SECTION A
MASS WASTING

INTRODUCTION

This section summarizes the methods and results of a mass wasting assessment conducted on the Mendocino Redwood Company, LLC (MRC) ownership in the Haupt Creek, Tobacco Creek, Annapolis Falls Creek, and Flat Ridge Creek watersheds. Throughout this report, ownership in these four watersheds will collectively be termed the Gualala Watershed Analysis Unit (Gualala WAU). This assessment is part of a Watershed Analysis initiated by MRC and utilizes watershed analysis modified methodology adapted from procedures outlined in the Standard Methodology for Conducting Watershed Analysis manual (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 management related activities.
3) Identify where the mass wasting processes are concentrated.
4) Partition the ownership into zones of relative mass wasting potential (Mass Wasting Map Units) based on the likelihood of future mass wasting and sediment delivery to stream channels.

Additionally, the role of mass wasting sediment input from shallow landslides to watercourses is examined. This information combined with the results of the surface erosion module will be used to construct a rapid sediment budget input summary for the Gualala 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 mass wasting map unit (MWMU) map (Map A-2), a mass wasting inventory database (Table A-1), and a SHALSTAB (digital terrain slope stability model)(Dietrich and Montgomery, 1998) map (Map A-3) for the Gualala WAU. The basis for these products are aerial photograph interpretation of 4 sets of aerial photographs, dated 1978 (1:15840), 1987 (1:12000), 1996 (1:12000), and 2000 (1:13000), field observations during the summer of 2000, and interpretation of SHALSTAB data. The analysis was done without the use of historic aerial photographs from the period prior to 1980. Therefore the analysis presented is, in general, representative for recent mass wasting conditions (over the last 32+ years).

The assembled information will enable forestland managers to make better forest management decisions to reduce management induced 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.

LANDSLIDE TYPES AND PROCESSES IN THE GUALALA 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 Gualala WAU were described using the following names: debris slides, debris torrents, debris flows, rockslides, and earth flows. These names are described in Cruden and Varnes (1996) with the exception of our use of debris torrent and debris flows.

Shallow-Seated Landslides

Debris slides, debris flows, and debris torrents are the shallow-seated landslide processes that were identified in the Gualala WAU. 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 larger than 2 mm. 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 the 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, by far, 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. The landslide deposit commonly slides a distance beyond the toe of the surface of rupture and onto the ground surface below the failure. While the landslide mass may deposit onto the ground surface below the area of failure, it generally does not slide more than the distance equal to the length of the failure scar. Landslides with deposits that traveled a distance below the failure scar would be defined by 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 rapidly-moving, 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. During this analysis these types of failures were mapped as debris flows.

Debris torrents are relatively rare, but have the greatest potential to destroy stream habitat and deliver large amounts of sediment. The main characteristic distinguishing a debris torrent is that the failure “torrents” downstream in a confined channel and scours the channel. As the debris torrent moves downslope and scours the channel, the liquefied landslide material increases in mass. A 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.

Sediment Input from Shallow-Seated Landslides

The overall time period used for mass wasting interpretation and sediment budget analysis is thirty-two years. Sediment input to stream channels by mass wasting is quantified for three time periods (1969-1978, 1979-1987, 1988-2000). This is assumed because of the use of 1978, 1987/90, 1996, and 2000 aerial photographs and field observations in 2000. The evaluation is initiated at 1969 based on the earliest aerial photograph year of 1978 and the assumption that landslides farther back than about ten years are too difficult to detect, with much certainty, from aerial photographs. This is because landslide surfaces can re-vegetate quickly, making them too difficult to see. We acknowledge that we have likely missed some small mass wasting events during the aerial photograph interpretation. The smallest sized mass wasting event that we confidently mapped had a minimum width or length of 20-30 feet. Anything smaller then this size was not easily recognizable on from aerial photographs.

We assume we have captured the majority of the larger mass wasting events in this analysis. It is the large mass wasting events that provide the greatest sedimentation impacts. In the case of the landslides observed in the Gualala WAU, landslides greater than 300 cubic yards in size represented over 85% of the sediment delivery estimated. Landslides greater than 200 and 100 cubic yards in size represented approximately 90% and 97%, respectively of the sediment delivery estimated.

Sediment delivery estimates from mapped shallow-seated landslides were used to produce the total mass wasting sediment input. 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.

Deep-Seated Landslides

The two deep-seated landslide processes identified in the Gualala WAU are rockslides and earth flows. The failure dates of the deep-seated landslides generally could not be estimated with confidence and the landslides are likely to be of varying age with some landslides potentially being thousands of years old. Many of the deep-seated landslides are considered “dormant”, but the importance of identifying them lies in the fact that if they are reactivated or their rate of movement accelerates, they have the potential to deliver large amounts of sediment and damage stream habitat. Accelerated or episodic movement in some landslides is likely to have occurred over time in response to seismic shaking or frequent high rainfall events. Deep-seated landslides can be very large, exceeding tens to hundreds of acres.

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 can fail in response to triggering mechanisms such as seismic shaking, adverse local structural geology, high rainfall, or channel incision that undermines the toe. Timber harvesting can have the effect of increasing the amount of subsurface water, which can accelerate movement. The stream itself can also 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 consist of 80% or more of the particles smaller than 2mm. Materials in an earth flow also commonly contain boulders, some very large, which move downslope 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.

Sediment Delivery from Deep-Seated Landslides

A large, active deep-seated slide can deliver large volumes of sediment to streams. 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 and usually occur in response to unusual storm events or seismic ground shaking, and may be more likely when rock strata dip parallel to the ground surface slope.

Movement of deep-seated landslides has definitely resulted in some sediment delivery in the Gualala WAU. Quantification of the sediment delivery from deep-seated landslides was not determined in this watershed analysis. Factors such as rate of movement and depth of the deep-seated landslide are difficult to determine without detailed geotechnical observations. Such observations are beyond the scope of the reconnaissance-level mapping of deep-seated landslides presented in this analysis. Sediment delivery to watercourses from deep-seated landslides (landslides typically $\geq$10 feet thick) 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 the slope is underlain by a deep-seated landslide should make little difference regarding sediment delivery generated by erosional processes that act at the ground surface. Of course 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. To determine this the slide surface should be carefully explored for evidence of movement. 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.

Use of SHALSTAB by Mendocino Redwood Company for the Gualala WAU

SHALSTAB, a coupled steady state runoff and infinite-slope stability model, is used by MRC as one tool to demonstrate the relative potential for shallow-landslide hazard across the MRC ownership. A detailed description of the model is available in Dietrich and Montgomery (1998). In the watershed analysis, mass wasting hazard is expanded beyond SHALSTAB. Inner gorge or steep streamside areas are mapped and designated as mass wasting map units. Relative areas of mass wasting and sediment delivery hazards are mapped using field and aerial photograph interpretation techniques. However, SHALSTAB output was used to assist in this interpretation of the landscape and mass wasting map 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. The 2000 (color), 1996 (color), and 1987 (B&W) photograph sets used to interpret landslides are owned by MRC. The 1980 (B&W) photograph set was borrowed from the Sonoma County Assessors office. The 2000 photographs are at a scale of 1:13,000, the 1996 and 1987 photographs at a scale of 1;12000 and the 1980 photographs at a scale of 1:20,000. MRC collected data regarding characteristics and measurements of the identified landslides. Since mass wasting events were essentially "sampled", we acknowledge that some landslides may have been missed, particularly small ones that may be obscured by vegetation. A description of select parameters inventoried for each landslide observed in the field and during aerial photograph interpretation is presented below and tabulated in Figure A-2.

Figure A-2. Description of Select Parameters used to Describe Mass Wasting in the Mass Wasting Inventory.

- Slide I.D. Number: Each landslide is assigned two numbers, the first number indicates the USGS designated map section number the slide is mapped in, and the second number indicates the consecutive amount of slides within the map section.
- Planning Watershed: Denotes the MRC planning watershed in which the landslide is located.
  - SH = Haupt Creek
  - ST = Tobacco Creek
  - SA = Annapolis Falls Creek
  - SR =Flat Ridge Creek
- MWMU # – Mass Wasting Map Unit in which landslide is located.

- Landslide Process:
  - DS = debris slide
  - DT = debris torrent
  - DF = debris flow
  - RS = rock slide
  - EF = earth flow
- Certainty: The certainty of identification is recorded.
  D - Definite, P - Probable; Q - Questionable.
- Approximate Failure Date: Minimum failure date is typically the photo year that the slide first appears on or the year observed in the field.
- Slope Form: Geomorphology of slope (D – divergent, P – planar, C – convergent).
- Physical Characteristics: Include average length, width, depth, and volume of individual slides.
- Sediment delivery and routing: Includes sediment delivered to streams (N - no sediment delivered; Y - sediment delivered), estimate of the percent of landslide mass delivered, the type of stream that sediment was delivered to (perennial or ephemeral).
  - Land Use Association: Road, landing, or skid trail association.
  - Deep seated landslides morphologic descriptions: toe, body, lateral scarps, and main scarp (see below for descriptions).

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 feature.

Physical and geomorphic characteristics of shallow-seated landslides are categorized in a database including identification number, planning watershed, type of landslide, approximate failure date, slope gradient, length, width, depth, volume, sediment delivery, sediment routing, and associated land use (Table A-1). Landslide dimensions and depths can be quite variable, therefore length, width, and depth values that are recorded are considered to be the estimated average distance of that feature. In conversion of the landslide masses from volumes to tons, we assume a uniform bulk density of 100 lbs/cubic foot.

The certainty of landslide identification is also designated 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 regarding the analyst's interpretation. Questionable means that the interpretation of the landslide identification may be inaccurate, the analyst has relatively low 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 larger 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. However, small landslides cumulatively may not deliver amounts of sediment that would significantly alter total sediment delivery. In any event, the primary purpose of the mass wasting inventory is to develop maps that assign relative levels of landslide hazard across the landscape. For this purpose, the identification of historic landslides is more important than the estimate of sediment delivery, hence the potential inaccuracy in estimating sediment delivery is somewhat less significant.

Dimensions (average length and width) for landslides not visited in the field were determined by measuring the failure as interpreted directly from aerial photographs to the nearest 0.1 inch on the photograph. To extrapolate depth to the shallow-seated landslides not visited in the field, the mean value of slide depths was extrapolated for shallow-landslides that were not visited in the field. It was determined that there was a difference between the depths of road associated landslides and non-road associated landslides. Therefore, the mean depth of road related landslides of 3 feet was assumed for unverified road related landslides and the mean depth of non-road related landslides of 4 feet was assumed for unverified non-road related landslides. Due to the relative lack of debris flows and torrents, no effort was made to differentiate landslide depths among differing shallow landslide processes.

Two techniques were employed in order to extrapolate a sediment volume delivery percentage to landslides not visited in the field. Landslides that were determined to be directly adjacent to a watercourse from topographic maps and aerial photograph interpretation were assigned 100% delivery. Landslides that were determined to deliver, but were not directly adjacent to a watercourse, were assigned the mean delivery percentage from landslides observed in the field.

Landslides were also classified according to observed land use practice that was associated with the slope failure, with limitations described below. Interpretations regarding the effects of silvicultural techniques on individual landslides or landslide frequency were not included in the inventory data. Because the Gualala WAU has been managed for timber production, both recently and historically, it was determined that it is not possible to make a confident interpretation regarding the effect of silvicultural practices on specific shallow landslides. Nevertheless, the loss of root strength and increased soil moisture expected following timber harvest are acknowledged in the development of mass wasting hazard maps.

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, landing, or skid trail 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 likely primary cause 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).

Extensive effort was put into the identification of deep-seated landslides throughout the Gualala WAU. The characteristics of deep-seated landslides received less attention in the landslide inventory than shallow-seated landslides mainly due to the fact that more intensive geotechnical analyses would have to be conducted to estimate such features as depth, failure date, activity, and sediment delivery. Few of the mapped deep-seated landslides were observed to have recent movement associated with them. Deep-seated landslides will be treated on a site by site basis in the Gualala WAU, likely during timber harvest plan preparation and review.

Systematic Description of Deep-seated Landslide Features

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 Gualala watershed suggest 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 four descriptions have been developed to classify each deep-seated landslide characteristic. The four descriptions are ranked in descending order from characteristics 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 “indeterminate”. 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 either definite, probable or questionable.

Finally, based on all the feature descriptions of a landslide, an assessment is made as to whether a deep-seated landslide is “active”, or of “indeterminate activity”. The range of interpretation of activity level allowed here is restricted in recognition of the limitations of aerial photo interpretation. It is expected that few deep-seated landslides will show unmistakable evidence of activity, in part because movement is usually slow. Most deep-seated landslides will probably be of indeterminate activity based on typical aerial photo observations.

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.

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.

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.

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.

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.

Mass Wasting Map Units

Mass Wasting Map Units (MWMUs) are delineated by partitioning the landscape into zones characterized by similar geomorphic attributes, shallow-seated landslide potential, and sediment delivery potential to stream channels. A combination of aerial photograph interpretation, field investigation, and SHALSTAB output were utilized to delineate MWMUs. The MWMU designations for the Gualala 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 MWMU 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 potential need for geologic review. The landscape and geomorphic setting in the Gualala WAU is certainly more complex than generalized MWMUs delineated for this evaluation. The MWMUs are intended to provide a starting point for gauging the need for site-specific field assessments.

The delineation of each MWMU is based on landforms, mass wasting processes, sensitivity to forest practices, mass wasting hazard, delivery potential, hazard potential, and forest management related trigger mechanisms for shallow seated landslides. A formal MWMU description incorporates a discussion of each of these criteria. The landform defines the terrain found within the MWMU. The mass wasting process section is a summary of landslide types found in the MWMU. 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 MWMU 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 (Figure A-1.). The trigger mechanisms are a list of forest management practices that may have the potential to create mass wasting in the MWMU.

Figure A-1. Ratings for Potential Hazard of Delivery of Debris and Sediment to Streams by Mass Wasting (letters designate hazard: L= low, M= moderate, H = high)(Version 3.0, 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 (Table A-1) was used to record attributes associated with each landslide. The spatial distribution and location of landslides is shown on Map A-1.

Table A-1. Landslide Inventory for the Gualala River WAU.

Slide Number	Planning Watershed	MWMU	Landslides Process	Landslides Certainty	Approx. Failure Date	Field Checked	Slope Gradient (%) Field	Slope Form	Average Landslide Dimensions (feet) Length	Width	Depth	Volume (cu. Yds.)	Sediment Delivery	Delivery (%)	Delivery Volume (cu. yds.)	Delivery Mass (tons)	Sediment Routing	Land Use Association	Deep Seated Landslide Morphologcal Descriptions Toe	Body	Lat. Scarps	Main Scarps	Veg.	Comments
9-5	SH		RS	Q																				small DSs at margins and opposite bank
9-4	SH		RS	D																				roads cross slide
9-3	SH	1	DS	D	80	N		P	80	65	4	770	Y	100	770	1040	perennial							stream failure
9-2	SH	1	DS	D	80	N		C	100	65	4	963	Y	100	963	1300	perennial							streamside failure
9-1	SH	1	DS	P	80	N		C	100	115	4	1704	Y	100	1704	2300	perennial							streamside failure
5-2	ST	3	DS	D	80	N		C	213	67	3	1586	N	0	0	0		road						above county road
5-1	ST		RS	P															3	4	4	4	4	River undercut of hillslope
4-9	SH	1	DS	Q	2000	N		C	20	64	4	190	Y	100	190	256								
4-8	SH	3	DS	D	99	Y	74	C	45	15	5	125	Y	100	125	169	perennial	road						inner gorge. creating log jam
4-7	SH	1	DF	P	87	N		C	130	10	3	144	Y	82	118	160	perennial	road						
4-6	SH	4	DF	P	87	N		P	115	50	4	852	Y	82	699	943	perennial							
4-5	SH	3	DS	D	87	N		P	320	80	4	3793	Y	82	3110	4198	perennial							
4-4	SH	1	DS	D	87	N		C	50	10	3	56	Y	100	56	75	perennial	road						inner gorge
4-3	SH	1	DS	D	80	N		P	80	50	4	593	Y	100	593	800	perennial							streamside failure
4-2	SH	1	DS	D	87	N		C	80	50	4	593	Y	100	593	800	perennial							meander bend
4-17	SH	1	DS	D	80	N		P	133	73	4	1438	Y	82	1179	1592	perennial							
4-16	SH		RS	Q																				grassy soils in parts of scarp hummocky terrain
4-15	SH	3	DS	D	90	Y	61	C	120	35	2	311	Y	45	140	189	perennial	road						hard to see from creek
4-14	SH	1	DS	D	92	Y	77	C	40	55	4	326	Y	85	277	374	perennial							inner gorge. moderate vegetation regrowth
4-13	SH	1	DS	D	95	Y	92	C	85	35	4	441	Y	85	375	506	perennial							inner gorge
4-12	SH	1	DS	D	95	Y	103	P	36	28	4	149	Y	100	149	202	perennial							bedrock at edge of toe. inner gorge
4-11	SH		RS	D															1	2	2	3	4	River undercut. potentially active
4-10	SH	3	DS	Q	2000	N		C	42	20	3	93	N	0	0	0		skid						
4-1	SH	1	DS	D	80	N		C	240	50	3	1333	Y	100	1333	1800	perennial	skid						
35-9	ST	1	DT	D	87	Y	76	C	100	50	3	556	Y	90	500	675	perennial							
35-8	ST	1	DT	D	87	Y	73	C	200	30	9	2000	Y	85	1700	2295	perennial							channel scour
35-7	ST	3	DT	Q	87	N		C	160	20	4	474	Y	82	389	525	ephemeral							
35-6	ST	3	DS	P	87	N		P	160	100	4	2370	Y	82	1944	2624	ephemeral							
35-5	ST	1	DS	D	87	N		P	80	30	3	267	Y	82	219	295	ephemeral	road						
35-4	ST	1	DS	D	87	N		C	80	35	3	311	Y	82	255	344	ephemeral	road						
35-3	ST	2	DS	P	87	N		C	180	65	3	1300	Y	82	1066	1439	ephemeral	skid						
35-2	ST	3	DS	P	87	N		C	80	60	4	711	Y	82	583	787	ephemeral							
35-19	ST	4	DF	P	80	N		P	123	27	4	492	N	0	0	0								
35-18	ST	3	DS	D	75	N		C	267	127	4	5024	Y	82	4119	5561	ephemeral							
35-17	ST	1	DS	P	2000	N		C	33	15	4	73	Y	82	60	81	ephemeral							
35-16	ST	4	DS	P	2000	N		C	17	19	4	48	N	0	0	0								mid-slope
35-15	ST		RS	P															3	3	3	2	3	likely dormant
35-14	ST	1	DS	Q	2000	N		C	59	23	4	201	Y	100	201	271	ephemeral							
35-13	ST		RS	Q															3	4	3	3	4	River undercut of hillslope
35-12	ST	3	DS	D	98	Y	87	P	70	25	2	130	Y	100	130	175	perennial	road						legacy road
35-11	ST	4	DS	Q	87	N		C	66	36	3	264	N	0	0	0		skid						
35-10	ST	1	DS	Q	87	N		C	96	36	4	512	Y	82	420	567	perennial							
35-1	ST	3	DS	D	87	N		C	80	20	3	178	Y	82	146	197	ephemeral	road						
35-1	GO		DS	P	2000	N		P	133	66	4	1308	Y	100	1308	1700	Intermittent	Road						
34-9	ST	1	DS	D	87	Y	74	P	70	25	3	194	Y	30	58	79	perennial	road						
34-8	ST	1	DS	D	87	Y	78	P	65	25	2	120	Y	100	120	163	perennial	road						legacy rd. slide goes thru break in slope @ top of inner gorge
34-7	ST	1	DS	P	87	N		P	320	50	4	2370	Y	100	2370	3200	perennial							
34-6	ST	1	DS	D	87	Y	68	C	80	55	3	489	Y	85	416	561	perennial	road						
34-5	ST	3	DS	D	87	Y	69	P	100	75	2	556	Y	100	556	750	perennial	road						county road
34-4	ST	2	DS	D	87	Y	56	P	25	55	2	102	Y	100	102	138	perennial	road						edge of skagg springs rd. rip-rapped
34-3	ST	1	DS	D	87	Y	54	P	90	100	3	1000	Y	80	800	1080	perennial	road						fill failure. scarp at edge of county road
34-2	ST	1	DS	D	87	Y	73	P	95	50	2	352	Y	80	281	380	perennial	road						fill failure. scarp at edge of county road
34-2	GD		DS	P	1987	N		P	130	35	4	674	Y	75	506	657	Intermittent	Road						
34-18	ST	1	DS	P	2000	N		C	25	35	4	130	Y	100	130	175	perennial							inner gorge
34-17	ST	3	DS	D	96	N		D	288	80	3	2560	N	0	0	0		road						
34-16	ST	3	DS	D	98	Y	53	P	20	30	3.5	78	N	0	0	0		road						mrc road at crown county rd. at toe. ground cracks on upper road
34-15	ST	3	DS	D	95	Y	111	P	18	35	1.5	35	Y	100	35	47	perennial	road						county rd.
34-14	ST	3	DS	D	95	Y	68	D	25	25	3	69	Y	80	56	75	perennial	road						inner gorge
34-13	ST	3	DF	D	87	Y	61	C	70	20	4	207	N	0	0	0		road						county road
34-12	ST	3	DS	D	87	Y	98	P	100	100	2	741	Y	100	741	1000	perennial	road						fill failure, county road
34-11	ST	1	DS	D	87	Y	102	P	40	20	2	59	Y	100	59	80	perennial							inner gorge
34-10	ST	1	DS	D	87	Y	60	C	40	18	3	80	Y	100	80	108	perennial	land						inner gorge
34-1	ST	4	DS	D	87	Y	69	P	160	115	2	1363	Y	40	545	736	perennial	road						
34-1	GO		DS	D	2000	N		P	133	66	4	1308	Y	100	1308	1700	Intermittent	Road						
33-6	ST	1	DS	D	87	Y	71	P	100	30	2	222	Y	100	222	300	perennial	road						fill failure, county road
33-5	ST	3	DS	D	97	Y	86	P	25	75	1.5	104	N	0	0	0		road						cut bank. skagg springs rd.
33-4	ST		RS	P															1	2	2	4	2	
33-3	ST	1	DS	D	87	Y	82	P	110	28	2	228	Y	100	228	308	perennial	road						county road
33-2	ST	3	DS	P	87	N		P	240	50	3	1333	Y	82	1093	1476	ephemeral	road						
33-1	ST	1	DS	D	87	Y	79	P	200	95	2	1407	Y	90	1267	1710	perennial	road						county road
32-9	ST		RS	Q																				road crosses upper portion
32-8	SA	1	DS	D	87	N		P	160	30	3	533	Y	100	533	720	perennial	road						
32-7	SA	1	DS	D	87	N		P	160	65	3	1156	Y	100	1156	1560	perennial	road						
32-5	SR	4	DS	D	95	Y	71	P	20	20	4	59	N	0	0	0								cut bank
32-4	SR	4	DS	D	98	Y	66	P	30	25	3	83	N	0	0	0								cut bank
32-3	SR	6	EF	D																				EF complex. movement rates vary within
32-2	SA	3	DS	D	96	Y	74	P	65	30	3	217	N	0	0	0								
32-16	SR	6	RS	D																				
32-15	ST	1	DS	D	96	Y	56	C	81	98	3	882	Y	50	441	595	perennial	road						grassy
32-14	SA	4	DS	D	96	Y	82	P	28	31	4	129	N	0	0	0		road						fill failure

Table A-1. Landslide Inventory for the Gualala River WAU.

Slide Number	Planning Watershed	MWMU	Landslides		Approx. Failure Date	Field Checked	Slope Gradient (%)	Slope Form	Average Landslide Dimensions (feet)			Volume (cu. Yds.)	Sediment Delivery	Delivery (%)	Delivery Volume (cu. yds.)	Delivery Mass (tons)	Sediment Routing	Land Use Association	Deep Seated Landslide Morphologcal Descriptions					Comments
			Process	Certainty			Field		Length	Width	Depth								Toe	Body	Lat. Scarps	Main Scarps	Veg.	
32-13	SA	1	DS	D	92	Y	57	P	65	50	3	361	Y	20	72	98		road						fill failure. riverbank
32-12	SA	1	DS	D	92	Y	64	P	65	35	2	169	Y	30	51	68	perennial	road						fill failure. riverbank
32-11	SA	4	DS	D	95	Y	55	C	36	34	2	91	N	0	0	0		road						in hummocky, grassy topography
32-10	ST		DF	P	98	N		C	128	32	4	607	N	0	0	0								
31-9	SA	4	DS	D	98	Y	81	P	68	38	2	191	N	0	0	0		road						fill failure
31-8	SA	1	DS	P	96	N		C	45	75	4	500	Y	100	500	675	ephemeral							toe of questionable EF #SA 31-7
31-7	SA	6	EF	P																				grassy soil patches on slide. hummocky. 48%slope at road
31-6	SA	3	DS	D	98	Y	63	C	90	63	4	840	N	0	0	0		road						slide across road
31-5	SA	2	DS	D	99	Y	74	C	45	39	3	195	Y	100	195	263	ephemeral	road						shotgun culvert@ lateral edge of slide
31-4	SA	1	DS	P	80	N		C	127	90	4	1693	Y	82	1389	1875	ephemeral	skid						high delivery
31-3	SA		RS	P																				moderately hummocky in field.
31-2	SA	3	DS	Q	96	N		C	68	20	4	201	Y	82	165	223	ephemeral							
31-14	SA	3	DS	D	80	N		C	70	43	4	446	Y	82	366	494								
31-13	SA	3	DS	Q	80	N		C	97	97	3	1045	Y	82	857	1157		skid						
31-12	SA		RS	P																				likely ancient. multiple failures on slide
31-11	SA		RS	P																				activity unclear but hummocky some DS on RS
31-10	SA	4	DS	D	96	Y	74	C	105	58	3	677	Y	100	677	914	perennial	skid						skid at scarp, toe at road
3-1	GD		DT	D	2000	N		C	133	44	3	654	Y	100	654	850	Intermittent							
30-9	SA	1	DS	Q	96	N		P	32	15	4	71	Y	100	71	96	ephemeral							stream failure
30-8	SA	3	DS	P	87	N		C	140	20	4	415	Y	82	340	459	ephemeral							
30-7	SA	2	DF	Q	87	N		C	160	15	4	356	Y	82	292	394	ephemeral							
30-6	SA	4	DS	D	80	N		P	190	65	3	1372	Y	82	1125	1519	perennial	road						
30-5	SA	3	DS	P	80	N		P	160	65	4	1541	N	0	0	0								
30-4	SA	1	DS	Q	87	N		P	80	20	3	178	Y	82	146	197	perennial	road						
30-3	SA	1	DS	D	87	N		C	130	30	3	433	Y	82	355	480	perennial	road						
30-2	SA	1	DS	D	87	N		P	65	20	4	193	Y	82	158	213	perennial							meander bend
30-19	SA	3	DS	P	98	N		P	100	100	3	1111	N	0	0	0		road						could be an unrevegetated sidecast scree slope
30-18	SA		RS	Q																				escarpment of Gual.river. little deposit remains
30-17	SA	3	DS	P	98	N		P	60	32	4	284	Y	82	233	315	perennial							
30-16	SA		RS	D																				Riverbank undercut of hillslope
30-15	SA		RS	D																				
30-14	SA		RS	D																				
30-13	SA		RS	D																				Gual.River undercut of slope
30-12	SA	4	DT	D	98	Y	32	C	200	115	5	4259	Y	85	3620	4888	perennial							torrent4585'long x 12' wide x 3'deep
30-11	SA		RS	D																				Riverbank undercut of hillslope
30-10	SA	1	DS	P	2000	N		P	35	70	4	363	Y	100	363	490	perennial							inner gorge
30-1	SA	1	DS	D	80	N		P	360	160	4	8533	Y	82	6997	9446	perennial	road						inner gorge
29-9	SR		EF	P																				near obvious grassy melange block, several benches
29-8	ST	1	DS	D	96	Y	110	C	35	43	5	279	Y	90	251	339	perennial							
29-7	SA		RS	D																				Riverbank undercut of hillslope
29-6	SR	3	DS	D	96	N		C	220	60	4	1956	Y	82	1604	2165	perennial							
29-5	SA	4	DS	P	96	N		C	24	20	3	53	N	0	0	0		skid						
29-4	SR	1	DS	D	96	Y	108	C	55	33	2	134	Y	100	134	182	perennial							stream failure into Fuller Ck.
29-3	SR	1	DS	D	80	Y	99	C	121	132	3	1775	Y	100	1775	2396	perennial							inner gorge
29-2	SR	1	DS	D	96	Y	111	P	310	143	7	11493	Y	100	11493	15516	perennial							bedrock exposed in face of slide. inner gorge
29-11	SR	1	DS	Q	80	N		C	70	43	3	334	Y	100	334	452	perennial	skid						
29-10	SR	1	DS	Q	80	N		C	43	30	3	143	Y	100	143	194	perennial	road						inner gorge
29-1	SA	1	DS	D	80	N		P	77	47	3	402	Y	100	402	543	ephemeral	land						
2-9	GO		DS	P	1987	N		P	100	50	4	741	Y	100	741	963	Perennial	Road						
28-6	SR	1	DS	P	96	N		P	40	16	4	95	Y	100	95	128	ephemeral							stream failure next to clearcut
28-5	ST	2	DS	D	95	Y	82	P	40	30	3	133	Y	40	53	72	ephemeral	road						
28-4	ST	2	DS	D	95	Y	71	P	55	25	3	153	Y	90	138	186	ephemeral							
28-3	ST	2	DS	D	87	Y	99	C	60	30	2.5	167	Y	100	167	225	ephemeral	road						steep streamside
28-2	ST	2	DS	P	87	N		C	80	65	4	770	Y	82	632	853	perennial							
28-1	ST	2	DS	P	87	N		C	80	50	4	593	Y	82	486	656	perennial							
2-8	GO		DS	Q	2000	N		C	44	44	3	218	N	0	0	0		Skid						
27-9	ST	1	DS	P	87	Y	74	P	88	48	3	469	Y	70	329	444	perennial							
27-8	ST	3	DS	Q	84	N		C	160	120	4	2844	N	0	0	0								slight vegetation on 1987 photo
27-7	ST	1	DS	Q	87	N		P	56	24	3	149	Y	100	149	202	ephemeral	skid						inner gorge
27-6	ST	4	DS	Q	87	N		P	300	65	3	2167	Y	82	1777	2399	ephemeral	road						
27-5	ST	4	DS	D	87	Y	78	P	40	30	2	89	Y	80	71	96	perennial	road						
27-4	ST	1	DS	P	87	N		P	50	30	3	167	Y	82	137	185	perennial	road						stream failure
27-3	ST	1	DS	D	80	Y	67	C	187	60	4	1662	Y	60	997	1346	perennial	road						starts above road
27-16	ST	4	DS	Q	90	Y	63	P	45	30	2	100	Y	30	30	41	perennial	road						questionable in field due to age
27-15	ST	1	DS	D	97	Y	91	P	35	35	3	136	Y	100	136	184	perennial							slide at toe of st 27-10
27-14	ST		RS	P															3	3	3	3	3	likely dormant
27-13	ST		RS	P															3	2	3	3	3	likely dormant
27-12	ST		RS	P															3	3	2	3	3	
27-11	ST		RS	D															3	4	3	3	4	
27-10	ST		RS	D															3	4	3	3	4	
27-1	ST	1	DS	D	80	Y	87	C	230	260	10	22148	Y	85	18826	25415	perennial							meander bend.
2-7	GO		DS	P	2000	N		P	89	89	3	872	Y	100	872	1133	Intermittent							
26-1	SA	3	DS	Q	80	N		P	93	47	3	486	Y	82	398	538	ephemeral	skid						
2-6	GO		DS	D	2000	N		P	89	44	3	436	Y	100	436	567	Intermittent							
25-9	SA	3	DS	Q	80	N		C	37	37	4	203	N	0	0	0								midslope colluvial hollow
25-8	SA	2	DS	P	96	N		P	64	32	4	303	Y	82	249	336								
25-7	SA	3	DS	Q	87	N		C	36	20	4	107	Y	100	107	144	ephemeral							colluvial hollow failure
25-6	SA	2	DS	D	96	N		P	112	60	4	996	Y	100	996	1344	ephemeral							
25-5	SA	5	DS	Q	87	N		P	50	20	3	111	Y	82	91	123	ephemeral	land						
25-4	SA	2	DS	D	87	N		P	80	20	4	237	Y	82	194	262	ephemeral							

Table A-1. Landslide Inventory for the Gualala River WAU.

Slide Number	Planning Watershed	MWMU	Landslides		Approx. Failure Date	Field Checked	Slope Gradient (%)	Slope Form	Average Landslide Dimensions (feet)			Volume (cu. Yds.)	Sediment Delivery	Delivery (%)	Delivery Volume (cu. yds.)	Delivery Mass (tons)	Sediment Routing	Land Use Association	Deep Seated Landslide Morphologcal Descriptions					Comments
			Process	Certainty			Field		Length	Width	Depth								Toe	Body	Lat. Scarps	Main Scarps	Veg.	
25-3	SA	3	DS	P	87	N		C	50	30	3	167	Y	82	137	185	ephemeral	skid						
25-2	SA	4	DS	P	87	N		P	80	50	3	444	Y	82	364	492	perennial	land						
25-1	SA	4	DS	P	87	N		C	50	20	3	111	N	0	0	0		road						
2-5	GO		DS	Q	2000	N		P	66	44	3	327	Y	100	327	425	Intermittent							
24-5	SA		RS	P																				likely dormant
24-4	SA	1	DS	P	96	Y	106	P	50	16	2	59	Y	100	59	80	perennial							stream failure
24-3	SA	3	DS	Q	80	N		C	32	16	4	76	Y	82	62	84	ephemeral							recently logged on 1980 photo
24-2	SA	3	DS	P	87	N		C	100	50	3	556	Y	82	456	615	perennial	road						
24-1	SA	3	DS	P	87	N		P	100	50	3	556	Y	82	456	615	perennial	road						
2-4	GO		DS	Q	2000	N		P	44	44	3	218	Y	100	218	283	Intermittent							
23-6	SA	1	DS	P	80	N		P	37	37	4	203	Y	82	166	225	ephemeral							high % delivery
23-5	SA	1	DS	Q	70	N		P	154	46	4	1049	Y	82	861	1162	ephemeral							
23-3	SA	3	DS	D	87	N		P	130	65	4	1252	Y	82	1027	1386	perennial							
23-2	SA	1	DS	P	87	N		P	50	50	3	278	Y	82	228	308	perennial	road						
23-1	SA	3	DS	D	87	N		P	115	50	4	852	Y	82	699	943	ephemeral							
2-3	GO		DS	D	2000	N		P	66	89	3	654	Y	100	654	850	Intermittent							
2-2	ST	1	DS	P	98	N		P	60	32	4	284	Y	82	233	315	perennial							
2-2	GD		DS	P	2000	N		P	177	44	3	872	Y	25	218	283	Perennial							
2-15	GO		DS	D	1987	N		P	180	75	4	2000	Y	50	1000	1300	Perennial	Road						
2-14	GO		DS	D	1987	N		P	120	75	3	1000	Y	100	1000	1300	Perennial							
2-13	GD		DS	D	1987	N		C	120	60	4	1067	Y	50	533	693	Intermittent	Road						
2-12	GO		DS	D	1987	N		P	100	55	3	611	Y	100	611	794	Intermittent							
2-11	GO		DS	P	1987	N		P	220	30	4	978	N	0	0	0		Road						
2-10	GO		DS	P	1987	N		P	100	120	3	1333	Y	100	1333	1733	Perennial							
2-1	ST	1	DS	D	87	Y	81	C	45	65	2	217	Y	100	217	293	perennial							
2-1	GD		DF	D	2000	N		P	310	111	4	5086	Y	50	2543	3306	Perennial	Road						
20-1	SR	4	DS	D	96	Y	75	P	300	100	6	6667	Y	100	6667	9000	perennial	road						failed to bedrock. some deposit on terrace-opposite bank
19-9	SA	3	DS	D	97	Y	61	C	40	30	2	89	N	0	0	0		road						
19-8	SA	1	DS	D	96	Y	95	P	80	55	2	326	Y	100	326	440	perennial							streamside
19-6	SA	3	DS	D	96	N		C	24	24	4	85	Y	100	85	115	ephemeral							failure in hollow
19-5	SA	2	DS	Q	96	N		C	20	20	4	59	Y	100	59	80	ephemeral							failure in hollow next to stream
19-4	SA		RS	P																				
19-3	SA	3	DS	P	87	N		C	80	20	3	178	Y	82	146	197	perennial	road						
19-2	SA	4	DS	P	87	N		C	80	10	3	89	Y	82	73	98	ephemeral	road						
19-14	SA		RS	P																				River undercut
19-13	SA	3	DS	P	80	N		C	30	20	4	89	Y	82	73	98	perennial							
19-12	SA	1	DS	P	2000	N		C	16	16	4	38	Y	82	31	42	perennial							
19-11	SA	1	DS	P	80	N		P	42	80	4	498	Y	100	498	672	perennial							inner gorge
19-1	SA	1	DS	P	87	N		P	50	20	4	148	Y	82	121	164	perennial							
13-7	SA	1	DS	P	80	N		C	103	43	4	656	Y	82	538	726	ephemeral							high % delivery
13-7	SA		RS	Q															2	4	4	4	4	
13-6	SA	1	DT	P	2000	N		P	60	18	4	160	Y	100	160	216	ephemeral							
13-5	SA	2	DS	Q	96	N		P	16	24	4	57	Y	100	57	77	ephemeral							stream failure
13-4	SA	1	DS	D	96	N		C	16	48	4	114	Y	100	114	154	ephemeral							stream failure
13-3	SA	1	DS	P	87	N		P	160	30	4	711	Y	82	583	787	ephemeral							
13-2	SA	1	DS	P	87	N		C	100	30	4	444	Y	82	364	492	ephemeral							
13-1	SA	4	DS	P	87	N		P	65	20	3	144	Y	82	118	160	ephemeral	road						

A total of 160 shallow-seated landslides (debris slides, torrents, or flows) were identified and characterized in the Gualala WAU. A total of 34 deep-seated landslides (rock slides or earth flows) were mapped in the Gualala WAU. A considerable effort was made to field verify as many landslides as possible to insure greater confidence in the results. A total of 38% of the identified shallow-seated landslides were field verified. From this level of field observations, extrapolation of landslide depth and sediment delivery was performed with a reasonable level of confidence. The mean depth of road related landslides of 3 feet was assumed for road related landslides that were not visited in the field and the mean depth of non-road related landslides of 4 feet was assumed for all non-road related landslides not field checked. The mean sediment delivery percentage assigned to shallow landslides determined to deliver sediment, but not visited in the field is 82%. Depth and sediment delivery data were not collected for mapped deep-seated landslides.

The temporal distribution of the 174 shallow-seated landslides observed in the Gualala WAU is listed in Table A-2. The spatial distribution by landslide process for the 213 deep seated and shallow seated landslides is shown in Table A-3.

Table A-2. Shallow-Seated Landslide Summary for the Gualala WAU Divided into Time Periods.

Planning Watershed	1971-1980 Landslides	1981-1987 Landslides	1988-2000 Landslides
Haupt Creek	6	5	7
Tobacco Creek	7	38	20
Annapolis Falls Creek	15	24	28
Flat Ridge Creek	3	0	7
Doty Creek	0*	2	3
Robinson Creek	0*	6	8

* - not analyzed for these areas.

Table A-3. Slide Summary by Type and Planning Watershed for MRC Ownership in the Gualala WAU.

Planning Watershed	Debris Slides	Debris Torrents	Debris Flows	Rock Slides	Earth Flows	**Total**	*Road Assoc.*
Haupt Creek	16	0	2	4	0	22	4
Tobacco Creek	59	3	3	12	0	77	34
Annapolis Falls Creek	64	2	1	14	1	82	22
Flat Ridge Creek	10	0	0	1	2	13	2
Doty Creek	3	1	1	0	0	5	3
Robinson Creek	14	0	0	0	0	14	6

The majority of landslides observed in the Gualala WAU are debris slides and rock slides. Only a few of the rockslides are likely to be active in the Gualala WAU, the remaining are assumed to be dormant features. Of the 174 shallow-seated landslides in the Gualala WAU, 71 are determined to be road-related. This is approximately 41% of the total number of shallow-seated landslides.

Thirteen debris torrents and flows were observed in the Gualala WAU. This is approximately 7 percent of the total shallow landslides observed in the Gualala WAU. Debris torrents or flows are not common in the Gualala WAU, but do occur and are processes that should be taken into account in relation to forest management practices.

Ninety-six percent of the shallow landslides inventoried were initiated on slopes of 60% gradient or higher. Six landslides occurred on slopes with gradients between 50% and 60%, and one debris torrent initiated at a pronounced break in slope between a nearly flat, broad surface and the crest of a relatively subtle headwall swale of 32% slope. That particular failure created a debris torrent that scoured a tributary from its headwall to its confluence, a channel length of over 4500 feet. Those six debris slides of less than 60% gradient are all attributed to road practices. 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 other geologic structures. Few landslides originated in divergent topography, where sub-surface water is routed to the sides of ridges. Such observations were, in part, the basis for the delineation of the Gualala WAU into Mass Wasting Map Units.

Mass Wasting Map Units

The landscape within MRC ownership in the Gualala River was partitioned into five Mass Wasting Map Units (MWMU) 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 MWMUs was based on qualitative observations and interpretations from aerial photographs, field evaluation, and SHALSTAB output. Deep-seated landslides are also shown on the MWMU 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 Mass Wasting Map Unit 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 some MWMUs and deep-seated landslides or specific areas of some MWMUs to assess the risk and likelihood of mass wasting impacts from a proposed management action. The Mass Wasting Map Units are compiled on the entitled Mass Wasting Map Unit Map (Map A-2).

The scale at which MRC maps MWMUs in this watershed analysis precludes the detail necessary to capture all terrain changes; thus, maps from the watershed analysis are considered a hypothesis to be confirmed or modified by field review.

MWMU Number: 1

Description: Inner Gorge on Low Gradient Watercourses

Materials: Commonly bedrock slopes with a veneer of colluvial or alluvial deposits or shallow soils formed from weathered marine sedimentary rocks. May include toes of deep-seated landslides.

Landform: Characterized by steep slopes or inner gorge topography along low gradient watercourses. Slope form is generally planar, although convergent and divergent topography is present, with slope gradients typically exceeding 70%. The upper extent of the unit is variable, but typically is bounded by a break in slope. The height of the unit ranges from about 15 to 360 feet (based on a range of observed landslide of the same lengths). Slopes commonly contain areas of multiple, coalescing shallow seated landslide scars of varying age. Steep slopes that are controlled by bedrock may be relatively stable at steeper angles; slopes in soil material with comparable stability are gentler. Landslides in this unit generally deposit sediment directly into Class I and II streams. Small terraces may be locally present. Non-inner gorge slopes have strong evidence of past landslide activity.

Slope: 70 % to vertical. (mean slope of observed mass wasting events is 85%, range: 54%-111%)

Total Area: 489 acres; 6 % of the total WAU area.

MW Processes: *36 road-associated landslides*

- 35 debris slides
- 1 debris flow

45 non-road associated landslides

- 43 debris slides
- 2 debris torrent

Non Road-related Landslide Density: 0.11 landslides per acre for the past 30 years

Forest Practices Sensitivity: High sensitivity to road construction due to proximity to watercourses. Bedrock underlying inner gorge slopes creates increased stability. High sensitivity to harvesting and forest management practices due to steep slopes with localized colluvial or alluvial soil deposits next 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, all 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.
- •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.
- •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.
- •Concentrated drainage from roads can increase groundwater, accelerating movement of rockslides or earth flows and over-steepening inner gorge slopes.
- •Removal of vegetation on or above these slopes can result in reduced of evapotranspiration and thus increase pore water pressures that could increase the potential for debris slides in this unit.

Confidence: High confidence for susceptibility of landslides and sediment delivery in this unit. Moderate confidence in mapping of this unit. This unit is locally variable and exact boundaries are better determined from field observations. Upper boundary can be difficult to define in the field in some locations.

MWMU Number: 2

Description: Steep slopes adjacent to select intermittent or ephemeral streams

Materials: Shallow soils formed from weathered marine sedimentary rocks with localized areas of thin to thick colluvial deposits.

Landforms: Characterized by steep slopes in the upper regions of some ephemeral streams. Slope form is largely concave or planar with gradients typically greater than 70%. The upper extent of this unit is typically about 100 feet from the watercourse (based on mean observed debris slide length of 87 feet; maximum observed landslide length is 160 feet). Landslides in this unit commonly are debris slides that deposit sediment directly into Class II and III watercourses. This unit shows strong evidence of past landslide activity. Occasionally the debris slides can form debris torrents that can transport material down the slope through and out of this unit. This unit typically extends upstream from MWMU 1.

Slope: >70%

Total Area: 312 acres; 4% of total WAU area

MW Processes: *6 non-road associated landslides*

- 5 Debris slides
- 1 Derbis torrent

Non Road-related Landslide Density: 0.02 landslides per acre for the past 30 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, due to the steep converging topography of the slope in both unmanaged and managed conditions.

Delivery Potential: High

Delivery Criteria Used: Steep slopes adjacent to stream channels, all 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 over-steepen the slope 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 remove support of the toe or expose potential failure planes of rockslides or earth flows.
- • 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.
- •Loss of evapotranspiration from forest harvest can increase groundwater levels initiating or accelerating movement in rockslides or earth flows or aid in the initiation of debris slides, torrents or flows.

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

MWMU Number:	3
Description:	Dissected and convergent topography
Materials:	Shallow soils formed from weathered marine sedimentary rocks with localized thin to thick colluvial deposits.
Landforms:	Steep gradient hillslopes typically converging on confined watercourse channels. The topography is dissected or has strongly convergent slope forms. This unit is typically mapped in steep colluvial hollows or headwater swales and in some areas of steep planar hillslope. The unit shows strong evidence of past landslide activity.
Slope:	>60%, (mean slope of observed mass wasting events is 73% range: 56%-99%)
Total Area:	1210 ac., 15% of the total WAU
MW Processes:	*24 road associated landslides* • 23 debris slides • 1 debris flow *21 non-road associated slides* • 19 Debris slides • 1 Debris flow • 1 debris torrent
Non Road-related Landslide Density:	0.02 landslides per acre for the past 30 years
Forest Practices Sensitivity:	Moderate to high sensitivity to road building, moderate to high sensitivity to harvesting and forest management practices due to moderately 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. Failures in headwater swales can torrent or flow down watercourses. Approximately 31% 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 over-steepen the slope creating debris slides in this unit.
- Cut-slope of roads can over-steepen the slope 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 remove support of the toe or expose potential failure planes of rockslides or earth flows.
- 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.
- Loss of evapotranspiration from forest harvest can increase groundwater levels initiating or accelerating movement in rockslides or earth flows or aid in the initiation of debris slides, torrents or flows.

Confidence: Placement of unit based on correlation with SHALSTAB output; overall confidence in placement is commensurate with accuracy of SHALSTAB modeling of slope stability, which is moderate. Some areas within this unit could have higher susceptibility to landslides and higher delivery rates due to localized areas of steep slopes and unusually adverse ground water conditions.

MWMU 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 is generally a midslope region of lesser slope gradient and more variable slope form than unit 4.

Slope: >40%, (mean slope of observed mass wasting events 68%, range: 32%-82%)

Total Area: 4142 acres, 57% of the total WAU

MW Processes: *15 road-associated landslides*

- 16 Debris slides
- 1 Debris flow

21 non-road associated slides

- 18 Debris slides
- 1 Debris flow
- 2 Debris Torrents

Non Road-related Landslide Density: 0.001 landslides per acre for the past 30 years

Forest Practices Sensitivity: Moderate to low 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 and even higher sensitivity to forest practices.

Mass Wasting Potential: Moderate

Delivery Potential: Moderate

Delivery Criteria Used: Sediment delivery in this unit results from landslides that occur adjacent to watercourses, or have long run-outs to a watercourse. Approximately 44% of landslides in this unit delivered sediment.

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 over-steepen the slope creating debris slides in this unit.
•Cut-slope of roads can over-steepen the slope 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 remove support of the toe or expose potential failure planes of rockslides or earth flows.
• 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.
•Loss of evapotranspiration from forest harvest can increase groundwater levels initiating or accelerating movement in rockslides or earth flows or aid in the initiation of debris slides, torrents or flows.

Confidence: Moderate confidence in hazard potential and mapping of unit. Some areas within this unit could have higher susceptibility to landslides and higher delivery rates due to localized areas of steep slopes and adverse groundwater conditions. The number of non-road associated landslides that delivered sediment was high in this analysis. Probably many areas of MWMU 3 are found within the mapped boundaries of MWMU 4 of this watershed analysis and should be watched for during field reviews.

MWMU Number: 5

Description: Low relief topography

Material: Moderately deep to deep soils, formed from weathered marine sedimentary rocks.

Landforms: Characterized by low gradient slopes generally less than 40%, although in some places slopes can 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: <40%

Total Area: 1116 acres, 15% of WAU area

MW Processes: *No observed landslides*

Non Road-related Landslide Density: 0 landslides per acre for past 30 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 Gualala WAU. Landslides were determined to have either no sediment delivery or to deliver all or a percentage of their total volume. Of the shallow-seated landslides mapped by MRC in this watershed analysis, 85 percent of the landslides delivered some amount of sediment (Table A-4). The bulk of the sediment delivery comes from a few very large shallow-seated landslides which skews the per unit watershed area sediment delivery rates. The ten landslides with the highest amount of sediment input are responsible for 55% of the total estimated sediment delivery amount.

Table A-4. Total Shallow-Seated Landslides Mapped for each Planning Watershed in the Gualala WAU (road associated landslides included).

Planning Watershed	Total Slides	Landslides with Sediment Delivery	Landslides with No Sediment Delivery
Haupt Creek	18	17	1
Tobacco Creek	65	55	10
Annapolis Falls Creek	67	56	11
Flat Ridge Creek	10	8	2
Doty Creek	5	5	0
Robinson Creek	14	12	2
sum	179	153	26
percentage	100%	85%	15%

Mass wasting was separated into three time periods for data analysis. The first time period is for mass wasting that occurred from 1971-1980, the second time period assessed is from 1981-1987, and the third time period assessed is from 1988-2000. The dates for each of the time periods are based on the date of aerial photographs used to interpret landslides (1980, 1987, 1996, and 2000) and field observations (2000). These time periods cover approximately ten year periods. The periods used in this analysis are useful to provide a general idea of the relative magnitude of sediment delivery for the time periods analyzed, particularly the sediment delivery rate estimates.

A total of 180,000 tons of mass wasting sediment delivery was estimated for the time period 1971-2000 in the Gualala WAU, equivalent to a per unit watershed area rate of 480 tons/sq. mi./yr. Of the total estimated amount, 73,000 tons (40% of total) occurred from 1971-1980, 51,500 tons (29% of total) occurred from 1981-1987,and 55,500 tons (31% of total) occurred in the 1988-2000 time period (Table A-5).

For the Haupt Creek, Tobacco Creek, and Annapolis Falls Creek planning watersheds, sediment input from mass wasting was highest during the 1971-1980 period (Table A-5, Chart A-1). For the Flat Ridge Creek planning watershed, no mass wasting sediment input was observed within the 1981-1987 time period (no landslides were observed from aerial photos in the period).

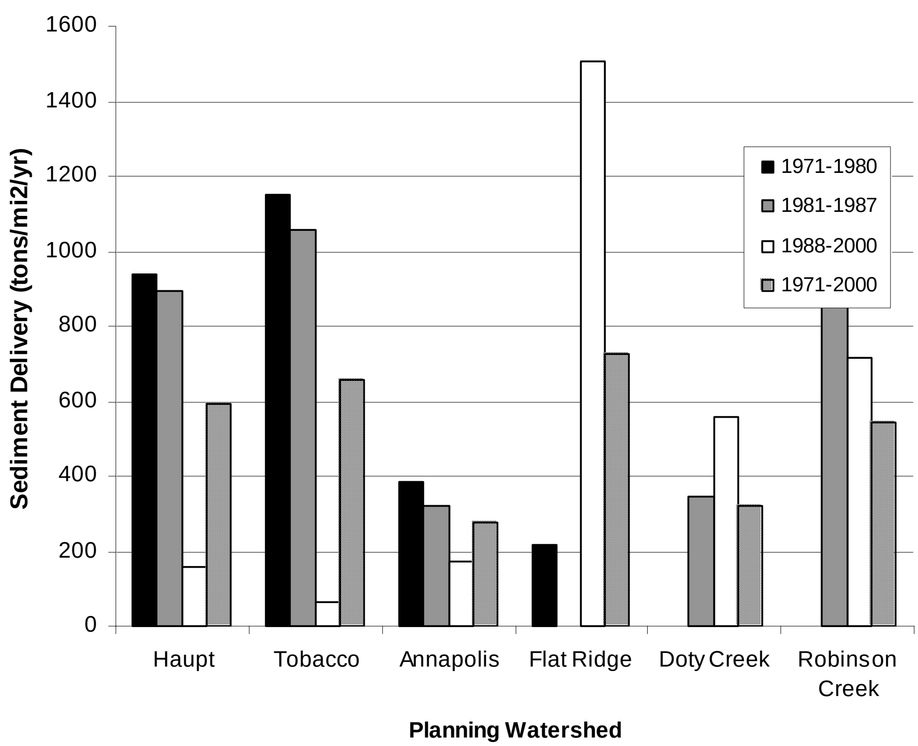
The highest overall sediment input from mass wasting occurred in the Tobacco Creek planning watershed. The higher sediment delivery appears to be due to a few very large landslides that contributed a high amount of sediment in the planning watershed. In particular, the highest sediment delivery estimate is for the Tobacco Creek planning watershed from 1971-1980, which is mainly attributed to a single very large debris slide. In contrast, Haupt Creek planning watershed has the lowest mass wasting input. The low input for Haupt Creek on Mendocino Redwood Company property is attributable to relatively small landslides with low sediment delivery.

Table A-5. Sediment Volume Input by Watershed for MRC Ownership. Data are Reported in Tons of Sediment Delivered.

Planning Watershed	1971-1980	1981-1987	1988-2000
Haupt Creek	9,000	6,000	2,000
Tobacco Creek	42,000	27,000	3,000
Annapolis Falls Creek	19,000	11,000	11,000
Flat Ridge Creek	3,000	0	27,000
Doty Creek	*	1500	4,500
Robinson Creek	*	6000	8,000
Total	73,000	51,500	55,500

*- Aerial photography not available

Chart A-1. Total Mass Wasting Sediment Input Rate (tons/yr/sq. mi.) from Landslides for MRC Ownership Shown by Watershed and Time Period.



Road associated mass wasting was found to have contributed 52,600 tons (140 tons/sq. mi./yr) of sediment over the 30 years analyzed (1971-2000) in the Gualala WAU (Table A-6). This represents approximately 31% of the total mass wasting inputs for the Gualala WAU for 1971-2000. In the Annapolis Falls Creek and Doty Creek planning watersheds, road associated landslide sediment delivery was a major sediment source, contributing 54% and 83% respectively. The Haupt Creek planning watershed does not contain as complex of a road network relative to other areas, therefore, the Haupt Creek planning watershed had a low percentage of road associated mass wasting delivery of 4%.

Table A-6. Road Associated Sediment Delivery for Shallow-Seated Landslides for the Gualala WAU by Planning Watershed, 1971-2000.

Planning Watershed	Road Associated Mass Wasting Sediment Delivery(tons)	Percent of Total Sediment Delivery in Planning Watershed
Haupt Creek	600	4%
Tobacco Creek	11,000	15%
Annapolis Falls Creek	22,000	54%
Flat Ridge Creek	9,000	30%
Doty Creek	5000	83%
Robinson Creek	5500	39%
Gualala WAU Total	***52,600***	***29%***

Sediment Input by Mass Wasting Map Unit (MWMU)

Total estimated mass wasting sediment delivery for the Gualala WAU was separated into respective mass wasting map units. It should be noted that not all planning watersheds contain all five MWMUs.

The mass wasting map unit with the highest sediment delivery is MWMU 1, inner gorge topography along low gradient watercourses (Table A-7); which is estimated to deliver 62% of the total sediment input for the Gualala WAU. Combining all streamside units (MWMU 1 and 2) would yield 65 % of the total sediment input. MWMU 3 and 4 are estimated to both have delivered similar amounts 17% each. MWMU 4 is not appreciably lower than MWMU 3 for proportion of total sediment delivery, however, it does encompass almost four times more area. In addition, the majority of the MWMU 4 landslides are road associated, indicating that silvicultural hazards in this unit are low. No delivery was observed in MWMU 5. MWMU 5 is a low hazard area with very gently sloping to flat topography and typically does not deliver landslide material except in extraordinary events, the one landslide that was observed in this MWMU was associated with a landing (road feature).

Table A-7. Total Sediment Delivery by Mass Wasting Map Units in the Gualala WAU (1969-2000).

	MWMU				
	1	2	3	4	5
Sediment Delivered (tons)	113,000	3000	32,000	32,000	0
% of total delivered	63%	2%	18%	18%	0%

This analysis suggest that the greatest risk of sediment delivery from mass wasting in the Gualala WAU is associated with MWMU 1. These steep streamside areas are contributing the majority of the sediment delivery in the watershed.

CONCLUSIONS

In natural forest environments of the California Coast Range, mass wasting is a common occurrence. In the Gualala WAU, factors influencing shallow landslide occurrence include steep slopes, the condition of weathered marine sedimentary rocks (interbedded sandstone and shale), locally thick colluvial soils, significant seismic events, a history of timber harvest practices, and high intensity rainfall events. Mass wasting events are episodic and many landslides may occur in a short period of time. Mass wasting features of variable age and stability are evident throughout the Gualala WAU. The vast majority of the landslides visited in the field during this assessment occurred on slopes greater than 60%, in areas of convergent or very steep planar topography. Groundwater was evident in the evacuated scarp at many sites. Extra caution should be considered when conducting any type of forest management activity in areas with convergent or locally steep topography.

Approximately 41% of the number of shallow-seated landslides are road associated in the Gualala WAU, though road related mass wasting only represented 31% of the sediment delivery. Roads appear to be a significant factor in the cause of shallow-seated mass wasting events. Better road construction practices combined with design improvement of existing roads should lower sediment input rates.

The greatest risk of sediment delivery from mass wasting in the Gualala WAU is associated with MWMU 1 these steep streamside areas are contributing the majority of mass wasting related sediment delivery in the watershed. In the moderate and low hazard units of MWMU 5, a large amount of road associated landslides are occurring suggesting needs for improvements on roads in WAU.

Mass wasting sediment input is estimated to be at least 480 tons/sq. mi./ yr. over the 1971-2000 time period for the entire Gualala WAU. Overall in the Gualala WAU, sediment delivery from mass wasting was highest in the Tobacco Creek planning watershed in the 1971-1980 time period. The forest harvesting technique utilized in the 1950's and 1960's was tractor skidding of logs. This skidding was performed on steep slopes and often in streamside environments and inner gorges, compacting and destabilizing the soil, probably increasing the frequency of mass wasting. Evidence of legacy harvesting practices can be seen along Tobacco Creek, where roads were constructed immediately adjacent to the channel and are heavily eroded, with a thin to absent forest canopy.

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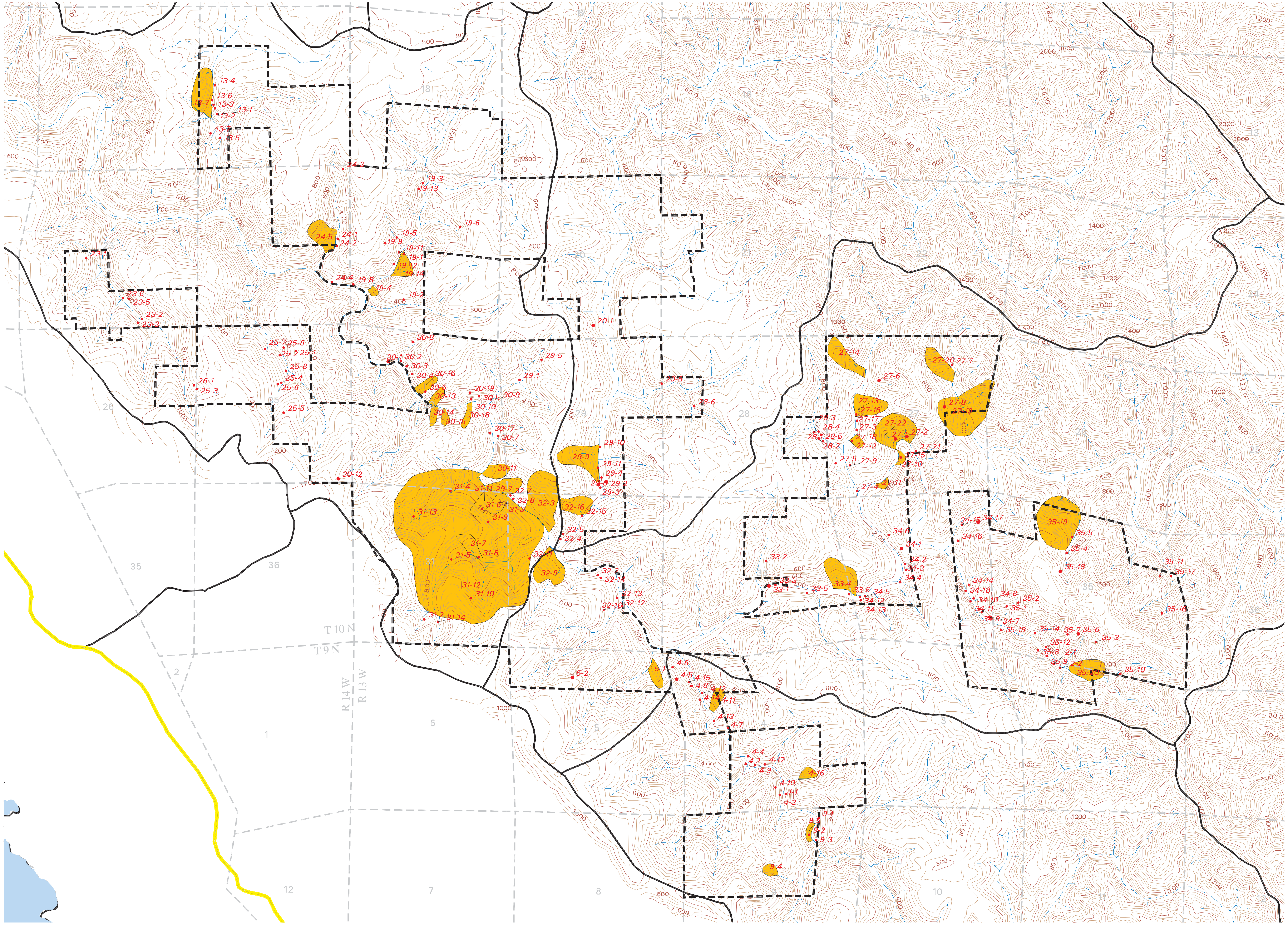


Gualala River Watershed Analysis Unit

Map A-1
Mass Wasting Inventory

This map presents the location of mass wasting features identified on the MRC land in the Gualala River watershed. The mass wasting features were developed from an interpretation of aerial photographs from 1980-2000 with field observations taken in 2000. 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 shallow-seated landslides are categorized in a database in the mass wasting report for the Gualala WAU (Section A).

Large Deep-Seated Landslides

Shallow-Seated Landslides

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

MRC Ownership

Planning Watershed Boundary

Gualala River Watershed Boundary

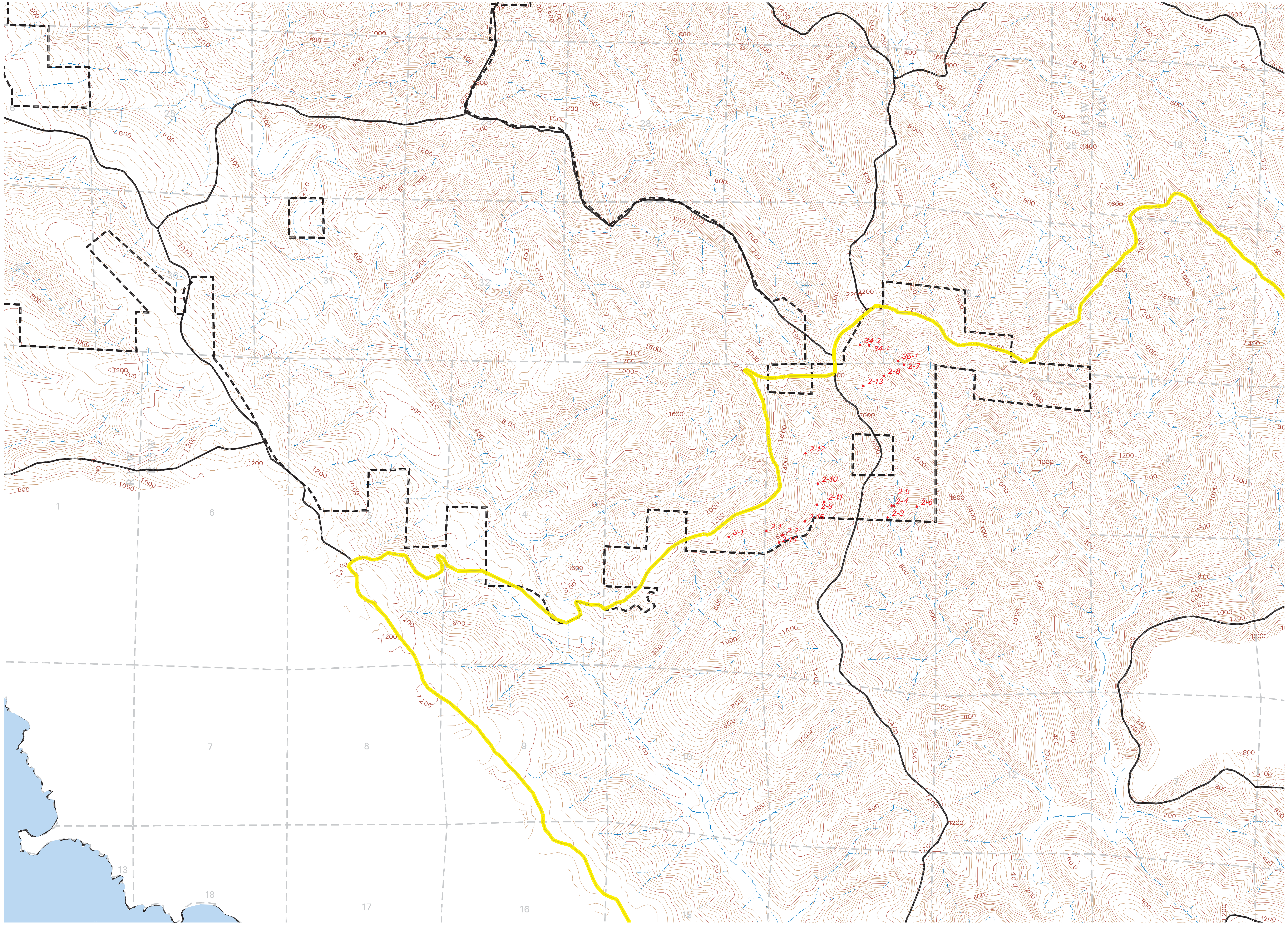
Flow Class

- Class I
- Class II
- Class III

Sheet 1

0 1/2 1 Mile

June 2003



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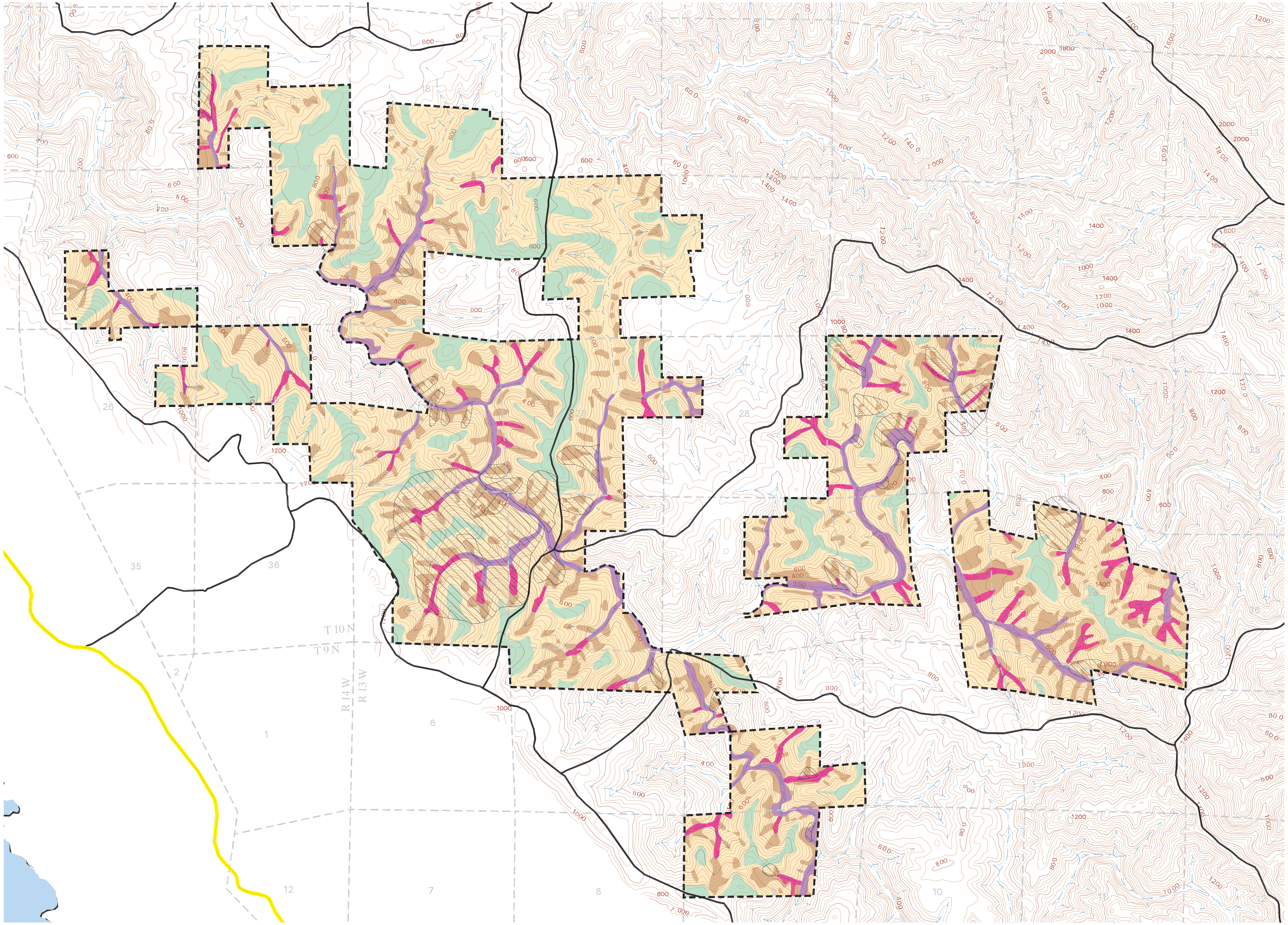
MRC Ownership
Planning Watershed Boundary
Gualala River Watershed Boundary

Flow Class
- Class I
- Class II
- Class III

Sheet 2

0 1/2 1 Mile

June 2003



Gualala River Watershed Analysis Unit

Map A-2
Mass Wasting Inventory

This map presents an interpretation of the mass wasting map units (MWMUs) delineated for the Gualala WAU. The MWMUs characterize the landscape by similar geomorphic attributes, shallow-seated landslide potential, and sediment delivery potential. The MWMU designations for the Gualala 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 Gualala WAU is certainly more complex than generalized MWMUs delineated for this evaluation. The MWMUs are only meant to be a starting point for gauging the need for site-specific field assessments.

- Unit 1: Steep slopes or inner gorge along low gradient watercourses
- Unit 2: Steep slopes or inner gorge adjacent to select intermittent or ephemeral streams
- Unit 3: Steep, dissected topography
- Unit 4: Non-dissected topography
- Unit 5: Low relief topography
- Unit 6: Identified earthflow complexes
- Unit 7: Accelerated creep terrain

Deep Seated Landslides

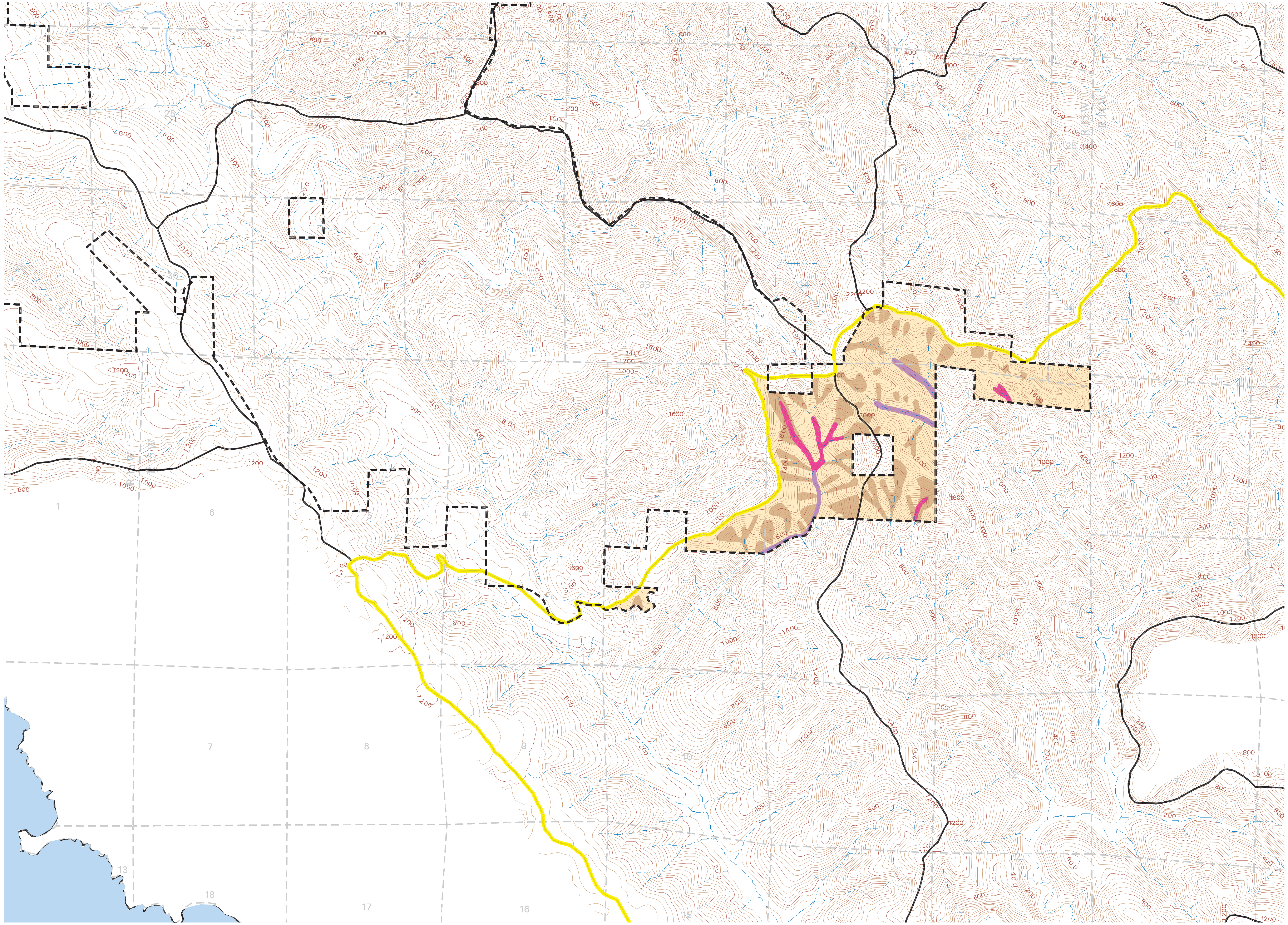
MRC Ownership
Planning Watershed Boundary
Gualala River Watershed Boundary

Flow Class
Class I
Class II
Class III

Sheet 1

0 1/2 1 Mile

June 2003



Gualala River Watershed Analysis Unit

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Deep Seated Landslides

MRC Ownership
Planning Watershed Boundary
Gualala River Watershed Boundary

Flow Class
Class I
Class II
Class III

Sheet 2

0 1/2 1 Mile

June 2003