DRAFT North Coast Watershed Assessment Program Manual

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CHAPTER 1: THE NORTH COAST WATERSHED ASSESSMENT PROGRAM

INTRODUCTION

This manual describes the approach and methods to be used to conduct watershed assessments under the State of California's North Coast Watershed Assessment Program. This interagency program will provide baseline environmental and biological information for approximately 6.5 million acres of land over a seven-year period. It is focused on conditions affecting anadromous fish, but it will compile and provide general data useful for other natural resource planning and management functions.

The manual is organized into four chapters. The first chapter provides an overview of the program. The second presents the conceptual framework for watershed assessment. The third chapter describes the three main products that will come out of the program. Chapter 4 explains programmatic data collection and management procedures. Appendices to this manual provide technical details on the approach and methods.

BACKGROUND AND GOALS

The North Coast Watershed Assessment Program (NCWAP) is a multi-agency effort led by the California Resources Agency. The principal goal of NCWAP is to compile and develop baseline scientific information about existing biophysical conditions in north coast watersheds. The Resources Agency initiated this program in response to requests from landowners, industry and environmental groups, watershed groups, a Science Review Panel on Forest Practices, and other stakeholders that the state take a leadership role in conducting interdisciplinary watershed assessments which could be used for guiding decision making. The goals of this program are:

- Provide a baseline of data for evaluating the effectiveness of various resource protection programs over time;
- Guide watershed restoration programs, e.g., targeting grant dollars to those projects that most efficiently and effectively recover salmonid populations, and assisting local watershed groups, counties, etc., to develop successful projects;
- Guide cooperative interagency, nonprofit and private sector approaches to "protect the best" through stewardship, easement and other incentive programs;
- Help landowners and agencies implement laws that require specific assessments such as the State Forest Practice Act, Clean Water Act and State Lake and Streambed Alteration Act.
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PARTICIPATING AGENCIES

The administrative lead agency for NCWAP is the Resources Agency. The five departments participating in NCWAP include the Department of Fish and Game (DFG), Department of Forestry and Fire Protection (CDF), Department of Conservation-Division of Mines and Geology (DOC/DMG), State Water Resources Control Board-North Coast Region (RWQCB) and Department of Water Resources (DWR). The Institute for Fisheries Resources is also a partner and participant in this program.

PUBLIC AND STAKEHOLDER INVOLVEMENT

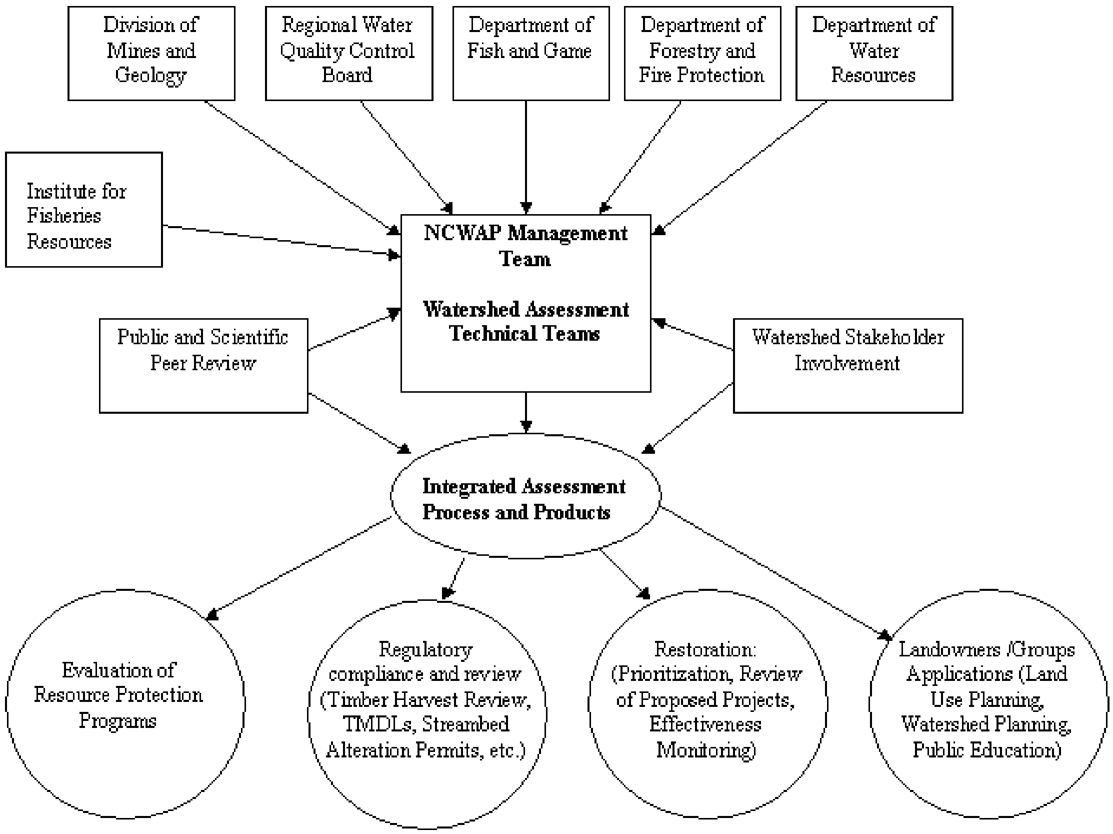
The North Coast Watershed Assessment Program was developed to improve decision-making by landowners, watershed groups, agencies, and other stakeholders. It is therefore essential that the program take steps to ensure that its assessment methods and products are understandable, relevant, and scientifically credible to users. NCWAP has provided for input by the general public and science community during program development and will also provide for ongoing review of products.

NCWAP will also work with local stakeholders in each basin to prioritize and refine assessment activities based on local conditions, needs, and existing information. This will include initial scoping sessions to identify issues, data sources, and opportunities for coordinating with local assessment and monitoring efforts. This process is described in greater detail in chapter two.

PROJECT MANAGEMENT

An interagency team comprised of top NCWAP managers from each participating agency and chaired by the Resources Agency is responsible for general policy and procedures. Interagency watershed assessment teams, led by one or more agency managers, will be assembled for each assessment area. The watershed assessment team leader is responsible for coordinating all work at the watershed level, including public outreach. Figure 1 illustrates the goals and participants described above.

Figure 1. North Coast Watershed Assessment Program Participation and Applications



ASSESSMENT AREA

The program area (Figure 2) corresponds to the North Coast Region as defined by the CALWATER system (Appendix A), which is a watershed delineation system used by the State Water Resources Control Board and other state and federal agencies in California (see *Spatial and Temporal Frameworks for Assessment* below). This region corresponds to the jurisdictional boundaries of the North Coast Regional Water Quality Control Board. It includes portions of several anadromous fish stocks listed or proposed for listing by the National Marine Fisheries Service (NMFS) under the Endangered Species Act.

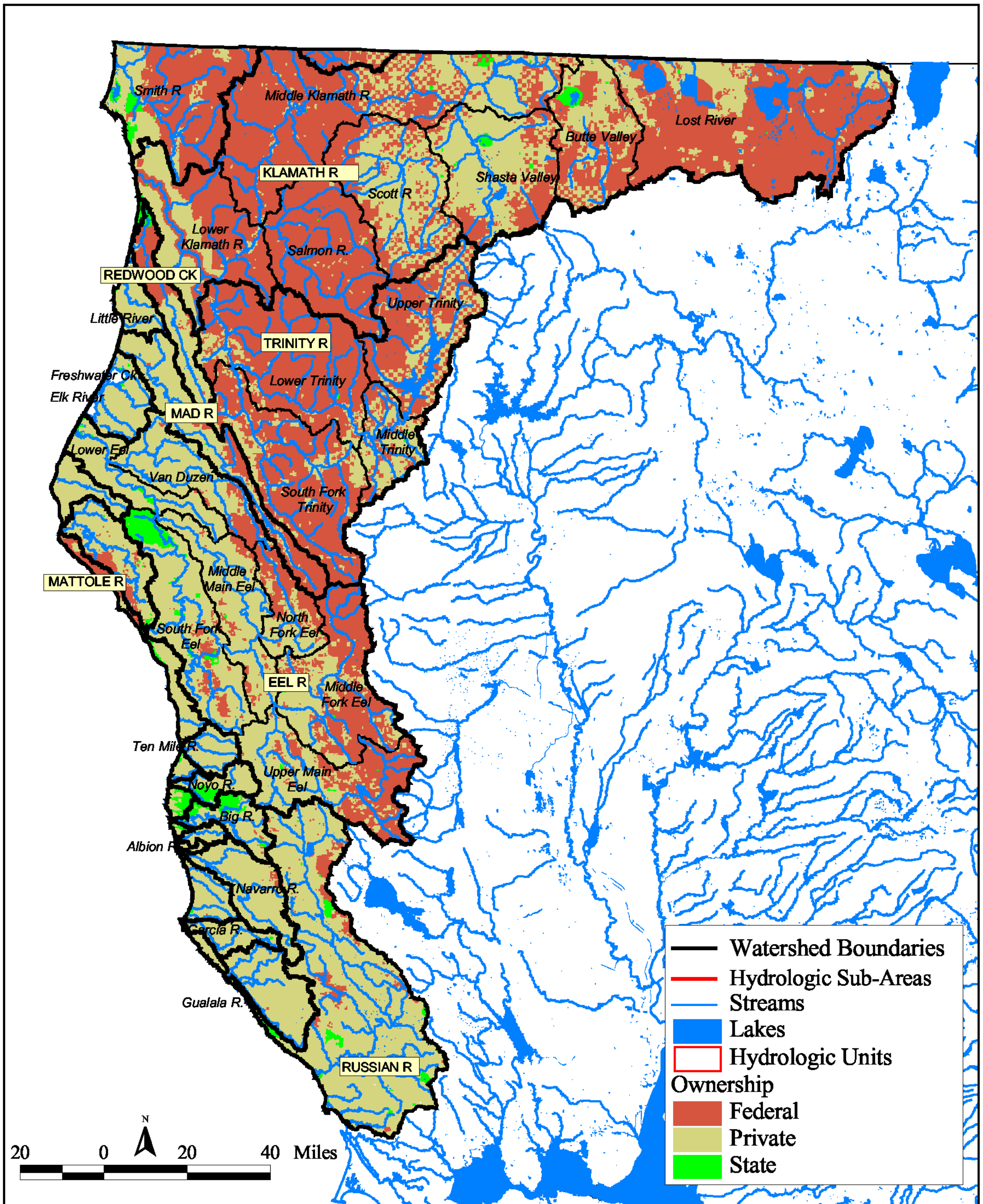


Figure 2.
North Coast Watershed Assessment Program Area

Completion of the watershed assessments for the North Coast will occur over seven years. To date, NCWAP has specifically scheduled only those basins that will be assessed in the first three years. This schedule was developed to provide timely input to Total Maximum Daily Load (TMDL) planning and implementation, and to threatened and endangered fish recovery planning by DFG and NMFS. These priorities will guide program planning for years 4 to 7. However, the program will coordinate with other opportunities or needs as possible.

NCWAP PRODUCTS

NCWAP will produce three main products for each watershed:

1. An environmental data base in electronic format of compiled and original information including aerial photos and satellite imagery; maps of landslides, landslide potential, land use and vegetation, fluvial geomorphology; GIS analytical tools; and reports;
2. An assessment of factors limiting anadromous salmonid production; and
3. A synthesis report describing the results and implications of the watershed assessment.

The roles of the participating agencies in these efforts are as follows:

- DFG will compile, develop, and analyze data related to anadromous fisheries habitat and production. It will also lead an interagency evaluation of factors limiting anadromous fisheries production at the watershed level and provide recommendations for restoration and monitoring in the final synthesis report.

- CDF will compile, develop, and analyze data related to historical land use changes in the watersheds. It will also take the lead on preparing reports that synthesize information, findings and recommendations, and develop a framework for assessing cumulative impacts.

- DOC/DMG will compile, develop, and analyze data related to the production and transport of sediment. Tasks will include baseline mapping of landslides, landslide potential, and instream sediment, as well as an analysis of stream geomorphology and sediment transport.

- RWQCB will compile, collect, and analyze water quality data for the assessments.

- DWR will install and maintain stream monitoring gages where needed to develop and analyze stream flow information.

All products will be made available electronically through the Resources Agency website (CERES) and the Institute for Fisheries Resources's (IFR) Klamath Resource Information System (KRIS) tool on CD and on their website. Further detail on the specific tasks and approaches that will be used by each agency is provided in later chapters of the manual.

APPLICATIONS AND RELATIONSHIPS TO OTHER AGENCY PROGRAMS

The usefulness of NCWAP to local landowners, watershed groups, and local, state and federal agencies will depend on its integration with existing agency programs. The state agencies involved in NCWAP recognize the importance of integrating NCWAP with other agency programs and already have begun efforts to achieve this integration. The discussion below presents the relationships between NCWAP and existing agency programs.

The Resources Agency

NCWAP is part of the Resources Agency's overall approach for protecting coastal watersheds that is parallel to efforts of CalFed for interior watersheds. This approach envisions watershed assessment as a critical first step in watershed management that will be followed by planning, implementation, monitoring, adaptive management, and ongoing outreach.

NCWAP was the first step of an 8-point coastal salmon and watersheds strategy released by the Agency in October 1999. This Coastal Salmon and Watersheds Program includes: 1) science-based assessment; 2) increasing landowner access to watershed and salmon information; 3) expanding partnerships with counties; 4) monitoring salmonid populations; 5) improving incentives for landowners; 6) correcting fish passage problems related to streams and small dams; 7) improving enforcement; and 8) demonstrating interagency, coordinated on-the-ground restoration. NCWAP directly addresses the first and second program actions. DFG assumed the lead for further refining and reporting on this program in November 1999. The Resources Agency continues to work across department lines and with CalEPA to develop or improve agency tools for watershed management. California Department of Fish and Game

NCWAP will support and is being coordinated with several existing DFG programs. The Department's Fishery Restoration Grants Program conducts annual grants program for coastal salmon and steelhead watershed projects including resource education, assessment and planning, and restoration projects affecting streams, riparian and upslope conditions and natal fish rearing facilities. NCWAP will provide watershed level information on fishery and stream habitat conditions which will guide restoration project development and help decision makers select projects for funding.

DFG is conducting Basin Planning in the Russian, Eel, Mattole, and Mad Rivers, and along the Sonoma and Mendocino Coast, and the North Coast from Redwood Creek to the Oregon Border, and in the Klamath/Trinity. Basin planners, who assisted with NCWAP methodology development, assess fish habitat conditions and recommend improvement projects for landowners and managers. NCWAP will incorporate these detailed inventories into its assessment process where available. In turn, NCWAP will provide the Basin Planners with upslope information about geology, vegetation, land use, and other conditions and with GIS-based tools to help them focus their efforts on activities and watersheds where restoration projects are most likely to physically succeed. Basin assessment efforts will be coordinated if possible with NCWAP activities to complement each other and better support landowner and watershed group activities.

NCWAP products will be used by DFG for developing Lake and Streambed Alteration Agreements (1600 Series). These agreements stipulate conditions that are to be associated with projects that will alter a stream or lake zone so that they do not impact fish and wildlife. DFG's Timber Harvest Review Program, Habitat Conservation Planning Review Program, and Timberland Monitoring and Assessment Program all rely on broad based, multi-discipline data and information in order to make decisions related to the wood products industry. NCWAP will benefit those programs by providing interdisciplinary findings and interpretations about the watershed context and the limiting factors framework within which they make decisions. NCWAP managers have already met with some of these staff to explain how NCWAP products and how they can use them.

NCWAP will provide useful information to DFG's six District Fisheries Biologists and to wildlife biologists for reviewing environmental documents and developing mitigation terms for a broad range of projects that can impact fishery resources within their county jurisdictions. NCWAP will, in turn, compile and incorporate finer grained information developed by the biologists.

DFG's Steelhead Research and Monitoring Program (SRAMP) is charged in an agreement with NMFS to conduct an extensive base line data about fish populations within the scope of NCWAP's assessment area. SRAMP and NCWAP will complement each other to provide a comprehensive framework for monitoring fish populations. Staff from both programs are actively collaborating and coordinating activities and resources in the Gualala and Mattole rivers, and Redwood Creek watersheds.

California Department of Forestry and Fire Protection

NCWAP has important linkages with CDF programs and responsibilities. In general, NCWAP watershed assessment products will improve environmental planning and regulatory review for forest management, timberland improvement and restoration, and other land use activities. NCWAP outputs also will contribute to CDF's broad resource assessment responsibilities under the Forest and Rangeland Resources Assessment Policy Act.

CDF regulates timber harvesting on nonfederal lands through several planning and permitting mechanisms, including timber harvesting plans (THPs), nonindustrial timber management plans (NTMPs), and sustained yield plans (SYPs). CDF expects landowners and registered professional foresters to incorporate NCWAP information and findings into these planning processes. NCWAP products will in turn be used by CDF staff to review proposed plans and will be available for use by other plan reviewers (state agencies such as DFG, RWQCB, and DMG; federal agencies such as NMFS and the Fish and Wildlife Service; local government, watershed groups, members of the public, and other nongovernmental entities).

The Board of Forestry and Fire Protection has indicated an interest in developing a watershed assessment approach as a part of THP requirements for landowners in watersheds where listed salmon are found or could be feasibly restored. NCWAP products will provide a comprehensive coarse assessment framework which landowners will be able to use to focus additional finer grained assessments for purposes of evaluating cumulative watershed effects of specific projects, such as THPs. Landowners, registered professional foresters, agencies, watershed groups, and other interested parties are expected to use NCWAP products, to address NCWAP findings in THP analyses, and to tier other analyses off of them as needed.

CDF administers several state and federal forestry assistance programs with the goal of reducing wildland fuel loads and improving the health and productivity of private forestlands. These programs include the Vegetation Management Program, California Forest Improvement Program, Forest Stewardship Program, Forest Incentive Program, and Forest Legacy Program. NCWAP products will be useful to landowners and agencies identifying priority areas for activities under these programs and for developing necessary planning and permitting documents.

As a part of its fire protection planning efforts, CDF evaluates the resources at risk to harm from large, damaging wildfires. NCWAP products should help CDF fire planners to better identify fish, aquatic, riparian vegetation, water quality and other watershed resources at risk from such fires and to better plan for their protection.

A recent expansion of the research program associated with the demonstration state forests provides opportunities for CDF to fund research activities that will support the generation of watershed information and the development of improved watershed assessment methods. The initial round of research projects funded on the state forests includes a number of projects of this sort.

North Coast Regional Water Quality Control Board

Section 305(b) of the federal Clean Water Act requires states to submit a report on the status of their waterbodies to the federal Environmental Protection Agency (EPA) in even-numbered years, and to assess waterbody conditions for beneficial use attainment under Section 303(d). Those waterbodies are then prioritized for waste reduction activities. The Regional Water Quality Boards prepare the assessments and submit them to the State Water Board for transmittal to EPA. NCWAP products will be incorporated as they become available, providing more detailed and comprehensive information to these processes and also documentation of health over time. As a result, subsequent listings and delistings will have a higher level of confidence and the Regional Water Board will know more specifically where to focus program activities.

NCWAP will provide a significant portion of the basic watershed information needed to support development and implementation of Total Maximum Daily Loads (TMDLs). This includes information (both historic and recent) for geologic, land use, fisheries, climate, water resources, and water quality factors that may influence the impairment of a beneficial use in a stream. NCWAP will also support the Nonpoint Source Program by providing direction for targeting NPS control efforts and assisting in interagency and stakeholder coordination.

The implementation of the Board's new Surface Water Monitoring (SWAMP) program is being coordinated with NCWAP. The SWAMP uses a two-component approach: 1) long-term monitoring sites for trend analysis, and 2) rotating intensive basin surveys. The rotation schedule is closely coordinated with the NCWAP assessment schedule, to provide additional and current information on water quality parameters to the NCWAP assessment. SWAMP methodology will be used to collect new field water quality data in NCWAP, as needed.

RWQCB is part of the multi-agency review team for THPs. Forest practice rules include considerations for cumulative watershed effects. NCWAP will provide watershed assessments that will allow landowners, the public, and the agencies to evaluate individual THPs in a watershed context. Having the data compiled into a single assessment that is made available to all provides a common base for planning discussions, and reduces conflict over data sources. In short, NCWAP assessments will provide data for timber landowners to use in planning timber harvest activities from a watershed perspective.

NCWAP will also be integrated into the North Coast Water Board's Watershed Management Initiative which seeks to integrate "…water quality monitoring, assessment, planning, standard setting, permit writing, nonpoint source management, groundwater protection and other programs at the State and Regional Boards…" within the context of designated Watershed Management Areas (WMAs). The NCRWQCB focuses on a few WMAs at a time, cycling back through them every five to seven years.

Since these management areas are larger than the scale at which most of the NCWAP assessments will take place, NCWAP products may be aggregated up, if available, to help the Board assess water quality problems and develop strategies to implement activities to address the problems, and evaluate the effectiveness of the WMA. Water quality goals to be addressed are prioritized and will be budgeted within the area's schedule.

The NCRWQCB has a Watershed Coordinator and watershed groups for each of the WMAs, who will assist in outreach and scoping activities with watershed groups and landowners. The coordinator also is responsible for managing the Proposition 13 and 319 grant programs. Outreach for grant development identifies issues and concerns from watersheds in the region that will benefit the NCWAP process. NCWAP will, in turn, provide information about restoration priorities that can be used in these grant programs.

California Department of Conservation, Division of Mines and Geology

NCWAP information will be used by DMG to assist in engineering geologic review of proposed THPs, Non-Industrial Timberland Management Plans, Sustained Yield Plans and regional-scale watershed management projects submitted to CDF as well as proposed watershed restoration projects submitted to DFG.

New geologic data collected by DMG within NCWAP will be used as appropriate by DMG geologic hazard evaluations for proposed school and hospital sites that are referred to the State Geologist for review and comment regarding seismic and geologic safety issues. Land use proposals, such as large housing developments or areas of land conversions (e.g., area conversion to vineyards) must also be reviewed by the Department of Conservation including DMG. Any landslide information collected under the NCWAP program that potentially affects geologic hazard identification in the aforementioned sites and areas must be incorporated into California Environmental Quality Act (CEQA) reviews. DMG is also responsible for identification and mapping of earthquake-triggered landslides for use in land-use planning and permitting. Landslide maps prepared by NCWAP would be considered in preparation of maps of Seismically Induced Landslide Hazard Zones by the Seismic Hazard Zone Mapping Program.

Another DMG project interprets and maps landslides and prepares geologic maps along selected highway corridors under contract to the California Department of Transportation (Caltrans). Landslide maps prepared by this project use the same landslide classification as NCWAP, but are prepared at twice the scale (1:12,000). Where "Caltrans Corridors" and NCWAP mapping overlap, the projects will avoid duplication of effort. NCWAP products will also be incorporated into DMG's program for producing regional geology and geologic hazard maps throughout the State.

DMG has responsibilities for identifying important mineral resources and for reviewing and commenting on mine reclamation plans under the Surface Mine and Reclamation Act. Geologic information developed under NCWAP may be used in these applications.

Finally, NCWAP will also benefit the Watershed Coordinator Grant Program for Resource Conservation Districts (RCD's) that is funded through the Department of Conservation's Division of Land Resource Protection. This program provided $2 million in grants for FY 2000/2001. NCWAP outreach efforts will make assessment products available use by local RCD's and their watershed coordinators to improve information and planning activities.

COMPLETION SCHEDULE

Completion of the watershed assessments for the North Coast will occur over seven years. The Program thus far has identified those basins that will be assessed in the first three years only. The schedule was developed to provide timely information for development of Total Maximum Daily Loads (TMDLs) by the North Coast Water Quality Control Board and EPA. (See Appendix B for TMDL schedule).

NCWAP will complete final or draft reports for the Gualala River, Redwood Creek, Mattole River, Albion River, Big River, and North Fork Eel River by spring 2002. The program will develop assessments for the following watersheds in year two and three: Scott River, Shasta River, Middle Fork Eel River, Lower Fork Eel River, coastal streams north of Shelter Cove; Upper Fork Eel, Middle Main Eel River, and coastal streams south of Shelter Cove. The schedule will continue to be refined as the program is fully implemented.

CHAPTER 2: CONCEPTUAL FRAMEWORK FOR WATERSHED ASSESSMENT

WATERSHED ASSESSMENT VERSUS WATERSHED ANALYSIS

The primary distinction between watershed assessment and watershed analysis as used by the North Coast Watershed Assessment Program is in their purpose and scale. For the purposes of this program, watershed assessment is a process that characterizes current watershed conditions at a coarse scale. Watershed analysis, as used in the state of Washington program, provides more detailed information for timber management objectives in order to develop site-specific prescriptions and to conduct cumulative effects analysis for specific projects. Both use an interdisciplinary approach to collect and analyze information.

The focus of NCWAP is on watershed assessment, not analysis. The main goal is to characterize current and past watershed conditions for the purposes of watershed protection and restoration, anadromous fisheries recovery planning, and land and water management planning. Watershed assessments contain hypotheses about the cause-effect relations between activities and watershed conditions, about reference watershed conditions, including soil and bedrock, and about linkages among activities, habitat conditions and fish recovery. Assessments can provide the basis for watershed-level planning, management and policy decisions and can lead to more detailed watershed analyses and development of prescriptions at the site scale. However, assessments themselves stop short of analysis and prescriptions. The North Coast Watershed Assessment Program will not develop specific management objectives, restoration projects or prescriptions.

CURRENT APPROACHES TO WATERSHED ASSESSMENT AND ANALYSIS

There are a number of state, federal, and private programs for watershed assessment and analysis. All have somewhat different goals and methods. In the Pacific Northwest, the best known are the systems used by the states of Washington and Oregon and by the USDA Forest Service.

The Oregon Watershed Assessment Manual (Oregon Governor's Office 1997) was developed for use by non-technical local watershed councils to guide watershed restoration efforts (Salminen et al. 1999). The goal is characterization and assessment of watersheds using existing data such as maps, reports, aerial photographs, and historical accounts. Evaluation of historical conditions and channel habitat types provide a descriptive framework for assessing current conditions including hydrology and water use, riparian areas and wetlands, sediment sources, channel modification, water quality, and fish habitat. The technical assessment is used to identify problem areas and prioritize potential restoration opportunities. A method for development of a monitoring plan is included.

The State of Washington developed a watershed analysis procedure (Washington Forest Practices Board 1997) that is used by natural resource professionals to regulate forest practices and develop site-specific forest management prescriptions. Regions within a watershed that may be sensitive to forest practices are identified using hazard and vulnerability ratings. The process provides for two levels of data development and analysis. The state mostly conducted Level One analyses that rely on remote imagery or other "reconnaissance" level data. The more detailed Level 2 analysis which requires field level data collection was generally done, if at all, by landowners. A rule matrix is developed to determine whether standard rules or more specific site prescriptions apply. The Washington methodology is regulatory in nature, does not identify restoration opportunities, and lacks specific assessment approaches for agricultural and urban land uses.

The Federal Guide for Watershed Analysis (Regional Interagency Executive Committee 1995) is used on much of the federally-managed public land in the Pacific Northwest. The approach uses a six-step process framed around a series of "core" topics to describe the condition of a watershed and identify issues of concern. Because the approach provides a large landscape level perspective, and does not evaluate impacts from site-specific projects, this approach more closely resembles watershed assessment rather than watershed analysis. The goal is to guide decision making for future management activities.

In California, watershed analysis on federal lands has relied on the Federal Guide described above. On private owned timberlands, modifications of the Washington Forest Practices Board procedure have been used by several timber companies (Pacific Lumber Company, Louisiana-Pacific Corporation, Mendocino Redwood Company) and CDF (draft Sustained Yield Plan for LaTour Demonstration State Forest). For watersheds on the central coast, watershed groups and others have begun using the Oregon assessment method for identifying restoration opportunities.

NCWAP APPROACH AND FRAMEWORK

- The North Coast Watershed Assessment Program will provide a progressive and iterative approach to assessment that uses public input, limiting factors modeling, and an evaluation of existing data quality to refine the assessment process and to focus field data collection efforts. The following principles guided the development of this approach and the selection of assessment methods:

- Provide useful information for several purposes including servicing of local agency, landowner and group watershed planning and restoration efforts, augmentation of local environmental databases, and enhancement of various State regulatory programs.

- Apply an adaptive assessment approach to each watershed that considers local needs and special conditions while retaining overall NCWAP program direction.

- Focus on interdisciplinary, interagency assessment processes.

- Ensure that the assessment includes an analysis of factors limiting production of anadromous fish on the north coast.

The need for interdisciplinary cooperation in watershed assessment cannot be overemphasized. In order for the assessment process to consider how anthropogenic and natural processes interact to affect watershed conditions for fisheries and other uses, and to assess their implications for management, NCWAP agencies will need to work closely together at all stages of the assessment process. Figure 3 demonstrates the interdisciplinary nature of watershed assessment.

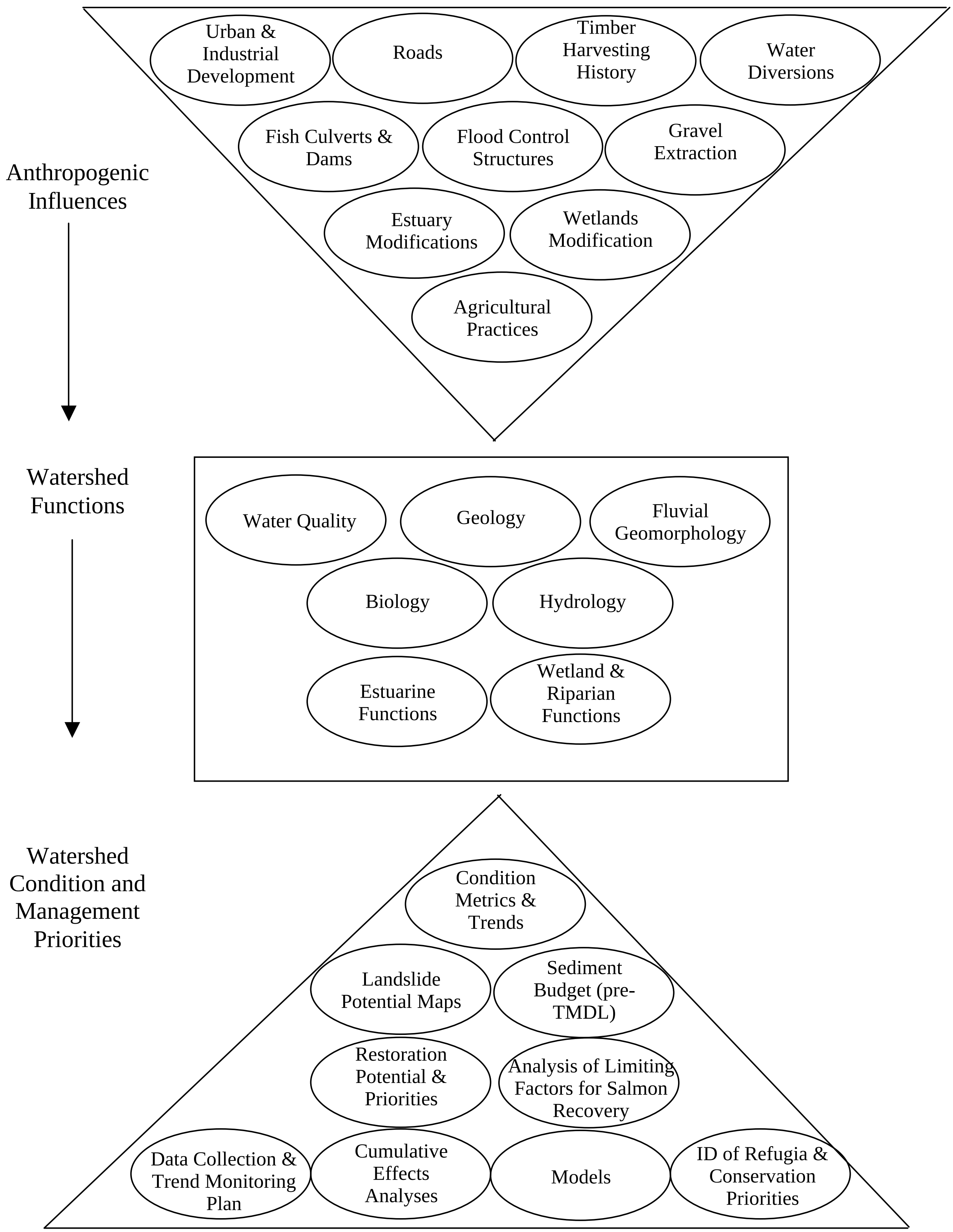


Figure 3. Watershed assessment as an interdisciplinary effort

Because NCWAP is also intended to provide useful information for several purposes, its approach emphasizes close coordination with clientele groups. NCWAP products are expected to provide both context and content for finer scale analysis, set priorities for detailed analysis and program planning, and identify areas for further work. Therefore, although a relatively uniform assessment process will be followed in each basin, key issues and information will be customized. Variability in watershed condition, public resource values and concerns, land use and ownership, and the availability of existing data may drive the assessment towards critical questions that may vary somewhat among basins. Public review of products will provide additional opportunities to adapt and enhance assessments in the future.

The steps of the NCWAP process in each basin are described below and captured in Figure 4:

- Step One: Scoping. The basin assessment team will meet several times 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. Critical questions are described in further detail later in this chapter.

- Step Two: Data compilation. The team will compile existing data and screen them according to its quality and its usefulness for answering critical questions and application to the program's spatially-driven limiting factors model. Quality control processes are described in greater detail in Chapter 4. Coordination on matters such as geographical information systems and mapping will be addressed.

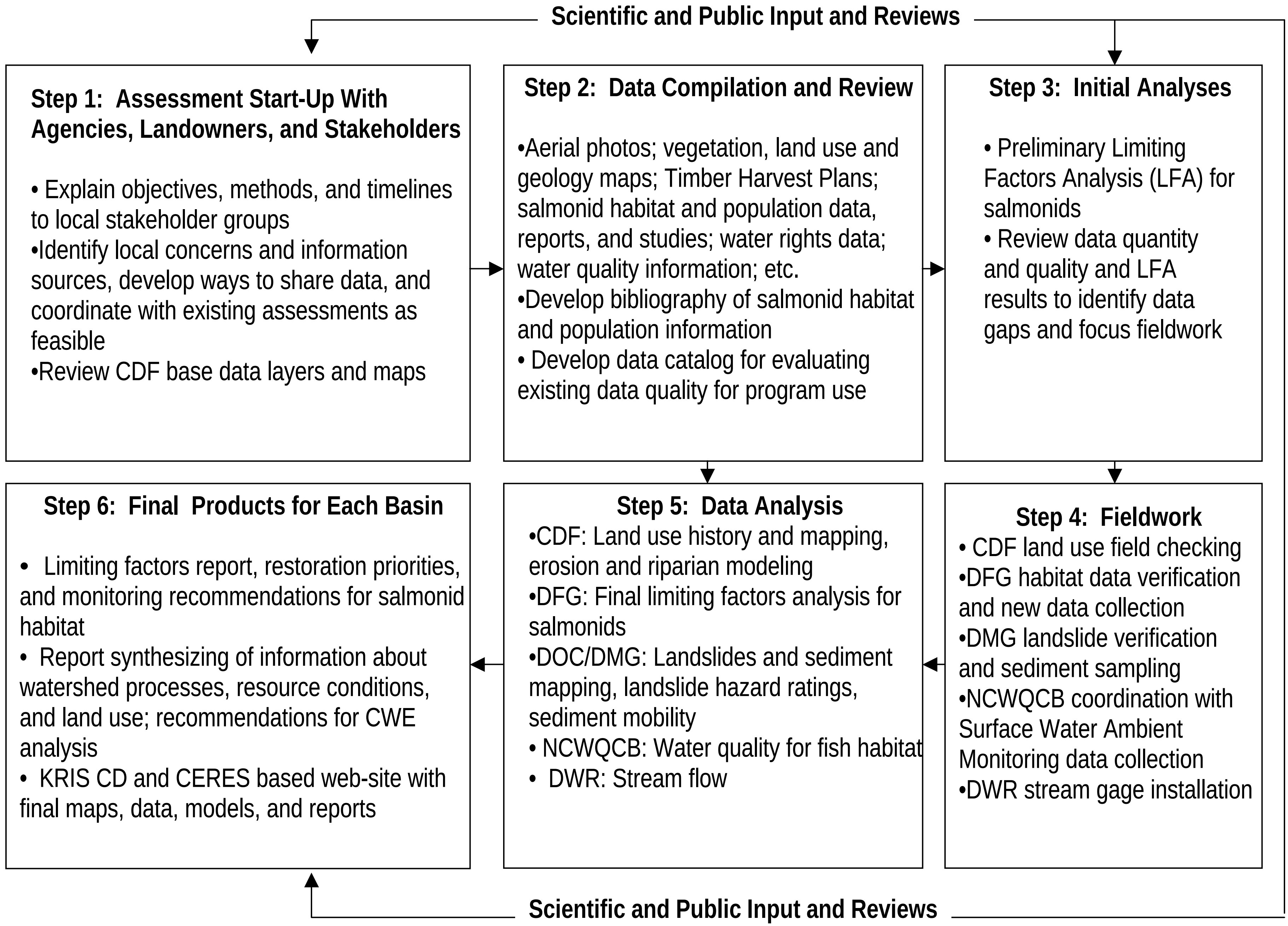
- Step Three: Initial Analyses. The team will use a limiting factors model (described in Chapter 3) to analyze the habitat factors limiting fish production. This initial run with existing data will help to identify significant data gaps (categories, location and scale) and to focus field data verification and collection by DFG and others. The model will be run again after new data has been collected or developed.

- Step Four: Fieldwork. Agencies will conduct necessary fieldwork, including validation of existing data, verification of imagery or photo-based analyses, and collection of new data to fill critical gaps. Throughout this process, there will be coordination with local groups and landowners on access to private property and other matters.

- Step Five: Analyze data. This includes generation of maps, databases, and the more integrative analyses. Data will be analyzed in an interdisciplinary fashion where needed, particularly when answering critical questions, applying the limiting factors analysis, and developing general management and cumulative effects recommendations.

- Step 6: Develop Assessment Reports for Public Review: Draft products will include data developed or compiled by all the agencies as licenses or agreements permit (including photos and imagery); analytical products such as maps, LFA results, GIS analyses, topical reports, etc.; and the overview summary report with recommendations. These products will be available through the Klamath Resources Information System CD and on-line. A public review process will be established for each basin. NCWAP team will summarize comments and revise preliminary products to reflect comments as feasible.

Figure 4. North Coast Watershed Assessment Program Approach



A completed watershed assessment will provide landowners, watershed groups, agencies, etc., a framework to use for periodic re-evaluation of watershed conditions and management strategies. Where the resources are available, interested entities could use interdisciplinary assessment teams to revisit these assessments as new information becomes available, issues and regulatory approaches change, and watershed disturbances occur.

Critical Questions

During the formulation of this methods manual, the participating agencies provided lists of questions that they considered important to understanding and implementing watershed assessments. From those lists, a short list of critical questions for the entire NCWAP program evolved and was agreed upon. Those questions are presented below in order of priority and will guide the assessment process as it proceeds through the six steps described in Figure 4.

Key Question: What factors are limiting salmonid and macroinvertebrate populations?

- What are the general relationships between land use history (development, timber harvest, agriculture, roads, dams and diversions) and the current vegetation and level of disturbance in North Coast watersheds? How can these kinds of disturbance be meaningfully quantified?

- What is the spatial and temporal distribution of sediment delivery to streams from landsliding, bank, sheet and rill erosion, and other erosion mechanisms, and what are the relative quantities for each source?

- What are the effects of stream, spring and groundwater uses on water quality and quantity?

- What role does large woody debris have within the watershed in forming fish habitat and determining channel class and storing sediment?

- What are the current salmonid habitat conditions in the watershed and estuary (flow, water temperature/shade, sediment, nutrients, instream habitat, LWD and its recruitment); how do these compare to desired conditions (life history requirements of salmon, Basin Plan water quality objectives)?

- What are the sizes, distributions and relative healthiness of populations of salmonids within watersheds?

- Do the current populations and diversity of aquatic communities (especially salmonid fishes, macroinvertebrates, and algae) reflect existing watershed and water quality conditions?

These critical questions will drive the data gathering and assessment procedures by individual team members and also provide direction for those analyses that require more interagency, interdisciplinary syntheses, including the analysis of factors limiting anadromous salmonid production.

The final question points out the importance of salmonid population information to validate the assessment and predictions of habitat conditions. In many watersheds, population data may not be available implying a need for future monitoring efforts.

SPATIAL AND TEMPORAL FRAMEWORKS FOR ASSESSMENT

Spatial Scale

Watersheds consist of hierarchical structures of spatial units ranging from the stream channel habitat unit (e.g., pool, riffle, etc.) to the stream reach to the subwatershed and finally whole watershed (Frissell et al. 1986). Although watershed assessment seeks to integrate information at the whole watershed scale, there is a need to gather and analyze data at multiple scales. In the NCWAP approach, the finest level of resolution will be the stream reach scale, on the order of 1-10 km in length. This is reflected in the NCWAP approach to stream reach classification (see *Data Collection, Analysis, and Management Procedures* chapter). Results, findings and interpretations, including recommendations, will be made at multiple scales from the stream reach to the whole watershed.

Temporal Scale

NCWAP will develop measures of landscape change over time, and begin to link them to changes that have occurred in streams. Within this context the program will look at changes in the watersheds in the framework of critical dates and periods defined by major natural perturbations, changing levels and technologies of land use, and evolving government policies.

The temporal framework for analysis defines the period of study and sets the historical context and underlying trends influencing the processes of interest. NCWAP will focus on the current state of a given watershed and its relationship to the land management activities of European-Americans over the past 150 years.

Natural processes have been at work shaping North Coast watersheds since they were formed millions of years ago. Since about 1850, changes have intensified as a result of the interplay between natural factors and increasing human uses. While some processes work slowly over many years, others can reshape the environment radically during infrequent high-impact events. Recent history has shown that several key episodes have been especially important in reshaping watersheds. These punctuating phenomena include major floods, earthquakes and fires (e.g., the flood of 1955, the earthquake of 1906, etc.). While human activities can exacerbate their impacts, these events are precipitated by nature.

The past 150 years has also witnessed profound changes in human technology. The adoption of inventions in the late 1800s (such as the Dolbeer steam donkey), and the post-WW II use of crawler tractors for logging, greatly increased our efficiency at resource extraction. However, these innovations often resulted in accelerated rates of key watershed processes, particularly hillslope erosion and stream deposition, which have in turn adversely influenced stream turbidity, temperature, overbank flooding and fish habitat. More recent decades have seen the development of equipment and techniques that have tended to result in a lesser level of impact on watershed processes. The dates of major technology changes are milestones in the histories of the North Coast watersheds, as they are often turning points in the rates of critical processes affecting stream structure and salmonid habitat

Administrative policies of the government and of private companies have also affected watershed conditions. Changes in the statutes governing development, timber, and other land uses, large-scale changes in land tenure, and new management directives have affected trajectories in human alteration of the landscape. As an example, California's 1973 Forest Practice Act significantly altered timber harvesting practices in North Coast watersheds. In addition, until the early 1990s stream structure was greatly affected in the region by government-sponsored programs to remove woody debris from stream channels. The dates associated with important managerial changes serve as critical points in understanding trends in the watersheds.

NCWAP will develop measures of landscape change over time, and begin to link them to changes that have occurred in streams and impaired salmon habitat. Within this context the program will look at changes in the watersheds in the framework of critical dates and periods defined by major natural perturbations, and periods wherein a new resource extraction tool, policy or program entered the scene.

PUBLIC AND SCIENTIFIC INPUT TO PROGRAM DEVELOPMENT

Working with the Public

NCWAP will provide for independent scientific peer and public review processes of program methods and products and will also work with local stakeholders in each basin assessment to refine assessment approaches and coordinate assessment activities. Extensive outreach was conducted during program development to address public and science community needs and concerns. These included:

- NCWAP presentation hosted by State Senator Wesley Chesbro's office in Eureka on April 18, 2000
- Forest Landowners of California
- Fish, Farm and Forest Communities group
- California Biodiversity Council
- Fish Passage Work Group, an interagency, public/private partnership developing ways to identify fish barriers and coordinate and expedite remediation.
- Cumulative Watershed Effects conference
- Coastal Provincial Advisory Committee (PAC) of the Northwest Forest Plan and the PAC's Aquatic Subcommittee
- Board of Forestry
- Three FishNet 4C workshops on watershed assessment
- Russian River Agency partners group
- Redwood Landowners Association and the National and State parks
- Gualala River Watershed Council
- Salmonid Restoration Federation conference

Common themes and comments have included the need for public and peer review of methods, working with communities to identify assessment needs, building on work already done by watershed groups and landowners, working with those groups to implement assessments, flexibility to focus on the most important factors, relationship to other regulatory and assistance programs, and interagency coordination to interpret and use assessment products and findings. The Resources Agency and departments also made several presentations to Legislative subcommittees and the Legislative Analyst's Office.

Working with the Science Community

Since a major impetus to the development of the NCWAP program were the recommendations for science-based, state-led, interagency assessments delivered by the Report of the Scientific Review Panel on California Forest Practice Rules and Salmonid Habitat (Ligon et al. 1999), NCWAP team members have worked to assure that scientifically sound assessment methods are used in the assessment program. The Resources Agency and several agency members met with Drs. Leslie Reid and Robert Ziemer from Pacific Southwest Station's Redwood Sciences Lab in Arcata. Dr. Reid commended the program for bringing together all the needed information and disciplinary experts, and emphasized the challenge of managing the interdisciplinary process to ensure success. She also stressed the need to: 1) include all relevant land uses; 2) be flexible and strategic in order to address the range of watershed protection issues which will vary from one watershed to another; and 3) include stakeholders and residents up front to define issues.

In addition, CDF organized two workshops in April and May 2000 to engage NCWAP team members in discussions with consultants from University of California, Berkeley, and Stillwater Ecosystem, Watershed, and Riverine Sciences. The second workshop focused on limiting factors analysis for fish and included a field component at Bothe-Napa State Park.

On February 9, 2001, NCWAP held a third workshop on watershed assessment science, with scientists from the USDA Forest Service Redwood Sciences Laboratory and the Corvallis Forestry Sciences Center. This workshop focused on integrated watershed assessment approaches and limiting factors analysis for fish.

METHODS MANUAL REVIEW

Public Review Process

This assessment manual will undergo a public review and comment process. During this process, the draft manual will be released to the public in printed and electronic format one to two weeks before public meetings are held in North Coast communities. At these public meetings, the NCWAP team will present a summary of the proposed assessment methods and receive comment on those methods. Written comments also will be accepted for one week following the close of the public meetings. Availability of the manual for review and the location of the meetings will be well publicized. University of California Cooperative Extension staff will facilitate these public meetings and document the public comments made at them.

Scientific Peer Review Process

The scientific peer review process for this methods manual will be managed similarly to the peer review process for manuscripts submitted to scientific journals. Dr. Richard Standiford, Director of the Center for Forestry and Assistant Dean for Forestry at the University of California, Berkeley, will serve as the "journal editor" in assembling the review panel and receiving their comments. The review panel members will be well-recognized experts in watershed assessment and related specialty fields. Unlike typical journal manuscript peer review panels, the names of the panel members will be made public.

The science peer reviewers will be asked to critique the draft methods manual and to make suggestions for its improvement. The panel will not be asked to rewrite the draft manual. That task will be the work of the NCWAP staff and any expert consultants whose assistance NCWAP may decide to seek. The NCWAP staff plans to complete the revision of the draft assessment methods manual within two weeks of receiving the comments of the science peer review panel. Upon its completion, the final NCWAP assessment methods manual will be released to the public.

The assessment methods used by NCWAP are expected to evolve over time as NCWAP gains additional insights from its work and as scientists and practitioners develop new assessment methods.

PUBLIC INPUT TO BASIN ASSESSMENTS

NCWAP explicitly recognizes that close collaboration with local parties is essential to successful watershed assessment work. NCWAP will work closely with watershed groups, landowners, local agencies, residents, resource conservation districts, watershed restoration workers, and others in each North Coast watershed. For each watershed, a specific NCWAP staff member will be designated the lead contact with local parties, to ensure that people in the watershed know whom to go to with questions or concerns.

The opportunities for interaction with the public are described above under "NCWAP Approach and Framework." NCWAP will ensure public input in Steps 1, 2, 4, and 6 of the NCWAP assessment process (Figure 4 above) to:

- shape the assessment process through the scoping process,
- obtain and utilize local data,
- coordinate new field data collection with local assessment and restoration efforts where possible, and
- get feedback on products so that we can answer questions, examine concerns, and reassess specific issues if needed.

As described earlier in this chapter, NCWAP will provide for formal public and scientific peer review of final assessment products. Products to be reviewed will include the assessment reports prepared for each watershed and key data sets or geographic information system data layers prepared for individual watersheds or region wide. Comments will be summarized and incorporated if appropriate, and will be made available for public review. The Governor's budget for 2001-02 includes funding to conduct scientific peer review of NCWAP products.

CHAPTER 3: MAJOR NCWAP PRODUCTS AND OVERARCHING ANALYTICAL APPROACH

INTRODUCTION

The work of NCWAP will begin with the basic step of compiling existing information on watersheds. Gaps in critical data can then be identified and lead to prioritization of efforts to collect new information. Once existing and new data have been compiled, the program will analyze specific topic areas (e.g., stream channel characteristics), conduct integrating limiting factors analyses for salmonids, and finally, produce a synthesis report for each watershed. Each of these steps will be responsive to the critical questions that guide the assessment work.

Figure 5 provides an illustration of how data and analytical pieces will build pyramid-wise to the culminating product of a synthesis report for each watershed. Work products from NCWAP will be made available to the public through paper and/or electronic formats.

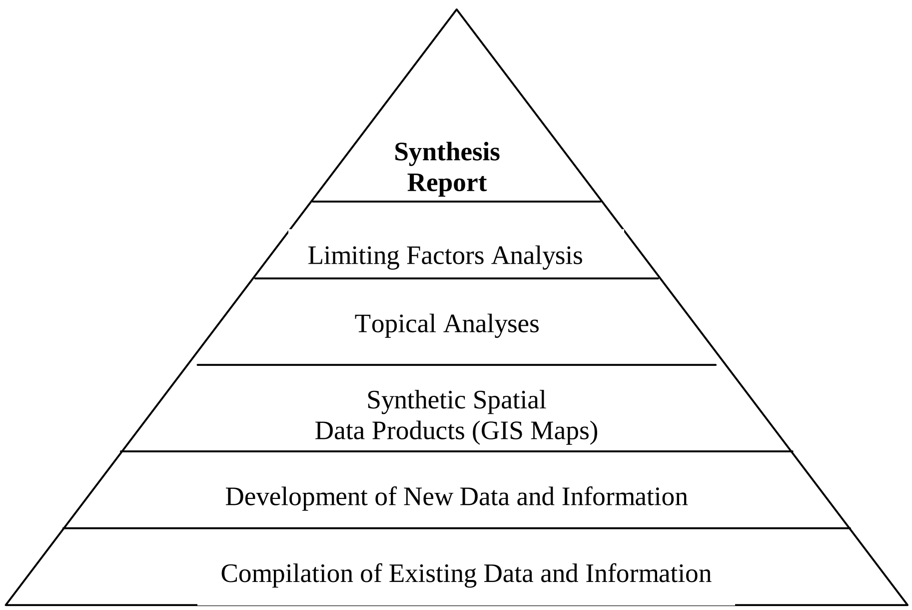


Figure 5. The NCWAP Information and Analysis Pyramid.

This chapter presents the major products forthcoming from NCWAP and the overarching analytical approach that the program will employ. The primary product will be a report prepared for each watershed that synthesizes the data collected and analyses conducted and provides recommendations for fisheries restoration and land management practices that will improve the factors that are limiting the populations of anadromous salmonids.

This chapter also presents the limiting factors analysis approach that is the integral step of NCWAP's watershed assessment efforts. This approach is based on an expert system model that moves away from older, simpler threshold-based model approaches toward the use of more robust functional relationships that better represent the interactions between habitat parameters (such as temperature, channel structure, etc.) and fish.

Next, the chapter provides a catalog of the major data products that will be assembled from existing sources or developed by NCWAP. Finally, the chapter discusses the development of a cumulative effects assessment framework, as called for in the NCWAP program proposal.

The subsequent chapter will provide more detail on the data collection and analysis processes that will feed into the creation of the synthesis report and the limiting factors analysis presented in the current chapter. These include topical analyses that will provide in-depth studies of specific areas, such as sediment, land use, water quality, etc. While focused on a particular subject area, the topical reports also will provide the biophysical process linkages to related watershed topics. For example, a report on sediment production and transport might estimate relative amounts of sediment that landslide features can deliver to a stream and, in turn briefly discuss the aquatic habitat impacts of such sediment delivery, as well as land use activities that have or could exacerbate sediment delivery from landslides.

Figure 6 provides a conceptual diagram of how land and resource use activities and natural elements (such as geology and climate) serve as drivers to affect the key factors for fish habitat. This figure also shows the scope of the limiting factors analysis approach and the scope of the watershed synthesis reports, including recommendations for restoration and land use activities.

SYNTHESIS REPORT

The capstone NCWAP product for each watershed will be an integrative summary report. This report will synthesize individual data pieces, the results from the topical analyses (presented in Chapter 4) and limiting factors analysis to provide:

- An overall view of the functioning and condition of watershed processes;
- The linkages among land use, natural processes (biologic, geologic, hydrologic), and watershed conditions presented in the critical questions, and the results of the limiting factors analysis for fish; and
- Recommendations for restoration activities, land management practices, cumulative effects assessment, and further study.

The summary report will clearly present the factors that are shown to be limiting salmonid habitat in the watershed and (within the limitations of the data and analysis) sort out the natural and/or anthropogenic causes responsible for the limiting factors. It will make recommendations on steps that can be taken to address the identified causes of limiting factors, for example, reducing sediment delivery from rural residential roads, retention of riparian conifers to provide higher levels of shade and large woody debris recruitment, or removing a fish migration barrier. NCWAP assessment reports will provide general recommendations for activities that can improve conditions for fish and fish habitat in North Coast watersheds. However, site-specific project recommendations will not be made in these reports, since the NCWAP assessments will not be at a level of detail adequate to recommend specific projects in specific places. For

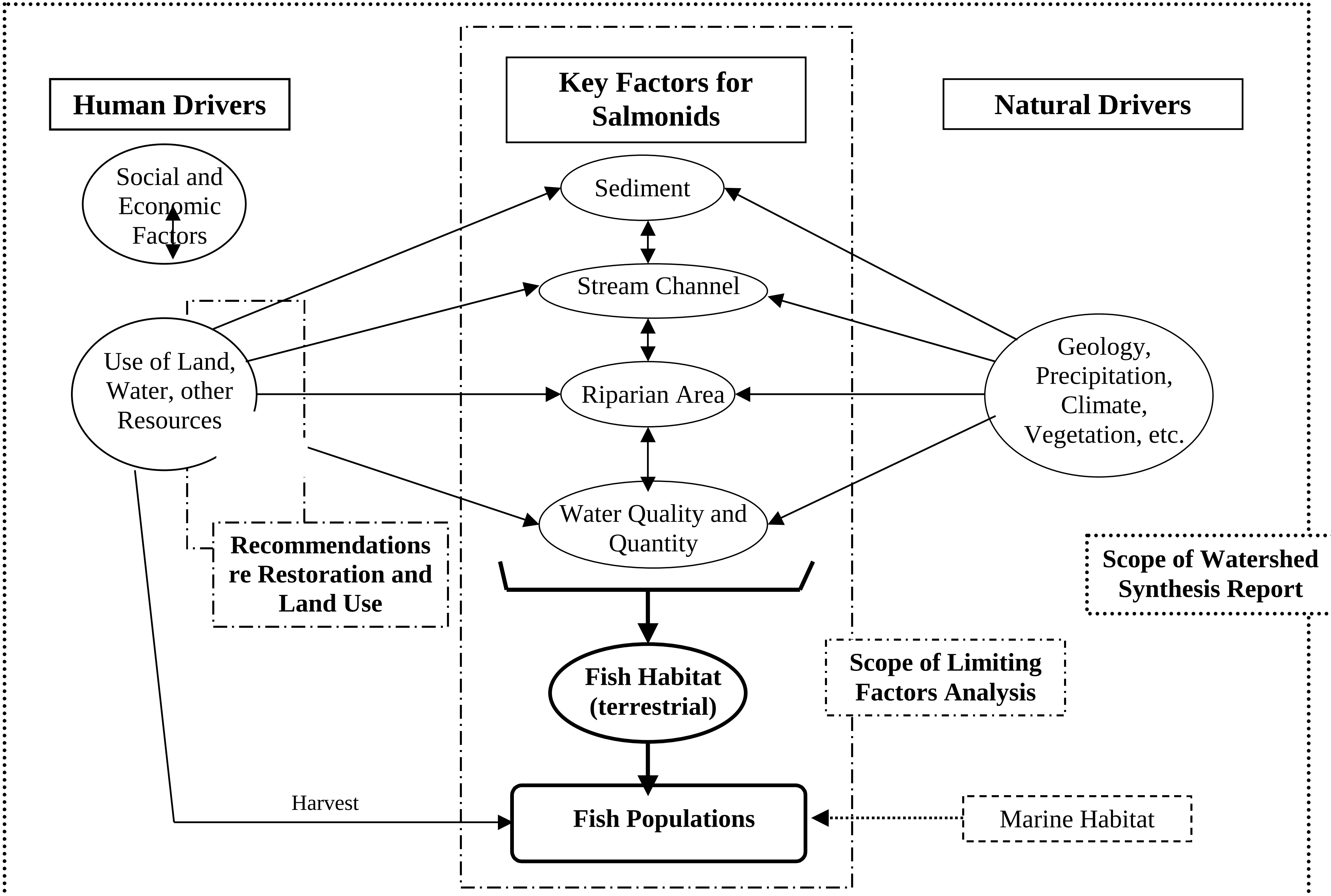


Figure 6. Integrative Diagram of Synthesis Report and Limiting Factors Analysis.

example, an assessment may conclude that a basin or planning watershed is seriously lacking large woody debris in stream channels. In such cases, the assessment report could make recommendations for the placement of large woody debris in certain kinds of stream reaches and for retention of large trees in riparian areas for LWD recruitment. These kinds of management-oriented recommendations will be useful to watershed groups, landowners, government agencies, TMDL planners, restoration workers, etc.

NCWAP assessment reports also will make recommendations on the need for additional assessment efforts, study, or institutional development. For example, on some watersheds there may be a significant lack of detailed information about estuary function or fish stocks. Where this is the case, the NCWAP assessment reports can point out the need for the collection of such information and call it to the attention of those in the position to collect it.

LIMITING FACTORS ANALYSIS OF SALMONID POPULATIONS

A main component of NCWAP will be analyses of stream habitat conditions to identify factors that limit production of anadromous salmonids in North Coast watersheds. A “limiting factors analysis” (LFA) for each NCWAP basin will provide a means to evaluate the status of key environmental factors that affect anadromous salmonid migration, spawning, and juvenile rearing. These analyses will be based on the comparison of key habitat components to a range of desirable conditions. If the component’s condition does not fit within the range of desired values, it may be viewed as a limiting factor. This information will be useful to identify the underlying causes of stream habitat deficiencies and help reveal the linkage to watershed processes and land use activities. Table 1 presents potential habitat parameters and their roles in the LFA.

The concept that fish production is limited by a single factor or by interactions between discrete factors is fundamental to stream habitat management (Meehan 1991). A limiting factor can be anything that constrains, impedes, or limits the growth and survival of a population. Environmental factors considered to limit anadromous fish production include:

- Deficient Stream flow
- High water temperature
- Lack of deep pools
- Lack of shade canopy
- Excessive turbidity
- Lack of large wood
- Excessive sediment yield
- Lack of instream cover

A simplified view is that the ecosystem component in least supply controls the upper limit of a population size (Lestelle et al. 1996). This concept is based on the assumption that there is a limit to the numbers of fish that can survive in a finite amount of habitat or that there is a “habitat carrying capacity.” Some level of reduced growth and/or mortality will occur when that limit or carrying capacity is exceeded due to interspecific and intraspecific competition for limited resources such as food and space required for juvenile rearing. Intense competition that influences growth or survival is referred to as a “density-dependent” mechanism. Density-dependent mechanisms regulate a population size according to the habitat carrying capacity. A possible consequence from this competition is stressed, undersized salmonid smolts entering the sea, which are less likely to survive to adulthood than healthy, large-sized smolts (Nicholas and Hankin 1989).

Table 1: Fish habitat components and parameters potentially applicable for limiting factors analysis.

Habitat Component	Limiting Factor Parameters	Habitat Concerns
Water Quality	Temperature Flow Turbidity Nutrients	Steam flow, water temperature, nutrients, and turbidity are important parameters of water quality that affect fish habitat. Adverse water quality may reduce growth rates, affect fish behavior, reduce disease resistance, and result in mortality.
Sediments	Pool tail embeddedness Gravel composition	Excessive sediment delivery may result in a loss of available cover as it fills interstitial spaces between substrates and decreases channel depth by filling in pools and causes shallowing and widening of channels which can increase the wetted area exposed to direct sunlight. Excessive quantities of fine sediment may adversely impact production of aquatic invertebrates needed as food for fish and impede the flow of water and oxygen to developing salmonid eggs and embryos.
Riparian zone	Shade canopy Species diversity Large wood recruitment Sediment filtration Bank stability Source of nutrients Overhead and instream cover	Riparian forests provide shade over streams and regulate water and air temperature. Large wood needed for channel forming process and stream habitat complexity is largely recruited from the riparian forest. Riparian vegetation acts to trap fine sediments mobilized from upslope areas. The root systems of riparian vegetation increase bank stability, protect land from erosion, and regulate sediments entering streams. Leaf litter and woody debris are sources of nutrients for insect production and primary productivity. Overhanging and instream vegetation provide cover for fish and slow water velocity. Removal or disturbance to riparian vegetation may have far reaching adverse cumulative impacts to stream ecosystems and fish production by eliminating or reducing the function of the critical elements listed above.
Large Wood	Abundance Size/Volume Distribution	Large wood strongly influences stream habitat and biota. It is a structural element involved in pool formation or is often associated with pools. Large wood affects sediment routing. Fish benefit from the cover and habitat diversity created by large wood. Large wood provides substrate for benthic invertebrates. The removal of large trees and woody debris from riparian zones and streams results in loss of pool habitat, reduces structural complexity within stream channels, and may interfere with sediment routing processes.
Pool and Riffle Habitat Characteristics	Pool depth Pool and riffle frequency Pool and riffle length Pool shelter complexity	Cumulative effects of land use activities have substantially altered pool, riffle, and off-channel habitats needed by salmonids for spawning, summer rearing, and winter refuge. These impaired habitats are factors limiting the recovery of salmonid populations to desired levels.
Fish Barriers	Stream gradient Stream crossings Debris jams Intermittent flows Water Temperature	Barriers or impediments to spawning migrations and upstream and downstream movements affect the distribution and survival of anadromous salmonids. Culverts and other structures used for stream crossings are often barriers or impediments to fish migrations or movements. Excessive gravel deposition in channels can cause stream flows to go prematurely intermittent and prevent fish from moving to suitable spawning and rearing areas. Unsuitable water temperature can delay spawning migrations and influence smolt downstream migrations.

Anadromous salmonids have adopted strategies to reduce competitive interactions so that they may co-exist. They spatially and temporally segregate by species and life history stage. However, cumulative impacts from watershed development activities that alter stream conditions may exacerbate limiting factors to salmonid production. For example, excessive sediment accumulation in stream channels reduces pool volume, buries boulders and wood needed for cover by fish, and influences channel forming processes. The loss of habitat will trigger density-dependent mechanisms to limit fish production. Adverse impacts from density-dependent mechanisms are aggravated when habitat quantity is reduced by natural or anthropogenic causes.

A second type of limiting factor, a "density-independent" mechanism, is not due to population density or habitat quantity, but is related to habitat quality (Moussalli and Hilborn 1986). For example, if water temperature exceeds lethal limits, fish will suffer mortality largely independent of population size. Another example of a density-independent factor is turbidity that limits the ability of sight feeders to find food. The interruption of feeding may reduce growth rates and fat accumulation needed before ocean entry. Fish exposure to excessive turbidity for prolonged time periods also may have other adverse physiological consequences.

Many recent salmon and steelhead habitat restoration efforts have been centered on modifying or eliminating specific habitat deficiencies viewed as limiting salmonid production. Improving the quality and quantity of habitat will influence the production of salmonid populations, but it is important to note that focusing on one aspect of habitat is of little value if other habitat limitations are left untreated. The idea that a single limiting factor controls production may be misleading because complex ecological processes are created from interactions by more than one habitat component (Reeves et al. 1991).

APPROACHES TO LIMITING FACTOR ANALYSIS

Salmon and steelhead restoration efforts in the Pacific Northwest over the last two decades have been centered on the concept of limiting factors. The State of Washington has adopted the limiting factors strategy for restoring salmon in that State (Kerwin 1999). The term is defined in a Washington State Law (ESHB 2496) aimed at restoring salmon habitat as "conditions that limit the ability of habitat to fully sustain populations of salmon." In northwestern California, there have been some scientists and agencies who have identified limiting factors for coho salmon and/or salmonids. This may be done through a TMDL study. For example, US EPA (1999) recognized several factors currently limiting the success of salmonids (especially coho salmon) throughout the Noyo River watershed. NMFS (1996) took the approach of describing limiting human factors as opposed to environmental attributes (Table 2).

Other than these and a few other examples, there have been no formal quantitative assessments of factors limiting anadromous fish production in the NCWAP assessment area. Moreover, the State of California currently has no formal approach that it uses for such studies. In general, approaches to limiting factor analysis vary from subjective expert or professional opinion, as illustrated by NMFS (1996) and the work currently underway in Washington State to extremely sophisticated modeling. In choosing an approach, several issues must be addressed: 1) availability of data, especially on salmonid populations; 2) available expertise and experience with approaches; 3) costs; 4) intended applications and audiences for results; and 5) time available to conduct the studies. In NCWAP, it was determined that given these considerations, the method used for limiting factor analysis should neither be completely subjective nor overly complex.

Table 2. Summary of Factors Affecting Northern and Central Coast California Steelhead ESU areas. Taken from NMFS (1996)

Name of ESU	Geographic Range of ESU	Factors Affecting ESU
Klamath Mountains Province	Elk River, OR to Klamath and Trinity Rivers in CA	Hatchery introgression Logging Water diversion/extraction Habitat blockages Poaching Agriculture Hydropower development Historic Flooding Mining
Northern California	Redwood Creek, Humboldt County, CA to Gualala River, CA.	Logging Agriculture Water diversion/extraction Poaching Minor habitat blockages Historic Flooding Predation Mining
Central California Coast	Russian River, CA to Soquel Creek and the drainages of San Francisco and San Pablo Bays, CA; excluded is the Sacramento/San Joaquin River Basin.	Urban development Water diversion/extraction Habitat blockages Agriculture Logging Historic flooding Hatchery introgression Poaching Mining Harvest

NCWAP'S APPROACH TO LIMITING FACTOR ANALYSIS

Introduction

To perform the LFA, NCWAP will employ a computer-based decision support system (Ecological Management Decision Support system or EMDS) to facilitate an improved understanding of the complex relationships between environmental factors, human activities, and overall habitat quality for fish. A description and details of the EMDS modeling procedures are presented below. Because different salmonid species have varying requirements, NCWAP will develop LFA models on an individual species and life stage basis. These analyses will be based on the comparison of key habitat components to a range of desirable conditions. If the component's condition does not fit within the range of desired values, it may be viewed as a limiting factor.

The results from the LFA will assist habitat management decision making by ranking habitat factors by their influence on the overall habitat quality. The analysis also will help reveal the linkage to watershed processes and land use activities. This information will be useful to identify the underlying causes of stream habitat deficiencies (limiting factors) and help focus restoration efforts and watershed management strategies to achieve the greatest salmonid production potential.

Constructing a Knowledge Base Computer Model for Limiting Factors Analysis

In order to implement analysis of the factors that limit salmon and steelhead production in California's North Coast watersheds, the NCWAP team will use computer models known as "knowledge base" or "expert" systems. These are analytical tools with graphics capabilities that scientists use to define precisely how they think a complicated system, such as a watershed, functions. The software allows scientists to bring together data concerning different environmental factors, such as stream temperature and sediment loads, into a common framework, and to produce a synthesis of watershed conditions for native salmonids. These tools also make possible a consistent and repeatable approach to evaluating watershed conditions across the region, or for evaluating the same watersheds over time. The knowledge base modeling software requires scientists to be very specific about how they believe various environmental factors interact to create conditions for anadromous salmonids on California's North Coast.

After a consideration of various approaches, NCWAP chose to employ a linked set of software: NetWeaver, Ecological Management Decision Support (EMDS) and ArcView™. NetWeaver (Saunders and Miller [no date]) was developed at Pennsylvania State University. It helps scientists to build graphical knowledge base networks that specify how each relevant environmental factor is incorporated into an overall stream or watershed assessment. Diagrams of these networks resemble branching tree-like flow charts, and graphically express the logic and assumptions used by the scientists that developed the LFA.

EMDS (Reynolds 1999), developed by Dr. Keith Reynolds at the USDA Forest Service, Pacific Northwest Research Station, uses the logic diagrams created with NetWeaver in conjunction with environmental data stored in a geographic information system (ArcView™) to perform the assessments and to facilitate rendering the results into maps. This combination of NetWeaver/EMDS/ArcView™ software is currently being used to implement the aquatic resource monitoring component for the federal lands included in the Forest Service's Northwest Forest Plan.

The Knowledge Base Network

Although a general modeling approach will be used, each NCWAP watershed assessment will have a knowledge base specifically tailored to local conditions. The knowledge base networks for the LFAs will be built using the best available scientific studies on how various environmental factors interact to create conditions for anadromous fish on the North Coast. For each anadromous salmonid species, NCWAP scientists will create a network to model limiting factors using what is termed a "top-down" approach.

The approach to be used may be illustrated with some preliminary work by scientists working on the Northwest Forest Plan (Tuchmann et al. 1996). In constructing a knowledge base for coho salmon, the NFP scientists started from the proposition that a given stream reach has optimal conditions for the species. Real data are then used to evaluate the "truth" of that assertion or hypothesis. A knowledge base network was constructed that graphically depicted the types of information needed for evaluation and how the each type of information was to be used.

The "ingredients" needed for the assessment were grouped into categories. To determine stream conditions for coho, scientists specified what data are required on several general environmental factors. The knowledge base network (Figure 7) shows that information on riparian vegetation, bank stability, width-to-depth ratio, water temperature and in-channel factors are all needed in the coho assessment. For the "stream in good shape for coho" proposition to be true, each factor fed through the model's "AND" node must be at a level or state that is beneficial to coho salmon.

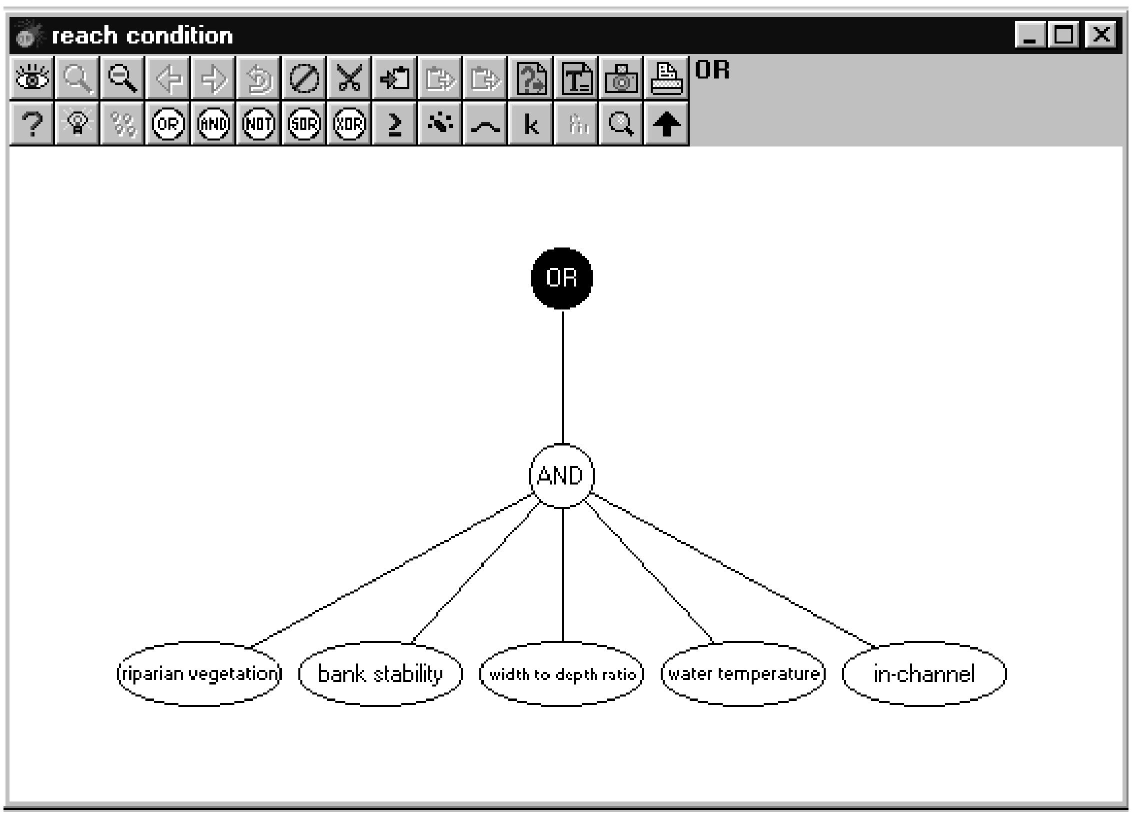


Figure 7. The knowledge base for assessing stream reach conditions for coho. Each of the elliptical boxes shows an environmental factor used in the assessment, and the lines indicate how they are linked to the 'AND' node, where they are combined. In a similar manner, each of the factors can be broken down into the more basic data components that define it (not shown). (from Reeves 2001)

Each environmental factor can then have a similar graphical breakdown into its smaller constituent components. For example, the “riparian vegetation” box may consist of a subnetwork of more detailed data that feed into it (but which are not shown in the above figure). Information fed into the model to describe riparian vegetation conditions could include data on stand structure (vegetation height), stand age, plant species composition, and so forth. Again, these factors would all have to be of high quality in order for the “AND” decision node to “agree” that “riparian conditions are in good shape for coho.” This pattern of logic can be repeated up or down as much as desired, until there is a full picture of all the factors affecting coho salmon conditions in the watershed.

At the base level, the beginning boxes in a knowledge base system are where the data are entered. At this level, the scientists create a graph that expresses their best understanding of how each type of factor affects coho salmon. Figure 8 shows an example for the Oregon Coast from the Northwest Forest Plan of the effect of the percentage of gravel in the streambed on coho spawning, egg incubation, and fry emergence suitability. The horizontal axis shows percent gravel ranging from 0 to 100%, while the vertical axis is labeled “Truth Value” and ranges from –1 to +1. The line expresses what the scientific studies show are unsuitable levels of gravel (-1), optimal levels of gravel (+1) and all the percentages that are in-between (> -1 and <+1). A similar graphic relation is created for all the different kinds of data used in the evaluation.

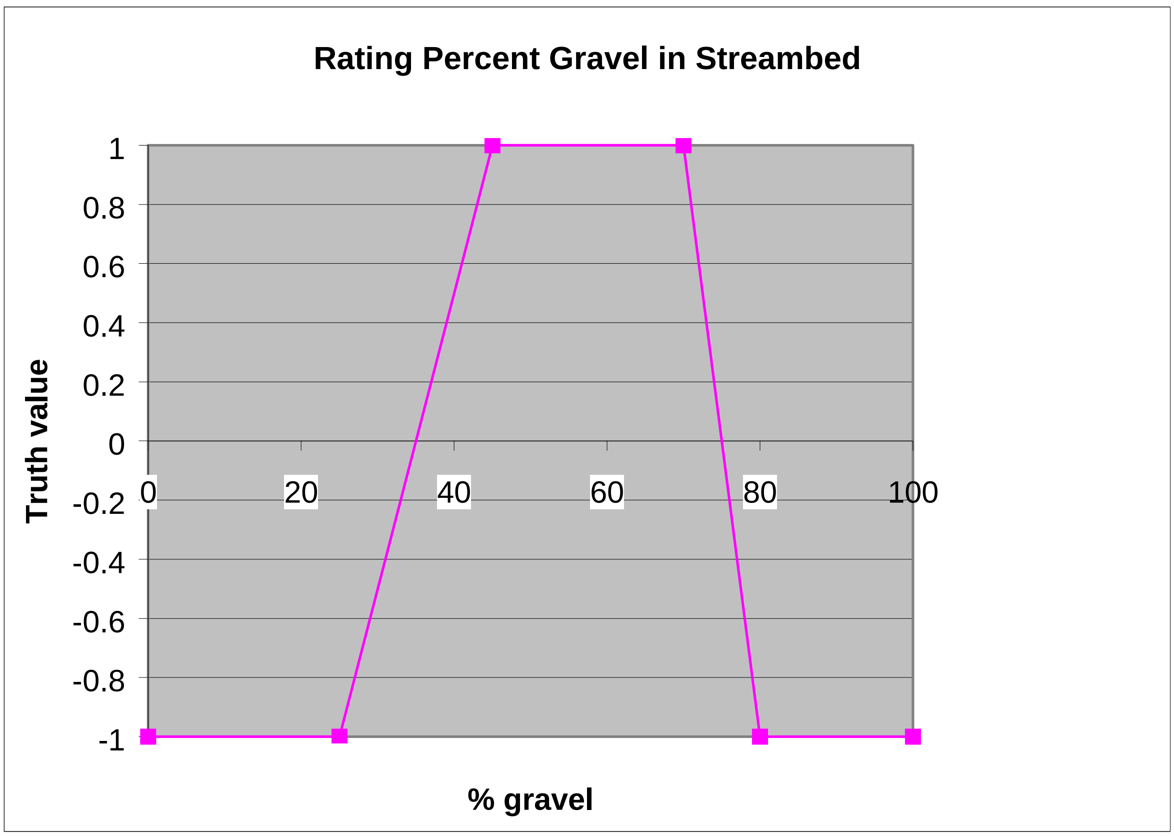


Figure 8. Graph showing the relationship between percent gravel in streambed and its suitability for coho salmon reproduction. EMDS software uses this relationship in conjunction with GIS based data on gravel in order to evaluate that particular factor for the salmonid species (Reeves 2001).

In the above example, the results of the coho salmon assessment for the stream reach will be a number that shows the degree to which the data support or refute the initial "good condition" proposition. Values can vary between –1 and +1, where +1 means that the proposition is "completely true," and –1 implies that it is "completely false." In-between values indicate "degrees of truth," with values approaching +1 being closer to true and those towards –1 approaching completely untrue. A zero value means that the proposition cannot be evaluated based upon the data available. The data that is fed to the knowledge base network will come from GIS layers stored and displayed using ArcView™ software. Thus, the GIS databases developed for NCWAP will be used directly in the LFA.

Advantages Offered By Netweaver/EMDS/ArcView™ Software

The NetWeaver/EMDS/ArcView™ software offers a number of advantages for use in NCWAP. At this time no other widely available package allows a knowledge base network to be linked directly with a geographic information system such as ArcView™. Such linkage is vital to the production of maps and other spatial analytical graphics capable of displaying watershed conditions in the NCWAP region.

The graphs and NetWeaver-based flow diagrams direct the scientists creating them to be explicit in how they are defining the good salmonid habitat conditions needed for the successful completion of the freshwater and estuarine phases of their lifecycle. In this way expert opinion can be formalized, quantified, and repeated systematically throughout the assessments of all watersheds. Equally important, this inherently graphical system facilitates wide public communication and understanding of the NCWAP limiting factors assessment process through simple graphics and flow diagrams of the network.

Another feature of the system is the ease of running alternative scenarios. These can be used to test the sensitivity of the assessments to different assumptions about the environmental factors and how they interact. "What-if" scenarios can be run by changing the shapes of graphs at the base level, 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. 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 larger hydrologic units. With sufficient sampling and data, analyses can even be done upon single or multiple stream reaches.

The results from NetWeaver rank the environmental factors according to their influence on the overall assessments. They also show which factors, given more complete and comprehensive data, would improve the quality of the assessment in the most cost-effective manner. EMDS and NetWeaver are public domain software, available to anyone at no cost over the Internet. Although NCWAP will initially rely on EMDS and NetWeaver for conducting LFAs, this does not preclude the use of other knowledge base expert systems, approaches, or models for further exploration of fish-environment relationships.

Management Applications of Limiting Factors Analysis

While LFAs are important tools for watershed assessment, they do not by themselves yield a course of action for management. LFA 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 expert opinion and knowledge base system constructed, how current and complete the data is for a stream or watershed will strongly influence the degree of confidence in the LFA results.

LFA will be used to support several levels of planning. At the regional level, the State anticipates the NCWAP limiting factors analysis to be incorporated into coho, chinook, and steelhead recovery plans being developed by NMFS. It will provide a finer level of analysis than factors identified at the Evolutionary Significant Unit (ESU) or domain level. This will enable recovery planning to focus on defined problems and potential corrective actions by landowners and others.

LFA can be used at the basin scale, to show current watershed status. Maps depicting those factors that are most limiting, as well as those areas where conditions are very good, can help guide protection and restoration strategies. LFA will support watershed level planning by watershed groups and others by identifying habitat "bottlenecks" to salmonid production and health that can be treated with restoration activities. It could also be used to assess the relative cost-effectiveness of different types of measures.

The EMDS model can also help to assess the cost-effectiveness of different restoration strategies. By running sensitivity analyses on the effects of altering 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 such investment would be cost effective.

At the project planning level, LFA will help landowners, watershed groups and others select the restoration measures and locales (i.e., planning watersheds or larger) that can best contribute to salmonid recovery. Advisory committees for DFG's Fisheries Restoration (SB 271) and Coastal Salmon Recovery grant programs may use the LFA to guide decisions on grant proposals. Those that incorporate NCWAP findings may have a greater chance of obtaining funding. The state also expects other types of project and permit proposals, such as THPs, to use LFA findings in project design, cumulative effects analyses, and mitigation strategies. Agencies will, in turn, use the information when reviewing projects on a watershed basis.

The main strength of using NetWeaver/EMDS/ArcView™ knowledge base software in performing LFAs is that it is flexible 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. In NCWAP, the analyses will be used not only for assessing conditions for fish in the watersheds and to help prioritize restoration efforts, but also to facilitate an improved understanding of the complex relationships between environmental factors, human activities, and overall habitat quality for native fish.

PUBLIC LIBRARY OF WATERSHED DATA

The third main product of NCWAP will be a compilation of all data collected for use in the watershed assessments and limiting factors analyses. These files will be made available at no charge on CDROM via the Klamath Resource Information System (KRIS – see below) and over the Internet, and will enable any interested party to review the inputs to the NCWAP reports. The data will thus be available for other analyses, according to the needs and interests of those concerned. The NCWAP program will maintain a single "data warehouse" at DFG that will be accessible to the public via a web site at DFG and at CERES. These web sites will also make available NCWAP reports, spatial data and associated documentation for public viewing. "Metadata" will be maintained and provided for all public files that are compatible with existing federal standards.

DFG will have the responsibility of maintaining and building the data warehouse. This task will include maintaining current and accurate data, synchronizing with the web access points to maintain currency, and of collecting and storing data from field offices and distributing it back to the NCWAP teams and to the general public.

Use of NCWAP data by the general public will be encouraged through the use of web-based mapping tools, portable document format files and downloadable files. In general, all data and information produced by the project will be made available to the public—the only exceptions being cases where data is proprietary or is incomplete. Appendix C, developed by the Institute for Fisheries Resources for KRIS (see below), lists some of the types of GIS files NCWAP will assemble in the course of the watershed assessments. Where other relevant data is available, these will be added to the watershed data catalog.

THE KLAMATH RESOURCE INFORMATION SYSTEM

The Klamath Resource Information System (KRIS) is one of the means by which NCWAP watershed information will be captured, integrated, and presented for use by the participating agencies and watershed-interested communities. KRIS support for NCWAP is currently provided by the nonprofit Institute for Fisheries Resources (IFR), which employs a team of watershed science and data management specialists for that purpose.

KRIS is an information integration tool that was developed by the IFR team, beginning in the Klamath River basin, for supporting watershed assessment, protection, and restoration planning. The tool integrates datasets, charts, graphs, map images and GIS data, photographs and bibliographic resources including reports, manuals and relevant correspondence. KRIS assimilates datasets in any standard format and uses ArcView™ software for viewing and updating map data.

KRIS has been designed with watershed analysts and restoration workers specifically in mind. Users can add information easily by cloning existing charts or slide tours. Any of its charts, photos, datasets, maps or document narratives can be cut and pasted easily from KRIS into reports or Power Point projects. KRIS has specialized functions such as the ability to download data directly from automated data probes or to reorganize its data contents through the use of

Build Table functions. KRIS has a full help system and tutorials to guide users in all commonly used applications and routines.

KRIS' ease of use and popularity with its users has increased as it has been employed over the past decade in major Northern California fishery protection and restoration programs in the Klamath, Trinity, North Coast and San Francisco Bay-Delta watersheds.

The specific steps that the IFR team will take in the development of KRIS/NCWAP include:

- identifying, acquiring, evaluating, and preparing relevant North Coast datasets, documents, and map projects for incorporation into KRIS
- developing KRIS "face plates" or shells [watershed-specific KRIS projects which have not yet been "populated" with information]
- training cooperating agency personnel and the interested watershed communities how to add information to the KRIS systems
- maintaining a website to enable NCWAP cooperators to track the development of KRIS/NCWAP projects
- assuring, through review and consultation, the quality of KRIS/NCWAP products
- developing at least two field-based coordination sites for the ongoing maintenance and use of North Coast KRIS projects
- fostering watershed community familiarity and use of KRIS/NCWAP projects

NCWAP team members will use watershed-specific KRIS projects to generate charts and to capture and annotate photos. A subset of this information, together with spatial data from KRIS Map projects, will be cut and pasted into the NCWAP watershed assessments s. Watershed assessment products, when available, will be incorporated into watershed-specific KRIS projects. NCWAP cooperators can then add to these completed KRIS projects their own data updates to support further data analysis and interpretation, and they can cut and past charts, photos, and maps from KRIS into their own reports and presentations.

CUMULATIVE EFFECTS ASSESSMENT FRAMEWORK

The NCWAP program proposal requires CDF to design a framework for assessing cumulative impacts for each watershed. The need for a better cumulative impacts assessment framework has been identified by multiple recent recommendations for better cumulative effects assessment and analysis, especially for timber harvesting activities.

The Scientific Review Panel was commissioned by the Resources Agency and NMFS to study the effectiveness of the Forest Practice Rules to protect salmonids. Its report (Ligon et al. 1999) concluded "the primary deficiency of the [Forest Practice Rules] is the lack of a watershed analysis approach capable of assessing cumulative effects attributable to other non-forestry activities on a watershed scale. As currently applied (the rules) do not provide the necessary cumulative effects assessment at the appropriate temporal and spatial scales."

The report of the CDF Director's THP Task Force (THP Task Force 1999) included among its key recommendations the need for clear guidance on cumulative impact analysis and related mitigation measures. The Report noted that neither CDF nor other State agencies have completed consistent or systematic watershed assessments that can provide information to project submitters to guide cumulative impact analysis. The Report also observed that, absent any guidance from CDF and review team agencies, it will be very difficult to consistently improve cumulative impact analysis in timber harvest plans.

The findings of these reports indicate that, despite many years of research and practitioner efforts (see, e.g., Reid 1993), there is still a lack of adequate data and methods for cumulative effects analysis.

CDF will meet its obligation for developing a cumulative effects assessment framework in major part through contracting with the Center for Forestry at the University of California, Berkeley. While a central focus of the contract will be assessment of timber management cumulative effects, the assessment of cumulative effects for other land use activities will be addressed as well. This framework is intended to guide project proponents and others to assess the potential cumulative effects of projects in the context of the planning watershed and larger watershed units. The framework will be designed to be compatible with the level of watershed assessment being conducted by NCWAP and to be responsive to watershed assessment approaches being considered by the Board of Forestry and Fire Protection. NCWAP summary reports for each basin will provide recommendations for using the framework.

The contract will require UC Berkeley to reach out to involve appropriate experts outside of the UC System for the development of the cumulative effects assessment framework. Further, UC will be required to conduct one or more workshops to get input from the public and professionals on what is needed in a cumulative effects assessment framework.

CHAPTER 4: DATA COLLECTION, ANALYSIS, AND MANAGEMENT PROCEDURES

INTRODUCTION

This chapter presents key components of the technical core of the watershed assessment work to be performed by the NCWAP team. The data collection and analysis procedures discussed here are responsive to the critical questions presented in Chapter 2 and will provide the information and analytical basis needed to conduct the limiting factors analysis and produce the synthesis report described in the previous chapter.

The chapter begins with a discussion of the technical elements of data collection and assessment for the areas of stream classification, riparian vegetation, sediment production and transport, water quality, water quantity, fish habitat, land use historical analysis, and social and economic factors. While these sections are presented individually for clarity of discussion, NCWAP recognizes that there is a significant amount of overlap across them.

In order to address potential overlap of data collection for the assessment, the NCWAP technical team selected methods that were acceptable to all members and determined primary leads for specific data. In cases where employing more than one agency to collect a particular type of data is useful for that basin, staff will be jointly trained to ensure consistency. While this chapter describes core NCWAP data collection and assessment activities, basin assessment teams may collect additional data if possible by working with local efforts or leveraging resources through other programs. Those efforts will also be conducted using existing methodologies and protocols whenever possible. Table 3 lists current methodologies that the program can use.

NCWAP team members will also work in a collaborative, interagency fashion to analyze data and to complete the assessment chapter 3 discussed how different areas of assessment will be integrated through the limiting factors analysis process.

The latter part of the chapter discusses quality control and assurance issues for data. This area is important, because NCWAP will be relying on various types and amounts of watershed-related data for its work. Therefore, it includes an explanation of the quality control and assurance procedures for existing information and for GIS and field data that will be collected and developed by NCWAP.

STREAM CHANNEL DATA AND CLASSIFICATION

Introduction

Channel classification is an important tool for stratifying data related to physical habitat features of streams. Channel types influence the formation of diverse stream habitats, which in turn contribute to the overall function of stream ecosystems and fish production by influencing sediment transport, pool formation, recruitment of woody debris, and access of salmonids to a stream reach. The general approach to stream classification that will be used for NCWAP is described in this section.

Table 3. Current Acceptable Methodologies and Protocols Available for Use in NCWAP

DFG Restoration Manual: (Available from Native Anadromous Fish Watershed Branch, 916-327-8838 or via Internet at http://www.dfg.ca.gov/habitats.html) • Habitat typing • Channel typing • Riparian / LWD survey • See spawner survey form (Page IV-11) • See elecrofishing form (Page IV-16) • Part Seven implementation methods Part Eight evaluation and monitoring methods
Fish, Farms, and Forestry Coalition Draft Protocols • Summer water temperatures (recording thermographs) • Substrate sampling for spawning quality • Channel profile (Trush) • Macroinvertebrate sampling (EPA Rapid bio-assessment) • Summer population estimates Genetic Research tissue sampling
Other: • PWA road assessment • Star worksheet road assessment • V-star residual pool volume • Multi-parameter data loggers for dissolved oxygen, pH, specific conductance, temperature • Chemical constituents for contract laboratory analysis include: standard minerals, nutrients, total organic carbon, heavy metals, chlorophyll • Additional field water quality parameters/observations: turbidity, relative humidity, wind speed, stream flow rate, algal assemblages, other interesting, descriptive, or unusual biota • Stream channel and streambed metrics, such as V*, pebble counts (D_{16}, D_{50}, D_{84}), substrate cores, channel cross-sections, thalweg profiles

Stream channel classification provides a conceptual framework for understanding how natural processes and land use practices may impact channel form. There are a number of stream classification systems in use (Frissel et al. 1986, Montgomery and Buffington 1993, Paustian 1992, Rosgen 1994). Two of the more common channel classification systems are Rosgen and Montgomery-Buffington. The simplest classifications use a single criterion for classification, such as the system used by the US Geological Survey to map streams on the basis of flow (ephemeral, intermittent and perennial) or the stream ordering system of Strahler (1975). More complex systems use additional discriminating features such as channel slope, substrate, etc.

Stream classification also is applied in a regulatory context such as those used for forest practice regulation and water quality control. In those applications, classification is often based on beneficial uses. There are a few instances in which stream classification combines both physical discriminating features and regulatory applications, as for example, the system used in the state of Washington for forest practice regulation.

The choice of a classification should be based on the intended objectives. In NCWAP, stream classification will be used to stratify streams into categories correlated with potential anadromous fish habitat. Consideration will also be given to different geomorphic and ecological functions, such as the role of large wood in creating and maintaining channel form. The general approach is similar to the one used in Washington that in turn, is based on Montgomery and Buffington (1993). NCWAP products may have regulatory applications, but the stream classification system used will not be literally based on beneficial uses.

Approach

Channel classification for NCWAP will be based primarily on gradient, confinement, and sinuosity. Stream reaches classified will be in the range of 1-10 km in length, as suggested by some researchers (Frissel et al. 1986). In some instances, shorter or longer reaches may be defined. Stream classification of perennial and intermittent streams will be done initially using two parameters: bed gradient and channel confinement. Ten-meter resolution digital elevation models (DEMs) generated from digitized USGS 1:24,000 quadrangles will be used to create an initial classification that will be refined, as needed, through interpretation of aerial photographs and limited field observations.

Special attention will be paid to low gradient unconfined reaches that are not well suited to an automated approach. In these areas the analyst will interpret the relevant parameters (gradient, confinement and sinuosity) using existing information (topographic maps, aerial photos and dems) and limited field verification to assign labels to channel segments.

In unconfined reaches, additional classification variables may be added (e.g., sinuousity, or the ratio of channel length to valley length, and bed substrate). Coincidentally, unconfined reaches tend to be very important anadromous fish habitat.

Questions and Issues

The principle objective is to identify stream reaches that are expected to behave in a similar way to inputs of sediment, streamflow and large woody debris and that have similar aquatic habitat characteristics. There are many ecological linkages to consider.

- What is the linkage between physical, climatic and human forces and channel form? Channel form is a geomorphic feature that results from the combination of geology, climate, hydrology, human uses, and biology. Just focusing on geology as an example, it describes the underlying materials that make up the watershed on which hydrologic and biologic processes act. The geology of an area controls the channel form through the differences in properties of various rock types, the three dimensional placement of geologic materials, and the geologic structures that determine rock weaknesses and discontinuities (often juxtaposes bedrock units that have widely different origins, ages, and erosional properties). Geologic linkage to channel form also occurs through plate tectonics which causes uplift, folding and faulting of mountains, forms depositional valleys, drives the creation of metamorphism and igneous rocks, and alters the drainage patterns of watersheds through the millions of years of deformation. The rate of tectonic uplift combined with the hydrology and biology determines the rate of sediment production, the gradient of streams, the incision of channels and the width of floodplains. In short, geology is the "canvas" on which the watershed is painted.

- What are the linkages between instream habitat and channel form? Stream channel classification is typically conducted at a lower level of resolution than the information that is collected and observed while conducting stream habitat surveys. However, a classification provides a framework within which habitat data from stream surveys can be summarized by response, transport and source reaches.

- What are the linkages between riparian forests and channel form? The channel classification provides a framework to address questions pertaining to large woody debris (LWD) recruitment and the influence of riparian forests on stream temperature. The amount and distribution of LWD varies with channel size and channel network position (Fetherston et al. 1995).

- What are the linkages between water quality and channel characteristics? While water quality is generally thought of as water chemistry, physical attributes that affect beneficial uses of water, such as water temperature and sediment transport and deposition that affect habitat are also water quality conditions. Channel form and riparian conditions influence sediment delivery, transport, and deposition, and thus influence habitat formation, complexity, and stability. Sediment delivery from upslope as well as streambank erosion is controlled in large part by channel morphology and riparian condition. Additionally, riparian condition influences water temperatures, moderated near-stream air temperature and shading being the major affectors.

- What are the linkages to Limiting Factors Analysis? Stratification of a channel network based on geomorphic conditions can be used to predict channel response to environmental and human disturbance (Montgomery and Buffington 1993 and 1998, Washington Forest Practices Board 1997). Spatially identifying source, transport and response reaches defines the sensitivity of channel segments to human and environmental impacts. This provides a geomorphic framework for interpreting the factors that limit fish production. The primary element in the channel classification (gradient and confinement) can be used for determining functional relationships that will be developed in the limiting factors analysis (see section on LFA). Although some information on stream habitat and channel condition will be collected at the stream reach level, the LFA will aggregate data to make interpretations of LFA for planning watersheds and entire river basins.

Data Sources and Gaps

There are a number of data sets that exist for the entire assessment area and will be used for stream classification:

- Ten-meter resolution digital elevation models (primary source)
- 1:24000 scale topographic maps (i.e., digital and paper USGS quadrangles)
- Aerial photos
- Digital orthophoto quadrangles (black and white with one meter cell resolution)
- Stream system (digitized from quadrangles, routed and centerlined)

Data Collection

Table 4 summarizes the stream classes that will be used in NCWAP. The following discussion describes how the necessary data will be obtained to permit classification.

Table 4. Channel classes created through combinations of gradient and confinement classes

< 1%	1 - 2%	2 - 4%	4 - 8%	8 - 20%	> 20%
UC	UC	UC	UC	UC	UC
MC	MC	MC	MC	MC	MC
C	C	C	C	C	C

UC - unconfined, MC - moderately confined, C – Confined

Channel Gradient. Channel gradient is determined by dividing the difference in elevation between points by the horizontal distance of any length of stream. There are several methods for estimating stream gradient. It can be done manually by measuring the distance between contour intervals, or the procedure can be automated using GIS. CDF has developed a computer program to calculate stream gradient that will be applied. Once gradient is calculated for each stream reach the following six gradient classes will be used: < 1%, 1-2%, 2 - 4%, 4 - 8%, 8 - 20%, > 20%. These classes correspond to those used in other states for similar applications (Washington and Oregon). They have meaning for stratifying fish habitat productivity and understanding the role of sediment transport and large wood in shaping channel form.

Channel Confinement. Channel confinement is difficult to interpret from topographic maps. However, the intent is to draw distinctions between reaches where lateral channel movement is restricted, versus less confined reaches where the floodplain is more fully developed. Channel confinement will be defined by three broad classes: unconfined (UC), moderately confined (MC), and confined (C). Confinement is a qualitative judgment based primarily on width of flood plain, channel gradient and sinuosity. At this level of analysis, interpretations of confinement may not match regulatory definitions and do not support project level work.

Channel Typing. Channel typing is done by grouping channel segments based on gradient and confinement classes. Grouping channels based on channel morphology is done because channel morphology integrates watershed processes and provides a conceptual framework for interpreting channel condition. The channel classification procedure supports the channel typing methods used in both Washington State Watershed Assessment Manual and Oregon State Watershed Assessment Manual (Washington Forest Practices Board 1997, Watershed Professionals Network 1999). The channel classes used in NCWAP are based on a modification of the Washington DNR method. The modifications are primarily due to slight differences in gradient classes. With six gradient classes and three confinement classes there are eighteen channel types possible (Table 4). However, gradient and the degree of confinement are generally expected to decrease in the downstream direction (Montgomery and Buffington, 1997).

Channel Sinuosity. Channel sinuosity will be used to further characterize channels in low gradient reaches. Channel sinuosity is defined as the ratio of channel length (curved line) to valley length (straight line). It can be derived through a combination of topographic map and aerial photograph interpretation. If automated, it is subject to potential error. As a result, it is usually done manually.

Data Analysis

The channel classification is designed to identify the amount and distribution of reaches with differing geomorphic functions and thus, fish habitat. This information will be presented both as maps and as tabulations. The classification will provide the framework for understanding erosion and deposition processes, riparian forest functions, and instream habitat as they relate to different geomorphic conditions. DOC/DMG, DFG, and RWQCB will conduct more detailed assessments of channel conditions, resulting in a stream assessment report for each watershed.

Assumptions and Limitations

The approach used assumes that channel form can be represented by (gradient, confinement, and sinuosity, and favors the use of an automated procedure that can be refined an enhanced as needed. This assumes that topographic maps and 10-meter DEMs can measure channel gradient with sufficient accuracy; channel confinement can be adequately interpreted from topographic maps, photos and limited field verification; and that reconnaissance level interpretations are not a substitute for field level investigation of channel conditions. The latter provide an initial interpretation that may guide fieldwork, but are also prone to errors and misinterpretations. As such, channel types can be used for a Level 1 assessment, but are not intended to be used solely for regulatory decisions. Stream Size is not represented in this classification.

RIPARIAN VEGETATION CONDITIONS

Introduction

Riparian zones are transitional areas between terrestrial and aquatic ecosystems. Riparian forests influence sediment delivery and transport processes, the amount of light reaching the stream and water temperature and productivity. They provide nutrients, stream bank cohesion, a metering of sediment from upslope areas, flood plain storage of sediment, and large woody debris, all of which are important to the health of salmonid populations. NCWAP's general approach to riparian forest assessment is described in this section. Riparian forests may be defined as the area of land located immediately adjacent to streams, lakes, or other surface waters, including the floodplain and terraces. The spatial extent of riparian areas varies laterally throughout the channel network and is strongly influenced by geomorphology (Naiman 1998). The boundary (i.e., ecotone) of the riparian area and the adjoining uplands is not always well defined, but there may be strong differences in microclimate within it (Brosofoske et al. 1997). Riparian areas differ from the uplands because of high levels of soil moisture, frequent flooding, and the unique assemblage of plant and animal communities found there. Riparian vegetation influences stream ecosystems by contributing wood and organic material to streams, providing shade, and regulating microclimates (Welsh 2000).

Riparian forests develop in response to disturbance. Flooding, fire, mass wasting and disease are all natural disturbance processes that affect riparian vegetation (Naiman 1998). The variability in disturbance processes among different stream types results in distinct differences in vegetation patterns. Table 5 summarizes many of the functions performed by riparian forests.

In addition to natural controls such as soils and geology, forest practices, agriculture, development and other land uses have the potential to affect many riparian processes and functions (Gregory 1997). In California prior to 1970 there was little or no protection given to riparian forests. As a result, riparian forests on the North Coast tend to lack old mature forest stands and reflect the legacy of past forest practices. Since the passage of the Forest Practice Act in 1973, and especially over the past decade, riparian buffers have been required in areas subject to timber harvesting to maintain ecosystem processes and promote the development of riparian forest conditions.

Table 5. Riparian forest ecosystem functions (Naiman 1998)

Scale/Element	Structure	Functions
Instream habitat	Large Woody Debris - recruited from hillslope and floodplain forests	Controls routing of water and sediment. Controls aquatic habitat dynamics: pools, riffles, cover. Provides wildlife habitat. Source of scour pools
Stream banks	Roots	Increased bank stability. Create overhanging bank cover. Nutrient uptake.
Floodplain	Stems and low-lying canopy	Retard movement of sediment, water and transported woody debris.
Above-ground or above-stream	Canopy and stems	Shade control of temperature and stream primary productivity. Source of large and fine plant detritus. Provides wildlife habitat.
Stream reach	Corridor	Movement of fish and wildlife.

Approach

The assessment of riparian forests will address the following factors: water temperature, air temperature, canopy, large woody debris (LWD), forest condition (type, size, height) and bank stability. A multi-scale approach will be used to investigate the importance of these issues within each watershed. This will be conducted in conjunction with the stream channel classification, previously described. In essence, riparian conditions will be described for the different classes of stream and synthesized at the reach, subwatershed and whole watershed levels.

Questions and Issues

Questions and issues to be addressed on riparian vegetation condition vary by scale: landscape, whole watershed, subwatershed or stream reach.

Landscape, whole watershed or subwatershed:

- What is the pattern and structure of riparian forests across the watershed? How do these relate to natural environmental controls such as climate and geology?

- Are there recognizable differences in riparian forest based on land management or ownership?

- What is the status of canopy cover and the potential implications for stream shade across the watershed?

- Which land management practices have the greatest potential to modify riparian condition (e.g., road/stream crossings, vegetation removal, land use conversion)?

- What is the potential for LWD recruitment?

Stream reach:

- How do natural controls, such as geology and stream class affect the distribution and ecology of riparian forests?

- How does the role and status of LWD vary according to stream class?

- Does the present forest condition limit nutrients (i.e., tree litter) into the stream?

- Have historic practices modified current channel conditions (i.e., stream clearing)?

Data Sources and Gaps

Riparian condition assessment will be undertaken in close coordination with stream channel classification and fish habitat assessments and will rely on some of the same data sources. The primary additional data source is USDA Forest Service vegetation type maps that exist for the entire NCWAP assessment area.

Data Collection

Interpretation of riparian forest condition requires a multi-scale approach. For an entire watershed, a first approximation of conditions can be made using existing vegetation maps. The USDA Forest Service and CDF mapping include the following attributes: species, canopy cover, and tree size. These data represent forest condition as of 1994. The vegetation data are being updated to current conditions and revisions are being made to improve canopy cover and size estimates. To the degree that the data exist, reach-level riparian conditions will be addressed using DFG stream habitat survey data. Where these data are not available, aerial photograph interpretation and field data will be collected using a sampling design based on the stream classification.

Data Analysis

On North Coast streams, riparian issues are focused on large woody debris (LWD) and stream shade. Historical forest practices and wood removal projects have left streams deficient in LWD. The purpose of the riparian analysis is to evaluate the riparian zone, its potential to contribute wood to streams and to provide stream shade.

At the landscape level the potential for LWD recruitment will be analyzed using current vegetation maps that are derived from Landsat thematic mapper imagery. Aerial photos and field verification will be used to assess the accuracy and revisions will be made to the extent possible. Vegetation data will be used to infer broad seral stage classes, based on species, size, and canopy cover. The functions of wood in streams have been shown to vary with stream size (i.e., gradient and confinement). As such, recruitment potential within a basin will be summarized in relationship to the stream classification system.

The channel classification procedure is designed to identify reaches that are most sensitive to disturbance through both human and natural processes. For these reaches CDF will utilize existing aerial photography to develop maps that provide more detailed (i.e., smaller minimum mapping unit) mapping of riparian forests. An emphasis will be placed on relating disturbance patterns to changes in vegetation structure using multi-date aerial photography. This work will be coordinated with the assessment of channel changes being conducted by DMG.

Riparian vegetation, particularly in coastal redwood forests provides shade that helps regulate stream temperatures. A GIS-based model will be developed to evaluate the spatial extent and distribution of stream shade. Vegetation data (species type, canopy cover) and topographic data will provide the primary information for interpretations of stream shade. To the extent possible, other models will be evaluated and incorporated to provide an accurate representation of stream shade. Models will be validated with limited fieldwork and existing stream temperature data.

At the reach level, stream surveys can be used to evaluate the functional use of wood to form pools, create habitat, and regulate fine sediment. Where available, stream habitat data will be used to describe riparian habitat conditions at the reach level. As described by the river continuum concept, this same geomorphic classification can be used to interpret the functional structure of ecological groups. The river continuum concept predicts a systematic change in functional groups from the headwaters to mouth of streams (Welsh 2000). To the extent possible, stream survey data will be used to evaluate aquatic habitat and make predictions about community structure as it varies throughout the stream network.

Assumptions and Limitations

The primary assumption is that existing vegetation mapping will provide the information necessary for characterizing riparian conditions at the watershed and subwatershed scales. There is limited information on historic or reference riparian or LWD conditions and this impairs analysis. In the absence of DFG stream habitat data, there may be limitations to the amount of detail that can be provided through aerial photograph and limited fieldwork.

SEDIMENT PRODUCTION AND TRANSPORT

Introduction

Sediments are composed of particles that range in size from fine organic matter, silt, and sand to large boulders. Sediments are important components of aquatic ecosystems because they provide the substrate for salmonid spawning, aquatic insect production, and nutrient storage. Stream systems can be viewed as out of balance if sediment deposition is excessive or when natural sources of sediment input are lacking. Both situations may be reflected in stream channel changes such as channel down-cutting, channel widening, and accelerated stream bank erosion. Some effects on fish habitat include pool filling, clogging of spawning gravels, and lack of spawning gravels. For example, large volumes of sediment deposited during a large storm event could fill several pool areas of streams, thereby altering the overall stream habitat by reducing the number of available pools. The general approach to evaluating sediment production and transport within watersheds to be used for NCWAP is described in this section. Appendix D provides a more detailed discussion of the procedures that NCWAP will follow to assess sediment production and transport.

Sediment sources include surface erosion (e.g., sheet and rill erosion), gully erosion, channel erosion, and mass wasting (e.g., landslides, soil creep, debris flows). These processes are often interrelated; for example, earth materials displaced by mass wasting processes such as landslides are often modified and reworked by surface erosion. Sediment produced by these processes may be directly deposited into a stream, such as a bank slumping into a stream, or by transport mechanisms such as raindrop splash, surface flow, or subsurface piping.

Hillslope erosion and sediment transport are highly variable in both space and time. However, statistical methods have been proposed to generalize about the frequency and magnitude of sediment supplied to channels relative to the position of channel segment in the drainage network. (Benda and Dunne 1997, Benda 1998). Factors relating to sediment sources and their likelihood to affect stream fish habitats will be assessed.

Drivers of sediment production and transport include:

- Natural factors such as the strength properties of the bedrock, soil composition (depth, permeability, cohesion, and structure), slope steepness and length, ground water levels, amount and type of vegetation on the slopes, rainfall intensity and duration, and fire;

- Human factors such as vegetation removal (e.g., livestock, clearing for agriculture or development, timber harvesting), surface disturbance and modification (e.g., road construction and drainage, ground-based timber operations, and watercourse diversions.)

Geology, seismicity, topography, and climate primarily determine erosion rates and mass wasting in Northern California. Land use practices that are inappropriate given the site conditions have the potential to lower the thresholds needed for slope failure, alter fluvial processes and are often chronic sources of suspended sediment. Studies have suggested that the majority of erosion from management related activities often occurs in a small portion of the total managed area (Rice and Lewis 1991). Road-related sediment is a major factor in most North Coast watersheds. The location of roads on basin slopes (near stream, mid-slope, and ridge top) can have major effects on both fluvial and mass wasting processes (Cafferata and Spittler 1998, Jones et al. 2000).

Sediment generation and transport into streams is generally measured in units of tons or cubic yards, or as rates of delivery (for erosion and mass wasting), such as (for sheet erosion) cubic yards generated per square mile of area per year.

Understanding the regional geologic framework of a watershed is critical to evaluating how sediment is produced and transported in the system. The spatial and temporal distribution of landslide occurrence can also provide a conceptual framework to better understand how natural phenomena and land use practices may impact slope stability and sediment production. For example, Kelsey et al. (1995) analyzed the spatial distribution of landslides for Redwood Creek and identified two high input reaches. NCWAP will provide base-level geologic and geomorphic information, and geologic expertise in interpreting the relationships between the dynamics of landsliding, sediment transport into and through stream channels, and the resulting impacts to fish habitat.

Approach

The mapping and data collection in each watershed will be separated into a landslide component and a stream channel component. Given the relationship between hillslope and fluvial sediment processes, the two components will be conducted concurrently and interactively. Data and maps generated will be included in the evaluation and assessment of streams and fish habitat.

The landslide-mapping component will build upon and update landslide mapping conducted by DMG in the early to mid-1980s. The new mapping will be GIS-based on an ArcInfo™ platform. Geology, landslides, geomorphic features related to landsliding, relative landslide potential, stream channel conditions, and other geomorphic characteristics throughout selected North Coast watersheds will be mapped at a scale of 1:24,000. Mapping will be performed at a reconnaissance level with more detailed assessment conducted at key locations for calibration and quality control purposes.

The digital data will contain a variety of physical, temporal, and spatial data collected for each feature of interest. For example, the data for a specific landslide will include such items as type, relative age, rock or soil type, underlying rock formation, and location. The fluvial geomorphic component will consist of the creation of numerous maps or profiles of key stream channel characteristics.

Questions and Issues

Existing data, newly collected data, and field observations will be used to complete an integrated analysis of the following:

Hillsides

Existing Conditions:

- What is the spatial distribution of landslides in each watershed?
- What are the dominant landslide features in each watershed?
- What are the primary geologic controls on landslides?
- Which geologic formations are susceptible to various types of landsliding?

Perturbations:

- What are the dates of past significant meteorological events?
- What peak flow events are recorded by stream gauges or otherwise?
- What is the history of land use, seismicity, and wildfire and their proximity to streams?

- What is the spatial relationship between land use practices and mass wasting?

Response of the System to Perturbation:

- Historically, how have hillsides responded to natural and anthropogenic perturbations?
- What are the likely responses of hillsides to potential changes in existing conditions such as runoff, vegetation, and land-use?
- What are the general timing of landsliding events, lag times for sediment delivery to streams, and the rates of occurrence?
- What are the spatial and temporal distribution of sediment delivery to streams from landsliding bank erosion, and other upland sediment sources, and what are their general relative quantities?

Stream Channels

- What is the spatial distribution of channel types, as classified by gradient and confinement?
- What role does the geology of the watershed have in spatial distribution of the type of channel?
- What are the geomorphic and geologic characteristics of those reaches historically important for fish populations?
- What is the evidence of historic channel change both anthropogenic and natural?
- What do existing conditions indicate about the present geomorphic stability of the channel network?
- What are the likely responses of channel reaches to potential changes in input factors such as sediment delivered, stream flows, woody debris?
- What role does large woody debris have within the watershed in forming fish habitat and determining channel class and storing sediment?
- What are the dominant channel- and habitat-forming processes in different portions of the watershed?
- What portions of the channel network are prone to aggradation or degradation in response to variations in erosion rates and sediment delivery potential?
- What is the character and magnitude of local channel response to recent sediment input from hillslopes, e.g., landslides?
- What is the timing of channel response to changed sediment inputs; i.e., what are the likely relative rates of sediment transport from source areas to depositional area of the channel network?

Data Sources and Gaps

All available relevant and current geologic literature regarding each watershed will be reviewed early in the assessment process. The vast majority of the geologic and geomorphologic interpretations will made through the examination of several series (up to 10 series or sets) of stereo-paired aerial photographs. Photographic coverage available for North Coast watersheds consists of about a dozen sets of photographs from the early-mid 1940s until the most recent taken in 2000. The data derived from the aerial photos will be incorporated and stored in the GIS.

A GIS coverage showing roads as displayed on US Geological Survey 1:24,000 scale quadrangles is available. While this will allow a basic level of roads/sediment analysis, this coverage misses a large number of roads, particularly smaller, unpaved forest and ranch roads that have the potential to be sources of sediment. As presented in the *Land Use* section of this manual, aerial photos, timber harvest plans, and locally available information will be used to enhance this coverage.

Limited fieldwork by helicopter, car, and foot will be conducted for verifying mapping derived from aerial photographs. Field work will likely be more intensive in unconfined stream reaches in order to develop information on the stream's potential response to changes in watershed inputs (sediment, wood and streamflow), relate stream channel characteristics to fish habitat quality and habitat forming processes, and evaluate the linkage between hillslope and stream processes.

Data Collection

Multiple sets of aerial photos will be used because different photos may reveal different features and because changes over time can be observed. Aerial photo interpretation will fail to reveal mappable landslides that are ambiguous, morphologically young, more recent than the photos, or hidden beneath heavy forest. Additionally, many small-scale features, although unmappable at 1:24,000, may be a significant component of the landsliding and erosion in the watershed. The significance of these features will be considered during fieldwork. Field review will greatly enhance the mapping. Rib and Liang (1978) provide a general explanation of the use of aerial photo analysis in the recognition and identification of landslides. Cruden and Varnes (1996) describe the typical morphology of various landslides.

Once a set of aerial photos has been interpreted and initial draft landslide, geology, and fluvial geomorphology maps have been created, ground truthing will be necessary to confirm or clarify the interpretations. Limited field studies will be run in tandem with aerial photograph interpretation and mapping as needed for the purposes of confirming interpretations and improving the capture and analysis of hillside and channel data.

The accuracy of data (i.e., maps, GIS layers) borrowed from other sources will also be reviewed in the field. Available descriptions of geologic formations generally do not present engineering characteristics that are needed for slope stability considerations.

Data Analysis

The data in the GIS will be analyzed in several ways to answer the critical questions.

In a GIS, there are many ways to study the terrain. The GIS can generate stream profiles, drainage network diagrams, slope maps, and any other platform-compatible slope stability models. Landslide layers can be overlain on slope maps, various geology, soils, orthophotoquads, and topographic maps, and on slope stability models. The process of superposing maps of various terrain information helps identify otherwise difficult to recognize relationships. The possible permutations are many and will be tried as is feasible.

The position of a road in a watershed (i.e., near stream, mid-slope, ridge top) and style of construction (outsloping, use of rolling dips, back-up drainage structures) can determine the extent to which the road network modifies the existing hydrologic network. The relationship between roads and streams will be analyzed using a combination of spatially explicit models and metrics that are derived through GIS. Simple GIS analyses will be run to estimate numbers of road-stream crossings, miles of roads in close proximity to streams, and other areas of disturbance in proximity to streams. CDF, in collaboration with the Forest Science Project at Humboldt State University, is continuing to investigate appropriate surface erosion sediment models for use in NCWAP. Any erosion models used will be thoroughly examined and, to the extent feasible, ground-validated before being used by NCWAP.

At a landscape level a model of erosion potential will be developed integrating factors of: geology, topography, climate, and land use. On the North Coast early attempts at this produced a model of Highly Erodible Watersheds. This model is a ranking of watersheds by erosion potential (McKittrick 1994). This model will serve as the basis for evaluating erosion potential at the sub-basin watershed scale (4,000 - 6,000 ac).

Assumptions and Limitations

There is limited available information on historic and natural conditions such as significant meteorological events, peak flow events, land-use history, seismic, and wildfire history. There are also limitations in aerial photograph coverage and some scale constraints. Mapping will be done at a scale that will not permit identification of some smaller features. Vegetation cover will impair mapping of ground features from aerial photographs.

It is initially assumed that ten-meter resolution digital elevation models closely match actual topography. That may not prove to be true. It is further assumed that existing geologic maps are relatively close to actual geologic conditions.

WATER QUALITY

Introduction

Water temperature, dissolved oxygen, turbidity, suspended and bedload sediment, nutrients, and chemical pollutants are important parameters of water quality that affect fish habitat. Water quality affects all salmonid life stages and influences growth, behavior, and disease resistance. Water quality data are sparse for most North Coast watersheds. Routine sampling occurred decades ago in some watersheds, but only occasional observations are available for the last 15 years or so. Exceptions apply where local watershed groups or industrial timber companies have conducted sampling.

Water quantity may affect water quality in a variety of ways, from changes in chemistry to water temperatures to sediment transport dynamics. While chemical changes are not expected to be a major factor in most coastal watersheds, the amount of water available to the stream affects the water chemistry to a large degree where land uses produce nutrient and other chemical inputs. Stream flow may be a factor in determining water temperatures under some situations, affecting the influence of air temperature and solar radiation. Alterations in the flow regime during winter periods may have a profound effect on sediment transport dynamics as well, since stream flow in large part determines the power applied to the channel.

Collection of new information is important for determining existing conditions and for planning watershed management activities. Data collection by agencies can be coordinated with landowners and watershed groups to fill gaps. Cumulative watershed effects tend to be reflected in stream and water quality characteristics. Loss of riparian function may manifest in increased temperatures and/or increased sediment (in the water column or in deposition in the streambed).

While it is difficult in many situations to identify specific causes of impairment, water quality, biological, and related sediment parameters provide a perspective on the overall health of a watershed. The assessment of water quality and establishment of baseline conditions can be a useful tool for gauging success of management practices designed to reduce human impact on the watershed. Likewise, it is useful for pointing out problem areas to address and properly functioning areas to protect.

Approach

New water quality data collection under NCWAP will occur primarily through the North Coast Regional Water Quality Control Board's Surface Water Ambient Monitoring Program (SWAMP), as described in the first chapter of this manual (also, see Appendix E). The schedule for SWAMP is closely coordinated with NCWAP assessment schedule, to provide additional and current information on water quality parameters for watershed assessments. SWAMP will include validation of data collected by local groups and landowners and will produce additional new data.

SWAMP sampling design is stratified by subwatershed and tempered by local knowledge and access concerns. Site selection is based on SWAMP needs and goals as well as any special NCWAP needs that are identified. The basic goal is to characterize water quality at the stream reach and subwatershed levels. Generally, data collection stations will be at the terminus of a subwatershed or in conjunction with other NCWAP reach surveys. Station locations will be documented for use by all NCWAP personnel and for possible subsequent use by landowners and groups.

Data collection will be coordinated among NCWAP agencies and with local watershed groups and landowners. For instance, while DFG personnel are performing fish presence and abundance surveys, water quality data can be collected. Channel measurements to assist in fluvial geomorphology assessments will be conducted in collaboration with similar DMG and DFG personnel, to the extent possible, using the same methods. Side-by-side sampling with watershed groups to provide data in addition to that which they are collecting is anticipated as well.

As outlined in Appendix E, there are numerous SWAMP parameters including macroinvertebrates, water chemistry, channel geometry, sediment transport, turbidity and bacterial analyses. SWAMP also includes funding for stream flow gage installation that will be coordinated with DWR. Data loggers will be used at selected sites for “round-the-clock” monitoring of dissolved oxygen, pH, conductance, and temperature.

Questions and Issues

New field data will assist in addressing the critical questions for water quality analysis:

- Is basic water column chemistry meeting Basin Plan water quality objectives and otherwise supportive of beneficial uses, especially drinking water supplies, cold water fishes, and contact and non-contact recreation? Most of the existing data are dated, and new data will bring current the understanding of how existing water quality compares with water quality objectives for the protection of beneficial uses of water.

- What are the current water temperature conditions relative to life history requirements of salmonid species? Current data will support the NCWAP limiting factors analysis, provide some idea of a trend, and point out areas for riparian evaluations and rehabilitation.

- What are the effects of stream, spring and groundwater uses on water quality and quantity? There are few data on current flows and uses in these watersheds. Current information will assist in painting a picture of conditions, though fully answering this question is beyond the scope of NCWAP. However, current data will provide a perspective to build upon.

- Is excessive sediment impairing cold water fish habitat or otherwise compromising beneficial uses? Decisions to this point regarding excessive sediment have been based largely on professional judgment. The collection of recent information will provide a basis on which to make more informed judgments.

- Do the populations and diversity of aquatic communities (especially macroinvertebrates and algae) reflect existing water quality conditions? This feedback loop is essential for adapting assessment processes and land use activities. Watershed conditions are integrated at the stream reach level, and macroinvertebrate population structure is sensitive to watershed level effects. Theoretically, the health of macroinvertebrate populations should correlate with physical conditions.

- Are there specific water quality problems identified by the data? In comparing water quality data to water quality objectives, areas with anomalous results will be reassessed to determine if unique conditions exist, if specific problems are occurring from natural or human influences.

- Are there specific temporal trends in water quality? New data provide information for comparison to older data, and a baseline from which to measure changes in the future.

Data Sources and Gaps

Sources of current water quality data are limited, but include agencies, large industrial timber landowners, and local watershed groups. Gathering these data and evaluating their utility in watershed assessment will identify numerous gaps, both temporally and spatially. New data collection will be aimed at filling those gaps. To the degree that programs like SWAMP and local watershed groups can assist in further sampling beyond a NCWAP assessment, data can be collected into the future, creating fewer temporal gaps and enhancing future assessments.

Data Collection

For new data collection, data quality assurance and control techniques common to water quality data collection will be employed. The quality assurance plan for SWAMP is currently under development. In the interim period, NCWAP will adopt the program developed by the Sacramento River Watershed Project as a guide (Larry Walker Associates 2000).

For methods not covered by the above reference, protocols presented in USGS (1999) will be adopted, with perhaps some modifications. Protocols USGS (2000), with appropriate modifications, will be used for multi-parameter dataloggers.

Other methodologies, such as macroinvertebrate sampling and channel geometry measurements, are detailed in the protocols for the SWAMP (Appendix E).

Data Analysis

Data will be entered into a database and converted to formats appropriate for analysis of the information, e.g., spreadsheets for dissolved oxygen, flow, temperature. Data analysis will be tailored to data type and its quality. For example, water temperature data from continuous data loggers will be evaluated using raw data plots over time and cumulative distribution plots against water quality criteria or water quality objectives (WQOs) to determine frequency of exceedances (percent of observations and number of days), duration of exceedances (how many hours was a particular standard exceeded in a day), and maximum daily excursions.

For example, Figure 9 is a raw data plot of continuous water temperatures graphed against a hypothetical preferred temperature range. There is a trend towards lower temperatures and reduced variability in the fall. The relative amount of time that water temperatures are within the preferred range for a species is evident, as is the relative amount of time spent above a short-term maximum (lethal) temperature level.

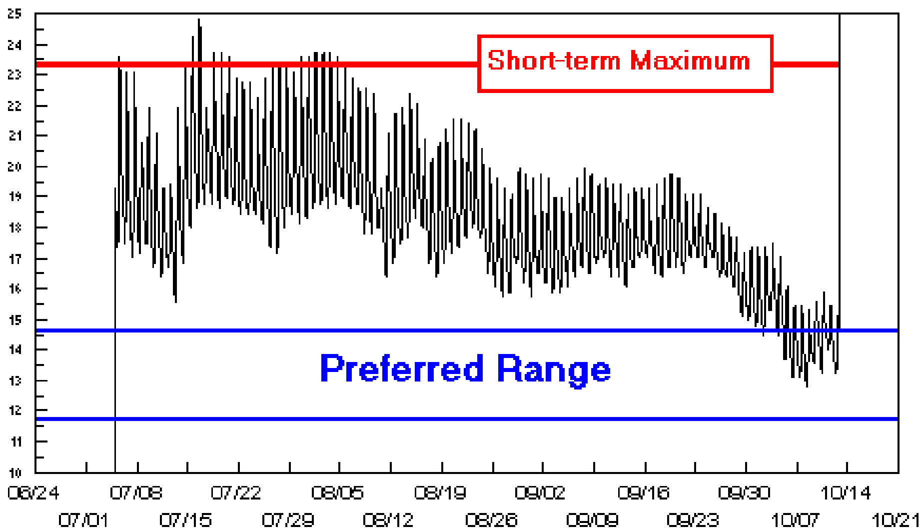


Figure 9. Raw data plot of continuous water temperatures.

The next plot (Figure 10) is a cumulative distribution of the same raw data. This type of plot will be used to determine the percentage of time that particular criteria or levels are met or exceeded. In this example, water temperatures are within the preferred range about five percent of the time (left axis). The species is subjected to temperatures outside the preferred range about 95% of the time, about 2% of the time exceeding the short-term maximum.

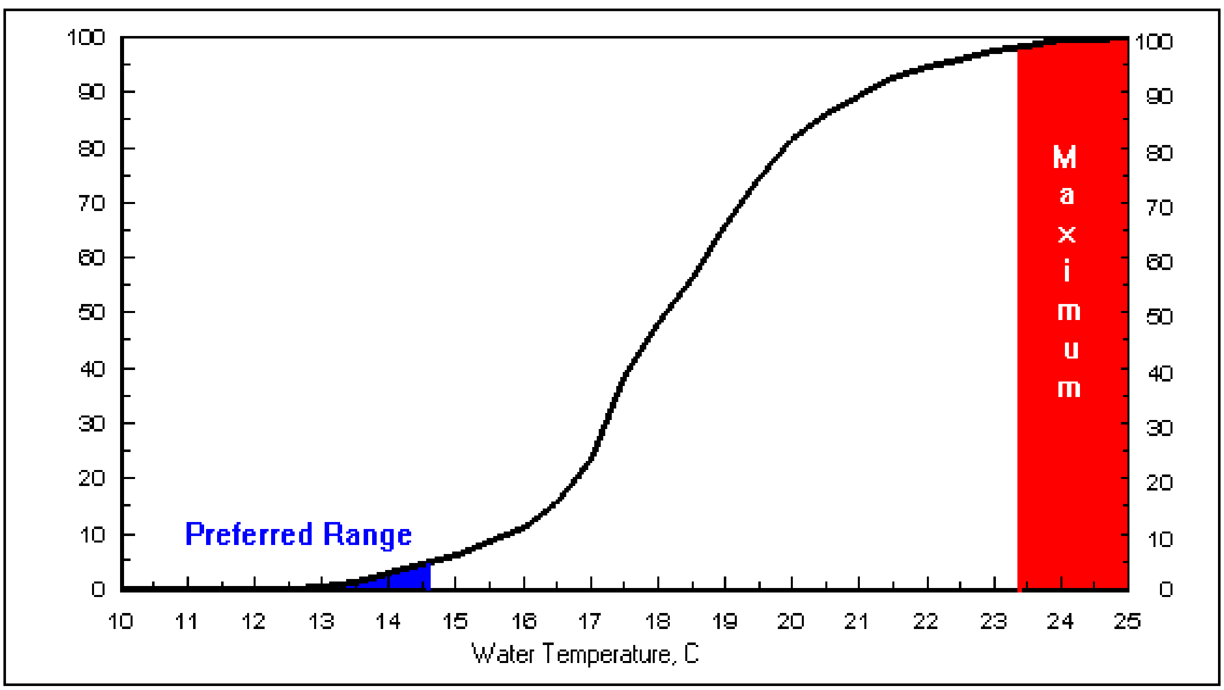


Figure 10: Cumulative distribution data plot of raw data plot of continuous water temperatures.

Other water quality parameters (including flow and diversion information) will be subjected to similar analyses using raw data plots and cumulative distribution plots, as well as statistical methods (e.g., nested analysis of variance to analyze data from stations in different watersheds).

The actual criteria for comparison to water quality data come from WQOs and TMDLs (see Appendix E for listing of WQOs). The NCWAP limiting factor analysis will use some of these criteria regarding the needs of cold water fish.

Assumptions and Limitations

A basic assumption is that watershed conditions are integrated at the stream reach or subwatershed level. Experience has shown that water quality and biological parameters are often useful in developing a perspective on watershed conditions. It is important to note that water quality and biological parameters include physical as well as chemical characteristics of water column quality, streambed substrate quality, and assemblages of aquatic life.

The extent to which these data are useful is limited by the clarity of linkages among watershed perturbations and the stream. Temporal considerations come into play in those linkages, with some current physical conditions the result of past disturbance in the watershed. Likewise, short-term disturbances not measurable today, may have translated to effects in the stream that are evident from distribution, diversity, and abundance of the biota.

Other factors that will limit the water quality assessment include the short time frame for each watershed assessment (<1 year) and the possibility that access for data collection may be limited due to landowner concerns.

WATER QUANTITY

Introduction

Water quantity or stream flow data are an important component in determining the existing conditions and assisting assessment, restoration, and management activities in North Coast watersheds. Stream flow can be a limiting factor for anadromous fisheries affecting migration and the quantity and quality of spawning, rearing and nesting areas and has a direct affect on other factors such as water temperature, dissolved oxygen, and sediment and chemical transport. Stream flow data are required to quantify stream sediment and chemical transport total loads. Although floodplain management and instream structural design and installation projects are not included in NCWAP, stream flow data is needed for these as well as other activities including State Water Resources Control Board water right application and license reviews and judicial water supply allocations.

Similar to water quality, stream flow data are sparse for North Coast watersheds. Stream flow gauging programs by federal and state agencies have been severely reduced over the last three decades. Stream gauging stations do not currently exist on many streams.

Approach

DWR's role in NCWAP is to provide new and compile historic stream flow data and to assist in compiling water rights information. NCWAP will also provide for the continued operation of selected existing stream flow gauging stations that are subject to discontinuation due to funding reductions. Additional support for new stream gauging station installation and operation within North Coast watersheds will be provided by SWAMP which is being coordinated with NCWAP's schedule. All new stream flow gauging stations will be equipped with water temperature sensors and some with other water quality sensors for measuring parameters such as turbidity, dissolved oxygen, pH, and conductance. Existing stations may also be equipped with additional water quality sensors. Certain selected stations will be equipped with telemetry to provide a portion of the collected data on a real-time basis via the California Data Exchange Center (CDEC) web site. Real-time stream flow and water quality data will assist in notifying this and other data collection efforts of event sampling opportunities or hazardous conditions for fish survival. Flood forecasters and emergency response personnel will also benefit.

Selection of sites, data collection type, and period of station operation will be based on available funding, existing stations, resumption of discontinued stations for historic comparisons, access, favorable site conditions, and special NCWAP or SWAMP identified needs. Stations located at the terminus of the watersheds or major sub-basins where none currently exist will be a priority. Some stations will be operated for the long term for trend and base correlation analysis, while others may only be operated for short periods. Electronic multiple parameter data loggers will be used at all stations to collect highly detailed time series data, normally every 15 minutes or hourly, for all sensors.

Historical stream flow and water rights data will be compiled from existing DWR, State Water Resources Board, and US Geological Survey information. Current water rights information will be compiled from DWR and State Water Resources Board files. The North Coast Regional Water Quality Control Board will assist in that compilation as well.

Questions and Issues

New data will assist in addressing the following questions regarding water quantity issues.

- What are the current stream flow conditions relative to the life history requirements of salmonid species? New data will support the NCWAP limiting factors analysis and point out the possible need for minimum instream flow requirements or augmentation. Detailed spatial watershed collection of new stream flow data is beyond the scope of NCWAP, but new data will assist in identifying additional stream flow monitoring needs.

- Have significant temporal changes in climate, land use, or water diversions and use adversely affected stream flow quantity relative to salmonid fish survival? New data will provide information for comparison with historic data and a baseline from which to measure changes in stream flow in the future. Long-term precipitation to runoff ratios can assist in determining the affect of historic land use on stream flow. Extensive compilation of riparian and appropriative water rights and monitoring actual diversion amounts are beyond the scope of NCWAP, but new stream flow data will assist in identifying additional monitoring needs in this area as well.

Will stream flow data be collected at a level of detail appropriate for watershed assessment? Detailed spatial and temporal stream flow data will not be available for every watershed. Only limited new data from NCWAP and SWAMP, intended to partially fill the data gaps, will be available for watershed assessments scheduled the first few years. Some flow data may need to be estimated by using various mathematical methods. Data Sources and Gaps

Sources of historic and current stream flow data are limited. The USGS and DWR are the main agencies that have collected stream flow data within North Coast watersheds. Historic average daily and instantaneous minimum and maximum stream flow data can be found in the agencies' published reports or web sites. NCWAP will compile this data for North Coast watersheds. Some industrial timber landowners and local watershed groups have recently begun to collect stream flow data, but these data are very sparse and need to be reviewed for quality assurance. Stream flow data collection efforts were much more prevalent by government agencies during the 1950s through the early 1970s. These programs have been severely reduced over the last three decades resulting in major gaps in temporal and spatial stream flow data.

A common complaint of watershed managers is the lack of data and the inability to compare current flow conditions to historic conditions. If long-term data collection programs are not established and supported, water resource managers are forced to sometimes make profound policy, management, and operational decisions based on limited scientific data. Similar to water quality, NCWAP and SWAMP data collection will assist in evaluating and filling data gaps.

Data Collection

DWR and the USGS will work cooperatively to install and operate the new stream flow gauging stations. USGS methodology will be used (Appendix F). Data quality assurance and control techniques developed by the USGS will be employed.

DWR and the USGS will work cooperatively to install and operate the new stream flow gauging stations. Data quality assurance and control techniques developed by the USGS will be employed.

The stations will be constructed to withstand substantial flood events and incidental vandalism. Stations installed for short-term operation will be constructed with the assumption that data collection may be resumed at a later date. About 9 to 12 direct stream discharge measurements along with simultaneous water stage (elevation) data over a wide range of water stages will normally be performed annually at each station. High discharge measurements may require the installation of cableway systems if bridges are not located nearby or if measurements by boat are impractical. Multiple direct field measurements of water stage and quality parameters will also be performed to verify and calibrate the station sensors.

Data Analysis

Water stage and quality time series data will normally be downloaded from the station data loggers and then uploaded into a database and reviewed and edited for accuracy on a monthly basis. Time series stream flow data will be determined by correlating the direct discharge measurements with the simultaneous water stage data. This stage vs. discharge relationship or rating curve is then applied to the stage recordings from the station's stage sensor and data logger to compute stream flow 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 through the Internet via the CDEC web site for those stations equipped with telemetry. Real-time telemetry also allows the station's operator to monitor the operation of the station remotely allowing a timely response to station malfunctions. Real-time data is normally 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. Reviewed finalized data for the October through September water year will normally be available about three to six months after the end of the water year.

The finalized base recording interval data will be collated to produce daily average and minimum and maximum values for the entire water year for each station parameter in comma-delimited text and graphical formats. This data will be made available via the CERES web site. Some statistical analysis of the new flow data such as for distribution, frequency, and duration may also be provided. Additional data collations and formats will be provided as needed by NCWAP.

The compilation of historic stream flow data and resulting presentation will depend on NCWAP needs and the collation and availability of the archived data. It is hoped that water year average daily and maximum and minimum values for the complete period of station operation can be assembled. A summary or statistical analysis of the period of record data could then be performed and made available via the CERES web site.

Assumptions and Limitations

Detailed spatial and temporal stream flow data will not be available for many watersheds. Only limited new data from NCWAP and SWAMP, intended to partially fill the data gaps, will be available for watersheds scheduled for assessment the first few years. Two or three years of stream flow data may not be adequate for certain watershed assessment tasks. Data collection should normally precede any assessment analysis, but this will not be possible for watersheds where gages are installed the same year as the assessment. Therefore, the program will install gages a year or more ahead of the assessment schedule where possible. Collecting new data now will also provide historic data for the future. Many program managers of water resource related projects or assessments of short duration in need of stream flow data and with funding to collect it, often discover that it is too late to collect temporal and spatial data significant enough to confidently design, operate, or analyze their project if the data do not already exist.

We cannot be sure of the accuracy of flow data that are estimated with mathematical methods. Therefore we will need to evaluate the quality and use of synthetic data.

FISH HABITAT

Introduction

Habitat requirements of anadromous salmonids vary by species, season, and life stage. All salmonids need spawning, incubation and rearing habitat to complete their complex life cycles. If habitat conditions needed during a particular life stage are impaired or absent, some level of reduced growth and/or mortality will occur in the population (Reeves et al. 1989).

This section addresses key habitat components that affect anadromous salmonid production and describes the approach that will be used by NCWAP to help assess the status of stream and fish habitat. This information will be essential to NCWAP's assessment of factors limiting production of salmonids. Further discussion of limiting factors and its underlying premises was provided in the previous chapter of this manual.

To understand present and potential fish production in stream systems, it is necessary to know the status of watershed processes and how their products work together to create or alter fish habitat. The integration of all the above components is realized in fish habitat and in success of fish in a stream system. As discussed previously, stream channel classification, sediment deliver and transport mechanisms, riparian conditions, water quality, and water quantity are ultimately expressed as instream habitat. A stream and fish habitat inventory provides information regarding the status of a basin, stream, or reach and insight to help evaluate its ability to support salmonid populations.

Stream and fish habitat inventory methods have been developed by state and federal agencies and private consultants (Platts et al. 1983, Reeves et al. 1989, Schuett-Hanes et al. 1994, Flosi et al. 1998, Berbach et al. 1998, O'Connor Environmental, Inc. 1999, Taylor 2000). These inventory methods may involve different levels of effort for data collection in order to use a multi-scale approach. Inventories can include: classification of channels; habitat typing; development of instream shelter ratings; substrate characterization and gravel composition surveys; riparian canopy measurements; inventories of large woody debris; monitoring water quality; and identification of upstream or downstream barriers to fish movements. Results from stream and fish habitat inventories can be compared to reference conditions considered essential to salmonids at different life stages. As described in the section of this manual on limiting factor analysis, reference conditions will be derived through a multidisciplinary NCWAP effort. Some values are contained in DFG's *California Salmonid Stream Restoration Manual* (Flosi et al. 1998) to help guide restoration and management decisions.

Approach

DFG, with coordinated participation with the NCWAP team, will investigate: water quantity, water quality, channel and habitat type, large woody debris, and substrate composition. Biological data on salmon and steelhead will be collected through spawner surveys, snorkel surveys, electrofishing, and downstream migrant trapping.

Questions and Issues

- What are the current salmonid habitat conditions in watersheds and how do these compare to target conditions favorable for fish?

- What is the linkage between current habitat conditions and the likelihood of salmon and steelhead populations to successfully reproduce and do well?

- What is the linkage between current habitat conditions and the numbers of salmon and steelhead returning to streams as adult spawners?

- Is the spawning gravel suitable for successful incubation and emergence of young fish?

- Do the channels provide the diverse habitats needed to support all life stages of salmon and steelhead?

- What status does large wood have within the watershed in creating fish habitat and determining channel morphology and sediment storage? What is the linkage between riparian zones and the amount or future supply of large wood in streams?

- What is the pool frequency compared to other habitats and how does this relationship vary within the watershed? What percentage of pools is considered primary pools?

- Do barriers affect upstream or downstream fish movement?

Data Sources and Gaps

DFG, other agencies, and landowners have conducted stream and fish habitat inventories for several streams on the North Coast. Existing data will be evaluated to determine if it is scientifically credible or useful for NCWAP purposes. Data gaps will be identified and addressed during the design of new field investigations.

Stream and fish habitat inventory data are not available for all NCWAP basins. Where stream habitat inventory data are lacking, basins will be stratified to capture the diversity of fish-bearing habitat and individual streams that best represent each stratum will be selected for field study. Landowner cooperation will be necessary to acquire privately held existing data and to gain access to lands for collecting new data.

Data Collection

Habitat Typing. The diversity of habitat necessary to support salmonid populations is formed by dynamic interactions between a stream ecosystem and its watershed. Climate, geology, stream flows, stream gradient, substrate, sediment routing, vegetation, inputs of woody debris, and land use activities all interact in channel and habitat forming processes. The cumulative interactions between these components are expressed as various channel classes and habitat types commonly described as pools, flatwaters, and riffles. These habitats become more complex considering the biotic and physical functions of large wood, riparian vegetation, and substrate. Habitat typing will be conducted according to methods presented in Flosi et al. (1998).

Habitat Inventory Component. A standardized habitat inventory form has been developed by DFG for conducting stream surveys. There are nine components to the standard habitat assessment process described on the form. All methods described are fully described in Flosi et al. (1998).

Water Quality. Water temperature is one of the most important environmental factors affecting virtually every aspect of a fish's life (Armour 1991). Steam flow, water temperature, dissolved oxygen, turbidity, nutrients, and chemical pollutants are important parameters of water quality that affect fish habitat. Adverse temperatures may reduce growth rates and can affect fish behavior, disease resistance, and result in mortality (Sullivan et al. 2000). Water quality data collection will be conducted by NCWAP according to methods previously presented in this manual (see above, *Water Quality*).

Large Woody Debris Inventory. The importance of large woody debris (LWD) in the development of a stream's morphology and biological productivity has been well documented (see review in Lassettre and Harris 2001). Fish populations benefit from cover and habitat diversity created by LWD and the substrate environment for benthic invertebrates that serve as food (Sedell et al. 1988). LWD inventories will be conducted according to methods presented in Flosi et al. (1998).

Substrate Composition. The substrate of stream channels provides important components of salmonid habitat and the aquatic ecosystem. In addition to sediment size, the amount of sediment in a stream and the filling of pools or silting of spawning gravels are all important habitat characteristics. Data on sediment sources and deposition in streams will be collected by NCWAP according to methods presented above in this manual (under *Water Quality* and *Sediment Production and Transport*). Additional information pertinent to fish habitat will be collected according to methods presented in Flosi et al. (1998).

Data Analysis

In addition to standard tabulations and mapping typically provided with DFG stream habitat surveys, the primary use of fish habitat data will be for analysis of factors limiting fish production (see previous chapter of this manual).

Assumptions and Limitations

Fish habitat assessment is based on the assumption that fish are responding to the cumulative interactions among physical, chemical, and biological components of watersheds. Fish population data are required to validate this assumption. Although some population data are available for the NCWAP assessment area, they are quite limited both spatially and temporally. Therefore, validation of the results of fish habitat studies and limiting factor analysis will depend on future population monitoring.

It is not likely that the same level of fish habitat data will be available for all assessments. In some watersheds, the level of existing data is high. In others, data may be nearly entirely lacking or of questionable quality. As a result, the degree of confidence in results will vary from basin to basin.

LAND USE HISTORICAL ANALYSIS

Introduction

Over the past two centuries, cumulative impacts from human land use activities coupled with natural events have caused significant impacts on floodplain and stream conditions. These impacts influence the ability of streams to support salmonid populations. Recent efforts to improve land use practices and stream habitat conditions are key elements in the recovery of salmonid populations.

Reconstructing the European-American history of land use and resource extraction is important to understanding the processes that continue to influence the current conditions of North Coast watersheds. While it will not be possible to determine strict causality between historic land use and current watershed conditions, such information can assist in relating stream and salmonid problems to their probable causes, both in type (natural vs. human, relative magnitude) and timing. Punctuating high-impact natural historical events such as major floods, fires and earthquakes, in conjunction with information on coincident land use activities, will help define timeframes for examining trends in stream and upland conditions.

There is a broad array of upland and instream issues influencing watershed processes and numerous interactions over space and time among those natural and anthropogenic processes. Table 6 provides a broad framework for considering these issues, the temporal scales at which they operate, and their relationship to our assessment.

Table 6. Potential Issues and Timeframes for Historical Watershed Analysis

Issue	Time Frame (yrs)	Data	Methods	Potential Sources
Near- and Instream Issues				
Fish populations (presence/absence & abundance)	150	Anecdotal, statistical	Archival research	DFG
Barriers to fish migration	150	Spatial, anecdotal	Sequential map/image analysis, field validation	DFG
Fish habitat quality	150	Spatial, anecdotal	Sequential map/image analysis, field validation	DFG, RWQCB, CDF
Stream cleaning of LWD	50	Anecdotal, statistical	Archival research	DFG, CDF
Snagging	100	Anecdotal	Archival research	DFG
Riparian vegetation	150	Spatial	Sequential map/image analysis, field validation	CDF, DFG
Channel conditions	150	Spatial, anecdotal	Sequential map/image analysis, archival research, field validation	DMG, DFG, DWR
Placer mining	150	Anecdotal	Archival research	DFG, RWQCB
Gravel mining	150	Anecdotal, spatial	Archival research, sequential map/image analysis, field validation	DFG, RWQCB
Estuarine conditions	150	Anecdotal, spatial	Archival research, sequential map/image analysis	DFG, RWQCB, DWR
Flood history	150	Anecdotal, statistical, spatial	Archival research, map analysis	RWQCB, DFG, DWR
Water use	150	Statistical	Archival research	RWQCB, DFG, DWR
Water quality	150	Anecdotal	Archival research	RWQCB,

Issue	Time Frame (yrs)	Data	Methods	Potential Sources
impacts				DFG, DWR
Upland Issues				
Land use history	150	Spatial, anecdotal	Sequential map/image analysis, archival research	CDF
Logging history	150	Spatial, anecdotal	Sequential map/image analysis, archival research, field validation	CDF, DFG
Road system	100	Spatial	Sequential map and airphoto analysis, field validation	CDF
Urban development	50	Spatial, anecdotal	Sequential map analysis, field validation	CDF, RWQCB, DFG, DWR
Upland vegetation	150	Spatial	Sequential map analysis, field validation	CDF
Fire history	150	Spatial, anecdotal	Sequential map analysis, archival research	CDF
Other Issues				
Future land use	current	Spatial	Review county general plans and zoning	CDF
Climate change	150	Statistical	Archival research	DWR, CDF
Mass wasting	150	Spatial	Sequential map/image analysis, field validation	DMG
Uplift/subsidence	10,000	Spatial, Statistical	Archival research	DMG
Native American uses	200	Anecdotal	Archival research	IFR, DFG
Nutrient cycling	150	Anecdotal	Archival research	DFG, CDF

Approach

Using a variety of data sources, quantitative and qualitative timelines of important historical events and land use trends will be established for each watershed. To the extent possible, data will be spatially explicit (i.e., points and areas georeferenced) to allow assessment within a geographic information system (GIS). The focus will include several key factors in the watershed, such as the timing, locations and extent of: 1) major timber harvesting, as well as predominant silvicultural practices; 2) land use conversions related to agricultural practices and development of towns; and 3) roads and other development in the watershed.

Taken together, the above factors can provide an index of disturbance of a watershed over time, and set the context for understanding the state of the watershed today. In addition to supporting an overall watershed assessment, such an index will prove useful for future CDF work in developing a risk assessment approach to cumulative effects analysis. The longer-term effort will incorporate other data such as frequency distributions of major disturbance events, along the lines of Benda et al. (1998).

Of special importance to NCWAP will be documenting historical human activities that are known typically to have high impacts on watershed processes. These activities may have large effects either because of the type of disturbance, the location of the disturbance (e.g., proximity to stream), the size of the area disturbed, or some combination thereof.

The ability to document land use changes is reduced the further back in time we look. Detailed and spatial data on recent watershed activities and events will be more readily available than older, perhaps long-gone land use practices and changes. Land use information for past will be obtained to the degree possible, but may not be used if it cannot be validated.

Questions and Issues

In collecting information on land use history on the North Coast, the fundamental questions include:

- What are the general relationship between historic land use, its changes over time, and the current condition of a given watershed?
- What are the time lags between land use activities and their effects upon a watershed?
- How can the cumulative effects of the historical and present land use activities on current water quality, salmonid habitat and stream structure be evaluated?
- Is there a relationship between natural stressing events such as major floods and land uses in terms of watershed effects?

Data Sources and Gaps

Data sources will include a combination of written and photographic records, historic maps, digitized timber harvest plans (THPs), satellite images, and personal interviews. The type of data used for a given watershed will depend largely on availability and extent. Unlike the data collection for other aspects of NCWAP, researching, locating and accessing (and in some cases reproducing) the data will take considerable effort.

Historic written accounts related to salmonids (runs, harvest, etc.), major flood events and other watershed-related phenomena have been collected from local sources for some North Coast watersheds. While descriptive in nature, these are often the only information source available for the earliest period of post-European-American colonization. They have proven valuable in indicating a watershed’s character before the major alteration of stream characteristics associated with subsequent dam construction and channelization, intensive agriculture, development and resource extraction activities.

Oral accounts may be obtained from interviews with persons knowledgeable about the watershed and its history. As with many written accounts, the information will be anecdotal and qualitative in nature, and may vary between individuals interviewed. However, such information can focus research on a previously overlooked event or activity in the watershed.

Historical maps, public land survey data, tax ledgers, and other systematically recorded data can also serve to recreate land use scenarios from past decades (Sisk 1998). While precise locations and areas might be difficult to determine, these records can help to provide information on the relative magnitudes of various activities in the watershed.

Photographic evidence is some of the most useful information available to establish prior watershed conditions and human activities. Such data are of two main types: Historic photos from the ground and aerial photographs taken from aircraft. The ground photograph record can in some cases extend nearly to the beginning of the period of European-American colonization, circa 1850. Aerial photographs extend back to at most the 1930s, limiting their use to the past 70 or so years. These will not be available for all watersheds. With comparisons of the same areas photographed in time series, the timing of important changes in the watershed can be observed, gaining insights into the relationships between land use activities, major natural drivers (e.g., floods, earthquakes), and apparent stream structure and processes (e.g., Gruell 1983).

Analysis of aerial photographs over time will provide detail on historical land uses, including timber harvesting. These can be supplemented for recent periods. CDF has been digitizing timber harvest plans for a number of the North Coast watersheds since about 1990. These data should prove especially useful in tracking recent land use and levels of impact from recent logging.

The earth resources (LANDSAT) satellite data record begins in the early 1970s. Through digital image processing change detection techniques, the approximate timing and areal extent of higher impact land use changes, as well as recovery rates, can be quantified for all NCWAP watersheds (Sample 1994).

Data Collection

Some of the data needed for the land use historical analysis will be readily available e.g., LANDSAT images, while other data may be located in museums and university collections. At this point the process for accessing and reproducing photos there has not been determined. With aerial photos, as with other data, researching the existence and whereabouts of historical data will be a significant effort.

An important source will be persons knowledgeable about a watershed's history. When located, efforts will be made to arrange for interviews with them (with their approval). Input from local watershed councils will also be important.

Data Analysis

The data compiled for historical land use will be used to reconstruct terrestrial watershed conditions that have occurred over the past 1.5 centuries. For the period predating aerial photography (before 1940), records of all types will be synthesized into an historical narrative on major disturbance events such as floods and fires and their effects, episodes of land clearing, timber harvesting, road building, and other eras of land ownership and management practices. This information will be presented in the context of other sorts of relevant data, such as the status of the local fisheries at the time and any changes in laws governing resource extraction practices.

For the period from 1940 to the present, statistics will be compiled on a Calwater planning watershed basis relating the percentage of the landscape of different seral stages of vegetation (not cut, harvested, showing regeneration, etc.), within various types of use and management, and showing the density of roads. These will be distilled from existing and newly created GIS data layers showing larger area and higher impact changes observed in the watershed from sequential aerial photographs and satellite images, timber harvest plan maps, and other spatial data sources.

The land use historical analysis will serve as an important component of the overall watershed synthesis report. It will provide a measure of the timing and magnitudes of impacts that have affected the watershed since the arrival of European-Americans.

Assumptions and Limitations

Robust historical analysis of any process is difficult, prone to the vagaries of existing and accessible data. The highest quality land use data will be sought, but it will be difficult to attain a level of information to support quantitative analyses of cause and effect within a watershed. Results will of necessity be qualitative. The central challenge of the land use change characterization of NCWAP is to document and present the best evidence of the timing and magnitudes of human activities in the watershed, to provide the historical context to other aspects of the NCWAP watershed assessments. The benefits in this regard should far outweigh the qualifications and limitations. However, it is unlikely that all potential issues listed in Table 6 can be fully addressed within the budgetary limitations of NCWAP.

SOCIAL AND ECONOMIC ASSESSMENT

Introduction

Watershed conditions and the limiting factors for fish are generally the result of both biophysical factors and human actions. Since social and economic factors are key determinants of human actions, they should be included as a part of watershed assessment.

One of the key social elements in many watersheds today is what might be called the rise of "watershed governance." This term refers to the increasing degree to which people and entities (companies, agencies, organizations) are coming together in various kinds of watershed groups to address natural resource issues on a watershed basis. Several recent studies (e.g., Huntington and Sommarstrom 2000; the work of the Watershed Partnership Project, University of California, Davis) shed light on the nature and significance of these groups.

Given the focus of NCWAP and the limited resources available for social and economic assessment, work in this area necessarily will be focused. To some extent, there is an overlap between social and economic assessment and land use history assessment, as described above.

Approach

Standard Social and Economic Factors. The approach here will be to use available, existing information about social and economic factors and standard reporting methods. Developing this information on a watershed basis can be challenging, since it is often reported on a county level and cannot easily be expressed on a watershed basis. The focus will be on current social and economic conditions rather than on historic ones.

Watershed Governance. NCWAP will develop preliminary information about watershed governance during initial scoping activities in each watershed. As watershed groups, coordinated resource management and planning efforts (CRMPs), resource conservation district activities, etc., are identified, NCWAP will contact these groups and collect information about their membership structure, decision-making processes, goals, and activities.

Questions and Issues

- What is the population of the watershed and how are people distributed throughout it (developed, intermix, wildlands and agriculture; see: http://frap.cdf.ca.gov/projects/bioregional_trends/patterns.htm)?

- What are the basic demographics of the watershed population: age, ethnic groups, education, income, etc.?

- What are the major economic activities and sources of employment in the watershed and how do these relate to potential impacts on limiting factors for fish?

- In what way have watershed governance mechanisms developed on the watershed; how do existing watershed organizations contribute to watershed governance?

Data Sources and Gaps

Data will be obtained from standard federal (e.g., US Census, Bureau of Economic Analysis), state (e.g., Employment Development Department, Department of Trade and Commerce, State Board of Equalization, Franchise Tax Board, Department of Finance Demographic Research Unit), local (e.g., county general plans, community plans, zoning maps, parcel maps, business license records, tax information, special districts) information, and commercial data vendors. As noted above, it can be difficult to impossible to break out some of this information on a watershed basis.

While full 1990 census data are available in GIS format at the relatively fine-grained census block level, the same level of 2000 census information will not be available until mid-2002 at the earliest. Basic demographic information collected from the standard census form will be available sooner than the more detailed information collected on the census "long form" that is sent to only a sample of households. This data delivery schedule for the detailed long form data will hamper the ability to produce more in-depth watershed-based social and economic information. The 1990 census information is too dated to be worthwhile to bring into the NCWAP watershed assessments.

Data Collection

Basic social and economic data will be collected through databases and websites, standard governmental statistical reports, various plans and publications, and contacts with local public (government agencies, economic development districts, etc.) and private entities (chambers of commerce, trade associations, businesses, etc.). Data will be spatially captured, to the extent feasible.

Information about watershed governance will be collected though contacts with organizations, government agencies, published studies, websites, etc.

Data Analysis

Basic social and economic data will be analyzed using standard social and economic assessment approaches. Results will be presented using narrative, tables, graphs, and maps. Watershed governance information will be presented largely in narrative format.

Assumptions and Limitations

It is assumed that a meaningful level of social and economic data can be developed on a watershed basis; some information will not be available on a watershed basis, in most cases (e.g., employment data). The social and economic assessment will be based largely on current conditions; minimal effort will be made to assess these factors historically. It is further assumed that watershed organizations will be willing to share information about their goals, activities, decision-making processes, and membership composition.

OUALITY CONTROL AND ASSURANCE ON EXISTING DATA

Introduction

Most existing data from agency and scientific sources is subject to quality control and assurance standards. This is not necessarily true for data from other sources. Local watershed groups, agencies, and landowners have collected data that may be useful to NCWAP. Experience shows that those data come in a variety of formats and were collected for various reasons using various techniques. Assimilating those data into NCWAP requires that the data first be evaluated for utility in the watershed assessment process, especially relative to the ability to answer the critical questions for the assessment. Having the data categorized according to quality with respect to assessment needs will help avoid drawing wrong conclusions from data, assigning equal weight to all data, or otherwise misusing data (Brossman et al. 1985, Montgomery 1996, Taylor 1985).

Metadata describes details about purpose and objectives, methodology, and other quality assurance and quality control factors. These factors can be evaluated to determine the relative quality of the information and thus its potential level of use in the assessment. Basically, the quality of data decreases with increased variability in the methods used for collection (Montgomery 1996). In the context of a watershed assessment, data collected with low precision may be useful for screening purposes, but not for answering specific questions. Likewise, data collected for one purpose may not be appropriate for another purpose due to the sampling design.

Some data are easier to evaluate than others. Traditional water quality data, like pH or dissolved oxygen, can be put through a fairly clear decision process to arrive at a categorization of quality in the context of watershed assessment. Spatial data present special problems, and habitat data may be rather subjective. There is an element of subjectivity in any data quality determination, and that subjectivity increases as one moves from strict regimented techniques to more loosely defined methodology.

Data Screening Approach

Four categories of data quality have been identified for the program:

1. Excellent (suitable for the highest detail and most robust analysis)
2. Good (suitable for most watershed assessment needs, characterizes a process or condition providing evidence from which to draw specific conclusions)
3. Fair (characterizes a process or condition on a broad basis to provide a perspective)
4. Poor (only useful for screening or broadly qualified statements)

A number of criteria will be considered in assigning existing data to a quality category. These pertain to the purpose for which the data were collected, the sampling design, methods used, precision and other factors. Different screening procedures will be used for spatial and non-spatial data. Some relevant questions include:

- Are these data collected at a level of detail appropriate to the analysis for assessment?

  For example, data collected at a subwatershed scale may not be useful for making conclusions about conditions on a stream reach basis. Data collected on a reach basis may be analyzed to make statements on a subwatershed scale, even providing statistical metrics to further define such statements. Data quality categorization will reduce the likelihood that data will be used inappropriately.

- Is there sufficient documentation accompanying these data to feel comfortable in drawing conclusions?

  The data may be robust (highly dense or large numbers of observations), but lacking in sufficient documentation to define specific methodology, thereby creating uncertainty about use. The level of uncertainty affects the ultimate use of the data (and perhaps the way in which the data are analyzed) as well as the conclusions drawn from the data. Clearly identifying the characteristics of the data that result in its categorization will assist in quantifying the uncertainty associated with a decision arising from the data.

- Are these data representative of conditions in a selected unit of scale (temporal and spatial)?

  Site selection, sampling design, and level of resolution are important considerations in determining if a data set represents conditions. For instance, water quality data collected in the summer low flow period in an estuary may adequately represent conditions at that site for that time of year, but are not useful in characterizing the site in the winter. Data quality categorizing will point out the representativeness of data sets in the context of the critical questions for the assessment.

QUALITY CONTROL AND ASSURANCE FOR GIS DATA LAYERS

NCWAP will develop several geographic information system (GIS) data layers, as previously described in this manual including current and historical land use, vegetation, road and stream networks, geology, landslides, and landslide potential. GIS data typically consist of point, linear, or areal data that represent some phenomenon of concern within a spatial (geographical) context. The inherently spatial nature of these data greatly facilitates a land-based approach to watershed assessment.

Two main types of errors typically occur in GIS data layers. First, the polygon area perimeter, linear feature or data point may be misplaced in the georeferenced framework (i.e., an error in position). This "spatial error" can cause incorrect inferences to be drawn with regard to the watershed and cumulative effects, depending on the magnitude of the error (i.e., distance from its actual location). For example, a misplaced road might show it as crossing a perennial stream twice in one locality, when in fact it does not cross at all. If uncorrected, this spatial error could lead an analyst to an unwarranted assessment of the level of disturbance on the given stream reach.

In addition to spatial errors, a second main type of error occurs when a feature (point, line or polygon) is incorrectly labeled. These "thematic errors" are misidentifications of the process observed at a given (correct) spatial location. In some cases the error may have negligible effects, as when the feature is labeled as a closely related category (e.g., dirt vs. paved road). In other cases, however, the error will have larger consequences in an assessment, as when a grossly incorrect label is applied.

Standard procedure for assessing GIS data accuracy is to compare the thematic labels (spatial locations are not usually directly addressed) against some independent source of very similar information, often collected from field visits. The field and GIS-developed data are then compared, in the form of a confusion or error matrix, and a parameter is derived (Kappa statistic) indicating the level of agreement between them. Type I (omission) and type II (commission) errors are computed. Any differences are typically ascribed to errors in the GIS-developed data layers.

The QA/QC for current and historical land use and road network will be conducted in the following ways:

1. As these products near completion, all data layers will be reviewed extensively internally by persons not directly involved in their development, to correct data inconsistencies and obvious errors both of the spatial and thematic variety.

2. GIS data layers of existing phenomena (i.e., not of historical conditions), may be validated using standard methods against field information. In those instances, a stratified random approach may be used to select sites to visit in the field, in some cases weighting them towards areas of greater concern or uncertainty. (About half of the field data points will be used to assist in the labeling of the GIS data, while the remainder may be used for validation.)

3. Catching errors in digitized historical data will likely be more involved than for other types of "existing-conditions" data. The field cannot be visited in the present day to record events that may have occurred decades ago, since evidence of the past events may have vanished. The only recourse with historical data may be to come to a consensus or majority opinion

from the judgment of several parties experienced in the watershed, or in the interpretation of aerial photography.

4. Analogous to "beta test" mode, some data may be pre-released to solicit input from watershed groups, stakeholders and other parties with interest or experience in the watershed to review the data layers and offer feedback on them. Comments and suggestions received will be reviewed and the data layers may be revised as a result.
5. Meta-data will be produced to explain the data layer development and important parameters and caveats. A protocol will be employed similar to that developed by the California Environmental Resources Environmental System (CERES). A final review of the data product will take place at this juncture, prior to its formal release.

The GIS layers produced should be viewed as "version 1" of the data they present, not as immutable output "written in stone." In this way they will be analogous to software releases, which although very valuable and useful, contain errors that over time will be addressed and "fixed" as the information improves with time and a more thorough long-term review occurs. Watershed groups and personnel from state agencies using the data could provide feedback on the GIS products, to assist in updates and maintenance.

QUALITY CONTROL AND ASSURANCE ON NEW FIELD DATA

Introduction

Just as categorizing data that others provide is important, defining the level of quality for new field data collection is essential (Mitchell et al. 1985, Taylor 1985). The first step in developing a program for quality control and assurance is defining the level of quality for data collection.

Quality assurance combines training and feedback with quality control checks for accuracy and precision. Data collectors must be trained and their work checked to assure collection of data is consistent with the data quality category selected for data collection.

Quality control involves checks on accuracy and precision with procedures to follow when a measurement does not fall within acceptable ranges. Quality control procedures are well developed for most routine water quality measurements, and can be adapted to other measurements such as channel geometry measurements and habitat typing.

Approach

Data quality goals for new collections must first be established (Mitchel et al. 1985, Montgomery 1996). For much of the fieldwork, the categories of data quality presented previously in the section on reviewing existing data will be used to define the characteristics of new field data collected under the program. The process is turned around from identifying the characteristics of existing data to put it into a category, to identifying the category of data quality needed for an assessment, then meeting the characteristics for that level of quality.

For instance, water quality data will be collected at a minimum quality of *Good*. This implies the following characteristics:

- Purpose/objectives: Specific and clearly stated

- Sampling design: Density of sites sensitive to tributaries and/or specific problem with seasonality addressed and a statistical design incorporated into the overall sampling design.

- Reliability: Precision at ±10%, measurement more than twice the detection limit (this factor comes into play after analysis of a sample and generally cannot be predicted), use a good field meter, collect the sample in the centroid of flow in the absence of confounding factors, well-documented and controlled.

- Robustness: 10-20 samples within the evaluation period

Having determined the quality of data to be collected, appropriate levels of quality assurance and quality control will be applied. Specifying the personnel and their roles, providing training at the appropriate level, and checking on performance are the basic tenets of quality assurance (Brossman et al. 1985, Stanley and Verner 1985). Before entering the field, those elements will be satisfied. Field sheets and guidance manuals will provide written protocols for reference and will assist in maintaining quality assurance by providing a standardized data capture format so that data elements are not overlooked. Field sheets will provide important documentation for meta-data needs as well.

Quality control checks will be applied as appropriate to the data collection effort. This is relatively easy for water column measurements like pH, where equipment calibration is routinely checked (accuracy) and duplicate samples are analyzed to measure instrument precision. Quality control charts with acceptable levels of accuracy and precision will be developed for measurements of that type.

Field collection of habitat data and channel characteristics will follow a modification of the classic example provided above. Those data can be collected within levels of accuracy and precision specified for specific equipment (levels, tapes, rulers). Precision can be tested by repeat measurements, but may also include repeat measurements by different teams for those observations that are more subjective (e.g., some habitat elements).

A quality control and assurance program ensures that collected data will be adequate to accomplish the assessment for a particular data type. Additionally, the confidence in the data can be quantified and is especially important when data from various sources are commingled (Mitchell et al. 1985, Taylor 1985). While an overview has been provided, details will vary according to the measurements and data use. An effective program will be responsive to the overall need to collect meaningful data on a scale and in a way that allows us to answer the critical questions for the program.

APPENDICES

A: Origin and Description of CalWater
B: TMDL Schedule for North Coast
C: Example of Spatial Data for NCWAP
D: Division of Mines and Geology Methods Manual
E: RWB NCWAP Methods Manual
F. Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation, and Reporting Water-Resources Investigations Report 00-4252
G: Flosi et al. 1998
H: CDF's Development of Land Use Histories in North Coast Watersheds
I: Definition of Terms

A: Origin and Description of CalWater

CALWATER is a geographic information system (GIS) developed to establish a common set of watershed definitions. CALWATER includes the State Water Resources Control Board watershed delineation system.

The term "watershed" is generally defined to be any area of land that drains to a common point. CALWATER divides the State into four levels (hydrologic regions, hydrologic units, hydrologic areas, and hydrologic subareas) and captures the State Water Resources Control Board (SWRCB) delineation. “Watersheds,” as commonly used in this system, are smaller than a river basin or sub-basin but larger than a drainage or site. The smallest units, planning watersheds are generally about 3,000 to 10,000 acres in size. Super planning watersheds are on the order of 50,000 acres in size. The hierarchical nature of this system means that smaller units of watersheds are nested inside larger units.

The current version of CALWATER was released September 21, 1998. The next version of CALWATER (version 3.0) will rectify existing (minor) differences between the U.S. Geological Survey delineation of watershed units and the SWRCB map.

B: TMDL Schedule for North Coast

1998 303 (d) List & TMDL Priority Schedule for the North Coast Region

Due Date	Name	Pollutant Stressor	Status
12/97	Garcia River	Sediment	SWRCB adopted 9/00. OAL comments received.
04/98	Estero de San Antonio	Nutrients	Adopted by NCRWQCB on 12/11/97.
04/98	Stemple Creek	Nutrients	Adopted by NCRWQCB on 12/11/97.
12/98	Redwood Creek	Sediment	EPA adopted.
12/98	Trinity River – South Fork	Sediment	EPA adopted 12/98
12/99	Eel River – South Fork	Sediment Temperature	EPA adopted 12/16/99
12/99	Noyo River	Sediment	EPA adopted 12/16/99
12/99	Van Duzen River	Sediment	EPA adopted 12/16/99
12/00	Garcia River	Temperature	Dependent upon Sediment TMDL.
12/00	Navarro River	Sediment Temperature	EPA adopted 12/27/00
12/00	Ten Mile River	Sediment	EPA adopted 12/27/00
12/01	Trinity River	Sediment	EPA lead
12/01	Albion River	Sediment	EPA lead
12/01	Big River	Sediment	EPA lead
12/01	Gualala River	Sediment	RWQCB lead
12/02	Eel River – North Fork	Sediment Temperature	EPA lead
12/02	Mattole River	Sediment Temperature	RWQCB lead
12/03	Eel River – Middle Fork	Sediment Temperature	EPA lead
12/04	Eel River – Upper Main Fork	Sediment Temperature	EPA lead
12/04	Tomki Creek	Sediment	EPA lead
12/04	Klamath River – Mainstem	Low DO	RWQCB lead
04/04	Klamath River – all	Nutrients Temperature	RWQCB lead
04/05	Scott River	Sediment Temperature	RWQCB lead
09/05	Shasta River	Low DO Temperature	RWQCB lead
12/05	Eel River – Middle Main Fork	Sediment Temperature	EPA lead
12/06	Eel River – Delta	Sediment Temperature	
02/06	Estero Americano	Nutrients Sediment	Stemple Creek TMDL hoping to increase voluntary measures of attainment.
02/06	Americano Creek	Nutrients	Adopted by NCRWQCB on 12/11/97.

Due Date	Name	Pollutant Stressor	Status
02/07	Mad River	Sediment Turbidity	EPA lead
12/08	Trinity River – South Fork	Temperature	
12/09	Elk River	Sediment	
12/10	Freshwater Creek	Sediment	
12/11	Lake Pillsbury	Mercury	
12/11	Russian River	Sediment	SCWA has begun ESA habitat assessment.

C: Example of Spatial Data for North Coast Watershed Assessment Program

Compilation by Institute for Fisheries Resources

This table lists some of the types of GIS files NCWAP will assemble in the course of the watershed assessments. Where other relevant data is available, these will be added to the watershed data catalog.

Theme	Description	Use in Analysis
USGS 1:24K-Based Data		
Topographic Quadrangles Digital Raster Graphics (DRGs)	Scanned Raster Topographic Maps	Watershed-scale planning, basic orientation
Topographic Quadrangle Index	Polygons showing quad locations	Region-scale planning
Hydrography Digital Line Graphics (DLGs)	Stream courses, irrigation canals and lakes	Stream locations, stream ordering, and stream density. Related to fish distribution mapping.
Roads DLGs	Road locations.	Determine location of stream crossings, road densities, erosion risk
Stream, Water and Watershed Data		
Cal-Water Planning Watersheds	Watershed boundaries w/ a maximum area of 10,000 acres	Aggregating statistics (e.g. THPs/time period, veg stats)
USGS Hydrologic Units (HUCs)	Large river basins or groupings	Regional planning
Channel Type	Montgomery-Buffington	Analysis of sediment supply and routing
Stream Gradient	Percent slope of stream	Assessing anadromous fish/amphibian distribution, sediment routing and Rosgen channel types
Habitat Typing	CDFG data available for many streams in spatially segmented form.	Width to depth ratio, pool frequency, pool depth, substrate quality, canopy, cover, embeddedness, Rosgen channel type
Monitoring Locations	Site locations for data collection (e.g. temperature, flow, electrofishing)	Allow spatial analysis of temporal data
Restoration Locations	Site of implemented restoration projects	Understanding channel changes and relating back to watershed condition
Stream Crossings	Where roads cross streams.	Assess fish barriers, sediment sources
Water Temperature	Highlight reaches or points to show temperature of streams	Suitability for coho/salmonids
Fish Distribution	Reaches of stream where particular fishes are (were) found	Essential regional and watershed assessment info

Theme	Description	Use in Analysis
Amphibian locations	Location of tailed frog, southern torrent salamander and other indicator species	Tailed frog and so. torrent salamander are good indicators of stream health upstream of coho habitat
Large Woody Debris Removal	Sections of stream subject to stream clearance activities as indicated by CDFG work order or completion forms	Understanding large wood budgets and fish habitat diversity
Water Rights	Point locations of appropriative water rights and selected riparian rights	Instream flows, fish habitat
Ground Water	Map of location of wells and associated well logs	Information on ground water supply, depletion, effects on stream flow and fish habitat
TMDL basin schedule	NCRWQCB/EPA defined basin areas	Regional planning
Land Administration and Ownership Data		
Towns, Counties, and State Boundaries	Basic Teale	Regional planning, cartographic projects
Ownership	Available with state and federal lands by specific designation	Regional planning, associating land use patterns
Public Land Survey System	Township, Range and Sections lines	Ownership, reference
State Agency Regional Boundaries	State Resources Agency boundaries	Regional planning
Topographic Data		
Digital Elevation Models (10 m resolution)	Digital elevation information	Data used for topographic representations (hillshades) and also to calculate slope and water convergence for SHALSTAB model
Slope	Slope steepness	Show areas of higher landslide risk
Hillshade	Shaded relief map	Representation of topography
Remote Sensing Data		
Digital Orthophoto Quadrangles	Aerial Photos used in production of USGS 1:24,000 quad map	Good backdrop to NCWAP ArcView projects. Direct observation of watershed conditions
Landsat Thematic Mapper and Multispectral Scanner	Changes in vegetation by periods between Landsat of different years.	Analysis of changes in vegetation related to THPs, vineyards or development
SPOT 1993	Panchromatic 10m pixels	reference for locations
Land Use, Land Cover and Management Data		
Current Land Use	Landsat derived watershed maps with forest types and	Modeling land use impacts. Emphasis on urbanization and agricultural impacts.

Theme	Description	Use in Analysis
	urbanization impacts	
Timber Harvest Plans	Timber harvest maps with silvicultural prescription, yarding method, etc.	Landscape disturbance index
Vegetation	Vegetation class by several possible categorizations	Vegetation patterns, landscape condition, coarse riparian analysis
Geologic and Soils Data		
Geology	Bedrock geology map	Erosion potential assessment, land use sensitivity
Geomorphology	Bedrock and land form	Erosion potential assessment, land use sensitivity
Landslides/Inner Gorges	Maps of landslides and steep areas near streams	Erosion potential assessment, land use sensitivity
Soils (erodibility)	Map of soil types	Erosion potential (surface/slide risk)
Miscellaneous		
Rainfall	Isopleths for annual precipitation	Watershed planning, water yield. High rainfall areas have higher erosion risk.

D: Division of Mines and Geology Methods Manual

Click to download.

E: Regional Water Quality Control Board Methods Manual

In progress

F. Guidelines and Standard Procedures for Continuous Water-Quality Monitors:

Site Selection, Field Operation, Calibration, Record Computation, and Reporting Water-Resources Investigations Report 00-4252. By Richard J. Wagner, Harold C. Mattraw, George F. Ritz, and Brett A. Smith

Click to download http://water.usgs.gov/pubs/wri/wri004252/

G. California Salmonid Stream Restoration Manual. 1998

Click to download http://www.dfg.ca.gov/fishing/manual3.pdf

H: CDF'S Development of Land Use Histories in N. Coast Watersheds

(not fully reviewed by NCWAP team at time of draft manual release–4/17/01)

Introduction

Land use and management practices have a significant influence on the condition of a watershed, both upland and aquatic ecosystems, including:

- water use (dewatering streams)
- sediment load
- shape of unit hydrograph (flood frequency, height and timing of peak flows)
- stream structure
- stream temperature
- habitat connectivity for fish

Land use changes often alter the rates of natural processes. For example, erosion from water has been an important part of the North Coast watershed landscape for all of geologic time. However, over the past 150 years rates of erosion by water have accelerated, due largely to the construction of roads and industrial timber harvest practices. Much larger quantities of sediment are being delivered to streams than under previous conditions, and this has caused major changes in stream morphology and fish habitat.

European-Americans have also introduced processes that were absent prior to their arrival. Industrial timber harvest practices have made intensive impacts in California's temperate rainforests at temporal and spatial scales that are distinct them from natural processes. Nitrogen fertilization of streams from agricultural wastes can create chemical and biological conditions which had never occurred in these watersheds prior to intensive agricultural land use.

Knowledge of historic and current land use helps frame a better understanding of the current watershed condition, the types and magnitudes of impacts it has experienced over history, and the legacy of past uses that are still observable in the system. It is an important step towards an examination of relationships between land use and the conditions in aquatic ecosystems (i.e. the net effect of human activities in the watershed).

Establishing definitive causal links will not be possible in most cases, due to the complexity of the interactions of natural processes and disturbances with land use practices, and their variation over time. Time lags of varying length occur between land use activities and their downstream effects, depend in part on other influences (floods, high precipitation). A single localized activity in a drainage can affect downstream conditions long after visible evidence of that event has disappeared. In addition, historical conditions are difficult to reconstruct, given the paucity of available data and the difficulty of linking land use information directly to their watershed impacts.

Conceptual Framework of Land Use History

NCWAP presents CDF with a unique set of challenges in creating watershed-specific land use histories. We developed the following set of questions to frame the land use history effort.

1. To what degree (level of confidence) can the vegetation and land use characteristics of the watershed at the time of European exploration/settlement be inferred from present knowledge and available spatial (and other) data?

2. Where are the locations of historic and current disturbance of floodplains, riparian areas, and uplands; what was/is the type and extent of disturbance?

3. Are there general relationships that can be inferred between land use history and the current state of health among north coast watersheds?

4. What are the relative magnitudes of disturbance—sediment generation, habitat alteration, etc.—resulting from these land uses and activities? What types of land use activities appear to have had the most influence on the current state of the watershed?

5. What are the historical and current trends and locations of land use and land-disturbing activities in the watershed, both transient and permanent? What continuing longer-term effects might they have on the watersheds?

6. Which watersheds have experienced the largest degree of high-impact human alterations? Where (if they exist) are the locations of less-impacted watersheds that could be used for paired watershed analyses, to assist in determining natural background environmental parameters? Which watersheds offer the best potential for short-term restoration efforts?

Reports and data products

Our land use history work will yield a mixture of qualitative and quantitative data. Qualitative, mostly non-spatial data will include a timeline of major landscape-altering events in watershed, milestones in technology, major changes in resource protection laws, significant demographic changes, the interpretation of historical photographs and maps, and the analysis of written and oral historical records and accounts. Quantitative data, which will be mainly in spatial digital format, will be comprised of the area of watershed within a particular land use, the amount of land converted from original vegetation to agriculture, rates of timber harvesting (and their changes over time), and the locations and occurrence of roads.

For each watershed, we will create:

- a timeline of important events, natural and human-related (quasi-spatial, qualitative)
- four coverages (spatially-explicit, quantitative data), .
    - Pre-1850; 1851 – 1900; 1901 – 1940
    - 1941 – 1950; 1951 – 1960; 1961 – 1970
    - 1971 – 1980; 1981 – 1990; 1991 – 1995; 1996 – 2000
    - current land use/management

The land use activities will be dated to within 10 years of occurrence, according to decade (for more recent data). Where possible we will note the actual date, if known, of the activity. Table 1 shows the variety of information sources we will use in compiling the land use histories, including the period for which each will be used. These vary according to the availability of the data.

Table H-1. Information sources for CDF's land use history development

Information Source	Pre-1940	1940-1970	1971-2000	Current Land Use
Written accounts	X	X	X	
Ground photos	X	X	X	
Maps from period	X	X	X	X
Oral accounts	X	X	X	X
Public land survey	X			
Tax records	X	X		
THP GIS			X	X
Aerial photos		X	X	X
Satellite images			X	X
Digital orthophotos			X	X
Land ownership GIS			X	X
USFS vegetation GIS			X	
Field observations				X
USGS 1:24K topo quads				X
US EPA Land Use GIS				X

Assembling and Interpreting Land Use History Data

Our methods encompass both researching and capturing existing land use related data. We will research what data exists, on a watershed basis, using catalogs from historical society museums, university and government libraries, newspaper and timber company archives, county tax records and the Internet (table 2). If a reference to data is found, but not the data itself, we will track down its current location. Where the data is deemed to be of high potential value to reconstructing the land use history, and its location is known and accessible, we will seek to capture it for the purposes of NCWAP.

Data capture for land use historical analysis can be a difficult, time consuming and expensive process. Depending on the type of data, we will obtain photocopies, scanned images, photographic reproductions or electronic copies. Usage of data will also vary according to its source. Our researchers will sift through and interpret information from written and oral accounts, public land survey data, tax records and the like. When possible we will corroborate information across the various accounts. From these records, historical maps and ground level old photographs we will synthesize a history of the watershed since the arrival of European-Americans in the 19th century up through about 1940.

For the post WWII era, aerial photographs will also be interpreted according to what constitutes a significant noteworthy change, and the timing and location of the photography (Avery and Berlin 1992). Digital data most useful for land use history research includes remote sensing information mainly from satellite images (Landsat Thematic Mapper (TM), Landsat Multispectral Scanner (MSS), SPOT, etc.) and digital orthophotography. Through image processing techniques, spectral changes between two date of satellite images can be enhanced and related to their likely significance on the ground. This method is especially effective at showing patterns of large fires, timber harvesting, and post-fire or harvest harvest vegetation regeneration. CDF has an ongoing program working with the region 5 office of the Forest Service to detect spectral changes using Landsat Thematic Mapper to detect land cover changes since 1994 (Levien, et al. 1999). In addition to using the results from that effort, NCWAP will augment it with MSS data extending back to the early 1970s. Digital orthophoto quads (DOQs) from recent aerial photography (1990s) are now available for the entire NCWAP region. These will serve as a georeferenced data layers to be used in conjunction with similar unrectified aerial photographs, to facilitate digitizing of land use activities.

We will equip our land use history personnel with the following technical equipment:

- Laptop Personal Computers with ArcView™ software
- Handheld GPS devices
- Mirror Stereoscope (one per office)
- Hardcopy USGS 1:24K topographic quadrangles of area

To the degree possible, we will work with DOC DMG to acquire and/or share sets of aerial photos. We will electronically scan airphotos to facilitate digital viewing and reproduction. GIS coverages will be created using ArcView tools (i.e., shape files). They will then be imported to ARC/INFO coverages.

Attributes of GIS Historical Land Use Coverages
For each polygon related to land use history digitized into GIS, a set of attributes will be entered including:

- approximate date of activity (if episodic)
- areal extent (i.e., how many hectares were in this land use? Implicit in GIS polygon)
- type of activity (cropland, grazing, timber cut, building development, new road)
- degree of impact (i.e., how impacting is this practice?)
- how permanent is the conversion (e.g., temporary timber harvest vs. permanent conversion to rangeland)
- any observable proximate impacts that may be ascribed to particular area of given land use
- Source of data
- Level of observer confidence in determining process at work

Proposed land use digitizing procedure (from historical aerial photos):

1) In ArcView: on screen have DOQ of local area, overlain with contour vectors
2) Create or open a shape file to edit with new entries
3) Have 1:24 K USGS quad sheet of locale nearby on desk to aid navigation through DOQ.
4) Have set of aerial photos of given date(s) nearby
    a. Set up on table for stereoviewing or
    b. On desktop
5) Look for patterns in airphotos giving the appearance of a land use practice or disturbance.
6) Correlate the location of the activity of interest with the location in the current DOQ in ArcView
7) If available, cross-correlate with satellite change detection images of area
8) To the best of one's abilities, digitize the area of disturbance.
9) Add a label, fill in a predetermined set of attributes about the observation

10) Label the age of roads observed in the given aerial photos

Validation and Accuracy Assessment

Little of the information available for the period prior to WWII is quantitative, and thus it cannot be assessed for validity except through comparison with other sources from the same era (Huntsinger 2001). It cannot therefore be evaluated for accuracy consistent with more quantitative data. However, historical narratives developed for NCWAP will be reviewed both within the agency and externally by the public and the scientific community. Materials used in developing the narratives will be referenced, allowing reviewers to weigh the evidence from more primary sources and, if desired, come to their own conclusions about historical trends and events.

Historical analysis using more quantitative data (mainly in digital spatial format) will also pose challenges to validation. Much of the information being developed concerns conditions which existed in the watershed prior to the present. Evidence of past events and land use clearly visible in historical photographs may be difficult to find in the landscape today.

CDF foresters assigned to the watershed will visit it in the field both for pre-analysis reconnaissance, in the process of compiling the land use historical information, and for later post-hoc accuracy assessment of the GIS-based products coming out of their efforts. Fieldwork on private lands will be coordinated with other NCWAP agency personnel also needing the same access. Location while in the field will be determined from GPS coordinates and ArcView coordinates on laptop computer.

Standard techniques will be used where possible (i.e. with most recent data), via constructing error matrices to compare mapped land usage with validation field data and computing Kappa statistics. Percent accuracy from both a producer's and user's perspective will be generated, as well as an overall accuracy (Congalton and Green 1999).

Table H-2. Data types, status and usage

Data Source/Type	Status	Usage
Historical photographs	Some digitized for Gualala, others unknown	Compare with other similar photos of later periods, today
Historical accounts	KRIS folks have compiled for some watersheds	Compare verbal accounts with later and current status
Tax Records	Unknown; '12.75 rule' records still exist in some counties	Area, amount and timing of timber harvesting
Historical maps	Unknown	Interpret/digitize areas of observable land use
Public land survey notes	Unknown	Interpret accounts of surveyors
Aerial photographs	Few historical in-house, more recent with DMG in SR; data bases (research) in progress.	Interpret land use, digitize using DOQ comparison
Satellite data	MSS data 1973-1992; SPOT 1993 & 1999(?); TM of various dates	Change detection sets context for areas to look in more detail; SPOT helps reference analog airphotos

Data Source/Type	Status	Usage
Digital orthophoto quads	Copy from DMG CDROMs	Current land use and georeference for historical airphoto interpretation
US Forest Service vegetation	Complete for north coast	Help to interpret vegetation types viewed in airphotos
USGS 1:24K Topo Quads	Available for all watersheds; DRGs might be preferable	Navigate airphoto interp. through watersheds; use with contour DLGs
Digitized THPs	Complete for several watersheds	Assist current land use coverage creation
DLGs of hydrography, land ownership, roads, etc.	Varying degrees of completion, (watershed)	Assist in interpreting land use features

Developing GIS Roads Coverages

Roads, as linear features, are a special case of land use. They will play a major part of watershed assessments, and will be captured in a parallel effort to the polygon-based land use history data. Here is how we will approach capturing roads data:

- Begin with 1:24K USGS DLGs of roads for a watershed, with enhancements by CDF
    - Add new roads from digitized Timber Harvest Plan maps
- Overlay roads GIS coverage and check against recent DOQ of same area
- Update the roads coverage where there are roads or other human-made linear features apparent in the remote sensing data but lacking in the coverage, and attribute new additions to best ability
- Validate results of digitized roads against field data
- For private industrial timberlands, we will seek to obtain any existing roads coverages from the timber company proprietors. If successful, we will assess its accuracy and quality and, if deemed acceptable, we will merge their roads vectors with ours. This will require strict attention to matching any differences in their GIS attribute tables
- Where possible we will digitize skid trails and landings, as well as old abandoned railroad beds.
- GIS attributes for the roads coverages will include:
    - Type (skid trail, haul roads, dirt, two-lane, county road, state highway, etc.);
    - Road width
    - Date or Era of construction (if known)
    - Apparent road condition (state of repair/disrepair from airphotos)
    - Apparent stream crossings (type, if discernible)

NCWAP will also examine opportunities for collect additional road data through coordination with TMDL studies, local road assessment studies, etc.

Quality control and assurance procedures for roads coverage.

The roads coverage will require field visits to calibrate airphoto interpretation before additions, so that observers will note what various types of roads look like in the airphotos, what is visible and what is not. After the additions we will conduct further field studies, visiting a set of selected sites to verify our data. Field validation will be conducted with the following criteria:

- roads accessible to public
- a sample (at least 10%) of the above will be selected to visit in field
- data collected in field will be compared to attributes for roads, then confusion matrix (or truth table) will be constructed to show coverage accuracy

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I: Definition of Terms

ADAPTIVE MANAGEMENT: Monitoring or assessing progress toward meeting management objectives and incorporating what is learned into future management plans.

AGGRADATION: The geologic process by which stream channels and floodplains are raised by deposition of material eroded from elsewhere.

ALEVIN: The life stage of salmonids that occurs after eggs have hatched but before young emerge from the gravel nests where they have incubated. Alevin still have yolk sacs attached to provide them with nutrition within the nest.

ANADROMOUS: Fish that leave freshwater and migrate to the ocean to mature then return to freshwater to spawn. Salmon, steelhead and shad are examples.

ANTHROPOGENIC: Impacts on nature from human land use activities.

BED LOAD: The portion of the total sediment load carried by a stream which consists of large-sized material that rolls or slides along the stream bottom.

BENEFICIAL USES: The priority uses of stream water for humans and non-humans, including drinking water, irrigation water, hydro-power generation, recreation, fisheries, and aquatic habitat.

BEST MANAGEMENT PRACTICES (BMPs): Methods, measures, or practices to prevent or reduce water pollution, including structural and nonstructural controls, and operation and maintenance procedures.

BENTHIC: Bottom dwelling or substrate oriented; at or in the bottom of a stream or lake, e.g., benthic aquatic insects.

BIOTA: The flora and fauna of a region.

CARRYING CAPACITY: The maximum number of organisms of a given species and quality that can survive in a given ecosystem without causing deterioration of the habitat within an interval of time.

CANOPY: The cover of branches and foliage formed collectively by the crowns of adjacent trees and other woody growth.

CANOPY COVER: The percent of an area covered by a canopy layer, typically the crowns of trees.

CENTROID: The center of water mass of a flowing stream at any location. This location usually correlates well with the thalweg, or deepest portion of the stream. Sampling in the centroid is intended to provide a representative sample of the stream.

CHANNEL CLASSIFICATION: Categorization of stream channels into discrete types based on physical criteria including channel slope, geometry, entrenchment, confinement or location within a watershed. Classification allows for comparison of channel condition and habitat of similar stream reaches.

CHANNEL CONFINEMENT: The ratio of the width of the valley floor to the width of the stream channel. This describes how restrictive the valley's walls are in limiting the channel's lateral movement (meandering).

CHANNEL ENTRENCHMENT: The relation of the channel to the valley flat or floodplain, i.e., downcutting or incising.

CHANNEL GEOMETRY: The physical size, shape, and characteristics of a channel caused by hydraulic factors of velocity, roughness, slope and flow frequency.

COBBLE EMBEDDEDNESS: The degree to which cobbles (small rocks 3-12 inches in diameter on the bottom of the stream) are surrounded or covered by fine sediment (sand or silt). Usually expressed as a percentage.

COLD WATER FISH HABITAT: Stream and lake waters that support fishes which require cold temperatures. Cold water fish include salmon, trout, and smelt. Salmon require water temperature below 56 degrees Farenheit as eggs, and 65 degrees as smolts and adults.

CONDUCTANCE: The readiness by which a material transmits an electrical current.

CUMULATIVE WATERSHED EFFECTS: Cumulative effects are those effects on the environment that result from the incremental effect of an action when added to past, present and reasonably forseeable future actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period of time.

DEGRADATION: The lowering of a stream channel by erosion of bed materials.

DISCHARGE: In a stream, the volume of water passing through a channel in a given time.

DISSOLVED OXYGEN: The amount of oxygen dissolved in stream water which determines the ability of organisms to survive there.

DRAINAGE BASIN: The area from which a stream and its tributaries receives its water.

ECOTONE: A transition area between two distinct habitats that contains species from each area, as well as organisms unique to it.

ELECTROFISHING: Stunning fish with electricity to facilitate counting fish populations in a stream.

EPHEMERAL: A stream or portion of a stream that flows only in direct response to precipitation. The stream channel is poorly defined, with little riparian vegetation, and is above the water table at all times.

ESTUARY: A water passage where the tide meets a river current.

FLATWATERS: In relation to a stream, low velocity pool habitat.

FLOODPLAIN: The area bordering a stream over which water spreads when the stream overflows its banks at flood stages.

FLUVIAL: Relating to or produced by a river or the action of a river. Situated in or near a river or stream.

FRESHET: A sudden rise or overflowing of a small stream as a result of heavy rains or rapidly melting snow.

FRY: The life stage of salmonids in which young fish leave gravel nests after their yolk sac is absorbed. Salmon fry live and grow in freshwater for to one or two years.

GEOGRAPHIC INFORMATION SYSTEM (GIS): A computerized information processing technology used to input, store, manipulate, analyze, and display spatial resource data to support the decision-making processes of an organization about the land base and its resources.

GEOMORPHOLOGY: The study of surface forms on the earth and the processes by which these develop.

GIS: See geographic information system.

GRADIENT: The slope of a streambed or hillside. For streams, gradient is quantified as the vertical distance of descent over the horizontal distance the stream travels.

GROUND TRUTHING: Conducting limited field studies to confirm interpretations of data collected by remote means such as aerial photography.

IN-STREAM FLOW: The amount of water in a stream passing a given point at a given time. A specific level of flow is necessary to maintain ecological balance or support a beneficial use within a river or stream.

INTERMITTENT STREAM**:** A stream that flows only during wet seasons of the year.

LARGE WOODY DEBRIS (LWD): Logs, stumps, and branches that enter and are transported by streams. LWD is an important influence on channel morphology and aquatic ecology by obstructing streamflow, storing and distributing sediment, and creating channel features, such as pools, riffles, and waterfalls.

LIFE STAGE: Critical stages in the life cycle of salmonids including alevin, fry, parr, smolt, and spawner. Each stage requires specific types of in-stream habitat including incubation, rearing, and spawning habitat.

LIMITING FACTOR: Any environmental factor that prevents an organism or population from reaching its full potential of population, distribution, or activity.

LIMITING FACTORS ANALYSIS FOR SALMONIDS: Analysis of the conditions limiting production of native anadromous salmonids including current physical and biological constraints which limit migration, spawning and offspring survival.

MACROINVERTEBRATE: Invertebrates large enough to be seen with the naked eye (e.g., most aquatic insects, snails and amphipods).

MASS WASTING: The mass movement downslope of material under the influence of gravity. Often used synonymously with landslide and debris flows.

MEANDER: The bends in a stream channel that serve to slow down stream flow, by forcing the water to cover more distance to reach a point than if it were traveling in a straight line.

METADATA: A description of the purpose, objectives, methodology, quality assurance, and quality control used to collect a specific data set. These factors are used to evaluate the relative quality and usefulness of the information for a particular purpose.

MICROCLIMATE: Climatic conditions found on a particular site or location. Microclimatic conditions vary significantly within larger climatic zones.

NONPOINT SOURCE POLLUTION: Polluted runoff from sources that cannot be defined as discrete points, such as areas of timber harvesting, surface mining, agriculture, and urban land use.

NUTRIENT CYCLING: The path taken by essential nutrients including nitrogen, carbon, phosphorous, and potassium within an ecosystem.

ORTHOPHOTOQUADS: A combined aerial photo and planimetric quad map (with no indication of contour) without image displacements and distortions.

PARR: Young trout or salmon actively feeding in freshwater; usually refers to young anadromous salmonids before they migrate to sea (See smolt).

PERENNIAL: A stream that continuously flows throughout the year in a well-defined channel.

PLATE TECTONICS: A theory in which the earth’s crust is divided into mobile plates which are in constant motion causing earthquake faults, volcanic eruptions, and uplift of mountain ranges.

POINT BAR: Accumulations of sand and gravel deposited in slack water on the inside of a winding or meandering river.

POLYGON: An area of land mapped in a Geographic Information System based on its uniformity in a particular criteria such as vegetation type, age, geology or other environmental characteristic.

POOL: An area of stream that has reduced water velocity; water depth is deeper than the surrounding areas. Pools are formed by features of the stream that cause local deepening of the channel.

QUALITY ASSURANCE: Procedures combining training of personnel and quality control checks to assure the accuracy and precision of data being collected.

QUALITY CONTROL: Checks made on the accuracy and precision of data collection and the procedures to be followed when a measurement does not fall within acceptable ranges.

REDDS: Nests made in gravel (particularly by salmonids) consisting of a depression that is created and then covered.

REGION: One of the 18 major geographic regions categorized by the U.S. Geological Survey within the continental United States. California is Region 18.

RIFFLE: A shallow area extending across a streambed, over which water rushes quickly and is broken into waves by obstructions under the water.

RILL: An erosion channel that typically forms where rainfall and surface runoff is concentrated on slopes. If the channel is larger than one square foot in size, it is called a gully.

RIPARIAN: A type of wetland transition zone between aquatic habitats and upland areas. Typically, moisture-loving vegetation grows in this area along stream channels.

RIVER BASIN: A hydrologic unit composed of a river system, a reach of a stream and its tributaries, a closed basin, or a group of streams composing a coastal drainage area (e.g., Northern California Coastal). The U.S. Geological Survey codes each river basin with a six digits code.

RUNOFF: Rainfall or snowmelt that flows overland across the surface of hillslopes and into a stream or body of standing water.

SALMONID: Fish of the family Salmonidae, including salmon, trout, chars, whitefish, ciscoes, and graylings.

SCOPING: Solicitation of involvement by stakeholders to identify important issues for consideration in natural resource management decision-making.

SEDIMENT LOAD: The total amount of sediment transported by a stream, composed of suspended and bed material.

SENSITIVITY ANALYSIS: A determination of the consequences of varying the level of one or several factors while holding other factors constant.

SERAL STAGE: The stage or recognizable condition of a plant community that occurs during its development from bare ground to climax community. Common stages in forest development include grass, forb, shrub seedling, pole-sapling, immature, mature, and old growth.

SHEET FLOW: The downslope movement of surface runoff over relatively smooth land surfaces in the form of a thin, continuous film that is not concentrated in channels. Sheet erosion is the detachment of soil particles by sheet flow.

SILVICULTURE: The management process whereby forests are manipulated through plantings, thinnings, and harvesting to control their growth, composition, health, and productivity

SINUOUSITY: The degree to which a stream channel curves or meanders across the land surface. Quantified as the ratio of channel length (measured as a curved line) to valley length (measured as a straight line).

SMOLT: A lifestage of salmonids occurring when a juvenile salmon migrates to the sea, or a young anadromous trout, salmon, or char is undergoing physiological changes to move from fresh water to the sea. The smolt stage follows the parr stage.

SPAWNER: A lifestage of salmonids occurring when adult fish return from the sea to their natal streams to reproduce.

STADIA RODS: Graduated rods observed through a telescopic instrument while surveying to determine distances and elevation.

STAKEHOLDER: A person or group that has a stake in the outcome of a natural resource management decision.

STOCK: A group of fish that is genetically self-sustaining and isolated geographically or temporally during reproduction. For anadromous salmonids, a stock originates from specific watersheds and returns to these birth streams to spawn as adults.

STREAM CLASS: The relative value of a stream based on its need for protection of its beneficial uses. Class I streams typically are very important for water supply, fisheries, or recreation values. Other stream classes denote streams of lesser value or streams that are intermittent or ephemeral.

STREAM FLOW: The amount of water flowing in a stream. This is often measured in units of cubic feet of water flowing past a cross section of stream per second. (See also discharge).

STREAM ORDER: A classification system for streams based on the number of tributaries to the stream.

STREAM REACH: A section of a stream between two points.

SUBBASIN: One of the smaller basins that makes up a river basin. The U.S. Geological Survey classifies subbasins using eight digit codes composed of four two-digit fields. Almost all Pacific Northwest subbasins are larger than 700 square miles.

SUBSIDENCE: The sinking of the earth's surface due to overlying geologic materials, or the removal of groundwater.

SUBSTRATE: The material (silt, sand, gravel, cobble, etc.) that forms a stream or lake bed.

SUBWATERSHED: One of the smaller watersheds that combine to form a larger watershed.

SUSPENDED LOAD: The amount of small-sized material (organic and inorganic) a stream carries in the water current.

SUSTAINED YIELD: The yield of commodities that a forest can theoretically produce continuously without impairment of the productivity of the land if managed intensively.

THALWAG: The portion of the stream with the deepest water and greatest flow. Also the line running longitudinally down the deepest portions of the stream channel.

TOTAL MAXIMUM DAILY LOAD: An estimate of the total quantity of pollutants from all sources, including point, nonpoint, and natural, that may be allowed into waters without exceeding applicable water quality criteria.

TURBIDITY: A measurement of the optical property of water that scatters light. Turbidity increases with suspended organic or inorganic particulate matter.

WATERSHED: The total area above a given point of a water body that contributes flow to that point.

WATERSHED ANALYSIS: An interdisciplinary process of information collection and analysis that provides detailed information for specific management objectives and site-specific prescriptions.

WATERSHED ASSESSMENT: An interdisciplinary process of information collection and analysis that characterizes current watershed conditions at a coarse scale.

WATERSHED CONDITION: The state of a watershed based on physical characteristics and processes (e.g., hydrologic, geomorphic, landscape, topographic, vegetative cover, and aquatic habitat), water flow characteristics and processes (e.g., volume and timing), and water quality characteristics and processes (e.g., chemical, physical, and biological), as it affects water quality and water resources.

WATERSHED GOVERNANCE: The coming together of entities including companies, agencies, organizations in watershed groups to address natural resource issues on a watershed basis.

WATERSHED MANAGEMENT AREA: A grouping of smaller watersheds with similar management objectives used to identify and address water quality problems, e.g., the Humboldt WMA includes all watersheds draining to the ocean or bays north of the Eel River to and including Redwood Creek.

WEIR: A device across a stream to divert fish into a trap or to raise the water level or divert its flow.

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