Francis Creek Annual Suspended Sediment Yield

Turbidity Threshold Sampling Summary Report

Hydrologic Year 2014

Site FRC – 1099 Van Ness Avenue Ferndale, California

A collaborative project between

National Marine Fisheries Service

Humboldt County

Coastal Conservancy

Humboldt County Resource Conservation District

North Coast Regional Water Quality Control Board

For the

Salt River Ecosystem Restoration Project

By Clark Fenton

7-25-14

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1. Introduction

The Salt River Ecosystem Restoration Project is a joint effort by various agencies, including The County of Humboldt, The California State Water Control Board, Ducks Unlimited, The State of California Coastal Conservancy, The California Department of Fish and Wildlife, The California Department of Conservation and the California Department of Water Resources.

The goals are to improve riparian and fish habitat, reduce flooding, enhance sediment routing and lessen sewer plant impacts on Francis Creek and the Salt River. Suspended sediment yields from the Francis Creek watershed will continue to be quantified to provide planning data for future dredging downstream. The EIR and current progress may be viewed on the HCRCD's web site (http://www.humboldtrcd.org, Salt River Restoration Project tab.

Thanks to Valentina Cabrera-Stagno, Duane James, Lucrina Jones, Greg Nagle and Peter Husby of the United States Environmental Protection Agency – Region 9 Laboratory for running the Francis Creek suspended sediment concentration samples for Hydrologic Year 2014. Funding for running the ssc samples locally was not obtained for this year. Summer Daughterty of the Humboldt County Resource Conservation District stepped up and persuaded the EPA to run our samples.

The following is from the Humboldt County Resource Conservation District Website 7-22-14

http://www.humboldtrcd.org/FishSurveysRestoredSaltRiverEstuary.pdf March 2014

"It's been six months since the completion of active construction on Phase 1 of the Salt River Ecosystem Restoration Project. In October 2013, 2.5 miles of the river channel was deepened 12' from an average depth of 8', and widened 83' from an average width of 11'. Over three miles of internal slough networks were excavated across 330 acres of a former organic dairy ranch. On October 28th, 2013, the newly constructed restoration site was opened to receive water from the Eel River and the Pacific Ocean for the first time in over 100 years.

This March (2014) a fisheries crew consisting of AmeriCorps and California Conservation members was led by Allan Renger, CDFW District Fish Biologist, to sample 10 sites over 4 days across the restoration area during low tides. Juvenile smelt were seined in the Salt River, though it is expected to have a multitude of marine fish utilizing the area as the month's progress. The slough network held some very happy surprises. Over 30 juvenile Federally Listed Endangered Coho Salmon (Oncorhynchus kisutch) were captured at sites near installed wood debris structures and at terminal branches of the slough network."

Unfortunately Humboldt County is experiencing drought conditions and a lack of rainfall has greatly reduced the stream flow and correspondingly the suspended sediment annual yield amounts in Francis Creek.

The Humboldt County Materials Testing Lab and Clark Fenton continue to maintain a Turbidity Threshold Sampling (TTS) Station on Francis Creek in Ferndale California. Hydrologic Year 2014 was the eighth year and seventh full year of TTS monitoring on Francis Creek. Sarah Wilson continues to analyze and report the annual suspended sediment yields.

Photo #1. Aerial view of mouth of the Eel River and Salt River looking west.

The excavated channel is on the right side of photo.

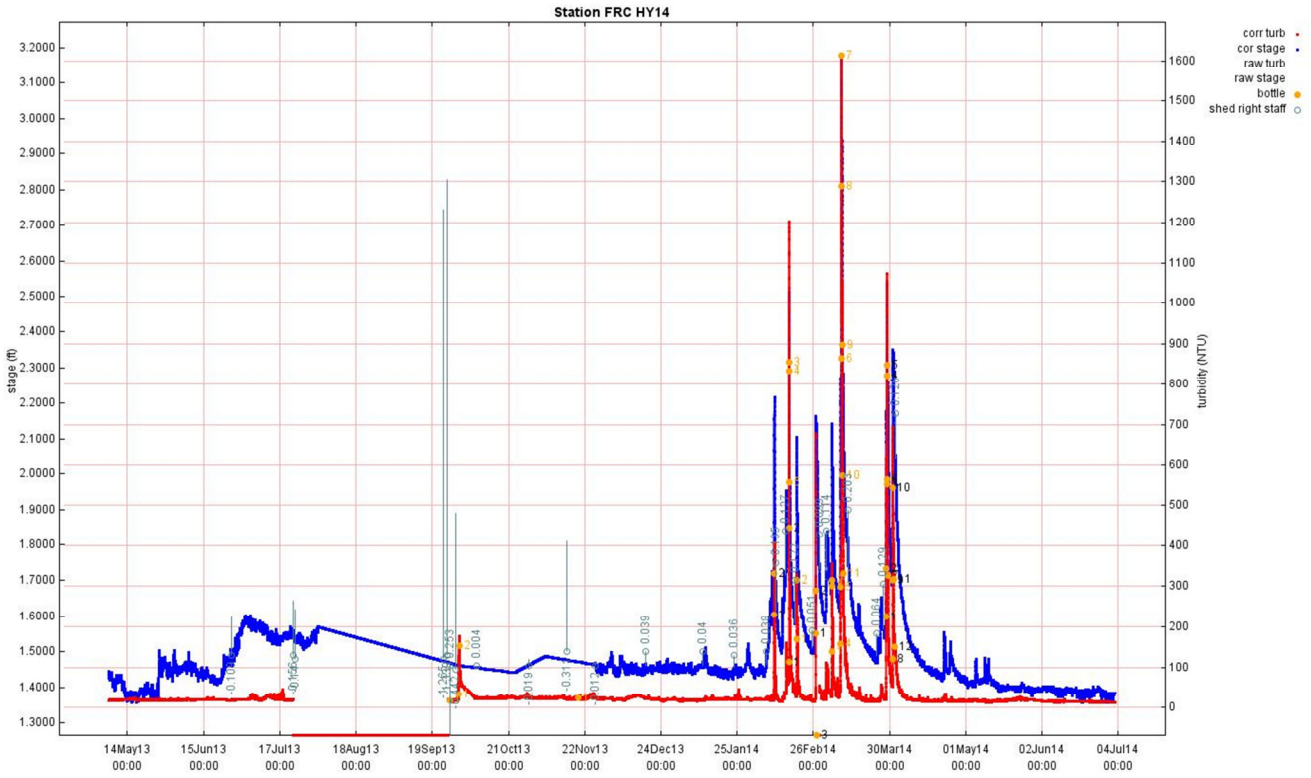
The annual suspended sediment yield from the Francis Creek watershed above Site FRC for **Hydrologic Year 2014 from May 6th 2013 to July 1st 2014 was 1,097,578 kilograms or 2.4 million pounds**. A bulk specific gravity of 85 lbs. per cubic foot was used to calculate cubic yards of fresh flood deposit sediment. (USDA, 93) The purpose of this TTS monitoring station is to provide guidance on how much suspended sediment can be expected to enter the Salt River dredge or detention areas over time from the Francis Creek watershed.

The Ferndale Enterprise reported on 7-3-14 that rainfall for Ferndale for "The weather year to date from 7-1-13 to 6-29-14 is **18.34** inches. Rainfall **last year** from 7-1-13 to 6-29-14 was **35.22** inches. The Weather Year average from 1971, July 1st to 6-29-14 **is 40.12** inches rainfall."

The results from the last 7 water years are summarized below. The HY 2011, 2012, 2013, 2014 totals include suspended sediment from the Francis Creek Ranch Slide in March 2011.

Hydrologic Year	Total Suspended Sediment **Lbs.**	Total Suspended Sediment **Kg**	Total Suspended Sediment Cubic Yards	Highest Single Storm Sediment Kg	Highest Single Storm Flow CFS	Annual Suspended Sediment Yield Tons/ Sq. Mile
2008	41,739,922	18,932,910	18,187	4,511,312	274	6,521
2009	12,578,664	5,705,593	5,480	1,351,049	135	1,965
2010	38,979,924	17,685,991	16,985	4,270,058	215	6,091
2011	70,342,760	31,915,953	30,650	17,045,608	268	10,991
2012	65,859,288	29,881,710	28,696	12,563,530	230	10,291
2013	139,352,629	63,209,938	60,720	28,228,313	462	21,774
2014	**2,419,062**	**1,097,578**	**1,054**	**355,314**	**46**	**378**

Table # 1 – Francis Creek Annual suspended sediment summaries



Plot # 1 Stage / turbidity plot of the HY 2014 water year at Site FRC on Francis Creek.

Maximum storm stage in blue was 3.15 feet @ 46 cfs and maximum turbidity in red was 1600 fbu.

The Salt River is a tributary of the Eel River that heads in the Wildcat Mountains above Ferndale, flows across the Eel River Delta, and enters the Eel River within one mile of the Pacific Ocean. The watershed is part of the Franciscan Complex and mainly underlain by Quaternary mudstones, siltstones and sandstones of the Wildcat formation (McLaughlin, R.J. and others. 2000). Habitats and land uses that characterize the Salt / Eel River delta include the fourth largest estuary in California, salt-, brackish-, and freshwater marshes, riverine wetlands, riparian wetlands, agricultural lands dominated by dairy farms and irrigated pastures, and small communities. (USDA, 1993)

Sedimentation in the Salt River Channel has resulted in problems associated with flooding and drainage, including:

Decreased agricultural production and land values;
Degradation of the estuary and its habitats as excess nutrients are transported from flooded dairy lands downstream, Loss of a once navigable waterway; and
Increased health hazards posed by water quality degradation. (USDA, 1993)

Humboldt County Public Works was awarded a grant from the Department of Fish & Wildlife's Fisheries Restoration Grant Program, supplemented with funds from the state Department of Water Resources, to replace the culverts on Francis Creek at Port Kenyon Road with a 42-foot-wide CON/SPAN modular bridge structure. The project will remove a fish migration barrier and open access to over three miles of spawning habitat in Francis Creek and remove a hydraulic constriction to allow more effective sediment transport and channel flushing. (Hank Seeman, personal communication 2013)

The Port Kenyon Culvert replacement project bids were opened on May 27th, 2014. Unfortunately this project is on hold due to landowner issues.

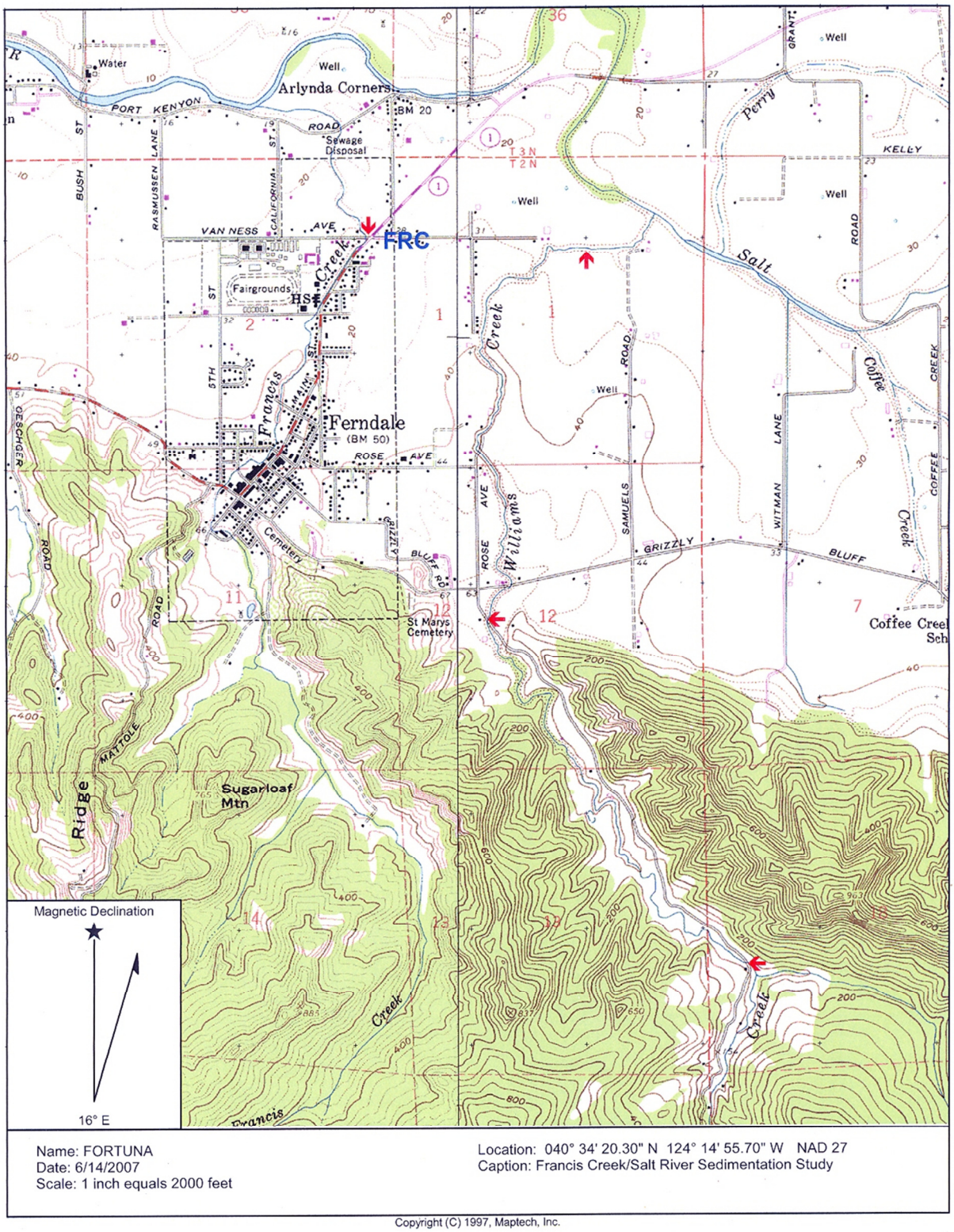


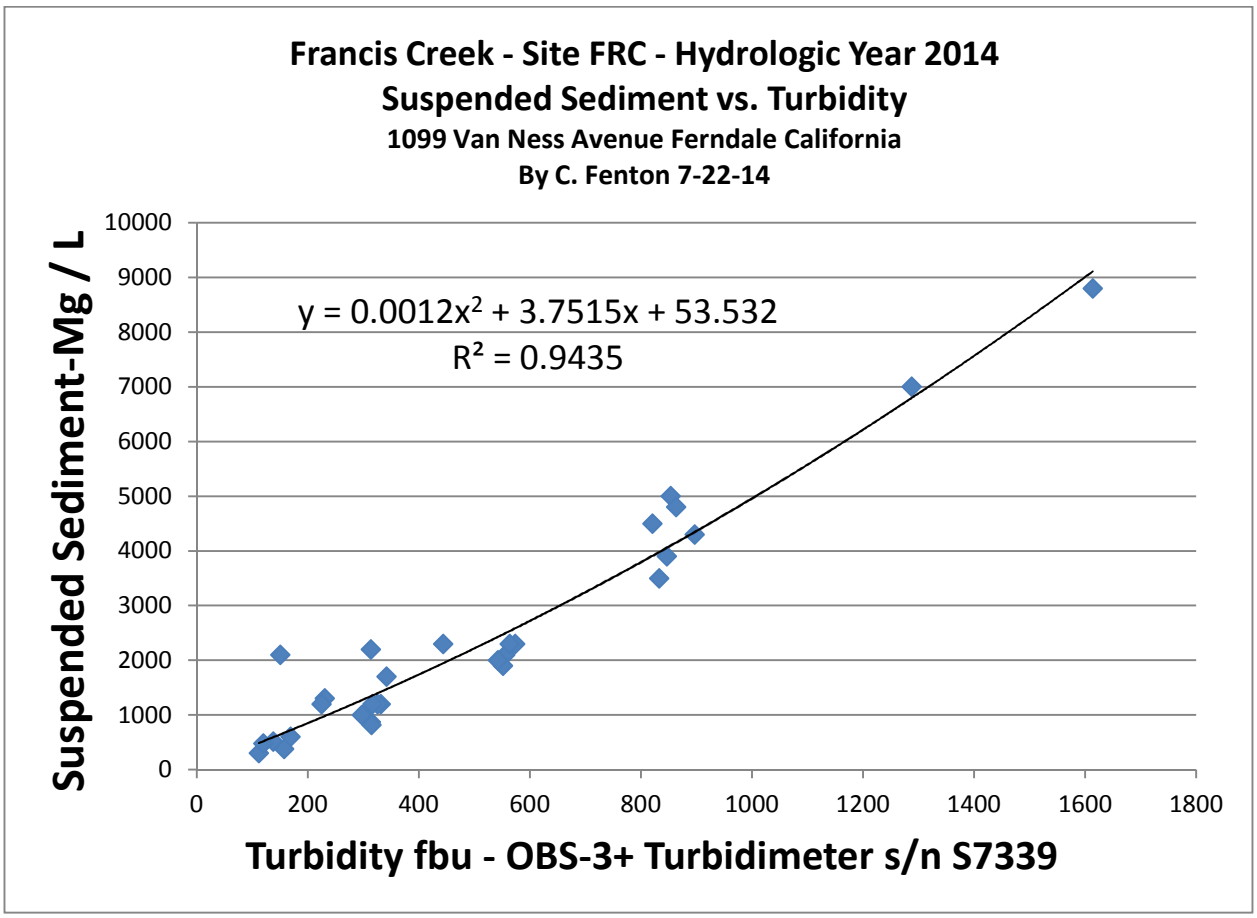
Figure # 1 Francis and Williams Creek monitoring locations

Turbidity Threshold Sampling (TTS)

Jack Lewis and Rand Eads at Redwood Sciences Lab developed turbidity Threshold Sampling over 10 years ago (Lewis, Eads, 2002). Redwood Sciences Lab is a research station for the USFS and deploys a network of these stations on Caspar Creek to monitor long-term sediment transport in the Jackson State Forest and other locations across Northern California. Redwood Sciences Lab provides all information and software for TTS sampling for free on their website. Implementation files, sampling software and TTS literature can be found at http://www.fs.fed.us/psw/topics/water/tts/.

TTS is used to calculate annual suspended sediment loads using turbidity measurements every 10 minutes as a surrogate for suspended sediment measurements every 10 minutes. A Druck 1830 pressure transducer and an in-stream OBS-3+ turbidimeter are installed in conjunction with an ISCO pump sampler to take water samples at direction from TTS sampling software. An algorithm is used to trigger an ISCO pump sampler to take water samples at rising and falling turbidity thresholds. The final 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 Site FRC 2007, 2008, 2009, 2010, 2011, 2012, 2013 and 2014 are included in Appendix 5. On-line real time plotting should be available on the HSU website http://nrs-isa.humboldt.edu/rsl/tts_plot.html.

TTS water samples for HY 14 were sent to the EPA Region 9 Laboratory by Summer Daughterty of the HCRCD for suspended sediment concentration determination by subtracting filtering (SSC / Sand Fraction - ASTM D3977 -02). A regression is developed for OBS-3+ turbidity versus suspended sediment concentration. The 10-minute turbidity data is converted to 10 minute calculated suspended sediment concentration. A discharge-rating curve is developed so flow is known for the every 10 min stage data. By multiplying flow / cfs and suspended sediment concentration, pounds of sediment passing by the station are calculated. TTS Adjuster software is used to do data correction and R Sed 2.2.0 software is used to calculate suspended sediment loads. The best equation fit for the turbidity vs. suspended sediment concentration from **bottles sampled from each storm is used to calculate loads for each storm** and the loads are summed up for the year.



Plot # 2 - Turbidity vs. Suspended Sediment Concentration

of Site FRC HY 2014 ISCO pump samples.

2. Francis Creek Ranch Slide – March 2011

During a set of 5 rainfall events starting 3-23-11 and ending 4-1-11 a large debris torrent occurred approximately 3.4 river miles upstream of the station. The forester of the upstream property, Chris Carroll, estimates the slide to be roughly 100,000 cubic yards in size.

The California Geological Survey visited the site on April 7, 2011. Details from their report by Don R. Braun dated April 18, 2011 include that a bridge was removed from its abutments by the debris. At the slide site bedrock materials "consisted predominantly of soft to moderately dark gray siltstone with minor amounts of fine sub rounded gravel. Significant precipitation in the area during the month of March may have been the main contributor to the recent failure. The debris is estimated to consist of about 50% wood or logs and about 50% dark gray silt. Information supplied by Mr. Mark Distefano of TRC suggests that the destroyed former bridge over Francis Creek was approximately 15 to 20 feet above the channel and that the current debris in the channel is about 4 to 5 feet above the height of the old bridge suggesting that the debris thickness at this location may be about 19 to 25 feet. Francis Creek will likely remain turbid with suspended sediment during future rainy seasons until a stable channel and side slopes develop." (CGS, 2011)

Photo # 2 Francis Creek Ranch Slide April 2011

Using turbidity threshold sampling analysis Sarah Wilson estimated that approximately **11 million kilograms / 24 million pounds / 10,600** cubic yards of suspended sediment presumably came from the Francis Creek Ranch Slide during this period. The suspended sediment is mainly fine sand and silt and totals do not include bed load gravel. During this slide event, the TTS station sucked over 40 water samples from Francis Creek, including 14 water samples over 35,000 milligrams/liter. Eight of those 14 bottles had over 65,000 mg/l, one bottle had 100,000 mg/l and one bottle had 180,000 mg/l.

This event in HY 11 contributed in 6 days almost the same amount of suspended sediment yield as all of Hydrologic Year 2010. The slide itself has already sent twice the amount as all of Water Year 2009 suspended sediment yield downstream. **HY 2012** suspended sediment yield was **65.8 million pounds**. The **HY 2013** suspended sediment yield was **139 million pounds**. The **HY 2014** suspended sediment yield was **2.4 million pounds** due to drought conditions.

After the large storm events in 2012, Tom Stephens, a local geologist, visited the slide and gave analysis and recommendations to the Ferndale City Council. His main recommendations were to continue close monitoring of the slide during storm events and encourage HSU students and faculty to survey cross sections annually to document changes.

His 2012 report said that the toe of the slide is migrating upstream as it erodes but most of the slide is still a slowly settling mass of trees and sediment. Some tree planting slide stabilization efforts by the CCC have been washed away but other revegetation efforts are holding. The stream is cutting down and widening and the previous waterfall at the base of the slide has disappeared. There is still a lot of sediment and debris in the stream channel above Ferndale and large storm events will continue to mobilize that sediment.

Sarah Wilson did not do a breakdown of the proportion of slide suspended sediment versus the total annual suspended sediment yield this year. As each year passes the slide's contribution gets more difficult to discern as the slide changes and annual rainfall totals change. The slide suspended sediment regime is now **baseline**.

The suspended sediment regime in Francis Creek was seeing higher concentrations of suspended sediment as more sediment in the slide and stream channel is easily mobilized. There will be more erratic pulses of sediment and debris of random size if there are any large slope failures at the slide site. The drought has slowed sediment delivery to Francis Creek.

"This year's annual stream survey (2014) of channel conditions, conducted by the City every June (channel walk from the WWTP to the water company bridge), surely is reflected in your data. It appears to be little sediment contribution from the slide and other sources above town. Since the slide debris is predominantly silt and clay, that source would show in your sampling data as it has since 2011. This year, channel gravel was much less embedded and there appeared to be a decrease in stored channel sediment (mostly sand and gravel). Since we don't have bed load measurements, might be tough to confirm this. Low flows probably had somewhat of a winnowing effect on the stored sediment. "(Tom Stephens personal communication 7-23-14)

3. Hydrologic Year 2014 Suspended Sediment Yield

The Francis Creek TTS Station (Site FRC) is located at 1099 Van Ness Avenue in Ferndale, California. Francis Creek is the second largest tributary to the Salt River watershed at 3.2 square miles (Buffleben, 2007). The Williams Creek watershed is the largest at 5.7 square miles. TTS Monitoring commenced at Site FRC on Francis Creek on 1-23-07.

Sarah Wilson continues to do suspended sediment analysis with Redwood Sciences Lab TTS Adjuster analysis software. Sarah Wilson received her Bachelors of Science in Biology from San Jose State University and a Master's of Science in Watershed Management from Humboldt State University. Her husband is an active duty member of the US Coast Guard. They have a son and a daughter and currently live in Dublin Ca.

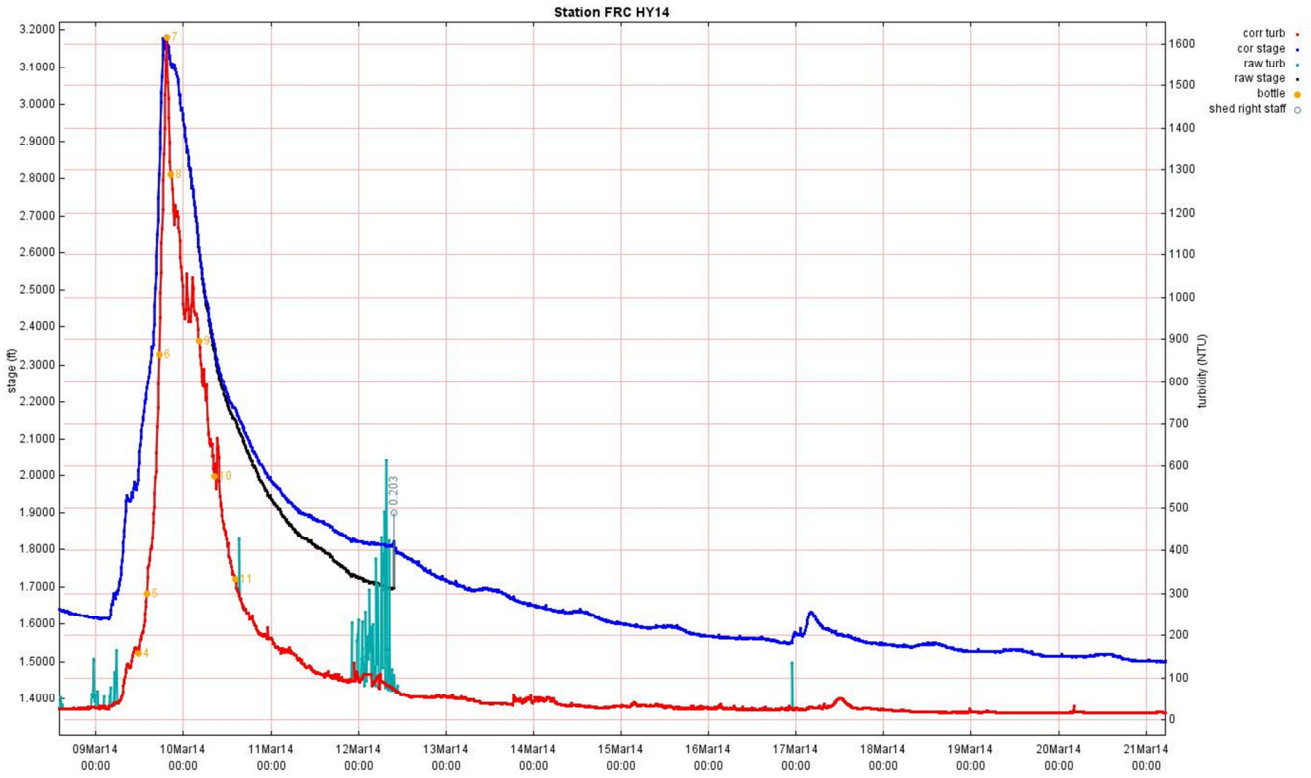
The annual suspended sediment yield from the Francis Creek watershed above Site FRC for Hydrologic Year **2014** from May 6th, 2013 to July 1st, 2014 **was 2.4 million pounds or 1,097,578 kilograms or 1054 cubic yards or 378 tons / square mile.**

The largest suspended sediment estimation period of HY 2014 was storm period 2 from February 2nd 2014 to March 28th 2014. The estimated load for period 2 was 795,380 kg, 72% of the total estimated load for HY14.

The annual suspended sediment yield from the Francis Creek watershed above Site FRC for Hydrologic Year **2013** from October 2nd, 2012 to May 6th 2013 was **139.3 million pounds or 63,209,938 kilograms or 60,720 cubic yards or 21,774 tons / square mile.**

The **Eel River at Scotia** carries an almost incredible **4,330 tons of sediment every year from every square mile** of its drainage basin. On average, 4 to 8 inches of soil is washing is washing off the slopes every hundred years. That is the highest regional rate of erosion ever measured in the United States, more than 13 times the national average. Most of that phenomenal load goes down the river in about 6 days of the largest discharges during the winter floods. (Roadside Geology of Northern and Central California – D. Alt / D. Hyndman – 2000)

The average annual suspended load for the **Mad River** is about 1,751,500 tons, or about **3,600 tons /sq. mi/yr.** for Qss. (Klein, R. 2007, Personal Communication.)



Plot # 3. A plot of the largest storm of HY 2014 showing water depth as blue peaking at 3.15 feet stage / 46 cfs and 1600 fbu from March 14th 2014 to March 16th 2014.

This storm event carried 783,325 pounds / 341 cubic yards of sediment past Station FRC.

This amount of suspended sediment was 72% of the total yield for HY 2014.

Summary of sediment load estimates for Station FRC, Water Year 2014

By Sarah Wilson

The table below is from the Sarah Wilson suspended sediment report for FRC **HY 2014**. Her complete report is in Appendix 1. The hydrologic year was broken up into storm-by-storm time periods and the suspended sediment load was calculated for each period. Ms. Wilson has done this same analysis for Redwood Sciences Lab.

Summary of sediment load estimates for station FRC, water year 2014

Each estimate is given one of five grades: excellent, very good, good, fair and poor.

Grading is based on the quality within the following categories:

Number of sample bottles within the period and the coverage of bottles across the entire period.

The strength of the relationship between the surrogate variable (usually turbidity) and sample ssc, as measured by CV and r2.

The complexity and number of models and object used to calculate the estimate for each period.

The quality of the surrogate variable data (usually turbidity).

An estimate cannot receive a high grade if the quality of the underlying data is questionable.

Discharge rating equation: Discharge = (9.8848*stage^2 - 19.996*stage + 10.582)

Same discharge equation as HY13

Period	Dates and Times	Dump: Bottles	Sediment Load (kg)	% of Total Load	Grade
1	130506,0940,140202,0000	dd 1-9, no bottles	115,498	10.52%	poor
2	140202,0010,140328,0000	10:1-2, 11:1-2, 13:1-2	795,380	72.47%	fair to poor
3	140328,0010,140701,0000	16:1-12	186,700	17.01%	good
		Total Load (kg)	**1,097,578**		

Table # 2 – HY 2014 Storm Period Suspended Sediment yields

4. Field Operations HY 2014

The station on Francis Creek – Site FRC – was made possible by funding from the Humboldt County Resource Conservation District, 5 Counties Salmonid Conservation Program, City of Ferndale and the Road Fund of the Humboldt County Public Works Department**.** The City of Ferndale Public Works constructed the Site FRC Equipment Enclosure Shed, and the equipment was installed in January of 2007.

Photo # 2 - Site FRC at 1099 Van Ness Avenue

The TTS station uses an ISCO Model 6700 automatic pump sampler, a Campbell CR101X data logger, Druck 1830 pressure transducer, and an OBS-3+ turbidity probe. The data logger and pressure transducer were up and running on 1-18-07. The OBS-3+ in-stream turbidimeter hangs from a boom off the ceiling of the culvert and has been operational since 1-23-07. The equipment has been mostly trouble free and the turbidimeter is sent in for calibration each summer.

Field Operations still include upgrading TTS station equipment, taking discharge measurements, making TTS Station FRC data dumps / sample bottle swaps, repairing storm damage to equipment and removing sediment and debris covering the pressure transducer pipe tip and/or hanging on the turbidimeter boom. Streambed aggradation has forced raising the boom and turbidimeter housing and pressure transducer pipe every year as the streambed rises to touch the housing.

A data logger modem was also purchased so that real time stage (water level) and turbidity data could be posted on the Redwood Sciences Lab website, which could function as part of an early warning network for flooding. This real time on-line data plotting has been available since the beginning of HY 2008 and will continue. Humboldt State University and Redwood Sciences Lab are upgrading plotting servers and software. This plotting should be accessible at http://nrs-isa.humboldt.edu/rsl/tts_plot.html.

Turbidity:

Francis Creek continues to maintain high turbidity levels with the Francis Creek Ranch landslide upstream.

Turbidity is a number derived from the amount of light suspended sediment blocks from passing through water. Turbidity is usually caused by rising water flow transporting increasing levels of suspended sediment. 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 flow and turbidity and suspended sediment concentrations elevated. Land use in a watershed can contribute to chronic turbidity. Elevated levels of turbidity can cause harm to aquatic species.

This watershed has a very energetic and long lasting elevated turbidity response compared to other North Coast watersheds. Sediment is mobilized fast and available longer after the peak of a storm event. Anomalous turbidity spiking may be land management activities or discrete bank failures or activity at the Francis Creek Ranch slide or some sediment delivery mechanism that keeps turbidity levels elevated.

The OBS-3+ Turbidimeter was chosen for this application because of the expected very high turbidities. The OBS-3+ sensor consists of a high intensity infrared emitting diode, which shines out into the water flow and a detector to measure light bounced back from the suspended sediment. The more infrared light bounced back the higher the turbidity. FBU turbidity units are used per the USGS turbidimeter nomenclature table from May 2012. The OBS-3+ has a stated range of 4000 fbu but has a practical high range of about 2900 fbu for Francis Creek Sediments, which is the highest available for an in-stream turbidimeter. Flow based suspended sediment loads will be used for turbidities above the range of the OBS-3+ Turbidimeter or where debris has pushed the turbidimeter instrument boom out of the water.

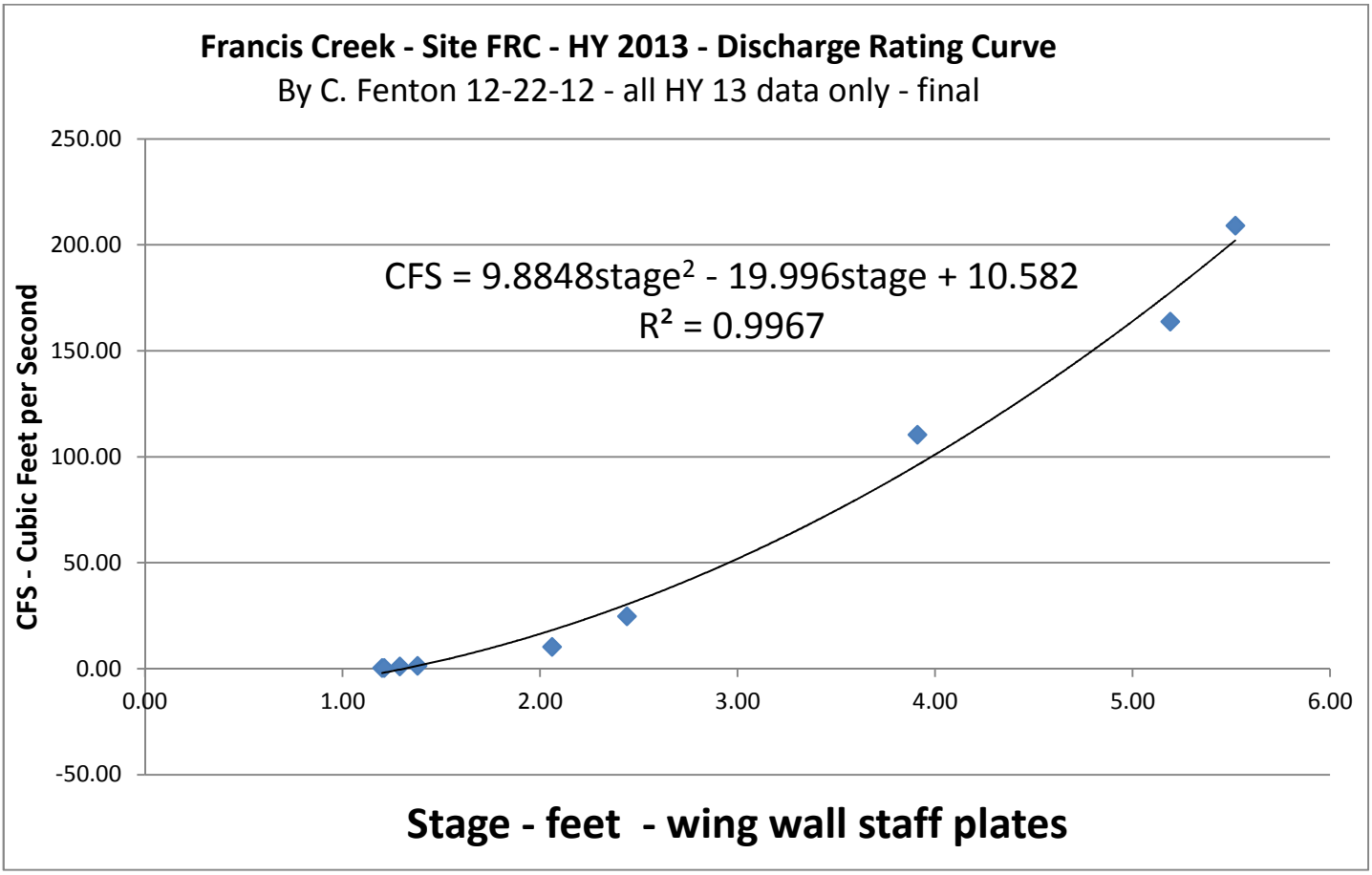
Discharge Measurements HY 2014:

The highest stage for Hydrologic Year 2014 was **3.15 feet @ 46 cfs on March 14th, 2014**.

A single discharge rating curve was used for HY 14. Funding was eliminated for Clark Fenton to conduct discharge measurements after HY 2013. Fortunately a solid discharge rating curve was obtained in HY 2013 and will be used for the foreseeable future. As time goes by and large storms mobilize bed load the discharge rating curve will become less and less accurate. Estimates of suspended sediment loads will also become less and less accurate.

USFS / USGS methods were used for obtaining flow measurements. (Harrelson 1994, USGS). 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, 30 lb. Columbus Weight, Price AA current meter and a bridgeboard were used. An accurate estimate of stream discharge is vital to accurate suspended sediment load calculations. See Appendix 3 for discharge sheets and rating curves.

Aggradation or rising of the streambed around the staff plates is still being observed. The streambed is mobile gravels and annual discharges are needed in this location to ensure representative discharge measurements.



Plot # 4. FRC HY 2014 Discharge Rating Curve

5. Lab Operations 2014

Clark Fenton continues to visit the station periodically to switch out sample bottles as they are filled.

The United States Environmental Protection Agency – Region 9 Laboratory ran the Francis Creek suspended sediment concentration samples for Hydrologic Year 2014. Suspended sediment concentration determination by subtracting filtering (SSC / Sand Fraction - ASTM D3977 -02) was used. Summer Daughterty of the Humboldt County Resource Conservation District stepped up and persuaded the EPA to run our samples.

The Francis Creek TTS sampling software triggered **34** ISCO Pump samples in HY 2014 compared to **193** ISCO pump samples for HY 2013 due to reduced rainfall. The suspended sediment concentration of each bottle is compared to the corresponding OBS-3+ Turbidity and a regression is developed for each storm period. See the FRC 2014 turbidity / suspended sediment concentration regression chart in Section 1.

EPA Region 9 Laboratory reports are on file at the Humboldt County Materials Testing Lab.

6. Closing Summary:

Completion of Phase 1 and Phase 2 of the Salt River Ecosystem project should allow better flushing of suspended sediment through the system into the Eel River and perhaps the Pacific Ocean. Timing and duration of rainfall events will determine how much is flushed through or drops out in the lower reaches of the Salt River. Detention basins that were constructed in the lower reaches should capture suspended sediment to the side instead of the main Salt River channel during high flows.

Perhaps a rough estimate can be made of the cubic yards of suspended sediment deposited in the detention basins each year to compare to amounts passing the monitoring station upstream to estimate how much of the total is dropping out before reaching the Eel River.

The annual suspended sediment yield from the Francis Creek watershed for HY 14 is **2%** of Hydrologic Year 2013 and **4%** of Hydrologic Year 2012. This illustrates the large effect of timing of rainfall amounts on the quantities of suspended sediment being mobilized each year.

The biggest field challenge is still to keep the instrument boom at proper depth during large storm events so turbidity data is not lost. Francis Creek has plentiful woody debris in stream and debris snagging on the boom can push the boom and turbidimeter out of the water. 40 or 50 pounds of lead have been attached to the lower end of the boom to keep it in the water during high flows. Even that is not enough at times.

The Francis Creek Slide will continue to dominate the suspended sediment regime on Francis Creek.

Thanks to Summer Daughterty of the HCRCD for convincing the EPA to run our ssc samples this year.

7. References / Bibliography

Alt, D. D., Hyndman, W. D. (2000). *Roadside Geology of Northern and Central California*, 2nd Ed., Mountain Press, Missoula, Montana.

California Integrated Seismic Network. (2010). "Earthquake Details." *USGS Earthquake Hazards Program*, <http://earthquake.usgs.gov/earthquakes/eqinthenews/2010/nc71338066/> (Jun. 23, 2010).

Focused Engineering Geologic Evaluation Recent Landslide Within Francis Creek Ranch, Upper Francis Creek Watershed, Ferndale California, Apri18, 2011, Don R. Braun, California Geological Survey, Eureka Ca. CGS (2011)

Harrellson, C. C., Rawlins, C. L., Potyondy, J. P. (1994). "Stream Channel Reference Sites: An Illustrated Guide to Field Technique." *General Technical Report RM-245,* United States Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Lewis, E., Lewis, R., & Lewis, J. (2002). *Continuous Turbidity Monitoring in Streams of Northwestern California. In: Turbidity and Other Sediment Surrogates Workshop* (ed. Glysson, G.D. & Gray, J.R.), 30 April – 02 May 2002, Reno, Nevada. 3 p.

Lewis, J. (2002). *Estimation of Suspended Sediment Flux in Streams Using Continuous Turbidity and Flow Data Coupled with Laboratory Concentrations. In: Turbidity and Other Sediment Surrogates Workshop* (ed. Glysson, G.D. & Gray, J.R.), 30 April – 02 May 2002, Reno, Nevada. 3 p.

McLaughlin, R.J., Ellen, S.D., Blake, M.C., Jr., Jayko, A.S., Irwin, W.P., Aalto, K.R., Carver, G.A., Clark, S.H. Jr. (2000). "Geology of the Cape Mendocino, Eureka, Garberville, and Southwestern part of the Hayfork 30 x 60 Quadrangles and Adjacent Offshore Area, Northern California." *USGS,* <http://pubs.usgs.gov/mf/2000/2336/> (Jun. 23, 2010).

(Salt River Watershed – Local Implementation Plan – Humboldt County CA – USDA Soil Conservation Service 1993)

United States Department of Agriculture, Soil Conservation Service, Water Resources Planning. (1993). "Salt River Watershed, Local Implementation Plan." *Volume 1 & Maps*, Library Documents Natural Resources Division, Department of Public Works, Humboldt County, California.

United States Department of Agriculture, Soil Conservation Service, Water Resources Planning. (1993). "Salt River Watershed, Local Implementation Plan." *Appendix A: Water Quality Report*. 1-26, Public Library Humboldt Room, Eureka, California.

Standard Methods and Test Guides

ASTM Standard D 3977, 1997 (2002), "Determining Sediment Concentration in Water Samples," ASTM International, West Conshohocken, PA, 2002, DOI: 10.1520/D3977-97R02, www.astm.org.

ASTM D3977 (2002) Test Method A – Evaporation of the sample in a crucible was used because of large suspended sediment concentrations. Usually 47 mm - 1-micron glass fiber filters are used to filter sediment but sediment levels in Francis Creek samples at high flows would overwhelm the filters.

AWWA Standard 2540 B, (1990), "Standard Methods for the Examination of Water and Wastewater: Total Solids."

Standard 2540 D, (1998), "Standard Methods for the Examination of water and Waste Water: Suspended Solids," 20th Edition.

United States Environmental Protection Agency:

EPA 841D 95001, Volunteer Stream Monitoring: A Methods Manual (April, 1995).

United States Environmental Protection Agency, Washington D. C., Office of Environmental Information:

EPA QA/G-4, Guidance for the Data Quality Objectives Process (Feb., 2006).
EPA QA/G-5, Guidance for Quality Assurance Project Plans (Dec., 2002).
EPA QA/G-6, Guidance for the Preparation of Standard Operating Procedures (Apr., 2007).
EPA QA/R-5, EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations (Mar., 2001).

United States Geological Survey
Techniques of Water-Resources Investigations of the USGS, Washington:

Buchanan, T. J., Somers, W. P. (1968). "Stage Measurements at Gaging Stations," Book 3, Chapter A7-A8.
Guy, H. P. (1969). "Laboratory Theory and Methods for Sediment Analysis," Book 5, Chapter C1.
Guy, H. P., Norman, V.W.(1970). "Field Methods for Measurement of Fluvial Sediment," Book 3, Chapter C2.

Surface Water Techniques:

Carter, R. W., Davidian, J. (1965). "Discharge Ratings at Gaging Stations," Book 1, Chapter 12.

Unpublished Sources

(Buffleben, 2007) Personal Communication Mon, 7 May 2007 13:23:53 -0700
10-m DEM and calculated the upland area to be 82,955 cells which translates to:
8,295,500 square meters or 2,050 acres or 3.2029 square miles.

Klein, R. 2007, Personal Communication.