# Francis Creek Annual Suspended Sediment Yield

## Turbidity Threshold Sampling Summary Report

## Hydrologic Year 2013

**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**
**7-16-13**

# Table of Contents

# 1. Introduction

"And so after many years of research and discussion, heartburn and disappointment, dedication and commitment, the project has finally begun. " (Ferndale Enterprise 6-13-13)

The Salt River Ecosystem Restoration Project is a joint effort by various agencies 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 may be reviewed on the HCRCD's web site (http://www.humboldtrcd.org, Salt River Restoration Project tab.

The Humboldt County Materials Testing Lab and Clark Fenton continue to maintain a Turbidity Threshold Sampling (TTS) Station on Francis Creek in Ferndale California with 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. Hydrologic Year 2013 was the seventh year and sixth full year of TTS monitoring on Francis Creek. Sarah Wilson continues to analyze and report the annual suspended sediment yields.

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 over **twice** that of last year at **139.35 million pounds** or **63.2 million kilograms** or **60,720 cubic yards** or **21,774 tons / square mile**. 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.

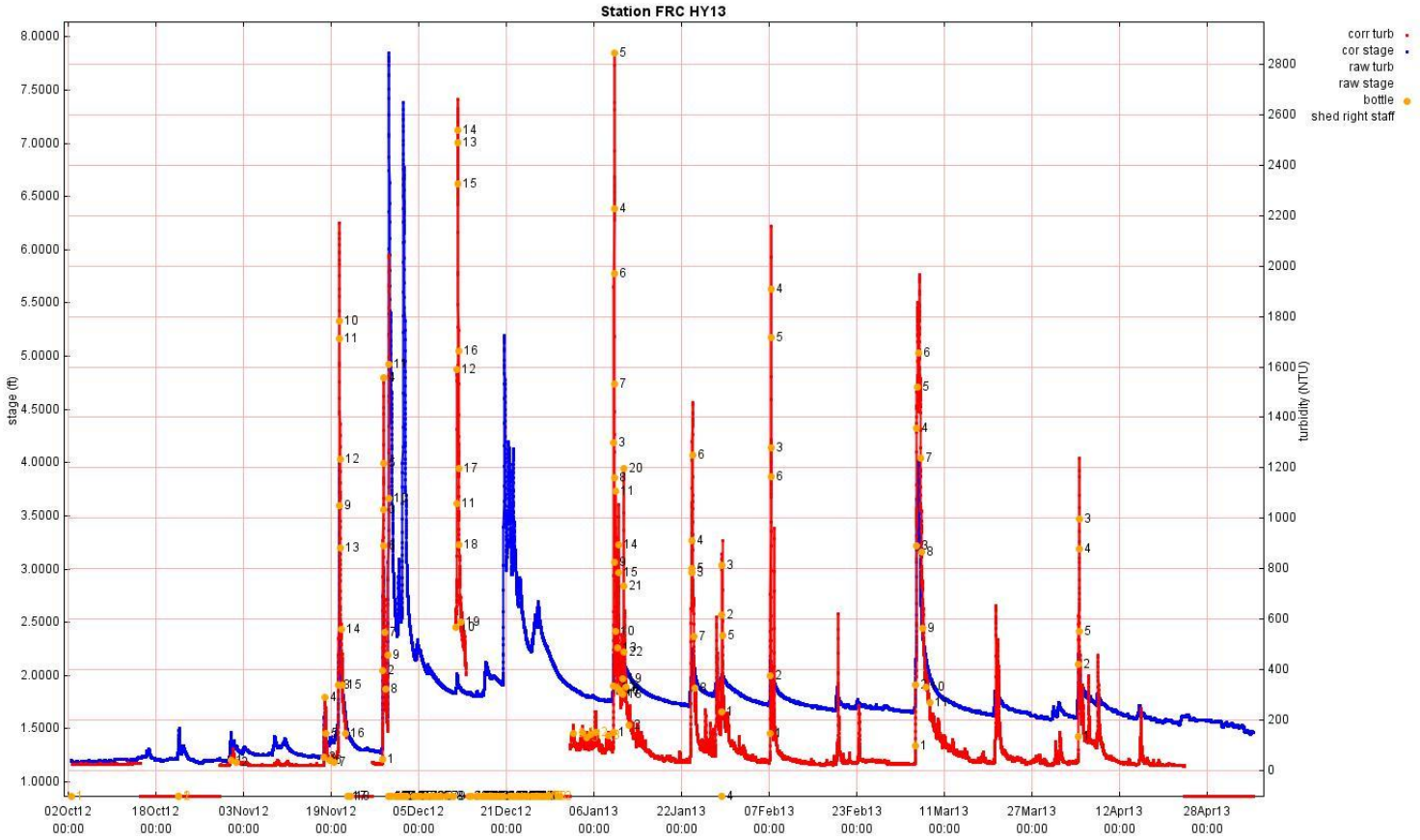
The March 2011 Francis Creek Ranch Slide is still delivering large amounts of sediment to Francis Creek and the City of Ferndale downstream. See Section 2 for more details.

The Ferndale Enterprise reported on 7-4-13 that rainfall for Ferndale for "The weather year to date from 7-1-12 to 6-23-13 is **35.22** inches. Rainfall last year from 7-1-11 to 6-23-12 was 38.95 inches. The Weather Year average from 1971, July 1st to 6-23-13 is 39.47 inches rainfall."

The results from the last 6 water years are summarized below. The HY 2011, 2012, 2013 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** |

Table # 1 – Francis Creek Annual suspended sediment summaries




Plot # 1 Stage / turbidity plot of the HY 2013 water year at Site FRC on Francis Creek.

Maximum storm stage in blue was 7.8 feet @ 462 cfs and maximum turbidity in red was 2800 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)

**The Salt River Ecosystem Restoration Project** has begun. Heavy equipment from Anderson Dragline is at work excavating channels and constructing berms as of June 2013.

Phase 1 focus on lower reaches of river include establishing a tidal marsh and estuary habitat on Riverside Ranch and excavating the channel from where it first begins to narrow and become shallow to where Reas Creek empties into the Salt. Phase 2 next year will focus on excavating approximately 7 miles of the Salt River channel to reestablish a functioning channel and floodplain corridor. (Ferndale Enterprise 6-13-13). Background material is available at www.saltriverwatershed.org and www.humboldtrcd.org.

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. The project will be constructed in 2014. (Hank Seeman, personal communication 2013)

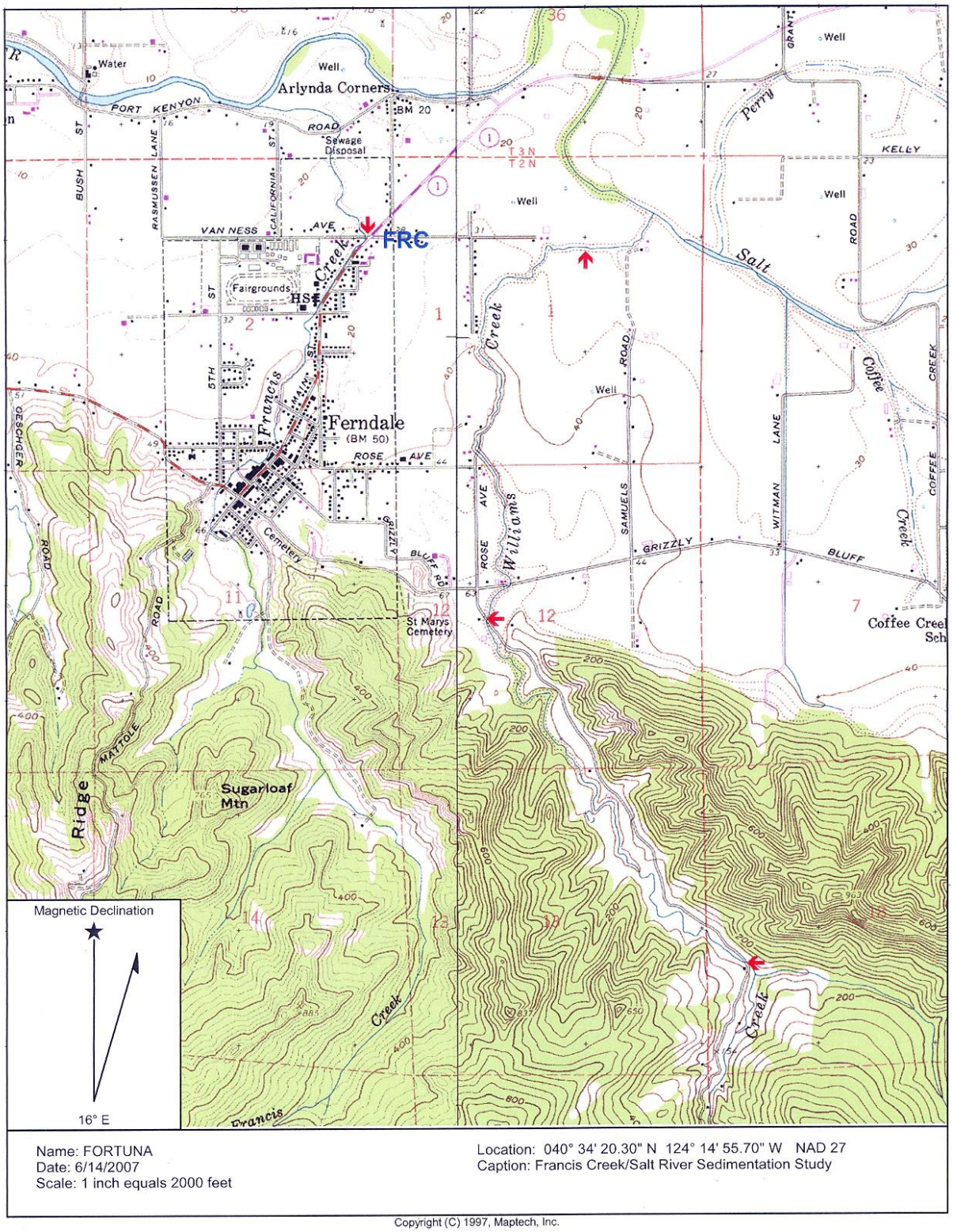


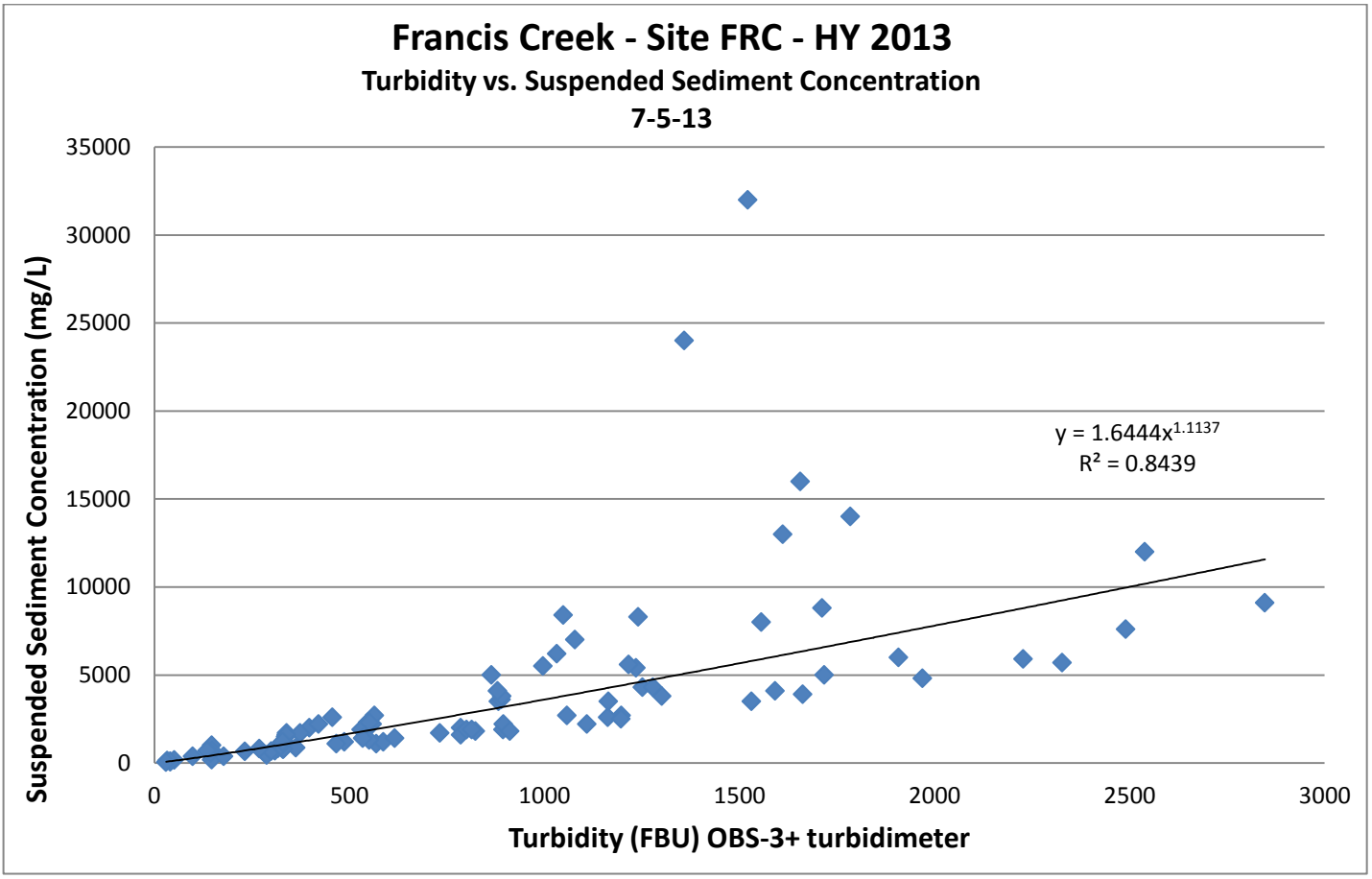

Figure # 1 Francis and Williams Creek monitoring locations

# 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 and 2013 are included in Appendix 5. On-line real time plotting is available on the HSU website http://nrs-isa.humboldt.edu/rsl/tts_plot.html.

TTS water samples continue to be taken to North Coast labs 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 2013 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 # 1 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 **139,352,629** million pounds. The large storm events in November and December 2012 mobilized large amounts of sediment presumably from the slide.

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 in June. His main recommendations are 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 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 is seeing higher concentrations of suspended sediment as more sediment in the slide and stream channel are 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. These large amounts of suspended sediment are increasing and even with annual rainfall differences, larger and larger amounts of sediment are routing past the TTS station at Van Ness Avenue.

Ferndale watch out!

# 3. Hydrologic Year 2013 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 San Pedro Ca.

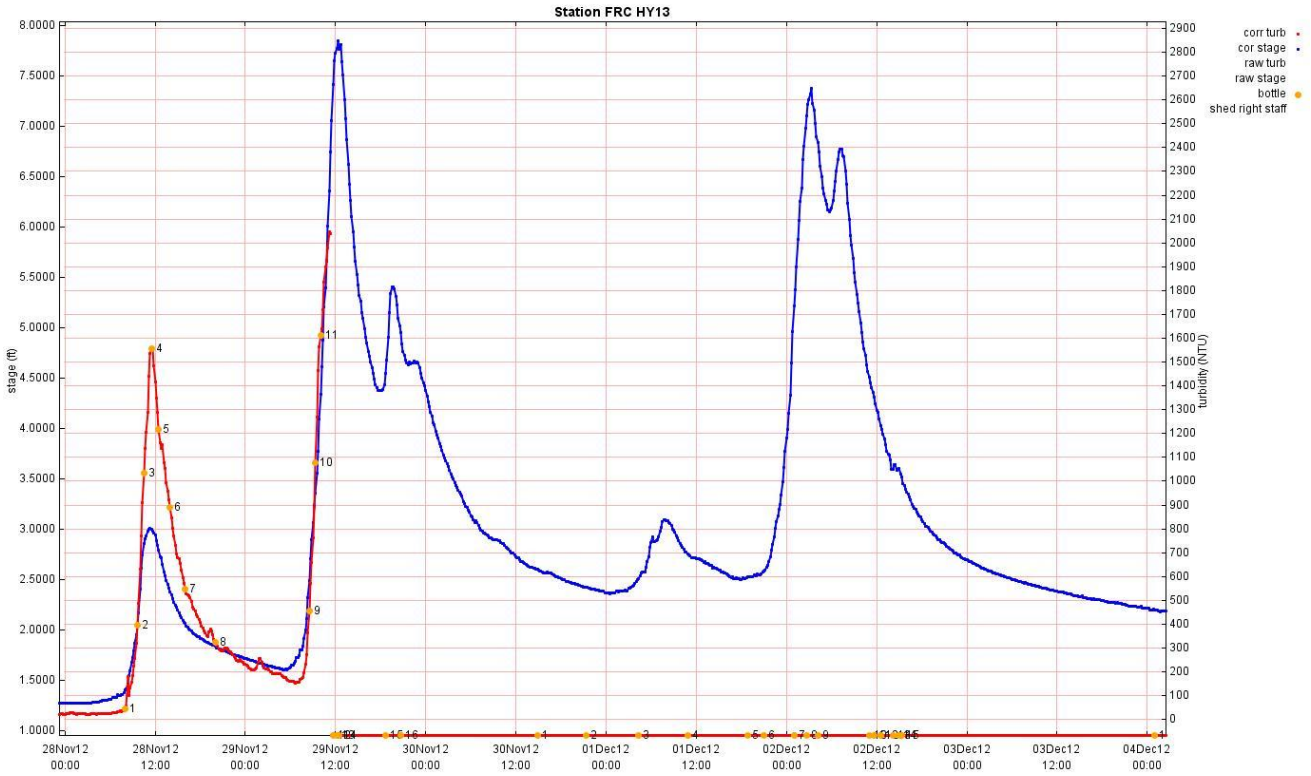
The annual suspended sediment yield from the Francis Creek watershed above Site FRC for Hydrologic Year 2013 from October 2nd, 2012 to May 6th 2013 was **139.3 million pounds or 63,209,938 kilograms or 60,720 cubic yards or 21,774 tons / square mile or twice as much as last year.**

The largest suspended sediment estimation period of HY13 was storm period 4 from November 30 to December 11, 2012. The total estimated load for period 4 was 28 million kg, 44% of the total estimated load for HY13. The two next largest estimation periods were storm period 6 (12-20-12 to 1-5-13) with 31% of the total and storm period 3 (12-11-26 to 11-30-12) with 16% of the total**. 93%** of HY 13's total suspended sediment came in in only 3 storm events.

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.)

The upstream Francis Creek Ranch Slide and heavy storm events in November and December 2012 appear to have doubled the annual amount of suspended sediment from last year.




**Plot # 4 A plot of the largest storm of HY 2013 showing water depth as blue peaking at 7.8 feet stage from November 29th, 2012 to December 3rd, 2012**

# Summary of sediment load estimates for Station FRC, Water Year 2013

By Sarah Wilson

The table below is from the Sarah Wilson suspended sediment report for FRC **HY 2013**. 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.

Each estimate is given one of 5 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 the 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.

2013 Discharge rating equation: Discharge = (9.8848*stage^2-19.996*stage+10.582)

| Period | Dates and Times | Dump: Bottles | Sediment Load (kg) | % of Total Load | Grade |
|---|---|---|---|---|---|
| 1 | 10-2-12 14:10 to 11-17-12 12:20 | 4 : 1 - 2 | 18,238 | 0.03% | fair |
| 2 | 11-17-12 12:30 to 11-26-12 12:00 | 4 : 3 - 18 | 322,991 | 0.51% | good |
| 3 | 11-26-12 12:10 to 11-30-12 14:00 | 5 : 1 - 16 | 10,399,458 | 16.45% | good |
| 4 | 11-30-12 14:10 to 12-11-12 17:20 | 6:1-15 ,7:1-7, 8:1-9 | 28,228,313 | **44.66%** | good |
| 5 | 12-11-12 17:30 to 12-20-12 08:00 | 8:10-20, 9:1-5, 10:1-8, 11:1-2 | 406,366 | 0.64% | good |
| 6 | 12-20-12 08:10 to 1-5-13 06:00 | 11:3-6, 12:1-15, 13:1-4 | 20,107,491 | 31.81% | fair |
| 7 | 1-5-13 06:10 to 1-18-13 10:00 | 16:1-22, 17:1-2 | 118,712 | 0.19% | very good |
| 8 | 1-18-13 10:10 to 2-6-13 13:00 | 17:3-8, 18:1-5 | 138,593 | 0.22% | good |
| 9 | 2-6-13 13:10 to 3-5-13 12:00 | 19:1-6 | 110,317 | 0.17% | fair |
| 10 | 3-5-13 12:10 to 3-29-13 09:00 | 20:1-11 | 3,267,109 | 5.17% | good |
| 11 | 3-29-13 09:10 to 4-14-13 20:00 | 22:1-6 | 87,793 | 0.14% | fair |
| 12 | 4-14-13 20:10 to 5-6-13 09:30 | none | 4,557 | 0.01% | poor |

**Total Load (kg) 63,209,938 kilograms**

Table # 2 – HY 2013 Storm Period Suspended Sediment yields

# 4. Field Operations HY 2013

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. Black mold in the enclosure will necessitate painting the inside with mildew resistant paint.


**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 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. This plotting can be accessed 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 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 2013:

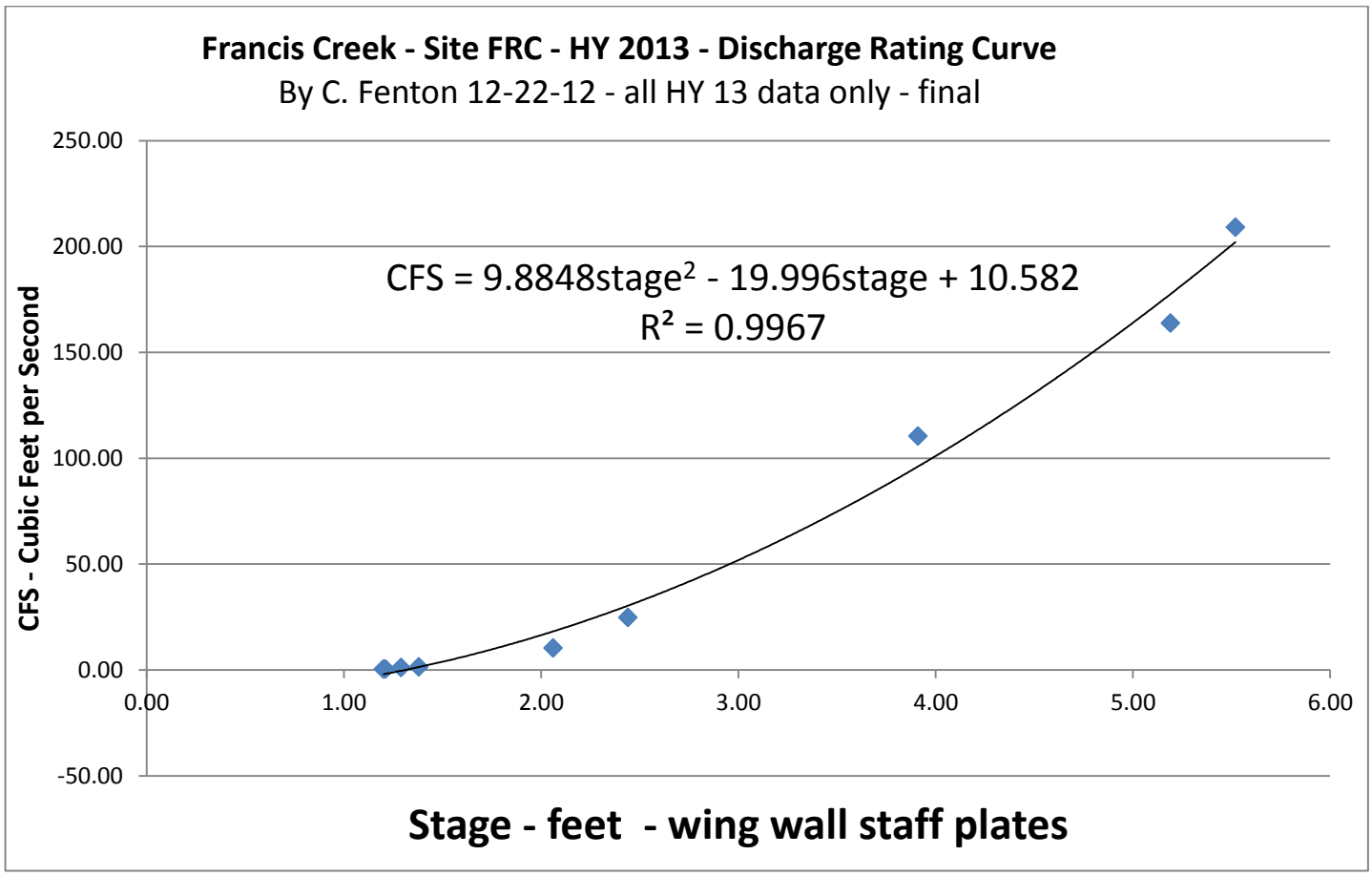
9 discharge (cubic feet per second) water measurements were taken on Francis Creek at the FRC site in HY 2013 ranging from 0.41 cfs at a 1.21-foot stage up to 209 cfs at 5.52-foot stage.

We were able to measure 2 moderately high discharges this year to provide better discharge accuracy at high flows. Clark Fenton measured a 5.19 foot stage / 163 cfs on 11-29-12 and a 5.52" foot stage / 209 cfs on 12-2-12. The high stage for this year was **7.8 feet / 462 cfs**.

A single discharge rating curve was used for HY 13. The new HY 2013 high flow measurements correlated strongly with a single polynomial curve instead of a low flow and high flow curve. High flow measurements are vital to load accuracy.

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 # 5 FRC HY 2013 Discharge Rating Curve

# 5. Lab Operations 2012

Clark Fenton continues to visit the station periodically to switch out sample bottles as they are filled. North Coast Labs is responsible for processing the ISCO Pump sampler bottles for suspended sediment concentration. The North Coast Lab contact is Bob Stuart at 707-822-4649.

The Francis Creek TTS sampling software triggered **193** ISCO pump samples at rising and descending turbidity thresholds at Site FRC from 10-31-12 to 4-4-13. 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 2013 turbidity / suspended sediment concentration regression chart in Section 1.

Test Methods consist of:

ASTM D 3977 (2002) Standard Test Methods for Determining Sediment Concentration in Water Samples. ASTM D 3977 (2002) was used for Total Solids and suspended sediment concentration.

North Coast Labs reports are on file at the Humboldt County Materials Testing Lab.

# 6. Closing Summary:

The annual suspended sediment yield from the Francis Creek watershed is twice as much as last year or four times as much as HY 11. Residents downstream of the Francis Creek Ranch Slide should prepare for the effects of that much sediment coming down the creek.

The biggest challenge is still to keep the instrument boom at proper depth during large storm events. Clark is forced to raise the transducer pipe and turbidimeter boom every summer now because of streambed aggradation.

After Francis Creek jumped it's banks at several locations on 12-6-12 many residents were frustrated at having complaints about debris in the creek heard by authorities. The Department of Fish and Game allowed debris to be cleared under emergency conditions. Tom Stephens said the only solution is a sediment basin on the Silva property at the end of Eugene Street.

The 900 acre NTMP Non-industrial timber management plan by Leland Timber that includes Francis Creek should strive to allow no discharge of sediment into Francis Creek.

A group of HSU Environmental Resource Engineering students as their Capstone senior project studied and made recommendations on 5-7-13 for flood mitigation measures in lower Ferndale and techniques to reduce sediment deposition in Francis Creek. Their analysis said doubling a storm water pipe from 12" to 24" would convey flows faster through the area. They also designed a 27 acre detention basin in upper Francis Creek to intercept and settle out storm flow suspended sediment. HSU anticipates having students study Francis Creek annually from now on.

The Francis Creek Slide continues to dominate the suspended sediment regime on Francis Creek. Perhaps after it flushes through the watershed the ecosystem can start recovering. I'm torn between wanting the slide to stay in place and the realization the sediment needs to be routed down and out the system to the Eel River for ecosystem healing and unfortunately to perhaps end up in Humboldt Bay.

In July the Salt River Watershed Council met to discuss funding ongoing maintenance and other costs once the project is completed. There are concerns over migratory birds nests slowing down construction until after the migration season and keeping who will keep vegetation cleared so birds don't come back next year. A special district of property owners could be created to fund future costs but this project could benefit people other than adjacent landowners.

Donna Chambers of the HCRCD says that the Salt River project remains substantially on track as of mid-July.

Thanks to Hank Seeman for supporting this program.

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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.