Appendix G

Watershed Analysis: Background and Methods

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G. WATERSHED ANALYSIS: BACKGROUND AND METHODS

G.1 Introduction

This appendix introduces the methods used in our watershed analysis reports prior to the initiation of the HCP/NCCP in order to

- Show how we produced our data summaries on aquatic habitat conditions (Table 3-8) and sediment input (Table 3-11).
- Allow comparison of past and future methods and data.
- Document any differences between MRC methods and standard methods.

Table G-1 lists our completed reports by watershed analysis unit (WAU), along with any updates.

Table G-1 Completed Watershed Analyses in the Plan Area as of 2010

WAU	Report Completion Date	
	Original Report	Latest Update
Garcia River	1998	2003
Albion River	1999	2004
Noyo River	2000	2004 mass wasting
Big River	2003	
Hollow Tree Creek	2004	
Navarro River	2003	
Greenwood Creek	2004	
Northern Russian River	2004	
Cottaneva Creek	2005	
Elk Creek	2005	

As of 2010, MRC has collected complete field data for all watershed analyses except road inventory. Table G-2 shows the expended effort during instream surveys for each watershed analysis unit. In creating the table, we summed the miles of Class-I habitat surveyed and divided by the total miles of Class-I habitat in the plan area. The table numbers describe the level of effort for surveys of LWD and instream shade, as well as for initial surveys of fish habitat; they do not include the level of survey effort for road inventory. In watershed analysis, MRC occasionally surveys Class-II and Class-III streams, but the majority of surveys are within Class-I streams. As of 2010, MRC surveyors have walked approximately 50 miles of Class-I stream habitat, making observations about potential recruitment of riparian stands, LWD quality, instream shade, and fish habitat typing.

The level of effort for other watershed analysis monitoring programs is as follows:

- Field observations of mass wasting included 25% to 45% of the landslides observed in aerial photographs over the entire watershed.
- Model efforts of surface erosion used complete road inventory data for an entire watershed.[1]

[1] Refer to specific watershed analysis reports for details on the level of effort in a particular watershed.

MRC will apply the same level of effort in future watershed analyses unless the plan area changes or the level of timber harvest deviates significantly from 30 mmbf per year.

Table G-2 Field Observation Effort

WAU	Field Survey Effort of Class I Stream as of 2010		
	Total Class I Miles in Plan Area	Class I Miles Observed	% of Class I Habitat Surveyed
Garcia River	23.1	5.7	24.6%
Albion River	34.9	2.6	7.5%
Southcoast Streams	19.0	3.5	18.5%
Cottaneva Creek	12.9	3.7	29.1%
Elk Creek	20.5	7.0	34.3%
Noyo River	37.6	3.4	9.2%
Rockport Coastal Streams	17.5	5.3	30.5%
Big River	60.6	4.2	7.0%
Hollow Tree Creek	45.7	3.5	7.6%
Navarro River	133.2	8.6	6.4%
Greenwood Creek	20.5	1.8	8.6%
Northern Russian River	8.1	0.6	7.8%
TOTAL	433.5	50.1	11.5%

G.2 Watershed Analysis Methods

Our watershed analyses follow guidelines from the Standard Methodology for Conducting Watershed Analysis (WFPB 1995). We modified these standard methods to suit the purpose of our assessments. In this subsection, we present our common methods for each watershed analysis module, along with a description of any deviations for specific watershed analysis units. In the future, we will use the unmodified standard methods (i.e., Standard Methodology for Conducting Watershed Analysis) for any re-surveys and for comparisons of data. The modules are

- Mass wasting.
- Surface and point source erosion
- Hydrology.
- Riparian function.
- Stream channel conditions
- Fish habitat.
- Amphibian distribution.
- Synthesis

G.2.1 Module: mass wasting

The primary objectives of mass wasting assessment are to

- Identify the types of mass wasting active in the basin.
- Identify the link between mass wasting and forest management.

- Identify pockets of concentrated mass wasting.
- Partition the plan area into potential zones of mass wasting and sediment delivery.

This module of the watershed analysis contains a wide range of geologic information including definitions, interpretations, and conclusions that constitute the practice of geology. The State of California regulates the practice of geology under the Business and Professions Code and the Geologist and Geophysicists Act. In order for MRC to be compliant with these statutes and regulations a professional geologist or registered certified specialty geologist, licensed in the State of California, will be in charge of this module and will sign or stamp the final document to indicate his or her responsibility.

Within the mass wasting module, we have categorized landslides as either shallow-seated or deep-seated and have modified descriptions of these categories from Cruden and Varnes (1996). In general, a landslide is shallow-seated if the slide plane is confined to regolith (soil, colluvium, and weathered bedrock). Deep-seated landslides typically have a slide plane that extends well into bedrock.

G.2.1.1 Shallow-seated landslides

The shallow-seated landslides that occur in the plan area are

- Debris slides.
- Debris flows.
- Debris torrents.

The material composition of debris slides, flows, or torrents is soil with a significant proportion of coarse material; 20–80% of the particles are larger than 2 mm. Shallow-seated landslides generally move quickly downslope and usually break apart during failure. They commonly occur

- On steep planar slopes.
- On convergent slopes.
- On oversteepened fill slopes along forest roads.
- On steep slopes adjacent to watercourses.

Slope steepness, saturation of soil, and material strength (i.e., friction angle and effective cohesion)—all affect the susceptibility of a slope to fail.

Debris slides

DEFINITION

Debris slides are composed of unconsolidated rock, soil, and organic material that move rapidly downhill.

Based on mass wasting inventories conducted to date, debris slides are, by far, the most common landslide in the plan area. Their landslide mass typically fails along a surface of rupture or along relatively thin zones of intense shear strain. The failure is usually by translational movement (Figure G-1) along an undulating or planar surface. While the landslide mass may deposit onto the ground surface below the area of failure, it generally does not slide more than a distance equal to the slide body's length. Upon reaching a watercourse, debris slides, by definition, do not continue downstream on their own momentum, but their debris is transported downstream by streamflow.

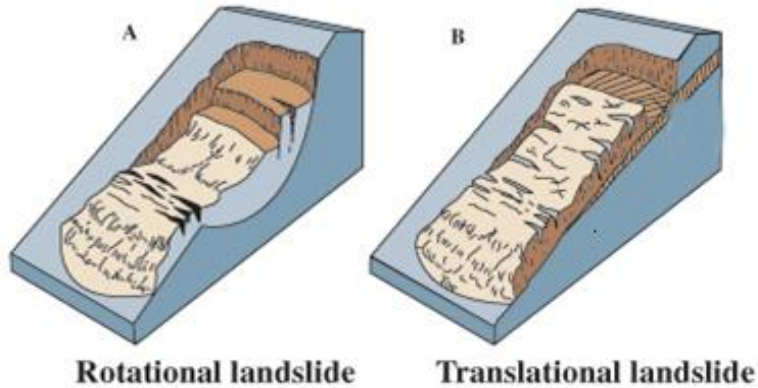

Figure G-1 Landslide Movement

A majority of the historic roads in the plan area were constructed using cut-and-fill techniques; fill generated by the cut was sidecasted rather than compacted in lifts onto a keyway or excavated trench. Most debris slides on our land originate from this loose, unkeyed, fill material. Current road building techniques, upgrades of existing historic roads, and decommissioning of outdated road alignments will reduce the total number of potential slide sites related to road fill.

Debris flow

DEFINITION

Debris flows are composed of saturated soil, rock, and organic material that move rapidly downhill and deposit well beyond the foot of the landslide.

A debris flow is similar to a debris slide with the exception that the landslide mass continues to *flow* downslope, below the failure and a considerable distance over the ground surface. This process requires high water content. 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 it moves downslope to a debris flow. Such failures are still classified as debris flows.

Debris torrent

DEFINITION

Debris torrents are composed of highly saturated soil, rock, and organic material that rush downhill like a muddy river and often scour a long stretch of stream channel below.

Debris torrents are a special subset of debris flows. They have the greatest potential to destroy stream habitat and deliver large amounts of sediment. As the debris torrent moves downslope, its liquefied material increases in mass. The distinguishing characteristic of a debris torrent is that the failure *torrents* downslope into a confined channel and scours it. Debris torrents can potentially move great distances down a channel. They typically initiate in headwall swales and move down intermittent watercourses. Often a failure will start as a debris slide, but will develop into a debris torrent upon reaching a channel. Such failures are still classified as debris torrents.

G.2.1.2 Deep seated landslides

The deep-seated landslides that occur in the plan area are rockslides and earthflows.

Many of the deep-seated landslides are *dormant*, but the importance of identifying them lies in the fact that, if reactivated or accelerated, they have the potential to deliver large amounts of sediment and destroy stream habitat. Accelerated or episodic movement in some landslides is likely to occur gradually in response to seismic shaking or stochastic rainfall events. Deep-seated landslides can be very large, exceeding hundreds of acres. Making connections between deep-seated landslides and management practices can be extremely difficult.

Rockslides

DEFINITION

Rockslides are deep-seated landslides that move a relatively intact mass of rock and overlying earth materials.

Failure may occur along an inclined plane with only translational movement or along a curved surface where the failing materials rotate about an axis. The mode of rock slide generally is not strictly rotational or translational, but involves some component of each. Failure surfaces typically develop along planes of structural weakness (bedding planes, folds, faults, etc.). Rockslides commonly create a flat or back-tilted mid-slope bench below a broad arcuate crown scarp.

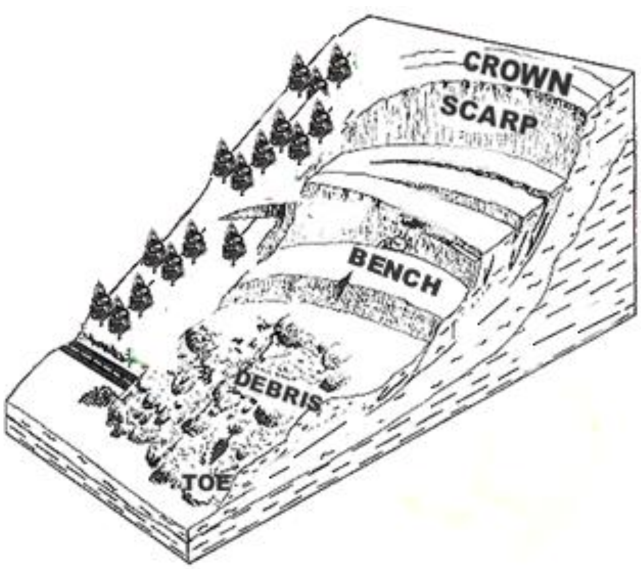

Figure G-1A Landslide Features

Generally, rockslides are not characterized by a single block failure, but rather consist of a series of nested landslide blocks which make up the rockslide complex. A prominent bench or series of benches, preserved over time, characterize the body of the rockslide. Lateral margins are typically poorly defined—likely due to the differential and infrequent movement of the rockslide blocks. Rockslides generally fail in response to triggering mechanisms, such as seismic shaking, stochastic rainfall events, or removal of buttressing support through stream channel incision. The stream itself can be the cause of chronic movement, if it periodically undercuts the toe of a rockslide.

Earthflows

DEFINITION

Earthflows are deep-seated landslides composed of fine-grained materials and soils derived from clay-bearing rocks.

By volume, more than 80% of earthflow materials consist of particles smaller than 2 mm. Earthflows also commonly contain boulders, some very large, which move downslope in the clay matrix. The *flow* creates a landslide *complex* that can be very irregularly shaped.

Some earthflow surfaces are dominantly grassland, while others are partially or completely forested. The surface of an earthflow is characteristically hummocky with locally variable slopes and relatively abundant gullies. The inherently weak materials within earthflows are not able to support steep slopes; therefore, slope gradients are low to moderate.

The rates of movement vary and can be accelerated by persistent high groundwater conditions. Since timber harvesting can increase the amount of subsurface water, it can also accelerate movement in an earthflow. Gully erosion from concentrated or diverted water is often a principal source of anthropogenic-created earthflows.

G.2.1.3 SHALSTAB

MRC uses SHALSTAB[2] to assist with the mapping of the hazard potential of shallow-seated landslides. 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 (Dietrich and Montgomery 1998). Generally, they found that the SHALSTAB model correctly distinguishes areas more prone to shallow landslide instability. In mass wasting studies conducted in 7 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 point out 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) does not represent the fine scale topography that dictates the convergence of subsurface flow and the locations where shallow landslides are likely to occur. This lack of resolution limits the model's performance when applied to the plan area. In our watershed analysis, we assess mass wasting hazards apart from SHALSTAB as well, using aerial photographs and field reconnaissance. However, we still use SHALSTAB output as a tool to configure the landscape into terrain stability units.

G.2.1.4 Landslide inventory

When assessing mass wasting, we rely on features identified from aerial photographs and field observations. A registered geologist conducts an aerial photograph assessment of the entire watershed using as many photo sets as possible. The registered geologist then verifies a percentage of aerial photo observations with field data solely for shallow-seated landslides; deep-seated slides tend to be too large and old to verify in the field or to connect with management impacts. In collecting and storing this data, we realize that we may overlook some landslides, particularly small ones obscured by vegetation. Table G-3 gives a brief description of select parameters in our mass wasting inventory.

Table G-3 Parameters to Describe Mass Wasting

Parameters to Describe Mass Wasting	
Parameter	**Description**
Slide identification	MRC assigns each landslide a unique identification number. The ID consists of a two-letter code that denotes the planning watershed in which the slide is located and a number that indicates the USGS map section for the slide location.
TSU #	Terrain stability unit in which the landslide is located (see G.2.1.8).

[2] William Dietrich and David Montgomery describe SHALSTAB as "a physically-based digital terrain model for mapping the relative shallow slope stability potential across a landscape."

Parameters to Describe Mass Wasting

Parameter	Description
Landslide type	Code denoting the type of landslide: DS - debris slide DF - debris flow DT - debris torrent RS – rockslide EF – earthflow
Certainty of identification	Code denoting the observer's level of certainty: D - definite P - probable Q - questionable
Physical characteristics	Includes average length, width, depth, and volume of individual slides; length of torrent, if present, will be noted in comments.
Sediment routing	Code denoting the type of stream the sediment was delivered to: P - perennial I - intermittent or ephemeral N - no sediment delivered
Sediment delivery	Relative percentage of the landslide volume and mass delivered to the stream.
Slope	Percent slope angle for all shallow-seated landslides observed in the field.
Age	Code denoting the estimated age of the slide: A - active (<5 years old) R - recent (5-10 years old) O - old (>10 years old)
Slope form	Code denoting the morphology of the slope where the landslide originated: C - concave D - divergent P – planar
Slide location	Code denoting the observer's interpretation of the location where the landslide originated: H - headwall swale S - steep streamside slopes I - inner gorge O - other

Parameters to Describe Mass Wasting	
Parameter	**Description**
Road association	Code denoting the association of the landslide to land-use practices: R - road S - skid trail L - landing N – none of the above I – indeterminate MRC will note details of failure (e.g., road drainage or fill construction).
Structure class	Code describing the current forest conditions (dominant species, dominant diameter, and % canopy cover) upslope of recent failures.
Soil type	Code denoting the NRCS (Natural Resources Conservation Service) mapped soil type generated from available GIS data and attributed to each slide point.
Contributing area	Categorical description of the area interpreted to concentrate surface or subsurface flow to the failure site for non-road related slide points: Small = <0.5 ac Medium = 0.5-3.0 ac Large = >3.0 ac
Aspect	Predominant cardinal direction where the hillslope failure originated.
Spring lines	Identification of spring lines from a review of USGS hydropoint and THP data that may suggest regional hydrogeologic conditions adverse to slope stability.
Bedrock structure	Geologic data identifying potentially adverse structural relationships in the watershed (e.g., regional dip slopes).
Bedrock lithology	Geologic data identifying dominant and anomalous rock types.
Toe, body, lateral scarps, and main scarp descriptions	MRC assigns categorical attributes to the various morphological features of deep-seated landslides.
Field observed	Yes or no

Landslide inventory map

MRC plots landslides identified in the field and in aerial photographs on a landslide inventory map. The map identifies all shallow-seated landslides as a plotted point at the interpreted head scarp of the failure. The interpreted perimeter (body and scarp) of a deep-seated landslide is represented as a polygon. Landslide dimensions and depths can be variable; recorded values for length, width, and depth are average dimensions. When converting landslide volumes to mass (tons), we assume a soil bulk density of 100 lbs/ft^3 (1.35 g/cm^3).

Certainty of identification

MRC assesses not only identified landslides but the certainty of the identification. Table G-4 shows the guidelines for each assessment.

Table G-4 Certainty Assessments

Definite	The analyst is certain the landslide exists.
Probable	The analyst has some doubt about the interpretation but suspects the landslide exists.
Questionable	The analyst has limited confidence in the interpretation and distrusts its accuracy.

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. An analyst has the highest level of confidence when mapped landslides are in areas recently logged or in areas with thin canopy. Sometimes the analyst's confidence in identifying a landslide depends on the quality and angle of the aerial photographs: (1) sun angle creates shadows which may obscure a landslide; (2) the print quality of some photos varies; and (3) small-scale photographs make identification of small landslides difficult. The certainty of identification does not factor numerically into landslide delivery volumes.

Air photo vs. ground-based analysis

Results from the landslide inventory are considered a minimum estimate of sediment production. This is because (1) landslides that were too small to identify on aerial photographs may have been missed; (2) landslide surfaces may have reactivated in subsequent years and gone unmeasured; and (3) secondary erosion by rills and gullies on slide surfaces may be difficult to see. Results from an Oregon Department of Forestry study on air photo analysis versus ground-based inventories of landslides reveal that air photo analysis alone is particularly problematic in mature forested environments. Roughly half of the landslides were detected in young forests (0-9 years old), while less than 5% were detected in mature (>100 years old) forest stands (Robison et al. 1999).

Landslide inventories based solely on air photo analysis will significantly overestimate the sediment delivery rate from recently harvested stands as compared to unharvested second growth stands. MRC employs a combination of air photo analysis and ground-based field verification in an effort to map and attribute all visible landslides over our large land base; we provide supplementary field estimates of depth and delivery percentages to more accurately reflect the actual conditions on the ground. Since the entire plan area was managed in the recent past, we have confidence in our ability to detect the majority of the sediment-delivering landslides.

Relationship of landslides and silviculture

In our initial analyses, we did not observe the effects of silvicultural techniques on rates of sediment delivery from landslides. Our reason for not doing so was that the plan area has been managed, recently and historically, by different land owners with different practices, making a landslide evaluation based on distinct silvicultures difficult if not impossible. However, as part of HCP implementation, we will classify future landsides according to the surrounding forest structure, including tree species, tree size, and the percentage of forest cover. Over the term of the HCP, this data may help us draw conclusions about the effects of silviculture on rates of sediment delivery from landslides. Meanwhile, we have based our landslide classifications—particularly those associated with roads—on certain assumptions and inferences:

- If a landslide was adjacent to a road, landing, or skid trail, we assumed that land use triggered it, either directly or indirectly.
- If a landslide appeared to be influenced by more than one practice, we inferred, based on professional judgment, the more causative one.
- If a cutslope failure did not cross the road prism, we assumed that the failure would remain perched on the road, landing, or skid trail and would not deliver to a watercourse.

G.2.1.5 Sediment input from shallow-seated landslides

MRC used estimates of sediment delivery from mapped shallow-seated landslides to produce our estimate of total sediment input from mass wasting, denoted as management-related or not. In some instances, we visited shallow-seated landslides in the field; in others, we did not. In order to extrapolate depth and percentage of sediment delivery for shallow-seated landslides not visited, we calculated the average depth and sediment delivery of landslides visited. We did not calculate delivery statistics for deep-seated landslides. Categorizing shallow-seated landslides as either road or non-road related, we determined an average depth for each category through field observations. Next we assigned an average depth, depending on category, to all landslides not observed in the field

Some of the sediment delivery from shallow-seated landslides is the result of conditions created by deep-seated landslides. A deep-seated failure, for example, may 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. We have accounted for these types of circumstances by estimating sediment delivery from shallow-seated landslides regardless of their source.

G.2.1.6 Sediment input from deep-seated landslides

Gradual and catastrophic sediment delivery

Large, active, deep-seated landslides can potentially deliver large volumes of sediment over long periods of time and increase sediment load downstream of the failure. Actual delivery can occur if the toe of the slide over-steepens and subsequently falls into the creek or if the slide pushes out into the creek. It is very important not to confuse normal stream bank erosion at the toe of a slide with 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 can 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 in the plan area and usually occur in response to unusual storm events or seismic ground-shaking.

Determining quantity of sediment delivery

In our watershed analyses, we did not determine the quantity of sediment delivery from deep-seated landslides. Movement of deep-seated landslides has definitely resulted, however, in sediment delivery in the plan area. Factors, such as rate of movement or depth of the slide plane, are difficult to determine without subsurface geotechnical investigations; we did not conduct such investigations in our analyses.

Sediment delivery to watercourses can occur by several processes, including 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, sheetwash (overland flow), and gullies or rills. Under these conditions, we assumed the sediment delivery from surficial processes to be the same as adjacent hillside slopes not underlain by landslide deposits. Materials within a landslide are disturbed and can be somewhat weaker. However, once a soil has developed, the fact that the slope is underlain by a deep-seated landslide should make little difference in sediment delivery from erosion at the ground surface. Fresh, unprotected surfaces can become a source of sediment until the bare surface becomes covered with leaf litter, vegetation, or soil.

Clearly, movement of a portion or all of a deep-seated landslide can result in delivery of sediment to a watercourse. However, movement must 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 landslide that "toes out" on a slope away from a creek or that moves only a short distance downslope will generally deliver little to a watercourse. Moreover, often only a portion of a deep-seated landslide will become active, even though that portion may 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. This would be particularly true in the case of very large deep-seated landslides that exhibit ground cracks 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. Even combined with the closing up or "bulking up" of the slide, ground cracking would not generate much movement, if any, at the toe of the slide. However, small incremental movement on a large deep-seated landslide over thousands of years can result in oversteepened toe slopes; these, in turn, can cause debris slides and flows. MRC will estimate such sources of sediment delivery during the inventory of shallow-seated landslides.

G.2.1.7 Characteristics of deep-seated landslides

The characteristics of deep-seated landslides received less attention in our landslide inventory than shallow-seated landslides. To investigate deep-seated landslides, we would have had to conduct subsurface analyses to estimate attributes such as depth, volume, failure date, current activity, and sediment delivery. Subsurface investigation was beyond the scope of our watershed analysis. Further assessment of deep-seated landslides will occur, however, on a site-by-site basis in the WAUs, likely during preparation of timber harvest plans and reviews.

Air reconnaissance mapping

MRC only interpreted deep-seated landslides by air reconnaissance techniques. Criteria for reconnaissance mapping includes observations of four morphologic features of deep seated landslides—toe, internal morphology, lateral flanks, main scarp—plus vegetation (after McCalpin 1984 as presented by Keaton and DeGraff 1996, p. 186, Table 9-1). The presence of tension cracks 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.

Morphologic features of deep-seated landslides

We have developed a set of 5 descriptions to classify each morphologic feature of a deep-seated landslide (Table G-5). The five descriptions are ranked in descending order from characteristics typical of active landslides, to those typical of dormant and relict landslides. One description should characterize a feature best. Nevertheless, overlap between classifications is neither unusual nor unexpected. We recognize that some deep-seated landslides may lack evidence for one or more of the observable features, but show strong evidence of other features. If there is no expression of a particular geomorphic feature (e.g., lateral flanks), the classification of that feature is considered undetermined. A deep-seated landslide associated with other deep-seated landslides may be classified as a landslide complex.

In addition to the classification of the deep-seated landslide features, there is a classification of the interpretation itself. Some landslides are obscured by vegetation, with areas that are clearly visible and areas that are not. In addition, weathering and erosion may obscure geomorphic features. The quality of aerial photographs varies; this can make interpretations difficult. Owing to these circumstances, each inference of a deep-seated landslide is classified according to the strength of the evidence as definite, probable or questionable (see Table G-4). At the THP scale, MRC expects to use field observations to reduce the uncertainty of interpretation inherent in air reconnaissance.

Table G-5 Morphologic Classification of Deep-seated Landslides

Feature	Criteria
Toe Activity	1. Steep streamside slopes with extensive unvegetated to sparsely vegetated shallow-seated landslides. Shallow-seated landslides occur on both sides of the stream channel, but more prominently on the side containing the deep-seated landslide. The stream channel in the toe region may contain coarser sediment than the adjacent channel. The stream channel may be pushed out by the toe. The toe may be eroding, exhibiting sharp topography/geomorphology. 2. Steep streamside slopes with few shallow-seated landslides ranging from unvegetated to sparsely vegetated. Shallow-seated landslides generally are distinguishable only on the streamside slope containing the deep-seated landslide. The stream channel may be pushed out by the toe. Sharp edges are becoming subdued. 3. Steep streamside slopes that are predominantly vegetated with little to no shallow-seated landslide activity. Topography/geomorphology subdued. 4. Gently sloping stream banks that are vegetated and lack shallow-seated landslide activity. Topography/geomorphology very subdued. 5. Undetermined.
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 that 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 are preserved and are very subdued. Could have standing water. May appear as amphitheater slope where slide deposit is mostly or all removed.

Feature	Criteria
	5. Undetermined.
Lateral Flanks	1. Sharp, well defined. Shallow-seated landslides 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, and essentially continuous. Might have small breaks; gullies/drainage may be developing down lateral edges of slide body. May have shallow-seated landslide 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.
Main Scarp	1. Sharp, continuous geomorphic expression, usually arcuate breaks in slope with bare spots to unvegetated; often has shallow-seated landslide activity. 2. Distinct, essentially continuous break in slope that may be smooth to slightly subdued in parts and sharp in others; apparent lack of shallow-seated landslide 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.
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.

G.2.1.8 Terrain stability units

The term *terrain stability unit* (TSU) is the preferred terminology for landslide zones. In earlier watershed analyses, MRC used the term *mass wasting map units* (MWMU). TSU and MWMU describe the same features; however, TSU is the term we will use in the HCP/NCCP and future MRC watershed analysis.

To delineate TSUs, MRC partitions the landscape into zones with similar geomorphic attributes, shallow-seated landslide potential, and sediment delivery to stream channels; in the delineation, we use a combination of aerial photograph interpretation, field investigation, and SHALSTAB output. Each TSU designation is based on land forms present; mass wasting processes; sensitivity to forest practices; mass wasting hazard; delivery potential; and forest management triggers for shallow-seated landslides.

TSUs are only meant to be general characterizations. Deep-seated landslides are shown on a TSU map in order to provide land managers with supplemental information for harvest planning and geologic review. The landscape and geomorphic setting in any given WAU is certainly more complex than generalized TSUs depict. The TSUs are only a starting point; they may point up the need for site-specific field assessments.

G.2.1.9 MRC methods for evaluating mass wasting

Landslide terminology

MRC has been consistent in our terminology for landslide names in all the watershed analysis reports.

SHALSTAB

MRC has been consistent in our use of SHALSTAB in all the watershed analysis reports.

Landslide inventory

Table G-6 shows how the methods MRC used to evaluate mass wasting in specific WAUs differed from the standard method.

Table G-6 MRC Methods for Evaluating Mass Wasting in Specific WAUs of the Plan Area

WAU	MRC Method vs. Standard Method
Garcia River	No difference
Albion River	No difference
Noyo River	Slide location class not included; relative age classification not performed from air photo interpretation; slope form not included; deep-seated landslide morphology description not included.
Big River	No difference
Hollow Tree Creek	Slide location class not included; relative age classification not performed from air photo interpretation; slope form not included.
Navarro River	Slide location class not included; relative age classification not performed from air photo interpretation; slope form not included.
Greenwood Creek	No difference
Northern Russian River	Slide location class not included; relative age classification not performed from air photo interpretation; deep-seated landslide morphology description not included.
Elk Creek	No difference
Cottaneva Creek	No difference
Rockport Coastal Streams	Complete by 2012
Southcoast Streams	Complete by 2012

G.2.1.10 MRC methods for estimating sediment input from mass wasting

Sediment input from deep-seated landslides

MRC has not quantified sediment inputs from deep seated landslides in any of the watershed analysis reports.

Systematic description of deep-seated landslide features

MRC has been consistent in our systematic description of deep-seated landslide features in all the watershed analysis reports except for Noyo River.

Terrain stability units

In the watershed analyses for Garcia River, Big River, and Navarro River, MRC referred to terrain stability units as mass wasting map units.

Landslide inventory

Table G-7 shows how the methods MRC used in estimating sediment input in specific WAUs differed from the standard method.

Table G-7 Estimating Sediment Input from Mass Wasting in Specific WAUs of the Plan Area

WAU	MRC Methods vs. Standard Method
Garcia River	No difference
Albion River	No difference
Noyo River	Landslides not visited in field received average sediment delivery percentage from field observations, except streamside landslides assumed to have delivered 100% of its mass.
Big River	Landslides not visited in field had sediment delivery percentage interpreted from aerial photographs by the following percentage classes: 0-25%, 25-50%, 50-75%, 75-100%.
Hollow Tree Creek	No difference
Navarro River	Landslides not visited in field received average sediment delivery percentage from field observations, except streamside landslides assumed to have delivered 100% of its mass.
Greenwood Creek	Landslides not visited in field received average sediment delivery percentage from field observations.
Upper Russian River	Landslides not visited in field received average sediment delivery percentage from field observations, except streamside landslides assumed to have delivered 100% of its mass.
Cottaneva Creek	Landslides not visited in field received average sediment delivery percentage from field observations.
Elk Creek	Landslides not visited in field received average sediment delivery percentage from field observations.
Southcoast Streams	Complete by 2012
Rockport Coastal Streams	Complete by 2012

G.2.2 Module: surface and point source erosion

G.2.2.1 Standard method: road erosion

Road inventory and reporting

MRC intends to complete an inventory of all roads within each WAU, with the exception of historical and decommissioned roads, by the end of 2011. Our surveyors use a Global Positioning System (GPS) to identify, map, and inventory all major features of the road network. We have collected data to evaluate surface and point source erosion. This includes field observations on watercourse crossings, crossing structures (e.g., culverts, bridges), and landings. The road inventory provides dimensions of the road network, such as road lengths and widths, as well as road segments contributing sediment—all useful information for surface erosion modeling.

Point source erosion delivering to a watercourse

Point source erosion from a road consists of major rills or gully erosion observed in close proximity to a watercourse or evidence of sediment delivery directly into a watercourse. MRC assumes that all observed sediment delivery from surface or point source erosion occurred within the past 5 years, unless there is contradictory information. During an inventory of road features, we estimate the past volume of point source erosion for a specific feature (e.g., watercourse crossing) and use these estimates to calculate the total volume of erosion delivered from the road. Finally, we convert the volume of erosion to a weight (in tons), assuming a soil bulk density of 100 lbs/ft^3 (1.35 g/cm^3).

Point source erosion differs from controllable erosion. The former is an estimate of erosion that has already delivered to a watercourse, whereas the latter is a measure of erosion that might still deliver.

Controllable erosion

During our road inventory, MRC road crew documents observed point source erosion. This includes gully or road-fill washouts; it excludes surface erosion or sheetwash because these non-point sources are quantified in the modeling for road surface erosion. Potential erosion is called controllable erosion, a term developed by the North Coast Regional Water Quality Control Board (Order # R1-2004-0016, *Categorical Waiver of Waste Discharge Requirements for Discharges Related to Timber Harvest Activities On Non-Federal Lands in the North Coast Region*). The source of controllable sediment discharge is a site or location, either pre-existing or created by timber harvest, lying within the project area and meeting all the following conditions:

1. Discharges sediment or has the potential to discharge sediment to state waters in violation of water quality requirements or other WDR provisions.
2. Caused or affected by human activity.
3. Responds to management measures for prevention and minimization.

Typically, controllable erosion is a measure of the fill material from a road that could erode if a road feature is left un-maintained or fails in the next 40 years (the duration of a TMDL). The amount of controllable erosion is the volume of soil that can be controlled with high design standards for road features (e.g., watercourse crossing and side-cast fill). While the North Coast Regional Water Quality Control Board considers only sites greater than 10 yd^3 as controllable erosion, MRC actually inventories even smaller volume sites and calls them controllable erosion as well. We also conduct an analysis for controllable erosion of skid trail sites, e.g., in the Garcia WAU.

Delivery potential and treatment immediacy

Controllable erosion sites are further designated by their potential for sediment delivery, immediacy of treatment, and diversion potential. Both the sediment delivery potential and the treatment immediacy are ranked low, moderate, or high. Ranking each controllable erosion site by these variables provides a hazard or risk assessment. This, in turn, allows MRC to prioritize road improvements and erosion control based on hazard rankings. In our reporting, MRC generates a map that shows road features and their treatment immediacy (see MAP B-2 in the watershed analysis reports on file).

An important variable of potential point source erosion is the likelihood of water diverting down the road prism—called diversion potential. This is a straightforward determination. If the crossing or culvert is plugged, will the water in the crossing or culvert divert—yes or no? In the case of a watercourse crossing that is plugged, dammed, or failed, a site has a diversion potential if water could divert from the natural watercourse channel onto the road prism. Water diverted out of its natural channel would erode the road prism and potentially create high sediment delivery.

Culvert sizing

Proper sizing of culverts is an important consideration for road erosion potential. To determine if existing culverts are the appropriate size, MRC inventories the area behind each culvert from topography data in the MRC Geographic Information System (GIS). We use the regression equation for the North Coast region (Waananen and Crippen 1977) to predict 50- and 100-year peak flow. With a nomograph, or calculating chart, we determine the appropriate culvert size for 50- and 100-year peak flow magnitudes based on a headwater depth-to-pipe diameter ratio of 0.67 (Cafferata et al. 2004); the predicted size is compared to the existing size of the culvert to determine if the culvert is large enough. This analysis of culvert sizing is only a “first cut.” We require a field visit to each culvert site to verify if the appropriate watershed drainage area was used and the culvert is, in fact, under-sized.

Factors influencing surface erosion

MRC did not estimate in the field the amount of surface erosion (or sheetwash) from roads; instead, we modeled the surface erosion. Our model was from the Standard Methodology for Conducting Watershed Analysis (WFPB 1995), which uses SEDMOD, an acronym for Spatially Explicit Delivery Model. In our road inventory, we collect information on most of the factors influencing surface erosion: contributing length of road erosion at watercourse crossings; the amount of road traffic (based on road type); road surface material; and width and size of road. Annual precipitation and vegetative cover are also factors in the model. Annual precipitation is derived from long-term climate records of the area; vegetation cover is assumed based on average observed conditions in the plan area. Our road inventory, however, does not provide *contributing length* for road segments adjacent to a watercourse but not associated with a culvert or crossing. Using GIS analysis, we can determine the contributing length of roads within a specified distance from a watercourse and assume certain estimates of sediment delivery (Table G-8). Our assumptions are based on sediment delivery ratios used in SEDMOD.

Table G-8 Estimates of Sediment Delivery

Distance of Road from Watercourse	Sediment Delivery to Watercourse
50 ft	100%
50-100 ft	35%
100-200 ft	10%

Assigning weights to factors

In modeling surface erosion from roads in each WAU, MRC made several general assumptions. Table G-9 shows these assumptions and, in some cases, the weights assigned to them. The purpose of *weighting* is to indicate the relative importance of evaluation factors; the higher the weight number, the more important the factor.

Table G-9 Assumptions for Surface Erosion Model

Assumptions
• Observed roads are older than 2 years and have a base erosion rate of 60 tons/ac/yr. • Width of road tread is 40% of the road prism. • Cut-and-fill slopes are 60% of the road prism (multiply road width by 1.5). • Cut-and-fill slopes have about 50% vegetation, giving a cover factor of .37. • Hauling on roads usually occurs during the drier times of year. As a result, we used the lowest annual precipitation category, i.e., <47 in. precipitation annually. In this annual precipitation category, a road with at least a 6 in. rock surface has a factor of 0.2; a native surface road has a factor of 1.

Table G-10 shows the weights specifically assigned to traffic factors.

Table G-10 Assigning Weights to Traffic Factors

Traffic Factors
• MAINLINE ROADS WITH HEAVY TRAFFIC These roads have a weight factor of 20 and are actively used and maintained for log haul traffic. • MAINLINE ROADS WITH MODERATE TRAFFIC These roads have a weight factor of 2 and are used for log haul traffic 2-3 times each decade. • SEASONAL ROADS These roads have a weight factor of 1.2 and are tributary roads which receive moderate log haul traffic 1-2 years each decade and light traffic the remainder of the time. • TEMPORARY ROADS These roads have a weight factor of 0.61 and receive moderate log haul traffic 1-2 times every 1-2 decades with little or no use in between.

Calculating sediment delivery from a road

Figure G-2 illustrates a sample calculation for determining the amount of sediment delivery from a specific road, including the assumptions behind the calculation.

EXAMPLE

Road material:	rock (0.5 factor)
Road traffic:	heavy use, mainline road (20 factor)
Road width:	16 ft. (assumption)
Contributing length:	1000 ft.
Vegetation cover:	50% on cut-and-fill slopes (0.37 factor)
Base erosion rate:	60 tons/ac/yr (assumption)

The calculations to estimate yearly surface and point source erosion from this road are:

Driving surface: 16’*1000’/43560 ft^2/ac *20 * 0.5 *60 tons/ac/yr = 220 tons/yr

Road cut/fill-slopes: 16’*1000’*1.5/43560 ft^2/ac *0.37 *60 tons/ac/yr = 12 tons/yr

Road surface erosion: 220 tons/yr (tread) +12 tons/yr (cut/fill-slope) = 232 tons/yr

Figure G-2 Sample Calculation of Sediment Delivery from a Road

Calculating sediment delivery from all roads in a WAU

MRC modeled each road in a WAU for surface erosion and summed the results in tons/yr for all roads. This sum was then divided by the number of plan area acres in the WAU (ac/mi^2) to provide a surface erosion delivery rate normalized by area (tons/mi^2/yr).

To get total surface and point source erosion from all roads in a WAU, we add the result from the surface erosion model to the total volume of point source erosion observed during the road inventory. We assume the point source erosion identified in the road inventory is representative of the past 5 years. In the total sediment delivery calculations, therefore, we divide the total point source erosion by 5. This result is then divided again by the total area of the WAU (mi^2) to provide a delivery rate normalized by area (tons/mi^2/yr).

EXAMPLE

Volume of surface erosion from model:	2000 tons/yr
Volume of point surface erosion observed:	3000 tons
Total area of WAU:	10,000 ac

The calculation to estimate the total surface and point source erosion is:

(2000 tons/yr +3000 tons/5 yr) / 10,000ac/640 ac/mi^2 = 132 tons/mi^2/yr

Figure G-3 Sample Calculation of Sediment Delivery from All Roads in a WAU

Classes of erosion hazard

With information on surface erosion, MRC assigns each road in the WAU an erosion hazard class. We determine the erosion hazard class from the amount of erosion a road has produced and the likelihood for that erosion to be delivered to a watercourse. In ranking roads for erosion hazard, we consider: (1) levels of traffic; (2) road surface; (3) proximity of a road to a stream; (4) past point source erosion; and (5) modeled surface erosion. We classify roads as high, moderate, or low erosion hazards depending on how much sediment and soil erosion they are likely to deliver. Finally, for forester use in prioritizing road work and decommissioning roads, we produce a map for each WAU with ratings for road erosion hazards (see MAP B-1 in the watershed analysis reports on file).

G.2.2.2 Standard method: skid trail erosion

Using aerial photos of an entire watershed analysis unit, MRC determines sediment delivery from skid trails. From the photos, we interpret skid trail density (high, moderate, low) for a specific year. Combining our surface erosion modeling with field observations from past watershed analyses, we develop our estimates of sediment delivery from skid trails (Table G-11).

Table G-11 Skid Trail Density and Sediment Delivery

Skid Trail Class	Skid Trail Density (watercourse crossing/mi^2	Sediment Delivery (tons/mi^2 /yr)
High	>100	600
Moderate	50-100	400
Low	<50 or significant re-vegetation	100

For each year of photo observation, the total area in a skid trail class was multiplied by the sediment delivery rate for that density. The estimate was then divided by the number of square miles of the plan area in each CalWater planning watershed to provide a sediment rate (tons/mi^2/yr) for each planning watershed. Finally, we assumed that the skid trail class and its sediment delivery rate represented skid trail activity in the decade prior to the year of photo observations (e.g., a 1970 photo shows skid trail activity from the 1960s).

Results from South Fork Caspar Creek in the early 1970's suggest that high density tractor logging—practices used at that time—generated approximately 600 tons/mi^2/yr (Rice et. al., 1979). This is double the estimates of sediment delivery from high density skid trails used in MRC watershed analysis reports to date. As a result, in preparing Table 3-11, we doubled our sediment estimates from those in the watershed analyses. Future watershed analyses will also use higher sediment delivery rates for the various skid trail densities. In fact, the watershed analysis at Greenwood Creek, completed in 2004, used this higher sediment rate for skid trail evaluations.

G.2.2.3 MRC methods for evaluating sediment delivery from roads in specific WAUs

G.2.2.3.1 Garcia WAU

MRC methods for determining surface and point source erosion in the Garcia WAU differed from the standard method described in G.2.2.1. In the Garcia WAU, we did not use the road inventory to define parameters for the model; instead, we used a separate sampling of roads in the watershed. If we did not observe a road in the field, we assigned it the average delivery rate extrapolated from similar roads in the area. Moreover, we did not do a sizing analysis of culverts in the Garcia WAU. Table G-12 lists the parameters for the surface erosion model in the Garcia WAU.

Table G-12 Parameters for Surface Erosion from Roads in the Garcia WAU

Garcia WAU					
Road Class	**Base Erosion Rate (tons/ac/yr)**	**Cover Factor for Cut and Fill Slopes**	**Surface Material Factor for Road Tread**	**Traffic + Precipitation Factor**	**Time in Heavy Use Factor (yr)**
Mainline					
<2 yrs old	110	0.37	0.75*	24.5	5
>2 yrs old	60				
Secondary					
<2 yrs old	110	0.37	0.75*	2.3	2
>2 yrs old	60				
Temporary					
<2 yrs old	110	0.37	0.75*	1	2
>2 yrs old	60				
Abandoned	60	0.37	0.75*	0.025	0

TABLE NOTE
* Most common factor; in some cases, based on field observations of road.

G.2.2.3.2 Big River WAU

The Big River WAU did not have a complete road inventory at the time of its initial watershed analyses. MRC had data on 40% of the road network. We determined surface and point source erosion from field observations and from a model for road surface erosion.

MRC sampled roads by planning watershed, hillslope class, and traffic use (mainline or secondary). In the case of hillslopes, we designated their relative location to Class I watercourses, as follows:

- Low slopes equate to the lower 20% of a hillslope between a watercourse and a ridge.
- Mid slopes equate to the middle 20-80% portion of a hillslope between a watercourse and a ridge.
- Top slopes equate to the upper 20% of a hillslope near a ridge.

Roads adjacent to watercourses typically deliver more erosion than upper slope roads; therefore, it was useful to segregate them during sampling. We also collected observations for potential point source erosion (controllable erosion) at road sites that appeared to have an immediate need for maintenance or upgrade.

In modeling surface erosion from roads in the Big River WAU, MRC made several general assumptions (see Table G-9). MRC assigned weights to various factors. Landing areas have a factor of 0.1; these areas receive moderate to high usage only 1-2 times every 1-2 decades with little or no use in between. A road with at least a 6-inch rocked surface has a 0.2 factor; a 3-6 in. rocked surface has a 0.5 factor; a native surface road has a factor of 1.0; a paved road surface has a factor of 0.03. We also assigned weights to traffic factors for mainline roads with moderate traffic, seasonal roads, and temporary roads (see Table G-10).

To arrive at an estimate of sediment delivery for roads not observed in the field, we extrapolated data from roads observed in the field. Estimates were for both surface erosion and point source erosion. MRC did not conduct sizing analysis of culverts in the Big River WAU.

G.2.2.3.3 Noyo WAU

The surface and point source erosion estimates for the Noyo WAU followed the standard methods in G.2.2.1. In some cases the road inventory lacked contributing road length. In these cases the contributing road length was assumed to be 200 ft. Estimates for the surface erosion model were only for watercourse crossing; they did not include road segments adjacent to, but not crossing, watercourses. MRC did not conduct sizing analysis of culverts in the Noyo WAU.

G.2.2.3.4 Albion WAU

The surface and point source erosion methods differed from the standard methods in G.2.2.1. In the Albion WAU, we did not use the road inventory to provide parameters for the model; instead we conducted a separate sampling of roads in the watershed. Roads not visited in the field were assigned the average delivery rate extrapolated from similar roads in the area. Table G-13 shows the parameters for the surface erosion model in the Albion WAU. It varies from the format in Table G-12. When we modeled erosion in the Albion, we used different model coefficients based on different categories within the factors, such as road class and vegetative cover. Again, MRC did not conduct sizing analysis of culverts in the Albion WAU.

Table G-13 Parameters for Surface Erosion in the Albion WAU

Traffic/Precipitation Factor for Road Classes				
Road Class	**Active/Mainline**	**Active/Secondary**	**Light/Non-active**	**No Traffic/ Abandoned**
Factor	24.5	2.3*	1	0.025

Vegetative Cover Factor for Cut/Fill Slopes						
% Vegetative Cover	**80**	**50**	**30**	**20**	**10**	**0**
Factor	0.18	0.37*	0.53	0.63	0.77	1.0

Surface Material Factor for Road Tread			
Road Type	**n** (native surface)	**n-2** (< 2” rock)	**2** (2-6” rock)
Factor	1.0	0.75*	0.5

Delivery Factors for Tread and Cut/Fill Slopes		
Prism Section	**Tread**	**Cut and Fill Slopes**
Factor	0.95	0.55

TABLE NOTES

* Most common factor, based on field observation.

Generally, calculations begin with a base erosion rate of 60 tons/ac/yr.

G.2.2.4 MRC methods for evaluating sediment delivery from skid trails in specific WAUs

G.2.2.4.1 Garcia WAU

In estimating sediment delivery from skid trails, MRC used the density of skid trail watercourse crossings per unit area, as determined from aerial photos. Next we multiplied the number of crossings per unit area by 300 since field observations determined that 300 ft is the average skid trail delivery length per water crossing. From aerial photographs and conversations with area foresters, we then determined the harvest areas that used skid trails. We multiplied the percentage of harvest area using skid trails by the deliverable length of skid trails per unit area to yield the total deliverable length of skid trails per time period. For a traffic factor, we selected temporary roads from Table G-10, even though, in the erosion calculations, skids trails have a narrower width than temporary roads. Because of TMDL issues in the Garcia watershed, our efforts, described above, were more intensive than the standard methods.

In the future, our non-source point erosion estimates of skid trails will be solely from aerial photographs for all watershed analyses (see G.2.2.2). Point source erosion (controllable erosion) estimates of skid trails will incorporate a field survey component to calibrate aerial photograph estimates.

G.3 Summary on Sediment Input

G.3.1.1 General method

This section combines and summarizes the sediment input results from two modules of the watershed analysis—mass wasting along with surface and point source erosion. MRC estimated sediment input for each WAU from hillslope mass wasting; road-associated mass wasting; surface and point source erosion from roads; and surface and point source erosion from skid trails. The road-associated mass wasting included the skid trail mass wasting. Future watershed analyses will summarize sediment inputs within a synthesis module.

G.3.1.2 MRC methods in specific WAUs

G.3.1.2.1 Big River WAU

Estimates for skid trail erosion are the sum of estimates for skid trail mass wasting and surface and point source erosion; we have removed the skid trail mass wasting from the road associated mass wasting.

G.3.1.2.2 Garcia WAU

For the Garcia WAU, we not only quantified sediment inputs but analyzed changes to sediment storage. We determined sediment storage in streamside terraces and in storage sites of the stream bed, such as behind woody debris dams. Terrace volumes of individual discrete terraces were calculated by measuring length, width, and depth values with pace and tape measuring techniques. Large continuous terrace volumes (usually at the mouths of sub-basins of the WAU) were calculated by averaging width and depth of the terrace and measuring length on the map. Channel storage volumes were determined by measuring the length, width, and depth of the active channel with the same techniques used on terraces. Depth is the limiting measurement in the accuracy of these techniques. For this study, the depth of terrace deposition was assumed to be the distance from the deepest scour in the active channel to the top of the terrace surface. Field evidence used to determine depth of channel storage included the depth of scour pools and the depth measured at the downstream side of debris dams. When this information was not available a channel storage depth of 1 ft was assumed to be an approximate average streambed scour depth. Since these techniques underestimate terrace and stream channel depths, storage volume was a minimum estimate.

Cumulative terrace and channel storage volume was then calculated as a sum of individual terrace and stream data collected in the field. This data was used to extrapolate storage volumes to stream reaches not visited in the field. Collected and extrapolated data was combined to calculate terrace and stream channel storage totals for each hydrologic unit. Based on field observations, the terraces in the response reaches of the hydrologic units in the WAU, with the exception of the main stem of the Garcia River, was assumed to have been created 30-40 years ago. This assumption was based primarily on even-aged alder stands about 30-40 years old found on the terraces. Furthermore, logging debris, such as cut logs and truck tires, were observed in the terrace stratigraphy, suggesting initial terrace deposition was during the period of modern forest management in the Garcia WAU, from the 1950's to the present. The stratigraphy of the terrace deposits shows many layers of sediment ranging in thickness from 1–10 in. Each individual layer is composed of a characteristic class size. Class sizes range from sand to gravel to cobble. The cobble layers are angular in shape, suggesting they have not been transported very far and were probably derived from hillslope erosion processes. We estimated the terraces were deposited over 3-15 years and represent multiple flood and sediment transport events. Hydrologic data for the Garcia River shows numerous flood events (magnitude > 2 yr. return interval) within the last 30-40 years, that are capable of moving large sediment loads, creating terraces as the flood wave recedes.

G.3.2 Module: hydrology

G.3.2.1 Standard methods

This section provides the available peak flow data for the WAUs. MRC uses peak flow data to show the magnitude of storms and when they occurred. To estimate the recurrence interval of floods, we use the annual peak flow series. An extreme value type I distribution (Gumbel 1958) was fitted to the data to provide return intervals for different levels of streamflow.

G.3.2.2 Hydrology methods used in the WAUs

Table G-14 shows how the methods MRC used in specific WAUs differed from the general hydrology method.

Table G-14 Differences in Hydrology Methods

Differences in Hydrology Methods	
WAU	**MRC Method vs. General Method**
Garcia River	The peak flow information was taken from the Garcia River Gravel Management Plan (Philip Williams and Assoc. 1996). Hydrologic data was collected by the United States Geological Survey (USGS) gage 11467600 from 1962-1983. The gauged period of record at the Garcia River USGS gaging station was extended using a synthesis of data from a continuous gaging record for the nearby Navarro River (Philip Williams and Associates 1996).
Albion River	The Navarro River peak flow data was the only long term river flow data available in close proximity to the Albion WAU. The Navarro River peak flow data probably does not provide a direct relationship with the peak flows of the Albion River. However, for the purpose of showing the timing and magnitude of large storm events of the area, the Navarro River peak flow data is assumed to be sufficient.
Noyo River	No difference
Big River	Other than the few years of stream flow information on the South Fork Big River, there is little information on peak storm events in Big River. Therefore, the information from the Noyo River and the Navarro River is presented to give an indication of storm timing and magnitude.

Differences in Hydrology Methods	
WAU	**MRC Method vs. General Method**
Hollow Tree Creek	The only available river peak flow data close to Hollow Tree Creek came from the South Fork Eel River (at Leggett). For the purpose of showing the timing and magnitude of large storm events of the area, this peak flow data is assumed to be sufficient.
Navarro River	No difference
Greenwood Creek	The Navarro River peak flow data was the only long term river flow data available in close proximity to the Greenwood Creek WAU. The Navarro River peak flow data probably does not provide a direct relationship with the peak flows of the Greenwood Creek. However, for the purpose of showing the timing and magnitude of large storm events of the area, the Navarro River peak flow data is assumed to be sufficient.
Northern Russian River	The only available river peak flow data close to Ackerman Creek came from the Russian River. For the purpose of showing the timing and magnitude of large storm events of the area, this peak flow data is assumed to be sufficient.
Cottaneva Creek	No difference
Elk Creek	No difference
Southcoast Streams	Complete by 2012
Rockport Coastal Streams	Complete by 2012

G.3.3 Module: riparian function

Our assessment of riparian function has two components:

1. Potential of the riparian stand to recruit LWD in order to meet the current demand of LWD in stream channels.

   This component evaluates the current condition of the riparian stands for generating LWD for stream habitat or stream channel stability. To determine current instream needs, we present field observations of current LWD levels in the stream channels and the ability of a riparian stands to recruit LWD in relation to channel sensitivity to LWD.

2. Canopy closure and stream temperature.

   This component shows current canopy closure above streams and its relation to stream temperature.

G.3.3.1 General methods for LWD recruitment

In general, MRC analyzes stream channels with a gradient below 20%. When channel gradients exceed 20%, we consider them to be source channels that are not as responsive to LWD.

They can, however, be a source for downstream LWD from mass wasting processes. To determine LWD-recruitment potential, we classify stands along selected watercourse segments[3] to cover a range of stream-side stand conditions using aerial photographs and field observations. For each re-survey of a watershed unit, we apply the same level of effort described in Table G-2. We evaluate these stands for a distance of approximately 1 site-potential tree-height on both sides of the stream channel, delineating a separate stand on each side of the watercourse. To classify the riparian stands, we use the codes in Table G-15 and Table G-16.

Table G-15 Vegetation Classes

Code	Description
RW	Coast redwood constitutes >75% of the stand basal area.
RD	Combined basal area of Douglas fir and coastal redwood exceeds 75% of the stand basal area, but neither species alone is 75% of the basal area.
MH	Mixed hardwoods constitute >75% of the stand basal area, but no one hardwood species is 75% of the basal area.
CH	Mix of conifer and hardwood exceeds 75% of the stand basal area, but no one hardwood or conifer species is 75% of the basal area.
BR	Brush

Table G-16 Vegetation Size Classes

Code	DBH
1	<8.0 in.
2	8.0-15.9 in.
3	16.0-23.9 in.
4	24.0-31.9 in.
5	>32.0 in.

MRC determines a stand's size class by starting with the proportion of basal area in size class 5 and summing the percentage of basal area in each lower size class. The size class at which the sum exceeds 50% of the total basal area becomes the size class for the stand. For example, if 30% of a stand is size class 5, 10% size class 4, 15% size class 3, 25% size class 2, and 20% size class 1, then the stand, as a whole, is size class 3 because the sum of size classes 5, 4, and 3 is greater than 50%.

Table G-17 Vegetation Density

Code	Tree Canopy Cover Range
O	5-20%
L	20-40%
M	40-60%
D	60-80%
E	>80%

[3] These can be watershed analysis, focus watershed studies, or long-term channel monitoring segments. Typically, segments are delineated at ownership boundaries, gradient breaks, and tributary junctions. Usually the length of each segment is at least 20-30 times the bankfull width or anywhere from 300 to 1500 ft. The average planning watershed where MRC owns a majority of the watershed contains roughly 10–20 segments for watershed analysis and 1 long-term channel monitoring segment.

MRC determines vegetation density in the field by ocular estimation of the amount of canopy cover within the riparian stand at the sampling location. Vegetation density is not the amount of instream shade, nor is it equivalent to timber inventory data on riparian canopy. Rather, a determination of vegetation density helps us classify the potential of a riparian stand for LWD recruitment.

To classify vegetation within streamside stands, we concatenate codes for vegetation class, size class, and vegetation density. For example, RW3D designates a redwood stand with more than 50% of its basal area in trees ≥16–23.9 in. dbh and a canopy cover of 60-80%.

Table G-18 summarizes our ratings of LWD recruitment potential based on vegetation, size, and density classifications.

Table G-18 Ratings of LWD Recruitment Potential

	Size and Density Classes					
	Size Classes 1-2 (Young)		**Size Class 3 (Mature)**		**Size classes 4-5 (Old)**	
	Sparse	**Dense**	**Sparse**	**Dense**	**Sparse**	**Dense**
Vegetation Type	**(O, L)**	**(M, D, E)**	**(O, L, M)**	**(D, E)**	**(O, L)**	**(M, D, E)**
RW	Low	Low	Low	Moderate	Moderate	High
RD	Low	Low	Low	Moderate	Moderate	High
CH	Low	Low	Low	Moderate	Low	High
MH	Low	Low	Low	Moderate	Low	Moderate

For all of the riparian stands in the watershed, MRC uses field observations to calibrate estimates of vegetation density from aerial photography. We may not always find a range of vegetation classes and recruitment potentials in each watershed; in some cases, for example, MRC only owns a small portion of a planning watershed. In these cases, we draw upon data collected throughout the ownership to calibrate our estimates.

LWD observed in streams

MRC inventories LWD in watercourses during the stream-channel assessment of a watershed analysis. LWD is classified as either a key piece or a functional piece, based on research on LWD in streams in the Pacific Northwest (Bilby and Ward 1989).

DEFINITION

A **key piece** is any piece of wood, meeting MRC criteria for length, diameter, and volume; MRC assumes that key pieces are stable and have the ability to retain other LWD.

Functional LWD is any piece of wood greater than 4 in. (10 cm) in diameter and at least 6 ft (2 m) in length that is within the bankfull dimensions of the channel; stumps can be functional LWD even if they are less than 6 ft in length.

We have observed in many MRC watercourses that certain pieces of LWD function as key pieces but do not meet either the diameter or length criterion for that channel size. For example, a massive stump may meet the diameter criterion of a key piece but not the length criterion. Though relatively short in length, large stumps can have enough mass to remain stable in the channel and act as a key LWD piece; consequently, we developed a supplemental criterion of minimum volume to capture the functional importance of such LWD pieces. We determined thresholds for minimum volume by stream size and calculated the volume of a key piece based on the diameter and length criteria for a key LWD piece. We then tripled these calculated volumes to decrease the probability of classifying non-key LWD pieces as key pieces. Table G-19 summarizes the MRC requirements for key LWD. LWD must meet the criteria for both diameter and length or the criterion for volume in order to be considered a key piece.

Table G-19 Minimum Diameter, Length or Volume for Key LWD[4]

Bankfull Width (ft)	Diameter (in.)	Length (ft)		Volume Alternative* (yds^3)
0-10	13	1.5 times the channel width		1
10-20	16	1.5 times the channel width		3
20-30	18	1.5 times the channel width	or	5
30-40	21	1.5 times the channel width		8
40-60	26	1.5 times the channel width		15
60-80	31	1.5 times the channel width		25
80-100	36	1.5 times the channel width		34

TABLE NOTE
A piece of LWD counts as a key piece if it does not meet the diameter and length criteria but exceeds this minimum volume.

For temporal or spatial comparison, MRC normalizes the observed quantity of LWD; we divide the quantity by distance (e.g., number of key LWD pieces per 328 ft). To determine if a watercourse contains appropriate amounts of LWD, MRC compares the quantity of key pieces in the bankfull channel (per 328 ft) to the desired key piece targets (Table G-20).[5]

Table G-20 Targets for Key LWD Pieces in Watercourses

Bankfull Width (ft.)	Minimum Number of Key LWD Pieces Per 328 ft
<15	6.6
15-35	4.9
35-45	3.9
>45	3.3

Channel sensitivity to LWD

MRC determines channel sensitivity during a stream channel assessment in a watershed analysis. Stream channels with similar physical characteristics are typed as geomorphic units based on similarity of response to coarse or fine sediment and LWD. We categorize channel sensitivity as high, moderate, or low based on the range of stream geomorphic conditions found on MRC property.

- HIGH SENSITIVITY TO LWD

  Channels with moderate-to-low confinement (Montgomery and Buffington 1993) or moderate-to-low entrenchment ratios[6] and gradients

[4] Adapted from Bilby and Ward 1989
[5] Derived from Bilby and Ward (1989) and Gregory and Davis (1992)
[6] Entrenchment ratio (floodprone width/bankfull width) is greater than 1.4, as defined by Rosgen 1994.

lower than 4% generally exhibit high response to LWD inputs. These channel types have room within canyon walls to provide some meander or floodplain interactions. This ability of the channel either to interact with a floodplain or to meander provides for a greater propensity of LWD to direct and influence water flow, which develops channel morphology and sediment scour or storage. At slope gradients below 3-4%, the water energy of the channel decreases, turning channels into response reaches (Montgomery and Buffington 1993). Water flow begins to take on a lateral component rather than a strictly vertical movement as found at higher channel gradients—typically above 2-4%; this allows LWD to have a higher influence (Montgomery and Buffington 1993). Avulsion channels and floodplains of channel migration zones (CMZ) also appear highly responsive to LWD. These zones typically have low gradients, which allow water flow to move throughout the migration zone over time. Because the channel water migrates throughout the zone, the entire migration zone needs LWD to provide potential aquatic habitat.

- MODERATE SENSITIVITY TO LWD

Channels with high confinement (Montgomery and Buffington 1993) or a high entrenchment ratio[7] and gradients typically 0-10% exhibit moderate response to LWD inputs The high confinement or entrenchment of these channels provides little opportunity for the channel to meander or develop a floodplain. Water energy remains concentrated within the confines of canyon walls or stream banks, reducing the influence of LWD. In the lower gradient watercourses (<3-4%) with high confinement or high entrenchment, LWD has a lower probability of entering the channel because it becomes suspended over the channel's narrower bankfull widths. In channels with slope gradients of 4-10%, LWD typically serves to store sediment or develop forced step-pools. Bed morphology in channels with slope gradients of 4-10% usually consists of step pools (Montgomery and Buffington 1993). The large bed-forming material of step-pools generally remains stable (Whittaker 1987; Grant et. al. 1990), decreasing the role of LWD in these channels. Channels with >10% gradient in Franciscan Mélange terrain, however, appear prone to degradation and bank erosion if the channel does not contain LWD. This characteristic makes high-gradient watercourses in this geologic formation of moderate sensitivity to LWD compared to similar channels on MRC property.

- LOW SENSITIVITY TO LWD

Channels with high-gradient transport segments and a slope gradient typically >10% (including source reaches) exhibit low response to LWD inputs—except for channels in Franciscan Mélange terrain. At about a 10% slope gradient, channel-type changes from step-pool morphology to a cascade morphology (Montgomery and Buffington 1993) that experiences less influence from LWD. Although LWD stores sediment and serves as a source for downstream LWD in these channels, downstream delivery of upstream LWD occurs only episodically and

[7] Less than 1.4, as defined by Rosgen 1994

smaller LWD stores sediment in these channels effectively. Regime channel-types, usually forced by point bar development toward the outlet of large river systems, also have low sensitivity to LWD inputs (Montgomery and Buffington 1993). Regime channels typically have relatively wide bankfull channels and low gradients. LWD plays a minor role as an organic food source and provides some scour and cover along regime channel edges; however, the size and pattern of regime channels typically make LWD stability in the channel unlikely.

To determine a stream segment's instream LWD demand, we use a table built upon the 3 factors discussed in this sub-section: LWD recruitment potential rating, key LWD, and channel LWD sensitivity rating.

Table G-21 Instream LWD Demand

Recruitment Potential Rating	Key LWD	Channel LWD Sensitivity Rating		
		Low	**Moderate**	**High**
Low	On Target	Low	Moderate	High
	Off Target	High	High	High
Moderate	On Target	Low	Moderate	Moderate
	Off Target	High	High	High
High	On Target	Low	Moderate	Moderate
	Off Target	Moderate	High	High

MRC produces a map for the WAUs (MAP D-1 in the watershed analysis reports on file) showing the LWD recruitment potential and instream LWD demand.

LWD quality rating
For each planning watershed with an analyzed stream segment, MRC determines an LWD quality rating. The LWD quality rating depends on

- The percentage of watercourse segments with low or moderate LWD demand.
- The percentage of watercourse segments (based on stream length) with an appropriate number of key LWD pieces.

Appendix S, *Targets for LWD and Effective Shade* (Table S-2) provides LWD quality ratings. In defining ratings for LWD conditions in watercourses, MRC assumed that streams and watersheds are dynamic. LWD loadings are variable. It is unrealistic to set a goal that 100% of stream segments will be on target for LWD demand. However, if less than 50% of the watercourses have low or moderate LWD demand, we conclude there is an LWD deficiency.

MRC wants to ensure that enough key LWD exists at both small (i.e., stream segment) and large (i.e., planning watershed) spatial scales. To do so, we consider key LWD, as opposed to all LWD or functional LWD, in determining both instream LWD demand and overall LWD condition

G.3.3.2 MRC methods for evaluating LWD recruitment in specific watershed analysis

Table G-22 shows how the methods MRC used to evaluate LWD recruitment in specific WAUs differed from the general method.

Table G-22 MRC Methods for Evaluating LWD Recruitment in the Plan Area

WAU	MRC Method vs. General Method
Garcia River	No difference
Albion River	No difference
Noyo River	No LWD quality rating developed in the watershed analysis report; however the rating was developed and presented in Section 3.0 of this HCP/NCCP. No minimum size requirement was used for functional LWD.
Big River	No difference
Hollow Tree Creek	No difference
Navarro River	No difference
Greenwood Creek	Additional LWD input information collected during the LWD surveys (see Table G-23).
Northern Russian River	No difference
Cottaneva Creek	No difference
Elk Creek	No difference
Southcoast Streams	Complete by 2012
Rockport Coastal Streams	Complete by 2012

Table G-23 shows the recommended classifications of instream LWD for use in future watershed analysis efforts. MRC identified LWD characteristics during our stream surveys for the Greenwood WAU.

Table G-23 Instream LWD Characteristics

Instream LWD Characteristics		
Category	**LWD Attribute**	**Description**
LWD species	Redwood	• Coast redwood
	Fir	• Douglas fir, hemlock, grand fir, nutmeg, spruce, or pine
	Alder	• Red or white alder
	Hardwood	• All other hardwoods (oak, bay laurel, maple, etc.)
	Unknown	• Cannot identify species
LWD dimensions	Length	Total exposed length including portion outside bankfull channel **NOTE** Any portion buried in streambed cannot be measured.
	Diameter	Diameter at center of LWD piece. **NOTE** The center of a piece of LWD is not always in the stream channel.
	Bankfull portion	Percent of length of LWD within bankfull channel
Association with other LWD	Debris accumulation	> 3 but < 10 functional LWD pieces in contact with each other
	Debris jam	≥ 10 functional LWD pieces in contact with each other

Instream LWD Characteristics		
Category	**LWD Attribute**	**Description**
Decay class (Robison and Beschta 1990a)	Decay class 1	Bark intact, twigs present, texture intact, round shape, original wood color
	Decay class 2	Bark intact, twigs absent, texture intact, round shape, original wood color
	Decay class 3	Trace of bark, twigs absent, texture smooth with some surface abrasion, round shape, original wood color or darkening
	Decay class 4	Bark absent, twigs absent, texture with surface abrasion, some holes and openings, round to oval shape, dark wood coloring
	Decay class 5	Bark absent, twigs absent, texture is vesicular with many holes and openings, round to oval shape, dark wood coloring
Special characteristics	Buried	Part of LWD is buried in the stream bed or banks.
	Rootwad	LWD has rootwad attached.
	Alive	LWD is alive.
Location	Station (ft)	Location of the center of each LWD piece within the longitudinal profile (i.e., station or distance along the longitudinal profile)
Input process **NOTE** Identify only one process per LWD piece—the dominant input process.	Windthrow	Entire tree uprooted and recruited by wind
	Wind fragmentation	Portion of tree broken and recruited by wind
	Bank erosion	Tree or LWD that was delivered from erosion of the bank
	Mass wasting	LWD delivered from a mass wasting event(s)
	Logging associated	LWD placed or delivered from past harvest activities (e.g., LWD from a Humboldt crossing) **NOTE** Only use this designation if harvesting processes (road building, yarding, or tree falling) deliver the LWD into the channel.
	Restoration	LWD placed as part of a restoration effort
	Unknown	Cannot identify the input process

G.3.3.3 Standard methods for instream canopy and shade

MRC estimates canopy closure over watercourses from aerial photos and field observations. Table G-24 shows the canopy closure classes. Using field observations, we calibrate estimates of instream canopy for all watercourses in the watershed. We may not observe all of the canopy closure classes in each watershed; in some cases, for example, MRC only owns a small portion of a planning watershed. In these cases, we draw upon data collected throughout the ownership to calibrate our estimates.

Table G-24 Estimated Levels of Canopy Closure from Aerial Photographs

Stream and Bank Visibility	Canopy Closure
Stream surface not visible	>90% canopy closure
Stream surface visible or visible in patches	70-90% canopy closure
Stream visible but banks are not visible	40-70% canopy closure
Stream surface and banks partially visible	20-40% canopy closure
Stream surface and banks visible	<20% canopy closure

Prior to 2006, MRC monitored canopy closure over select stream channels. In most instances, we used a spherical densiometer, although we did occasional estimates with a solar pathfinder based on the August sun path line. All of our observations of instream canopy since 2006 have been exclusively with a solar pathfinder. A solar pathfinder provides a better estimate of canopy by taking into account aspect and topography. It measures watercourse shade resulting from both topography and canopy, whereas the spherical densiometer usually only measures shade from vegetation. We will rectify data collected with a spherical densiometer so that it is comparable with data from a solar pathfinder. In all cases, we estimate at approximately 1-3 evenly spaced intervals along a channel sample segment, typically a length of 20–30 bankfull widths. Calculating an average of all the readings for the channel segment gives the estimated canopy closure for the entire segment.

MRC monitored stream temperature in Class I and select Class II watercourses in the WAU. Monitoring occurs during the summer months when the water temperatures are highest. The stream temperature recorders were typically placed in shallow pools (less than 2 ft in depth) directly downstream of riffles—sections in a stream where water breaks over rocks or other obstructions (Figure G-4).

Figure G-4 Pools, Riffles, and Temperature Recorder

We calculate maximum and mean daily temperatures for each temperature monitoring site and year. For maximum weekly average temperatures (MWATs) and maximum weekly maximum temperatures (MWMTs), we use a 7-day average of the mean and maximum daily stream temperatures. Figure G-5 depicts the typical placement of stream temperature monitoring probes (purple stars) and channel segment assignments (numbered 1-9) for a hypothetical watershed.

Instream effective shade rating
MRC assesses conditions for instream effective shade based on 2 factors: stream temperature and stream canopy cover. A stream is on-target for effective shade if stream temperatures at that location are below 15°C, even if canopy cover is deficient. We take measurements of instream canopy at discrete points rather than continuously throughout surveyed stream segments. Next we apply an average canopy value to that segment. In the future, we will base targets for effective shade on the number of segments surveyed since we assume that canopy cover will likely increase evenly across our land, except in those areas receiving restoration treatments.

Moreover, MRC assumed that the amount of natural canopy closure is a function of the width of the stream, i.e., larger streams will naturally have lower levels of canopy closure and smaller streams will naturally have higher levels of canopy closure. We used an EPA-based assessment canopy closure as a function of bankfull width (see Figure G-6, Figure G-7, and Figure G-8, taken from the USEPA 2000).

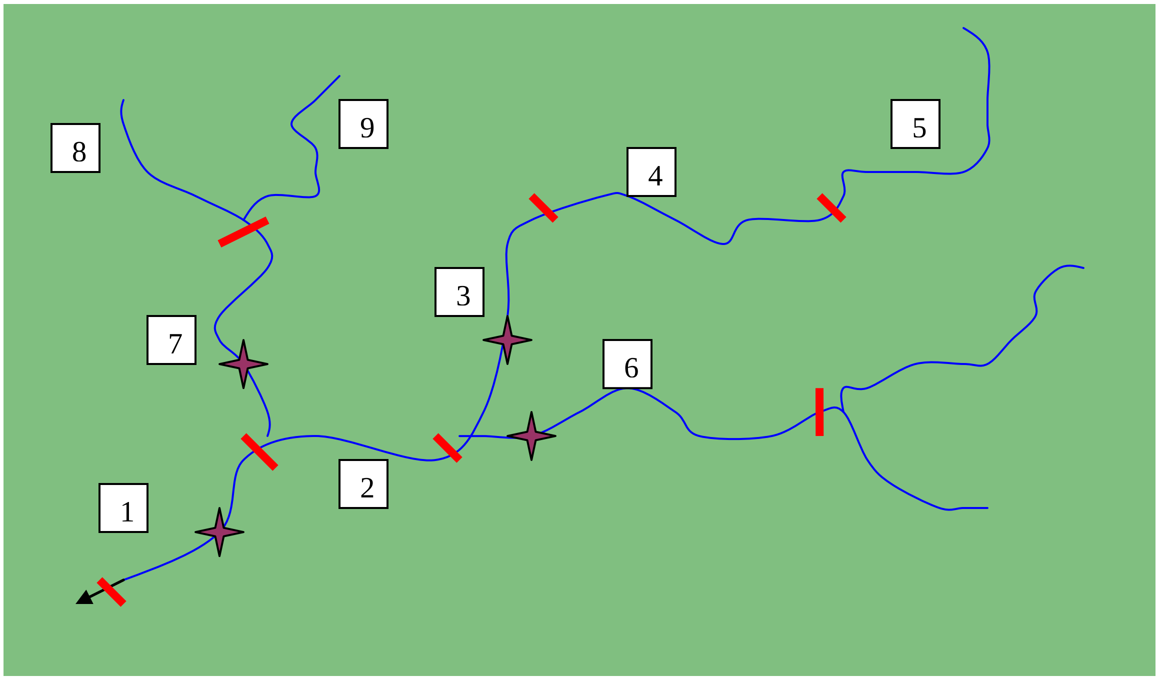

Figure G-5 Typical Stream Temperature Monitoring and Segment Locations

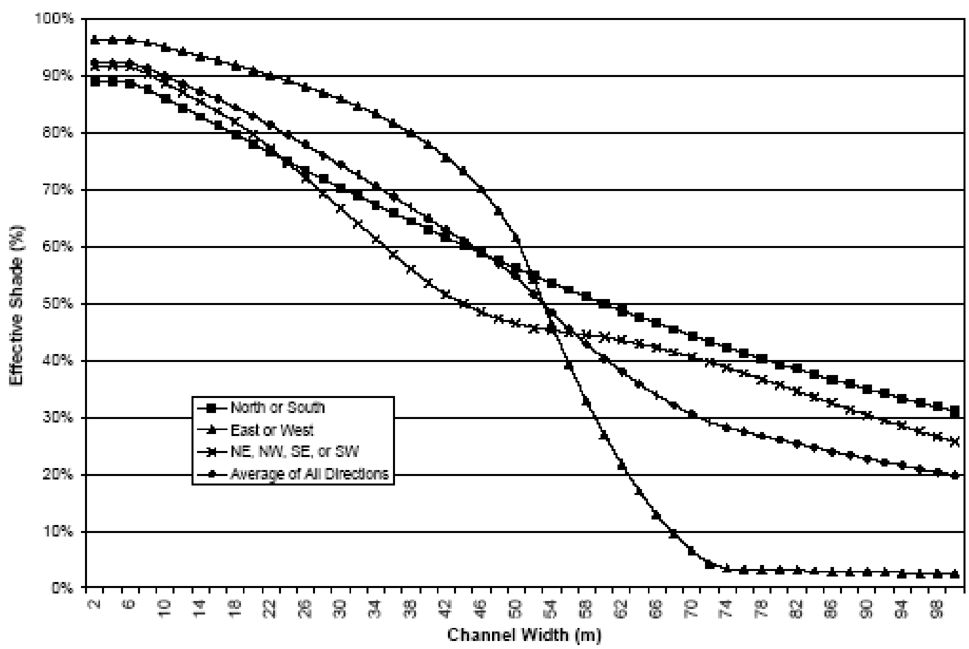

Figure G-6 Effective Shade vs. Channel Width (Redwood)

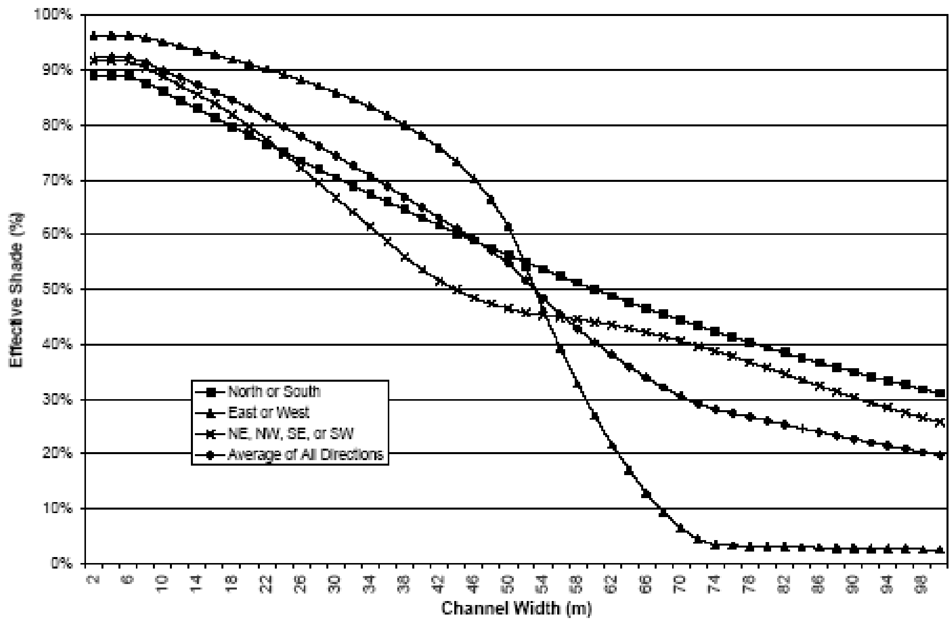

Figure G-7 Effective Shade vs. Channel Width (Douglas Fir/Hardwood-Conifer)

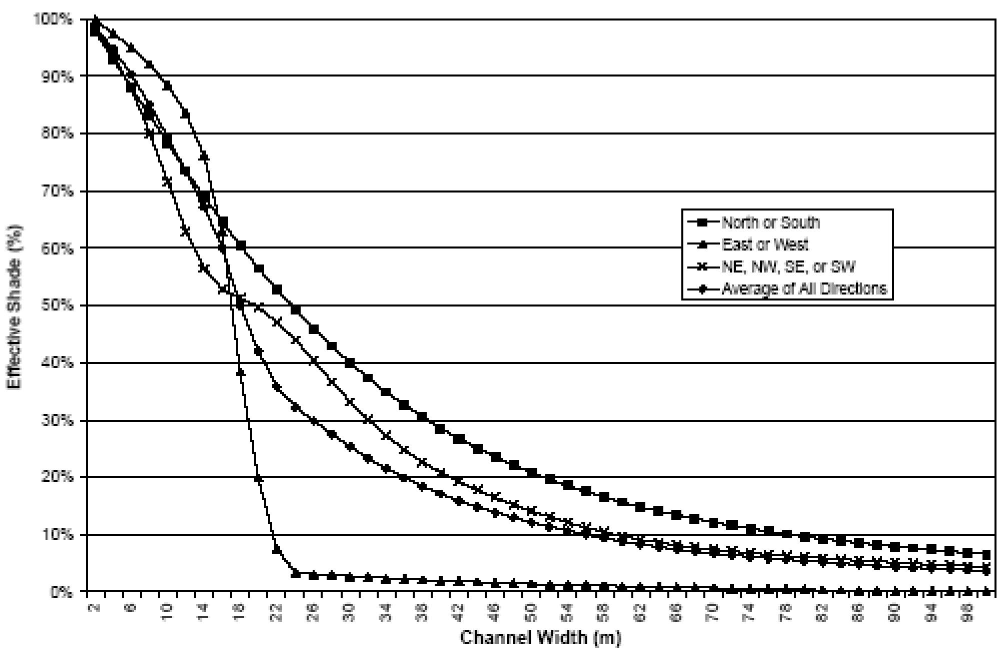

Figure G-8 Effective Shade vs. Channel Width, (Oak Woodland)

The North Coast Regional Water Quality Control Board (NCRWQCB) originally developed the graphs in Figures G-6 through G-8 for the EPA Navarro TMDL. The basis of the graphs were GIS models of effective shade under current (impaired) conditions and under future site-potential conditions predicted to achieve desired temperature targets. Figures G-7 and G-8 depict future site-potential shade conditions over a stream, versus bankfull width. However, MRC is using these curves to determine achievable levels of canopy cover based on segment width. Clearly, smaller streams will achieve more canopy than larger streams. MRC also includes stream temperature data, where available, in the analysis of effective shade.

Looking closer at Figures G-6 through G-8, we can see that the amount of canopy closure for a 30-ft wide stream (roughly 10 m) is approximately 90% (averaged across all directions) for a redwood forest and less for a mixed hardwood forest and oak woodland. MRC chose 90% canopy cover for this channel size as the most conservative value; however, we recognize that other types of habitat may not achieve this target. For a 100-ft stream (30 m), the effective shade (or canopy closure) in coniferous-hardwood forest (Figures G-6 and G-7) drops to around 70%; for oak woodland, effective shade drops to about 40% (Figure G-8). As a result, we use a conservative canopy cover value of 40% for all channels between 100 and 150 ft. Table G-25 summarizes the target canopy cover values by bankfull width that MRC uses to assess riparian stand conditions. We did not choose values for mid-point canopy cover (from Figures G-6 through G-8) for the bankfull widths indicated in Table G-25 since the wider streams would not achieve the higher target; in addition, temperature is also a component in determining the overall rating for effective shade.

Table G-25 Canopy Cover as a Function of Bankfull Width

Rating	Bankfull Width (ft) of Watercourse Segment	Percent Canopy Closure
ON TARGET	< 30	> 90
ON TARGET	30–100	> 70
ON TARGET	100–150	> 40

The process of determining effective shade for each watercourse segment is as follows:

1. What is the maximum weekly average temperature (MWAT) for the watercourse segment?

    a. If the MWAT value for the watercourse segment (averaged over the past 3 seasons) is below 15°C, conclude that current shade conditions provide "on-target" effective shade.
    b. If the MWAT value for the watercourse segment is above 15°C, proceed to Step 2.
    c. If no temperature data is available for the watercourse segment, assume that the segment does not meet the temperature target and proceed to Step 2.
2. Does the segment[4], based on bankfull width, meet the average canopy requirement (see Table G-25)?

The number of stream segments (not weighted by stream length) that meet their requirements for stream temperature or canopy cover is the basis for the assessment of effective shade in a planning watershed, as shown in Table G-26.

Table G-26 Rating Effective Shade by Planning Watershed

ON TARGET	More than 80% of surveyed watercourse segments within the planning watershed have on-target effective shade.
MARGINAL	60-80% of surveyed watercourses segments within the planning watershed have on-target effective shade or at least 70% canopy.
DEFICIENT	Less than 60% of surveyed watercourses segments within the planning watershed have on-target effective shade or <70% canopy.

G.3.3.4 MRC methods for evaluating stream canopy in specific WAUs

Table G-27 shows how the MRC method for evaluating stream canopy in specific WAUs differs from the general method.

Table G-27 MRC Methods for Evaluating Stream Canopy in the Plan Area

WAU	MRC Method vs. General Method
Garcia River	No difference
Albion River	Only 3 canopy closure classes were interpreted from aerial photographs: >70%, 40-70%, <40%.
Noyo River	Only 3 canopy closure classes were interpreted from aerial photographs: >70%, 40-70%, <40%. No shade quality rating was developed in the watershed analysis; however, it was developed was Table 3-9.
Big River	No difference
Hollow Tree Creek	Only 4 canopy closure classes were interpreted from aerial photographs: >90%, 70-90%, 40-70%, <40%.
Navarro River	Only 4 canopy closure classes were interpreted from aerial photographs: >90%, 70-90%, 40-70%, <40%.
Greenwood Creek	No difference
Northern Russian River	No difference
Cottaneva Creek	No difference
Elk Creek	No difference
Southcoast Streams	Complete by 2012
Rockport Coastal Streams	Complete by 2012

G.3.4 Module: stream channel condition

G.3.4.1 General method

The methods of the stream channel assessment are designed to identify channel segments that are likely to respond similarly to changes in sediment or wood and group them into distinct geomorphic units. These geomorphic units enable an interpretation of habitat-forming processes dependent on similar geomorphic and channel morphology conditions. The channels are also evaluated for current condition to provide baseline information for the evaluation of channel conditions over time.

Initial stream segment delineation from GIS

GIS analysis partitions the stream channel network for the WAU into stream segments based on 3 classes of channel confinement and several classes of channel gradient. These classifications are based on channel classifications prepared from digital terrain data in our GIS. The slope classes used for delineation are 0-3%, 3-7%, 7-12%, and 12-20%. Channel confinement is classified as confined, moderately confined, and unconfined. Confined channels have a valley-to-channel width ratio of <2, moderately confined channels have a valley-to-channel width ratio of <4, and unconfined channels have a valley to channel width ratio of >4.

MRC delineates channel segments for observations or analysis based on ownership boundaries, gradient breaks, tributary junctions or change in channel confinement. Usually the length of each segment is a minimum 20-30 times the bankfull width or anywhere from 300 to 1500 ft. The average planning watershed (where MRC owns a majority of the watershed) contains roughly 10–20 segments for watershed analysis and 1 long-term channel monitoring segment. The channel segments are numbered with a 2-letter code, corresponding to the planning watershed the channel segment is located, followed by a unique number (1 through n for each planning watershed). The delineated stream segments are shown on MAP E-1 in the watershed analysis reports on file.

Field measurements and observations

Selection of field sites for stream channel observations are based on gathering a sub-sample of response (0-3% gradient) and transport (3-20% gradient) channels from each planning watershed of the WAU. No attention is focused on the source reaches (>20% gradient); this is covered in the mass wasting analysis. Conducting a survey of the entire WAU is too labor-intensive. Our first priority in determining segments for field observation is to ensure that sampling occurs at (or upstream of) all stream temperature monitoring sites. MRC selects segments based on our ownership within each planning watershed (i.e., the larger the ownership the more segments selected) with equal emphasis given to response and transport segments.

After viewing the entire segment, the hydrologist chooses a location for a representative cross-section. At this location, the hydrologist measures bankfull width, bankfull maximum depth, bankfull average depth, floodprone depth, floodprone width, and channel bankfull width-to-depth ratio. Regional curves aid the hydrologist in estimating bankfull channel dimensions (Dunne and Leopold 1978). These curves provide information on channel dimensions (average depth, width, and cross-sectional area) based on drainage area size. The secondary diameters of 50 randomly selected pebbles at the cross section determine the D50 (median particle size) of the streambed. The hydrologist interprets streambed sediment characteristics from observations of gravel bars, channel aggradation or degradation and particle size of the stream bed material, classifying morphology types based on Montgomery and Buffington (1993) and Rosgen (1994). Flood plain interaction for the segment (continuous, discontinuous, inactive, none) and characteristics of channel roughness permit further interpretation of channel morphology. The hydrologist inventories LWD functioning in the channel and observes the number and type of pools (LWD forced, bank forced, boulder forced, free formed). Watershed analysis reports summarize all these field observations.

Stream geomorphic units

Channel segments were grouped into geomorphic units by similar attributes of channel condition, position in the drainage network, gradient class, and confinement class. The intent of the geomorphic units are to stratify channel segments of each WAU into units which respond similarly to the input factors of coarse and fine sediment, as well as LWD. These geomorphic units can then be interpreted to have similar habitat-forming processes.

Interpretations related to sediment supply, transport capacity, and LWD response were the basis for sensitivity of geomorphic units to coarse sediment, fine sediment, and LWD inputs. These interpretations were based primarily on existing conditions observed in the stream channels of the WAU.

Long-term stream monitoring sites
To monitor stream channel morphology conditions and stream sediment characteristics related to fish habitat, MRC established long-term stream channel monitoring segments in the initial watershed analysis for each WAU. We select channel segments within response channels (3% gradient), near the outlet of the stream or river that is representative of a range of channel conditions across the plan area; the selected segments should have reasonable access for surveys. As of 2010, there were a total of 40 long-term channel monitoring segments located across the plan area, with each segment averaging approximately 1000 ft in length. MRC will increase the total number of long-term channel monitoring segments to 60, with the goal of monitoring all of them every 6 years (i.e., 10 segments per year).

Table G-28 Monitoring Long-term Channel Segments

Long-term Channel Monitoring Segments		
WAU	Planning Watershed	Segments
Hollow Tree Creek	Middle Hollow Tree	2
	Upper Hollow Tree	2
Rockport Coastal Creeks	Juan Creek	1
Cottaneva Creek	Cottaneva	1
Noyo River	North Fork Noyo	2
	Hayworth	3
	Middle Fork Noyo	2
Albion River	Lower Albion	1
	Middle Albion	2
	South Fork Albion	2
Big River	East Branch Big River	1
	Daugherty Creek	1
	South Fork Big River	1
	Big River (near Two Log Creek)	1
Northern Russian River	Upper Ackerman Creek	1
	Lower Ackerman Creek	1
Navarro River	John Smith Creek	1
	Little North Fork Navarro	2
	Lower South Branch Navarro	1
	Upper South Branch Navarro	1
	Lower Navarro	1
	Flynn Creek	1
	Middle Navarro	1
Greenwood Creek	Upper Greenwood	1

Long-term Channel Monitoring Segments		
WAU	Planning Watershed	Segments
	Lower Greenwood	1
Elk Creek	Upper Elk	1
	Lower Elk	1
Garcia River	South Fork Garcia	2
	Rolling Brook	1
Southcoast Streams	Mallo Pass Creek	1
Segments to be added to current set		20
	Total	60

Along these segments, we conduct longitudinal profile and cross section surveys, and measure streambed size distribution. We also measure the fraction of pool volumes filled with fine sediment (V*) and permeability of spawning gravels (Appendix H). An MRC hydrologist will re-survey these long-term segments and monitor them over time to provide insight into long term trends in channel morphology, sediment transport, presence of LWD, and fish habitat conditions.

The stream monitoring segments are typically 20-30 bankfull channel widths in length. Permanent benchmarks (PBMs) are placed at the upstream and downstream ends of the monitoring segment. The PBMs are monumented with a re-bar pin concreted into the ground or nails hammered into the base of large trees.

The longitudinal profile is a survey of the thalweg, the deepest point of the channel, excluding any detached or "dead end" scours or side channels. At every visually apparent change in thalweg location or depth, the station along the channel and the elevation is recorded. In the absence of visually apparent changes, thalweg measurements are taken every 15-20 ft along the channel. Further each LWD piece of functional size or greater is recorded[8] along with its dimensions and attributes (Table G-23).

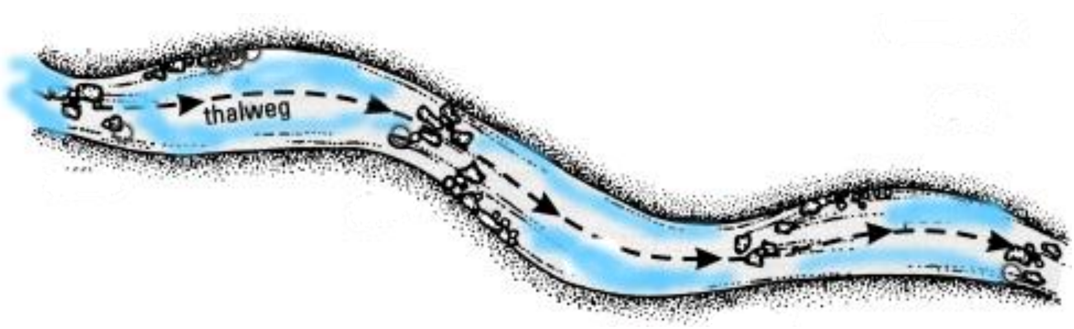

Figure G-9 Thalweg

A profile graph of the channel's thalweg is created from the longitudinal survey. MRC used a computer program (Longpro 2) developed by the United States Geological Survey for Redwood National Park to analyze the profiles. This program converted the surveys into standardized data sets with uniform 5-foot spacing between points and determined the residual water depth of each point. The residual water depth is the depth of water in pools of the channel segment defined by the riffle crest height at the outlet of the pool. No minimum pool depth is specified. The distribution, mean, and standard deviation of the residual water depths for the longitudinal profile

[8] Up until 2003, long term channel monitoring observations did not include LWD or its characteristics; however, after 2003, all long term channel monitoring included LWD information.

segment are calculated. This provides the ability to statistically evaluate changes in the residual water depths from the thalweg profile over time.

Along the longitudinal profile, we survey 3-5 channel cross sections (i.e., locations permanently monumented). The cross sections are located along relatively straight reaches in the monitoring segment. We survey cross sections from above the floodprone depth of the channel and create a graph of the cross section. At each cross section, we measure 100 randomly selected pebbles to determine the particle size distribution and median particle size (D50).

The fraction of pool volume filled with fine sediment (or V*) can be used to evaluate and monitor channel condition and to identify and quantify effects of discrete sediment sources (Hilton and Lisle 1993). Fine sediment thickness is measured by driving a graduated metal probe into a fine-grained deposit until the underlying coarser substrate is felt. Ten to 20 pools are needed to estimate V^*_w (the weighted mean value of V* for a reach), depending on acceptable error and variability between pools. MRC will follow protocols outlined in Hilton and Lisle (1993).

Permeability and bulk gravel samples

MRC collected steam gravel permeability and bulk gravel samples in the long-term monitoring segments in the WAUs to provide an index of spawning gravel quality within the monitoring segments. The stream gravel permeability was measured using a 1-inch diameter standpipe similar to the standpipe discussed in Terhune (1958) and Barnard and McBain (1994) with the exception that our standpipe is smaller in diameter. We used the smaller diameter standpipe because we hypothesize that it creates fewer disturbances to the stream gravel when inserted. Bulk stream gravel samples were taken with a 12-inch diameter sampler as described in Platts et al. (1983).

An electric pump was used to create the water suction in the standpipe for the permeability measurements. The permeability measurements were taken at a depth of 25 cm, near the maximum depth of coho salmon and steelhead spawning. From a power analysis it was determined that 26 measurements per segment were needed to predict within 20% accuracy.[9/1] The measurements were evenly distributed among all pool tail-outs in the segments; any additional measurements were taken in tail-outs behind the deepest pools. The measurement location in each tail-out was randomly selected from an evenly selected 12-point grid in the tail-out. At each measurement location, permeability repetitions were taken until the permeability readings no longer were increasing.

The median permeability measurement for each permeability site in the monitoring segment was used as representative of the site. To characterize the entire monitoring segment the natural log of the geometric mean of the median permeability measurements was determined. The natural log of the permeability was used based on a relationship between permeability and survival-to-emergence developed from data in Tagart (1976) and McCuddin (1977).[10/2] This relationship equates the natural log of permeability to fry survival ($r^2 = 0.85$, $p<10^{-7}$). This index needs further improvements, but is currently all we have for interpreting permeability information and biological implications. This relationship is:

$$\text{Survival} = -0.82530 + 0.14882 * \ln \text{permeability}$$

[9/1-2] Peter Baker (Senior Mathematician, Stillwater Sciences, Berkeley, CA) relayed to Chris Surfleet (MRC) in August 2000 the information about sample sizes necessary to evaluate the effects of permeability on egg survival of coho salmon and steelhead.

It is important to understand that the use of this survival relationship is only an index of spawning gravel quality in the segment. The permeability measurements were taken in randomly selected pool tail-outs and are not indicative of where a salmon may select to spawn. Furthermore, spawning salmon have been shown to improve permeability in gravel where redds are developed (see Appendix H). Therefore the survival percentage developed is only indicative of the quality of potential spawning habitat and not as an absolute number.

Prior to 2006, MRC collected bulk gravel samples in each long-term channel monitoring segment. Bulk gravel samples were taken in each of the 4 randomly selected pool tail-outs. The gravel sample was taken directly over the permeability site that is closest to the thalweg of the channel. After the bulk gravel samples were collected, the gravel was dried and sieved through 7 different size-class screens (50.8, 25.4, 12.5, 6.3, 4.75, 2.36, 0.85 mm). The weight of each gravel size class was determined for each of the bulk gravel samples using a commercial quality scale.

From the sieved bulk gravel samples, the percent of fine particles less than 0.85 mm and 9.5 mm was determined. The survival index for steelhead trout and Chinook salmon was calculated from the bulk gravel samples using the method described in Tappel and Bjorn (1983).

MRC will conduct bulk gravel sampling as part of focus watershed studies.

G.3.4.2 MRC method for evaluating stream channel condition in specific WAUs

For all watershed analysis units, the development of stream geomorphic units and long-term channel monitoring segments has been consistently applied. The only differences between the various watershed analyses have been the field observations taken. Generally, the stream channel field surveys have had similar observations. The subtle differences in the observations really do not warrant discussion as they do not affect the interpretations of channel conditions or the geomorphic units. However, we did mention a few of them below to disclose potential shortcomings. For example, in the Albion WAU (Table G-29), a few of the instream channel observations such as floodplain connectivity, bankfull width, and bankfull depth were different.

Table G-29 shows how the MRC method for evaluating stream channel conditions in specific WAUs differs from the general method.

Table G-29 MRC Method for Evaluating Stream Channel Conditions in the Plan Area

MRC Method for Evaluating Stream Channel Conditions in the Plan Area	
WAU	**MRC Method vs. General Method**
Garcia	The bankfull width and depth were collected without use of a regional curve.
Albion	A few of the instream channel observations such as floodplain connectivity, the bankfull width and depth (without use of a regional curve), and lack of residual pool depths were different.
Noyo	The bankfull width and depth were collected without use of a regional curve.
Big River	No difference
Hollow Tree	The bankfull width and depth were collected without use of a regional curve.

MRC Method for Evaluating Stream Channel Conditions in the Plan Area	
WAU	**MRC Method vs. General Method**
Navarro	No difference
Greenwood	No difference
Northern Russian	No difference
Cottaneva Creek	No difference
Elk Creek	No difference
Southcoast Streams	Complete by 2012
Rockport Coastal Streams	Complete by 2012

G.3.5 Module: fish habitat

MRC will analyze fish habitat only during initial watershed analyses. Subsequently, we will rely upon long-term channel monitoring observations, focus watershed studies, and data from CDFG. The remainder of this sub-section describes the original MRC surveys for fish habitat.

G.3.5.1 General method

The survey used to evaluate the habitat condition of each WAU was conducted during low flow conditions using methods modified from the California Salmonid Stream Restoration Manual (Flosi et al. 1998). Stream segments were created based on stream gradient and channel confinement. Fish habitat conditions were determined by sampling representative stream segments throughout the watershed. Factors that determined fish habitat assessment locations included fish presence, accessibility, and stream channel type (response, transport or, source reach). Since high gradient streams were likely to be non-fish bearing, survey efforts were concentrated on low gradient reaches of the stream network. The fish habitat assessments were conducted in the same locations as the stream channel observations (with few exceptions).

A distance of 20-30 bankfull widths determined the survey length to ensure that approximately two meander bends of the stream channel were observed. Data collected during the fish habitat and stream channel surveys provided information on: pool, riffle, and flatwater frequency; pool spacing; spawning gravel quantity and quality; over-wintering substrate; shelter complexity; and LWD frequency, condition, and future recruitment.

The quality of fish habitat was evaluated for each life stage of the anadromous salmonid: spawning, summer rearing, and over-wintering. Table G-30 displays the targets used for rating measured habitat parameters. These indices are based on scientific literature (Bilby and Ward 1989; Bisson et al. 1987; Bjornn and Reiser 1991; CDFG 1998b; Montgomery et al. 1995; WFPB 1995) and professional judgment. Spawning habitat conditions are evaluated on the basis of gravel availability and quality (gravel sizes, sub-surface fines, embeddedness), as well as for preferred spawning areas located at the tail-outs of pools. Summer rearing habitat conditions are evaluated on the size, depth, and availability of pools along with the complexity and quantity of cover (particularly LWD). Over-wintering habitat is evaluated on the size, depth, and availability of pools, the proportion of habitat units with cobble or boulder-dominated substrate, and the quantity of cover.

Habitat data is combined into indices of habitat quality for the different life stages of anadromous salmonid. Measured fish habitat parameters were weighted and given a numeric scale to develop a quality rating for individual life history stages. Parameters were divided into subsets that correspond with individual life history stages (spawning, summer rearing, and over-wintering habitat). Parameters were scored as follows: 1 (poor), 2 (fair), and 3 (good). Figure G-10 shows the parameter codes and calculation for habitat quality.

Spawning Habitat

E (0.25) + **F** (0.25) + **G** (0.25) + **H** (0.25)

Summer Rearing Habitat

A (0.20) + **B** (0.15) + **C** (0.15) + **D** (0.15) + **F** (0.15) + **I** (0.20)

Over-wintering Habitat

A (0.20) + **B** (0.15) + **C** (0.15) + **D** (0.10) + **I** (0.20) + **J** (0.20)

The overall score is rated as follows:

1.00 - 1.66 = Deficient
1.67 - 2.33 = Marginal
2.34 - 3.00 = On Target

Figure G-10 Weights and Ratings for Habitat Quality

Table G-30 Fish Habitat Condition Indices for Measured Parameters

Fish Habitat Condition Indices for Measured Parameters				
Fish Habitat Parameter	**Feature**	**Fish Habitat Quality**		
		Deficient	**Marginal**	**On Target**
Percent pool (by length) (A)	Anadromous salmonid streams	<25%	25-50%	>50%
Pool spacing (reach length/bankfull/#pools) (B)	Anadromous salmonid streams	≥6.0	3.0–5.9	≤2.9
Shelter rating (shelter value x% of habitat covered) (C)	Pools	<60	60–120	>120
% of pools that are ≥3 ft residual depth (D)	Pools	<25%	25–50%	>50%
Spawning gravel quantity (% of surface area) (E)	Pool tail-outs	<1.5%	1.5–3%	>3%
% embeddedness (F)	Pool tail-outs	>50%	25–50%	<25%
Subsurface fines (L-P watershed analysis manual) (H)	Pool tail-outs	2.31–3.0	1.61–2.3	1.0–1.6
Gravel quality rating (L-P watershed analysis manual) (H)	Pool tail-outs	2.31–3.0	1.61–2.3	1.0–1.6

Fish Habitat Condition Indices for Measured Parameters				
Fish Habitat Parameter	**Feature**	**Fish Habitat Quality**		
		Deficient	**Marginal**	**On Target**
Key LWD + rootwads/328 ft of stream (I)	Streams < 40 ft BFW	<4.0	4.0–6.5	>6.6
	Streams ≥ 40 ft BFW	<3.0	3.0–3.8	>3.9
Substrate for over-wintering (J)	All habitat types	<20% Units cobble or boulder dominated	20–40% Units cobble or boulder dominated	>40% Units cobble or boulder dominated

Distribution of anadromous salmonids

Apart from watershed analysis, MRC has a separate program to monitor the distribution of anadromous salmonids (M§13.6.1.1-2). The results from this program are then used in watershed analysis reports. The location of the distribution survey is indicated on a map (MAP F-1) along with the actual and potential distribution of anadromous salmonids. Actual distribution is based on data, potential distribution on the interpretation of a fishery biologist. The latter is typically only done for larger watercourses.

G.3.5.2 MRC methods for evaluating fish habitat in specific watershed analysis

Table G-31 shows how the MRC method for evaluating fish habitat in specific WAUs differs from the general method.

Table G-31 MRC Methods for Evaluating Fish Habitat in Specific WAUs

MRC Methods for Evaluating Fish Habitat in Specific WAUs	
WAU	**MRC Method vs. General Method**
Garcia	• 2 sets of observations of permeability and bulk samples (1997 and 2000) were presented. The 1997 permeability and bulk sample observations differ in methods. In 1997, samples were taken inside and outside of abandoned redds throughout the watershed. • Only an interpretation of potential anadromous salmonid distribution is shown, compared to a separate presentation of known and potential anadromous salmonid distribution.
Albion	• 2 sets of observations of permeability and bulk samples (1998 and 2000) were presented. The 1998 permeability and bulk sample observations differ in methods. In 1998, only 12 permeability samples were taken per long-term monitoring segment. • Only an interpretation of potential anadromous salmonid distribution is shown, compared to a separate presentation of known and potential anadromous salmonid distribution.
Noyo	• The 1998 permeability and bulk sample observations reported used only 12 permeability samples per long-term monitoring segment. • The fish distribution maps are presented as 2 maps. MAP F-1 is the potential distribution for anadromous salmonid and non-salmonid species. MAP F-2 shows the potential distribution of coho salmon and steelhead spawning, over-wintering, and rearing habitat.

MRC Methods for Evaluating Fish Habitat in Specific WAUs	
WAU	**MRC Method vs. General Method**
Big River	No difference
Hollow Tree	No difference
Navarro	Only an interpretation of potential steelhead distribution is shown, compared to a separate presentation of known and potential distribution.
Greenwood	• Fish habitat typing was conducted for entire stream segments (not just the 20-30 bankfull widths). • Habitat data was not analyzed using the weighted scoring procedures described. Habitat data was qualitatively described for the different life stages without scoring the variables.
Northern Russian	No difference
Cottaneva Creek	No difference
Elk Creek	No difference
Southcoast Streams	Complete by 2012
Rockport Coastal Streams	Complete by 2012

G.3.6 Module: amphibian distribution

As part of our watershed analysis, MRC has completed surveys for amphibian distribution in the following WAUs: Greenwood, Elk, Cottaneva, Alder, Rockport Coastal Streams, and South Coast Streams. We have described the methods for monitoring amphibian distribution under HCP/NCCP implementation in M§13.6.2.1-1 (red-legged frog monitoring) and M§13.6.3.1-2 (coastal tailed frog monitoring).