Turbidity and Suspended Sediment Yields

Freshwater Creek and Elk River Operations Report

Humboldt County, California

Salmon Forever / Watershed Watch

Hydrologic Year 2005

Prepared For the Redwood Community Action Agency
Humboldt Bay Water Quality Improvement Program
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Introduction

Salmon Forever / Watershed Watch received a grant of approximately $15,000 by WQ - RCAA for Hydrologic Year (HY) 2005 to support turbidity and suspended sediment concentration sampling in Freshwater Creek and Elk River watersheds. This was the latest in a series of support grants from the Water Quality Control Board and the Redwood Community Action Agency for Watershed Watch Operations in these watersheds. Watershed Watch accurately records turbidity, suspended sediment concentration (SSC), stream discharge, annual sediment yields and stream cross section changes in a cost effective manner and provides the information to the public and State and Federal Agencies. In the near future, with financial support, we are determined to make available on-line real-time stream depth (stage) data on Elk River, for use in flood warnings and predictions by agencies such as NOAA, just as we currently provide on Freshwater Creek.

Freshwater Creek Monitoring Stations

The Freshwater Creek watershed drains into the northern end of Humboldt Bay in Northern California just north of Eureka. The Redwood and Doug-fir forested watershed trends southeast to northwest. The watershed is mainly underlain by Franciscan, Yager and Wildcat geological formations. Portions of the northeast watershed are composed of Franciscan melange formation. Maxxam Corporation is the major landowner in the Freshwater Creek Watershed.

Watershed Watch maintains two Continuous Turbidity Monitoring Stations in Freshwater Creek, one on the mainstem at Howard Heights Bridge (HHB) in the lower portion of the watershed and one on the mainstem Freshwater Creek (FTR) 200 yards above Freshwater Park in the upper portion. The watershed area above Site FTR covers 13.2 square miles. The watershed area draining to Site HHB is 27.8 square miles. TTS Monitoring commenced at Site FTR in 1999 and at Site HHB in 2005. The average suspended sediment yield from Site HHB for HY 2005 was 173 tons per sq. mile. The average suspended sediment yield from Site FTR for HY 2005 was 259 tons per sq. mile.

Elk River Monitoring Stations

The Elk River Watershed drains into Humboldt Bay just south of Eureka. The watershed area is 56.1 square miles. The Redwood and Doug-fir forested watershed also trends northwest to southeast. The main geologic units are the Wildcat Group underlain by the Yager Formation. Maxxam Corporation and the BLM / Headwaters Preserve are the primary landowners in Elk River watershed. Elk River is the largest watershed to drain into Humboldt Bay.

Watershed Watch operates two Continuous Turbidity Monitoring Stations in Elk River as well. TTS Monitoring commenced at Sites SFM and KRW in HY 2003. Site KRW is located on the North Fork Elk River 1.0 miles above the confluence of North and South Fork Elk Rivers. The watershed area above Site KRW is 22.2 square miles. The average suspended sediment yield from Site KRW on the North Fork Elk River for HY 2005 was 330 tons per sq. mile. Site SFM is located on the South Fork Elk River approximately 0.5 miles above the confluence. Watershed area above Site SFM is 19.3 square miles. The average suspended sediment yield from Site SFM for HY 2005 on the South Fork Elk River was 563-tons/sq. mile.
Why Monitor?

Since 1999, Salmon Forever has been monitoring sediment impairment in the Freshwater and Elk River watersheds, which were among only 6 streams in California capable of supporting viable wild populations of endangered Coho salmon during the decadal downturn in oceanic conditions that occurred during the late 1980’s and early 1990’s. Chronic turbidity and sediment accumulation in these stream channels correlate directly to local salmon declines and to increasing flood damage and water quality impairment to over 200 streamside properties.

The effectiveness of efforts to restore the coastal and inland fisheries will benefit from monitoring turbidity, suspended sediment concentration (SSC), and duration of exposures to assess whether restoration has reduced sediment transport within the channel and whether the turbidities and SSCs present will allow recovery of the fishery. Many North Coast streams and rivers, including Freshwater Creek and Elk River, have been identified as impaired due to sediment under the Clean Water Act, Section 303d (CSWRCB, 1998). Total Maximum Daily Loads (TMDL’s) are being developed to identify and mitigate the impacts of sediment and to provide for attainment of North Coast Regional Water Quality Control Board (NCRWQCB) Basin Plan water quality objectives. In addition, these watersheds are identified as key watersheds for salmonid production by the Northwest Forest Plan (USDA, 1997). Anadromous fish stocks on the North Coast of California have declined well below historical levels (Brown et al., 1994). Increased sediment delivery to stream channels is thought to be a significant contributor to the decline of fish populations. Sediment can contribute to the decline of fish populations through several mechanisms including, but not limited to: clogging spawning gravel (Chapman, 1988), impacting feeding ability and growth rates (Newcombe and MacDonald, 1991), and simplifying habitat by filling in pools and low gradient reaches (Frissel, 1992).

The data collected is intended to inform TMDL development and implementation and watershed analyses by providing monitoring data that can be compared to action levels for turbidity and suspended sediment concentrations found in applicable regulations and guidelines. Water quality objectives in the North Coast Basin Plan provide action levels for turbidity (e.g. turbidity shall not be increased more than 20% above naturally occurring background levels) and suspended sediment (the suspended sediment load and suspended sediment rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial use) (NCRWQCB, 1993).

Widespread perception of political and economic dependence on the timber industry has historically impeded effective regulatory enforcement resulting in widespread watershed impairment. Total Maximum Daily Loads (TMDL’s) and the establishment of watershed-wide Waste Discharge Requirements (WWWDR’s) by the North Coast Water Quality Control Board are the most promising actions to date. Salmon Forever’s data has been used in the Empirical Peak Flow Reduction Model and Empirical Harvest Related Landslide Sediment Delivery Reduction Model developed by the North Coast Regional Water Quality Control Board’s WDR’s.

Field Operations HY 2005

Watershed Watch, led by Clark Fenton, deployed another Turbidity Threshold Sampling (TTS) station in HY 2005 bringing the total to four. The new station on Freshwater Creek – Site HHB – was made possible by a grant from RCAA and the State Water Quality Board. Watershed Watch is now able to determine annual suspended sediment loads for the majority of the Freshwater Watershed with the addition of the HHB site. Clark Fenton constructed the HHB Equipment Enclosure Shed and Jesse Noell, also of Watershed Watch, fabricated the HHB mast and turbidimeter boom in the fall of 2004.

The TTS stations HHB and FTR on Freshwater Creek and at Sites KRW and SFM on Elk River each use an ISCO Model 2100, 6700 or 6712 automatic pump sampler, a Campbell CR101X or CR510 data logger, Druck 1830 pressure transducer, and a DTS-12 turbidity probe. Sites FTR and KRW also use Campbell TR525I Tipping Bucket rain gauges.

Field Operations include upgrading TTS station equipment, taking discharge measurements, surveying channel cross sections, making TTS Station data dumps / bottle swaps, repairing storm damage to equipment booms, and removing sediment and debris covering pressure transducer pipes.
With a new data logger modem provided to Salmon Forever for HY 2005 by the Regional Water Quality Control Board, our real time stage (water level) and turbidity data was posted on the Redwood Sciences Lab website, which functions as part of an early warning network for flooding. Residents of Freshwater Creek can find this up-to-the-minute information on-line and can use it to protect their property and their lives.

A new ISCO 6712 pump sampler was installed at Site FTR with this grant money. A CR10X Campbell Data logger and a DTS-12 Turbidimeter were purchased for Site HHB. Clark Fenton donated funds to purchase two additional DTS-12 Turbidimeters for Sites KRW and SFM.

Field Sampling training sessions were held for Watershed Watch Work Study Students and residents in the Freshwater area on 11-6-04 and Elk River residents on 12-8-04. Volunteers and students were trained and certified, and went on to perform grab sampling, measuring channel cross-sections, measuring discharge, and entering data for analysis. All field sampling was done in accordance with Standard Operating Procedures provided in Appendix 1.

Some cross sections were revisited in HY 2005 in Freshwater Creek and Elk River as time and personnel allowed. Crosssections are robust ways to measure channel aggradation, channel scour and conveyance capacity changes. See Appendix 8 for analysis of cross sections at Sites FTR and SFM. Crosssections are measured using United States Forest Service (USFS) methods (Harrelson 1994). Decreases in channel capacity and conveyance were found at Site FTR and SFM. Existing levels of suspended sediment concentration are beyond the carrying capacity of these rivers and aggradation and accretion of banks and floodplains is occurring in numerous places.

A study of flooding in Lower Elk River was commissioned by the NCRWQCB in 2004 which illustrates the importance of annual cross sections in study areas. Rose Patenaude – staff at NCRWQCB – was commissioned to study at a site on the Mainstem Elk River just below the confluence of North and South Fork Elk Rivers (Patenaude 2004). USGS records from 1958 to 1967 were examined and compared to recent studies. By comparing old and new cross sections she found Lower Elk River bank full discharge capacity had decreased by 60% due to sedimentation. Watershed Watch contributed discharge data for this study. Channel conveyance capacity has been diminished significantly during the interim of the systematic monitoring periods. She found that a significant volume of sediment had been deposited between 1956 and 1998 in Lower Elk River that is hindering its ability to convey frequent discharge events. Channel capacity as a function of cross sectional area is 65% of what is was in 1965 compared to 2003.

**Discharges HY 2005:**

Over 20 discharge (cubic feet per second) water measurements were taken at sites in the Freshwater and Elk River watersheds in HY 2005. In the Fall of 2004, training days were held to instruct volunteers in USFS / USGS methods for obtaining flow measurements. (Harrelson 1994, USGS). Two methods were employed throughout the year, one for low flows and one for high. Low flows were measured with a Wading Rod using either a Pygmy current meter or a Price AA current meter. For higher flows an A-55 Reel, 75 lb. Columbus Weight, Price AA current meter and a pick-up bumper mounted crane were used. High flow measurements were limited by boom-truck access on bridges over Freshwater Creek and Elk River.

Storms were braved and people got wet but many important flow measurements were collected. An accurate estimate of stream discharge is vital to accurate suspended sediment load calculations. Local residents helped on numerous occasions. Discharges are dependent on rainfall, and high flows cannot be expected to occur at convenient times. It is difficult for volunteers to make themselves available at a moments notice of a storm to get out in the field to collect discharges at high flows in the cold and likely dark, soaking rain. High flow measurements may require waiting long periods for conditions to mature, and the resulting measurements themselves may take as long as five hours or more to complete when flows are 100 or more feet wide in the channel and overbank area. Roads to the stations are often flooded and ingress and egress become impossible at high flows. Volunteers who staff the discharge crews on these long, wet, cold, dark, stormy nights are thankful for the understanding, patience and support of their day job employers and spouses.
Discharge Rating Curve at Site SFM. Peak velocities are over 3 feet per second. Streambed aggradation may be affecting stage / discharge relationship.

Choosing a final discharge rating equation for a site using Excel can be problematic. Several different ways are available to apply a rating equation to a data set. A single equation can be fitted to the data set, or multiple equations can be fitted to separate portions of the data. Watershed watch at this time is using a single discharge rating curve equation to calculate cubic feet per second for all stages at a single site and water year. With adequate data points several different stage / discharge equations could be used for low flow, medium flow, or combinations thereof at a site.

The problem with using a single equation is that fitting a curve to a set of data using Excel can cause the stage discharge equation to underestimate or overestimate flow at certain stages. Low flows may be overestimated or underestimated. The y-intercept of a flow equation was altered to try to match low flow data for this operations report. This stage/flow relationship can be improved with more flow measurements. The more conservative rating curve equation was used in most situations.
Pick up mounted crane and current meter in use at Site HHB – Howard Heights Bridge. Peak velocities at HHB can be over 5 feet per second.

Lab Operations 2005

The SunnyBrae Sediment Lab, managed by Clark Fenton, processed over 1100 turbidity and suspended sediment concentration samples from Continuous Turbidity Monitoring Stations in the Freshwater and Elk River Watersheds for Hydrologic Year 2005. Freshwater Creek yielded 576 ISCO pump samples from Sites FTR and HHB. Elk River yielded 540 ISCO pump samples. Lab technicians were Lorien Reynolds, Gareth Blakemore and Maddy Amelin. The suspended sediment concentration of each site is compared to the corresponding DTS-12 Turbidity and a regression is developed for that relationship. See SFM 2005 turbidity / suspended sediment concentration chart below.

The SunnyBrae Sediment Lab follows the Redwood Sciences Lab SOP for suspended sediment concentration determination. Suspended Sediment Concentration is determined by vacuuming water samples through tared 1-micron glass fiber filters with a vacuum assembly. Filters will be dried in a 105°C oven, cooled in a dessicator and then weighed on a Precisa XB-120 balance to the nearest 0.0001 g. Sample water weight and sediment weight is used to calculate suspended sediment concentrations in mg/L and PPM. (Redwood Sciences Lab 2001, Salmon Forever QAPP 2001, Lab SOP 2005)

Lab Technicians were trained and certified using proficiency checklists for HACH turbidity determination, suspended sediment processing and filter weighing. HACH turbidity training was held on 12-11-04. Suspended Sediment Processing Training was held on 11-18-04 and 12-11-04. Suspended Sediment Filter weighing training was held 11-18-04, 11-21-04 and 11-23-04.
The SunnyBrae Sediment Lab also provided lab equipment for the processing over 160 suspended sediment samples for Randy Klein and the Jacoby Creek Land Trust. These samples were used to calculate the annual suspended sediment load for Jacoby Creek watershed which lies just to the north of Freshwater Creek watershed. The SSL also ran 12 suspended sediment samples for Ridges to River, a non-profit working on the Garcia River in Mendocino County. The Lab continues to provide support and equipment to the Friends of the Van Duzen River. All sampling and sample processing was done in accordance to Standard Operating Procedures provided in Appendix 1.

Results of Site SFM HY 2005 ISCO pump samples. Storm by Storm variation and hysteresis can be seen in ntu / ssc relationships.
Suspended Sediment Yields

Salmon Forever’s estimate for the HY 2005 suspended sediment yield for combined Elk River and Freshwater watersheds totals over **45 million pounds** flowing downstream past our stations towards Humboldt Bay. Elk River contributed the most suspended sediment with 36.2 million pounds while Freshwater Creek contributed 9.6 million pounds. Suspended Sediment Yield data sets and spreadsheets are in Appendices.

**Freshwater Creek and Elk River Annual Suspended Sediment Delivery - HY 2005**

Total Annual Suspended Sediment Loads - 45.7 million pounds

<table>
<thead>
<tr>
<th>Site</th>
<th>Total Sed Load Lbs</th>
<th>Total Sed Load Tons</th>
<th>Total Sed Load Metric Tonnes</th>
<th>Total Sed Load Cubic Yds</th>
<th>Max Sed lbs per 10 min.</th>
<th>Washed M lbs, Washed Sq. Mi.</th>
<th>Washed Sq. KM</th>
<th>Tons</th>
<th>M Tones</th>
<th>NTU</th>
<th>Max DTS-12</th>
<th>Peak Discharge CFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site FTR</td>
<td>6,790,380</td>
<td>3395</td>
<td>3080</td>
<td>1521</td>
<td>95,185</td>
<td>13.12</td>
<td>34.0</td>
<td>259</td>
<td>91</td>
<td>1025</td>
<td>1109</td>
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<td>Site HHB</td>
<td>9,596,470</td>
<td>4799</td>
<td>4354</td>
<td>2149</td>
<td>90,236</td>
<td>27.78</td>
<td>71.9</td>
<td>173</td>
<td>61</td>
<td>1095</td>
<td>1821</td>
<td></td>
</tr>
<tr>
<td>Lower Freshwater only</td>
<td>2,808,090</td>
<td>1,404</td>
<td>1,274</td>
<td>629</td>
<td>14.66</td>
<td>37.9</td>
<td>96</td>
<td>34</td>
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<td></td>
<td></td>
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<td>Site KRW</td>
<td>14,651,204</td>
<td>7326</td>
<td>6646</td>
<td>3281</td>
<td>46,033</td>
<td>22.19</td>
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<td>330</td>
<td>116</td>
<td>1063</td>
<td>1062</td>
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<td>Site SFM</td>
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<td>4868</td>
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<td>19.30</td>
<td>50.0</td>
<td>563</td>
<td>195</td>
<td>1638</td>
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<td>Elk River all</td>
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<td>16398</td>
<td>8149</td>
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<tr>
<td>Elk River and Freshwater</td>
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<td>220,575</td>
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<td>179.4</td>
<td>332</td>
<td>116</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Site HHB is downstream of FTR and includes Upper Freshwater, Graham Gulch, Cloney Gulch, McCready Gulch and Little Freshwater combined

Lower Freshwater only - Taking Site FTR loads away from Site HHB will leave loads for Graham Gulch, Cloney Gulch, McCready Gulch and Little Freshwater combined

Site KRW is the North Fork Elk River approximately 1 mile above the confluence with the South Fork Elk River

Site SFM is the South Fork Elk River approximately 1/2 mile above the confluence with the North Fork Elk River

Cubic Yards conversion factor of 2.65 grams per cubic centimeter or 2.2329 tons per cubic yard for solid sediment

* Watershed Area from N Coast Water Quality Control Board - 10 meter digital resolution

Turbidity Threshold sampling methodology, developed by Redwood Sciences Lab, was used to determine suspended sediment yields. Turbidity has been found to be a much better surrogate than flow in estimating suspended sediment loads. An algorithm is used to trigger ISCO pump samples at rising and falling turbidity thresholds. ISCO pump samples were used to create a turbidity / suspended sediment concentration regression. Discharge Rating curves along with 10 minute stage data was used to calculate the volume of water. These suspended sediment concentrations were multiplied by volume of water to determine suspended sediment loads.

Ideally SSC loads for each site would be calculated on a storm by storm basis using the storm by storm turbidity / suspended sediment concentration regression for each storm and the loads summed up for the year.

“In one of the storm events, applying separate turbidity – ssc regressions to periods of rising and falling turbidity significantly improved the estimation. In another storm quadratic regression had a slight 1-2% edge over linear regression. But, in most cases, a single linear regression performed nearly as well or better as the other methods, and caution should be exercised in applying nonlinear fits or multiple fits, particularly in the presence of outliers.” (Lewis 2003)
For this report a single site specific linear or polynomial turbidity / ssc regression was used for the entire year for each site. Use of linear or polynomial equations to characterize turbidity / suspended sediment regressions can result in negative mg/l concentrations at turbidities less than 20 ntu. This is due to the 1 micron glass fiber filters used to process ssc samples. A minor portion of the suspended sediment is less than 1 micron in diameter and passes through the filter. Negative SSC concentrations were deleted from datasets used in compiling annual ssc loads. Therefore all annual loads in this program are conservative totals.

The largest storm of HY 2005 was on April 6th through April 9th.

In Elk River, at Site SFM this resulted in a peak stage of 16.8 feet, peak turbidity of 1636 ntu, peak mg/l of 2334 mg/l, peak flow of 1034 cfs and a peak 10 min load of 84,306 pounds of suspended sediment at Site SFM.

In Elk River, at Site KRW this resulted in a peak stage of 17.37 feet, peak turbidity of 1063 ntu, peak mg/l of 1159 mg/l, peak flow of 1062 cfs and a peak 10 min load of 46,033 pounds of suspended sediment.

In Freshwater Creek, at Site FTR this resulted in a peak stage of 6.3 feet, peak turbidity of 1025 ntu, peak mg/l of 2280 mg/l, peak flow of 1115 cfs and a peak 10 min load of 95,185 pounds of suspended sediment.

In Freshwater Creek at Site HHB, this resulted in a peak stage of 12.08 feet, peak turbidity of 1095 ntu, peak mg/l of 1369 mg/l, peak flow of 1821 cfs and a peak 10 min load of 90,236 pounds of suspended sediment.

The ability to track suspended turbidity and suspended sediment loads on a storm by storm basis can be vital in revealing discrete watershed events such as landslides when they occur. Landslide delivery events can be tracked and delivery volumes can be verified.
Freshwater Creek - Site FTR - upper watershed / Site HHB - upper and lower watershed
Elk River / Site KRW - N. Fork Elk River / Site SFM - S. Fork Elk River

Suspended Sediment Load        Hydrologic Year 2005 - CF 2-22-06
**Turbidity:**

**Chronic Turbidity**

Turbidity is caused by water flows carrying suspended sediment. As flow increases, turbidity and suspended sediment concentration increases. Chronic turbidity is the tendency for streams to remain at elevated levels of turbid water for long periods. Causes of chronic turbidity can include landslides into a stream bleeding sediment for long periods to several storms in a row hitting a watershed in close intervals and keeping stage and flow and turbidity and suspended sediment concentration elevated. Land use in a watershed can contribute to chronic turbidity. Elevated levels of turbidity can cause harm to aquatic species. One goal of Watershed Watch is to document chronic turbidity in Freshwater Creek and Elk River.

![Turbidity Graph](image)

Site HHB – Freshwater Creek for HY 2005 – TTS Adjuster jpg image.
Stage scale on left - top is 12.5 feet.
Turbidity scale on right – top is 1150 ntu.

“Suspended Sediment transport at low concentrations can occur during small storms and between storms for some lengths of time after the peak has passed. Traveling around the north coast of California, it is easy to notice that some streams tend to clear up much faster than others following the cessation of rainfall. Differences between streams are especially apparent during recessional storm flows and winter base flows; times when some streams have become virtually clear while others remain quite turbid. To protect and restore water quality and beneficial uses, it is important to determine the extent to which land management contributes to elevated fine sediment loads and the tendency for streams to experience extended periods of turbidity during the winter. “(Klein 2003)
Land management uses in these watersheds certainly contributes large amounts of suspended sediment and chronic turbidity. Long term trends in land use and sediment levels can be investigated and documented with the TTS sampling methodology used in this report. Data from previous and future water years will be made available to interested parties as time allows to determine long term trends in chronic turbidity in these watersheds. Watershed Watch data has been shared with Randy Klein for his recent and future studies of chronic turbidity.

Watershed Watch also strives to determine HACH 2100P turbidity for each of our ISCO pump samples in the lab in addition to the instream DTS-12 turbidity measured at 10-minute intervals. Other researchers in the Humboldt Bay area also run samples with the HACH 2100P turbidimeter. This allows turbidity data from different studies to be normalized for comparisons with one another. Readings from the same turbidimeter may vary from watershed to watershed for various reasons including geology of rock units and placement of the turbidimeter in the water column. Randy Klein is in the process of looking at what the data shows about various turbidimeters and different watersheds.

"Although turbidity has been used as a means to assess water quality for decades, its usefulness as a surrogate for suspended sediment concentration (SSC), along with recent technological advances that allow in situ collection of high-quality, continuous data, account for a recent surge in interest. And increasingly, water quality regulations governing sediment-producing land disturbance activities (e.g., timber harvest, vineyard development) require turbidity monitoring. The cumulative effect of the burgeoning interest in turbidity has been to generate a great variety of instrument types and a great number of individuals collecting turbidity data for a diversity of intended uses. Ideally, all these data would be directly comparable and would be accompanied by meta-data sufficient for describing important aspects of the data set (e.g., instrument type, sampling method, site location, etc.). Unfortunately, these conditions are not always met."(Klein 2006)

Watershed watch hopes turbidity data from HY 2005 can help answer questions about comparability of turbidimeters.

**Correction Methods and Parameter Accuracy**

Watershed Watch used software called TTS Adjuster developed by the Jack Lewis of Redwood Sciences Lab to correct the raw stage and turbidity data for HY 2005. TTS Adjuster was developed by Jack Lewis of Redwood Sciences Lab as a PC based software to use with TTS 4.1 sampling software data output. The resulting 10 minute data file is called a flo file and displays raw and corrected stage and turbidity data side by side for easy comparison. The flo files for Watershed Watch sites are included in Appendix 2.

Clark Fenton’s visits to each site recorded the staff plate levels (Observer Records) which were then compared to the Druck electronic pressure transducer / stage records at that visit. Electronic stage was adjusted using methods in TTS Adjuster to match staff plate readings. See Appendix 7 for the user manual for TTS Adjuster explaining correction methods.

Turbidity anomalies in the DTS-12 Turbidimeter data sets were also corrected using TTS Adjuster. Obvious debris spikes or the sensor boom washing ashore or the DTS-12 Turbidimeter touching bottom were corrected by connecting linearly across to good data points from the beginning to the end of turbidity spikes. Less obvious anomalies were checked by comparing suspended sediment concentrations of any bottles taken during anomalies and comparing to the storm regression relationship of turbidity to suspended sediment concentration or comparing to the annual turbidity / suspended sediment regression. Turbidity spikes that had bottles not supporting the spike were corrected. TTS Adjuster outputs a dataset that has columns of raw and corrected data beside each other for comparison.

Early data for Site FTR for 1999, 2000 and 2001 was corrected on Redwood Sciences Lab mainframe computers but this was not easy to do. Requests were made to RSL for PC based correction software. This software is now available for free to the public on the Redwood Sciences Lab website with numerous implementation files, some with input from Watershed Watch.
Table 1 summarizes the accuracy, precision, and measurement range estimated for the parameters of interest for the study. Values are derived from knowledge of measurement device characteristics and accuracy and also accounting for expected field and laboratory conditions. (Salmon Forever QAPP 2001)

<table>
<thead>
<tr>
<th>Matrix</th>
<th>Parameter</th>
<th>Measurement Method</th>
<th>Precision</th>
<th>Accuracy</th>
<th>Measurement Range</th>
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<td>Water</td>
<td>Turbidity</td>
<td>Nephelometer</td>
<td>± 5.0%</td>
<td>± 2.0%²</td>
<td>0-2000 NTU</td>
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<tr>
<td>Water</td>
<td>Turbidity</td>
<td>Probe</td>
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<td>± 2.0%²</td>
<td>0-2000 NTU</td>
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<td>Water</td>
<td>Suspended Sediment</td>
<td>Gravimetric</td>
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<td>± 2.0%²</td>
<td>0.00001-2.0 g/L</td>
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<td>0-10 ft/sec</td>
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<tr>
<td>Velocity</td>
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<td>± 8.0%</td>
<td>± 8.0%²</td>
<td>0.25 - 8.0 ft/sec</td>
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<td>Water</td>
<td>Depth</td>
<td>Staff Plate</td>
<td>± 5.0%</td>
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<td>0-20 feet</td>
</tr>
<tr>
<td>Water</td>
<td>Pressure Transducer</td>
<td>Not Applicable</td>
<td></td>
<td>0.05 ft</td>
<td>0 - 10 feet</td>
</tr>
</tbody>
</table>

¹ The accuracy and precision for these parameters is a function of the magnitude of the measurement value. (QAPP 2001)

Closing Summary:

Areas to improve

**Sunspikes on DTS12 Turbidimeters** – Sites KRW and FTR – Sunlight hitting or bouncing off streambed is causing turbidity spikes and triggering extra bottles. This is causing more frequent visits and man hours wasted and more samples run than needed. The manufacturer is aware and says light filters are already in place. We are still getting Sunspikes. These are seen in several other projects. Unfortunately large shields are needed. These can cause problems if storm events occur while shields are on.

**On-line stage and turbidity** – This should provide man hour and cost savings. Field crews are able to see conditions without visiting site. Field crews can tell how many bottles have been pumped and if more empty bottles are needed soon. Stage and discharge can be seen without visiting the site and plans made to measure needed discharge levels for discharge rating curves. – Recommend Site SFM go on-line.

**Discharge measurements** – More manpower is needed collect data. Currently a lack of personnel is causing many high flow and low flow measurements to be missed or not taken as quickly as possible. Discharge measurements are ideally taken during the falling limb of storms. Usually the storm has passed by and weather is dry. Sometimes high flows are only available at the height of the storm with a rapidly changing stage level. The quicker a discharge can be taken the better. A bridge crane needs to be kept at Site FTR for measurements there. A second pick up mounted crane is needed as the existing one is locked in by flooded roads in Elk River when it is needed in Freshwater and vice versa.

**Processing samples.** Work-Study students are not all motivated workers. Samples are not being processed in a timely fashion. A half time or full time position person is needed to run samples exclusively.

**Infrastructure at Sites** – Masts and Booms and Winches and Turbidimeter Housings desperately need upgrades. Watershed Watch is losing data and man-hours dealing with nuisance problems that could be avoided with stronger equipment.
**Data Entry and corrections** – A lack of personnel is making timely data entry and corrections unable to be done in a timely manner. Analysis Personnel are tied up with these tasks when their time would be better spent in analysis.

**Rainfall Equipment:** Tipping Bucket rain gauge mounts need to be improved. Catch buckets used to catch rainfall from tipping bucket rain gauges needs to be improved. Better tipping bucket rain gauges need to be purchased. Funds for manufacturer calibration of tipping bucket rain gauges needs to be found.

Significant amounts of suspended sediment are being routed through these river systems. Cost effective methods are available to accurately determine annual suspended sediment loads. TTS sampling methodology is an important tool in restoring beneficial uses of the Freshwater Creek and Elk River watersheds and providing data for the recovery of the Coho salmon living there.

It is hoped that turbidity and suspended sediment data collected by Watershed Watch can be used to determine long term trends in chronic turbidity, annual suspended sediment yields and turbidity discharge relationships in Freshwater Creek and Elk River Watersheds. As time allows data from preceding years will be used towards those endeavors.

Salmon Forever will continue to work with Regional Water Quality on the TMDL process for Freshwater Creek and Elk River, providing data showing significantly reduced channel capacity from sediment accumulation, relationships between nuisance flooding and changing flood recurrence interval and annual suspended sediment loads in these watersheds.

Using a modem provided by the North Coast Regional Water Quality Control Board, water depth and turbidity data was on-line in real time at Site FTR for the HY 2005 season. Residents and researchers were able to monitor flood conditions in upper Freshwater Creek as they happened. Clark Fenton was able to gauge how many bottles had been pumped and determine whether a site visit was necessary soon. Residents could gauge flooding risk.

At our TTS station FTR in upper Freshwater Creek we began long term collaboration with a Canadian company called Forest Technology Systems and the Redwood Sciences Lab. They primarily sell weather and water monitoring instruments. They make the DTS-12 Digital Turbidimeters that are now deployed at all of our TTS stations. They contributed a second set of stage and turbidity sensors to test their own version of TTS sampling software developed by Redwood Sciences Lab that we use. A real world environment was used to compare the triggering / sampling of both systems. Their software performed well and more collaboration is planned for HY 2006.

Watershed Watch would like to thank Ruth Blyther and Nicole Murano of the Redwood Community Action Agency for their support in our monitoring programs. We would also like to thank Adona White of the North Coast Regional Water Quality Control Board for her actions and support for our monitoring programs in Elk River and Freshwater Creek. We would like to thank the work study students who did a great deal of sample processing and fieldwork to make this data possible. We would also like to thank the Freshwater Creek and Elk River watershed residents who gave us permission to use their property for TTS Stations and for helping keep the TTS Stations operating through storms and high water. Bless Luna Leopold.
Appendices

Appendix 1 – Standard Operating Procedures HY 2005
Appendix 2 – Salmon Forever Quality Assurance Project Plan (QAPP) 2001
Appendix 3 – Discharge Data and Discharge Rating Curves HY 2005
Appendix 4 – ISCO Pump Sampler Suspended Sediment Data and Sediment Rating Curves HY 2005
Appendix 5 – Data definitions for flo files HY 2005
Appendix 6 - flo files – stage / turbidity HY 2005
Appendix 7 – Suspended Sediment Loads HY 2005
Appendix 8 – TTS Adjuster Manual
Appendix 9 – Images
Appendix 10 – Site Maps

References / Bibliography


California State Water Resources Control Board. 303d lists of impaired watersheds http://www.waterboards.ca.gov/tmdl/303d_lists.html


Klein, R. 2003. Duration of Turbidity and Suspended Sediment Transport in Salmonid Bearing Streams, North Coastal California. USEPA Report – Interagency Agreement # DW-1495553501-0


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USEPA:
EPA QA/G-4 Guidance for the Data Quality Objectives Process
EPA QA/G-5 Guidance for Quality Assurance Project Plans
EPA QA/G-6 Guidance for the Preparation of Standard Operating Procedures (SOP's) for Quality Related Documents
EPA QA/R-5 EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations

USGS:
Techniques of Water-Resources Investigations of the USGS:
    Stage Measurements at Gaging Stations Book 3 Chapter A7
    Discharge Measurements at Gaging Stations Book 3 Chapter A8
    Laboratory Theory and Methods for Sediment Analysis Chapter C1 Book 5
    Field Methods for Measurement of Fluvial Sediment Chapter C2 Book 3
Surface Water Techniques: Discharge Ratings at Gaging Stations - Hydraulic Measurement and Computation Book 1 Chapter 12 1965