Chapter 2

Assessment Strategy and General Methods

The North Coast Watershed Assessment Program (NCWAP) developed in 2000, a draft methods manual that identified a general approach to conducting a watershed assessment, described or referenced methods for collecting and developing new watershed data, and provided a preliminary explanation of analytical methods for integrating interdisciplinary data to assess watershed conditions. NCWAP methods continued to evolve over the course of this assessment.

This chapter provides brief descriptions of data collection and analysis methods used by each of NCWAP's participating departments, and an introduction to methods for analyzing data across departments and disciplines. Additional explanation and discussion of interdisciplinary data analysis is provided in Chapter 4. While the information contained in the report is extensive, more detail is included in a set of appendices to this report:

1. Hydrology
2. Geology
3. Land Use
4. Water Quality
5. Fish Habitat Conditions
6. Interdisciplinary Synthesis
7. Public Responsiveness Summary

The reader is referred to those appendices for more detail on methods, data used in the assessment, and assessments of the data.

2.1 Methods by Department

2.1.1 HYDROLOGIC ANALYSES

The Gualala River Watershed assessment team has divided the watershed into five principal watersheds for assessment purposes: Wheatfield Fork (37 percent of drainage), South Fork (21 percent), North Fork (16 percent), Buckeye Creek (14 percent), and Rockpile Creek (12 percent).

Precipitation

The California Department of Water Resources (DWR) analyzed precipitation data for 12 gages with long-term periods of record within or near the Gualala River Watershed, summarizing and graphing gages, location, period of record, and annual, and maximum daily precipitation. Details about this process are available in Appendix 1.

Streamflow

DWR also analyzed streamflow data. Since few streamflow gaging stations have operated historically within the Gualala River Watershed, and streamflow data had not been collected by any agency since

1994, DWR installed three stream gaging stations during the fall of 2000. NCWAP gage installations were prioritized by the need for data at the terminus of the watersheds or major subbasins. Stations were installed near each of the confluences of the North Fork and Wheatfield Fork with the South Fork and another on the South Fork above the Wheatfield Fork. The three new gages were also equipped with water temperature sensors.

The new gages will measure the discharge from about 207 square miles or 69 percent of the entire drainage watershed and provide runoff data from subbasins with varying hydrological, geographical, and land use characteristics. The new Wheatfield and South Fork gages combined will be comparable to the long-term historic gage "South Fork Gualala River near Annapolis." Electronic multiple parameter data loggers may be used at stations to collect detailed time series data, normally every 15 minutes or hourly, for all sensors.

Water stage and water quality time series data will be downloaded from the station data loggers, uploaded into a database, and reviewed and edited for accuracy on a monthly basis. Time series streamflow data will be determined by correlating the direct discharge measurements with the simultaneous water stage data. This stage vs. discharge relationship or rating curve will be applied to the stage recordings from the station's stage sensor and data logger to compute streamflow for the same time series interval as water stage, normally every 15 minutes.

Once the rating curves are developed, real-time flow data will be provided over the Internet via the California Data Exchange Center (CDEC) website (http://cdec.water.ca.gov/) for those stations equipped with telemetry. Real-time telemetry also allows the station's operator to remotely monitor the operation of the station allowing a timely response to station malfunctions. Real-time data are not reviewed and edited for inaccuracies such as telemetry transmission error, sensor drift or malfunction, or discharge rating curve shift and are considered preliminary and subject to revision. The reviewed and finalized data for the October through September water year will usually be available about three to six months after the end of the water year.

DWR provided information about new and discontinued streamflow gaging stations on location, flow data type, and period of record in Appendix 3 (Table III-1, Figure III-1) and graphically illustrates the period of record for each gage (Chart III-1).

Water Rights

California law recognizes surface and groundwater rights, the latter with few exceptions not being subject to California law. The two predominate types of water rights within the Gualala River Watershed are riparian and appropriative. No State permit is required for a riparian water right, however, current water appropriation requires a permit which establishes a record. Appendix 1 provides a more detailed discussion of water rights law, history, and application processes.

DWR searched the California State Water Resources Control Board's (SWRCB) Water Right Information System (WRIMS) to determine the number and types of water rights within the Gualala River Watershed. The WRIMS database is under development and may not contain all post-1914 appropriative water right applications that are on file with the SWRCB at this time. Some pre-1914 and riparian water rights are also contained in the WRIMS database for those water rights whose users have filed a "Statement of Water Diversion and Use." A list of water rights and associated information contained within WRIMS for the Gualala River Watershed is presented in Table IV-1, Appendix 1. A location map of the point of diversion is shown in Figure IV-1, Appendix 1. CDWR also estimated municipal water use based on 1986 land and water use surveys by its Statewide Planning Program, coupled with delineations of cultivated agricultural lands from 1997 aerial photographs (Table IV-2, Appendix 1).

2.1.2 GEOLOGIC ANALYSIS

Landslide Assessment

CGS developed detailed information on landslide and geomorphic features as a keystone of its NCWAP work. Landslides that appeared to be fresh or to have moved within the last 150 years are classified as historically active; older landslides are classified as dormant. The historically active landslides are presumed to represent a major source area of natural sediment that entered the stream system over the past 150 years. Much of the coarser fraction of that sediment, mixed with older sediment, likely remains in the channels as indicated by the presence of well-rounded gravels and cobbles stored in the active channels. Historically active and dormant landslides and geomorphic features were mapped from primarily two sets of aerial photos (1984 and 1999/2000) and limited fieldwork. The mapped landslides were separated into multiple layers. Historically active landslides and dormant landslides were differentiated (page 2-6, Activity of Landslides), and landslides too small to capture at the map scale (less than the minimum mapping unit for polygons of approximately 100 feet in diameter) were captured as lines or points. If a historically active landslide observed on the 1984 photos appeared to be the same as was mapped from the 2000 photos, it was not redigitized into the 1984 layer. Thus, the 1984 layer does not include all the landslides observed in these photos, but only those that were not observed in the 2000 photos, or appeared to differ substantially between the two sets of photos.

Each landslide is classified according to the materials involved and the movement type, as deduced from the associated landforms. A two-part designation is given to each slide, based on the system of Cruden and Varnes (1996). Materials are called either rock or soil, and soil is subdivided into fine-grained (earth) and coarse-grained (debris). This system was designed to allow a series of names that describes the materials and processes involved in a landslide. California Geologic Survey (CGS) simplified the system to use it in preparing the landslide maps of the watershed. The terms and definitions of Cruden and Varnes (1996) were used, but were simplified to listing only the primary classification of a given landslide. For example, a rotational rock slide-flow in which the upper part of the slide has moved by sliding, but the lower part has disaggregated and is flowing is shown simply as a rockslide in the NCWAP landslide map. In the north coast of California, many geologic formations are not hard or indurated rock and it is possible to find all gradations between weak, soil-like rocks, and hard rocks. Therefore, CGS simplified the classification of rock versus soil and called material “rock” if it had a geologic formation name and the original geologic structure could be discerned.

The following landslide types and geomorphic features were used to develop the Geologic and Geomorphic Features Related to Landsliding maps (Plate 1) developed under NCWAP. The features are described below as well as general management and mitigation guidelines for each feature.

Rock Slide

Rock slides involve bedrock in which much of the original structure is preserved, and the strength of the rock is usually controlled by zones of weakness such as bedding planes or joints. Movement occurs primarily by sliding on a narrow zone of weakness as an intact block. Typically these landslides move downslope on one or several shear surfaces called slide planes. The failure surface(s) may be curved (rotational slide) or planar (translational slide). In some older classification systems, slides with curved failure surfaces are commonly referred to as slumps, while those with planar failure surfaces are called block glides.

The major management objectives for mitigating potential problems on translational/rotational slides are to: 1) minimize water concentration on the steep scarp and lateral margins of the slides, 2) avoid undercutting of the toe areas, 3) minimize loading the upper bench of the slide, and 4) avoid the activation of debris sliding on steep scarp and toe areas.

Earth Flow

Earth flows are a mixture of fine-grained soil, consisting of surficial deposits and deeply weathered, disrupted bedrock. The material strength is low through much of the slide mass, and movement occurs on many discontinuous shear surfaces throughout the landslide mass. Although the landslide may have a main slide plane at the base, many internal slide planes disrupt the landslide mass leading to movement that resembles the flow of a viscous liquid. Earth flows commonly occur on less steep slopes than rock slides, and in weak, clay-rich soils or disrupted rock units.

Because earthflow materials are so easily erodible, the main objective is to minimize the physical disturbance of the slide by avoiding the concentration of water onto the slide mass, and avoiding deep cut slopes into slide deposits.

Debris Slide

Debris slides are composed of coarse-grained soil, commonly consisting of a loose combination of surficial deposits, rock fragments, and vegetation. The strength of the material is low, and there may be a very low strength zone at the base of the soil or within the weathered bedrock. Debris slides typically move initially as shallow intact slabs of soil and vegetation, but break up after a short distance into rock and soil falls and flows.

Debris slides are characterized by unconsolidated materials above a shallow slide plane, therefore, the main management objectives are to: 1) retain root support, 2) minimize water flow along the soil/rock interface, 3) avoid the undercutting of materials above the slide plane, and 4) minimize the weighting of unconsolidated materials on steep slope

Debris Slide Slopes

Debris slide slopes are geomorphic features characterized by steep, usually well-vegetated slopes that appear to have been sculpted by numerous debris slides and debris flows. Upper reaches (source areas) of these slopes are often tightly concave and very steep. Soil and colluvium atop bedrock may be disrupted by active debris slides and debris flows. Slopes near the angle of repose may be relatively stable except where weak bedding planes, bedrock joints, and fractures parallel the slope.

Road construction and other activities should be avoided on debris slide slopes. If a road must be constructed it should be done using a full bench cut and the spoils should be removed to prevent discharge into any nearby watercourses.

Debris Flow

A debris flow is a mass of coarse-grained soil that flows downslope as a slurry. Material involved is commonly a loose combination of surficial deposits, rock fragments, and vegetation. High pore water pressures, typically following intense rain, cause the soil and weathered rock to rapidly lose strength and flow downslope. Debris flows commonly begin as a slide of a shallow mass of soil and weathered rock. Their most distinctive landform is the scar left by the original shallow slide. In many cases debris flows leave a linear scar called a torrent track.

The main management objectives in mitigating areas containing debris flow/torrent tracks are to: 1) protect water quality and 2) to avoid or minimize the possibilities of reactivating debris flow and debris torrent failures. Efforts should be made to identify colluvial-filled hollows that may develop into debris flows. Concentrated drainage into colluvial-filled hollows should be avoided.

Rock Fall

A rock fall is where a fragment or fragments break off of an outcrop of rock and falls, tumbles or rolls downslope. Rock falls typically begin on steep slopes composed of hard rocks and result in piles of loose rubble at the base of the slope.

It is recommended that excavation near the base of the rock fall be avoided. A site-specific evaluation is advised before any land use alterations are made on or adjacent to a rock fall.

Disrupted Ground

This category is defined as irregular ground surface caused by complex landsliding processes resulting in features that are indistinguishable or too small to delineate individually at 1:24,000 scale, and also may include areas affected by downslope creep, expansive soils, and/or gully erosion.

Because disrupted ground may include a variety of landslide features, site-specific management recommendations must be developed before any land-use changes are undertaken.

Inner Gorge

An inner gorge is a geomorphic feature consisting of steep slopes adjacent to channels. The gorge typically is created by accelerated down cutting in response to regional uplift. It is defined as an area of streambank between the channel and the first break in slope.

Extreme caution should be exercised before any land use modifications are undertaken on an inner gorge. The Forest Practice Rules require that any construction activities associated with timber management on an inner gorge area be approved by a Certified Engineering Geologist.

Gullies

Gullies are distinct, narrow channels formed by the erosion of soil or soft rock material by running water. Channels are larger and deeper than rills and usually carry water only during and immediately after heavy rain, or following the melting of ice or snow.

A site-specific evaluation must be conducted prior to any land use activity in a gullied area.

Activity of Landslides

Landslides are classified based on the recency of activity as modified from Keaton and DeGraff (1996). Under NCWAP, landslides were categorized as historically active or dormant. In some cases, dormant landslides were further subdivided.

The classification system of Keaton and DeGraff (following Varnes, 1978) uses the term "active" to mean active in the past year and "dormant-historic" to mean active within the last 100 years. These terms were combined as "historically active" for NCWAP and the time period increased 150 years to reflect the time since European settlers arrived in the North Coast. In the North Coast, landslides that have not revegetated with mature forest or grasslands that show immature drainage are considered to be historically active (less than 150 years old). Historically active landslides under NCWAP are landslides that can be actively moving or have moved within the past 150 years, based on freshness of features related to most recent movement.

Landslides with movement more than 150 to over thousands of years ago based on geomorphic features are classified as dormant. Some of the dormant landslides are further classified based on relative age and geomorphic features. These classifications are dormant young, dormant old, and dormant mature. Dormant young landslides are characterized by rounded scarps, the absence of cracks, and partially filled depressions or ponds. Dormant old are characterized by extensive erosion of landforms related to the landslide, including substantial gullies or canyons cut into the landslide mass by streams, and rounding of original headscarp benches and hummocky topography. Dormant mature slides are recognized by the fact that the landforms have been smoothed by erosion, re-vegetated, main scarp rounded, erosion of the toe area, and well established drainage.

In many cases in the Gualala River Watershed landslide mapping, dormant landslides were not differentiated as dormant young, dormant old, or dormant mature due to time constraints. Therefore, many dormant landslides are classified simply as dormant.

CGS considers both dormant and historically active landslides capable of generating natural sediment loads in proportion to their size, rate of movement, geologic materials, steepness of slope, density and type of vegetation, and hydrologic setting. Although the CGS's distinction between dormant and historically active landslides is characterized by movement within the last 100 to 150 years, this criterion does not place an upper limit on the age of any landslide. Thus, a historically active landslide may be hundreds of years old. In fact, many historically active landslides are found within larger areas of older dormant landslides, suggesting that some recent landslides are the result of reactivation of dormant landslides. The activity rating of a landslide is based on geomorphic characteristics that suggest recent movement as observed either in the field or on aerial photos.

Historically active landslides have an overall higher rate of movement than dormant or stable ground that results in more disruption to the terrain, which produces sharper topography, hummocky undrained depressions, angular blocks and scarps. These in turn provide more opportunity of infiltration of rainfall that maintains the instability and accelerated surface erosion. In comparison, the rate of movement of dormant landslides is sufficiently low to allow surface geomorphic processes to erode and smooth the landscape reducing topographic irregularities and allowing the development of internal drainage networks.

There is a general relationship between the area of earthflows and rockslides and the depth of failure. Typically, the depth of rotational landslides in soils range from 15 to 33 percent, and are less than 10 percent for translational landslides in soils (Cruden and Varnes, 1996). The deep-seated earthflows and rockslides mapped by CGS as polygons are larger than 1/5 of an acre with moderate (11 to 50 feet) to deep (> 50 feet) depths. In the Gulalala River Watershed, the average area of an historically active earthflow and rockslide mapped as a polygon is approximately 40 acres. Thus, the mass of an average deep-seated landslide is approximately 1,000,000 tons. While recent land uses can increase their sediment yield, it is not likely these historically active landslides are the result solely of recent land uses.

Other Attributes

The landslide data were captured as different attributes in the Geographic Information System (GIS) database. These attributes include landslide type, confidence of interpretation, relative age of the feature, thickness, whether material was delivered directly to a watercourse, and whether features such as roads, timber harvests, or stream undercutting were observed in the immediate vicinity of the landslide (Appendix 2). However, it should be noted that due to resource constraints, not all attributes were captured for all features for the Gualala River Watershed. As such, a blank in a specific attribute field does not necessarily mean that the specific attribute is not present or does not apply, but could be that it was not captured during the mapping efforts.

Additional details are located in Appendix 2 and in the electronic database .

Confidence of Interpretation

Each mapped landslide is also classified as definite, probable, or questionable. Because landslides are mapped based on their landforms, the confidence of identification is dependent on the distinctness of those landforms. Landslide size also limits the confidence. Those that are too small to see clearly or those that have been altered substantially are more difficult to identify. Confidence of interpretation is classified according to the criteria below.

Definite Landslide

Nearly all of the diagnostic landslide features are present, including but not limited to headwall scarps, cracks, pronounced toes, well-defined benches, closed depressions, springs, and irregular or hummocky topography. These features are common to landslides and are indicative of mass movement of slope materials. The clarity of the landforms and their relative positions clearly indicate downslope movement.

Probable Landslide

Several of the diagnostic landslide features are observable, including but not limited to headwall scarps, rounded toes, well-defined benches, closed depressions, springs, and irregular or hummocky topography. These features are common to landslides and are indicative of mass movement of slope materials. The shapes of the landforms and their relative positions strongly suggest downslope movement, but other explanations are possible such as faulting.

Questionable Landslide

One or a few, generally very subdued, features commonly associated with landslides can be discerned. The area typically lacks distinct landslide morphology, but may exhibit disrupted terrain or other abnormal features that vaguely to strongly imply the occurrence of mass movement. Includes bulges low on the slope below upper slope concavities.

Relative Landslide Potential

Once relevant relationships between geology and landsliding were recognized, a landslide potential map was created in GIS. The landslide potential map was compared with the slope maps, landslide density thematic map, and other available slope models for important variations. Any important variations were interpreted and subclassified, which are explained in further detail in Appendix 2. The relative landslide potential was defined and illustrated in five categories from 1 (most stable) to 5 (least stable). Additional modifiers, which supplement the primary definitions, were added as relevant.

The assignment of the categories was an interpretative process and was based on relations drawn from the Landslide and Geomorphic Features Related to Landsliding Map, statistical analysis, and general field observations.

The landslide potential map was constructed as an individual GIS layer and produced at a scale of 1:24,000. Further explanation of the categories and their implications for land use follows:

- ***Category 1, Very Low Landslide Potential:*** Landslides and other features related to slope instability are very rare to non-existent within this area. This area includes relatively flat marine terraces, lower stream valleys, and flat-topped ridges in the Gualala River Watershed. There is the possibility that small areas with much higher landsliding potential (similar to Categories 3, 4, or 5) could be present. A limited site-specific evaluation is recommended to address slope stability issues prior to changes in existing slopes or drainage.
- ***Category 2, Low Landslide Potential:*** Gentle to moderately steep slopes underlain by relatively competent material that is considered unlikely to mobilize as landslides under natural conditions given the current understanding of regional seismicity. Landsliding in these areas is not common. This area generally includes the flat-topped ridges of the Ohlson Ranch Formation and marine terraces west of the San Andreas Fault. There is the possibility that small areas with much higher landsliding potential (similar to Categories 3, 4, or 5) could be present. A site-specific evaluation is recommended to address slope stability issues prior to changes in existing slopes or drainage.
- ***Category 3, Moderate Landslide Potential:*** Moderate to moderately steep, relatively uniform slopes that are generally underlain by competent bedrock, and may also include older dormant landslides. Some slopes within this area may be at or near their stability limits due to weaker materials, steeper slopes, or a combination of these factors. This area dominantly occurs in dormant landslides west of the San Andreas Fault and in the rocks of the Coastal Terrane west of the Tombs Creek Fault zone. Landslides in this category typically occur as small (less than an acre) debris flows, debris slides, and rockslides. In addition, there is the possibility that isolated areas within Category 3 could include features that represent higher likelihood of landsliding more similar to categories 4 and 5. A site-specific review is recommended to evaluate effects of proposed changes to existing land use with respect to slope stability.
- ***Category 4, High Landslide Potential:*** Moderately steep to steep slopes that include many dormant landslides in upslope areas and slopes upon which there is substantial evidence of down slope creep of surface materials. This area consists of large dormant earthflows dominantly occurring (earthflows occur in earth not rocks) east of the Tombs Creek Fault zone, areas of disrupted ground on moderately steep (30-64 percent) slopes, and much of the incised and moderately steep area of the Coastal Terrane. A site-specific review is recommended to evaluate effects of proposed changes to existing land use with respect to slope stability. Additional caution is advised in these areas.
- ***Category 5, Very High Landslide Potential:*** Areas include historically active landslides (<150 years old) and inner gorges, as well as debris slide/flow source areas on steep to very steep slopes (>65 percent). Landslides typically occur as large earthflows in the Central Terrane east of the Tombs Creek Fault zone and as small (less than one acre) rock slides, debris slides, and debris flows in the Coastal Terrane. A site-specific review is recommended to evaluate effects of proposed changes to existing land use with respect to slope stability. Extreme caution is advised in these areas.

Management practices that are adaptive to various levels of slope stability can reduce or avoid adverse sediment effects within the watershed. Preventing slope failures and/or avoiding naturally unstable areas prior to land use changes or operations are generally more cost effective and achieve better results than mitigating slope failures and stream impacts after the fact. Therefore, consideration of the landslide potential and the relevant recommendations during land use planning is recommended. Areas in landslide potential categories 4 and 5 deserve particular attention and caution based on the known presence of factors affecting unstable slopes, including active and dormant landslides, steep slopes, inner gorges and debris slide slopes. In many cases, several interrelated factors can affect the natural slope stability and anthropogenic activities can worsen the conditions.

Fluvial Geomorphic Analysis

The CGS evaluated, compiled, and mapped channel fluvial characteristics for the Gualala River Watershed. Mapping was done through interpretation of aerial photographs from two time periods, 1984 and 1999/2000, and calibrated with limited field studies. CGS mapped 32 types of fluvial geomorphic attributes (Table 2-1). The purpose of the time-series analysis was to document site conditions using multiple sources of information, and to obtain information that reveals changes in channel characteristics.

The methodology developed by CGS for mapping fluvial geomorphic features was modified after the RAPID technique (Grant 1988) for evaluating downstream effects of forest practices on riparian zones. The basic technique of mapping channel change is the same for both methods. However, the methodology used by RAPID to measure patterns of riparian canopy disturbance was modified to include additional information on channel geomorphic characteristics that are observable on aerial photos. These features were then attributed in the GIS database for map preparation and data analysis.

CGS's fluvial geomorphic mapping identified 32 features indicative of stored channel sediment or sources of sediment that could be resolved on the available aerial photographs. The attributes in Table 2-1 in bold are those that may be indicators of excess sediment in storage or sediment sources that could be considered detrimental to optimum habitats for anadromous salmonids. While most of these features are always associated with increased sediment or impaired conditions, others, such as lateral bars, may or may not represent impairment. To be conservative, if one of the features in Table 2-1 is assigned an attribute that indicates excess sediment storage or sediment sources, it is included with those characteristics considered as a "negative" attribute.

While the significance of each mapped feature relative to channel habitat quality varies, the time-series mapping helps track changes and trends in channel conditions. As an example, the lateral bars were considered a detrimental feature, whereas, the point bars were not. The lateral bars were considered detrimental because they appeared more dynamic than the point bars (i.e., changing their size and position more readily than point bars). Lateral bars were often observed directly adjacent to a source of channel sediment, such as a landslide, and often remain for some time after the landslide has revegetated. The association of lateral bars and sediment sources is not unique to the Gualala River Watershed. By tracking all of the lateral bars, the changes in channel deposits can be better documented. Lateral bars that remain stable become a measure of the baseline condition. This method was applied to all of the north coast watersheds being studied by the NCWAP program.

Table 2-1
Database Dictionary for GIS Mapped Fluvial Geomorphic Attributes

wc - wide channel	**ag – aggrading reach**
br – braided channel	**dg – degrading reach**
rf – riffle	**in – incised reach**
po – pool	ox – oxbow meander
fl – falls	ab – abandoned channel
uf – uniform flow	am – abandoned meander
tf – turbulent flow	**cc – cutoff chute**
bw – backwater reach	**tf – tributary fan**
pb - point bar	lj - log jam
lb - lateral bar	**ig - inner gorge**
mb – mid-channel bar	**el - eroding left bank (facing downstream)**
jb - bar at junction of channels	**er - eroding right bank (facing downstream)**
tb - transverse bar	**la - active landslide deposit**
vb - vegetated bar	**lo - older landslide deposit**
vp - partially vegetated bar	**dr – displaced riparian vegetation**
bc – blocked channel	ms – man-made structure

The CGS developed maps of the fluvial geomorphology for all watercourses in the Gualala River Watershed designated by blue lines on published U.S. Geological Survey (USGS) 1:24,000-scale topographic quadrangle maps. Time-series fluvial geomorphic mapping conducted for the project provided data to allow for evaluation of changes in channel geomorphology between 1984 and 1999/2000. Other fluvial parameters mapped by CGS at this reconnaissance scale include channel slope calculated from a 10-meter Digital Elevation Model (DEM) (provided by Fire and Resource Assessment Program [FRAP]) and channel type, using the Rosgen classification system (Rosgen, 1996).

2.1.3 Vegetation and Land Use

Progression of Timber Harvest Operations and Ranchland Development

Presenting the progression of timber operations and ranchland conversions was limited by air photo availability. This includes 1936 (Mendocino), 1942 (Sonoma), 1952 (Mendocino) 1961 (Entire Watershed) 1963 (Mendocino) 1965 (Sonoma) and 1981 (Entire Watershed). A few gaps in air photo coverage have been age projected back by vegetational typing (i.e., 1952 and some 1965 interpretations). For the 1974 to 1990 era, a combination of LANSAT imagery and 1988/1996 air photo interpretation was used. The CDF GIS overlays of Timber Harvest Plans were used to develop the 1991 to 2001 harvest mapping.

Road Networks

CDF examined both historic and modern road networks to characterize impacts by road debris slides and road crossing failures on stream channel morphology. Maps of road networks were interfaced with CGS Relative Landslide Potential maps and historically active landslides to show slide prone areas with roads. CGS mapping of landslides and selected fluvial geomorphic features allowed comparison of landslide activity to instream sediment accumulations and comparison of instream sediment levels between 1984 and 1999/2000. This analysis then compared the naturally occurring historically active landslides with the road network. In addition, CDF used 1965 air photos at close scale (1:1200) to compare evolving stream channel morphology with the CGS 1984 and 1999/2000 fluvial geomorphology mapping.

CDF mapped the historic timber and ranchland roads using 1961, 1963, 1965, and 1981 aerial photographs. CDF mapped only those road segments that were in the streambed or following the stream channel at an equal elevation to the outer streambank. Maps of the modern road network used the "ICE", or U.C. Davis roads layer developed for the Gualala Total Maximum Daily Load (TMDL) (NCRWQCB 2001b). We clipped the "ICE" roads within 50 feet of a watercourse to show lengths of current roads within 50 feet of blue line streams within each subbasin.

Riparian Canopy Cover

CDF mapped riparian canopy cover throughout the watershed during three time periods that capture pre and post land use impacts to stream cover. The intent of this analysis was to provide information on trends in stream conditions thru time. The three time periods were:

1. 1942 –a period of general inactivity after the Great Depression. Approximately 80 percent of the watershed consisted of undisturbed old growth timberstands in the central and upper reaches at this time.
2. 1968 – marked the end of the tractor era when most of the old growth timber base had been harvested by timber operations and ranchland conversions.
3. Current canopy cover conditions. Mapping of current conditions incorporated both the CDFG habitat inventory surveys and GRWC/GRI stream measurements where available.

Stream reaches exposed on each side of the channel streambank at a cross section were mapped. This method mapped those reaches of blue line streams exposed bank-to-bank along the immediate stream channel, not the streambank vegetational transition line, or the flood line. Aerial photos dating to the summer low flows were used. These were the same photo sets used with the land use mapping.

2.1.4 WATER QUALITY

The NCRWQCB's Water Quality Control Plan for the North Coast Region (Basin Plan) (NCRWQCB 1994) designates ten existing and one potential beneficial use of water for the Gualala River Watershed. The NCRWQCB has responsibility for protecting all beneficial uses of water. Accordingly, the water quality parameters assessed in this report are compared to water quality objectives for the protection of all beneficial uses. However, the assessment is focused primarily on the salmonid fishery beneficial uses of COLD (cold freshwater habitat), SPWN (spawning, reproduction, and/or early development), MIGR (migration of aquatic organisms), EST (estuarine habitat), and REC-1 (water contact recreation-fishing). A complete list of beneficial uses is available in Appendix 4.

Collection of water quality data was according to standard techniques at the time of sampling. Water chemistry information collected at four sites in the watershed by the NCRWQCB in 2001 were according to standard protocols. All other data were obtained from various sources. The data from USEPA's StoRet system were collected by USGS, DWR, and NCRWQCB according to standard protocols at the time of collection. Water temperature, aquatic macroinvertebrates, streambed particle sizes, canopy, streambed coring data, and channel profiles were collected by Gualala Redwoods, Inc. and the Gualala River Watershed Council according to accepted protocols. More detail on methods is available in Appendix 4 and the draft water quality methods manual (NCRWQCB 2001a).

Surface water quality data obtained from the USEPA's StoRet system and from NCRWQCB files were compared to water quality objectives from the Basin Plan, the Total Maximum Daily Load suggested targets, EMDS dependency relationships (thresholds) and other ranges and thresholds derived from the literature as cited in Table 2-2, below. Only the Basin Plan objectives are legal regulatory thresholds. All of the reference criteria were based on available information at the time, and may change as new data and analyses become available.

The stream water temperature range for salmonids was developed by the NCWAP team as an average of the needs of several cold water fish species, including coho salmon and steelhead trout. As such, the range does not represent fully suitable conditions for the most sensitive cold water species (usually considered to be coho salmon). The breakdowns follow:

50-60 F (10-15.6 C)	"fully suitable"
61-62 F	"moderately suitable
63 F	"somewhat suitable"
64 F	"undetermined"
65 F	"somewhat unsuitable"
66-67 F	"moderately unsuitable"
68 F	"fully unsuitable"

The literature supports a critical lethal temperature threshold of 75 F, above which death is usually imminent for many Pacific Coast salmonid species (NCRWQCB 2000).

Knopp (1993) measured a variety of instream parameters on 60 north coast streams within the Franciscan Complex. The watersheds were divided into three disturbance categories based on relative upslope disturbance and erosion potential: Index (little or no land use in the prior 40 years), Moderately Disturbed (recent land management, good stream course protection, avoidance of unstable areas), and Highly Disturbed (recent land management, large areas of disturbed soil, poor stream course protection, inconsistent avoidance of unstable areas). Knopp concluded that the median particle size of instream sediment samples was bstantially different at the 95 percent confidence level between the Index reaches and those of Moderate and High disturbance. Knopp's relationships were not used for median particle size data from the Gualala River Watershed as explained below.

Table 2-2
In-Channel Criteria Used in the Assessment of Water Quality Data

Water Quality Parameter	Range or Threshold	Source of Range or Threshold
pH	6.5-8.5	Basin Plan, p 3-3.00
Dissolved Oxygen	7.0 milligrams per liter (mg/L)	Basin Plan, p 3-3.00
Temperature	No alteration that affects BUs[1] No increase above natural > 5 F 50-60 F MWAT[2] – "fully suitable"(see EMDS breakdown above) 75 F daily max (lethal)	Basin Plan, p 3-3.00 Basin Plan, p 3-4.00 EMDS Fully Suitable Range[3] Cold water fish rearing, NCRWQCB (2000), p. 37
Settleable matter	Not to cause nuisance or adversely affect BUs	Basin Plan, p 3-2.00
Suspended load	Not to cause nuisance or adversely affect BUs	Basin Plan, p 3-2.00, 3-3.00
Turbidity	no more than 20 percent increase above natural occurring background levels	Basin Plan, p 3-3.00
Percent fines <0.85 mm	<14 percent in fish-bearing streams[4]	Gualala TSD, NCRWQCB (2001b)
Percent fines <6.4 mm	<30 percent in fish-bearing streams	Gualala TSD, NCRWQCB (2001b)
V* in 3rd order streams with slopes 1-4 percent	<0.15 (mean)<0.45 (max)	Gualala TSD, NCRWQCB (2001b)
Median particle size	Please see the discussion below	Knopp (1993)

1 BUs = Basin Plan beneficial uses

2 MWAT = maximum average weekly temperature, to be compared to a 7-day moving average of daily average temperature

3 EMDS = Ecological Management Decision Support model used as a tool in the fisheries limiting factors analysis.

4 Fish-bearing streams = streams with cold water fish species

Median particle size data were available from Gualala Redwoods Inc./Gualala River Watershed Council and Coastal Forest Lands at 38 low-gradient sites (<2 percent slope) in the Gualala watershed from 1995-2001. However, those sites were predominantly less than 1 percent slope, and Knopp used sites of 1-4 percent slope. Additionally, the analysis provided in Knopp (1993) does not account for variation in the Franciscan Complex. For those reasons, the Knopp (1993) relationship of median particle size to watershed disturbance was not used. However, the NCRWQCB intends to create a workgroup to evaluate Knopp's raw data (which includes information on local site geology) to consider moving the current Gualala Redwoods, Inc./Gualala River Watershed Council (GRI/GRWC) monitoring locations to sites more comparable to Knopp, and to work towards building upon and improving the work that Knopp started.

The water quality data used in this assessment and summary plots are included in Appendix 4. The following parameters were compared to the above ranges and thresholds:

- Dissolved oxygen, pH, conductance (dissolved solids), nutrients (nitrogen, phosphorus)
- Continuous water temperature recordings from data loggers

- Turbidity and suspended solids data were not available for this assessment, and represent a limitation in the water quality part of the assessment

2.1.5 FISH HABITAT AND POPULATIONS

Data Compilation and Gap Identification

CDFG compiled existing available data and anecdotal information pertaining to salmonids and the instream habitat on the Gualala River and its tributaries and entered it into a database. Anecdotal and historic information was cross referenced with other existing data whenever possible, and rated for quality. Both were used when the information was of good quality and applicable. Instream habitat gaps were mapped and matched with corresponding land parcels. Where data gaps were identified, access was requested from landowners to conduct habitat inventory and electrofishing surveys.

Data Collection

Habitat inventories and biological data were collected following the protocol presented in the California Salmon Stream Habitat Restoration Manual (Flosi et al. 1998). Two-person crews trained in those methods conducted physical habitat inventories June through November 2001. Stream reaches were stratified based upon Rosgen channel types, and the habitat type and stream length determined for all habitat units within a survey reach.

The parameters measured were streamflow, channel type, temperature, fish habitat type, embeddedness (amount of fine sediment surrounding larger substrate particles) , shelter rating (habitat complexity based on elements such as overhanging banks, boulders, large woody debris, submerged vegetation, etc.), substrate composition (percent of different sizes), riparian canopy cover, bank composition, and bank vegetation. The data reflect instream conditions at the time of the survey.

During basin level habitat typing, full sampling of each habitat unit requires recording all characteristics of each habitat unit as per the “Instructions for completing the Habitat Inventory Data Form” (Part III). It was determined that similar stream descriptive detail could be accomplished with a sampling level of approximately 10 percent (Flosi et al. 1998).

When sampling 10 percent of the units all habitat types are measured when encountered for the first time. Thereafter, approximately 10 percent of the habitat units are randomly selected for measurement of all the physical parameters. The habitat unit type, mean length, mean width, mean depth, and maximum depth are determined for the other 90 percent of the units. Pool habitat types are also measured for instream cover and embeddedness.

Streams were surveyed until the end of anadromy was determined. Crews based this judgment on the presence of physical barriers to fish passage, a steep gradient of 8-10 percent, or a dry section of the stream 1,000 feet or more in length.

Canopy cover, embeddedness, pool depth, pool frequency, and pool shelter/cover were reported in bar charts for each of the streams surveyed. Salmonid distribution in the Gualala River Watershed was obtained using the Modified Ten Pool Protocol (Preston et al. 2001) with Smith Root Model 12 backpack electro-fishing units on eight tributaries. The Ten Pool Protocol was designed to detect the presence of coho salmon and is not a valid method for calculating fish density or age class structure (pers comm. L. Preston).

2.2 Interdisciplinary Synthesis

The interdisciplinary synthesis process involved the development of a number of tools, including models, maps, and matrices for integrating information from multiple disciplines on a watershed and subbasin scale to explore linkages among watershed processes, conditions and use. The process resulted in an expression of relationships of the landscape and its features, both natural and human-induced, to fish habitat. These tools provided a framework for identifying limiting factors and potential refugia, for developing restoration, management and conservation recommendations, and for understanding the potential for cumulative impacts.

2.2.1 Ecological Management Decision Support

To assist in the assessment, NCWAP selected the Ecological Management Decision Support (EMDS) software (Reynolds 1999) to evaluate and synthesize information on watershed and instream conditions important to salmonids during the freshwater phases of their life history. The EMDS is described in more detail in the Interdisciplinary Synthesis section of this report.

The NCWAP scientists constructed "knowledge base" models to help them evaluate how numerous management-related and environmental factors (e.g., watershed geology, stream sediment loading, land use) interact to shape anadromous salmonid habitat. Based upon these models, EMDS evaluates available data to provide insight into the conditions of the streams and watersheds for salmonids.

The NCWAP watershed assessment teams used EMDS model outputs in conjunction with other information as indicators to help them determine the patterns and processes that appear to be most important in shaping a given watershed. A scientific peer review process conducted in April of 2002 indicated that, while NCWAP's initial efforts at EMDS modeling were laudable, substantial changes to NCWAP's EMDS modeling approach were needed. At the time of the production of this report, NCWAP has implemented some, but not all of the review panel's recommendations. Hence, the model outputs are used with caution at this time. However, NCWAP staff are continuing to work to refine and improve the EMDS models, based on the peer review and further internal review.

2.2.2 Integrated Analyses Tables

NCWAP developed a number of large tabular presentations of data intended to help identify and highlight relationships across a number of important watershed factors. Key relationships examined were those among land use, landslides, relative landslide potential, and instream fish habitat. They include comparisons of:

- Landslides (acres and percent of watershed) to land type or use (woodland/grassland, areas with recent timber harvest (1991-2000), and timberland with no harvest since 1990
- Relative landslide potential classes (acres and percent watershed) to land type or use (woodland/grassland, areas with recent timber harvest (1991-2000), and timberland with no harvest since 1990
- Relative landslide potential classes (acres and percent watershed) by silviculture systems (e.g., clearcut, shelterwood, selection, etc.) and harvest practices (tractor, cable and helicopter)
- Historically active landslides and geomorphic features at different distances from streams.

These analyses are presented at the level of the overall watershed, subbasins, and planning watersheds. These are discussed in more detail in Chapter 4.

2.2.3 Limiting Factors Analysis

A main objective of the NCWAP and a task assigned to CDFG was to identify factors that limit production of anadromous salmonid populations in north coast watersheds. A loosely termed approach to identify these factors is often called a "limiting factors analysis" (LFA). The limiting factors concept is based upon the assumption that eventually every population must be limited by the availability of resources (Hilborn and Walters 1992) or that a population's potential may be constrained by an over abundance, deficiency, or absence of a watershed habitat component. Identifying stream habitat factors that limit or constrain anadromous salmonid populations is an important step towards setting priorities for habitat improvement projects and management strategies aimed at the recovery of declining fish stocks and protection of viable fish populations. The NCWAP LFA was centered on evaluating summer aquatic habitat conditions. Only the freshwater habitat requirements of anadromous salmonids were addressed.

Two general categories of factors or mechanisms limit salmonid populations: density independent and density dependent mechanisms. Density independent mechanisms generally operate without regard to population density. These include factors related to habitat quality such as stream flow and water temperature. In general, if water temperatures exceed lethal levels, fish will die regardless of the population density. Density dependant mechanisms generally operate according to population density and habitat carrying capacity. Competition for food, space, and shelter are examples of density dependant factors, which affect growth and survival when populations reach or exceed the habitat carrying capacity. The NCWAP's approach considers these two types of habitat factors before prioritizing recommendations for habitat management strategies. The LFA was a simplified approach to identify ecosystem components that constrain habitat capacity, fish production, and species life history diversity (Mobrand et al. 1997). The Gualala River Watershed LFA was developed for assessing coarse scale stream habitat components and may not satisfy the need for site-specific analysis at an individual landowner scale.

Components essential to the health of anadromous fish populations in freshwater habitat include canopy cover, embeddedness, pool depth, pool frequency, pool quality, and shelter/cover. Unsuitable components were associated with their effects on salmonid health and productivity. Unsuitable canopy cover was associated with increases in water temperature; unsuitable embeddedness was related to poor spawning substrate; unsuitable pool depth and frequency was associated with poor summer conditions; unsuitable shelter was related to decreased escape cover, which relates to increased predation and decreased high-flow refuge.

Both the analysis of data collected during habitat inventory surveys taken in 1999 and 2001, and the EMDS outputs identified unsuitable key components for each stream surveyed. After identifying the potential limiting factors, the factors were ranked according to the most detrimental habitat deficiencies. Higher rankings indicated higher unsuitability. The biologist's professional judgment took precedence when partial surveys were conducted which did not represent the limiting factor or data and observations inconsistencies that existed. Last, recommendations were selected and prioritized for potential habitat improvement activities.

2.2.4 RESTORATION NEEDS

Habitat Restoration Needs

Restoration priorities were developed for surveyed streams to assist landowners and watershed groups in identifying future improvement projects and watershed management strategies. CDFG used habitat survey data coupled with field observations to identify habitat restoration needs. They then considered which activities would need to come first in time in order for restoration objectives to be successful. For example, recommendations for erosion and sediment reduction would likely take priority in time over instream recommendations because instream projects would likely fail without treating upslope sediment sources. These are described in more detail in Chapter 4.

A map of potential restoration areas, Plate 3, *Potential Restoration Sites and Habitat Limiting Factors for the Gualala River Watershed*, was developed to incorporate multi-disciplinary sets of data to look at limiting factors that are potentially sediment-related in relationship to potential sediment sources. It includes CGS landslide data, CGS fluvial sediment mapping, CDFG instream habitat surveys, CDF mapping of historic roads that were either in streams or near streams, and U.C. Davis's Information Center for the Environment (ICE) map of the current roads in the watershed. All of the GIS data are available to the public.

The map shows:

1. Segments of the modern roads that cross or are within 60 meters of an historically active landslide.
2. Segments of the modern roads that are both within 60 meters of historically active landslides and within 60 meters of eroding stream banks.
3. The segments of the modern roads that are within 60 meters of dormant landslides.
4. The segments of the historic instream or near stream roads that may be active sediment sources.
5. Areas of upslope stream reaches in which embeddedness is a limiting factor.
6. Limiting factor for salmonids for each stream reach that was surveyed.
7. The extent of the CDFG stream surveys in 2001.

This map can be used to quickly locate:

1. Limiting factors for salmonid habitiat in surveyed streams.
2. Streams that were surveyed in 2001.
3. Areas upslope of stream reaches in which embeddedness is a limiting factor.
4. Potential sediment sites in upslope areas that may be contributing to embeddedness or shallow pool depths.

The steps involved in generating this map and the results are described in more detail in Chapter 4 and in the subbasin sections of Chapter 5.

2.2.5 POTENTIAL SALMONID REFUGIA

Establishment and maintenance of refugia or watershed reserves that contain the best existing aquatic habitat is a vital course of action toward conservation of anadromous salmonid resources (Moyle and Yoshiyama 1992, Li et al. 1995, Reeves et al. 1995). The concept of refugia is based on the premise that “patches” of aquatic habitat provide the critical ecologic functions to support wild anadromous salmonids. Anadromous salmonids exhibit typical features of “patchy populations”; they exist in dynamic environments and have developed various dispersal strategies including juvenile movements, adult straying, and relatively high fecundity for an animal that exhibits some degree of parental care through nest building (Reeves et al. 1995). Conservation of patchy populations requires conservation of several suitable habitat patches and maintaining passage corridors between them.

Spatial and Temporal Scales of Refugia

Refugia may exist in areas where the surrounding landscape is marginally suitable for salmonid production or altered to a point that stocks have shown dramatic population declines in traditional salmonid streams. If altered streams or watersheds recover their historic natural productivity, the abundant “source” populations from nearby refugia can potentially re-colonize these areas or help sustain existing salmonid populations in marginal habitat. Protection of refugia areas is noted as an essential component of salmonid conservation to ensure long-term survival of viable stocks, and is a critical element towards recovery of depressed salmonid populations (Sedell et al. 1990, Moyle and Yoshiyama 1992, Frissell 1993, Trombulak and Frissell 2000).

Refugia habitat is defined as: areas that provide shelter or protection during times of danger or distress; locations and areas of high-quality habitat that support populations limited to fragments of their former geographic range, and centers from which dispersion may take place to re-colonize areas after climate readjustment.

This definition soon becomes more complex upon considering the wide range of spatial and temporal habitat required by viable salmonid populations. Refugia habitat varies in scale from a piece of wood that provides instream shelter for a single fish or individual pools that provide cool water for groups of juveniles during hot summer months, to watersheds where conditions support viable populations of salmonid species. Refugia may also be areas where critical life stage functions such as migrations and spawning occur. Refugia of the reach scale or larger are generally more resilient than those of smaller scale to the deleterious effects of landscape and riverine disturbances such as large floods, persistent droughts, and human activities (Sidell et al. 1990). Although fragmented areas of suitable habitat may be important, watershed scale refugia may be needed to recover aquatic species (Moyle and Sato 1991).

Li et al. (1995) suggested three steps to use the refugia concept to conserve salmonid resources: first priority is to identify salmonid refugia and insure they are protected; second, to identify potential habitats that can be rehabilitated quickly; and third, determine how to connect dispersal corridors to patches of adequate habitat.

Refugia and Metapopulation Concept

The concept of anadromous salmonid metapopulations is important when discussing refugia. The “classic” metapopulation model proposed by Levins (1969) assumes the environment is divided into discrete “patches” of suitable habitat. These patches include streams or stream reaches that are inhabited by different breeding populations, or sub-populations (Barnhart 1994, McElhany et al. 2000).

A metapopulation consists of a group of these sub-populations which are geographically located such that over time, there is likely genetic exchange between the sub-populations (Barnhart 1994).

Anadromous salmonids fit nicely into the sub-population and metapopulation concept because they exhibit a strong homing behavior to natal streams forming sub-populations, and also have a tendency to stray into new areas. The straying or movement into nearby areas results in genetic exchange between sub-populations or "seeding" of other areas where populations are at low levels. This seeding comes from abundant or "source" populations supported by high-quality habitat patches which may be considered as refugia.

Habitat patches differ in suitability and population strength. In addition to the classic metapopulation model, other theoretical types of spatially structure populations have been proposed (Li et al. 1995, McElhany et al. 2000). For example, the "core and satellite" (Li et al. 1995) or "island-mainland" population (McElhany et al. 2000) model depicts a core or mainland population from which dispersal to satellites or islands results in smaller surrounding populations. Most straying occurs from the core or mainland to the satellites or islands. Satellite or island populations are more prone to extinction than the core or mainland populations (Li et al. 1995, McElhany et al. 2000). Another model termed "source-sink populations" is similar to the core-satellite or mainland-island models, but straying is (one way) only from the highly productive source towards the sink subpopulations. Sink populations are not self-sustaining and are highly dependant on migrants from the source population to survive (McElhany et al. 2000). Sink populations may inhabit typically marginal or unsuitable habitat, but when environmental conditions strongly favor salmonid production, sink population areas and may serve as important sites to buffer populations from disturbance events (Li et al. 1995) and increase basin population strength. In addition to testing new areas for potential suitable habitat, the source-sink strategy adds to the diversity of behavior patterns salmonids have adapted to maintain or expand viable populations in a dynamic aquatic environment.

The metapopulation and other spatially structured population models are important to consider when identifying refugia because in dynamic habitat, the location of suitable habitat continually changes (McElhany et al. 2000) from natural disturbance regimes and human activities (Reeves et al. 1995). Satellite, island, and sink populations need to be considered in the refugia selection process because they are an integral component of the metapopulation concept and may become the source population or refugia areas of the future.

Refugia Identification and Categorization Methods

Currently there is no established methodology to designate refugia habitat for California's anadromous salmonids. This is mainly due to a lack of sufficient data describing fish populations, meta-populations and habitat productivity across large areas. This lack of information holds true for NCWAP basins especially in terms of metapopulation dynamics. Studies are needed to determine population growth rates and straying rates of salmonid populations and sub-populations to better utilize spatial population structure to identify refugia habitat.

Classification systems, sets of criteria and rating systems, have been proposed to help identify refugia type habitat in north coast streams, particularly in Oregon and Washington (Moyle and Yoshiyama 1992, FEMAT 1993, Li et al. 1995, Trombulak and Frissell 2000, Kisup County 2000). Upon review of these works, several common themes emerge. A main theme is that refugia are not limited to areas of pristine habitat. While ecologically intact areas serve as dispersal centers for stock maintenance and potential recovery of depressed sub-populations, lower quality habitat areas also play important roles in long term salmonid production. These areas may be considered the “islands, satellites, or sinks” in the metapopulation concept. With implementation of ecosystem management strategies aimed at maintaining or restoring natural processes, some of these areas may improve in habitat quality, show an increase in fish numbers and add to the metapopulation strength. Another common conclusion is that over time as good habitats “wink out” either through human caused, natural disturbances, or succession to new ecological states, other areas “wink on”. It is important that a balance is maintained among the “winking out” sites and the “winking on” sites to insure adequate good quality habitat is available to support viable anadromous salmonid populations (Reeves et al. 1995).

NCWAP Approach

The NCWAP interdisciplinary team identified and categorized refugia habitat by using professional judgment and criteria developed for north coast watersheds. The criteria considered different values of watershed and stream ecosystem processes, the presence and status of fishery resources, forestry and other land uses, land ownership, potential risk from sediment delivery, water quality, and other factors that may affect refugia productivity. Information from CDFG’s habitat inventory surveys, NCWAP’s EMDS stream reach, professional judgment, and local Gualala expertise were used to assess streams as potential refugia.

To help identify refugia, evaluation scores from the EMDS stream condition model were summed and ranked by highest total scores at the stream scale. The higher scores indicate higher habitat quality as measured by EMDS evaluations. Stream reach scale parameters used were canopy cover, embeddedness, pool depth, and pool shelter rating. Water temperature data were used when available. The individual parameter scores identified which habitat factors support or limit fish production (see limiting factors section). See attachments to Appendix 6 for examples of how the stream reach conditions parameters are used to rank streams according to EMDS evaluation scores.

Road density, number of stream crossings, roads proximity to streams, riparian cover, and LWD potential comprised the parameters used at the planning watershed scale. See attachments to Appendix 6 for examples of how landscape condition parameters are used to rank planning watersheds according to EMDS evaluation scores.

High Quality Refugia

- Maintains a high level of ecologic integrity (Trombulak and Frissell 2000)
- Contains the range and variability of environmental conditions necessary to maintain community and species diversity and supports natural salmonid production (Moyle and Yoshiyama 1992, Trombulak and Frissell 2000)
- Relatively undisturbed and intact riparian corridor
- All age classes of historically native salmonids present in good numbers, and a viable population of an ESA-listed salmonid species is supported (Li et al. 1995)
- Provides population “seed sources” for dispersion, gene flow and re-colonization of nearby habitats from straying local salmonids
- Contains a high degree of protection from degradation

High Potential Refugia

- Ecological integrity is diminished but remains good (Trombulak and Frissell 2000)
- Instream habitat quality remains suitable for salmonid production and is in the early stages of recovery from past disturbance
- Riparian corridor is disturbed, but remains in fair to good condition
- All age classes of historically native salmonids are present including ESA-listed species, although in diminished numbers
- Salmonid populations are reduced from historic levels, but still are likely to provide straying individuals to neighboring streams
- Currently is managed to protect natural resources and has resilience to degradation, which demonstrates a strong potential to become high-quality refugia (Moyle and Yoshiyama 1992, Trombulak and Frissell 2000)

Potential Refugia

- Ecological integrity is degraded or fragmented (Trombulak and Frissell, 2000)
- Components of instream habitat are degraded, but support some salmonid production
- Riparian corridor components are somewhat disturbed and in degraded condition
- Native anadromous salmonids are present, but in low densities; some life stages or year classes are missing or only occasionally represented
- Relative low numbers of salmonids make bstantial straying unlikely
- Current management or recent natural events have caused impacts, but if positive change in either or both occurs, responsive habitat improvements should occur

Low Quality Habitat

- Ecological integrity is impaired (Trombulak and Frissell 2000)
- Most components of instream habitat are highly impaired
- Riparian corridor components are degraded
- Salmonids are poorly represented at all life stages and year classes, but especially in older year classes
- Low numbers of salmonids make bstantial straying very unlikely
- Current management and/or natural events have substantially altered the naturally functioning ecosystem and major changes in either of both are needed to improve conditions

Potential Future Refugia

- Areas where habitat quality remains high but does not currently support anadromous salmonid populations

- An area of high-habitat quality, but anadromous fish passage is blocked by man made obstructions such as dams or poorly designed culverts at stream crossings etc.

Critical Contributing Areas

- Area contributes a critical ecological function needed by salmonids such as providing a migration corridor, conveying spawning gravels, or supplying high-quality water (Li et al. 1995)
- Riparian areas, floodplains, and wetlands that are directly linked to streams (Huntington and Frissell 1997)

Other

- Areas with insufficient data describing fish populations, habitat condition watershed conditions, or management practices

2.2.6 DEVELOPMENT AND EVALUATION OF HYPOTHESES

NCWAP provides a first cut at watershed assessment by evaluating current watershed conditions, exploring linkages among current and historic conditions and processes, and providing concrete direction for future activities. Given the challenge of accomplishing so complex a task at multiple watershed scales, the program has not established controlled experimental studies, but has instead brought together many types of information and examined it from various perspectives.

Using this material, NCWAP has formulated a set of reasonable hypotheses that can be used to take immediate steps to protect and improve watersheds and streams and to implement additional focused monitoring, assessment or research to fill information. This approach provides a framework for adaptive management.

NCWAP uses hypotheses to assess watershed conditions for supporting salmonids, to identify likely "limiting factors" and potential causes for areas with unsuitable conditions, and to consider potential trends.

The NCWAP team used a weight-of-evidence approach to reach conclusions and to develop appropriate restoration, management, conservation, and monitoring recommendations. They articulated both supportive and contrary findings as well as limitations of the information. This process included results from both disciplinary and interdisciplinary data analyses. Hypotheses and recommendations are provided for each subbasin in Chapter 5.

2.3 Watershed Assessment Approach in the Gualala

The NCWAP approach emphasizes close coordination with stakeholders. The Method Manual provides six general steps for working with local groups and other interested and knowledgeable groups or individuals. The following describes how these were implemented in the Gualala River Watershed:

- **Step One:** ***Scoping.*** The watershed assessment team met with stakeholders to identify watershed concerns, local assessment interests, existing data and gaps, and opportunities to work with local interests to answer the critical questions about watershed condition.
- **Step Two:** ***Data compilation.*** The team compiled and screened existing data according to the quality and usefulness for answering critical questions and its application to the program's EMDS

system model. Quality control processes are described in more detail in Chapter 4 of the NCWAP's draft Method Manual. Information was coordinated among the several departments.

- **Step Three:** ***Initial Analyses*****.** Preliminary reviews and assessments of the data compiled from existing sources resulted in recommendations for field work to ground-truth information from the desk top, fill data gaps, and provide perspective on the watershed that was not available from written and spatial information from the initial data compilation. While the team considered data needs in light of the guiding questions and relative importance in addressing those questions, it was not realistic within time and resource constraints to address all data gaps. For example, it was not possible to collect current water diversion information from the streams in the Gualala.

- **Step Four:** ***Fieldwork.*** Some agencies conducted necessary fieldwork, including validation of existing data, verification of imagery or photo-based analyses, and collection of new data to fill critical gaps. CGS field verification of existing data and photo interpretation was limited. This process was coordinated with the Gualala River Watershed Council, other groups, and landowners on access to private property and validation of findings.

- **Step Five:** ***Analyze data.*** This included the generation of maps, databases, and the more integrative analyses such as potential sediment restoration sites, EMDS outputs, Integrated Analysis tables, limiting factors analysis, and restoration and management recommendations.

- **Step Six:** ***Develop Watershed Synthesis Reports for Public Review.*** This included development of draft reports, workshops to review them with the public, and responses to public and peer review comments. Final products include a revised report with synthesis and detailed appendices, a state website with the report, spatial data, and an interactive GIS, and Institute for Fisheries Resources' (IFR) Klamath Resource Information System (KRIS) Gualala.

2.4 Assessment Report Conventions and Use

2.4.1 REPORT UTILITY AND USAGE

This report is intended to be useful to landowners, watershed groups, agencies, and individuals to help guide restoration, land use, and management decisions. As noted above, the assessment operates on multiple scales ranging from the detailed and specific stream reach level to the very general basin level. A user can focus down from the subbasin finding and recommendation concerning sediment levels, for example, to the stream reach level information to determine which streams in the subbasin may be affected by a limiting factor.

2.4.2 NCWAP PRODUCTS

NCWAP products available through this synthesis report, appendices, and website (www.ncwatershed.ca.gov) include the following :

- Databases of information that the NCWAP has used and collected for its analyses.

- A data catalogue which identifies all the information we considered, as well as a bibliography of other references cited in the assessment report.

- Maps showing geology, geomorphic features related to landsliding, instream sediment, relative landslide potential, and map of potential restoration sites and habitat limiting factors developed by the Department of Conservation/California Geologic Survey (DOC/CGS). Also an electronic database with information not available on the maps.

- An EMDS model that describes how watershed conditions interact at the stream reach and watershed scale to affect suitability for salmonids.
- GIS-based models and analyses such as timber harvest frequency, vegetation history, stream buffers, road locations, road density, road and stream interactions, and roads on unstable slopes.
- An interdisciplinary analysis of the results of fieldwork, historical analyses, EMDS data, and other analytical products about the suitability of stream reaches and the watershed for salmonids.
- An interagency description of historic and current conditions as they relate to suitability for salmonid production: vegetation cover and change, land use, geology and geomorphology, water quality, stream flow, water use, and instream habitat conditions for salmonids.
- Hypotheses and evaluation about watershed conditions that contribute to factors affecting salmonids.
- Recommendations for management and restoration to address limiting factors.
- Recommendations for additional monitoring to improve the assessment process.
- A CD developed through the IFR which uses the KRIS tool to store data, provide a regional bibliography of watershed studies and reports (including some NCWAP products), and store community based data over time (www.krisweb.com).

2.4.3 Calwater 2.2a Planning Watersheds

NCWAP is using the California Watershed Map (Calwater version 2.2a) to delineate watershed units. Calwater is a set of standardized watershed boundaries meeting standardized delineation criteria. The hierarchy of watershed designations consists of six levels of increasing specificity: Hydrologic Region (HR), Hydrologic Unit (HU), Hydrologic Area (HA), Hydrologic Subarea (HSA), Super Planning Watershed (SPWS), and Planning Watershed (PWS). The primary purpose of Calwater is the assignment of a single, unique indentifier code to a specific watershed polygon. The Calwater Planning Watersheds are generally from 3,000 – 10,000 acres in size.

Primary purposes for Calwater 2.2a include, but are not limited to, mapping, reporting, and statistical analysis of water resources, water supply, water quality, wildlands, agriculture, soils, forests, rangelands, fish habitat, wildlife habitat, and cross-referencing state and federal hydrologic unit or watershed codes and names.

Calwater version 2.2a is the third version of Calwater (after versions 1.2 and 2.0), and is a descendent of the 1:500,000-scale SWRCB Basin Plan Maps drawn in the late 1970s.

Line work was captured by overlaying the Basin Plan Maps on 1:24,000-scale USGS quad sheets, redrawing and digitizing lines to match 1:24,000-scale watershed boundaries, and subdividing the 4th level Hydrologic Subareas (HSAs) into 5th level Super Planning Watersheds (SPWS) and 6th level Planning Watersheds (PWS).

2.4.4 Hydrology Hierarchy

Watershed terminology often becomes confusing when discussing the different scales of watersheds involved in planning and assessment activities. The conventions used in the Gualala assessment follow the guidelines established by the Pacific Rivers Council. The descending order of scale is from basin level (e.g., Gualala Watershed); subbasin level (this corresponds in many cases to the "super planning watershed" level in Calwater 2.2a, e.g., North Fork Gualala); watershed level (e.g., Little North Fork); and sub-watershed level (e.g., Doty Creek). The Calwater 2.2a designations are identified at the beginning of each subbasin section.

The subbasin is the assessment and planning scale used in this report as a summary framework; subbasin findings and recommendations are based upon the more specific watershed and sub-watershed level findings. Therefore, there are usually exceptions to the subbasin findings and recommendations at the finer scales. As such, the findings and recommendations at the subbasin level are somewhat more generalized than at the finer scales of watershed and sub-watershed levels. In like manner, subbasin findings and recommendations are somewhat more specific than the even more generalized, larger scale basin level findings and recommendations that are based upon a group of subbasins.

The term "watershed" is used in both the generic sense, as to describe "watershed" conditions at any scale, and as a particular term to describe the watershed scale introduced above, which contains, and is made up from multiple, smaller sub-watersheds. The watershed scale is often approximately 20 to 40 square miles in area; its sub-watersheds can be much smaller in area, but for our purposes contain at least one perennial, un-branched stream. Please be aware of this multiple usage of the term watershed, and consider the context of the term's usage to reduce confusion.

For purposes of assessment and its presentation, the Gualala River Watershed (Hydrologic Area 113.8) was subdivided into the five subbasins further defined below:

North Fork Subbasin

Same as the Calwater North Fork HSA (#113.81)

Same as the Calwater North Fork Super Planning Watershed.

Rockpile Creek Subbasin

Same as the Calwater Rockpile Creek HSA (#113.82)

Same as the Calwater Rockpile Creek Super Planning Watershed.

Buckeye Creek Subbasin

Same as the Calwater Buckeye Creek HSA (#113.83)

Same as the Calwater Buckeye Creek Super Planning Watershed.

Wheatfield Fork Subbasin

Same as the Calwater Wheatfield Fork HSA (#113.84)

Includes the following Calwater Super Planning Watersheds:

- Lower Wheatfield Fork
- Hedgepeth Lake
- Walters Ridge

South Fork/Main Gualala Subbasin

Same as the Calwater Gualala HSA (#113.85)

Includes the following Calwater Super Planning Watersheds:

- Lower South Fork Gualala River
- Marshall Creek

2.4.5 ELECTRONIC DATA CONVENTIONS

The NCWAP collected or created thousands of data records for synthesis and analysis purposes and most of these data were either created in a spatial context or converted to a spatial format. Effective use of these data between the five partner departments required establishing standards for data format, storage, management and dissemination. Early in the assessment process, we held a series of meetings designed to gain consensus on a common format for the often widely disparate data systems within each department. Our objective was to establish standards which could be used easily by each department, that were most useful and powerful for selected analysis, and would be most compatible with standards used by potential private and public sector stakeholders.

As a result, we agreed that spatial data used in NCWAP and base information disseminated to the public through the program would be in the following format (see the data catalog, Appendix 6d, for a complete description of data sources and scale):

Data form**:** standard database format usually associated with a GIS shapefile© (ESRI) or coverage. Data were organized by watershed and distributed among watershed synthesis teams. Electronic images were retained in their current format.

Spatial Data Projection**:** spatial data were projected from their native format to both Teale albers, North American Datum (NAD) 1927 and Universal Transverse Mercator (UTM), Zone 10, NAD 1983. Both formats were used in data analysis and synthesis.

Scale**:** most data were created and analyzed at 1:24000 scale to (1) match the minimum analysis scale for planning watersheds, and (2) coincide with base information (e.g., stream networks) on USGS quadrangle maps (used as Digital Raster Graphics [DRG]).

Data Sources**:** data were obtained from a variety of sources including spatial data libraries with partner departments or were created by manually digitizing from 1:24000 DRG.

The metadata available for each spatial data set contain a complete description of how data were collected and attributed for use in NCWAP. Spatial data sets that formed the foundation of most analysis included the 1:24000 hydrography and the 10 meter scale Digital Elevation Models (DEM). Hydrography data were created by manually digitizing from a series of 1:24000 DRG then attributing with direction, routing, and distance information using a dynamic segmentation process (for more information, please see http://arconline.esri.com/arconline/whitepapers/ao/ArcGIS8.1.pdf). The resulting routed hydrography allowed for precise alignment and display of stream habitat data and other information along the stream network. The DEM was created from base contour data obtained from the USGS for the entire NCWAP region.

Source spatial data were often clipped to watershed, planning watershed, and subbasin units prior to use in analysis. Analysis often included creation of summary tables, tabulating areas, intersecting data based on selected attributes, or creation of derivative data based on analytical criteria. For more information regarding the approach to analysis and basis for selected analytical methods, see Chapter 2, Assessment Strategy and General Methods, and Chapter 4, Interdisciplinary Synthesis and Findings.