CHAPTER 3. SEDIMENT

Key Points

- The sediment source analysis addresses both natural and human-caused sources of sediment.
- Road-generated sediment rates calculated from road inventories and modeling in the South Fork subwatershed were applied to other parts of the watershed.
- Granitic bedrock and decomposed granite soils were considered separately in the road-generated sediment estimates.
- Large mass-wasting features were inventoried for the entire watershed from aerial photos.
- Streamside sediment source estimates were based on inventories of stream banks and streamside features contributing sediment in sample reaches.
- Streamside sample reaches were identified using a stratified random sampling approach. The results were then extrapolated to other stream reaches based on geology.
- The largest sediment sources are from streamsides and are the result of multiple interacting human activities.
- Results show current sediment delivery is 167% of natural sediment delivery.
- The TMDL is set at 125% of natural sediment delivery.
- The sediment TMDL for the Scott River watershed is 560 tons of sediment per square mile per year.

This chapter describes the sediment source analysis, study methods, sediment TMDL, sediment load allocations, and margin of safety for the Scott River watershed. Please note that all figures and tables for this chapter are located at the end of the Staff Report.

3.1 STUDY METHODS

3.1.1 Sampling Approach and Rationale

The sediment source inventory and analysis is divided into three components:

- Road-generated sediment as calculated based on modeling (SEDMODL2) and road inventories.
- Large mass-wasting features inventoried on aerial photos.
- Streamside sediment sources as calculated from inventories of stream banks and discrete erosion and mass-wasting features contributing sediment.

Because not all stream reaches can be inventoried, a sample of stream banks was inventoried based on a stratified random sampling approach.

3.1.2 Subwatersheds Used in Compilation

For the purpose of the TMDL analysis, the Scott River watershed was divided into seven subwatersheds, each of which has more continuity of characteristics within it than it has with the other subwatersheds. The sub-watersheds, shown on Figure 3.1, are as follows:

- **West Canyon.** Steep rugged mountains. Mostly sedimentary and metamorphic bedrock with smaller areas of mafics and only a small area of granite. Greatest concentration of landslides in the Scott is in the western portion of this area. Mostly high precipitation except lower slopes of the mountains.

- **East Canyon – Scott Bar Mountains**. Steep rugged mountains, almost all sedimentary and metamorphic bedrock. Only one landslide mapped. Mostly drier than West Canyon except in highest Scott Bar Mountains.

- **Eastside**. Moffett Creek drainage. Steep country, but not as high as mountains that ring the rest of Scott Valley. Mostly sedimentary and metamorphic bedrock with a little mafic bedrock in the mountains and a little Quaternary in the valley bottom. No significant landslides were mapped or observed on aerial reconnaissance. Least precipitation of the seven subwatersheds.

- **East Headwater**. East Fork and Noyes Valley Creek drainages. Steep, rugged mountains, more than half sedimentary and metamorphic bedrock, but has largest area of mafic bedrock and a little granitic bedrock. One upland valley has Quaternary glacial deposits, other Quaternary deposits too small to map at scale shown. Few landslides. High country is intermediate in precipitation between the Westside/West Headwater area and the Eastside.

- **West Headwater - South Fork Drainage**. Steep, rugged mountains. Largely granitic and mafic bedrock, small amount of sedimentary and metamorphic bedrock. High precipitation in the high country and lower precipitation at lower elevations. Has several landslides and several hydraulic mining sites. High precipitation in the high country and lower precipitation at lower elevations.

- **Westside**. Steep, rugged mountains. Mixed bedrock geology but has largest areas of granitic bedrock, which produces unique problems. Landslides widely distributed in the steep country, particularly in granitics, but not great concentrations of landslides. High precipitation in the high country and lower precipitation at lower elevations.

- **Scott Valley and Eastern Valley Side**. Valley bottom is low relief, low precipitation, and underlain by Quaternary alluvium. Eastern valley side has low precipitation like the valley bottom, and much of the drainage does not reach the Scott, so it is a low sediment contribution area.

3.1.3 Combined Geologic Units

The geologic material and structure underlying a particular area is a primary factor in determining not only sediment delivery under natural conditions but also sediment delivery in response to human activities. For this reason staff chose bedrock composition as the factor on which to stratify sampling. The GIS geology coverage used (Saucedo et al., 2000) shows not less than twelve geologic units mapped in the Scott. Because applying all of these units would create too many strata for a practical sampling program, similar mapped units were combined. For the purposes of the streamside sampling program, staff aggregated the mapped units into four geologic units:

- Quaternary Deposits
- Granitic Bedrock
- Mafic and Ultramafic Bedrock
- Sedimentary and Metamorphic Bedrock

3.1.4 Description of Geologic Units

3.1.4.1 Quaternary Deposits

This unit is primarily unconsolidated gravel, sand, and soil that make up the floor of Scott Valley and the lower reaches of some tributary valleys. For the most part this unit forms flat or gently sloping land, as the land surface is the surface on which these materials were deposited. For this reason, the main means of erosion over most of the area of this unit is not slope processes but rather bank erosion of streams and occasional gullying. The primary management-related sediment delivery over most of the unit is associated with crop production, livestock management, and dredging legacy. Small areas within this unit include glacial deposits in the high valleys of the Scott Mountains, and landslide deposits.

3.1.4.2 Granitic Bedrock

This unit is exposed in the mountains paralleling the west side of Scott Valley. The suite of granitic rocks ranges in composition from granite to granodiorite (Mack, 1958, p. 24), and is generally fine grained and weathers to noncohesive and highly erodible soil. In the Klamath Mountains and the Sierra Nevada of California this decomposed granite soil is known as DG, both in the scientific literature and in popular parlance. During weathering of the granitic rock, cohesion between grains is lost, leaving the material as a mass of separate grains ranging in size from fine sand to small pebbles and lacking enough clay to bond it together. Consequently, the DG is highly susceptible to dry ravel, rill and gully erosion, debris slides, and debris torrents (Kellogg, 1992, p. 64). In addition, disturbance of the surface, or an increase in the degree of slope, tends to accelerate these processes. The problems of stability and sediment contribution associated with DG are sufficiently severe, widespread, and costly that a conference dedicated to these problems and their solutions was convened in Redding, California in 1992 (Sommarstrom, 1992).

3.1.4.3 Mafic and Ultramafic Bedrock

This unit is largely serpentine along with minor basalt, peridotite, and gabbro (Jennings, 1977). These rocks occur in parts of the Marble Mountains in the northwest part of the watershed, in the Scott Mountains in the southeast, and in a disconnected belt that runs from the south part of the Scott watershed to the northeast part. Some outcrops are the original igneous rock, but most are partly or wholly altered to serpentine. Much of the area underlain by mafic and ultramafic rocks is steep mountains. The rocks weather to form soil that is finer-grained and more clay-rich than soil formed on granitic rocks. The result is less tendency toward dry ravel, sheetwash, and rillwash. Some limited areas of sheared bedrock are vulnerable to landsliding.

3.1.4.4 Sedimentary and Metamorphic Bedrock

This unit makes up more than half of the area of the Scott River watershed and includes sedimentary rocks of many lithologies, mostly of Mesozoic age; metamorphic rocks of low to medium grade including amphibolite, greenschist, blueschist, and metavolcanics; and some Tertiary metavolcanics (Wagner and Saucedo, 1987). Although these suites of sedimentary and metamorphic rocks vary in geomorphic expression and potential for sediment contribution, in general they have more in common among themselves in terms of soils formed, structural strength, and slope stability than either suite has with the granitic or mafic rocks. For that reason the sedimentary and metamorphic rocks form a natural grouping in the context of this study.

3.1.4.5 Extent of Geologic Units

Table 3.1 summarizes the areal extent of geologic units in the Scott River watershed. The GIS geology coverage (Figure 3.2) has proved satisfactory for the job at hand. Field observations in October and November of 2003 and May-July of 2004 at computer-generated random stream sample locations showed no significant differences between geologic units shown on the GIS coverage and geologic units observed on the ground.

Table 3.2 summarizes the distribution of the geologic units in the seven subwatersheds used in this analysis. Granitic rocks, which are a major sediment contributor, especially when disturbed, underlie twenty-eight percent of the Westside subwatershed, forty-eight percent of the West Headwater subwatershed, and lesser amounts of the West Canyon and East Headwater subwatersheds. The East Canyon and Eastside subwatersheds are underlain mostly by sedimentary and metamorphic rocks. The highest proportion of mafic and ultramafic rocks occur in the East Headwater subwatershed where they underlie forty-three percent of the area. The Scott Valley subwatershed contains most of the Quaternary deposits in the Scott, as they cover most of the valley floor, but this subwatershed also is underlain by a substantial area of sedimentary and metamorphic rocks, primarily on the east side of the valley and in the hills at the north end of the valley. A discontinuous belt of mafic and ultramafic rocks trends northward from the Callahan area along the base of the mountains on the east side of the valley.

3.1.5 The Role of DG Soils

A significant portion of the Scott River watershed, 10.6 percent of the area (derived from Table 3.2), is underlain by granitic bedrock. The soils that form on this suite of rocks are widely recognized as some of the most erosive soils anywhere. This susceptibility to erosion not only applies to natural conditions but produces greatly accelerated and persistent erosion when the soil is disturbed, especially on steep slopes (Sommarstrom et al., 1990; USSCS, 1991; Sommarstrom, 1992).

The Granitic Sediment Study (GSS) of Sommarstrom and others (1990) is an evaluation of the role of DG soils in the Scott River watershed, and an estimate of the sediment contribution of DG in the watershed. The authors estimated the amount of sediment mobilized by different processes in different settings: sheetwash and rill erosion, road cuts, road fills, road surfaces, skid trails, streambanks, and landslides. They did not include a category defining soil creep, and staff interpret that they included soil creep processes in this highly granular soil in the sheetwash and rill erosion category. That study centered on contribution to the mainstem Scott River and recognized that much of the sediment mobilized is not transported immediately to the Scott but is stored on hillslopes and in swales, streambanks, and the channel bedload of tributaries.

In the GSS (Figure 2-11, p. 2-44), the authors estimated for each process the amount of sediment mobilized and the amount delivered to the Scott River. The proportion delivered ranges from five percent for sheetwash and rill erosion to 35 percent for stream bank erosion. For all processes combined, they estimated that 79 percent of mobilized sediment goes into storage and 21 percent is delivered to the Scott River. The GSS applied a different approach than the TMDL study, but the results can be compared in important ways.

The TMDL study is concerned not only with the Scott River, but also with the tributaries as they provide spawning and rearing areas for salmonids. Also, the TMDL study is less concerned with upslope processes and how much sediment is mobilized than with the interface between mountainside and stream system and how much sediment actually crosses into the stream system, including tributaries.

To assure uniformity of methods on all areas, staff applied the same system of field observations and data compilation to the DG areas as to the areas of other bedrock units. These results are presented first in the summary section.

However, DG produces sediment through a significantly different balance of processes than the other bedrock units. For example, roadcuts in DG are a dominant generator of sediment (Sommarstrom et al., 1990, p. 2-32), in contrast with other units. Also, DG is particularly susceptible to disturbance, and disturbed areas are slow to heal. For these reasons, staff did a separate calculation of the sediment estimate using the DG sediment contribution rates estimated in the GSS for areas of Granitic Bedrock, and rates from the TMDL study for the other bedrock units. These calculations are discussed in the individual inventory sections and are summarized in separate summary tables.

3.1.6 Effects of Multiple Interacting Human Activities (EMIHAs)

In published literature on forest management and surficial processes (e.g. Reid, 2001; Dunne et al., 2001), the term cumulative watershed effects is used to designate long-term cumulative and/or synergistic effects from multiple episodes of human activities. In addition, the term cumulative impacts is used in legal documents with its own specific meaning under the California Environmental Quality Act (CEQA) (Pub. Resources Code section 21000 et seq.). In order to avoid confusion or ambiguity, this TMDL document does not use the term cumulative effects and instead uses the term Effects of Multiple Interacting Human Activities (EMIHAs). In the following discussion, the published literature on cumulative watershed effects is referenced. Although this discussion is introduced in the Sediment TMDL chapter, the effects discussed may also affect other properties of a water body, including temperature conditions.

EMIHAs are changes in a watershed that affect processes in the watershed and are influenced by multiple human activities in the watershed. The multiple activities may be simultaneous or at different times, but they exert multiple influences on the processes in the watershed (Coats and Miller, 1981; Reid, 1993, 2001). Many EMIHAs are incremental and synergistic effects of multiple controlling factors, and the very fact of interaction creates difficulty in ascribing the cause of a particular effect to a specific action. One key concept is that the effects may not be concentrated at their point of origin and they may not be immediate.

EMIHAs take many forms. Reid (1993) discusses:

- Changes in hydrology including water input, runoff generation, water transport on hillslopes, water transport in channels, and water budgets.
- Changes in sediment generation and transport including erosion and sediment transport on hillslopes, gullies, and landslides; sediment delivery to streams; erosion, transport, and deposition in channels.
- Environmental change in organic material including changes in streamside vegetation, in-channel production of organic material, and in-channel transport of organic material.

Impacts of EMIHAs take many forms, a few of which are noted here:

- Impacts on fisheries due to changes including flow characteristics and channel morphology, water temperature, food availability, predation, and grain-size of the stream bed, combinations of which affect spawning and rearing success. These affect the commercial fishery as well as sport fishing.
- Water quality for agricultural, domestic, recreational, or industrial use.
- Other beneficial uses that are enumerated in Section 2.2.1.

A system to analyze and predict EMIHAs was developed by The University of California Committee on Cumulative Watershed Effects (Dunne et al., 2001). That report advocates a watershed approach that ideally would involve stakeholders in the watershed and time and resources to do modeling of many factors in the watershed and carry through to changes in policy and operations within a watershed. This TMDL study lacks the resources to apply such a broad approach, but neither can it ignore the presence and impacts of EMIHAs. What follows is a brief description of EMIHAs in the Scott River watershed and the Regional Water Board staff's approach to them. The methodologies used for identifying streamside sediment delivery features attributing sediment delivery to EMIHAs are discussed in more detail in Section 3.4.3.

3.1.7 Sources of Information

Information for this Sediment TMDL comes from a variety of sources. The Siskiyou Resource Conservation District (RCD) contributed information on environmental and habitat conditions and made their library of published reports and consultant reports available.

Timber Products Corporation and Fruit Growers Supply Company have allowed use of road inventory data in the South Fork Scott River watershed and permitted access to timberlands in that watershed. Resource Management, a consulting company in Fort Jones, analyzed road inventory data supplied by timber companies and the United States Forest Service (USFS). Regional Water Board staff field checked random samples of the road inventory data. VESTRA Resources produced the landslide inventory using an aerial photo survey.

Regional Water Board staff researched sediment contributions and trends using field studies, reports from other government agencies, consulting reports, and published literature. The USFS contributed data on road inventories and landslides and consultation on conditions in the watershed.

A Technical Advisory Group (TAG) consisting of stakeholders and representatives of other government agencies met at intervals with Regional Water Board staff to provide evaluation and guidance in the research and preparation of the TMDL. Dr. Sari Sommarstrom, also a member of the TAG, contributed her considerable expertise and local knowledge and access to her library.

California Department of Forestry and Fire Protection coordinated the road inventory and associated GIS work of Resource Management. Published scientific literature was used extensively and is referenced in this document.

3.1.8 South Fork Pilot Study

The South Fork Pilot Study was conducted in the South Fork Scott River (South Fork) as a demonstration project to illustrate the methods used in preparing a sediment TMDL with respect to gathering data and estimating sediment contribution to the stream system. The study was done at the request of Fruit Growers Supply, Inc. and Timber Products Company (the Companies) with the understanding that should the Companies find the methods to be appropriate and satisfactory they would grant access to Regional Water Board staff to gather specified data on other company lands throughout the Scott River watershed and would supply road inventory data for the companies' holdings in other parts of the Scott River Watershed to Regional Water Board staff. The Companies granted Regional Water Board personnel access to gather data along streams on company properties in the South Fork watershed. A Fruit Growers forester accompanied Regional Water Board staff in the field to observe sampling methods and field practice.

In addition, the Companies made their road inventory data in the South Fork watershed available to a third party, Resource Management Inc. (RM), for the purpose of calculating summaries and performing analyses of the data on behalf of Regional Water Board and the California Department of Forestry and Fire Protection (CDF). These data were used to estimate road surface erosion using SEDMODL2 (NCASI 2003) and provide summaries of other road-related sediment delivery sources in the South Fork. Under this agreement Regional Water Board staff did not take possession of the road inventory data. Regional Water Board staff field checked road-associated point sources of sediment in the company of RM staff.

After review of the South Fork Pilot Study, the Companies did not feel sufficiently confident in the process used in the Study, and declined to provide access to other company lands or associated data. Given time constraints in the TMDL consent decree schedule, Regional Water Board staff were not able to pursue resolution of the outstanding issues in the context of the South Fork Pilot Study. Instead, the road inventory data for the South Fork Pilot Study was used to calculate rates of sediment delivery per road mile in each geologic unit, and these rates were applied to other roads in the watershed. This process is discussed in Section 3.2.

3.2 ROAD RELATED SEDIMENT DELIVERY

3.2.1 Two Estimates Made

Road-related sediment was estimated in two ways. The first estimate treats roads on all geologic units in the same way. RM applied a computer model, SEDMODL2, to estimate contributions from road tread and cutslope on roads in the South Fork (West Headwaters) watershed in all four geologic units. As part of this process, RM applied information from road inventories on private land in the South Fork watershed to estimate contributions from road-related discrete features in that subwatershed. The inventories were conducted on about 5.5 square miles in the South Fork. Regional Water Board staff field checked many of these features as part of the South Fork Pilot Study (NCRWQCB, 2005b) to verify volume and to estimate age in order to estimate rate of contribution. Because this type of road inventory was not available in other subwatersheds, the rates estimated in the South Fork were applied to the rest of the subwatersheds in the Scott River watershed. Assumptions used in this application are:

- Distribution of road surface types (paved, unpaved) is similar
- Distribution of travel intensities on roads is similar
- Precipitation and storm intensity are similar
- Distribution of vegetative cover alongside roads is similar.

Variations occur in all of these factors, but in the context of the estimate many of the variations are opposite in effect. For example parts of the Westside Subbasin have more precipitation than the South Fork, which may deliver more sediment per road mile, but the Eastside Subbasin has less precipitation, and thus less runoff. The assumptions were based on the best information available.

Thus, the basic assumption is that the amount of sediment produced per mile of road in the geologic types in the South Fork subwatershed is the same as the amount of sediment produced per mile of road in those same units in the other subwatersheds. The assumption is made that road conditions on private land in the South Fork can be used to represent conditions along similar roads in the same geologic units in the other subwatersheds. Regional Water Board staff believe this is a reasonable assumption, based on observations of road construction and conditions in other subwatersheds.

The second estimate applies SEDMODL2 to roads in all geologic units except Granitic bedrock. For roads on granitic bedrock the sediment delivery rates applied are derived from the GSS in the Scott River watershed. The GSS found significantly higher DG sediment delivery from both anthropogenic and natural causes than did SEDMODL2. Sediment delivery from road-associated discrete sediment sources on granitic bedrock was treated as in the second estimate. All other geologic units were treated as in the first estimate.

In the four subwatersheds that include areas of granitic bedrock the difference between the first and second estimates of the sediment delivery processes from roads considered in SEDMODL2 range from nine percent to fifty-nine percent greater using the second estimate. The differences are approximately proportional to the proportion of the subwatersheds that is underlain by granite. Nonetheless, the estimate of total delivery of sediment from roads is relatively small in the big picture.

Because sediment generated on roads is not all delivered immediately to a stream, the distance of a road from a stream is a factor to consider in estimating sediment delivery. Both models include calculations based on the distance of roads from a stream. Table 3.3 presents the lengths of roads of different types and their distances from a stream through the whole of the Scott River watershed. For a more detailed comparison, Table 3.4 shows the same data divided out by subwatershed. These tables also include numbers of stream crossings, road miles, and road densities.

3.2.2 Discrete Sediment Sources (Road Inventory and Field-Check)

Inventories of discrete sources of sediment along roads are not presently available for most of the Scott River watershed. However, staff had access to an inventory of road-related erosion and sediment delivery completed by Resource Management (RM) in 2000 on all timber company roads in the South Fork subwatershed. That survey documented road-associated discrete sources of sediment including road-stream crossings, crossing failures, fill and cutbank failures, and gullies, along with the volume of each discrete sediment source. The purpose of the inventory was related to road maintenance, for which the age of features was not needed so age was not estimated. For that reason, and to evaluate the inventory, Regional Water Board staff, accompanied by RM staff, visited individual sites to verify volume and estimate age. The method is detailed in the South Fork Pilot Study (NCRWQCB, 2005b) and summarized below.

The RM road survey documented erosion at sixty-nine discrete features. Regional Water Board staff and RM personnel visited thirty of those features in 2004 and estimated age of erosion where possible. The remaining thirty-nine features were not visited, some because they had been repaired and some because time and resources did not permit total coverage. Of the thirty features visited, nine had been modified by repairs so that the age could not be estimated; staff estimated the age of the remaining twenty-one.

Of those twenty-one features, sixteen have estimated ages of less than fifteen years. Most of these are estimated to be within the 5-10 year age category. A major rain-on-snow event occurred in 1997, seven years before the field inspection, and, on the basis of anecdotal evidence and field estimates, staff attribute the major part of the erosion or failure of these features to that storm. The US Forest Service estimated runoff of the 1997 event in the Scott River to be equivalent to a 14-year recurrence interval event (de la Fuente and Elder, 1998, p. 10), and that event apparently caused more erosion than any other storm during the last 15 years. A flood risk evaluation in the area of Callahan prepared for the Siskiyou County Department of Public Works (Norman Braithwaite Incorporated, 1999) estimated a 30-year recurrence interval for the 1997 flood in that area. Staff chose to use the fourteen-year recurrence interval in our estimates.

Because the recurrence interval of this significant storm event brackets the age categories of a majority of the sites whose age staff could estimate, staff chose to isolate that time interval for the estimate of the rate of sediment contribution. The calculations of sediment input in the South Fork watershed in Section 3.1.8 are based on the volume of measured features divided by fourteen.

The estimated rate of sediment delivered from road-associated large and small features in the South Fork (exclusive of the anomalous features described below) was extrapolated to the other subwatersheds on the basis of road type and geologic units. This extrapolation is based on the assumption that similar road types, on similar substrate, at similar distances from the streams, will deliver similar amounts of sediment. While these assumptions surely vary in accuracy over different areas, staff believe, on the basis of field studies in many areas in the Scott, that conditions in different parts of the watershed have sufficient commonality to group in this way for the purpose of the watershed-wide TMDL study. Any land management decisions made in the future should be based on more detailed studies of the areas in question.

RM estimated the number of stream crossings using SEDMODL2. Water Board staff conducted a GIS exercise to estimate the number of stream crossings. RM and Water Board staff were within 97% agreement in the respective estimates. For that reason, the number of stream crossings estimated by RM were accepted.

In the RM South Fork road survey, the largest contributing features were all located within a single quarter-mile-long section of failing road. These few features accounted for seventy-five percent of the total contribution from road failures. Thus, these features are anomalous in context. For that reason they were not included in the group that was used to calculate the rates used to extrapolate to the South Fork watershed but instead were combined and treated separately as a single discrete feature added to the South Fork sub-watershed sediment summary.

Outside the South Fork, such anomalous features pose a problem in estimating sediment delivery. At present we cannot determine how many such features may have been unaccounted for in the other sub-watersheds, although some are large enough that VESTRA found and included them in the aerial photo landslide survey (Section 3.3). However, staff may have slightly underestimated anthropogenic sediment contributions because some anomalous features that were not large enough to be found on the landslide analysis may have not been counted.

The road dataset used was that developed for this project by VESTRA Resources, the contractor that performed the aerial photo analysis described in Section 3.3. During the field inventory, RM identified a few additional roads and added them to the dataset.

3.2.3 Granitic Substrate and Road-Associated Sediment – The DG Factor

The computer model used (SEDMODL2) takes into account road class, traffic volume, and a geologic erosion factor that is a multiplier to account for different rates of erosion on different substrates. However, the model does not specifically take into account the particularly high sediment contribution of the DG in the Scott River watershed and the tendency for elevated erosion rates to continue following disturbance.

Megahan (1992, p. 18), citing studies primarily in the Idaho Batholith, which has granitic rocks with weathering characteristics similar to those in the Scott, found that the highest erosion rates on cut banks occurred in the first two years. During this time rates decreased rapidly as the cut surfaces seasoned and litter and vegetation came to cover parts of them. After two years rates stabilized. Nonetheless, Megahan (1992, p. 18, 21) found that, “Erosion rates at this time were still accelerated, averaging about 50 times greater than undisturbed.”

Megahan (1992, p. 24) noted that, “While some road builders advocate constructing vertical cuts in granitic terrain, the data reveals that if you build them steeper, they are going to erode faster. Granitic road cuts will eventually end up at the natural angle of repose; it depends whether you want it now or later.”

The GSS in the Scott (Sommarstrom et al., 1990, p.5-3) also estimated that most of the road-associated sediment production was from cut banks. That study reached two conclusions that staff must consider in estimates for the TMDL:

- Average annual erosion for the entire road prism in granitic areas was 737 tons per mile, or 149 tons per acre of road prism. In the road prism the GSS includes cut slope, ditch, and fill slope as well as road surface. Erosion from the road surface alone averaged 11 tons per acre. The GSS cites these values (p. 2-31) as falling within the range reported by others on sandy loam soils.
- Sixty-four percent of road-associated erosion was found to come from the cut bank, which was the highest category of soil loss from all sources and made up 40 percent of the total.

Based on the GSS, the thickness of road surface eroded annually in the granitic area is calculated as follows:

1 acre = 43,560 sq ft.
11 tons / acre = 22,000 pounds per 43,560 sq ft
43,560 sq ft / 22,000 lb = 2 lb per sq ft. per year.
1 cu ft of sediment weighs 100 lb
2 lb per sq ft /100 lb per cubic ft = .02 ft thickness per year = .24 inch per year.

Most of the roads in the Scott were constructed before 1970, 35 years ago. Assuming they were all built in 1970, then:

35 yr x .24 inch = 8.4 inches of road surface lowering in 35 years. This rate of road surface erosion is significant, but considering the occasional resurfacing of eroded and failed parts of the road surface, it is reasonable.

To account for differences in erosivity of substrate, SEDMODL2 uses a multiplier that ranges from one for the least erosive rocks to five for the most erosive. In other words the model assumes that the most erosive rocks are on the order of five times as erosive as the least erosive rocks. Megahan (1992), Sommarstrom and others (1990) and others cited by these authors, as well as our field observations, suggest that the multiplier of five is substantially too low. Even with the model assuming no cover at all, SEDMODL2 estimated that only 23 percent of road-associated sediment generated on granite substrate comes from the cut bank.

The GSS was based on field studies and observations along many miles of road, and staff judged that its results must be considered within the area of DG soils. Accordingly, staff did a second estimate of road sediment contribution, applying the GSS rate of erosion in DG areas.

The GSS (Sommarstrom et al., 1990, Fig. 2-11) classified road-related sources into the categories of road cuts, road fills, and road surface. Taken together, these sources yielded an estimated 212,196 tons/year in their study area. Of that amount, an estimated 40,242 tons (19%) was delivered to the Scott River. The remainder went into storage in hillslope swales, hillslopes, channel margins, upper banks, alluvial fans, and channel bedload in tributaries.

The GSS approach is different from the TMDL approach in that the GSS authors were evaluating delivery to the mainstem Scott River, while the TMDL is evaluating delivery to the stream system as a whole, including tributaries. For that reason, the TMDL study cannot exclude the sediment that goes into storage in the channel bedload of tributaries.

3.2.4 Estimates of Road-Related Sediment Contribution

SEDMODL2 is a computer model developed to estimate the delivery of sediment to streams from roads using as parameters road width and type of surface, slope, geologic substrate, road use pattern, and distance of each road segment from a stream.

The creator of SEDMODL2, the National Center for Air and Stream Improvement (NCASI, 2004; and website accessed 4/4/05) describes SEDMODL2 as follows:

> …a GIS-based road erosion and delivery model designed to identify road segments with high potential for delivering sediment to streams. The model uses an elevation grid combined with road and stream information layers to produce what is essentially a computer-generated version of the Washington surface road erosion model. It estimates background sediment and generation of sediment for individual road segments, finds road/stream intersections, and estimates delivery of road sediment to streams.

SEDMODL2 was used to estimate contributions from road surfaces, cutbanks, and background. SEDMODL2 defines background as the contribution of sediment delivered to streams by soil creep. The soil creep contribution is included in Section 3.4 of this report.

For the stream network part of the model, RM first applied the GIS stream dataset from USGS 1:24,000 scale topographic maps. However, the stream network as observed on the ground during the inventories proved to be considerably denser than the USGS dataset. That is, a significant number of road/stream crossings were found where the stream dataset did not indicate a stream. RM then applied the Klamath National Forest (KNF) GIS stream network, as it is significantly denser, although it too was found to be under-dense relative to field observations. In some places RM field personnel found streams that were not shown even on the KNF coverage. In those cases, RM used a ten-meter digital elevation model to generate the stream course, and the stream feature was cut off just above the highest road/stream crossing identified in the watershed.

Tables 3.3 and 3.4 summarize parameters that go into the calculations of road-related sediment delivery in the Scott River watershed.

Table 3.3 shows the number of road-stream crossings and the miles of paved and unpaved roads at different distances from streams in the Scott River watershed. In SEDMODL2 the term direct delivery means that sediment from a road, once mobilized, is delivered directly to a stream; this happens primarily where the road surface, fill slope, and cut slope all meet at a stream crossing. Under all other conditions, fill slopes are assumed to not deliver sediment. For situations other than direct delivery, SEDMODL2 calculates percent sediment delivery from a road on the basis of distance from a stream. Distance categories are 0-100 feet, 100-200 feet, and greater than 200 feet from a stream.

Table 3.4 summarizes the number of road-stream crossings and miles of road at different distances from a stream sorted by geologic unit in each subwatershed. The information in this table serves as the basis for calculation of sediment contribution using SEDMODL2.

The next three tables (3.5, 3.6, and 3.7) develop the estimate of road-associated sediment.

Table 3.5 is in two sections. The upper section shows the estimated road-related sediment delivery rates in tons/road mi-yr from the South Fork Pilot Study (b 2005a) from roads on all geologic units. The South Fork is the area where the most detailed information was available. This table includes estimates of delivery from discrete features in the RM South Fork road survey and SEDMODL2 estimates of road tread and cut slope delivery. The lower section of the table is a separate estimate of road-associated sediment from granitic terrane derived from the GSS through the following procedure: The GSS estimate of total road-associated sediment generated was divided by the number of miles of road in the Granitic study area to derive an average rate of sediment mobilized in tons/road mile-yr. The proportion of mobilized sediment that is delivered to a stream is estimated by applying the delivery rates used in SEDMODL2 for direct delivery and delivery from distances from a stream of 0-100, 100-200, >200 feet.

The road survey-SEDMODL2 estimate and the GSS estimate use different categories to some extent, but the point to note is that delivery from cut banks is much greater in the GSS estimate. The rates for both estimates are carried forward to Table 3.6.

Table 3.6, in three sections, shows the estimated rates of road-associated sediment delivery in the Scott River watershed based on the rates estimated in the South Fork in Table 3.5. The upper section of Table 3.6 applies the estimated sediment delivery rates in the South Fork based on SEDMODL2 and the RM road survey (upper section of Table 3.5) to roads on all geologic units in the Scott River watershed. The middle section of Table 3.6 applies sediment delivery rate estimates on Granitic substrate in the South Fork from the GSS (middle section of Table 3.5). As seen in the right hand column in Table 3.6, the estimated sediment delivery from Granitic substrate using the GSS is about twice the tons/sq mi-year as what was estimated using SEDMODL2 and the road survey. Much of the increase comes from cut slopes.

Table 3.7, in five sections, shows the road-related sediment estimates broken out by geologic unit within each subwatershed. The upper section of the table shows estimates for Quaternary, Mafic, and Sedimentary/Metamorphic substrates. The Granitic contribution from the SEDMODL2-road survey estimate is summarized separately in the middle section for easy comparison with the GSS influenced estimate in the bottom section. In each subwatershed that has granitic rocks, the estimate that takes the GSS into account is a bit greater than twice the estimate that does not. The bottom section summarizes the road-associated sediment estimates. Despite a significant difference in estimated rates from Granitic substrate (Table 3.8), the difference in road-related sediment delivery rate from all units combined is increased only from 11 to 14 tons/sq mi-yr (Table 3.7), a 27% increase. The large difference in the estimates of Granitic contribution is minimized by the small percentage of the Scott River watershed underlain by granite and the large percentage underlain by Sedimentary/Metamorphic rocks, which have a relatively low contribution (Table 3.1).

3.3 AERIAL PHOTO LANDSLIDE SURVEY

Sediment delivery from landslides was estimated using photo interpretation from stereo aerial photos taken several years apart. Changes in presence or size and configuration of landslides between the photo sets were analyzed, and a proportion of the interpreted features were field checked to estimate volume and age. Additional information was used from USFS photo inventories that used 1992 and 1997 aerial photos. Four subwatersheds have significant sediment delivery from landslides: The West Canyon subwatershed delivers about 250 tons/sq mi-yr and the East Canyon, Westside, and West Headwater subwatersheds deliver in the range of 15-20 tons-sq mi-yr.

3.3.1 Methods

Landslides in the Scott River watershed were inventoried by VESTRA Resources using stereo aerial photos and compiled in ArcView GIS. VESTRA evaluated available photo coverages to obtain a baseline to evaluate changes in landslides through time. In this TMDL study the last 20 years are of most interest to use as a basis in understanding what processes are active at present.

No single set of existing aerial photographs covers the entire Scott River watershed, and private land and Forest Service land are photographed at different times and as separate projects. On both private and Forest Service land staff selected two coverages on the basis that (a) each coverage includes a large portion of the Scott River watershed, (b) they are recent, and (c) they are separated by an interval appropriate to the time scale of the study. The four coverages chosen (Figure 3.3) include three different types of photography and four different scales.

With these photo sets, 88.3 percent of the Scott watershed has coverage at two times, 8.1 percent has coverage at one time, and only 3.6 percent of the area is not covered. The areas of single coverage and no coverage are in the lower mountains in the Kidder Creek-Shackleford Creek area (Figure 3.3), an area where landslides are not a significant factor. The areas of most abundant landslides – West Canyon, Westside, and West Headwater subwatersheds – have excellent coverage with the Forest Service photos.

Results were compiled on digital ortho quarter-quads (DOQQs) based on 1993 aerial photography. Landslide features were identified and attributed using the following procedures.

3.3.2 VESTRA Aerial Photo Interpretation

Stereo pairs of the 1999 photos were examined under a mirror stereoscope for evidence of active or recent landslides. Features interpreted as possible landslides were marked as polygons, lines, or points, according to the following criteria:

- <u>Polygon</u> – Non-linear landslide feature larger than 1 acre.
- <u>Line</u> – Linear landslide feature – most are debris torrent scars in steep channels.

- Point – Landslide feature less than 1 acre in size. Pilot work indicated that features smaller than 1 acre cannot be consistently and repeatably identified and delineated; however, it is important to note their presence and density.

Landslide features were identified and marked on the newer photographs, then the location of each feature was reviewed on the older photos to determine whether it was present and if its boundary was different. If the boundary of a feature has changed, appropriate delineations were made on the newer photo record to modify polygons or line segments. The older photos were also reviewed for the presence of landslide features that may not be apparent on the newer photos.

Each landslide feature was attributed with codes representing status of vegetation in each set of photos, intersection with an anthropogenic feature, landslide type, and hydrologic connectivity. Presented in the following sections is a summary of results of this analysis.

Using the 1993 DOQQs as a base, polygons, points, and lines were digitized in a GIS coverage and attributed with their codes. As part of the South Fork Pilot Study, Regional Water Board staff and VESTRA staff were able to field check the photointerpretation on all sites but one in the South Fork (b 2005a). In the remainder of the Scott River watershed, approximately 15 percent of photointerpreted sites were field checked.

3.3.3 Estimation of Sediment Delivery Rates

In the aerial photo survey VESTRA assigned a causal effect based on categories of Harvest, Roads, Roads and Harvest, Fire, and Natural. Mining was not assigned a category but is noted in some comments. Staff estimated sediment delivery based on the VESTRA photo-interpreted slide features and the field verification as completed by VESTRA and Regional Water Board staff.

3.3.4 Volume Estimate of Slide Features

The volume of slide features and the rate of sediment contribution were estimated using a combination of photointerpretation, field observations, and extrapolation. It was not possible to investigate in the field every slide feature interpreted from the photos. Accordingly, a sampling of the photointerpreted features, which came to 26 percent, was visited in the field. The area and depth of each were measured or estimated in the field so that volume could be calculated. In addition, the age of each feature was estimated. The combination of depth and area allow calculation of volume, and the age estimate allows estimation of rate of mobilization of sediment.

3.3.4.1 Polygon Features

The area of polygon landslide features was estimated through digitizing on the DOQQs, and then a sampling of features was measured or closely estimated in the field. The average surface area of the polygon features measured in the field was 50 percent of the average as estimated in the digitized photointerpretation. The average of 50 percent was applied to the area of all polygon features in the photo survey. Average depth of the 10 polygon features measured in the field was 7 feet. This 7-foot average depth was applied to all polygon features in the photo survey.

3.3.4.2 Line Features

Line features were assigned no depth or width in the photointerpretation. Of line features surveyed in the field, the average depth was 4 feet, and the average width was 16 feet. The average length of the line features measured in the field was 42 percent of the average estimated in the photointerpretation. These average depth, width, and length percentages were applied in estimating volume of all linear features in the photo survey.

3.3.4.3 Point Features

Points were assigned no dimensions in the photointerpretation. The average estimated delivery from point features examined in the field was 25 tons/year. This contribution rate was applied to all point features in the photo survey.

3.3.5 Initial Estimate of Connectivity and Age

3.3.5.1 Connectivity

Using photointerpretation, VESTRA estimated whether or not each feature was hydrologically connected. When VESTRA field-checked the features, they evaluated the connectivity of each feature. Of the features they estimated to be fully connected, they found in the field that 68 percent were fully connected, 11 percent were partially connected, and 21 percent were not connected. Of the features they photointerpreted to be partially connected, they found 13 percent to be fully connected, 33 percent to be partially connected, and 54 percent not connected. Of the features they photointerpreted to be not connected, they found in the field that 70 percent were not connected, 20 percent were partially connected, and 10 percent were fully connected. These percentages were applied in estimating connectivity and rates of sediment contribution from photointerpreted landslide features (Table 3.9).

3.3.5.2 Age

VESTRA made field estimates of the age of features visited. Of these features, 72 percent were estimated to be approximately 18 years in age. The remaining 28 percent were estimated to be 30 years in age. Age was not estimated for the features that were identified only through the photo-interpretation process. Staff applied the age estimate percentages established in the field to the estimation of sediment delivery rates for all features that are calculated in section 3.6.

3.3.6 U.S. Forest Service Landslide Inventory

The U.S. Forest Service has done two aerial photo inventories of landslides on Forest Service land in the Scott River watershed. The first was done in 1992 using photos from earlier years, and the second was done in 1997 with new photos following the rain-on-snow flood event in the winter of 1996-1997.

3.3.6.1 1992 U.S. Forest Service Photo Inventory

The 1992 inventory in the Scott was part of a more widespread project on Forest Service land, using photos of several scales. Photos used ranged in date from 1971 to 1988 and covered all USFS holdings in the Scott. Flight lines and photo coverage spilled onto a small amount of surrounding properties, and the landslide inventory included all areas that had stereo coverage, including the small spillover to private land. In this survey 305 features were identified in the Scott River watershed. These features fall in four subwatersheds; Westside, West Canyon, West Headwater and East Canyon.

3.3.6.2 1997 U.S. Forest Service Photo Inventory

Following the 1997 storm event, a new set of color infrared photos at 1:40,000 scale was flown to evaluate resulting landslides and other changes in the Klamath National Forest, which includes Forest Service land in the Scott. On these photos, 192 features were identified in the Scott River watershed. Don Elder of the USFS reported that most of these appeared to be new rather than reactivated older features (Coates, 2006). Seventy four percent of the landslide features identified were field checked and dimensions measured. Associations were determined and delivery amounts estimated at the same time. Using a regression analysis derived from field checking more than 800 sampled slide features throughout Klamath National Forest, an area-volume relationship was determined and applied to the 26 percent of the features that were not visited in the field. Their size and association or non-association with human activity were estimated through the photo-interpretation process.

These 192 identified slide features fall in three subwatersheds; Westside, West Canyon, and East Canyon. Of the 192 features, USFS estimated that 52 features were natural, 57 were road-related, 2 were related to either harvest or fire greater than 20 years of age, and 81 were related to a harvest or fire within the last 20 years. The last two categories, classified without distinction between harvest and fire, are ambiguous as to whether human activity was involved in a given case, and for that reason they are of limited use in the TMDL study.

The USFS arrived at volumes mobilized and volumes delivered through field visits and the application of GIS estimation. The USFS estimated delivery percent for each feature and went on to estimate amount of sediment delivered. Sixteen of the slide features were estimated to have no delivery; for the remaining 177 features the estimated delivery values varied from 5 percent to 100 percent.

3.3.6.3 Discussion of USFS Landslide Inventory

Age of features was not estimated, except that those captured after the 1997 flood were directly related to the 1997 event. These features should be treated as discrete features in time and evaluated with that in mind. However, without further field work there is no way to quantify the continuing contribution from these features. Further study is required to evaluate their contribution to the system.

In comparing VESTRA and USFS inventories, staff noted that of the total 498 features mapped in the two USFS inventories, 250 do not appear to have a corresponding feature in the VESTRA GIS layer. Of the 192 features mapped in 1997 with volumes and associations, 79 do not appear to have a corresponding feature in the VESTRA GIS layer. One reason for this apparent discrepancy appears to be that the USFS was mapping many small features that VESTRA did not include in their inventory.

Of the 250 features in the USFS GIS layer that have no corresponding features in the VESTRA study, 78 are less than 0.5 acres, and 52 are between 0.5 and 1 acre in size. Thus 130 (52 percent), of these features are smaller than the one-acre size that VESTRA considered a minimum for repeatable estimation in their survey. Fifty-two (21 percent) of the USFS features are between one and two acres. Field-checked sites were on average 50 percent of the GIS size estimation. Applying a correction factor of .50 yields a figure of 182 features less than one acre out of the 250 features identified in the USFS inventory that did not appear in the VESTRA survey.

In summary, the USFS inventories picked out many landslides smaller than one acre that were not counted in the VESTRA inventory. In this investigation, landslide features less than one acre were accounted for in the streamside sediment surveys, described in Section 3.4.2. Problems in trying to apply this USFS inventory to the TMDL study arise because anthropogenic and non-anthropogenic features are not adequately distinguished, and lack of age estimates precludes estimating average delivery rates. Therefore, the USFS landslide inventory was not used to quantify landslide contributions.

3.3.7 Estimate of Sediment Delivery Rate

Delivery rate was estimated for the features examined by VESTRA in the field using calculations based on the percentages estimated through photo-interpretation and associated field work. These rates were then applied to all the features that were photo-interpreted but not field checked. The general equation is:

Delivery = (Connectivity Value) x (Volume-Size factor) x (Age factor)

Table 3.9 is in two parts. The first part summarizes the numbers of slide features that are interpreted as delivering sediment. The first section shows results of field checking of 97 photo-interpreted landslide features. Field observation showed that 26 percent of these features are delivering sediment. The second part summarizes numbers of features that were not field checked and interpretation of hydrologic connectivity. Of 265 features, 151 (57 percent) are interpreted as partially or fully hydrologically connected.

Table 3.10 is in two parts. The first part summarizes estimates of sediment delivery from photo-interpreted landslide features that are associated with human activity. The second part summarizes estimates of sediment delivery from photo-interpreted landslide features that are not associated with human activity. The left columns in both parts show estimated tons/yr of sediment delivered from field-verified features. The right hand columns show estimated tons/yr delivered from features that have not been verified. Some sediment is counted as delivered from features that were photo-interpreted as not hydrologically connected. The reason for this goes back to the field-checked features, some of which were photo-interpreted as not hydrologically connected but were found in the field to be connected and delivering. This estimation is discussed in the section on Connectivity above. The estimates show a total of 66 tons/yr of sediment delivered from landslides of which 26 tons (39 percent) is attributed to human causes.

3.3.8 Summary of VESTRA Landslide Inventory

This survey shows that landslides are not a dominant source of sediment in the streams in most of the Scott River watershed. Table 3.10 estimates the landslide sediment delivery based on size, age, and hydrologic connectivity of features. Table 3.11 is a summary of human activity-related landslide delivery broken down by type of human activity and subwatershed.

3.3.8.1 West Canyon Subwatershed

The West Canyon Subwatershed has the largest human-associated contribution, and both roads and harvest are strongly associated with landslide delivery (Tables 3.10 and 3.11). This subwatershed is very steep mountains of the north end of the Marble Mountains. Ownership is primarily Forest Service. Landslides are more abundant than in any other subwatershed, particularly in the drainages of Kelsey Creek and Middle Creek (Figure 3.4). The estimated anthropogenic contribution of 254 tons/sq mi-yr (Table 3.11) is the highest in the Scott River watershed. This subwatershed has had considerable harvest activity, is densely roaded, and underwent severe fires in 1988.

3.3.8.2 East Canyon Subwatershed

The East Canyon Subwatershed has a low rate of sediment delivery from landslides, and that delivery is mainly associated with roads (Table 3.11). This subwatershed covers both the north and south flanks of the Scott Bar Mountains, which are steep, but not as high as the Marble Mountains to the west. Land ownership is largely a mix of National Forest and private timberlands, some in checkerboard pattern, with other private holdings more abundant in the southeast portion. The few landslides occur mostly near the west end of the Scott Bar Range above the great bend of the Scott River (Figure 3.4).

3.3.8.3 Eastside Subwatershed

The Eastside subwatershed has very low landslide delivery. Table 3.10 shows no delivery from non-anthropogenic sources and only a small delivery from anthropogenic sources, which is entirely associated with harvest (Table 3.11). This subwatershed is essentially the watershed of Moffett Creek and is the lowest and driest of the six mountainous subwatersheds. The north half of the area is a mixture of National Forest and private timberlands with inliers of other private lands. The south quarter of the area is largely private timberlands, and the middle parts are a mixture of private grazing land and timberland. No significant landslides were mapped in this subwatershed (Figure 3.4, Table 3.11).

3.3.8.4 East Headwater Subwatershed

The East Headwater Subwatershed was inventoried as having no major landslide delivery in spite of having a history of harvest and mining (Tables 3.10 and 3.11). This subwatershed is the drainage of the East Fork Scott River including Noyes Valley Creek. Surrounded on the south and east by high country of the Scott Mountains, this subwatershed is a mixture of environments. The northwest flank of the Scott Mountains, above the East Fork, are largely a checkerboard of Forest Service and private timberlands. The upper part of South Fork drainage and the drainage of Noyes Valley Creek are largely grazing land with inliers of private timberlands. Only a few landslides occur, primarily on the middle slopes of the Scott Mountains.

3.3.8.5 West Headwater Subwatershed

The West Headwater Subwatershed is the watershed of the South Fork Scott River, reported in detail in the South Fork Scott River Watershed Pilot Study for the Total Maximum Daily Load for Sediment (NCRWQCB, 2005b). The West Headwater Subwatershed has significant landslide delivery, of which about 60 percent is anthropogenic (Table 3.10). The largest anthropogenic contribution is from mining legacy on mafic bedrock along Slide Creek, which is discussed in some detail in the south Fork Pilot Study. As the tables in this report do not include a mining legacy category, this mining legacy is included under the Harvest category in Table 3.11. Landslide contribution per square mile is estimated at only 18 tons/year (Tables 3.10 and 3.11), a low rate considering the steep country and a history of human activity.

3.3.8.6 Westside Subwatershed

The Westside Subwatershed is second only to the West Canyon Subwatershed in total landslide sediment delivery per square mile (Table 3.10). The inventory showed the human activity-related landslide delivery to be significant at 20 tons/yr-sq mi falling about equally in the categories of Roads, Harvest, and Roads-and-Harvest (Table 3.10). This is the largest subwatershed and is underlain by significant areas of granite in the south and mafic rocks in the north (Figure 3.2). The higher country along the crest and east flank of the Marble Mountains is in federal ownership as National Forest and Wilderness. The middle and lower mountainous part is largely in timber company ownership. Both National Forest and private timberlands have been roaded and harvested. Landslide activity is widespread (Figure 3.4).

3.3.8.7 Scott Valley-Eastern Valley Side Subwatershed

The Scott Valley Subwatershed has negligible landslide delivery from either anthropogenic or non-anthropogenic sources (Tables 3.10 and 3.11). The floor of Scott Valley is an alluvial plain sloping gently toward the Scott River from each side. Surrounded by mountains, this valley receives much less precipitation than the surrounding high country. Low relief and dry climate combine to produce a terrain that does not produce landslides. In the north end of the valley Quartz Hill and Chaparral Hill rise above the plain, but they are low enough to participate in the drier climate of the valley bottom and this inventory found no landslides. The east flank of the valley, up to the divide between Scott Valley and Noyes Valley Creek in the south and Moffett

Creek in the north is included in this subwatershed because it too produces almost no landslides (Figure 3.4, Table 3.10).

3.3.8.7 Confirmation by SHALSTAB model

SHALSTAB, a computer model to evaluate risk of shallow landslides was applied in the Scott River watershed by Derksen (2005). This model shows the highest hazard ratings in the areas where the TMDL landslide inventory and USFS studies found the highest incidence of actual landslides (Section 3.3).

3.4 STREAMSIDE SEDIMENT DELIVERY

Streamside sediment delivery was estimated in three categories:

- Soil creep is the downslope migration of soil and rock under the influence of gravity. This is a natural process that probably is little affected by human activities and is considered as a natural background source. It was estimated using SEDMODL2.
- Small streamside discrete mass-wasting and erosion features are the result of lateral stream erosion and a variety of natural and human-influenced causes. These features include bank failure, gullies, small landslides, and other small features.
- Large streamside discrete mass-wasting and erosion features result from both natural and human-induced causes. They generally extend from the stream up onto the mountainside above and include landslides, debris flows, and sites of ongoing wasting. They tend to be long-term ongoing sediment sources.

3.4.1 Soil Creep Contribution

Three approaches were used to estimate sediment delivery associated with soil creep:

1) For comparative purposes, staff investigated the results of other authors who estimated soil creep in the nearby Trinity River and Eel River watersheds.
2) Staff applied to all geologic units the soil creep rate accepted in SEDMODL2 (NCASI, 2003), which includes a function to estimate the soil creep contribution to a stream system.
3) Staff applied the soil creep rate from SEDMODL2 in all geologic units except granitic bedrock and used the delivery rate from the Sommarstrom et al. (1990) granitic sediment Study to the areas of granitic bedrock.

Approach 3 seems to give the most credible estimate.

In their Trinity River Sediment Source Analysis, Graham Matthews and Associates (GMA, 2001, p. 79, Table 48) used a rate of 30 tons/sq mi-yr as a basis to estimate soil creep contribution (Table 3.12). They arrived at this rate by starting with the rate of 75 tons/sq mi-yr derived by Roberts and Church (1986) in the coastal areas. GMA took into account that in the coastal areas the geology is less stable and uplift rates are higher than in the Trinity and used 40 percent of the coastal rate, or 30 tons/sq mi-year, for the Trinity.

In the South Fork Eel River watershed, Stillwater Sciences (1999) used two methods to calculate creep in different geologic terranes. For Coastal Belt and Yager terrane they assumed that soil creep was shallow and used SEDMODL2. They considered it likely that their estimate of 9 tons/sq km-yr (23 tons/sq mi-yr) (Stillwater Sciences, 1999, Table 3.15) is an underestimate but believed that the effect on the overall budget was probably small. For areas in the Franciscan mélange matrix, they considered creep to be soil mantle creep, a deeper process, and applied a rate of 146 tons/sq km-yr (378 tons/sq mi-yr), which they derived from intensive study of one area within the mélange.

In the Scott River watershed, staff estimated the soil creep contribution to the stream system using parameters from SEDMODL2 and applying NRCS STATSGO data on soil strength, density, and depth. SEDMODL2 takes into account not only downslope soil movement from gravity but also downslope soil transfer from biological activity such as animal burrowing and soil attached to roots of fallen trees. Default parameters for SEDMODL2 are 36-inch soil depth, creep rates of 1 mm/year for slopes less than 30 percent and 2 mm/year for slopes greater than 30 percent, and contribution length equal to twice the stream length, to account for both banks.

A 10-meter digital elevation model (DEM) of the Scott River watershed shows 748.8 sq mi (92 percent of the watershed) as being steeper than 30 percent grade. The remaining 64.7 sq mi (eight percent of the watershed) that is lower than 30 percent grade lies almost entirely in the floor of Scott Valley (the Scott Valley Subwatershed).

Calculation of the soil creep contribution to a stream system using SEDMODL2 depends on the hydrography used. A higher density of hydrographic depiction will yield a higher estimate of soil creep contribution, because it shows a greater length of stream banks. The hydrography used to calculate soil creep contribution, the densest hydrography available, is a hydrography GIS layer developed by David Lamphear at Humboldt State University, College of Natural Resources and Sciences Institute for Forest and Watershed Management, as supplemented by RM on the basis of field studies. Lamphear digitized the USGS 1:24,000 scale blue-line streams into GIS. As RM was doing road survey work, they found that there were many more road/stream crossings than the USGS stream coverage would indicate. Accordingly they used the 10-meter DEM to supplement the stream coverage and show the streams that roads crossed as high in the watershed as the highest road crossing. While this may not capture the uppermost parts of many small streams, this is the best available data.

Slopes in much of the Scott River watershed average very steep. The 10-m DEM shows 92 percent of the slopes steeper than 30 percent grade. Furthermore, large areas have slopes between 50 percent and 100 percent grade. Accordingly, staff calculated soil creep assuming that the grade of all slopes is steeper than 30 percent.

The assumptions in this calculation are as follows:

Slope	All slopes steeper than 30% grade
Creep rate	2 mm/year
Soil depth	3 feet
Tonnage	1.35 tons/cubic yard

Table 3.13 summarizes the soil creep contribution estimates in the Scott River watershed by subwatershed. In the steep country of the subwatersheds surrounding Scott Valley, contributions range from 29 to 37 tons/sq mi-yr, and the Scott Valley subwatershed contributes only about 13 tons/sq mi-yr. In subwatersheds other than Scott Valley, because assumptions used for slope, creep rate, and soil depth are the same, differences in tons/sq mi-yr are the function of differences in stream miles per square mile.

In a second calculation, staff applied the SEDMODL2-derived soil creep rates to streams in the Sedimentary/Metamorphic, Mafic/Ultramafic, and Quaternary units, and applied the sediment contribution rates from the GSS to streams on Granitic substrate. Table 3.14 shows the results of this exercise minus the granitic contribution. The granitic contribution from Sommarstrom and others (1990) is included in the sediment contribution summary in Section 3.5.1. In Sommarstrom's calculation, soil creep is not separated out from other streamside erosion processes. However, in the final calculations in section 3.5, soil creep is accounted for.

Sommarstrom and others (1990, p. 5-3) concluded that:

> Granitic terrane streambanks average 382 tons per mile per year. Nearly three times the average streambank erosion is estimated for Boulder and Fox Creeks because of large areas of upper bank scour. About 17 miles of granitic streams in the Study Area are gutted on their upper banks. In most cases, this occurred with the 1964 flood. There has been only limited revegetation of these banks since 1964, as viewed in historic and current aerial photos. This activity appears unrelated to timber harvest as it generally occurs in upper watershed areas where little if any harvesting has occurred.
>
> Total erosion is estimated to be about 340,450 tons per year. Road cuts constitute 40 percent of this amount, and streambanks 23 percent.

3.4.2 Streamside Mass Wasting and Erosion Features - Stratified Random Sampling

Random sampling is a standard and effective means to characterize a population. A simple random sample is applicable where a population is all governed by the same major factors. In the Scott, however, a number of different factors apply to different areas in the landscape. A more efficient system of sampling is to divide the landscape into more nearly homogeneous units and apply stratified random sampling. One accepted description of this process is:

"A stratified random sample is obtained by separating population elements into non-overlapping groups (strata) and selecting a simple random sample from each stratum" (http://www.sph.uth.tmc.edu:8053/biometry/Elee/ph1745/doc/Strata.ppt accessed 4/6/05).

Stratified random sampling provides a systematic way to include in the sampling more than one important factor in sediment generation. A major factor that affects the inherent erodibility and rate of sediment contribution from a given locality in the study area is bedrock geology.

These aggregated geologic units are described in detail in the document, *Scott River Basin Sediment TMDL Stratified Random Sampling for Streamside and Road-Associated Sediment*

Contribution (Coates and McFadin, 2004). Table 3.1 summarizes the areal extent of these units in the Scott River watershed. This GIS geology coverage (modified from Saucedo et al., 2000) has proved satisfactory for the job at hand. Field observations in October and November of 2003 and May-July of 2004 at computer-generated random stream sample locations showed no significant differences between geologic units shown on the GIS geology coverage and geologic units observed on the ground.

Stream reaches for streamside sampling were chosen using GIS to select stratified random reaches along streams using the four geologic units as sampling strata (Figure 3.5). During sampling of sites on bedrock units, observations were recorded both of geology, to verify the GIS site selection, and of evidence of fire and timber harvest. During sampling of sites on Quaternary deposits, observations were recorded on presence or absence of riprap or levee, fencing of riparian corridors, adjacent land use, and other factors.

In selecting stream segments to sample, a digital elevation model was applied to define a minimum area of drainage into a stream before considering the stream valid for selecting a random sampling reach. A satisfactory minimum area was found to be one half square mile.

Within each sampled stream segment, each erosion feature that has contributed five cubic yards or more of sediment to the stream was inventoried. Such features include debris slides, gullies, stream bank failures, fill failures, road and skid-trail washouts, small landslides, and other features. Some features are not obviously associated with human activities while others are associated with skid trails, stream crossings, landings, road ditches, road cuts or fills, or other anthropogenic features. Association or lack of association with anthropogenic features was noted. The eroded void of the feature was measured or estimated, and the percent of that volume that entered the stream system was estimated. Age of the feature was estimated on the basis of freshness of scarps and sediment, age or maturity of vegetation within the feature, presence of the feature in aerial photos, or other relevant criteria.

In all, 63 segments with a total length of 21.3 miles were sampled. The total estimated length of streams in the watershed is 2,500 miles.

3.4.3 Effects of Multiple Interacting Human Activities in the Scott River Watershed

Most of the Scott River watershed has been affected by mining, timber harvest, or agriculture over the past one hundred fifty years and longer, and the effects from repeated episodes of human activities are evident in many areas.

Different parts of the landscape show abundant roads from both mining and timber harvest, skid trails of several ages, harvest units of several ages, evidence of mining both in the riparian zones and on mountainsides, and conversion from wetlands and forest to agricultural land. Past filling of channels and valley bottoms by sediment related to human activities has caused bank erosion. Downcutting into valley-bottom fill deposits generates further second-generation sediment. Sidecutting into banks resulting from aggradation adds large amounts of sediment to the channel and triggers gullying. Old roads and skid trails contribute varying amounts of sediment depending on design, age, and position in the landscape. Sediment is generated by landslides and debris flows are triggered, or reactivated, by human activities.

It is clear that both human activities and natural processes affect sediment contribution from both dispersed and discrete sources. At the present state of knowledge, however, it is not possible to determine with certainty for each sediment delivery feature the exact proportion of natural and human-activity-induced contribution. Lacking that certainty, Regional Water Board staff used the best available information to estimate the human-caused portion of sediment contribution by sediment delivery features that were not directly associated with a particular anthropogenic feature. Field observations and aerial photographs of several ages were used along with GIS coverages of disturbance, including extent and age of timber harvest, extent and date of fires, and extent of roads, to estimate the long-term effect of human activities on sediment contribution from features in each stream reach sampled.

The sources of information used in this process include:

- California Department of Forestry GIS coverage of timber harvest. This data goes back only to 1990 but is complete from 1990 to present.
- USFS GIS coverage of timber harvest. This data set includes pre-1990 information but does not include all timber harvest on Government land.
- USGS DOQQ Aerial photographs from 1993 and 1998.
- USFS Landslide data. (please refer to the data discussion in section 3.3.6)
- Vestra Landslide data. (please refer to the data discussion in section 3.3.8)
- USFS "Tweener" GIS coverage. This data documents erosional and mass wasting features that occur between road/stream crossings. This was compiled by the USFS from Road Sediment Source Inventories, 1999 to 2001.
- USFS "Damage_all" GIS coverage. This theme captures 1997 Flood damage to roads and other Forest facilities.
- USGS Mineral Resources Data System. Documents historical mining activities.
- Vestra-developed GIS roads coverage.
- USFS-developed stream layer.
- Field observations of human activity not documented elsewhere.

Water Board staff evaluated each of the above data sets in estimating the level of human contribution in each subbasin, upstream and upslope of the sediment sample survey reach. Also used were the USFS and CDF timber harvest records, which include the level of impact and age of the harvest, and additional harvest areas that staff digitized from the USGS aerial photographs in which impact and age of harvest was indeterminate. The Vestra and USFS landslide data used documented human-related or natural cause of slides. The impact of road-associated failures documented in the USFS "Damage_all" and "Tweener" coverages and those documented by Water Board staff during field work were included in the analysis. Analysis by Water Board staff incorporated all of these factors. The Human Contribution Factor assigned to each sample survey reach was based on the type, extent, and age of the activity and the proximity to the sample survey location.

Table 3.15 summarizes the estimates of EMIHAs for each stream reach sampled in the Scott River watershed. In this table:

- The stream reaches are the reaches selected by stratified random sampling.
- The Total Contribution column gives the contribution from streamside discrete features including bank failure, landslides, and gullies that were not associated directly with a proximate human activity in field examination.
- The Human-Activity Related Contribution column gives the estimate of proportion of sediment contribution resulting from human activity, in categories of 25 percent. A zero means that the estimate was closer to zero than to a quarter. A 0.25 estimate means that the estimate was closer to one-fourth than to zero or to one half, and so forth.
- Comments are primarily a narrative description of amount, age, and intensity of human activity adjacent to, and upstream of, the stream reach summarized from GIS coverages, aerial photographs, and field observations.

Four sampled stream reaches were selected as examples to illustrate the factors that were taken into account. Figure 3.6 shows the locations and relative sizes of the watersheds above these sample reaches. Each of these areas is shown in more detail in two figures to illustrate the factors taken into account. In each pair of figures, the first is an orthophoto or orthophoto mosaic with an overlay of timber harvest as depicted in CDF GIS coverage and additional timber harvest interpreted by Regional Water Board staff on aerial photos and/or in the field. Because the digital orthophoto quarter quads used come from both 1993 and 1998 photography, not all of the orthophoto coverage is the same age.

The second figure in each pair shows the same GIS and interpretive information as the first, but without the visual clutter (and verification) of the orthophoto. Note that while each figure of a pair is the same scale, different pairs are different scales. Figures 3.7 to 3.14 are examples of interpretation of different percentage categories of EMIHAs.

Example in zero percent category

Figure 3.7 (1993 and 1998 photography) shows a drainage basin of 2,800 acres upstream of the terminal point of stream reach M-09-04. This area is high in the Marble Mountains and heads at the divide between the Scott River and Salmon River watersheds. The GIS layers show timber harvest over 22 acres in 1978 and 111 acres in 1992 (total 133 acres, 5 percent of the area). Photointerpretation shows an additional 244 acres (9 percent of the area) harvested (Figures 3.7 and 3.8). Several roads lie within the area. Because only 14 percent of the area has been harvested and there is little evidence of other disturbance, staff estimated that anthropogenic contribution was closer to zero than to 25 percent.

Example in 25 percent category

Figure 3.9 (1998 photography) shows several factors used in interpreting anthropogenic sediment delivery. This small drainage basin covers 390 acres upstream of the terminal point for streamside sample reach S-05-04. GIS layers from CDF and DOQQs from 1993 and 1998 aerial photos were examined. The CDF GIS layers show pre-1997 timber harvest over 240 acres (61 percent of the area). On the DOQQs, Regional Water Board staff, interpreted thinned timber and skid trails to show an additional 64 acres of harvest in two areas in the head and on the north side of the basin, bringing harvest in the basin to 304 acres or 78 percent of the basin (Figures 3.9 and 3.10). The only permanent road within the basin is a short segment that crosses the headwaters. Although the area of harvest was high, 78 percent, the harvest practices were low impact, and staff estimated the anthropogenic contribution to be closer to one fourth than to one half.

Example in the 50 percent category

Figure 3.11 (1993 photography) shows the headwater area of North Fork French Creek and sample reach G-14-04. The available GIS coverage does not show timber harvest plans in this area, but interpretation of aerial photos shows a timber harvest area covering the mountainsides both north and south of the creek along the sampling area and other harvest areas higher in the basin (Figures 3.11 and 3.12). This is a granitic area (Figure 3.2) and the DG that makes up the surface is known to ravel extensively when disturbed. The photos (Figure 3.11) show a large amount of bare ground exposed in the harvest area, which is a steep slope. For these reasons, staff estimated anthropogenic contribution in this area to be in the 50 percent range.

Example in the 75 percent category

Figure 3.13 (1993 and 1998 photography) shows the drainage basin of North Fork Kelsey Creek, which has had extensive and intense management activities immediately upstream of the terminal point of sample reach M-18-04. Of the 11,110 acres in this drainage, USFS GIS coverage shows 2,060 acres (18.5%) as included in timber harvest plans. Most of these areas are immediately upstream of, and draining into, the sample area. Roads are abundant in the harvested area. Landslides are significantly more abundant in the harvest areas than in unharvested areas to the west and south, and aerial photos show association between several landslides and harvest activity (Figures 3.13 and 3.14). Because of the association with extensive disturbance, staff estimated anthropogenic contribution in this area to be in the 75 percent range.

The proportion of natural and anthropogenic contributions generated in Table 3.15 is applied to streamside large discrete features in Section 3.4.5 and to streamside small discrete features in Section 3.4.6. This application is based on the assumption that the contribution proportions and rates estimated for the randomly sampled areas are applicable throughout the Scott River watershed.

3.4.4 Estimation of Sediment Delivery from Small and Large Discrete Features

The sediment delivery per stream mile from both large and small features in all four geologic units was estimated using data from all random samples throughout the Scott River watershed. Then for the purpose of the TMDL study the delivery rate for each geologic unit, in tons/sq mi-yr, was applied in each subwatershed.

Streamside sediment sources were classified in two categories: streamside large discrete features and streamside small discrete features. The large features generally are long-term continuing sources of sediment and typically originate on, or extend up onto, the mountainside. The small-features category includes streambank failure, gullies, and a variety of other small failures that mostly deliver episodically to the stream.

While there can be some overlap in the middle ground, the large and small feature categories have fundamental differences in duration and mechanism. Most of the large features have much in common with the landslides that were inventoried by the aerial photo survey. Many in the large-feature category, however, are small enough that they would be marginal to be picked up in the aerial photo survey. In addition, some, although large enough to fit the criteria for the aerial photo survey, lie in steep inner gorges and are too obscured by trees and shadow to pick out on the photos. Also, in this extremely steep country, photo angle can be critical in finding and defining these features.

Some features, both large and small, are clearly associated with a specific anthropogenic feature such as a road or a road-stream crossing. These are counted simply as related to human activity.

3.4.5 Streamside Large Discrete Features

Ten features examined in the Scott River watershed meet the criteria of this category. Though small in number, these features are significant and generally long-term contributors to stream sediment. In Table 3.16, the average annual large-discrete-feature contribution per stream mile in the Scott River watershed is calculated on the basis of the random sampling along streams. Contribution from large features on granitic substrate is totaled separately from the other three geologic units for the purpose of comparison, as a separate calculation was done applying rates from the GSS to areas of granite.

In Table 3.17, the rates estimated in Table 3.16 are applied to individual sub-watersheds throughout the Scott River watershed, based on stream miles in Quaternary, Granitic, Mafic, and Sedimentary/Metamorphic substrates. The Scott Valley Subwatershed is not included as no large discrete features were found there and slopes are lower than in the areas where such features occur. In the bottom half of Table 3.17 is a summation of estimated large-feature sediment contribution. The first block shows tons per year for each subwatershed and for the Scott and tons/sq mi-yr per subwatershed and for the Scott including granitic substrate, based on SEDMODL2 and RM road survey rates for all geologic units. The second block shows results from the same sources, but without results from granitic substrate. These rates are carried forward to the summary in Section 3.5.

3.4.5.1 Feature 92 – A Special Case

Feature 92 of the air-photo landslide inventory, discussed in the South Fork Pilot Study (NCRWQCB, 2005b, Figure 2, Table 5), is not a landslide. It is a stream segment that has had extreme erosion. While this feature is not within one of the stratified random samples of stream segments, its very size puts it in a category that cannot be ignored. Staff visited one locality in the lower-middle portion of the feature and found it at that spot to be a steep-sided, downcutting gully as deep as 60 feet and as wide as 150 feet rim-to-rim. At that spot, it is essentially V-shaped in cross section, and the walls are so bare as to be conspicuous on aerial photographs. This is much larger than any other active gully, natural or anthropogenic, that staff have found in

the Scott River watershed. USFS data suggest that this feature originated in 1944 as a failure on steep upper slopes of the mountainside in an area that has not undergone mining or timber harvest. The feature has evolved over the years and created a debris flow channel extending from the upper flank of Craggy Peak down to East Boulder Creek.
Estimated dimensions and yield of Feature 92:

5,000 feet long
Avg. depth 30 feet
Avg. width 100 feet
V-shaped cross section = Avg. 1500 sq ft
1,500 sq ft (cross section) x 5,000 ft (length) = 7,500,000 cu ft
7,500,000 cu ft / 27 cu ft per cu yd = 280,000 cu yd
280,000 cu yd x 1.35 tons per cubic yard = 378,000 tons

Assuming an age of 60 years, then average yield has been 378,000/60 = 6,300 tons per year. But this needs some interpretation.

The total volume calculated above assumes that there was no prior depression where the gully now is, which is probably not true; water and sediment flowing downhill from the area of origin would follow the lowest course. The USGS 1:62,500 scale topographic map shows Feature 92 as the only blue-line stream incised into the west flank of Craggy Peak, suggesting that it existed as a stream course before the 1944 debris flow event. Assuming that the course of Feature 92 followed one of these shallow depressions to channel the water in the first place, staff decrease volume and tonnage by ten percent and arrive at a yearly average of 5,670 tons. Aerial photo analysis reveals that Feature 92 is a debris flow channel that has had at least two debris flows, probably in 1964 and 1997, in addition to the 1944 event that originated the channel, and any undocumented events that might have taken place between 1944 and the 1980 photos. However, debris flows are not the only source of erosion and sediment delivery. The V-shaped stream channel and steep, unvegetated gully walls indicate that downcutting of the channel and backwasting of the walls are ongoing processes.

Sediment is delivered from Feature 92 every wet season when the stream runs, but delivery has been punctuated by the episodic debris flow events, the timing of which is unpredictable. Seeking the average annual contribution over a long period, staff include the debris flow events as an integral part of the long term sediment delivery. 5,670 tons/yr divided by 43 sq mi = 132 tons/sq mi-yr in the South Fork Scott River subbasin. This figure is included in natural sediment delivery in Section 3.5.

3.4.5.2 East Boulder Creek – A Special Case

One reach of East Boulder Creek, G-06-04, has four large erosion features strung together along 300 m of stream course. This in an anomalous stream segment that is incising into glacial till deposits on the valley floor, and the features described are undercut banks on the outside of bends in the stream course. Although limited timber harvest has taken place upstream, and some legacy roads remain, no direct connection was seen between human activity and the downcutting. For the TMDL estimate, staff attribute it to natural causes. Staff combined the four described features into one causal feature, estimated sediment contribution for the last twenty years, and calculated the rate on that basis. This figure is applied in Table 3.22. The calculation is as follows:

$$(7255\ yd^3) \times (1.35\ tons/yd^3) / (20) / (43.91) = 11.15\ tons/sq\ mi\text{-}yr$$

3.4.6 Streamside Small Discrete Features

The rate of contribution per stream mile from streamside small discrete features throughout the Scott River watershed was calculated on the basis of stream survey data collected from all geologic units in 2003 and 2004 (Table 3.18). Delivery from features that are clearly associated with an anthropogenic feature were accounted for in the left of the table. To the right in Table 3.18 is delivery from features for which direct association with human activity is not obvious within the stream reach where sampling took place. A factor generated in Table 3.15 was applied to estimate anthropogenic contribution to take into account the effects of multiple interacting human activities in the watershed produced by many decades of human activity.

Table 3.19 presents the same calculation as Table 3.18 in areas of Quaternary, Mafic, and Sedimentary/Metamorphic substrate. However the delivery rate from granitic substrate is taken from the Granitic Sediment Study instead of from data collected in this study. The total delivery estimated by the two different approaches is so close as to be within the margin of error.

Estimates of sediment delivery per geologic unit per subwatershed are calculated in Table 3.20 for small discrete features that have no direct human-activity association. Estimates of rates of sediment delivery attributed to different human activities are summarized in Table 3.21.

3.4.7 Callahan Area Dredger Tailings

Gold dredging along a 4.7 mile reach of the Scott River below the town of Callahan from 1934 to 1948 created disruptions of channel processes as well as in surface and subsurface hydrology that persist today. Dredging in the river and adjacent terrace deposits went as deep as 50 feet below river level. This process not only left behind windrows of cobble gravel, but it disrupted the stratigraphy of the deposits greatly increasing permeability as fine material was washed out. Consequently a significant part of the river flows underground through this stretch and the surface flow dries up most summers (Hesseldenz et al., 1999; U.S. Forest Service, 1997). Lateral cutting of the river into the dredger tailings along the west side of the river delivers sediment into the channel, but the quantity of sediment delivered is not clear. Sediment discharged from the dredger tailings was not included in the TMDL calculation.

3.5 SEDIMENT ANALYSIS SUMMARY, TMDL, ALLOCATIONS, & MARGIN OF SAFETY

3.5.1 Sediment Source Analysis Results

The results of the sediment source analysis are summarized in Table 3.22 in tons per square mile per year from different natural and anthropogenic sources. The bottom section of Table 3.22 summarizes estimates of current natural and human-activity-related delivery and calculates the percentage of the total contribution above natural delivery. Sources of information for these calculations are as follows:

- Delivery from discrete features is taken from stream surveys.
- Delivery from landslides comes from the aerial photo survey with field checking.
- Road-related delivery is taken from SEDMODL2 and the RM road survey for Quaternary, Mafic, and Sedimentary/Metamorphic geologic units and from the Scott Granitic Sediment Study (Sommarstrom et al., 1990) in areas of Granitic substrate for reasons explained in Section 3.1.5.
- In Scott Valley, delivery from discrete features and soil creep was calculated only from observations in Scott Valley and not extrapolated from values in the mountainous subwatersheds.

3.5.2 Sediment TMDL

This TMDL is set equal to the loading capacity of the Scott River and its tributaries. The TMDL is the estimate of the total amount of sediment, from both natural and human-caused sources, that can be delivered to streams in the Scott River watershed without exceeding applicable water quality standards. Staff are assuming that there can be some increase above the natural amount of sediment without adverse effects to fish habitat. Staff postulate this because fish populations were thriving throughout the Klamath River watershed after human activities had begun to produce some sediment. For the Scott River, the sediment TMDL is set equal to 125 percent of natural sediment delivery, based on past experience in other Northern California watersheds.

For the Noyo River, the U.S. EPA (1999) used a reference time period to calculate the sediment TMDL. The TMDL was set at the estimated sediment delivery rate for the 1940s. Because salmonid populations were substantial during this time period, which was assumed to be a quiescent period between the logging of old growth at the turn of the century and logging of second growth in the middle of the 20th century, U.S. EPA postulated that there could be increases above the natural amount of sediment and still maintain healthy watershed conditions. Analysis of sediment sources during this period indicates that there was about one part human induced sediment delivery for every four parts natural sediment delivery (i.e. a 1:4 ratio, or a 25% increase).

The U.S. EPA reached similar results in the TMDL analysis of the Trinity River (USEPA, 2001). For that TMDL U.S. EPA used reference streams within the watershed to calculate TMDLs for all the subwatersheds of the Trinity. Again, the reference streams were subwatersheds in which there was some management accompanied by healthy watershed conditions. As with the Noyo, it appeared that in these watersheds fish populations could be supported under TMDLs set at a level equivalent to a 4:1 ratio.

Based on these analyses, staff have determined that setting the TMDL at 125 percent of natural sediment delivery is appropriate for the Scott River. Using the estimated natural sediment delivery rate of 448 tons/sq mi-yr (Table 3.22), the TMDL for the Scott River (rounded to two significant figures) is:

TMDL = Loading Capacity = (125%) x (448 tons/sq mi-yr) = 560 tons/sq mi-yr

Because of the natural variations in sediment delivery, the TMDL is to be evaluated as a ten-year, rolling average of total annual sediment yield. The ratio approach has several potential advantages. Stillwater Sciences (1999) indicates that looking at the ratio of human to natural sediment sources can detect the effects of land use changes better than an annual sediment loading alone, because the ratio may very with hydrology less than the annual sediment load. The ratio could be measured periodically and provide an indication of progress toward meeting sediment reduction goals. The ratio may also be less dependent upon spatial and hydrologic variability.

The approach taken focuses on sediment delivery, rather than on a more direct measure of salmonid habitat (i.e., instream conditions). Sediment delivery can be subject to direct management by landowners (for example roads can be well maintained and landslides mitigated).

While it would be desirable to be able to mathematically model the relationship between salmon habitat and sediment delivery, these tools are not available for watersheds with landslides and road failure hazards. Sediment movement is complex both over space and through time. Sediment found in some downstream locations can be the result of sediment sources far upstream; instream sedimentation can also be the result of land management from decades past. Nonetheless, management activities clearly can increase sediment delivery, and instream habitat can be adversely affected by increased sediment inputs. Therefore it is reasonable to link human activities to decreased stream habitat quality. The French Creek project, discussed in Section 2.4.2.7, demonstrates the linkage between upslope and instream conditions, and the potential for improvement in instream habitat that can result from upslope sediment delivery reductions.

The approach also relies upon the assumption that salmon populations can be self sustaining even with the yearly variation of natural rates of erosion observed in the 20th century. Although the sediment delivered to the streams varied, salmon adjusted to the natural variability by using the habitat complexity created by the stream’s adjustments to the naturally varying sediment loads.

3.5.3 Load Allocations

In accordance with EPA regulations, the loading capacity (TMDL) is allocated to the various sources of sediment in the watershed, with a margin of safety. That is:

TMDL = sum of the wasteload allocations for individual point sources
+ sum of the load allocations for nonpoint sources
+ sum of the load allocations for background sources.

The margin of safety in this TMDL is not added as a separate component of the TMDL. Instead it is incorporated into conservative assumptions used to develop the TMDL. As there are no point sources of sediment in the Scott River watershed, the wasteload allocation for point sources is set at zero.

In addition to ensuring that the sum of the load allocations equals the TMDL, the Regional Water Board considered several factors related to the feasibility and practicability of controlling various nonpoint sources of sediment. The load allocations for nonpoint sources reflect professional judgment as to how effective best management practices are in controlling these sources. For example, techniques are available for greatly reducing sediment delivery from roads (Weaver and Hagans, 1994). In the Scott River watershed, the effectiveness of mitigation measures with respect to roads has been demonstrated in the French Creek watershed and in improved road design in other areas since implementation of the Forest Practice Rules.

For the Scott River TMDL, source categories that are more controllable receive load allocations based on a higher percentage reduction from current levels. For example, road stream crossing failures are more readily controlled than road related mass wasting, particularly in weathered granite. Therefore, the load allocation for road stream crossing failures is based on a loading reduction of 75 percent, whereas the load allocation for road related mass wasting is based on a loading reduction of 42 percent.

The load allocations for the Scott River watershed are presented in Table 3.23. The allocations clarify the relative emphasis and magnitude of erosion control programs that need to be developed during implementation. The load allocations are expressed in terms of yearly averages (tons/sq mi-yr). They could be divided by 365 to derive daily loading rates (tons/sq mi-day), but the Regional Water Board is expressing them as yearly averages, because sediment delivery to streams is naturally highly variable on a daily basis. In fact, the Water Board expects the load allocations to be evaluated on a ten-year rolling average basis, because of the natural variability in sediment delivery rates. In addition, the Water Board does not expect each square mile within a particular source category to necessarily meet the load allocation; rather, the Water Board expects the average for the entire source category to meet the load allocation for that category.

3.5.4 Margin of Safety

The Clean Water Act, Section 303(d) and the associated regulations at 40 CFR §130.7 require that a TMDL include a margin of safety that takes into account any lack of knowledge concerning the relationship between the pollutant loads and the desired receiving water quality. The margin of safety may be incorporated implicitly by making conservative assumptions in calculating loading capacities, waste load allocations, and load allocations (USEPA, 1991). The margin of safety may also be incorporated explicitly as a separate component in the TMDL equation. For the Sediment TMDL analysis, conservative assumptions were made that account for uncertainties in the analysis.

Specific conservative assumptions used to account for margin of safety:

- Section 3.4.1. In estimating sediment delivery by soil creep it was recognized that the hydrography used directly affects the estimate of delivery from this source. Because no available hydrography GIS layer shows all streams, as evidenced in field studies, the delivery from this natural source is underestimated. This underestimate affects the allocation of anthropogenic sediment, as the allocation is calculated as a percentage of the natural delivery.

- Ages of small features tended to be estimated low. The majority of small features described and estimated were along streams and the majority of these are natural. This would tend to result in higher yearly rates of sediment delivery for these features and is therefore conservative. If features attributed to the 1997 flood event actually were initiated before this event, yearly rates of sediment delivery estimated for these features would be higher and are therefore conservative in the context of calculating the TMDL.

- The estimation of EMIHAs is a part of the margin of safety. Some anthropogenic features are not accounted for in their proper category. For example, the VESTRA-developed GIS layer of roads used under-represents roads and does not include skid trails. In some areas only major haul roads are included, which means that many temporary roads and skid roads that can increase erosion remain unaccounted for in that road survey. Addition of the EMIHA factor accounts for roads and skid trails that are not documented in the survey.

3.5.5 Seasonal Variation and Critical Conditions

The TMDL must discuss how seasonal variations were considered. Sediment delivery in the Scott River watershed inherently has considerable annual and seasonal variability. The magnitudes, timing, duration, and frequencies of sediment delivery events fluctuate naturally depending on intra- and inter-annual variations in storm patterns. Because the storm events and the mechanisms of sediment delivery are largely unpredictable year to year, the TMDL and load allocations are designed to apply to the sources of sediment, not the movement of sediment across the landscape, and to be evaluated on the basis of a ten-year rolling average. The Water Board assumes that by controlling the sources to the extent specified in the load allocations, sediment delivery will be controlled within an acceptable range for supporting aquatic habitat, regardless of the variability of storm events.

The TMDL must also account for critical conditions for stream flow, loading, and water quality parameters. Rather than explicitly estimating critical flow conditions, this TMDL uses indicators that reflect net long term effects of sediment loading and transport for two reasons. First, sediment impacts may occur long after sediment is discharged, often at locations downstream of the sediment source. Second, it is impractical to accurately measure sediment loading and transport, and the resulting short term effects, during high magnitude flow events that produce most sediment loading and channel modifications.