Francis Creek Annual Suspended Sediment Yield

Turbidity Threshold Sampling Summary Report

Hydrologic Year 2018

Site FRC – 1099 Van Ness Avenue Ferndale, California

A collaborative project between

Humboldt County Resource Conservation District
County of Humboldt
City of Ferndale
State Coastal Conservancy
Ocean Protection Council
California Department of Water Resources
National Marine Fisheries Service
Natural Resources Conservation Service
California Department of Fish and Wildlife
Wildlife Conservation Board
U.S. Fish and Wildlife Service
Redwood Sciences Lab

For the

Salt River Ecosystem Restoration Project

By Clark Fenton and Sarah Wilson
8-29-18

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1. Introduction

The Francis Creek Hydrological Year 2018 annual suspended sediment yield was the second lowest in this 11 year study at **1680** tons / square mile / year. Annual suspended sediment yields from the Francis Creek Watershed from HY 2007 to HY 2018 have ranged from a low of **378** tons / square mile / year in 2014 to a high of **22,922** tons / square mile / year in HY 2017. This variation is due in part to annual rainfall totals, storm intensities, landslides and large storm event durations. This 3.2 square mile watershed is still contributing large amounts of suspended sediment into the Salt River, the Eel River and the Pacific Ocean.

The goal of the Salt River Ecosystem Restoration Project is 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 were 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 or at the Salt River Watershed Council website http://saltriverwatershed.org/.

The largest HY 2018 storm event on Francis Creek on January 18th, 2018 transported **1,995 cubic yards** of suspended sediment and was **42%** of the WY 2018 annual total of **4,684 cubic yards and the second smallest annual total in the last 10 years**. Since starting operation in HY 2007 the Francis Creek Turbidity Threshold Sampling station has measured over **300,000 cubic yards** of suspended sediment passing the station.

The turbidity threshold sampling (TTS) software developed by USFS Pacific Southwest Research Station, Arcata -Redwood Sciences Lab triggered **78** ISCO pump sample bottles for HY 2018. The Francis Creek sample bottle suspended sediment concentrations peaked at **14,000 mg/l** this year.

Annual rainfall for the City of Ferndale for Water Year 2018 was **86%** of normal.

Francis Creek transported **10 million pounds** in suspended sediment past Site FRC in HY 2018.

Once again this year HCRCD and GMA ran suspended sediment % sand fraction analysis on various ISCO bottle point samples. The % sand fraction of the 15 Francis Creek suspended sediment samples for HY 2017 ranged from 3% sand at low flows to **34 % sand** at the highest flow sampled of 269 cfs on 2-9-17. For HY 2018 another set of sand fraction samples were taken but because of the lack of large storm events, sampling was limited to low flows.

Site FRC stream channel elevation cross sections were taken with a transit in 2007, 2009 and 2017. Comparing Francis Creek streambed elevations reveals **streambed aggradation of about 1.7 feet** and terrace deposition of about 2 feet from 2007 to 2017. The Van Ness Avenue box culvert has lost about 18% of it's existing area cross section from 2007 to 2017 due to streambed aggradation of bed load gravel. Aggradation continues.

This was the last year the Turbidity Threshold Sampling (TTS) Station on Francis Creek in Ferndale California will be operated. The City of Ferndale will take over and continue the stage data recording only. Hydrologic Year 2018 was the eleventh full year of TTS monitoring on Francis Creek. Thanks to all who made it happen.

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)

Photo #1. 2014 aerial view of mouth of the Eel River and Salt River looking west.

The excavated Francis Creek channel is on the right side of photo.

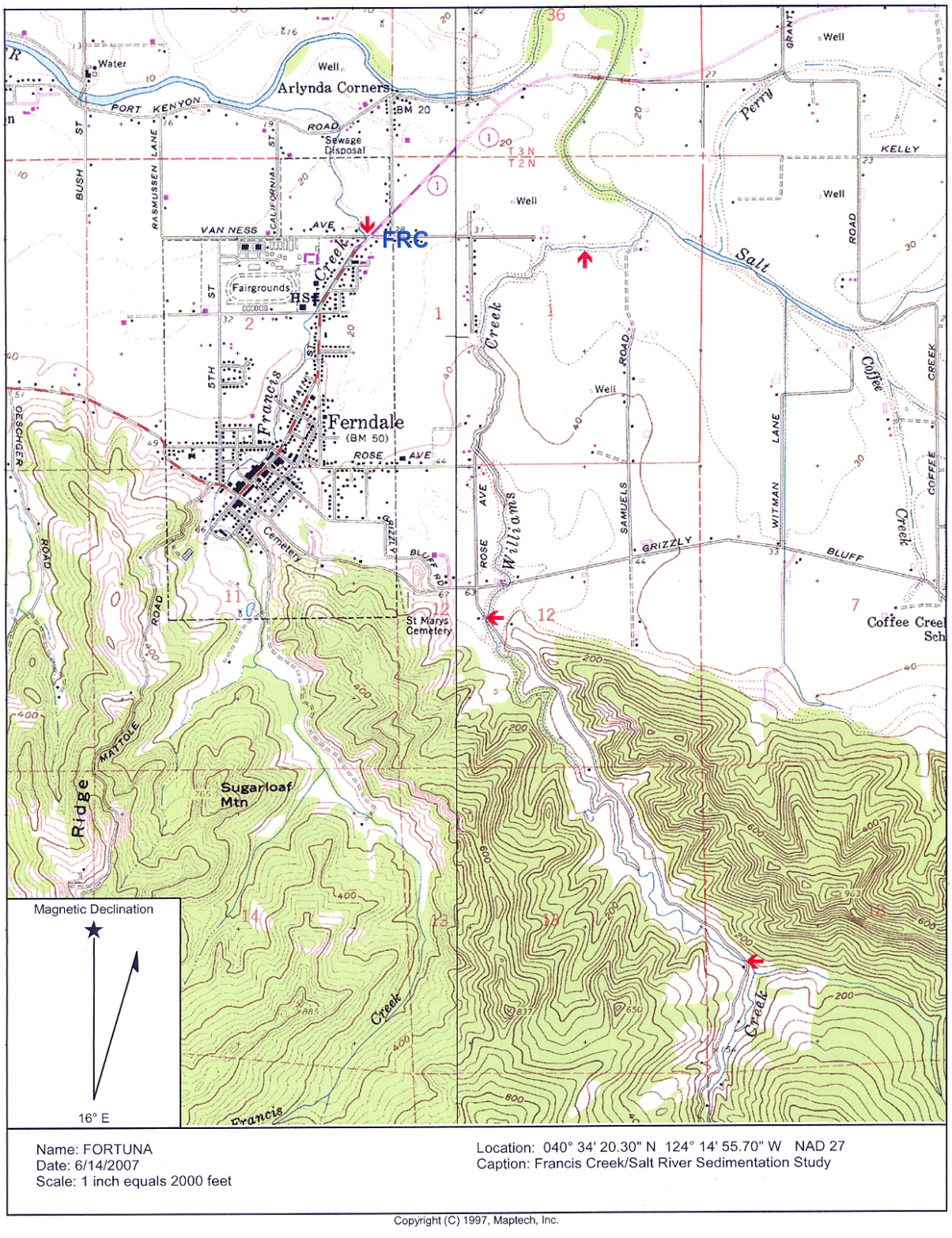


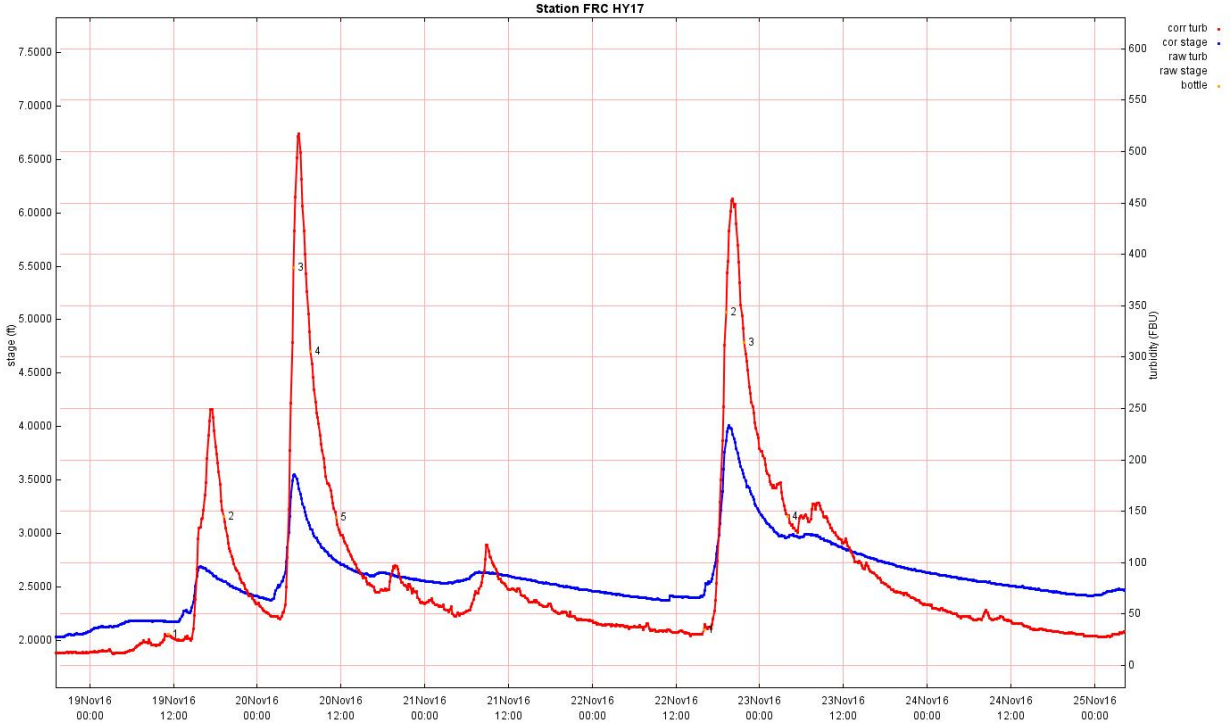
Figure # 1 Francis and Williams Creek monitoring locations

Turbidity Threshold Sampling (TTS)

Jack Lewis and Rand Eads at the USFS Pacific Southwest Research Station, Arcata -Redwood Sciences Lab developed turbidity Threshold Sampling over 15 years ago (Lewis, Eads, 2002). RSL is a research station located above Humboldt State University 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 should be found at http://www.fs.fed.us/psw/topics/water/tts/.

TTS is used to calculate 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, 2014, 2015, 2016 and 2017 are included in Appendix 5. **On-line real time plotting should be available on the HSU website.**
http://fs-server.humboldt.edu/RTMC/FrancisCreek_DetailView.gif

TTS water samples for HY 2018 were sent to the EPA Region 9 Laboratory 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 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 # 1 – Water stage in blue and turbidity in red and sample bottle number.

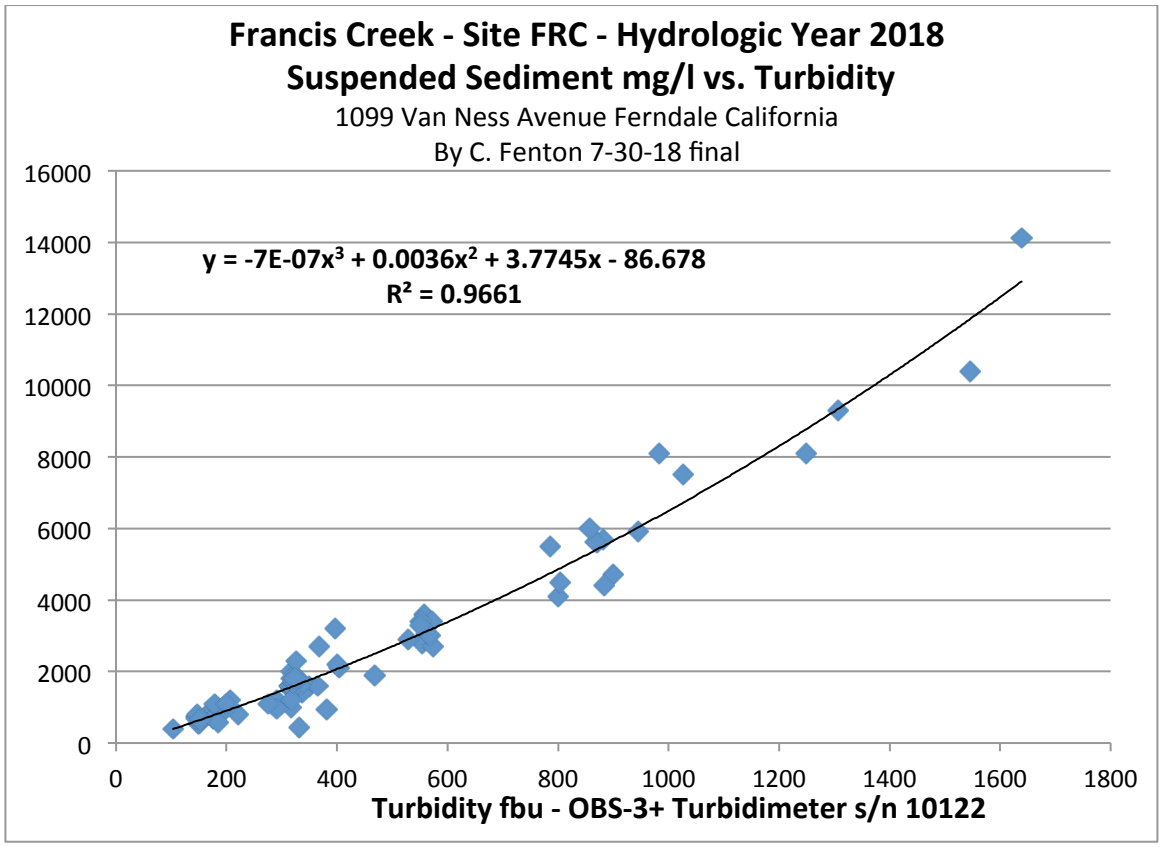
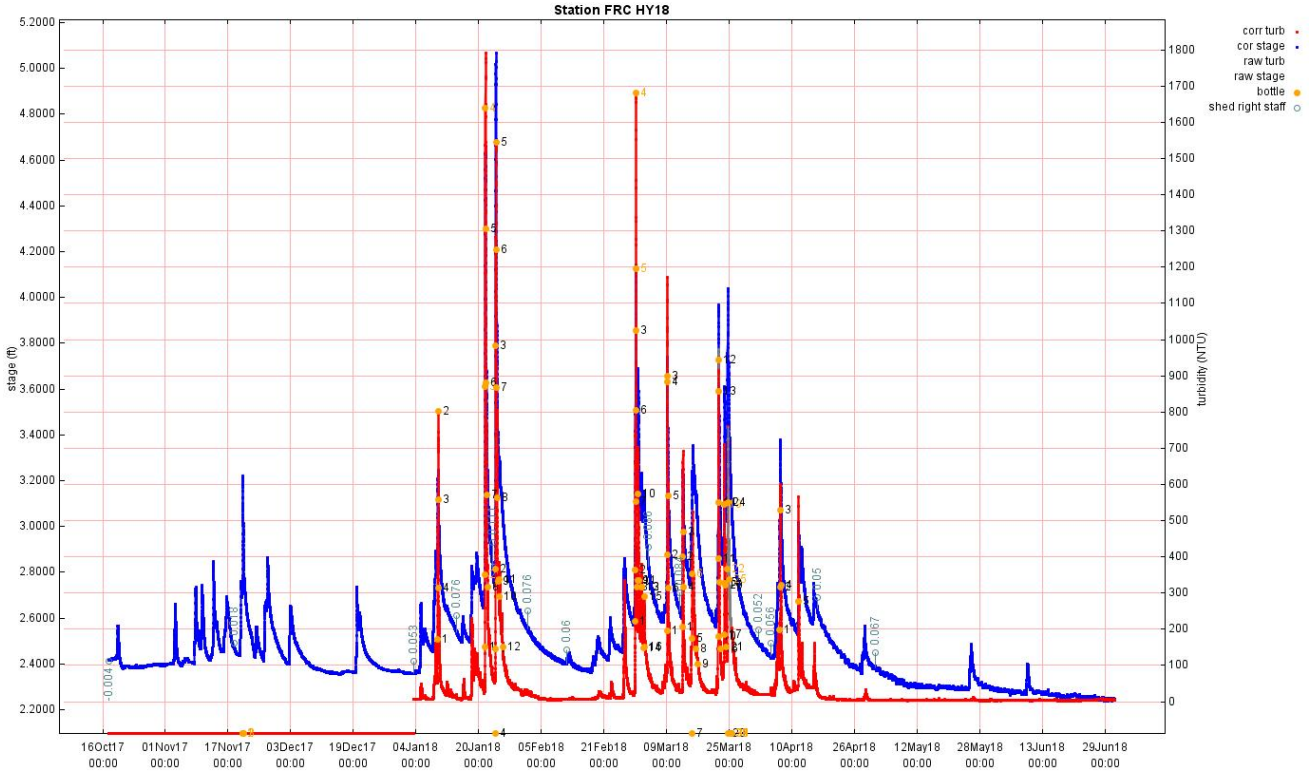
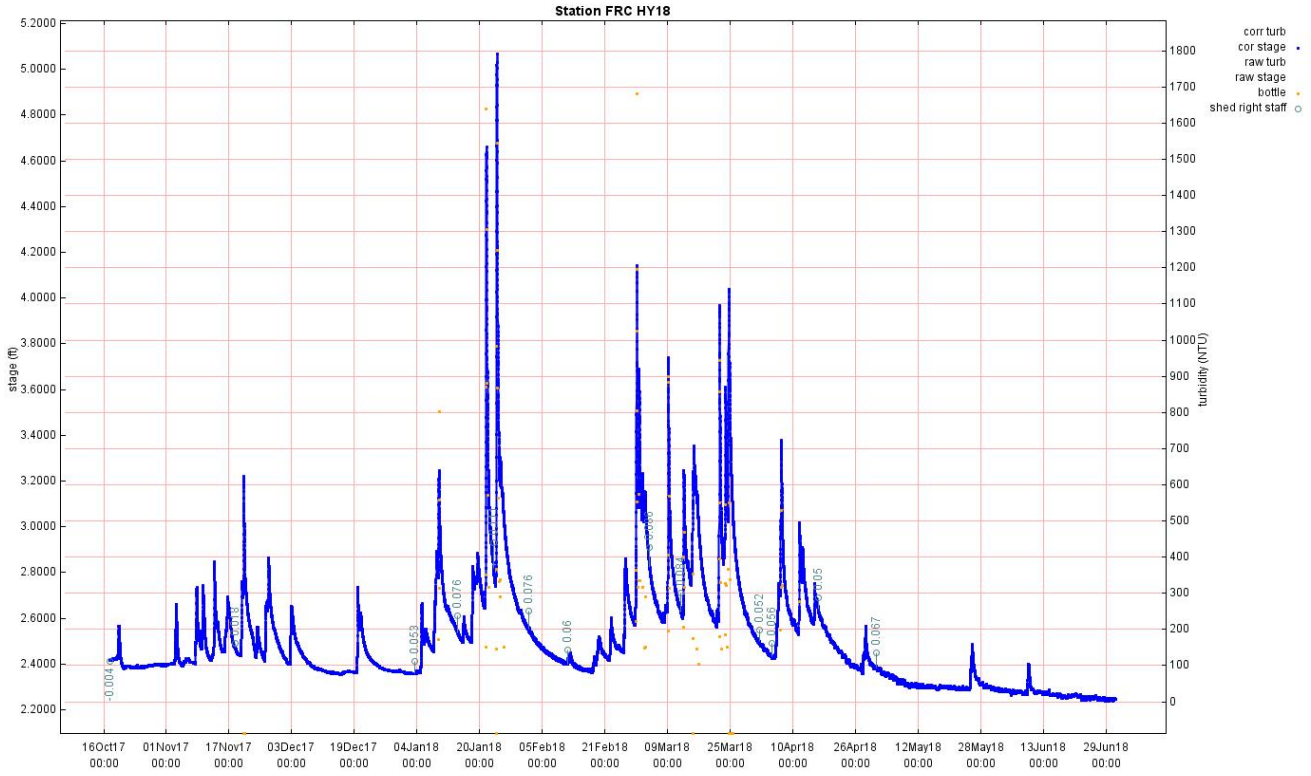


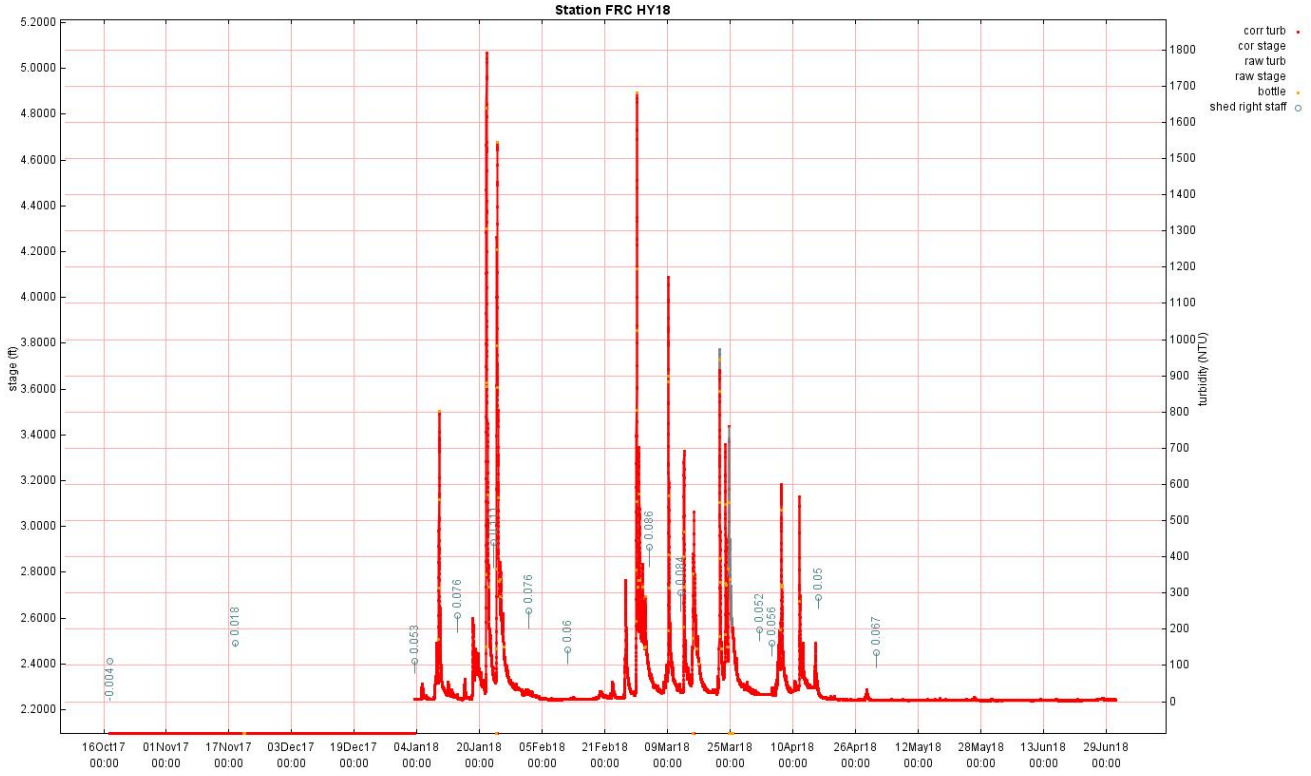
Chart # 1 Turbidity vs. Suspended Sediment Concentration



Plot # 2 Stage / turbidity / bottles plot of HY 2018 at Site FRC on Francis Creek.



Plot # 3 Stage plot of HY 2018. Max storm stage 1-24-18 was 5.07 feet at 180 cfs.



Plot # 4 Turbidity (fbu) maxed out at1800 fbu on 1-24-18 for HY 2018.

2. Francis Creek 2018 Suspended Sediment Load

The Francis Creek TTS Station (Site FRC) is located at the intersection of State Hwy 211 and 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.

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 Susp. Sed. 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
2015	84,450,445	38,316,899	36,798	20,380,963	488	13,195
2016	77,129,899	34,995,417	33,608	10,855,762	335	12,052
2017	146,698,718	66,560,217	63,921	14,357,492	326	22,922
2018	10,748,930	4,877,010	4,684	2,076,931	180	1,680
Totals	**690,246,992**	**313,179,216**	**300,761**			**Avg. 9,805**

Table # 1 – Francis Creek Annual suspended sediment load summaries 2008 to 2018.

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. A bulk specific gravity of 85 lbs. per cubic foot was used to calculate cubic yards of fresh flood deposit sediment. (USDA, 93)

The Ferndale Enterprise reported on 6-28-18 that rainfall for Ferndale for "The weather year to date from 7-1-17 to 6-24-17 was **86%** of average at **35.13** inches. The Weather Year average from 1971, July 1st to 6-24-18 **is 470.72** inches rainfall. Rainfall **last year** from 7-1-17 to 6-24-18 was **66.76** inches. This is the main reason Francis Creek transported so little suspended sediment this year.

The annual suspended sediment load / yield from the Francis Creek watershed above Site FRC for Hydrologic Year **2018** from 6-29-17 to 7-1-18 was **10,748,930 pounds** / **4,877,010 kg** / **4,684 cubic yards** or a annual yield of **1,680 tons per square mile per year** of suspended sediment.

The annual suspended sediment yield from the Francis Creek watershed above Site FRC for Hydrologic Year **2017** from 7-5-16-15 to 6-29-17 was 146,698,718 pounds / 66,560,217 kg / 66,921 cubic yards or a annual yield **of 22,922 tons** per square mile per year of suspended sediment. The annual suspended sediment yield from the Francis Creek watershed above Site FRC for Hydrologic Year **2016** from 7-2-15 to 7-5-16 was 77,129,899 pounds / 34,995,417 kg / 33,608 cubic yards or **12,052 tons** per square mile per year of suspended sediment.

The TTS station at the Van Ness Culvert on Francis Creek has measured a total of just over 300,000 cubic yards of suspended sediment passing by Site FRC since 2007.

The largest suspended sediment estimation period of HY 2018 was storm period 2, the 1-18-18 storm event, yielded **4.6 million pounds** passing the Francis Creek TTS station or 42 % of the HY 18 suspended sediment annual yield.

The **Eel River at Scotia** carries an almost incredible **4,330 tons of suspended 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 yield 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.)

Summary of individual storm suspended sediment estimates:

The table below is from the Sarah Wilson suspended sediment report for FRC **HY 2018**. 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.

FRC18 Summary of Sediment Load Estimates

Summary of sediment load estimates for station FRC, water year 2018
The quality of the estimate for each period depends on 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 (stage or 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 stage, which is coverted to discharge).
An estimate cannot receive a high grade if the quality of the underlying data are questionable.

Discharge rating equation is in three parts this year, until Jan 20, from Jan 20 to April 4, and after April 4
before Jan 20 total discharge = (-2.3195*stage^3 + 35.989*stage^2 - 108.95*stage + 93.756)
Jan 20 to April 4 discharge = (-1.9731*stage^3 + 30.072*stage^2 - 76.233*stage + 35.415)
after April 4 discharge = (-6.1027*stage^3 + 80.113*stage^2 - 264.8*stage + 258.32)
Updated equation for HY 2018

Period	Dates and Times	Dump: Bottles	Sediment Load (kg)	% of Total Load
01	171017,1600,180118,1230	4:1-3 not processed, no data	726,102	14.88%
02	180118,1240,180218,0600	6:1-4, 7:1,5-8, 8:1-12	2,076,931	42.57%
03	180218,0610,180307,0000	9:1-16	595,247	12.20%
04	180307,0010,180321,0000	10:1-6, 11:1-9	485,115	9.94%
05	180321,0010,180404,0000	11: 10-24	856,318	17.55%
06	180404,0010,180601,0750	12:1-5	139,606	2.86%
		Total Load (kg)	**4,879,319**	

Table # 2 – HY 2018 Storm Period Suspended Sediment loads

Sarah Wilson continues to do suspended sediment load analysis with Redwood Sciences Lab TTS Adjuster and R Sed 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 were just transferred to Seattle. I would like to thank Sarah for her loads analysis these last 10 years.

3. Francis Creek 2018 Large Storm Events

The largest sediment producing storm event of Hydrologic Year 2018 was storm period 2 occurring 1-18-18 to 2-18-18 producing 2 million kilograms of suspended sediment.

The highest stage of the year, a 5.07' foot peak / 179.8 cfs on 1-24-18, had 66,000 pounds / **28 cubic yards** of suspended sediment was flowing past the Francis Creek TTS Station **every 10 minutes**. That's comparable to **3 10-yard dump trucks** full of sediment driving by every 10 minutes. That's using the equation ssc = 3953.08(stage)^0.45.

1 Storm Period # 2 – 42.6 % 4,577,556 pounds 1-18-18 to 2-18-18

2 Storm Period # 5 – 17.5 % 1,887,325 pounds 3-21-18 to 4-4-18

3 Storm Period # 1 – 14.9 % 1,600,329 pounds 10-17-18 to 1-18-18

The top 3 storm events / periods contributed over 75 % of the annual suspended sediment load out of 6 storm periods.

Photo # 2. Instrument Shed TTS Station FRC

4. Suspended Sediment % Sand Fraction Analysis HY 2018

HCRCD and GMA determined % sand fraction on various ISCO bottle point samples collected for HY 2017 and HY 2018.

The % sand fraction of the 15 Francis Creek storm event suspended sediment samples for Water Year 2017 ranged from **3% sand at 12 cfs low flow to 34 % sand at the highest flow sampled of 269 cfs** at a 6 foot staff plate / 4 foot water depth on 2-9-17.

Another set of 9 suspended sediment % sand fraction samples were taken for Hydrological Year 2018 but no high flow events occurred to sample. These samples ranged from 13% sand at 30 cfs to 25% sand at 179 cfs.

The HY 2018 samples support the trends seen with the HY 2017 samples.

There are now several active slides in the upper watershed and recent samples probably reflect those sites. Bed load aggradation looks to be about what we expected. Very little, if any of the gravel is generated by the landslide. Qls parent material is predominantly silt, fine sand and clay (mid to upper Rio Dell fm). The gravel source is higher in the section (downstream of the Qls) in the upper Scotia Bluffs, Carlotta, and Hookton formations. (Tom Stephens, personal communication, 2017)

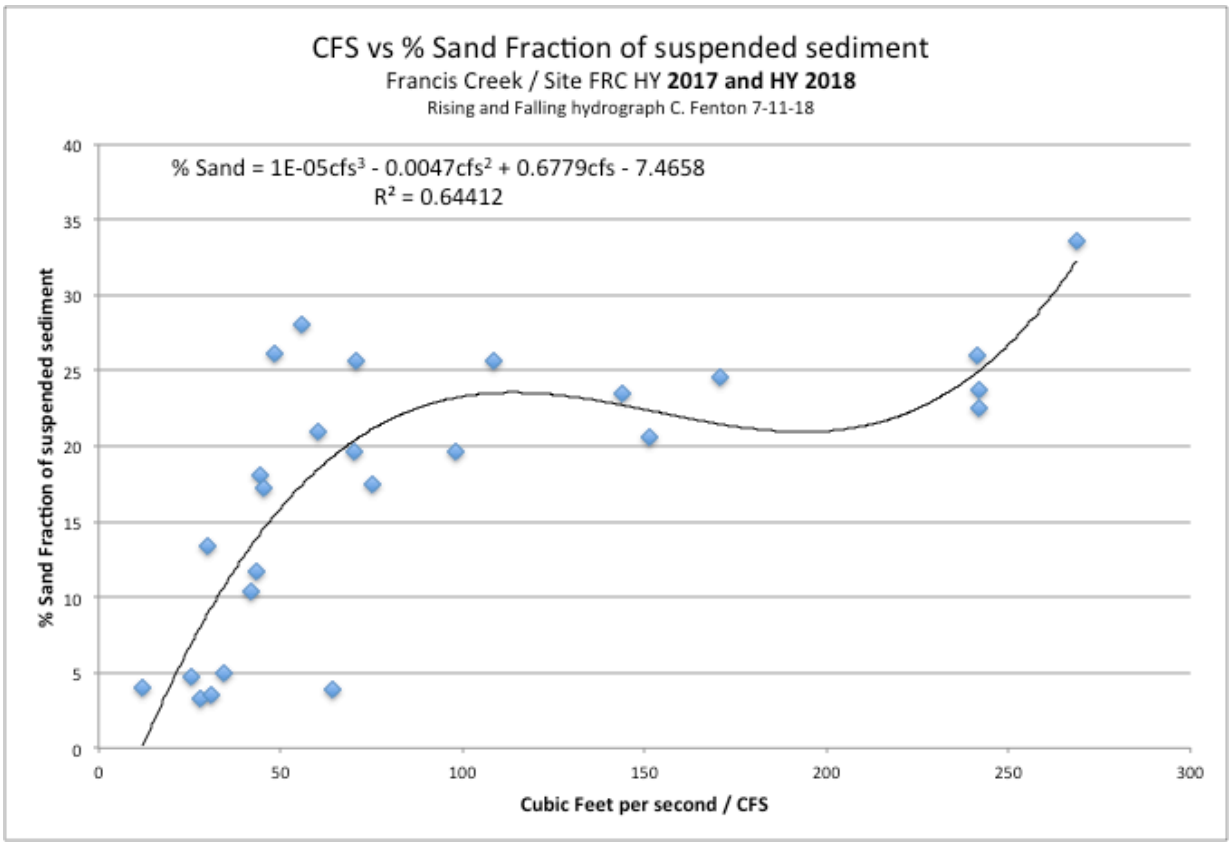


Chart # 2 CFS vs % sand fraction of Francis Creek suspended sediment 2017 / 2018.

Suspended Sediment Sand / Fine Fraction Results from GMA - Francis Creek Site FRC 2017 / 2018

Hydrologic Year 2017 Peak Flow 269 cfs Site FRC cf 7-10-17

Bottle #	Date	Time	Analysis	Fine	Sand	%	%	Flow	limb	Turbidity	SSC		Lab	Lab
	sampled	sampled	Performed	Conc.	Conc.	Sand	Fine	cfs	rise / fall	fbu	Conc.	Unit	Code	Notes
5FRC07	10/30/16	14:00	S/F Split	4250	489	10	90	42	r	301	4,740	mg/l	1	3.246 peak
12FRC01	12/23/16	7:40	S/F Split	239	9.94	4	96	12	f	31	249	mg/l	1	2.447 feet elec stage
12FRC02	12/23/16	15:00	S/F Split	3930	133	3	97	28	r	na	4,060	mg/l	1	2.922
12FRC03	12/23/16	16:00	S/F Split	5210	187	3	97	31	r	na	5,400	mg/l	1	2.991
12FRC04	12/24/16	1:50	S/F Split	4390	228	5	95	34	f	na	4,620	mg/l	1	3.076
12FRC05	12/24/16	14:50	S/F Split	1950	96.3	5	95	26	f	148	2,050	mg/l	1	2.849
14FRC05	1/19/17	18:20	S/F Split	1950	429	18	82	44	f	na	2,380	mg/l	1	3.299
14FRC06	1/20/17	2:30	S/F Split	4120	1420	26	74	71	r	na	5,540	mg/l	1	2 particles > 1 mm 3.818
14FRC07	1/20/17	10:40	S/F Split	8610	1790	17	83	45	f	na	10,400	mg/l	1	4.524
14FRC10	1/20/17	23:10	S/F Split	25610	1050	4	96	64	f	na	26,660	mg/l	1	3.703
14FRC11	1/21/17	13:10	S/F Split	7690	3000	28	72	56	f	na	10,690	mg/l	1	several large particles > 2 mm 3.540
14FRC15	1/22/17	21:50	S/F Split	2140	285	12	88	43	f	na	2,430	mg/l	1	3.282
16FRC06	2/9/17	10:20	S/F Split	18510	9370	34	66	269	r	na	27,880	mg/l	1	aux B 5 10:10 26,000 mg/l per EPA 6.279
16FRC07	2/9/17	12:30	S/F Split	23670	8330	26	74	242	f	na	32,000	mg/l	1	aux sample 5 minutes after GMA DI sample 6.012
16FRC09	2/9/17	16:00	S/F Split	16390	4260	21	79	151	f	na	20,650	mg/l	1	aux B 8 15:50 23,000 mg/l per EPA 5.005
3476Q-6005Q	2/9/17	12:25	S/F Split	21670	6750	24	76	242	f	na	28,420	mg/l	1	GMA DI sample 1 of 2 6.155
3715Q-6272Q	2/9/17	12:25	S/F Split	21890	6370	23	77	242	f	na	28,260	mg/l	1	GMA DI sample 2 of 2

ntu / stage final flo file 7-23-17

Final 7-23-17 HY 17 Discharge Rating Curve is CFS = $-2.3195x^3 + 35.989x^2 - 108.95x + 93.756$

Hydrologic Year 2018 Peak Flow 171 cfs raw

Bottle #	Date	Time	Analysis	Fine	Sand	%	%	Flow	limb	Turbidity	SSC		Lab	Lab
	sampled	sampled	Performed	Conc.	Conc.	Sand	Fine	cfs	rise / fall	fbu	Conc.	Unit	Code	Notes
7 FRC 02	1/21/18	15:20	S/F Split	1360	211	13	87	30	r	350	1,570	mg/l	1	3.174' elec stage
7 FRC 03	1/21/18	16:50	S/F Split	4500	1100	20	80	71	r	871	5,600	mg/l	1	3.754
7 FRC 04	1/21/18	18:10	S/F Split	10810	3320	23	77	144	r	1639	14,130	mg/l	1	4.628
8 FRC 05	1/24/18	10:50	S/F Split	7830	2550	25	75	171	r	1546	10,380	mg/l	1	4.956
8 FRC 07	1/24/18	13:50	S/F Split	4180	1440	26	74	109	f	867	5,620	mg/l	1	4.214'
8 FRC 08	1/24/18	18:40	S/F Split	2400	635	21	79	60	f	562	3,040	mg/l	1	3.622'
9 FRC 04	3/1/18	3:20	S/F Split	8330	2030	20	80	98	r	1682	10,400	mg/l	1	4.092' peak
9 FRC 05	3/1/18	4:30	S/F Split	5520	1170	17	83	75	f	1195	6,690	mg/l	1	3.811'
6008-6017	3/22/18	10:53	S/F Split	1670	591	26	74	49	f	446	2,260	mg/l		GMA / FRAN 3.461'

Final 4-4-18 HY 2018 Discharge Rating Curve CFS = -6.1027 * stage ^3+ 80.113* stage^2 - 264.8 * stage + 258.32

GMA Lab Codes

1 All analysis performed in accordance with Quality Manual, dated December 28, 2012

2 The following exceptions to EPA Method 180.1 were noted:

3 Sample concentrations are below reporting limits Sand > # 230 sieve per GMA rising or falling limb?

cf 7-10-18

Table # 3 Suspended sediment % Sand Fraction data 2017 / 2018.

5. Stream Channel Aggradation Survey 2007 to 2016

The Francis Creek stream bed and stream bank terrace here are rising over time. Site FRC stream channel elevation cross sections were taken with a transit in 2007, 2009 and 2017. Comparing Francis Creek streambed elevations reveals streambed aggradation of about 1.7 feet and about 2 feet of suspended sediment deposit on the lawn / terrace of 1099 Van Ness Avenue since 2007. The Van Ness Avenue box culvert has lost about 18% of it's existing area cross section since 2007 due to streambed aggradation of bedload gravel.

Photo # 3. Baseline Streambed transit survey 2-5-07

Francis Creek / Van Ness Culvert stream bed gravels aggradation / deposition:
Crossection surveys from 3-12-09 and 12-29-16 / 7.7 years.
1.7 feet stream bed aggradation river left or 0.22 feet per year
0.7 feet stream bed aggradation river right or 0.09 feet per year
Mean stream bed aggradation 1.2 feet per 7.7 years or 0.16 feet per year

From downstream foot bridge mid plank end to stream bed surveys 2-5-07 and 12-29-16 / 9.9 years.
1.36 feet stream bed aggradation mid channel in 9.9 years
0.14 feet stream bed aggradation per year

Suspended sediment aggradation / deposition lower terrace river right yard of 1099 Van Ness Avenue:
Surveys 2-5-07 and 12-29-16.
2.36 feet suspended sediment aggradation in 9.9 years
0.24 feet suspended sediment aggradation per year

Van Ness Box culvert reduction in capacity 2-5-07 to 12-29-16:
87.96 square feet reduced to 71.64 square feet = **18.6% reduction crossectional area**

Bed load aggradation looks to be about what we expected. Very little, if any of the gravel is generated by the landslide. Qls parent material is predominantly silt, fine sand and clay (mid to upper Rio Dell fm). The gravel source is higher in the section (downstream of the Qls) in the upper Scotia Bluffs, Carlotta, and Hookton formations. (Tom Stephens, personal communication, 2017)

Since bedload sampling isn't happening, can't tell how much is moving through the section. For now, the stream bedload appears to be in kind of dynamic equilibrium; what comes in passes through with a little accumulation. Aggradation of 0.16'/yr is about the diameter of a medium gravel clast.
(Tom Stephens, personal communication, 2017)

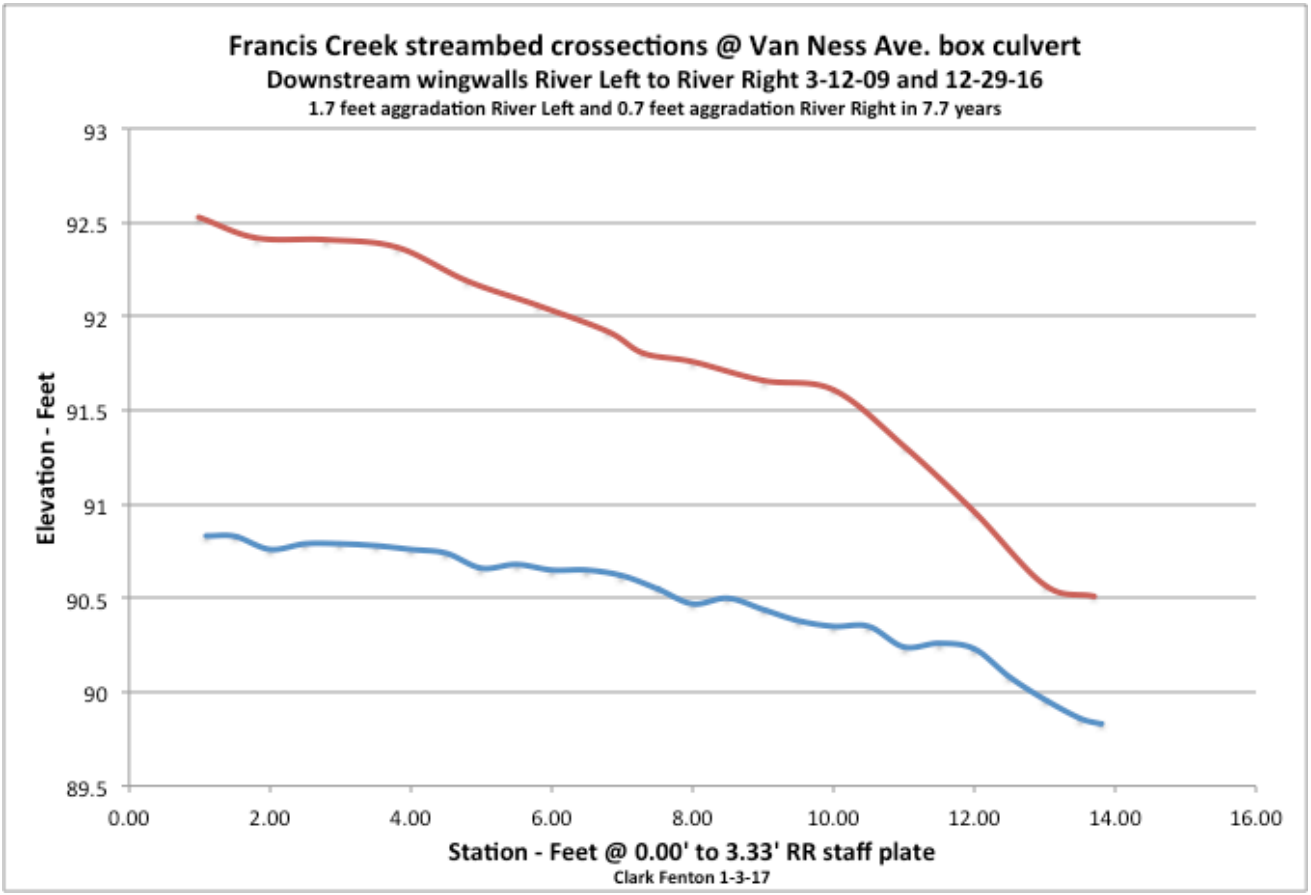


Chart # 3 Francis Creek Streambed Aggradation 2009 to 2016

6. 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.

Photo # 4. Francis Creek Ranch Slide April 2011

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)

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.

7. Field and Lab Operations HY 2018

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. Funding has stopped for maintaining a TTS station and the City of Ferndale will take over doing stage / flow monitoring.

Photo # 5. - Site FRC at 1099 Van Ness Avenue 2007

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. http://fs-server.humboldt.edu/RTMC/FrancisCreek_DetailView.gif

The sampling / tubidity sensor boom was raised this spring due to streambed aggradation**.** The instrument boom is right where the most stream bed aggradation is occurring. The instrument shed was raised about 2 feet on 7-17-18 by volunteers Wayne, Martin, Tom, Tom and Clark.

Turbidity:

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.

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.

Photo # 6 Francis Creek culvert sampling boom with OBS-3+ turbidimeter and Chestnut.

Discharge Measurements HY 2018:

A single discharge rating curve 4-4-18 was used for HY 18. A 3rd order polynomial discharge rating curve equation was used to try to reflect the low flows better and be conservative for the high flow calculations.

Clark Fenton collected 5 discharge measurements for Hydrologic Year 2018. The deepest wading rod measurement was at 2.91 feet @ 13.4 cubic feet per second and the baseline HY 17 wading rod measurement was 2.41 feet at 0.39 cfs. Zero gage height / flow for HY 2018 was 2.35 feet.

The highest stage for Hydrologic Year 2015 was **8.04 feet @ 488 cfs** on February 6th, 2015.
The highest stage for Hydrologic Year 2016 was **6.754 feet @ 335 cfs** on March 5th, 2016.
The highest stage for Hydrologic Year 2017 was **7.59 feet @ 326 cfs** on December15, 2016.
The highest stage for Hydrologic Year 2018 was 5.07 feet @ 180 cfs on January 24th, 2018

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.

Photo # 7. Clark Fenton discharge measurements

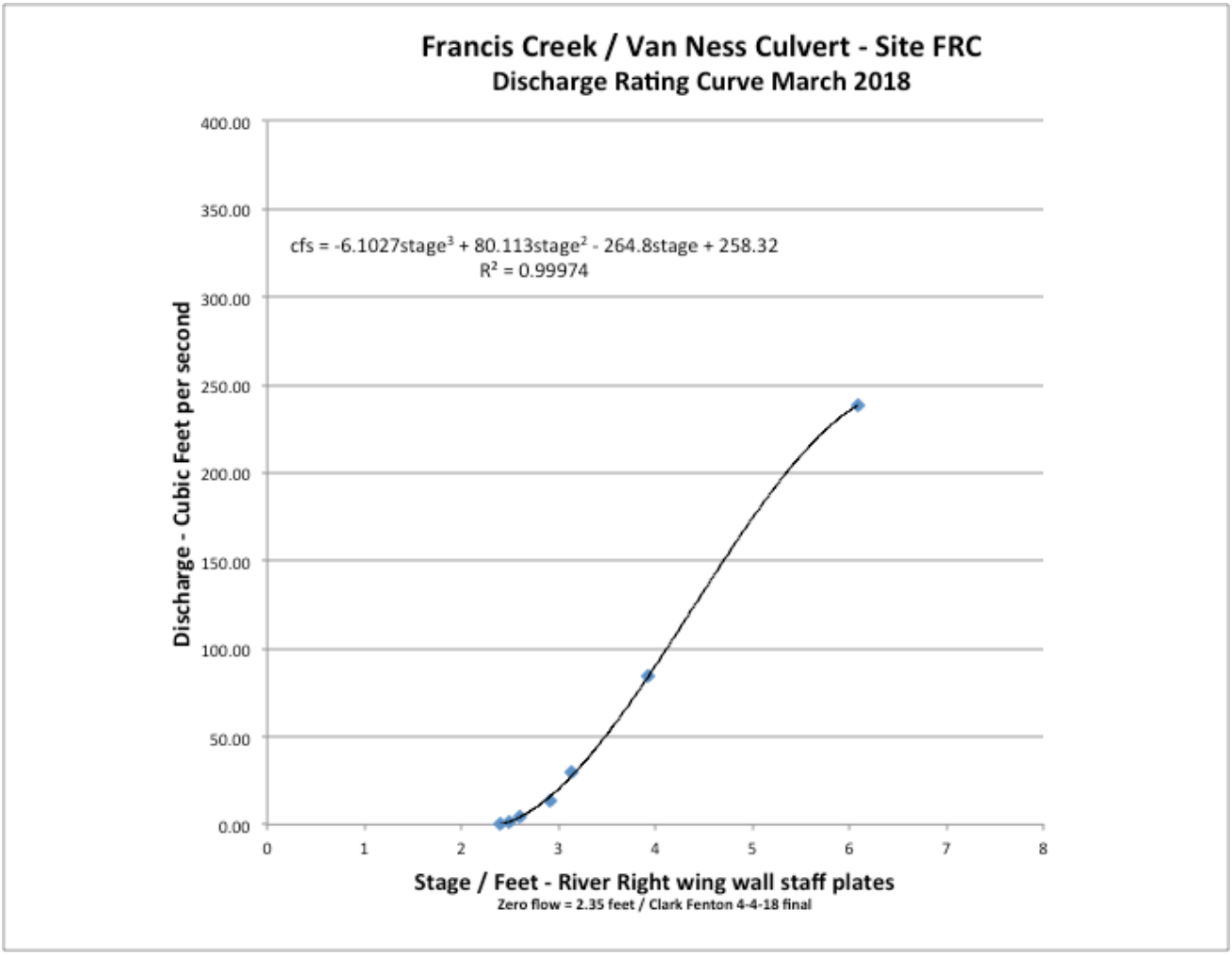


Chart # 4. Site FRC HY 2018 Discharge Rating Curve

See Appendix 3 for discharge sheets and rating curves.

Aggradation or rising of the streambed around the staff plates from bed load mobilization is still being observed. The streambed is mobile gravels and annual discharges are needed in this location to ensure representative discharge measurements. A streambed aggradation correction to stage measurements of about 2 feet is being considered. **A 6-foot staff plate water depth was about a 3.65-foot water depth in 2018.**

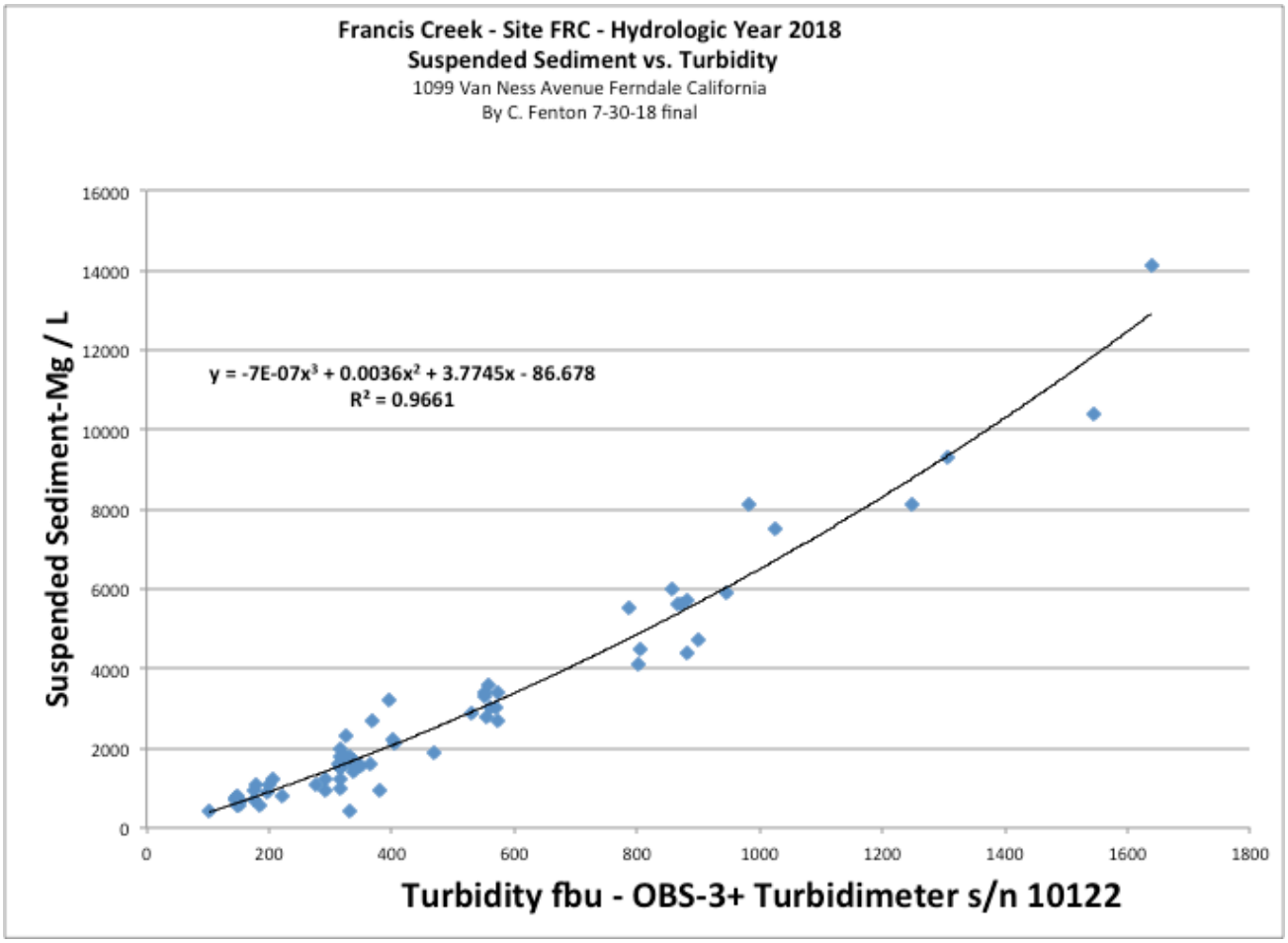
Lab Operations 2018

The United States Environmental Protection Agency – Region 9 Laboratory ran the Francis Creek suspended sediment concentration (mg/l) samples for Hydrologic Year 2018. Suspended sediment concentration determination by subtracting filtering (SSC / Sand Fraction - ASTM D3977 -02) was used.

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.

The suspended sediment concentration of each bottle is compared to the corresponding OBS-3+ Turbidity and a regression is developed for each storm period. **If turbidity data isn't available a regression with flow vs. ssc is developed and used.**

The Francis Creek TTS sampling software triggered **78** ISCO pump samples in HY 2018, **192** ISCO Pump samples in HY 2017, **234** ISCO Pump samples in HY 2016, **100** ISCO Pump samples in HY 2015, **34** ISCO Pump samples in HY 2014 and **193** ISCO pump samples for HY 2013. Francis Creek 2018 sample bottle suspended sediment concentrations peaked at 14,000 mg/l.



8. Closing Summary:

Francis Creek has been transporting an average of 30,000 cubic yards of suspended sediment each year over the last 10 years for a total of over 300,000 cubic yards. The Francis Creek watershed contributed 4,684 cubic yards of suspended sediment this year. Some of this sand, silt and clay is transported down to the Salt River and to the mouth of the Eel River. The mouth of Humboldt Bay is 8 miles north up the coast.

The Francis Creek Hydrological Year 2018 annual suspended sediment yield was the second lowest in this 10 year study at **1680** tons / square mile / year. Annual suspended sediment yields from the Francis Creek Watershed from HY 2008 to HY 2018 have ranged from a low of **378** tons / square mile / year in 2014 to a high of **22,922** tons / square mile / year in HY 2017. This variation is due in part to annual rainfall totals, storm intensities, landslides and large storm event durations. This 3.2 square mile watershed is still contributing large amounts of suspended sediment into the Salt River. Williams Creek is the biggest tributary to the Salt River and the HCRCD is exploring working there in the future.

The streambed gravel bedload aggradation at the Van Ness Avenue box culvert has been 1.7 feet and the adjoining streambank terrace aggradation has been about 2.0 feet over the last 10 years. The Francis Creek stream channel at the Van Ness Culvert is losing it's conveyance capacity and raising the chances smaller storms to cause flooding similar to larger storms earlier.

The Francis Creek March 2011 large slide has not had any major movement in awhile. Various smaller slides and mass wasting issues are occurring in the Francis Creek and Williams Creek watersheds.

It was a surprise to measure up to 34% suspended sediment sand fraction in HY 17 at moderate to high flows. HY 18 sand fraction samples were all low flow. At higher flows we can expect the % sand fraction to be over 50%.

The pair of high quality 12-volt equipment batteries that HCRCD bought several years ago are still working well. The datalogger is 10 years old now and is still faithfully functioning. Unfortunately Campbell Scientific no longer supports the datalogger and PC208W software at the Francis Creek TTS monitoring station and a complete upgrade is needed for the next 10 years of monitoring.

A cellular modem for transmitting data is needed as Redwood Sciences Lab, who hosts the on-line plotting site with the HSU Geospatial Center, is moving all their TTS stations to cellular modems and software. This would make the Francis Creek on-line stage plotting more secure and easier for RSL to support.

I would like to thank Hank Seeman, Jay Parish, Summer Daughterty, Jill Diemers and everyone else who made this Turbidity Threshold Sampling Station a reality for 11 years.

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