Assessment Strategy and General Methods

Assessment Strategy

In 2000, the North Coast Watershed Assessment Program (NCWAP) developed 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. While the information contained in the report is extensive, more detail is included in a set of appendices to this report:

- California Geological Survey — Appendix A
- California Department of Forestry — Appendix B
- Ecological Management Decision Support — Appendix C
- Department of Water Resources — Appendix D
- North Coast Regional Water Quality Control Board — Appendix E
- California Department of Fish & Game — Appendix F

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

Watershed Assessment Approach

The NCWAP approach emphasizes close coordination with stakeholders. The 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 Mattole Basin:

Step One: ***Scoping.*** The basin assessment team met with stakeholders to identify watershed problems or concerns, local assessment interests, existing data and gaps, and opportunities to work with local interests to answer the critical questions.

Step Two: ***Data compilation.*** The team compiled and screened existing data according to the quality and usefulness for answering critical questions and application to the program's Ecological Management Decision Support system model (EMDS). Quality control processes are described in greater detail in Chapter 4 of the NCWAP's draft Methods Manual. The collected information was shared and coordinated among the several departments.

Step Three: ***Initial analyses.*** The team used a preliminary run of the EMDS stream reach model (described in Chapter 3 of the NCWAP's Methods Manual) to help analyze the habitat factors affecting fish production. Air photo interpretation and GIS analysis also enabled the team to identify data needs and questions. Most importantly, in the Mattole Basin assessment, a series of meetings with landowners and interested parties provided the team with local, historic knowledge and valuable critical discussion with which to establish the value of the information in hand.

Step Four: ***Fieldwork.*** Identified, necessary fieldwork was conducted by some team members, dependent upon landowner cooperation. This fieldwork helped validate existing data and verify imagery or photo-based analyses, and provided new data to fill identified gaps. Throughout this process, there was coordination with local groups and landowners on access to private property and validation of findings.

Step Five: ***Analyze data.*** This includes generation of maps, databases, and more integrative analyses like EMDS outputs, GIS layers, Integrated Analysis tables, Limiting Factors Analyses, and watershed improvement recommendations.

Step Six: ***Develop assessment reports for public review.*** This included development of draft reports, public workshops to discuss the drafts, and the collection and distribution of 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.

Mattole Assessment Process Summary

The NCWAP Mattole Team initial public meeting was held in April 2001 to introduced the NCWAP program, solicit public participation in identifying issues, and solicit interested participants from the watershed. As a result, CDFG recruited and hired one contract field technician and one Scientific Aide from within the watershed community. These employees conducted data research and limited data collection. They have also assembled a good portion of the bibliography for CDFG. Additionally, NCWAP was able to hire, on a consultancy basis, a 22-year veteran Mattole River fishery biologist to submit historical information about the fisheries, and analyze with our staff two decades of fishery information.

NCWAP had another public meeting on October 17, 2001. At that time, the nine-person NCWAP team presented the current product status and discussed issues with 25 interested group participants. As a result, specific CGS staff members were invited to conduct verification fieldwork on four major non-industrial properties. Outreach meetings were also held with Pacific Lumber Company (PALCO). Peer review has involved meeting with scientists from Redwood Sciences Lab, BLM, and EPA.

A first draft of the Synthesis Report was completed in November 2001 for internal and agency review. Subsequent drafts for departmental peer review and public comment were completed in January and March 2002. This draft of the Synthesis Report was posted to the NCWAP website (http://www.ncwatershed.ca.gov) and hard copies were distributed to county libraries and constituents.

A public meeting to solicit stakeholder comment was held on February 23, 2002. The workshop was held at the Triple Junction High School near Honeydew. Registration was in the library, and all attendees were given a series of handouts including a copy of the Mattole Synthesis Report, a public comment sheet, geologic maps of the various subbasins, and updated versions of the NCRWQCB and CGS Appendices. The meeting consisted of a general session to orient attendees and focus sessions concerning issues and recommendations to stimulate discussion about the Synthesis Report, and closed with a General Session to recap the day's proceedings.

General sessions were held in a large classroom, and focus sessions were held in five different rooms across the high school campus. The morning general session consisted of an introduction to the workshop and NCWAP process by Scott Downie, CDFG; a presentation explaining the Ecological Management Decision Support System (EMDS) by Rich Walker, CDF; and an introduction to KRIS by Gary Reedy, IFR.

issue and subbasin focus sessions were conducted as discussions led by different agency personnel, with AmeriCorps members taking notes. Issue focus sessions included posters of condensed issues, hypotheses, and recommendations delineated for the Mattole Basin in the Synthesis Report, maps of the Mattole Basin hydrography and CalWater units, and other materials provided by session leaders. Subbasin focus sessions included posters of the condensed issues, hypotheses, and recommendations delineated for the individual subbasins in the Synthesis Report, handouts of these posters, and other materials provided by session leaders. Participants were urged to move between sessions and provide input on the Mattole Synthesis Report.

The afternoon general session consisted of a recap of focus sessions by session leaders, a discussion of important points brought up during the workshop, and discussion of further public input. Another public meeting to generate input was held March 23, 2002.

A follow-up meeting of landowners in the Mattole Basin was held on March 7, 2002 to generate comments on the Synthesis Report. The official public comment period ended on March 11, 2002. Public comments were entered into a database and distributed to all NCWAP team members. Responses to public comments have been entered into the database on an on-going basis. Input is still welcome to the NCWAP team.

A revised draft of the Synthesis Report was prepared on March 22, 2002 for distribution at the March 23, 2002 workshop in Honeydew. The comments received to date were also distributed at the meeting. The report was available on the NCWAP website March 30, 2002.

NCWAP Products

The NCWAP will produce and make available to the public a consistent set of products for each basin assessed.

NCWAP products include:

- A basin level Geologic Report that includes:
    - Maps of landslides and geomorphic features related to landsliding;
    - Relative landslide potential maps;
    - A map of features indicative of excess sediment production, transport and/or deposition;
    - Maps of stream reaches classified by gradient and by Rosgen stream type.
- A basin level Synthesis Report that includes:
    - Collection of Mattole Basin historical and sociological information;
    - Description of historic and current vegetation cover and change, land use, geology and fluvial geomorphology, water quality, stream flow, water use, and instream habitat conditions;
    - Hypotheses and evaluation about watershed conditions affecting salmonids;
    - An interdisciplinary analysis of the suitability of stream reaches and the watershed for salmonid production and refugia areas;
    - Tributary and watershed recommendations for management, refugia protection, and restoration activities to address limiting factors and improve conditions for salmonid productivity;
    - Monitoring recommendations to improve the adaptive management efforts.
- Ecological Management Decision Support system (EMDS) models to help analyze data;
- Databases of information used and collected;
- A data catalogue and bibliography;
- Web based access to the Program's products: http://ncwatershed.ca.gov/, and http://imaps.dfg.ca.gov/.
- A Compact Disk (CD) developed through the Institute for Fisheries Resources (IFR) which uses the Klamath Resources Information System (KRIS).

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. Therefore, findings and recommendations also vary in specificity from being particular at the finer scales, and general at the basin scale. In the Mattole River, for example, there is a general problem with elevated amounts of sediment in lower gradient stream channels. These are reaches used by Chinook and coho salmon and steelhead trout. This sediment is generally harmful to salmonid habitat as discussed above, and further considered in the following discussion about the EMDS model. Today, this general elevated sediment condition is not uncommon throughout most of the overall NCWAP region. To improve upon that and other unsuitable conditions, and therefore salmonid habitat, will require long periods of time even with reduced levels of erosion brought about by careful watershed stewardship. A goal of this program is to help guide, and therefore accelerate that recovery process, by focusing stewardship and improvement activities where they will be most effective. Scaling down through finer levels guided by the recommendations should help accomplish this focus.

To do so, the report is constructed to help provide guidance for that focus of effort. A user can scale down from the general basin finding and recommendation concerning high sediment levels, for example, to the various subbasin sections, to the stream reach level information to determine which streams in the subbasin may be affected by sediment. There is a list of surveyed streams in each subbasin section. In the general recommendation section, a tributary finding and recommendation summary table indicates the findings and recommendations for the surveyed streams within the subbasin. If indicated, field investigations at the stream reach or project site level can be conducted to make an informed decision on a land use project, or to design improvement activities.

For example in the Mattole's Eastern Subbasin, sediment is an issue in the findings and recommendations. From the list of tributaries in a subbasin section the tributary table can be referenced for potential project sites. For example, Westlund Creek is an Eastern Subbasin stream on that list that has both streambank and road-sourced erosion as issues for treatment related to land use projects or improvement activities. Interestingly, during the past two years, over seventy percent of the landowners in Westlund Creek gave permission for erosion control training and surveys to be conducted on their lands in cooperation with the Mattole Restoration Council and the CDFG Restoration Grants Program. That effort was primarily based upon the recommendations in the 1996 CDFG Westlund Creek Stream Report, which is summarized in this Report's CDFG Appendix F. The NCWAP, using these reports, other watershed assessments, its EMDS analytical tool and the resultant spatial presentations of its findings, will provide the opportunity to conduct better coordinated stewardship and improvement work like this example, but at the much broader, basin scale.

Assessment Report Conventions

Subbasins

In order to be more specific and useful to planners, managers, and landowners, it is useful to subdivide the larger Mattole Basin into smaller subbasin units whose size is determined by the commonality of many distinguishing traits. Variation among subbasins is at least partially a product of natural and human disturbances. Other variables that can distinguish areas, or subbasins, in larger basins include differences in elevation, geology, soil types, aspect orientation, climate, vegetation, fauna, human population, land use and other social-economic considerations.

The NCWAP Mattole assessment team subdivided the Mattole Basin into five subbasins (Figure 6) for assessment and analyses purposes. These subbasins are the Estuary, Northern, Eastern, Southern, and Western Subbasins. In general, each subbasin has somewhat unique attributes that are generally common to the several CalWater 2.2a Planning Watersheds (PWs) contained within a subbasin. These PWs are explained below. Common PW attributes pertain to a subbasin's landslide propensity, vegetation, climate, land use, streams, fisheries, towns and communities, access corridors, etc.

CalWater 2.2a Planning Watersheds

The NCWAP used the California Watershed Map (CalWater Version 2.2a) to delineate planning watershed units (Figure 7). This hierarchy of watershed designations consists of six levels of increasing specificity: Hydrologic Region, Hydrologic Unit, Hydrologic Area, Hydrologic Sub-Area, Super Planning Watershed, and Planning Watershed (PW). 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 State Water Resources Control Board Basin Plan Maps drawn in the late 1970s.

NCWAP used the PW level of specificity in many analyses. PWs generally range from 3,000-10,000 acres in size and each PW consists of a specific watershed polygon, which is assigned a single unique code. NCWAP used PWs for mapping, reporting, EMDS, and statistical analysis of geology, vegetation, land use, and fluvial geomorphology.

An important aspect of CalWater 2.2a PWs is that individual PWs often do not represent true watersheds. In other words, PWs often cut across streams and ridgelines and do not cover the true catchment of a stream or stream system. Large streams, such as the North Fork Mattole River, can flow through multiple PWs. In addition, a stream may serve as a border between two CalWater 2.2a PWs. An example is that a large portion of the North Fork Mattole River is the border between the Oil Creek PW and the Rattlesnake Creek PW. This disconnect with hydrologic stream drainage systems is an artifact of the creation of CalWater 2.2a as a tool for managing forest lands in fairly consistent sized units. NCWAP conventions for describing watersheds are discussed below.

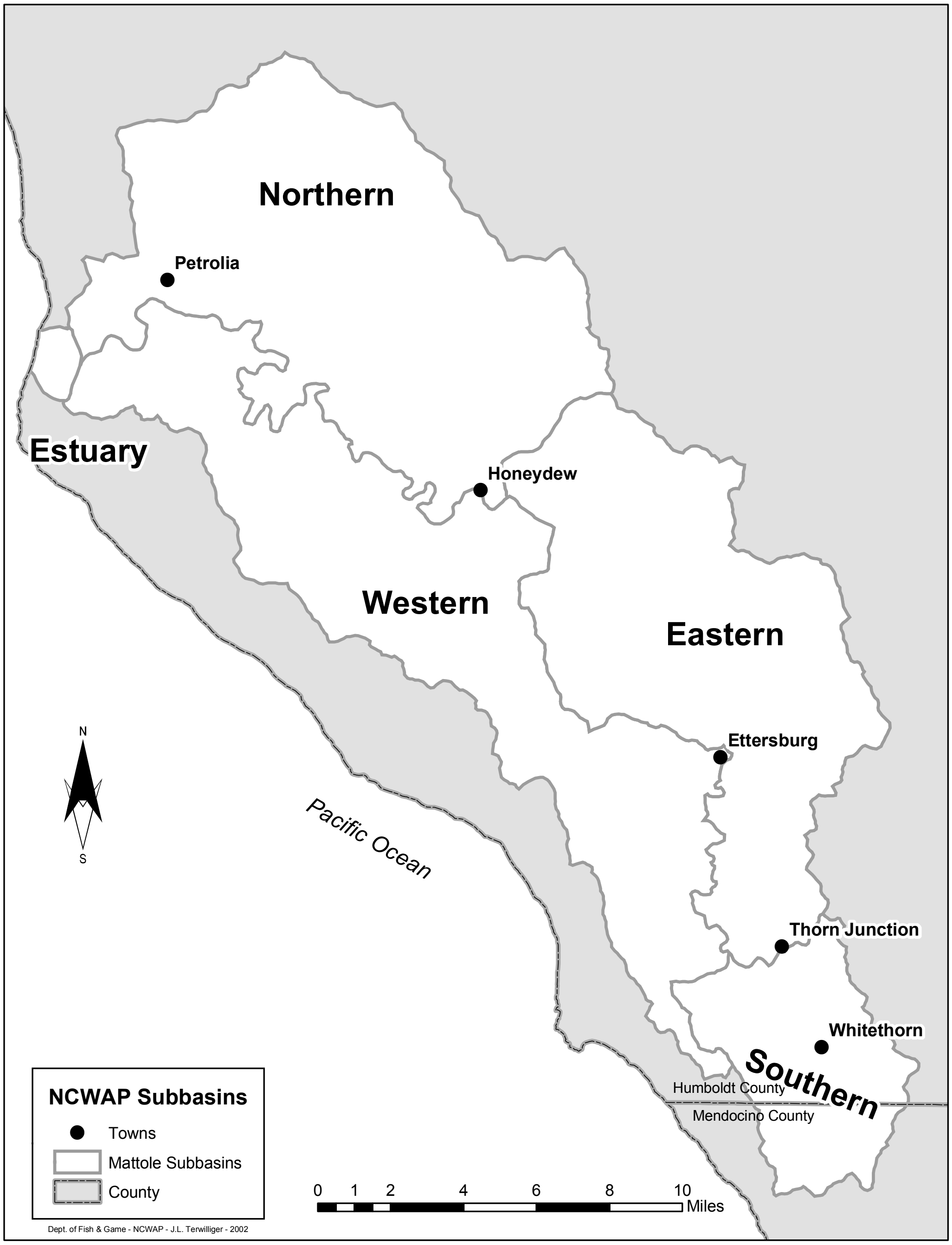


Figure 6. Mattole River subbasins.

Figure 7. NCWAP Mattole subbasins and CalWater 2.2a Planning Watersheds.

Hydrology Hierarchy

Watershed terminology often becomes confusing when discussing different scales of watersheds involved in planning and assessment activities. The conventions used in the Mattole Basin assessment follow guidelines established by the Pacific Rivers Council. The descending order of scale is from *basin* level (e.g., Mattole Basin) – *subbasin* level (e.g., Western Subbasin) – *watershed* level (e.g., Honeydew Creek) – *sub-watershed* level (e.g., Bear Trap Creek) (Figure 8).

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 at the finer scales to subbasin findings and recommendations. Thus, findings and recommendations at the subbasin level are somewhat more generalized than at the watershed and sub-watershed scales. 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 – 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.

Another important watershed term is river mile (RM). River mile refers to a point that is a specific number of miles upstream from the mouth of a river. In this report, RM is used to differentiate between different points along the Mattole River. For example, there are three Mill Creeks in the Mattole Basin. One at RM 2.8, one at RM 5.5, and one at RM 56.2.

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 at the end of this report 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.

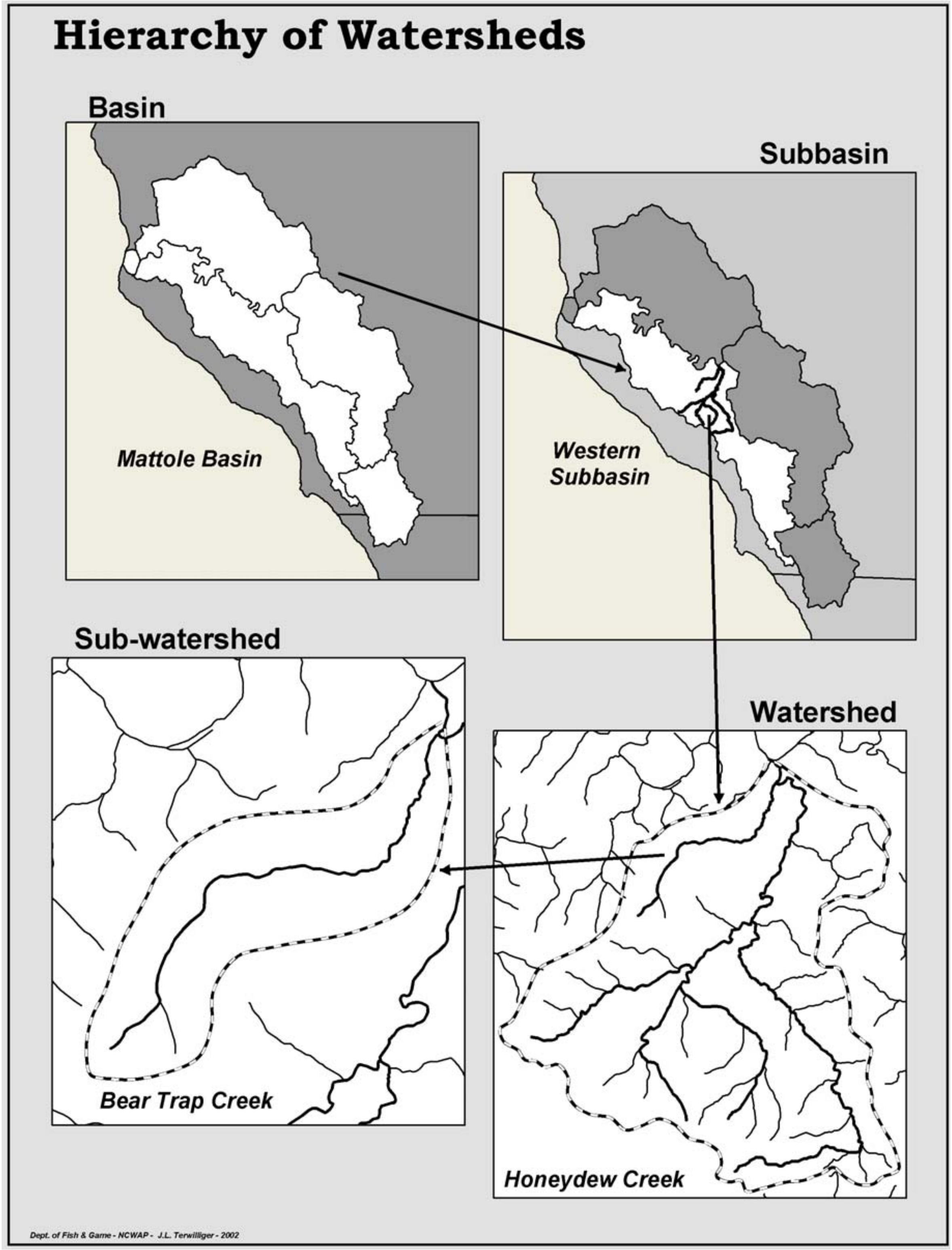


Figure 8. Watershed hierarchy.

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.

Methods by Department

Hydrologic Analyses

Precipitation

The California Department of Water Resources (DWR) analyzed precipitation data for 12 gages with long-term periods of record within the Mattole Basin, summarizing and graphing gages, location, period of record, and annual, and maximum daily precipitation. Five of these gages were in operation longer than 20 years. There are another eight gages located within 10 miles of the watershed boundary. Details about this process are available in the DWR Appendix D.

Streamflow

DWR also analyzed streamflow data. Similar to other watersheds within the North Coast, only a few streamflow gaging stations have historically operated within the Mattole watershed. Only one gage, Mattole River near Petrolia, was operating at the end of water year 2000 and was scheduled to be discontinued due to budget reductions. Beginning in water year 2001, NCWAP began funding this stream. Only one streamflow gage, Mattole River near Petrolia, USGS station #11469000, operated for a significant period (November 1911 – December 1913 and October 1950 – present). This station is located approximately one mile upstream from the town of Petrolia on the main stem of the Mattole River and measures the runoff from 245 or 81% of the total 304 square mile Mattole River watershed.

To gain additional streamflow data, another gage was installed for NCWAP in June 2001 on the Mattole River near Ettersburg in the upper portion of the watershed. The gage will measure the discharge from 58 or 19% of the entire 304 square mile Mattole River watershed. The new gage was also equipped with a temperature sensor. Installation of the new gage by DWR and the USGS was completed in June 2000. The USGS operated the gage during water year 2001and have provided preliminary data for stage, discharge, and water temperature.

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 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 is not reviewed and edited for inaccuracies such as telemetry transmission error, sensor drift or malfunction, or discharge rating curve shift and is 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 DWR Appendix D.

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 Mattole Basin 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. The appendix 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 Mattole Basin. The WRIMS database is under development and may not contain all post-1914 appropriative water right applications that are on file with the CSWRCB 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 Mattole Basin is presented in DWR Appendix D.

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. To determine current potential water use by the permanent population of the Mattole watershed, DFG personnel compiled Year 2000 population census data, then applied unit per capita water use factors from the American Water Works Association and the EPA.

Geologic Analyses

Geologic Base Map

The geologic base map (see Plate 1 of Geologic Report, Appendix A) for the Mattole watershed was compiled from a digital version of a previously published-map, interpretation of aerial photographs, and limited field checking where access was available. The map shows the spatial distribution of major geologic units and geologic structures, and describes the general rock types. Most of the bedrock geology was modified from digital version 1.0 of the 1:100,000-scale geologic map MF-2336 (McLaughlin and others, 2000) published by the USGS that covers the portion of the watershed within Humboldt County. Photointerpretive mapping of black-and-white aerial photos (WAC, 2000) was performed by CGS staff to extrapolate bedrock map units and structural elements from the MF-2336 map to cover the southernmost portion of the watershed, located within Mendocino County. It is important to note that although the bedrock geology of MF-2336 has been presented herein at a scale of 1:24,000, the detail and accuracy of the data is limited to the spatial resolution of 1:100,000 scale in which the digital database was originally compiled by the USGS. Mapped landslide deposits, alluvium, and terrace deposits included in the USGS MF-2336 geospatial database were replaced by more detailed mapping of landslides and Quaternary units performed for this and previous CGS studies.

Assessment of Landslides and Geomorphic Features

CGS developed detailed information on landslide and geomorphic features and compiled them into a GIS database, which forms the keystone of its NCWAP work. Mapped landslides were separated into multiple GIS data layers based on activity (historically active or dormant) and the photo set from which the landslide was mapped. Landslides too small to capture as polygons (below the minimum mapping unit of approximately 100 feet in diameter) were captured as lines or points. The majority of the landslide and geomorphic mapping was accomplished through analysis of stereo-paired aerial photographs from 1984 and 2000 using a mirrored stereoscope. Due to better photo quality and smaller scale, landslides were first mapped on the 2000 photos. The 1984 photos were then examined to determine whether additional landslides could be located and whether a given slide appeared larger or smaller. 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 re-digitized 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 significantly between the two sets of photos. Debris slide slopes and inner gorges were mapped using the 2000 photos; re-mapping of these features on 1984 photos was not needed, since the geomorphic features are not expected to have changed significantly during that time period.

Additional aerial photographs (USDA, 1965; DOD, 1940/1942) that had been scanned and placed on compact disks were provided to us late in the photo-assessment stage. These images were used in select locations to verify or disprove hypotheses on the presence, age, and/or confidence of interpretation of landslide-related features. Finally, data from the previous CGS watershed mapping program was incorporated into the NCWAP program database.

The terminology used in this document to describe landslide types and geomorphic features related to landsliding was updated from DMG Note 50. The terminology and language is derived from the previous Watersheds Mapping program conducted by DMG in the early 1980s. Our nomenclature is consistent with that presented in Cruden and Varnes (1996), and our mapping protocols and assessment of activity follows that proposed by Keaton and DeGraff (1996). Protocols used to assign landslide type and activity are described further below.

Rockslide

Rockslides were referred to in previous CGS publications as translational/rotational landslides. This slide type is characterized by a somewhat cohesive slide mass and a failure plane that is relatively deep-seated when compared to that of a debris slide of similar areal extent. The sense of the motion is linear in the case of a translational slide, and is arcuate or rotational in the case of the rotational slide (i.e., slump). Complex versions involving rotational heads with translation or earthflow downslope are common.

Earthflow

An earthflow results from slow to rapid flowage of saturated rock, soil, and debris in a semi-viscous, highly-plastic state. Typically composed of clay-rich materials that swell and loose much of their already-low shear strength when wet, slide materials erode easily, resulting in gullying and irregular drainage patterns. The irregular, hummocky ground characteristic of earthflows is generally free of conifers; grasslands and meadows predominate. Failures commonly occur on slopes that are gentle to moderate, although they may also occur on steeper slopes where vegetation has been removed.

Debris Slide

A debris slide is characterized by weathered and fractured rock, colluvium, and soil that moves downslope along a relatively shallow translational failure plane. Debris slides form steep, unvegetated scars in the head region and irregular, hummocky deposits (when present) in the toe region. Debris slide scars are likely to ravel and remain unvegetated for many years. Revegetated scars can be recognized by the even-faceted nature of the slope, steepness of the slope, and the light bulb-shaped form left by many mid- and upper-slope failures.

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.

Disrupted Ground

The disrupted ground designation is used to capture areas with a hummocky ground surface caused by multiple landslides, possibly of different types of movement, with individual features too numerous and/or too small to delineate at map scale. This classification is also applied to areas that appear disturbed, but where the ground disturbance cannot be positively attributed to specific landslide types or processes, and may include areas affected by downslope creep, differential erosion, and/or expansive soils. Boundaries are typically indistinct, and activity levels may vary throughout the slope. These features are most often mapped in clay-rich, mélange bedrock units.

Debris Slide Slope

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.

Inner Gorge

An inner gorge is a geomorphic feature formed by coalescing scars originating from landsliding and erosional processes caused by active stream erosion. The feature is identified as that area of stream bank situated immediately adjacent to the stream channel, having a side slope of generally over 65%, and being situated below the first break in slope above the stream channel. Inner gorges were identified from the 2000 air photos based on breaks in slope or active zones of debris sliding along stream channels. Where map scale permitted, inner gorges were mapped on each bank if appropriate; where the inner gorge was too narrow to differentiate the separate banks at 1:24,000 scale, a single symbol was drawn along the stream channel.

Gullies

Gullies are erosional channels produced by running water in earth or unconsolidated material. The channels usually carry water only during and immediately after heavy rains. They generally have steep sides and near-vertical headcuts, which are generally unvegetated. Gullies typically increase in size by surface flow concentrated near the gully's head, and by subsurface flow undercutting the head scarp or the gully walls.

Landslide Attributes

A variety of landside attributes were evaluated as part of the landside mapping process for NCWAP, with the findings incorporated into the 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. The interpretation of landslide activity and the level of confidence in the actual existence of mapped landslides are discussed further below.

Activity

Under NCWAP, landslides were categorized as historically active or dormant. In some cases, dormant landslides were further subdivided. The recency of movement was assessed based on the apparent freshness of features, as outlined in Keaton and DeGraff (1996), with a slight modification to accommodate the lack of man-made structures in much of the Mattole study area. Landslide activity was noted because those landslides that have moved recently are considered more likely to remobilize in the future, as well as to have had some influence on local stream conditions. Activity criteria were not applied to geomorphic features (debris slide slopes, inner gorges, and disrupted ground).

Historically-active slides include those believed to have moved within the last 100 to 150 years, based primarily on observations from the aerial photographs. Historically-active rock slides and earthflows typically have crisp or sharp scarps and lateral flanks, the internal portions of the slide have undrained, hummocky topography, vegetation is typically absent on the lateral and main scarps, and toes are clearly present and well-defined, often pushing out into streams or alluvial flats. Debris slides and debris flow/torrent tracks are considered historically active when recognizable, as are gullies.

Dormant slides are categorized as young, mature, or old. Landslide-related features are still clearly recognizable in dormant-young slides, but some features may appear to have been softened by stream and/or weathering activities. Drainages are just becoming established along the lateral margins of the slide mass. Dormant-mature landslide features are typically recognizable, but have been "smoothed over" significantly, with drainages being incised into the body of the slide. Dormant-old landslides have been extensive modified by stream and/or weathering activities, often are heavily dissected internally, and occasionally other geologic features, such as terraces, can be observed within the slide area.

Confidence of Interpretation

Each mapped landslide is classified as definite, probable, or questionable. Confidence of interpretation is dependent on the distinctness of landforms, variations in vegetation, and other features indicative of landsliding that can be observed from aerial photos or in the field. The classification definite is applied where features common to landslides are clearly distinguishable, including, but not limited to, headwall scarps, ground cracks, pronounced toes, well-defined benches, closed depressions, displaced vegetation, springs, and irregular or hummocky topography. The classification probable is applied where the shapes of the landforms and their relative positions strongly suggest downslope movement, but other explanations are possible such as faulting. The classification questionable is typically applied to an area that lacks distinct landslide morphology, but may exhibit disrupted terrain or other abnormal features that vaguely to strongly imply the occurrence of mass movement.

Relative Landslide Potential

Once relevant relationships between geology and landsliding were recognized, a landslide-potential map was created, using the GIS as a tool to capture the geologists' interpretation of relative landslide potential within the watershed. The landslide-potential map was generated using a decision matrix (see Table 2 of the Geologic Report) prepared by CGS geologists. The matrix format is similar to, and the ranking criteria consistent with that developed for other watersheds within the NCWAP program and used in other CGS programs, but has been crafted to reflect conditions within the study area.

Elements considered, interpreted, and applied iteratively within the GIS by the geologists include: 1) the occurrence and distribution of historically-active and dormant landslides, debris slide slopes and disrupted ground; 2) actively-eroding areas such as inner gorges and gullies; 3) geologic conditions relative to steepness and observed behavior of slopes within the study area, and 4) Shalstab values (Deitrich and Montgomery, 1999) suggestive of additional potential debris flow source areas. Dependant on the nature of these elements, landslide potential was categorically assigned, ranging from 1 (very low) to 5 (very high). Where differing criteria resulted in a region being assigned different potential values, the highest ranking was used on the map.

The landslide-potential map was generated at a scale of 1:24,000, the same as the geologic and landslide-inventory map. Accordingly, local variations in landslide potential may exist at a site that are too small to capture at the map scale. Explanation of the five landslide potential categories are as 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 within the moderate to hard terrains in the Mattole River Watershed.
- 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. Landsliding in these areas is not common. This area generally includes the narrow flat-topped ridges and gentler side slopes in the hard and moderate terrains, gentler slopes and broad ridgetops within the soft terrain, and Quaternary units with gentler slopes.
- 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 includes portions of dormant landsides with gentler slopes, flat-topped ridges within the soft terrain, many slopes in the moderate and hard terrains, and debris slide/flow source areas with moderate slope.
- 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 includes many of the larger dormant rockslides and dormant old/mature earthflows, moderately steep to steep debris slide slopes, disrupted ground, moderate to moderately steep slopes in the soft terrain, steeper slopes within the moderate terrain, and historically active debris torrent tracks.
- Category 5, **Very High Landslide Potential:** Areas include historically active landslides (<150 years old), inner gorges, and gullies, as well as debris slide/flow source within soft terrain or on steep to very steep slopes. Dormant-young rockslides with very steep slopes and dormant-young earthflows with moderately steep to very steep slopes are also included.

Fluvial Geomorphic Analysis

A reconnaissance-level, fluvial-geomorphic study was made of the Mattole River watershed to document the geomorphic characteristics of streams and upland areas. Our assessment focused primarily on mapping specific stream features associated with sediment source, transport, and response (depositional) areas within the watershed (Investigation findings of the Geologic Appendix A). Fluvial-geomorphology data sets collected for this study were developed from observations of 1984 and 2000 aerial photographs that cover the entire watershed, and are described below. Older photographs were spot-checked in selected portions of the watershed to confirm interpretations.

Rosgen Channel Classification

Channel types were characterized within the study area using a reconnaissance-level interpretation based on Rosgen (1996) channel type. The Rosgen classification system uses three-dimensional properties (entrenchment ratio, width/depth ratio, and sinuosity) to distinguish between stream types (see detailed description in the Geologic Report). These properties are best determined by field measurements; however, for this study they were estimated from air photos and topographic base maps.

Rosgen stream type is further subdivided based on channel slope. For this study, the 10m DEM was used to code the stream drainage network for gradient based on Rosgen class gradient breaks (0.1%, 1%, 2%, 4%, and 10%). The final level of Rosgen classification, differentiating by channel materials, could not be estimated using air photos.

Mapped Channel Characteristics

Thirty-two types of stream characteristics (mapped channel characteristics; MCCs) were considered in the aerial photograph review, and added to the fluvial database where observed (Table 3). Channel characteristics are generally only visible when the channel canopy cover is sufficiently open to allow observation and observations are dependent on imagery scale and quality. Nevertheless, the use of aerial photo mapping of channel geomorphic characteristics taken at different times allows for documentation and detection of channel change. These mapped channel characteristics can be used in assessing relative channel changes, aid in delineation of areas for field studies and document channel associations with upland characteristics and processes. Fluvial geomorphic features mapped by aerial photo interpretation should be considered reconnaissance data.

Table 3. 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

Note: Features in bold represent channel characteristics indicative of excess sediment in the channel.

Within the database, channel characteristics were listed in order of importance for influencing the stream channel. The primary characteristic field (Sed type 1 in the attribute fields) represents that channel characteristic best reflecting conditions observed throughout the mapped channel reach. The secondary characteristic fields (Sed type 2, 3 and 4 in the attribute fields), records channel characteristics also observed within the reach, if present, but they were considered to be of subordinate importance. Images of these mapped features are presented and described in the "Photographic Dictionary of Mapped Channel Characteristics" (Appendix 3 of the Geologic Report).

For the purpose of the EMDS watershed modeling exercise, some channel characteristics were considered indicators of excess sediment in storage (e.g., mid-channel bars), channel instability (e.g., eroding banks), or sediment sources that are less than optimum for fishery habitat. Those indicative of excess sediment production, transport, and/or response (deposition) are referred to as negative mapped channel characteristics (NMCCs) within this report and are shown in boldface type on Table 3. The EMDS modeling used only the "negative" characteristics in the primary data field characteristic (sed_type1) for relative ranking of watershed channel geomorphic conditions. While most of these features are always associated with increased sediment or impaired conditions, others, such as lateral bar, may or may not represent impairment. The actual fisheries habitat value should be determined through field surveys.

Vegetation

CalVeg2000 – California Department of Forestry and Fire Protection / United States Forest Service Remote Sensing Laboratory.

This land cover data was developed based on 1:24,000 aerial photograph interpretation of land cover (primarily vegetation) as the foundation for an automated, systematic processing of 1998 LANDSAT imagery. It is the only available data set that characterizes vegetation at the Mattole watershed scale. This data is still preliminary and is currently receiving an accuracy assessment that includes comparison to permanent inventory plots. Despite the lack of an accuracy assessment, it was used for this report because this update was specifically designed to increase accuracy in the life form, dominant tree size, and crown closure typing, all identified as weaknesses in the 1994 data set. The minimum mapping size is 2.5 acres for contrasting types and no minimum mapping size for lakes and conifer plantations. The minimum mapping size of 2.5 acres limits the use of this data to a general descriptor of vegetation type. In a forest vegetation type, this data does not register habitat attributes of low or occasional frequency such as large trees or snags that may play a vital role in large woody debris recruitment or wildlife habitat. It is also limited in selecting thin ribbons of higher canopy closure along streams or narrow tree and shrub ribbons of vegetation along streams in a grassland vegetation type although improving the ability to capture this characteristic is one of the objectives of this new data set. For the Mattole watershed, the percentage of area in the broad vegetation types essentially remained the same in both the 1994 and 1998 versions, the mixed forest category increased two percent while the herbaceous type decreased the same amount. The most noticeable difference between the two data sets is in tree vegetation size. The 1998 data set reduced the percentage of area in pole (6- 11 inch dbh) and large (>24 inch) tree sizes and increased the percentage in the small (11-24 inch dbh) tree size class.

Land Use

Timber Harvest History

CDF 1941 and 1954 aerial photograph interpretation:

Land use was delineated by placing transparent plastic sleeves directly over the photos and classifying land use change while viewing through a stereoscope. Categories that were delineated were fire, timber harvest, pasture, irrigated crops, orchard, buildings, and urban. Since this is a land use change classification, not all grassland or timberland was delineated or typed. While the full extent of many areas burned by fire could not be estimated, if the fire created a change in vegetation, it was recorded. For example, in 1941, many areas appeared to be burned as evidenced by standing dead trees. In some cases this was recorded as a permanent conversion, usually subjectively determined by proximity to existing grasslands, barns or other buildings, roads, and high fire intensity. This was recorded as a temporary conversion if the fire appeared to be far from existing roads and buildings, thus indicative of a wildfire, or if the fire intensity was low and left substantial tree cover.

Timber harvest activity was broken into silviculture and logging system categories using the closest approximation to the standard definitions. It was apparent that the early harvesting was often a conversion attempt. There is no way of knowing whether the trees removed were old- growth stands that were present prior to European-American settlement or if these were trees that had grown in due to changes in land-use practices between 1860 and 1941. In much of the tan-oak dominated forestland, individual tree crown diameters were often very large and seemed indicative of open growing conditions at some point in time perhaps, as a result of tan-oak bark harvesting or possibly of wildfire. These areas were not mapped since the canopy closure was high at the time of the photos and the cause could not be determined. In some instances trees had been removed or killed and the closest silvicultural category was used. In many of the 1941 photographs, there were no roads or skid trails visible and no logging system was recorded. Since trees were often girdled or burned on-site during this era, this seemed reasonable.

Minimum acreage mapped varied by land use classification. Crops and orchards were mapped when seen. It was assumed that fenced grassland was grazed. Area harvested and silvicultural treatments were the two most difficult categories. The large proportion amount of hardwood and brush was very apparent because there was often a lot of vegetative cover remaining after a harvest that removed most of the conifer. There were many pockets that looked lightly entered with skid trails, may have had a few trees removed, or were excluded from harvest because there was no conifer present. The resultant silviculture was highly variable in many instances. Seed tree removal step was delineated as the silvicultural system used when it appeared that the dominant conifer cover was removed, but considerable hardwood and/or brush remained. When the excluded areas were large relative to the adjacent harvested areas, they were also excluded from the harvest land use polygon.

Disturbance categories were broadly grouped into low, medium and high. Disturbance was based on potential sediment delivery to watercourses. High intensity fire areas, cultivated land and grazed areas immediately adjacent to streams or on steep slopes, and virtually all tractor logging during this time period were classified as high disturbance potential areas. Slides were not mapped although sometimes included as a comment.

The information from the mylar sleeves was inputted as polygon features into the ArcView GIS system by onscreen or "heads-up" digitizing (i.e., creating point, line, or polygon features in a mapping program without using georeferenced data; generally done using aerial photos, Digital Orthophoto Quads, or USGS topographical maps) using 1993 black and white orthographic quadrangles as the background. Distortion was corrected by using watercourses, ridges, and roads as reference indicators. The scale distortion apparent in the aerial photographs compared to the orthoquads during the heads-up digitizing was manually corrected by changing the scale of the orthoquad to match the area near the polygon to provide the best fit.

Recommendations

This data are similar to other aerial photograph interpretations of various types of land use. The aerial photos used appeared to be of the same age as the flight date. Many were faded and had hand-drawn line work on them from past projects. When using these data, it is important to note that timber harvesting is often used as a surrogate for a change in vegetation type, size, or density. In a general sense, this is true, but early harvesting did not follow the classic silvicultural methodology and even-aged harvests in particular varied widely in the application on the ground. Disturbance was based on potential sediment delivery to watercourses and was evaluated based on the project level. The harvest data in these layers were not included in the summary harvest tables because the data did not appear to closely match the Mattole Restoration Council Maps and acreage. There were many similarities and differences could be qualitatively adjusted, but the end result would have mixed numbers without providing advantages. The data are used to describe conditions as they appeared in the earliest basin-wide photographic record.

Harvest History 1940 Through 1984

Harvest history information up to 1978 is based on the Humboldt and Mendocino County Assessor maps prepared for tax purposes while harvest history between 1978 and 1984 was based on aerial photograph interpretation by MRC staff.

The Assessor maps and the information on them were used for tax assessments when both timberland and standing timber were assessed annually. The base maps were developed especially for Humboldt County and, while similar, the maps are not the equivalent of the USGS maps for the same area. The vegetation typing is based on 1960 aerial photograph interpretation work by the office of H. G. Chickering Jr., a consulting aerial photogrammetrist company based in Eugene, Oregon. Harvested timberland that had more than 70 percent of the commercial timber volume removed and thus not taxed was indicated by an "X." Grassland, not forested, brush, and tree vegetation type and size class information was provided based on 1960 data. The harvested areas in these maps were updated when harvesting removed standing timber from the tax rolls. This was recorded by manually delineating the areas on the map by dashed lines and an "X" with the harvest date. The typing was done by foresters who had local knowledge of the county. Silviculture and logging system type are not specified in the maps because it was common knowledge that the logged areas had at least 70 percent of the commercial conifer removed, thus similar to a shelterwood seed cut or clear-cut and tractor logging was the overwhelmingly dominant operating system. Despite the fact that these maps may under-estimate logged acreage, the maps indicate that most of the available timberland, approximately 93 percent, was harvested by 1983. While the maps were not identical to USGS maps, the digitized acreage for the entire Mattole watershed was within 1 percent. Harvest dates in the digitized maps were grouped into time categories by MRC staff.

CDF Northern Region Forest Practice GIS Timber Harvesting Plan Data 1983 to 2000 – Mattole Hydrologic Area

Spatial timber harvesting plan data are digitized into the GIS at a scale of 1:12,000 or better using the on-screen or "heads-up" digitizing method. Digital USGS 1:24,000 topographic quadrangles and USGS 24K DLGs (Digital Line Graphs) serve as base data layer. Timber harvesting plan data are derived from THP maps, amendments, and completion reports contained in the THP of record on file with the California of Forestry and Fire Protection in Santa Rosa, California. The USGS 24K DLG data is augmented with features derived from the THP of record. These records were updated by CDF-NCWAP staff to include all filed and approved NTMPs and completion dates.

The State of California and the Department of Forestry and Fire Protection make no representations or warranties regarding the accuracy of data or maps. Neither the State nor the Department shall be liable under any circumstances for any direct, special, incidental, or consequential damages with respect to any claim by any user or third party on account of or arising from the use of data or maps.

These records are not fitted to aerial photographs or orthoquads and may not be precise in location, but timber harvesting plan boundaries appeared to fit pretty well when qualitatively viewed with 1993 orthoquads and 2000 aerial photographs. As mentioned previously, one should be cautious about using silviculture as a surrogate for vegetative cover descriptions; some of the rehabilitation and seed tree removal step prescriptions were almost indistinguishable to the pre-harvest condition when viewing aerial photographs. The files are organized by the date of THP submittal. The time between plan submittal and actual harvest varies, often by several years. This time delay occurs for a variety of reasons including long THP review periods for controversial plans, litigation, and landowner attempts to harvest when the market is most favorable.

Road Networks

NCWAP Mattole Roads Layer

This roads layer was developed to provide additional information for the assessment of the Mattole Basin as part of the North Coast Watershed Assessment Program. Editing of existing roads layers consisted of at least partially spatially rectifying roads to the 1993 USGS Orthographic Quadrangles available as GIS images. Due to time restrictions, this was not completed, but roads adjacent to watercourses were the highest priority areas. This dataset was based on 1:24,000 for road segment spatial accuracy. This data set incorporates existing datasets and maps while also adding road segments digitized from 1993 USGS Orthographic quadrangles. The number of roads in this dataset underestimates the number of logging roads that have been constructed over the years in the Mattole watershed since many of the abandoned roads were not clearly visible. The number of miles of roads increased by one-third compared to previous watershed-wide data sets. Information describing road segments is partial and biased since some areas are more completely characterized than others due to the incorporation of existing datasets for portions of the watershed. While this data set contains the most comprehensive roads information for the watershed, it is still partial and may be useful for resource management or land use purposes. It does not contain addressing information used by emergency services.

Water Quality

Data Collection:

The North Coast Regional Water Quality Control Board staff in the NCWAP program, in cooperation with staff from the Surface Water Ambient Monitoring Program, and TMDL units, cooperated in collecting physical-chemical data and measurements during 2001 in the Mattole Basin. Sample collection, and analysis followed protocols described in the draft NCWAP Methods Manual and other procedures established by various entities, such as field sample collection guidelines developed by, and/or acceptable to the USEPA, USGS, Forest Science Project (FSP), and others.

Data Analysis and Presentation:

Gathered data were computerized into formats appropriate for the information, e.g., spreadsheets for dissolved oxygen, specific conductance, pH, temperature, sediment, etc. Analysis of the data is specific to the data type and its quality. Specific guidelines for temperature and sediment used in this report are outlined below and apply to all Mattole Subbasins where they are discussed. All of the data were reported in tables, point graphs, and/or a combination of the two depending on the data type.

Other sediment data were gleaned from previous efforts, particularly those of the Mattole Salmon Group, that included year 2000 residual pool filling, or V* (MSG, 2000). V* is the fraction (percent) of residual pool volume filled with fine sediment (silt, fine sand to small- to medium-gravel). It can be used as one of many indicators of the sediment supply and substrate habitat in gravel bed channels. It has proven to be a useful tool to evaluate and monitor stream channel conditions and determine upstream and upslope sediment sources (Knopp, 1993; Hilton and Lisle, 1993).

Temperature data were collected by the TMDL unit and analyzed by NCWAP Regional Water Board staff. The TMDL unit also contracted with a consultant to have aerial thermal infrared radar projections capable of assessing shade canopy and surface water temperatures, the results of which were available from the consultant and included in the Water Quality Appendix E. All temperature data gathered and analyzed followed currently accepted scientific protocols developed by the FSP (FSP, 1998). Summary temperature data was also provided by the MSG and was considered of high quality as it followed similar protocols developed by the FSP.

Temperature plots derived from maximum weekly average temperatures (MWATs) were also compared to the fully suitable range of conditions, between 50-60 °F (10-15.6 °C), that are agreed as optimal for various salmonid life stages. The 50-60 °F range was developed as an average of the needs of several cold water fish species, including coho salmon and steelhead trout (Armour, 1991, FSP, 1998). In addition, stream water temperature ranges of varying suitability to unsuitability above the 50-60 °F fully suitable MWAT range for salmonids were developed and referenced to specific reaches and streams by the NCWAP Team.

Peak temperatures were also derived and are also important to consider as they may reflect short-term thermal extremes that, unless salmonids are able to escape to cool water refugia, may be lethal to fish stocks. A temperature of 75 °F was used as the maximum critical peak temperature that the literature supports, above which death is usually imminent for most Pacific Coast salmonid species (Brungs and Jones, 1977; Sullivan, et al., 2000).

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 Mattole 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. 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 stream flow, 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% 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%, 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 Mattole Basin 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 (personal communication, L. Preston).

Interdisciplinary Synthesis

Ecological Management Decision Support (EMDS)

The NCWAP has selected the Ecological Management Decision Support system (EMDS) (Reynolds 1999) software to help evaluate and synthesize information on watershed and stream conditions important to salmonids during the freshwater phases of their life history. The EMDS Appendix C describes the general workings of EMDS and the details of the models NCWAP is developing in conjunction with it.

NCWAP scientists have constructed knowledge base models to identify and evaluate environmental factors (e.g. watershed geology, stream sediment loading, stream temperature, land use activities, etc.) that 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 synthesis EMDS provides can then be compared to more direct measures of salmonid production—i.e., the number of salmonids recently found in streams. EMDS offers a number of benefits for the assessment work that NCWAP is conducting, and also has some known limitations. Both the advantages and drawbacks of EMDS are provided in some detail here and in the EMDS Appendix C.

Our use of the EMDS model outputs in this report is tentative. As discussed below, a scientific peer review process conducted in April of 2002 indicated that substantial changes to NCWAP's EMDS modeling approach are needed. At the time of the production of this report, we have been able to implement some, but not all of these recommendations. Hence, we use the model outputs with caution at this time. NCWAP will continue to work to refine and improve the EMDS model, based on peer review.

Details of the EMDS Model

EMDS system (Reynolds 1999), was developed at the USDA-Forest Service, Pacific Northwest Research Station. It employs a linked set of software that includes MS Excel, NetWeaver, the Ecological Management Decision Support (EMDS) ArcView Extension, and ArcView™. Microsoft Excel is a commonly used spreadsheet program for data storage and analysis. NetWeaver (Saunders and Miller (no date), developed at Pennsylvania State University, helps scientists build graphics of the models (knowledge base networks) that specify how the various environmental factors will be incorporated into an overall stream or watershed assessment. These networks resemble branching tree-like flow charts, and graphically show the logic and assumptions used in the assessment, and are used in conjunction with environmental data stored in a Geographic Information System (ArcView™) to perform the assessments and facilitate rendering the results into maps. This combination of software is currently being used for watershed and stream reach assessment within the federal lands included in the Northwest Forest Plan (NWFP).

NCWAP staff began development of EMDS knowledge base models with a three-day workshop in June of 2001 organized by the University of California, Berkeley. In addition to the NCWAP staff, model developer Dr. Keith Reynolds and several outside scientists also participated. As a starting point, NCWAP used an EMDS knowledge base model developed by the NWFP for use in coastal Oregon. Based upon the workshop, subsequent discussions among NCWAP staff and scientists, examination of the literature, and consideration of California conditions, NCWAP scientists then developed preliminary versions of the EMDS models. The first model was for assessing Stream Reach Condition, and the second was designed to assess conditions over the area of the Watershed Condition.

The two initial NCWAP models were reviewed over 2 days in April 2002 by an independent nine-member science panel, which provided a number of suggestions for model improvements. According to these suggestions, NCWAP scientists revised their EMDS models, as presented below.

The Knowledge Base Network

For California's north coast watersheds, the NCWAP team has constructed five knowledge base networks reflecting the best available scientific studies and information on how various environmental factors combine to affect anadromous fish on the north coast. All five models are geared to addressing current conditions (instream and watershed) for salmonids, and to reflect a fish's perspective of overall habitat conditions:

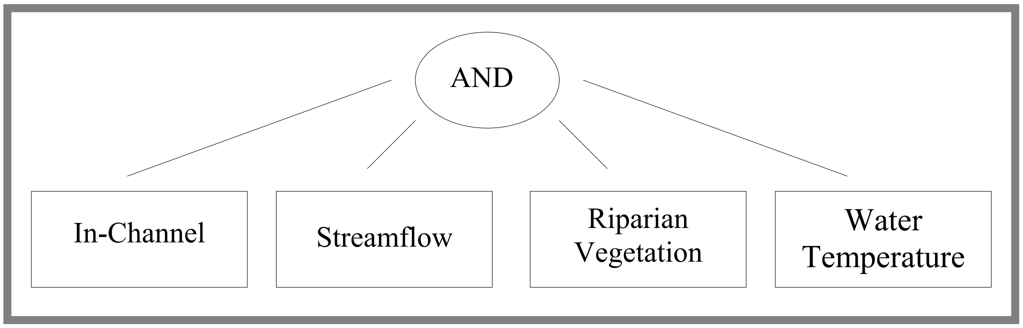
- The Stream Reach model (Figure 12, Table 4), addresses conditions for salmon on individual stream reaches and is largely based on data collected under the Department of Fish and Game's stream survey protocols;
- The Sediment Production model (Figure 11, Table 5), evaluates the magnitudes of the various sediment sources in the basin according to whether they are natural or management related;
- The Water Quality model (Figure 13) offers a means of assessing characteristics of instream water (flow and temperature) in relation to fish;
- The Fish Habitat Quality model (Figure 13) incorporates the Stream Reach model results in combination with data on accessibility to spawning fish and a synoptic view of the condition of riparian vegetation for shade and large woody debris;
- The Fish Food Availability model (Figure 13) has not yet been constructed, but will evaluate the watershed based upon conditions for producing food sources for anadromous salmonids.

In creating the EMDS models listed above, NCWAP scientists have used what is termed a top-down approach. This approach is perhaps best explained by way of example. The NCWAP Stream Reach Condition model began with the proposition: *The overall condition of the stream reach is suitable for maintaining healthy populations of native coho and Chinook salmon, and steelhead trout*. A knowledge base (network) model was then designed to evaluate the truth of that proposition, based upon data from each stream reach. The model design and contents reflect the specific information NCWAP scientists believe are needed, and the manner in which it should be combined, to test the proposition.

In evaluating stream reach conditions for salmonids, the NCWAP model uses data on several environmental factors. The first branching of the knowledge base network (Figure 9) shows that information on in-channel condition, stream flow, riparian vegetation and water temperature are all used as inputs in the stream reach condition model. In turn, each of the four branches is progressively broken into more basic data components that contribute to it (not shown). The process is repeated until the knowledge base network incorporates all information believed to be important to the evaluation.

Although model construction is typically done top-down, models are run in EMDS from the bottom up. That is, data on the stream reach is usually entered at the lowest branches of the network tree (the leaves), and then is combined progressively with other information as it proceeds up the network. Decision nodes are intersections in the model networks where two or more factors are combined before passing the resultant information on up the network. For example, the AND at the decision node in Figure 12 means that the lowest value of the four general factors coming in to the model at that point is taken to indicate the potential of the stream reach to sustain salmon populations.

Figure 9. EMDS stream reach knowledge base network.



EMDS models assess the degree of truth (or falsehood) of each model proposition. Each proposition is evaluated in reference to simple graphs called reference curves that determine its degree of truth/falsehood, according to the data's implications for salmon. Figure 10 shows an example reference curve for the proposition *is the stream temperature is suitable for salmon*. The horizontal axis shows temperature in degrees Fahrenheit, while the vertical is labeled Truth Value and ranges from – 1 to +1. The line shows what are fully unsuitable temperatures (-1), fully suitable temperatures (+1) and those that are in-between (> -1 and <+1). In this way, a similar numeric relation is required for all propositions evaluated in the EMDS models.

For each evaluated proposition in the EMDS model network, the result is a number between –1 and +1. The number relates to the degree to which the data support or refute the proposition. In all cases a value of +1 means that the proposition is completely true, and –1 implies that it is completely false, while in-between values indicate degrees of truth (i.e. values approaching +1 being closer to true and those approaching –1 converging on completely untrue). A zero value means that the proposition cannot be evaluated based upon the data available. Breakpoints (where the slope of the reference curve changes) in Figure 10 example occur at 45°, 50°, 60° and 68 °F. For the Stream Reach model, NCWAP fisheries biologists determined these temperatures by a review of the scientific literature.

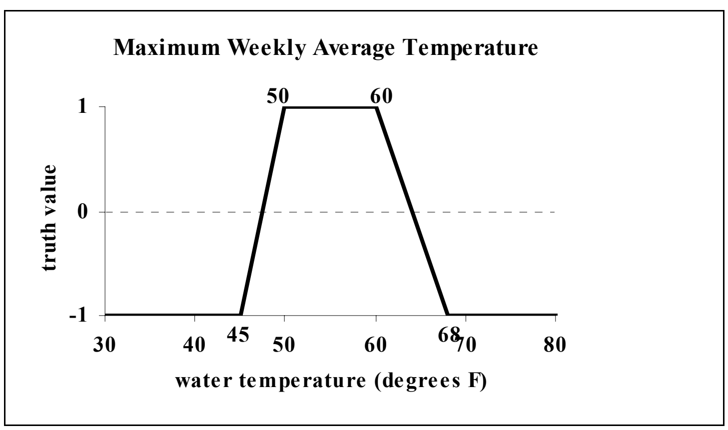


Figure 10. EMDS reference curve.

EMDS uses this type of reference curve in conjunction with data specific to a stream reach. This example curve evaluates the proposition that the stream's water temperature is suitable for salmonids. Break points can be set for specific species, life stage, or season of the year. Curves are dependent upon the availability of data.

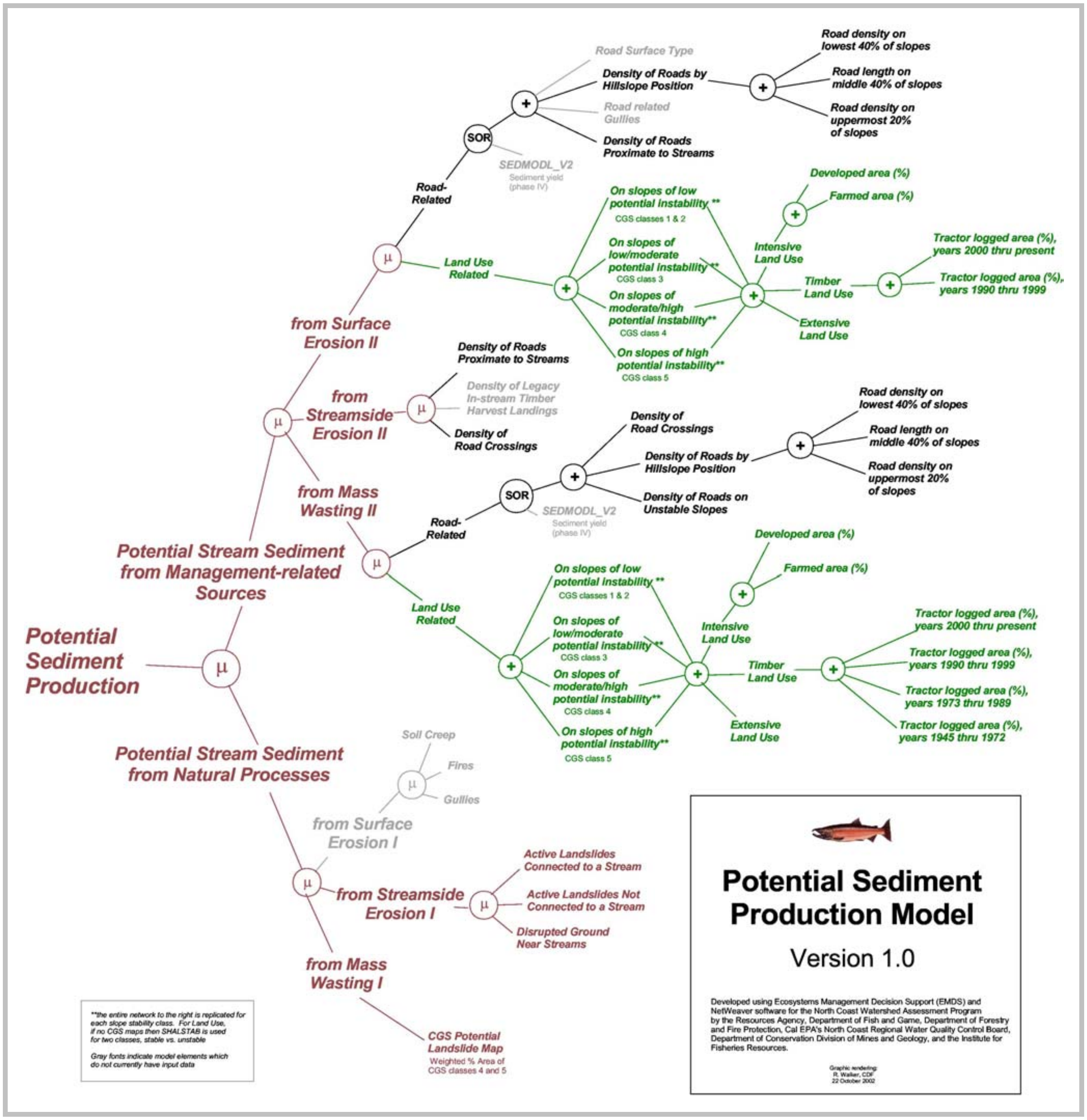


Figure 11. NCWAP EMDS potential sediment production model.

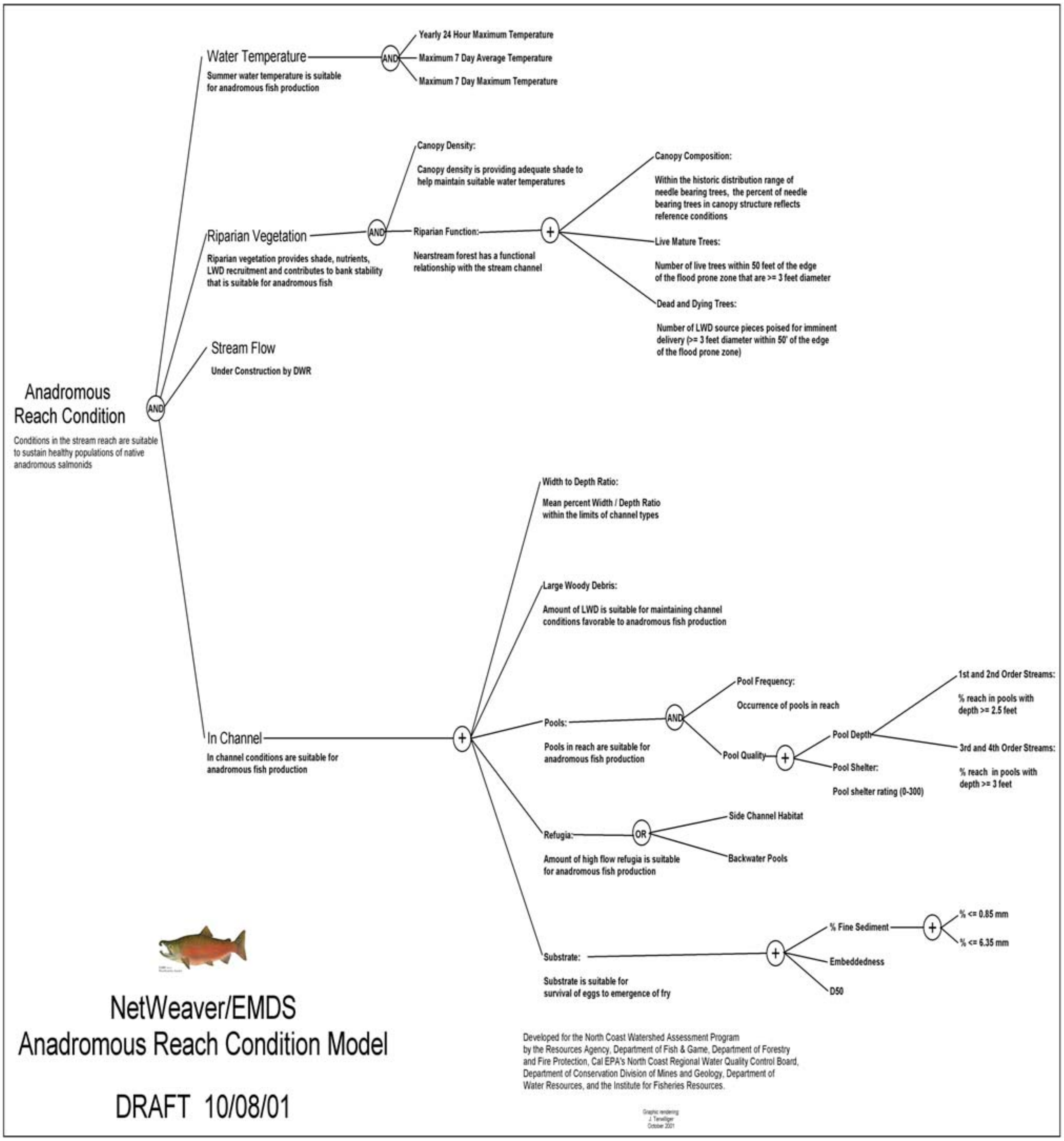


Figure 12. NCWAP EMDS anadromous reach condition model.

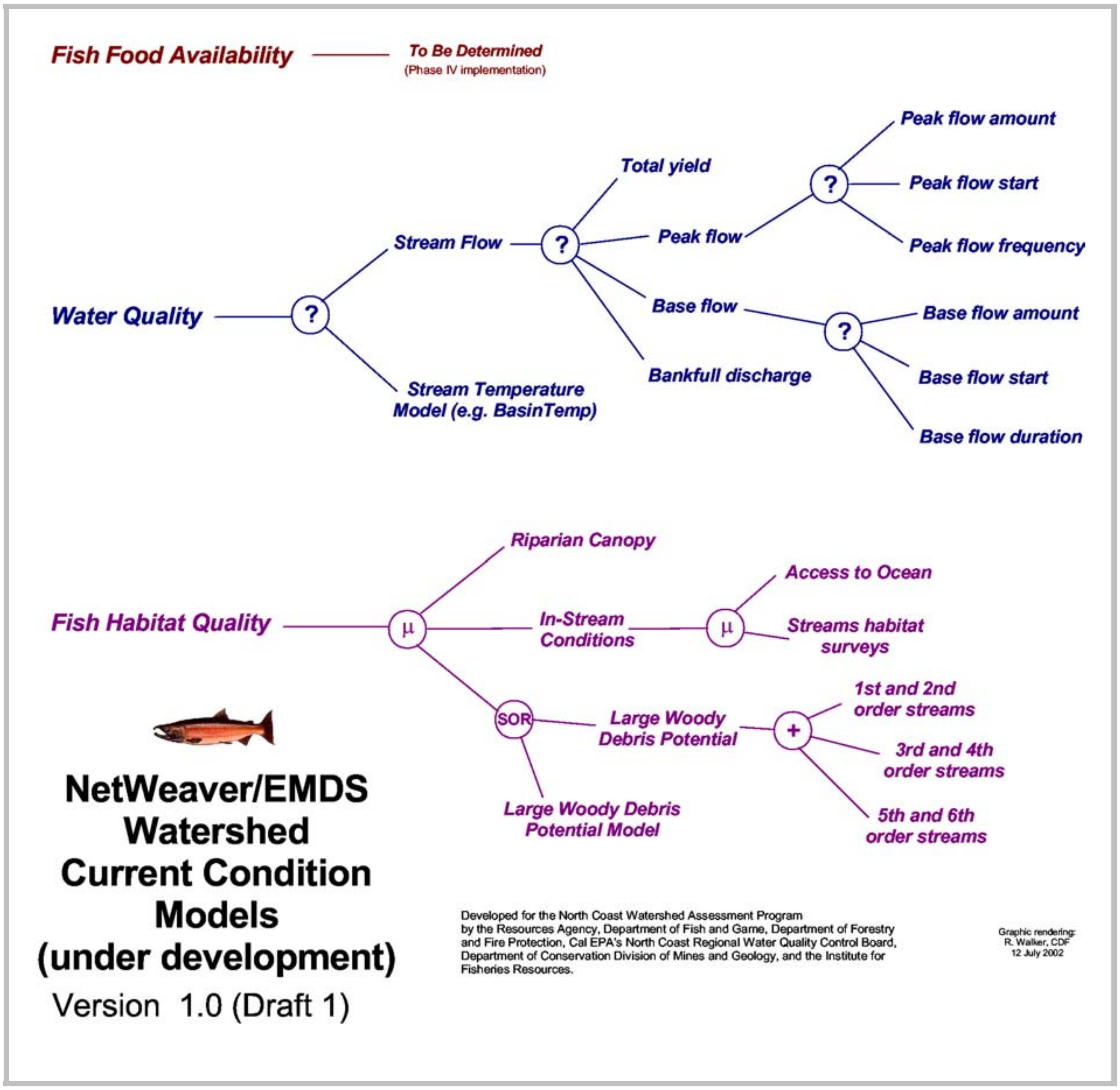


Figure 13. NCWAP EMDS fish food availability, water quality, and fish habitat quality models

Note: None of these models has yet been implemented. This graphic shows their current states of development.

For many NCWAP parameters, particularly those relating to upland geology and management activities, no scientific literature is available to assist in determining breakpoints. Because of this, the NCWAP has had little alternative but to use a more empirically based approach for breakpoints. Specifically, for each evaluated parameter, the mean and standard deviation are computed for all planning watersheds in a basin. Breakpoints are then selected to rank each planning watershed for that parameter in relation to all others in the basin. We used a simple linear approximation of the standardized cumulative distribution function, with the 10^{th} and 90^{th} percentiles serving as the low and high breakpoints (Figure 14). Thus, the truth values for all Potential Sediment Production model variables are relative measures directly related to the percentile rank of that planning watershed. While these relative rankings are not comparable outside of the context of the basin, they do provide an indication of relative conditions within the basin.

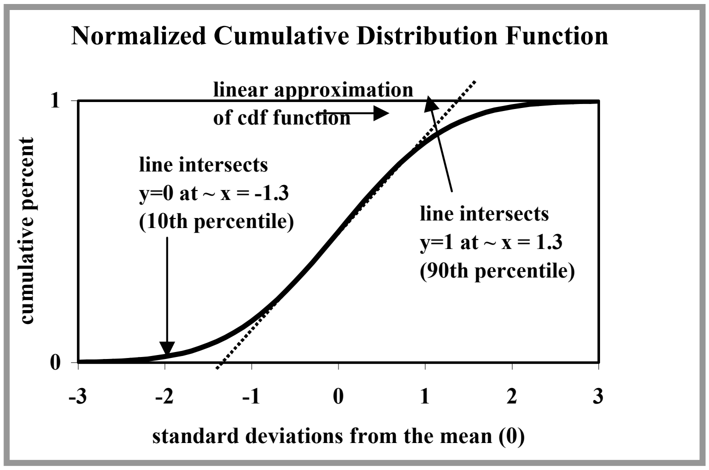


Figure 14. Normalized cumulative distribution function.

Using the 10th and 90th percentiles as breakpoints (as with Land Use) is a linear approximation of the central part of the normalized cumulative distribution function

The science review panel recommended that this method developed by NCWAP scientists be changed. They advised the use of a set of reference watersheds from the region, computing the distributions of land use and other parameters from those watersheds to determine breakpoints. At this point, NCWAP staff have not had the resources to select the reference watersheds, nor to process the data for them. This issue will be addressed in future watershed assessments and the breakpoints adjusted as the information from reference watersheds becomes available.

NCWAP map legends use a seven-class system for depicting the EMDS truth-values. Values of +1 are classed as the highest suitability; values of –1 are classed as the lowest suitability; and values of 0 are undetermined. Between 0 and 1 are two classes which, although unlabeled in the legend, indicate intermediate values of better suitability (0 to 0.5; and 0.5 to 1). Symmetrically, between 0 and –1 are two similar classes which are intermediate values of worse suitability (0 to –0.5; and –0.5 to –1).

In EMDS, the data that are fed into the knowledge base models come from GIS layers stored and displayed in ArcView. Thus, EMDS is able to readily incorporate many of the GIS data layers developed for the program into the watershed condition syntheses. Figure 15 portrays an example map of EMDS results. Reference curves are used in the NCWAP's Current EMDS Models.

The following tables summarize important EMDS model information. More technical details and justification for each parameter are supplied in the EMDS Appendix C.

- The Stream Reach Condition model. Parameter definition and breakpoints for this model (shown in Table 4) are based upon reviews of the scientific literature;
- The Sediment Production Risk model. Parameter definitions and respective weights are shown in Table 5. Parameters currently not being used in the model for lack of data are noted in the table. All breakpoints for this model are determined empirically (i.e. based upon percentiles of the data distribution, Figure 14), due to the use of parameters that have no equivalents nor surrogates in the scientific literature;
- The Fish Habitat Quality model. This model is still in early stages of development. It will incorporate the results of the Stream Reach model, and breakpoints will be based upon the scientific literature of properly functioning reference watersheds;
- The Water Quality model. This model is also under development. Water temperature will be modeled with software such as Stillwater Sciences' BasinTemp. Methods for modeling flow parameters have not yet been determined;
- The Fish Food Availability model. Recommended by the science panel review, this model has yet to be designed and implemented by the NCWAP.

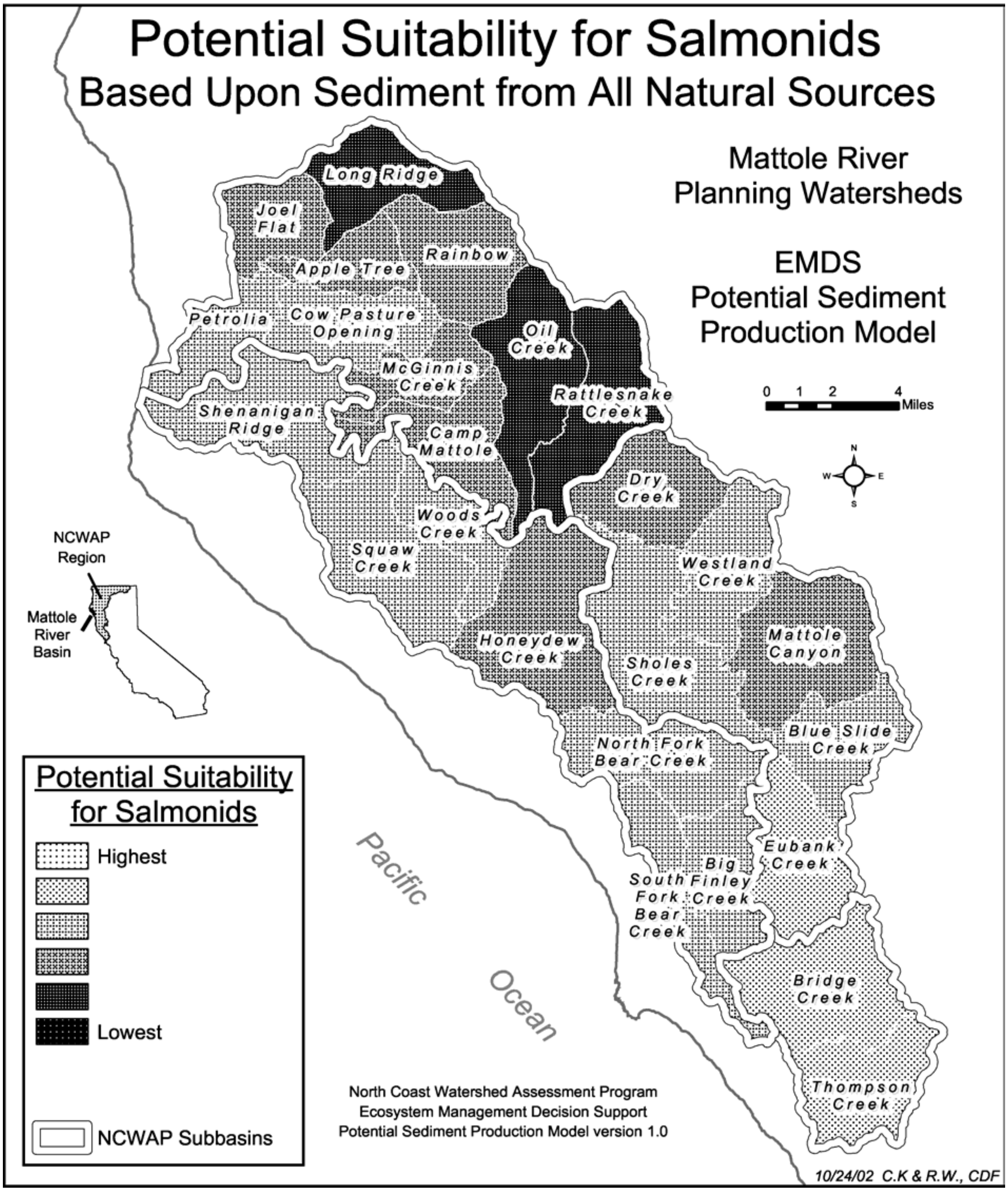


Figure 15. EMDS graphical output.

This example illustrates the graphical outputs of an EMDS run. This demonstration graphically portrays the relative amounts of potential sediment production in the Mattole Basin that comes from natural sources.

Table 4. Reference curve metrics for EMDS stream reach condition model.

Stream Reach Condition Factor	Definition and Reference Curve Metrics
Water Temperature	
Summer MWAT	Maximum 7-day average summer water temperature $<45^{o}$ F fully unsuitable, 50^{o} -60^{o} F fully suitable, $>68^{o}$ F fully unsuitable. Water temperature was not included in current EMDS evaluation.
Riparian Function	
Canopy Density	Average percent of the thalweg within a stream reach influenced by tree canopy. <50% fully unsuitable, ≥85% fully suitable.
Seral Stage	Under development
Vegetation Type	Under development
Stream Flow	Under development
In-Channel Conditions	
Pool Depth	Percent of stream reach with pools of a maximum depth of 2.5, 3, and 4 feet deep for first and second, third, and fourth order streams respectively. ≤20% fully unsuitable, 30 – 55% fully suitable, ≥90% fully unsuitable
Pool Shelter Complexity	Relative measure of quantity and composition of large woody debris, root wads, boulders, undercut banks, bubble curtain, overhanging and instream vegetation. ≤30 fully unsuitable, ≥100 - 300 fully suitable
Pool frequency	Under development
Substrate Embeddedness	Pool tail embeddedness is a measure of the percent of small cobbles (2.5" to 5" in diameter) buried in fine sediments. EMDS calculates categorical embeddedness data to produce evaluation scores between –1 and +1. The proposition is fully true if evaluation sores are 0.8 or greater and -0.8 evaluate to fully false
Percent fines in substrate <0.85mm (dry weight)	Percent of fine sized particles <0.85 mm collected from McNeil type samples. <10% fully suitable, > 15% fully unsuitable. There was not enough of percent fines data to use Percent fines in EMDS evaluations
Percent fines in substrate < 6.4 mm	Percent of fine sized particles <6.4 mm collected from McNeil type samples. <15% fully suitable, >30% fully unsuitable. There was not enough of percent fines data to use Percent fines in EMDS evaluations
Large Woody Debris (lwd)	The reference values for frequency and volume is derived from Bilby and Ward (1989) and is dependent on channel size. See EMDS Appendix C for details. Most watersheds do not have sufficient lwd surveys for use in EMDS.
Refugia Habitat	Refugia is composed of backwater pools and side channel habitats and deep pools (>4 feet deep). Not implemented at this time.
Pool to Riffle Ratio	Under development
Width to Depth Ratio	Under development

Table 5. Reference curve metrics for EMDS sediment production risk model, version 1.0.

Sediment Production Factor	Definition*	Weights**
Total Sediment Production	The mean truth value from Natural Processes and Management-related Processes	
Natural Processes	The mean truth value from Mass Wasting I, Surface Erosion I, and Streamside Erosion I knowledge base networks	0.5
Mass Wasting I	The mean truth value from natural mass wasting: Landslide Potential, Deep-seated Landslides, and Earth Flows	0.33
Landslide Potential	A selective OR (SOR) node takes the best available data to determine landslide mass wasting potential.	1.0
CGS Landslide Potential Map	(1st choice of SOR node) Percentage area of planning watershed in the landslide potential categories (4 and 5)	1.0
Landslide Potential Class 5	Percentage area of watershed in class 5 (CGS rating)	0.8
Landslide Potential Class 4	Percentage area of watershed in class 4 (CGS rating)	0.2
Probabilistic Landslide Model	(2nd choice of SOR node) Where option 1 is missing, the Probabilistic Landslide Model is used to calculate area of planning watershed with unstable slopes	1.0
SHALSTAB	(3rd choice of SOR node) Where options 1 and 2 are missing, SHALSTAB model is used to calculate area of planning watershed with unstable slopes	1.0

Sediment Production Factor	Definition*	Weights**
Surface Erosion I	The mean truth value from natural processes of surface erosion: Gullies, Soil Creep, and Fires	0.33
Gullies	Density of natural gullies in planning watershed (currently no data supplied to model here)	0.33
Soil Creep	Percentage area of planning watershed with soil creep (currently no data supplied to model here)	0.33
Fires	Percentage area of planning watershed with high fire potential (currently no data supplied to model here)	0.33
Streamside Erosion I	The mean truth value from natural processes of streamside erosion: Active Landslides Connected to Watercourses; Active Landslides Not Connected to Watercourses; Disrupted Ground Near Watercourses	0.33
Bank Erosion	Percentage of stream length in planning watershed with bank erosion	0.33
Inner Gorge Landslides	Percentage of stream length in planning watershed with inner gorge landslides	0.33
Non-inner Gorge Landslides	Percentage of stream length in planning watershed with non-inner gorge landslides	0.33
Management-related Processes	The mean truth value from Mass Wasting II, Surface Erosion II, and Streamside Erosion II knowledge base networks	0.5
Mass Wasting II	The mean truth value from management-related mass wasting: Road-related and Land Use-related	0.33
Road-Related	Coarse sediment contribution to streams from roads from either SEDMODL_V2 (first choice) or the mean of Density of Road/Stream Crossing, Density of Roads by Hillslope Position, and Density of Roads on Unstable Slopes	0.5
SEDMODL-V2	(when model is available – 1st choice of SOR node)	1.0
Density of Road/Stream Crossings	(2nd choice of SOR node, averaged with DRHP directly below) Number of road crossings/km of streams	0.33
Density of Roads / Hillslope Position	Weighted sum of road density by slope position (weights determine relative influence, and sum to 1.0)	0.33
Road length on lower slopes	Density of roads of all types on lower 40% of slopes	0.6
Road length on lower slopes	Density of roads of all types on mid-slope (41-80 % of slope distance)	0.3
Road length on upper slopes	Density of roads of all types on upper 20% of slopes	0.1
Density of Roads on Unstable Slopes	Density of roads on geologically unstable slopes	0.33
Land Use related	Coarse sediment contribution to streams from intensive, timber harvest, and ranched areas (see below in table*) <10th percentile highest suitability; >90th percentile lowest suitability	0.5
On slopes of low potential instability	Slope stability defined by CGS map classes 1 and 2 (or SHALSTAB if CGS maps unavailable)	0.04
On slopes of low/moderate potential instability	Slope stability defined by CGS map class 3 (or SHALSTAB if CGS maps unavailable)	0.09
On slopes of moderate/high potential instability	Slope stability defined by CGS map class 4 (or SHALSTAB if CGS maps unavailable)	0.17
On slopes of high potential instability	Slope stability defined by CGS map class 5 (or SHALSTAB if CGS maps unavailable)	0.7
Land Use related mass wasting parameter details (evaluated separately for each category of potential slope instability)	(Weights, showing the relative influence of each parameter, sum to 1.0)	
Intensive land use		
- - developed areas	Percentage of the planning watershed area in high density buildings and pavement	0.2
- - farmed areas	Percentage of planning watershed area in intensive crop cultivation	0.2
Area of timber harvests	Percentage of planning watershed area tractor logged weighted by time period (years)	
- - Era 0 (2000 – present)	Tractor logged area 2000-present	0.2
- - Era 1 (1990 – 1999)	Tractor logged area 1990-1999	0.12
- - Era 2 (1973 – 1989)	Tractor logged area 1973-1989	0.06
- - Era 3 (1945 – 1972)	Tractor logged area 1945-1972	0.12
Ranched area	Percentage of watershed area used for grazing livestock; estimated based on vegetation type and parcel type	0.1

Sediment Production Factor	Definition*	Weights**
Surface Erosion II	The mean truth value from management-related surface erosion: Road-related and Land Use-related	0.33
Road-Related	Fine sediment contribution to streams from roads from either SEDMODL_V2 (first choice) or the mean of Density of Roads Proximate to Streams, Density of Road-related Gullies, Density of Roads by Hillslope Position, and Road Surface Type	0.5
SEDMODL-V2	(when model is available – first choice of SOR node)	1.0
Density of Roads Proximate Streams	(2nd choice of SOR node, averaged with 3 subsequent road-related measures directly below)	0.25
Density of Roads Hillslope Position	Weighted sum of road density by slope position	0.25
Road length on lower slopes	Density of roads of all types on lower 40% of slopes	0.6
Road length on lower slopes	Density of roads of all types on mid-slope (41-80 % of slope distance)	0.3
Road length on upper slopes	Density of roads of all types on upper 20% of slopes	0.1
Density of Road-related Gullies	Density of gullies related to roads	0.25
Road Surface Type	Percentage of roads with surfaces that are more likely to deliver fine sediments to streams (no data currently supplied to model here)	0.25
Land Use related	Fine sediment contribution to streams from intensive, timber harvest, and ranched areas (see below in table**)	0.5
On slopes of high potential instability	Slope stability defined by CGS map class 5	0.7
On slopes of moderate/high potential instability	Slope stability defined by CGS map class 4	0.17
On slopes of low/moderate potential instability	Slope stability defined by CGS map class 3 (or SHALSTAB if unavailable)	0.09
On slopes of low potential instability	Slope stability defined by CGS map classes 1 and 2 (or SHALSTAB if unavailable)	0.04
Land Use related surface erosion parameter details	(evaluated separately for each of the four categories of potential slope instability)	
Intensive land use	Land where human activity is intensive	
- - Developed areas	Percentage of the planning watershed area in high density buildings and pavement	0.2
- - Farmed areas	Percentage of planning watershed area in intensive crop cultivation	0.2
Area of timber harvests	Percentage of planning watershed area tractor logged, by time period	
- - Era 0 (2000 – present)	Tractor logged area 2000-present	0.3
- - Era 1 (1990 – 1999)	Tractor logged area 1990-1999	0.2
Ranched area	Percentage of planning watershed area used for grazing livestock; estimated based on vegetation type and parcel type	0.1
Streamside Erosion II	The mean truth value from management-related streamside erosion: Road-related and Land Use-related	0.33
Density of Roads Proximate to Streams	Length of all roads within 200’ of stream ÷ length of all streams	0.33
Density of Road/Stream Crossings	Number of road crossings/km of streams	0.33
Density of Instream Timber Harvest Landings	Number of legacy timber harvest landings instream per unit length of stream	0.33

*All breakpoints for the sediment production risk model were created from the tails of the cumulative distribution function curves for each parameter, at the 10th and 90th percentiles. Thus all resultant values are relative to the basin as a whole, but are not rated on an absolute basis
**weights for parameters at each node sum to 1.0; indentation of weight shows the tier where it is summed

Advantages Offered by EMDS

EMDS offers a number of advantages for use by the NCWAP. Instead of being a hidden black box, each EMDS model has an open and intuitively understandable structure. The explicit nature of the model networks facilitates open communication among agency personnel and with the general public through simple graphics and easily understood flow diagrams. The models can be easily modified to incorporate alternative assumptions about the conditions of specific environmental factors (e.g., stream water temperature) required for suitable salmonid habitat.

Using ESRI Geographic Information System (GIS) software, EMDS maps the factors affecting fish habitat and shows how they vary across a basin. At this time no other widely available package allows a knowledge base network to be linked directly with a geographic information system such as ESRI's ArcView™. This link is vital to the production of maps and other graphics reporting the watershed assessments. EMDS models also provide a consistent and repeatable approach to evaluating watershed conditions for fish. In addition, the maps from supporting levels of the model show the specific factors that, taken together, determine overall watershed conditions. This latter feature can help to identify what is most limiting to salmonids, and thus assist to prioritize restoration projects or modify land use practices.

Another feature of the system is the ease of running alternative scenarios. Scientists and others can test the sensitivity of the assessments to different assumptions about the environmental factors and how they interact, through changing the knowledge-based network and breakpoints. What-if scenarios can be run by changing the shapes of reference curves (e.g. Figure 10), or by changing the way the data are combined and synthesized in the network.

NetWeaver/EMDS/ArcView tools can be applied to any scale of analysis, from reach specific to entire watersheds. The spatial scale can be set according to the spatial domain of the data selected for use and issue(s) of concern. Alternatively, through additional network development, smaller scale analyses (i.e., subwatersheds) can be aggregated into a large hydrologic unit. With sufficient sampling and data, analyses can be done even upon single or multiple stream reaches.

Management Applications of Watershed Synthesis Results

EMDS syntheses can be used at the basin scale, to show current watershed status. Maps depicting those factors that may be the largest impediments, as well as those areas where conditions are very good, can help guide protection and restoration strategies. The EMDS model also can help to assess the cost-effectiveness of different restoration strategies. By running sensitivity analyses on the effects of changing different habitat conditions, it can help decision makers determine how much effort is needed to significantly improve a given factor in a watershed and whether the investment is cost-effective.

EMDS results can be fed into other decision support software, such as Criterium Decision Plus. CDP employs a widely used approach called Analytic Hierarchy Process (AHP) to assist managers in determining their options based upon what they believe are the most important aspects of the problem.

At the project planning level, EMDS model results can help landowners, watershed groups, and others select the appropriate types of restoration projects and places (i.e., planning watersheds or larger) that can best contribute to recovery. Agencies will also use the information when reviewing projects on a watershed basis.

The main strength of using NetWeaver/EMDS/ArcView knowledge base software in performing limiting factors analysis is its flexibility, and that through explicit logic, easily communicated graphics, and repeatable results, it can provide insights as to the relative importance of the constraints limiting salmonids in North Coast watersheds. NCWAP will use these analyses not only to assess conditions for fish in the watersheds and to help prioritize restoration efforts, but also to facilitate an improved understanding of the complex relationships among environmental factors, human activities, and overall habitat quality for native salmon and trout.

Limitations of the EMDS Model and Data Inputs

At the time of the production of this report, we have not been able to implement all of the recommendations made by our peer reviewers. Hence, the current model outputs should be used with caution. NCWAP will continue to work to refine and improve the EMDS model, based on peer review.

While EMDS-based syntheses are important tools for watershed assessment, they do not by themselves yield a course of action for restoration and land management. EMDS results require interpretation, and how they are employed depends upon other important issues, such as social and economic concerns. In addition to the accuracy of the EMDS model constructed, the currency and completeness of the data available for a stream or watershed will strongly influence the degree of confidence in the results. Where possible, external validation of the EMDS model using fish population data and other information should be done.

One disadvantage of linguistically based models such as EMDS is that they do not provide results with readily quantifiable levels of error. However, we are developing methods of determining levels of confidence in the EMDS results, based upon data quality and overall weight given to each parameter in the model.

The NCWAP will use EMDS only as an indicative model, one that indicates the quality of watershed or instream conditions based on available data and the model structure. It is not intended to provide highly definitive answers, such as from a statistically based process model. It does provide a reasonable first approximation of conditions through a robust information synthesis approach; however, its outputs need to be considered and interpreted in the light of other information sources and the inherent limitations of the model and its data inputs. It also should be clearly noted that EMDS does not assess the marine phase of the salmonid lifecycle, nor does it consider fishing pressures.

The NCWAP staff have identified a number of model or data elements needing attention and improvement in the next version. These include:

- modification of canopy density standards for wide streams;
- completion of quality control evaluation of several data layers;
- adjusting the model to better reflect differences between stream mainstems and tributaries;

The NCWAP team will address these limitations as the EMDS model undergoes further development.

Integrated Analyses Tables

The NCWAP Mattole team constructed a series of tables, referred to as the Integrated Analysis tables, to track watershed processes that determine conditions in streams for salmon and steelhead. This approach followed the down-slope movement of watershed products delivered to streams. Fundamental to these watershed processes and products are the underlying geology and geomorphology of the watershed. Geologic conditions determine, in large part, the landslide and sediment production potential of the terrain. Geologic processes are influenced in varying degrees by the vegetative community, which is often linked to human activities across the landscape. Current watershed conditions combine with natural events like fire, flood, and earthquakes to affect the fluvial geomorphology and water quality in the stream reaches of a watershed. Finally, the effects of these combined processes are expressed in the stream habitats, including flow, encountered by the organisms of the aquatic riparian community, including salmon and steelhead.

These integrated analyses are presented at the overall watershed, subbasin, and planning watershed scales.

Limiting Factors Analysis

A main objective of the NCWAP and a task delegated to the CDFG is 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 ecosystem component. Identifying stream habitat factors that limit or constrain anadromous salmonids 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.

Although several factors have contributed to the decline of anadromous salmonid populations, habitat loss and modification are major determinants of their current status (FEMAT 1993). Our approach to a LFA integrates two habitat based methods to evaluate the status of key aspects of stream habitat that affect anadromous salmonid production, species life history diversity, and the stream's ability to support viable populations. The first method uses priority ranking habitat categories based on a CDFG team assessment of data collected during stream habitat inventories. The second method uses the EMDS to evaluate the suitability of key stream habitat components to support anadromous fish populations. These habitat-based methods assume that stream habitat quality and quantity play important roles in a watershed's ability to produce viable salmonid populations. The LFA assumes that poor habitat quality and reduced quantities of favorable habitat impairs fish production. The NCWAP LFA is focused mainly on those physical habitat factors within freshwater and estuarine ecosystems that affect spawning and subsequent juvenile life history requirements during low flow seasons.

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 that 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. Priority steps are given to preserving and increasing the amount of high quality (density independent) habitat in a cost effective manner. More details of the LFA are presented in the CDFG Appendix F.

Restoration Needs/Tributary Recommendations Analysis

The California Department of Fish and Game (CDFG) inventoried 59 tributaries to the Mattole River and the headwaters of the Mattole from 1991 to 2002 using protocols in the *California Salmonid Stream Habitat Restoration Manual*. The tributaries and the headwaters of the Mattole River surveyed were composed of 93 stream reaches, defined as Rosgen channel types. The stream inventories are a combination of several stream reach surveys: habitat typing, channel typing, biological assessments, and in some reaches LWD and riparian zone recruitment assessments. An experienced biologist and/or habitat specialist conducted QA/QC on field crews and collected data, performed data analysis, and determined general areas of habitat deficiency based upon the analysis and synthesis of information.

The CDFG biologist selected and ranked recommendations for each of the inventoried streams, based upon the results of these standard CDFG habitat inventories, and updated the recommendations with the results of the stream reach condition EMDS and the refugia analysis (Table 6). It is important to understand that these selections are made from stream reach conditions that were observed at the times of the surveys and do not include upslope watershed observations other than those that could be made from the streambed. They also reflect a single point in time and do not anticipate future conditions. However, these general recommendation categories have proven to be useful as the basis for specific project development, and provide focus for on-the-ground project design and implementation. Bear in mind that stream and watershed conditions change over time and periodic survey updates and field verification are necessary if watershed improvement projects are being considered.

Table 6. List of tributary recommendations in stream tributary reports

Recommendation	Explanation
Temp	Summer Water Temperatures Were Measured To Be Above Optimum For Salmon And Steelhead
Pool	Pools Are Below Target Values In Quantity And/Or Quality
Cover	Escape Cover Is Below Target Values
Bank	Stream Banks Are Failing And Yielding Fine Sediment Into The Stream
Roads	Fine Sediment Is Entering The Stream From The Road System
Canopy	Shade Canopy Is Below Target Values
Spawning Gravel	Spawning Gravel Is Deficient In Quality And/Or Quantity
LDA	Large Debris Accumulations Are Retaining Large Amounts Of Gravel And Could Need Modification
Livestock	There Is Evidence That Stock Is Impacting The Stream Or Riparian Area And Exclusion Should Be Considered
Fish Passage	There Are Barriers To Fish Migration In The Stream

In general, the recommendations that involve erosion and sediment reduction by treating roads and failing stream banks, and riparian and near stream vegetation improvements precede the instream recommendations in reaches that demonstrate disturbance levels associated with watersheds in current stress. Instream improvement recommendations are usually a high priority in streams that reflect watersheds in recovery or good health. Various project treatment recommendations can be made concurrently if watershed and stream conditions warrant.

Fish passage problems, especially in situations where favorable stream habitat reaches are being separated by a man-caused feature (e.g., culvert), are usually a treatment priority. Good examples of these are the recent and dramatically successful Humboldt County/CDFG culvert replacement projects in tributaries to Humboldt Bay. In these regards, NCWAP's more general watershed scale upslope assessments can go a long way in helping determine the suitability of conducting instream improvements based upon watershed health. As such, there is an important relationship between the instream and upslope assessments.

Additional considerations must enter into the decision process before these general recommendations are further developed into improvement activities. In addition to watershed condition considerations as a context for these recommendations, there are certain logistic considerations that enter into a recommendation's subsequent ranking for project development. These can include work party access limitations based upon lack of private party trespass permission and/or physically difficult or impossible locations of the candidate work sites. Biological considerations are made based upon the propensity for benefit to multiple or single fishery stocks or species. Cost benefit and project feasibility are also factors in project selection for design and development.

Potential Salmonid Refugia

Establishment and maintenance of salmonid refugia areas containing high quality habitat and sustaining fish populations are activities vital to the conservation of our anadromous salmonid resources (Moyle and Yoshiyama 1992; Liet al. 1995; Reeves et al. 1995). Protecting these areas will prevent the loss of the remaining high quality salmon habitat and salmonid populations. Therefore, a refugia investigation project should focus on identifying areas found to have high salmonid productivity and diversity. Identified areas should then be carefully managed for the following benefits:

- Protection of refugia areas to avoid loss of the last best salmon habitat and populations. The focus should be on protection for areas with high productivity and diversity;
- Refugia area populations which may provide a source for re-colonization of salmonids in nearby watersheds that have experienced local extinctions, or are at risk of local extinction due to small populations;
- Refugia areas provide a hedge against the difficulty in restoring extensive, degraded habitat and recovering imperiled populations in a timely manner (Kaufmann, et al. 1997).

The concept of refugia is based on the premise that patches of aquatic habitat provide habitat that still retain the natural capacity and ecologic functions that support wild anadromous salmonids in such vital activities as spawning and rearing. 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 relative 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.

Potential 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, either through restoration efforts or natural processes, 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 conservation efforts to ensure long-term survival of viable stocks, and a critical element towards recovery of depressed populations (Sedell, 1990; Moyle and Yoshiyama 1992; Frissell 1993, 2000).

Refugia habitat elements include the following:

- 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
- A center from which dispersion may take place to re-colonize areas after a watershed and/or sub-watershed level disturbance event and readjustment.

Spatial and Temporal Scales of Refugia

These refugia concepts become more complex in the context of the wide range of spatial and temporal habitat required for viable salmonid populations. Habitat can provide refuge at many scales from a single fish to groups of them, and finally to breeding populations. For example, refugia habitat may range from a piece of wood that provides instream shelter for a single fish, or individual pools that provide cool water for several rearing juveniles during hot summer months, to watersheds where conditions support sustaining populations of salmonid species. Refugia also include areas where critical life stage functions such as migrations and spawning occur. Although fragmented areas of suitable habitat are important, their connectivity is necessary to sustain the fisheries. Today, watershed scale refugia are needed to recover and sustain aquatic species (Moyle and Sato 1991). For the purpose of this discussion, refugia are considered at the fish bearing tributary and subbasin scales. These scales of refugia are generally more resilient than the smaller, habitat unit level scale to the deleterious effects of landscape and riverine disturbances such as large floods, persistent droughts, and human activities (Sidell et al. 1990).

Standards for refugia conditions are based on reference curves from the literature and CDFG data collection at the regional scale. NCWAP uses these values in its EMDS models and stream inventory, improvement recommendation process. Li et al. (1995) suggested three prioritized steps to use the refugia concept to conserve salmonid resources.

- Identify salmonid refugia and ensure they are protected;
- Identify potential habitats that can be rehabilitated quickly;
- Determine how to connect dispersal corridors to patches of adequate habitat.

Refugia and Meta-population Concept

The concept of anadromous salmonid meta-populations 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 sub-populations which are geographically located such that over time, there is likely genetic exchange between the sub-populations (Barnhart 1994). Metapopulations are characterized by 1) relatively isolated, segregated breeding populations in a patchy environment that are connected to some degree by migration between them, and 2) a dynamic relationship between extinction and re-colonization of habitat patches.

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 structured 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 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 into a dynamic aquatic environment.

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

Methods to Identify Refugia

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 conditions and productivity across large areas. This lack of information holds true for NCWAP basins especially in terms of meta-population 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; Frissell et al. 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 metapopulation maintenance. 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.

A second common theme is that over time within the landscape mosaic of habitat patches, good habitat areas will suffer impacts and become less productive, and wink out and other areas will recover and wink in. These processes can occur through either human caused or natural disturbances or succession to new ecological states. Regardless, it is important that a balance be maintained in this alternating, patchwork dynamic to ensure that adequate good quality habitat is available for viable anadromous salmonid populations (Reeves et al. 1995.)

NCWAP Approach to Identifying Refugia

The NCWAP interdisciplinary team identified and characterized refugia habitat by using expert professional judgment and criteria developed for North Coast watersheds. The criteria used 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. The expert refugia team encouraged other specialists with local knowledge to participate in the refugia identification and categorization process.

The team also used results from information processed by NCWAP's EMDS at the stream reach and planning watershed/subbasin scales. Stream reach and watershed parameter evaluation scores were used to rank stream and watershed conditions based on collected field data and air photo analysis. Stream reach scale parameters included pool shelter rating, pool depth, embeddedness, and canopy cover. Water temperature data were also used when available. The individual parameter scores identified which habitat factors currently support or limit fish production (see EMDS and limiting factors sections).

Planning watershed scale parameters used are road density, number of stream crossings, road proximity to streams, riparian cover, and LWD loading potential. The refugia team used the potential sediment production and other planning watershed scale EMDS evaluations in a similar manner as they became available.

When identifying anadromous salmonid refugia, the NCWAP team took into account that anadromous salmon have several non-substitutable habitat needs for their life-cycle. A minimal list (NMFS 2000) includes:

- Adult migration pathways;
- Spawning and incubation habitat;
- Stream rearing habitat;
- Forage and migration pathways;
- Estuarine habitat.

The best refugia areas are large and meet all of these life history needs and therefore provide complete functionality to salmonid populations. These large, intact systems are scarce today and smaller refugia areas that provide for only some of the requirements have become very important areas, but cannot sustain large numbers of fish. These must operate in concert with other fragmented habitat areas for life history support and refugia connectivity becomes very important for success. Therefore, the refugia team considers relatively small, tributary areas in terms of their ability to provide at least partial refuge values, yet contribute to the aggregated refugia of larger scale areas. Therefore, the team's analyses use the tributary scale as the fundamental refugia unit.

The NCWAP team created a tributary scale refugia-rating worksheet (CDFG Appendix F). The worksheet has 21 condition factors that were rated on a sliding scale from high quality to low quality. The 21 factors were grouped into five categories:

- Stream condition;
- Riparian condition;
- Native salmonid status;
- Present salmonid abundance;
- Management impacts (disturbance impacts to terrain, vegetation, and the biologic community).

Tributary ratings were determined by combining the results of air photo analyses results, EMDS results, and data in the CDFG tributary reports by a multi-disciplinary, expert team of analysts. The various factors' ratings were combined to determine an overall tributary rating on a scale from high to low quality refugia. Tributary ratings were subsequently aggregated at the subbasin scale and expressed a general estimate of subbasin refugia conditions. Factors with limited or missing data were noted. In most cases there were data limitations on 1 – 3 factors. These were identified for further investigation and inclusion in future analysis.

The NCWAP has created a hierarchy of refugia categories that contain several general habitat conditions. This descriptive system is used to rank areas by applying results of the analyses of stream and watershed conditions described above and are used to determine the ecological integrity of the study area. A basic definition of biotic integrity is "the ability [of an ecosystem] to support and maintain a balanced, integrated, and functional organization comparable to that of the natural habitat of the region" (Karr and Dudley 1981).

The Report of the Panel on the Ecological Integrity of Canada's National Parks submitted this definition:

The Panel proposes the following definition of ecological integrity: "An ecosystem has integrity when it is deemed characteristic for its natural region, including the composition and abundance of native species and biological communities, rates of change and supporting processes. "In plain language, ecosystems have integrity when they have their native components (plants, animals and other organisms) and processes (such as growth and reproduction) intact.

NCWAP Salmonid Refugia Categories and Criteria:

High Quality Habitat, High Quality Refugia

- Maintains a high level of watershed ecological integrity (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; 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 of its native components.

High Potential Refugia

- Watershed ecological integrity is diminished but remains good (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; Frissell 2000).

Medium Potential Refugia

- Watershed ecological integrity is degraded or fragmented (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 significant 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, Low Potential Refugia

- Watershed ecological integrity is impaired (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 significant straying very unlikely;
- Current management and / or natural events have significantly altered the naturally functioning ecosystem and major changes in either of both are needed to improve conditions.

Other Related Refugia Component Categories:

Potential Future Refugia (Non-Anadromous)

- 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).

Data Limited

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

Development and Evaluation of Hypotheses

NCWAP provides a first cut at watershed assessment 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 the Subbasin Profiles and Synthesis.

Working Hypotheses

After conducting public scoping meetings and initial analyses of available data, the NCWAP team compiled a preliminary list of issues affecting the Mattole Basin.

Issues

- Sediment, temperature, pool habitat, escape and ambush cover, and substrate embeddedness in the estuary are thought to be outside of supportive levels for salmonids in the estuary;
- Predation upon depressed fish populations by birds and mammals in the estuary;
- Excessive extraction of water occurs during low flow periods;
- Artificial fish passage barriers exist at some road crossings of streams;
- Abandoned roads, new road construction, and road maintenance issues related to landsliding and sediment input to streams;
- High water temperatures occurring in summertime;
- Pollutant spills, such as some recent bulk diesel spills into tributaries;
- Herbicides used on industrial timberlands;
- Location and conduct of timber harvest operations;
- Sub-division development and construction;
- Low stream habitat diversity and complexity;
- Low stream shade canopy cover;
- Large woody debris recruitment to streams;
- Absence of salmonid information, low fish densities, or absences of fish;
- Access for agency personnel to private land for field studies.

Assessment Focus Areas:

Based on these issues, a list of Assessment Focus Areas was developed, including:

- Variability in the geology, climate, vegetation, and land use in the Mattole Basin is too high for a single general analysis and assessment to be representative of the entire basin. The establishment of an analytical framework comprised of large subbasins with common attributes and characteristics will provide a more satisfactory assessment scale;

- The current abundance and distribution of salmonid populations observed in the basin are indicators of the current habitat conditions;
- Summer stream temperatures in parts of the basin are not within the range of temperatures that fully support healthy anadromous salmonid populations;
- Aggradation from fine sediment in some stream channels has reduced channel diversity needed to fully support anadromous salmonid populations and has compromised salmonid health;
- High natural rates of sediment input to streams are augmented by human land use activities in some parts of the basin;
- Some stream reaches in the basin are not fully supportive of salmonids due to stream flow reductions related to human diversion;
- A lack of large woody debris in some stream reaches has reduced channel diversity needed to fully support anadromous salmonid populations and has compromised salmonid health;
- Air photo documentation after the 1955 and 1964 floods indicate significant changes instream channel and riparian conditions as a result of those events;
- Watershed and stream conditions in the Southern Subbasin are the most supportive of salmonids in the Mattole Basin;
- Watershed and stream conditions in the Eastern and Western Subbasins vary between being supportive and non-supportive of salmonids;
- Watershed and stream conditions in the Northern Subbasin are the least supportive of salmonids in the Mattole Basin;.
- The present state of estuarine habitat is limiting the production of salmonids, especially Chinook, in the Mattole Basin.

Guiding Assessment Questions and Responses

The NCWAP assessment team developed lists of questions that they considered important to understanding and implementing watershed assessments. From those lists, a short list of guiding assessment questions evolved and was adopted to provide focus for the assessments and subsequent analyses, conclusions, and recommendations.

- What are the history and trends of the sizes, distribution, and relative health and diversity of salmonid populations within this subbasin?
- What are the current salmonid habitat conditions in this subbasin? How do these conditions compare to desired conditions?
- What are the relationships of geologic, vegetative, and fluvial processes to natural events and land use history?
- How has land use affected these natural processes?
- Based upon these conditions, trends, and relationships, are there elements that could be considered to be limiting factors for salmon and steelhead production?
- What habitat improvement activities would most likely lead toward more desirable conditions in a timely, cost effective manner?

These six questions focus the assessment procedures and data gathering within the individual disciplines and also provide direction for those areas of analyses that require more interagency, interdisciplinary syntheses, including the analysis of factors limiting anadromous salmonid production. The questions systematically progress from the relative status of the salmon and steelhead resource, to the focus of the NCWAP assessment effort, and lastly to the watershed components encountered directly by the fish – flow, water quality, nutrients, and instream habitat elements, including free passage at all life stages. These habitat elements are shaped by the products delivered to streams by watershed processes and the influence of human activities on those processes. The watershed processes and human influences determine what factors might be limiting fishery production and what can be done to make improvements for the streams and fish.

The first two assessment questions point out the importance of salmonid population information for validating the assessment and predicting habitat conditions. In many watersheds, robust population data may not be available, implying a need for future monitoring efforts. In some watersheds, a need for additional physical habitat sampling may be indicated.

The third and fourth assessment questions consider the past and present conditions of the watersheds and their natural and man-caused watershed processes. The answers to these questions provide us with insights into the future of NCWAP watersheds and streams, and the feasibility of different management techniques for salmon and steelhead in each watershed.

The last two assessment questions consider factors directly encountered by fish that could be limiting salmonid production. These questions seek to identify opportunities and locations for prudent management practices and pro-active salmonid habitat improvement activities.

These six guiding assessment questions are presented and answered in the overall basin section and in each of the subbasin sections of the assessment report. They are also considered in the DFG Refugia Rating process at the subbasin and tributary scales. The responses become more specific as the assessment focuses from the course to the finer scales.