Big River Water Quality Assessment

Compiled for the
North Coast Watershed Assessment Program

PRELIMINARY DRAFT

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North Coast Regional Water Quality Control Board
June 2, 2003

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List of Abbreviations & Acronyms

Abbreviation /Acronym	Description
AVG	Average
Basin Plan	Water Quality Control Plan for the North Coast Region
CARA	California Resources Agency
CDF	California Department of Forestry and Fire Protection
CFL	Coastal Forestlands
CGS	California Geological Survey
D_{50}	Median Pebble Diameter
DFG	California Department of Fish and Game
DHS	California Department of Health Services
DIS	Depth Integrated Sample
DPR	Department of Pesticide Regulation
DWR	Department of Water Resources
EMDS	Ecological Management Decision Support
FSP	Forest Science Project
GMA	Graham Matthews & Associates
HTC	Hawthorne Timber Company / Campbell Timberland Management
IRIS	Integrated Risk Information System (US EPA)
JSF	Jackson State Demonstration Forest
KRIS	Klamath Resource Information System
LNF	Little North Fork (Big River)
LWD	Large Woody Debris
MAX	Maximum
MCL	Maximum Contaminant Level
MIN	Minimum
MRC	Mendocino Redwoods Company
MWA	Mendocino County Water Agency
MWAT	Maximum Weekly Average Temperature
MWMT	Maximum Weekly Maximum Temperature
NA	Not Applicable / Available
NCWAP	North Coast Watershed Assessment Program
NIST	National Institute of Standards and Technology
NPDES	National Pollution Discharge Elimination System
RWQCB	North Coast Regional Water Quality Control Board
Regional Water Board	North Coast Regional Water Quality Control Board
SNARL	Suggested No Adverse Response Level (US EPA)
SONAR	Mendocino High School, School of Natural Resources
SWAMP	Surface Water Ambient Monitoring Program
TDS	Total Dissolved Solids
THP	Timber Harvest Plan
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WDR	Waste Discharge Requirement

Abbreviation /Acronym	Description
WY	Water Year
WQ	Water Quality

Unit Measurements	Description
ac	Acre
ºC	Degrees Celsius
cc	Cubic Centimeters
cm	Centimeter
ºF	Degrees Fahrenheit
ft	Feet
hr	Hour
L	Liter
lb	Pound
mg	Milligram
mi	Mile
mi^2	Square Mile
mm	Millimeter
NTU	Nephelometric Turbidity Units
µg	Microgram
µS	Microsiemen
yr	Year

Acknowledgements

The North Coast Regional Water Quality Control Board would like to thank Chris Surfleet from the Mendocino Redwood Company, Stephen Levesque from Campbell Timberland Management, Gary Reedy from the Institute for Fisheries Resources, Dennis Slota from the Mendocino County Water Agency, Graham Matthews of Graham Matthews & Associates, Marc Jameson and the staff of the California Department of Forestry and Fire Protection at Jackson Demonstration State Forest, and the Forest Sciences Project at Humboldt State University for their generous contribution of data for the water quality assessment of the Big River.

Summary of Issues, Conclusions, and Recommendations

Water Chemistry

Water chemistry sampling was generally limited in duration and even non-existent in some areas, including the Big River Estuary, the Middle and the Upper subbasins. In every subbasin where it was tested, sodium exceeded the applicable water quality criteria. On other occasions, there were unusual concentrations of boron, copper, aluminum, and zinc that exceeded water quality criteria. Boron concentrations in the South Fork Big River were particularly troubling because they were collected in 2001 with known methods. However, with the other metals, it is likely that they were artifacts of the sample collection method or location.

In February 2001, a tanker truck on highway 20 spilled roughly 7,000 gallons of waste oil. Some of this waste oil discharged into a tributary to James Creek. Subsequent sampling indicated that petroleum constituents had reached James Creek. While it is likely that this event harmed some aquatic life, this site is in active cleanup and it is unlikely that this episodic event will have a long-term effect on the local ecology.

It is unknown which, if any, of the pesticides and herbicides make their way into the stream channels from activities such as agriculture, timber harvesting, and right-of-way maintenance on County roads. This would depend on the method of application, solubility, and the persistence of these chemicals. However, this was not studied in this assessment due to the lack of sample data. A summary of select pesticides and herbicides used in Mendocino County (although not specifically the Big River watershed) in 2000 is given in Table 41 on page 199. Further study of pesticides and herbicides is warranted to ensure that drinking water supplies and wildlife resources are protected in the Big River (and other watersheds).

Based on the information available for this assessment, water chemistry in the Big River watershed does not appear to be a limiting factor for aquatic organisms or a health hazard to humans. However, long-term sampling should be conducted to verify that the detected metals are, in fact, not in the surface water at the detected concentrations. Sodium concentrations should be looked at more carefully to determine the source of the sodium and if it is naturally occurring. No water quality information exists for the estuary, which is unique and should be studied further. Sampling for pesticides and herbicides throughout the watershed is also recommended.

Water Temperature

With the exception of the Big River Estuary, continuous water temperature data loggers were available in every subbasin. Water temperatures in the mainstem Big River were high in virtually every location tested, and the daily maximum temperatures sometimes exceeded the lethal threshold for salmonids.

Tributaries in the Lower Big River subbasin had fully suitable to moderately suitable water temperatures. It is likely that this is due, in large part, to the cooling marine influence in this subbasin. Although not supported by any data, it is probable that higher precipitation in this subbasin also assists in the rapid re-growth of the forest and understory vegetation that offers stream shading. Overall, the water temperature in the Lower Big River tributaries appear to be in the best condition of any subbasin in the Big River watershed. Also, it is likely that the Little North Fork has some cooling effect as it enters the mainstem Big River.

Tributaries in the Middle Big River subbasin had fully suitable to undetermined water temperatures. While the data in this subbasin is relatively spare, it is likely that the marine influence in this subbasin and rapid re-growth of vegetation also helps keeps water temperatures relatively low. The tributaries that were monitored in this subbasin appear to be in good condition with respect to water temperature for salmonids. Also, it is likely that the Two Log Creek has some cooling effect as it enters the mainstem Big River.

Tributaries in the Upper Big River subbasin had fully suitable to somewhat unsuitable water temperatures. However, except for the site on Russell Brook and two other sites that appear to be dominated by groundwater, the tributaries that were monitored in this subbasin appear to be in poor condition with respect to water temperature for salmonids. It also appears as that the upper mainstem Big River is one of the origins of the warm water seen downstream. Water leaves this subbasin with an MWAT of roughly 66-68°F.

Tributaries in the North Fork subbasin, including the North Fork itself, had fully suitable to moderately unsuitable water temperatures. Generally, the tributaries that were monitored in this subbasin appear to be in good condition with respect to water temperature for salmonids. The notable exceptions to this is Lower Chamberlain Creek, most of the East Branch of the North Fork, and the mainstem of the North Fork. The mainstem North Fork is unusual in that it exhibits a rapid increase in water temperature upstream of the JSF boundary, and then slowly declines until it leaves JSF, and again shows a rapid increase near the confluence with the mainstem Big River. The obvious hypothesis is that it may be due to naturally poor canopy or to commercial timber harvesting on either end of the North Fork. In any case, this should be investigated further. It also appears as that the North Fork is one of the origins of the warm water seen downstream in the mainstem Big River. Water leaves this subbasin with an MWAT of roughly 67°F.

Tributaries in the South Fork subbasin, including the South Fork Big River, had fully suitable to fully unsuitable water temperatures. Except for the tributaries that appear to be dominated by groundwater and the one site in the Montgomery Reserve, the sites in this subbasin were poor with respect to water temperature. In fact, the lower mainstem South Fork had the highest daily water temperature (74°F) of any stream other than the mainstem Big River. Conversely, the site in the Montgomery Reserve is a good example of what can be achieved with adequate canopy in the warmer interior portion of the Big River watershed. Water leaves the South Fork subbasin with an MWAT of roughly 67-69°F.

Sediment

A variety of sediment related field data have been collected in the Big River watershed, including pebble counts, V*, permeability, stream cross-sections, thalweg profiles, bulk sediment samples (McNeil), and turbidity and suspended sediment samples. Unfortunately, a large portion of this data is of limited duration or is not comparable to other data collected by others in the Big River watershed due to differing analysis techniques.

In the Lower Big River subbasin, pebble counts, V*, bulk sediment samples, and turbidity samples were collected at various locations and times. Pebble count and V* measurements collected at one site in Berry Gulch during one year indicated excessive amounts of fine material in the stream. Bulk sediment samples collected in the Little North Fork indicate excessive sediment in sub-0.85 mm and sub-6.5mm size classes that generally exceed the TMDL limits for these size fractions. A total of 88 useable turbidity samples were taken on the mainstem Big River, both upstream and downstream of the confluence with the Little North Fork Big River.

Measurements indicate that 90% of all samples collected were at or below 52 NTU with a maximum recorded level of 600 NTU.

Preliminary data by GMA indicates that the relative disturbance index for the Lower Big River was the second highest of the five subbasins in the Big River watershed during the 1989-2000 time period. Within the Lower Big River subbasin, the Mouth of Big River planning watershed had the highest relative disturbance index. When estimated landsliding and surface erosion is compared to the TMDL load allocations, it appears that landsliding related to roads and timber harvesting need to be addressed. Roads, in particular, seem to be significant problem. Surface erosion from roads and timber harvest areas (including skid trails) indicate that both also exceed the TMDL load allocation for surface erosion.

In the Middle Big River subbasin, bulk sediment samples, stream cross-sections, thalweg profiles, and permeability measurements were collected at various locations and times. Bulk sediment samples collected in Two Log Creek indicate excessive sediment in sub-0.85 mm size class that generally exceeds the TMDL limits for this size fraction. Other bulk sediment data was collected by GMA and MRC. However, due to differing analysis techniques, these data are not comparable to each other or the TMDL limits. Permeability measurements on the mainstem Big River indicate low to moderate amounts of fine sediment when compared to similar sites at other locations in the Big River watershed. This is somewhat verified by the bulk sediment sample collected at the same location. Stream cross-sections and thalweg profiles were only collected during one year, so they are reported but not used in this assessment.

Preliminary data by GMA indicates that the relative disturbance index for the Middle Big River was the third highest of the five subbasins in the Big River watershed during the 1989-2000 time period. Within the Middle subbasin, there is only one planning watershed (Two Log Creek). When estimated landsliding is compared to the TMDL load allocations, it appears as though landsliding related to roads and timber harvesting need to be addressed. Grassland areas are not a significant problem. Surface erosion from roads and timber harvest areas (including skid trails) indicate that both also exceed the TMDL load allocation for surface erosion. Surface erosion related to roads, in particular, appear to be a significant problem.

In the Upper Big River subbasin, turbidity and suspended sediment samples were collected at various locations and times. Limited turbidity and suspended sediment samples were collected on the mainstem Big River during winter flows. Measurements indicate that all of the turbidity samples were below 42 NTU, except one sample with a maximum recorded level of 240 NTU. There also appeared to be a strong correlation between turbidity and suspended sediment at the sites sampled.

Preliminary data by GMA indicates that the relative disturbance index for the Upper Big River was the highest of the five subbasins in the Big River watershed during the 1989-2000 time period. Within the Upper Big River subbasin, the Martin Creek planning watershed had the highest relative disturbance index. When estimated landsliding is compared to TMDL load allocations, it appears that landsliding related to roads, timber harvesting, and grassland areas need to be addressed. Estimates of surface erosion from roads and timber harvest areas (including skid trails) indicate that both also exceed the TMDL load allocation for surface erosion. Surface erosion and landslides related to roads, in particular, appear to be a significant problem.

In the North Fork Big River subbasin, bulk sediment, permeability, stream cross-sections, thalweg profiles, and suspended sediment and turbidity samples were collected at various locations and times. Bulk sediment samples collected at various locations in the North Fork and in Chamberlain Creek suggests a significant amount of fine sediment may be entering the North Fork Big River either from James Creek, or between James Creek and Chamberlain Creek. Permeability measurements on the East Branch North Fork site indicate low to moderate amounts of fine sediment when compared to similar sites at other locations in the Big River watershed. This is somewhat verified by the bulk sediment sample collected at the same location. Limited turbidity measurements indicate that at the five locations, turbidity varied between 2 and 214 NTU. The North Fork Big River above Chamberlain Creek had the highest average turbidity levels and the James Creek above the North Fork Big River site had the lowest turbidity levels. There also appeared to be a strong correlation between turbidity and suspended sediment at the sites sampled. Stream cross-sections and thalweg profiles were only collected during one year, so they are reported but not used in this assessment.

Preliminary data by GMA indicates that the relative disturbance index for the North Fork Big River was the lowest of the five subbasins in the Big River watershed during the 1989-2000 time period. Within the North Fork subbasin, the East Branch North Fork Big River planning watershed had the highest relative disturbance index. When estimated landsliding is compared to TMDL load allocations, it appears that that landsliding related to timber harvesting needs to be addressed to meet the TMDL load allocation goals. Estimates of surface erosion from skid trails and timber harvest areas indicate that it also slightly exceeds the TMDL load allocation. Road related landslides do not appear to significantly exceed the TMDL load allocation. On the other hand, surface erosion from roads may be a significant issue in the North Fork subbasin.

In the South Fork Big River subbasin, bulk sediment, permeability, stream cross-sections, thalweg profiles, and suspended sediment and turbidity samples were collected at various locations and times. Bulk sediment samples collected at various locations indicate mostly mixed results with no trends evident. Permeability sampling indicated significant fine material at the Daugherty Creek site and the Ramon Creek site. The South Fork Big River site appeared to have less fine material and likely better spawning success. The permeability conclusions are somewhat supported by bulk sediment sampling at the same locations, particularly in the sub 0.85 mm size class. Limited turbidity measurements indicate that at the four locations, turbidity was between 2.3 and 811 NTU. The South Fork below Daugherty Creek had the highest average turbidity level, while the Daugherty Creek site had the lowest average turbidity level. There also appeared to be a strong correlation between turbidity and suspended sediment at the sites sampled. Stream cross-sections and thalweg profiles were only collected during one year, so they are reported but not used in this assessment.

Preliminary data by GMA indicates that the relative disturbance index for the South Fork Big River was the fourth highest of the five subbasins in the Big River watershed during the 1989-2000 time period. Within the South Fork subbasin, the South Daugherty Creek planning watershed had the highest relative disturbance index. When estimated landsliding is compared to TMDL load allocations, it appears that landsliding related to timber harvesting and grassland areas need to be addressed to meet the TMDL load allocation goals. Road related landslides do not appear to significantly exceed the TMDL load allocation. Estimates of surface erosion from skid trails and timber harvest areas indicate that it does not significantly exceed the TMDL load allocation. On the other hand, surface erosion from roads may be a significant issue in the South Fork subbasin.

The recent purchase of a large portion of the estuary and transfer to the State of California for management as a park will also likely improve temperature and sediment conditions.

Program Overview

The North Coast Watershed Assessment Program (NCWAP) is a multi-agency effort led by the California Resources Agency. The State Legislature initiated this program in response to requests from landowners, industry groups, environmental groups, and stakeholders that expressed a need for these assessments to help guide decision making.

The five agencies that are participating in NCWAP are: the Department of Fish and Game (DFG), Department of Forestry and Fire Protection (CDF), Department of Conservation-California Geological Survey (CGS), Department of Water Resources (DWR), and the State Water Resources Control Board-North Coast Regional Water Quality Control Board (Regional Water Board). The Institute for Fisheries Resources was subcontracted to assist each of the NCWAP agencies and participate in the assessment, and to make much of the technical data available to the public through the Klamath Resource Information System (KRIS) product.

KRIS will be used by the NCWAP team to integrate and analyze a variety of related watershed information including data sets, charts, map data and images, photographs, and bibliographic resources including reports, manual, and relevant correspondence. Each of the NCWAP agencies will be creating information for the KRIS product, which will in turn be available to the public through the KRIS web site.

Ultimately, NCWAP will provide baseline environmental and biological information for approximately 6.5 million acres of watersheds in the north coast region over a seven-year period. Although the assessments are focused on conditions affecting anadromous fish, they will also provide data that is useful for prioritizing grant proposals, provide agencies and landowners with a more complete picture of watershed conditions so that existing regulations can be better implemented, and assist in other natural resource planning and management functions.

Within the Regional Water Board, NCWAP is a separate program that is dedicated to researching, analyzing, and compiling data for watershed assessments. However, the Surface Water Ambient Monitoring Program (SWAMP), and the Total Maximum Daily Load (TMDL) program are inter-related programs at the Regional Water Board that are either directly or indirectly involved in NCWAP. Staff within these programs have been and continue to work closely together to collect and analyze data that are pertinent to each of these programs (and other Regional Water Board programs not mentioned here).

For example, as a result of the NCWAP assessment, three SWAMP sampling stations were established in the Big River watershed for 2001. SWAMP and NCWAP staff jointly participated in two sampling events in the Big River watershed to gather basic water chemistry and physical data. At the present time, sampling in the Big River watershed was only funded for 2001. However, based on the extent of funding that is available, all three involved programs will continue to collect and analyze water quality information from both third party sources and from newly collected data by the Regional Water Board. Ideally, these new data could then be incorporated into subsequent updates to the watershed assessment and the KRIS product.

Guiding Questions

Evaluation and analysis of Big River watershed data will be guided by some critical questions developed by NCWAP participants regarding beneficial uses on a watershed and sub-watershed scale. The key question on which the bulleted critical questions are predicated is:

What factors are limiting salmonids 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 disturbances 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 (LWD) 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 and shade, sediment, nutrients, in-stream 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, distribution, and relative healthiness of populations of salmonids within watersheds?

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

These critical questions laid the groundwork and guidance for data gathering, collection, and assessment procedures by team and individual agency participants. They are addressed collectively in the interagency Big River Watershed Synthesis Report.

Program Goals

The principal overall goal of NCWAP is to compile and develop baseline scientific information about existing biophysical conditions in north coast watersheds. However, more specifically, the goals of the program are:

1. Provide a baseline of data for evaluating the effectiveness of various resource protection programs over time;

2. 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);

3. Guide cooperative interagency, non-profit and private sector approaches to “protect the best” through stewardship, easement, and other incentive programs;

4. Help landowners and agencies implement laws that require specific assessments such as the State Forest Practice Act, Clean Water Act, and the State Lake and Streambed Alteration Act.

In the cases where little or no data is available, the NCWAP assessments are to identify the gaps in data and suggest a future course of action to help further our understanding of the watershed.

Role of Regional Water Quality Control Board

The primary responsibility for the protection and enhancement of water quality in California has been assigned by the California legislature to the State Water Resources Control Board (State Water Board) and the nine regional water quality control boards. The State Water Board provides state-level coordination of the water quality control program by establishing statewide policies and plans for the implementation of state and federal laws and regulations. The regional water boards adopt and implement water quality control plans (Basin Plans) which recognize the unique characteristics of each region with regard to natural water quality, actual and potential beneficial uses, and water quality problems.

Comprehensive water quality planning is mandated by both California and federal law. The federal Clean Water Act contains the law protecting navigable waters, and the California Water Code is the state body of law protecting groundwaters and fresh and marine surface waters. The federal Clean Water Act requires states to adopt water quality standards (water quality objectives and beneficial uses) for navigable waters of the United States and to review those standards on a triennial basis. The State Water Board and regional water boards implement the federal Clean Water Act in California under the oversight of the United States Environmental Protection Agency (US EPA), Region 9. The California Water Code (which contains the Porter-Cologne Water Quality Control Act) authorizes the State Water Board to adopt, review and revise state water policy, which may include water quality objectives, principles, and guidelines. The California Water Code also directs regional water boards to adopt, review, and revise basin plans, and provides specific guidance on factors which must be considered in adoption of water quality objectives and implementation measures. More specifically, the California Water Code specifies that each water quality control board shall establish water quality objectives which, in the regional water boards judgment, are necessary for the reasonable protection of the beneficial uses and the prevention of nuisance.

The goal of the Basin Plan is to provide a definitive program of actions designed to preserve and enhance water quality and to protect beneficial uses of water in the north coast region. The Basin Plan for the north coast region has seven components, which are briefly described in the following numbered items:

1. **Introduction.** This section describes the history of basin planning in the north coast region and the legal authority of the state and regional water boards. The section also discusses the basin plan review process and describes the geography and water uses in the Klamath River Basin and the North Coastal Basin. These two basins together comprise the geographic extent of the north coast region.
2. **Beneficial Uses.** The general descriptions of the beneficial uses are provided in this section, along with a table of the existing and potential beneficial uses associated with many of the major water bodies in the north coast region. Unless specifically listed otherwise, tributaries have the same beneficial uses as the major water body into which they feed. This section also discusses the projected water demands in the north coast region.

3. **Water Quality Objectives.** This section provides both numeric and narrative water quality objectives for the north coast region as a whole, and more specific objectives for ocean waters, groundwaters, inland surface waters, enclosed bays, and estuaries. In the case of salmonid protection, the water quality objectives on temperature, dissolved oxygen, pH, and a variety of narrative objectives related to settleable and suspended material, turbidity, and sediment are of particular importance in the Big River watershed.
4. **Implementation Plans.** This section presents the actions intended to meet water quality objectives and protection of beneficial uses of the Klamath River Basin and North Coastal Basin. The implementation plans can be further divided into "Point Source Measures" and "Non-Point Source Measures". Point sources, such as discharges from a waste water treatment plant into a stream, are typically controlled through use of waste discharge prohibitions (which are specifically outlined in the Implementation Plans section of the Basin Plan), waste discharge requirements (WDRs), and/or national pollution discharge elimination system (NDPES) permits. These permits are discussed in more detail in the Data Reviewed In-House section on page 11. Non-point sources, such as run-off from timber harvest operations, are typically controlled through the use of the implementation plans. Of particular importance to the Big River watershed are the Action Plan for Logging, Construction, and Associated Activities, together with the Guidelines for Implementation and Enforcement of Discharge Prohibitions Relating to Logging, Construction, or Associated Activities. Other important components in this section include the Policy for the Control of Discharges of Herbicide Wastes from Silvicultural Applications and the Action Plan for Control of Discharges of Herbicide Wastes from Silvicultural Applications.
5. **Plans and Policies.** Unlike the north coast region specific implementation plans discussed in the previous item, the Regional Water Board is required to implement the provisions of several statewide plans and policies. The state wide plans the Regional Water Boards implement include the Thermal Plan, the Ocean Plan, and the Nonpoint Source Management Plan. The Regional Water Boards also implement several state wide policies, including the Policy with Respect to Maintaining High Quality Waters in California (Resolution No. 68-16) often referred to as the "anti-degradation policy", and the Sources of Drinking Water Policy (Resolution No. 88-63), both of which are important policies with respect to the Big River watershed.
6. **Surveillance and Monitoring.** The effectiveness of a water quality control plan cannot be judged without information supplied by a strong and systematic surveillance and monitoring program. This section describes the goals and objectives of the water quality monitoring programs, and discusses in general terms each of the various types of monitoring conducted in the north coast region to ensure water quality protection. Also included in this section is discussion of the statewide monitoring programs, including the Toxic Substances Monitoring Program, the State Mussel Watch Program, and SWAMP. With the respect to the NCWAP assessment of the Big River, the SWAMP program is directly involved in feeding current water quality data to the assessment.
7. **Appendix Section.** This section includes a summary of Basin Plan amendments, the full text of various waivers of waste discharge requirements for the north coast region, and the full text of each of the various plans and policies described in the Basin Plan and in item 5 above.

For the NCWAP assessment, the Regional Water Board's role is defined by our legislative authority over water quality protection. This entails assessing the water quality with respect to water pollution, general water chemistry, water temperature, and in-stream sediment. Although every watershed in the north coast region has some unique and some common beneficial uses, some of the most sensitive beneficial uses in the Big River watershed are those related to cold water fisheries. Specifically, anadromous fish appear to be sentinel species that respond to the

types of chronic degradation of water quality seen in many watersheds in the north coast region. Therefore, although all of the beneficial uses of the Big River are considered in this assessment, the focus is water quality conditions with respect to anadromous fish habitat.

To ensure that all of the beneficial uses are protected, the water quality criteria used for the Big River watershed assessment are discussed in the Water Quality Criteria section, beginning on page 28.

Summary of Assessment Process

The assessment process involves four basic steps, as outlined below:

1. *Collection and gathering water quality data and other pertinent information.*
   This involves collection of new data, gathering existing data internally or from other agencies, landowners, etc. In some cases, there may be related information that is not numeric, but useful to the assessment process. This is discussed in further detail in the Data Sources section.

2. *Compile and assess the data based on the data quality.*
   Once the new data have been collected and the existing data have been gathered, all of the data are compiled to prepare it for analysis. Each of the references reviewed is cataloged in a database and raw/summary data are compiled into spreadsheets or some other electronic file appropriate for the data type. At this point, the data are also reviewed for data quality to determine the level of confidence in the data for use in the assessment. The data are then analyzed and compared to various criteria that have been established. This is discussed in further detail in the Water Quality Criteria, the Data Analysis Methods, and the Limitations and Data Quality sections.

3. *Form hypotheses based on the water quality data.*
   Where possible, hypotheses are drawn on the stream conditions based primarily on the water quality analysis. This is discussed in detail in the Data Analysis Methods section, and in general in the Summary of Issues, Conclusions, and Recommendations section.

4. *Confirm/refute hypotheses during the synthesis process with data from other NCWAP team members and draft the synthesis report.*
   Once the individual water quality assessment report has been drafted and preliminary hypotheses have been formed, each of the NCWAP agencies meet to create a "synthesis report". During the report synthesis, the hypotheses are tested against the data and findings from the other agencies to provide additional evidence that will either support or detract from the hypotheses. At this point, each of the agencies will combine the knowledge and data into a single comprehensive synthesis report that covers all of the disciplines brought to the table by the NCWAP agencies. The discipline specific report and the combined synthesis report is then reviewed internally until a draft is released for public review.

Data Sources

The Regional Water Board compiled and evaluated existing data that are available and also collected new water quality data. The data analysis in this water quality assessment includes basic water chemistry, water temperature, in-stream sediment, and biological parameters. Although the data gathering, data collection, and data analysis techniques are explained in the following sections, additional detail can be found in the NCWAP methods manual (CARA 2001).

All of the raw data that was used in this assessment has been compiled and integrated into KRIS Big River for future access by interested parties. A summary of this data is also available in the Figures and Summary Data Tables sections of this assessment.

Data Reviewed In-House

Within the Regional Water Board, there are four divisions, each with distinct responsibilities in the various areas of water quality protection. These four divisions are the Timber Harvest Division, the Regional Watershed Management Division (under which NCWAP is run), the Watershed Protection Division, and the Cleanups and Special Investigations Division. Various units within each of these divisions compile data for program specific needs. However, these data are also available to the public and the entire organization (including NCWAP). Therefore, this section discusses the internal sources of pre-existing data that were used in the assessment of the Big River.

Under the Watershed Protection Division, the Regional Water Board administers several federal and state permits for discharges on work in and out of the stream channel that could potentially harm water quality. For any discharge that affects the "waters of the State" (which includes surface and groundwater), the Regional Water Board must issue WDRs. If the discharge also happens to go to surface waters, it requires a dual WDR and NPDES permit. Whereas the WDR is a State permit, the NPDES permit is a federal permit that is administered by the State. Both the WDR and NPDES permits typically set out the conditions of discharge and establish a water quality monitoring program. If a monitoring program exists, the data generated by this program could be useful for a watershed assessment.

At the time of this assessment, there has been only one WDR/NPDES permit issued in the Big River watershed. This is a permit for the City of Mendocino Sanitary District (CAD 980584916), which primarily covers effluent discharges to an ocean outfall. However, since this outfall is not expected to have any noticeable impact on the Big River watershed, the data from this facility were not evaluated.

The only WDR that was found in the Big River watershed that contained provisions for a water quality monitoring program was a permit for the California Department of Transportation (WDR 95-1, WDID 1B94029RMEN) for work on the Highway 1 bridge that spans the mouth of the Big River. Data specified for collection included total suspended solids (TSS), settleable solids, turbidity, and pH. However, at the time of this assessment, there was no record of any data collection under this permit.

The Regional Water Board also administers federally funded grants for watershed restoration programs. Two such grants, which are named after their respective sections in the Federal Clean

Water Act, are the 205(j) and 319(h) grants. 205(j) grants fund water quality planning projects to reduce, eliminate, or prevent water pollution and to enhance water quality. 319(h) grants fund watershed management and implementation projects to reduce, eliminate, or prevent water pollution from non-point sources and to enhance water quality.

The Regional Water Board also administers various grants in the North Coast Region, such as the proposition 13 grants. Proposition 13 grants are used to support safe drinking, water quality, flood protection and water reliability projects throughout the state.

In some cases, 319(h), 205(j) or proposition 13 funded projects will have water quality data associated with them. However, as of the date of this assessment, there have been no 319(h), 205(j) or proposition 13 grants in the Big River watershed.

Under the Timber Harvest Division, there is extensive summary data in the form of timber harvest plans (THPs) on file. In the context of NCWAP, these THPs are primarily useful in that they provide summary water temperature information on various streams and also give us a good indication of what raw water temperature data exist. There are also some watershed specific files that the Timber Harvest Division has compiled that were used in this assessment. However, these were primarily summary information only and usually only contain water temperature information. A complete list of the THPs reviewed can be found in the Document Data Catalog section on page 126.

Under the Regional Watershed Management Division, the TMDL unit has extensive files on watershed specific water quality monitoring (where it exists), and also the more generally applicable studies on water quality related subject matter such as sediment and water temperature. A complete list of the documents in the TMDL files that are applicable to the Big River watershed can be found in the Document Data Catalog section on page 126.

Finally, under the Cleanups and Special Investigations Division, there are extensive files on sites of spills, leaking underground tanks, and other toxic releases. While in general these files were not used in this assessment, there has been one instance of a tanker truck spill in the Big River watershed. During this type of event, there typically is extensive water quality data collected until the Regional Water Board determines that “no further action” is necessary because the water meets applicable objectives with respect to anthropogenic pollution.

Data Gathering

Data gathering is the process of compiling existing data, which comes primarily from landowners, Regional Water Board files, and other agency files or databases. As data are gathered, the location and general characteristics of the data was catalogued in a database regardless of if it was directly applicable to the Regional Water Board portion of the watershed assessment. This was done to track internal data and also to provide a record of the data that are reviewed. All of the catalogued data are made available to the other NCWAP agencies for their use and is included in this report (see the Document Data Catalog section, beginning on page 126).

California Department of Health Services (DHS)

Water column chemistry samples were collected for the California DHS Community Well database by the operators of the respective water systems. In the Big River watershed, only two surface water sites were sampled; one in the Lower Big River subbasin (Vista Water Company), and one in the North Fork Big River subbasin (CDF Chamberlain). The Vista Water Company

site had 3 samples collected, one in 1988, 1993, and 1994. The CDF Chamberlain site had 14 samples collected at various times between 1991 and 2000.

A summary of the available data for the DHS sites are presented in Table 30 on page 180. The locations of the DHS water column chemistry sites are shown in Figure 35 and Figure 38, beginning on page 147.

Coastal Forestlands (CFL)

Water temperature data compiled by the Forest Science Project (FSP) included data on land that is currently owned by Pioneer Resources. However, the land was owned by Coastal Forestlands when FSP was actively compiling data from this landowner (1996-1998). Coastal Forestlands sold their land in the Big River to Pioneer Resources in July 1998.

Water temperature data was collected in the Upper Big River and North Fork subbasins for 1996-1998, as identified in Table 29 on page 178. It is unknown if data was collected by CFL in the years prior to 1996. However, no new data has been collected by Pioneer Resources since it purchased the land in the Big River.

The locations of the CFL water temperature sites are shown in Figure 32 and Figure 33, beginning on page 144. It should be noted that from this point forward, all CFL water temperature monitoring sites are designated as "FSP" sites (i.e. FSP 5234). This was done to reflect the fact that the data provider was FSP.

Forest Science Project (FSP)

FSP was actively compiling and analyzing water temperature data in the North Coast area from 1990 to 1998. During one or more years over this time period, all of the major landowners in the Big River watershed contributed water temperature data for each of the Big River subbasins. This included Jackson Demonstration State Forest (JSF), Louisiana Pacific, Georgia Pacific, and CFL. Subsequently, Louisiana Pacific sold their land in the Big River to the Mendocino Redwood Company (MRC); Georgia Pacific sold their land in the Big River to Hawthorne Timber Company (HTC); and CFL sold their land in the Big River to Pioneer Resources.

In most cases, the original data was available from the data contributor and was therefore used for this assessment. However, in the case of CFL, the water temperature data was taken directly from FSP because we were not able to contact any CFL representatives who could provide us with raw data or collection protocols.

Graham Matthews & Associates (GMA)

As part of the US EPA TMDL for the Big River, Graham Matthews & Associates (GMA) was subcontracted to develop estimates of sediment loading in the Big River watershed. As a result of this work, GMA collected original data in the form of bulk sediment samples, turbidity sampling, and suspended sediment sampling. GMA also measured flow during some of the sampling events. Bulk sediment sampling was conducted at a total of eleven sites by GMA in 2000 (GMA 1-GMA 13, except GMA 3 and GMA 6). Turbidity sampling, suspended sediment sampling, and flow measurements were taken at nine sites by GMA in 2000 and 2001 (GMA 1-GMA 9). A summary of the available data for the GMA sites are presented in Table 30 on page 180.

GMA had one or more sites in each of the Big River subbasins, the locations of which are shown in Figure 35 through Figure 39, beginning on page 147.

Hawthorne Timber Company / Campbell Timberland Management (HTC)

HTC acquired holdings of the Georgia Pacific (GP) Corporation in 1999, which primarily consists of land in the Lower and Middle sub-basins in the Big River. Collectively, GP and HTC have monitored fine sediment at two sites (BIG 4, BIG 8) in 1996, 1997, and 2000. Fine sediment was also monitored at BIG 8 in 2001. At both sites, fine sediment monitoring consists of stream substrate samples using a McNeil bulk sampler. A summary of the available sediment data for the HTC sites are presented in Table 30 on page 180.

Monitoring of water temperature began in 1993 by Georgia-Pacific and is continued currently by Campbell Timberland Management, who manages the timberland for the Hawthorne Timber Company. Water temperature was monitored during one or more years at each of HTC's monitoring sites in the Big River, as identified in Table 29 on page 178.

The locations of the HTC water temperature monitoring sites are shown in **Figure 30** and **Figure 31**, beginning on page 142. The locations of the HTC in-stream sediment monitoring sites are shown in **Figure 35** and **Figure 36**, beginning on page 147.

Jackson Demonstration State Forest (JSF)

The Jackson Demonstration State Forest (JSF) covers large portions of the Lower and North Fork subbasins of the Big River, as well as Caspar Creek, the Noyo River watershed and other coastal watersheds in the area. In 1994, JSF monitored water temperatures in upper and middle James Creek along with the Lower North Fork Big River. It is reported that JSF began a regular water temperature monitoring program in 1995 to assess summer stream temperature at many locations in JSF using Onset Hobo, Stowaway, and Optic StowAway temperature sensing probes. However, data for 1995, if it exists, was not found for this assessment. Water temperature monitoring has been conducted and was available from 1996 through 2001 at locations in the Lower and North Fork subbasins. However, the data for 1999 was lost and is not available. A summary of the available water temperature data for the JSF sites are presented in Table 29 on page 178.

On May 13, 1995, a one time benthic macroinvertibrate sampling was conducted on Lower Little North Fork Big River at the Mendocino Woodlands Camp. A total of four teams of students collected specimens at this site.

Channel characteristics were also recorded in the lower portion of the Little North Fork as part of a 1995 timber sale at Wonder Crossing. This also included quantification of pool dimensions, large woody debris volume in the active channel and embeddedness over a 3.5 mile section of the Little North Fork. The survey worked upstream from the upstream-most cabin area of Mendocino Woodlands. A total of 70 samples were taken, with 10 samples collected at each 0.5 mile interval. For the water quality assessment, only embeddedness would typically be evaluated by the Regional Water Board. However, there is little information on the emdeddedness collection protocol, so this information was not used. There has been no water quality or in-stream sediment sampling (other than embeddedness) done by JSF.

The locations of the JSF water temperature monitoring sites are shown in Figure 30 and Figure 33, beginning on page 142. The location of the JSF macroinvertebrate monitoring site is shown in Figure 35, beginning on page 147.

Mendocino County Water Agency (MWA)

Water temperature data for the South Fork subbasin were made available for this assessment by the Mendocino County Water Agency (MWA). MWA provided stream temperature data for two sites in the Big River for 1999, 2000, and 2001. A summary of the available water temperature data for the MWA sites are presented in Table 29 on page 178.

The locations of the MWA water temperature monitoring sites are shown in Figure 34 on page 146.

Mendocino High School, School of Natural Resources (SONAR)

As of the date of this assessment, no new water quality information has been collected in the Big River. However, it is anticipated that some water quality data will be collected and available in the future.

Mendocino Redwood Company (MRC)

MRC contributed water temperature and various in-stream sediment data. Water temperature data was collected by MRC between 1992-2001 in the Middle, Upper, North Fork, and South Fork subbasins. Data included that collected by Louisiana Pacific Lumber Company during the 1992-1997 period before the land was purchased by MRC. A summary of the available water temperature data for the MRC sites are presented in Table 29 on page 178.

MRC also studied channel geometry and in-stream sediment at five stream segments in the Big River watershed in 2000. This included stream cross-sections, thalweg profiles, pebble counts, and bulk sediment sampling, as identified in Table 30 on page 180.

The locations of the MRC water temperature monitoring sites are shown in **Figure 31**, **Figure 32**, **Figure 33** and **Figure 34**, beginning on page 143. The locations of the MRC in-stream sediment monitoring sites are shown in Figure 36, Figure 38, and Figure 39, beginning on page 148.

North Coast Regional Water Quality Control Board (Regional Water Board)

Various water quality samples were collected at one site on the mainstem of the Big River between 1959 and 1988. This data is available at the Regional Water Board office and also in US EPA's Legacy StoRet database, which is available on US EPA's website.

Various in-stream sediment and related measurements were also taken in Berry Gulch in 1992. The parameters measured include reach slope, D_{50}, V*, and various parameters related to pools and large woody debris.

Additional water quality samples have been collected at various sites on and near James Creek as part of a monitoring program instituted after a waste oil tanker truck overturned on Highway 20. This monitoring began in 2001 immediately following the accident and is still in progress.

Finally, the Regional Water Board collected water quality samples at three sites in the Big River watershed in 2001. A total of two rounds of samples were collected under the SWAMP program for NCWAP.

A summary of the available water quality data for the Regional Water Board sites are presented in Table 30 on page 180. The locations of the Regional Water Board water quality monitoring sites are shown in Figure 35, Figure 38, and Figure 39, beginning on page 147.

United States Environmental Protection Agency (US EPA)

While the US EPA did not collect any original data on the Big River, it made data from USGS and the Regional Water Board available through its Legacy StoRet database. This is available on the US EPA's website and includes all of the data collected by USGS and the Regional Water Board at two closely located sites. For the purposes of this assessment, these sites are treated as one site because they are in close proximity to one another and appear to have only one small seasonal tributary discharging to the Big River between them. It is believed that this will have a negligible effect on water chemistry.

United States Geological Survey (USGS)

Various water quality samples were collected at one site on the mainstem of the Big River between 1960 and 1966, with additional sampling occurring in 1977. This data now resides in the USGS sample database and also the StoRet database, both of which are available at the respective agencies' website. However, the data in the StoRet database was used for this assessment, as it also contains the Regional Water Board data mentioned in the North Coast Regional Water Quality Control Board (Regional Water Board) section on page 15. Therefore, it is a more comprehensive database.

A summary of the available water quality data for the USGS site are presented in Table 30 on page 180. The location of the USGS water quality monitoring site is shown in Figure 35 on page 147.

Watershed Groups

Watershed groups active in the Big River include the Big River Watershed Alliance, Friends of Daugherty Creek and Big River, and the Mendocino Land Trust. At the time of publication, no data existed or were made available to the Regional Water Board from these or any other watershed group. The exception to this is extensive summary climatological data that was made available by a private citizen.

Data Collection

Data collection is distinguished from data gathering in that it discusses field work that is currently on-going or is complete but was done specifically for NCWAP. Data gathering is defined here as the process of compiling historical data.

The only data that falls into the data collection category is data collected by the Regional Water Board under the SWAMP program and data collected by a responsible party following the crash of a waste oil tanker truck on Highway 20.

North Coast Regional Water Quality Control Board (Regional Water Board)

The NCWAP and SWAMP programs collected new water quality related information that was designed in such a way that it could be directly used in the NCWAP assessments. During the assessment process, each of the other divisions at the Regional Water Board were also actively collecting information for their own programs. In many cases, the data collected by the other divisions also have direct use in the NCWAP watershed assessments.

During 2001, Regional Water Board staff collected water quality measurements two times in the Big River watershed. This sample collection and analysis was done under the SWAMP program by SWAMP and NCWAP staff. While in the field, staff recorded basic "point in time" water chemistry that included pH, specific conductance, temperature, turbidity, and dissolved oxygen. Grab water samples were also collected and analyzed by an independent, certified laboratory. Water quality parameters that were analyzed included chlorophyll-a, alkalinity, hardness, various metals, and other compounds shown in Table 45, Table 46, and Table 47 beginning on page 212. While we had hoped to collect stream channel information such as pebble counts, we were unable to accomplish this due to access and resource constraints.

In total there were three (3) SWAMP sampling points in the Big River Watershed in 2001: the mainstem Big River just below the confluence of the Little North Fork of the Big River; the North Fork of the Big River, just below the confluence with Chamberlain Creek; and Daugherty Creek, just below the confluence of the South Fork of the Big River. The locations of the Regional Water Board water quality monitoring sites are shown in Figure 35, Figure 38, and Figure 39, beginning on page 147.

Sample collection (including field measurements) was done in accordance with the protocols described in the Regional Water Board appendix to the NCWAP Methods Manual (CARA 2001). Laboratory analysis was done by a contract lab in accordance with the appropriate US EPA analytical method.

On February 27, 2001, an tanker truck containing approximately 7,000 gallons of used motor oil and diesel overturned on highway 20 at mile marker 21.76 (measured from the highway 1/highway 20 intersection at Fort Bragg). While some of the liquid remained on the roadway and adjacent unpaved shoulders, a portion of it ultimately discharged to a tributary to James Creek. In an attempt to stop continued discharge of pollutants to James Creek, a dam was constructed on the tributary. Water contained at the dam is run through a treatment system consisting of two in-series 55-gallon granular activated carbon drums. This removes organic pollutants prior to discharge of the treated water into the tributary downstream of the dam. In the event of high flows, two 24-inch pipes were installed in the top of the dam for overflow.

To monitor the containment and treatment of pollutants, nine monitoring locations were established that have been monitored or continue to be monitored. They include one location on the tributary above the spill site (before it crosses under highway 20); one location at the containment dam; one location at the discharge of the treatment system; one location at the 24-inch overflow pipe on the containment dam (sampled during high flows); one location on the tributary at the furthest point were oil was observed immediately after the spill (downstream of the dam); one location on the tributary approximately 50 feet upstream from the confluence with James Creek; one location on James Creek approximately 50 feet upstream of the tributary; one location approximately 50 feet downstream of the tributary; and one location on James Creek approximately ¼ mile downstream of the tributary (at Fire Road 100).

All samples that were collected in conjunction with this spill were processed using US EPA approved sampling and analysis techniques. Therefore, this data can be expected to be of high quality and reliability.

Field Collection Methods

This section consists of methods for all of the data contributors, grouped by parameter.

Channel Measurements

Several large landowners in the Big River watershed provided in-stream sediment and channel measurement data that are used in this watershed assessment. This included bulk sediment, permeability, thalweg profiles, pebble counts and stream cross-sections from MRC, and bulk sediment samples from HTC.

Thalweg Profile & Stream Cross-Sections

Mendocino Redwood Company

MRC studied channel geometry and in-stream sediment at five stream segments in the Big River watershed in 2000. Channel geometry was measured through the use of thalweg profiles in all of the stream segments and further defined by surveying multiple cross-sections along each of the thalweg profiles. The thalweg profiles were run for a length of 20-30 bankfull channel widths upstream from a known reference point, which defined the distance of the stream segments. Evidently, channel geometry measurements were also conducted by MRC in 1998 at or near the stream segments studied in 2000. Based on anecdotal descriptions of this field work, it appears as though this data was collected without permanent benchmarks, making repeatability difficult. In any case, the data from this survey was not available for this assessment. In each of the stream segments, pebble counts, McNeil bulk samples, and permeability measurements comprised the in-stream sediment measurements. The five stream segments studied were Daugherty Creek above the South Fork Big River, Lower Ramon Creek, South Fork Big River above the Big River, Big River below the North Fork Big River, and the Lower East Branch of the North Fork Big River.

For the thalweg profiles and cross section surveys, reference points that mark the upstream and downstream ends of the monitoring segments were permanently monumented using nails driven into trees that appeared stable. This allows for a more permanent “benchmark” that can be used in future surveys. Distances and azimuths from these benchmarks to the start of a thalweg or a cross-section survey were recorded. By doing this, it is possible to begin and end surveys in the exact same location each year. These also provide a place of “known” elevation that should not change over time. This will presumably increase accuracy and confidence in comparability of data between years.

Working upstream, the thalweg depth (elevation) and distance along the stream was surveyed. The thalweg is the deepest point of the flowing channel, excluding any detached or “dead end” scours and/or side channels. As specific landmarks were encountered along the reach, (e.g. tributary channels, particularly large pieces of woody debris, permanent survey stakes, armored bend, or other features of interest) the recorder made note of their location and size. Where a channel split into two components, the surveyor decided which was the main channel and then continued moving upstream (making measurements) along that channel.

Approximately every 5 to 8 bankfull channel widths along the thalweg profile, the location for a cross section survey was monumented and recorded in the thalweg profile survey notes. The cross sections were located across riffles on relatively straight reaches of channel. Cross sections

were surveyed from above the bankfull channel margins on both banks. Typically 2 to 4 cross sections were measured along each stream segment.

Cross section rebar pins were established at both ends of the cross section well above the flood-prone channel margin to monument the cross section location. The elevation and the distance from the left bank pin was measured at least every five feet or at any visually apparent topographic change along the cross section.

Pebble Counts

Mendocino Redwood Company

At each stream cross section a pebble count was conducted to determine the median particle size of the stream bed (D_{50}) by measuring 100 randomly selected pebbles along a single transect. The pebble counts collected in this manner may corroborate data collected by DFG and can provide a snapshot of the median size of surface material at the cross-section. When the median pebble counts at multiple cross-sections are reviewed as a whole, it may be an indicator of trends in the amount of fine sediment moving through the stream segment. However, it may not be comparable to pebble counts that are taken along multiple closely spaced transects, such as the pebble counts conducted by Knopp (1993). Further study is necessary to determine the comparability of these two different pebble count measurement techniques.

North Coast Regional Water Quality Control Board

In 1992, Chris Knopp and Regional Water Board conducted V* measurements in Berry Gulch (Knopp 1993). At the time of this study, Berry Gulch was described as a “Highly Disturbed” watershed. This was defined as “drainages that exhibited large areas of disturbed soil, unpaved, low slope roads, inconsistent or poor stream course protection, and inconsistent avoidance of unstable terrain” (Knopp 1993). Sample locations were stratified by geology, channel slope and channel substrate. Each of the 1,000-meter sample reaches were limited to areas of Franciscan geology with slopes from 1 to 4 percent and coarse gravel to small cobble substrates.

From the pebble count, Knopp determined the D_{50} within the respective reach. The D_{50} was determined using a modified Wolman Pebble Count within the bankfull channel. The count used 200 points per riffle, and included 3 riffles per reach. The particle size data was then tallied using Udden-Wentworth size classes.

Bulk Sediment Sampling

Mendocino Redwood Company

Bulk substrate samples (McNeil cores) were taken from four randomly selected pool tail-outs in each segment deemed suitable for spawning (i.e., not dominated by bedrock or covered in substrate too large for a fish to make a redd). Bulk substrate samples were taken at the permeability site closest to the thalweg of the channel (the deepest spot) in a given tail-out. Bulk substrate samples were collected using a modified McNeil sampler (a 12" cylinder placed on the streambed and worked downward as the sample is manually removed). The original McNeil sampler allowed for suspended material dislodged during the removal process to be included in the sample. This is done by using a stopper in opening to the McNeil sampler to retain the water, and therefore the suspended sediment, in the sample. Because the MRC methods do not use a stopper to retain the free water, it may slightly under-represent the finer fraction of the bed substrate (Hames et al. 1996).

To sort the streambed substrate samples, MRC used a gravimetric (dry sieve) method. This consisted of drying their gravel samples, weighing the total sample, and then passing the sample

through seven progressively finer screens (50, 25, 12.5, 6.3, 4.75, 2.36, 0.85 mm). The material retained on each screen was then weighed to calculate the percent finer for each size class. None of the size classes were truncated and the entire sample was used.

Hawthorne Timber Company / Campbell Timberland Management

Fine sediment monitoring by HTC consists of a collection of stream substrate samples using a McNeil bulk sampler. The HTC methods for McNeil sampling follow those recommended by Valentine (Valentine 1995), and the Timber-Fish-Wildlife Ambient Monitoring Program Manual (Schuett-Hames et al. 1994).

Samples were collected with a modified McNeil sampler (modified with a Koski plunger to avoid loss of core material) with a core measuring 15.5 centimeters (cm) in diameter, 13.5 cm in length and capable of holding 2547 cubic centimeters (cc) of material. Samples were taken from the pool/riffle juncture during the late summer and early fall low flows. Two riffles were sampled at each station (BIG 4 and BIG 8), with four cores taken at each riffle, for a total of eight cores per station. None of the core samples were truncated or separated into surface and subsurface; the entire core was used for analysis. These individual core samples were averaged and the geometric mean and Fredle index values were calculated by HTC. To classify the overall particle-size distribution of the sample based on a geometric progression, eight 30.5 cm frame-diameter sieves were used (63.0, 31.5, 16.0, 8.0, 4.0, 2.0, 1.0, and 0.85 millimeters (mm)). The sediment cores were wet sieved (volumetric method). However, correction factors were not applied, possibly causing a slight over-representation of fine sediment as water is increasingly retained with the finer fraction of a bulk sample. In-stream characteristics noted during collection were stream gradient and stream flow. As recommended by Valentine (Valentine 1995), measurements were taken along the second medial axis of the three largest rocks collected per individual core. If the largest particles were greater than 1/3 – 1/4 the diameter of the sampling core, a larger sampler with a core measuring 25 cm in diameter, 21 cm in length and capable of holding 10308 cc was used (ibid).

Graham Matthews & Associates

Bulk sediment sampling sites were designed by GMA to correspond closely with existing MRC sediment sampling sites for comparability. The following methods for data collection are taken primarily from excerpts in the Big River Sediment Source Analysis (Matthews 2001), and were supplemented with other protocols made available by GMA (Matthews 2002, Matthews personal comm.)

A total of 11 bulk sediment sampling sites were established in the Big River Watershed based on access permission and access availability (all weather roads) during storm events. To a large extent, the monitoring sites coincided with MRC bulk sediment sampling sites.

Bulk sediment samples were collected using methods similar to those used by MRC, except that the top surface layer was collected separately and 2 bulk sediment samples were collected at each site, instead of the 4 bulk sediment samples collected at each site by MRC. Once a site was selected, a transect was established. At each site, two bulk samples were taken along a transect in undisturbed locations which were characteristic of spawning areas. A modified McNeil method was used, where a 1.0 foot diameter cylinder was worked down into the gravel bed, and the bed material was removed into buckets until the hole was excavated to a depth of about 1.0 foot. The top surface layer, defined as the depth of the largest surface particle, was kept separate from the subsurface. Once removed, the samples were transported to a laboratory for analysis. Samples were oven-dried, split, sieved, and weighed in the lab. Sieving of material through the 2

mm size was done using a Gilson TS-1 Testing Screen. This screen allows up to one cubic foot of a sample to be sieved in a period of 3-5 minutes. The material finer than 2 mm was then weighed and split into quarters. One of the split samples was randomly selected and run through 8-inch sieves with a Gilson SS-15 Sieve Shaker. For several samples, multiple splits were sieved independently to verify that each split sample was truly representative of the entire fine fraction of the sample. For this assessment, modified McNeil samples performed by GMA are reported using subsurface particles only, as the surface particle fraction or the combined fraction were not available. Because the surface layer is often characterized as an armoring layer with larger size fractions, the absence of surface material data will likely skew the results to the smaller size fractions when compared to data collected by MRC.

Stream Bed Permeability

Mendocino Redwood Company

MRC measured gravel permeability in the Big River following the methods of Barnard and McBain (1994). A perforated standpipe was driven into the streambed to a depth of 25 cm, which was chosen as an intermediate depth for a coho redd. The perforations in the bottom of the standpipe allow the interstitial water in the streambed to flow into the standpipe up to the height of the stream surface. An electric pump was then used to draw a suction on the standpipe and evacuate 2.54 centimeters of water in the standpipe into a sealed graduated cylinder. The lowered hydraulic head in the standpipe induces interstitial water in the streambed to flow into the standpipe at a rate equal to the water flowing into the graduated cylinder. The flow into the graduated cylinder was measured and timed, resulting in values for flow rate. Through a calibration curve, these flow rate values can be related to gravel permeability in units of centimeters per hour (cm/hr), which describe the interstitial flow rate in the streambed. At each measurement location, repetitive measurements were taken until the permeability readings ceased to increase.

MRC determined through power analysis that a total of 26 permeability measurement locations were needed for each stream segment to predict the survival of emerging fry within 20 percent accuracy. In general, 26 permeability measurement locations were distributed equally among each of the pool tail-outs in each stream segment, with any extra measurements taken in tail-outs behind the deepest pool(s). On two of the five stream segments, only 25 permeability measurement locations were established (East Branch North Fork Big River [MRC S4], Daugherty Creek above South Fork Big River [MRC S1]). The measurement location in each pool tail-out was randomly selected from an evenly spaced 12 point grid. For example, if there are six pool tail-outs in a given stream segment, there might be four permeability measurements taken at each tail-out with the remaining two permeability measurements taken in the tail-outs behind the two deepest pools. In this example, the permeability measurements at each pool tail-out would consist of four randomly selected points in a 12 point grid with an additional two random grid points in the tail-out below the deepest pool. In all cases, the permeability measurements were adjusted for the viscosity of the water, which is a function of the water temperature. This required recording the temperature of the water at each location.

To calculate the overall permeability in each stream segment, the raw data had to be reduced. This consisted of calculating the median value from the multiple measurements taken at each grid point. These values are shown in Table 68 through Table 70, beginning on page 239. Then the median permeability value at each pool tail out was calculated by taking the median of the grid point medians in a given pool tail out. The median value of these pool tail out medians was then calculated to arrive at an overall median value for the stream segment. While it is not expected to be significantly different than taking the median value of all of the raw data, the

median of the medians was used to minimize the impact of very low or high values on the overall median value. To see the spread in the median pool tail out values, the 25th percentile and 75th percentile values for each stream segment were also calculated. The overall median permeability and the 25th and 75th percentile values were plotted in Figure 87 on page 176.

The overall median permeability values were used for direct comparisons against the other sites monitored by MRC, and also to relate the permeability values with chinook and coho survival to emergence. The findings of Tagart (1976) and McCuddin (1977) (as cited in McBain and Trush 2000), were used to derive a relationship between permeability and survival to emergence using the following best fit regression curve (r^2=0.8521):

$$PercentSurvival = 14.615 \times \ln\left(Permeability \frac{cm}{hr} \right) - 81.132$$

EQUATION 1: PERCENT SURVIVAL TO EMERGENCE

In a few cases, the survival index was a negative number. In these cases, the index was reported as zero. The survival relationship is an index of spawning gravel quality and interpretations based on this can be only considered preliminary. However, this is currently one of the few approaches that quantitatively links a biological relationship to permeability data.

V*

North Coast Regional Water Quality Control Board

In 1992, Chris Knopp and Regional Water Board conducted V* measurements in Berry Gulch (Knopp 1993). At the time of this study, Berry Gulch was described as a "Highly Disturbed" watershed. This was defined as "drainages that exhibited large areas of disturbed soil, unpaved, low slope roads, inconsistent or poor stream course protection, and inconsistent avoidance of unstable terrain" (Knopp 1993). Sample locations were stratified by geology, channel slope and channel substrate. Each of the 1,000-meter sample reaches were limited to areas of Franciscan geology with slopes from 1 to 4 percent and coarse gravel to small cobble substrates.

To arrive at V* values for a stream Knopp measured the residual pool volume of six pools per reach and calculated the average V* for the combined pools.

Water Temperature

Forest Science Project

Generally, if data was available from the landowner that collected it, that original data was used in this assessment. However, we were not able to contact CFL company representatives to obtain their data directly. As mentioned previously, because we obtained this data through a third party (FSP), we have designated all CFL data with an FSP prefix (e.g. FSP 5213).

Thus, because we were not able to confirm the collection protocols, the study design is unknown. The only requirements that FSP placed on data contributors was that the data was collected using a "continuous monitoring device capable of taking an integrated or instantaneous reading every 2.5 hours" and that monitors be placed in a class I or class II stream.

Mendocino Redwood Company
MRC also provided extensive water temperature data within the Lower, North Fork, Upper, South Fork sub-basins of the Big River for 1992-2001. Data included that collected by Louisiana Pacific Lumber Company during the 1992-1997 period before acquisition by MRC.

Data were collected using Onset StowAway® continuous water temperature monitors. Prior to placement in the stream, each temperature monitor was calibrated with a 0ºC ice bath to ensure proper response to temperature. Monitoring occurred during the summer months when the water temperatures are highest, and recorders were typically placed in shallow pools (<2 feet [ft.] in depth) directly downstream of riffles. Data collection intervals varied from 72 to 144 minutes, but the majority of probes were set to collect temperature measurements every 120 minutes. Generally, a 96 minute collection interval is used to ensure capture of the daily maximum water temperatures (T.E. Lewis et al 2000). As the collection interval increases beyond 96 minutes, the peaks may be missed and it becomes increasingly likely that the recorded daily maximum water temperatures are lower than the actual daily maximum water temperatures.

To accurately locate the water temperature monitoring sites, MRC also provided an ArcView map coverage of monitoring locations in the Big River watershed.

Mendocino County Water Agency
MWA used Onset Hobo® Temp water temperature monitors. Prior to placement in the streams, the temperature monitors were started and then immersed in an ice bath (0ºC) overnight. Although a National Institute of Standards and Technology (NIST) traceable thermometer was not used to check the temperatures during calibration, the response of this non-NIST thermometer has been checked against a NIST-traceable thermometer. Within two weeks, the temperature monitors were placed in the stream at the deepest locations with good shading. Deep, well shaded area are chosen due to an interest in refugia temperature. However, the temperature monitors are not necessarily placed in thermally well-mixed locations. Therefore, due to the potential for influences of groundwater and thermal stratification, the water temperatures recorded by the MWA may vary somewhat from the average water temperature conditions in their respective thermal reaches.

Units were placed in pools by hand at a depth of about 1.5 to 2.5 feet (actual depths, deepest water available is selected) and are typically tied to a rock and then covered with rocks. If this is not possible, they were tethered to rebar that was driven into the streambed or placed close to the bank and hidden beneath vegetation to prevent vandalism. At the time of deployment, the stream temperature, air temperature, pool depth and time was recorded. Probes were set to collect temperature measurements every 96 minutes. Generally, a 96 minute collection interval is used to ensure capture of the daily maximum temperatures (T.E. Lewis et al 2000). During retrieval the water temperature, air temperature, pool depth and time were recorded. After retrieval, the data set was checked for proper response to the room and ice bath temperatures recorded prior to placing the temperature monitors in the field. This extraneous data was then trimmed from the data set prior to analysis.

Jackson Demonstration State Forest
JSF covers large portions of the Lower and North Fork subbasins of the Big River, as well as Caspar Creek, part of the Noyo River watershed and other coastal watersheds in the area. In 1994, JSF monitored water temperatures in upper and middle James Creek along with the Lower North Fork Big River. It is reported that JSF began a regular water temperature monitoring program in 1995 to assess summer stream temperature at many locations in JSF using Onset

Hobo, Stowaway, and Optic StowAway® temperature sensing probes. However, data for 1995, if existing, was not found for this assessment. Water temperature monitoring has been conducted at select locations through 2001 (the most recent data set available for this assessment). However, the data for 1999 was lost and is not available.

The temperature probes were placed at sites intended to represent average temperature conditions for that portion of the watershed. Generally, the probes were anchored beneath rocks in well mixed areas of the stream channel thalweg or within 15 cm of the residual pool surface at the head of a pool. To avoid direct sunlight, the probes were placed in shaded locations Although not available for this assessment, air temperature was also monitored at some locations.

With the exception of data from 2001, each of the temperature monitors were checked for accuracy by calibrating them using an ice bath immersion. Data collection intervals varied from 60 to 96 minutes, but the majority of probes were set to collect temperature measurements every 96 minutes. Stowaways had the 'max' feature turned on which allows the unit to take multiple samples between the recording interval, but only records the maximum value during that interval.

FSP in Arcata was contracted to analyze and compile JSF water temperature data in 1996, 1997, and 1998. Although the data from 2000 and 2001 was not analyzed by FSP, it was available from JSF. For this assessment, FSP provided the 1996-1998 water temperature data, and a spatial point coverage of monitoring site locations. JSF provided the water temperature data from 2000 and 2001.

Hawthorne Timber Company / Campbell Timberland Management

Prior to placement, all temperature probes are calibrated for response to a 0ºC ice bath. All devices that exceed a maximum error of 2.3°F (1.3°C) are discarded. Generally the maximum error is considerably less. Temperature monitoring probes are placed in well-mixed areas that are out of direct sunlight. To keep the probes in-place, they are tethered to a piece of rebar driven into the streambed or to large rocks, typically near the bottom of the stream. Beginning in 2002, temperature monitoring will also include pairing the water temperatures probe with air temperature probes.

The majority of devices are from the HOBO H8 family of thermal data-loggers; the minority are optical StowAway devices, all of which are produced by the Onset corporation. Data collection intervals varied from 72 to 144 minutes, but the majority of probes were set to collect temperature measurements every 144 minutes. Generally, a 96 minute collection interval is used to ensure capture of the daily maximum temperatures (T.E. Lewis et al 2000). As the collection interval increases beyond 96 minutes, the peaks may be missed and it becomes increasingly likely that the recorded daily maximum water temperatures are lower than the actual daily maximum water temperatures.

However, it should be noted that the longer collection intervals were first established by GP before standard protocols had been developed for stream water temperature monitoring. The longer collection interval was established as biologists for GP experimented through trial and error to determine the optimal balance between the length of the entire period monitored and the interval. The memory in thermal data-loggers is limited; consequently, as the collection interval decreases (more captures per day), the length of the sampling period also decreases. Initially, GP biologists, reacting to the lack of available information on these coastal watersheds, programmed the devices to sample for 5 – 6 months, covering a longer sampling period but sacrificing some

resolution. As the program continued, the 144-minute interval was continued for consistency. In 2002, all HTC thermal data-loggers will capture data in 96-minute intervals.

Suspended Sediment & Turbidity

Graham Matthews & Associates
The following methods for data collection are taken primarily from excerpts in the Big River Sediment Source Analysis (Matthews 2001), and were supplemented with other protocols made available by GMA (Matthews 2002)

A total of 10 turbidity/suspended sediment/discharge sampling sites were established in the Big River Watershed based on access permission and access availability (all weather roads) during storm events. To a large extent, the monitoring sites coincided with MRC bulk sediment sampling sites.

Prior to sampling for turbidity and suspended sediment, it was first determined whether it was safe to collect depth-integrated samples (DIS) or only a grab sample. If DIS sampling was appropriate a US DH-48 Depth-Integrating Sediment Sampler was used for data collection, which had handles of different lengths depending on the flow depth. The stream was divided into 10-20 verticals for the DIS method. The sampler was lowered vertically into the flow at a uniform rate until it touched the bottom, and then it was raised at the same rate. Then the sampler moved to the next vertical and this process was repeated until the entire width of the wetted channel was sampled.

If a grab sample for turbidity or suspended sediment was taken, the sampler waded or leaned into the channel as far as was safe, and then dipped the sampler into the flow and tried to integrate one or more verticals as far out as could be reached. Sampling performed from bridges during high flows was performed with a rope-deployed US DH-59 sampler. Standard methods were used for sampling, although for the DH-59 sampler velocity criteria were occasionally exceeded. A tag line was not always set during sampling because of the number of samples, and instead the distance between verticals was estimated. At each sample site the location, time, stage, number of verticals, distance between verticals, and bottle number was recorded. Samples were stored in an ice chest or refrigerator until they were transferred to the laboratory for analysis. Processing and analysis of sediment data was modeled after Guy and Norman (1970), and Edwards and Glysson (1988).

Stream Discharge

Graham Matthews & Associates
In addition to collecting turbidity, suspended sediment, and bulk sediment samples, GMA also measured flow during some of the sampling events. The following methods for data collection are taken primarily from excerpts in the Big River Sediment Source Analysis (Matthews 2001), and were supplemented with other protocols made available by GMA (Matthews 2002).

A total of 10 turbidity/suspended sediment/discharge sites were established in the Big River Watershed based on access permission and access availability (all weather roads) during storm events. To a large extent, the monitoring sites coincided with MRC bulk sediment sampling sites.

In water year (WY) 2000, stream flow measurements (discharge) data were done manually, while in WY2001 (November 2000-April 2001) continuous dataloggers were installed at 4 of the 10 sites. For the continuous monitoring, all sites used Global WL-14 dataloggers. However, the continuous flow data was not made available for this assessment. Also, in WY2001 the California Department of Water Resources and the USGS re-installed a gauging station at the former "South Fork Big River near Comptche" site.

Manual stream flow measurements were taken using standard or modified USGS methods. Stream flow measurements were computed by converting gauge-height records to discharge records through the application of stage-discharge relationships that were created for each site. The stage of the stream was generally measured by fenceposts driven into the streambed. During the sampling of turbidity and suspended sediment, the river stage was measured from the water surface to the top of the fence post using a pocket surveyor's tape. Some of the sites had standard staff plates installed in the streambed. Most stage locations were surveyed to an established benchmark in case the sites were disturbed and the stage measurements had to be reestablished.

To establish the stage-discharge relationship for a specific site, measurements were obtained by wading at the location, although bridge measurements were obtained for one site. Stream flow equipment used when wading included a 4 foot top-set wading rod, JBS Instruments AquaCalc 5000-Advanced Stream Flow Computer, and either a Price AA or Pygmy current meter. Bridge measurements were taken with a bridge board, A- or B-reel, Aquacalc 5000, a 50 pound (lb) sounding weight, and a Price AA meter. The Price AA current meter was used where water velocity was over 3 feet/second and at locations where surging flow or poor hydraulics were encountered. This meter usually performs better in these locations because of its weight. It is not generally used in depths less than 1.5 feet, but due to the poor hydraulics and steep gradient of many of the sampling sites, the Price AA current meter was used in depths as shallow as 0.3 feet.

It was noted that due to the large number of study sites, some of the stream flow methods were modified (Matthews 2001). In order to streamline the time required to complete flow measurements, fewer verticals were taken than is standard. This allowed the field personnel to do more measurements in a day. Most discharge measurements consisted of 15 to 25 verticals, and were usually collected on the falling limb of storm hydrographs. Efforts were made to obtain at least one measurement near the peak of a large storm. Typically four to six discharge measurements were obtained at each site over a range of differing flows.

Water column Chemistry

Regional Water Board, USGS, DHS

Extensive data on water quality was extracted from the US EPA StoRet, USGS, and the DHS community well databases. While the USGS and US EPA databases contained much of the same information, it was found that the USGS database is not as complete as the US EPA StoRet database in that it did not contain the sampled collected by the Regional Water Board. Therefore, only the StoRet database was used for this assessment. Summary information on pesticide/herbicide use in Mendocino County was also obtained from the State of California Department of Pesticide Regulation (DPR).

The various water quality samples collected by the USGS and Regional Water Board (contained in the US EPA StoRet legacy database) were collected using accepted methods for the

parameters during the time period in which they were collected. In some cases, collection and analysis methods may have changed substantially through the years of record. However, the data is of adequate quality for the level of assessment presented here. Water quality issues noted by the analysis of this data is considered an initial indicator and should be followed up with a systematic sampling program using contemporary sampling and analysis techniques.

The water quality samples collected for the DHS community well database were collected by the operators of the respective water systems. For this reason, there is little data quality control of these samples. Therefore, water quality issues noted by the analysis of this data is considered screening-level and should be followed up with a systematic sampling program using US EPA approved sampling and analysis techniques.

Biological

Jackson Demonstration State Forest

Macroinvertibrate sampling was conducted by Dr. Vince Resh of UC Berkeley and a group of students using a close approximation of the field methods described using an older version of DFG's California Stream Bioassessment Proceedure (Harrington 1994). Sampling differed from this protocol in that macroinvertibrates were not collected from three locations along a transect across the stream, but rather in several locations along a few hundred feet of stream by four student teams. Sampling was not exactly three minutes at each location. A strict subsample of the complete collection was not analyzed, but rather an informal subsample was made of subsamples collected by several students.

Raw data was provided from one of the four student teams, as shown in **Table 57** on page 229. The analysis of this subset of data was done as described in Harrington & Born (2000), using more current stream bioassessment procedures. Due to the small sample size and variations in the sampling technique, the summary data presented in **Table 58** on page 230 should be viewed as preliminary only. Other commonly used diversity indices (i.e. Simpson and Shannon) were not calculated due to a lack on information on species type. The information provided was only classified by family, which is less specific. Note that the EPT acronym in Table 58 refers to Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).

Water Quality Criteria

The water quality analysis included comparison of available data to water quality objectives from the Basin Plan, TMDL targets, Ecological Management Decision Support (EMDS) dependency relationships (thresholds), and other ranges and thresholds derived directly from the literature (and therefore not already incorporated by reference into one of the aforementioned documents). With the exception of the Basin Plan objectives, these ranges and thresholds are not enforceable. Rather, they are criteria based on information available at the time of this assessment and may change as new data, analyses, and research becomes available.

Basin Plan

As discussed in the Role of Regional Water Quality Control Board section on page 8, the Basin Plan has many components including descriptions of the beneficial uses for the specific water body, both narrative or numeric water quality objectives, and in some cases prohibitions on discharges to a specific water body. Each of these components is described in detail in the following sections, while primarily focusing on how they apply to the Big River watershed.

Beneficial Uses

The Basin Plan (RWQCB 2001) identifies the following existing beneficial uses of water in the Big River watershed:

- Municipal and Domestic Supply (MUN)
- Agricultural Supply (AGR)
- Industrial Service Supply (IND)
- Groundwater Recharge (GWR)
- Recreational Uses (REC-1 & REC-2)
- Commercial and Sport Fishing (COMM)
- Cold Freshwater Habitat (COLD)
- Wildlife Habitat (WILD)
- Migration of Aquatic Organisms (MIGR)
- Spawning, Reproduction, and/or Early Development (SPWN)
- Estuarine Habitat (EST)

The Basin Plan also identifies the following potential beneficial uses of water in the Big River watershed:

- Aquaculture (AQUA)

The beneficial uses identified above as COMM, COLD, MIGR, WILD, SPWN, and EST are all related to cold water fisheries in the Big River, the primary focus of this assessment. However, if data are available, we will relate the data to other beneficial uses such as Municipal and Domestic Supply (MUN), for which there are human consumption criteria.

The COMM beneficial use applies to water bodies in which commercial or sport fishing occurs or historically occurred for the collection of fish, shellfish, or other organisms, including, but not limited to, the collection of organisms intended either for human consumption or bait purposes. The COLD beneficial use applies to water bodies that support or historically supported cold water ecosystems, including, but not limited to, the preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates. The MIGR beneficial use applies to water bodies that support or historically supported the habitats necessary for migration or

other temporary activities by aquatic organisms, such as anadromous fish. The WILD beneficial use applies to water bodies that support terrestrial ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources. The SPWN beneficial use applies to water bodies that support or historically supported high quality aquatic habitats suitable for the reproduction and early development of fish. The EST beneficial use applies to water bodies that support or historically supported estuarine ecosystems, including, but not limited to, the preservation or enhancement of estuarine habitats, vegetation, fish, shellfish, or wildlife (e.g., estuarine mammals, waterfowl, shorebirds). The AQUA beneficial uses applies to water bodies that use water for aquaculture or mariculture operations including, but not limited to, propagation, cultivation, maintenance, or harvesting of aquatic plants and animals for human consumption or bait purposes.

Water Quality Objectives

Water quality objectives are necessary to protect those present and potential future beneficial uses stated above and also to protect existing high quality waters of the state. Narrative Basin Plan (RWQCB 2001) water quality objectives that are applicable to all watersheds in the north coast region, including the Big River watershed, are presented in Table 1 on page 30. Numeric Basin Plan (RWQCB 2001) water quality objectives that may be either generally applicable or specific to the Big River watershed are presented in Table 2 on page 31. However, each numeric water quality objective that is specific to the Big River is noted as such. As new information becomes available, the Regional Water Board will review the appropriateness of existing and proposed water quality objectives and amend the Basin Plan accordingly.

TABLE 1: NARRATIVE WATER QUALITY OBJECTIVES

OBJECTIVE	DESCRIPTION
Biostimulatory Substance	Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses.
Chemical Constituents	Waters designated for use as agricultural supply (AGR) shall not contain concentrations of chemical constituents in amounts which adversely affect such beneficial uses.
Color	Waters shall be free of coloration that causes nuisance or adversely affects beneficial uses.
Floating Material	Waters shall not contain floating material, including solids, liquids, foams, and scum, in concentrations that cause nuisance or adversely affect beneficial uses.
Oil and Grease	Waters shall not contain oils, greases, waxes, or other materials in concentrations that result in a visible film or coating on the surface of the water or on objects in the water, that cause nuisance, or that otherwise adversely affect beneficial uses.
Pesticides	No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses. There shall be no bioaccumulation of pesticide concentrations found in bottom sediments or aquatic life.
Radioactivity	Radionuclides shall not be present in concentrations which are deleterious to human, plant, animal or aquatic life nor which result in the accumulation of radionuclides in the food web to an extent which presents a hazard to human, plant, animal, or indigenous aquatic life.
Sediment	The suspended sediment load and suspended sediment discharge rate of surface water shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.
Settleable Material	Waters shall not contain substances in concentrations that result in deposition of material that causes nuisance or adversely affect beneficial uses.
Suspended Material	Waters shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses.
Tastes and Odors	Waters shall not contain taste- or odor-producing substances in concentrations that impart undesirable tastes or odors to fish flesh or other edible products of aquatic origin, or that cause nuisance or adversely affect beneficial uses.
Temperature	The natural receiving water temperature of intrastate waters shall not be altered unless it can be demonstrated to the satisfaction of the Regional Water Board that such alteration in temperature does not adversely affect beneficial uses. At no time or place shall the temperature of any COLD water be increased by more than 5°F above natural receiving water temperature.
Toxicity	All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in human, plant, animal, or aquatic life.

TABLE 2: NUMERIC WATER QUALITY OBJECTIVES

OBJECTIVE	DESCRIPTION
Bacteria	The bacteriological quality of waters of the north coast region shall not be degraded beyond natural background levels. Based on a minimum of not less than five samples for any 30-day period, the median fecal coliform concentrations in waters designated for contact recreation (REC-1) shall not exceed 50/100 ml. Nor shall more than ten percent of total samples during any 30-day period exceed 400/100 ml.
Dissolved Oxygen[1]	At a minimum, waters shall contain 7.0 mg/L at all times. Ninety percent of the samples collected in any year must contain at least 7.5 mg/L. Fifty percent of the monthly averages in any calendar year shall contain at least 10.0 mg/L.
pH[1]	The pH of waters shall always fall within the range of 6.5 to 8.5.
Specific Conductance[1]	Ninety percent of the samples collected in any year must not exceed 300 micromhos at 77°F. Fifty percent of the monthly means in any calendar year shall contain at least 195 micromhos at 77°F.
Total Dissolved Solids[1]	Ninety percent of the samples collected in any year must not exceed 190 mg/L. Fifty percent of the monthly means in any calendar year shall contain at least 130 mg/L.
Turbidity	Turbidity shall not be increased more than 20 percent above naturally occurring background levels.

[1] Numeric water quality objectives specific to the Big River watershed.

Specific dose related turbidity and suspended sediment numeric water quality targets or objectives are proposed, in addition to those already in the Basin Plan. When adopted, these watershed specific numeric targets or objectives would help identify suspended sediment exposure that may be harmful to optimal salmonid growth and survival.

If the surface water body is also a source of drinking water (a beneficial use designation of MUN), there are additional numeric water quality objectives for inorganic, organic and fluoride concentrations. These criteria, referred to as maximum contaminant levels (MCLs), can be found in part in Basin Plan Table 3-2. A complete list of primary and secondary MCLs established by the DHS can be found in California Code of Regulations, Title 22, Division 4, Chapter 15, Article 4. Additionally, separate MCLs are also established on a federal level by the US EPA.

Although DHS enforces the MCLs in public drinking water systems, the Regional Water Board typically applies the MCLs in a manner that protects source waters. For example, in cases of anthropogenic pollution, the Regional Water Board will enforce the MCLs at the point of discharge to waters of the state. Conversely, DHS regulates the contaminants in the drinking water system. In the case of the Big River watershed, there are no dischargers permitted by the Regional Water Board to discharge to surface waters. However, in those instances where anthropogenic pollution is detected through various water quality monitoring programs, the detections are compared to the primary or secondary MCL values for the polluting compound.

Ultimately, depending on the beneficial use designation of a waterbody, various other water quality criteria besides an MCL can apply.

Prohibitions

In addition to water quality objectives, the Basin Plan includes two discharge prohibitions specifically applicable to logging, construction, and other associated non-point source activities which cover the predominant land use in the Big River watershed. The prohibitions state:

1. The discharge of soil, silt, bark, slash, sawdust, or other organic and earthen material from any logging, construction, or associated activity of whatever nature into any stream or

watercourse in the basin in quantities deleterious to fish, wildlife, or other beneficial uses is prohibited.

2. The placing or disposal of soil, silt, bark, slash, sawdust, or other organic and earthen material from any logging, construction, or associated activity of whatever nature at locations where such material could pass into any stream or watercourse in the basin in quantities which could be deleterious to fish, wildlife, or other beneficial uses is prohibited.

TMDL Targets

Development and implementation of a TMDL is one means of attaining water quality objectives and protecting beneficial uses in the Big River. The TMDL program, required by Section 303(d)(1)(A) of the federal Clean Water Act, states, "Each State shall identify those waters within its boundaries for which the effluent limitations . . . are not stringent enough to implement any water quality standard applicable to such waters." The same part of the federal Clean Water Act also requires that the State "establish a priority ranking for such waters, taking into account the severity of the pollution and the uses to be made of such waters." The Big River was included on the 1998 list based on the finding that sedimentation is, in part, responsible for the impairment of the cold water fisheries. Section 303(d)(1)(C) of the federal Clean Water Act requires that "Each State shall establish for the waters identified in paragraph (1)(A) of this subsection, and in accordance with the priority ranking, the total maximum daily load..."

As part of California's 1998 303(d) list submittals, the Regional Water Board identified the Big River as impaired by sediment. As a result, the US EPA published a Big River TMDL for sediment (US EPA 2001). At the time of this assessment, the Regional Water Board has not yet adopted an implementation plan for the Big River sediment TMDL.

TABLE 3: NUMERIC TARGETS OUTLINED IN THE US EPA BIG RIVER TMDL

INDICATOR	TARGET	COMMENTS	PURPOSE
Instream	Monitoring recommendations: annually (e.g., sediment substrate, embeddedness, V*, aquatic insect abundance) or periodically following large storms (thalweg profile, pool distribution, turbidity, LWD)		
Sediment Substrate Composition	≤ 14% < 0.85 mm ≤ 30% < 6.4 mm	McNeil (bulk) sample during low-flow period, at riffle heads in potential spawning reaches	Indirect measure of spawning support: improved quality & size distribution of spawning gravel
Riffle Embeddedness	≤ 25% or improving (decreasing) trend toward ≤ 25%	Estimated visually at riffle heads where spawning is likely, during low-flow period	Indirect measure of spawning support; improved quality & size distribution of spawning gravel
V*	< 0.21 (Franciscan) or < 0.10 (other)	Residual pool volume. Measure during low-flow period.	Estimate of sediment filling of pools from disturbance
Thalweg profile	increasing variation from the mean	Measured in deposition reaches during low-flow period.	Estimate of improving habitat complexity & availability
pool/riffle distribution & depth of pools	increasing trend toward >40% length in primary pools	Primary pools (>2' in low order, >3' in 3rd & higher order), measured low-flow period.	Estimate of improving habitat availability
Turbidity	≤ 20% above naturally occurring background	Measured regularly, continuously, or during storm flows. Future data may suggest a modified turbidity indicator.	Indirect measure of overall water quality, feeding/growth ability related to sediment, protection of water supplies
Aquatic Insect Production	improving trends	EPT, Richness & % Dominant Taxa indices.	Estimate of salmonid food availability, indirect estimate of sediment quality.
Large Woody Debris (LWD)	increasing distribution, volume & number of key pieces	Increasing number & volume of key pieces or increasing distribution of LWD-formed habitat.	Estimates improving habitat availability
Watershed	Monitoring recommendations: prior to winter		
Diversion potential & stream crossing failure potential	≤ 1% of crossings divert or fail in 100 yr storm	Measured prior to winter.	Estimate of potential for reduced risk of sediment delivery from hillslope sources to the watercourse
Hydrologic connectivity of roads	decreasing length of connected road to ≤ 1%	Measured prior to winter.	Estimate of potential for reduced risk of sediment delivery from hillslope sources to the watercourse
Annual road inspection & correction	increasing proportion of road to 100%	Roads inspected and maintained, or decommissioned or hydrologically closed prior to winter. No migration barriers.	Estimate of potential for reduced risk of sediment delivery from hillslope sources to the watercourse
Road location, surfacing, sidecast	decreasing length next to stream, increased % outsloped and hard surfaced roads	See TMDL (US EPA, 2001)	Minimized sediment delivery
Activities in unstable areas	avoid or eliminate	Subject to geological/geotechnical assessment to minimize delivery or show that no increased delivery would result	Minimized sediment delivery from management activities
Disturbed area	decrease	See TMDL (US EPA, 2001)	Measure of chronic sediment input.

Source: US EPA Big River TMDL, 2001

As described in the TMDL for the Big River, the percent of fine material less than 0.85 mm in the channel is known to impact salmonids during the incubation stage. Once the eggs are laid and fertilized, the spawners cover the redds with material from upstream, including clean gravels and cobbles. The interstitial spaces between the particles allow for water to flow into the interior cavity where dissolved oxygen, needed by the growing embryos, is replenished. Similarly, the interstitial spaces allow water to flow out of the interior cavity carrying away metabolic wastes. However, fine particles either delivered to the stream or mobilized by storm flow can intrude into those interstitial spaces, blocking the flow of oxygen into the redd and the metabolic wastes out

of it. The reduced permeability into and out of the redd results in a reduction in the rate of embryo survival. The target of less than 14% fines in the less than 0.85 mm size class is generally supported by literature sources as a level that is reasonably protective, recognizing the fact that spatial and temporal variability exists around that value.

Similarly, the percent of fine material less than 6.5 mm in the channel is known to impact salmonids during the emergence stage. After 4 to 6 weeks, the embryos are ready to emerge from the gravel as fry (young swimming fish). The presence of fine sediment in the gravel interstices can impede fry emergence. However, the size of fine particles likely to fill the interstices of redds sufficient to block passage of fry are larger than those likely to suffocate embryos. That is, particles ranging from 0.85 mm to 9.5 mm are capable of blocking fry emergence, depending on the sizes and angularity of the framework particles, while still allowing sufficient water flow through the gravels to support embryo development. Besides a correlation between percent fines and the rate of survival to emergence, there is also a correlation between percent fines and the length of incubation; i.e., the amount of time it takes for the fry to emerge from the egg. Percent fines is also inversely related to the size of emerging fry (Chapman 1988). Each of these factors impacts the ultimate survivability of the embryos and fry. The target of less than 30% fines in the less than 6.5 mm size class is generally supported by literature sources as acceptable for survival to emergence, recognizing the fact that spatial and temporal variability exists around that value.

Another commonly used measure of habitat quality is the quantity of fine sediment in a pool, or V-star (V*). V* is the fraction (percent) of residual pool volume filled with fine sediment (silt, fine sand to small- to medium-gravel). It can be used as one of many indicators of the sediment supply and substrate habitat in gravel bed channels. It has proven to be a useful tool to evaluate and monitor stream channel conditions and determine upstream and upslope sediment sources (Knopp 1993; Hilton and Lisle 1993).

The TMDL target for V* in the Big River is less than 0.21 (Franciscan geology) or less than 0.10 (other), as shown in Table 3 on page 33. It should be noted that V* numeric thresholds were not adopted for use in the EMDS reach model. This model can sequentially choose from percent fine sediment (e.g. McNeil core samples), pool tail embededdness, and pebble counts or D_{50}s to evaluate substrate composition suitability for salmonid spawning. However, at this time, only percent fine sediment is being used in the EMDS reach model.

EMDS Targets

EMDS is a “knowledge-based expert system” that is used to evaluate data gathered and collected during NCWAP assessments. Essentially, EMDS is called a knowledge-based expert system because experts on the various factors that affect salmonid habitat have established a transparent, consistent set of logic parameters that the EMDS model uses to rate habitat conditions relative to salmonids. EMDS takes the data gathered for the watershed and, through a series of logic trees, evaluates the data with respect to watershed factors to assist in representing areas that are supportive of salmonids, and those that are not. Therefore, by running the EMDS model on a consistent set of criteria, a transparent “knowledge-based expert system” is created that will allow reviewers to easily see how NCWAP arrived at its determinations on the quality of salmonid habitat in the various streams.

To further document the logic behind EMDS, graphical diagrams of the EMDS logic network are used which show the relationships between the environmental factors and conditions for salmonids. These diagrams are intended to be explicit and intuitive, and to communicate the

process used in the synthesis in an understandable manner. A full diagram of the logic network can be obtained from DFG.

To evaluate data with respect to salmonid populations, specific criteria had to be developed to rate habitat conditions. The MWAT temperature range for "fully suitable conditions" of 50-60°F (10-15.6°C) used in the EMDS model was developed as an average of the needs of several cold water fish species, including coho salmon and steelhead trout (Armour 1991; Lewis, et al. 2000). As such, this range does not represent fully suitable conditions for the most sensitive cold water species (usually considered to be coho).

The water quality criteria used for the water quality model are shown below in Table 4.

TABLE 4: EMDS CRITERIA

EMDS CRITERIA	LOWER LIMIT	OPTIMAL CONDITIONS	UPPER LIMIT
Percent Fine Sediment			
Particles <0.85 mm	NA	<10%	15%
Particles <6.5 mm	NA	<15%	30%
Water Temperature (MWAT)[1]	40°F	50-60°F	68°F

[1] See Table 5 on page 37 for the distribution of EMDS thresholds between 60 and 68°F.
NA: Criteria not applicable

The EMDS model evaluated the water quality data based on these criteria using a "truth" curve with values from –1 (poor conditions) to +1 (good conditions). For example, if the MWAT for a location is within 50-60°F, the EMDS value is +1. However, if the MWAT for a location is less than 68°F but greater than 60°F, the EMDS value is somewhere between +1 and –1 which indicates that the water temperature is somewhere between optimal and poor. If the MWAT is greater than 68°F, the EMDS value will be –1, indicating that the water temperature conditions are not suitable with respect to salmonids. If no data (or insufficient data) are available, a neutral value of zero (0) is used. Typically, the maximum MWAT (if multiple years worth of data are available) is used for a given location in the reach EMDS model.

EMDS is explained in greater detail in the interagency Big River Watershed Synthesis Report, the NCWAP Methods Manual (CARA 2001), and is referred to in this document where applicable.

Literature Sources

Each of the documents previously mentioned, including the US EPA TMDL, the Basin Plan, and the EMDS model contain target values or water quality objectives that were developed based on previous original research. Therefore, these documents represent a compilation of previous research and were used for this assessment to establish target water quality values. This section discusses other original research that was used in this assessment but has not been incorporated into any of the previously mentioned documents.

In conjunction with other sediment measuring techniques mentioned previously in the TMDL Targets section, pebble counts can provide a good measure of the surface composition of the streambed. Pebble counts to determine the median particle size, or D_{50}, have long been used by hydrologists, geomorphologists, and others to characterize streambed material particle size distributions, usually in riffles, of wadable, gravel-bed streams. The pebble count procedure has been adopted in fisheries studies as a preferred alternative to visually characterizing surface particle sizes of riffles (Bundt 2001; Kondolf and Li 1992). Trends toward smaller sizes indicate influx of fine sediments and low stream power or transport capability overloaded by small

particles (inability to move new sediment through the area). Trends towards larger particles indicate a flushing of smaller particles and sediment transport capability exceeding the influx of new sediment.

Knopp (1993) calculated D_{50} values for various drainages in the North Coast region, as described in the Pebble Counts section on page 19. Knopp found for 18 index streams a range of D_{50}s of 37-183 mm, with an average of 69 mm. The Garcia River TMDL adopted targets of a minimum of 37 mm and an average of 69 mm as protective of salmonids for 3rd order streams. However, a TMDL numeric target for D_{50} has not been determined for the Big River. Therefore, the Garcia River TMDL values are used in this assessment as a measure of substrate quality in those cases where comparable data was collected in the Big River.

Much of the narrative water quality objectives found in the Basin Plan must be quantified using water quality criteria found in the literature. Marshack (2000) was used for this purpose. Essentially, this document is a compilation of available water quality criteria for a variety of organic and inorganic compounds. Generally, the most conservative applicable criteria is chosen and used to protect beneficial uses such as freshwater aquatic life, agricultural uses, and drinking water. By default, this value will also protect all other less sensitive beneficial uses.

Criteria Used for Assessment

The criteria used for the assessment of the Big River watershed is a compilation of criteria from the Basin Plan, the Big River TMDL, EMDS, and other literature sources as discussed in the previous sections. Therefore, the water quality assessment of the Big River watershed will discuss the state of the watershed according to comparisons to the appropriate water quality objective or target as noted in Table 5 on page 37.

TABLE 5: CRITERIA USED IN THE ASSESSMENT OF WATER QUALITY DATA

WATER QUALITY PARAMETER	RANGE OR THRESHOLD	REFERENCE
WATER COLUMN CHEMISTRY		
pH	6.5 - 8.5	Basin Plan, Table 3-1, p 3-7.00
Dissolved Oxygen	7.0 mg/L	Basin Plan, Table 3-1, p 3-7.00
Specific Conductance	≤ 90% of upper limit at 300 micromhos ≤ 50% of upper limit at 195 micromhos	Basin Plan, Table 3-1, p 3-7.00 Basin Plan, Table 3-1, p 3-7.00
Nutrients (Biostimulatory Substances)	No increase in concentrations that promote growths and cause nuisance or adversely affect beneficial uses	Basin Plan, p 3-3.00
General Inorganic & Organic Compounds	Various numeric and narrative Basin Plan objectives.	Basin Plan, Table 3-2 Various numeric criteria to implement Basin Plan narrative objectives as found in Marshack (2000). The numeric criteria used are also described in the Water Column Chemistry section beginning on page 45.
TEMPERATURE		
Water Temperature	No alteration that affects BUs[1] No increase above natural > 5°F	Basin Plan, p 3-3.00 Basin Plan, p 3-4.00
	MWAT[2] Range — Description 50-60°F — Fully Suitable 61-62°F — Moderately Suitable 63°F — Somewhat Suitable 64°F — Undetermined 65°F — Somewhat Unsuitable 66-67°F — Moderately Unsuitable = 68°F — Fully Unsuitable	EMDS[3]
	Daily Maximum — Description 75°F — Lethal	Cold water fish rearing, RWQCB (2000), p. 37
SEDIMENT		
Settleable Material	Cannot cause nuisance or adversely affect BUs[1]	Basin Plan, p 3-2.00
Suspended Material/Load	Cannot cause nuisance or adversely affect BUs[1]	Basin Plan, p 3-2.00, 3-3.00
Turbidity	No more than 20 percent increase above natural occurring background levels	Basin Plan, p 3-3.00
V* in 3rd order streams with slopes 1-4 %	≤0.21 (mean) <0.45 (max)	Big River TMDL, US EPA (2001) Knopp (1993)
Median particle size (D_{50}) in 3rd order streams of slopes 1-4 %	69 mm mean (for index yes/no streams) 38 mm mean (for highly disturbed streams)	Knopp (1993)
Percent fines <0.85 mm	<14% in fish-bearing streams[4] ≤10% - fully suitable	Big River TMDL, US EPA (2001)
Percent fines <6.4 mm	<30% in fish-bearing streams[4] ≤15% - fully suitable	Big River TMDL, US EPA (2001)

[1] BUs = Basin Plan beneficial uses
[2] MWAT= maximum average weekly temperature, to be compared to a 7-day moving average of daily average temperature
[3] EMDS = Ecological Management Decision Support model used as a tool in the fisheries limiting factors analysis. These ranges and thresholds were derived from the literature and agreed upon by a panel of NCWAP experts.
[4] Fish-bearing streams are streams with cold water fish species

It is worth noting that the criteria for fine sediment are based on wet sieve (percent by volume) determinations. In some cases, stream substrate cores are dry sieved, resulting in a percent by weight determination. The percent of fine sediment arrived at by wet sieving and dry sieving are sufficiently different so that the dry sieve results are not directly comparable to the target values. In those instances where the percent fine sediment was arrived at through dry sieving, it is explicitly noted.

All of the summary data are included in the Summary Data Tables section beginning on page 177. In instances where there are no numeric target or objective, the data is still included in this

section for future reference even if it is not discussed in this assessment. For example, there are some data for which there are only Basin Plan narrative objectives. However, these data are generally not charted or specifically discussed in this assessment unless a meaningful observation can be made.

Data Analysis Methods

All of the available data were compiled into electronic formats appropriate for the information, such as spreadsheets, databases, etc. The exact method of data analysis was specific to the data type and its quality. However, in general, during the analysis of the water quality data, data were evaluated for exceedences of the criteria established in Table 5 and other patterns or abnormalities in the data. Based on this analysis and the quality of the data, broader hypotheses about potential causes for the exceedences, patterns, or abnormalities were developed. Often, these hypotheses concerned factors that the other NCWAP partners were assessing. Therefore, as the synthesis of the data from each of the NCWAP agencies proceeded, the water quality data were evaluated in the context of influencing factors such as canopy for temperature and land use and/or erosional features/fluvial geomorphology for sediment. These larger scope multi-media evaluations are presented in the synthesis report. Thus the synthesis report is an interdisciplinary effort to recognize and hypothesize about the linkages and understanding the data in a broader context.

To the extent possible, all monitoring sites are referenced using the contributors identification number prefaced by the contributors acronym. For example, MRC provided a water temperature data for a site that MRC refers to as "74-1". In this assessment, that site is referenced as "MRC 74-1". If no site identifier is provided by the data contributor, a unique identifier was created and assigned to the monitoring location. In those instances where a numbering sequence already exists, that numbering sequence was continued.

Channel Measurements & Sediment Sources

For sediment parameters, we used data available for pebble counts, bulk sediment sampling, suspended sediment sampling, and turbidity sampling. We also utilized values in the preliminary sediment budget for the Big River (Matthews 2001) to estimate the up-slope contribution of sediment. These values enable us to draw some correlation with in-channel sediment conditions and up-slope activities.

The primary metrics used to analyze percent of fine material in core samples was percent less than 0.85 mm and percent less than 6.5 mm as shown in Table 5 on page 37. The thresholds were maximas of 14% and 30% by volume, respectively (US EPA 2001). We applied the TMDL targets where data was available in the appropriate size classes or data where other size classes could be reasonably evaluated. For example, the target for fines less than 6.5 mm states that the fraction of this size class in the total sample of stream bed material is less than 30% by volume. If the percentage of fines less than 4 mm was measured as 50%, then the target for the 6.5-mm size class was exceeded.

The data used for this analysis came primarily from bulk sediment sampling done by MRC, HTC, and GMA. Typically, after collecting a substrate core in the field, it is "wet sieved" in the field to separate the material into its various size fractions. While the dry sieve technique can be more accurate, wet sieving avoids the need to carry out what is sometimes hundreds of pounds of wet gravel for the dry sieve technique. Therefore, wet sieving has become common practice when analyzing core samples in the field.

When using the wet sieve technique, the material retained on each of the sieves is measured volumetrically. This allows for the "percent less than values" to be calculated on a volumetric

basis by using the volume retained on the sieve divided by the total volume of material sieved. With smaller size fractions, there can be significant error using the wet sieve method due to the amount of water retained by the particles (Shirazi, Seim, and Lewis, 1979). Therefore, for size fractions less than 4 mm, it is preferable to drain the material in the field or to collect a sample to determine density at a later date.

In the Big River watershed, the streambed substrate (bulk sediment sampling) data occurred at 15 sites. In some cases, the same site was sampled by both MRC and GMA. However, the MRC and GMA sediment cores were dry sieved and the HTC sediment cores were wet sieved. Because the TMDL target values were developed based on research using the wet sieved technique, we were not able to compare the MRC and GMA data to the TMDL target values. Even the MRC and GMA values could not be directly compared to each other because the GMA values did not include the surface material. In an attempt to describe the difference that removing the surface particles had on the size distribution, complete bulk sediment data sets for the Albion River were reviewed (Matthews 2001b). One would expect that removing the surface armoring layer would remove the larger rocks from the size distribution, substantially reducing the total sample volume and thus increasing the relative percentages in each of the smaller size classes. However, there was no apparent pattern to indicate how the removal of the surface material shifted the percentages in the size distribution. As a result, GMA bulk sediment data is not directly comparable to the MRC data, neither of which are comparable to the TMDL targets.

The HTC percent fine sediment values, because they were calculated using the wet sieve technique, were able to be directly compared to the TMDL targets for fine sediment in the sub 6.5 mm and 0.85 mm size classes. All of the data that was provided for this assessment was already reduced into the percent finer classes. No raw data was provided by any contributor. The HTC data is presented in Table 62 and Table 63 on page 234 and charted in Figure 79 through Figure 82 beginning on page 172. The MRC and GMA data is presented together in Table 64 through Table 67, beginning on page 235. The GMA data is also charted in Figure 75 through Figure 78, beginning on page 170.

With streambed substrate samples, it is important to keep in mind that conditions in a riffle may vary considerably and large sample sizes are needed to describe the conditions for salmonids. Nevertheless, streambed substrate samples can provide a perspective on the composition and dynamics of the streambed and add validity to other observations such as the embeddedness and dominant particle sizes data from habitat surveys done by DFG.

As discussed in the Water Quality Criteria section on page 28, other common techniques for measuring substrate particle size in streambeds include pebble counts and D_{50}'s. Unfortunately, there was no raw pebble count data and only one D_{50} data point calculated by Knopp (1993) in Berry Gulch and one D_{50} data point calculated by MRC at each of the stream cross-sections measured in 2000. In any case, because there is no D_{50} target or objective for the Big River and the D_{50} values for each site were only collected during one year, these values are only reported and not evaluated for salmonid suitability.

To be able to directly compare sediment input conditions from up-slope activities, subbasins were compared against one another using the calculated relative disturbance index and sediment input values by activity. Generally, the estimated sediment input values were converted to tons/mi^2/yr to eliminate the factors of watershed size and the number of years in the discrete time period analyzed. This enabled direct comparisons across time periods and between different planning and superplanning watersheds, regardless of size.

For the analysis, the 1989-2000 time period was evaluated (1989-2000) to determine the current source(s) of sediment. The sediment input values for this time period were further broken down into specific activities that contributed to the discharge to develop focused restoration and/or activity modification recommendations. If the subbasin being analyzed also had in-channel sediment data (e.g. bulk sediment data, pebble counts, etc.), the estimated sediment inputs were evaluated next to the in-channel sediment conditions in the attempt to draw associations.

It should be noted that in the preliminary sediment budget for the Big River (Matthews 2001), estimated background levels of sediment input were not reported by planning watershed. However, it was estimated over the entire watershed using several short discrete time periods within the overall study period (1921-2000). The long term background sediment input rate was estimated to be 315 tons/mi^2/yr, which consists of background landslides, surface erosion, and fluvial and bank erosion. It was further estimated that 175 tons/mi^2/yr of the total represents background landslides, 75 tons/mi^2/yr represents background surface erosion (soil creep), and 65 tons/mi^2/yr represents background fluvial and bank erosion. However, to discuss background sediment inputs over shorter time periods, these estimated values were adjusted with a factor that represented the hydrologic conditions of the shorter discrete time period. For example, during the 1989-2000 time period, the hydrologic conditions were such that a factor of 0.91 was applied to the input rates, yielding an adjusted background rate of 286 tons/mi^2/yr, an adjusted landslide rate of 159 tons/mi^2/yr, an adjusted soil creep rate of 68 tons/mi^2/yr, and an adjusted fluvial rate of 59 tons/mi^2/yr.

Finally, landslides picked up in the aerial photo analysis were assigned a mean thickness of 5.5 feet if road-related, and a mean thickness of 4.0 feet if non-road related. These values were based on field verified slides from an Albion River watershed analysis conducted by MRC (Matthews 2001). Earthflows were assigned a thickness of 10 feet, while rotation/translation slides were assigned a thickness of 25 feet. The resulting volumes were then converted to tons using a factor of 1.48 tons/yd^3 (Matthews 2001). Also, the 1936 aerial photographs were not available for the eastern portion of the watershed (Upper Big River, North Fork Big River, and South Fork Big River). Therefore, the 1921-1936 time period was not available for analysis in these subbasins.

The sediment sampling sites, including bulk sediment sampling, pebble counts, cross-sections and thalweg profile locations are shown in Figure 35 through Figure 39, beginning on page 147. All available raw data was imported into KRIS Big River for later use by the public.

Water Temperature

Water temperature data were typically collected through one of two techniques: grab measurements with a thermometer or continuous measurement with a data logger. Most of the grab measurements taken in the Big River watershed were done by DFG at every tenth habitat unit during stream surveys. However, for the purpose of evaluating the water temperature for suitability for anadromous fish, these data were not used. This is primarily because these measurements only represent a single point in time and are not useful for drawing any larger conclusions about the stream condition with respect to water temperature.

Continuous water temperature measurements were conducted by large landowners or government agencies. For this assessment, continuous water temperature measurements were available for various years and locations from 1990 to 2001. Because high water temperature can be a limiting factor with respect to cold water fisheries, summer data were evaluated to

capture the highest temperatures during the year. No temperature data were available for other times of the year, as it was assumed that water temperatures during non-summer months are not limiting for salmonids.

Prior to using the data, raw temperature charts were created for each data set and checked for abnormalities as shown in Table 6 and to trim out any erroneous data at the beginning or end of the data sets where the data loggers were exposed to air. In no cases were the data trimmed or modified other than at either end of the data set.

TABLE 6: CONTINUOUS WATER TEMPERATURE DATA REVIEW STEPS

REVIEW STEPS	PURPOSE
Plot raw data	Check data set for obvious abnormalities such as exposure to air. Check data irregularities against the same time period at other monitoring sites to determine if caused by climatological conditions.
Check data set for interruptions in the recording period.	Check if logger was removed from the water or stopped data collection, and if it would affect the quality of the summary data.
Record number of times that temperature exceeds 4°F (2.2°C) between measurements. Record the maximum of these fluctuations.	Check data for abnormalities such as exposure to air, stream withdrawals/discharges, data logger errors. The value 4°F was arbitrarily chosen as a screening number because it is an unusually large change in water temperature between measurements, which are typically 96 to 144 minutes apart.
Record the number of measurements that did not change between consecutive readings.	Check for data logger errors, dead or dying batteries, thermally stratified or groundwater dominate pools.
Record the seasonal maximum temperature for each data set. Any data sets that recorded temperatures in excess of 70°F were reviewed in closer detail.	Check data for exposure to air, or other abnormal conditions. Any exceedences of the lethal limit (75°F) were also recorded.
Check period of record and raw data plot for time of peak temperature.	If the raw data plot indicated that the peak temperature may have been missed, the data is generally not used as it would not be representative or comparable to other years or sites.
Record maximum diurnal fluctuation.	Assist in understanding of flow/shading conditions and check for exposure to air.

Analysis of data quality involved plotting all of the raw temperature files and verifying that the warmest part of the year was captured with reasonable certainty. The raw data plots are also useful in that they clearly show how the temperature changes at a specific site, which can lead one to hypotheses about flow and shading conditions. In some cases, particularly where a temperature monitor was placed in a short stream or gulch, the raw temperature plots can clearly show an atypical “flat” data record. Assuming that the data logger is operating properly, a flat data record suggests that the data logger may be recording a predominately groundwater flow regime with little or no surface flow, or a thermally stratified pool. This situation can occur when the data logger is placed in what becomes a partially or entirely isolated pool, or placed in a deep pool that is thermally stratified. The fact that this behavior was seen primarily in short streams or gulches, it is speculated that the former is true. In any case, if the data logger still appeared to respond to area wide temperature changes (as seen in other nearby sites), or if there were multiple years of data at a “flat” site to confirm the characteristics of the site, it was assumed that the data logger was recording representative stream conditions and was therefore used in this assessment.

Across all of the available water temperature monitoring sites in the Big River watershed between 1990 and 2001, the maximum water temperatures occurred between May 31 and September 10. However, on average, the maximum water temperatures occurred between the last week of June and the second week of August. Therefore, all of the data sets were checked to ensure that data collection began by June 21 and continued until at least August 15. The data sets were also checked visually to ensure that the highest temperatures appeared to have been

captured. If either one of these conditions were not met, the data was qualified or not used at all in those cases where the peak water temperatures were clearly missed. Potential data quality issues, including the resolution to the potential problem, are given in Table 36 through Table 40, beginning on page 190.

If the data did not exhibit any significant abnormalities, the summary values were then calculated. These summary values included: the maximum weekly average temperature (MWAT), the maximum weekly maximum temperature (MWMT), the seasonal maximum temperature, and the daily minimum, average, and maximum temperatures. The MWAT is the maximum value of a seven day moving average of the daily average temperatures. The MWMT is the maximum value of a seven day moving average of the daily maximum temperatures. Where we did not have the raw data set, we evaluated only the summary statistics provided to us by the contributor. Due to the large amount of data generated during the calculation of the daily minimum, maximum and average, these data are not presented in tabular form in this assessment. For the same reason, raw data are generally not included in either tabular or graphical form in this assessment. However, this raw data is made available to the public in the KRIS Big River database.

Other summary statistics were calculated for each data set, as described in Table 6 on page 42; including the number of times the water temperature varied by more than 4°F between consecutive measurements and the maximum diurnal temperature fluctuations. If the water temperature did fluctuate more than 4°F between consecutive measurements, then the maximum fluctuation was recorded. These statistics were used to help identify potential problems with the data and to better understand the dynamics of a stream at a particular monitoring location. For example, large fluctuations between measurements could indicate that the data logger came out of the water, was affected by discharges/withdrawals from the stream, or could possibly be the result of short term direct exposure to sunlight. In most cases where several large fluctuations were observed, they tended to be cyclical increases in temperature that occurred at the same time each day; primarily in the late morning or early afternoon. This type of repetitive, consistent temperature jump would suggest that the cause is not anthropogenic because the jumps happen at the same time for days or weeks in a row. This type of repetitive temperature effect is more likely climatological. It is speculated that it is due to rapid heating of the data logger by direct sunlight exposure or direct sunlight exposure to shallow water in the thermal reach, which then is recorded by the data logger. In the Big River watershed, no data loggers were placed in the estuary, where tidal fluctuations could be another influencing factor.

The maximum diurnal temperature fluctuation recorded at each site is related to climatological, flow (which is related to climatological conditions), and shading conditions. In many cases, the maximum diurnal fluctuations in water temperature tend to be similar between multiple years and can point to shading and/or flow conditions in that thermal reach. This parameter is useful in that it can assist in developing hypotheses about shading conditions at the various monitoring sites. In general, any diurnal fluctuations in the range of 0-6°F was considered good, >6-10 was considered moderate, and >10 was considered poor. These guidelines do not mean anything with respect to salmonids, but are used as a loose guide for interpreting flow and/or shading conditions in a thermal reach. Also, large changes in diurnal fluctuations between years may indicate some change in shading conditions.

Once the summary statistics were obtained, these values were compared against the water quality criteria shown in Table 5 on page 37. As indicated in this table, the calculated MWATs were compared against the EMDS targets. The seasonal maxima are also important to consider as

they may reflect short-term thermal extremes that, unless salmonids are able to escape to cool water refugia, may be lethal to fish. The literature supports a critical peak lethal temperature threshold of 75°F (24°C), above which death is usually imminent for most Pacific Coast salmonid species (Brett 1952; Brungs and Jones 1977; RWQCB 2000; Sullivan, et al. 2000). As a rule, if the instantaneous maxima at any site exceeded 70°F, the data record was scrutinized in detail as an additional data quality check to ensure that the data logger remained submerged.

To quantify the trend in the MWATs for each site, an "MWAT Trend" was calculated. This simple calculation consisted of subtracting the MWAT value for the current year from the value from the previous year. These values are then added together to arrive at the MWAT Trend. For example, if there are MWAT values for 1993 (58.60°F), 1995 (57.30°F), and 1998 (60.40°F), the MWAT value for 1993 is subtracted from the 1995 value (-1.3°F). Then the MWAT value for 1995 is subtracted from the 1998 value (+3.1°F). These two numbers are then added together to get the MWAT Trend (+1.8°F). For this assessment, any MWAT trend greater than 2°F was considered a significant trend and discussed in the subbasin analysis sections.

To provide a visual aid in analysis, a chart was made for each subbasin that summarizes the range of MWATs at a given site. For each stream, the monitoring sites are plotted in order from upstream to downstream. In addition, all of the EMDS thresholds are plotted on the same charts as a point of reference.

A complete list of temperature monitoring sites and years of data is given in Table 29 on page 178. Summary statistics for all of the water temperature sites are given in Table 31 through Table 35, beginning on page 182. The temperature monitoring sites are shown in Figure 30 through Figure 34 beginning on page 142. As mentioned previously, all raw water temperature data that was used in this assessment was imported into and is available in KRIS Big River.

Suspended Sediment & Turbidity

Another common metric to measure in-stream sediment are turbidity and suspended sediment. While both of these parameters were sporadically monitored in the Big River watershed, the samples were typically only grab samples and were relatively infrequent. The data that are available are charted for the respective sub-basin sections. While the amount of data available is insufficient to assess the impacts to the cold water fisheries and other beneficial uses in the Big River, the data did provide at least a preliminary look at the relationship between turbidity and suspended sediment in the Big River watershed. This relationship is shown in Figure 65 through Figure 74, beginning on page 165, for several sites sampled by GMA. The existing turbidity data is also useful in that it provides the beginning of the data that will be needed to eventually establish a baseline for this parameter.

The sediment sampling sites, turbidity samples, and suspended sediment samples, are shown in Figure 35 through Figure 39, beginning on page 147. All available raw data was imported into KRIS Big River for later use by the public.

Stream Discharge

While stream discharge rates were measured on one or more occasions at most of the GMA sites, many of the reported discharge rates were derived by GMA using a synthetic hydrograph. While the actual and derived discharge rates were provided for this assessment, this data was not used directly in any new calculations. Instead, this data was used in the context of the conclusions presented in the sediment source analysis for the Big River (Matthews 2001).

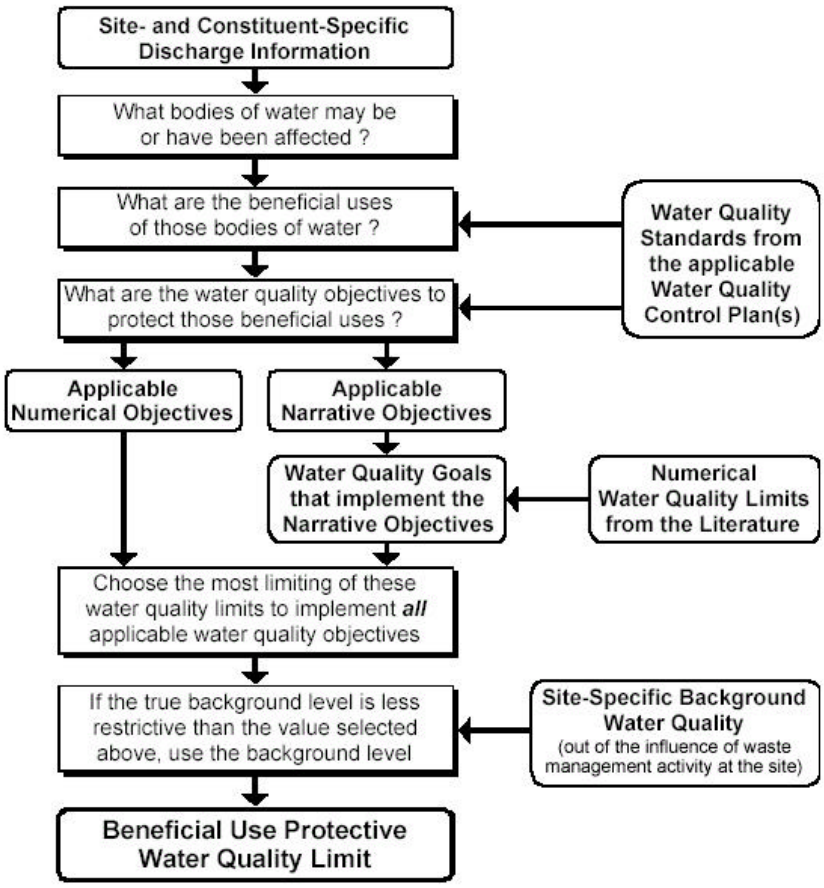
The discharge rates that were derived from the synthetic hydrograph are not presented in this assessment. However, the actual discharge measurements are shown in Table 59 through Table 61, beginning on page 231.

Water Column Chemistry

Water column chemistry samples were collected in the Big River watershed by the USGS, the Regional Water Board, and community drinking water system operators. In general, these samples were tested for basic water quality chemistry. Additional on-going sampling began after a tanker truck turned over on Highway 20 on February 27, 2001 and spilled approximately 7,000 gallons of recycled motor oil and diesel, some of which discharged to James Creek. The subsequent sampling consisted of testing for a variety of organic and inorganic compounds.

The analysis of water column chemistry is divided into parameters with numeric water quality objectives in the Basin Plan, parameters with narrative water quality objectives in the Basin Plan (which can be quantified using numeric criteria found in the literature), and other important parameters that may have applicable narrative water quality objectives, but no available numeric criteria. The applicable numeric water quality objectives found in the Basin Plan are contained in Table 5 on page 37. When quantifying narrative water quality objectives, any number of criteria can apply, depending on the designated beneficial uses for the water body. Therefore, these are only incorporated by reference and discussed in detail when used in this assessment. However, to help clarify the process of selecting numeric criteria, Figure 1 from Marshack (2000) is included below.

FIGURE 1: SELECTING BENEFICIAL USE PROTECTIVE NUMERICAL LIMITS IN WATER



Source: Marshack 2000

Normally, if selecting an *enforceable* numeric criteria, the lowest applicable value may not apply. For example, if an MCL and a PHG both apply to a selected beneficial use, the MCL will usually be the value used to enforce provisions of the Basin plan, even though the PHG value is typically lower. However, for the purposes of this water quality assessment, the most conservative scientifically-based criteria is used so that interested parties are fully informed. To assist resource managers in decision making, *all* applicable criteria is given in those instances where the most conservative scientifically-based criteria is exceeded.

The various categories of criteria used in this assessment has been defined below for ease of reference. More detail on these criteria, which were used to quantify the narrative water quality objectives, is available in Marshack (2000).

Action Levels

"Action levels, published by DHS, are based mainly on health effects. An incremental cancer risk estimate of 10^{-6} [an increase of 1 cancer case per 1 million people] *is used for carcinogens and a threshold toxicity limit is used for other constituents. As with MCLs, the ability to quantify the amount of the constituent in a water sample using readily available analytical methods may cause action levels to be set at somewhat higher concentrations than purely health based values. Organoleptic (taste- and odor-based) values are also included as action levels for some chemicals. Action levels are advisory to water suppliers. If exceeded, DHS urges the supplier to correct the problem or to find an alternative raw water source"* (Marshack 2000).

Integrated Risk Information System (IRIS)

"The US EPA Office of Research and Development, National Center for Environmental Assessment maintain a chemical data base called the Integrated Risk Information System. IRIS contains US EPA's most current information on human health effects that may result from exposure to various substances found in the environment. Two types of criteria are presented in IRIS. Reference doses (RfDs) are calculated as safe exposure levels with respect to non-cancer health effects. They are presented in units of milligrams of chemical per kilogram body weight per day of exposure (mg/kg-day)" (Marshack 2000). For this assessment, these values have been converted into drinking water concentrations using the assumption of 70 kg (154 lbs) body weight, 2 liters/day (0.5 gallons/day) consumption, and a 20% relative source contribution from drinking water.

Maximum Contaminant Levels (MCLs)

"MCLs are part of the drinking water standards adopted by the California Department of Health Services (DHS) pursuant t the California Safe Drinking Water Act. California MCLs may be found in Title 22 of the California Code of Regulations (CCR), Division 4, Chapter 15, 'Domestic Water Quality and Monitoring'. US EPA also adopts MCLs under the federal Safe Drinking Water Act. DHS's drinking water standards are required to be at least as stringent as those adopted by the US EPA. Some California MCLs are more stringent than US EPA MCLs.

Primary MCLs are derived from health-based criteria (by US EPA from MCL Goals; by DHS from Public Health Goals or from one-in-a-million [10^{-6}] incremental cancer risk estimates for carcinogens and threshold toxicity levels for non-carcinogens). MCLs also include technologic and economic considerations relating to the feasibility of achieving and monitoring for these concentrations in drinking waters supplies and at the tap…..Secondary MCLs are derived from human welfare considerations (e.g., taste, odor, laundry staining) in the same manner as Primary MCLs" (Marshack 2000).

National Ambient Water Quality Criteria (NAWQC)
"These criteria, also called the National Recommended Water Quality Criteria, are developed by the US EPA under Section 304(a) of the Clean Water Act [Act] *to provide guidance to the states in adopting water quality standards under Section 304(c) of the Act to interpret narrative toxicity standards (water quality objectives in California). These criteria are designed to protect human health and welfare and aquatic life from pollutants in freshwater and marine surface waters.*

[For the protection of freshwater and/or saltwater aquatic life] *two types of limits are presented. Criteria Maximum Concentrations (CMCs) protect aquatic life from acute exposures (expressed as 1-hour average or instantaneous maximum concentrations) to pollutants. Criteria Continuous Concentrations (CCCs) protect aquatic organisms from chronic exposures (expressed as 4-day or 24-hour average concentrations). To be able to derive these criteria, the US EPA method requires toxicity data for species representing a minimum of eight families of organisms, including both vertebrate and invertebrate species. Important aquatic plant species are also considered. Fundamental to the method is protection of all species, even at sensitive life stages, for which there are reliable measurements in the data set. Criteria derived by this method are also intended to protect species for which those in the data set serve as surrogates. Toxicity information, in the form of the lowest observed effect levels, is often presented in the US EPA criteria documents where there is insufficient toxicological information with which to develop recommended criteria.*

In December 1992, US EPA promulgated the 'National Toxics Rule', which updated many of these criteria and made them directly applicable standards for surface waters in many states, including California waters" (Marshack 2000). To ascertain compliance with the aquatic life protective criteria for metallic constituents, water quality samples are to be analyzed for total dissolved concentrations. Also, as described in the subbasin analysis sections, some of the criteria are not fixed values, as the toxicity to freshwater aquatic life is dependant on temperature, pH, or hardness of the water. Unless otherwise noted, the water quality grab samples were only compared to the CCCs (4-day or 24-hour average concentrations). These values are generally lower than the CMCs (1-hour average or instantaneous maximum concentrations), and represent limits on "normal" long term background conditions. Because the CCCs are typically lower, they also are the more conservative numeric criteria.

Suggested No-Adverse-Response Levels (SNARLs)
"These human health-based criteria were published by the National Academy of Sciences (NAS) in the nine volumes of 'Drinking Water and Health' (1977 to 1989). US EPA's health advisories were also formally published as 'SNARLs'. SNARLs do not reflect the cancer risk that may be posed by these chemicals. Incremental cancer risk estimates for carcinogens are presented separately in these NAS and US EPA documents. NAS criteria from 'Drinking Water and Health' may not contain the most recent toxicological information" (Marshack 2000).

While the preceding descriptions cover the bulk of the numeric criteria, the remaining numeric criteria used in the subbasin analysis sections (e.g., agricultural water uses, etc.) have been pulled together from a variety of sources, all of which are referenced in Marshack (2000).

The data analysis was done by reducing the raw data and generating summary statistics on the various water quality parameters. This data, to the extent possible, was compared to the criteria either directly or indirectly. In some cases, the periodicity of data collection did not lend itself

well to direct comparison to criteria that may have been developed differently. For example, the criteria for specific conductance assumes that there is adequate regular sampling to generate monthly and yearly medians. However, in most cases, the sampling is sporadic which makes direct comparisons to the criteria difficult. In these cases, the available sampling data were used to "screen" the water quality parameters for potential problems and are not directly compared to the criteria.

In all of the data sets, if any organic compounds were detected, they are discussed in the subbasin analysis sections. Compounds which are not discussed in the analysis, have been excluded because they were either not tested for, not detected, or not felt to be directly useful to the water quality assessment. However, all of the additional data beyond what is presented in the subbasin analysis is available in summary form in Table 42 through Table 56, beginning on page 201. In addition, all of the raw data is included in KRIS Big River.

A map of the water column chemistry monitoring sites are shown in Figure 35, Figure 38, and Figure 39, beginning on page 147. All available raw data were imported into KRIS Big River for later use by the public.

Biological

Biological sampling related to water quality consists primarily of macroinvertebrate and chlorophyll-A sampling. The population size and distribution of specific macroinvertebrates can be used as an indicator of stream health. Chlorophyll-A concentrations are typically used to determine algal content in the water, which in turn can be an indicator of excessive nutrient inputs into a stream.

For the Big River watershed assessment chlorophyll-A and macroinvertebrate data is presented, but the infrequency of sampling made these data of limited value for assessing suitability for salmonids.

Limitations and Data Quality

This section describes the assumptions or other limitations that are integral in this assessment, and provides examples of the process that was used to include or exclude data.

This assessment only addresses habitat conditions in the Big River watershed. Ocean habitat conditions are not addressed.

Monitoring of two water temperature sites on James Creek in 1994 was conducted by JSF. Although the raw data is not available, summary data such as MWAT and maximum temperature was reported (Valentine 1994). Neither of these sites appeared in the FSP data.

Many of the water temperature data loggers were set to collect data at 120 or 144 minutes. Previous research (Lewis et al. 2000) suggests that monitoring intervals greater than 96 minutes may result in missing the instantaneous peak temperatures. Therefore, it is possible that the MWMT and overall maximum temperatures may be slightly understate these values.

It is presumed that all of the monitoring locations, except the MWA sites, are representative of the conditions in their respective stream reaches. For example, for water temperature monitoring sites, it was assumed that the data loggers were placed in a location that was representative of the average summer water temperatures in their respective thermal reach. MWA's stated goal was to monitor thermal refugia for salmonids. Therefore, these temperature monitors were generally placed in deep pools and other areas where you would expect water temperatures to be lower than the average for the thermal reach.

In many sites throughout the Big River watershed, jumps in water temperatures in excess of 4°F were observed in consecutive measurements as shown in the summary statistics table in the Summary Data Tables section beginning on page 177. In no case was it determined that a data set should be excluded because of this temperature variation. In absence of any other abnormal data characteristics, it was hypothesized that the observed temperature jump was likely the result of sudden direct exposure of sunlight in the thermal reach. If this is the case, it would be naturally occurring and representative of stream conditions. However, study of these cyclical temperature increases should be undertaken to verify the cause.

Only surface water quality was assessed. In the instances where the streams are "gaining" (receiving groundwater input), the surface water will be a combination of surface run-off and groundwater. Therefore, surface water quality was assessed under the assumption that any influence from groundwater would appear in the overall surface water quality. Groundwater water quality data, if it exists, was not incorporated separately into this assessment.

As mentioned previously, the bulk sediment sampling for both MRC and GMA were collected using a gravimetric technique, which can lead to significantly different results from the volumetric technique that the Big River TMDL target is based on. Furthermore, MRC reported the gravimetric fractions of the entire bulk sediment samples, while GMA only reported the subsurface fractions of the samples. Therefore, even through data from MRC and GMA was reportedly collected in a similar manner, the data may be skewed relative to each other.

The primary types of information that was evaluated included data from continuous water temperature data loggers, water column chemistry data from field instruments and analytical laboratories, and McNeil, turbidity, suspended sediment or pebble count sediment data.

During the review of the raw water temperature data plots, it was noted that there were, in some cases, unusual diurnal fluctuations. A more extreme example of this type of issue is the HTC Big 8 water temperature record for 2001, as shown below in Figure 2.

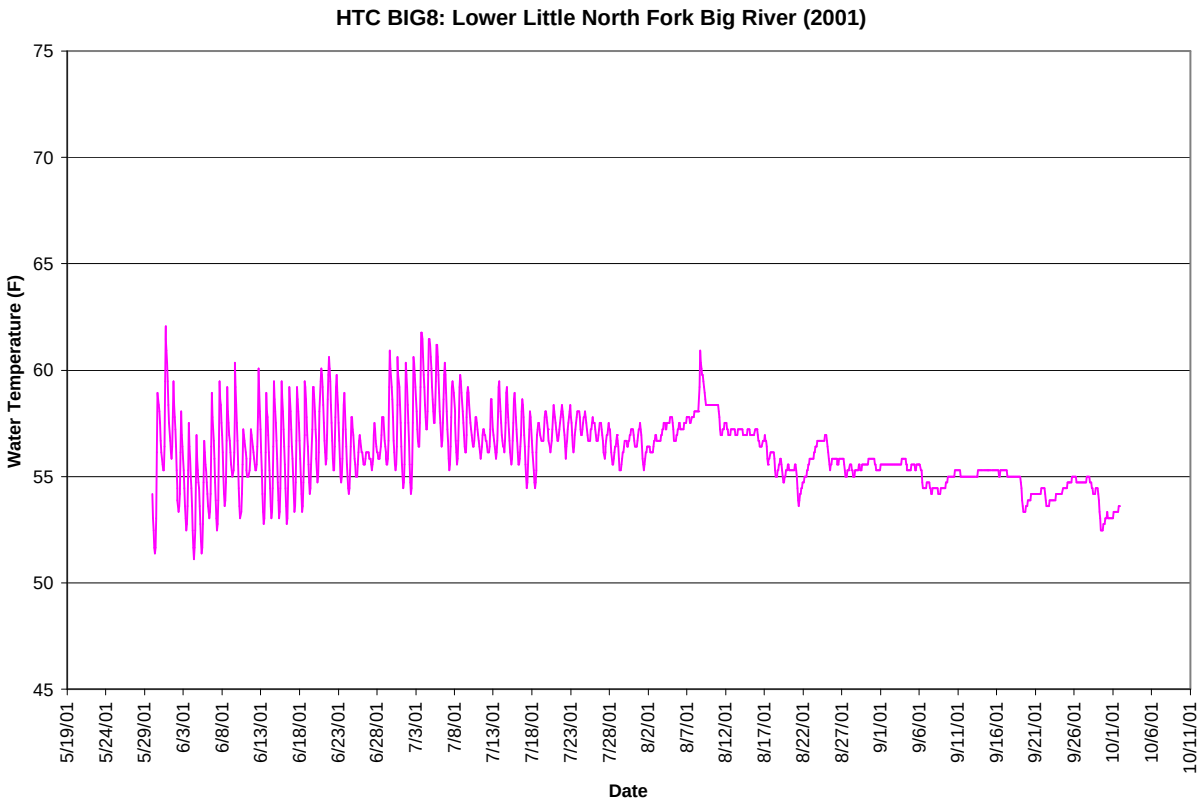


FIGURE 2: EXAMPLE OF UNUSUAL DIURNAL WATER TEMPERATURE FLUCTUATIONS

Typically, these types of issues were resolved by comparing the periods of unusual fluctuations with the same period of record at other sites in the subbasin. By close inspection of other nearby sites, it was often discovered that while they do not exhibit such dampened diurnal fluctuations, they do show a similar pattern in the fluctuations. In this example, this can be observed in the nearby site HTC Big 9 shown in Figure 3.

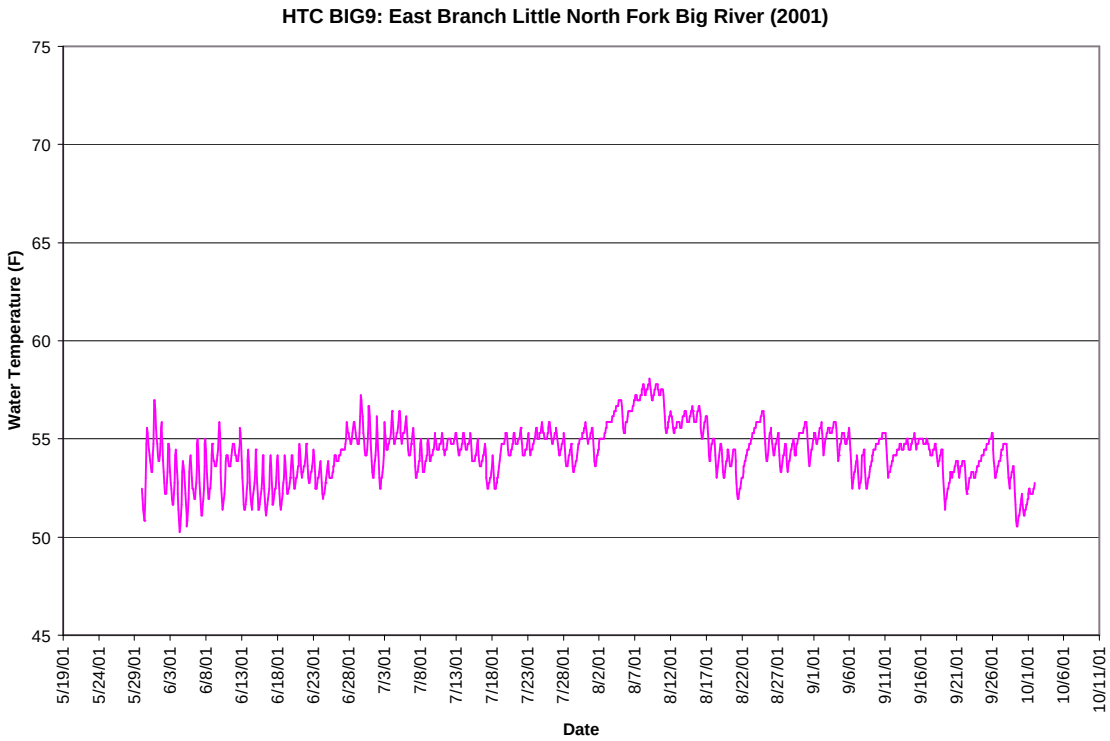


FIGURE 3: NEARBY DATA LOGGER EXHIBITING SIMILAR DIURNAL FLUCTUATIONS

While the raw data plotted in Figure 3 is not as dampened as the site in Figure 2, it is clear that the site shown in Figure 2 is still responding to temperature changes as can be seen when compared to the nearby site shown in Figure 3. Therefore, it appears as though the data logger shown in Figure 2 is operating properly, but that the location transitions into a groundwater dominate regime or a thermally stratified pool around early August. Assuming this logger was properly placed, this would be representative of the stream conditions and still useful information.

Data loggers that exhibited unusual diurnal fluctuations that appeared to be unresponsive to temperature changes in their respective subbasin would be indicative of equipment or battery failure. In the Big River watershed, only one data set was "thrown out" for this type of problem. This was the single season recorded at Lower Quail Gulch (MRC 75-20), which did not appear to respond to basin-wide temperature variations and may have malfunctioned. Additional years of data are needed at this site to determine if it is characteristic of the site or if it was indeed a malfunctioning unit.

Any file that did not cover the period of June 21 to August 15 or by visual inspection appeared to miss the peak temperatures were flagged. In the Big River watershed, six such temperature files were not used because it was determined that the recorded period likely missed the peak temperatures. The six sites not used were: Big River below North Fork Confluence (MRC 76-1, 2001), Lower Two Log Creek (HTC Big 4, 2000), Middle Big River (HTC Big 7, 1993), Martin Creek above unnamed tributary (FSP 5235, 1998), Big River at Wildhorse Opening (MRC 74-1, 1993), and Chamberlain Creek below West Chamberlain Creek (FSP 538, 1996). This was determined by inspecting these records against other longer records for the same year and determining when the MWAT and instantaneous maxima occurred. If these event occurred outside of the recorded time period in the flagged data sets, they were not used for this assessment.

For a detailed description of the data quality issues for temperature, including how these data quality issues were handled, refer to Table 36 through Table 40, beginning on page 190.

Analysis and Results by Subbasin

The Big River subbasins were partitioned along CalWater planning or superplanning watershed boundaries so that they were generally consistent with the subbasins identified in the Big River TMDL and the Sediment Source Analysis for the Big River watershed (Matthews 2001). The notable exception is the further partitioning of the Big River estuary. It was felt that due to the marine influence in this portion of the watershed, it would behave significantly different from the other portion of the Lower Big River subbasin, thus warranting a separate discussion where marine influences are significant.

Estuary Big River

It is commonly cited that during periods of low flow and high tide, the estuarine influence on the Big River can extend approximately 8.3 miles from the mouth of the Big River to roughly the confluence of Laguna Creek. For this assessment, the boundaries of the Big River estuary were not specifically delineated, but were treated as a subset of the Lower Big River subbasin. This area is discussed separately because of the estuarine influence on water quality in this portion of the Big River watershed. Larger features included in the Big River estuary are the mouth of the Big River, and Dry Dock Gulch.

The major streams in the estuary area of the Lower Big River subbasin are shown in Figure 25 on page 137. This figure also shows the names and boundaries of the CalWater 2.2 planning watersheds in the Lower Big River subbasin. Water quality and sediment sampling sites are shown in Figure 35 on page 147. No water temperature monitoring sites are in the estuary. A summary of the existing water temperature and water quality data can be found in Table 29 and Table 30, respectively. These tables can be found beginning on page 178.

Water Column Chemistry

Overall, there is little known about water quality in the Big River estuary. Searches for available water quality data revealed only two water quality sampling locations; one at the Highway 1 bridge and another in what appears to be a small unnamed tributary near the mouth of the Big River. The Highway 1 bridge sampling location was established in a WDR permit issued to the California Department of Transportation for water quality monitoring during bridge retrofit activities. However, no data associated with this permit was discovered and it is unclear if any water quality monitoring has occurred as to date.

The sampling associated with the unnamed tributary to the Big River occurred as part of routine testing for DHS in a cistern well that is now inactive. A cistern well is a shallow well, typically set in a creek or spring that primarily draws surface water. In this case, the description of the source was a “cistern well, creek diversion”. Based on the water quality and the fact that this site was used as a drinking water source, it is most likely not representative of the more saline water found in the Big River estuary. Therefore, because of the limited amount of data associated with this site and unknowns about data quality, data from the cistern well was used for screening purposes only.

The cistern well was operated by the Big River Vista Mutual Water Company and was sampled on three occasions; once in 1988, 1993, and 1994. The well itself was physically located approximately 0.5 miles upstream from the Highway 1 bridge, along what appears to be an intermittent stream on the south bank of the Big River.

The analysis of water column chemistry is divided into parameters with numeric water quality objectives in the Basin Plan, parameters with narrative water quality objectives in the Basin Plan (which can be quantified using numeric criteria found in the literature), and other important parameters that may have applicable narrative water quality objectives, but no available numeric criteria. This division of analytes is discussed in more detail in the Water Column Chemistry section, beginning on page 45.

Basic water chemistry data, including specific conductance, and hydrogen ion concentration (pH) were compared to numeric water quality objectives in the Basin Plan. Dissolved oxygen

and total dissolved solids were not sampled at this site. The summary data for basic water quality at the Vista Mutual Water Company site is shown in Table 7.

TABLE 7: BASIC WATER CHEMISTRY, BIG RIVER ESTUARY

PARAMETER	COUNT ALL	COUNT DETECTS	MIN.	DATE MIN[1]	MAX.	DATE MAX	AVG.	WQ OBJECTIVES MIN	WQ OBJECTIVES MAX
Site Name, Location: Vista Water Company, unnamed tributary to Big River estuary									
pH, Lab (pH units)	2	2	6.3	1/26/93	6.3	1/26/93	NA	6.5	8.5
Specific Conductance (µS/cm)	2	2	115	1/26/93	117	6/8/94	NA	NA	300[1] / 195[2]

[1] Value represents the 90th percentile upper limit. 90% of the values in a calendar year must be equal to or less than the 90% upper limit.
[2] Value represents the 50th percentile (median) upper limit. 50% of the monthly means in a calendar year must be equal to or less than the 50% upper limit.

As can be seen in Table 7, the pH of the water was detected at 6.3 in both sampling events, which is lower than the minimum Basin Plan water quality objective. Specific conductance appeared to be within the acceptable range in both samples.

Narrative water quality objectives in the Basin Plan apply to a variety of metals and other constituents that were detected during the sampling events. This includes alkalinity, chloride, iron, sodium, and sulfate. However, unlike the constituents shown in Table 7, the numeric criteria for these parameters are derived from the literature to support the narrative water quality objectives. These constituents and the most conservative applicable criteria are shown in Table 8.

TABLE 8: GENERAL WATER COLUMN CHEMISTRY, BIG RIVER ESTUARY

PARAMETER	COUNT ALL	COUNT DETECTS	MIN.	MAX.	AVG.	CRITERIA	CRITERIA EXCEEDED?	COMMENTS ON CRITERIA[1]
Site Name, Location: Vista Water Company, unnamed tributary to Big River estuary								
Total Alkalinity (mg/L as $CaCO_3$)	2	2	7.0	14.0	NA	= 20 mg/L	Yes	Protection of freshwater aquatic life
Chloride, Dissolved (mg/L)	2	2	29.0	32.0	NA	= 106 mg/L	No	Protection of agricultural water uses
Iron, Dissolved (µg/L as Fe)	2	1	0	120.0	NA	= 300 µg/L	No	Secondary California MCL for drinking water
Sodium, Dissolved (mg/L as Na)	2	2	17.0	17.0	NA	= 2 mg/L	Yes	SNARL for drinking water toxicity other than cancer risk, US EPA[2]
Sulfate, Dissolved (mg/L as SO_4)	2	1	0	3.7	NA	= 250 mg/L	No	Secondary California MCL for Drinking Water

[1] See the **Water Column Chemistry** section beginning on page 45 for description of criteria.
[2] Assumes a relative source contribution of 10% from drinking water and 90% from other dietary sources.

As can be seen in Table 8, most of the constituents did not exceed their respective criteria, with the exception of sodium and total alkalinity (which was below the criteria). No other criteria was found in Marshack (2000) relating to either sodium or total alkalinity. It is not clear if these water samples were filtered or not filtered, and how they were collected and analyzed. Each of these factors could affect the extent to which the sample results are representative of the true concentrations. Finally, with only two samples collected on what appears to be a small intermittent stream near the mouth of the Big River, these results are only a beginning of the

[1] Date on which the minimum value occurred is the first date that the value occurred. For example, if there were several "non-detects", represented here as a zero, the date given is the first instance of non-detect (chronologically).

sample set that is needed to characterize the surface water in this tributary. Therefore, these values are useful as screening values only and additional sampling should occur if the water quality in this tributary is to be characterized.

Total hardness was also reported in the water quality sampling, but does not have water quality criteria at this time. However, it can effect the toxicity of metals to aquatic life and is therefore important beyond just being a basic water quality indicator. Samples for total hardness as calcium carbonate ($CaCO_3$) were collected on two occasions. The first sample, collected on January 26, 1993, was reported to be 20 mg/L. The second sample, collected on June 8, 1994, was reported to be 18 mg/L.

No anthropogenic chemicals were detected in any of the samples. For a complete list of water quality parameters that were sampled for, including those that were not detected, refer to Table 43 on page 204.

Water Temperature

No continuous water temperature data was found in the estuary of the Big River.

In-Channel Sediment

The summary data for turbidity samples in the small unnamed tributary are shown below in Table 9.

TABLE 9: TURBIDITY SUMMARY, BIG RIVER ESTUARY

PARAMETER	COUNT ALL	COUNT DETECTS	MIN.	DATE MIN[2]	MAX.	DATE MAX	AVG.	50TH PERCENTILE	90TH PERCENTILE
Site Name, Location: Vista Water Company, unnamed tributary to Big River estuary									
Turbidity, Lab (NTU)	2	2	0.8	1/26/93	6.0	6/8/94	NA	NA	NA

It should be noted that there is not sufficient turbidity data to make more than broad statements about this constituent. In the two samples collected, the turbidity levels in the water was very low. However, far more sampling is needed to begin to characterize the turbidity conditions in this stream.

As part of the Sediment Source Analysis done by GMA (Matthews 2001), the estuary area was delineated along non-planning watershed boundaries. To simplify the discussion of the results, it was decided to adhere to CalWater 2.2 planning watershed boundaries. Therefore, discussion of results is not specific to the estuary but is instead discussed in the larger context of the Lower Big River subbasin. This discussion can be found in the In-Channel Sediment section in the Lower Big River subbasin analysis, beginning on page 65.

Issues, Hypotheses, and Recommendations

Water Chemistry

1. The only water chemistry data available in the estuary area is on a small stream that is apparently unrelated to the water chemistry in the estuary itself. However, of the

[2] Date on which the minimum value occurred is the first date that the value occurred. For example, if there were several "non-detects", represented here as a zero, the date given is the first instance of non-detect (chronologically).

parameters tested, only alkalinity and sodium appeared to be outside the applicable criteria.

2. A program called the School of Natural Resources (SONAR) at the Mendocino High School is beginning to collect data on the estuary which, in the future, may help our understanding of this portion of the Big River

Water Temperature

1. No continuous water temperature data was found in the estuary of the Big River. However, due to the marine influence it is expected that the water temperatures in the mainstem Big River quickly cool once in the estuary.

Sediment

1. The only turbidity data available in the estuary area is on a small stream that is apparently unrelated to the turbidity in the estuary itself. No other sediment related parameters have been collected.
2. GMA did a preliminary analysis of sediment input into all of the subbasins in the Big River. However, the discussion of the estuary portion of the sediment analysis is discussed in the Lower Big River subbasin section.

Lower Big River

The lower Big River is delineated by the CalWater 2.2 planning watersheds of Mouth of Big River, Berry Gulch, and Laguna Creek. Larger streams included in the lower Big River subbasin are the lower mainstem of the Big River, the Little North Fork of the Big River, Laguna Creek, and the streams previously discussed in the estuary. The watershed area encompassed by the lower Big River is approximately 32.5 mi^2.

The major streams in this subbasin are shown in Figure 25 on page 136. This figure also shows the names and boundaries of the CalWater 2.2 planning watersheds in the Lower Big River subbasin. Water temperature and water quality/sediment sampling sites are shown in Figure 30 and Figure 35 on pages 142 and 147, respectively. A summary of the existing water temperature and water quality data can be found in Table 29 and Table 30, respectively. These tables can be found beginning on page 178.

Water Column Chemistry

Water chemistry data was collected at three closely spaced surface water locations in the lower Big River subbasin. The first sampling site is located on the Big River, immediately downstream of the confluence with the Little North Fork of the Big River. This site was sampled by the Regional Water Board (under the SWAMP program) on two occasions in 2001. The second sampling site is located on the Big River, immediately upstream of the Little North Fork of the Big River confluence near the Mendocino Woodlands. Established by the Regional Water Board in 1959, it was generally sampled monthly until about 1966 and then typically sampled every two months from 1968 until 1988. The third surface water sampling site, located approximately 1.5 miles upstream from the Regional Water Board site, was sampled by the USGS. Originally established in 1960, it was generally sampled monthly through 1966, and then once in 1977.

Other than what appears to be one short unnamed tributary, there are no streams converging with the Big River between the Regional Water Board and USGS locations, and therefore the water chemistry should be similar and comparable between these sites. Thus, these data sets were combined and treated as a single data set for this assessment.

The analysis of water column chemistry is divided into parameters with numeric water quality objectives in the Basin Plan, parameters with narrative water quality objectives in the Basin Plan (which can be quantified using numeric criteria found in the literature), and other important parameters that may have applicable narrative water quality objectives, but no available numeric criteria. This division of analytes is discussed in more detail in the Water Column Chemistry section, beginning on page 45.

Basic water chemistry data, including specific conductance, total dissolved solids, dissolved oxygen, and hydrogen ion concentration (pH) were compared to numeric water quality objectives in the Basin Plan. The summary data for basic water quality at all sites in the Lower Big River subbasin are shown in Table 10.

TABLE 10: BASIC PHYSICAL WATER PARAMETERS, LOWER BIG RIVER SUBBASIN

PARAMETER	COUNT ALL	COUNT DETECTS	MIN.	DATE MIN	MAX.	DATE MAX	AVG.	WQ OBJECTIVES MIN	WQ OBJECTIVES MAX
Site Name, Location: SWAMP BIGMWD, Mainstem Big River downstream of LNF Big River									
Dissolved Oxygen, Field (mg/l)	2	2	8.96	06/28/01	9.38	05/10/01	NA	7.0 / 7.5[1] / 10.0[2]	NA
pH (pH units)	2	2	8	05/10/01	8	05/10/01	NA	6.5	8.5
pH, Field (pH units)	2	2	7.79	06/28/01	7.81	05/10/01	NA	6.5	8.5
Specific Conductance (uS/cm)	1	1	190	06/28/01	190	06/28/01	NA	NA	300[3] / 195[4]
Specific Conductance, Field (uS/cm)	2	2	195	06/28/01	203	05/10/01	NA	NA	300[3] / 195[4]
Total Dissolved Solids (mg/l)	2	2	110	05/10/01	140	06/28/01	NA	NA	190[3] / 130[4]
Site Name, Location: RWQCB 1 & USGS, Mainstem Big River upstream of LNF Big River									
Dissolved Oxygen (mg/L)	207	207	4.5	10/13/82	13.0	1/5/67	10.1	7.0 / 7.5[1] / 10.0[2]	NA
pH (pH units)	269	269	0.76	12/5/60	8.4	6/4/65	7.4	6.5	8.5
pH, Lab (pH units)	135	135	7.0	1/6/59	8.4	6/4/65	7.8	6.5	8.5
Specific Conductance (uS/cm)	202	202	76.0	2/13/75	292.0	6/12/63	182.6	NA	300[3] / 195[4]
Specific Conductance, Field (uS/cm)	95	95	79.0	2/13/75	581.0	8/30/77	184.6	NA	300[3] / 195[4]
Total Dissolved Solids (mg/l)	9	9	107.0	5/7/63	136.0	9/13/63	123.8	NA	190[3] / 130[4]

[1] Value represents the 90th percentile lower limit. 90% of the values in a calendar year must be equal to or greater than the 90% lower limit.
[2] Value represents the 50th percentile (median) lower limit. 50% of the monthly means in a calendar year must be equal to or greater than the 50% lower limit.
[3] Value represents the 90th percentile upper limit. 90% of the values in a calendar year must be equal to or less than the 90% upper limit.
[4] Value represents the 50th percentile (median) upper limit. 50% of the monthly means in a calendar year must be equal to or less than the 50% upper limit.

Given the limited data that is available, it does not appear as though any of the basic water column chemistry parameters at the site downstream of the confluence with the Little North Fork (SWAMP BIGMWD) are significantly outside of the range of Basin Plan water quality objectives.

At sites upstream of the Little North Fork (RWQCB 1 & USGS), two dissolved oxygen points, and one pH data point (see Figure 83 through Figure 86, beginning on page 174) fall outside of the numeric Basin Plan water quality objectives. However, given that these skewed data points are from a data set of 207 and 269 points, respectively, it is unlikely that these are significant. The specific conductance and total dissolved solids values appear to within the numeric Basin Plan water quality objectives.

Narrative water quality objectives in the Basin Plan apply to a variety of metals and other constituents that were detected during sampling events. This includes alkalinity, ammonia, boron, chloride, copper, iron, nitrate, sodium, sulfate, turbidity, and zinc. However, unlike the constituents shown in Table 10, the numeric criteria for these parameters are derived from the literature to support the narrative water quality objectives. These constituents and the most conservative applicable criteria are shown in Table 11.

TABLE 11: GENERAL WATER COLUMN CHEMISTRY, LOWER BIG RIVER SUBBASIN

PARAMETER	COUNT ALL	COUNT DETECTS	MIN.	MAX.	AVG.	CRITERIA	CRITERIA EXCEEDED?	COMMENTS ON CRITERIA[1]
Site Name, Location: SWAMP BIGMWD, Mainstem Big River downstream of LNF Big River								
Total Alkalinity (mg/L as $CaCO_3$)	2	2	82	84	NA	= 20 mg/L	No	Protection of freshwater aquatic life
Boron (µg/L)	2	2	250	330	NA	= 630 µg/L	No	IRIS reference dose for drinking water, US EPA
Chloride (mg/L)	1	1	6.5	6.5	NA	= 106 mg/L	No	Protection of agricultural water uses
Copper (µg/L)	2	0	NA	NA	NA	= 7.0 µg/L	No	Protection of freshwater aquatic life with a hardness of 75 mg/L[2]
Iron (µg/L)	2	1	0	190	NA	= 300 µg/L	No	Secondary California MCL for drinking water
Nitrate/Nitrite as N (mg/L)	2	0	NA	NA	NA	= 10 mg/L	No	Primary US EPA MCL for drinking water
Sodium (mg/L)	2	2	12	12	NA	= 2 mg/L	Yes	SNARL for drinking water toxicity other than cancer risk, US EPA[3]
Sulfate as SO_4 (mg/L)	1	1	7.1	7.1	NA	= 250 mg/L	No	Secondary California MCL for drinking water
Zinc (µg/L)	2	0	0	0	NA	= 93 µg/L	No	Protection of freshwater aquatic life with a hardness of 75 mg/L[2]
Site Name, Location: RWQCB 1 & USGS, Mainstem Big River upstream of LNF Big River								
Total Alkalinity (mg/L as $CaCO_3$)	103	103	30.0	103.0	76.8	= 20 mg/L	No	Protection of freshwater aquatic life
Chloride, Dissolved (mg/L)	136	136	1.0	19.0	7.1	= 106 mg/L	No	Protection of agricultural water uses
Copper (µg/L)	7	2	0	10.0	NA	= 6.8 µg/L	Yes	Protection of freshwater aquatic life with a hardness of 73 mg/L[2]
Iron, Dissolved (µg/L as Fe)	8	4	0	130.0	36.3	= 300 µg/L	No	Secondary California MCL for drinking water
Nitrate, Dissolved (mg/L as NO_3)	44	34	0	1.7	0.35	= 10 mg/L	No	Primary US EPA MCL for drinking water
Sodium, Dissolved (mg/L as Na)	201	201	4.5	17.0	10.4	= 2 mg/L	Yes	SNARL for drinking water toxicity other than cancer risk, US EPA[3]
Sulfate, Dissolved (mg/L as SO_4)	37	37	0.8	15.0	6.4	= 250 mg/L	No	Secondary California MCL for drinking water
Zinc (µg/L)	7	3	0	70.0	22.9	= 90 µg/L	No	Protection of freshwater aquatic life with a hardness of 73 mg/L[2]

[1] See the **Water Column Chemistry** section beginning on page 45 for description of criteria.
[2] See text below for details on derivation of criteria.
[3] Assumes a relative source contribution of 10% from drinking water and 90% from other dietary sources.

As can be seen in Table 11, all of the constituents that have numeric criteria did not exceed their respective criteria, with the exception of sodium at both sites and copper at the site upstream of the Little North Fork (RWQCB 1 & USGS). No other criteria was found in Marshack (2000) relating to sodium or copper. It should also be noted that in the downstream site (SWAMP BIGMWD), alkalinity was speciated into carbonate, bicarbonate, and hydroxide alkalinity. At SWAMP BIGMWD, the alkalinity was entirely bicarbonate alkalinity. In the upstream water samples (RWQCB 1 & USGS), it is not clear if the water samples were filtered or not-filtered, and how they were collected and analyzed. Each of these factors could affect the extent to which the sample results are representative of the true concentrations of dissolved sodium in the water column. While this should be investigated further, it is probable that sodium in the water is

naturally occurring and not anthropogenic pollution. All of these sites are also outside of the estuary area, and therefore should not be saline.

Some constituents, including copper and zinc, vary in toxicity depending on the hardness of the water and therefore have hardness dependant criteria. At the upstream sampling sites (RWQCB1 & USGS), a total of 199 samples were analyzed for hardness with an average hardness of 73 mg/L as calcium carbonate ($CaCO_3$). This value was used to determine the toxicity criteria for copper and zinc. However, it should be noted that the sampling for hardness and these metals did not necessary coincide.

In two occasions, dissolved copper concentrations were reported as 10 µg/L, with the remaining five samples reported as zero. Presumably, the sample detections reported as zero were in fact "non-detects", below some unknown detection limit less than 10 µg/L. Given an average hardness of the 73 mg/L, the maximum one hour average concentration of dissolved copper is 10 µg/L. Based on the two positive detections out of a total of seven samples, copper concentrations at the upstream sites appear to be at or below the criteria to protect freshwater aquatic life.

Surface water at the downstream site (SWAMP BIGMWD) was also analyzed for copper on two occasions. Hardness at this site averaged 75 mg/L. Copper samples were reported as "non-detect" at or above the laboratory detection limit of 10 µg/L. Therefore, if copper did exist in the downstream samples, the concentrations were below the detection limits.

Dissolved zinc concentrations were reported as 30, 60, and 70 µg/L at the upstream sites (RWQCB 1 & USGS), with the remaining four samples reported as zero. Presumably, the sample detections reported as zero were in fact "non-detects", below some unknown detection limit less than 30 µg/L. Given an average hardness of 73 mg/L, the criteria for the maximum one hour average concentration of dissolved zinc is 90 µg/L. Based on the three positive detections out of a total of seven samples, zinc concentrations in the Big River appear to be below the criteria to protect freshwater aquatic life.

Surface water at the downstream site (SWAMP BIGMWD) was also sampled for zinc on two occasions. Both samples were reported as "non-detect" at or above the laboratory detection limit of 20 µg/L. Therefore, if zinc did exist in the downstream samples, the concentrations were below the detection limits.

Other constituents, such as ammonia, vary in toxicity depending on the temperature and pH of the water. Ammonia was only sampled at the downstream site (SWAMP BIGMWD) on two occasions. On both occasions, no ammonia (as nitrogen) was detected at or above the laboratory detection limit of 0.05 mg/L.

Turbidity, phosphorus, and chlorophyll-a were also reported, but none have specific numeric criteria at this time. However, they are broken out separately because they are significant constituent of water quality. Turbidity, for the purposes of this assessment, is considered a sediment related parameter and is discussed further in the In-Channel Sediment section on page 65.

Phosphorus can enter surface water bodies through fertilizer run-off or from the natural weathering of rocks in some watersheds. Phosphorus is a biostimulantory substance for algae, and excessive amounts can lead to algae blooms which can impact other aquatic life by

negatively affecting dissolved oxygen concentrations. The summary data for phosphorus samples are shown in Table 12.

TABLE 12: PHOSPHORUS SUMMARY, LOWER BIG RIVER SUBBASIN

PARAMETER	COUNT ALL	COUNT DETECTS	MIN.	DATE MIN[3]	MAX.	DATE MAX	AVG.
Site Name, Location: SWAMP BIGMWD, Mainstem Big River downstream of LNF Big River							
Phosphorus (mg/L)	2	0	0	NA	0	NA	NA
Orthophosphate as P (mg/L)	2	0	0	NA	0	NA	NA
Site Name, Location: RWQCB 1 & USGS, Mainstem Big River upstream of LNF Big River							
Total Phosphorus (mg/L as P)	4	4	0.03	5/5/76	0.07	2/5/86	0.04
Orthophosphate, Dissolved (mg/L as P)	19	17	0	5/13/64	0.07	9/5/61	0.02

There is not sufficient data to make more than broad statements about phosphorus. However, there was not an apparent problem with elevated phosphorus levels in the samples that were collected at the upstream sites (RWQCB 1 & USGS). Although both phosphorus and orthophosphate samples were collected at the downstream site (SWAMP BIGMWD) on two occasions for each analyte, it was not detected at or above the laboratory detection limits of 0.05 mg/L.

Chlorophyll-a was also sampled once at the downstream site (SWAMP BIGMWD)and was detected with a concentration of 0.00071 mg/L. Chlorophyll-a is a measurement of the chlorophyll in the suspended algae in the water column. High chlorophyll-a content, which directly relates to high algal concentrations in freshwater, can be an indicator of nutrient contamination of the surface water (such as in fertilizer run-off). However, there is no water quality criteria for this constituent and therefore it is used primarily to screen for other potential water quality problems.

In the upstream sites (RWQCB1 & USGS), total and fecal coliform bacteria was detected at a maximum most probable number (MPN) of 900/100 ml and 30/100 ml, respectively. While total coliform bacteria can come from a variety of sources, the presence of the fecal coliform subset in aquatic environments indicates that the water has been contaminated with the fecal material of man or other animals. At the time this occurred, the source water may have been contaminated by pathogens or disease producing bacteria or viruses which can also exist in fecal material. Some waterborne pathogenic diseases include typhoid fever, viral and bacterial gastroenteritis and hepatitis A. The presence of fecal contamination is an indicator that a potential health risk exists for individuals exposed to this water. Fecal coliform bacteria may occur in ambient water as a result of the overflow of domestic sewage or nonpoint sources of human and animal waste

The Basin Plan water quality objective for fecal coliform states that “the median fecal coliform concentration based on a minimum of not less than five samples for any 30-day period shall not exceed 50/100 ml, nor shall more than ten percent of total samples during any 30-day period exceed 400/100 ml” (RWQCB 2001). While not directly comparable, fecal coliform appears to be within the water quality objective.

[3] Date on which the minimum value occurred is the first date that the value occurred. For example, if there were several “non-detects”, represented here as a zero, the date given is the first instance of non-detect (chronologically).

Macroinvertibrate data was collected downstream of Mendocino Woodlands on the Little North Fork. This stream segment, which has been labeled JSF M1, can be seen in Figure 35 on page 147. While there is not enough data to make any conclusions about this data, for reference, it is presented in Table 57 and Table 58, beginning on page 229.

A complete list of water quality parameters that were sampled for, including those that were not detected, refer to Table 42 on page 201 for the upstream sites (RWQCB 1 & USGS) and Table 46 on page 213 for the site downstream (SWAMP BIGMWD) of the confluence with the Little North Fork Big River.

Water Temperature

Continuous water temperature data logging devices were deployed by HTC and JSF at a total of twelve (12) locations in the lower Big River sub-watershed. In general, water temperature was monitored in one or more locations in the lower Big River watershed during the years 1993 to 2001. A table of abbreviated summary values is presented in this section in Table 13 on page 65, with the full summary available in Table 31 on page 182. The observed MWAT values are plotted in Figure 4 on page 64.

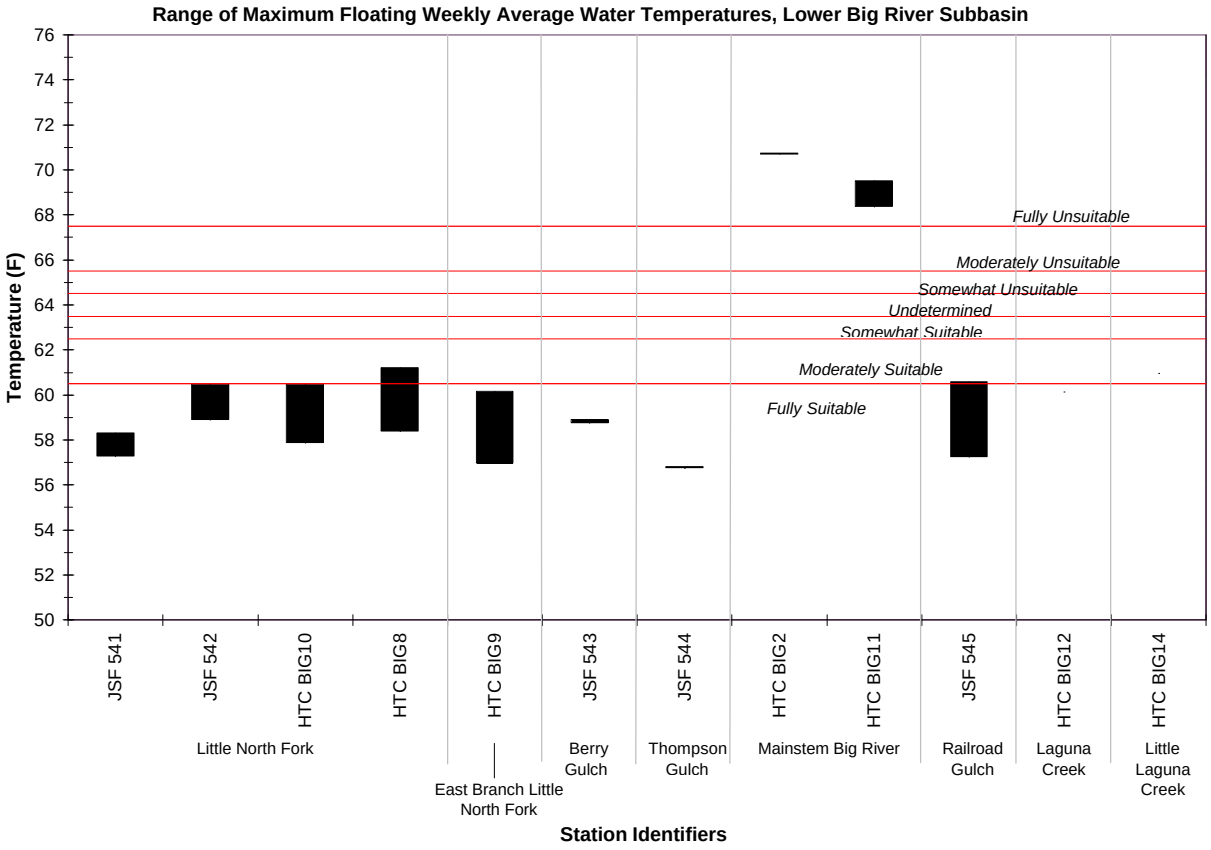
During the initial data review, the several potential issues with the water temperature data were noted as shown in Table 36 on page 193. Data was reviewed according to the criteria established in the Water Quality Criteria section, with the intent that only data that appeared representative of stream conditions were used. In the lower Big River subbasin, all of the available water temperature data sets met the data quality criteria and were used for this assessment. An explanation of why data was or was not used is included in the table.

There are a total of four monitoring sites on the Little North Fork (JSF 541, JSF 542, HTC BIG10, and HTC BIG8). These monitoring sites are all located in the upper and middle reaches of the Little North Fork. JSF 541 was monitored for two years, JSF 542 was monitored for two years, HTC BIG10 was monitored for seven years, and HTC BIG8 was monitored for seven years. Based on data from these sites, the water temperature varies between fully suitable with a minimum observed MWAT of 57ºF, to moderately suitable with a maximum observed MWAT of 61ºF. As would be expected, the water temperatures appear to gradually increase further downstream, as evident in Figure 4 on page 64. None of the tributaries that were monitored appear to significantly alter the water temperatures in the Little North Fork. This includes the East Branch Little North Fork (HTC BIG9) which was monitored for six years, Berry Gulch (JSF 543) which was monitored for two years, and Thompson Gulch (JSF 544) which was monitored for one year. Based on the data from these sites, the maximum observed MWATs varied from 57-60°F. Furthermore, most of the Little North Fork and tributary monitoring sites exhibited low diurnal fluctuations suggesting good shading, and/or good flow conditions and/or a tempering marine influence. As listed in Table 13 on page 65, the sites which exhibited the highest diurnal fluctuations were HTC BIG8, HTC BIG9, and HTC BIG10. These three sites also appear to have a downward trend in the MWAT values, which may reflect regrowth canopy. Available THP maps (KRIS Big River) indicate that harvesting occurred in the vicinity of these sites in approximately 1989. A 1994 Landsat map (KRIS Big River) shows open areas and small trees near these monitoring sites, but a map of the change in vegetation between 1994 and 1998 did not indicate a loss or gain of vegetation. However, this relationship should be explored further in the Big River Synthesis Report.

The one site in Railroad Gulch (JSF 545), a tributary to the mainstem Big River, was monitored for three years. During the three years monitored, the water temperature varied between fully

suitable with a minimum observed MWAT of 57°F to moderately suitable with an observed MWAT of 61ºF. Diurnal fluctuations were minimal and there was no apparent trend in MWAT values. Available THP maps (KRIS Big River) of Railroad Gulch indicate no harvesting near the stream during the period of 1987-1999.

FIGURE 4: RANGE OF MWATS, LOWER BIG RIVER SUBBASIN



Laguna Creek, a tributary to the mainstem Big River, was also monitored at one location (HTC BIG12) in the middle portion of the stream for one year. During the one year monitored, the water temperature was fully suitable with a maximum observed MWAT of 60ºF. A tributary to Laguna Creek, Little Laguna Creek, was monitored at one location (HTC BIG14) in the lower portion of the stream for one year. During the one year monitored, the water temperature was moderately suitable with a maximum observed MWAT of 61ºF. Based on the available data, it appears as though Little Laguna Creek has no significant effect on the water temperature of Laguna Creek. Diurnal fluctuations were minimal and there was insufficient data to establish a trend at either site.

There are a total of two monitoring sites on mainstem Big River (HTC BIG2 and HTC BIG11). One site is located before the confluence with the Little North Fork (HTC BIG2) and was monitored for one year. The other site is located above the confluence with Laguna Creek (HTC BIG11) and was monitored for two years.

The monitoring site above the confluence with the Little North Fork (HTC BIG2) recorded water temperatures that were fully unsuitable with an maximum observed MWAT of 71ºF. In addition,

the maximum water temperature recorded was 76ºF, over the lethal limit for salmonids (75ºF). The diurnal fluctuations (9.9ºF) at this site also suggest moderate to poor cover and/or low flows.

The monitoring site on the mainstem Big River above Laguna Creek (HTC BIG11) recorded water temperatures that were fully unsuitable with a maximum observed MWAT of 70ºF. In addition, the maximum water temperature recorded was 75ºF, the lethal limit for salmonids (75ºF). The diurnal fluctuations at this site (7.9-9.5°F) suggest poor canopy and/or flow conditions.

Water temperature data was also collected and is available in StoRet. However, this data represents only 208 point readings over more than 11 years. Therefore, it was not used in this assessment, but a summary of the data is available in Table 42 on page 201.

The summary values for each of the monitoring sites in the lower Big River are presented in Table 31 on page 182. This summary data, plus the MWAT trends, are included and ranked in Table 13 below.

TABLE 13: WATER TEMPERATURE SUMMARY, LOWER BIG RIVER SUBBASIN

SITE	MAX MWAT	MWAT TREND	RANGE OF MAX DIURNAL FLUCTUATIONS		SEASONAL MAX	YEARS OF DATA
Fully Suitable (50-60°F)						
JSF 544	57	NA	2.5	2.5	58	1
JSF 541	58	1.0	2.8	3.1	60	2
JSF 543	59	-0.2	4.8	4.8	61	2
HTC BIG 12	60	NA	4.0	4.0	62	1
HTC BIG 9	60	-3.2	4.7	7.2	64	6
JSF 542	60	0.9	4.8	5.6	62	2
HTC BIG 10	60	-2.6	4.3	6.8	65	7
Moderately Suitable (61-62°F)						
JSF 545	61	0.6	4.5	5.0	62	3
HTC BIG 14	61	NA	5.7	5.7	64	1
HTC BIG 8	61	-2.8	6.2	8.1	66	7
Somewhat Suitable (63°F)						
--	--	--	--	--	--	--
Undetermined (64°F)						
--	--	--	--	--	--	--
Somewhat Unsuitable (65°F)						
--	--	--	--	--	--	--
Moderately Unsuitable (66-67°F)						
--	--	--	--	--	--	--
Fully Unsuitable (68°F)						
HTC BIG 11	70	-1.2	7.9	9.5	75	2
HTC BIG 2	71	NA	9.9	9.9	76	1

In-Channel Sediment

As mentioned previously, although there are non-specific and/or narrative criteria for turbidity, it is discussed here because it is a significant aspect of water quality. The summary data for turbidity samples are shown below in Table 14.

TABLE 14: TURBIDITY SUMMARY, LOWER BIG RIVER SUBBASIN

PARAMETER	COUNT ALL	COUNT DETECTS	MIN.	DATE MIN[4]	MAX.	DATE MAX	AVG.	50TH PERCENTILE	90TH PERCENTILE
Site Name, Location: RWQCB 1 & USGS, Mainstem Big River upstream of LNF Big River									
Turbidity, Hellige (ppm as Silicon Dioxide)	96	94	0	9/16/70	340.0	1/23/69	20.7	3.0	40.0
Turbidity, HACH Turbidimeter (NTU)	87	76	0	5/4/72	600.0	2/13/75	33.4	1.0	51.6
Site Name, Location: SWAMP BIGMWD, Mainstem Big River downstream of LNF Big River									
Turbidity (NTU)	1	1	0.19	06/28/01	0.19	06/28/01	NA	NA	NA

There is not sufficient data to make more than broad statements about turbidity. Of the 87 samples collected with the Hach turbidimeter, 90% of the samples were equal to or less than 51.6 NTU, with a maximum recorded value of 600 NTU. Also, at the SWAMP station located downstream of the Little North Fork Big River confluence, one turbidity sample was collected that had turbidity level of 0.19 NTU.

Another set of 96 turbidity samples collected at the same location indicated that 90% of the samples were equal to or less than 40 ppm as SiO_2, with a maximum recorded value of 340 ppm as SiO_2. However, Hellige turbidity samples (measured as ppm as SiO_2) cannot be directly compared to the other turbidity measurements.

Turbidity that is significantly elevated above background levels can impede the ability of salmonids to feed and can be an indicator of potential problems with suspended sediment. This in turn may point to potential problems with heavy sediment loads. The turbidity sampling conducted at these sites, combined with additional sampling, can eventually establish the range of background levels.

Pebble counts and V* measurements were conducted by Chris Knopp (Knopp 1993) in Berry Gulch, a tributary to the Little North Fork Big River (see Figure 35 on page 147) in 1992. Berry Gulch was selected as a "highly disturbed watershed", indicating that it exhibited large areas of disturbed soil, unpaved, low-slope roads, inconsistent or poor stream course protection, and inconsistent avoidance of unstable terrain during the last 40 years. This site was one of 21 sites chosen by Knopp that were highly disturbed.

The pebble count conducted in Berry Gulch had a median pebble size was calculated to be 28 mm. This value is significantly lower than the 69 mm median particle size from the combined "index yes" and "index no" streams (Knopp 1993). However, even when compared to the median pebble sizes from the other highly disturbed streams measured by Knopp (1993), Berry Gulch was significantly lower. For example, the average of all median pebble sizes in highly disturbed streams was 38 mm compared to the 28 measured at Berry Gulch. For salmonids, the smaller the median pebble size, the more potentially detrimental during the early life stages, as described in the TMDL Targets section beginning on page 32. The criteria used for comparison are also referenced in Table 5 on page 37.

[4] Date on which the minimum value occurred is the first date that the value occurred. For example, if there were several "non-detects", represented here as a zero, the date given is the first instance of non-detect (chronologically).

V* is a measure of fine sediments that occupy the scoured residual volume of a pool. This is measured as the depth of the sediment layer in a pool from the apparent bottom of the pool to the armor layer beneath the loose sediment. As the amount of sediment in transport increases, the amount of sediment deposition in pools should increase. For the reach measured in Berry Gulch, the V* was calculated to be 38%. In other words, 38% of the scoured residual pool volume was filled with sediment. As described in Table 5 on page 37, the target value for this measurement is less than an average of 21% or maximum of less than 45% sediment for Franciscan formations. While a measurement of 38% is on the high side, it is only one measurement during one year. Further sampling is necessary to confirm the results of this measurement.

In 1996 and 1997, the Hawthorne Timber Company collected McNeil samples at one site in the Lower Big River subbasin (BIG 8), located on the Little North Fork Big River below the confluence with the East Branch Little North Fork. These McNeil core samples were collected using a volumetric method, and are therefore directly comparable to the Big River TMDL targets described in Table 5 on page 37. In general, four McNeil cores were collected at each of the two riffles sampled. A summary of McNeil data collected at BIG 8 is shown in Table 15. Summary data broken out by riffle is provided in Table 62 on page 234. Raw data was not available for this assessment.

TABLE 15: BULK SEDIMENT DATA SUMMARY (VOLUMETRIC), LNF BIG RIVER (HTC)

SITE NAME	SITE LOCATION	YEAR	SIEVE SIZE (mm)	MEDIAN PERCENT LESS THAN
BIG 8	Little North Fork Big River	1996	4.0	32.8%
			0.85	18.3%
		1997	4.0	28.1%
			0.85	17.1%

Based on the summary data shown in Table 15, the sediment in the sub 6.5 mm size class exceeded the Big River TMDL target of = 30% in 1996 and may have exceeded it in 1997. Because a 4-mm sieve was used, the comparison was made with the 4-mm value instead of 6.5 mm. Therefore, for comparisons to the TMDL target, it is conservative. The sediment in the sub 0.85 mm size class exceeded the Big River TMDL target of = 14% in both 1996 and 1997. In both size classes, the sediment values improved from 1996 to 1997. However not enough data is available and the apparent improvement could be due to sample variability.

In 2001, Graham Matthews & Associates collected McNeil core samples in the Lower Big River subbasin at one site located approximately 150 feet downstream of the confluence with Railroad Gulch (see Figure 35 on page 147). However, the core samples were collected using the gravimetric method (dry sieve), it is not comparable to the Big River TMDL target for fine sediment. A chart of the McNeil data is presented in Figure 75 on page 170.

Based on the GMA Sediment Source Analysis for the Big River (Matthews 2001), the relative disturbance index for the CalWater 2.2 planning watersheds in the Lower Big River subbasin indicated that Mouth of Big River was the most disturbed with a disturbance index of 1,550, followed by Laguna Creek (1,510), and Berry Gulch (575). Figure 24 on page 136 is a map of these planning watersheds. It should be noted that in Matthews (2001), these planning watersheds are also referred to as Big River Estuary and Lower Big River (which combined make up the Mouth of Big River), Laguna Creek, and Little North Fork, respectively. As a whole, the Lower Big River subbasin had a relative disturbance index of 1,139 for the 1989-2000 time period. Out of five subbasins, the disturbance index value for the Lower Big River was the second largest (behind the Upper Big River subbasin). The relative disturbance index is the

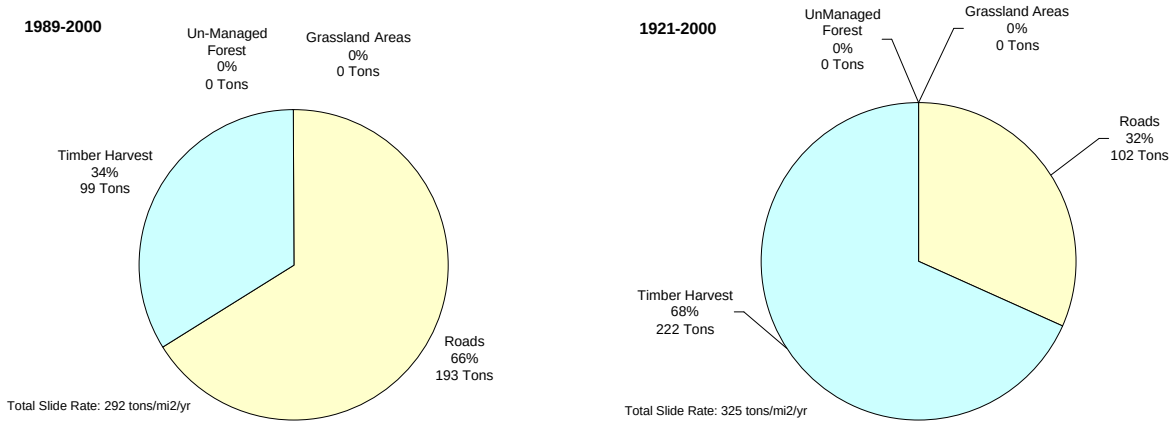
product of the road density (mi/mi^2), the percent harvested in the 1989-2000 period (acre/acre), and the unit slide volume for delivering slides during the 1989-2000 period (tons/mi^2). Each of these values are discussed in more detail in the following text. Also, unless specifically mentioned, all of the following values apply to the entire Lower Big subbasin during the 1989-2000 time period.

The road density, calculated to be 7.65 mi/mi^2 was estimated to be 4% paved and 96% rocked or native. Of these roads, it is estimated that 21% are located in the riparian zone with the remaining 79% located mid-slope or on the ridge. Road density was calculated by the cumulative miles of roads constructed during the entire study period (1921-2000). Also, if any roads were decommissioned, it was not quantified by GMA and is therefore not reflected in these values.

The harvest density, a measure of the acres of timber harvested in a given time period divided by the total acreage in the watershed, was calculated to be 51 ac/ac (or 51% of the watershed). This was the most intense harvesting during any of the decades studied. Over the entire study period (1921-2000), an estimated 133% of the Lower Big River subbasin was harvested, with roughly 38% of that happening from 1989-2000. The percentage harvest exceeds 100% in part because some areas were harvested multiple times. Of the harvesting that occurred in the 1989-2000 time period, it was reported that approximately 23% was clear cut and 77% partial cut, with less than one percent skid trails.

The unit volume of delivering landslides, calculated to be 292 tons/mi^2/yr, is comprised of the total of delivering landslides in unmanaged forest, brush and grasslands, roads and timber harvest areas. In the Lower Big River subbasin, it was reported that 100% of the landslides occurred in timber harvest areas or was related to roads (see Figure 5). Of the delivering landslides from harvest related activities and roads, it was estimated that 66% was related to roads and 34% was related to timber harvesting (including skid trails). When compared to these same percentages over the entire study period (1921-2000), it is estimated that 32% of the delivering landslides were road related, 68% were related to timber harvesting (including skid trails), and none were related to grassland areas or unmanaged forest. When comparing the 1989-2000 time period to that of the entire study period (1921-2000), the percentage of delivering landslides due to roads versus timber harvesting was reversed. This switch in the primary cause of delivering landslides may be the result of timber harvesting methods that are less disruptive, or it may be the result of years of building roads that are now triggering more landslides. It is important to note that the total estimated slide rate decreased from 325 tons/mi^2/yr (1921-2000) to 292 tons/mi^2/yr (1989-2000), a moderate drop in sediment input by landslides.

FIGURE 5: DELIVERING LANDSLIDES BY CATEGORY, LOWER BIG RIVER SUBBASIN (GMA)

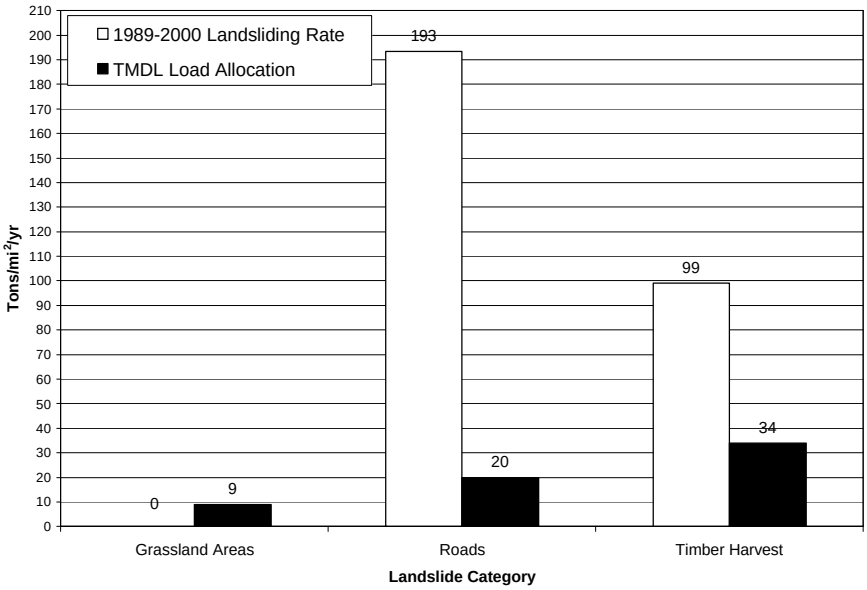


It should also be noted that background landslides, other than what was observed in unmanaged forest, has not been included in the direct comparisons discussed thus far (and shown in Figure 5). Background landslide estimates are discussed separately because they were estimated from past studies, rather than through direct observation in aerial photographs. Background landslide rates were estimated based on previous observation of natural "background" landslides in the South and North Fork of Caspar Creek (Matthews 2001). However, this presented a potentially significant difference in data quality and could be misleading if compared directly.

The background landslide rate for the 1989-2000 time period was estimated to be 159 tons/mi^2/yr. The background landslide rate for the 1921-2000 time period was estimated to be 175 tons/mi^2/yr. Regardless of data quality concerns, these estimates point to background landslides as a potentially significant component of sediment input. As a point of reference, all other landslides during the 1989-2000 time period contributed an estimated 292 tons/mi^2/yr. This would indicate that background landslides may have contributed roughly 35% of the total sediment input by all categories of landslides.

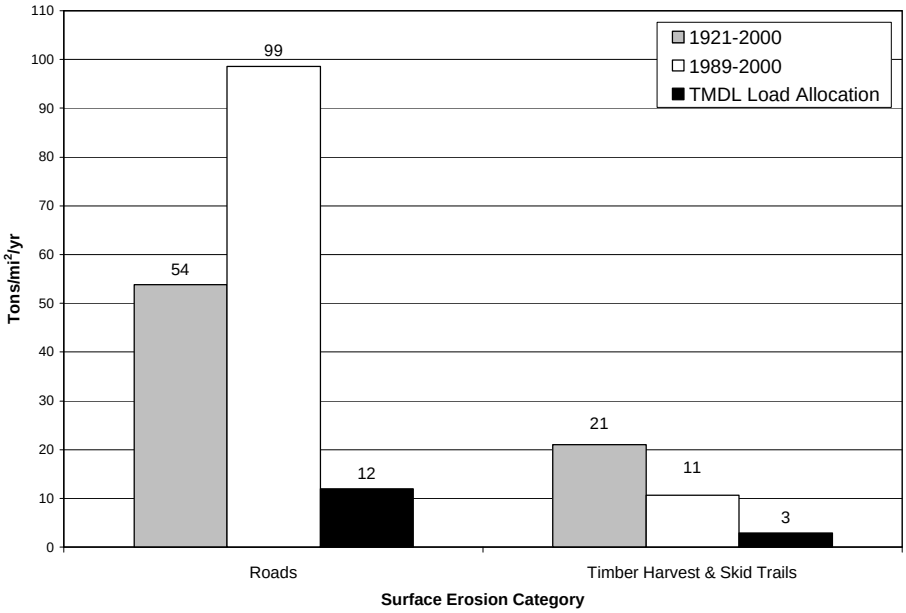
When compared to the TMDL load allocations for each category of landslide, there is no reduction needed for background landslides, as it is naturally occurring. However, each category of landslide that is related to human management has been assigned a load allocation (US EPA 2001). The overall goal of the load allocation is to limit sediment input to no more than 125% of naturally occurring background levels by reducing sediment input from the various categories accordingly. These are charted in Figure 6 for comparison to the estimated landsliding rates during the 1989-2000 time period. Note that estimated values and TMDL load allocations for timber harvest also include landslides related to skid trails.

FIGURE 6: LANDSLIDE RATE VS TMDL LOAD ALLOCATIONS, LOWER BIG RIVER SUBBASIN (GMA)



Based on these preliminary comparisons, it appears as though landsliding related to roads and timber harvesting need to be addressed to meet the TMDL load allocation goals. Roads, in particular, seem to be significant problem. As can be seen in Figure 7, estimates of surface erosion from roads and timber harvest areas (including skid trails) indicate that both also exceed the TMDL load allocation for surface erosion. The increase in surface erosion from roads in the 1989-2000 time period versus the entire study period (1921-2000) is likely due to continued road building through the years which has resulted in greater road surface area.

FIGURE 7: SURFACE EROSION RATE VS. TMDL LOAD ALLOCATIONS, LOWER BIG RIVER SUBBASIN (GMA)



Issues, Hypotheses, and Recommendations

Water Chemistry

1. The two closely spaced water quality sampling sites on the mainstem Big River above the Little North Fork Big River were combined and analyzed as one site. These are the RWQCB and USGS sites.
2. Basic water chemistry on the mainstem Big River both upstream and downstream of the Little North Fork appear to be within applicable numeric Basin Plan water quality objectives. However, the site downstream (SWAMP BIGMWD) has limited data.
3. Other water quality parameters tested were generally within the applicable criteria. However, sodium at the mainstem sites upstream and downstream of the Little North Fork confluence exceed the criteria. At the sites upstream of the Little North Fork, copper also exceeds it's criteria. However, with the data provided, it is unclear if these detections are artifacts from the sampling or actually represent water quality conditions. For example, copper sampling at the SWAMP BIGMWD did not detect any copper.
4. Total and fecal coliform was detected at the sites upstream of the Little North Fork confluence. It appears as though the levels detected are not hazardous.
5. Some basic macroinvertibrate data was collected on the lower Little North Fork Big River.

Water Temperature

1. Continuous water temperature data logging devices were deployed by HTC and JSF at a total of twelve (12) locations in the lower Big River sub-watershed. In general, water temperature was monitored in one or more locations in the lower Big River watershed during the years 1993 to 2001.
2. With the exception of the temperature monitoring sites on the mainstem of the Big River (HTC BIG2, HTC BIG11), water temperatures in the Lower Big River subbasin were fully or moderately suitable. The mainstem Big River sites were fully unsuitable in all years monitored with high diurnal fluctuations (7.9-9.9°F) and high maximum temperatures (75-76°F).
3. Most of the Little North Fork and tributary monitoring sites exhibited low diurnal fluctuations suggesting good shading, and/or good flow conditions and/or a tempering marine influence.
4. It is probable that the Little North Fork has a cooling effect on the mainstem Big River. However, the magnitude of that effect is unknown as it is dependant on the temperature differentials and flows.

Sediment

1. All turbidity samples were collected on the mainstem Big River, both upstream and downstream of the confluence with the Little North Fork. Turbidity levels varied significantly, but 90% of all samples collected (88 total) were at or below 52 NTU, with a maximum recorded level of 600 NTU. It is unknown what normal background levels are, but these samples can assist in establishing background levels for future monitoring efforts.
2. Pebble counts and V* measurements were collected in Berry Gulch only. Measurements there indicate excessive amounts of fine material in the stream. However, this data was collected in a single monitoring study, and needs to be repeated to verify conditions in Berry Gulch.

3. McNeil samples collected by HTC in the Little North Fork indicate excessive sediment in the sub 6.5 mm and 0.85 mm size classes that generally exceeded the TMDL limits. Other McNeil data was collected by GMA and is presented in this assessment, but it is not comparable to the TMDL limits.
4. Based on preliminary data by GMA, the relative disturbance index for the Lower Big River was the second highest of the five subbasins in the Big River watershed during the 1989-2000 time period. Within the Lower Big River subbasin, the Mouth of Big River planning watershed had the highest relative disturbance index.
5. Based on preliminary comparisons of GMA data to TMDL load allocations, it appears as though landsliding related to roads and timber harvesting need to be addressed. Roads, in particular, seem to be significant problem. Surface erosion from roads and timber harvest areas (including skid trails) indicate that both also exceed the TMDL load allocation for surface erosion.

Middle Big River

The middle Big River is delineated by the CalWater planning watershed of Two Log Creek. Larger streams included in the middle Big River subbasin are the middle mainstem of the Big River and Two Log Creek. The watershed area encompassed by the middle Big River is approximately 17.9 mi^2.

The major streams in this subbasin are shown in Figure 26 on page 138. This figure also shows the names and boundaries of the CalWater 2.2 planning watersheds in the Lower Big River subbasin. Water temperature and water quality/sediment sampling sites are shown in Figure 31 and Figure 36 on pages 143 and 148, respectively. A summary of the existing water temperature and water quality data can be found in Table 29 and Table 30, respectively. These tables can be found beginning on page 178.

Water Column Chemistry

No water column chemistry data was found in the middle Big River subbasin.

Water Temperature

Continuous water temperature data logging devices were deployed by HTC and MRC at a total of nine (9) locations in the middle Big River sub-watershed. With the exception of 1997, water temperature was monitored in one or more locations in the middle Big River sub-watershed during the years 1993 to 2001. A table of abbreviated summary values is presented in this section in Table 16 on page 76, with the full summary available in Table 32 on page 184. The observed MWAT values are plotted in Figure 8on page 75.

During the initial data review, the several potential issues with the water temperature data were noted as shown in Table 37 on page 191. Data was reviewed according to the criteria established in the Water Quality Criteria section, with the intent that only data that appeared representative of stream conditions were used. In the middle Big River subbasin, all but three of the available water temperature data sets met the data quality criteria and were used for this assessment. A brief explanation of why data was or was not used follows the table.

The three data sets that were not used were excluded either because the period of record was too short or the loggers began recording too late or stopped recording too early. In each of these cases, there is evidence that the peak temperatures and MWATs were missed based on more complete records at other sites during the same season.

There are a total of three monitoring sites on Two Log Creek (HTC BIG5, HTC BIG4, and MRC 76-2). These monitoring sites are all located in the middle and lower reaches of Two Log Creek. HTC BIG5 was monitored for one year, HTC BIG4 was monitored for five years, and MRC 76-2 was monitored for two years. Based on data from the middle Two Log Creek (HTC BIG5) site, the water temperature was fully suitable with a maximum observed MWAT of 60ºF. Data collected at the two lower Two Log Creek Sites (HTC BIG4 and MRC 76-2), indicated water temperatures between fully suitable with a minimum observed MWAT of 58 F and undetermined with a maximum observed MWAT of 64 F. The only tributary to Two Log Creek that was monitored was Beaver Pond Gulch (MRC 76-20), which was monitored for one year. Based on this data, the water temperatures at this site was fully suitable with a maximum MWAT of 56°F. This may contribute to lower water temperatures in Two Log Creek if flows are sufficient. However, based on the flat peaks in the thermograph for MRC 76-20, the temperatures recorded

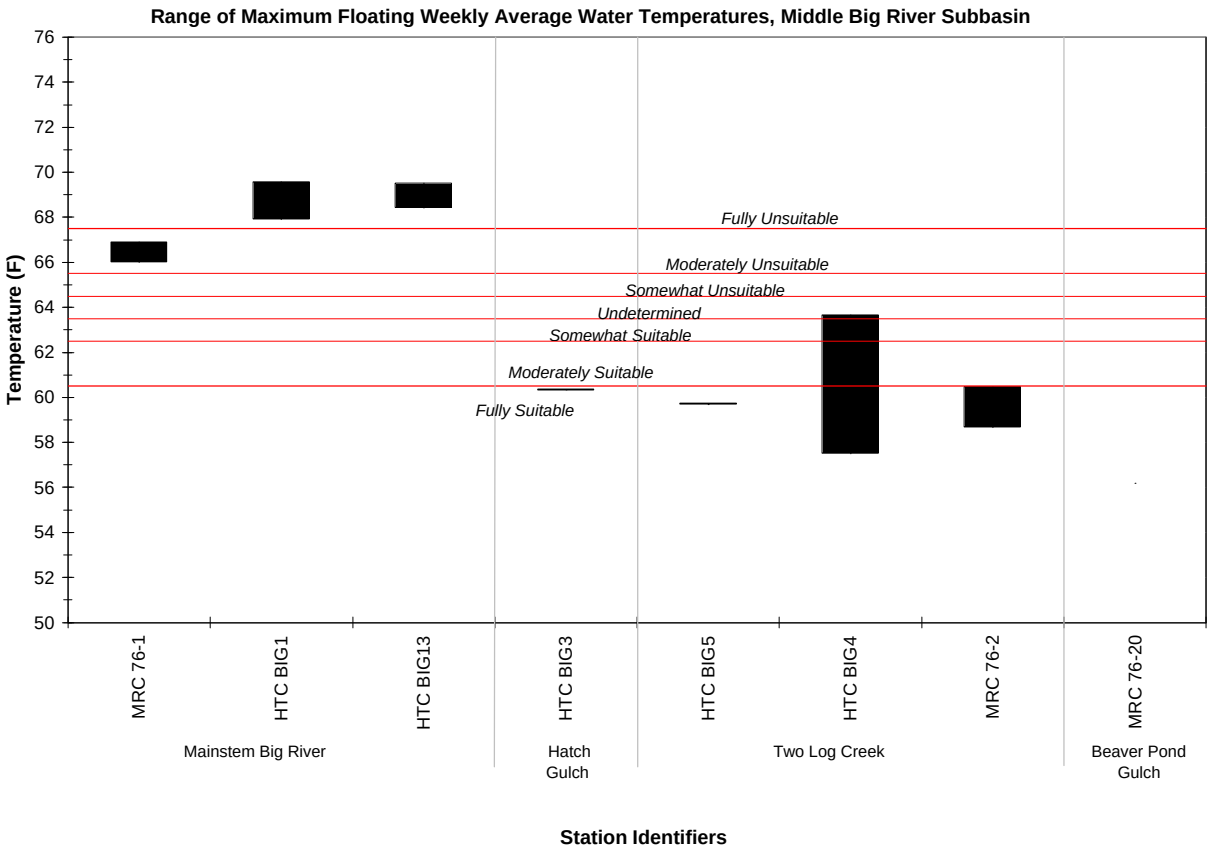
may more representative of a thermally stratified pool or a site with a significant groundwater component. It does appear that Two Log Creek does provide some cooling effect to the mainstem Big River.

With the existing information, there is no apparent trend in water temperatures in Two Log Creek as it moves downstream. This is evident in Figure 8 on page 75. However, large diurnal temperature fluctuations (6.7-12.0°F) were recorded at both lower Two Log Creek sites (MRC 76-2 and HTC BIG4). In addition, there also appear to be a downward trend in MWATs at the lower Two Log Creek sites, which may reflect regrowth canopy. Available THP maps (KRIS Big River) indicate that harvesting occurred in the vicinity of these sites in approximately 1988 and 1993. A 1994 Landsat map (KRIS Big River) shows open areas and small trees near these monitoring sites, but a map of the change in vegetation between 1994 and 1998 did not indicate a loss or gain of vegetation. However, this relationship should be explored further in the Big River Synthesis Report.

There are a total of three monitoring sites on mainstem Big River (MRC 76-1, HTC BIG1, and HTC BIG13). One site is located after the confluence with the North Fork (MRC 76-1) and was monitored for three years. The next site downstream is located between the North Fork and Two Log Creek (HTC BIG1) and was monitored for seven years. The last site is located below the confluence with Two Log Creek (HTC BIG13) and was monitored for three years.

The monitoring site below the confluence with the North Fork (MRC 76-1) recorded water temperatures that were moderately unsuitable with a maximum observed MWAT of 67ºF. In addition, the maximum water temperature recorded was 73ºF, slightly below the lethal limit for salmonids (75ºF). The diurnal fluctuations (9.7-12.8ºF) at this site also suggest poor cover and/or low flows.

FIGURE 8: RANGE OF MWATS, MIDDLE BIG RIVER SUBBASIN



The monitoring site on the mainstem Big River between the North Fork and Two Log Creek (HTC BIG1) recorded water temperatures that were fully unsuitable with a maximum observed MWAT of 70ºF. In addition, the maximum water temperature recorded was 76ºF, above the lethal limit for salmonids (75ºF). The diurnal fluctuations at this site (7.5-11.4°F) suggest poor canopy and/or flow conditions.

The monitoring site on the mainstem Big River below Two Log Creek (HTC BIG13) recorded water temperatures that were fully unsuitable with a maximum observed MWAT of 70ºF. In addition, the maximum water temperature recorded was 77ºF, above the lethal limit for salmonids (75ºF). The diurnal fluctuations at this site (10.8-11.1°F) suggest poor canopy and/or flow conditions.

A site on Hatch Gulch (HTC BIG3), a tributary to the mainstem Big River between the North Fork and Two Log Creek (but below HTC BIG1), was monitored for one year. Monitoring at this site recorded water temperatures that were fully suitable with a maximum observed MWAT of 60ºF. The diurnal fluctuations at this site were minimal. It is likely that Hatch Gulch provides some cooling effect to the mainstem Big River.

In general, water temperatures appear to increase between MRC 76-1 and HTC BIG1. While there are no significant tributaries between these sites, it appears that poor canopy in the vicinity of MRC 76-1 may be contributing to the apparent rise in water temperature. Available THP maps (KRIS Big River) indicate that harvesting occurred in the vicinity of this site in approximately 1997. A 1994 Landsat map (KRIS Big River) shows open areas and small trees

near these monitoring sites, and a map of the change in vegetation between 1994 and 1998 indicated a loss of vegetation in the area. However, this relationship should be explored further in the Big River Synthesis Report.

The summary values for each of the monitoring sites in the middle Big River are presented in Table 32 on page 184. This summary data, plus the MWAT trends, are included and ranked in Table 16 below.

TABLE 16: WATER TEMPERATURE SUMMARY, MIDDLE BIG RIVER SUBBASIN

SITE	MAX MWAT	MWAT TREND	RANGE OF MAX DIURNAL FLUCTUATIONS		SEASONAL MAX	YEARS OF DATA
Fully Suitable (50-60ºF)						
MRC 76-20	56	NA	4.2	4.2	57	1
HTC BIG5	60	NA	3.9	3.9	62	1
HTC BIG3	60	NA	5.6	5.6	62	1
MRC 76-2	60	-1.8	6.7	7.6	64	2
Moderately Suitable (61-62ºF)						
--	--	--	--	--	--	--
Somewhat Suitable (63ºF)						
--	--	--	--	--	--	--
Undetermined (64ºF)						
HTC BIG4	64	-2.2	6.7	12.0	68	5
Somewhat Unsuitable (65ºF)						
--	--	--	--	--	--	--
Moderately Unsuitable (66-67ºF)						
MRC 76-1	67	0.9	9.7	12.8	73	3[1]
Fully Unsuitable (68ºF)						
HTC BIG13	70	-1.1	10.8	11.1	77	3
HTC BIG1	70	-1.5	7.5	11.4	76	7

[1] Only 2 years diurnal.

In-Channel Sediment

In 1996 and 1997, the Hawthorne Timber Company collected McNeil samples at one site in the Middle Big River subbasin (BIG 4), located on Lower Two Log Creek. In 2001, GMA collected McNeil core samples at two locations (GMA 10 and GMA 11). MRC collected McNeil core samples in one location in 2000 (MRC S5), including permeability measurements, thalweg profiles, and stream cross-sections. All of these sites are shown in Figure 36 on page 148.

The HTC McNeil core samples were collected using a volumetric method, and are therefore directly comparable to the Big River TMDL targets described in Table 5 on page 37. In general, four McNeil cores were collected at each of the two riffles sampled. A summary of McNeil data collected at BIG 4 is shown in Table 17. Summary data broken out by riffle is provided in Table 62 on page 234. Raw data was not available for this assessment.

TABLE 17: BULK SEDIMENT DATA SUMMARY (VOLUMETRIC), TWO LOG CREEK (HTC)

SITE NAME	SITE LOCATION	YEAR	SIEVE SIZE (mm)	MEDIAN PERCENT LESS THAN
BIG 4	Lower Two Log Creek	1996	4.0	29.8%
			0.85	18.3%
		1997	4.0	27.0%
			0.85	20.2%

Based on the summary data shown in Table 17, the sediment in the sub 6.5 mm size class may have met the Big River TMDL target of = 30% in 1996 and 1997. Because a 4-mm sieve was used, the comparison was made with the 4-mm value instead of 6.5 mm. Therefore, the actual percentage under 6.5 mm is likely somewhat higher. The sediment in the sub 0.85 mm size class exceeded the Big River TMDL target of = 14% in both 1996 and 1997. In the sub 0.85 mm size class, the amount of fine sediment appeared to increase between 1996 and 1997. However not enough data is available to establish a trend and it could be due to sample variability.

In 2001, GMA collected McNeil core samples in the Middle Big River subbasin at two sites. One site is located on the Big River, just upstream of the confluence with Two Log Creek (GMA 10). The other site is also located on the Big River, downstream of the confluence with the South Fork Big River and upstream of the confluence with the North Fork Big River (GMA 11). In all size classes, more fine sediment was present at the mainstem Big River site above Two Log Creek (GMA 10) than was present at the site above the confluence with the North Fork Big River (GMA 11). However, because the core samples were collected using the gravimetric method (dry sieve), it is not comparable to the Big River TMDL target for fine sediment. A chart of the McNeil data is presented in Figure 76 on page 170. The data is also presented in a tabular form in Table 65 on page 236.

MRC also collected McNeil core samples at one site in the Middle Big River subbasin in 2000. The site is located below the confluence with the North Fork Big River on the mainstem of the Big River (MRC S5). As with the GMA McNeil data, MRC also collected the McNeil cores using the gravimetric method. As a result, this data was not comparable to Big River TMDL target for fine sediment. However, the summary data for MRC are presented in Table 65 on page 236.

MRC also recorded permeability measurements at pool tail-outs in the same stream segments where bulk sediment samples, cross-sections, and thalweg profiles were collected. In the one stream segments measured, a total of 25 or 26 median permeability values were recorded and are shown in Table 68 on page 239. The 25th, 50th, and 75th percentile values for each of these stream segments were then plotted in Figure 87 on page 176. The mainstem Big River site (MRC S5) had moderate median permeability values. Using the empirical formula shown in Equation 1 on page 22 (McBain and Trush 2000), this stream segment was expected to have roughly 31-38% survival to emergence. The McNeil sample collected in the same stream segment also suggests relatively good fine sediment conditions when compared to other MRC samples in other subbasins.

Although not used in this assessment, MRC also provided thalweg profiles and stream cross-sections for the year 2000. These are provided for reference in the event that future monitoring efforts repeat these surveys. They can be found in Figure 40 through Figure 64, beginning on page 152.

Based on the GMA Sediment Source Analysis for the Big River (Matthews 2001), the relative disturbance index for the CalWater 2.2 planning watersheds in the Middle Big River subbasin indicated that Two Log Creek had a disturbance index of 418. Figure 24 on page 136 is a map of these planning watersheds. It should be noted that in Matthews (2001), this planning watershed was split into two smaller watersheds that are referred to as Two Log Creek and Middle Big River. Out of five subbasins, the disturbance index value for the Middle Big River was the third largest (behind the Lower and Upper Big River subbasins). The relative disturbance index is the

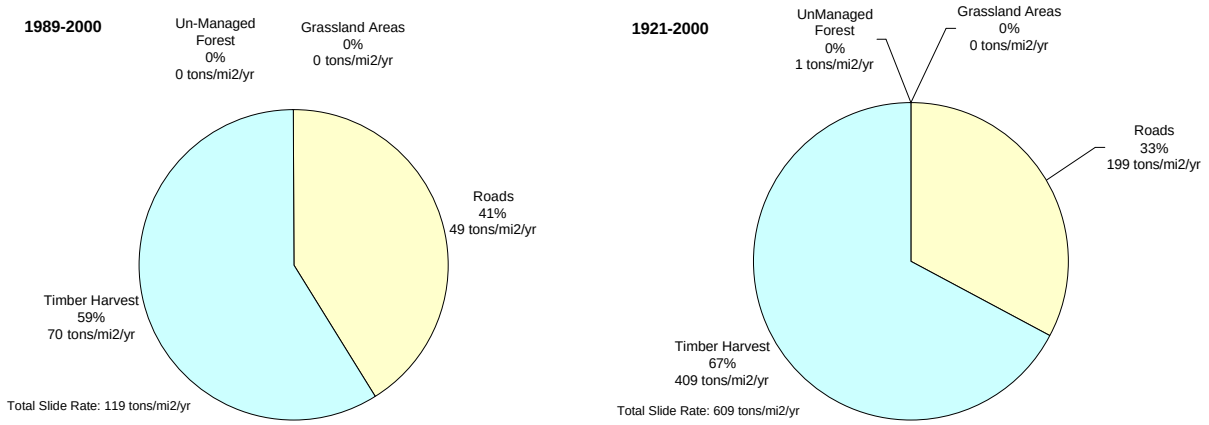
product of the road density (mi/mi^2), the percent harvested in the 1989-2000 period (acre/acre), and the unit slide volume for delivering slides during the 1989-2000 period (tons/mi^2). Each of these values are discussed in more detail in the following text. Also, unless specifically mentioned, all of the following values apply to the entire Middle Big River subbasin during the 1989-2000 time period.

The road density, calculated to be 8.6 mi/mi^2 was estimated to be 1% paved and 99% rocked or native. Of these roads, it is estimated that 20% are located in the riparian zone with the remaining 80% located mid-slope or on the ridge. The road density was calculated by the cumulative miles of roads constructed during the entire study period (1921-2000). Also, if any roads were decommissioned, it was not quantified by GMA and is therefore not reflected in these values.

The harvest density, a measure of the acres of timber harvested in a given time period divided by the total acreage in the watershed, was calculated to be 41 ac/ac (or 41% of the watershed). This was the most intense harvesting during any of the decades studied. Over the entire study period (1921-2000), an estimated 113% of the Middle Big River subbasin was harvested, with roughly 36% of that happening from 1989-2000. Of the harvesting that occurred in the 1989-2000 time period, it was reported that approximately 18% was clear cut and 80% partial cut, with 2% skid trails.

The unit volume of delivering landslides, calculated to be 119 tons/mi^2/yr, is comprised of the total of delivering landslides in unmanaged forest, brush and grasslands, roads and timber harvest areas. In the Middle Big River subbasin, it was reported that 100% of the landslides occurred in timber harvest areas or was related to roads (see Figure 9). Of the delivering landslides from harvest related activities and roads, it was estimated that 41% was related to roads and 59% was related to timber harvesting (including skid trails). When compared to these same percentages over the entire study period (1921-2000), it is estimated that 33% of the delivering landslides were road related, 67% were related to timber harvesting (including skid trails), and none were related to grassland areas or unmanaged forest. When comparing the 1989-2000 time period to that of the entire study period (1921-2000), the percentage of delivering landslides due to roads increased while those due to timber harvesting decreased. This may primary be the result of timber harvesting methods that are less disruptive, or it may be the result of years of building roads that are now triggering more landslides. It is important to note that the total estimated slide rate decreased from 609 tons/mi^2/yr (1921-2000) to 119 tons/mi^2/yr (1989-2000), a substantial drop in sediment input by landslides.

FIGURE 9: DELIVERING LANDSLIDES BY CATEGORY, MIDDLE BIG RIVER SUBBASIN (GMA)

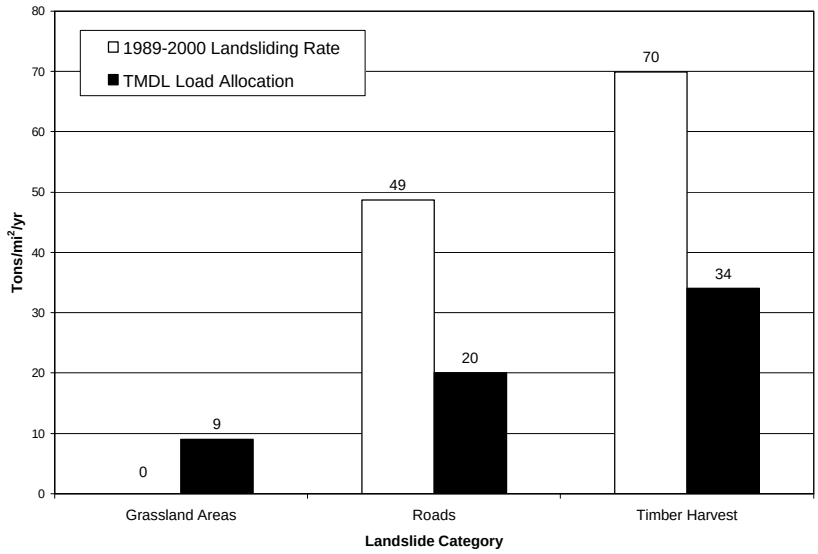


It should also be noted that background landslides, other than what was observed in unmanaged forest, has not been included in the direct comparisons discussed thus far (and shown in Figure 9). Background landslide estimates are discussed separately because they were estimated from past studies, rather than through direct observation in aerial photographs. Background landslide rates were estimated based on previous observation of natural "background" landslides in the South and North Fork of Caspar Creek (Matthews 2001). However, this presented a potentially significant difference in data quality and could be misleading if compared directly.

The background landslide rate for the 1989-2000 time period was estimated to be 159 tons/mi^2/yr. The background landslide rate for the 1921-2000 time period was estimated to be 175 tons/mi^2/yr. Regardless of data quality concerns, these estimates point to background landslides as a potentially significant component of sediment input. As a point of reference, all other landslides during the 1989-2000 time period contributed an estimated 119 tons/mi^2/yr. This would indicate that background landslides may have contributed roughly 43% of the total sediment input by all categories of landslides.

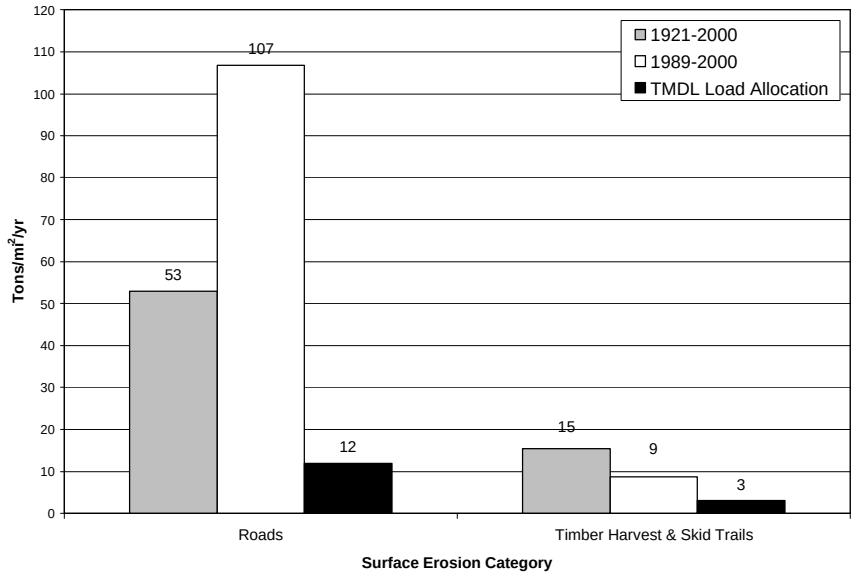
When compared to the TMDL load allocations for each category of landslide, there is no reduction needed for background landslides, as it is naturally occurring. However, each category of landslide that is related to human management has been assigned a load allocation (US EPA 2001). The overall goal of the load allocation is to limit sediment input to no more than 125% of naturally occurring background levels by reducing sediment input from the various categories accordingly. These are charted in Figure 10 for comparison to the estimated landsliding rates during the 1989-2000 time period. Note that estimated values and TMDL load allocations for timber harvest also include landslides related to skid trails.

FIGURE 10: LANDSLIDE RATE VS TMDL LOAD ALLOCATIONS, MIDDLE BIG RIVER SUBBASIN (GMA)



Based on these preliminary comparisons, it appears as though landsliding related to roads and timber harvesting need to be addressed to meet the TMDL load allocation goals. Grassland areas are not a significant problem. As can be seen in Figure 11, estimates of surface erosion from roads and timber harvest areas (including skid trails) indicate that both also exceed the TMDL load allocation for surface erosion. Surface erosion related to roads, in particular, appear to be a significant problem. The increase in surface erosion from roads in the 1989-2000 time period versus the entire study period (1921-2000) is likely due to continued road building through the years which has resulted in greater road surface area.

FIGURE 11: SURFACE EROSION RATE VS. TMDL LOAD ALLOCATIONS, MIDDLE BIG RIVER SUBBASIN (GMA)



Issues, Hypotheses, and Recommendations

Water Chemistry

1. No water column chemistry data was found in the middle Big River subbasin.

Water Temperature

1. Continuous water temperature data logging devices were deployed by HTC and MRC at a total of nine (9) locations in the middle Big River sub-watershed. With the exception of 1997, water temperature was monitored in one or more locations in the middle Big River sub-watershed during the years 1993 to 2001.
2. Data collected at the two lower Two Log Creek Sites (HTC BIG4 and MRC 76-2), indicated water temperatures between fully suitable with a minimum observed MWAT of 58 F and undetermined with a maximum observed MWAT of 64 F. Large diurnal temperature fluctuations (6.7-12.0°F) were recorded at both lower Two Log Creek sites, which may indicate poor canopy and/or low flows.
3. The only tributary to Two Log Creek that was monitored was Beaver Pond Gulch (MRC 76-20), which was monitored for one year. Based on this data, the water temperatures at this site was fully suitable with a maximum MWAT of 56°F, but based on the thermograph, it may more representative of a thermally stratified pool or a site with a significant groundwater component.
4. A site on Hatch Gulch (HTC BIG3), a tributary to the mainstem Big River between the North Fork and Two Log Creek (but below HTC BIG1), was monitored for one year. Monitoring at this site recorded water temperatures that were fully suitable with a maximum observed MWAT of 60ºF. The diurnal fluctuations at this site were minimal. It is likely that Hatch Gulch provides some cooling effect to the mainstem Big River.
5. All of the water temperature monitoring sites on the mainstem Big River (MRC 76-1, HTC BIG1, and HTC BIG13) had MWATs that varied from moderately to fully unsuitable (67-70°F) with maximum daily temperatures (73-77°F) in excess of the lethal limit for salmonids. High diurnal fluctuations were also recorded (7.5-12.8°F), suggesting poor canopy and/or low flows.
6. It is probable that Two Log Creek has a cooling effect on the mainstem Big River. However, the magnitude of that effect is unknown as it is dependant on the temperature differentials and flows.
7. In lower Two Log Creek, both MRC and HTC have temperature monitoring sites in nearly the same location. It may be more effective if one company monitored the site and shared the information with the other.

Sediment

1. McNeil samples collected by HTC in Two Log Creek indicate sediment in the sub 0.85 mm size classes that exceed the TMDL limits. Sediment data in the sub 4 mm size classes were within the TMDL limits specified for the sub 6.5 mm size classes. However, it is expected that the quantity of sediment in the sub 6.5 mm size classes is somewhat higher. Other McNeil data was collected by GMA and MRC, which is also presented in this assessment. Due to differing analysis techniques, these data are not comparable to the TMDL limits.

2. Permeability sampling by MRC in 2000 indicated low to moderate amounts of fine material at the Big River below North Fork site (MRC S5). The permeability measurements are somewhat supported by the MRC bulk sediment sampling.
3. Based on preliminary data by GMA, the relative disturbance index for the Middle Big River was the third highest of the five subbasins in the Big River watershed during the 1989-2000 time period. Within the Middle subbasin, there is only one planning watershed (Two Log Creek).
4. Based on preliminary comparisons of GMA data to TMDL load allocations, it appears as though landsliding related to roads and timber harvesting need to be addressed to meet the TMDL load allocation goals. Grassland areas are not a significant problem. Estimates of surface erosion from roads and timber harvest areas (including skid trails) indicate that both also exceed the TMDL load allocation for surface erosion. Surface erosion related to roads, in particular, appear to be a significant problem.

Upper Big River

The upper Big River is delineated by the CalWater 2.2 super-planning watershed of Upper Big River, which is comprised of the Russell Brook, Martin Creek, and Rice Creek planning watersheds. Larger streams included in the middle Big River subbasin are the upper mainstem of the Big River, and Martin Creek. The watershed area encompassed by the upper Big River is approximately 32.8 mi^2.

The major streams in this subbasin are shown in Figure 27 on page 139. This figure also shows the names and boundaries of the CalWater 2.2 planning watersheds in the Lower Big River subbasin. Water temperature and water quality/sediment sampling sites are shown in Figure 32 and Figure 37 on pages 144 and 149, respectively. A summary of the existing water temperature and water quality data can be found in Table 29 and Table 30, respectively. These tables can be found beginning on page 178.

Water Column Chemistry

No water column chemistry data was found in the upper Big River subbasin.

Water Temperature

Continuous water temperature data logging devices were deployed by MRC and JSF at a total of eight (8) locations in the upper Big River sub-watershed. With the exception of 1996, water temperature was monitored in one or more locations in the upper Big River sub-watershed during the years 1990 to 2001. A table of abbreviated summary values is presented in this section in Table 18 on page 86, with the full summary available in Table 33 on page 185. The observed MWAT values are plotted in Figure 12 on page 85.

During the initial data review, the several potential issues with the water temperature data were noted as shown in Table 38. Data was reviewed according to the criteria established in the Water Quality Criteria section, with the intent that only data that appeared representative of stream conditions were used. In the upper Big River subbasin, all but three of the available water temperature data sets met the data quality criteria and were used for this assessment. A brief explanation of why data was or was not used follows the table.

The two data sets that were not used were excluded because the period of record was insufficient to capture the peak temperatures. In those instances where the period of record is insufficient, there is evidence that the peak temperatures and MWATs were missed based on more complete records at other sites during the same season.

There are a total of two monitoring sites on Martin Creek (FSP 5235 and FSP 5219). These monitoring sites are all located in the upper and lower reaches of Martin Creek. FSP 5235 was monitored for one year, and FSP 5219 was monitored for two years. Based on data from the upper Martin Creek (FSP 5235) site, the water temperature was somewhat suitable with a maximum observed MWAT of 63ºF. Based on data collected at the lower Martin Creek site (FSP 5219), the water temperature was somewhat unsuitable maximum observed MWAT of 65 F. The only tributary to Martin Creek that was monitored was and un-named tributary (FSP 5240) in upper Martin Creek, which was monitored for two years. Based on this data, the water temperatures at this site varied between somewhat suitable with a minimum MWAT of 63 F and undetermined with a maximum MWAT of 64°F.

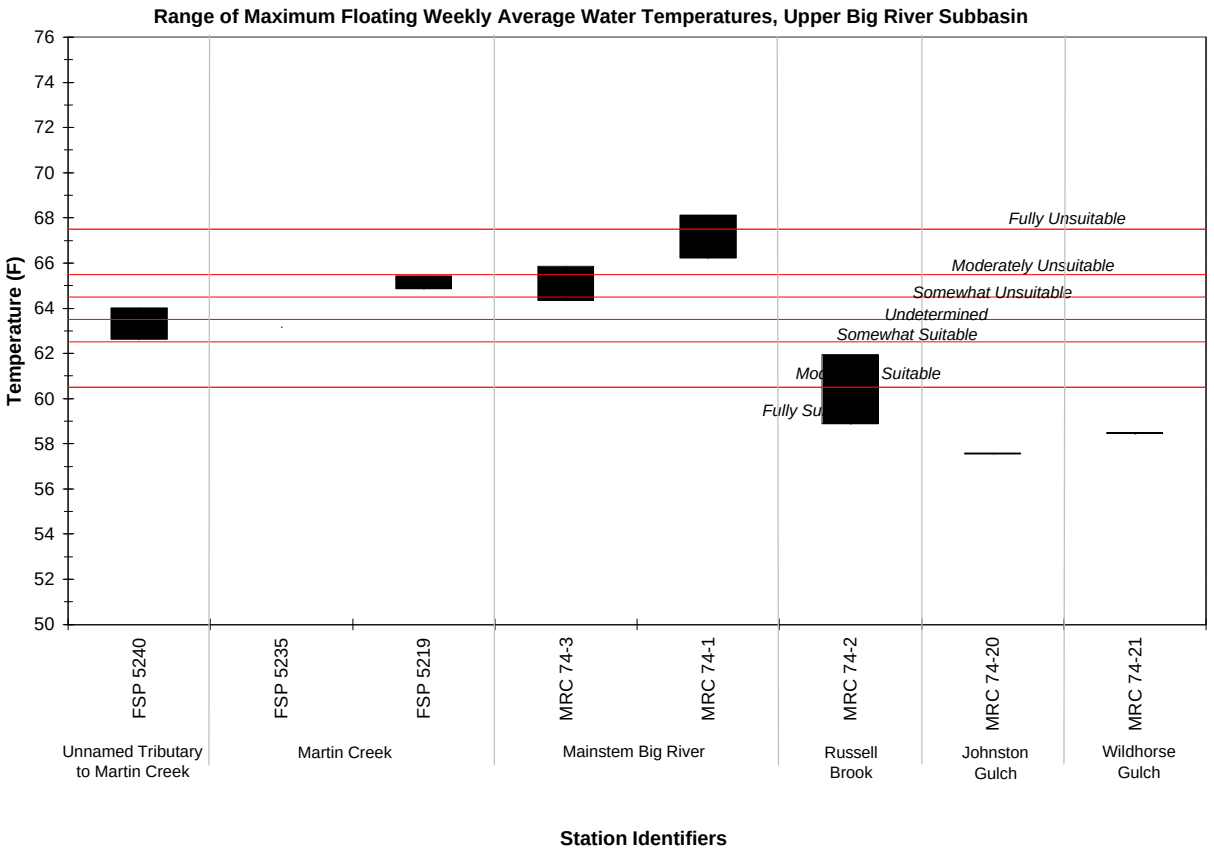
There are a total of two monitoring sites on mainstem Big River (MRC 74-3 and MRC 74-1). One site is located on the mainstem between Martin Creek and Russell Brook (MRC 74-3) and was monitored for four years. The second mainstem site is located between Russell Brook and the South Fork Big River (MRC 74-1) and was monitored for four years.

The monitoring site between Martin Creek and Russell Brook (MRC 74-3) recorded water temperatures that were undetermined to moderately unsuitable with a maximum observed MWAT of 66ºF. In addition, the maximum water temperature recorded was 73ºF, slightly below the lethal limit for salmonids (75ºF). The diurnal fluctuations (9.2-14.8ºF) at this site also suggest poor cover and/or low flows.

The monitoring site between Russell Brook and the South Fork Big River (MRC 74-1) recorded water temperatures that were moderately unsuitable to fully unsuitable with a maximum observed MWAT of 68ºF. In addition, the maximum water temperature recorded was 75ºF, which is the lethal limit for salmonids (75ºF). The diurnal fluctuations (10.8-12.9ºF) at this site also suggest poor cover and/or low flows.

Water temperatures at several tributaries that feed into the mainstem Big River below Martin Creek were also monitored. These include Russell Brook (MRC 74-2), Johnston Gulch (MRC 74-20), and Wildhorse Gulch (MRC 74-21). These sites were monitored for four years, one year, and one year, respectively. The monitoring site on Russell Brook (MRC 74-2) recorded water temperatures that were fully suitable to moderately suitable, with a maximum observed MWAT of 62 F. The diurnal fluctuations (6.7-8.4 F) at this site suggest moderate to poor cover and/or low flows. The monitoring site on Johnston Gulch (MRC 74-20) recorded water temperatures that were fully suitable, with a maximum observed MWAT of 58 F. The monitoring site on Wildhorse Gulch (MRC 74-21) recorded water temperatures that were fully suitable, with a maximum observed MWAT of 58 F. The diurnal fluctuations at each of these sites are minimal.

FIGURE 12: RANGE OF MWATS, UPPER BIG RIVER SUBBASIN



As would be expected, there appears to be an upward trend in water temperatures as the water moves lower in the both the mainstem Big River and Martin Creek. While there is insufficient information to determine if the un-named tributary to Martin Creek has an effect on the water temperatures in Martin Creek, it appears as though Russell Brook does provide some cooling effect to the mainstem Big River. The two other tributaries that were monitored were significantly cooler than the mainstem Big River. However, they were only monitored for one year and the thermographs from these sites indicate that they may be in stratified pools or possibly a groundwater dominant regime. In either case, it is unknown how much flow they contribute to the mainstem Big River and thus if they provide any cooling effect.

Available THP maps (KRIS Big River) indicate that harvesting occurred in large portions of the Martin Creek watershed between 1989-1999. A 1994 Landsat map (KRIS Big River) shows many open areas and small trees near many of the monitoring sites, which may be contributing to the large diurnal fluctuations and generally higher water temperatures. However, this relationship should be explored further in the Big River Synthesis Report.

The summary values for each of the monitoring sites in the upper Big River are presented in Table 33 on page 185. This summary data, plus the MWAT trends, are included and ranked in Table 18 below.

TABLE 18: WATER TEMPERATURE SUMMARY, UPPER BIG RIVER SUBBASIN

SITE	MAX MWAT	MWAT TREND	RANGE OF MAX DIURNAL FLUCTUATIONS		SEASONAL MAX	YEARS OF DATA
Fully Suitable (50-60ºF)						
MRC 74-20	58	NA	2.8	2.8	59	1
MRC 74-21	58	NA	4.1	4.1	60	1
Moderately Suitable (61-62ºF)						
MRC 74-2	62	-0.6	6.7	8.4	66	4[1]
Somewhat Suitable (63ºF)						
FSP 5235	63	NA	12.4	12.4	72	1
Undetermined (64ºF)						
FSP 5240	64	1.4	11.0	15.0	75	2
Somewhat Unsuitable (65ºF)						
FSP 5219	65	-0.6	11.7	12.4	72	2
Moderately Unsuitable (66-67ºF)						
MRC 74-3	66	1.5	9.2	14.8	73	4
Fully Unsuitable (68ºF)						
MRC 74-1	68	1.6	10.8	12.9	75	4[2]

[1] Only 3 years of diurnal
[2] Only 2 years of diurnal

In-Channel Sediment

Graham Matthews & Associates collected turbidity and suspended sediment samples in the upper Big River subbasin in 2001. A single site was chosen on the mainstem of the Big River in support of the US EPA Big River TMDL. A total of seven turbidity and suspended sediment samples were taken over the sampling period. In addition, three flow measurements were also taken.

At the suspended sediment/turbidity sampling location on the mainstem Big River, background conditions cannot be established due to the lack of data. Of the data that does exist, all of the samples were collected during the winter. Six of the seven turbidity values were reported between 3.8 and 41.9 NTU, which appears reasonable. One turbidity sample was reported at 240 NTU. However, due to the inherent variability in turbidity and suspended sediment sampling and lack of any background sampling, further data is needed to determine the condition of this site with respect to suspended sediment concentrations. Summary turbidity data is presented in Table 59 on page 231.

As can be seen in Figure 65 on page 165, suspended sediment and turbidity appear to be closely related. With the small sample set available for this site, the coefficient of determination (r^2) value is 0.99. This indicates that there is probably very good correlation between turbidity and suspended sediment.

While turbidity and suspended sediment concentrations did not correlate well with flow, it was found that the suspended sediment load did correlate well with flow at this site (r^2=0.86) (GMA, 2001).

Based on the GMA Sediment Source Analysis for the Big River (Matthews 2001), the relative disturbance index for the CalWater 2.2 planning watersheds in the Upper Big River subbasin

indicated that Martin Creek was the most disturbed with a disturbance index of 2,280, followed by Rice Creek (1,563), and Russell Brook (988). Figure 24 on page 136 is a map of these planning watersheds. It should be noted that in Matthews (2001), these planning watersheds are also referred to as Martin Creek, Upper Mainstem Big River, and Lower Mainstem Big River, respectively. As a whole, the Upper Big River subbasin had a relative disturbance index of 1,550 for the 1989-2000 time period. Out of five subbasins, the disturbance index value for the Upper Big River was the largest of any subbasin. The relative disturbance index is the product of the road density (mi/mi^2), the percent harvested in the 1989-2000 period (acre/acre), and the unit slide volume for delivering slides during the 1989-2000 period (tons/mi^2). Each of these values are discussed in more detail in the following text. Also, unless specifically mentioned, all of the following values apply to the entire South Fork subbasin during the 1989-2000 time period.

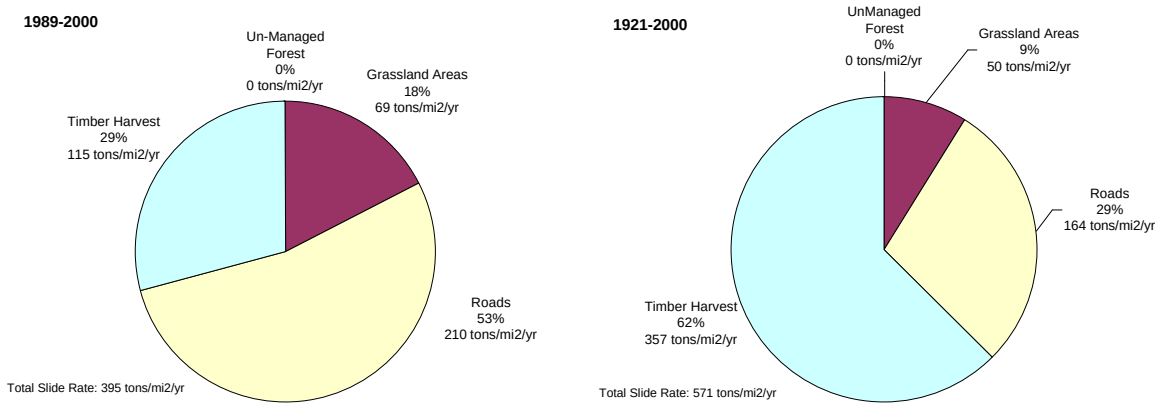
The road density, calculated to be 7.1 mi/mi^2 was estimated to be 0% paved and 100% rocked or native. Of these roads, it is estimated that 23% are located in the riparian zone with the remaining 77% located mid-slope or on the ridge. It should be noted that the road density was calculated by the cumulative miles of roads constructed during the entire study period (1921[5]-2000). Also, if any roads were decommissioned, it was not quantified by GMA and is therefore not reflected in these values.

The harvest density, a measure of the acres of timber harvested in a given time period divided by the total acreage in the watershed, was calculated to be 55 ac/ac (or 55% of the watershed). This was the most intense harvesting during any of the decades studied. Over the entire study period (1936-2000), an estimated 123% of the Upper Big River subbasin was harvested, with roughly 45% of that happening from 1989-2000. Of the harvesting that occurred in the 1989-2000 time period, it was reported that approximately 4% was clear cut and 96% partial cut, with less than one percent skid trails.

The unit volume of delivering landslides, calculated to be 395 tons/mi^2/yr, is comprised of the total of delivering landslides in unmanaged forest, brush and grasslands, roads and timber harvest areas. In the Upper Big River subbasin, it was reported that 18% of the landslides occurred in grassland areas, none occurred in unmanaged forest, and the remaining 82% occurred in timber harvest areas or was related to roads (see Figure 13). Of the delivering landslides from harvest related activities and roads, it was estimated that 53% was related to roads and 29% was related to timber harvesting (including skid trails). When compared to these same percentages over the entire study period (1921-2000), it is estimated that 29% of the delivering landslides were road related, 62% were related to timber harvesting (including skid trails), 9% were related to grassland areas, and none occurred in unmanaged forest areas. This switch in the primary cause of delivering landslides may be the result of timber harvesting methods that are less disruptive, or it may be the result of years of building roads that are now triggering more landslides. It is important to note that the total estimated slide rate decreased from 571 tons/mi^2/yr (1921-2000) to 395 tons/mi^2/yr (1989-2000), a substantial drop in sediment input by landslides.

[5] No 1936 aerial photographs are available for this subbasin.

FIGURE 13: DELIVERING LANDSLIDES BY CATEGORY, UPPER BIG RIVER SUBBASIN (GMA)

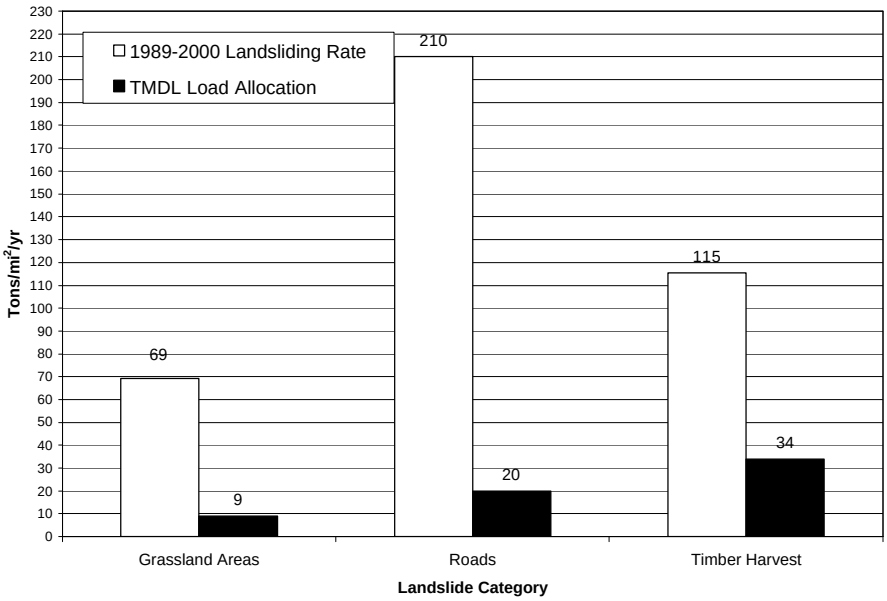


It should also be noted that background landslides, other than what was observed in unmanaged forest, has not been included in the direct comparisons discussed thus far (and shown in Figure 14). Background landslide estimates are discussed separately because they were estimated from past studies, rather than through direct observation in aerial photographs. Background landslide rates were estimated based on previous observation of natural "background" landslides in the South and North Fork of Caspar Creek (Matthews 2001). However, this presented a potentially significant difference in data quality and could be misleading if compared directly.

The background landslide rate for the 1989-2000 time period was estimated to be 159 tons/mi^2/yr. The background landslide rate for the 1921-2000 time period was estimated to be 175 tons/mi^2/yr. Regardless of data quality concerns, these estimates point to background landslides as a potentially significant component of sediment input. As a point of reference, all other landslides during the 1989-2000 time period contributed an estimated 395 tons/mi^2/yr. This would indicate that background landslides may have contributed 29% of the total sediment input by all categories of landslides.

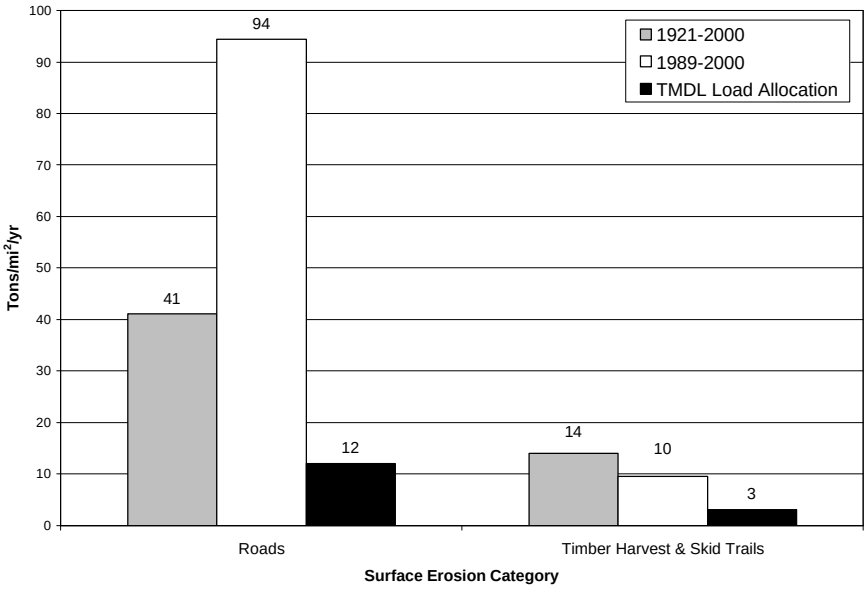
When compared to the TMDL load allocations for each category of landslide, there is no reduction needed for background landslides, as it is naturally occurring. However, each category of landslide that is related to human management has been assigned a load allocation (US EPA 2001). The overall goal of the load allocation is to limit sediment input to no more than 125% of naturally occurring background levels by reducing sediment input from the various categories accordingly. These are charted in Figure 14 for comparison to the estimated landsliding rates during the 1989-2000 time period. Note that estimated values and TMDL load allocations for timber harvest also include landslides related to skid trails.

FIGURE 14: LANDSLIDE RATE VS TMDL LOAD ALLOCATIONS, UPPER BIG RIVER SUBBASIN (GMA)



Based on these preliminary comparisons, it appears as though landsliding related to roads, timber harvesting, and grassland areas need to be addressed to meet the TMDL load allocation goals. As can be seen in Figure 15, estimates of surface erosion from roads and timber harvest areas (including skid trails) indicate that both also exceed the TMDL load allocation for surface erosion. Surface erosion and landslides related to roads, in particular, appear to be a significant problem. The increase in surface erosion from roads in the 1989-2000 time period versus the entire study period (1921-2000) is likely due to continued road building through the years which has resulted in greater road surface area.

FIGURE 15: SURFACE EROSION RATE VS. TMDL LOAD ALLOCATIONS, SOUTH FORK BIG RIVER SUBBASIN (GMA)



Issues, Hypotheses, and Recommendations

Water Chemistry

1. No water column chemistry data was found in the upper Big River subbasin.

Water Temperature

1. Continuous water temperature data logging devices were deployed by MRC and JSF at a total of eight (8) locations in the upper Big River sub-watershed. With the exception of 1996, water temperature was monitored in one or more locations in the upper Big River sub-watershed during the years 1990 to 2001.
2. Based on limited data from two sites in the Martin Creek watershed, the water temperatures were somewhat suitable to somewhat unsuitable with a maximum MWAT of 65°F.
3. There are two monitoring sites on the mainstem Big River, both of which were recorded for four years. Both sites had MWATs that were undetermined to fully unsuitable with a maximum MWAT of 68°F. In addition, the site between Russell Brook and the South Fork Big River (MRC 74-1) had a maximum daily temperature of 75°F and large diurnal fluctuations of between 10.8-12.9°F.
4. Several tributaries to the mainstem Big River were monitored for one to four years. Russell Brook (MRC 74-2) had a maximum MWAT of 62°F and moderate diurnal fluctuations of between 6.7-8.4°F. This suggests moderate to poor cover and/or low flows and probably contributes cooler water to the mainstem Big River. The other two sites at Johnston Gulch (MRC 74-20) and Wildhorse Gulch (MRC 74-21) have MWATs that are fully suitable (58°F), with low diurnal fluctuations. It is likely that the temperature probes at these sites are heavily influenced by subsurface flows (groundwater).

Sediment

1. Turbidity was measured in the winter by GMA on the mainstem of the Big River above the confluence with the South Fork Big River. Six of the seven turbidity values were reported between 3.8 and 41.9 NTU. One turbidity sample was reported at 240 NTU.
2. Suspended sediment and turbidity are closely related. With the small sample set available for this site, the coefficient of determination (r^2) value is 0.99.
3. Based on preliminary data by GMA, the relative disturbance index for the Upper Big River was the highest of the five subbasins in the Big River watershed during the 1989-2000 time period. Within the Upper Big River subbasin, the Martin Creek planning watershed had the highest relative disturbance index.
4. Based on preliminary data from GMA, it appears as though landsliding related to roads, timber harvesting, and grassland areas need to be addressed to meet the TMDL load allocation goals. Estimates of surface erosion from roads and timber harvest areas (including skid trails) indicate that both also exceed the TMDL load allocation for surface erosion. Surface erosion and landslides related to roads, in particular, appear to be a significant problem.

North Fork Big River

The north fork Big River is delineated by the CalWater 2.2 super-planning watershed of North Fork Big River, which is comprised of the Chamberlain Creek, James Creek, Lower North Fork Big River, Upper North Fork Big River, and East Branch North Fork Big River planning watersheds. Larger streams included in the north fork Big River subbasin are the upper north fork of the Big River, James Creek, Chamberlain Creek, East Branch of the North Fork, and lower north fork of the Big River. The watershed area encompassed by the north fork of the Big River is approximately 43.5 mi^2.

The major streams in this subbasin are shown in Figure 28 on page 140. This figure also shows the names and boundaries of the CalWater 2.2 planning watersheds in the Lower Big River subbasin. Water temperature and water quality/sediment sampling sites are shown in Figure 33 and Figure 38 on pages 145 and 150, respectively. A summary of the existing water temperature and water quality data can be found in Table 29 and Table 30, respectively. These tables can be found beginning on page 178.

Water Column Chemistry

The North Fork Big River subbasin contained two water quality sampling sites. One water quality sampling site is a community water system at the CDF Chamberlain Creek Conservation Camp under DHS purview. The intake to the drinking water system (the sampling point) is on lower Chamberlain Creek, immediately above the confluence with the North Fork Big River. The other water quality sampling site is a SWAMP sampling site on the North Fork Big River below the confluence with Chamberlain Creek.

A creek diversion (surface water) system is operated by CDF at the Chamberlain Creek Conservation Camp that has been typically sampled two to three times a year from 1991 through 2000 (last available data). The source water was not sampled in 1992, 1994, 1995, and 1998. The SWAMP sampling site on the North Fork Big River was sampled on two occasions in 2001.

The analysis of water column chemistry is divided into parameters with numeric water quality objectives in the Basin Plan, parameters with narrative water quality objectives in the Basin Plan (which can be quantified using numeric criteria found in the literature), and other important parameters that may have applicable narrative water quality objectives, but no available numeric criteria. This division of analytes is discussed in more detail in the Water Column Chemistry section, beginning on page 45.

Basic water chemistry data, including dissolved oxygen, specific conductance, total dissolved solids, and hydrogen ion concentration (pH) were compared to numeric water quality objectives in the Basin Plan. Dissolved oxygen and total dissolved solids were not sampled at the Chamberlain Creek site. The summary data for basic water quality at the North Fork Big River subbasin sites are shown in Table 19.

TABLE 19: BASIC PHYSICAL WATER PARAMETERS, NORTH FORK BIG RIVER SUBBASIN

PARAMETER	COUNT ALL	COUNT DETECTS	MIN.	DATE MIN[6]	MAX.	DATE MAX	AVG.	WQ OBJECTIVES MIN	WQ OBJECTIVES MAX
Site Name, Location: CDF Chamberlain (DHS), lower Chamberlain Creek									
pH, Lab (pH units)	1	1	7.9	2/14/96	7.9	2/14/96	NA	6.5	8.5
Specific Conductance (µS/cm)	1	1	134	2/14/96	134	2/14/96	NA	NA	300[3] / 195[4]
Site Name, Location: SWAMP BIGH20, North Fork Big River									
Dissolved Oxygen, Field (mg/L)	2	2	9.86	06/28/01	10.33	05/10/01	NA	7.0 / 7.5[1] / 10.0[2]	NA
pH, Lab (pH units)	2	2	8.3	05/10/01	8.46	06/28/01	NA	6.5	8.5
pH, Field (pH units)	2	2	8.22	05/10/01	8.38	06/28/01	NA	6.5	8.5
Specific Conductance (µS/cm)	1	1	220	06/28/01	220	06/28/01	NA	NA	300[3] / 195[4]
Specific Conductance, Field (µS/cm)	2	2	209	05/10/01	226	06/28/01	NA	NA	300[3] / 195[4]
Total Dissolved Solids (mg/L)	2	2	140	05/10/01	150	06/28/01	NA	NA	190[3] / 130[4]

[1] Value represents the 90th percentile lower limit. 90% of the values in a calendar year must be equal to or greater than the 90% lower limit.
[2] Value represents the 50th percentile (median) lower limit. 50% of the monthly means in a calendar year must be equal to or greater than the 50% lower limit.
[3] Value represents the 90th percentile upper limit. 90% of the values in a calendar year must be equal to or less than the 90% upper limit.
[4] Value represents the 50th percentile (median) upper limit. 50% of the monthly means in a calendar year must be equal to or less than the 50% upper limit.

As can be seen in Table 19, the pH of the water at the Chamberlain Creek site (CDF Chamberlain) was reported at 7.9, which is within the Basin Plan water quality objective. Specific conductance appeared to be within or slightly below the acceptable range in the one sample collected. However, in all cases, the amount of data available for this site, combined with unknown data quality, limit the data to screening purposes only.

At the North Fork Big River site (SWAMP BIGH20), water samples for pH, total dissolved solids, and specific conductance were collected for laboratory analysis. Additional measurements of dissolved oxygen, pH, and specific conductance were taken in the field. Each of these constituents appeared to be within the acceptable range in both samples.

Narrative water quality objectives in the Basin Plan apply to a variety of metals and other constituents that were detected during the sampling events. This includes alkalinity, aluminum, ammonia, barium, boron, chloride, copper, iron, sodium, sulfate, and zinc. Unlike the constituents shown in Table 19, the numeric criteria for these parameters are derived from the literature to support the narrative water quality objectives. The constituents and the most conservative applicable criteria are shown in Table 20.

TABLE 20: GENERAL WATER COLUMN CHEMISTRY, NORTH FORK BIG RIVER SUBBASIN

PARAMETER	COUNT ALL	COUNT DETECTS	MIN.	MAX.	AVG.	CRITERIA	CRITERIA EXCEEDED?	COMMENTS ON CRITERIA[1]
Site Name, Location: CDF Chamberlain (DHS), lower Chamberlain Creek								
Alkalinity, Total (mg/L as $CaCO_3$)	1	1	54	54	NA	= 20 mg/L	No	Protection of freshwater aquatic life
Aluminum (µg/l)	3	2	0	1300	NA	= 87 µg/L	Yes	Protection of freshwater aquatic life
Barium (µg/l)	3	1	0	21	NA	= 1000 µg/L	No	Primary California MCL for

[6] Date on which the minimum value occurred is the first date that the value occurred. For example, if there were several "non-detects", represented here as a zero, the date given is the first instance of non-detect (chronologically).

PARAMETER	COUNT ALL	COUNT DETECTS	MIN.	MAX.	AVG.	CRITERIA	CRITERIA EXCEEDED?	COMMENTS ON CRITERIA[1]
								drinking water
Chloride (mg/l)	1	1	14	14	NA	= 106 mg/L	No	Protection of agricultural water uses
Copper (µg/l)	1	1	190	190	NA	= 4.0 µg/L	Yes	Protection of freshwater aquatic life with a hardness of 39 mg/L[2]
Iron (µg/l)	1	1	140	140	NA	= 300 µg/L	No	Secondary California MCL for drinking water
Sodium (mg/l)	1	1	9.7	9.7	NA	= 2 mg/L	Yes	SNARL for drinking water toxicity other than cancer risk, US EPA[3]
Sulfate (mg/l)	1	1	4.1	4.1	NA	= 250 mg/L	No	Secondary California MCL for drinking water
Zinc (µg/l)	1	1	88	88	NA	= 53 µg/L	Yes	Protection of freshwater aquatic life with a hardness of 39 mg/L[2]
Site Name, Location: SWAMP BIGH20, North Fork Big River								
Alkalinity, Total (mg/L)	2	2	90	98	NA	= 20 mg/L	No	Protection of freshwater aquatic life
Boron (µg/L)	2	2	240	300	NA	= 630 µg/L	No	IRIS reference dose for drinking water, US EPA
Chloride (mg/L)	1	1	8.1	8.1	NA	= 106 mg/L	No	Protection of agricultural water uses
Copper (µg/L)	2	0	0	0	NA	= 7.6 µg/L	No	Protection of freshwater aquatic life with a hardness of 83 mg/L[2]
Iron (µg/L)	2	0	0	0	NA	= 300 µg/L	No	Secondary California MCL for drinking water
Sodium (mg/L)	2	2	12	13	NA	= 2 mg/L	Yes	SNARL for drinking water toxicity other than cancer risk, US EPA[3]
Sulfate as SO_4 (mg/L)	1	1	6.3	6.3	NA	= 250 mg/L	No	Secondary California MCL for drinking water
Zinc (µg/L)	2	0	0	0	NA	= 101 µg/L	No	Protection of freshwater aquatic life with a hardness of 83 mg/L[2]

[1] See the **Water Column Chemistry** section beginning on page 45 for description of criteria.
[2] See text below for details on derivation of criteria.
[3] Assumes a relative source contribution of 10% from drinking water and 90% from other dietary sources.

As can be seen in Table 20, several constituents, including aluminum, copper, sodium, and zinc exceeded their numeric criteria at the Chamberlain Creek site (CDF Chamberlain). At the North Fork Big River site (SWAMP BIGH20), neither copper nor zinc was detected at or above the detection limits for the analytical method used, which were 10 µg/L and 20 µg/L, respectively. However, sodium was detected at similar concentrations at both sites; all of which were above the water quality criteria. The aluminum concentration at the lower Chamberlain Creek site (CDF Chamberlain) exceed all of the applicable primary and secondary MCLs, including the US EPA MCL (20-200 µg/l), the California primary MCL (1,000 µg/l), and the California secondary MCL (200 µg/l). No other criteria were found in Marshack (2000) relating to sodium, copper, or zinc.

At the Chamberlain Creek site (CDF Chamberlain), it is not clear if the water samples were filtered or not-filtered, and how they were collected and analyzed. Each of these factors could affect the extent to which the sample results are representative of the true concentrations. It is unclear if the metals in the water are naturally occurring or anthropogenic pollution from the CDF camp. While samples collected for DHS are generally located at the system intake, it is

also possible that the sample is from some other point in the water system. Also, with only one to three samples, these results are only a beginning of the sample set that is needed to characterize the surface water in Chamberlain Creek and the North Fork Big River. Therefore, these values are useful as screening values only and additional sampling should occur to adequately characterize the water quality.

It should also be noted that at the North Fork Big River site (SWAMP BIGH20), alkalinity was speciated into carbonate, bicarbonate, and hydroxide alkalinity. At this site, the alkalinity was almost entirely bicarbonate alkalinity, with small amounts of other alkalinity at levels below the detection limits. Samples for total hardness as calcium carbonate ($CaCO_3$) were also collected on one occasion at the Chamberlain Creek site and two times at the North Fork Big River site. The sample collected at the Chamberlain Creek site (CDF Chamberlain) on February 14, 1996 was reported to be 39 mg/L. The samples collected at the North Fork Big River site (SWAMP BIGH20) on May 10, 2001 and June 28, 2001 was 82 and 85 mg/L, respectively. These values were used to determine the water quality criteria for the metals such as copper and zinc, whose toxicity depends on the hardness of the water.

Water samples were also collected for ammonia at the North Fork Big River site (SWAMP BIGH20). Of the two samples collected, one of the samples, collected on June 28, 2001 contained 0.12 mg/L of ammonia nitrogen. Ammonia in the other water sample was not detected at or above the analytical detection limit of 0.05 mg/L. The toxicity of ammonia to freshwater organisms depends on several factors, including the water temperature and pH. During the sample collection, the pH was measured at 8.38 and the water temperature was measured at 16.2°C (61.2°F). Based on these values, the water quality criteria for ammonia is approximately 1.17 mg/L (US EPA 1999). Nitrate/Nitrite nitrogen was also sampled for, but was not detected at or above the analytical detection limit of 0.05 mg/L.

Turbidity, phosphorus, and chlorophyll-a were also reported, but none have specific numeric criteria at this time. However, they are broken out separately because they are significant constituents of water quality. Turbidity, for the purposes of this assessment, is considered a sediment related parameter and is discussed further in the In-Channel Sediment section, beginning on page 101.

Phosphorus can enter surface water bodies through fertilizer run-off or from the natural weathering of rocks in some watersheds. Phosphorus is as a biostimulantory substance for algae, and excessive amounts can lead to algae blooms which can impact other aquatic life by negatively affecting dissolved oxygen concentrations. The summary data for phosphorus samples collected at the North Fork Big River site (SWAMP BIGH20) are shown in Table 21. No samples for phosphorus were collected at the Chamberlain Creek site (CDF Chamberlain).

TABLE 21: PHOSPHORUS SUMMARY, NORTH FORK BIG RIVER SUBBASIN

PARAMETER	COUNT ALL	COUNT DETECTS	MIN.	DATE MIN	MAX.	DATE MAX	AVG.
Site Name, Location: SWAMP BIGH20, North Fork Big River							
Phosphorus (mg/L)	2	0	0	NA	0	NA	NA
Orthophosphate as P (mg/L)	2	1	0	06/28/01	0.058	05/10/01	NA

There is not sufficient data to make more than broad statements about phosphorus. However, there was not an apparent problem with elevated phosphorus levels in the samples. However,

orthophosphate was detected on one occasion. Orthophosphate, one of several species that together make up total phosphorus, is believed to be the more bio-available variety to plants such as algae. However, there is no water quality criteria for this constituent and therefore it is used primarily to screen for other potential water quality problems.

Chlorophyll-a was also sampled once at the North Fork Big River site (SWAMP BIGH20) and was detected with a concentration of 0.00078 mg/L. Chlorophyll-a is a measurement of the chlorophyll in the suspended algae in the water column. High chlorophyll-a content, which directly relates to high algal concentrations in freshwater, can be an indicator of nutrient contamination of the surface water (such as in fertilizer run-off). However, there is no water quality criteria for this constituent and therefore it is used primarily to screen for other potential water quality problems.

On February 27, 2001, a tanker truck containing approximately 7,000 gallons of used motor oil and diesel overturned on highway 20 at mile marker 21.76 (measured from the highway 1/highway 20 intersection at Fort Bragg). While some of the liquid remained on the roadway and adjacent unpaved shoulders, a portion of it ultimately discharged to a tributary to James Creek. In an attempt to stop continued discharge of pollutants to James Creek, a dam was constructed on the tributary. However, testing at various locations along the un-named tributary and James Creek itself (RWQCB 2-RWQCB 10) indicated that some of the constituents discharged to James Creek. This included 1,2,4-trimethylbenzene, toluene, xylene, tetrachlorethene, methyl tert-butyl ether (MtBE), petroleum hydrocarbons in the diesel and motor oil ranges, and others (see Table 48 through Table 56, beginning on page 215). Many of these compounds exceeded their numeric water quality criteria, but the event was episodic and has been in active cleanup. Because of the active cleanup and frequent verification monitoring, this spill is unlikely to have a sustained impact on wildlife.

A complete list of water quality parameters that were sampled for, including those that were not detected, refer to Table 44 on page 208 for the Chamberlain Creek site and Table 47 on page 214 for the North Fork Big River site.

Water Temperature

Continuous water temperature data logging devices were deployed by MRC and JSF at a total of thirty (30) locations in the North Fork subbasin. However, one site on the lower North Fork (MRC 75-4) apparently had no raw data associated with it or it was not made available for this assessment. Therefore, there were a total of twenty-nine active sites in this subbasin with summary values for one additional site. With the exception of 1995, water temperature was monitored in one or more locations in the North Fork subbasin during the years 1991 to 2001. However, the majority of the temperature monitors were deployed during the summer seasons of 1996, 1997, and 1998. Only nine (9) sites were monitored during other years.

During the initial data review, the several potential issues with the water temperature data were noted as shown in Table 39 on page 195. Data was reviewed according to the criteria established in the Water Quality Criteria section, with the intent that only data that appeared representative of stream conditions were used. In the North Fork subbasin, all but two of the available water temperature data sets met the data quality criteria and were used for this assessment.

The two data sets that were not used were excluded either because the period of record was insufficient to capture the peak temperatures (FSP 538) or the data logger appeared to produce erroneous data (MRC 75-20). In the instance where the period of record is insufficient, there is

evidence that the peak temperatures and MWATs were missed based on more complete records at other sites during the same season. The other data logger that apparently produced erroneous data may have been malfunctioning (possibly due to a dead or dying battery), may have been poorly placed, or may have been placed in a pool that was thermally stratified and/or placed in a pool that was fed almost entirely by groundwater. In any case, because there were no clear patterns to indicate that the data logger was responding to temperature changes observed at other sites, the data was not used for this assessment. However, if future monitoring at MRC 74-20 proves that this behavior is representative of this site, it may be used in future assessments.

There are a total of nine monitoring sites on the North Fork of the Big River (FSP 5238, FSP 5220, JSF 527, JSF 528, JSF 529, JSF 530, JSF 531, JSF 532, and MRC 75-4). These monitoring sites are all located in the throughout all of the reaches in the North Fork and were recording temperatures for the following durations: two years at FSP 5238, two years at FSP 5220, one year at JSF 527, three years at JSF 528, one year at JSF 529, three years at JSF 530, one year at JSF 531, three years at JSF 532, and one year at MRC 75-4.

In the upper reaches of the North Fork (FSP 5238 and FSP 5220), the water temperature was somewhat suitable with an observed maximum MWAT of between 63 and 64°F. The North Fork then enters the Jackson State Demonstration Forest, and the first monitoring site (JSF 527) that is encountered is near the forest boundary. At this site (JSF 527), water temperature was moderately unsuitable with an observed maximum MWAT of 66°F. The reason for this temperature jump is unclear. However, it could be due to any one or more of the following: the influences of a small un-named tributary between the monitoring sites; a lack of canopy or flow in the vicinity of JSF 527; or the placement of the FSP temperature probes may not follow the standard protocol used by JSF. Based on a 1994 Landsat vegetation map (KRIS Big River), the position in the watershed (e.g. headwaters) and the diurnal temperature fluctuations at the FSP sites, it is likely that the canopy and/or flow is poor at these sites. While the canopy appears to be good at JSF 527, the large temperature jump is likely due to a particularly exposed section of stream immediately upstream which heats the water quickly, possibly combined with a different protocol for probe placement.

After entering the Jackson State Forest, the temperatures in the North Fork remain relatively high, but generally appear to decline downstream. Two probes were place on either side of the confluence with James Creek, JSF 528 and JSF 529. Water temperatures at these sites were moderately unsuitable, with a maximum observed MWAT of 66°F before the confluence with James Creek to somewhat unsuitable with an MWAT of 65°F. This, combined with temperature data from James Creek, suggest that James Creek has somewhat of a cooling effect on the North Fork. There are two monitoring sites on James Creek (JSF 534 and JSF 567) and one on the North Fork of James Creek (JSF 533). Water temperatures at the North Fork James Creek site (JSF 533) were fully suitable with a maximum observed MWAT of 59°F. Farther down on James Creek, the next monitoring site (JSF 534) had water temperatures that were moderately unsuitable, with an observed MWAT of 61°F. In the lower portion of James Creek, the next site (JSF 567) had water temperatures that were somewhat suitable, with an observed MWAT of 63°F. At these sites, diurnal fluctuations ranged from good to poor (6.2-11.5°F).

The next group of monitoring sites on the North Fork was placed on either side of the confluence with Chamberlain Creek (JSF 530 and JSF 531). Water temperatures at these sites were somewhat unsuitable to undetermined, with an observed maximum MWAT of 65°F before the confluence and an observed MWAT of 64°F after the confluence. This, combined with temperature data from Chamberlain Creek suggests that Chamberlain Creek has a somewhat

cooling effect on the North Fork. There are six monitoring sites on Chamberlain Creek (JSF 536, JSF 557, JSF 537, JSF558, JSF 538, and JSF 539) and one on West Chamberlain Creek (JSF 540). Water temperatures at the West Chamberlain Creek site (JSF 540) were fully suitable with a maximum observed MWAT of 59°F. In the headwaters of Chamberlain Creek JSF 536 is the first monitoring site. JSF 536 had water temperatures that were fully suitable, with a maximum observed MWAT of 58°F. The next monitoring site downstream is JSF 557, which is located immediately before the confluence with Arvola Gulch. The observed water temperatures at this site, while significantly higher than JSF 536, was still fully suitable with an observed MWAT of 60°F. The monitoring site immediately downstream of the confluence with Arvola Gulch (JSF 537), exhibited water temperatures that were fully suitable to moderately suitable with a maximum observed MWAT of 61°F. Based on the observed Chamberlain Creek stream temperatures upstream and downstream of Arvola Gulch, and temperature monitors in upper and lower Arvola Gulch, it appears that Arvola Gulch as little or no effect on Chamberlain Creek water temperatures. Both sites in Arvola Gulch (upper and lower) appeared to have essentially the same water temperature in the year monitored. Water temperatures in Arvola Gulch were moderately suitable with observed MWATs of 61°F at both sites.

Immediately downstream of the paired monitoring sites on Chamberlain Creek around the confluence with Arvola Gulch, is JSF 558. Water temperatures at this site was moderately suitable with an observed MWAT of 61°F, which is essentially the same as that seen in JSF 536 (immediately upstream). The next monitoring site on Chamberlain Creek (JSF 538) is placed immediately after the confluence with West Chamberlain Creek. Water temperatures at this site were moderately suitable with an observed MWAT of 61°F. It is uncertain what effect West Chamberlain Creek has on Chamberlain Creek, but it appears as though West Chamberlain Creek has little effect or possibly a slight cooling effect.

Water Gulch, a tributary to Chamberlain Creek, converges with Chamberlain Creek between West Chamberlain Creek and the confluence with the North Fork. The monitoring site located in Water Gulch (JSF 560) exhibited water temperatures that were fully suitable, with a maximum observed MWAT of 58°F. The thermograph from this site suggests that that the monitoring location may have a significant groundwater component and/or possibly a thermally stratified pool, especially in August and September. This is indicated by the atypical “flat” fluctuations. While the site at Water Gulch is much cooler than Chamberlain Creek, it is unknown what effect, if any, Water Gulch may have on the water temperature in Chamberlain Creek after the confluence.

The final site in lower Chamberlain Creek (JSF 539) appears to have substantially higher water temperatures than JSF 538. Water temperatures at this site were moderately suitable to somewhat suitable, with a maximum observed MWAT of 63°F. Based on a 1994 Landsat vegetation map (KRIS Big River), it may be that the elevated temperatures seen at this site are due to a large clearing in this portion of Chamberlain Creek.

After the paired monitoring sites on either side of the confluence with Chamberlain Creek, the next North Fork site is JSF 532. Water temperatures at this site were undetermined to somewhat unsuitable, with a maximum observed MWAT of 65°F. However given the range of fluctuations in the MWAT at this site, it does not appear to be substantially different from JSF 531 (the site upstream of it).

The East Branch of the North Fork, a tributary to the North Fork, has four water temperature monitoring sites (FSP 5234, FSP 5213, MRC 75-1, and MRC 75-3). These sites are spread along

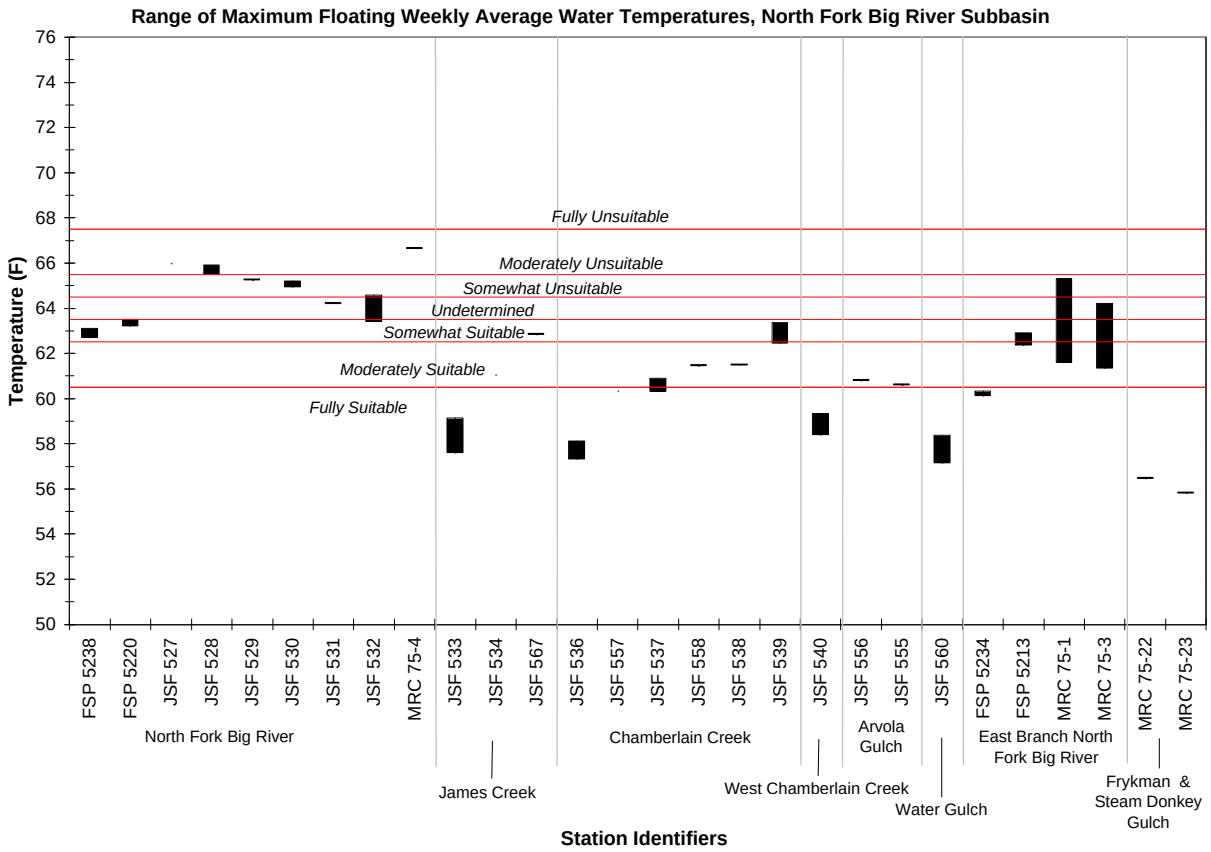
length of the East Branch of the North Fork and were monitored for two years, two years, six years, and two years, respectively. The first site in upper East Branch of the North Fork (FSP 5234), had water temperatures that were fully suitable with an observed maximum MWAT of 60°F. Further downstream, located in the middle portion of the East Fork of the North Fork, are FSP 5213 and then MRC 75-1. FSP 5213 had water temperatures that were moderately suitable to somewhat suitable, with a maximum observed MWAT of 63°F. MRC 75-1 had water temperatures that were moderately suitable to somewhat unsuitable, with a maximum observed MWAT of 65°F. However, the MWATs at MRC 75-1 appear to have a downward trend.

A site in lower Frykman Gulch (MRC 75-22), a tributary to the East Branch North Fork, was monitored for one year. The confluence of this tributary is downstream of MRC 75-1. The thermograph from MRC 75-22 suggests that the monitoring probe at this site was in a stratified pool and/or a location that is significantly influenced by groundwater. This is evident by the atypical diurnal fluctuations and flat peaks. The water temperatures at this site were fully suitable with a maximum observed MWAT of 56°F. It is unclear if Frykman Gulch contributes a significant amount of flow to the East Branch of the North Fork, and thus it is not known if it provides any cooling effect.

The last site on the East Branch of the North Fork, near the confluence with the North Fork, is MRC 75-3, which was monitored for two years. Water temperatures at this site were moderately suitable to undetermined, with a maximum observed MWAT of 64°F. While there is a substantial difference in the observed MWATs at this site (-2.9°F) between 1997 and 2001, there is insufficient information to determine if there is a possible trend. This drop could be due to climatic conditions, differences in placement of the monitoring probe, or some alteration of the canopy. A review of available THP maps (KRIS Big River), did not indicate any harvesting at this location during the late 1990's.

After the confluence with the East Branch of the North Fork, the next tributary to the North Fork that was monitored is Steam Donkey Gulch (MRC 75-23). This site was monitored for one year. Inspection of the thermograph for this site suggests that the probe was placed in either a stratified pool or in a location with a significant groundwater influence, particularly in the middle to late summer. Water temperatures at this site are fully suitable, with an observed MWAT of 56°F. It is unclear what, if any, contribution of cooler water Steam Donkey Gulch makes to the North Fork. However, based on the thermograph, it is suspected that flows are minimal, particularly in the middle to late summer.

FIGURE 16: RANGE OF MWATS, NORTH FORK BIG RIVER SUBBASIN



The final site on the North Fork, downstream of the confluence with Steam Donkey Gulch, is MRC 75-4. This site was monitored for one year. Water temperatures at this site are moderately unsuitable, with an observed MWAT of 67°F. However, the maximum diurnal temperature fluctuations are low (5.4°F). Unlike the North Fork sites in the Jackson State Demonstration Forest, water temperatures at this site does not follow a downward trend, and in fact MRC 75-4 had the highest recorded MWAT in the North Fork subbasin. However, it should be noted that this site was only monitored in 1992, while the other upstream sites were monitored during different years. Therefore, it is possible that 1992 was an abnormally hot year.

Nevertheless, a 1994 Landsat vegetation map (KRIS Big River) indicates a substantially younger forest on the North Fork downstream of the JSF boundary. With the low diurnal fluctuations recorded at MRC 75-4, it is suspected that there is a significant amount of flow to give the water some thermal buffering capacity. The predominance of small trees in the reaches upstream of MRC 75-4 would also suggest significant solar exposure. It is unknown if the vegetation shown in the 1994 Landsat map was essentially the same in 1992. However, presuming it was, this may be the reason for the relatively high MWAT observed at MRC 75-4. In any case, further monitoring is necessary to conclusively make any connections.

As shown in Figure 16 on page 99, water temperatures in the North Fork are apparently dropping as the water moves downstream. However, this only seems to apply to sites within the Jackson State Demonstration Forest. Of the portions of the North Fork outside of JSF, the limited amount of water temperature data appears to show upward spikes in water temperature. In general, the 1994 Landsat vegetation map (KRIS Big River), indicates younger forests outside of

the Jackson State Forest boundaries, with a preponderance of tree sizes in the sapling through small/medium tree size. There also appears to be more areas without trees. Available THP maps (KRIS Big River) also indicate that a large portion of the land outside of JSF has been harvested in some manner in the 1990's. While more years' of data is needed to confirm this pattern, the limited amount of data from a large number of monitoring sites suggest that the North Fork is significantly heated on the private lands surrounding JSF.

The summary values for each of the monitoring sites in the North Fork subbasin are presented in Table 34 on page 186. This summary data, plus the MWAT trends, are included and ranked in Table 22 below.

TABLE 22: WATER TEMPERATURE SUMMARY, NORTH FORK BIG RIVER SUBBASIN

SITE	MAX MWAT	MWAT TREND	RANGE OF MAX DIURNAL FLUCTUATIONS		SEASONAL MAX	YEARS OF DATA
Fully Suitable (50-60ºF)						
MRC 75-22	56	NA	3.5	3.5	57	1
MRC 75-23	56	NA	3.5	3.5	58	1
JSF 536	58	-0.8	3.6	4.5	60	3
JSF 560	58	-1.2	3.4	3.9	61	2
JSF 533	59	1.0	6.2	8.2	63	4
JSF 540	59	-0.1	5.0	5.9	62	3
FSP 5234	60	0.2	4.8	5.6	63	2
JSF 557	60	NA	6.1	6.1	64	1
Moderately Suitable (61-62ºF)						
JSF 534	61	NA	8.3	8.3	66	1
JSF 537	61	-0.6	6.5	7.4	65	2
JSF 538	61	NA	7.9	7.9	65	1
JSF 555	61	NA	7.0	7.0	64	1
JSF 556	61	NA	9.2	9.2	67	1
JSF 558	61	NA	9.8	9.8	69	1
Somewhat Suitable (63ºF)						
FSP 5213	63	-0.6	9.0	10.3	69	2
FSP 5238	63	0.4	9.1	11.1	70	2
JSF 539	63	-0.9	7.4	8.5	69	3
JSF 567	63	NA	11.5	11.5	69	1
Undetermined (64ºF)						
FSP 5220	64	0.3	8.3	11.0	71	2
JSF 531	64	NA	8.0	8.0	70	1
MRC 75-3	64	-2.9	9.3	11.8	69	2
Somewhat Unsuitable (65ºF)						
JSF 529	65	NA	9.7	9.7	71	1
JSF 530	65	-0.3	8.0	8.4	71	3
JSF 532	65	0.6	5.8	6.9	68	4
MRC 75-1	65	-2.9	8.7	13.7	72	6
Moderately Unsuitable (66-67ºF)						
JSF 527	66	NA	11.2	11.2	74	1
JSF 528	66	-0.4	9.5	10.2	71	3
MRC 75-4	67	NA	5.4	5.4	70	1
Fully Unsuitable (68ºF)						
--	--	--	--	--	--	--

In-Channel Sediment

There were five turbidity/suspended sediment sites established by GMA in 2000 and 2001 in support of the US EPA TMDL for the Big River. Additional turbidity samples were collected at the Chamberlain Creek Conservation Camp under the DHS community water supply testing program and on the North Fork Big River immediately below the confluence with Chamberlain Creek under the SWAMP program at the Regional Water Board. MRC collected McNeil core samples in one location in 2000 (MRC S4), including permeability measurements, thalweg profiles, and stream cross-sections. All of these sites are shown in Figure 38 on page 150.

The stations that were sampled by GMA for sediment and turbidity are as follows: Chamberlain Creek above North Fork Big River (GMA 1), North Fork Big River above Chamberlain Creek (GMA 2), James Creek above North Fork Big River (GMA 3), East Fork of North Fork Big River above North Fork Big River (GMA 4), and North Fork Big River above Big River (GMA 5). Flow measurements were also taken at each of these stations, except James Creek, at least two times. The locations of these sites are shown in Figure 38 and data is presented in Table 60 on page 231.

As can be seen in Figure 66, Figure 67, Figure 68, Figure 69, and Figure 70 beginning on page 165, suspended sediment and turbidity appear to be closely related at each of these sites. With the small sample set available for this site, the coefficient of determination (r^2) value is between 0.83 and 0.96. This indicates that there is probably very good correlation between turbidity and suspended sediment at all of these sites.

While turbidity and suspended sediment concentrations did not correlate well with flow, it was found that the suspended sediment load did correlate well with flow at these sites (r^2=0.74 to 0.90) (GMA, 2001).

At the suspended sediment/turbidity locations, background conditions cannot be established due to the lack of data. Of the data that does exist, all of the samples were collected during the winter. Overall, turbidity was reported between 1.6 and 214 NTU. Each of these sites have limited data associated with them and the sample times at the various sites do not necessarily correspond. However, of the data reported, the North Fork Big River above Chamberlain Creek had the highest average turbidity levels and the James Creek above the North Fork Big River site had the lowest turbidity levels.

As stated previously, DHS and the Regional Water Board also collected turbidity data. The summary data for turbidity samples collected at the Chamberlain Creek Site and the North Fork Big River site are shown in Table 23. The turbidity levels in the waters collected were low during the collection of the single sample.

TABLE 23: TURBIDITY SUMMARY, CHAMBERLAIN CR. & NF BIG RIVER (DHS & SWAMP)

PARAMETER	COUNT ALL	COUNT DETECTS	MIN.	DATE MIN[7]	MAX.	DATE MAX	AVG.	50TH PERCENTILE	90TH PERCENTILE
Chamberlain Creek Site (DHS)									
LAB TURBIDITY (NTU)	1	1	6.6	2/14/96	6.6	2/14/96	NA	NA	NA
North Fork Big River Site (SWAMP BIGH20)									
Turbidity (NTU)	1	1	0.34	06/28/01	0.34	06/28/01	NA	NA	NA

Turbidity that is significantly elevated above background levels can impede the ability of salmonids to feed and can be an indicator of potential problems with suspended sediment. This in turn may point to potential problems with heavy sediment loads. While the information collected is useful preliminary data, consistent long-term sampling is needed to determine the condition of these sites with respect to suspended sediment concentrations.

GMA also collected McNeil core samples in 2001 at most of the turbidity/suspended sediment sampling sites mentioned previously. No McNeil sample was collected at the James Creek site above the North Fork (GMA 3), but a sample was collected on the North Fork above James Creek, a site not sampled for turbidity/suspended sediment. When possible, the locations also coincided with MRC McNeil sampling sites. However, because the core samples were collected using the gravimetric method (dry sieve), it is not comparable to the Big River TMDL target for fine sediment. This data is only comparable to other data collected using the gravimetric method. A chart of the McNeil data is presented in Figure 78 on page 171.

The subsurface streambed material in the North Fork Big River shows large increases in the amount of fine sediment between James Creek and Chamberlain Creek (GMA 13 to GMA 2). Lower Chamberlain Creek (GMA 1) and the lower East Branch North Fork Big River (GMA 4) appear to contribute moderate amounts of fine sediment in the sub 5.6 mm and 0.85 mm size classes to the North Fork Big River. However, based limited sampling, both tributaries appear to have less fine sediment in these size classes than found in the North Fork Big River immediately above the confluence with Chamberlain Creek. At the lower end of the subbasin, the North Fork Big River site (GMA 5) shows a decrease in fine sediment in all size classes compared to any of the measured tributaries and mainstem North Fork samples, except the one sample collected upstream of James Creek (GMA 13).

The observed changes in fine sediment may be due to fine sediment coming from James Creek into the North Fork Big River. At the bottom of the North Fork Big River (GMA 5), it appears as though sub 5.6 mm sediment is significantly lower than observed in any of the sediment sampling locations except for the single site on the North Fork Big River upstream of James Creek (GMA 13). This may be due to a lag in the downstream transport of fine sediment or the higher flows in this area may more effectively transport fine sediment out of this reach of the North Fork. At all of the sediment sampling sites, the observed differences may also be due to in part to normal sample variability.

In 2000, MRC also collected McNeil core samples at one site in the North Fork Big River subbasin (MRC S4). The MRC site is located in the lower portion of the East Branch North Fork Big River. Like the GMA samples, these sediment samples were collected using the gravimetric method and are therefore not directly comparable to the Big River TMDL target for fine

[7] Date on which the minimum value occurred is the first date that the value occurred. For example, if there were several "non-detects", represented here as a zero, the date given is the first instance of non-detect (chronologically).

sediment. However, they are unfortunately also not comparable to the GMA samples because the GMA samples do not include surface particles.

MRC also recorded permeability measurements at pool tail-outs in the same stream segments where bulk sediment samples, cross-sections, and thalweg profiles were collected. In the one stream segments measured, a total of 25 or 26 median permeability values were recorded and are shown in Table 69 on page 240. The 25th, 50th, and 75th percentile values for each of these stream segments were then plotted in Figur 87 on page 176. The East Branch North Fork Big River site (MRC S4) had generally low to moderate median permeability values. Using the empirical formula shown in Equation 1 on page 22 (McBain and Trush 2000), this stream segment was expected to have roughly 10-35% survival to emergence. The McNeil sample collected in the same stream segment also suggests relatively good fine sediment conditions when compared to other MRC samples in other subbasins.

Although not used in this assessment, MRC also provided thalweg profiles and stream cross-sections for the year 2000. These are provided for reference in the event that future monitoring efforts repeat these surveys. They can be found in Figure 40 through Figure 64, beginning on page 152.

Based on the GMA Sediment Source Analysis for the Big River (Matthews 2001), the relative disturbance index for the CalWater 2.2 planning watersheds in the North Fork Big River subbasin indicated that the East Branch North Fork Big River was the most disturbed with a disturbance index of 1,168, followed by Upper North Fork Big River (348), Lower North Fork Big River (158), James Creek (48), and Chamberlain Creek (0.1). Figure 24 on page 136 is a map of these planning watersheds. It should be noted that in Matthews (2001), these planning watersheds are referred to by their CalWater 2.2 planning watershed names. As a whole, the North Fork Big River subbasin had a relative disturbance index of 228 for the 1989-2000 time period. Out of five subbasins, the disturbance index value for the North Fork Big River was the fifth largest (behind the Upper, Lower, Middle, and South Fork subbasins). The relative disturbance index is the product of the road density (mi/mi^2), the percent harvested in the 1989-2000 period (acre/acre), and the unit slide volume for delivering slides during the 1989-2000 period (tons/mi^2). Each of these values are discussed in more detail in the following text. Also, unless specifically mentioned, all of the following values apply to the entire North Fork subbasin during the 1989-2000 time period.

The road density, calculated to be 6.6 mi/mi^2 was estimated to be 4% paved and 96% rocked or native. Of these roads, it is estimated that 28% are located in the riparian zone with the remaining 72% located mid-slope or on the ridge. It should be noted that the road density was calculated by the cumulative miles of roads constructed during the entire study period (1921[8]-2000). Also, if any roads were decommissioned, it was not quantified by GMA and is therefore not reflected in these values.

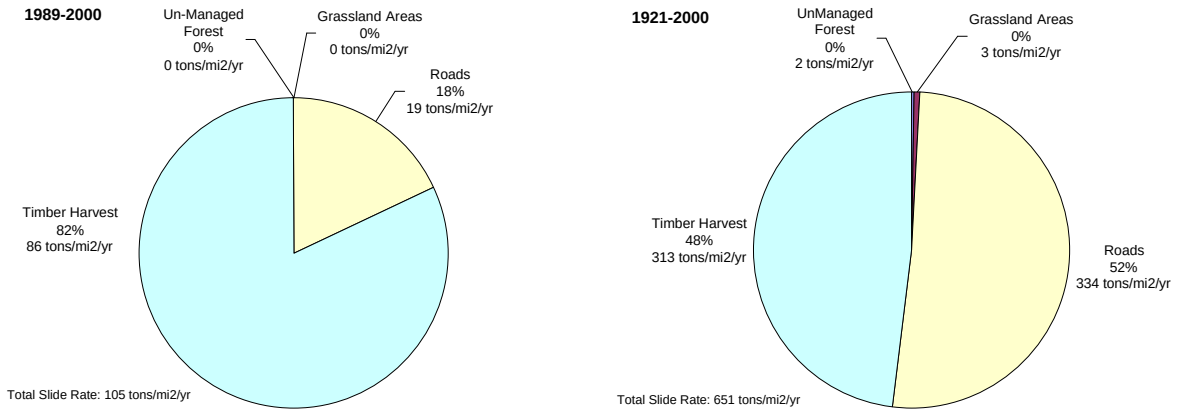
The harvest density, a measure of the acres of timber harvested in a given time period divided by the total acreage in the watershed, was calculated to be 33 ac/ac (or 33% of the watershed). This was the most intense harvesting during any of the decades studied. Over the entire study period (1921-2000), an estimated 125% of the South Fork Big River subbasin was harvested, with roughly 26% of that happening from 1989-2000. Of the harvesting that occurred in the 1989-

[8] No 1936 aerial photographs are available for some portions of the subbasin.

2000 time period, it was reported that approximately 99% was partial cut, with less than one percent skid trails and clear cut.

The unit volume of delivering landslides, calculated to be 105 tons/mi^2/yr, is comprised of the total of delivering landslides in unmanaged forest, brush and grasslands, roads and timber harvest areas. In the North Fork Big River subbasin, it was reported that 100% of the landslides occurred in timber harvest areas or was related to roads (see Figure 17). Of the delivering landslides from harvest related activities and roads, it was estimated that 18% was related to roads and 82% was related to timber harvesting (including skid trails). When compared to these same percentages over the entire study period (1921-2000), it is estimated that 52% of the delivering landslides were road related, 48% were related to timber harvesting (including skid trails), and <1% were related to grassland areas and unmanaged forest areas. As can be seen in Figure 17, timber harvest activities appear to contribute to the majority of the delivering landslides in the North Fork subbasin during 1989-2000. This appears to be largely due to a significant increase in timber harvest related landslides in the East Branch North Fork subbasin, which by itself contributes 52% of the total volume from all timber harvest activities. Road related landslides also have greatly decreased in the 1989-2000 time period. However, it is important to note that the total estimated slide rate decreased from 651 tons/mi^2/yr (1921-2000) to 105 tons/mi^2/yr (1989-2000), a substantial drop in sediment input by landslides.

FIGURE 17: DELIVERING LANDSLIDES BY CATEGORY, NORTH FORK SUBBASIN (GMA)

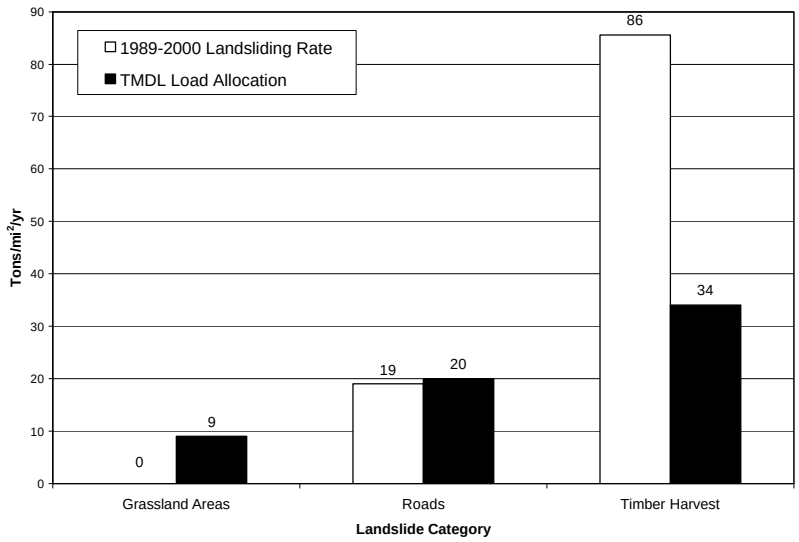


It should also be noted that background landslides, other than what was observed in unmanaged forest, has not been included in the direct comparisons discussed thus far (and shown in Figure 18). Background landslide estimates are discussed separately because they were estimated from past studies, rather than through direct observation in aerial photographs. Background landslide rates were estimated based on previous observation of natural "background" landslides in the South and North Fork of Caspar Creek (Matthews 2001). However, this presented a potentially significant difference in data quality and could be misleading if compared directly.

The background landslide rate for the 1989-2000 time period was estimated to be 159 tons/mi^2/yr. The background landslide rate for the 1921-2000 time period was estimated to be 175 tons/mi^2/yr. Regardless of data quality concerns, these estimates point to background landslides as a potentially significant component of sediment input. As a point of reference, all other landslides during the 1989-2000 time period contributed an estimated 105 tons/mi^2/yr. This would indicate that background landslides may have contributed roughly 60% of the total sediment input by all categories of landslides.

When compared to the TMDL load allocations for each category of landslide, there is no reduction needed for background landslides, as it is naturally occurring. However, each category of landslide that is related to human management has been assigned a load allocation (US EPA 2001). The overall goal of the load allocation is to limit sediment input to no more than 125% of naturally occurring background levels by reducing sediment input from the various categories accordingly. These are charted in Figure 18 for comparison to the estimated landsliding rates during the 1989-2000 time period. Note that estimated values and TMDL load allocations for timber harvest also include landslides related to skid trails.

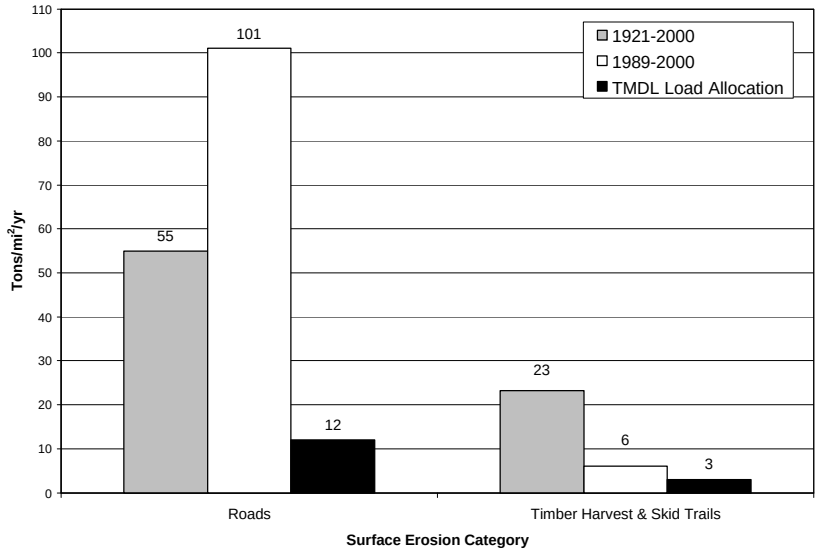
FIGURE 18: LANDSLIDE RATE VS TMDL LOAD ALLOCATIONS, NORTH FORK SUBBASIN (GMA)



Based on these preliminary comparisons, it appears as though landsliding related to timber harvesting needs to be addressed to meet the TMDL load allocation goals. As can be seen in Figure 19, estimates of surface erosion from skid trails and timber harvest areas indicate that it exceeds the TMDL load allocation by 3 tons/mi^2/yr.

Road related landslides do not appear to significantly exceed the TMDL load allocation. On the other hand, surface erosion from roads may be a significant issue in the North Fork subbasin. The increase in surface erosion from roads in the 1989-2000 time period versus the entire study period (1921-2000) is likely due to continued road building through the years which has resulted in greater road surface area.

FIGURE 19: SURFACE EROSION RATE VS. TMDL LOAD ALLOCATIONS, NORTH FORK SUBBASIN (GMA)



Issues, Hypotheses, and Recommendations

Water Chemistry

1. Limited water quality data was collected at the CDF Chamberlain and SWAMP BIGH20 site. At the CDF Chamberlain site, specific conductance appeared to be at or slightly below Basin Plan standards. Several other water quality parameters, including aluminum, copper, sodium, and zinc exceeded their respective criteria. Given the limited nature of this sampling effort and uncertainties about the method and exact location of sampling, it is suspected that this does not represent actual in-stream water quality but possibly water quality at some point in the drinking water system. Also, the same compounds were analyzed during the SWAMP collection effort, and only showed high levels of sodium. Therefore, it is more likely that sodium detected at both sites is present in the surface water.
2. In one of the SWAMP BIGH20 samples collected showed low levels of ammonia below any criteria. Orthophospate was also detected, but there is no applicable criteria for this compound.
3. On February 27, 2001 a tanker truck containing approximately 7,000 gallons of used motor oil and diesel overturned on highway 20 at mile marker 21.76 (measured from the highway 1/highway 20 intersection at Fort Bragg). Subsequent sampling indicated that numerous petroleum compounds had discharged to James Creek. However, this event was episodic and is in active cleanup. Because of the active cleanup and frequent verification monitoring, this spill is unlikely to have a sustained impact on wildlife.

Water Temperature

1. The North Fork Big appears to heat relatively quickly upstream of, and at, the boundary of the JSF. The observed MWATs go from 63°F in the headwater area to 66°F at the JSF

boundary. This is likely due to poor canopy, low flows, and possibly different temperature probe placement protocols between FSP and JSF.

2. Once in JSF, water temperatures begin a steady decline. Based on temperature monitors in the North Fork on either side of the James Creek confluence and monitors in James Creek, it appears as though James Creek has a slight cooling effect on the North Fork. Recorded MWATs in the North Fork around James Creek were 65-66°F.
3. James Creek appears to be fully suitable at the headwaters and progressively becomes warmer until the confluence with the North Fork. The one year of monitoring near the confluence of the North Fork indicated an MWAT of 63°F.
4. Based on temperature monitors in the North Fork on either side of the Chamberlain Creek confluence and monitors in Chamberlain Creek, it appears as though James Creek has a cooling effect on the North Fork. Recorded MWATs in the North Fork around Chamberlain Creek were 64-65°F.
5. Chamberlain Creek appears to be fully suitable at the headwaters and progressively becomes warmer until the confluence with the North Fork. Monitoring near the confluence of the North Fork indicated MWATs of 62-63°F.
6. Other monitoring was conducted on several tributaries to Chamberlain Creek, including West Chamberlain Creek, Arvola Gulch, and Water Gulch. Each of these tributaries were fully to moderately suitable in the years monitored with MWATs of 57-61°F. The thermograph from the Water Gulch site suggests that that the monitoring location may have a significant groundwater component and/or possibly a thermally stratified pool, especially in August and September. To the extent that Water Gulch and West Chamberlain Creek contribute flow to Chamberlain Creek, it is likely that they contribute some amount of cooling to Chamberlain Creek.
7. The final site in lower Chamberlain Creek (JSF 539) appears to have substantially higher water temperatures than JSF 538. Based on a 1994 Landsat vegetation map (KRIS Big River), it may be that the elevated temperatures seen at this site are due to a large clearing in this portion of Chamberlain Creek.
8. Water temperatures downstream of Chamberlain Creek and upstream of the East Branch North Fork appear to remain relatively constant, if the data from JSF 532 can be extrapolated. In any case, the MWAT at this site, it does not appear to be substantially different from JSF 531 (the site upstream of it). The MWAT in this area, with three years of monitoring, is approximately 64°F.
9. The East Branch of the North Fork has some indication of headwaters with an MWAT of approximately 60°F, but with increasing water temperatures between the headwater monitoring site (FSP 5234) and the next site (FSP 5213), which had recorded MWATs of approximately 62-63°F in the two years of monitoring. Water temperatures appear to remain relatively constant to the mouth of the East Branch North Fork, with MWATs between 61-65°F.
10. Frykman and Steam Donkey Gulch, two small tributaries of the East Branch North Fork were monitored. However, while the water temperatures in both tributaries were fully suitable in the years monitored, it appears as though these temperature probes were placed in a deep stratified pool or are dominated by groundwater influences. In any case, it is unlikely that they contribute significantly to the mainstem of the East Branch North Fork.
11. Water temperatures in the North Fork below the confluence with the East Branch North Fork appears to increase significantly from what was recorded in JSF 532 (upstream of the East Branch North Fork). The maximum MWAT increases between JSF 532 and MRC 75-4 approximately 65 to 67°F. While it does not appear the confluence of the East

Branch North Fork would significantly affect water temperatures, it may be due to local conditions upstream of MRC 75-4 such as poor canopy, or just could be an artifact of the fact that MRC 75-4 was only monitored during one year, which did not coincide with the years monitored at JSF 532.

Sediment

1. Turbidity and suspended sediment was sampled by GMA at five locations in North Fork subbasin. Overall, turbidity was reported between 1.6 and 214 NTU. The North Fork Big River above Chamberlain Creek had the highest average turbidity levels and the James Creek above the North Fork Big River site had the lowest turbidity levels. DHS and the Regional Water Board also collected one turbidity sample each.
2. Suspended sediment and turbidity appear to be closely related at each of the five GMA sites.
3. GMA and MRC both collected McNeil samples in the North Fork Subbasin. Although mostly mixed results are presented, it appears as though a significant amount of fine sediment may be entering the North Fork Big River either from James Creek, or between James Creek and Chamberlain Creek.
4. Permeability sampling by MRC in 2000 indicated low to moderate amounts of fine material at the East Branch North Fork site (MRC S4). The permeability measurements are somewhat supported by the MRC bulk sediment sampling.
5. Based on preliminary data by GMA, the relative disturbance index for the North Fork Big River was the lowest of the five subbasins in the Big River watershed during the 1989-2000 time period. Within the North Fork subbasin, the East Branch North Fork Big River planning watershed had the highest relative disturbance index.
6. Based on preliminary data from GMA, it appears as though landsliding related to timber harvesting needs to be addressed to meet the TMDL load allocation goals. Estimates of surface erosion from skid trails and timber harvest areas indicate that it also slightly exceeds the TMDL load allocation. Road related landslides do not appear to significantly exceed the TMDL load allocation. On the other hand, surface erosion from roads may be a significant issue in the North Fork subbasin.

South Fork Big River

The South Fork Big River is delineated by the CalWater 2.2 super-planning watershed of South Fork Big River, which is comprised of the Mettick Creek, Dark Gulch, South Daugherty Creek, and Leonaro Lake planning watersheds. Larger streams included in the South Fork Big River subbasin are Daugherty Creek and the South Fork of the Big River. The watershed area encompassed by the South Fork of the Big River is approximately 54.5 mi^2.

The major streams in this subbasin are shown in Figure 29 on page 141. This figure also shows the names and boundaries of the CalWater 2.2 planning watersheds in the Lower Big River subbasin. Water temperature and water quality/sediment sampling sites are shown in Figure 34 and Figure 39 on pages 146 and 151, respectively. A summary of the existing water temperature and water quality data can be found in Table 29 and Table 30, respectively. These tables can be found beginning on page 178.

Water Column Chemistry

The South Fork Big River subbasin contained one water quality sampling site. The water quality sampling site is a SWAMP sampling site on the South Fork Big River below the confluence with Daugherty Creek (SWAMP SFBIGD). This site was sampled on two occasions in 2001.

The analysis of water column chemistry is divided into parameters with numeric water quality objectives in the Basin Plan, parameters with narrative water quality objectives in the Basin Plan (which can be quantified using numeric criteria found in the literature), and other important parameters that may have applicable narrative water quality objectives, but no available numeric criteria. This division of analytes is discussed in more detail in the Water Column Chemistry section, beginning on page 45.

Basic water chemistry data, including dissolved oxygen, specific conductance, total dissolved solids, and hydrogen ion concentration (pH) were compared to specific numeric water quality objectives in the Basin Plan. The summary data for the basic water quality at the South Fork Big River site is shown in Table 24.

TABLE 24: BASIC PHYSICAL WATER PARAMETERS, SOUTH FORK BIG RIVER SUBBASIN

PARAMETER	COUNT ALL	COUNT DETECTS	MIN.	DATE MIN	MAX.	DATE MAX	AVG.	WQ OBJECTIVES MIN	WQ OBJECTIVES MAX
Site Name, Location: SWAMP SFBIGD, South Fork Big River below Daugherty Creek									
Dissolved Oxygen, Field (mg/L)	2	2	9.34	06/28/01	10.82	05/09/01	NA	7.0 / 7.5[1] / 10.0[2]	NA
pH (pH units)	2	2	8.3	06/28/01	8.36	05/09/01	NA	6.5	8.5
pH, Field (pH units)	2	2	8.14	06/28/01	8.3	05/09/01	NA	6.5	8.5
Specific Conductance (µS/cm)	1	1	300	06/28/01	300	06/28/01	NA	NA	300[3] / 195[4]
Specific Conductance, Field (µS/cm)	2	2	263	05/09/01	297	06/28/01	NA	NA	300[3] / 195[4]
Total Dissolved Solids (mg/L)	2	2	160	05/09/01	170	06/28/01	NA	NA	190[3] / 130[4]

[1] Value represents the 90th percentile lower limit. 90% of the values in a calendar year must be equal to or greater than the 90% lower limit.
[2] Value represents the 50th percentile (median) lower limit. 50% of the monthly means in a calendar year must be equal to or greater than the 50% lower limit.
[3] Value represents the 90th percentile upper limit. 90% of the values in a calendar year must be equal to or less than the 90% upper limit.
[4] Value represents the 50th percentile (median) upper limit. 50% of the monthly means in a calendar year must be equal to or less than the 50% upper limit.

Given the limited data that is available, specific conductance and total dissolved solids measurements were relatively high compared to Basin Plan water quality objectives.

Narrative water quality objectives in the Basin Plan apply to a variety of metals and other constituents that were detected during sampling events. This includes alkalinity, ammonia, boron, chloride, sodium, sulfate, and zinc. However, unlike the constituents shown in Table 24, the numeric criteria for these parameters are derived from the literature to support the narrative water quality objectives. These constituents and the most conservative applicable criteria are shown in Table 25.

TABLE 25: GENERAL WATER COLUMN CHEMISTRY, SOUTH FORK BIG RIVER SUBBASIN

PARAMETER	COUNT ALL	COUNT DETECTS	MIN.	MAX.	AVG.	CRITERIA	CRITERIA EXCEEDED?	COMMENTS ON CRITERIA[1]
Site Name, Location: SWAMP SFBIGD, South Fork Big River below Daugherty Creek								
Ammonia as N (mg/L)	2	1	0	0.24	NA	= 1.39 mg/L	No	Ambient water quality for ammonia, US EPA[2]
Boron (µg/L)	2	2	1000	2400	NA	= 630 µg/L	Yes	IRIS reference dose for drinking water, US EPA
Chloride (mg/L)	1	1	9.9	9.9	NA	= 106 mg/L	No	Protection of agricultural water uses
Sodium (mg/L)	2	2	16	19	NA	= 2 mg/L	Yes	SNARL for drinking water toxicity other than cancer risk, US EPA[3]
Sulfate as SO_4 (mg/L)	1	1	9.7	9.7	NA	= 250 mg/L	No	Secondary California MCL for Drinking Water
Total Alkalinity (mg/L)	2	2	110	130	NA	= 20 mg/L	No	Protection of freshwater aquatic life
Zinc (µg/L)	2	1	0	21	NA	= 123 µg/L	No	Protection of freshwater aquatic life with a hardness of 105 mg/L[2]

[1] See the **Water Column Chemistry** section beginning on page 45 for description of criteria.
[2] See text below for details on derivation of criteria.
[3] Assumes a relative source contribution of 10% from drinking water and 90% from other dietary sources.

As can be seen in Table 25, boron and sodium exceeded their numeric criteria at the South Fork Big River site (SWAMP SFBIGD). In the case of boron, both samples also equaled or exceeded the DHS action level (1,000 µg/l) and agricultural use criteria (700-750 µg/l). However, with only one to two samples, these results are only a beginning of the sample set that is needed to characterize the surface water in South Fork Big River. Therefore, additional sampling should occur to adequately characterize the water quality and determine the source(s) of constituents that exceed their criteria.

It should also be noted that at the South Fork Big River site (SWAMP SFBIGD), alkalinity was speciated into carbonate, bicarbonate, and hydroxide alkalinity. At this site, the alkalinity was entirely bicarbonate alkalinity. Samples for total hardness were also collected at the South Fork Big River site (SWAMP SFBIGD). The samples collected for hardness on May 9, 2001 and June 28, 2001 were 100 and 110 mg/L, respectively. The average of these values were used to determine the water quality criteria for zinc, whose toxicity depends on the hardness of the water.

Water samples were also collected for ammonia at the South Fork Big River site (SWAMP SFBIGD). Of the two samples collected, one of the samples, collected on May 9, 2001, contained 0.24 mg/L of ammonia nitrogen. Ammonia in the other water sample was not detected

at or above the analytical detection limit of 0.05 mg/L. The toxicity of ammonia to freshwater organisms depends on several factors, including the water temperature and pH. During the sample collection, the pH was measured at 8.3 and the water temperature was measured at 16.1°C (61.0°F). Based on these values, the water quality criteria for ammonia is approximately 1.39 mg/L (US EPA 1999). This criteria is for a 30-day average concentration with fish in the early life stages present. Therefore, ammonia was detected but did not exceed the numeric criteria. Nitrate/Nitrite nitrogen was also sampled for, but was not detected at or above the analytical detection limit of 0.05 mg/L.

Turbidity, phosphorus, and chlorophyll-a were also reported, but none have specific numeric criteria at this time. However, they are broken out separately because they are significant constituent of water quality. Turbidity, for the purposes of this assessment, is considered a sediment related parameter and is discussed further in the In-Channel Sediment section on page 65.

Phosphorus can enter surface water bodies through fertilizer run-off or from the natural weathering of rocks in some watersheds. Phosphorus is a biostimulantory substance for algae, and excessive amounts can lead to algae blooms which can impact other aquatic life by negatively affecting dissolved oxygen concentrations. The summary data for phosphorus samples collected at the South Fork Big River site (SWAMP SFBIGD) are shown in Table 26.

TABLE 26: PHOSPHORUS SUMMARY, SOUTH FORK BIG RIVER SUBBASIN

PARAMETER	COUNT ALL	COUNT DETECTS	MIN.	DATE MIN	MAX.	DATE MAX	AVG.
Site Name, Location: SWAMP SFBIGD, South Fork Big River below Daugherty Creek							
Phosphorus (mg/L)	2	0	0	NA	0	NA	NA
Orthophosphate as P (mg/L)	2	0	0	NA	0	NA	NA

There is not sufficient data to make more than broad statements about phosphorus, as there were only two sampling events. However, there was not an apparent problem with elevated phosphorus levels in the samples. Neither orthophosphate or total phosphorous were detected at or above the analytical detection limits of 0.05 mg/L.

Chlorophyll-a was also sampled once at the South Fork Big River site (SWAMP SFBIGD) but was not detected at or above the analytical detection limit of 0.0005 mg/L. Like phosphorous, because there is no water quality criteria for this constituent, it is used primarily to screen for other potential water quality problems.

A complete list of water quality parameters that were sampled for, including those that were not detected, refer to Table 45 on page 212.

Water Temperature

Continuous water temperature data logging devices were deployed by MRC, JSF, and MWA at a total of twelve locations in the South Fork Big River sub-watershed. With the exception of 1992, water temperature was monitored in one or more locations in the South Fork Big River sub-watershed during the years 1990 to 2001.

The most extensively monitored locations in the South Fork Big River watershed were the South Fork Big River above the confluence with the Big River (MRC 79-1) and lower Daugherty

Creek (MRC 79-4 and MWA 154). These sites were monitored for five, six, and three years, respectively. Three other sites, including Montgomery Creek (JSF 552), Lower Ramon Creek (MRC 79-2), and the South Fork Big River below Daugherty Creek (MWA 155) were monitored for three years each. The remaining sites were monitored for one year, with the exception of Lower Gates Creek (MRC 79-9), which was monitored for two years. For summary water temperature values, including the number of years monitored, see Table 27 on page 115. Additional information can be found in Table 29 on page 178 (overview of years monitored in all subbasins) and Table 35 on page 189 (additional summary values for the South Fork Subbasin).

During the initial data review, several potential issues with the water temperature data were noted as shown in Table 40 on page 197. Data was reviewed according to the criteria established in the Water Quality Criteria section, with the intent that only data that appeared representative of stream conditions were used. In the South Fork Big River subbasin, all of the available water temperature data was used for this assessment, as all of the data sets appeared to be valid and likely captured the peak temperatures in the respective years. It should be noted, however, that the MWA sites were typically positioned at the bottom of pools to assess thermal refugia. Therefore, data from these loggers may not represent average water temperature conditions in their respective thermal reaches.

There are a total of three monitoring sites on Daugherty Creek (MRC 79-4, MRC 79-5, and MWA 154). Lower Daugherty Creek was monitored at two locations: one site (MRC 79-4) was monitored for six years, and the other nearby site (MWA 154) was monitored for three years. Based on data from these Lower Daugherty Creek sites, the water temperature varies between moderately suitable with a minimum observed MWAT of 62ºF, to moderately unsuitable with a maximum observed MWAT of 67ºF. Also, in general, the water temperatures at MRC 79-4 are higher than those observed at MWA 154, as seen in Figure 20 on page 114. This is probably due to the fact that MWA typically deploys their temperature monitors in areas of thermal refugia, such as the bottom of a pool. However, even with the data logger deployed to capture thermal refugia, water temperature exceeded the fully supportive range.

The one site in Upper Daugherty Creek (MRC 79-5) was only monitored during one year. The data from this site suggest that the MWATs are similar to those observed in Lower Daugherty Creek, as MRC 79-5 was within the range of MWATs observed in Lower Daugherty Creek. However, further monitoring is necessary to confirm this relationship. In any case, during the one year monitored, the water temperature was moderately unsuitable with an observed MWAT of 66ºF.

On the whole, both upper and lower Daugherty Creek exhibited relatively large diurnal temperature fluctuations (7.6-11.3ºF), indicating possible low flow and/or poor canopy conditions. Based on 1994 Landsat vegetation images (KRIS Big River), it appears as though much of Daugherty Creek has small trees within the riparian corridors, which may contribute to increased solar exposure and the large diurnal temperature fluctuations observed. However, this relationship should be explored further in the Big River Synthesis Report.

Gates Creek, a tributary to Daugherty Creek, was also monitored at one location (MRC 79-9) in the lower portion of the stream for two years. During the two years monitored, the water temperature varied between moderately suitable with a minimum observed MWAT of 62ºF, to somewhat unsuitable with a maximum observed MWAT of 65ºF. By comparing the range of MWATs in Lower Gates Creek against the single year of monitoring in Upper Daugherty Creek (MRC 79-5), it appears that Gates Creek may have a cooling effect on Daugherty Creek.

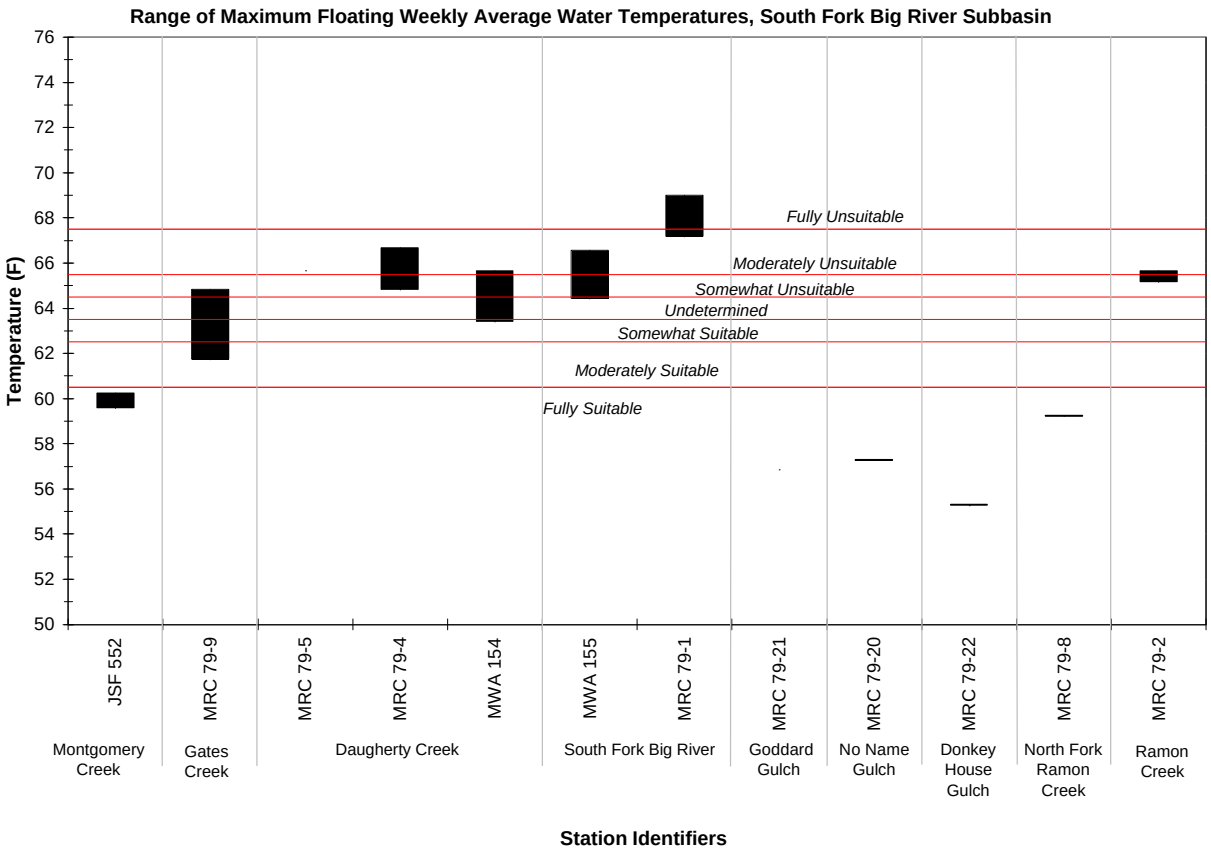
However, more data must be collected in both sites to confirm this relationship. Also, like the sites on Daugherty Creek, the site at Lower Gates Creek experienced large diurnal fluctuations (9.6-9.9ºF) suggesting low flow and/or poor canopy conditions. Based on 1994 Landsat vegetation images (KRIS Big River), it appears as though much of Gates Creek has small trees within the riparian corridors, which may contribute to increased solar exposure and the large diurnal temperature fluctuations observed. However, this relationship should be explored further in the Big River Synthesis Report.

There are a total of two monitoring sites on South Fork Big River (MRC 79-1 and MWA 155). One site is located below the confluence with the mainstem Big River (MRC 79-1) and was monitored for five years. The other site is located below the confluence with Daugherty Creek (MWA 155) and was monitored for three years.

The monitoring site above the confluence with the mainstem of the Big River (MRC 79-1) recorded water temperatures between moderately unsuitable with a minimum observed MWAT of 67ºF, to fully unsuitable with a maximum observed MWAT of 69ºF. In addition, the maximum water temperature recorded was over 74ºF, close to the lethal limit for salmonids (75ºF). The diurnal fluctuations (7-11ºF) at this site also suggest moderate to poor cover and/or low flows.

The monitoring site on the South Fork Big River below Daugherty Creek (MWA 155) recorded water temperatures between "undetermined" with a minimum observed MWAT of 64ºF, to moderately unsuitable with a maximum observed MWAT of 67ºF. While, in general, the diurnal fluctuations were slightly lower at this site than MRC 79-1, it still averaged around 8ºF suggesting moderate canopy and/or flow conditions. By comparing MWATs at this MWA 155 against MRC 79-1 (see Figure 20 on page 114), it is apparent that MWA 155 is cooler, with no overlap in the MWAT ranges. However, this could be due to one of several factors: MWA 155 was placed in an area of thermal refugia and would be expected to be lower than the average temperature in that thermal reach; MRC 79-1 is significantly lower in the watershed than MWA 155, increasing the possibility of solar heating.

FIGURE 20: RANGE OF MWATS, SOUTH FORK BIG RIVER SUBBASIN



Montgomery Creek (JSF 552), Lower Goddard Gulch (MRC 79-21), and Lower No Name Gulch (MRC 79-20) are all tributaries to the South Fork Big River. Montgomery Creek and Lower Ramon Creek were monitored for three years each, and the other streams were monitored for one year. During the years monitored, the Montgomery Creek (JSF 552) site recorded water temperatures that were entirely within the fully suitable range with a maximum observed MWAT of 60ºF. This suggests good stream flow and/or good stream shading.

Lower No Name Gulch (MRC 79-20) and Lower Goddard Gulch (MRC 79-21), tributaries to the South Fork of the Big River, both exhibited stream temperatures well within the fully suitable range for salmonids in the one year monitored. These sites had observed MWATs of 57ºF and 57ºF, respectively. However, the thermographs for Lower Goddard Gulch suggest that the data loggers were placed in an area dominated by groundwater, and/or the monitors were placed in a thermally stratified pool. By contrast, based on the thermographs for Lower No Name Gulch, it appears though the stream was flowing until early August, at which time it may have become isolated and dominated by groundwater. This is evident by diurnal temperature fluctuations that gradually become essentially flat.

Lower Donkey House Gulch (MRC 79-22) and Lower North Fork Ramon Creek (MRC 79-8), tributaries to Ramon Creek, both exhibited stream temperatures within the fully suitable range for salmonids in the one year monitored. These sites had observed MWATs of 55ºF and 59ºF, respectively. The site on the North Fork Ramon Creek (MRC 79-8) appeared to have moderate diurnal fluctuations (8ºF), which would suggest moderate shading and/or stream flow along the thermal reach. By inspection of the thermograph, it appears as though this stream continued to

flow during the year monitored and probably had some cooling effect on Ramon Creek. However, Lower Donkey House Gulch (MRC 79-22) appeared to have little to no flow for a large part of the summer in what appears to be a groundwater dominated flow regime. The temperature monitor may have been placed in a relatively deep pool which may thermally insulate it from the normal diurnal temperature fluctuations. Conversely, water temperatures observed in Lower Ramon Creek (MRC 79-2) were somewhat unsuitable with a minimum observed MWAT of 65ºF, to moderately unsuitable with a maximum observed MWAT of 66ºF. The large diurnal temperature fluctuations (8-14ºF) in this site in Lower Ramon Creek indicate moderate to poor shading or low stream flows.

The summary values for each of the monitoring sites in the South Fork Big River are presented in Table 35 on page 189. A complete table of all water temperature monitoring sites and the years monitored are shown in Table 29 on page 178.

TABLE 27: WATER TEMPERATURE SUMMARY, SOUTH FORK BIG RIVER SUBBASIN

SITE	MAX MWAT	MWAT TREND	RANGE OF MAX DIURNAL FLUCTUATIONS		SEASONAL MAX	YEARS OF DATA
Fully Suitable (50-60ºF)						
MRC 79-22	55	NA	3.5	3.5	55	1
MRC 79-21	57	NA	2.1	2.1	58	1
MRC 79-20	57	NA	7.7	7.7	61	1
MRC 79-8	59	NA	7.5	7.5	63	1
JSF 552	60	0.4	4.5	4.6	63	3
Moderately Suitable (61-62ºF)						
--	--	--	--	--	--	--
Moderately Suitable (63ºF)						
--	--	--	--	--	--	--
Undetermined (64ºF)						
--	--	--	--	--	--	--
Somewhat Unsuitable (65ºF)						
MRC 79-9	65	-3.1	9.6	9.9	71	2
Moderately Unsuitable (66-67ºF)						
MRC 79-2	66	0.0	8.3	13.6	73	3
MRC 79-5	66	NA	10.0	10.0	70	1
MWA 154	66	-1.1	7.6	8.6	70	3
MWA 155	67	-0.4	7.5	8.3	71	3
MRC 79-4	67	-0.6	9.0	11.3	73	6
Fully Unsuitable (68ºF)						
MRC 79-1	69	-1.8	6.8	10.6	74	5

In-Channel Sediment

In the South Fork subbasin, in-channel sediment measurements included turbidity, suspended sediment, and McNeil core samples. In 2001, GMA collected turbidity and suspended sediment at four locations, and McNeil core samples at three locations. Turbidity samples were also collected by the Regional Water Board under the SWAMP program at one location in 2001. MRC collected McNeil core samples in three locations in 2000, including permeability measurements, thalweg profiles, and stream cross-sections.

The stations that were sampled by GMA for suspended sediment and turbidity are as follows: South Fork Big River above the confluence with the Big River (GMA 7), South Fork Big River above the confluence with Daugherty Creek (GMA 8), South Fork Big River below the confluence with Daugherty Creek (GMA 14), and Daugherty Creek above the confluence with the South Fork Big River (GMA 9). Flow measurements were also taken at each of these stations two to three times. In general, these sites were designed to be located closely to MRC sediment sampling sites. The locations of the GMA sites are shown in **Figure 39** on page 151 and data is presented in Table 61 on page 232.

At the suspended sediment/turbidity locations, background conditions cannot be established due to the lack of data. Of the data that does exist, all of the samples were collected during the winter. Overall, turbidity was reported between 2.3 and 811 NTU. Of the data reported, the South Fork Big River below Daugherty Creek (GMA 14) had the highest average turbidity levels (178 NTU) and the Daugherty Creek above the South Fork Big River site (GMA 9) had the lowest average turbidity levels (52 NTU). Of all of the turbidity monitoring sites, the South Fork below Daugherty Creek (GMA 14) also had the highest spikes in turbidity.

The turbidity sample taken at the SWAMP sampling site on the South Fork below Daugherty Creek, shown below in Table 28, did not exhibit significant levels of turbidity. However, this only represents one sample.

TABLE 28: TURBIDITY SUMMARY, SOUTH FORK BIG RIVER SUBBASIN

PARAMETER	COUNT ALL	COUNT DETECTS	MIN.	DATE MIN[9]	MAX.	DATE MAX	AVG.
Site Name, Location: SWAMP SFBIGD, South Fork Big River Below Daugherty Creek							
Turbidity (NTU)	1	1	0.23	06/28/01	0.23	06/28/01	NA

As can be seen in Figure 71, Figure 72, Figure 73, and Figure 74 beginning on page 168, suspended sediment and turbidity appear to be closely related at each of these sites. With the relatively small sample set available for these sites, the coefficient of determination (r^2) value is between 0.83 and 0.98. This indicates that there is probably very good correlation between turbidity and suspended sediment at all of these sites.

While turbidity and suspended sediment concentrations did not correlate well with flow overall in other subbasins, it was found that the suspended sediment load did correlate well with flow at the GMA sites in the South Fork Big River subbasin (r^2=0.77 to 0.91) (Matthews 2001).

GMA also collected McNeil core samples in 2001 at each of the turbidity/suspended sediment sampling sites mentioned previously, except the site located on the South Fork Big River below Daugherty Creek (GMA 14). Therefore, GMA collected bulk sediment samples at South Fork Big River above the Big River (GMA 7), South Fork Big River above Daugherty Creek (GMA 8), and Daugherty Creek above the South Fork Big River (GMA 9).

As can be seen in **Figure 77** on page 171, there is substantially less fine sediment in nearly all of the size classes at the Daugherty Creek site (GMA 9) than at the other two South Fork Big River sites (GMA 7 and GMA 8). By looking at the GMA data in Table 67 on page 238, it appears there is a significant amount of fine sediment in all sub 5.6 mm size classes in the South Fork

[9] Date on which the minimum value occurred is the first date that the value occurred. For example, if there were several "non-detects", represented here as a zero, the date given is the first instance of non-detect (chronologically).

Big River above the confluence with Daugherty Creek. By the bottom of the subbasin, the one GMA sample in the South Fork Big River suggests that the fine sediment moving through this area is somewhat less than found upstream of Daugherty Creek.

However, inspection of the MRC data collected the previous year (2000) at nearby sites indicate that the MRC Daugherty Creek site (MRC S1) contained more fine sediment than either the South Fork site (MRC S3) or the Ramon Creek site (MRC S2). As a group the MRC samples do not necessarily endorse the pattern seen with the GMA samples only one year later.

Bulk sediment data for both GMA and MRC, including all of the size classes is provided in Table 67 on page 238. The sample sites are shown in Figure 39 on page 151. It should be reiterated that the GMA bulk sediment data is not directly comparable to the MRC data, neither of which are comparable to the TMDL targets.

MRC also recorded permeability measurements at pool tail-outs in the same stream segments where bulk sediment samples, cross-sections, and thalweg profiles were collected. In each of the three stream segments measured, a total of 25 or 26 median permeability values were recorded and are shown in Table 70 on page 241. The 25th, 50th, and 75th percentile values for each of these stream segments were then plotted in Figure 87 on page 176. The Daugherty Creek (MRC S1) and Ramon Creek (MRC S2) stream segments each had very low median permeability values. Using the empirical formula shown in Equation 1 on page 22 (McBain and Trush 2000), these stream segments were expected to have roughly 12-17% and 0-2% survival to emergence, respectively. The South Fork Big River (MRC S3) stream segment was expected to have roughly 22-47% survival to emergence. Based on this one year of data (2000), the South Fork Big River stream segment (MRC S3) had significantly better streambed gravel permeability than either the Daugherty Creek (MRC S1) or Ramon Creek (MRC S2) stream segments. Both MRC S1 and MRC S2 had substantial amounts of fine sediment in the streambed gravel interstitial spaces, and it is likely that spawning success in these stream segments was relatively poor. Conversely, MRC S3 appeared have less fine material plugging the interstitial spaces and was more likely to support successful spawning. To some degree, particularly in the sub-0.85 mm size class, the MRC bulk sediment samples appear to support this conclusion.

Although not used in this assessment, MRC also provided thalweg profiles and stream cross-sections for the year 2000. These are provided for reference in the event that future monitoring efforts repeat these surveys. They can be found in Figure 40 through Figure 64, beginning on page 152.

Based on the GMA Sediment Source Analysis for the Big River (Matthews 2001), the relative disturbance index for the CalWater 2.2 planning watersheds in the South Fork Big River subbasin indicated that South Daugherty Creek was the most disturbed with a disturbance index of 601, followed by Dark Gulch (166), Mettick Creek (127), and Leonaro Lake (44). Figure 24 on page 136 is a map of these planning watersheds. It should be noted that in Matthews (2001), these planning watersheds are also referred to as Daugherty Creek, Middle South Fork Big River, Lower South Fork Big River, and Upper South Fork Big River, respectively. As a whole, the South Fork Big River subbasin had a relative disturbance index of 231 for the 1989-2000 time period. Out of five subbasins, the disturbance index value for the South Fork Big River was the fourth largest (behind the Lower, Upper, and Middle Big River subbasins). The relative disturbance index is the product of the road density (mi/mi^2), the percent harvested in the 1989-2000 period (acre/acre), and the unit slide volume for delivering slides during the 1989-2000 period (tons/mi^2). Each of these values are discussed in more detail in the following text. Also,

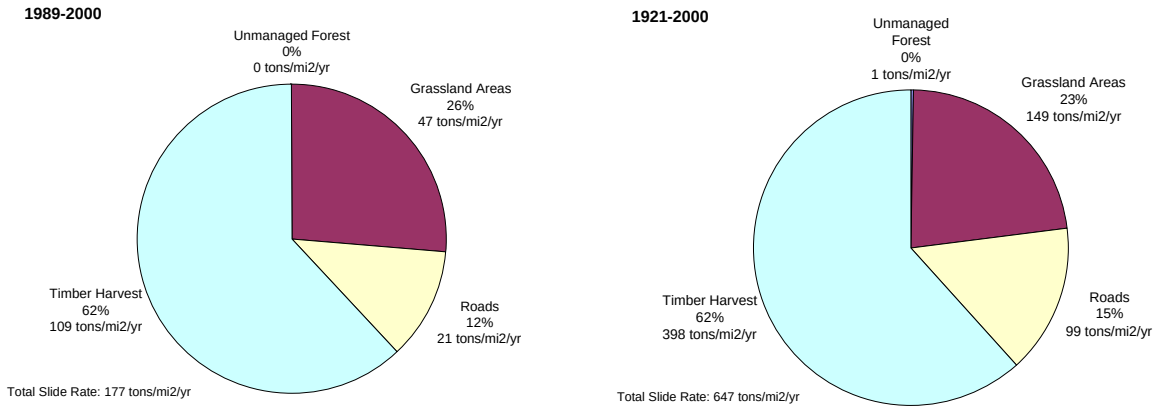
unless specifically mentioned, all of the following values apply to the entire South Fork subbasin during the 1989-2000 time period.

The road density, calculated to be 5.8 mi/mi^2 was estimated to be 6% paved and 94% rocked or native. Of these roads, it is estimated that 25% are located in the riparian zone with the remaining 75% located mid-slope or on the ridge. It should be noted that the road density was calculated by the cumulative miles of roads constructed during the entire study period (1921[10]-2000). Also, if any roads were decommissioned, it was not quantified by GMA and is therefore not reflected in these values.

The harvest density, a measure of the acres of timber harvested in a given time period divided by the total acreage in the watershed, was calculated to be 22 ac/ac (or 22% of the watershed). This was the most intense harvesting during any of the decades studied. Over the entire study period (1936-2000), an estimated 72% of the South Fork Big River subbasin was harvested, with roughly 20% of that happening from 1989-2000. Of the harvesting that occurred in the 1989-2000 time period, it was reported that approximately 4% was clear cut and 96% partial cut, with less than one percent skid trails.

The unit volume of delivering landslides, calculated to be 177 tons/mi^2/yr, is comprised of the total of delivering landslides in unmanaged forest, brush and grasslands, roads and timber harvest areas. In the South Fork Big River subbasin, it was reported that 26% of the landslides occurred in grassland areas, none occurred in unmanaged forest, and the remaining 74% occurred in timber harvest areas or was related to roads (see Figure 21). Of the delivering landslides from harvest related activities and roads, it was estimated that 12% was related to roads and 62% was related to timber harvesting (including skid trails). When compared to these same percentages over the entire study period (1921-2000), it is estimated that 15% of the delivering landslides were road related, 62% were related to timber harvesting (including skid trails), 23% were related to grassland areas, and the remaining <1% occurred in unmanaged forest areas. While the relative percentages remained similar, it is important to note that the total estimated slide rate decreased from 647 tons/mi^2/yr (1921-2000) to 177 tons/mi^2/yr (1989-2000), a substantial drop in sediment input by landslides.

FIGURE 21: DELIVERING LANDSLIDES BY CATEGORY, SOUTH FORK SUBBASIN (GMA)



It should also be noted that background landslides, other than what was observed in unmanaged forest, has not been included in the direct comparisons discussed thus far (and shown in Figure

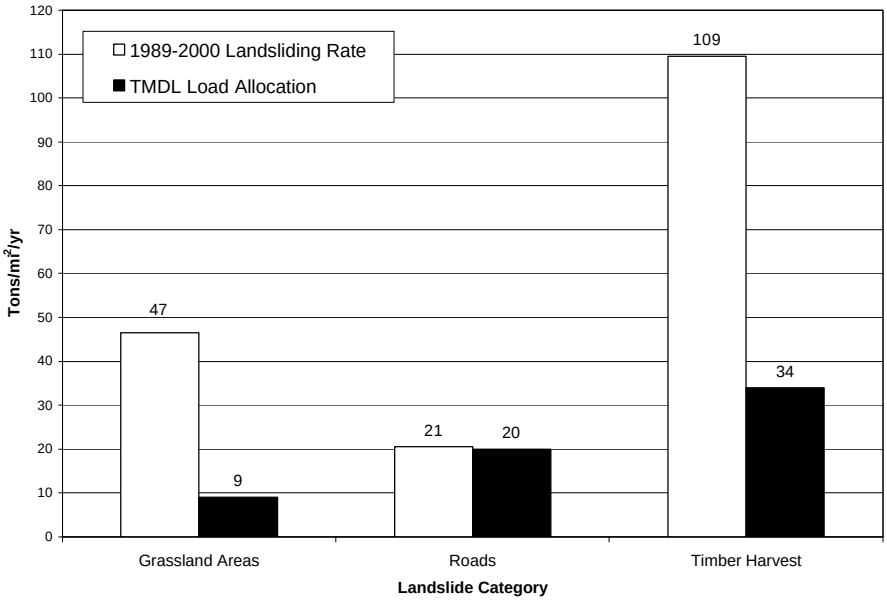
[10] No 1936 aerial photographs are available for this subbasin.

21). Background landslide estimates are discussed separately because they were estimated from past studies, rather than through direct observation in aerial photographs. Background landslide rates were estimated based on previous observation of natural "background" landslides in the South and North Fork of Caspar Creek (Matthews 2001). However, this presented a potentially significant difference in data quality and could be misleading if compared directly.

The background landslide rate for the 1989-2000 time period was estimated to be 159 tons/mi^2/yr. The background landslide rate for the 1921-2000 time period was estimated to be 175 tons/mi^2/yr. Regardless of data quality concerns, these estimates point to background landslides as a potentially significant component of sediment input. As a point of reference, all other landslides during the 1989-2000 time period contributed an estimated 177 tons/mi^2/yr. This would indicate that background landslides may have contributed roughly 53% of the total sediment input by all categories of landslides.

When compared to the TMDL load allocations for each category of landslide, there is no reduction needed for background landslides, as it is naturally occurring. However, each category of landslide that is related to human management has been assigned a load allocation (US EPA 2001). The overall goal of the load allocation is to limit sediment input to no more than 125% of naturally occurring background levels by reducing sediment input from the various categories accordingly. These are charted in Figure 22 for comparison to the estimated landsliding rates during the 1989-2000 time period. Note that estimated values and TMDL load allocations for timber harvest also include landslides related to skid trails.

FIGURE 22: LANDSLIDE RATE VS TMDL LOAD ALLOCATIONS, SOUTH FORK BIG RIVER SUBBASIN (GMA)

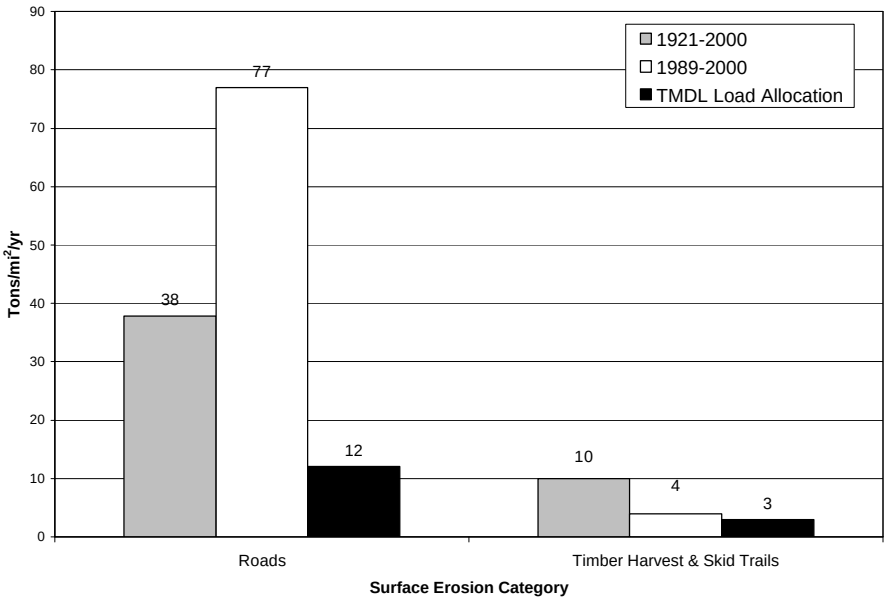


Based on these preliminary comparisons, it appears as though landsliding related to timber harvesting and grassland areas need to be addressed to meet the TMDL load allocation goals. Road related landslides do not appear to significantly exceed the TMDL load allocation.

As can be seen in Figure 23, estimates of surface erosion from skid trails and timber harvest areas indicate that it does not significantly exceed the TMDL load allocation. On the other hand,

surface erosion from roads may be a significant issue in the South Fork subbasin. The increase in surface erosion from roads in the 1989-2000 time period versus the entire study period (1921-2000) is likely due to continued road building through the years which has resulted in greater road surface area.

FIGURE 23: SURFACE EROSION RATE VS. TMDL LOAD ALLOCATIONS, SOUTH FORK BIG RIVER SUBBASIN (GMA)



Issues, Hypotheses, and Recommendations

Water Chemistry

1. The South Fork Big River subbasin contained one water quality sampling site on the South Fork Big River below the confluence with Daugherty Creek (SWAMP SFBIGD).
2. Given the limited data, specific conductance and total dissolved solids measurements were relatively high compared to Basin Plan water quality objectives.
3. The two samples of boron and sodium exceeded their numeric criteria. In the case of boron, both samples also equaled or exceeded the DHS action level (1,000 µg/l) and agricultural use criteria (700-750 µg/l).
4. One water quality sample contained low levels of ammonia, but the detection was less than the applicable criteria.

Water Temperature

1. Although upper Daugherty Creek (MRC 79-5) has only one year of data, it appears as though upper and lower Daugherty Creek (MRC 79-4) were similar in temperature with MWATs between 65-67°F. The other downstream site (MWA 154) appears to be generally lower than MRC 79-4, but that is to be expected as MWA places it's monitoring devices in areas of thermal refugia.

2. During two years of monitoring on Gates Creek, a tributary to Daugherty Creek, MWATs of between 62-65°F were recorded. Based on this, it would appear that Gates Creek provides some cooling effect to Daugherty Creek.
3. Montgomery Creek (JSF 552) was within the fully suitable range at approximately 60°F during all three years monitored. The maximum diurnal fluctuations varied between 4-5°F. This site is in an undisturbed location in the Montgomery Woods Reserve and is probably a good example of what can be achieved with adequate canopy in the warmer interior portion of the Big River watershed. It should be noted that much of the interior watershed is naturally grasslands, and could not reasonably be expected to achieve these water temperatures.
4. As would be expected, the mainstem of the South Fork Big River appears to get progressively warmer as it moves towards the bottom of the watershed. However, by the time it reaches the bottom of the watershed (MRC 79-1), MWATs are generally in the fully unsuitable range as high as 69°F with maximum daily temperatures as high as 74°F.
5. During the one year of monitoring water temperatures in the North Fork Ramon Creek (MRC 79-8), it appeared that it was much cooler than Ramon Creek itself (MRC 79-2), which was monitored for three years. The North Fork Ramon Creek site had a fully suitable MWAT of 59°F, whereas Ramon Creek downstream of the North Fork confluence had MWATs from 65-66°F. However, it is not clear if Ramon Creek is much warmer from the headwaters and the North Fork provides only minimal cooling, or if the combined flow of the North Fork and Ramon Creek become warmer in the segment of stream below the confluence.
6. Donkey House Gulch (MRC 79-22) is a tributary to Ramon Creek, but in the one year of monitoring, it exhibited fully suitable water temperatures with an MWAT of 55°F. Nevertheless, diurnal fluctuations in this stream appeared to indicate that the monitoring site is either in a thermally stratified pool or is dominated by groundwater. Therefore, it is expected that this would be associated with low flows and probably have little cooling effect on Ramon Creek.
7. Goddard Gulch (MRC 79-21) and No Name Gulch (MRC 79-20), both tributaries to the mainstem South Fork Big River, were each monitored for one year and had fully suitable MWATs of 57°F. In Lower No Name Gulch, it appears though the stream was flowing until early August, at which time it may have become isolated and dominated by groundwater. This is evident by diurnal temperature fluctuations that gradually become essentially flat. Diurnal fluctuations in Goddard Gulch appeared to indicate that this monitoring site is either in a thermally stratified pool or is dominated by groundwater. Therefore, it is expected Goddard Gulch, and to a lesser degree Lower No Name Gulch would be have low flows making it unlikely that either site would have a significant cooling effect on the mainstem South Fork Big River.
8. Relatively large diurnal fluctuations in virtually all of the monitored sites indicate that throughout the South Fork subbasin there is poor canopy and/or low flows. The only exceptions to this are the monitoring sites at Montgomery Woods Reserve (JSF 552), and the sites located in gulches that are apparently dominated by groundwater. These sites were Goddard Gulch, Donkey House Gulch, and No Name Gulch.

Sediment

1. The results of the GMA and MRC McNeil sampling is mostly mixed. No firm hypotheses can be drawn based on this data alone.

2. Turbidity samples were collected by GMA at four sites in the South Fork Subbasin. Overall, turbidity was reported between 2.3 and 811 NTU. The South Fork below Daugherty Creek (GMA 14) had the highest average turbidity level, while the Daugherty Creek site (GMA 9) had the lowest average turbidity level.
3. Permeability sampling by MRC in 2000 indicated significant fine material at the Daugherty Creek site (MRC S1) and the Ramon Creek site (MRC S2). The South Fork Big River site (MRC S3) appeared to have less fine material and likely better spawning success. The permeability conclusions are somewhat supported by the MRC bulk sediment sampling, particularly in the sub 0.85 mm size class.
4. Based on preliminary data by GMA, the relative disturbance index for the South Fork Big River was the fourth highest of the five subbasins in the Big River watershed during the 1989-2000 time period. Within the South Fork subbasin, the South Daugherty Creek planning watershed had the highest relative disturbance index.
5. Based on preliminary data by GMA, it appears as though landsliding related to timber harvesting and grassland areas need to be addressed to meet the TMDL load allocation goals. Road related landslides do not appear to significantly exceed the TMDL load allocation. Estimates of surface erosion from skid trails and timber harvest areas indicate that it does not significantly exceed the TMDL load allocation. On the other hand, surface erosion from roads may be a significant issue in the South Fork subbasin.

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Figures

FIGURE 24: BIG RIVER PLANNING WATERSHEDS

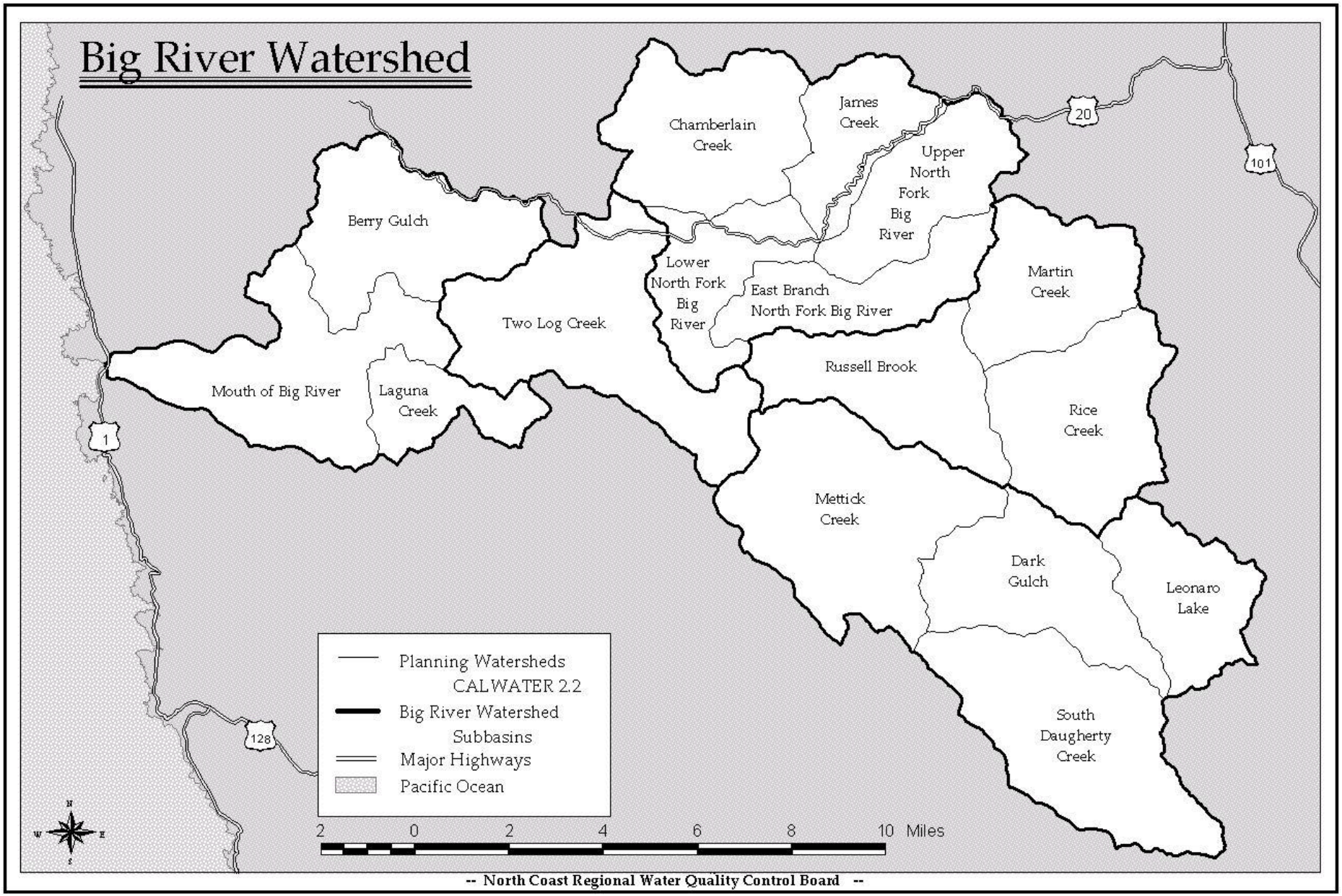

FIGURE 25: LOWER BIG RIVER SUBBASIN

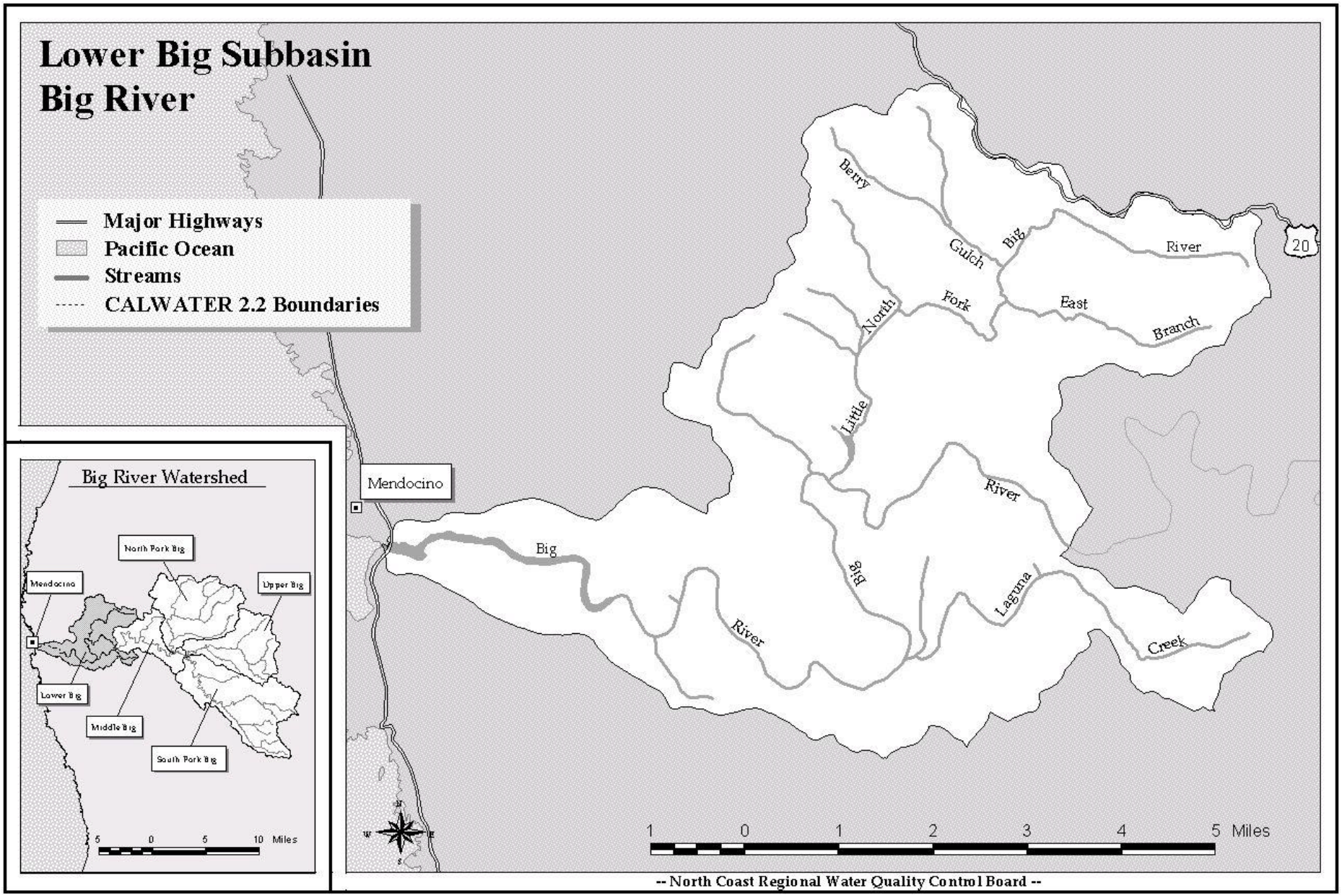

FIGURE 26: MIDDLE BIG RIVER SUBBASIN

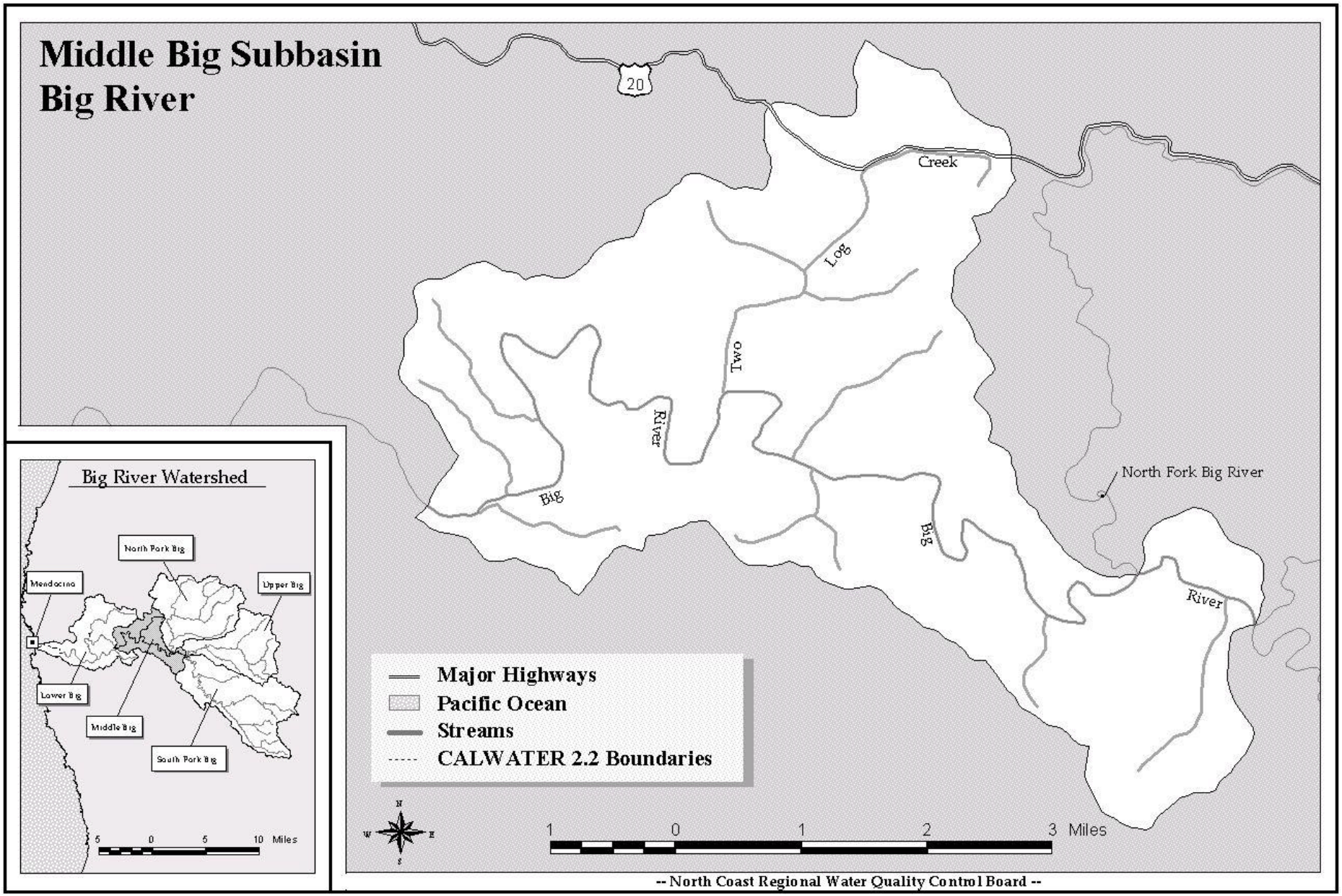
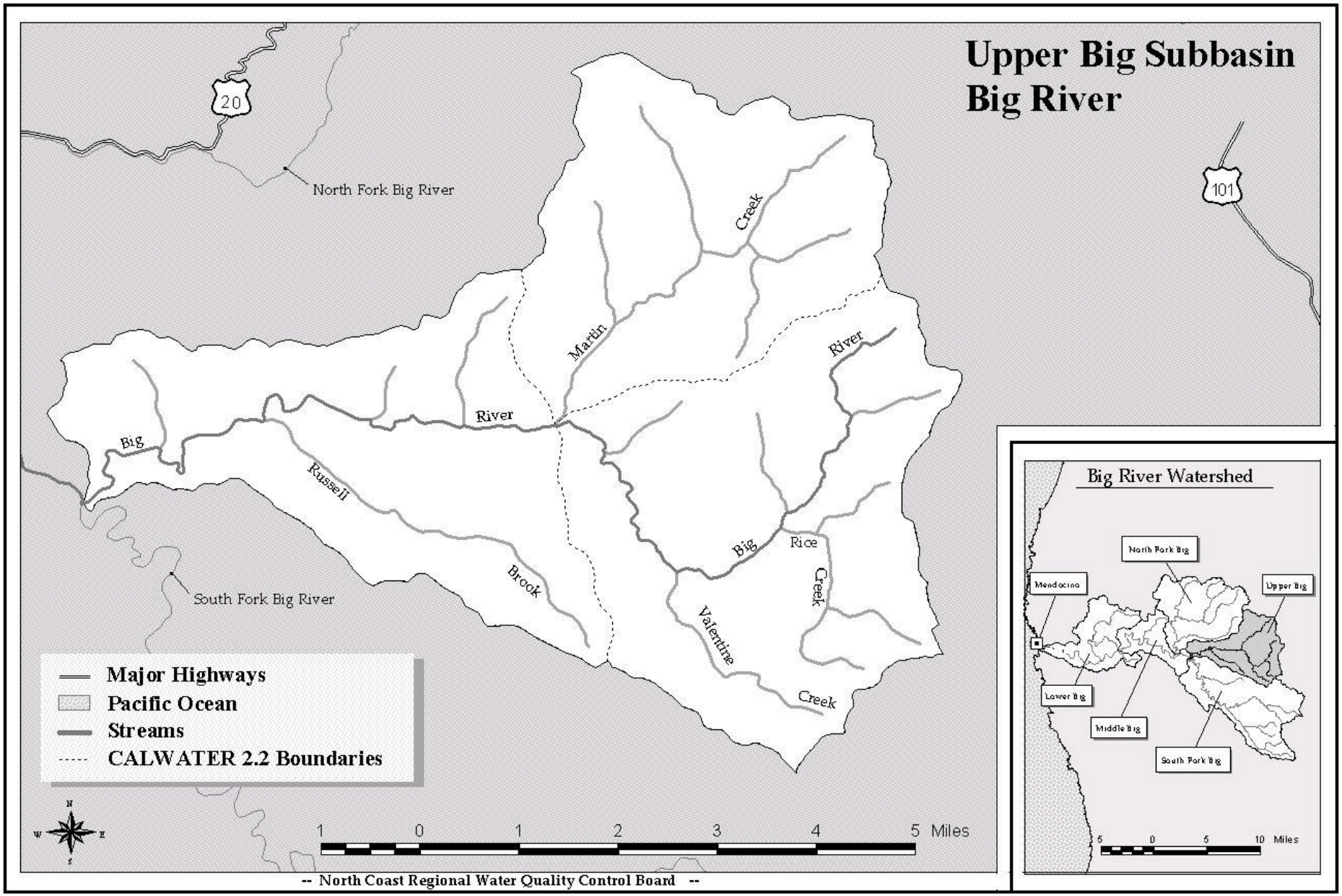
FIGURE 27: UPPER BIG RIVER SUBBASIN