

**PROJECT SCALE
EFFECTIVENESS MONITORING
for the
SOUTH FORK WAGES CREEK WATERSHED**



Prepared for:

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Note: this is the second draft of a proposal for project scale effectiveness monitoring for the SF Wages Creek watershed. The first draft was circulated in September 2003. Constructive comments on the first draft were received from the following parties:

- Bob Ziemer, Redwood Sciences Laboratory
- Jack Lewis, Redwood Sciences Laboratory
- Cajun James, Sierra Pacific Industries
- Bruce Krumland, Sierra Pacific Industries
- Lee Benda, Earth Island Institute
- Chris Surfleet, Mendocino Redwood Company
- Charles Martin, California Department of Forestry and Fire Protection

Installation of equipment and preliminary data collection in the study area occurred in WY2004. The first annual report will be available in December 2004.

PROJECT SCALE EFFECTIVENESS MONITORING PROPOSAL FOR THE SOUTH FORK WAGES CREEK WATERSHED

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Background:

One of the primary goals of monitoring programs developed by the Board of Forestry (BOF) is to assess the effectiveness of the Forest Practice Program (i.e., the Rules and the Review Process) in protecting the beneficial uses of water. The BOF's Monitoring Study Group (MSG) has concluded that instream monitoring has the ability to assess current condition and long term trends in channel conditions and that the best way to document these trends is through the establishment of *cooperative monitoring watersheds*. Due to increasing needs for information relative to forest management and coho salmon fish habitat because of the federal listing, cooperative monitoring watersheds within the range of this fish are of primary interest to the MSG. In these basins, private landowners and government agencies will work together on both instream and hillslope monitoring using mutually acceptable protocols, quality assurance, and quality control standards. As a result of this cooperation, landowners will gain mutually acceptable and verifiable data on how their practices are impacting critical beneficial uses, such as coldwater fisheries. The overall goal in coastal watersheds is to improve habitat conditions for declining numbers of anadromous fishes.

The instream component of this proposed cooperative project will provide information on the condition and trend of instream parameters based on periodic measurements in selected cooperative monitoring watersheds. This will be combined with implementation and effectiveness monitoring of the Rules at various hillslope locations subject to timber operations. Conclusions regarding the Rules and instream conditions will be based on measurements made over several years. For example, if channel conditions show recovery through a range of climatic events, it may be concluded that modern hillslope forestry practices are not degrading the aquatic ecosystem. Collection of instream monitoring and hillslope monitoring data will occur as part of this contract.

Due to limited state and federal budgets, the cooperative monitoring watershed approach appears to be the only viable method of accomplishing the needs of the BOF. Other potential benefits of cooperative monitoring watersheds include testing and refinement of alternative or additional hillslope and instream monitoring techniques.

Opportunities to implement this cooperative monitoring approach are currently available on the Hawthorne Timber Company ownership (Hawthorne). Hawthorne, managed by Campbell Timberland

Management, owns approximately 184,000 acres of commercial timberlands in Mendocino County (Figure 1).

The science staff at Campbell Timberland Management shares the interest and need to verify to what extent (and by what causal mechanisms) current forest practices are increasing the rate of sediment delivery to the stream network. However, the literature suggests that the prediction of erosion processes (particularly mass wasting) is virtually impossible at small spatial scales (project/THP) and over short time scales. It is important that the limitations of science are given full consideration in this endeavor.

To intelligently conduct water quality monitoring in mountain drainage basins at the project (THP) scale, it is necessary to establish pre-harvest (background) water quality conditions. This alone renders the idea of quantitative measurement programs of turbidity at the project scale extremely problematic. In the absence of pre-logging water quality data, Campbell proposes to treat the South Fork of Wages Creek as an experimental watershed, collecting a **minimum** of three years of pre-treatment data to establish “ambient” conditions. At the end of this pre-treatment period, Hawthorne will implement a Timber Harvest Plan consistent with standard operational practices, which will be followed by 3-5 years of post-treatment monitoring. Without question, this research will better inform Campbell staff in their efforts to develop and implement effective prescriptions in a watershed recovering for historic land use practices.

Problem Statement:

Accelerated surface erosion from land management activities is well recognized. Erosion from road surfaces is often a persistent source of sediment in logged basins due to the large network of native surface roads associated with harvest activities and the increased connectivity of the roads to the stream channels. Numerous studies have documented the role of road construction in increased sediment yields (e.g. Reid and Dunne 1984, Rice et al. 1979). Road-related sediment is a major factor in most North Coast watersheds. The location of roads on basin slopes (near stream, mid-slope, and ridge top) can have major effects on both fluvial and mass wasting processes (Cafferata and Spittler 1998, Jones et al. 2000).

Studies describing the negative impacts on water quality from such forest management activities and road networks are well represented in the literature. However, the effects of recent substantial changes in the methods of Timber Harvest Plan (THP) implementation have not been subject to detailed effectiveness monitoring. Failure to distinguish between the effects of legacy management activities and present THP implementation methods, particularly road rehabilitation, has hindered full understanding of the effects of current practices as they affect stream health and reflect watershed condition.

Study Area

Wages Creek Watershed

Wages Creek is located in Mendocino County, intersecting HWY 1 approximately two miles north of Westport, CA (Figure 2). The legal description to the mouth is T21N R17W SEC 29 (Calwater Version 2.2 #1113.120202, Ryder Gulch). Hawthorne owns 8.2 sq mi. of the entire 13.41 sq mi. drainage area. The basin contains four Class 1 watercourses: Ryder Gulch, North Fork Wages, South Fork Wages and Tank Gulch. Elevations over the entire watershed range from sea level at the mouth, to approximately 2,660 feet in the headwaters. The hardwood canopy is comprised of tanoak (*Lithocarpus densiflorus*) and Pacific madrone (*Arbutus menziesii*), while the conifer canopy includes redwood (*Sequoia sempervirens*) and Douglas fir (*Pseudotsuga menziesii*).

In 1993, Georgia Pacific Corporation initiated a property-wide aquatic monitoring program¹. As part of this program, an indexed monitoring reach was established in the mainstem of lower Wages Creek (Figure 2). A total of eight bulk sediment samples were taken from two separate riffles on an annual basis

¹ Hawthorne has continued to monitor index reaches since acquiring the property in 1999.

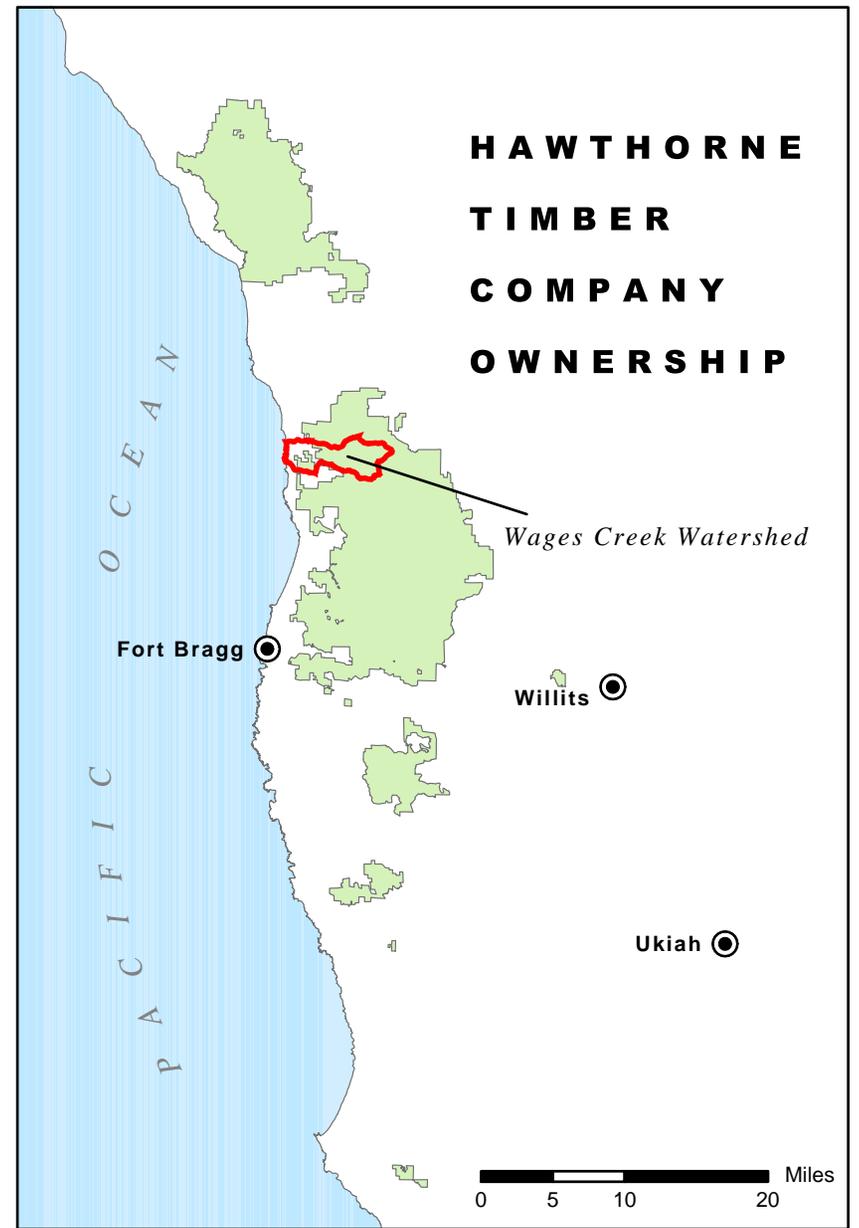
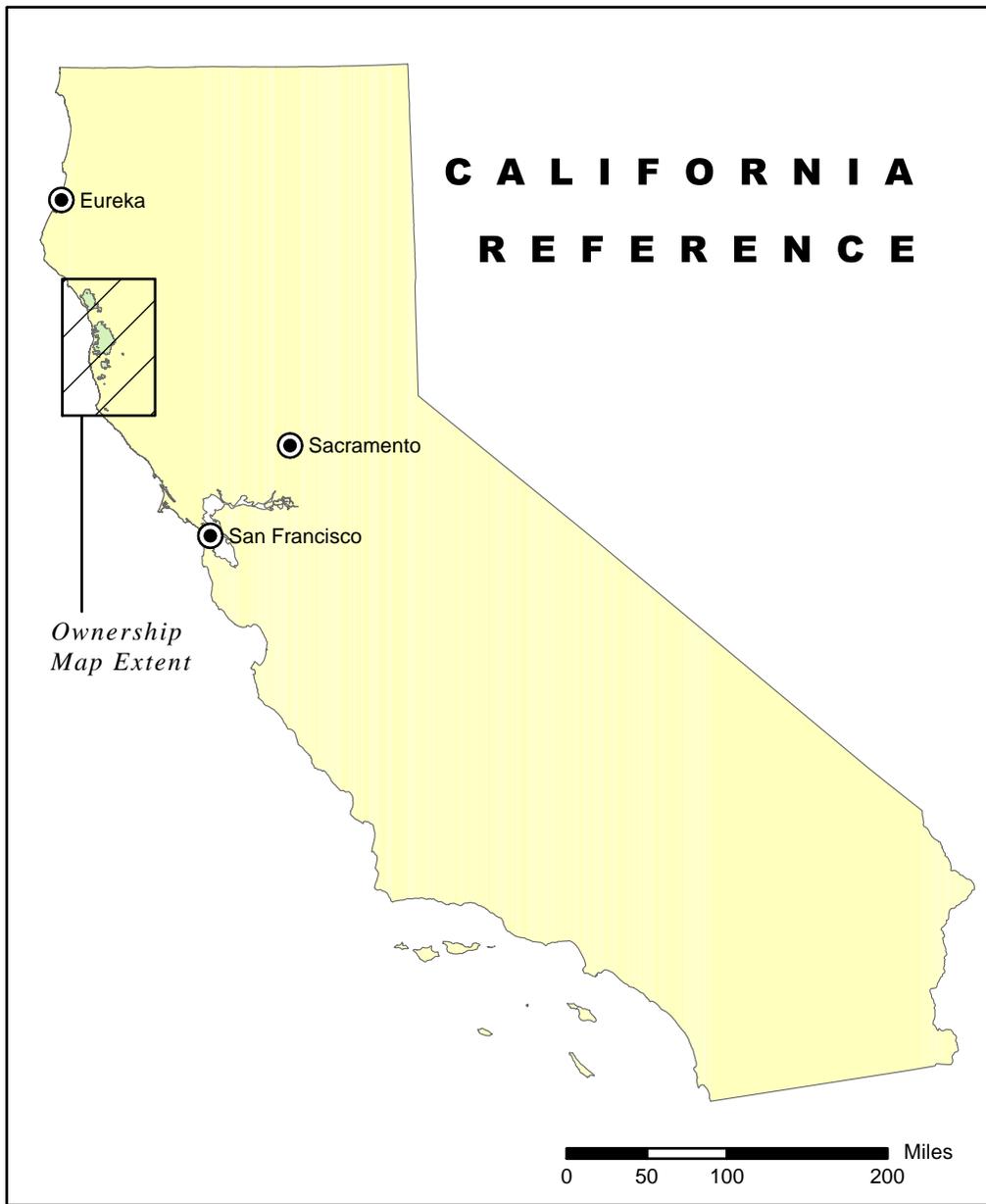


Figure 1. Regional Vicinity Map for The Hawthorne Timber Company

 Hawthorne Timberlands
(Total Acres = 184,168)

 Wages Creek Watershed
(Total Acres = 8,583)



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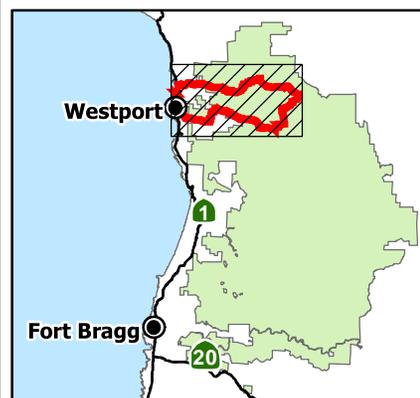
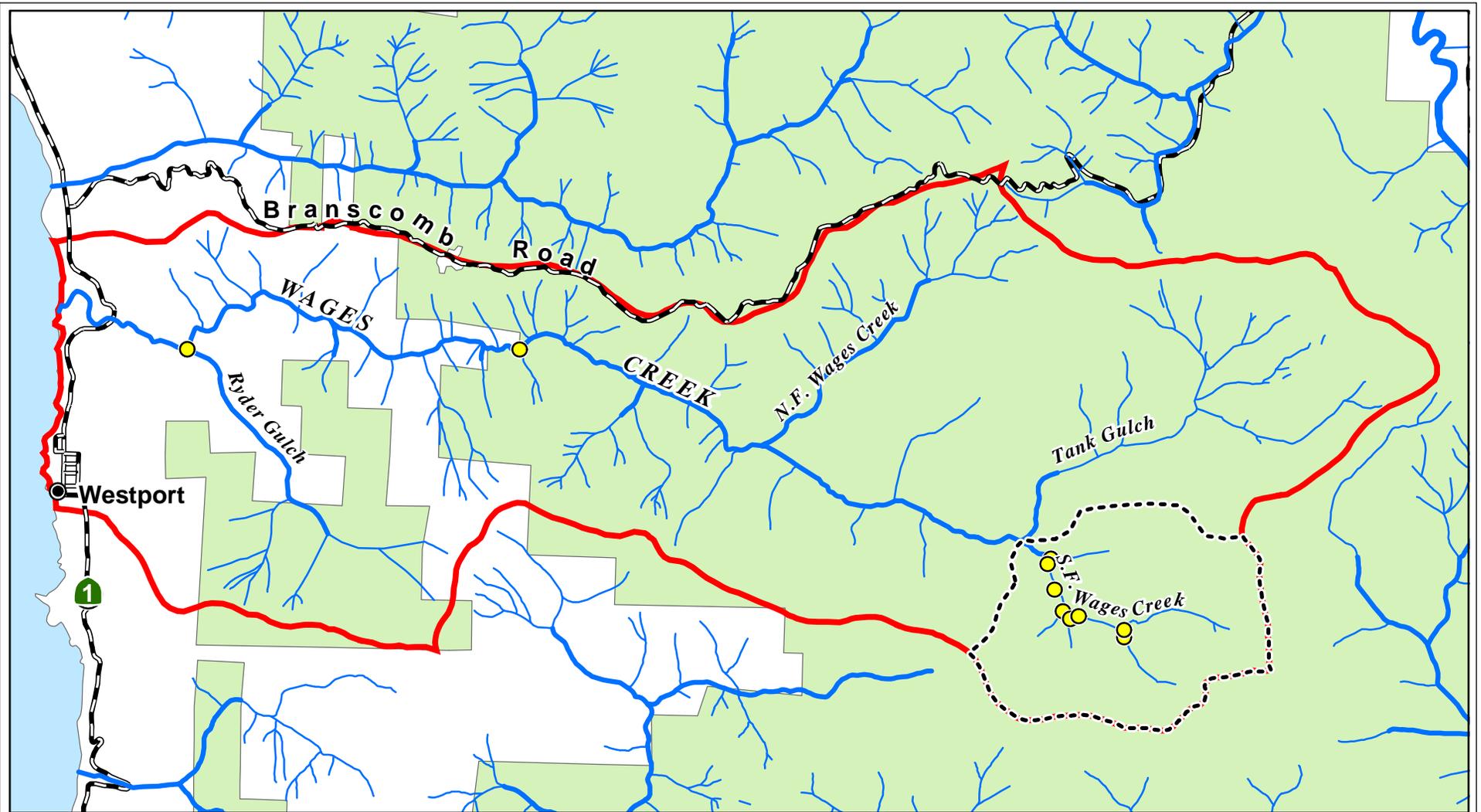
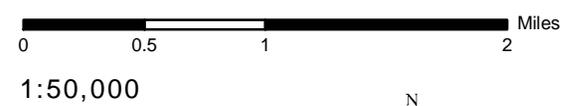


Figure 2. Local Vicinity Map - S.F. Wages Creek Effectiveness Monitoring Project



- Wages Creek Watershed
(Total Acres = 8,583)
- Hawthorne Timberlands
(Total Acres in Wages Creek Watershed = 6,657)
- Effectiveness Monitoring Project
(Total Acres in S.F. Wages Creek Watershed = 907)
- Road Surface**
 Paved
- Watercourses**
 Class I
 Class II
- Monitoring Site
- City Center



9/9/2004 SH

during the low-flow period. Samples are wet-sieved in the field and analyzed to determine what fraction of the sample consisted of sediment particles less than 1.0 mm in diameter (Table 1). Fine sediment levels currently exceed established water quality standards, and may be a limiting factor for salmonids in this watershed. Instantaneous water temperatures were recorded with Hobo data loggers. Data were analyzed to determine the Maximum Weekly Average Temperature (MWAT) for each year sampled (Table 1). As expected, a strong coastal influence greatly moderates the thermal regime in Wages Creek. Temperature certainly does not appear to be a limiting factor for salmonids in this watershed.

Sample Year	Fine Sediment (% < 1.0mm)	Water Temperature (MWAT)
1993	Not Sampled	13.9
1994	Not Sampled	14.8
1995	17.1	14.2
1996	18.7	14.9
1997	17.4	14.8
1998	15.5	14.1
1999	Not Sampled	14.1
2000	Not Sampled	13.9
2001	19.5	13.7
2002	14.5	Not Sampled

The presence of both coho salmon (*Oncorhynchus kisutch*) and steelhead (*O. mykiss*) has been documented in the watershed consistently since 1995. Department of Fish and Game staff also observed spawning king salmon (*O. tshawytscha*) in 2003. It is important to note that between 1995 and 1996, approximately 32,000 juvenile coho (Noyo River broodstock) were planted in Wages Creek. Unfortunately, there is not enough species and life-stage specific information available to evaluate the overall viability of the current populations.

South Fork Wages Sub-Watershed

The 907-acre South Fork Wages sub-watershed has been proposed for study after careful review of the Hawthorne property (Figure 3). Ultimately, this location was selected for four primary reasons:

- There has not been intense timber harvest activity in the sub-watershed since 1974.
- The 60's era mid-slope road with multiple stream crossings has not been upgraded.
- Presence of actively eroding features associated with the legacy of historic land use practices.
- Site is reasonably accessible in the winter period via company logging roads.

Harvest history suggests the first entry into the South Fork Wages sub-watershed occurred with the construction of stream adjacent and mid-slope roads prior to 1962 (Figure 4). These roads enabled tractor logging of the entire basin within a four-year period (Figure 5). Additional mid-slope road construction occurred in 1973 and 1974 to facilitate a tractor-yarded overstory removal harvest.

Field observations confirmed the footprint left by the prior two harvests was consistent with observations in similar coastal watersheds on the Hawthorne property. Current stand conditions will support a future stand improvement harvest that will also be consistent with methods Campbell is prescribing on current Timber Harvest Plans for similar site conditions.

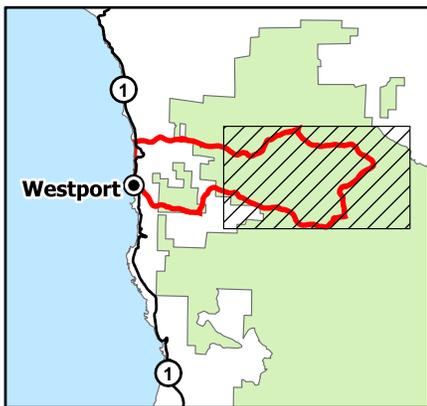
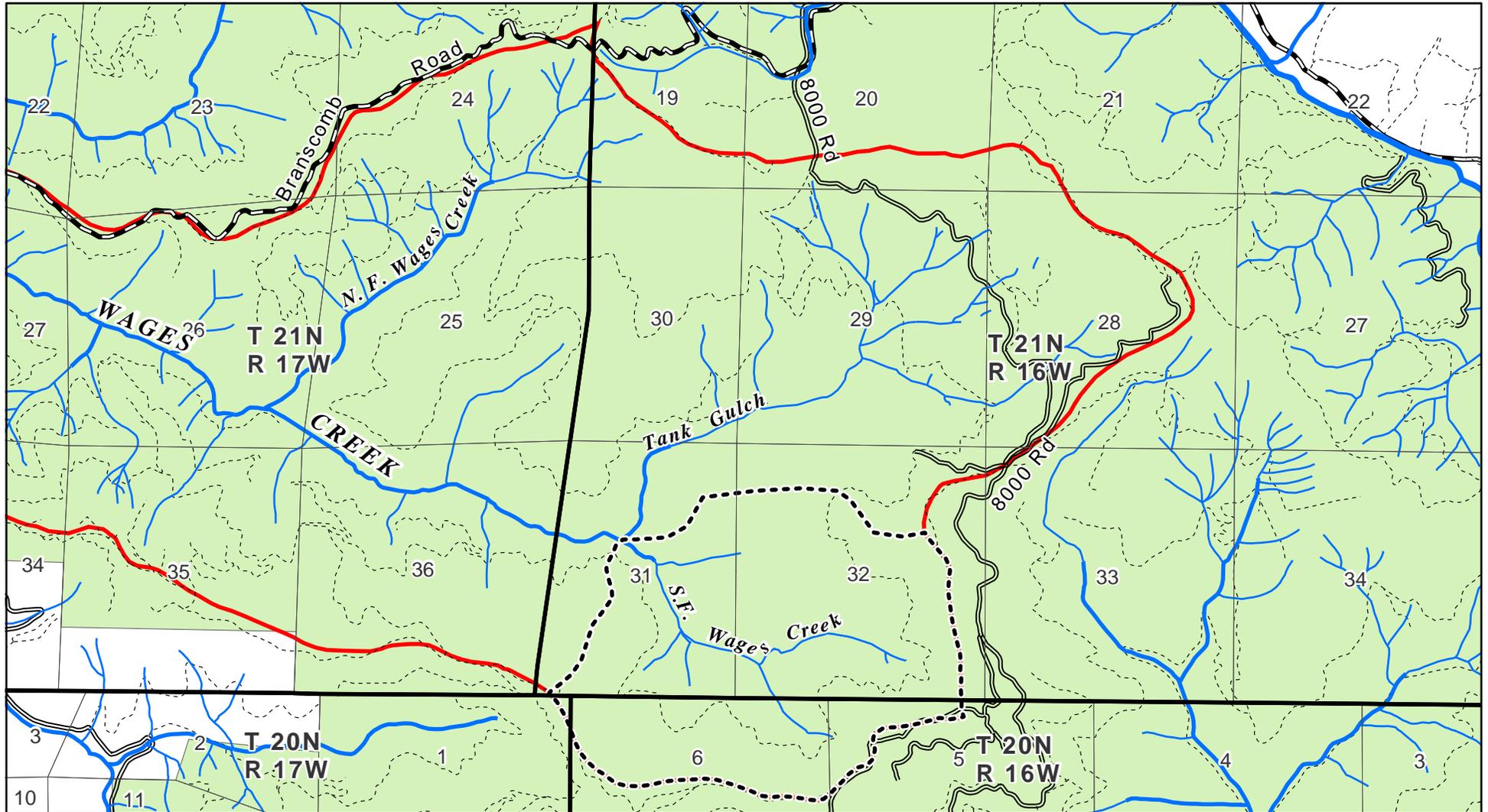
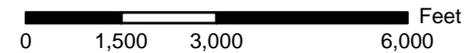


Figure 3. Location Map - S. F. Wages Creek Effectiveness Monitoring Project

-  Wages Creek Watershed
(Total Acres = 8,583)
-  Hawthorne Timberlands
(Total Acres in Wages Creek Watershed = 6,657)
-  Effectiveness Monitoring Project
(Total Acres in S. F. Wages Creek Watershed = 907)

- Watercourses**
-  Class I
 -  Class II

- Road Surface**
-  Paved
 -  Rocked
 -  Dirt



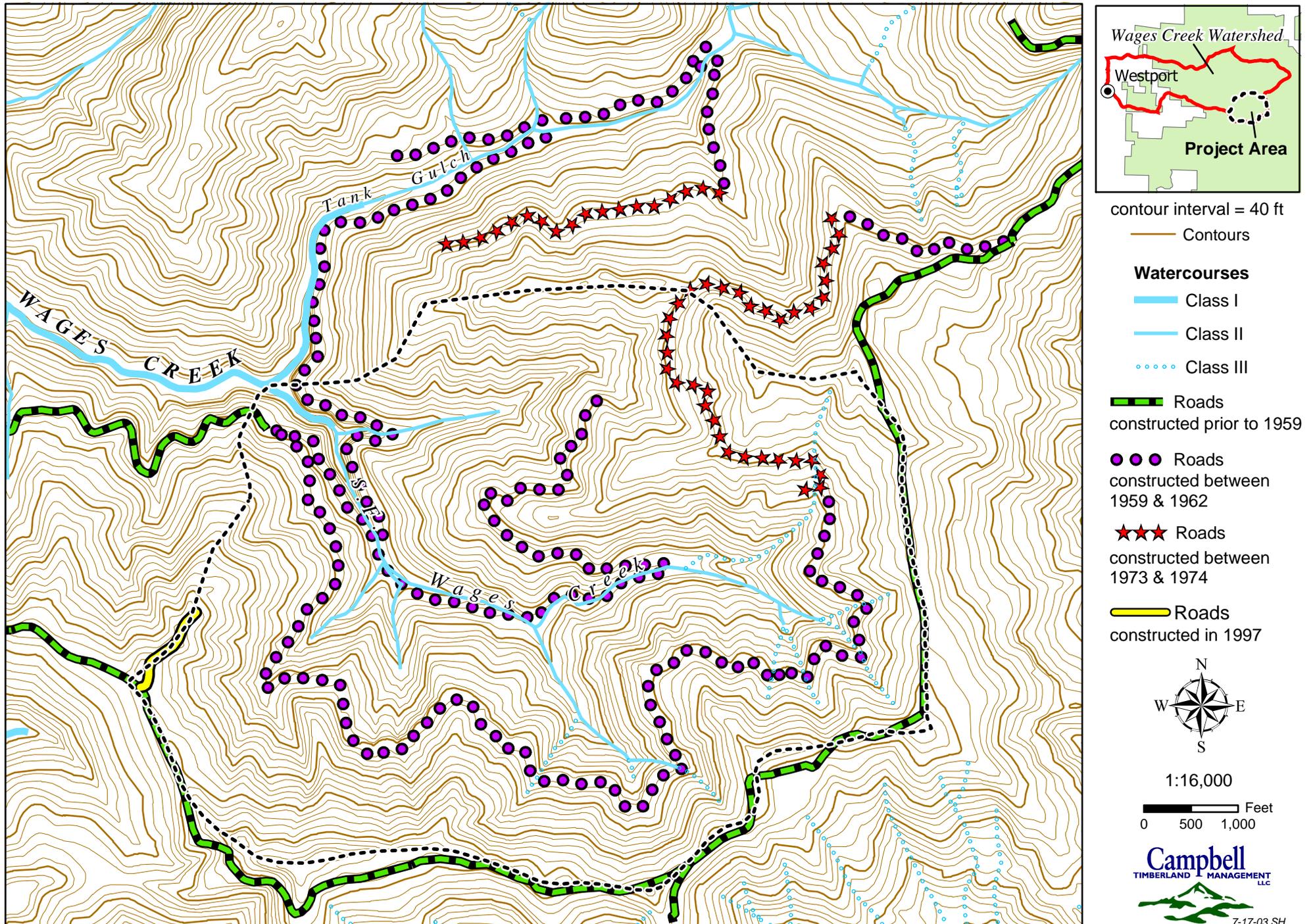
1 inch equals 3,000 feet



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Figure 4. Road Construction History in the S. F. Wages Creek Watershed

(Portion of Cal Water v2.2# - 113.120202)



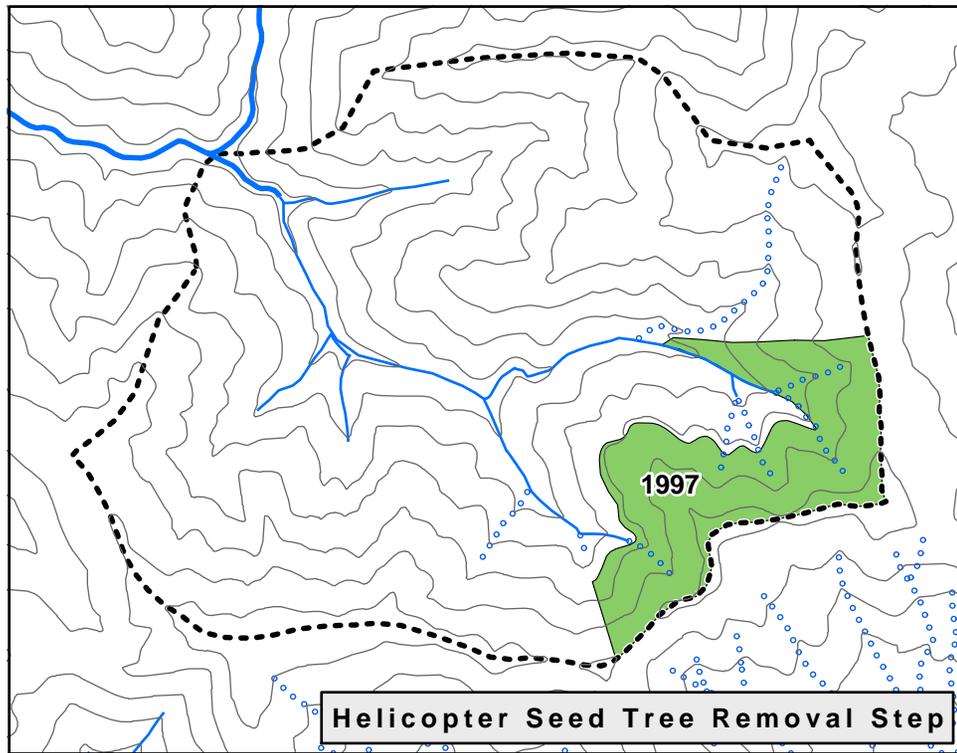
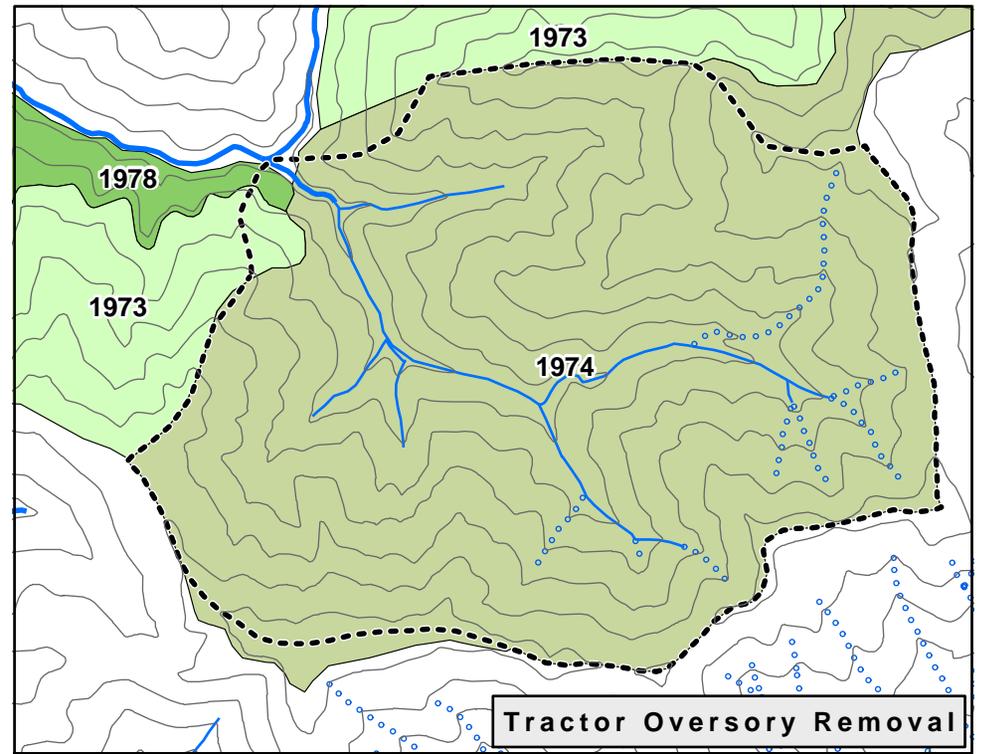
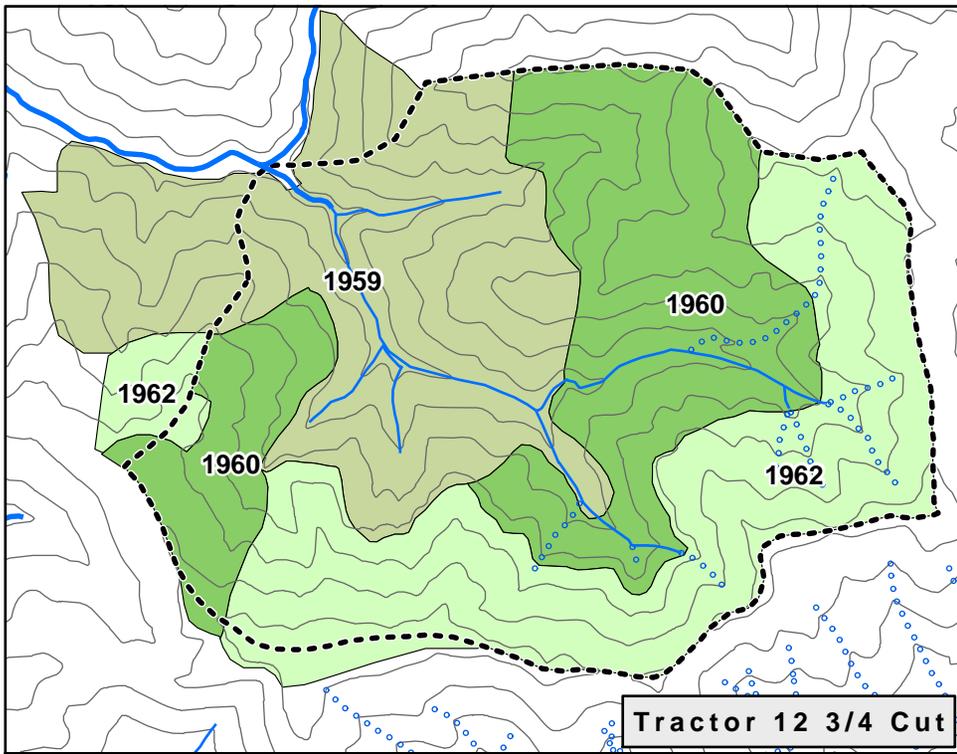


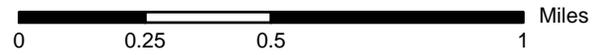
Figure 5. Timber Harvest History in the S. F. Wages Creek Watershed
 (Portion of Cal Water v2.2# - 113.120202)

-  Project Area
-  Contours 200 ft
-  Watercourses Class I
-  Class II
-  Class III



1:24,000

1 inch equals 2,000 feet



Objectives and Scope:

The overall objective of the proposed monitoring project is to evaluate the relative importance of sediment generated by THP activities, as currently practiced by Campbell Timberland Management, compared to legacy sources and background rates within the SF Wages Creek watershed. In addition, monitoring data from the study area in SF Wages Creek will be compared to similar data collected near the bottom of the entire Wages Creek watershed.

The study will involve detailed watershed mapping of sediment sources as well as extensive stream gaging and sediment sampling over a lengthy study period. A detailed sediment budget will be developed, based on geomorphic data as well as continuous turbidity and suspended sediment records. Suspended sediment and water discharge will be sampled on rising and falling limbs of flood hydrographs throughout the year, and sediment concentration will be analyzed by standard laboratory techniques (Guy 1969, Edwards and Glysson 1988). Quality Assurance Protocols developed for this proposed project are included in Appendix B.

The following specific project objectives have been developed:

Objective 1: Characterize the streamflow, turbidity and suspended sediment transport regimes for Wages Creek, SF Wages Creek and tributary streams.

Purpose – quantify existing watershed conditions, provide regional context

Parameters – continuous stream flow and turbidity, periodic suspended sediment

Scale – watershed (~8,600ac), sub-watershed (~1,000ac), tributary (<200 acres)

Methods – standard hydrologic practice for streamflow and Redwood Sciences Lab Turbidity Threshold Sampling (TTS) protocols for turbidity and suspended sediment at 5 continuous sites

Analysis – compare Wages and SF Wages data (streamflow, turbidity and suspended sediment) to other coastal watersheds (SF Ten Mile River, Caspar Creek, etc.)

Hypothesis – Stream flow, turbidity and suspended sediment regimes are similar to other coastal Mendocino watersheds of comparable size.

Objective 2: Identify primary sediment sources and their relative volumetric contributions to the sediment budget.

Purpose – develop a detailed sediment source analysis that compares natural, legacy, and current management practices.

Parameters – geomorphic mapping/watershed Inventory

Scale – Sub-watershed (~1000ac), tributary (<200 acres)

Methods – detailed field mapping of all sediment sources in study area, including landslides, roads, bank erosion, other legacy features (landings, etc.). Estimate timing and volumes associated with each feature.

Hypothesis – Current management practices contribute less than 20 percent of the post-treatment sediment budget.

Objective 3: Determine changes in turbidity regimes following timber operations relative to pre-treatment conditions.

Purpose – Determine if there is a detectable change in the turbidity regime associated with implementation of timber operations in SF Wages Creek.

Parameters – Turbidity

Scale – watershed (~8,600ac), sub-watershed (~1,000ac) and tributary (<200 acres)

Methods – Redwood Sciences Lab Turbidity Threshold Sampling (TTS) protocols for development and validation of continuous turbidity record

Analysis – Magnitude and duration of turbidity. Compare pre- and post-treatment periods. Compare upstream-downstream turbidity records for sites on the mainstem SF Wages. Compare each site to data from control tributary watershed using standard regression theory. Adjust continuous turbidity records for lag times between sites by cross correlation. Transform data if necessary to obtain normal distribution.

Hypothesis – **Changes in the magnitude and duration of turbidity following treatment will not be detectable.**

Objective 4: Determine the effect of stream crossing reconstruction on turbidity above and below treatment sites.

Purpose – Evaluate effect of reconstruction practices on turbidity

Parameters – Turbidity

Scale – Site

Methods – Above and below periodic grab samples taken during storm events

Hypothesis – **Initial increases in chronic turbidity from reconstruction will be followed by recovery to levels less than pre-treatment within three years.**

The following sections describe the specific tasks and methods required to meet the study objectives:

TASK 1: Gaging Station Network

The gaging network consists of continuous and manual sites. The current program consists of 5 continuous and up to 4 manual stations (Figure 6). After final selection of each proposed gage site, a staff gages was installed to provide permanent stage datum. Due to the size of the channels in the study area, 1 staff plate was installed which should cover virtually all flows. The staff plates are standard Type C enameled gages, installed on channel iron driven into the edge of the streambank. After staff plate installation, a station benchmark was established and surveys were made between these reference marks and the staff plates to provide a permanent datum record. A crest-stage gage (CSG) was also be mounted on the channel iron to provide records of peak flow stage for manual sites, or as a back-up to the sites with continuous stage recorders. The continuous recording stations consist of a datalogger, pressure transducer, turbidimeter, pump sampler, as well as a staff gage, crest-stage gage, turbidity boom, and a small equipment shelter. Photographs and a brief description of each site are provided in Appendix A.

The datalogger (a Campbell Scientific CR510 unit) was installed in a 3'x 2'x 2' steel enclosure to prevent vandalism and provide a secure area to hold deep cycle batteries, and excess cable. A cable-mounted boom was fabricated and installed to allow operation of the turbidity sensor during a wide range of flows and debris loads, and followed USDA Forest Service guidelines (Redwood Sciences Lab). Then boom allows access to the sensor at all flows and is counterweighted to keep the sensor in the water at all channel velocities. The pressure transducer (Design Analysis H-310) with an accuracy of 0.025% was installed in flexible armored conduit down the streambank near the stage plate. The turbidity sensors is Forest Technologies Systems DTS-12 units with wipers. An ISCO 6700 series pump sampler was installed at each continuous site and connected to the datalogger.

Figure 6. S.F. Wages Creek Study Area

(Portion of watershed # 113.120202 Cal Water v2.2)

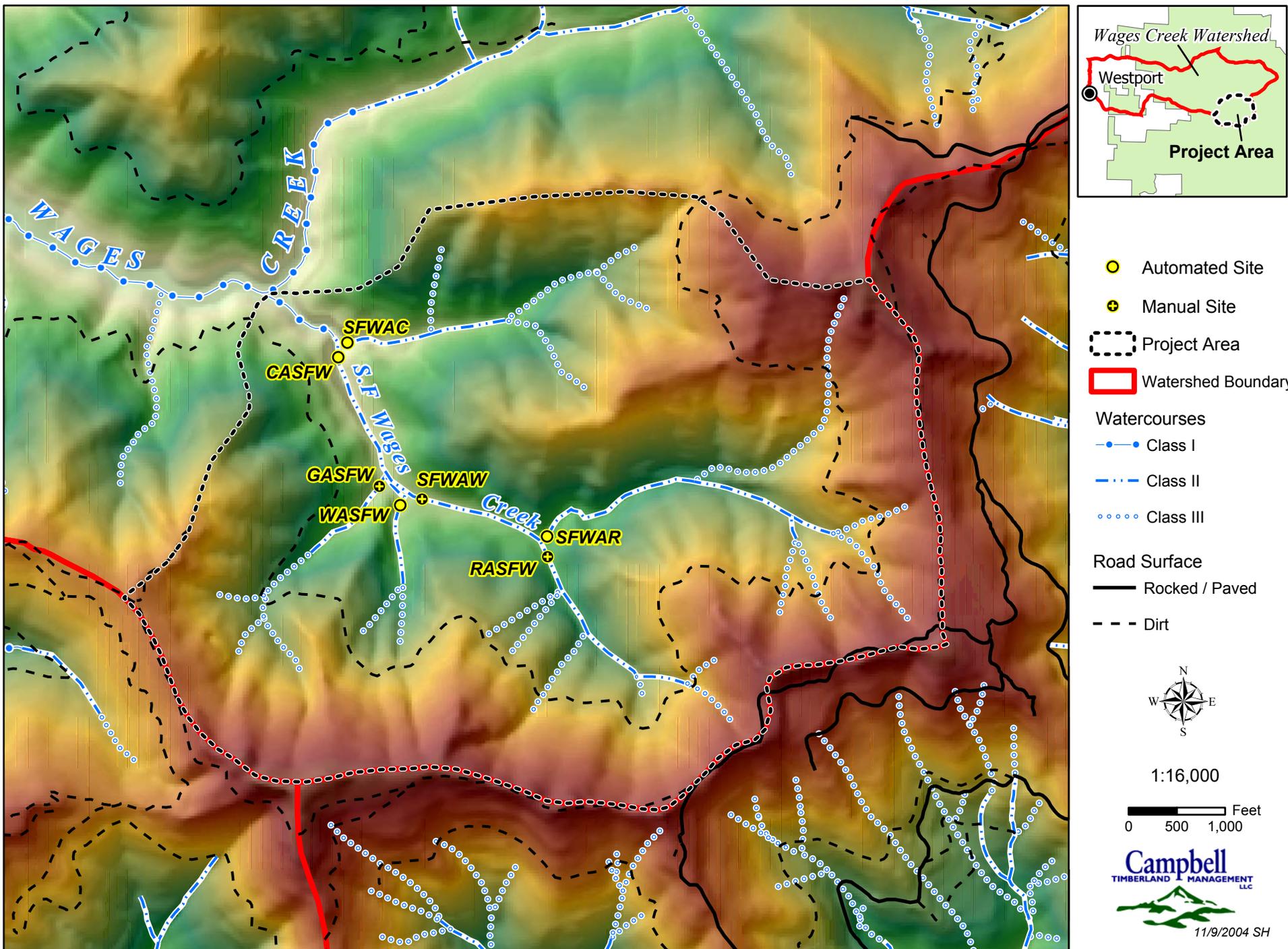
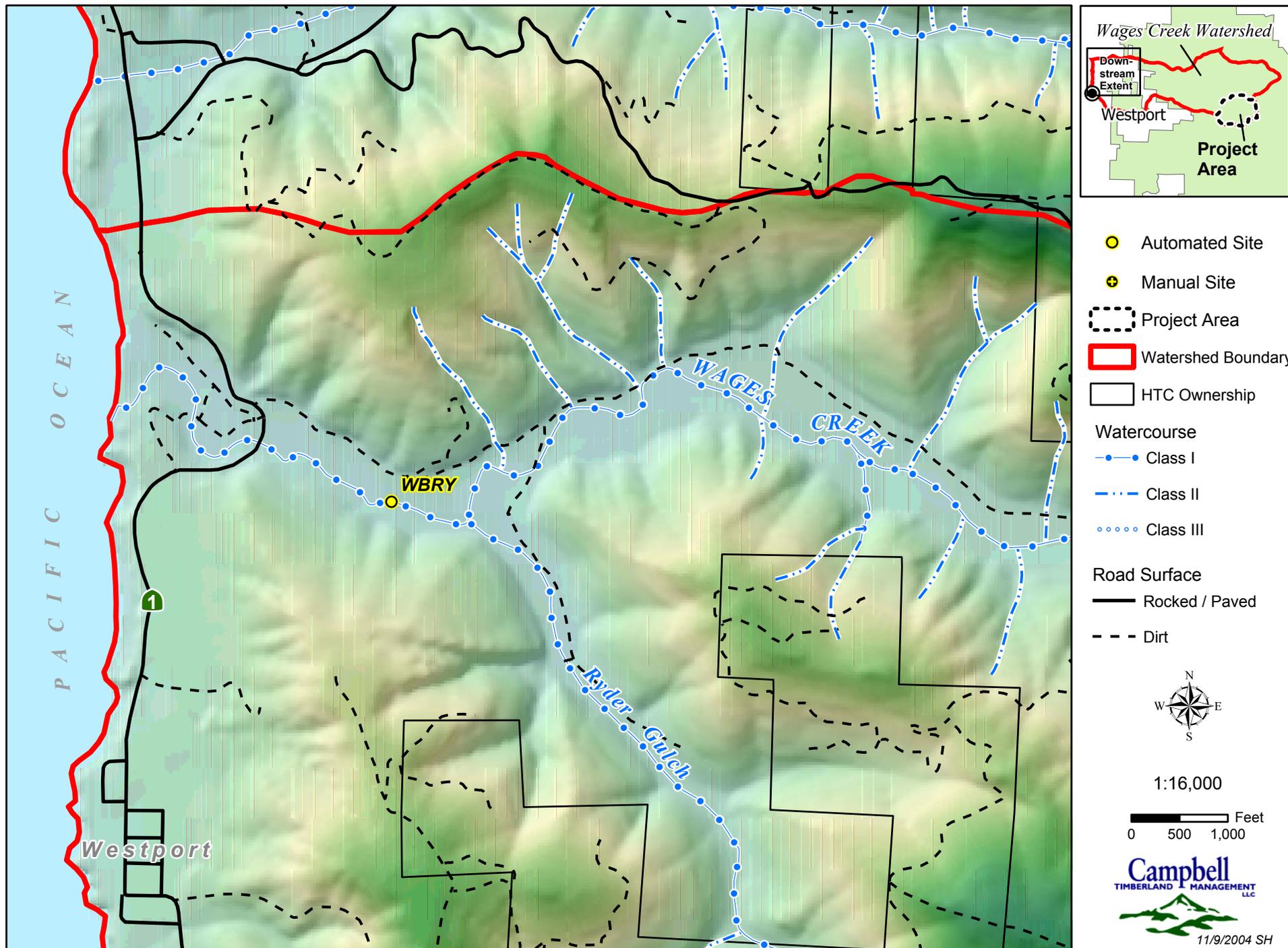


Figure 7. Wages Creek Downstream Monitoring Site



A number of the sites needed improvement of the channel at the gage location in order to collect reliable streamflow data. At these sites, small weirs were constructed using on-site rock, with wood and/or concrete hauled in, as needed. Some sites will need further channel modifications to facilitate the collection of reliable data. Small sampling bridges may be constructed out of locally felled logs to allow high flow measurements where needed and access along the channel for field personnel movement between sites during storms. Care was taken to minimize ground and vegetation disturbance during the installation of equipment and the development of access to and between sites.

It should be noted that as of the completion of this study plan, the proposed site located at the downstream end of the Wages Creek watershed (Figure 7.) has yet to be installed, but will be similar to the other stations and will consist of the same equipment.

TASK 2: Operate and Maintain Streamflow Gages

Gage operation at the 5 continuous sites and 4 manual sites began in December 2003 and will continue thereafter through the study period. One site, Rock Creek, has been abandoned due to an inability to collect satisfactory streamflow and sediment data due to the extremely high gradient. Another site, near the downstream end of the Wages Creek watershed (below Ryder Gulch) will be added (Figure 7.). Several of the sites with smaller drainage areas are ephemeral. No attempt will be made to collect streamflow data at very low flows, except along the mainstem. Gage downloading and maintenance will typically occur on a monthly basis, although it is likely to be considerably more often during winter months when field personnel are on-site often collecting data during storm events. Discharge measurements will be made at each site periodically during the fall, winter, and spring seasons. The measurements will be made using standard USGS streamflow measurement protocols and the GMA QAPP, and we expect 5-8 discharge measurements to be collected at each site annually to define a satisfactory stage-discharge relationship. Equipment to be used includes Price AA and Pygmy velocity meters using an AquaCalc 5000 datalogger to record data. All discharge measurements are entered and cataloged using a form similar to the standard USGS 9-207 discharge measurement summary form. Forms summarizing all discharge measurements made over the course of each water year for each site are maintained. After collection of the discharge measurements, a discharge-rating curve is developed for each station by plotting the stage/discharge pairs and electronically hand fitting a curve. Stage/discharge pairs are evaluated and ratings developed within the WISKI Suite software, and are completed following USGS protocols. The WISKI Suite is a comprehensive hydrologic time series database management system developed by Kisters AG. The suite is broken down into three parts, WISKI, BIBER, and SKED. WISKI manages all time series data, BIBER is used to evaluate discharge measurements, and SKED is used to develop rating curves.

If very high flows occur such that extrapolation of current meter measured flows would be necessary beyond 100% above the highest standard flow measurement, a slope-area measurement will be made at each site of the peak discharge. A Quality Assurance Project Plan (QAPP) for both the field and laboratory portions of this project will be submitted for approval prior to the initiation of sampling.

TASK 3: Collect Sediment Data

At all study sites, sediment samples are needed to relate turbidity to suspended sediment loads, to calibrate the turbidity sensors, and to calibrate pumped samples versus cross-stream depth-integrated samples. It is expected that 30-80 sediment samples will be collected at each site during each water year, depending on the number of storms that occur. Samples will be collected at moderate flows by wading, which should be feasible at all sites in virtually all conditions. Some sites will have log sampling bridges constructed to allow sampling at the full range of discharges. This program of sediment sampling will include both measurements of turbidity and suspended sediment. The continuous stations will be operated following the TTS protocols developed by USFS, Pacific Southwest Research Station, Redwood Sciences

Lab (Redwood Sciences Laboratory 2002). As noted earlier, the turbidimeters will be Forest Technology Systems DTS-12 units mounted on a boom. Frequent maintenance is needed to verify that the turbidimeter is not contaminated and/or drifting. In-field plotting and verification of data will occur, because problems can be identified and immediately corrected. Field staff typically stays on-site during storm events. Suspended sediment will be sampled with depth-integrating samplers (DH-48 or D-76), using procedures standardized by the USGS (Guy and Norman 1970, Edwards and Glysson 1988). Bedload sediment will not be sampled.

Suspended sediment samples are taken to a suspended sediment lab for analysis. Turbidity values are typically measured in the field shortly after data collection in order to meet the 48-hr EPA time frame for sample analysis. All samples will be analyzed for both turbidity and suspended sediment concentration following EPA and USGS/ASTM protocols. Per GMA protocols, a minimum of 10% of the samples will have replicates for QA/QC purposes.

TASK 4: Compute Streamflow and Sediment Transport Records

Continuous stage records will be combined with the stage-discharge relationships to compute continuous records of streamflow for all sites in the SF Wages Creek study area. The crest stage gages will allow measurement of storm peak discharges at other sites without continuous dataloggers. Data from the nearest continuous stations will be used to create synthetic hydrographs for the remaining manual stations. Synthetic hydrographs are always adjusted based on the periodic observations collected at each site during a given storm.

All streamflow data reduction, computation, and processing occur in the WISKI Suite, which includes complete USGS standards for surface water programs. These standards include USGS computational methods according to WSP 2175, Measurement and Computation of Streamflow vols.1 and 2, Multiple Ratings with log offsets, shifts and stage adjustments, gage height and datum correction, and standard printouts such as primary computation sheets, mean daily value summaries, rating tables, and shift tables. In Water Year 2005, the WISKI suite will be used to develop all rating tables and perform all computations for continuous surface water gaging stations.

Streamflow results for each gaging station for each water year will be reported as follows: a complete station analysis, an updated copy of the station description, a listing of discharge measurements, the rating curves and tables, the 10-minute interval stage record showing all manual observations of stage, the 10-minute interval discharge hydrograph, a summary table of mean daily flows, and a table of instantaneous peaks above a selected base. Complete electronic files of the continuous (10-minute intervals) record of stage and discharge will be provided to interested parties on CD.

Continuous records of turbidity will come directly from the project turbidity sensors (10-minute intervals), while suspended sediment loads will be computed using the relationship between turbidity and suspended sediment developed from pumped and depth-integrated paired samples collecting during storm events. Turbidity and suspended sediment transport results for each gaging station for each water year will be reported as follows: a complete station analysis of sediment data, a listing of sediment measurements, the sediment rating curves (turbidity vs. SSC relationship), the 10-minute interval turbidity record showing all manual and pumped observations of turbidity, the computed 10-minute interval suspended sediment concentration and sediment load sedigraphs showing all pumped and depth-integrated values, a summary table of daily suspended sediment transport totals, and a table of suspended sediment transport totals by storm event. Complete electronic files of the continuous (10-minute intervals) record of turbidity and suspended sediment concentration and load will be provided to interested parties on CD.

TASK 5: Forensic Analysis of Sediment Delivery

Having staff on-site during significant storm events will allow forensic analysis of specific sediment delivery events. Large or unusual turbidity spikes will be tracked by staff based on field review of datasets and visual observations. Once a spike is identified, staff will walk the channel and/or hillslope in question in an attempt to locate the sediment source, although this may not be possible until after the storm. New sites will be photographed, located on the detailed base maps, and volumes entrained estimated.

TASK 6: Geomorphic Inventory and Preliminary Sediment Budget of Entire Study Watershed

Base Map Preparation

A base map will be prepared using 2004 aerial photography, historic aerial photography and key geographic information systems layers. Base maps will be used to coordinate all study activities. Ground surveys will be conducted to verify aerial photography interpretation and identify additional erosion sites not identified by aerial photography.

Development of a Sediment Budget

Preparation of a preliminary sediment budget (Swanson et al. 1982, Reid and Dunne 1996) for the study area is one of the primary WY2006 tasks. An analysis of the relative contributions of sediment from different sources is valuable in understanding the interactions between natural conditions, land use activities, and resource conditions.

Typically, a sediment budget quantifies sediment sources (inputs), by each erosional process, as well as changes in the amount of channel-stored sediment, and sediment outputs as measured at a gaging station over a designated time frame or several time periods (Reid and Dunne, 1996). Quantifying sediment sources involves determining the volume of sediment delivered to stream channels by the variety of erosional processes operating within the watershed. For the SF Wages Creek study area, these can be divided into three primary processes or sediment delivery mechanisms: 1) mass movement (landslides), 2) fluvial erosion (gullies, road and skid trail crossing failures, and stream bank erosion), and 3) surface erosion (rills and sheetwash).

These three processes can deliver sediment to stream channels both naturally and as a result of land use activities. Sediment production by mass movement processes occurs commonly during large, infrequent storm events, whereas fluvial and surface erosional processes can occur during small storms in virtually every water year or as a result of large storms. Direct sedimentation into stream channels by heavy equipment involved with road/railroad construction and timber harvest was probably commonplace in the study area prior to 1974. However, some areas are still likely experiencing elevated sediment yields as a legacy of the former practices. The residence time of such introduced sediments is highly variable, but may well be on the order of decades to centuries.

Changes in the amount of sediment stored in stream channels are usually measured in the field by analyzing surveyed channel cross sections or by field surveys which estimate the amount of past channel filling and subsequent downcutting that has occurred. Analyzing changes in channel stored sediment can answer questions such as how much of what type of sediment is transported and where is it deposited, how does introduced sediment interact with sediment which was already in storage in the channel, and how does the transport affect overall stream morphology (Reid and Dunne, 1996).

Erosion Feature Inventory

Given the objectives of this project, a complete inventory of the study area will be made for the sediment budget. Field personnel will map all erosional features within the boundaries of the study area by walking its entire area. Each feature will have the following data recorded: (1) type of sediment source, (2) any apparent land use or management associations, (3) area, thickness and volume of erosion, (4) estimate of the percentage of sediment delivered to the stream, (5) estimate of the features age, and (6) specific location characteristics such as geomorphic form, hillslope steepness, dominant vegetation, and canopy cover. All data will be entered on a data form that will then be input into the project database.

Data analysis includes evaluation of sediment delivery by process (slides, gullies, rill erosion, bank erosion) and by land use association (non-management, harvest-related, road/skid-trail related). Data collected will allow differentiation between system roads (currently in use) and abandoned or legacy roads and other legacy features (landings, etc).

The individual sediment budget items are discussed below:

Landslides

Landslides will be mapped following standard geologic protocols. All landslide features in the study area will be located, placed on the base map, and attributes measured. Historic aerial photographs will be used to locate landslides from previous time periods.

Roads

Field Inventory will be used to verify traffic and surfacing information, to verify segment types and grouping, to determine road attributes (tread, ditch, cutslope, fillslope) and prism dimensions, to collect information on cover percentage on cut- and fill-slopes, to review localized problem areas, and to determine potential delivery to streams. During field surveys, information on road sediment delivery will also be collected for each segment. At each drainage site, the potential for sediment delivery to the stream will be determined. Each drainage feature on a surveyed reach of road will be considered a site and a site sheet filled out for each.

Drainage feature types include; watercourse crossings, ditch relief culverts, rolling dips, and waterbars. Road attributes affecting the amount of sediment produced from the road segment will be recorded. A delivery percentage will then be assigned to the site. Delivery is based on the road shape (insloped, outsloped, crowned), distance to stream, and geomorphic evidence of connectivity (gullies and rills). Other sources of erosion directly related to the drainage feature will also be recorded on the site sheet. Other erosional features associated with the road prism include; cut bank failures, fill failures, crossing failures, and gullies. Site sheets will also be filled out at every erosional feature not directly associated with a drainage feature.

Legacy temporary roads and skid trails will have the same inventory and evaluation as active roads. Historic aerial photographs will be used to delineate skid trail networks prior to field inventory.

Surface Erosion

Surface erosion beyond that derived from road surface erosion is primarily hillslope erosion from skid roads and harvest areas. Surface erosion will be estimated based on rill dimensions and the extent of exposed soil.

Bank Erosion

In order to quantify the amount of sediment contributed to stream channels from bank erosion, all reaches of channels within the study area will be inventoried for past erosion. Stream length and site location will be identified using a tape, hip chain or range finder and aerial photography mapping. All apparent erosional features will be recorded. Features will be given a volume, delivery percentage, and an age.

Channel Storage

Sediment generated from upslope processes is transported through downstream reaches and frequently stored in landforms of various ages and often behind woody debris jams. In order to develop a sediment budget, an evaluation of changes in channel storage must be made. In narrow, low-order tributary channels, opportunities for significant storage of alluvial deposits are often limited. Areas of stored sediment will be mapped using standard total station survey equipment, if feasible, and will include, at a minimum a series of cross sections and a long profile.

Development of Project GIS

All sites identified in the sediment budget will be located precisely on the detailed base maps and entered into the project GIS database.

TASK 7: Annual, Progress, and Final Report Preparation

This monitoring project is expected to have a duration of about 10 years. Over the project period, a series of deliverable products are required as listed below.

This task involves preparing results of streamflow and sediment gaging at all of the sites and presenting these results and analyses in an annual technical report. The annual report will present all data collected, compare sediment loads for individual tributaries or basin areas, and from the South Fork Wages Creek study area as a whole. A separate report will be prepared for the geomorphic mapping and sediment budget developed in the second and third years. All data will be available by the month of December following the end of each water year. If possible, these data will be available on-line.

In addition, a comprehensive pre-treatment report will be prepared that combines the streamflow and sediment transport data for all pre-treatment years (3 or more) along with the results and findings of the sediment budget. Similarly, a final report will be prepared at the end of the project that includes all pre- and post-treatment data and analyses, along with a comprehensive summary of the all geomorphic and hydrologic data and the analysis of these data..

Peer reviewed publications at the completion of the study, or as appropriate, during the study. Such publications would include, at a minimum, a methods paper, and a results paper.

BUDGET:

CDF will purchase all of the monitoring equipment, while Campbell will provide labor to operate the gages and collect streamflow, sediment transport, and geomorphic data. Capital equipment costs are approximately \$60,000, while annual operating costs are estimated at \$80,000.

PROJECT SCHEDULE:

First Year (WY2004)

Project Authorization	May 1, 2003
Site Recon for Installation Requirements	June 1
Order all long-lead time Equipment	July 1
Equipment Fabrication	September 1
Equipment arrives	September 15
Equipment Installation	September 15-October 1
Sediment Sampling	November 1-April 1
Gage Operation	October 1, 2003-September 30, 2004
First Year Report	December 1, 2004

Second Year (WY2005)

Gage Operation	October 1, 2004-September 30, 2005
Sediment Sampling	November 1, 2004-April 1, 2005
Second Year Report	December 1, 2005

Third Year (WY2006)

Gage Operation	October 1, 2005-September 30, 2006
Sediment Sampling	November 1, 2005-April 1, 2006
Geomorphic Mapping	July 1-August 30, 2005
Develop Sediment Budget	Summer 2006
Harvest Plan Assessment	Summer 2006
Third Year Report	December 1, 2005

* Depending on the magnitude and duration of storms that occur in the first three years of the monitoring project, a decision will be made in Spring 2006 whether to continue with additional years of pre-treatment monitoring. Regional data sets will be used to evaluate the recurrence intervals of the largest storms that occurred in the three sampling years.

QUALIFICATIONS OF HYDROLOGY/GEOMORPHOLOGY CONSULTANT:

Graham Matthews & Associates (GMA) specializes in hydrologic and geomorphic data collection and analysis, as well as stream restoration project design and implementation. GMA is in a unique position to undertake this project based on experience, equipment, and personnel available. GMA currently operates 15 continuous streamflow gaging stations in the Wood River Valley of Oregon, 7 stations in the Trinity River basin, 5 in the SF Ten Mile, 2 in the Tahoe Basin, and 4 in the SF Trinity River watershed. GMA has collected hundreds of discharge measurements and thousands of sediment transport measurements in the last 5 years on a wide variety of streams and rivers. GMA has an outstanding array of state-of-the-art streamflow and sediment transport monitoring equipment and is able to fully equip at least 5 sampling teams and most equipment for 5 more individual hydrographers. GMA has installed over 10 turbidity threshold monitoring stations (TTS) in the last two years, and is currently operating 7 TTS stations for a variety of clients.

GMA has established a sediment lab that processes samples at a very reasonable cost while meeting strict laboratory procedures and QA/QC protocols. The lab participates in the USGS QA/QC program for suspended sediment concentration. GMA has implemented similar projects in the Trinity, South Fork Trinity, SF Ten Mile, and Wood River watersheds in recent years. GMA is led by Graham Matthews who has over 20 years experience in hydrology and geomorphology.

In addition, GMA will be supported by the science staff of Campbell Timberland Management who has added technical positions in 2004 to better assist in winter data collection. The presence of local technicians will greatly assist in storm response and data collection.

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APPENDIX A

SITE DESCRIPTIONS



Site Name: South Fork Wages Creek above Center Gulch

Site Acronym: SFWAC

Watershed Area: 706 acres

WY2004 Peak Discharge: 55cfs

Bankfull Width: 9 ft

Bankfull Depth: 1.5 ft

Channel Control: Bedrock, boulders and channel banks



Site Name: Center Gulch above South Fork Wages Creek

Site Acronym: CASFW

Watershed Area: 184 acres

WY2004 Peak Discharge: 16cfs

Bankfull Width: 5 ft

Bankfull Depth: .8 ft

Channel Control: Boulders



Site Name: Wood Creek above South Fork Wages Creek

Site Acronym: WASFW

Watershed Area: 67 acres

WY2004 Peak Discharge: 5 cfs

Bankfull Width: 5 ft

Bankfull Depth: .5 ft

Channel Control: Wooden weir



Site Name: Rock Creek above South Fork Wages Creek

Site Acronym: RASFW

Watershed Area: 151 acres

WY2004 Peak Discharge: 14 cfs

Bankfull Width: 8 ft

Bankfull Depth: .7 ft

Channel Control: Boulders



Site Name: South Fork Wages Creek above Rock Creek

Site Acronym: SFWAR

Watershed Area: 250 acres

WY2004 Peak Discharge: 20 cfs

Bankfull Width: 9 ft

Bankfull Depth: .8 ft

Channel Control: Boulders and channel banks



Site Name: South Fork Wages Creek above Wood Creek

Site Acronym: SFWAW

Watershed Area: 464 acres

WY2004 Peak Discharge: 37 cfs

Bankfull Width: 12 ft

Bankfull Depth: .8 ft

Channel Control: Cobbles and channel banks



Site Name: Grey Creek above South Fork Wages Creek

Site Acronym: GASFW

Watershed Area: 107 acres

WY2004 Peak Discharge: 9 cfs

Bankfull Width: 5 ft

Bankfull Depth: .6 ft

Channel Control: Boulders and channel banks



Site Name: Wages Creek below Ryder Gulch

Site Acronym: WBRY

Watershed Area: 8480 acres

WY2004 Peak Discharge: 1000 cfs (estimated)

Bankfull Width: NA

Bankfull Depth: NA

Channel Control: Gravels and channel banks

APPENDIX B

SURFACE-WATER QUALITY-ASSURANCE PLAN

**SURFACE-WATER QUALITY-ASSURANCE PLAN FOR THE SOUTH FORK WAGES
CREEK EFFECTIVENESS MONITORING PROJECT**

Streamflow and Sediment Transport Monitoring Program – Field and Office

Graham Matthews & Associates

July 2003

Principal Investigator Signature _____

Name/Date _____

CTM Project Manager Signature _____

Name/Date _____

CDF Project Manager Signature _____

Name/Date _____

CDF QA Officer Signature _____

Name/Date _____

SURFACE-WATER QUALITY-ASSURANCE PLAN FOR THE SOUTH FORK WAGES CREEK EFFECTIVENESS MONITORING PROJECT

Abstract

This Surface-Water Quality-Assurance Plan documents the standards, policies, and procedures to be used for activities related to the collection, processing, analysis, storage, and reporting of surface-water data for the SF Wages Creek THP Effectiveness Project Monitoring program.

INTRODUCTION

Surface-water information, including stream-flow, stage, and sediment data, is used for resources planning and management. The purpose of this Surface-Water Quality-Assurance Plan (QA Plan) is to document the standards, policies, and procedures used by GMA for activities related to the collection, processing, storage, and publication of surface-water data for the SF Wages Creek THP Effectiveness Project under a contract to Campbell Timberland Management. Significant portions of this document are based on a QA Plan developed by the California District of the USGS and a previous and more detailed QA Plan developed by GMA for other hydrologic and geomorphic monitoring projects.

This plan identifies responsibilities for ensuring that stated policies and procedures are carried out. The plan also serves as a guide for all GMA personnel involved in surface-water activities and as a resource for identifying publications, and other literature that describe in more detail associated techniques and requirements. The scope of this report includes discussions of the policies and procedures followed by GMA for the collection, processing, analysis, storage, and reporting of surface-water data. Specific types of surface-water data include stage, streamflow, and sediment transport measurements. In addition, issues related to the management of the computer database and employee safety and training are presented.

RESPONSIBILITIES

Quality assurance (QA) is an active process. Achieving and maintaining high-quality standards for surface-water data are accomplished by specific actions carried out by specific persons. Errors and deficiencies can result when individuals fail to carry out their responsibilities. Clear and specific statements of responsibilities promote an understanding of each person's duties in the overall process of assuring surface-water data quality. The following is a list of responsibilities of GMA personnel involved in the collection, processing, analysis, storage, or publication of surface-water data.

The Principal Investigator (PI) is responsible for:

1. Managing and directing the GMA program, including all surface-water activities.
2. Ensuring that surface-water activities in GMA meet the needs of its clients including, the Federal government, State and local agencies, other cooperating agencies, and the general public.
3. Ensuring that all aspects of this QA Plan are understood and followed by GMA personnel. This is accomplished by the GMA PI's direct involvement or through clearly stated delegation of this responsibility to other personnel in GMA.
4. Performing technical reviews of all surface-water programs on a regular basis.
5. Ensuring that all reports and other technical communications released by GMA are accurate and are in accord with GMA policy.

The Project Manager (PM) is responsible for:

1. Designing data-collection activities in the field area.
2. Assuring the accuracy of the gaging station records.
3. Providing leadership for staff members.
4. Maintaining expertise in all phases of data-collection, compilation, and computation.
5. Providing On-the-job training (OJT) and formal training for subordinates.

The Staff Hydrologist (SH) is responsible for:

1. Correctly and accurately making discharge measurements of various types.
2. Installing, servicing, and repairing gaging station instruments.
3. Entering data retrieved from gaging station instruments into the WHS data base.
4. Developing ratings and entering them into WHS.
5. Computing discharge records and writing station descriptions and analyses.
6. Helping construct gaging facilities.

COLLECTION OF STAGE AND STREAMFLOW DATA

Reliable surface-water data are necessary for planning and resource management. The collection of stage and streamflow data is a primary component in the ongoing operation of streamflow-gaging stations (referred to in the remainder of this report as gaging stations) and other water-resource studies performed by GMA.

The objective of operating a gaging station is to obtain a continuous record of stage and discharge at the site (Carter and Davidian, 1968, p. 1). A continuous record of stage is obtained by installing instruments that sense and record water-surface elevation in the stream. Discharge measurements are made at periodic intervals to define or verify the stage-discharge relation and to define the time and magnitude of variations in that relation.

It is the policy of GMA that all personnel involved in the collection of stage and discharge data shall be properly trained, well informed, and follow the surface-water data collection policies and procedures established by GMA.

Gage Installation and Maintenance

Proper installation and maintenance of gaging stations are critical activities for ensuring quality in streamflow data collection and analysis. Effective site selection, correct design and construction, and regular maintenance of a gage can make the difference between efficient and accurate determination of discharge or time-consuming, poor estimations of flow. Sites for installation of gaging stations are selected to meet specific data-collection needs. Additionally, sites should have, to the greatest extent possible, ideal hydraulic conditions. The individual responsible for selecting sites for new gaging stations is the PI or PM.

Measurement of Stage

It is GMA policy that surface-water stage records at stream sites be collected with instruments and procedures that provide sufficient accuracy to support computation of discharge from a stage-discharge relation, given the budgetary constraints of such a program.

In general, operation of gaging stations for the purpose of determining daily discharge includes the goal of collecting stage data at the accuracy of + or - 0.01foot. The types of instrumentation installed at all continuous gaging sites for the SF Wages Creek THP Effectiveness Monitoring Project are Design Analysis H-310 pressure transducers wired to Campbell Scientific CR510 dataloggers. Ensuring that new equipment has been installed correctly is the responsibility of the PM. Proper maintenance of gage instrumentation or replacement, if appropriate, of equipment is the responsibility of field personnel who service the gage.

Accurate stage measurement requires not only accurate instrumentation but also proper installation and continual monitoring of all system components to ensure the accuracy does not deteriorate with time.

At pressure transducer installations, the reference gage should be a sturdy low-water section of outside staff gage near the orifice. The principal gage will be the readout for the transducer. Generally, the instrument should be reset to the reference gage only when the stage in the stream is low and there is no

wind or wave action, and there is minimal pile-up or drawdown around the reference gage. At high stages, the instruments usually are a more reliable index of gage height than the upper staff readings. Significant gage-height differences can be corrected later with datum adjustments if analysis shows that the instrument was truly in error.

Gage Documents

It is GMA policy that certain documents are maintained with the SH for the purpose of keeping a record of observations, equipment maintenance, structural maintenance, and other information helpful to field personnel. Documents maintained by the SH for each gaging station include: (1) the most recent digital stage-discharge relation (rating table); (2) a graph of the rating upon which each new measurement is plotted; and (3) a list of discharge and CSG measurements for each site. It is the responsibility of personnel, who run a field trip regularly, to maintain updated forms for each gaging station.

Levels

The various gages at a gaging station are set to register the height of a water surface above a selected level reference surface called the gage datum. Levels are run periodically to all bench marks, reference marks, reference points, and gages at each station for the purpose of determining if any datum changes have occurred (Rantz and others, 1982, p. 545).

Photographs

Photographs of newly installed gages, station controls, possible indirect measurement sites, reference marks, and damaged structures are made by field personnel for the purpose of documenting gage construction, changes in control conditions, or to supplement various forms of written descriptions. Digital cameras are made available by the PM as needed. Each digital photograph that becomes part of the station record is identified by using a file naming convention that includes station name and date. Digital photographs are placed in station digital files.

Site Documentation

Thorough documentation of qualitative and quantitative information describing each gaging station is required. This documentation, in the form of a station description and photographs, provides a permanent historic record of site characteristics, structures, equipment, instrumentation, altitudes, location, and changes in conditions at each site. Information pertaining to where these forms of documentation are maintained is discussed in the section of this report entitled "Office Setting." A station description is prepared for each gaging station, water quality, or sediment data-collection site and becomes part of the permanent record for each station. The responsibility for ensuring that station descriptions are prepared correctly and in a timely manner is held by the PM.

Station Descriptions

For a short-term project such as this one, station descriptions are only updated if significant change has occurred. It is the responsibility of the PM to ensure that station descriptions are updated. Descriptions are reviewed and updated by the responsible field person. Station descriptions are written to include specific types of information in a consistent format (Kennedy, 1983, p. 2).

Direct Measurements

Direct measurements of discharge are made with any one of a number of methods used by GMA. The most common is the current-meter method. A current-meter measurement is the summation of the products of the subsection areas of the stream cross-section and their respective average velocities (Rantz and others, 1982, p. 80). Procedures used for current-meter measurements are described by Rantz and others, 1982, p. 139; Carter and Davidian, 1968, p. 7; and Buchanan and Somers, 1969, p. 1. When personnel make measurements of stream discharge, attempts are made to minimize errors. Sources of errors are identified by Sauer and Meyer, 1992. These include random errors such as depth errors associated with soft, uneven, or mobile streambeds, or uncertainties in mean velocity associated with vertical-velocity distribution errors and pulsation errors. These errors also include systematic errors, or bias, associated with improperly calibrated equipment or the improper use of such equipment. To

minimize systematic errors field trips are typically rotated to different personnel throughout the water year.

Exchange of current meters among field personnel is expected for each trip or on a specified, regular basis. The idea is to eliminate the possibility of one group of station records being biased by a meter that deviated from the standard meter rating. The exchange has an additional advantage in that it may raise the general level of meter maintenance. The PM assigns a specific SH to manage the exchange of meters. A chronological log of meter maintenance and exchange is maintained. GMA policies related to the measurement of discharge by use of the current-meter method are in accordance with standard USGS policies. No other discharge methods beyond the current meter method will be used in this project, unless extremely high flows occur during the project time period and subsequent slope-area measurements of peak flows are made.

Field Notes

Thorough documentation of field observations and data-collection activities performed by field personnel is a necessary component of surface-water data-collection and analysis. To ensure that clear, thorough, and systematic notations are made during field observations, discharge measurements are recorded by field personnel on standard GMA discharge-measurement forms and are summarized in field books as a backup.

Measurement Checking

1. Each trained person making discharge measurements is solely responsible for completely and accurately filling out the GMA Discharge Measurement sheet, and the computational accuracy of the measurement, although this is usually done by the Aquacalc 5000, stream discharge computer.
2. Each person immediately upon completion of a measurement computation is expected to:
 - a. Scan the measurement for obvious errors in velocity, depth, partial areas, partial discharges.
 - b. Scan for misplaced decimal points.
 - c. Check the sum of partial widths against total width.
 - d. Re-compute the sum of partial areas and discharges.
3. If a measurement, when compared to the rating, is more than 10 percent off the existing trend, a check of that measurement is required.

Acceptable Equipment

Equipment used by GMA for the measurement of surface-water discharge has been found acceptable by the USGS through use and testing. An array of acceptable equipment for measuring discharge includes current meters, timers, wading rods, bridge cranes, tag lines, and others (Rantz and others, 1982, p. 82; and Smoot and Novak, 1968). Although an official list of acceptable equipment is not available, Buchanan and Somers (1969), Carter and Davidian (1968), and Edwards and Glysson (1988) discuss the equipment used by the USGS.

The meters most commonly used by GMA personnel for measuring surface-water discharge are the Price AA current meter and the Price pygmy current meter, and generally those with the magnetic head version. Methods followed by GMA personnel for inspecting, repairing, and cleaning these meters are described by Smoot and Novak (1968, p. 9), Rantz and others (1982, p. 93), and Buchanan and Somers (1969, p. 7). The ultimate responsibility for the good condition and accuracy of a current meter rests with the field person who uses it. A timed spin test made a few minutes before a measurement does not ensure that the meter will not become damaged or fouled during the measurement. Field personnel must assess apparent changes in velocity or visually inspect the meter periodically during the measurement to ensure that the meter continues to remain in proper operating condition.

Spin tests.--It is GMA policy that spin tests are required prior to each field trip. Spin-test results are documented in a log that is maintained for each instrument. The log is located in the project office. Repairs are made to meters when deficiencies are identified through the spin test or inspection. Review of

this log by the PM is made annually. If deficiencies are observed during this review of the log, the field person responsible is informed and the problem is corrected immediately.

Crest-Stage Gages

Crest-stage gages are used as tools by GMA for determining peak stages at otherwise ungaged sites, confirming peak stages where pressure transducers are used, and determining peak stages along selected stream reaches or other locations, such as upstream and downstream from bridges and culverts. GMA requires quality-assurance procedures comparable to those used at continuous-record stations for the operation of crest-stage gages and for the computation of annual peaks at crest-stage gages.

The operation of crest-stage gages is part of GMA's surface-water program. Procedures followed by GMA in the operation of crest-stage gages are presented by Rantz and others (1982, p. 9, 77, 78). One or more gages are maintained at each selected site where peak water-surface elevations are required on a stream. Upstream and downstream gages are maintained at culverts or other structures where water surface elevations are required to compute flow through the structure and to establish the resulting type of flow. Except at sites where crest-stage gages are used only to confirm or determine peak stages, stage-discharge relations are developed in association with the gage based on direct or indirect high-water measurements. Field observations are written on standard field forms. All field notes are required to include: initials and last name of field person, date, time of observation, gage height(s), outside high-water marks, and condition of control.

PROCESSING AND ANALYSIS OF STREAMFLOW DATA

The computation of streamflow records involves the analysis of field observations and field measurements, the determination of stage-discharge relations, adjustment and application of those relations, and systematic documentation of the methods and decisions that were applied. Streamflow records are computed and reported for each gaging station annually (Rantz and others, 1982, p. 544). This section of the QA Plan includes descriptions of procedures and policies pertaining to the processing and analysis of data associated with the computation of streamflow records. The procedures followed by GMA coincide with those described by Rantz and others (1982) and by Kennedy (1983).

Measurements and Field Notes

The gage-height information, discharge information, control conditions, and other field observations written by personnel onto the measurement note sheets and other field note sheets form the basis for records computation for each gaging station.

Measurements and other field notes for the water year that is currently being computed are filed in the current record folder. After the measurement data are entered into computer files by use of Excel software then a paper printout of that information may be filed. Original data obtained by direct observation in the field is called "observed data" here; subsequent values derived from the observed data are called "computed data." The distinction between observed data and computed data is that observed data cannot be recovered if lost; computed data can always be recovered from the observed data. Therefore, observed data should never be altered or destroyed. The same basic principles can be applied to sediment, water quality, and ground water field notes, level and survey notes, and the observations recorded on charts or tapes.

Measurement Summary List (9-207)

The GMA Discharge Measurement listing will be the official final documentation to accompany the station record and, as such, must be complete and accurate. Print out the GMA form and file with the final record.

Continuous Record

Surface-water gage-height data are collected as continuous record (typically hourly, 30-minute, or 15-minute values) in the form of electronic storage by data loggers. Streamflow records are computed by

converting gage-height record to discharge record through application of stage-discharge relations. Ensuring the accuracy of gage-height record is, therefore, a necessary component of ensuring the accuracy of computed discharges. Gage-height record is assembled for the period of analysis as completely as possible. Periods of inaccurate gage-height data are identified, then corrected (see the section “Datum corrections, gage-height corrections, and shifts”) or deleted as appropriate. Items included in the assembly of gage-height record and procedures for processing the data are discussed by Kennedy (1983, p. 6) and Rantz and others (1982, p. 560 and p. 587).

Records and Computation

Records computed for each station are often worked as a whole each year by a single individual. A SH who has demonstrated proficiency in stream gaging record computation should not require a 100-percent check on work produced. All records receive a summary review by the PM. Approximately 10 percent of all records are reviewed in detail by the PM or PI.

Procedures for Working and Checking Records

Procedures for ensuring the thoroughness, consistency, and accuracy of streamflow records are described in this section. The goals, procedures, and policies presented in this section are *grouped in association with the separate components that are included in the records-computation process*. Quality standards should be tempered by practical considerations of time and money resources. This applies only to revisions based on interpretations, and not to corrections of unquestionable errors. True errors are corrected regardless of their magnitude. When reviewing surface-water records, daily discharges do not have to be revised unless the day in question would be changed by more than 10 percent, or if the monthly mean would be changed by 5 percent or more.

Gage height

The accuracy of surface-water discharge records depends on the accuracy of discharge measurement, the accuracy of rating definition, and the completeness and accuracy of the gage-height record. Computation of streamflow records includes ensuring the accuracy of gage-height record by comparisons of gage-height readings made by use of independent reference gages, comparison of inside and outside gages, examination of high-water marks, comparisons of the redundant recordings of peaks and troughs by use of maximum and minimum indicators, examination of data obtained at crest stage gages, and confirmation or updating of gage datums by levels. Records computation includes examination of gage-height record to determine if the record accurately represents the water level of the body of water being monitored. Additionally, it includes identifying periods of time during which inaccuracies have occurred and determining the cause for those inaccuracies. When possible and appropriate, inaccurate gage-height record is corrected. When corrections are not possible, the erroneous gage-height data are removed from the set of data used for streamflow records computation.

Gage height records and time changes

Set the times of all electronic recorders to Pacific Standard Time and leave them there year-round. This affects all Electronic Dataloggers (EDL) and all data-collection Platforms (DCP).

Ratings

The development of the stage-discharge relation, also called the rating, is one of the principal tasks in computing discharge record. The rating is usually the relation between gage height and discharge (simple rating). GMA personnel follow procedures for the development, modification, and application of ratings that are described by Kennedy (1984). GMA personnel also follow guidelines pertaining to rating and records computation that are presented by Kennedy (1983, p. 14) and by Rantz and others (1982, Chap. 10-14 and p. 549). For each gaging station, the most recent digital rating table can be obtained from a computer file. A graphical plot of the most recent rating can be obtained from file folders (original hand-drawn curve), or from computer files sent to an output device. The PM is ultimately responsible for ensuring that ratings are correctly developed, entered into the computer, checked, and stored.

Station Analysis

A complete analysis of data collected, procedures used in processing the data, and the logic upon which the computations were based is documented for each year of record for each station to provide a basis for review and to serve as a reference in case questions arise about the records at some future date (Rantz and others, 1982, p. 580). Topics discussed in detail in the station analysis include equipment, hydrologic conditions, gage-height record, datum corrections, shifts, rating, discharge, special computations, remarks, and recommendations, (Rantz and others 1982, p. 582 and Kennedy 1983, p. 46). The station analysis is written by the individual who prepares the final update for the water year. Individuals who work portions of the computations for the year should write sections of the station analysis pertaining to the work they completed. The checker is expected to discuss changes or corrections with the individual who worked the records. The PM holds the responsibility for resolving disputes. The record worker has the responsibility for ensuring that station analyses are prepared using the approved format. The PM is responsible for ensuring that an updated version resides in the correct computer directory.

Review of records

In preparing the annual data report for publication, GMA follows the guidelines presented in the report, "WRD Data Reports Preparation Guide," by Charles E. Novak, 1985 edition. To ensure that correct surface-water information is presented in the annual report, each report page is reviewed by the PM. Findings of the review are presented to the record worker orally. The record worker is responsible for correcting deficiencies, and documenting corrective actions.

GMA check list

GMA maintains a record of progress on discharge computation for each gaging station. GMA finds it helpful to have a checklist for each station for each water year. This checklist is a means of tracking the status of records computation for each station and ensuring that errors do not occur by omitting the necessary procedural steps. The checklist is filed with the primary computations during the year. There is no need to maintain the completed checklist after discharge records for each station have been finalized.

COLLECTION OF WATER QUALITY DATA

Reliable surface-water water quality data are necessary for planning and resource management. The collection of water quality data is sometimes a primary component in the ongoing operation of gaging stations and other water-resource studies performed by GMA.

The objective of collecting water quality data within the SF Wages Creek THP Effectiveness Monitoring Project area is to produce reliable records of turbidity as part of the Redwood Sciences Lab TTS Protocol to compare pre-and post-project conditions.

It is the policy of GMA that all personnel involved in the collection of physical water quality data shall be properly trained, well informed, and follow the surface-water data collection policies and procedures established by GMA.

Sampling Procedures

Field water quality parameters in this study include water temperature and turbidity. Water temperature will be measured with the H-310 pressure/temperature transducer, while turbidity will be measured with an FTS DTS-12 turbidity probe. Both units will log data to a Campbell Scientific CR10X datalogger. Data will be downloaded into a PC and compiled by the GMA. A laptop or PDA will be used for downloading.

Parameter	Bottle Type	Matrix	Sample Preservation	Holding Time
Turbidity	1000 ml	aqueous	NA	48 hrs
Turbidity	Real time	aqueous	NA	NA
Temperature	Real time	aqueous	NA	NA

Calibration Procedures and Frequency

ency

All calibrations will follow manufacturer's instructions and those developed for the TTS protocols. The calibrations will be recorded on a field calibration sheet, which will be filed in a project notebook. Field personnel have all experience needed to calibrate the sensors. All calibration solutions are purchased from the manufacturer. GMA staff will conduct periodic recalibration of the instruments using proper solutions. For the first few months the instrument probes will be checked more frequently to ensure proper calibrations.

Troubleshooting Procedures

When a parameter cannot be calibrated with standard solutions, the SH must determine if the problem resides with the monitoring sensor or with the monitor itself and make necessary corrections to ensure that the monitor is operational. The SH will carry spare sensors so that troubleshooting, if necessary, can be accomplished at the time of the service visit. Troubleshooting in the field can prevent the need for extra trips and greatly reduce lost record and the amount of time spent in processing the records in the office later. A successful service trip results in a properly calibrated and operating monitor.

Field Notes and Instrument Logs

Field notes and instrument logs are the basis for the accurate and verifiable computation of water quality monitoring records. Minimum requirements in the field notes for water-quality monitors include the following items:

- Station number and name
- Name(s) of data collector(s)
- Date and times of each set of measurements
- Field meter and monitor serial numbers
- Purpose of the site visit
- Horizontal and vertical locations of sensors in the cross section (if applicable)
- Recorded monitor values and corresponding field values (initial, after cleaning, and final instream readings)
- Cross-section measurement data (locations of verticals, constituent values, and measurement time)
- Cross-section measurement summaries and corrections
- Pertinent gage-height data
- Remarks that describe channel conditions, condition of the sensors, and so forth
- Battery voltage of monitor at arrival and departure (replaced?)
- Were sensors changed or replaced? (other remarks or observations that may aid in further processing of the record)

Forms including these items encourage consistency and help to avoid the costly omission of critical information. GMA uses a field form, based on USGS version that constitutes a comprehensive checklist for data collection at many water-quality monitoring sites. Each field meter and water-quality monitor has an instrument logbook, and all pertinent information regarding the monitor is recorded in the instrument logbook. One of the most significant pieces of recorded information is the instrument calibration—both field and laboratory. Calibration information can be recorded initially on field forms or field notebooks, but the information then must be copied into the instrument logbook. The instrument logbook should contain a complete record of all maintenance in the field, the laboratory, or by the

manufacturer. Permanent instrument logs contain critical calibration and maintenance information that document instrument performance throughout the useful service life of the instrument. Calibration log information that is important from a record-processing standpoint includes:

- Calibration dates, times, and temperatures
- Calibration standard values and lot numbers
- Initial and final monitor calibration data
- Field meter calibration values

Field notes and calibration log information will be clearly written, and all notations should be self-explanatory. The goal is to have sufficient information for another individual to complete the record processing steps, if necessary. Clear notes simplify the record check and review processes.

PROCESSING AND ANALYSIS OF PHYSICAL WATER QUALITY DATA

Processing and analysis of physical water quality data involves the analysis of field observations and field measurements, adjustment of those data based on calibration data, and systematic documentation of the methods and decisions that were applied. Water quality data are reported for each gaging station annually.

This section of the QA Plan includes descriptions of procedures and policies pertaining to the processing and analysis of water quality data.

Data-Processing Procedures

The processing of water-quality monitoring records will be completed in a timely manner according to water-quality-assurance plan policies. Complete and accurate field notes are an important part of the data processing and reduce the amount of time required to process the data. Corrections to data should not be made unless the causes of errors can be validated or explained by notes or by comparison to information from adjacent stations. Data processing can be classified in six major categories: (1) initial data evaluation, (2) application of corrections and shifts, (3) application and evaluation of cross-section corrections, (4) final data evaluation, (5) record checking, and (6) record review.

Initial Data Evaluation

The initial data evaluation checks the success of the transfer of raw field data (instrument readings) to the office data base and provides the opportunity for initial checks to evaluate and correct erroneous data (daily, if telemetry is available). Raw field data may be stored in a variety of formats, depending on the recording equipment and the means of downloading data from the recording equipment. The conversion of raw data from a variety of recording devices into a standard entry format to the GMA Project data base generally is accomplished with the use of standard software. Sensors, recorders, transmitters, receivers, relays, transmission systems, or unforeseen events can, at times, produce unexplainable data. Data should be reviewed daily, if possible, to edit obviously erroneous data caused by data transmission problems. Data should be processed immediately after the service visit and viewed graphically. In addition to confirming the accurate transfer of data, this may aid in detecting instrument or sensor errors. Data that are missing (for example, because of instrument or transmission problems) should not be estimated, but missing data should be documented and no statistics should be calculated that involve missing data.

Application of Corrections and Shifts

The application of corrections and shifts allows data to be adjusted to compensate for errors that occurred during the service interval as a result of environmental or instrumentation effects. Three types of measurement-error corrections are described here—fouling, drift, and cross-section correction. Corrections only should be made to measurements when the type and degree of correction is known. The sequence for determining the type and degree of measurement error in the field and the application of corrections is fouling, drift, and cross-section correction. If the deviation between actual value and sensor reading exceed the criterion for water-quality data shifts (Table 1), a correction is required. The correction is a linear interpolation over the time between sensor inspections.

The same measurement criteria used to determine the need for calibration are used to determine the need for water-quality data shifts. In general, shifts are required when the deviation between actual and recorded data exceed the shift criteria listed in table 1. Decisions for data shifts and corrections will be resolved by the SH and the GMA QA/QC team.

Table 1. Criteria for water-quality data shifts [+ , plus or minus value shown; NTU, nephelometric turbidity unit]

Measured physical property Shift criteria (apply shift when deviation exceeds this value)

•	Turbidity	The greater of + 2 NTU or + 5 percent of the measured value
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Fouling

Fouling may result from several sources and also may be event-related. Identification of electronic drift or loss of sensor sensitivity should be distinguished from fouling drift, if at all possible. The degree of fouling is determined from the difference between sensor measurements before and after the sensors are cleaned. Modern temperature sensors are sturdy, dependable, and resistant to fouling. Turbidity sensors can be affected by fouling problems when mineralization, severe sedimentation (for example, during the recession period of a flood), or aquatic growth occurs. In general, the FTS sensors with wipers have been shown to provide excellent service and are sturdy, easy to clean, and the calibrated field meters are reliable.

Continuous records of turbidity are often the most difficult to maintain within acceptable limits for accuracy and precision. Because of this, the time period between service visits may need to be shortened to maintain the quantity and quality of the turbidity record. Sensor fouling, as a result of biological or chemical particles accumulating on the sensors, can occur on any monitor left in the stream for a period of time. Although fouling frequently begins as soon as the monitor is placed in the stream for deployment, a rise in gage height generally will contribute more to fouling overall. If a turbidity probe is equipped with wiper or shutter technology and is properly maintained, the need for a fouling correction will be minimized. The optic mechanism on the turbidity sensor is extremely sensitive to build up; if the probe is not equipped with wiper or shutter technology, accuracy of turbidity data will be impaired significantly. A fouling shift generally is applied as a datum correction from either the last time the sensor was cleaned, from the last rise in gage height, or from a significant event noted in the field notes.

Drift

A calibration drift is an electronic drift in the equipment from the last time it was calibrated and is determined by the difference between readings of a cleaned sensor in standards or buffers and a calibrated sensor. If, after checking, the deviation from calibrations is within the calibration criteria of the sensor, then no sensor drift is present. Drift is assumed to occur at a constant rate across the service interval. If the sensor readings exceed the shift criteria (table 1), then the correction is a linear interpolation over the time between calibration checks. This is called a prorated shift. Corrections to the record can be applied as a 3-point variable shift in the project database. This value-dependent adjustment is called a variable shift and is applied in situations where standards at the beginning and ending of the service interval have different amounts of deviation (variable shifts). Variable shifts can be accomplished for any parameter, and this is the recommended technique for corrections related to instrument drift. Because three standards frequently are used for monitor calibration, the variable shift is the preferred method of correction for drift. The treatment for suspected sensitivity loss is sensor reconditioning or replacement.

Evaluation and Application of Cross-Section Corrections

The purpose of cross-section corrections is to adjust the measurements of the monitoring equipment to reflect conditions more accurately in the entire stream cross section, from bank to bank and surface to bottom. The principal value of such adjusted measurements is realized when concurrent discharge

measurements permit the computations of constituent loads transported past the station. The application of cross-section corrections is intended to improve the accuracy and representativeness of monitoring measurements; however, cross-section corrections should be made only if the variability in the cross section exceeds the shift criteria. Corrections to the cross section are based on field measurements taken both horizontally and vertically in the stream cross section. Specific corrections for temperature and turbidity are that they may differ from each other at each site, and they all are site dependent and may be discharge and seasonally dependent as well. Several considerations govern the use of corrections. Cross section measurements must be made under a variety of flow conditions (minimum of six), all seasonal conditions, and at least twice annually to confirm that the correction being applied to the water-quality measurements truly represents the median or mean cross-section values. Corrections should not be applied to water-quality measurements beyond the range of discharge measurements nor during periods of unsteady flow. If the correction for a measured physical property is consistent across a range of discharges and seasons, then correction of the measurement values by simple adjustment is warranted. Seasonal changes in water quality may be representative of the hydrologic system, but they also may be a result of local conditions. Professional judgment and observations in the field logs will assist in evaluating the need for the application of cross-section corrections. Continuous water-quality monitoring has great value in recognizing the interdependence of water-quality physical properties under varying flow regimes. Understanding these relations is essential in the appropriate application of discharge-dependent corrections.

Final Data Evaluation

Final data evaluation consists of reviewing the data record, checking shifts, and making any needed final corrections. When completed, the data are verified for publication and then rated for quality.

COLLECTION OF SEDIMENT DATA

Reliable surface-water data are necessary for planning and resource management. The collection of sediment data is often a primary component in the ongoing operation of streamflow-gaging stations and other water-resource studies performed by GMA, and is critical to the SF Wages Creek THP Effectiveness Monitoring Project.

The objective of collecting sediment data at a monitoring site is to allow computation of sediment transport loads. Sediment loads are obtained by combining streamflow records with sediment discharge rating curves. Methods for developing streamflow records have been described in other sections of this report.

Turbidity Controlled Sampling

For estimating suspended sediment concentration (SSC) in rivers, turbidity has been demonstrated to be a much better predictor than water discharge. Since about 1990, it has been feasible to automatically collect high frequency turbidity data at remote sites using battery-powered turbidity probes that are properly mounted in the river or stream. A few (less than 10) data pairs spanning the range of concentrations should be sufficient to reliably establish the relation between SSC and turbidity during such events (Lewis, 1996). This relationship provides a means for accurately estimating suspended sediment loads during storm runoff events.

For estimating monthly or annual sediment loads, the relation between SSC and turbidity will vary over time with changes in sediment sources, organic loading, or sensor calibration. Thus, the use of a single curve describing the long-term mean relation will yield greater errors than for short-event estimation. Nevertheless, turbidity is generally considered a more useful than water discharge as a long-term predictor of SSC. If the turbidity-SSC relation is roughly linear, load estimates will be nearly unbiased. Redwood Sciences Laboratory (USDA Forest Service, Pacific Southwest Research Station) has been experimenting with various approaches to estimating suspended sediment loads in small streams. They have developed a prototype system where a data logger program employs nephelometric turbidity to make SSC sampling decisions (i.e., to activate a pumping sampler) in real time (Lewis, 1996; Lewis and Eads, 1996). The algorithm uses a separate rising and falling series of threshold turbidity values. A falling

condition is detected when turbidity drops a given percentage below the previous maximum, and a rising condition is detected when turbidity rises a given percentage above the prior minimum. Because the falling condition is usually much longer than the rising condition, the falling series has more thresholds. SSC specimens are collected whenever a threshold for the current condition is crossed. Additional constraints are imposed to limit sampling when turbidity is spiking or fluctuating rapidly.

This project will utilize the Turbidity Threshold Sampling (TTS) protocol at four sample sites within the project area. Additional manual stations will collect non-automated data on sediment at tributaries and along the mainstem of SF Wages Creek to aid in evaluation of point sources either along the creek or from tributaries.

Turbidity threshold sampling (TTS) collects physical samples that are distributed over a range of rising and falling concentrations (see Lewis and Eads: 1996, 1998, and 2001). The resulting set of samples can be used to accurately determine suspended sediment loads by establishing a relationship between sediment concentration and turbidity for any sampled period and applying it to the continuous turbidity data. A comprehensive operations manual for a TTS station has been developed by Redwood Sciences Laboratory (Redwood Science Laboratory 2002) and the specific operational steps will not be repeated in this QA Plan. Standard depth-integrated (DIS) cross stream samples are collected during storms to adjust point (TTS pump samples) values to the entire cross section. Procedures for the collection of DIS samples, whether at TTS sites or at manual sites, are described in the following section.

Turbidity and Suspended Sediment Data Collection

1. Sites should be established prior to planned storm sampling, with site selection considerations based on access, local hydraulics, and high-flow sampling access. If possible, have a fiberglass tape left at sampling section so that same stations are used each time, or section pins may also be left in place.
2. Upon arriving at site, record gage height and time (24hr clock).
3. Determine if it is safe to collect depth-integrated sample (DIS) or only a grab sample.
4. Attach extension handles to DH-48 sampler as necessary to collect DIS. Fit pint bottle into sampler and make sure it is properly seated and that nozzle is not clogged.
5. Divide stream into 10-20 verticals for DIS, EWI (Equal Width Increment) method, sampling at stations on tape, if possible. Lower sampler vertically into flow at a uniform rate, reversing immediately upon touching bottom. Raise sampler at same rate as lowering. Move to next vertical and repeat. Continue across entire width of wetted channel. The spacing between all verticals is uniform across the entire channel.
6. If grab sample, wade or lean as far out as is safe, dip sampler into flow and try to integrate one or more verticals as far out as can be reached with sampler and extensions.
7. The sample bottle must be 60-90% full after a complete pass. If the sample bottle is more than 90% full, discard sample, rinse bottle, and collect another sample at a slightly faster rate. If the sample bottle is less than 60% full, repeat the sample collection (another full cross section) at a rate that will not overflow sample bottle. One may also use a second bottle or even multiple bottles to collect a single cross channel sample. Sample bottles will be composited in the lab.
8. Remove sample bottle. Tightly cap sample bottle. Store in ice chest or refrigerator until transferred to lab for processing.
9. Record the following information for each sample:

Date, Time, Site, Gage Height, Sampler used (DH-48, DH-59, D-74), sample type (DIS or grab), # of verticals sampled, stations sampled if tape is available, Bottle #, # of bottles (if multiple bottles are used), and any general notes as to weather, unusual site conditions, etc.

10. Every 10 samples, a second pass at the same site should be made (10% of the samples with have a replicate) using identical stations or procedures. The purpose of the replicate is for Quality Control documentation. In addition, at high discharges, much more frequent replicates are made, as the variability of the sample concentrations is greater.

Samples are kept chilled and processed for turbidity within 48 hours using a Hach 2100p portable turbidimeter which is frequently calibrated. Suspended sediment samples are kept cool, typically in ice chests, and transported to the GMA Lab in Weaverville, where they are processed within 30 days. A separate QA Plan is available for the GMA sediment lab to interested parties. The GMA lab is certified by the USGS and participates in the USGS Nationwide SLQA Program.

PROCESSING AND ANALYSIS OF SEDIMENT DATA

The computation of sediment records involves the analysis of field observations and field measurements, the determination of discharge-sediment relations, adjustment and application of those relations, and systematic documentation of the methods and decisions that were applied. Sediment transport records are computed and reported for each monitoring site where sediment data are collected.

This section of the QA Plan includes descriptions of procedures and policies pertaining to the processing and analysis of data associated with the computation of sediment records. The procedures followed by GMA generally coincide with those described by Guy and Norman (1970) and by Edwards and Glysson (1988).

Measurements and Field Notes

The gage-height information, discharge information, control conditions, and other field observations written by personnel into field books and other field note sheets form the basis for records computation for each monitoring site.

Sediment Measurement Summary List (SS 9-207)

The GMA Sediment Measurement listing will be the official final documentation to accompany the station record and, as such, must be complete and accurate. Print out the GMA form and file with the final record.

Ratings

At TTS sites, the development of the turbidity-suspended sediment concentration relation, also called the T-SSC rating, is one of the principal tasks in computing sediment records. The sediment rating is usually the relation between discharge and suspended sediment load (simple rating). Ratings for some sites involve additional factors such as rising and falling limb differentiation (complex ratings).

GMA personnel follow procedures for the development, modification, and application of ratings that are described by Porterfield (1972) as modified for the TTS method by Redwood Sciences Laboratory.

Development of Continuous Suspended Sediment Records

Application of the turbidity-suspended sediment concentration relation to the continuous turbidity record produces suspended sediment concentrations on a 15-minute time step. The values of concentration at each time step are then converted to sediment load by application of the formula (Load = SSC (mg/l) * Q (cfs) * .0027). Values are summed and averaged for mean daily values and totaled for annual values.

OFFICE SETTING

The PM is responsible for maintaining surface-water data and related information in a systematic and organized manner. This increases the efficiency and effectiveness of data-analysis and data-dissemination efforts. Good organization of files reduces the likelihood of misplaced information. Misplaced data and field notes can lead to analyses based on inadequate information, with a possible decrease in the quality of analytical results.

Work plan

Because the type of work and the amount of work, the manner in which a work plan is prepared also tends to vary. Duties are assigned and communicated to personnel by the PI or PM in most cases. This is an informal system where duties are assigned verbally throughout the year. Individuals are assigned stations for which they are accountable by certain deadlines.

Station Descriptions

Permanent copies of the surface-water station descriptions are maintained as computer files. A copy is kept in the current file folder. Individuals are expected to make updates in the computer files (which are available to everyone) whenever there is a significant change or every three years. The PM is responsible for ensuring that files are updated. (A list of files, sorted by year of update, may be obtained on request).

Archiving

All GMA personnel are required to safeguard all original field records containing hydrologic measurements and observations. Selected material not maintained in field offices are placed in archival storage. Detailed information on what records have been removed to archives are retained in the GMA office. The types of original data that should be archived include, but are not limited to, original data and edited data, observer's notes and readings, station descriptions, analyses, and other supporting information (Hubbard, 1992, p. 12).

REPORTING OF SURFACE-WATER DATA

Data collected in this project are not expected to be formally published, but will be included in annual and project data reports.

All data, including surface-water and sediment data collected for this project will be published in an Annual Data Report. The objective of this instruction is to make sure that all data collected are made available to the public. In general, any measurements made or samples collected and analyzed following GMA approved procedures are considered reportable data.

SAFETY

Performing work activities in a manner that ensures the safety of personnel and others is of the highest priority for GMA. Beyond the obvious negative impact unsafe conditions can have on personnel, such as accidents and personal injuries, they also can have a direct effect on the quality of surface-water data and data analysis. For example, errors may be made when an individual's attention to detail is compromised when dangerous conditions create distractions. So that personnel are aware of, and follow, established procedures and policies that promote all aspects of safety, GMA communicates information and directives related to safety to all personnel by in-house training classes, memorandums, and email. It is the responsibility of each employee to remain current on First Aid and CPR certification. Each employee is expected to read the GMA Safety Handbook.

An individual has been designated as Safety Officer by the GMA. Personnel who have questions or concerns pertaining to safety or who have suggestions for improving some aspects of safety, may direct those questions, concerns, and suggestions to their supervisor, the mentioned Safety Officer, or any senior GMA personnel. GMA has developed a Safety Program, to be implemented through the following items.

1. Training - GMA will provide ongoing general training, both formally and on the job, along with required training and specific training related to potentially hazardous operations or procedures.
2. Promotion - Safety and health will be promoted by communication and enforcement of safety and health rules and practice.
3. Occupational Hazards and Industrial Hygiene and Inspections - Hazard inspections of buildings, vehicles, and equipment, and duty space to be used by employees will be conducted. Chemical-handling inspections will be completed, and deficiencies will be corrected.
4. Public Safety - All facilities will be maintained and inspected to ensure that the premises are safe for the employees and the public.
5. Accident/Incident Investigations, Reporting and Analysis - Accident and Incidents will be reported and tracked in order to ensure there is no trend, and prevention measures will be sought.

It is the policy of GMA to promote safety and health in our working environment. Because some employees of GMA must perform potentially unsafe duties in the scope of their work, we must establish safety measures to minimize the potential dangers and be constantly aware of those potential dangers. The goal is to create a work environment that is free from injuries or work-related illnesses. To meet this goal, every employee must cooperate in detecting and controlling hazardous and potentially hazardous conditions. Any hazardous situation or practice must be immediately reported in writing to the employee's supervisor and the Safety Officer unless the employee feels that the hazardous condition poses an imminent danger to other employees or the public; then notification should be done by the most expeditious means. No employee shall be subjected to coercion, reprisal, restraint, discrimination, or other adverse actions as a result of reporting hazardous or potentially hazardous conditions. In the work environment, there is always potential for illness and injury. Removal of preventable exposures to illness and injury is of primary importance and should always receive priority consideration over any operation. Management will provide all practical, physical, and educational resources to maintain personal health and safety. All employees must maintain a preventative and cooperative attitude relating to safety issues. Everyone will adhere to all safety-related policies, rules, and procedures and help ensure that any person on our premises or that works with us does the same.

SUMMARY

Information included in this GMA Surface-Water Quality-Assurance Plan documents the policies and procedures of GMA that ensure high quality in the collection, processing, storage, analysis, and publication of surface-water data. Specific types of surface-water data discussed in this report include stage, streamflow, water quality, and sediment transport. The roles and responsibilities of GMA personnel for carrying out these policies and procedures are presented, as are issues related to management of the computer data base and issues related to employee safety and training.

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