly, septic leakage can result in bacterial action and reduce DO levels. High inputs of sewage or fertilizer can reduce DO levels to the point of killing fish in a section of stream. Aquatic plant growth can also create daily fluctuations in DO levels. During daylight hours, when plants and algae are photosynthesizing, oxygen is created, but during the night, the plants respire and may use up much of the DO in the stream. Excessive aquatic plant or algal growth can result in very low DO levels in the early morning hours.

Ammonia – contains nitrogen, a plant nutrient, which if available at a high level, will induce algal blooms and eventually lower DO levels. Ammonia typically comes from livestock waste, sewage and septic leakage and fertilizer runoff. High levels of ammonia in the water keep fish from excreting ammonia wastes from their bodies and can result in a toxic condition. At higher pH or water temperatures, ammonia changes from the ionized form (NH_4^+) to the un-ionized form (NH_3) and becomes far more toxic to aquatic life.

Nitrate – is another form of nitrogen that is found in creeks at low levels under natural conditions. Bacteria in the water extract nitrogen from the air and convert it into nitrate. Soil bacteria convert plant material into nitrate. Excessive nitrate will induce algal blooms and ultimately reduce DO levels in the stream. Sources of nitrate include livestock waste, eroded agricultural and residential soil, fertilizers, septic leakage and sewage.

Phosphate – is another nutrient that, when available in excessive amounts, can induce algal blooms and ultimately lower DO levels. Under natural conditions phosphate, a form of phosphorous, binds to soil particles and, if released through erosion into streams, is quickly taken up by plants or algae. Sources of excessive phosphate include soap and detergent such as from car washing, sewage and septic leakage, fertilizer runoff and livestock waste.

Monitoring Results

Staff from the Sotoyome RCD monitored ambient water quality in monitoring site 2 for the July to September 2004 period. As this area of Copeland Creek dried out, the monitoring site was moved from Station 10 to Station 30. Table 16 lists the results of the monitoring. Ammonia, pH, nitrate and phosphorous are within water quality standards; however, dissolved oxygen levels were consistently below 50 percent saturation, making rearing conditions unfavorable for steelhead juveniles. DO conditions at the upstream stations in Monitoring Area 1, where continuous streamflow occurred, were favorable for steelhead rearing.

Another source of water quality data for Copeland Creek is the First Flush Water Quality Monitoring program. Trained volunteers gather water samples in urban creeks during the first rainstorm. During the first rainstorm, built up material on pavement, houses and gardens is washed into creeks. The first flush measures urban runoff at the beginning of the rainy season when pollutant levels can be greatest and effects on aquatic life can be dramatic. Urban runoff is the largest source of pollution in California waterways. All oversight, lab work and sample analysis for the First Flush is done by qualified scientists, assisted by volunteers.

Table 17 outlines the results of the First Flush monitoring in 2002 and 2003 for several sites in the Copeland Creek watershed. Only the urban lower watershed was sampled in the First Flush program and the results represent non-point pollutants from the urban area. The results for bacteria are high. Total coliform represents both fecal coliform and non-fecal coliform from decaying vegetation and other sources. E. coli results are also high. E. coli are a type of fecal coliform bacteria that is known to cause illness in humans. Water quality standards for coliform, and specifically E. coli, are listed in Table 18.

California water quality objectives for coliform bacteria allow a median of less than 240 to a maximum of 10,000 total coliform per 100 ml. for water contact recreation. While Copeland Creek is not used for water recreation, these standards indicate the levels of coliform and E. Coli measured in Copeland Creek far exceed these standards.

Another result of the First Flush monitoring on Copeland Creek is Diazinon levels in excess of 90 ng/l. This level was defined by the California Department of Fish and Game as the amount of the insecticide, Diazinon that the water flea (*Daphnia* sp.) can tolerate. Diazinon is a common urban garden insecticide.

Table 16. 2004 Copeland Creek Water Quality Data.

Creek Name	Copeland	Copeland	Copeland	Copeland
Site	Copeland-10	Copeland-10	Copeland-50	Copeland-30
Date	7/16/04	8/12/04	8/12/04	9/15/04
Time	13:00	12:15	14:00	11:30
Air Temperature (ºF)	83º	73º	65º	84º
DO (ppm)*	4.0/0.8	3.0/2.6	7.5	5.0/2.2
Water Temperature (ºF)*	67º/66º	64º/64º	60º	64º
% Oxygen Saturation*	45%/9%	32%/28%	75%	53%/24%
pH	7.1/7.1	7.1	—	7.0
Ammonia Nitrogen (mg/l)	0.2	0.2	—	0.3
Nitrate-Nitrogen (mg/l)	0.2	0.2	—	0.2
Phosphorus (mg/l)	0.5/0.4	0.5	—	0.2
Conductivity (uS)	560/560	660	—	410
Comments	Stagnant with pools	Stagnant with isolated pools	Continuous flow	Stagnant with isolated pools

* Measurement on left is done with Chemettes kit; measurement on right is done with modified-Winkler kit. The Winkler kit is considered the more reliable and accurate method (P. Otis, Regional Water Quality Control Board, 2004, pers. comm.).

Table 17. 2002 and 2003 First Flush Program Results for Copeland Creek.

Station	Collection Date	Stream-flow Stage (cm)	Specific Conductivity (uS)	pH	Temperature (ºF)	Total Ammonia Nitrogen (mg-N/L)	Ortho-phosphate (mg-P/L)	Nitrate (mg/L)	Turbidity	TSS (mg/L)	E. coli. (MPN/ 100ml)	Total coliform (MPN/ 100 ml)	Diazinon (ng/l)
Copeland Creek at Commerce Blvd.	11/7/02	12.2	400	7	57	0.83	0.68	1.0	7 TUN	—	17,000	>240,000	180
		15.2	410	7	57	0.78	0.79	0.8	6 TUN	—	26,000	>240,000	230
		18.2	350	7	59	0.88	0.8	0.8	7 TUN	—	22,000	>240,000	110
		—	—	—	—	0.75	0.59	0.3	7 TUN	—	16,000	>240,000	110
Copeland Creek at Commerce Blvd.	11/7/03	15.2	290	6.7	55	.36	0.37	20.5	—	11.26	1300	240,000	ND*
		15.2	290	6.7	55	0.31	0.5	—	—	11.33	1900	240,000	ND
		15.2	290	6.7	55	0.5	0.5	—	—	12.67	2200	240,000	230
Copeland Creek at Country Club Dr.	11/7/03	24	150	7.0	57	1.82	0.48	4.52	95.6 NTU	56.77	17,000	240,000	—
		24	150	7.0	56	1.38	0.33	1.9	55 NTU	36.87	44,000	240,000	—
		23	150	7.0	56	1.17	0.31	1.69	43.7 NTU	24.9	20,000	240,000	

* ND = no detect.

Table 18. EPA Ambient Water Quality Criteria for E. coli.

Geometric Mean of E. Coli. (per 100 ml. of freshwater)	
Maximum per 100 ml at:	
Designated Beaches	235
Moderately Used Areas	298
Lightly Used Areas	406
Infrequently Used Areas	576

Land Use Planning

The City of Rohnert Park General Plan, revised in 2002, sets out policies and land use designations for lands within City boundaries and the City's Sphere of Influence. Petaluma Hill Road is designated as the urban growth boundary and edge of the City's Sphere of Influence. Several elements of the City's General Plan are relevant to the likely future condition of the Copeland Creek watershed.

City of Rohnert Park

The City's General Plan designates the area outside and east of the City in the Copeland Creek watershed for open space/agriculture and resource management and as a priority open space acquisition area. The Copeland Creek channel in the City is designated for Open Space – Environmental Conservation (see Figure 66).

The Open Space Element includes the following goals and policies:

GOALS: OPEN SPACE

OS-A Maintain a greenbelt around the city that provides a physical and visual space between Rohnert Park-Cotati and Santa Rosa, Petaluma, and Penngrove.

OS-B Maintain land surrounding the city as open space for the enjoyment of scenic beauty, recreation, and protection of natural resources of the community.

OS-C Minimize conflicts between agricultural and urban uses.

OS-D Maintain and enhance the Petaluma Hill Road scenic corridor.

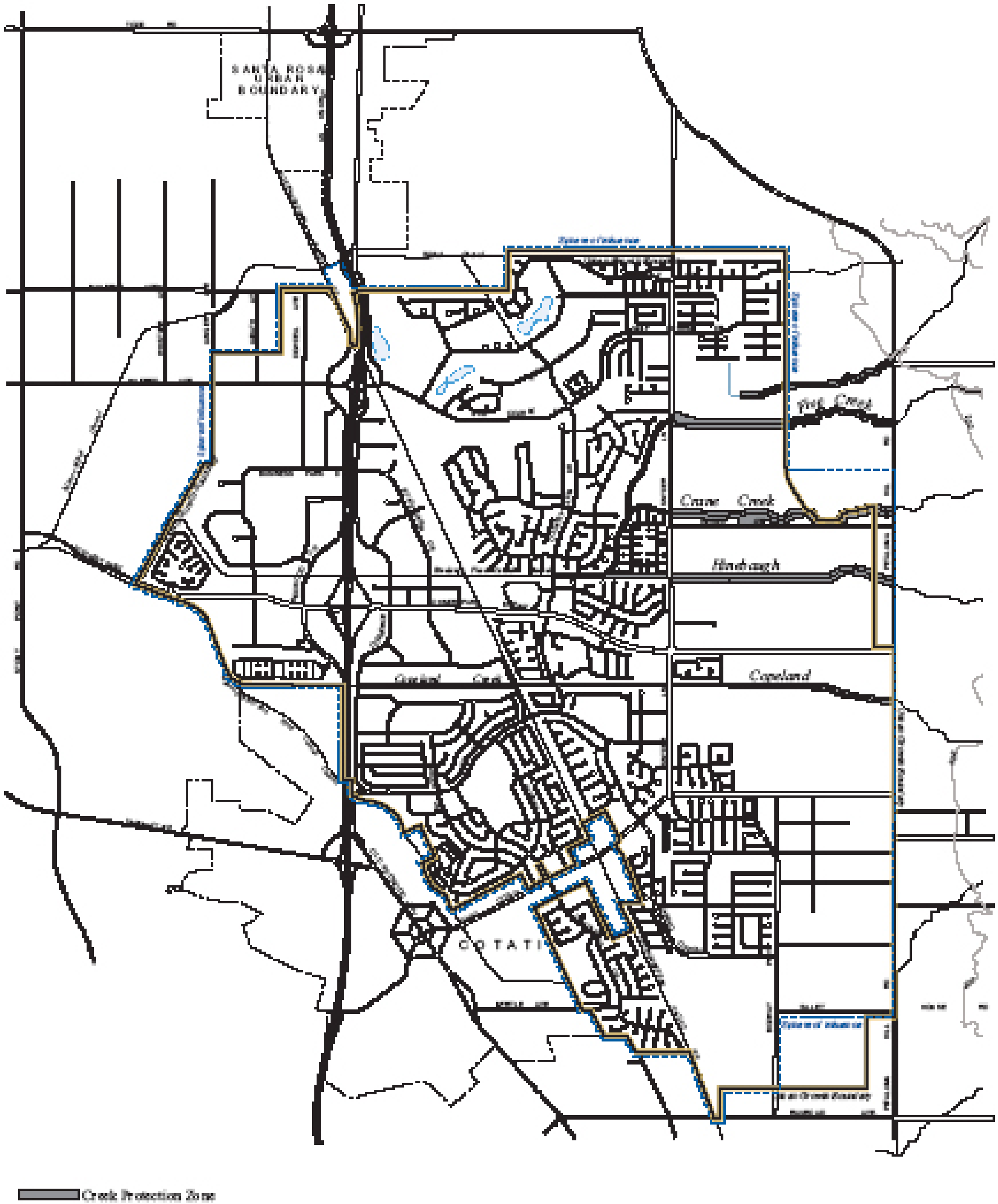
OS-E Maintain publicly owned open space areas in their natural state; provide public access in a manner that is compatible with the conservation of habitat.

POLICIES: OPEN SPACE

OS-1 Work with Sonoma County to ensure that land in the Planning Area designated as Open Space in the Rohnert Park General Plan is maintained in rural use or as permanent open space.

Because the City is not contemplating annexation of any land to the east of Petaluma Hill Road or open space land in the northeast, development in these areas will continue to be regulated by the County General Plan and Zoning Ordinance. The City can take several steps to encourage the County to maintain the area in open space or rural land uses, including:

Figure 66. City of Rohnert Park General Plan, Environmental Conservation Element.



- *Formal agreement with the County to ensure that the County and the City will maintain land outside the Rohnert Park Urban Growth Boundary as open space in their general plans at least until the year 2020; and*
- *Seeking language in the County General Plan requiring the County to consult with the City for any development within the Rohnert Park Planning Area.*

OS-2 Encourage dedication of the open space buffers along the westside of Petaluma Hill Road as part of the University District and Northeast Specific Plans. Crane Creek marks the northern edge of the University District Specific Plan Area. As shown on the General Plan Diagram, the open space buffer between the University District Specific Plan Area and Petaluma Hill Road is about 30 acres in size. Policy CD-36 requires preparation of an Open Space Plan as part of the Specific Plan and a minimum 30-acre open space buffer. Open Space buffers in the Northeast Specific Plan area would include the proposed Community Fields.

OS-7 Use creek protection zones (see Section 6.2) for permanent public open space and compatible purposes including habitat conservation, bike and walking paths, wildlife habitat, and native plant landscaping. Creeks are located in close proximity to residential neighborhoods, providing accessible open space getaways for residents. Adverse impacts to ecologically sensitive habitat, wildlife, and wetlands should be minimized in the planning, construction, and maintenance of paths.

The Environmental Conservation, Habitat and Biological Resources element of the City General Plan indicates the Copeland Creek riparian corridor as habitat for Foothill yellow-legged frog and tri-colored blackbird, both Species of Special Concern and the floodplain north of this corridor as moderate potential wetlands area. The Copeland Creek riparian corridor is designated as a creek protection zone.

This element includes the following goals and policies:

GOALS: HABITAT AND BIOLOGICAL RESOURCES

EC-B Protect special status species and supporting habitats within Rohnert Park, including species that are State or federally listed as Endangered, Threatened, or Rare.

New development projects in ecologically sensitive areas should consider impacts on valuable and sensitive natural habitats.

EC-C Protect sensitive habitat areas and wetlands in the following order of protection preference: 1) avoidance, 2) on-site mitigation, and 3) off-site mitigation.

These priorities are in accordance with the California Department of Fish and Game guidelines.

EC-D Maintain existing native vegetation and encourage planting of native plants and trees.

POLICIES: HABITAT AND BIOLOGICAL RESOURCES

Special Habitat Areas

EC-4 Cooperate with State and federal agencies to ensure that development does not substantially affect special status species appearing on any State or federal list of rare, endangered, or threatened species. Require assessments of biological resources prior to approval of any development within 300 feet of any creeks, high potential wetlands, or habitat areas of identified special status species.

Ecologically sensitive sites include areas that are classified as having high wildlife habitat value, high wetlands potential or high vernal pool and rare plant habitat potential. Also, special status species have been observed in the vicinity of Rohnert Park. Conservation will provide for the perpetuation of threatened, endangered, and other rare species, as well as the protection of the unique and diverse ecology of these areas as a whole. Development located in or adjacent to these ecologically sensitive areas must complete a site-specific assessment of biological resources as part of the development review process. The City's environmental review process would be used to impose appropriate mitigation measures on development to reduce impacts on sensitive habitat and special status species.

Wetland Conservation

EC-5 Require development in areas with high and moderate wetlands potential and habitat areas delineated in Figure 6.2-1, as well as other areas where wetland or habitat for special-status species is present, to complete assessments of biological resources."

Assessments of biological resources would consider the impacts on wetlands and the special status species supported by this habitat. Appropriate mitigation measures may be required as a condition of approval for development that significantly impacts wetlands or special status species. If any development is permitted within wetlands, mitigation measures must be considered. This mitigation may include providing wetland habitat of the same type as the lost habitat, equal in size or larger than existing conditions. Off-site mitigation in designated open space, the community separator, or other similar areas should be required in cases where on-site avoidance or mitigation is not possible. Off-site mitigation sites should be as close to the project site as possible.

Wetlands are a subset of "waters of the United States" and receive protection under the Clean Water Act § 404. Wetlands are defined by the federal government [CFR § 328.3(b), 1991] as those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Under normal circumstances, the federal definition of wetlands requires all three wetland identification parameters to be met, whereas the CDFG definition requires the presence of at least one of these parameters. For this reason, identification of wetlands by CDFG consists of the union of all areas which are periodically inundated or saturated, or in which at least seasonal dominance by hydrophytes may be documented, or in which hydric soils are present. The CDFG does not normally have direct jurisdiction over wetlands unless they are subject to jurisdiction under Streambed Alteration Agreements or they support State-listed endangered species. The CDFG recommends a minimum buffer, measured outward from the edge of any wetland, be established to protect the wetlands.

EC-6 Work with private, non-profit conservation, and public groups to secure funding for wetland protection and restoration projects.

Since the City's ability to fund these projects is limited, funding for restoration projects should be sought from a variety of sources. The City should consider creation of a "wetlands bank" on the westside areas not contemplated for development or in the proposed golf course. The bank would provide a large area for off-site mitigation of development located elsewhere in the city, in the event that onsite avoidance or mitigation is not feasible.

Native Species

EC-7 Encourage planting of native vegetation in new development sites, parks, public areas, and open space.

Guidelines should be developed that include a list of native species that may be planted as part of landscaping associated with future development. Drought tolerant and low maintenance species should be emphasized.

EC-8 As part of the City's Park, Recreation, and Open Space Master Plan (see Chapter 5: Open Space, Parks, and Public Facilities), institute an ongoing program to remove and prevent the re-establishment of invasive plant species from ecologically sensitive areas, including City parks and other City-owned open space.

Removal of invasive species from public parks and open space or in areas with high wetland potential, is required only where these species are known to threaten habitat for special status plant and animal species. Removal of invasive species may also be required if they are a notable fire hazard in parks or open space.

Creeks

EC-13 Maintain creek protection zones extending a minimum of 50 feet (measured from the tops of the banks and a strip of land extending laterally outward from the top of each bank) for creeks, with extended buffers where significant habitat areas or high potential wetlands exist (Figure 6.2-2). Where high potential wetland or other biological resources exist, require appropriately wide buffers to encompass and protect the resource. Development shall not occur within this zone, except as part of greenway enhancement (for example, trails and bikeways). Require City approval for the following activities within the creek protection zones:

- *Construction, alteration, or removal of any structure;*
- *Excavation, filling, or grading;*
- *Removal or planting of vegetation (except for removal of invasive plant species); or*
- *Alteration of any embankment.*

Rohnert Park's creeks are a key part of the City's open space network. They are valuable physical, aesthetic, recreational, and ecological assets. Protection of creeks protects not only surface water quality, but also reduces flood risks, preserves bio-diversity and habitat, minimizes erosion of stream banks, and prevents downstream siltation. The General Plan designates 3.5 miles of creekways in the new growth areas on the City's eastside. Wider buffers—up to about 150 feet from the creek bank—could be required because high potential wetland areas alongside creeks in some areas extend to about a 150-foot width.

EC-14 As part of specific plans, require evaluation and implementation of appropriate measures for creek bank stabilization, and any necessary steps to reduce erosion and sedimentation, but preserve natural creek channels and riparian vegetation.

<u>Sonoma State University</u>

In 2000, SSU approved a Master Plan for the portion of Copeland Creek that flows through the campus. The Master Plan includes the following goals:

GOAL 1: Maintain and protect the native biodiversity, ecological processes, and conditions of Copeland Creek and its associated in-stream, riparian, transitional, and upland habitats.

GOAL 2: Restore native species, biotic communities, ecological processes, and conditions in Copeland Creek and its associated in-stream, riparian, transitional, and upland habitats.

GOAL 3: Increase community awareness and appreciation of Copeland Creek and its associated habitats as an important campus amenity by providing opportunities for public access, recreation, and education, in forms not inconsistent with Goals 1 and 2.

GOAL 4:	*Increase knowledge and understanding of native biodiversity, ecological processes, ecological restoration, and human impacts in and around riparian ecosystems in general, and Copeland Creek in particular, through research and educational activities undertaken by Sonoma State University faculty and students, provided these activities are not inconsistent with Goals 1 and 2.*
GOAL 5:	*Maintain and improve hydraulic function of Copeland Creek in a manner that combines flood control requirements with ecological restoration and water quality considerations.*

For each of these goals, the Plan outlines a number of policies and implementation measures. These measures include: maintenance measures to reduce impacts on creek vegetation, methods to monitor and maintain flood (hydraulic) capacity in the channel, development restrictions with a 150-foot setback from each bank of Copeland Creek, a set of measures to inventory the corridor, remove invasive plants and revegetate the corridor and measures to increase appropriate access to the creek, reduce debris and pollutants from campus stormdrains and coordinate research and activities in the corridor.

County of Sonoma

The Sonoma County General Plan has not been updated since 1989 and has a few general policies that are relevant to the Copeland Creek watershed.

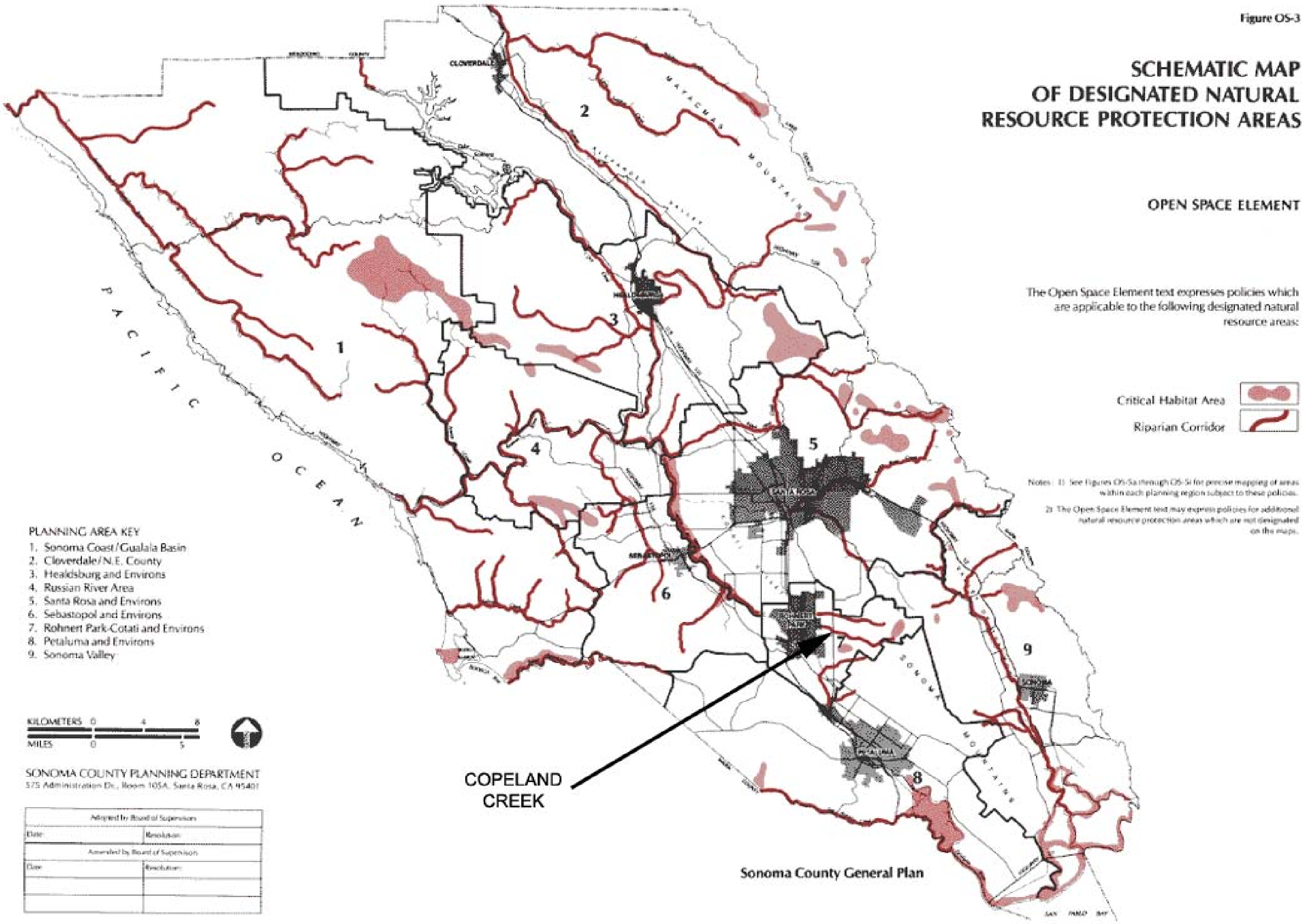
The Sonoma County General Plan was approved in 1989 and is currently being revised. The County General Plan applies to the unincorporated lands of the eastern Copeland Creek watershed (see Figure 67). The General Plan Open Space Element designates this area of the watershed as a scenic landscape unit and includes the following goals and objectives:

Goal OS-2:	*Retain the largely open, scenic character of important scenic landscape units.*
Objective OS-2.1:	*Retain a rural, scenic character in scenic landscape units with very low intensities of development. Avoid their inclusion within spheres of influence for public service providers.*
Objective OS-2.2:	*Provide opportunities for consideration of additional development in scenic landscape units in exchange for permanent open space preservation.*

The following policies in addition to those of the Land Use Element shall be used to accomplish the above objectives:

OS-2a:	*Avoid amendments to increase residential density in scenic landscape units in excess of one unit per ten*

Figure 67. County of Sonoma General Plan Open Space Element.



acres. The land use plan may designate a lower density or larger minimum lot size.

OS-2b: *Avoid commercial or industrial uses in scenic landscape units other than those which are permitted by the agricultural or resource land use categories.*

The Open Space Element also identifies Copeland Creek as a riparian corridor and recommends the following goals and objectives:

Goal OS-5: *Provide protective measures for riparian corridors along selected streams which balance the need for agricultural production, urban development, timber and mining operations, and flood control with preservation of riparian values.*

Objective OS-5.1: *Classify important streams with native vegetation as "riparian corridors". Develop guidelines to protect and manage these areas as valuable resources.*

The County shall use the following policies to achieve the above objective:

OS-5a: *Classify riparian corridors designated in the open space element as follows:*

1) *"Urban Riparian Corridors" include those portions of designated corridors within urban residential, commercial, industrial, or public/quasi-public land use categories.*
2) *"Russian River Riparian Corridor" includes the corridor adjacent to any part of the Russian River which is neither located within the above urban riparian corridor nor within the jurisdiction of a city.*
3) *"Flatland Riparian Corridors" include the corridors adjacent to any streams which flow through predominantly flat or very gently sloping land, generally with alluvial soil. This classification excludes areas covered by 1) and 2) above.*
4) *"Upland Riparian Corridors" include the corridors adjacent to streams not included in the above three categories.*

IV. SUMMARY OF CONDITIONS:

- The watershed of Copeland Creek encompasses 5.1 square miles. The 9.1-mile Copeland Creek has three reaches – headwaters, alluvial fan and valley.

- Copeland Creek watershed is composed of Sonoma Volcanics in its headwaters reach, alluvial fan deposits and alluvium. The Rodgers Creek Fault crosses through the headwaters area. The headwaters area is mapped as mostly landslides and has springs and wetlands, slumps and landslides.

- Vegetation in the headwaters reach includes hardwood forest in the Copeland Creek canyon, tributary streams and on some hillsides. Annual grassland has replaced native bunchgrasses throughout the watershed following Euro-American settlement in the 1800s. Freshwater wetlands likely dominated the valley reach interspersed with riparian forest and native grasslands.

- Land use in the Copeland Creek watershed has changed significantly over the past 200 years. Spanish/Mexican settlement involved cattle ranching with most of the watershed part of the Carrillo Rancho. After statehood in 1850, smaller farms were developed with sheep and cattle grazing in the hilly areas, dairies, hayfields and other crops on the flatter lands. Oaks in the valley and alluvial fan reach were cut for firewood. In the valley reach, Copeland Creek was channelized and wetlands drained, removing most natural habitat areas.

  Since incorporation in 1962, the City of Rohnert Park has grown tremendously and occupies the downstream half of the watershed. The valley reach of Copeland Creek in the city is managed as a flood control channel with the goal of eliminating flood flows onto the urban floodplain. The upland area of the watershed remains rural.

  The Copeland Creek flood control channel requires maintenance and it is believed that the channel has been filling with sediment at a faster and greater degree in recent years. However, there are no quantitative measurements of sediment accumulation or removal from the channel.

- The headwaters reach with its steep and numerous channels, transports sediment generated in the watershed from landslides and other types of erosion to the alluvial fan reach.

  The head or apex of the alluvial fan reach of Copeland Creek is located at Lichau Road Bridge where the creek leaves the canyon and spreads out, depositing bedload made up of cobble, gravel and sand, and forming a fan. Alluvial fans usually have many channels, which during floods, will fill, erode and change locations over the face of the fan. One channel may entrench, capturing the flow from other channels and moving larger amounts of sediment downstream to the valley. However, the entrenched channel as it moves sediment, may backfill and the multiple channel form return to the fan.

The alluvial fan reach is steeper (1 to 4 percent slope) than the valley reach (less than one percent slope). The valley floor is a very low slope depositional area for finer sediment.

- The channel of Copeland Creek in the alluvial fan reach was surveyed and appears to have entrenched and over-widened at some point in the past. The current channel is about four times its expected bankfull width, as predicted using several methods based on watershed area. Large cobble armors the channel bed. A similar channel condition was measured in Carrigan Creek, just to the east.

  A review of historic aerial photographs of the alluvial fan reach of Copeland Creek documented changes in the width of the multi-channel area, but showed the main channel at the same over-widened size dating back to at least 1942. There are several possible causes for the over-widening and entrenchment. The over-widening and entrenchment may date to the 1800s, or early 1900s, when the introduction of cattle changed the primary vegetation in the headwaters from native perennial bunchgrasses to introduced European annual grasses. This vegetative change, along with soil compaction from numerous cattle, increases stormwater runoff and reduces infiltration, creating much larger volumes of floodwater into Copeland Creek. One of the largest floods in California occurred in 1861/62 and a number of large storms have been recorded since 1905. One or several large floods, coupled with changes in runoff conditions in the watershed could have caused the over-widening.

  Another potential cause of the entrenchment/over-widening in the alluvial fan reach is the channelization of the valley reach. Channelization shortens the channel length and results in a steeper slope. The steeper slope causes channel incision to move upstream and could have entrenched the channel through the alluvial fan reach. A third possible cause is tectonic uplift in the watershed in the headwaters reach, changing channel slope and causing entrenchment downstream.

  The alluvial fan reach serves as a depositional area for bedload, including sand. The fan processes of having multiple changing channels creates a broad area for sediment to deposit. With the entrenchment and widening of the Copeland Creek channel, even very large flows do not spread out over the fan, but are contained in the entrenched channel. Since the alluvial fan reach has a 1 to 4 percent slope under natural conditions, most fine sediment would not settle out and is transported to the valley reach and deposited. Based on a review of the 1942 to 2000 aerial photos, the current over-widened channel appears to be stable.

  Without detailed channel monitoring, it is not possible to say the alluvial fan channel is continuing to widen and generating excessive amounts of sand into the valley reach. Instead, the source of excessive amounts of fine sediment may be activities in the watershed that increase sheet and rill erosion.

The valley reach was once a wetland/lake complex and is very flat in slope, creating a natural depositional area for fine sediment. Sediment deposition in the channelized valley reach of Copeland Creek is also likely increased in certain size storms by the backwater effect of the Laguna de Santa Rosa.

- The riparian corridor varies from a dense canopy in the headwater reach, sparse vegetation in the alluvial fan reach, and a narrow corridor of native and non-native trees along the valley reach. Historically, it is likely that the alluvial fan reach with its high porosity, had sparse riparian vegetation and the valley reach with its higher water table and fine sediment substrate had more extensive riparian forest. The creek in the headwaters reach is confined and, in comparison with 1942 conditions, doesn't appear to have any lost riparian canopy.

- Water temperature monitoring in the summer of 2004 found continuous flow and cool water temperatures suitable for steelhead rearing in the headwaters reach and intermittent to dry channel conditions, warm water temperatures and unsuitable conditions in the alluvial fan reach.

- Water quality monitoring was carried out in the summer of 2004 in the alluvial fan reach and results were consistent with water quality standards.

- First flush monitoring in the valley reach found high levels of total coliform, E. coli. and Diazinon as a result of urban runoff during the first seasonal rainfall in 2002 and 2003.

- Land use plans for the City of Rohnert Park, SSU and the County of Sonoma support maintaining the riparian corridor of Copeland Creek and keeping the watershed east of Petaluma Hill Road rural and the watershed west of Petaluma Hill Road urban.

V. RECOMMENDATIONS

Based on the watershed assessment, there are several types of management and restoration actions that would improve water quality, creek and riparian habitats and flood control channel maintenance. These are:

- Reduction in sources of fine sediment in the watershed
- Revegetation/restoration of natural channel functions
- Reduction of urban runoff pollutants
- Flood control channel management
- Quantitative monitoring of channel conditions

Reduction in Sources of Fine Sediment in the Watershed

Sheet and rill erosion is the most common type of erosion. Sheet erosion occurs when raindrops strike bare ground; the surface layer of soil is mobilized and carried off in the stormwater. Rill erosion is visible where water concentrates into small rivulets and moves soil particles off even slight hillslopes into flatter areas. Sheet and rill erosion are common forms of erosion in numerous types of land uses, from urban construction to agriculture, to roads to rural residential areas. The most effective methods of reducing sheet and rill erosion are to:

- cover bare soil with grass, straw, erosion blanket or other measures
- reduce sources of concentrated runoff such as culverts, or dissipate the energy and reduce the erosion potential
- avoid ground-disturbing actions in winter months
- place seasonal barriers to catch or filter sediment-laden stormflows

These methods are termed Best Management Practices (BMPs) and each land use type has different BMPs. The following section outlines the potential erosion problems for a land use and recommends BMPs. Appendices 3 to 5 include a broad range of information on BMPs and erosion control.

Agriculture

There are several types of agricultural operations in the Copeland Creek watershed – cattle grazing, vineyards and row crops. Each of these has the potential to produce fine sediment through sheet and rill erosion.

Vineyards

Most vineyards are managed with a cover crop of grasses underneath the vines and in the avenues and turn-arounds to prevent sheet erosion. Vineyard roads can also be a source of fine sediment as can historic erosion sites on a vineyard property. Fish Friendly Farming is a local, comprehensive program to inventory erosion on vineyard property and formulate sediment control projects and apply BMPs.

Recommendations:

- Complete outreach to vineyard owners in Copeland Creek watershed to enroll in the Fish Friendly Farming program. This program will be administered by the Sotoyome Resource Conservation District in 2004/2005 and by the California Land Stewardship Institute thereafter. This green certification program can address erosion issues on the vineyard lands in the watershed. More details can be found at http://www.FishFriendlyFarming.org.

Cattle Grazing

Cattle grazing is carried out at a number of locations in the Copeland Creek watershed, including steep hillsides and riparian areas. Cattle grazing can have a number of environmental effects:

- Reduction in the density of grass cover on hillslopes with an increase in sheet erosion and runoff, producing a potential increase in erosion in ephemeral creeks and potential gully formation.
- Soil compaction with an increase in runoff and rill erosion.
- Creation of compacted animal trails with an increase in runoff and rill erosion.
- Ranch roads with the potential for rill and sheet erosion and gully formation
- Grazing of riparian areas can significantly reduce the size and extent of riparian trees and eliminate seedlings. As remaining trees grow old and no new trees grow, the banks of the creek may erode.
- Reduction to elimination of native deep-rooted grasses with replacement by shallow-rooted annual European grasses.

The way a cattle grazing operation is managed, the number of animals per acre, the quality and seasonality of the range, pasture size and cross-fencing, as well as the soil type, slope, climate and other site features will determine the level of soil erosion and other environmental effects (see Figure 68). There are many practices that can be used to revise grazing operations and reduce soil erosion and riparian impacts, but BMPs must be applied on a site specific basis.

- Typically, each site needs a grazing management plan that incorporates the economic goals of the operation with BMPs for attaining water quality and

Figure 68. Interacting Factors That Affect the Hydrologic Cycle in Rangeland and Pastureland Watersheds.

Soils	Plants	Environmental	Management
Soil morphology	Types of plants	Climate	Grazing intensity
Texture	Rooting morphology	Types of storms	Timing of grazing
Bulk density	Plant growth form (bunch, sod)	Precipitation type	Continuous vs. rotational systems
Compaction	Plant life form (grass, shrub, forb, tree)	Duration of storm	Pitting
Organic matter	Plant biomass, cover, density	Intensity of storm	Chiseling
Aggregate stability	Cryptogams (mosses, lichens, algal crusts)	Topography	Herbicides
Nutrient levels	Plant canopy layers	Geology	Seeding
Soil structure	Plant architecture	Aspect	Brush management
Infiltration rates	Successional dynamics	Slope	Fire
Percolation rates	Native vs. introduced plants	Microtopography	Prescribed burning
Saturated hydraulic conductivity	Plant competition		Past management history
Runoff characteristics	Physiological characteristic of plant species		Fencing
Rills and gullies	Physiological response to grazing		Hoof impact
Porosity	Biodiversity		Class of livestock
Erosion dynamics	Phenological stages		Type of livestock
Salinity			Disturbance
Alkalinity			Stockwater location
Biotic components			Past disturbance from farm implements
Parent material			Recreation
Pedogenic processes			Kinds and types of wildlife
Soil chemistry			

From: Natural Resources Conservation Service, Grazing Lands Technology Institute, 2003. National Range and Pasture Handbook.

environmental benefits. Appendix 3 includes a selection of documents on BMPs and grazing management plans.

Recommendations:

- Complete outreach to rangeland owners and cattle grazing operations. Priority should be given to properties along Copeland Creek. The Sotoyome RCD should be the primary implementation agency.

- The Sotoyome RCD should seek funds and work with the Natural Resource Conservation Service (NRCS) to prepare detailed grazing management plans for willing owners.

- Operations along Copeland Creek should implement either exclusionary fencing to keep cattle out of the creek or create riparian pastures. Riparian pasture allows limited grazing use of riparian forest with fencing of a wider corridor than exclusionary fencing. The concept is to revegetate the corridor and allow the cattle operation use of the corridor, but limit this use to a few weeks per year to reduce negative impacts on the riparian plants. In some cases, alternative water sources may need to be developed to allow cattle to remain outside of the riparian area. See Figures 69 and 70.

- Filter strips may also be needed along ephemeral creeks and the main creek corridor as well as next to any animal holding facilities. These strips are planted for the winter with rapid-growing grasses so that runoff is filtered before entering waterways. Large areas with confined animals may need additional measures, especially if the facility is near a waterway, including manure management (see Appendix 3).

- The effect of grazing on the many springs in the headwaters should be analyzed in the grazing plans. Fencing springs and providing alternative water sources could reduce ground disturbance and erosion at the spring site.

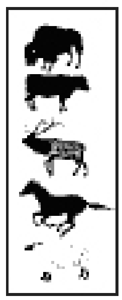
- The semi-arid climate of Sonoma County does not provide forage for year-round grazing and plans need to address rotation of cattle and resting of pasture to provide a defined minimum level of plant cover to protect soil from erosion.

- Appendix 3 includes a variety of resources on grazing practices and BMPs.

Figure 69. Diagrammatic Representation of Grazing and the Relationship to Soil Modification, Plant Species Compositional Change and the Consequential Effects on Hydrology and Erosion.

Increase	Decrease
• plant cover • soil organic matter • infiltration rate • soil water content • subsurface flow • aquifer recharge potential • ET potential • litter • cryptogam response where present on ecol. site • rangeland health • plant community integrity • enhances soil structure • soil aggregate stability • balance nutrient and energy cycle	• runoff • soil bulk density • soil detachment and erosion • sedimentation • site entropy

Proper grazing management and expected plant community response



Excessive grazing and expected plant community response

Increase	Decrease
• runoff • soil bulk density (compaction) • soil detachment and erosion • sedimentation • site entropy • risk of a nonrecoverable situation	• plant cover • soil organic matter • infiltration rate • soil water content • litter • cryptogam response where present on ecol. site • rangeland health • plant community integrity • soil structure • soil aggregate stability • subsurface flow and aquifer recharge potential • soil surface stability • balanced nutrient and energy cycle • ET potential

From: Natural Resources Conservation Service, Grazing Lands Technology Institute, 2003. National Range and Pasture Handbook.

Figure 70. Decision Support for Consideration of Riparian Areas as Key Grazing Area.

Factors	Riparian area characteristics		
Proportion of unit	< 5%	5 – 10%	> 10%
Livestock accessibility	Difficult because of surface rock, steep slopes, debris, etc.	Some difficulty, but consistently used by livestock classes able to deal with limitations (e.g., yearlings)	Readily accessed and consistently used by all classes of livestock.
Habitat/forage for livestock	Livestock do not congregate for protection or forage based on season of grazing, geographic location.	Livestock congregate for water, protection, or forage based on season of grazing, geographic location.	Livestock congregate for water, protection, and forage based on season of grazing, geographic location.
Ecological site	Similar to associated upland sites.	Different from associated sites; e.g., woody versus herbaceous species.	Different from associated sites; e.g., woody versus herbaceous species.
Ecological rating	No less than associated sites.	Less than associated sites.	N/A
Decision-support riparian area key grazing area status	Consider area as an integral part of the associated sites, but not necessarily as a key grazing area.	Consider area an integral part of the associated sites, and possibly as a key grazing area.	Consider area separate from associated sites; identify a key grazing area within.

* Select column based on preponderance of characteristics or a critical characteristic as determined by landowner.

From: Natural Resources Conservation Service, Grazing Lands Technology Institute, 2003. National Range and Pasture Handbook.

Row Crops

There is one area in the watershed where row crops are being grown on relatively flat land. The primary erosion concern with this type of operation is making sure that stormwater runoff and any applied chemicals do not enter a waterway. Winter filterstrips, or a cover crop if no winter crop is grown, will stabilize soil and filter out soil particles. Appendix 3 has detailed information on filterstrips.

Recommendations:

- The Sotoyome RCD should complete outreach to landowners and offer assistance in erosion control.

Roads

Copeland Creek watershed has both paved and unpaved roads in its headwaters area. Roads can be a major source of fine sediment in a creek. The road cut interferes with the movement of groundwater though the subsoil of the hillside. The groundwater reaches the road and changes to surface flow. Water flowing along a road can erode the road surface and potentially cause the road to fail. Soil eroded from the road surface or from a slope failure can be discharged into the creek.

Another change roads make in slope drainage occurs when the road crosses a swale or a creek channel. Typically the channel is filled and a road is constructed on top of the fill. A culvert is placed to direct water through the road fill. In large storms the culvert can plug, or be of inadequate size, causing the stormwater to erode away the fill. The road is damaged and a great deal of sediment enters the stream.

In general there are three types of roads: insloped, outsloped and crowned. The various types of road surfaces collect and direct runoff differently. Rilling of a road, caused by poor design, can introduce tons of sediment into a stream over the life of the road.

Insloped Roads

Insloped roads drain water inward toward the cut bank and usually into an inboard ditch. The ditch directs the runoff into a culvert, or other drainage facility, which crosses under the road and discharges the water onto the hillside below the road. The majority of roads in the Copeland Creek headwaters area are insloped. Problems with insloped roads include too few culverts, undersized culverts, and lack of energy dissipaters at the culvert outlet. The inboard ditch can also erode significantly, particularly in steep areas, around turns, or where the culverts are too widely spaced. The eroded soil adds to the silt load in the creek, or can settle out in the portions of the ditch where gradients are lower and fill the ditch, causing runoff to flood over and erode the road surface. When ditch relief culverts are undersized or there are not enough, they can rapidly plug with debris. The resulting dam backs-up water that eventually spills over the road surface, resulting in a gully.

Outsloped Roads

An outsloped road is constructed so that the roadbed slants to the outer edge of the road directing storm runoff outward onto the hillslope below the road. If properly designed, water sheets off the road before it can concentrate. Generally, there is no inboard ditch and culvert system for runoff. Instead rolling dips, a slight rise and dip in the road bed that divides the road into smaller units, are used. However, stream crossings may still be culverted and some areas of the road may still be insloped.

Outsloped roads are environmentally preferable, but there are sites where out-sloping can pose certain problems. These situations include: steep gradient roads; roads used in the winter season; certain types of curves; and areas with large amounts of runoff from upslope needing a ditch. It may be possible for much of a road system to be outsloped with certain sections insloped, or requiring ditches.

Crowned roads

Crowned roads drain both outward and inward from a central raised crown in the middle of the road. Crowned roads can work well on steep ridges, or for high quality, all weather roads. Crowned roads spread drainage both ways and are typically paved, all weather roads. Crowned roads may have an inboard ditch, ditch culverts, rolling dips, and possibly no ditch at all, depending on the site.

Stream Crossings

Stream crossings are another major drainage feature of road systems. These crossings consist of all the locations where the road crosses an ephemeral, intermittent, or permanent watercourse. It is important that all stream crossings are properly sized, designed, and installed, not just those over year-round creeks. Headwater streams and swales that flow only during large storms are often very steep and carry large amounts of flow and debris over short periods. This flow must be accounted for in the road crossing structure, or the road will fail resulting in silted creeks, property damage, and require costly repairs.

Culverts covered with fill are the most common type of road crossing structure and one of the most problematic. Culverted crossings fail often and by design require constant maintenance and frequent replacement. The road crossing over the swale or channel is filled with material and fitted with culvert(s) to transmit water through the fill. However, the creek or channel also transports sediment and debris as well as flood flows. Culverts easily plug or become overwhelmed in large floods. Flood flows come over the top of the road fill. If the slope and orientation of the road allows, the flood flows will flow into the inboard ditch and the road surface, damaging the road. Culverts should be sized to transmit a 100-year storm and installed at the same gradient as the bottom of the creek channel. If placed at this slope, the culvert is less likely to fill with sediment or erode at the outlet.

Bridges can have the least impact on stream processes if they are designed at an adequate length that avoids squeezing and filling the creek to create a smaller crossing. However, bridges with piers in the channel can collect debris during floods. The bridge can also fail due to undercutting of the piers or supports. Railroad flatcars can be used as year round bridges, or can be placed over the summer and removed during winter.

A ford consists of a road crossing over the bed of the stream channel. Another term is an at-grade, or Arizona, crossing. The ford may be made from compacted gravel, a lens of gravel set into the road bed for ephemeral creeks, or a concrete structure. Since the crossing is in the streambed, on large creeks winter floods may cause scour. Use of these crossings should be limited to avoid water quality effects and disturbance of the streambed. These types of crossings should never be used near fish spawning and rearing habitat.

Maintenance

All roads require regular maintenance as well as inspection during and after large storms to remove debris from culverts. In the headwaters of Copeland Creek watershed, most public roads are maintained by Sonoma County and private roads are maintained by individual landowners or road associations. Some required regular maintenance activities include:

- Clean inboard ditches of built-up sediment and debris, remove of slumps from road cut.

- Grade rilled areas and assessment of the cause of the erosion. Never dispose of sediment by pushing it off to the roadside or into a creek or swale. Create a spoils pile at a stable location away from waterflows and revegetate the material.

- Replace rock or energy dissipater at outlets of all ditch relief culverts, culverted crossings, water bars, and rolling dips. Use rock large enough to withstand storm flows. If the rock keeps getting washed out, buy a larger size or install a basin to hold the rock.

- Inspect all culverts for rust, failure, or filling. Replace culverts before they fail and increase small ditch relief culverts to at least 18 inches in diameter. Size stream crossing culverts for a 100-year flow or if possible replace culverted crossings with bridges.

Dirt driveways are roads. If the driveway is steep, cover it with angular gravel (3/4 to 1 inch) on a semi-annual basis and make sure that the driveway has drainage facilities such as water bars, culverts, or outsloping with rolling dips. Plant a dense grassy filter strip or other vegetation along driveway edges to catch sediment and oil and grease residues.

Riparian or streamside roads have direct and often deleterious impacts on streams. The best approach is to relocate the road further away from the stream. If this is not possible, plant a dense vegetation filter strip between the creek and road and maintain the road.

Recommendations

- The Sotoyome RCD should complete outreach to private landowners in the headwaters reach and provide assistance for road assessments and repairs. A road workshop for the residents in the headwaters area could be a first step.

- The County of Sonoma's Department of Public Works should review the condition of its roads in the watershed and determine maintenance and repair needs to reduce fine sediment generation. Most public roads are maintained for road safety and function not to control or correct environmental impacts.

Rural Residential Areas

There are scattered houses in the headwaters area. Given the steep topography and highly erodible soil, erosion control measures in these areas are important. Some rural residential sites also have horses on relatively small areas of land.

The following measures address some of the actions an individual homeowner can take to reduce generating fine sediment.

Recommendations:

Maintain Native Vegetation

- Dense native vegetation is the most effective protection for soil. Plants leaves and branches intercept rain drops and roots hold subsoil layers. Duff layers of leaves and needles protect surface soil.

- Do not clear native vegetation without replanting equally dense vegetation or protecting the soil. Limit tree and shrub removal, especially on the slope or stream bank below your house

- Ornamental plants, like roses or annuals, do little to hold soil and should not be used to replace native plants.

- Never remove vegetation from ephemeral streams or swales. These become creeks when it rains a lot and they will erode. Revegetate with native trees, shrubs or grasses.

- If you severely prune or remove trees on the hillside below your house or along your creek bank, you may be weakening the plants that help to stabilize your home.

- Remove ivy from your trees by cutting vines at the base of the tree trunk. Ivy can weaken the health of the tree and even kill it, thereby causing the tree to fall.

Stormwater Management

- Do not direct additional stormwater from your roof, patio or driveway into ephemeral streams. You may create erosion for your neighbor or destabilize your hill. Spread out stormwater, use French drains or other means to reduce problems.

- If you are near a road, look for culverts, waterbars, and rolling dips which direct road runoff onto your property and could cause erosion.

- Place large rocks to serve as energy dissipaters at the culvert or waterbar outlet.

- Revegetate below the dissipater if possible to protect the slope. Other steps to reduce the effects of roads are listed in the Roads section.

Construction on Hillsides

- Never start a project that involves grading, soil excavation, or major construction unless it can be completed and the bare soil seeded or revegetated prior to October 31.

- If you are planning any major grading, road building, diversion or redirection of an ephemeral stream or change to a creek/river bank or channel, you may be changing the direction of the flow of water and could damage other properties. Hire a civil engineer or geologist to review the project and avoid a costly liability problem.
- Construct retaining walls carefully even for gardens. Use long lasting materials that can hold up the area behind the wall and remember to include proper drainage to avoid failure.

Emergency Erosion Control Measures

- Temporarily reduce the small erosion problems with one of the following emergency erosion control measures and stabilize the site with vegetation or rock or other permanent means as soon as possible.

    - Strawbale check dam – Place strawbales as a temporary water bar across the entire width of the slope. Trench the strawbale into the slope surface at least four inches. Install several waterbars on a long slope and anchor with rebar into slope at least twelve inches deep.

    - Silt fence – Place near base of slope, anchor posts three feet into the ground and trench the base of the fabric into the ground several inches. Posts should pull fabric tight forming a barrier.

    - Jute netting – Anchor netting, burlap or other "fabrics" with rigid pins at least 10 inches long and overlap material pieces by 12 inches on edges.

    - Plastic – Place heavy plastic sheets over small gully or rill. Anchor with rebar or rigid pins, not rocks or sand bags. Overlap edges of sheets by 12 inches. Do not use on sites over 400 feet long. Re-adjust after storms to assure plastic covers the ground.

    - Straw wattles – These are installed the same as the strawbale checkdams above.

    - If you have large gullies or cracked or slumping areas on your hillside, contact a geologist or civil engineer to assess the situation.

Controlling Runoff from Horse Corrals, Stables and Pastures

Horses are often kept on small parcels of land in rural residential areas. The headwaters area of Copeland Creek contains a number of horses, many in areas adjacent to creeks.

Horses have several effects on water quality:

- Overgrazing in confined corral/stable areas and production of fine sediment.
- Production of manure, which runs off into stormwater.
- Compaction of ground, increasing runoff amounts.

Recommendations

There are a number of BMPs that can be carried out by horse owners to reduce environmental impacts (Appendix 4). These include:

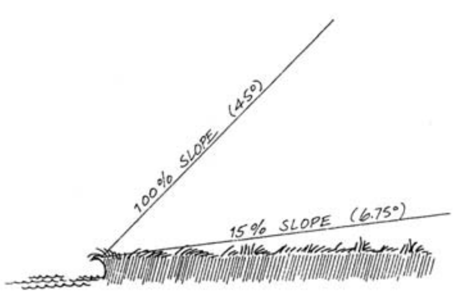
- Install vegetated buffers or filterstrips along the edges of the corral and stable areas. The vegetation should not be available to the animal for grazing. In grassland areas, filterstrips can consist of dense, fast-growing grasses seeded in spring and/or fall and irrigated, if necessary to create a filterstrip. Native trees and shrubs can also be effective as long as a dense understory of vegetation is present. Do not plant ornamental or invasive, non-native species and do not plant species that can poison or sicken horses. The width of the filterstrip is determined based on the slope of the pasture (see Figures 71 and 72).

- Fence horses out of all creeks, including ephemeral waterways. If a small winter-only creek flows through the pasture or corral, it is directly carrying mud and manure into the larger creek. This small, ephemeral creek should be underground with a pipe system or fenced out of the pasture. If the creek is used for water for the horse, an alternative trough site should be developed away from the creek and riparian corridor

- Manure must be managed on the site and kept out of waterways. Manure and soiled bedding must be collected from stalls, paddocks and pastures on a daily basis and stored away from creeks and to avoid contaminating runoff, protected by a tarp from rainfall. A containment berm should be built around the manure pile to hold any water that seeps into or under the pile. Manure can be composted and used as a fertilizer.

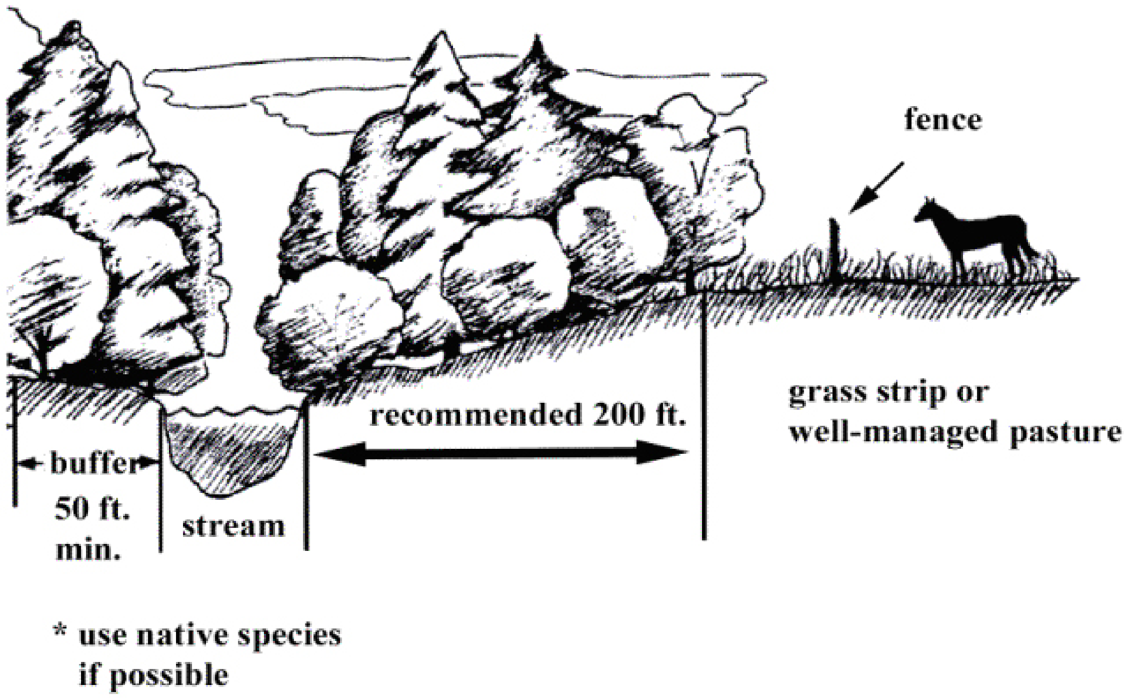
- Manage your pasture to avoid over-grazing and soil erosion. Rotate use of the pasture by cross-fencing and re-seed and rest the grazed area. Plant vegetative filterstrips between all pasture areas and waterways and on the downhill side of pastures. Manure removal will reduce spots with little to no grass.

Figure 71. Recommended Buffer Strip Widths Based on Slope.



Slope of Land (%)	Minimum Width of Buffer Strip (feet)
0	50
5	70
10	90
15	110
20	130
25	150

Figure 72. Filterstrips and Vegetated Buffers for Corral and Stable Areas.



Reduction in Urban Runoff Pollutants

Urban Runoff

Urban areas, such as the City of Rohnert Park have different types of pollutants in stormwater than rural areas. Most cities have a high degree of impervious surface area, such as asphalt and cement. When rainfall hits impervious surfaces it does not infiltrate, but runs off carrying any substance on the surface, such as oil, chemicals, dirt and garbage (Appendix 5). The management actions, such as chemicals used, bare soil and oil disposal taken by homeowners and gardeners have an enormous effect on the pollutant load in urban runoff.

- The City and County stormwater pollution prevention programs address urban pollutants as part of a broader regional effort and have community events and resources available. A focused program for Copeland Creek completed by the City and County in conjunction with Friends of Copeland Creek and other community groups would benefit creek water quality.

- Another useful resource is the *House and Garden Audit* - a fully-illustrated, color book written by Laurel Marcus and published under a grant from the City of Santa Rosa. Copies are available from the author (see Appendix 5).

Revegetation/Restoration of Natural Channel Functions

This assessment reviews the extent and density of riparian habitat along Copeland Creek. Two reaches – valley and alluvial fan had primarily sparse or low-density vegetation.

Alluvial Fan Reach

The alluvial fan reach has physical processes that differ somewhat from a gravel bed valley stream. The fan is steeper at 1 to 4 percent slope and as Copeland Creek exits its confined canyon, it deposits large-sized bedload – cobble, as well as gravel and sand in the form of a fan. The fan had numerous channels in historic aerial photographs. In all the aerial photographs, the alluvial fan has scattered oaks, not a linear, streamside riparian forest. It is likely that the high porosity and distributed and changing channels of the alluvial fan support scattered, deep-rooted vegetation.

The alluvial fan reach of Copeland Creek is entrenched and over-widened, a condition that creates a main channel and gives the impression of a single-thread gravel channel. However, the channel is still in the 1 to 4 percent slope class. It is likely that future flood events, especially in El Niño years, could see the more typical alluvial fan processes with large deposits of bedload.

There is currently a riparian restoration project on-going since 1998 in the section of Copeland Creek between Roberts Road and Petaluma Hill Road. The purpose of the project, directed by the SCWA, is "to restore riparian and salmonid habitat along 6,000 feet of Copeland Creek". The project description also states the project will stabilize banks and decrease sediment loads. There is no design available for this project; however, a number of parameters are being monitored, including:

- Groundwater monitoring: 8 piezometer wells were established in pairs located at the toe of the floodplain slope and up on the adjacent terrace (approx. 20-foot distance between wells) at a depth of approximately 6 feet.

- Geomorphic monitoring: 2-3 cross sections per treatment area were established for a total of 12 cross sections along the length of the project area. A longitudinal profile was surveyed for the 6000' length of the project area.

- Pebble Counts: 10 transects are surveyed within each treatment area using the pebble count method to characterize substrate particle size in the streambed.

- Vegetation transects: 36 permanent transects have been established to monitor plantings and natural regeneration along the length of the project area.

- Other biological monitoring: reptiles and amphibians are being monitored annually in spring and summer using visual surveys and pit traps; bird monitoring includes point count surveys conducted during breeding season (April – June); small mammal traps are put out in spring at 15 meter intervals for a total of 10 transects in the project area.

There are few examples of this type of restoration being applied to higher slope alluvial fans. The monitoring data is expected to be available in 2008 (Sonoma County Water Agency 2004) and success of this project, particularly in a flood year, should be used to guide restoration activities in the section of the alluvial fan upstream of Roberts Road.

Recommendations:

- The monitoring data and success in flood events of the restoration approach for the section of the alluvial fan between Roberts Road and Petaluma Hill Road should be reviewed prior to any major actions in the upstream portion of the alluvial fan reach

- Two interim measures could be taken in the upstream section of Copeland Creek through outreach by the Sotoyome RCD and collaboration with landowners:

    - Fence cattle out of the creek either through the use of an exclusionary fencing or creation of riparian pasture. In many instances, native plants will expand once grazing pressure is limited. Invasive Himalayan blackberry should be controlled and removed.

    - Revegetate the broader alluvial fan with oaks. This reach of the creek previously had many more oaks. Oaks will need to be fenced from cattle and provided water, either through irrigation, hand-watering or dry water.

    - Restoring the multi-channel form of the alluvial fan should be considered to increase the area for deposition of bedload over the fan, reduction of entrenchment and improved sediment and water storage functions. Such a project would require detailed site surveys and analysis.

Valley Reach

The maintenance measures used in the valley reach have changed since this area urbanized and pubic attitudes toward creeks have changed. The maintenance option

3 involves removal of vegetation from the channel bottom, tree trimming to create single trunk trees and possibly removal of invasive plant species. This option has a minimal effect on tree and understory riparian species, but doesn't involve removal of accumulated sediment from the channel.

No records of sediment removal were available for Copeland Creek, but as the watershed assessment demonstrated, the valley reach is a natural deposition area for fine sediment. Revegetation work in the alluvial reach is unlikely to change the fine sediment input to the valley reach because, due to its higher slope, the alluvial fan is not a natural depositional area for fine sediment from the watershed nor is it likely the primary source of fine sediment to the valley reach. Given the very low slope of the valley reach, fine sediment deposited in the channel, is not likely to be scoured out by subsequent flood flows.

Recommendations:

- With the amount of development adjacent to the Copeland Creek flood control channel, removal of accumulated sediment will be needed and provision for a higher level of flood control than option 3 creates. If there is a large flood and the creek floods residences, it is likely that emergency maintenance will be done, which will not likely address environmental concerns. Excavation depths should be based on a detailed survey of the channel bed elevation, elevation of backwater created by Laguna de Santa Rosa and the bed elevation just upstream of the flood control channel.

- Based on this information, excavation could be maximized in the upstream portion of the channel or another option developed to minimize excavation quantities. There is currently concern regarding fine sediment deposition in the Laguna de Santa Rosa. The flood control channel of Copeland Creek is a better location to excavate sediment than the Laguna de Santa Rosa for both environmental and economic reasons.

- Due to the permit requirements and controversy regarding flood control channel maintenance, it might be beneficial for the Sotoyome RCD in conjunction with the City, SCWA, SSU and environmental groups to convene a discussion group and develop a maintenance procedure that not only addresses environmental issues and aesthetics, but provides flood control for the 100-year event, thus protecting property and public safety.

Quantitative Monitoring Channel Changes

There is a need for more monitoring of changes in the Copeland Creek channel to develop a better understanding of channel processes and adjust management and restoration actions.

The set of cross-sections and the longitudinal profile currently being monitored by the SCWA for the alluvial fan reach should be integrated with the cross-sections in the study reach. Additional cross-sections should be added upstream through SSU and downstream in the flood control channel.

This type of data collection and analysis should be used to evaluate sediment accumulation in the flood control channel and volumetric change in the alluvial fan for future maintenance and restoration actions.

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