Section A
MASS WASTING

INTRODUCTION

This module summarizes the methods and results of a mass wasting assessment conducted on the Mendocino Redwood Company, LLC (MRC) ownership in the Cottaneva Creek watershed, the Cottaneva Creek Watershed Analysis Unit (Cottaneva Creek WAU). The Cottaneva Creek WAU lies completely within the Cottaneva Creek California Planning Watershed (RC). This assessment is part of a watershed analysis initiated by MRC and utilizes modified methodology adapted from procedures outlined in the Standard Methodology for Conducting Watershed Analysis (Version 4.0, Washington Forest Practices Board).

The principle objectives of this assessment are to:
1) Identify the types of mass wasting processes active in the basin.
2) Identify the link between mass wasting and forest management related activities.
3) Identify where the mass wasting processes are concentrated.
4) Partition the ownership into zones of relative mass wasting potential based on the likelihood of future mass wasting and sediment delivery to stream channels.

Additionally, the role of mass wasting sediment input to watercourses is examined. This information combined with the results of the Surface and Fluvial Erosion module is used to construct a sediment input summary for the Cottaneva Creek WAU, contained in the Sediment Input Summary section of this watershed analysis.

The products of this report are: a landslide inventory map (Map A-1), a Terrain Stability Unit (TSU) map (Map A-2), and a mass wasting inventory database (Appendix A). The assembled information will enable forestland managers to make better forest management decisions to reduce management-induced risk of mass wasting. The mass wasting inventory will provide the information necessary to understand the spatial distribution, causal mechanisms, relative size, and timing of mass wasting processes active in the basin with reasonable confidence.

The Role of Mass Wasting in Watershed Dynamics

Mass wasting is a naturally occurring process, but can be accelerated by anthropogenic disturbances. Forest management practices can alter the natural frequency and magnitude of mass wasting events by changing the relative resisting and driving forces acting on a hillslope, altering soil and bedrock pore water pressures, and/or altering the effective cohesion of soil and bedrock. Increases in sediment yield due to mass wasting can disrupt the dynamic equilibrium of stream channels, resulting in a decline in the quality and quantity of amphibian and anadromous fish habitat, water quality, or stream ecology.

Mass wasting events are able to alter stream environments by increasing bed and suspended sediment loads, modifying the grain-size distribution of channel sediment, introducing woody debris, altering channel morphology by aggradation, damming and obstructing the channel, and in extreme cases scouring the channel to bedrock. Stream systems ultimately adjust to major alterations downstream, as well as upstream of individual mass wasting events. However, the consequences may last for a long while.

In the Pacific Northwest where anadromous fish are present, mass wasting can have both beneficial and adverse effects on salmonid habitat. Beneficial effects include formation of new spawning, rearing, and over-wintering habitat due to addition of coarse gravels to the channel.

The introduction of woody debris and boulders from landslides can increase cover and improve pool:riffle ratios. Adverse effects include filling of pools and scouring of riffles, blockage of fish access, disturbing side-channel rearing areas, and siltation of spawning gravels. The magnitude of these effects are dependent on the frequency, location, and intensity of mass wasting events, as well as the sediment transporting capabilities of a particular stream. Beneficial and adverse effects typically occur simultaneously, and the relative relationship between the two will vary, even for individual events. Because of their greater stream powers, larger streams and rivers adjust to mass wasting perturbations faster than smaller streams.

LANDSLIDE TYPES AND PROCESSES IN THE COTTANEVA CREEK WAU

The terminology used to describe landslides in this report closely follows the definitions of Cruden and Varnes (1996). This terminology is based on two nouns, the first describing the material that the landslide is composed of and the second describing the type of movement. Landslides identified in the Cottaneva Creek WAU were described using the following names: debris slides, debris torrents, debris flows, and rockslides. These names are described in Cruden and Varnes (1996) with the exception of our use of debris torrent.

Shallow-Seated Landslides

Debris slides, debris flows, and debris torrents are terms used throughout Mendocino Redwood Company's ownership to identify shallow-seated landslide processes. The material composition of debris slides, flows, or torrents is considered to be soil with a significant proportion of coarse material; 20 to 80 percent of the particles are larger than 2 mm (Cruden and Varnes, 1996). Shallow-seated slides generally move quickly downslope and commonly break apart during failure. Shallow-seated slides commonly occur in converging topography where colluvial materials accumulate and subsurface drainage concentrates. Susceptibility of a slope to fail by shallow-seated landslides is affected by slope steepness, saturation of soil, soil strength (friction angle and cohesion), and root strength. Due to the shallow depth and fact that debris slides, flows, or torrents involve the soil mantle, these are landslide types that can be significantly influenced by forest practices.

Debris slides are the most common landslide type observed in the WAU. The landslide mass typically fails along a surface of rupture or along relatively thin zones of intense shear strain located near the base of the soil profile. The landslide deposit commonly slides a distance beyond the toe of the surface of rupture and onto the ground surface below the failure; it generally does not slide more than the distance equal to the length of the failure scar. Landslides with deposits that traveled a longer distance below the failure scar would likely be defined as a debris flow or debris torrent. Debris slides commonly occur on steep planar slopes, convergent slopes, along forest roads and on steep slopes adjacent to watercourses. They usually fail by translational movement along an undulating or planar surface of failure. By definition debris slides do not continue downstream upon reaching a watercourse.

A debris flow is similar to a debris slide with the exception that the landslide mass continues to "flow" down the slope below the failure a considerable distance on top of the ground surface. A debris flow is characterized as a mobile, potentially rapid, slurry of soil, rock, vegetation, and water. High water content is needed for this process to occur. Debris flows generally occur on both steep, planar hillslopes and confined, convergent hillslopes. Often a failure will initiate as a debris slide, but will change as its moves downslope to a debris flow.

Debris torrents have the greatest potential to destroy stream habitat and deliver large amounts of sediment. The main characteristic distinguishing a debris torrent is that the mass of failed soil and debris "torrents" downstream in a confined channel and erodes the channel. As the debris torrent moves downslope and scours the channel, the liquefied landslide material increases in mass. Highly saturated soil or run-off in a channel is required for this process to occur. Debris torrents move rapidly and can potentially run down a channel for great distances. They typically initiate in headwall swales and torrent down intermittent watercourses. Often a failure will initiate as a debris slide, but will develop into a debris torrent upon reaching a channel. While actually a combination of two processes, these features were considered debris torrents.

Deep-Seated Landslides

Rockslides and earthflows are terms used throughout Mendocino Redwood Company's ownership to identify deep-seated landslide processes. The failure dates of the deep-seated landslides could not be estimated with any confidence, they are likely to be of varying age with some potentially being over 10,000 years old. Many of the deep-seated landslides are considered "dormant", but the importance of identifying them lies in the fact that if reactivated, they have the potential to deliver large amounts of sediment and impair stream habitat. Accelerated or episodic movement is likely to have occurred over time in response to seismic shaking or high rainfall events.

Rockslides are deep-seated landslides with movement involving a relatively intact mass of rock and overlying earth materials. The failure plane is below the colluvial layer and involves the underlying bedrock. Mode of rock sliding generally is not strictly rotational or translational, but involves some component of each. Rotational slides typically fail along a concave surface, while translational slides typically fail on a planar or undulating surface of rupture. Rockslides commonly create a flat, or back-tilted, bench below the crown of the scarp. A prominent bench is usually preserved over time and can be indicative of a rockslide. Rockslides fail in response to triggering mechanisms such as seismic shaking, adverse local structural geology, high rainfall, offloading or loading material on the slide, or channel incision (Wieczorek, 1996). The stream itself can be the cause of chronic movement, if it periodically undercuts the toe of a rockslide.

Earth flows are deep-seated landslides composed of fine-grained materials and soils derived from clay-bearing rocks. Earth flow materials typically consist of 80% or more of particles smaller than 2mm (Cruden and Varnes, 1996). Materials in an earth flow also commonly contain boulders, some very large, which move down slope in the clay matrix. Failure in earth flows is characterized by spatially differential rates of movement on discontinuous failure surfaces that are not preserved. The "flow" type of movement creates a landslide that can be very irregularly shaped. Some earth flow surfaces are dominantly grassland, while some are partially or completely forested. The areas of grassy vegetation are likely due to the inability of the unstable, clay-rich soils to support forest vegetation. The surface of an earth flow is characteristically hummocky with locally variable slope forms and relatively abundant gullies. The inherently weak materials within earth flows are not able to support steep slopes, therefore slope gradients are low to moderate. The rates of movement vary over time and can be accelerated by persistent high groundwater conditions. Timber harvesting can have the effect of increasing the amount of subsurface water, which can accelerate movement in an earth flow (Swanston et al, 1988).

Use of SHALSTAB by Mendocino Redwood Company for the Cottaneva Creek WAU

MRC uses SHALSTAB—a coupled steady state runoff infinite slope stability model—to assist with the mapping of the hazard potential of shallow-seated landslides (Dietrich and Montgomery, 1998). William Dietrich of the University of California (Berkeley) and David Montgomery of the University of Washington (Seattle) have published a validation study of the SHALSTAB model. Generally, they found that the SHALSTAB model correctly distinguishes areas more prone to shallow landslide instability. In mass wasting studies conducted in seven basins in northern California, they concluded that a log (q/T) threshold of less than -2.8 identifies the portion of the basin within which on average 57% of the shallow landslides mapped from aerial photographs are found. However, they also found that the performance of SHALSTAB depends strongly on the quality of the topographic data. The best readily available topographic data (10-m grid data from digitized USGS 7.5' quad maps) do not represent the fine scale topography that dictates the convergence of subsurface flow and the locations where shallow landslides are likely to occur. In our watershed analysis, we assess mass wasting hazards apart from SHALSTAB, using aerial photographs and field reconnaissance. However, we still use SHALSTAB output as one tool to assist with the interpretation of the landscape into terrain stability units.

METHODS

Landslide Inventory

The mass wasting assessment relies on an inventory of mass wasting features collected through the use of aerial photographs and field observations. Aerial photographs from 2000 (color, 1:12,000), 1990 (color, 1:12,000), 1978 (color, 1:15,840), 1963 (black and white, 1:20,000), and 1952 (black and white, 1:20,000) were used to interpret landslides. A small portion of MRC property in the South Fork Cottaneva Creek drainage was not covered by the 1952 photo set. In order to get complete coverage, four frames from the 1956 photo set (black and white, 1:12,000) were analyzed.

MRC collected data regarding characteristics and measurements of the identified landslides. We acknowledge that some landslides may have been missed, particularly small ones that may be obscured by vegetation. A brief description of select parameters inventoried for each landslide observed in the field and during aerial photograph interpretation is presented in Figure A-1. A detailed discussion of these parameters follows.

Figure A-1. Description of Select Parameters used to Describe Mass Wasting in the Mass Wasting Inventory.

- Slide Identification: Each landslide is assigned a unique identification number, a two letter code (see below) that denotes which planning watershed (PWS) the slide is located, and a number which indicates the USGS designated map section number the slide is mapped in.
  - Planning Watershed Codes:
  - RC – Cottaneva Creek
- TSU # – Terrain Stability Unit in which landslide is located.
- Landslide Type:
  - DS – debris slide
  - DF – debris flow
  - DT – debris torrent
  - RS – rockslide
  - EF – earthflow
- Certainty: The certainty of identification is recorded.
  - D – Definite
  - P – Probable
  - Q – Questionable
- Physical Characteristics: Includes average length, width, depth, and volume of individual slides. Length of torrent, if present, is recorded as a comment.
- Sediment Routing: Denotes the type of stream the sediment was routed into.
  - P – Perennial

I – Intermittent or Ephemeral
N – no sediment delivered

- Sediment Delivery: Quantification of the relative percentage of the landslide volume and mass delivered to the stream.
- Slope: Percent slope angle is recorded for all shallow-seated landslides observed in the field.
- Age: Relative age of the observed slide is estimated.
  - N – new (<5 years old)
  - R – recent (5-10 years old)
  - O – old (>10 years old)
- Slope Form: Denotes morphology of the slope where the landslide originated
  - C – concave
  - D – divergent
  - P – planar
- Slide Location: Interpretation of the location where the landslide originated
  - H – Headwall Swale
  - S – Steep Streamside Slopes
  - I – Inner Gorge
  - N – Neither
- Road Association: Denotes the association of the landslide to land-use practices.
  - R – Road
  - S – Skid Trail
  - L – Landing
  - N – Neither
  - I – Indeterminate
- Deep-seated landslides morphologic descriptions: toe, body, lateral scarps, and main scarp (see section below on Systematic Description of Deep-seated Landslide Features).

Landslides identified in the field and from aerial photograph observations are plotted on a landslide inventory map (Map A-1). All shallow-seated landslides are identified as a point plotted on the map at the interpreted head scarp of the failure. Deep-seated landslides are represented as a polygon representing the interpreted perimeter of the landslide body. Physical and geomorphic characteristics of all inventoried landslides are categorized in a database in Appendix A. Landslide dimensions and depths can be quite variable, therefore length, width, and depth values that are recorded are considered to be the average dimension of that feature. When converting landslide volumes to mass (tons), we assume a soil bulk density of 1.35 grams/cubic centimeter.

The certainty of landslide identification is assessed for each landslide. Three designations are used: definite, probable, and questionable. Definite means the landslide definitely exists. Probable means the landslide probably is there, but there is some doubt in the analyst's interpretation. Questionable means that the interpretation of the landslide identification may be inaccurate; the analyst has the least amount of confidence in the interpretation. Accuracy in identifying landslides on aerial photographs is dependent on the size of the slide, scale of the photographs, thickness of canopy, and logging history. Landslides mapped in areas recently logged or through a thin canopy are identified with the highest level of confidence. Characteristics of the particular aerial photographs used affects confidence in identifying landslides. For example, sun angle creates shadows which may obscure landslides, the print quality of some photo sets varies, and photographs taken at small scale makes identifying small landslides difficult. The landslide inventory results are considered a minimum estimate of sediment production. This is because landslides that were too small to identify on aerial photographs may have been missed, landslide surfaces could have reactivated in subsequent years and not been quantified, and secondary erosion by rills and gullies on slide surfaces is difficult to assess.

The technique employed to extrapolate a sediment volume delivery percentage to landslides not visited in the field relied on an average of those that were visited in the field. While this averaging technique is an oversimplification of actual on the ground sediment delivery measurements, it provides a means for estimating sediment delivery from the slides not visited in the field.

Landslides were classified based on the likelihood that a road associated land use practice was associated with the landslide. In this analysis, the effects of silvicultural techniques were not observed. The Cottaneva Creek WAU has been managed, recently and historically, for timber production. Therefore, it was determined that the effect of silvicultural practices was too difficult to confidently assign to landslides. There have been too many different silvicultural activities over time for reasonable confidence in a landslide evaluation based on silviculture. The land use practices that were assigned to landslides were associations with roads, skid trails, or landings. It was assumed that a landslide adjacent to a road, skid trail, or landing was triggered either directly or indirectly by that land use practice. If a landslide appeared to be influenced by more than one land use practice, the more causative one was noted. If a cutslope failure did not cross the road prism, it was assumed that the failure would remain perched on the road, landing, or skid trail and would not deliver to a watercourse. Some surface erosion could result from a cutslope failure and is assumed to be addressed in the road surface erosion estimates (Surface and Fluvial Erosion Module).

Sediment Input from Shallow-Seated Landslides

The overall time period used for mass wasting interpretation and sediment budget analysis is twenty-three years. Sediment input to stream channels by mass wasting is quantified for five time periods (1943-1952, 1953-1963, 1964-1978, 1979-1990, 1991-2000). The evaluation assumes that approximately the last 10 years of mass wasting can be observed in the aerial photograph. This is due to landslide surfaces revegetating quickly, making mass wasting features older than about 10 years difficult to see. We acknowledge that we have likely missed an unknown quantity of small mass wasting events during the aerial photograph interpretation. However, we assume we have captured the majority of the larger mass wasting events in this analysis.

Sediment delivery estimates from mapped shallow-seated landslides were used to produce the total mass wasting sediment input. In order to extrapolate depth to the shallow-seated landslides not visited in the field, an average was taken from the measured depths of landslides visited in the field. Field measurements revealed a bimodal distribution of depths for management associated (which includes roads, skid trails, and landings), and non-management associated shallow-seated landslides. Therefore, the shallow-seated landslides were categorically defined as management associated, or non-management associated, and assigned the appropriate average depth. In order to extrapolate sediment delivery percentage to landslides not verified in the field, an average was taken from the estimated delivery percentage of field verified landslides.

Delivery statistics were not calculated for deep-seated landslides, however, some of the sediment delivery from shallow-seated landslides is the result of conditions created by deep-seated landslides. For example, a deep-seated failure could result in a debris slide or torrent, which could deliver sediment. Furthermore, over-steepened scarps or toes of deep-seated landslides may have shallow failures associated with them. These types of sediment delivery from shallow-seated landslides associated with deep-seated landslides are accounted for in the delivery estimates.

Sediment Input from Deep-Seated Landslides

Large, active, deep-seated landslides can potentially deliver large volumes of sediment. Delivery generally occurs over long time periods compared to shallow-seated landslides, with movement delivering earth materials into the channel, resulting in an increased sediment load downstream of the failure. Actual delivery can occur by over-steepening of the toe of the slide and subsequent failure into the creek, or by the slide pushing out into the creek. It is very important not to confuse normal stream bank erosion at the toe of a slide as an indicator of movement of that slide. Before making such a connection, the slide surface should be carefully explored for evidence of significant movement, such as wide ground cracks. Sediment delivery could also occur in a catastrophic manner. In such a situation, large portions of the landslide essentially fail and move into the watercourse “instantaneously”. These types of deep-seated failures are relatively rare on MRC property and usually occur in response to unusual storm events or seismic ground shaking.

Movement of deep-seated landslides has definitely resulted in some sediment delivery in the Cottaneva Creek WAU. Quantification of the sediment delivery from deep-seated landslides was not determined in this watershed analysis. Factors such as rate of movement, or depth to the slide plane, are difficult to determine without subsurface geotechnical investigations that were not conducted in this analysis. Sediment delivery to watercourses from deep-seated landslides can occur by several processes. Such processes can include surface erosion and shallow-or deep-seated movement of a portion or all of the deep-seated landslide deposit.

The ground surface of a deep-seated landslide, like any other hillside surface, is subject to surface erosion processes such as rain drop impact, sheet wash (overland flow), and gully/rill erosion. Under these conditions the sediment delivery from surficial processes is assumed the same as adjacent hillside slopes not underlain by landslide deposits. The materials within the landslide are disturbed and can be arguably somewhat weaker. However, once a soil has developed, the fact that a deep-seated landslide underlies the slope should make little difference regarding sediment delivery generated by erosional processes that act at the ground surface. Although fresh, unprotected surfaces that develop in response to recent or active movement could become a source of sediment until the bare surface becomes covered with leaf litter, re-vegetated, or soils developed.

Clearly, movement of a portion or all of a deep-seated landslide can result in delivery of sediment to a watercourse. Exploring for any evidence of movement makes this determination. However, movement would need to be on slopes immediately adjacent to or in close proximity to a watercourse and of sufficient magnitude to push the toe of the slide into the watercourse. A deep-seated slide that toes out on a slope far from a creek or moves only a short distance downslope will generally deliver little to a watercourse. It is also important to realize that often only a portion of a deep-seated slide may become active, though the portion could be quite variable in size. Ground cracking at the head of a large, deep-seated landslide does not necessarily equate to immediate sediment delivery at the toe of the landslide. Small incremental movement of large deep-seated landslides can create void spaces within the slide mass. Though movement can be clearly indicated by the ground cracks, many times the toe may not respond or show indications of movement until some of the void space is “closed up”. This would be particularly true in the case of very large deep-seated landslides that exhibit ground cracks that are only a few inches to a couple of feet wide. Compared to the entire length of the slide, the amount of movement implied by the ground crack could be very small. This combined with the closing up or “bulking up” of the slide, would not generate much movement, if any, at the toe of the slide. However, small incremental movements on a large deep-seated landslide over thousands of years can result in oversteepened toe slopes which can be the source area for debris slides and flows; this sediment delivery is estimated during the inventory of shallow-seated landslides.

Systematic Description of Deep-seated Landslide Features

The characteristics of deep-seated landslides received less attention in the landslide inventory than shallow-seated landslides mainly due to the fact that subsurface analyses would have to be conducted to estimate attributes such as depth, volume, failure date, current activity, and sediment delivery. Subsurface investigation was beyond the scope of this report. Few of the mapped deep-seated landslides were observed to have recent movement associated with them, mainly due to oversteepening of the slope at the toe or scarp. Further assessment of deep-seated landslides will occur on a site-by-site basis in the Cottaneva Creek WAU, likely during timber harvest plan preparation and review.

Deep-seated landslides were only interpreted by reconnaissance techniques (aerial photograph interpretation rather than field observations). Reconnaissance mapping criteria consist of observations of four morphologic features of deep seated landslides – toe, internal morphology, lateral flanks, main scarp, and vegetation (after McCalpin 1984 as presented by Keaton and DeGraff, 1996, p. 186, Table 9-1). The mapping and classification criteria for each feature are presented in detail below.

Aerial photo interpretation of deep-seated landslide features in the Cottaneva Creek WAU suggests that the first three morphologic features above are the most useful for inferring the presence of deep-seated landslides. The presence of tension cracks and/or sharply defined and topographically offset scarps are probably a more accurate indicator of recent or active landslide movement. These features, however, are rarely visible on aerial photos.

Sets of five descriptions have been developed to classify each deep-seated landslide morphologic feature or vegetation influence. The five descriptions are ranked in descending order from characteristics more typical of active landslides to dormant to relict landslides. One description should characterize the feature most accurately. Nevertheless, some overlap between classifications is neither unusual nor unexpected. We recognize that some deep-seated landslides may lack evidence with respect to one or more of the observable features, but show strong evidence of another feature. If there is no expression of a particular geomorphic feature (e.g. lateral flanks), the classification of that feature is considered “undetermined”. If a deep-seated landslide is associated with other deep-seated landslides, it may also be classified as a landslide complex.

In addition to the classification criteria specific to the deep-seated landslide features, more general classification of the strength of the interpretation of the deep-seated landslide is conducted. Some landslides are obscured by vegetation to varying degrees, with areas that are clearly visible and areas that are poorly visible. In addition, weathering and erosion processes may also obscure geomorphic features over time. The quality of different aerial photograph sets varies and can sometimes make interpretations difficult. Owing to these circumstances, each inferred deep-seated landslide feature is classified according to the strength of the evidence as definite, probable or questionable as defined with respect to interpretation of shallow landslides.

At the project scale (THP development and planning), field observations of deep-seated landslide morphology and other indicators by qualified professionals are expected to be used to reduce uncertainty of interpretation inherent in reconnaissance mapping. Field criteria for mapping deep-seated landslides and assessment of activity are presented elsewhere.

Deep Seated Landslide Morphologic Classification Criteria:

I. Toe Activity

1. Steep streamside slopes with extensive unvegetated to sparsely vegetated debris slide scars. Debris slides occur on both sides of stream channel, but more prominently on side containing the deep-seated landslide. Stream channel in toe region may contain coarser

sediment than adjacent channel. Stream channel may be pushed out by toe. Toe may be eroding, sharp topography/geomorphology.
2. Steep streamside slopes with few unvegetated to sparsely vegetated debris slide scars. Debris slides generally are distinguishable only on streamside slope containing the deep-seated landslide. Stream channel may be pushed out by toe. Sharp edges becoming subdued.
3. Steep streamside slopes that are predominantly vegetated with little to no debris slide activity. Topography/geomorphology subdued.
4. Gently sloping stream banks that are vegetated and lack debris slide activity. Topography/geomorphology very subdued.
5. Undetermined

II. Internal Morphology

1. Multiple, well defined scarps and associated angular benches. Some benches may be rotated against scarps so that their surfaces slope back into the hill causing ponded water, which can be identified by different vegetation than adjacent areas. Hummocky topography with ground cracks. Jack-strawed trees may be present. No drainage to chaotic drainage/disrupted drainage.
2. Hummocky topography with identifiable scarps and benches, but those features have been smoothed. Undrained to drained but somewhat subdued depressions may exist. Poorly established drainage.
3. Slight benches can be identified, but are subtle and not prominent. Undrained depressions have since been drained. Moderately developed drainage to established drainage but not strongly incised. Subdued depressions but are being filled.
4. Smooth topography. Body of slide typically appears to have failed as one large coherent mass, rather than broken and fragmented. Developed drainage well established, incised. Essentially only large undrained depressions preserved and would be very subdued. Could have standing water. May appear as amphitheater slope where slide deposit is mostly or all removed.
5. Undetermined

III. Lateral Flanks

1. Sharp, well defined. Debris slides on lateral scarps fail onto body of slide. Gullies/drainage may begin to form at boundary between lateral scarps and sides of slide deposit. Bare spots are common or partially unvegetated.
2. Sharp to somewhat subdued, rounded, essentially continuous, might have small breaks; gullies/drainage may be developing down lateral edges of slide body. May have debris slide activity, but less prominent. Few bare spots.
3. Smooth, subdued, but can be discontinuous and vegetated. Drainage may begin to develop along boundary between lateral scarp and slide body. Tributaries to drainage extend onto body of slide.
4. Subtle, well subdued to indistinguishable, discontinuous. Vegetation is identical to adjacent areas. Watercourses could be well incised, may have developed along boundary between lateral scarp and slide body. Tributaries to drainage developed on slide body.
5. Undetermined

IV. Main Scarp

1. Sharp, continuous geomorphic expression, usually arcuate break in slope with bare spots to unvegetated; often has debris slide activity.
2. Distinct, essentially continuous break in slope that may be smooth to slightly subdued in parts and sharp in others, apparent lack of debris slide activity. Bare spots may exist, but are few.
3. Smooth, subdued, less distinct break in slope with generally similar vegetation relative to adjacent areas. Bare spots are essentially non-existent.
4. Very subtle to subdued, well vegetated, can be discontinuous and deeply incised, dissected; feature may be indistinct.
5. Undetermined

V. Vegetation

1. Less dense vegetation than adjacent areas. Recent slide scarps and deposits leave many bare areas. Bare areas also due to lack of vegetative ability to root in unstable soils. Open canopy, may have jack-strawed trees; can have large openings.
2. Bare areas exist with some regrowth. Regrowth or successional patterns related to scarps and deposits. May have some openings in canopy or young broad-leaf vegetation with similar age.
3. Subtle differences from surrounding areas. Slightly less dense and different type vegetation. Essentially closed canopy; may have moderately aged to old trees.
4. Same size, type, and density as surrounding areas.
5. Undetermined

Terrain Stability Units

Terrain Stability Units (TSUs) are delineated by partitioning the landscape into zones characterized by similar geomorphic attributes, shallow-seated landslide potential, and sediment delivery to stream channels. A combination of aerial photograph interpretation, field investigation, and SHALSTAB output were utilized to delineate TSUs. The TSU designations for the Cottaneva Creek WAU are only meant to be general characterizations of similar geomorphic and terrain characteristics related to shallow seated landslides. Deep-seated landslides are also shown on the TSU map (Map A-2). The deep-seated landslides have been included to provide land managers with supplemental information to guide evaluation of harvest planning and subsequent needs for geologic review. The landscape and geomorphic setting in the Cottaneva Creek WAU is certainly more complex than generalized TSUs delineated for this evaluation. The TSUs are only meant to be a starting point for gauging the need for site-specific field assessments.

The delineation of each TSU described is based on landforms present, the mass wasting processes, sensitivity to forest practices, mass wasting hazard, delivery potential, and forest management related trigger mechanisms for shallow seated landslides. The landform section of the TSU description defines the terrain found within the TSU. The mass wasting process section is a summary of landslide types found in the TSU. Sensitivity to forest practice and mass wasting hazard is, in part, a subjective call by the analyst based on the relative landslide hazard and influence of forest practices. Delivery potential is based on proximity of TSU to watercourses and the likelihood of mass wasting in the unit to reach a watercourse. The hazard potential is based on a combination of the mass wasting hazard and delivery potential (Table A-1). The trigger mechanisms are a list of forest management practices that may have the potential to create mass wasting in the TSU.

Table A-1. Ratings for Potential Hazard of Delivery of Debris and Sediment to Streams by Mass Wasting (L= low hazard, M= moderate hazard, H = high hazard)(from Version 4.0, Washington Forest Practices Board, 1995).

		Mass Wasting Potential		
		Low	Moderate	High
Delivery Potential	Low	**L**	**L**	**M**
	Moderate	**L**	**M**	**H**
	High	**L**	**M**	**H**

RESULTS

Mass Wasting Inventory

A Landslide Inventory Data Sheet (Appendix A) was used to record attributes associated with each landslide. The spatial distribution and location of landslides is shown on Map A-1.

A total of 164 shallow-seated landslides (debris slides, torrents, or flows) were identified and characterized in the Cottaneva Creek WAU. A total of 26 deep-seated landslides (all rockslides) were mapped in the Cottaneva Creek WAU. A considerable effort was made to field verify as many landslides as possible to insure greater confidence in the results. Approximately 38% of the identified shallow-seated landslides were field verified. From this level of field observations, extrapolation of landslide depth and sediment delivery is assumed to be performed with a reasonable level of confidence.

The temporal distribution of the 164 shallow-seated landslides observed in the Cottaneva Creek WAU is listed in Table A-2. The distribution by landslide type is shown in Table A-3.

Table A-2. Shallow-Seated Landslide Summary for Cottaneva Creek WAU by Time Periods.

Planning Watershed	1943 - 1952 Landslides	1953 - 1963 Landslides	1964 - 1978 Landslides	1979 - 1990 Landslides	1991 – 2000 Landslides
Cottaneva Creek	42	13	62	33	14

Table A-3. Landslide Summary by Type and Planning Watershed for Cottaneva Creek WAU.

Planning Watershed	Debris Slides	Debris Flows	Debris Torrents	Rock-slides	Earth-flows	Total	Road[a] Assoc.
Cottaneva Creek	137	27	0	26	0	190	111

a – Includes roads, skid trails, and landings

The majority of the landslides observed in the Cottaneva Creek WAU are debris slides. Additionally, a majority of the landslides observed are determined to be road associated; of the 164 shallow-seated landslides in the Cottaneva Creek WAU, 111 are determined to be road associated (includes roads, skid trails, or landings). This is approximately 68% of the total number of shallow-seated landslides. There were 27 debris flows observed in the Cottaneva Creek WAU. This is approximately 16% of the total shallow-seated landslides observed in the Cottaneva Creek WAU.

Of the 63 field observed shallow-seated landslides, all were initiated on slopes of 65% gradient or greater. The majority of inventoried landslides originated in convergent topography where subsurface water tends to concentrate, or on steep, planar topography, where sub-surface water can be concentrated at the base of slopes, in localized topographic depressions, or by local geologic structure. Few landslides originated in divergent topography, where subsurface water is routed to the sides of ridges. Such observations were, in part, the basis for the delineation of the WAU into Terrain Stability Units.

Terrain Stability Units

The landscape was partitioned into five Terrain Stability Units representing general areas of similar geomorphology, landslide processes, and sediment delivery potential for shallow-seated landslides (Map A-2). The units are to be used by forest managers to assist in making decisions that will minimize future mass wasting sediment input to watercourses. The delineation for the TSUs was based on qualitative observations and interpretations from aerial photographs, field evaluation, and SHALSTAB output. Deep-seated landslides are also shown on the TSU map (Map A-2). The deep-seated landslides have been included to provide land managers with supplemental information to guide evaluation of harvest planning and subsequent needs for geologic review.

Shallow-seated landslide characteristics considered in determination of map units are size, frequency, delivery to watercourses, and spatial distribution. Hillslope characteristics considered are slope form (convergence, divergence, planar), slope gradient, magnitude of stream incision, and overall geomorphology. The range of slope gradients was determined from USGS 1:24,000 topographic maps and field observations. Hillslope and landslide morphology vary within each individual TSU and the boundaries are not exact. This evaluation is not intended to be a substitute for site-specific field assessments. Site-specific field assessments will still be required in TSUs and at deep-seated landslides or specific areas of some TSUs to assess the risk and likelihood of mass wasting impacts from a proposed management action. The TSUs are compiled on the entitled Terrain Stability Unit Map (Map A-2).

TSU Number:	1
Description:	Inner Gorge or Steep Streamside Slopes adjacent to Low Gradient Watercourses
Materials:	Shallow soils formed on weathered marine sedimentary rocks. Maybe composed of toe sediment of deep-seated landslide deposit.
Landform:	Characterized by steep streamside slopes or inner gorge topography along low gradient watercourses (typically less than 6-7%). An inner gorge is a geomorphic feature created from down cutting of the stream, generally in response to tectonic uplift. Inner gorge slopes extend from either one or both sides of the stream channel to the first break in slope. Inner gorge slope gradients typically exceed 70%, although slopes with lower inclination are locally present. Inner gorge slopes commonly contain areas of multiple, coalescing shallow seated landslide scars of varying age. Steep streamside slopes are characterized by their lack of a prominent break in slope. Slopes are generally planar in form with slope gradients typically exceeding 70%. The upper extent of TSU 1 is variable. Where there is not a break in slope, the unit may extend 400 feet upslope (based on the range of lengths of landslides observed, 50-400 feet). Landslides in this unit generally deposit sediment directly into Class I and II streams. Small areas of incised terraces may be locally present.
Slope:	Typically >65 %, (mean slope of observed mass wasting events is 90%, range is 75%-100%)
Total Area:	261 acres; 3% of the total WAU area.
MW Processes:	11 *road-associated landslides* • 6 Debris slides • 5 Debris flow • 0 Debris torrent *7 non-road associated landslides* • 7 Debris slides • 0 Debris torrent • 0 Debris flows
Non Road-related Landslide Density:	0.03 landslides per acre for the past 59 years.
Forest Practices Sensitivity:	High sensitivity to road construction due to proximity to watercourses, high sensitivity to harvesting and forest management practices due to steep slopes with localized colluvial or alluvial soil deposits adjacent to watercourses.
Mass Wasting Potential:	High localized potential for landslides in both unmanaged and managed conditions.

Delivery Potential: High

Delivery Criteria Used: Steep slopes adjacent to stream channels, a majority of the observed landslides delivered sediment into streams.

Hazard-Potential Rating: **High**

Forest Management Related Trigger Mechanisms:

- Sidecast fill material placed on steep slopes can initiate debris slides or flows in this unit.
- Concentrated drainage from roads onto unstable areas can initiate debris slides or flows in this unit.
- Poorly sized culvert or excessive debris at watercourse crossings can initiate failure of the fill material creating debris slides, torrents or flows in this unit.
- Cut-slope of roads can expose potential failure planes creating debris slides, torrents or flows in this unit.
- Cut-slope of roads can remove support of the toe or expose potential failure planes of rockslides or earth flows.
- Sidecast fill material created from skid trail construction placed on steep slopes can initiate debris slides or flows in this unit.
- Concentrated drainage from skid trails onto unstable areas can initiate debris slides or flows in this unit.
- Cut-slope of skid trails can remove support of slope creating debris slides, torrents or flows in this unit.
- Cut-slope of skid trails can remove support of the toe or expose potential failure planes of rockslides or earth flows.
- Concentrated drainage from roads can increase groundwater, accelerating movement of rockslides or earth flows and over-steepening TSU 1 slopes.
- Removal of vegetation from these slopes can result in loss of evapotranspiration and thus increase pore water pressures that could initiate slope failure in this unit.
- Post timber harvest root decay of hardwood or non-redwood conifer species can be a contributing factor in the initiation of debris slides, torrents or flows in this unit.

Confidence: High confidence for susceptibility of landslides and sediment delivery in this unit. Moderate confidence in placement of the unit boundary. This unit is locally variable and exact boundaries are best determined during field observations. Within this unit there are likely areas of low gradient slopes that are less susceptible to mass wasting.

TSU Number:	2
Description:	Inner gorge or Steep Streamside Slopes adjacent to high gradient intermittent or ephemeral watercourses.
Materials:	Shallow soils formed from weathered marine sedimentary rocks with localized areas of thin to thick colluvial deposits.
Landforms:	Characterized by steep streamside slopes or inner gorge topography along low gradient watercourses (typically greater than 6-7%). An inner gorge is a geomorphic feature created from down cutting of the stream, generally in response to tectonic uplift. Inner gorge slopes extend from either one or both sides of the stream channel to the first break in slope. Inner gorge slope gradients typically exceed 70%, although slopes with lower inclination are locally present. Inner gorge slopes commonly contain areas of multiple, coalescing shallow seated landslide scars of varying age. Steep streamside slopes are characterized by their lack of a prominent break in slope. Slopes are generally planar in form with slope gradients typically exceeding 70%. The upper extent of TSU 2 is variable. Where there is not a break in slope, the unit may extend 200 feet upslope (based on the range of lengths of landslides observed, 30-200 feet). Landslides in this unit generally deposit sediment directly into Class II and III streams.
Slope:	Typically >65% (mean slope of observed mass wasting events is 83%, range is 65%-100%).
Total Area:	808 acres; 10% of total WAU area
MW Processes:	31 *road-associated landslides* • 30 Debris slides • 1 Debris flow • 0 Debris torrent *19 non-road associated landslides* • 17 Debris slides • 2 Debris flow • 0 Debris torrent
Non Road-related Landslide Density:	0.02 landslides per acre for the past 59 years.
Forest Practices Sensitivity:	High sensitivity to roads due to steep slopes adjacent to watercourses, high to moderate sensitivity to harvesting and forest management due to steep slopes next to watercourses. Localized areas of steeper and/or convergent slopes may have an even higher sensitivity to forest practices.

Mass Wasting Potential: High in both unmanaged and managed conditions due to the steep morphology of the slope.

Delivery Potential: High

Delivery Criteria Used: Steep slopes adjacent to stream channels, a majority of the observed landslides delivered sediment into streams.

Hazard-Potential Rating: **High**

Forest Management Related Trigger Mechanisms:

- Sidecast fill material placed on steep slopes can initiate debris slides, torrents or flows in this unit.
- Concentrated drainage from roads onto unstable areas can initiate debris slides, torrents or flows in this unit.
- Poorly sized culvert or excessive debris at watercourse crossings can initiate failure of the fill material creating debris slides, torrents or flows in this unit.
- Cut-slope of roads can expose potential failure planes creating debris slides, torrents or flows in this unit.
- Cut-slope of roads can remove support of the toe or expose potential failure planes of rockslides or earth flows.
- Sidecast fill material created from skid trail construction placed on steep slopes can initiate debris slides, torrents or flows.
- Concentrated drainage from skid trails onto unstable areas can initiate debris slides, torrents or flows.
- Cut-slope of skid trails can expose potential failure planes creating debris slides, torrents or flows in this unit.
- Cut-slope of skid trails can remove support of the toe or expose potential failure planes of rockslides or earth flows.
- Removal of vegetation from these slopes can result in loss of evapotranspiration and thus increase pore water pressures that could initiate slope failure in this unit.
- Post timber harvest root decay of hardwood or non-redwood conifer species can be a contributing factor in the initiation of debris slides, torrents or flows in this unit.

Confidence: High confidence for susceptibility of unit to landslides and sediment delivery. Moderate confidence in the placement of this unit. This unit is highly localized and exact boundaries are better determined from field observations. Within this unit there are likely areas of low gradient slopes that are less susceptible to mass wasting.

TSU Number:	3
Description:	Dissected and convergent topography
Materials:	Shallow soils formed from weathered marine sedimentary rocks with localized thin to thick colluvial deposits.
Landforms:	These areas have steep slopes (typically greater than 65%) that have been sculpted over geologic time by repeated debris slide events. The area is characterized primarily by 1) steep convergent and dissected topography located within steep gradient collivial hollows or headwall swales and small high gradient watercourses, and 2) locally steep planar slopes where there is strong evidence of past landsliding. MRC intends this unit to represent areas with a high hazard potential for shallow landsliding, while not constituting a continuous streamside unit (otherwise it would classify as TSU 1 or 2). The mapped unit may represent isolated individual “high hazard” areas or areas where there is a concentration of “high hazard” areas. Boundaries between higher hazard areas and other more stable areas (i.e. divergent and lower gradient slopes) within the unit should be keyed out as necessary based on field observation of landslide features.
Slope:	Typically >65%, (mean slope of observed mass wasting events is 89%, range is 75%-100%)
Total Area:	383 ac., 5% of the total WAU
MW Processes:	13 *road associated landslides* • 13 Debris slides • 0 Debris flow • 0 Debris Torrent *11 non-road associated landslides* • 10 Debris slides • 1 Debris flow • 0 debris torrent
Non Road-related Landslide Density:	0.03 landslides per acre for the past 59 years.
Forest Practices Sensitivity:	Moderate to high sensitivity to road building, moderate to high sensitivity to harvesting and forest management practices due to moderate to steep slopes within this unit. Localized areas of steeper and/or convergent slopes have even higher sensitivity to forest practices.
Mass Wasting Potential:	High
Delivery Potential:	Moderate

Delivery Criteria Used: The converging topography directs mass wasting down slopes toward watercourses. Delivery potential may be high based on relatively high number of debris slides. Landslides in headwater swales often torrent or flow down watercourses. Approximately 80% of landslides in this unit delivered sediment.

Hazard-Potential Rating: **High**

Forest Management Related Trigger Mechanisms:

- Sidecast fill material placed on steep slopes can initiate debris slides, torrents or flows in this unit.
- Concentrated drainage from roads onto unstable areas can initiate debris slides, torrents or flows in this unit.
- Concentrated drainage from roads can increase groundwater, accelerating movement of rockslides or earth flows in this unit.
- Poorly sized culvert or excessive debris at watercourse crossings can initiate failure of the fill material creating debris slides, torrents or flows in this unit.
- Cut-slope of roads can expose potential failure planes creating debris slides, torrents or flows in this unit.
- Cut-slope of roads can remove support of the toe or expose potential failure planes of rockslides or earth flows.
- Concentrated drainage from skid trails onto unstable areas can initiate debris slides, torrents or flows.
- Cut-slope of skid trails can expose potential failure planes creating debris slides, torrents or flows in this unit.
- Cut-slope of skid trails can remove support of the toe or expose potential failure planes of rockslides or earth flows.
- Sidecast fill material created from skid trail construction placed on steep slopes can initiate debris slides, torrents or flows.
- Removal of vegetation from these slopes can result in loss of evapotranspiration and thus increase pore water pressures that could initiate slope failure in this unit.
- Post timber harvest root decay of hardwood or non-redwood conifer species can be a contributing factor in the initiation of debris slides, torrents or flows in this unit.

Confidence: Moderate confidence in placement of unit. This unit is locally variable and exact boundaries are best determined from field observations. Some areas within this unit could have higher susceptibility to landslides and higher delivery rates due to localized areas of steep slopes with weak earth materials, and unusually adverse ground water conditions.

TSU Number:	4
Description:	Non-dissected topography
Materials:	Shallow to moderately deep soils formed from weathered marine sedimentary rocks.
Landforms:	Moderate to moderately steep hillslopes with planar, divergent, or broadly convergent slope forms with isolated areas of steep topography or strongly convergent slope forms. Unit 4 is generally a midslope region of lesser slope gradient and more variable slope form than unit 3.
Slope:	Typically 40% - 65%, (mean slope of observed mass wasting events is 79%, range is 65% - 110%)
Total Area:	6375 acres, 80% of the total WAU
MW Processes:	56 *road-associated landslides* • 43 Debris slides • 13 Debris flows • 0 Debris torrents *16 non-road associated landslides* • 11 Debris slides • 5 Debris flows • 0 Debris Torrents
Non Road-related Landslide Density:	0.003 landslides per acre for the past 59 years.
Forest Practices Sensitivity:	Moderate sensitivity to road building, moderate to low sensitivity to harvesting and forest management practices due to moderate slope gradients and non-converging topography within this unit. Localized areas of steeper slopes have higher sensitivity to forest practices.
Mass Wasting Potential:	Moderate
Delivery Potential:	High
Delivery Criteria Used:	This unit constitutes a majority of the WAU, which accounts for it having the highest number of landslides. This unit has a low non-road related landslide density, and therefore has a moderate mass wasting hazard. Although landslides in this unit are localized, when landslides occur, the landslide has a high potential to deliver. Approximately 90% of the landslides in this unit delivered sediment. This unit has a moderate sensitivity to road building due to low road landslide density.

Hazard-Potential Rating: **Moderate**

Forest Management Related Trigger Mechanisms:

- Sidecast fill material placed on steep slopes can initiate debris slides, torrents or flows in this unit.
- Concentrated drainage from roads onto unstable areas can initiate debris slides, torrents or flows in this unit.
- Concentrated drainage from roads can increase groundwater, accelerating movement of rockslides or earth flows in this unit.
- Poorly sized culvert or excessive debris at watercourse crossings can initiate failure of the fill material creating debris slides, torrents or flows in this unit.
- Cut-slope of roads can expose potential failure planes creating debris slides, torrents or flows in this unit.
- Cut-slope of roads can remove support of the toe or expose potential failure planes of rockslides or earth flows.
- Concentrated drainage from skid trails onto unstable areas can initiate debris slides, torrents or flows.
- Cut-slope of skid trails can expose potential failure planes creating debris slides, torrents or flows in this unit.
- Cut-slope of skid trails can remove support of the toe or expose potential failure planes of rockslides or earth flows.
- Sidecast fill material created from skid trail construction placed on steep slopes can initiate debris slides, torrents or flows.
- Removal of vegetation from these slopes can result in loss of evapotranspiration and thus increase pore water pressures that could initiate slope failure in this unit.
- Post timber harvest root decay of hardwood or non-redwood conifer species can be a contributing factor in the initiation of debris slides, torrents or flows in this unit.

Confidence: High confidence in placement of unit, however, this unit is locally variable and exact boundaries are best determined from field observations. Some areas within this unit could have higher susceptibility to landslides and higher delivery rates due to localized areas of steep slopes with weak soils, and adverse groundwater conditions.

TSU Number:	5
Description:	Low relief topography
Material:	Moderately deep to deep soils, derived from weathered marine sedimentary rocks.
Landforms:	Characterized by low gradient slopes generally less than 40%, although in some places slopes may be steeper. This unit occurs on ridge crests, low gradient side slopes, and well-developed terraces. Shallow-seated landslides seldom occur and usually do not deliver sediment to stream channels.
Slope:	Typically <30% (based on field observations)
Total Area:	140 acres, 2% of WAU area
MW Processes:	0 *landslides*
Non Road-related Landslide Density:	0 landslides per acre for past 59 years.
Forest Practices Sensitivity:	Low sensitivity to road building and forest management practices due to low gradient slopes
Mass Wasting Potential:	Low
Delivery Potential:	Low
Delivery Criteria Used:	Sediment delivery in this unit is low.
Hazard-Potential Rating:	**Low**
Forest Management Related Trigger Mechanisms:	•Poorly sized culvert or excessive debris at watercourse crossings can initiate failure of the fill material creating debris slides, torrents or flows in this unit. •Concentrated drainage from roads and skid trails can initiate or accelerate gully erosion, which can increase the potential for mass wasting processes.
Confidence:	High confidence in placement of unit in areas of obviously stable topography. High confidence in mass wasting potential and sediment delivery potential ratings.

Sediment Input from Mass Wasting

Sediment delivery was estimated for shallow-seated landslides in the Cottaneva Creek WAU. Depth values were estimated to facilitate approximation of mass for the landslides not observed in the field. In order to extrapolate depth to the shallow-seated landslides not visited in the field, an average was taken from the measured depths of landslides visited in the field. The mean depth of all shallow-seated landslides interpreted as being unrelated to road systems was 6 feet. The mean depth of all shallow seated landslides interpreted as being associated with road systems was 5 feet. Due to the relative lack of debris flows and torrents, no effort was made to differentiate landslide depths among different shallow landslide types. The mean depths of 6 feet for non road related landslides, and 5 feet for road related landslides, were assigned to all landslides not verified in the field.

The mean sediment delivery percentage assigned to shallow landslides determined to deliver sediment, but not field verified, is 53%. Of the 164 shallow-seated landslides mapped by MRC in this watershed analysis, 143 of the landslides delivered some amount of sediment (Table A-4).

Table A-4. Total Shallow-Seated Landslides Mapped in Cottaneva Creek WAU.

Planning Watershed	Total Landslides	Landslides with Sediment Delivery	Landslides with No Sediment Delivery
Cottaneva Creek	164	143	21
Percentage	***100%***	***87%***	***13%***

Mass wasting was separated into five time periods for analysis: 1943-1952, 1953-1963, 1964-1978, 1979-1990, and 1991-2000. The dates for each of the time periods are based on the date of aerial photographs used to interpret landslides (1952, 1963, 1978, 1990, and 2000) and field observations (2004 and 2005). The available aerial photography did not correspond exactly to ten year time periods for mass wasting assessment, however the time periods and the aerial photographs analyzed approximate decadal intervals. These time periods allow for a general evaluation of the relative magnitude of sediment delivery rate estimates across the Cottaneva Creek WAU.

A total of approximately 235,800 tons of mass wasting sediment delivery was estimated for the time period 1943-2000 in the Cottaneva Creek WAU. This equates to approximately 321 tons/sq. mi./yr. Of the total estimated amount, 22% delivered from 1943-1952, 9% delivered from 1953-1963, 26% from 1964-1978, 38% from 1979-1990, and 5% delivered in the 1991-2000 time period (Table A-5).

Table A-5. Sediment Delivery (in tons) by Time Period for Cottaneva Creek WAU[a].

PWS	1943-1952		1953-1963		1964-1978		1979-1990		1991-2000	
Cottaneva Creek	RR[b]	NRR[c]	RR	NRR	RR	NRR	RR	NRR	RR	NRR
	33,500	18,500	14,000	7,000	50,200	10,900	7,200	81,300	7,800	5,400
Total	**52,000**		**21,000**		**61,100**		**88,500**		**13,200**	
% of Total	**22%**		**9%**		**26%**		**38%**		**5%**	

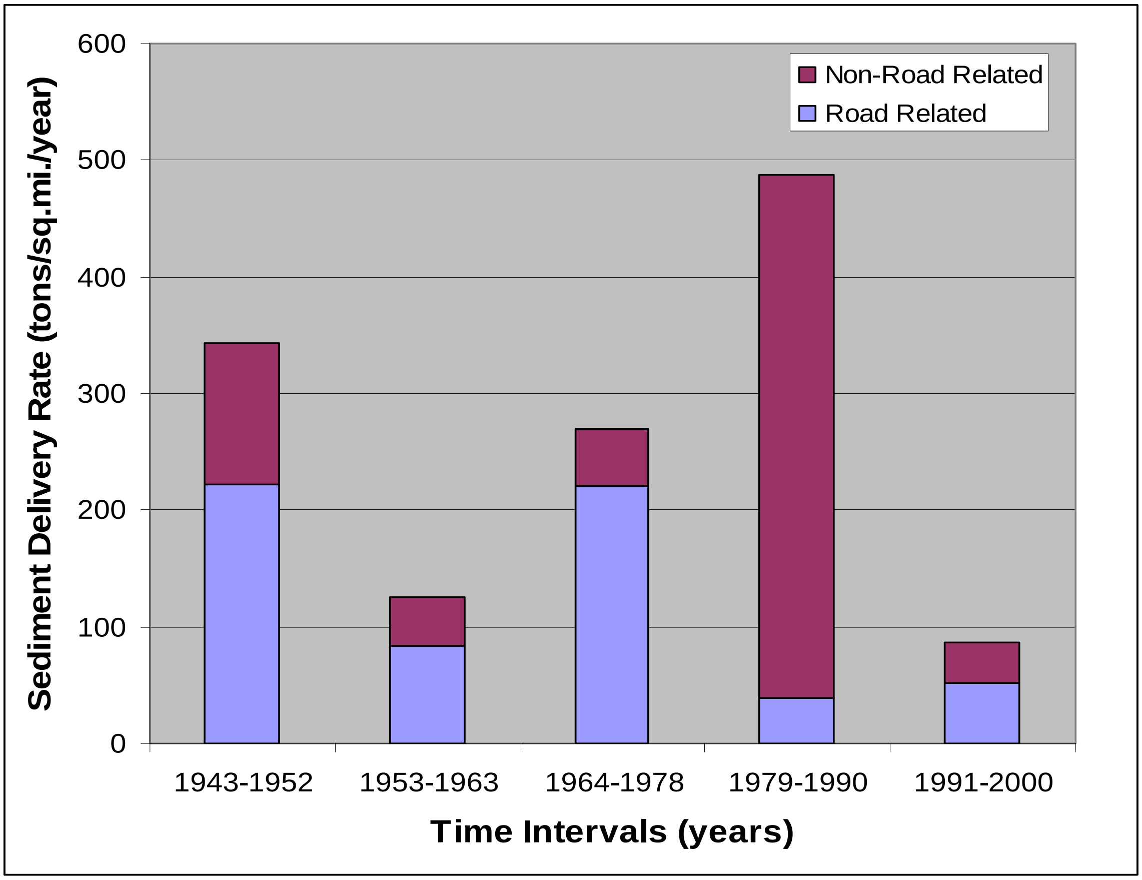
a – Sediment delivery rounded to the nearest 100 tons
b – Road related (including roads, skid trails, and landings)
c – Non-road related

Relatively large amounts of sediment delivered from 1943-1978 is likely the result of poor forest management techniques. Poor forest management techniques employed during this era of forest management include poor road and skid trail layout and the practice of sidecasting excavated fill material on steep slopes adjacent to watercourses. Additionally, according to local rainfall data, the December 1964 storm event produced the wettest days on record at 80 precipitation stations on the northwest coast (Goodridge, 1997). Although the 1964 storm was most intensely focused in Humboldt County, the area around Cottaneva Creek was subjected to a 100 year recurrence interval precipitation event. Numerous studies reveal there is a pronounced effect of pore water pressure changes on factor of safety for shallow-seated landslides (Sidle et al., 1985).

High sediment delivery in the 1979-1990 time period can be attributed to one particular slide in Rockport Creek, a tributary to South Fork Cottaneva Creek. This particular non-road related slide delivered an estimated 79,000 tons of material, approximately 90% of the sediment delivered during the 1979-1990 time period, and approximately 34% of the sediment delivered during the 59 year period of analysis. This demonstrates the influence that one large event can have on the total sediment delivery estimate generated from this type of an assessment. With the exception of the large slide in Rockport Creek, relatively less sediment delivery over the 1979-2000 time period is attributed to improved forest management under implementation of the forest practice rules.

The sediment delivery estimates were normalized by time (years) and area (square miles) for the purposes of relative comparison between time intervals. The resulting sediment delivery rates in the Cottaneva Creek WAU change dramatically over the time period investigated (Chart A-1).

Chart A-1. Mass Wasting Sediment Delivery Rate (tons/sq.mi./year) from Landslides for MRC Ownership in Cottaneva Creek.



Road associated mass wasting (including roads, skid trails, and landings) was found to have contributed 112,700 tons (153 tons/sq. mi./yr) of sediment over the 59 years analyzed in the Cottaneva Creek WAU (Table A-6). This represents approximately 48% of the total mass wasting inputs for the Cottaneva Creek WAU for 1943-2000.

Table A-6. Road Associated Sediment Delivery (in tons) for Shallow-Seated Landslides for Cottaneva Creek WAU by Planning Watershed.

Planning Watershed	Road Associated Mass Wasting Sediment Delivery (tons)	Percent of Total Sediment Delivery From Planning Watershed
Cottaneva Creek	112,700	48%

Sediment Input by Terrain Stability Unit

Total mass wasting sediment delivery for the Cottaneva Creek WAU was separated into respective Terrain Stability Units. Sediment delivery statistics for each TSU are summarized in Table A-7. It should be noted that not all planning watersheds contain all six TSUs.

Table A-7. Total Sediment Delivery (in tons) by TSU in the Cottaneva Creek WAU (tons)

TSU	1	2	3	4	5
Road Related Sediment Delivered (tons)	22,000	31,100	17,700	41,900	0
Non-Road Related Sediment Delivered (tons)	89,700	13,700	9,700	10,000	0
Total Sediment Delivered (tons)	111,700	44,800	27,400	51,900	0
% road related delivery	19%	28%	16%	37%	0%
% non-road related delivery	73%	11%	8%	8%	0%
% of total delivered	47%	19%	12%	22%	0%
% of WAU area	3%	10%	5%	80%	2%
% ratio: delivery %/area %	15.7	1.9	2.4	0.3	0.0

The TSU with the largest estimated sediment delivery is TSU 1, which is estimated to deliver 47% of the total sediment inputs for the Cottaneva Creek WAU. This is mainly due to the large slide in Rockport Creek which delivered a disproportionately large mass of sediment. The next largest contributor of sediment is TSU 4, which delivered an estimated 22% of the total sediment inputs. The high road density within TSU 4 makes the actual hazard of the unit appear artificially high; 80% of the total delivered sediment in TSU 4 came from road related features. Combining all high hazard units (TSU 1, 2, and 3) would yield 92% of the estimated non-road related sediment input off approximately 18% of the MRC owned acreage. Combining the moderate and low hazard units (TSU 4 and 5) would yield 8% of the estimated non-road related sediment input off the remaining 82% of the property.

One measure of the intensity of mass wasting processes in a given TSU is the amount of sediment produced divided by the area in the TSU. The last row in Table A-7 expresses landslide intensity as the ratio of the percentage of total sediment delivered by the percentage of watershed area in the TSU. A ratio of 1.0 would indicate that the map unit is producing a proportion of the sediment delivery equal to the proportion of the map unit area within the WAU. Values of this ratio greater than 1.0 indicate high landslide rates in a relatively concentrated area. The TSUs with the largest ratios were units 1, 2, and 3, with ratios of 15.7, 1.9, and 2.4, respectively. The smallest ratios are found in units 4 and 5; 0.3 and 0.0, respectively. The ratios suggest that the delineation of the high hazard TSUs has captured the majority of the estimated sediment delivery from mass wasting over the past 59 years in the Cottaneva Creek WAU.

CONCLUSIONS

In forest environments of the California Coast Range, mass wasting is a common, natural occurrence. In the Cottaneva Creek WAU this is due to steep slopes, the condition of weathered and intensely sheared and fractured marine sedimentary rocks, seismic activity, locally thick colluvial soils, a history of timber harvest practices, and the occurrence of high intensity rainfall events. Mass wasting events are episodic and many landslides may happen in a short time frame. Mass wasting features of variable age and stability are observed throughout the Cottaneva Creek WAU. All of the landslides visited in the field during this assessment occurred on slopes greater than 65%. Seeps and springs were evident in the evacuated cavity at many sites. Particular caution should be exercised when conducting any type of forest management activity in areas with convergent or locally steep topography.

Mass wasting sediment input is estimated to be at least 321 tons/sq.mi./yr. over the 1943-2000 time period for the entire Cottaneva Creek WAU. However, approximately 68% of the shallow-seated landslides inventoried in the Cottaneva Creek WAU are road associated (includes roads, skid trails, and landings). Road associated mass wasting represented 48% of the estimated sediment delivery, or at least 153 tons/sq. mi./yr of sediment over the 59 years analyzed. Road construction is thus a significant factor in the cause of shallow-seated mass wasting events. Improved road construction practices combined with design upgrades of old roads can reduce anthropogenic sediment input rates and mass wasting hazards

Evidence of the influence of one large event on the total sediment delivery estimate can be found in Rockport Creek where a large slide delivered nearly 79,000 tons of sediment in the 1979-1990 time period. This slide accounted for roughly 33% of the total sediment delivered for the 59 year period of this assessment. Even without this slide, the steep streamside areas of TSU 1, 2, and 3 contribute the highest amount of the sediment per unit area in the watershed.

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Cottaneva Creek Mass Wasting Inventory
Appendix A

Watershed: Cottaneva Creek

													Shallow-seated landslides								Deep-seated landslides							
Unique ID#	PWS	T & R Sec. #	Air Photo year	Air Photo frame	Landslide Type	TSU	Certainty	Size Length	Width	Depth	Slide Vol.	Sed. Routing	Sed. Del. Ratio	Sed. Delivery	Sed. Delivery	Slope (field)	Age	Slope Form	Slide Loc.	Road Assoc.	Toe Activity	Body Morph.	Lat. Scarps	Main Scarps	DS Veg.	Complex	Field Obs.	Comments
					DS DF DT EF RS	1 2 3 4 5 6	D P Q	feet	feet	feet	yd^3	P I N	25 50 75 100 (%)	yd^3	tons	(%)	N R O	C D P	H S I N	R S L N I	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4	Y N	Y N	
1	RC	36	1952	4K-101	DS	4	D	100	50	5	926	P	53	491	663		N	P	S	R								
2	RC	36	1952	4K-101	DS	4	Q	100	100	5	1852	P	53	981	1325		N	D	S	R								
3	RC	1	1952	4K-103	DS	4	P	350	150	6	11667	N	0	0	0		O	C	H	N								
4	RC	1	1952	4K-103	DS	3	P	150	100	5	2778	P	53	1472	1988		O	C	S	R								
5	RC	1	1952	4K-103	DF	2	D	150	50	6	1667	P	53	883	1193		N	C	H	N								800' LONG TORRENT TRACK
6	RC	1	1952	4K-103	DS	4	D	250	100	5	4630	P	53	2454	3313		N	C	S	S								
7	RC	1	1952	4K-103	DS	4	D	100	50	6	1111	N	0	0	0		N	P	S	N								
8	RC	1	1952	4K-103	DS	1	D	250	150	8	11111	P	50	5556	7500	85	N	P	S	N							Y	ASSOC. W/DSL INSTABILITY
9	RC	1	1952	4K-103	DS	1	P	100	50	5	926	P	53	491	663		R	P	S	R								
10	RC	1	1952	4K-103	DS	1	P	100	100	5	1852	P	53	981	1325		R	P	S	R								
11	RC	1	1952	4K-103	DS	1	D	100	50	5	926	P	53	491	663		R	C	S	R								
12	RC	12	1952	4K-103	DS	1	D	250	150	5	6944	P	53	3681	4969		R	C	S	R								
13	RC	11	1952	4K-103	DF	4	D	100	50	6	1111	P	53	589	795		N	C	H	N								500' LONG TORRENT TRACK
14	RC	11	1952	4K-103	DS	4	P	200	100	5	3704	P	53	1963	2650		R	C	S	R								
15	RC	13	1952	4K-103	DS	4	D	150	150	5	4167	P	53	2208	2981		R	P	S	R								
16	RC	25	1952	4K-105	DS	4	D	200	150	5	5556	I	53	2944	3975		N	C	H	R								
18	RC	12	1952	4K-170	DS	4	D	100	50	5	926	P	53	491	663		N	P	S	R								
19	RC	12	1952	4K-170	DS	4	D	100	50	5	926	P	53	491	663		N	P	S	R								
20	RC	12	1952	4K-170	DS	4	D	100	50	5	926	P	53	491	663		N	P	S	R								
21	RC	12	1952	4K-170	DS	2	D	50	50	5	463	P	53	245	331		N	P	S	R								
22	RC	7	1952	4K-170	DS	2	D	150	100	5	2778	P	53	1472	1988		N	P	S	R								
23	RC	7	1952	4K-170	DS	2	D	100	50	6	1111	P	53	589	795		N	P	S	N								
24	RC	18	1952	4K-170	DS	3	D	50	50	6	556	N	0	0	0		N	P	N	N								
25	RC	18	1952	4K-170	DS	3	D	50	50	6	556	N	0	0	0		N	C	H	N								
26	RC	18	1952	4K-170	DS	2	D	150	50	5	1389	P	53	736	994		N	P	S	R								
27	RC	18	1952	4K-170	DS	2	D	100	100	5	1852	P	53	981	1325		N	P	S	R								
28	RC	18	1952	351-3-8	DS	2	P	100	50	5	926	I	53	491	663		N	C	H	S								
29	RC	18	1952	351-3-8	DS	2	P	50	50	5	463	I	53	245	331		N	C	N	S								
30	RC	18	1952	351-3-8	DS	2	P	50	50	6	556	N	0	0	0		R	C	N	N								
31	RC	17	1952	351-3-8	DS	2	P	100	50	6	1111	I	53	589	795		N	C	S	N								
32	RC	17	1952	351-3-8	DS	3	D	150	50	6	1667	I	53	883	1193		R	C	H	N								
33	RC	17	1952	351-3-8	DS	2	D	150	100	6	3333	I	53	1767	2385		R	C	S	N								
34	RC	19	1952	351-3-8	DS	1	D	100	50	5	926	P	53	491	663		N	P	S	R								
35	RC	19	1952	351-3-8	DS	1	P	50	25	6	278	P	53	147	199		N	P	S	N								
36	RC	19	1952	351-3-8	DS	1	D	200	150	5	5556	N	0	0	0		O	P	S	R								
37	RC	19	1952	351-3-8	DS	4	P	100	50	6	1111	P	53	589	795		R	C	H	N								
38	RC	19	1952	351-3-8	DS	3	D	100	50	5	926	P	53	491	663		N	P	S	R								
39	RC	19	1952	351-3-8	DS	1	D	50	50	6	556	P	53	294	398		N	C	S	N								
40	RC	30	1952	351-3-6	DS	1	D	100	50	6	1111	P	53	589	795		R	P	S	N								
41	RC	30	1952	351-3-6	DS	2	D	50	50	5	463	P	50	231	313	75	R	C	N	N							Y	
42	RC	30	1952	351-3-6	DS	1	D	75	50	4	556	P	75	417	563	100	R	P	S	N							Y	
43	RC	30	1952	351-3-6	DS	2	D	100	50	6	1111	P	53	589	795		R	P	S	N								
100	RC	13	1963	15-112	DS	2	P	50	25	6	278	I	53	147	199		N	C	N	N								
101	RC	18	1963	15-112	DS	2	P	50	25	6	278	I	53	147	199		N	P	S	N								
102	RC	18	1963	15-112	DS	4	D	250	200	5	9259	P	53	4907	6625		N	C	S	R								
103	RC	1	1963	15-114	DS	3	P	100	50	6	1111	N	0	0	0		N	C	H	N								
104	RC	36	1963	15-116	DS	4	D	150	50	5	1389	I	53	736	994		N	P	S	R								
105	RC	20	1963	9-75	DS	3	P	100	50	4	741	P	50	370	500	100	N	C	H	N							Y	
106	RC	20	1963	9-75	DS	3	P	75	100	7	1944	P	75	1458	1969	95	N	C	H	N							Y	
107	RC	17	1963	9-76	DF	4	P	100	50	5	926	I	53	491	663		N	C	H	R								
108	RC	17	1963	9-76	DF	4	P	100	50	5	926	I	53	491	663		N	C	H	R								
109	RC	12	1963	field obs	DS	2	D	100	50	4	741	P	75	556	750	75	O	P	S	N							Y	EVIDENCE OF RECENT ACTIVITY
110	RC	12	1963	field obs	DS	2	D	150	150	6	5000	P	50	2500	3375	80	O	P	S	N							Y	

Watershed: Cottaneva Creek

								Size					*Shallow-seated landslides*								*Deep-seated landslides*							
Unique ID#	PWS	T & R Sec. #	Air Photo year	Air Photo frame	Landslide Type	TSU	Certainty	Length	Width	Depth	Slide Vol.	Sed. Routing	Sed. Del. Ratio	Sed. Delivery	Sed. Delivery	Slope (field)	Age	Slope Form	Slide Loc.	Road Assoc.	Toe Activity	Body Morph.	Lat. Scarps	Main Scarps	DS Veg.	Complex	Field Obs.	Comments
111	RC	12	1963	field obs	DS	2	D	150	150	8	6667	P	50	3333	4500	75	O	P	S	R							Y	
112	RC	20	1963	field obs	DS	2	D	50	75	4	556	P	75	417	563	75	O	P	S	S							Y	
200	RC	25	1978	2-5	DF	1	D	150	75	6	2500	P	75	1875	2531	90	N	P	N	R							Y	
201	RC	25	1978	2-5	DF	1	D	100	50	5	926	P	75	694	938	95	N	P	N	R							Y	
202	RC	25	1978	2-5	DF	1	D	150	75	6	2500	P	75	1875	2531	95	N	C	H	R							Y	
203	RC	25	1978	2-5	DF	1	D	125	100	6	2778	P	75	2083	2813	90	N	C	H	R							Y	
204	RC	30	1978	2-5	DF	1	D	150	125	7	4861	P	75	3646	4922	95	N	P	N	R							Y	
205	RC	30	1978	2-5	DF	4	D	100	100	6	2222	I	75	1667	2250	90	N	C	S	R							Y	
206	RC	25	1978	2-5	DS	4	P	50	35	4	259	I	50	130	175	65	N	C	N	R							Y	
207	RC	30	1978	2-5	DS	4	P	33	33	5	202	I	53	107	144		N	C	H	R								
208	RC	19	1978	2-5	DF	4	D	66	99	5	1210	I	53	641	866		R	C	H	R								1320' TORRENT TRACK
209	RC	19	1978	2-7	DS	2	D	50	40	4	296	I	25	74	100	90	N	C	S	R							Y	
210	RC	19	1978	2-7	DF	4	D	66	33	6	484	I	53	257	346		N	C	H	N								
211	RC	13	1978	2-7	DF	4	P	100	40	5	741	I	25	185	250	80	N	C	H	R							Y	
212	RC	13	1978	2-7	DS	4	D	100	50	8	1481	I	75	1111	1500	80	N	C	H	R							Y	
213	RC	13	1978	2-7	DS	2	D	100	50	6	1111	P	75	833	1125	85	N	P	S	R							Y	
214	RC	13	1978	2-7	DF	4	D	75	50	5	694	N	0	0	0	90	N	P	N	R							Y	600' RUNOUT
215	RC	13	1978	2-7	DS	2	D	50	40	5	370	N	0	0	0	80	N	C	S	R							Y	
216	RC	13	1978	2-7	DF	4	D	66	33	5	403	P	53	214	289		N	P	S	S								
217	RC	13	1978	2-7	DS	2	P	66	33	5	403	P	53	214	289		N	P	S	S								
218	RC	13	1978	2-7	DS	4	P	66	66	5	807	I	53	428	577		N	P	N	S								
219	RC	12	1978	2-7	DF	4	D	132	66	6	1936	I	53	1026	1385		N	C	H	N								660' TORRENT TRACK
220	RC	11	1978	2-7	DS	4	D	132	99	6	2904	P	53	1539	2078		R	C	H	N								
221	RC	18	1978	2-7	DS	2	D	66	33	6	484	P	53	257	346		N	P	S	N								
222	RC	18	1978	2-7	DS	2	D	66	66	6	968	P	53	513	693		N	P	S	N								
223	RC	18	1978	2-7	DS	4	D	66	33	5	403	I	53	214	289		N	P	N	R								
224	RC	13	1978	2-7	DF	4	P	99	33	5	605	P	53	321	433		N	P	N	S								
225	RC	13	1978	2-7	DS	3	D	99	33	5	605	P	53	321	433		N	P	N	S								
226	RC	13	1978	2-7	DS	3	D	99	33	5	605	P	53	321	433		N	P	N	S								
227	RC	7	1978	2-9	DS	2	D	125	75	6	2083	P	75	1563	2109	100	N	P	S	S							Y	
228	RC	7	1978	2-9	DS	2	D	66	33	5	403	P	53	214	289		N	P	N	S								
229	RC	6	1978	2-9	DF	2	D	99	33	5	605	I	53	321	433		N	C	H	R								660' TORRENT TRACK
230	RC	12	1978	2-9	DS	2	D	66	66	5	807	I	53	428	577		N	P	S	S								
231	RC	1	1978	2-9	DS	4	D	66	33	5	403	P	53	214	289		N	P	S	S								
232	RC	1	1978	2-9	DS	3	D	132	99	6	2904	I	53	1539	2078		N	P	H	N								
233	RC	1	1978	2-9	DS	3	D	99	66	5	1210	P	53	641	866		N	C	N	R								ROCKPIT CUTSLOPE FAILURE
234	RC	1	1978	2-9	DS	3	D	132	132	5	3227	P	53	1710	2309		N	C	N	R								ROCKPIT CUTSLOPE FAILURE
235	RC	1	1978	2-9	DF	4	Q	66	33	6	484	I	53	257	346		N	P	H	N								
236	RC	1	1978	2-9	DS	4	D	99	66	6	1452	P	53	770	1039		N	P	S	N								
237	RC	1	1978	2-9	DS	4	P	99	33	5	605	N	0	0	0		N	P	N	R								
238	RC	7	1978	2-9	DS	2	P	33	33	6	242	I	53	128	173		N	P	N	N								
239	RC	36	1978	2-11	DS	4	D	33	33	6	242	I	53	128	173		N	P	S	N								
240	RC	20	1978	3-6	DF	4	D	50	40	5	370	I	50	185	250	90	N	P	N	N							Y	200' RUNOUT
241	RC	20	1978	3-6	DS	3	D	200	75	5	2778	P	25	694	938	95	N	C	H	N							Y	
244	RC	20	1978	3-6	DS	2	D	75	50	4	556	P	75	417	563	75	N	P	S	S							Y	
245	RC	17	1978	3-8	DS	4	P	66	33	5	403	I	53	214	289		N	C	N	S								
246	RC	17	1978	3-8	DS	2	D	50	100	6	1111	P	100	1111	1500	65	N	P	S	S							Y	ASSOC W/DSL INSTABILITY
247	RC	18	1978	3-8	DS	4	D	99	33	5	605	I	53	321	433		N	P	S	S								
248	RC	18	1978	3-8	DS	2	P	33	33	5	202	I	53	107	144		N	P	N	S								
249	RC	18	1978	3-8	DS	2	P	75	50	5	694	I	75	521	703	70	N	C	S	S							Y	
250	RC	18	1978	3-8	DS	4	D	50	40	5	370	I	25	93	125	65	N	P	N	S							Y	
251	RC	17	1978	3-8	DS	4	D	50	25	4	185	I	50	93	125	65	N	C	N	S							Y	
252	RC	17	1978	3-8	DF	2	D	99	66	6	1452	I	53	770	1039		N	C	H	N								
253	RC	7	1978	3-8	DS	4	D	66	33	5	403	I	53	214	289		N	C	H	R								
254	RC	7	1978	2-9	DS	2	D	150	75	6	2500	P	75	1875	2531	100	R	P	S	S							Y	

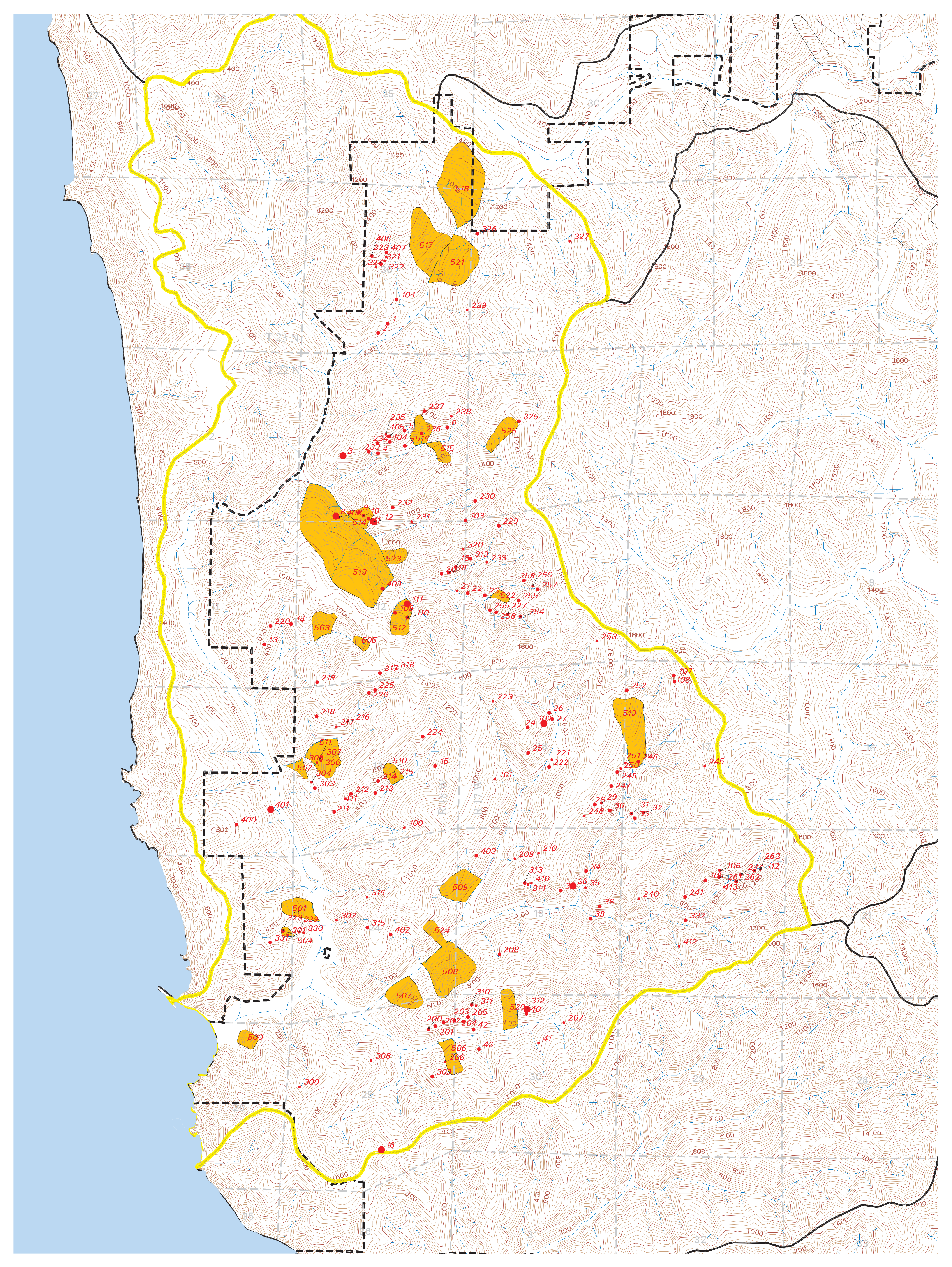
Watershed: Cottaneva Creek

Mass Wasting Inventory Sheet
Mendocino Redwood Company, LLC

													Shallow-seated landslides								*Deep-seated landslides*							
Unique ID#	PWS	T & R Sec. #	Air Photo year	Air Photo frame	Landslide Type	TSU	Certainty	Size Length	Width	Depth	Slide Vol.	Sed. Routing	Sed. Del. Ratio	Sed. Delivery	Sed. Delivery	Slope (field)	Age	Slope Form	Slide Loc.	Road Assoc.	Toe Activity	Body Morph.	Lat. Scarps	Main Scarps	DS Veg.	Complex	Field Obs.	Comments
255	RC	7	1978	2-9	DS	2	D	200	75	8	4444	P	75	3333	4500	90	R	P	S	S							Y	
256	RC	7	1978	2-9	DS	4	D	150	100	5	2778	N	0	0	0	75	N	C	N	N							Y	ON DORMANT DSL CROWN SCARP
257	RC	7	1978	2-9	DS	2	D	150	75	6	2500	P	75	1875	2531	90	N	C	H	S							Y	
258	RC	7	1978	field obs	DS	2	D	100	50	7	1296	P	50	648	875	90	O	P	S	S							Y	
259	RC	7	1978	field obs	DS	3	D	170	100	6	3778	P	75	2833	3825	80	O	P	S	S							Y	
260	RC	7	1978	field obs	DS	2	D	50	30	5	278	P	25	69	94	80	O	P	S	S							Y	
261	RC	20	1978	field obs	DS	3	D	50	100	6	1111	P	75	833	1125	90	O	C	S	S							Y	
262	RC	20	1978	field obs	DS	2	D	50	75	5	694	P	75	521	703	95	O	P	S	S							Y	
263	RC	20	1978	field obs	DS	2	D	30	25	3	83	P	100	83	113	90	O	P	S	S							Y	
300	RC	25	1990	M1-2	DS	2	P	50	25	6	278	P	53	147	199		N	P	S	N								
301	RC	23	1990	M1-4	DS	2	D	50	25	3	139	I	50	69	94	75	R	P	N	N							Y	
302	RC	24	1990	M1-4	DS	2	D	50	50	5	463	I	53	245	331		N	P	N	S								
303	RC	13	1990	M1-4	DF	4	D	100	50	5	926	I	53	491	663		N	C	N	S								1000' TORRENT TRACK
304	RC	13	1990	M1-4	DF	4	P	50	25	5	231	I	53	123	166		N	P	N	R								
305	RC	13	1990	M1-6	DS	2	P	50	25	6	278	I	53	147	199		N	P	S	N								
306	RC	13	1990	M1-6	DS	4	P	50	25	5	231	N	0	0	0		N	D	N	R								
307	RC	13	1990	M1-6	DS	4	D	50	25	5	231	N	0	0	0		N	D	N	R								
308	RC	25	1990	M2-4	DS	4	D	100	25	5	463	I	53	245	331		N	P	N	S								
309	RC	25	1990	M2-4	DS	4	D	125	50	5	1157	N	0	0	0		R	C	H	R								
310	RC	30	1990	M2-4	DS	3	D	75	50	5	694	I	53	368	497		N	C	N	R								
311	RC	30	1990	M2-4	DS	3	D	50	25	5	231	I	53	123	166		N	C	N	R								
312	RC	30	1990	M2-4	DS	1	D	400	350	15	77778	P	75	58333	78750	75	N	P	S	N							Y	TEMP. DAMMED ROCKPORT CREEK
313	RC	19	1990	M2-6	DS	4	D	75	50	5	694	N	0	0	0	80	N	C	N	R							Y	
314	RC	19	1990	M2-6	DS	4	D	50	40	4	296	I	25	74	100	75	N	P	N	R							Y	
315	RC	24	1990	M2-6	DS	4	D	75	50	5	694	I	53	368	497		N	C	N	R								
316	RC	24	1990	M2-6	DS	4	D	50	25	5	231	I	53	123	166		R	C	N	R								
317	RC	12	1990	M2-8	DS	4	D	75	50	5	694	I	53	368	497		R	C	N	S								
318	RC	12	1990	M2-8	DS	4	D	50	50	5	463	I	53	245	331		R	C	N	S								
319	RC	7	1990	M2-8	DS	3	D	150	50	5	1389	P	53	736	994		N	P	S	R								
320	RC	12	1990	M2-8	DS	2	D	50	25	6	278	I	53	147	199		N	P	S	N								
321	RC	36	1990	M2-12	DS	4	D	50	25	3	139	N	0	0	0	85	N	C	N	R							Y	
322	RC	36	1990	M2-12	DS	4	D	50	25	4	185	N	0	0	0	80	N	P	N	R							Y	
323	RC	36	1990	M2-12	DF	4	D	100	75	5	1389	I	75	1042	1406	85	N	P	N	R							Y	400' TORRENT TRACK, REACHED SR1
324	RC	36	1990	M2-12	DS	3	D	50	40	4	296	I	50	148	200	75	N	C	H	R							Y	
325	RC	6	1990	M3-12	DS	3	D	100	50	6	1111	I	53	589	795		N	C	H	N								
326	RC	31	1990	M3-14	DS	4	P	100	50	6	1111	I	53	589	795		N	P	S	N								
327	RC	31	1990	M3-14	DS	4	D	50	25	5	231	N	0	0	0		N	P	N	R								
328	RC	23	1990	M3-14	DS	4	D	100	50	5	926	P	25	231	313	80	N	C	S	N							Y	
329	RC	24	1990	field obs	DS	4	D	75	30	3	250	P	25	63	84	80	O	P	S	S							Y	
330	RC	24	1990	field obs	DS	4	D	25	50	4	185	N	0	0	0	80	O	P	S	S							Y	
331	RC	23	1990	field obs	DS	4	D	100	50	4	741	I	50	370	500	70	O	C	N	S							Y	
332	RC	20	1990	field obs	DS	2	D	60	90	4	800	I	25	200	270	100	O	P	S	R							Y	ORIGINATED IN CUTSLOPE
400	RC	14	2000	1-3	DF	4	D	100	100	5	1852	I	53	981	1325		R	C	H	R								800' LONG RUNOUT
401	RC	14	2000	1-3	DS	4	D	200	100	10	7407	N	0	0	0	65	R	P	N	N							Y	EVIDENCE OF ROTATIONAL MOVEMENT
402	RC	24	2000	2-5	DF	4	D	100	50	5	926	I	53	491	663		N	C	N	R								350' LONG TORRENT TRACK
403	RC	19	2000	2-5	DS	4	D	100	50	6	1111	N	0	0	0	75	N	C	N	R							Y	
404	RC	1	2000	2-9	DF	3	D	150	75	6	2500	I	53	1325	1789		N	C	N	N								500' LONG TORRENT TRACK
405	RC	1	2000	2-9	DS	3	D	50	50	6	556	I	53	294	398		N	C	N	N								
406	RC	36	2000	2-11	DS	3	D	250	75	5	3472	I	90	3125	4219	90	N	P	N	R							Y	800' LONG RUNOUT, REACHED SR1
407	RC	36	2000	2-11	DS	4	D	150	75	5	2083	I	25	521	703	85	N	C	N	R							Y	ENLARGEMENT OF #321
408	RC	1	2000	field obs	DS	1	D	250	40	4	1481	P	75	1111	1500	85	N	P	S	N							Y	ENLARGEMENT OF #8
409	RC	12	2000	field obs	DS	4	D	150	60	5	1667	P	75	1250	1688	110	N	P	S	N							Y	
410	RC	19	2000	field obs	DS	4	D	35	50	5	324	I	50	162	219	80	N	C	N	R							Y	
411	RC	13	2000	field obs	DS	4	D	20	40	4	119	I	75	89	120	70	R	P	H	R							Y	
412	RC	20	2000	field obs	DS	2	D	40	25	4	148	I	100	148	200	85	R	P	S	R							Y	

Watershed: Cottaneva Creek

													Shallow-seated landslides								Deep-seated landslides							
Unique	PWS	T & R	Air Photo	Air Photo	Landslide	TSU	Certainty	Size			Slide	Sed.	Sed. Del.	Sed.	Sed.	Slope	Age	Slope	Slide	Road	Toe	Body	Lat.	Main	DS	Complex	Field	
ID#		Sec. #	year	frame	Type			Length	Width	Depth	Vol.	Routing	Ratio	Delivery	Delivery	(field)		Form	Loc.	Assoc.	Activity	Morph.	Scarps	Scarps	Veg.		Obs.	Comments
413	RC	20	2000	field obs	DS	2	D	50	40	4	296	P	100	296	400	80	R	P	S	S							Y	
500	RC		2000	1-1	RS		P	500	500			P									4	3	3	3	4	N		
501	RC		2000	1-3	RS		P	800	500			P									4	3	2	3	4	N		
502	RC		2000	1-5	RS		P	600	400			P									4	4	4	4	4	N		
503	RC		2000	1-5	RS		P	600	500			I									4	4	4	4	4	N		
504	RC		2000	1-3	RS		D	250	250			P									2	3	3	2	4	N		
505	RC		2000	1-5	RS		P	500	300			I									4	4	4	4	4	N		
506	RC		2000	2-3	RS		P	1100	400			P									4	3	3	4	4	N		
507	RC		2000	2-3	RS		P	1000	800			P									2	3	4	3	4	N		
508	RC		2000	2-3	RS		Q	1300	1200			P									3	4	4	4	4	N		
509	RC		2000	2-5	RS		P	800	1000			P									2	3	4	4	4	N		
510	RC		2000	2-7	RS		P	600	400			P									2	3	3	3	4	N		
511	RC		2000	2-7	RS		Q	1100	800			P									4	4	4	4	4	N		
512	RC		2000	2-7	RS		P	1400	600			P									2	3	4	3	4	N		
513	RC		2000	2-9	RS		D	1200	4000			P									2	3	3	4	4	Y		
514	RC		2000	2-9	RS		P	600	500			P									4	3	4	3	4	N		
515	RC		2000	2-9	RS		P	700	300			P									4	4	4	4	4	N		
516	RC		2000	2-9	RS		P	800	500			P									4	2	4	3	4	N		
517	RC		2000	2-11	RS		P	1500	1200			P									4	2	3	3	4	Y		
518	RC		2000	2-11	RS		P	1700	1500			P									4	3	4	4	4	N		
519	RC		2000	3-10	RS		D	1000	1500			P									2	3	4	3	4	Y		
520	RC		2000	3-6	RS		P	1200	400			P									3	3	4	3	4	N		
521	RC		2000	3-14	RS		P	1100	1500			P									4	4	4	4	4	N		
522	RC		2000	3-10	RS		D	500	350			P									3	3	4	3	4	N		
523	RC		2000	2-7	RS		P	750	450			P									4	3	4	3	4	N		
524	RC		2000	3-8	RS		P	800	400			P									3	3	4	3	4	N		
525	RC		2000	3-12	RS		P	1400	400			P									3	3	4	3	4	N		



Cottaneva Creek Watershed Analysis Unit

Map A-1 Mass Wasting Inventory

This map presents the location of mass wasting features identified on the MRC land in the Cottaneva Creek watershed. The mass wasting features were developed from an interpretation of aerial photographs from the 1950's-2000 with field observations taken in 2004 and 2005. All shallow-seated landslides are identified as a point plotted on the map at the interpreted head scarp of the failure. Deep-seated landslides are represented as a polygon representing the interpreted perimeter of the landslide feature. Physical and geomorphic characteristics of the landslides are categorized in a database in the mass wasting section of the Cottaneva Creek watershed analysis.

Deep-Seated Landslides

Shallow-Seated Landslides

- < 500 cubic yards
- 500 - 5000 cubic yards
- > 5000 cubic yards

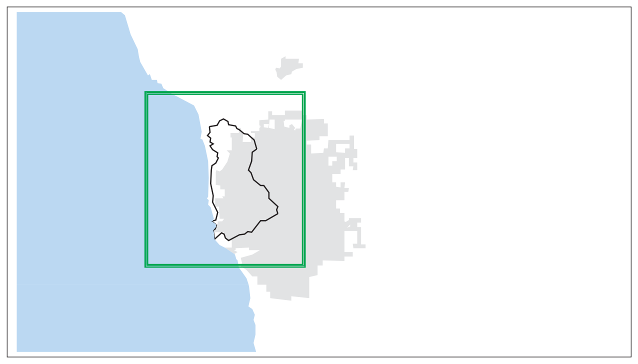
MRC Ownership

Planning Watershed Boundary

Cottaneva Creek Watershed Analysis Unit Boundary

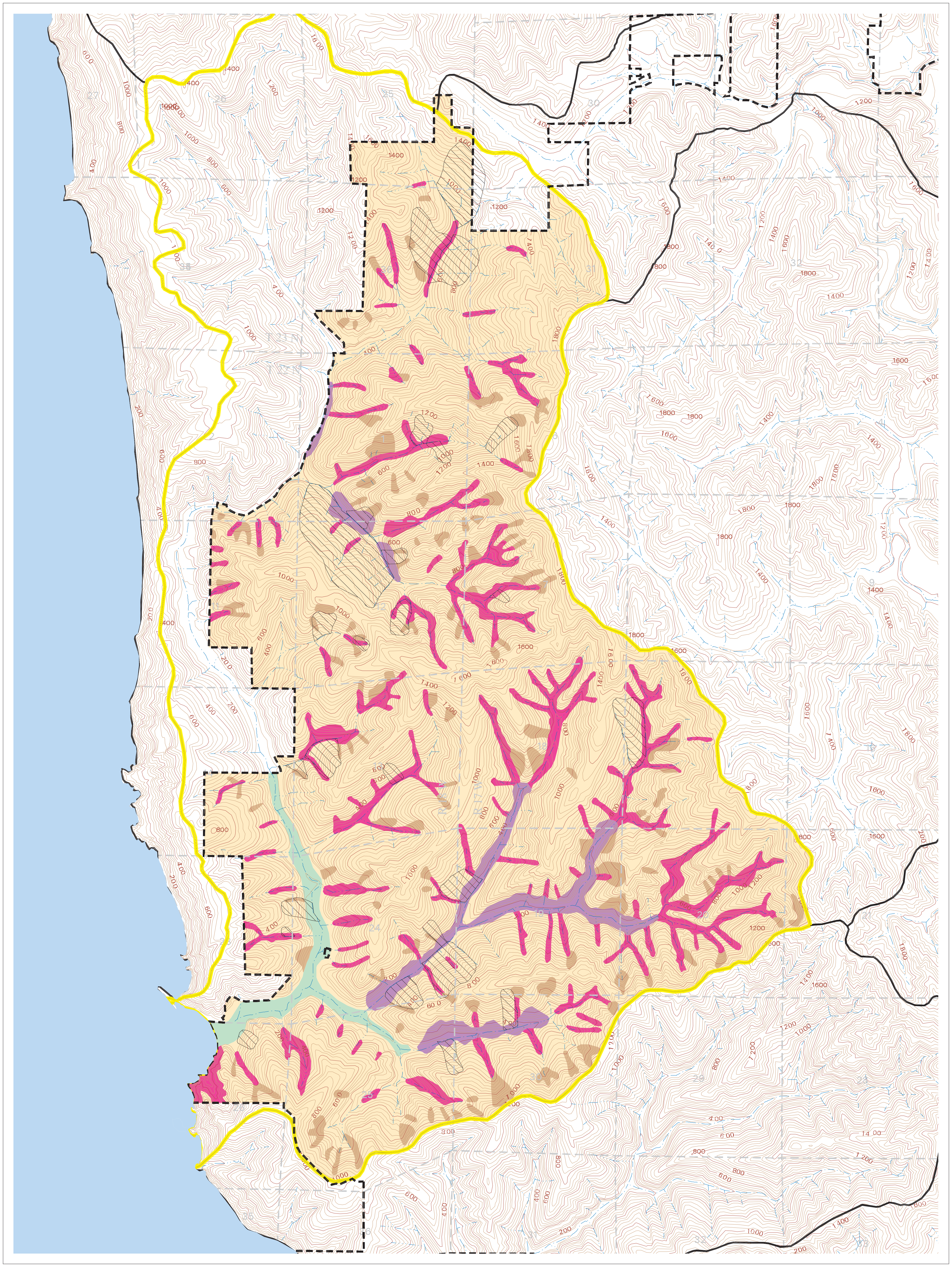
Flow Class

- Class I
- Class II
- Class III



0 1/2 1 Mile

November 2005



Cottaneva Creek Watershed Analysis Unit

Map A-2 Terrain Stability Units

This map presents an interpretation of the terrain stability units (TSUs) delineated for the Cottaneva Creek WAU. The TSUs characterize the landscape by similar geomorphic attributes, shallow-seated landslide potential, and sediment delivery potential. The TSU designations for the Cottaneva Creek WAU are only meant to be general characterizations of similar geomorphic and terrain characteristics related to shallow seated landslides. Deep-seated landslides are also shown on this map. The deep-seated landslides have been included to provide land managers with supplemental information to guide evaluation of harvest planning and subsequent needs for geologic review. The landscape and geomorphic setting in the Cottaneva Creek WAU is more complex than generalized TSUs delineated for this evaluation. The TSUs are only meant to be a starting point for gauging the need for site-specific field assessments. Field observations will over-ride unit boundaries of this map.

Unit 1: Inner gorge or steep slopes adjacent to low gradient watercourses

Unit 2: Steep slopes or inner gorge topography adjacent to high gradient intermittent or ephemeral watercourses

Unit 3: Dissected and convergent topography

Unit 4: Non-dissected topography

Unit 5: Low relief topography

Deep Seated Landslides

MRC Ownership

Planning Watershed Boundary

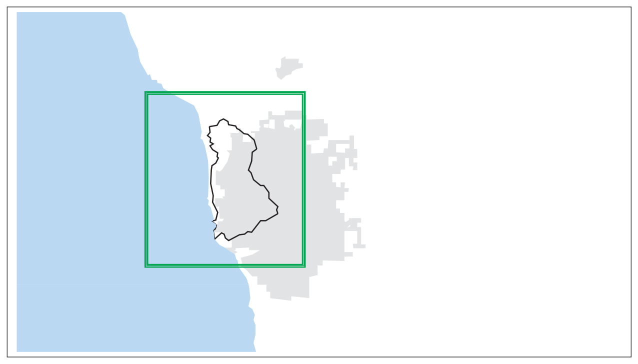
Cottaneva Creek Watershed Analysis Unit Boundary

Flow Class

Class I

Class II

Class III



0 1/2 1 Mile

November 2005