**PREDICTING SOIL EROSION IN THE SANTA ROSA CREEK WATERSHED
USING RUSLE2 AND GEOGRAPHIC INFORMATION SYSTEMS**

**A Thesis
presented to
the Faculty of California Polytechnic State University,
San Luis Obispo**

**In Partial Fulfillment
of the Requirements for the Degree
Master of Science in Agriculture with a Specialization in Soil Science**

**by
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May 2011**

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Using RUSLE2 and Geographic Information Systems

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ABSTRACT

Predicting Soil Erosion in the Santa Rosa Creek Watershed
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The Santa Rosa Creek watershed is one of the most pristine watersheds on California's Central Coast. Preserving this watershed is of great interest because it provides rich soils for agriculture, vast rangelands for cattle, and flowing streams for federally threatened species such as steelhead trout. Soil erosion could impact these resources. Using prediction tools, it is possible to study the erosion that could be occurring in a watershed and identify locations which could contribute the highest amounts of sediment. The objectives of this study were to use RUSLE2 and Geographic Information Systems (GIS) to predict soil erosion rates for each soil map unit in every drainage of the upper Santa Rosa Creek watershed and to determine areas where soil erosion could surpass a soil development rates. Environmental and anthropogenic factors that influence soil erosion such as topography, climate, soil, geology, vegetation, and land use, were described for the entire watershed to provide supplementary data used in the RUSLE2 model and to explain erosion in highly erosive areas. Predicted soil erosion rates were studied to determine if correlations exist between other factors such as slope, existing erosion features, and vegetation.

Predicted soil erosion rates calculated using RUSLE2 confirmed that the watershed is healthy and that 98 percent of the drainages are within sustainable soil erosion rates (five tons/acre/year). There were 37 soil map units totaling 1,617 acres (5.6 percent of the entire upper watershed area) with predicted soil erosion rates above a sustainable rate. In Perry Creek watershed, these sites were located on steep slopes tangent to streams. Along the main-stem of Santa Rosa Creek these sites were found in the headwaters where on average slopes are steep, soils are shallow, and rock outcrops exist. There appeared to be no relationship between

predicted high soil erosion rates and mapped upland erosion sites, however upland erosion features could not be identified where vegetation canopy restricted view of the soil surface. Additionally, RUSLE2 predicts rill and interrill erosion while upland erosion sites identified using GIS identified larger erosion features, such as gullies. Correlations between predicted soil erosion rates and vegetation formations were confirmed with shrub and tree formations having the highest average predicted soil erosion values. In addition, there was a moderate positive correlation between slope percent and predicted soil erosion ($r=0.76$), affirming that predicted soil erosion rates increased with increasing slopes.

ACKNOWLEDGMENTS

I would like to thank the many people who helped guide me through this project and supported me along the way. First of all, I would like to thank the Land Conservancy of San Luis Obispo County and the California Coastal Conservancy for funding such an excellent project that will provide insight in future conservation efforts in the Santa Rosa Creek watershed. I'd especially like to thank Kaila Dettman for her diligence in seeing the project through, providing guidance in the report's structure, and her editing support.

I'd also like to share my sincere gratitude for the faculty and staff at California Polytechnic State University who assisted me with this project. Dr. Brent Hallock in the Earth and Soil Sciences Department (ERSS) was instrumental in helping me define my RUSLE2 strategy and run the model. I am also extremely grateful for the resources and insight provided by Dr. Thomas Rice, also in the ERSS Department. In addition, Tom Mastin in the BioResource Agriculture Engineering Department provided technical support in editing and using digital data and Dr. Gregory Bohr (Social Sciences Department) assisted report editing.

I'd also like to express my gratitude for multiple professionals in local agencies and non-profit organizations who provided a multitude of tools used to complete this project. Bobby Jo Close, from the County of San Luis Obispo, supplied several datasets used in this project. Joy Fitzhugh of the San Luis Obispo County Farm Bureau offered insight into the watershed's history, ranches, and environmental issues. Rick Hawley of Greenspace the Cambria Land Trust and Stephanie Wald of Central Coast Salmon Enhancement made numerous reports and planning documents available to me, which informed this report and helped to create its structure.

And finally, there are no words to express the extreme blessing this experience was in my life. I would not have been able to do it without the support and love of my family, friends, and God. Big thanks to my husband, Bryan, and my girls, Kelsey and Charlotte, for their patience in seeing me through this. I owe this all to you guys!

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CHAPTER 1

INTRODUCTION

The Santa Rosa Creek watershed, located in northern San Luis Obispo County, is considered by many to be one of the most pristine areas on California's Central Coast. The watershed is over 30,395 acres in size and is predominantly agricultural with orchards, vineyards, row crops, grain fields, and rangelands common. The area hosts smaller communities and rural residences with a population of approximately 6,232 (County of San Luis Obispo, 2001). Tourism is another major industry that has influenced the watershed's development. There are numerous restaurants, hotels, boutiques, galleries, and a lodge within miles of the ocean. In addition, the watershed hosts unique botanical and biological populations. In the lower watershed is one of only three naturally occurring Monterey Pine (*Pinus radiata*) stands located in the United States (Holland and Keil, 1995). Several federally listed animal species exist within the watershed as well, including Tidewater Goby (*Eucyclogobius newberryi*), California red-legged frog (*Rana aurora draytonii*), and steelhead trout (*Oncorhynchus mykiss*) (CDFG, 2008). Although Santa Rosa Creek watershed is presumed by many to be a healthy ecosystem, evidence of soil erosion is found throughout the watershed. As a result valuable farmland could be lost and sensitive habitat could be impacted.

There are several soil erosion types that exist within the watershed, including rill, interrill, ephemeral gully, gully, road, and stream erosion. In the upper watershed gullies are common on foothill slopes tangent to streams. Cattle grazing is a common activity in the upper watershed. The watershed's rangelands are vegetated by cool-season grasses that are dormant in summer months. Grazing can reduce the amount of vegetative cover on the soil surface (Allen-Diaz and Jackson, 2000). Reduced vegetative cover during winter months, when precipitation

occurs, can lead to soil erosion. Exposed soil erodes when soil is detached from raindrop splash and transported downslope in a process known as overland flow (Torres et al., 1992).

Soil eroded in upland areas is transported by water and deposited into local streams and basins in a process called sedimentation. Sedimentation impacts steelhead trout habitat in Santa Rosa Creek. Stream surveys conducted by Don Alley and Associates (2006) found Santa Rosa Creek mean pool depths decreased in the past decade, forcing steelhead to live in marginal habitats, such as riffles. According to Alley, spawning gravels that have been buried by sediment reduces steelhead reproductive success in the Santa Rosa Creek and decreases fish populations throughout time. Erosion and sedimentation are not only local issues, but are major concerns across the planet.

In order to address soil erosion issues, sources of erosion must be identified and management measures must be put in place. The Revised Universal Soil Loss Equation 2 (RUSLE2) was developed by the United States Department of Agriculture (USDA). It is a tool commonly used in the United States to predict soil erosion rates on agricultural parcels and to help identify the best suited management measures for the site. RUSLE2 can be expanded for use on a larger watershed scale, by acquiring data using Geographic Information Systems (GIS).

Currently, it is uncertain how much erosion could be occurring in the Santa Rosa Creek watershed and where high-risk sites exist. Stream bank erosion has been identified as a source of sediment (CalFish, 2010); however upland erosion sources have not been assessed. By implementing RUSLE2 in this watershed, areas that are more susceptible to soil erosion can be identified. With additional data such as climate, topography, geology, soils, vegetation, and land use, erosion can be further explained in the watershed. Using a GIS-based RUSLE2 method could provide a standard in which a conservation-level soil erosion assessment could be conducted for other watersheds in the future.

Objectives

The objectives of this study were to classify environmental conditions, including: climate, topography, geology, soils, vegetation, and land use for the Santa Rosa Creek watershed; then to predict soil loss values for each soil map unit in the upper watershed using RUSLE2 and GIS. From these data, drainages with predicted erosion values greater than sustainable erosion rates (five tons/acre/year) were identified. Existing erosion features were mapped throughout the watershed using GIS and aerial imagery allowing an assessment for existing erosion occurring in the watershed. Finally, environmental conditions were considered for sites with high erosion rates, to describe the key factors that affect soil erosion rates at these locations.

CHAPTER 2

LITERATURE REVIEW

Human activities have degraded nearly half, or 43 percent, of the world's vegetated land (Brady and Weil, 2004). Poor land management has accelerated natural soil erosion processes which reduces soil fertility, affects habitat quality, and impacts human infrastructure. In addition, soil erosion affects food systems, natural ecosystems, and human safety. As the world's population continues to grow, soil erosion impacts will be magnified.

In order to address this problem the sources of erosion must be identified and studied. Locating sites where soil erosion is above a sustainable level can be accomplished using tools such as soil erosion prediction models, Geographic Information Systems (GIS), and remote sensing. Sustainable levels of soil loss are loosely defined as five tons of soil, per acre, per year (B. Hallock, personal communication, 2008). Soil prediction models allow users to input field conditions, simulate water erosion forces, and calculate predicted sediment yields. Results from these models allow land and resource managers to implement management practices that stabilize soil and reduce soil erosion.

Soil Detachment

Factors that control soil formation are parent materials, climate, biota, topography, and time. Parent materials are the organic or geologic sources in which soils are formed. They are important because they dictate soil characteristics which determine important watershed functions. For instance, parent material directly influences soil texture, which in turn controls the rate of water percolation, thereby directing a soil's susceptibility to water erosion. The chemical and mineral components of soils also influence how soils weather and what vegetation grows. Some soils are highly productive, such as those found in valley floodplains, while other soils are characteristically unproductive (Brady and Weil, 2004).

Weathering processes that affect soil erosion-sediment yield are complex. Hillslope morphology integrates site conditions that determine soil stability. Hillslope morphology includes gravity, surface resistance properties, solar radiation, precipitation, kinetic energy, surface resistance properties, vegetation cover, and regolith strength. The ways that raindrop splash can alter a landscape is determined by these morphological features and forces (Ritter et al., 2002).

There are several factors working together to determine soil erosion from raindrop splash. They include kinetic energy (according to surface cover and vegetation), soil type (soil texture and aggregation), slope angle, and antecedent soil moisture levels between precipitation events (Ritter et al., 2002). When raindrops are intercepted by vegetation or surface litter, kinetic energy is altered from raindrop's terminal velocity to smaller or sometimes even greater forces. In recent research, raindrop velocity increased and had three-times greater kinetic energy under forest canopies, in comparison to open fields (Cerdá, 1998). Rainsplash impacts soil physical properties by destroying soil structure and dispersing clay particles, forming surface crusts. This reduces soil aggregation and water infiltration rates, causing the soil to be more susceptible to erosion from water flow over the surface (Cerdá, 1998; Ritter et al., 2002).

Soil aggregation plays a central role in rainsplash erosion regulation by controlling the rate at which erosion occurs throughout an event. Soil erosion usually begins slowly after precipitation occurs, but increases as soil aggregates are destroyed (Ritter et al., 2002). Soil macro-aggregation is improved with increasing amounts of vegetation and organic matter (Cerdá, 1998). Different vegetative communities could have different influences on soil erosion, with certain communities contributing more or less soil erosion than others.

Other factors exist that could impact soil erosion, such as slope and soil moisture. The relationship between slope and soil erosion rates is complex and variable and is often difficult to generalize. The relationship between erosion and soil moisture is more direct. As soil moisture

levels increase, the shear strength of a soil increases which protect the soil from erosive forces (Ritter et al., 2002). The factors described above can create soil erosion features of many types.

Erosion Types

There are four distinct soil erosion types that are caused by water. These are rainsplash, sheet, rill, and gully erosion (Brady and Weil, 2004; Ritter et al., 2002). Rainsplash erosion occurs as the force from raindrop impact disturbs soil particles at an exposed soil surface, which detaches soil and creates soil pedestals. Sheet erosion occurs as water runs uniformly over a slope. Most natural slopes are too irregular for sheet erosion to occur. Water usually concentrates deeper in depressions and is shallower over high topographic features (Ritter et al., 2002). Rill erosion features are small channels on a hillside, small enough to be eliminated by conventional farm equipment. Gully erosion causes channels on a hillside that are too large to be plowed over by conventional farm equipment. Gully erosion is the “erosion process whereby water accumulates and often recurs in narrow channels and, over short periods, removes the soil from this narrow area to considerable depths, often defined for agricultural land in terms of channels too deep to easily ameliorate with ordinary farm tillage equipment, typically ranging from 0.5 m to as much as 25-30 m” (Soil Science Society of America, 2011). Gullies are typically formed by improper land management, such as clearing (Aksoy, 2005). Ephemeral gullies are an additional type of erosion and are small channels created by concentrated water flow that can easily be filled by normal tillage, but typically reform during runoff events at the same location (Soil Science Society of America, 2011).

Factors Affecting Sediment Yield

The most important factors that affect sediment yield are climate (and its correlation with precipitation and vegetation), basin size, topography, geology, and land use. In 1958, Langbein and Schumm studied the relationship between sediment yield and effective precipitation (the

magnitude of precipitation at a mean temperature of 10°C). From their study, erosion rates were correlated with effective precipitation and vegetation. They found that an increase in precipitation over 30 cm decreased sediment yield. At that level, vegetation density and type protected the slopes from erosion. These results are applicable at locations with more continuous rainfall, but may not be valid in areas with more distinct wet and dry cycles. The maximum amount of sediment yield at a site might not correlate with precipitation values directly, but rather the climatic setting, and are difficult to generalize (Ritter et al., 2002).

Vegetation's role in soil stabilization is important. Vegetation not only covers the soil surface protecting it from erosive forces, but can also increase soil aggregate stability (Cerdá, 1998) and change the surface strength of a soil, which is largely influenced by a soil's susceptibility to crusting (Folorunso et al., 1992). Soil micro-aggregate stability is based on parent material composition and the clay content in the soil. Soil macro-aggregate stability is more reflective of the vegetation and organic matter found on the site (Cerdá, 1998). Vegetation can significantly reduce soil crusting, thereby increasing soil infiltration rates, cumulative water intake, and promoting seedling emergence (Folorunso et al., 1997). With increased plant propagation, vegetation density increases and the conditions for a more stable soil surface exist.

Basin size also relates to soil erosion yields. Larger basins have more topographic features that allow soils to deposit within the system. Smaller basins generally have steeper slopes and smaller depositional features, such as alluvial fans, which capture sediment. As a result more sediment is transported out of a smaller system than larger, more complex systems (Ritter et al., 2002).

Rock types also impact soil erosion; however the relationship is not completely understood. Properties associated with water infiltration, such as rock fractures, are directly related to soil erosion rates. These properties cause lithologic (rock) units to behave similarly in their relation to soil erosion. It was once thought that soluble, more-clastic sedimentary rocks and low-rank metamorphic rocks produce more soil erosion than areas of more resistant, crystalline

rocks (Ritter et al., 2002). However, recent studies in Iran have shown cases of soil erosion at sites tangent to roads decrease with decreasing resistance of parent material (Mohammedkhan et al., 2011). Distinct variations of sediment influx into the Pacific Ocean from southern and central California were also found to be closely linked to lithology. Sediment yields were highest from faulted Cenozoic sediments, moderate in the Coast Ranges, and least in the Peninsular Ranges (Ritter et al., 2002).

Soil erosion is also impacted by land use. Agricultural and urban development, as well as mineral mining, removes climax vegetation and impacts soil erosion (Moreno-de las Heras et al., 2008; Moreno-de las Heras et al., 2011; Ritter et al., 2002). Agricultural land use can change the type and density of vegetation at a site. For instance, grazing can reduce vegetative cover from species removal, compaction, and decreased seed propagation. Studies have shown, however that light grazing can have minimal effects to vegetative cover and cover can become stable within a few years from introducing grazing activities at a site (Allen-Diaz and Jackson, 2000). In addition, watersheds with a large amount of undeveloped land, or open space, have greater amounts of water infiltration and groundwater recharge than developed watersheds. Watersheds that are largely developed with many paved surfaces and few areas for water infiltration have more flashy hydrologic systems that promote soil erosion (Steuer and Hunt, 2001). Areas surrounding roads and reclaimed sites have also shown to have increased sediment yield (Mohammedkhan et al., 2011).

The above factors illustrate the complex processes that impact soil erosion across a landscape. The processes are variable and interconnected, making studying soil erosion complex as well. Assuming that key variables can be identified and data acquired to represent these variables, soil erosion prediction models can be used to provide useful soil erosion data (Ritter, et al., 2002).

Soil Erosion Prediction Models

Soil erosion prediction models are empirical, conceptual, or physically-based.

Conceptual models represent watersheds as a water-storage catchment or basin. Empirical models are designed around a set of conditions existing at a site. Physically-based models are developed using “mass conservation of equation and sediment” (Aksoy, 2005).

RUSLE2 model is the revised version to the RUSLE model and predicts the amount of soil erosion occurring at a site produced by sheet and rill erosion. The equation used for the calculation integrates six variables, as shown below.

$$A = RKLSCP \quad (1)$$

where:

A = average soil loss (tons/acre/year)

R = rainfall erosivity (index)

K = soil erodibility (index)

L = length of slope (feet)

S = slope steepness (percent)

C = cover management (factor)

P = supporting conservation practices (factor)

Users should be cautious when using RUSLE2 predicted soil erosion values.

Calculations used in RUSLE2 are based on extrapolations and not actual data. Users should analyze the data by comparing expected values with empirical evidence to the extent feasible (Cal Trans, 2008). Additionally, RUSLE2 was developed for application on short slopes on farming parcels. Using RUSLE2 to predict larger scale soil erosion will produce comparative values, not absolute ones (Terranova et al., 2009).

The Water Erosion Prediction Project (WEPP) is the most popular physically-based model used in the United States. Physically-based models are more widely applicable because they are successful at spatially and temporally integrating elements of erosion processes (Amore, 2004). They are, however harder to use in larger watersheds because more data are needed to run the model and the probability of errors are greater than empirical models (Ismail and

Ravichandran, 2008). There are several different variables used in WEPP calculations including hydrology, plant growth, and soil water balance (Ranieri et al., 2002). Overestimation of soil erosion results occur when using “coarse” data at a large scale, rather than high resolution data at smaller scales (Amore, 2004). It is important when using any soil prediction model to gather the appropriate data according to the capabilities of each model.

GIS in Prediction Modeling

GIS is a valuable tool in soil erosion prediction modeling because it allows individuals to create, acquire, assimilate, and analyze data. Data can be created using resources such as aerial imagery, topographic maps, and information gathered through global positioning systems (GPS). There are endless possibilities in ways to create data in GIS for use in prediction models.

Existing data can be acquired through numerous data sources and search engines. Digital data such as soil, precipitation, vegetation, and land use data have been digitized for areas throughout the United States. These data can be downloaded online and brought into a GIS project. When and how the data were created is important when considering the data's compatibility with a project, therefore metadata should always be consulted when considering data. Digital data may not be sufficient and field data collection may be necessary to increase accuracy.

Multiple GIS layers representing variables used in prediction models can be brought into a map project to show spatial relationships. Statistical analysis can be conducted with tabular data in a GIS platform, such as ArcGIS. GIS also produces elements that can be integrated into reports and presentation materials such as maps, tables, graphs, charts, and reports. Maps produced using GIS are powerful analysis tools for viewing erosion values over large geographic areas. A map produced in GIS (Fig. 2-1) summarizes the predicted soil erosion rates for the Veppanapalli subwatershed in India using 2003 site conditions (Ismail and Ravichandran, 2008).

The dark areas represent study sites (hillslopes) with high predicted soil loss values (29.8-39.3 and 39.2-50.7 t/ha/yr).

Figure 2-1. Soil erosion prediction values for hillslope sites in the Veppanapalli subwatershed, India, using 2003 data. Darker areas represent high soil erosion rates (t/ha/yr) (Ismail and Ravichandran, 2008).

Remote Sensing in Prediction Modeling

Remote sensing captures satellite imagery of a region and assists in data acquisition for erosion modeling. Remote sensing is often used to describe vegetation communities and land use components of soil erosion prediction models (Vrieling, 2006). Additionally, remote sensing programs create Digital Elevation Models (DEM) of a watershed using digitized topographic maps (Shi, 2004). Once a DEM is created, it is used in GIS to calculate slope length and

steepness values for use in RUSLE2. Methods used to determine slope data on a landscape are variable among case studies and may alter the model's accuracy.

Although using satellite data provides information with reduced time in the field, it may not be a valid tool for use in the RUSLE2 model (Vrieling, 2006). RUSLE2 was developed to assess soil erosion on relatively short slopes. Accuracy of model results decreases with increased slope length. The model cannot be used to assess slopes greater than 1000 feet in length (Foster, 2004). The resolution at which satellite imagery is produced is generally between 30 meters and one kilometer. The low accuracy of data produced from these images can affect soil loss estimates (Schoorl et al., 2000 in Vrieling, 2006).

CONCLUSION

Soil is a valuable natural resource impacted by numerous variables that interplay to determine soil stability and soil erosion. Globally, soil erosion is an issue in which science can provide insight into where and why erosion is occurring and how conservation strategies could protect this resource. Soil erosion prediction models, such as RUSLE2, are valuable tools used to identify areas of potentially high erosion levels and to assess the impacts of soil conservation measures applied to a site. By using spatial software, such as GIS, soil erosion prediction models can capture and assimilate data efficiently. The capabilities of GIS and remote sensing technologies have expanded the amount of information available to resource managers and landowners. Caution should be used when gathering data to be used in prediction models. Standardized methods used for collecting data have not been established and inaccuracies could result.

CHAPTER 3

MATERIALS AND METHODS

Location

Santa Rosa Creek watershed is located in northern San Luis Obispo County, California, in the southern portion of the Coast Ranges. The unincorporated community of Cambria is located in the northwestern portion of the watershed while the small community of Harmony is located on the southern edge of the watershed (Fig. 3-1). Santa Rosa Creek flows east to west, with the headwaters situated in the Santa Lucia Mountains, and the outlet draining into the Pacific Ocean. The upper watershed is characterized by mountain topography with a maximum elevation of 2,933 feet above mean sea level at Cypress Mountain. The outlet of Santa Rosa Creek is located in Township 27 South; Range 8 East; Section 22. The western extent of the watershed is located approximately 35°34'19.16"N Latitude, 121°6'46.70"W Longitude, and the eastern extent of the watershed is located approximately 35°32'50.57"N Latitude, 120°54'2.03"W Longitude. The northern extent of the watershed is located approximately 35°36'28.05"N Latitude, 120°59'35.44"W Longitude, and the southern extent of the watershed is located approximately 35°29'59.38"N Latitude, 121°0'4.80"W Longitude.

Figure 3-1. Santa Rosa Creek watershed, located in northern San Luis Obispo County, California.

The Santa Rosa Creek watershed is composed of two major drainages: the Santa Rosa Creek drainage, and the Perry Creek drainage (Fig. 3-2). The upper Santa Rosa Creek sub-watershed is nearly 16 thousand acres and drains water from the surrounding landscape into the Santa Rosa Creek and numerous unnamed tributaries upstream of the Santa Rosa and Perry Creek confluence. The Perry Creek sub-watershed is nearly 15 thousand acres and is composed of Green Valley and Fiscalini Creeks, as well as numerous unnamed tributaries. Green Valley Creek is a tributary to Perry Creek, which is a tributary to Santa Rosa Creek.

Figure 3-2. Santa Rosa Creek watershed blue-line streams, including Santa Rosa, Perry, and Green Valley Creeks.

Watershed Conditions Assessment

Digital climate, topography, geology, faults, soils, vegetation, roads, streams, watershed boundary, and land use data were obtained through various online sources and the County of San Luis Obispo. ArcGIS 9.2 and 2007 aerial imagery were used to analyze the data. In 2009, spatial vegetation data for the watershed were created by the County of San Luis Obispo and Aerial Information Systems, Inc. (AIS). Digital vegetation data were acquired from the County of San Luis Obispo, through the Land Conservancy of San Luis Obispo.

Land Use

Land use for the Santa Rosa Creek watershed was described using rural land use data created by the County of San Luis Obispo (2008a). These data were created by digitizing county-

wide land use information by township, range and section. The categories are general designations that provide a simplified land use description for the entire watershed. County Assessor's Office digital parcel data were used to define land use in greater detail. Other data used to inform the land use assessment included parks, coastal zone, and roads GIS data obtained online at SLO Datafinder (<http://lib.calpoly.edu/gis/>). Rangelands were classified using parcel data and aerial imagery to identify additional parcels that appeared to be grazed with cattle, but not identified in the parcel data. Crop data were also updated using aerial imagery and GIS.

Land use results were verified through field reconnaissance. To confirm general land use in the upper watershed the San Luis Obispo County Farm Bureau was consulted. The Farm Bureau verified the approximate boundaries between crop and grazing locations.

RUSLE2

Land uses and vegetative communities in the lower watershed are highly diverse and are difficult to model. Impermeable surfaces such as roads, parking lots, and buildings exist throughout the lower watershed but cannot be assessed using RUSLE2. Therefore it was determined to only apply RUSLE2 to the upper watershed. The upper watershed land uses are less variable and the area is largely undeveloped therefore RUSLE2 could be applied there.

Predicted annual erosion rates were calculated for the upper watershed using ArcView 9.2, RUSLE2, Microsoft Excel 2007, and Soil Surveys. The upper watershed boundary extends from the headwaters in the Santa Lucia Mountains, downstream to the Main Street and Santa Rosa Creek intersection. Using GIS, the upper watershed was divided into 159 smaller assessment areas, or sites (Fig. 3-3). Each of these drainages is a tributary to a blue-line stream within the upper watershed. RUSLE2 was run for each soil map unit in each assessment area throughout the upper watershed.

Figure 3-3. Assessment areas created using GIS for the upper Santa Rosa Creek watershed, used to summarize RUSLE2 results.

Geographic Information Systems (GIS) spatial data were acquired from the County of San Luis Obispo Planning and Building Department, the County's Assessor's Office, Geospatial Data Gateway (<http://datagateway.nrcs.usda.gov/>), Cal-Atlas (<http://atlas.ca.gov/>), and SLO Datafinder (<http://lib.calpoly.edu/gis/>). Data input into the RUSLE2 program were obtained using these resources. Precipitation data were acquired from the Geospatial Data Gateway to describe the erosivity of the site (R). Digital Soil Survey data were obtained from SLO Datafinder and used to identify the soils in the watershed and describe erodibility (K). The DEM of the site was obtained from the County of San Luis Obispo on CD and used to determine slope length (L) and percent (P) (Fig. 3-4). Published Soil Survey reports were used in conjunction with the GIS data to describe cover management (C). Supporting practices were defined as none.

Figure 3-4. Digital Elevation Model (DEM) of the Santa Rosa Creek watershed, in feet. Low elevations are characterized by dark colors, and high elevations appear light to white. Slope topography data were acquired using this DEM in ArcGIS 3D Analyst.

A DEM is a digital representation of ground surface topography using a grid of regularly spaced elevation data. Using the ArcGIS 3D Analyst extension, slope percent and slope length were calculated. Contour lines for each soil map unit were created from the DEM. Slope lines were drawn perpendicular to the contour lines from the highest point of elevation, along the longest length of slope represented in each map unit. This would allow one to assess the maximum slope length and an averaged slope percent at each map unit. Lines were drawn and terminated where soil deposition would occur, such as a break in slope or in catchment areas such as drainages. Map unit slope lines were converted to three-dimensional features and slope length and percent were calculated using ArcGIS 3D Analyst.

Once climate, soil, slope, cover management, and supporting practices were defined in a RUSLE2 uniform slope profile, the predicted soil loss value was calculated. This value was multiplied by the soil map unit size to determine the total predicted soil loss from that site, in one year. Soil map unit predicted values were then summarized by drainages. Detailed procedures for RUSLE2 data acquisition and input are included in Appendix A.

Upland Erosion Mapping

Upland erosion features, such as gullies, were mapped to identify the location of existing sediment sources throughout the watershed. Upland erosion was mapped using ArcView 9.2, 2007 digital aerial imagery, and field reconnaissance. ArcView 9.2 was used to digitize erosion features observed in the aerial imagery. Digital aerial imagery was flown in the summer of 2007 with a ground resolution of one foot, and obtained from the County of San Luis Obispo through licensing agreements with the Land Conservancy of San Luis Obispo County. Field reconnaissance was conducted to verify mapping results on public lands.

Several erosion types were identified in the watershed, including: rill, interrill, ephemeral gully, gully, road, and stream bank erosion. Exposed soil in cultivated fields were not mapped as sediment sources, however erosion likely occurs in these areas as well. Rill and interrill erosion are the two most common erosion features in the watershed. These types of occur from soil detachment caused by rainsplash and the associated overland water flow during rain events. The overland flow path begins at the top of slope and ends in a concentrated flow channel. RUSLE2 was used to calculate annual predicted soil loss from rill and interrill erosion in the watershed. Rill and interrill erosion were not mapped using GIS because they usually cannot be identified using aerial imagery.

Locations where gully, ephemeral gully, and road erosion occur were more distinct than rill and interrill erosion, and therefore could be digitized using GIS. Gullies associated with cattle trails, cattle grazing, and stream banks were distinguished from other gullies identified.

Ephemeral gullies can be difficult to identify using aerial photography because they are smaller, more-subtle features. Ephemeral gullies distinct enough to be viewed using the aerial imagery were mapped, however additional ephemeral gullies likely exist. Stream bank erosion has been identified as an additional source of sediment in the watershed and was recently studied by the California Department of Fish and Game (J. Nelson, personal communication, 2008). At the time of this study, the CDFG report had not been published.

CHAPTER 4

RESULTS AND DISCUSSION

Watershed Conditions

CLIMATE

The Santa Rosa Creek watershed is located along the Pacific coastline where climate is cool and mild, and there are little daily or seasonal temperature fluctuations. According to the Köppen System of climate classification, the climate of this watershed is characterized as a Mediterranean cool summer with fog, typified by warm, dry summers and mild, moist winters (Holland and Keil, 1995). Average annual precipitation ranges from 17 inches at the coast to 23 inches in the Santa Lucia Mountains. Most precipitation occurs between the months of December and March, with January exceeding all months, averaging between 3.75 and 4.75 inches. In contrast, very little precipitation occurs for several months in the summer. Precipitation data from local farmers show precipitation ranges can be much greater than the average data. In recent years, rainfall amounts have exceeded 40 inches in the headwaters, with some areas in the mountains receiving up to 56 inches of rain in a year (J. Fitzhugh, personal communication, 2008). The average annual temperature shows the watershed is a mild 55° F to 59° F, with minimum temperatures ranging between 33° F and 43° F. Average maximum temperatures range between 67° F at the coast and 83° F in the mountains (USDA, 2008).

TOPOGRAPHY

Santa Rosa Creek watershed is a coastal watershed with elevations ranging from mean sea level at the beach to nearly 3,000 feet above mean sea level in the Santa Lucia Mountains. Average elevation in the lower watershed is around 200 feet above mean sea level and increases to approximately 600 to 800 feet above mean sea level in the foothills. In the upper watershed

elevation climbs to a maximum value of 2,933 feet above mean sea level at Cypress Mountain. Average elevations are around 2,300 feet in the mountains (Fig. 4-1). Alluvial fans and wide alluvial valleys exist in lower elevations of the Santa Rosa, Perry, and Green Valley Creeks. As elevation increases towards the mountains, slopes steepen and drainages become narrower. This topography can allow erosion from the upper watershed to enter streams and deposit lower in the watershed. Soil erosion that occurs in the foothills has a greater chance of depositing on alluvial fans and terraces reducing total sediment entering streams.

GEOLOGY

There are 37 geologic units distributed throughout the watershed (Fig. 4-2). Appendix B includes each geologic unit and its relative abundance in the watershed. Major geologic units are described below, beginning with the Franciscan Formation (KJf). This geologic unit was created from the Cretaceous period (66 mya) through the Eocene period (38 mya) from subducted basalts and sediments falling into the subduction zone. Franciscan *mélange* (KJfme) is a mixture of igneous and metamorphic rocks, such as greywacke, greenstone, diabase, gabbro, serpentine, chert, shale, tuff, blue schist, and other metamorphic rocks (Yates and Van Konyenbur, 1998). Approximately 48 percent of the total watershed area is composed of Franciscan *mélange* rocks, common in the upper elevations of the watershed. Red chert metavolcanic outcrops of the Franciscan Formation occur in just a few locations along the eastern edge of the Santa Rosa groundwater basin and east of the Santa Rosa Creek and Perry Creek confluence near town.

Figure 4-1. Topography of upper Santa Rosa Creek watershed, including the highest elevation located at Cypress Mountain (USGS, 2000).

Ultramafic outcrops in the Franciscan Formation are highly fractured and faulted. They contain springs, seeps, and other continuous water sources. In climates where seasonal streams go dry in the summer, ultramafic areas such as those that contain serpentine rocks tend to foster year-round water flow. Because these areas are typically barren of vegetation, sheet erosion is common. Other forms of erosion are common on soils derived from serpentine where excavation activities occur, such as road development (Kruckeberg, 1984).

Between the Cenozoic and uppermost Mesozoic periods (144 mya and younger), marine sedimentary rocks, also known as the Cambria Slab, were thrust over the Mesozoic rocks of the Franciscan Complex. During the late Cretaceous period (66 mya), the Franciscan Complex was fragmented and mixed. This created an aggregation of rocks while the Cambria Slab was moved relatively intact (Chipping, 1987).

Approximately 40 mya, sediments deposited by water, created the Lospe Formation (Tl). The Lospe Formation occurs in small areas along north-west trending inactive faults (Chipping, 1987), in the western portion of the watershed. Cambria Felsite (Tc) exists within the Lospe Formation. It is an Oligocene (38-24 mya) aged volcanic complex and is found near the center of the town of Cambria. This Cambria Felsite is the same age as the Morro Rock-Islay Hill Complex of volcanic rock outcroppings located between Morro Bay and San Luis Obispo (Hall, 2007). Franciscan Formation pebbles are also present within the Lospe Formation which correlates with continental uplift (Chipping, 1987), and erosion deposition.

The Monterey Formation (Tm) was created during the Miocene epoch (24-5 mya) and is dominated by thin bedded, siliceous shales, siltstones, and claystones. At this time, the Coast Ranges were submerged and the coastline was located near where the present-day San Andreas Fault lies (Chipping, 1987). The Monterey Formation exists along the northern watershed boundary and is nearly completely surrounded by the Franciscan Formation.

The Pismo Formation (Tp) was developed between 2-5 mya and is closely associated with the Monterey Formation. It was deposited as the Coast Ranges were created and sea levels

dropped (Chipping, 1987). Near the coast, stream terrace deposits overlie sedimentary rocks. These marine deposits formed during a middle-to-late Pleistocene period, approximately 2 mya, in which sea levels were high (Yates and Van Konyenbur, 1998). Cyclical changes in sea level, occurring during the Ice Ages. This created extensive marine terraces, such as the one located at Moonstone Beach. The more recent stream terraces have developed from alluvium. In the lower watershed, stream bank deposits sit atop relatively impermeable bedrock, forming the Santa Rosa groundwater basin. It is estimated that the alluvium in this basin is approximately 130 feet thick (Chipping, 1987).

Several inactive north-west trending faults lie within the watershed. There are six faults with maximum earthquake magnitudes between 6.25 and 8.25 within 66 miles of the watershed (Cambria, Hosgri, Oceanic, Los Osos, Rinconada, and San Andreas Faults) (County of San Luis Obispo, 2008b). On December 22, 2003 a moment magnitude 6.5 earthquake occurred with its epicenter located seven miles northeast of San Simeon, California, north of Cambria. Landslides were observed along State Highway 46 (Green Valley Highway). Due to seismic compression and slope instability, significant road damage occurred along State Highway 46 (EERI, 2004). The estimated recurrence interval with faults located within the watershed is long, the hazards associated with these faults remains low (County of San Luis Obispo, 2008b).

Impacts of seismic activity can still be felt as a result of the 2003 San Simeon earthquake. Local ranchers have noticed significant differences in detention pond water levels. Ranchers in the upper portions of the watershed experienced a draining of their detention ponds and overall decrease in their water supply, while ranches located in the lower watershed gained water in areas that were previously dry (J. Fitzhugh, personal communication, 2008).

SOILS

The geologic diversity in the Santa Rosa Creek watershed is the foundation of the complex soils present in the area. There are 64 soil map units within the Santa Rosa Creek watershed. Soil map units are mapped for the lower and upper watershed and summarized in Appendix C. The most common soil map unit within the watershed is the “Diablo-Lodo complex, 15 to 50 percent slopes”. This soil is located on moderately steep to steep terrain and accounts for approximately 13 percent of all soils within the watershed. The Diablo-Lodo complex is mostly vegetated by grasslands with some woodland habitats located along stream corridors. The component soil within this complex has moderate to high water erosion hazards, rapid surface runoff, low productivity, and is sensitive to overgrazing, leading to excessive sheet erosion (USDA, 1984).

Soil texture impacts water infiltration rates and water runoff. Water infiltration is slower in finer textured soils (clay) and faster in coarser soils (sands). Soil depth affects water holding capacity of a soil. Water holding capacity is decreased for same textured soils that are reduced in soil depth. For instance, a deep loamy soil will hold more water than a shallow loamy soil (Brady and Weil, 2004). The Santa Rosa Creek watershed is characterized by several different soil textures of various depths. Shallow soils are associated with Vaqueros sandstone (Tv) and Rincon shale (Tr) geologic formations as well. They are also commonly found on slopes greater than 30 percent and sometimes associated with rock outcrop soil complexes. Claypans and clayey soils are common throughout the watershed and are typically found on moderate to low slopes (Fig. 4-3).

Soil erodibility is described using the K-factor of the whole soil. The K-factor is a soil’s susceptibility to sheet and rill erosion from water. In general, K-factor values range from 0.02 to 0.69 with higher values more susceptible to erosion (USDA, 1984). Soils found in the Santa Rosa Creek watershed have K-factor values ranging from 0.02 to 0.32. These soils are described as “low” to “moderately” erosive. Most of the soils in the upper watershed have low K-factor

values, and soils in the lower watershed have moderate erosion values and are more susceptible to erosion (Fig. 4-4). Soils with rock outcrop complexes, mostly located in the upper watershed, have no “K-Factor” values. Soils formed from serpentine-rich parent materials are typically unproductive due to their high magnesium content, and are subject to accelerated erosion on steep slopes (White and Dixon, 2002). Additionally, Aquoll soils, which has an aquatic moisture regime and thick organic-rich topsoil (mollic epipedon), do not have a “K-Factor” value. This soil is located in the lower watershed near the confluence of Santa Rosa Creek and the Pacific Ocean. It is located in a wetland vegetated with wooded wetland species.

Figure 4-3. Soil texture and depth for map units in the Santa Rosa Creek watershed (USDA NRCS, 2005).

Figure 4-4. Soil erodibility (K Factor) for soil map units in the Santa Rosa Creek watershed.

VEGETATION

The geographic classification system used in *The Jepson Manual: Higher Plants of California* (1993) divides California into geographic systems, or provinces, according to several landscape features such as natural vegetation types, as well as geologic, topographic, and climatic variations. Using this classification system the Santa Rosa Creek watershed is located in the Central Coast (CCo) of the Central Western California Floristic Province. The boundaries of CCo extend along the Pacific Ocean, from Point Conception in the south, to Bodega Bay in the north, and by the Great Valley province to the east. The Mediterranean climate of this region allows a wide range of vegetative species to grow here, including rare species.

Monterey Pine (*Pinus radiata*) and Sargent Cypress (*Cupressus sargentii*) are two rare tree species found in the watershed. One of only three naturally occurring stands of Monterey Pine found within California is located in the watershed (Sawyer and Keeler-Wolf, 1995). Additionally, locally rare Sargent Cypress is the name-sake for Cypress Mountain, located on the eastern boundary of the watershed. Sargent Cypress grows at a few sites near Cambria in the Santa Lucia Mountains (Coffman, 1995). In addition to rare species, the watershed is a mosaic of vegetative species which have adapted to the diverse habitats here.

Grasslands, riparian forests, hardwood forests, and an estuary are just a few of the ecosystems found in the Santa Rosa Creek watershed. Being largely undeveloped, the watershed is full of trees, shrubs, and herbs. The County/AIS data describe vegetative communities within the watershed (Fig. 4-5). Vegetation formations include: Mesomorphic Tree Vegetation-Forest and Woodlands (Tree), Mesomorphic Shrub Vegetation (Shrub), Mesomorphic Herbaceous Vegetation (Herbaceous), Temperate Flooded Riparian Vegetation (Wooded Wetland), Temperate Meadow and Freshwater Marsh (Herbaceous Wetland), Lithomorphic or Wetland Associated Naturally Sparse or Unvegetated Areas (Natural Unvegetated), Water, Urban Built Up (Urban), and Agriculture categories. Guidelines used to define vegetation formation and oak communities follow the National Vegetation Classification Hierarchy summarized in the San Luis

Obispo County Vegetation Mapping Report, Photo Interpretive and Mapping Guidelines (2009) and are described in Appendix D.

While the 2009 County vegetation data provided precise locations of general vegetative communities, geographic data produced by the County in 1998 provided detailed data for generalized locations. These data reveal where estuary, riparian scrub, riparian woodland, coastal oak woodland, coast mixed scrub (chaparral and coastal scrub), Monterey Pine, and annual grassland communities exist in the watershed. These data are less accurate than the 2009 vegetation data however they provide reference data for vegetative species found in the watershed. The more precise data (2009) were used to map vegetation in the watershed while the older datasets (1998) were sometimes used to explain the data in greater detail.

Using the County's 2009 vegetation data, the total acreage and percent of watershed area was calculated for vegetation formations (Table 4-1). Mesomorphic Herbaceous Vegetation (Herbaceous) is the most common vegetation type accounting for over 19 thousand acres in the watershed, or 63 percent of the entire watershed area. Mesomorphic Tree Vegetation (Tree) is the second most abundant formation accounting for 5,536 acres, or 18 percent. Mesomorphic Shrub Vegetation (Shrub) is the next abundant with 2,961 acres, or nearly ten percent of the total watershed area.

Figure 4-5. Vegetation formations within the Santa Rosa Creek watershed (County of San Luis Obispo, 2009a).

Table 4-1. Santa Rosa Creek watershed vegetation formation categories, total acres, and percent of watershed area, (County of San Luis Obispo, 2009a).

Vegetation Formation	Acres	Percent Watershed Area
Mesomorphic Tree-Forest and Woodlands	5,536	18
Mesomorphic Shrub	2,962	10
Mesomorphic Herbaceous	19,200	63
Temperate Flooded Riparian	671	2
Temperate Meadow and Freshwater Marsh	50	<1
Lithomorphic or Wetland Associated Naturally Sparse or Unvegetated Areas	17	<1
Water	17	<1
Urban Built Up†	1,141	4
Agriculture	789	3

†Using 2007 aerial imagery of the watershed, it was discovered that Urban Built Up areas correlated with rock outcrops or exposed soil in the upper watershed and that observable mapping errors exist within this formation type in this watershed.

Land Use

Rural Land Use Classification

Lower watershed land uses are distinctly different than upper watershed land uses. The lower watershed is predominately urban while the upper watershed is almost entirely agricultural.

A map showing rural land use designations for the entire watershed is included in Figure 4-6.

Table 4-2 lists total acres and percent of total watershed area of each land use designation in the Santa Rosa Creek watershed. Rural lands are loosely defined by the County of San Luis Obispo

as large parcel low density residential zones. The “Cambria LCP Urban Reserve Area” is generally comprised of smaller parcel higher density residential zones.

Table 4-2. Rural land use classification, sum of acres and percent of total watershed area (County of San Luis Obispo, 2008a).

DESCRIPTION	ACRES	PERCENT
Agriculture	27324	90%
Cambria LCP Urban Reserve Area	1506	5%
Commercial Retail	1	<1%
Public Facility	44	<1%
Rural Lands	1518	5%
TOTAL	30393	100%

Lower Watershed Land Use

The lower watershed is 1,349 acres and accounts for less than five percent of the entire watershed. This portion of the watershed includes land draining into the Santa Rosa Creek from the Santa Rosa Creek and Main Street crossing, extending to the ocean. The lower watershed is densely populated with 4,012 parcels, or 83 percent of parcels located in the entire watershed. The primary land use designations for the lower watershed, by land area, used by the County of San Luis Obispo Assessor’s Office are presented in Figure 4-7. Primary land uses in the lower watershed include school/church, commercial/business, government, recreational, residential, water company, agriculture, vacant, and none.

Figure 4-6. Land use classifications for the Santa Rosa Creek watershed (County of San Luis Obispo, 2008a).

Figure 4-7. Lower Santa Rosa Creek watershed land uses based on Primary Land Use Codes from the County of San Luis Obispo Assessor's Office parcel data.

Upper Watershed Land Uses

The upper Santa Rosa Creek watershed includes all land draining upstream of the Santa Rosa Creek and Main Street crossing. A residential area located along the western edge of the Perry Creek sub-watershed was not included in the upper watershed land use assessment. This area has 436 parcels totaling approximately 67 acres, or less than one percent of the entire upper watershed area, and is nearly 100 percent residential.

The rural area of the upper Santa Rosa Creek watershed is 28,057 acres with 383 parcels. A large portion of the upper watershed is owned by 17 families that own 20,962 acres, or 69 percent of the total Santa Rosa Creek watershed area. The average size of these family parcels is 1,165 acres, with one family owning over 3,000 acres. Nearly 100 percent of the family parcels are agricultural.

The primary land use in the upper Santa Rosa Creek watershed is agriculture (cattle grazing, irrigated crop, and dry farming) with rural residential land uses also occurring in the upper watershed. Approximately 79 percent or 22,690 acres of the upper watershed land area is designated for grazing. Most crops grown in the watershed are used as feed on associated ranges (County of San Luis Obispo, 2008b). There were 988 acres, or 3.5 percent of the upper Santa Rosa Creek watershed area, of various crop sites identified using 2007 aerial imagery, in the upper watershed.

Additional land uses in the upper watershed include residential, roads, and abandoned mineral mines. There are 75 miles of roads within the upper Santa Rosa Creek watershed. Three major roads exist in the watershed, including Santa Rosa Creek Road (11.7 miles in length), Green Valley Road (9.7 miles in length), and State Highway 1 (4.4 miles in length). There are three rock quarries within the watershed that total 30 acres. They include the Cambria Pit, Bianchi Quarry, and Red Rock Pit. The Oceanic Mine is a retired mercury mine located tangent to Curti Creek. The site is abandoned and is in the process of reclamation. The retired Oceanic Mine is 1.3 acres in size.

RUSLE2

There were 159 assessment areas created for the RUSLE2 study. RUSLE2 soil erosion prediction assessment results were summarized for the upper watershed, by soil map units and assessment areas. Potential soil loss values for the upper watershed are described in Table 4-3. It was determined using RUSLE2 that potentially 56,270 tons, or 1.97 tons/acre, of soil could erode each year in the upper Santa Rosa Creek watershed. Although the Santa Rosa Creek sub-watershed is a smaller drainage, it could potentially erode approximately 32,757 tons of soil each year, or 58 percent of the total soil erosion occurring in the upper watershed.

Table 4-3. Acreage and predicted annual soil loss values for the upper Santa Rosa Creek watershed and sub-watersheds, as determined using RUSLE2.

Watershed	Acres	Upper Watershed Area (%)	Predicted Soil Loss (tons/year)	Total Predicted Soil Loss (%)
Upper Santa Rosa Creek	28,624		56,270	
Santa Rosa Creek (sub-watershed)	13,941	49%	32,757	58%
Perry Creek (sub-watershed)	14,683	51%	23,513	42%

National Resources Conservation Service (NRCS) considers five tons of soil loss, per acre as the sustainable annual soil loss threshold of deep soils. Soil erosion values greater than five tons/acre/year are considered non-sustainable. The threshold soil loss value was established according to the time it takes for one inch of topsoil to develop, equating 30 years and weighing approximately 150 tons (B. Hallock, personal communication, 2008).

Total predicted soil loss values (tons/year) were summarized for each assessment area (drainage) in the upper watershed (Fig. 4-8). Average RUSLE2 values (tons/acre/year) were also summarized for each assessment area (Fig. 4-9), which allowed sites that were high-erosion risks to be identified. The greatest total amount of sediment was determined to be coming from the headwater reaches of the watershed and along Fiscalini Creek in the Perry Creek sub-watershed (Fig. 4-8). Steep north-facing slopes in the upper Santa Rosa Creek sub-watershed had the highest values of potential soil loss (Fig. 4-9). A high frequency of gully erosion was observed using 2007 aerial imagery and observations made during field reconnaissance in 2008, confirming these results.

Figure 4-8. Total predicted soil loss (tons/year), calculated using RUSLE2, for drainages in the upper Santa Rosa Creek watershed.

Figure. 4-9. Average predicted soil loss (tons/acre/year) calculated from RUSLE2 for each soil map unit in the upper Santa Rosa Creek watershed.

RUSLE2 predicted soil erosion values exceeded five tons, per acre, per year in 37 soil map units of 14 different soils (Appendix E). These sites accounted for approximately 1,617 acres, or 12 percent of the total upper watershed area. These sites occurred throughout the watershed, but were more common in the upper Santa Rosa Creek sub-watershed headwaters (Fig. 4-10). Conditions of highly erosive sites varied between upper Santa Rosa Creek sub-watershed and Perry Creek sub-watershed. In general, the highly erosive sites did not appear to correlate with upland erosion sites that were mapped using the aerial imagery in GIS. This could have been due to tree and shrub canopy which restricted view of the soil surface and masked any existing soil erosion. Vegetation impacts soil physical and chemical properties, such as soil depth

and structure (Brady and Weil, 2004), and therefore could impact water infiltration and soil stability as well.

Figure 4-10. Potential soil loss values (tons/acre/year) from RUSLE2 analysis of upper Santa Rosa Creek watershed soil map units.

Soil map units that potentially contribute the highest amount of soil from erosion using the RUSLE2 prediction model were “Gazos-Lodo clay loams, 30 to 50 percent slopes”, “Los Osos-Diablo complex, 15 to 30 percent slopes”, and “Los Osos-Diablo complex, 30 to 50 percent slopes”. Although “Diablo-Lodo complex, 15 to 50 percent slopes” were the most common soils in the upper watershed, accounting for over 4,050 acres, or 14 percent of the total upper watershed area, they were only contributing a possible 2,793 tons of soil each year, or an average 0.7 tons/acre/year. These soils have clay texture with high shrink-swell potential and low erodibility (K-factor 0.15) (USDA NRCS, 2005).

Gazos-Lodo clay loams were the second most abundant soils in the upper watershed and accounted for approximately 2,575 acres, or nine percent of the total upper watershed area. The total predicted soil loss from these soils was 4,294 tons per year, or an average 1.7 tons/acre/year. Gazos-Lodo clay loams have moderate shrink-swell and low erodibility (K-factor 0.17) (USDA NRCS, 2005).

Los Osos-Diablo complexes (15 to 50 percent slopes) were significant contributors to soil loss in the upper watershed. These soils accounted for 3,286 acres, or nearly 12 percent of the total upper watershed area. They could contribute up to 9,316 tons of soil each year, or an average of 2.8 tons/acre/year. Los Osos-Diablo complexes are loamy claypans with moderate erodibility (K-factor 0.32) and moderate shrink-swell potential (USDA NRCS, 2005). Although these soils had the greatest total potential soil erosion than any other soil map unit, they had low predicted soil loss values (RUSLE2 values).

There were 14 soil map units with predicted soil erosion values above sustainable rates (Appendix E). Most of these soils had average RUSLE2 values around five tons/acre/year, however three soils exceeded this amount: “Cieneba-Millsap loams, 30 to 75 percent slopes”, “Gaviota fine sandy loam, 15 to 50 percent slopes”, and “Gaviota sandy loam, 50 to 75 percent slopes”. Cieneba-Millsap loams accounted for 93 acres (less than one percent of the total upper watershed area), and averaged 6.6 tons/acre/year. Cieneba-Millsap loams have moderate erodibility (K-factor 0.24), low shrink-swell, and are very shallow loamy soils (USDA NRCS, 2005). Gaviota fine sandy loams accounted for 129 acres (less than one percent of the total upper watershed area), and averaged 7.0 tons/acre/year. Gaviota fine sandy loams have moderate erodibility (K-factor 0.24), low shrink-swell, and are shallow soils with coarse loam texture (USDA NRCS, 2005). Lastly, Gaviota sandy loam soils accounted for 90 acres (less than one percent of the total upper watershed area), and averaged 7.5 tons/acre/year. Gaviota sandy loams have the same properties as Gaviota fine sandy loams described above, but have slightly coarser textures and are located on steeper slopes (USDA NRCS, 2005). These soils have variable

erodibility and shrink-swell, however their soil depth are shallow to very shallow. Although these soils had the highest RUSLE2 values, per acre, they accounted for very little of the upper watershed total area. These potentially highly erosive areas were located in two regions of the Santa Rosa Creek watershed: in the headwaters along the main-stem of Santa Rosa Creek, and in the lower Perry Creek sub-watershed.

UNSUSTAINABLE EROSION IN HEADWATERS

In the upper Santa Rosa Creek sub-watershed, geology and topography did not appear to have a direct influence on predicted soil erosion values. The geology is diverse with Rinconada shale (Tr), Vaqueros sandstone (Tv) and Franciscan mélange (Kjfm) prevalent. Sites with predicted high erosion values were not more prevalent in any one formation. Additionally, slope steepness and length were thought to be a factor influencing soil erosion in this area, however sites with greater slope steepness and lengths surround these potentially highly erosive sites and therefore slope may not be a direct influence on erosion here.

Comparing 2009 vegetation data (County of San Luis Obispo, 2009a) with predicted soil erosion values showed there could be an association with vegetation types and predicted soil erosion values. The highly erosive sites were not as prevalent in grassland vegetation, as they were in shrub and tree communities (Fig. 4-11). To expand on vegetation's influence on soil erosion, soils associated with various vegetation types were studied to determine if they influenced predicted soil erosion rates. Soil properties were variable in sites with high predicted soil erosion values, however there were several sites with the same soil (Lopez very shaly clay loam). In the upper Santa Rosa Creek sub-watershed, vegetation appeared to be the biggest influence on predicted soil erosion values. Other factors, such as geology, slope, and soils influenced soil erosion as well, but appeared less significant than vegetation.

Figure 4-11. Soil map units in the Santa Rosa Creek watershed headwaters where RUSLE2 predicted soil erosion values exceeded five tons of soil, per acre, per year highlighted in red, with vegetation and upland erosion sites overlaid over aerial imagery.

UNSUSTAINABLE EROSION IN PERRY CREEK SUB-WATERSHED

There were six soil map units in the Perry Creek sub-watershed with high predicted soil loss values. They were located in the same general geographic area, near Fiscalini Creek. There were only six units with predicted high values in this area, so trends were difficult to determine with limited data. The geologic formations were highly variable here, and included serpentine (s), Lospe formation (Tl), Franciscan mélange (Kjfm) with chert (ch) and metavolcanic rocks (mv), Quaternary-aged landslide deposits (Qls), and unnamed sedimentary rocks (Ks). The soils at these sites were Los Osos (loamy claypan) and Gaviota (shallow). Vegetation was herbaceous (grassland) and tree (Monterey Pine forest). The factor that appeared to influence soil erosion the

greatest at this site was topography (Fig. 4-12). The highly erosive sites had steep slopes greater than 40 percent and were located in narrow channels tangent to Fiscalini and Perry Creeks.

Figure 4-12. Sites where RUSLE2 values exceed sustainable rates of five tons/acre/year, in the Perry Creek sub-watershed.

AREAS NOT ASSESSED

Approximately 76 acres, or less than one percent of the entire upper watershed area, could not be assessed because of data gaps. This occurred in areas with little vegetation and therefore had no rangeland production data in Soil Surveys (USDA Soil Conservation Service, 1998). Soil erosion is possible at some of these sites, and therefore could impact RUSLE2 results. Soils that typically produce very little to no vegetation include complexes with rock outcrops, soils derived from serpentine rock parent material, riverwash soils, Xerorthents, and water. Approximately 60 acres of the upper watershed were “Riverwash” soils, located tangent to streams. These soils are highly susceptible to erosion and should be evaluated using other

methods. In addition “Xerorthents, escarpment” soils accounted for approximately six acres within the upper watershed, but could not be assessed. Soil Surveys describe “Xerorthents, escarpment” soils as highly erosive, having rapid runoff, fairly well stabilized, but in bare areas, gullies do exist (USDA Soil Conservation Service, 1984). These soils occurred along Green Valley Road on the southern boundary of the Perry Creek sub-watershed. Using 2007 aerial imagery no gullies existed in this area. There were also approximately seven acres of “Water” which did not apply to the erosion assessment. In addition, soil map units less than 0.065 acres were not assessed because accurate slope length and slope percent could not be captured using the Digital Elevation Model in GIS.

Upland Erosion Mapping

There were 877 upland erosion sites identified in the watershed. From these data, it was determined that approximately 9,558 acres of land is currently susceptible to soil loss in the Santa Rosa Creek watershed. Upland erosion sites ranged from 0.1 acre to 233 acres in size, with a mean size of 10.9 acres. Figure 4-13 shows upland erosion locations in the watershed while Table 4-4 includes erosion statistics for the entire watershed and sub-watersheds. The mean upland erosion size was likely skewed due to the presence of a few outlier values, or values that fell far above the normal size of gully erosion occurring within the watershed. Only 35 sites with approximately four percent of the total upland erosion area were over 50 acres in size; of these, two sites were over 200 acres. Large erosion sites were typically observed in sparsely vegetated drainages where the entire drainage appears as one large gully (ephemeral gully) with eroding banks and exposed soil throughout the site. When this occurred, the entire area was mapped as “gully/drainage” to represent gully erosion occurring in association with drainages. A histogram of upland erosion sizes show most gullies were less than 24 acres in size (Fig. 4-14). Very few sites were larger than 46 acres.

Figure 4-13. Upland erosion sites in the Santa Rosa Creek watershed, mapped using aerial imagery in GIS.

Figure 4-14. Histogram of ephemeral gully and gully erosion site size in the Santa Rosa Creek watershed, as identified using GIS and 2007 aerial imagery.

Areas most impacted by gully erosion were observed to be foothill grasslands with steep slopes. Many gully erosion sites were located in association with small, unnamed drainages, as described above. Headcuts were commonly found at the top of sparsely vegetated drainages and tributaries throughout the watershed. Cattle trails were commonly observed in association with these sites. This could result because cattle could not cross drainages and tributaries in other locations due to steep banks. Upland erosion appeared more prominent throughout the Perry Creek sub-watershed than along the main-stem. There were approximately 6,837 acres of upland erosion there, or 72 percent of the total upland erosion occurring within Santa Rosa Creek watershed.

Generally there were fewer gullies identified in the headwaters. This could have occurred because camera glare on the digital aerial imagery created viewing restrictions. Less than five percent of the entire watershed area, or less than 1,520 acres, could not be viewed due to reflective glare on the aerial image. At locations where glare was present, the ground surface

appeared almost white and distinct features such as vegetation were muted making mapping erosion features difficult. In addition, grassland communities of the lower foothills were replaced by chaparral, coastal scrub, and forests in upper elevations of the Santa Lucia Mountains. Gullies could exist within densely vegetated areas however the ground surface could not be viewed due to obstructions resulting from vegetation canopy.

Cattle grazing activities occur in the upper watershed however less upland erosion was identified there. In these areas, vegetation is diverse and rocky outcrops exist. Impacts to riparian areas surrounding streams and drainages appeared to decrease as well. Although the amount of erosion appeared less in the upper watershed, there were issues viewing the aerial imagery at some locations, as discussed above, and additional erosion features could exist. These upper watershed areas vegetated with trees and shrubs were, on average, the highest predicted soil erosion soil map units in the watershed. Sheet and rill erosion could be occurring below the vegetation's canopy but could not be detected using the aerial imagery. If this were the case, then cattle's role in exacerbating soil erosion could become more diminished.

Additional sediment sources identified in the mapping portion of this project included mineral extraction and rock quarry sites. These sites were observed as areas of excavated land and/or exposed rock. Approximately 30.6 acres of land was observed to be excavated in the watershed. The Bianchi Quarry was the largest site at 16.1 acres, with the Cambria Pit being the second largest site at 9.7 acres. Both sites are active rock quarries. The Bianchi Quarry is located in the upper Santa Rosa Creek sub-watershed and the Cambria Pit is located in the Perry Creek sub-watershed, along a tributary to Fiscalini Creek.

Data Correlations

The data from this study were analyzed to determine any relationships between the predicted soil erosion values and key variables. These variables were used in the RUSLE2 calculation, and therefore were expected to show influence on resulting predicted erosion values.

The relationship between soils and erosion has been extensively studied. A description of a soil's susceptibility to erosion is defined in the soil's K-factor. Further information about how a soil influences water infiltration and holding capacity, and therefore influences runoff and soil erosion, is available online at the USDA NRCS website, Web Soil Survey (<http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>). The geologic formations of a site directly influence soil formation and therefore have a complex relationship to soil erosion as well. Other factors were studied in greater detail to help define major influences on soil erosion in the Santa Rosa Creek watershed.

Slope percent data were compared to predicted soil loss values using a linear regression model in Minitab. The results showed that a positive relationship between RUSLE2 values and slope percent existed, and a moderate statistical relationship existed as well ($r=0.76$) (Fig. 4-15). As slope increases, the predicted soil loss value could increase at a value of roughly 0.0655 times the slope. This was not a strong correlation value, and it appeared that although slope may influence soil erosion, other factors could be involved as well.

Figure 4-15. Correlation between RUSLE2 predicted soil loss (tons/acre/year) and slope percent of soil map units in the upper Santa Rosa Creek watershed.

Additionally, the density of upland erosion sites that were mapped in GIS using the 2007 aerial imagery, and 2009 vegetation formation data (County of San Luis Obispo, 2009a) were studied to see if there was a relationship to RUSLE2 values. Upland erosion sites that were mapped using GIS and aerial imagery were limited by viewing restrictions provided by vegetative canopy and camera glare. Upland erosion sites were distributed throughout the watershed. There appeared to be no trends between existing erosion sites and RUSLE2 erosion values. Sites with high predicted erosion values did not, on average, have more mapped upland erosion features than other sites. However, in viewing the aerial imagery a link between predicted soil erosion rates and vegetation type appeared to be a possibility.

Mapped upland erosion sites appeared to be more prominent in herbaceous, grasslands. High RUSLE2 values were obtained at sites with varying vegetation types. In order to determine if there were any correlations with RUSLE2 values and vegetation, these data were studied using Minitab. Vegetation formations and RUSLE2 values were studied for each soil map unit using a one-way ANOVA in Minitab. This allowed categorical data (vegetation) to be correlated with quantitative data (RUSLE2 values). The null hypothesis was that all vegetation communities have the same average RUSLE2 value, and the alternative hypothesis was that at least one vegetative community had a statistically significant different average RUSLE2 value than the rest. The results showed that there was sufficient evidence ($p < 0.05$) to reject the null hypothesis and that there was statistical evidence that not all the vegetation formation average predicted erosion values were the same (Fig. 4-16). There was evidence that vegetation formations trees (Level 1) and shrub (Level 2) had higher average predicted soil erosion rates than the rest of the vegetation formations, with shrubs having the highest RUSLE2 values. Vegetation formation herbaceous (Level 3) was higher than wooded wetland riparian (Level 4) and agricultural (Level 9), but there was overlap in formation herbaceous, herbaceous wetland riparian (Level 5), and urban (Level 8) average predicted soil erosion values. Both riparian and urban areas had small sample sizes and additional data may reveal differences exist.

Figure 4-16. One-way ANOVA test of RUSLE2 predicted soil erosion values from soil map units and vegetation formations in the upper Santa Rosa Creek watershed.

CONCLUSIONS

The objectives of this study were to classify the environmental factors of the Santa Rosa Creek watershed using GIS data; then to use these data to run RUSLE2 and predict soil erosion rates for each soil map unit in the watershed. This allowed potentially highly erosive areas to be identified. Using RUSLE2 results, correlations between predicted soil erosion and key variables were studied.

There is potentially 56,270 tons, or 1.97 tons/acre, of soil that is eroded each year in the upper Santa Rosa Creek watershed. RUSLE2 predicted soil erosion values exceed five tons, per acre, per year, in 37 assessment sites (soil map units) of 14 different soils. These sites account for approximately 1,617 acres, or 12 percent of the total upper watershed area. These sites occur throughout the watershed, but are more common in upper Santa Rosa Creek sub-watershed headwaters where slopes are generally steeper and vegetation is variable. Sites that potentially erode at unsustainable rates appear to be more influenced by vegetation in the upper Santa Rosa Creek sub-watershed, and topography in the Perry Creek sub-watershed.

Factors such as soil, geology, and topography influence predicted soil erosion values as they are variables used in the RUSLE2 calculation. Their relationships with soil erosion are complex and difficult to generalize. Slope steepness, for instance, influences soil erosion

however has only a moderate correlation when studied statistically ($R^2=0.58$). Upland erosion sites mapped using GIS and digital aerial imagery do not show any direct correlations with soil map units with predicted high erosion rates. Using a One-way ANOVA test in Minitab, it was determined that different vegetation communities have different average predicted soil erosion values. Shrub and tree communities have higher RUSLE2 values than the other formations.

In general, the Santa Rosa Creek watershed is likely functioning at sustainable soil development and erosion rates. Restoration and conservation efforts could be implemented where existing erosion is occurring to reduce soil loss and protect natural resources in the watershed. Locations that are more susceptible to erosion should be monitored to prevent soil loss in the future. Degradation of steelhead trout habitat could be less influenced by natural variables that predict soil erosion, and more influenced by land use and local erosion and deposition occurring in areas tangent to streams, which was not studied extensively in this project.

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APPENDIX A

RUSLE2 PROFILE DATA ENTRY METHODS

The following is a detailed procedure of data input from geographic data sources obtained using Geographic Information Systems (GIS) into RUSLE2 to predict soil erosion in the Santa Rosa Creek watershed:

STEP 1: Choose location to set climate

A San Luis Obispo County “R value” based on rainfall was selected in a drop-down menu. Average annual precipitation amounts were distinctly different from the lower to upper watershed boundaries, averaging 17” a year at the coast and 23” a year at the headwaters. Depending on the location of the soil being analyzed, one of the following values were selected from a drop-down list: “CA_San Luis Obispo County_R 16-18”, “CA_San Luis Obispo County_R 18-20”, “CA_San Luis Obispo County_R 20-22”, and “CA_San Luis Obispo County_R 22-24”.

STEP 2: Choose soil type

The “soils” layer was “clipped” using “drainage” and “other drainage” boundaries to assess target areas. Each “soil map unit” within the “soils” layer was analyzed separately using a RUSLE2 profile. The “soil map unit” name was selected in the drop-down menu on the profile screen. For soil “complexes” and “associations”, the most prominent soil type in the map unit was selected. For “undifferentiated group” soils, the soil with the highest soil erodibility was selected to conservatively represent erosion potential of that group. The “soil map unit” with “rock outcrop” as the dominant component soil, the “Lodo” soil series was selected.

STEP 3: Set slope topography

Slope length and percent were manually entered according to calculated values produced for each line drawn in every “soil map unit” using GIS. A slope length of 1,000 feet was not exceeded. USDA NRCS recommends avoiding slope lengths greater than 1,000 feet to increase accuracy.

STEP 4: Describe management

Land use analysis using parcel data and digital agricultural data acquired on SLO Datafinder (<http://lib.calpoly.edu/gis/>) showed the upper watershed consists of two primary land uses: cattle grazing and crops. The GIS data acquired from the County Assessor's Office and the Agricultural Commissioner's Office was edited using information acquired from 2007 digital aerial photography. Crop locations that are retired were deleted from the layer and additional crop locations were digitized in GIS using 2007 aerial imagery. The result showed that approximately 988 acres, or three percent, of the land use in the upper watershed is used for crops, with an average crop size of 12 acres. The remaining area in the upper watershed is either grazed, rural residential, or "watershed" as described by the Soil Surveys. Parcel data, aerial photographs, site surveys, and consultations with San Luis Obispo County Farm Bureau support that the upper watershed's land use is mostly rangeland.

In order to streamline the procedure, generalizations for land management were made. With nearly 600 soil map units analyzed separately, it was not possible to describe specific management practices for each unit. In the "Base Management" drop-down menu, the "Strip/barrier management" file is chosen, and "Cool season grass; not harvested" was selected. After the "Base Management" was selected in the drop-down menu, the chosen field was displayed in the Base Management window on the profile screen. Edits were made to describe site conditions by clicking on the yellow folder next to the selected Base Management. The "Operations and Information" tabs are displayed in a new window. In the "Vegetation" field of the Operations tab, the "Permanent cover not harvested" folder was selected and "Brome, California, established cover" is chosen. After a selection was made it was displayed in a drop-down window beneath the "Vegetation" field. For each soil map unit the vegetation "Yield (# of harvestable units)" was edited to represent the "normal rangeland production" value for each "soil map unit" according to Table 5 in the Soil Surveys. All other fields were left unchanged in order to preserve the integrity of the management data developed by the Agricultural Resources

Service. The “Base Management” selection was made with consultation from B. Hallock of Cal Poly to choose a vegetation type that best represents the growth characteristics of vegetation present in this watershed.

STEP 5: Set supporting practices

Practices such as contouring, strip systems, terrace/diversion, impoundments, and tile drainages, are be defined in this step. Supporting practices in the Santa Rosa Creek watershed were unknown. In Step 5 of the RUSLE2 analysis, “default” supporting practice was selected for “Contouring”. Input fields for “strips/barriers”, “diversion/terrace” and “sediment basin” were left at “none”.

APPENDIX B

SANTA ROSA CREEK WATERSHED GEOLOGIC UNITS

Geologic GIS Data created by County of San Luis Obispo in 2007 and
obtained online from SLO Datafinder (<http://lib.calpoly.edu/gis/>).

GEOLOGIC UNIT	ACRES	PERCENT OF WATERSHED
Franciscan Rocks mélange (KJfme)	14322.90	47.10%
Alluvial Deposits (Qal)	2871.91	9.45%
Unnamed Sedimentary Rocks (Ks)	2716.73	8.93%
Rincon Shale (Tr)	2560.16	8.42%
Vaqueros Sandstone (Tv)	1659.99	5.46%
Stream Terrace Deposits (Qt)	807.05	2.65%
Lospe Formation conglomerate, sandstone, claystone (Tl)	618.66	2.03%
Franciscan Rocks graywacke and micrograywacke (KJfg)	611.76	2.01%
Landslide Deposits (Qls)	527.15	1.73%
(sp)	432.05	1.42%
Monterey Formation siltstone, claystone/siltstone (Tmb)	430.34	1.42%
Franciscan Rocks metavolcanic rocks (greenstone) (mv)	418.86	1.38%
Franciscan Rocks (KJf)	382.23	1.26%
Pismo Formation claystone and siltstone (Tpsl)	289.85	0.95%
(Tml)	273.71	0.90%
(Tb)	262.93	0.86%
Cambria Felsite (Tc)	220.94	0.73%
Pismo Formation Squire Member (Tps)	205.26	0.68%
Obispo Formation crystal-bearing vitric tuff (To)	149.63	0.49%
Franciscan Rocks melange? (KJfme?)	130.04	0.43%
(Trh)	116.48	0.38%
Serpentinite (s)	110.96	0.36%
Franciscan Melange chert (ch)	105.79	0.35%
Monterey Formation diabase and basaltic rocks (Tmv)	63.24	0.21%
Franciscan Melange greywacke (gw)	43.06	0.14%
Monterey Formation hard tuff (Tmt)	40.07	0.13%
Cambria Felsite basalt (Tcb)	18.91	0.06%
Pismo Formation pebble/cobble conglomerate (Tpcg)	5.82	0.02%
Franciscan Melange blueschist (bs)	3.85	0.01%
Unnamed Sedimentary Rocks? (Ks?)	3.31	0.01%
(Qaf)	1.44	<0.01%
Cambria Felsite? (Tc?)	0.94	<0.01%
Franciscan Melange silica-carbonate rocks (sc)	0.14	<0.01%
Franciscan Melange conglomerate (cg)	0.11	<0.01%
Franciscan Melange shale (sh)	0.09	<0.01%

APPENDIX C

SANTA ROSA CREEK WATERSHED SOIL MAPS

APPENDIX D

**VEGETATIVE COMMUNITIES WITHIN THE SANTA ROSA CREEK
WATERSHED**

Vegetation identified using 1998 County Vegetation data (<http://lib.calpoly.edu/gis/>),
Vegetation Formation and Oak Formation Data (County of San Luis Obispo, 2009a and 2009b),
and San Luis Obispo County Vegetation Mapping Report, Photo Interpretive
and Mapping Guidelines (2009c). Vegetative communities were further described using
California Vegetation (Holland and Keil, 1995) and the *Manual of California Vegetation*
(Sawyer and Keeler-Wolf, 1995).

Summarized below are vegetative communities found within the Santa Rosa Creek watershed as described by 1998 County Vegetation data (County of San Luis Obispo, 1998), Vegetation Formation and Oak Formation Data (County of San Luis Obispo, 2009a and 2009b), and San Luis Obispo County Vegetation Mapping Report, Photo Interpretive and Mapping Guidelines (2009c). Vegetative communities were further described using California Vegetation (Holland and Keil, 1995) and the Manual of California Vegetation (Sawyer and Keeler-Wolf, 1995).

Mesomorphic Tree Vegetation-Forest and Woodlands

The National Vegetation Classification Hierarchy defines this category as locations where all tree forms dominate the canopy with at least eight to ten percent cover (County of San Luis Obispo, 2009a). There are approximately 5,536 acres of trees in the watershed. They are located throughout the lower watershed, including developed areas, along drainages in the upper foothills, and scattered in the headwaters with shrubs and herbs. Trees in the lower watershed are mostly Monterey Pine, while oak communities are dominant in the foothills and headwaters.

The watershed tree formation data were divided in the 2009 County data into three categories of oak communities: Coast Live Oak, Coast Live Oak-mixed Hardwood, and Valley Oak (also with other hardwood including Coast Live Oak). There are a total of 4,348 acres of oak communities in the watershed, or about 14 percent of the total watershed area. Coast Live Oak-mixed Hardwood is the most common with 2,346 acres, or approximately eight percent of the total watershed area. Coast Live Oak accounts for 1,979 acres, or nearly seven percent of the total watershed area. Valley Oak with Hardwoods including Coast Live Oak accounts for only 23 acres, or less than one percent of the entire watershed area. The Mesomorphic Tree Vegetation-Forest and Woodland mapping unit could be described in greater detail by identifying the forest and woodland communities that exist in the watershed.

Oak Woodland

In the Santa Rosa Creek watershed, coastal live oak woodlands occur in two conditions. The first is in moist, often north-facing slopes, where coast live oak (*Quercus agrifolia*) form dense communities and intermix with species such as California bay-laurel (*Umbellularia californica*), madrone (*Arbutus menziesii*), and big-leaf maple (*Acer macrophyllum*) with shade-tolerant understory plants. The second condition in which coastal live oak woodlands occur is in drier, more exposed areas where sparsely scattered oaks are associated with shrubby or herbaceous understory plants, or grasslands, in open woodland communities. The most common shrubs associated with open woodlands are Manzanita (*Arctostaphylos spp.*), gooseberries and currants (*Ribes spp.*), lavender (*Ceanothus spp.*), bush monkeyflower (*Mimulus aurantiacus*), black sage (*Salvia mellifera*), coyote bush (*Baccharis pilularis*), and California sagebrush (*Artemisia californica*) (Holland and Keil, 1995).

Coast live oak communities usually exist on slopes tangent to streams in the Santa Rosa Creek watershed. As elevation increases oak communities integrate into riparian vegetation and become more complex. In the lower foothills oak communities are classified exclusively as coast live oak. In the headwaters, the oak forests intermingle with other hardwood species. Valley oak (*Quercus lobata*) exists in the watershed as well. A small patch of valley oak is located along the northeastern border, southeast of Cypress Mountain. Valley oak woodlands are found on alluvial terraces and low rolling hills from Lake Shasta to Los Angeles. They are usually found in fertile alluvial valleys where they grade into foothill woodlands (Holland and Keil, 1995). In the Santa Rosa Creek watershed, the valley oak population is located on a steep hillslope with coast live oak mixed hardwood forests, shrubs, and herbs.

Monterey Pine Forest (Closed Cone Coniferous Forest)

Monterey Pines only grow naturally in three locations in the state, including Cambria. Natural stands of Monterey pine are in danger due to a fatal pine pitch canker disease and urban

development. In Cambria, stands of Monterey Pine grow as a closed canopy forest with Coast Live Oak and toyon growing as a short-tree understory (Holland and Keil, 1995). There are approximately 777 acres of undeveloped Monterey Pine forest in the watershed, or three percent of the total watershed area. An additional 772 acres of developed Monterey Pine forest exists in the watershed, and is impacted by residential areas and the community of Cambria. These developed areas account for an additional three percent of the total watershed area. Stands of Monterey Pine are exclusive to the lower watershed.

Sargent Cypress

Although Sargent Cypress is not identified in the County's vegetation data, it is recorded in the upper watershed by Coffman in his book *The Cambria Forest: Reflections of its Native Pines and Eventful Past* (1995). Cypress Mountain, located in the upper Santa Rosa Creek watershed is named after a stand of Sargent Cypress trees that grow there. The Sargent Cypress series is described by Sawyer and Keeler-Wolf (1995) as typically found in upland slopes and ridges, and in raised stream benches or terraces. These trees grow in sterile soils derived from ultramafic material. Ultramafic rock is an igneous rock formed from magma, and is usually high in magnesium and iron .

Mesomorphic Shrub Vegetation

The National Vegetation Classification Hierarchy defines Mesomorphic Shrub Vegetation when the dominant canopy is shrub forms, covering at least ten percent of a site. Oaks may occur in the stand but are generally not important in the canopy nor are they distributed regularly throughout the unit. Emergent trees may occupy eight to ten percent cover, but are not distributed evenly throughout the site (County of San Luis Obispo, 2009a). There are approximately 2,962 acres of shrubs in the watershed, or roughly ten percent of the total

watershed area. The 1998 vegetation data show chaparral and coastal scrub communities exist in the watershed.

Chaparral

In the Coast Range, chaparral communities form on steep, dry slopes and are often closely associated with southern coastal scrub plant communities. Species composition can be highly variable, and depending on dominant species, several different chaparral communities can be found throughout the state. In general, chaparral vegetation grows in dense thickets. Plants form a canopy of needle-leaved or broad-leaved drought-tolerant plants. Chaparral species are characteristically very stiff, woody, and long-lived. Within mature stands, there is often no herbaceous undergrowth present. Chaparral vegetation is diverse with nearly 900 vascular species occurring in these communities; with approximately 240 different woody plants from several different plant families (Holland and Keil, 1995).

Coastal Scrub

Southern coastal scrub communities often form in shallow, nutrient-poor soils with little plant-available water. As a result, vegetation is shallow-rooted and deciduous in the summer when leaves typically drop due to little or no water in the upper soil horizons. In contrast, vegetative growth often occurs in the winter, when moisture is available. Species common in coastal scrub communities include: California sagebrush (*Artemisia californica*), bush monkey-flower (*Mimulus aurantiacus*), sages (*Salvia sp.*), coyote bush (*Baccharis pilularis*), coffeeberry (*Rhamnus californica*), and poison-oak (*Toxicodendron diversilobum*) (Holland and Keil, 1995).

Chaparral and coastal scrub communities are mixed throughout the watershed, occurring tangent to one another at some locations. These communities are common throughout foothills near streams on moderate slopes. As elevation and slope steepness increase, chaparral and coastal scrub become more common. In the headwaters these shrub communities are usually

associated with tree formations and some herbaceous vegetation. There are fewer shrub communities in the Perry Creek Watershed. Shrubs here are more common on south-facing, moderate slopes and along the southwestern boundary of the watershed near the ocean.

Mesomorphic Herbaceous Vegetation

The National Vegetation Classification Hierarchy defines Mesomorphic Herbaceous Vegetation when all upland herbaceous life forms (forb-like and grassland vegetation) dominate the ground layer with at least ten percent cover. Emergent tree or shrub vegetation, or all woody life forms, can occupy up to ten percent of the site. Herbaceous cover can be present in “fallow” agricultural lands where annual grasses and forbs exist. This can occur as little as one season after harvesting a crop. Some areas classified as herbaceous may contain more than ten percent shrub communities due to the difficulty in distinguishing seral scrub growing in post disturbance situations (County of San Luis Obispo, 2009a). There are approximately 19,200 acres of herbs in the watershed, or roughly 63 percent of the total watershed area. The 1998 vegetation data show grassland communities exist in the watershed.

Grassland

In California, grasslands have been altered more than any other plant community. Experts speculate what unaltered, natural grasslands look like in California, because none exist. Coastal grasslands are often located on marine terraces and grow with coastal scrub, chaparral, and coast live oak woodland communities. Native grasses growing in coastal areas would have been dominated by slender needlegrass (*Nassella lepida*), large needlegrass (*Achnatherum coronatum*), purple needlegrass (*Nassella pulchra*), and nodding needlegrass (*Nassella cernua*). Junegrass (*Koeleria macrantha*), melic grass (*Melica imperfect*), three-awn (*Aristida spp.*), and deergrass (*Muhlenbergia rigens*) would have also been common (Holland and Keil, 1995).

Today, grassland communities are altered landscapes composed of annual cool-season Mediterranean non-native grasses. These non-native grasses were introduced for livestock grazing during early Spanish colonization. Over time, un-grazed native grasslands were inevitably overtaken by non-native grasses, such as wild oats (*Avena fatua*). Many non-native grasses out-competed native grasses for water, nutrients, and space. Other common introduced grasses occurring in southern coastal grassland communities are: slender wild oats (*Avena barbata*), rip-gut brome (*Bromus diandrus*), soft chess brome (*Bromus hordeaceus*), and annual ryegrass (*Lolium multiflorum*) to name a few (Holland and Keil, 1995).

Grassland vegetation is the dominant vegetation throughout the watershed's foothills. It exists on land used for rangeland, grain production, residential, or open space. Grasslands occur sparsely in the lower watershed, where Monterey Pine forests are dominant. Grasslands are also less frequent in the headwaters where they are usually found along steep slopes near streams.

Temperate Flooded Riparian Vegetation

The National Vegetation Classification Hierarchy defines Temperate Flooded Riparian Vegetation as a woodland and shrubby riparian dominated canopy with at least eight to ten percent cover. Either trees or shrubs can dominate or co-dominate the site. Stands are temporarily or seasonally flooded, generally early in the growing season. Valley or coast live oak can be a component to a mixed community of riparian woodland but they do not dominate the canopy (County of San Luis Obispo, 2009a). There are approximately 671 acres of temperate flooded riparian vegetation in the watershed, or roughly two percent of the total watershed area. The 1998 vegetation data show scrub and woodland riparian communities exist in the watershed.

Riparian Communities (Scrub and Woodland)

Riparian communities border streams, lakes and springs and usually consist of deciduous trees and various shrubs and herbs. Riparian vegetation is typically confined to banks and

floodplains of waterways. Riparian scrub communities occur on relatively fine-grained sand and gravel bars, close to gravel bars, and along streambanks. Riparian scrub communities consist of various willow species, such as arroyo willow (*Salix lasiolepis*), that form scrubby streamside thickets. Additional species found in riparian scrub communities include California blackberry (*Rubus ursinus*) and stinging nettle (*Urtica dioica ssp. holosericea*). Common Central Coast riparian woodland species include: arroyo willow (*Salix lasiolepis*), red willow (*Salix laevigata*), sycamore (*Platanus racemosa*), box elder (*Acer negundo*), black cottonwood (*Populus balsamifera*), and coast live oak (*Quercus agrifolia*) (Holland and Keil, 1995).

Scrub and woodland riparian communities are found throughout the watershed tangent to streams. This vegetation forms an almost continuous line from the Santa Rosa Creek outlet at the Pacific Ocean, to the headwaters. Some discontinuity occurs in the foothills where water flow is subterranean. As elevation increases riparian corridors become narrower and coast live oak forests encroach riparian communities. In the Perry Creek sub-watershed riparian vegetation is less apparent. Riparian corridors are not continuous and are extremely narrow here. The dominant land use in this watershed is rangeland with grassland vegetation prevalent.

Temperate Meadow and Freshwater Marsh

The National Vegetation Classification Hierarchy defines Temperate Meadow and Freshwater Marsh Vegetation in meadow settings (temporarily to seasonally flooded environments typically with species from *Carex* or *Juncus* genera) or marsh-like settings (permanently flooded environments) where *Typha sp.* and or *Scirpus sp.* dominate the stand. Stands are usually less than five acres in size (County of San Luis Obispo, 2009a). There are approximately 50 acres of temperate flooded riparian vegetation in the watershed, or roughly less than one percent of the total watershed area. The 1998 vegetation data show marsh and meadow communities exist in the watershed. Only the estuary, located at the confluence of Santa Rosa

Creek and the Pacific Ocean, is defined below, however temperate meadow communities associated with seeps and springs likely exist throughout the watershed as well.

Estuary (Coastal Estuarine Community)

Estuaries occur where freshwater and saltwater mix at the confluence of a stream and an ocean. Because estuaries are protected from waves and wind, brackish water and thick layers of sediment can form. Estuarine vegetation is adaptable to extreme variations of salinity levels due to daily tidal fluctuations, along with seasonal fluctuations occurring with increased precipitation in the winter months. Plants occurring in estuaries are often soft-bodied and flexible because they are continuously saturated. Common estuary plants include eel-grass (*Zostera marina*), ditch-grass (*Ruppia maritime*), and algae (Holland and Keil, 1995).

The watershed's estuary is located at the confluence of Santa Rosa Creek and the Pacific Ocean. It provides habitat for two federally listed fish species, Tidewater goby (*Eucyclogobius newberryi*) and steelhead (*Oncorhynchus mykiss*). Tidewater goby spend their entire lives in coastal lagoons/estuaries, spawning when freshwater flows increase during higher creek flows. In contrast, steelhead are an anadromous species that hatch in freshwater, enter the ocean as adults, and return to their natal stream to spawn. Steelhead use the brackish waters in the estuary to acclimate from freshwater to saltwater as smolts. During this stage, fish feed heavily to increase their size.

APPENDIX E

POTENTIALLY HIGHLY EROSIONAL SOIL MAP UNITS IN THE UPPER SANTA ROSA CREEK WATERSHED

Determined using RUSLE2 program

Soil	Count	Total Acres	Average Slope Length (ft)	Average Slope Steepness (%)	Average RUSLE2 Value (tons/acre/year)
Gaviota sandy loam, 50 to 75 percent slopes	2	90.6	465.6	59.5	7.5
Gaviota fine sandy loam, 15 to 50 percent slopes	4	128.6	558.3	50.9	7.0
Cieneba-Millsap loams, 30 to 75 percent slopes	7	93.3	485.9	57.7	6.6
Lompico-McMullin complex, 50 to 75 percent slopes	1	58.1	353.6	80.0	5.9
Los Osos-Diablo complex, 15 to 30 percent slopes	1	122.0	676.6	49.8	5.7
Los Osos-Diablo complex, 9 to 15 percent slopes	1	3.8	369.9	62.6	5.7
Lompico-McMullin loams, 30 to 75 percent slopes	6	286.8	358.5	65.6	5.5
Lopez very shaly clay loam, 30 to 75 percent slopes	7	467.1	742.9	73.5	5.4
Los Osos-Lodo complex, 30 to 75 percent slopes	2	225.4	646.0	44.1	5.4
Los Osos-Diablo complex, 30 to 50 percent slopes	1	14.5	488.9	56.2	5.3
Los Osos loam, 30 to 50 percent slopes	1	31.3	324.0	59.5	5.2
Rock outcrop-Lithic Haploxerolls complex, 30 to 75 percent slopes	2	65.9	799.8	63.6	5.2
Gaviota-Rock outcrop complex, 30 to 75 percent slopes	1	14.0	247.0	68.3	5.0
Lodo-Rock outcrop complex, 30 to 75 percent slopes	1	15.4	516.8	80.8	5.0