ANNUAL REPORT FOR MONITORING OF SUSPENDED SEDIMENT CONCENTRATIONS AND TURBIDITY DURING THE 2016 WATER YEAR IN MCCLOUD CREEK, HUMBOLDT COUNTY, CALIFORNIA

Pursuant to:
Monitoring and Reporting Program (MRP)
Order No. R1-2012-0088

Submitted:
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GREEN DIAMOND
RESOURCE COMPANY

1.0 Introduction

Elk River is listed as an impaired water body under Section 303(d) of the Federal Clean Water Act (USEPA, 1999) due to high instream sediment loads and associated adverse impacts to the beneficial uses of water. To address the Elk River sediment impairment, the North Coast Regional Water Quality Control Board (NCRWQCB) adopted Watershed Waste Discharge Requirements (WWDRs), Order No. R1-2006-0042. In addition to this order the NCRWQCB is developing a Total Maximum Daily Load (TMDL) for sediment in Elk River. Monitoring and Reporting Program (MRP), Order No. R1-2008-092, describes the monitoring and reporting efforts Green Diamond Resource Company (GDRCo) has been conducting since 2006, as part of the South Fork (SF) Elk River WWDRs. In October 2012, new property wide WDRs (Order No. R1-2012-0087) and an associated MRP (Order No. R1-2012-0088) superseded the SF Elk River WWDRs and incorporated its substantive conditions and monitoring program.

As part of the MRP (Order No. R1-2012-0088), GDRCo has agreed to conduct a water-quality trend monitoring study in McCloud Creek, a tributary of SF Elk River. Using Turbidity Threshold Sampling (TTS), GDRCo measured stage, water velocity, turbidity and suspended sediment concentration in McCloud Creek during the 2016 water year (WY). This report covers the period from September 23, 2015 through July 1, 2016, during which TTS monitoring occurred.

2.0 Data Collection and Analysis Activities

Data collection and analysis have been conducted as outlined in the MRP (Order No. R1-2012-0088), Standard Operating Procedures, and the Turbidity Threshold Sampling Quality Assurance Project Plan for McCloud Creek. See this document for further details on the monitoring parameters, protocols, and frequencies.

2.1 Station Installation and/or Adjustments

Equipment was installed at the McCloud Creek TTS station for the 2016 WY on September 23, 2015. The surface hydrology was inadequate for monitoring at that time and subsequent dry channel and low flow conditions prohibited monitoring until November 15th. On November 15, the station was turned online in anticipation of forecasted rain. Suitable monitoring conditions at the site continued through the remainder of the WY.

2.2 Continuous Measurement Stations

The TTS station was established in McCloud Creek on BLM property, approximately 400 feet upstream from the confluence with SF Elk River (Figure 1). The watershed area above the McCloud TTS monitoring site is approximately 1,482 acres. The specifications for the construction and operation of the TTS station are based on procedures developed by the United States Forest Service Redwood Science Laboratory (Lewis and Eads 2008). The station automatically records stage height (i.e., water depth) and turbidity at 10-minute intervals and collects and stores automated grab samples of creek water, which are transported to the lab and analyzed to quantify turbidity and suspended sediment concentration. Table 1 displays all of the parameters and frequency of measurements collected at the McCloud Creek TTS station.

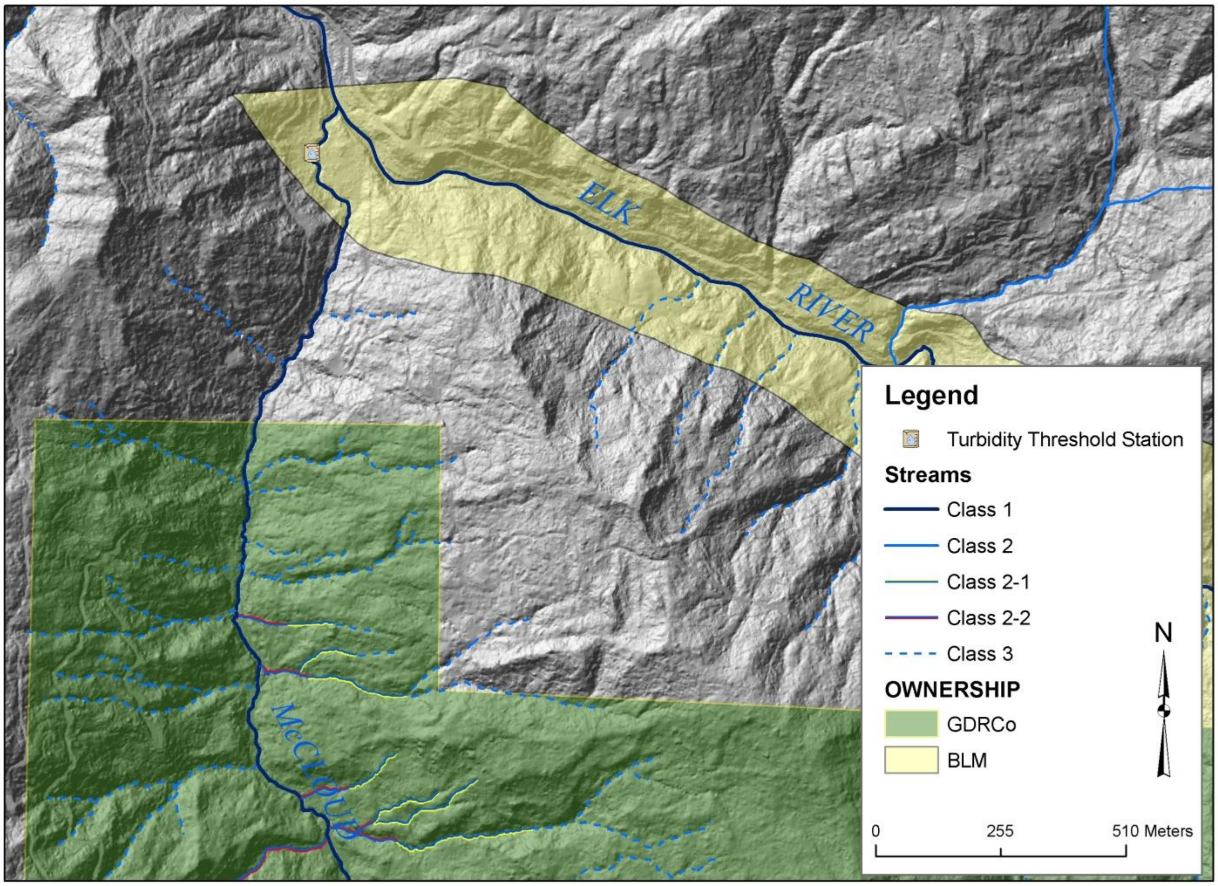

Figure 1. Location of the McCloud Creek TTS station.

2.2.1 Field Visits – Summary of Logs

A total of 45 field visits (frequency ≈ 5 per month) were conducted during the 2016 WY. Visits were conducted to exchange bottles and batteries, download data, take flow measurements, or perform other storm related and maintenance activities. A summary of the activities conducted during the 2016 WY is provided below (Table 2).

2.2.2 Site Observations

A summary of site observations were compiled for the 2016 WY (Table 3). These site visit observations included notable items, unrelated to the station status but related to the site conditions. Observations for this WY included hydrologic conditions.

Table 1. McCloud Creek TTS station, parameters and specifications.

Parameter	Units	Sampling Method	Sampling Frequency
Turbidity	FNU	DTS-12 (turbidimeter, *in situ* measurement	Continuous (10 minute interval)
Turbidity	NTRU	Manual ISCO sample	Weekly[1]
Suspended sediment	mg/L	Manual ISCO sample	Weekly[1]
Suspended sediment	mg/L	Automated ISCO sample.	Turbidity threshold sampling
Discharge	cfs	Direct measurement	Weekly[1] and as needed for stage-discharge relationship
Stage	feet	Druck (pressure transducer, *in situ* measurement)	Continuous (10 minute interval)
Stage	feet	Staff plate	Weekly[1] and when present for stream flow measurements

[1] This frequency varies at times due to high flows during storm events, which restrict access to the McCloud Creek TTS station and low flow conditions where velocity is below minimum required for flow-meters.

Table 2. Summary of field activities at the McCloud Creek TTS station during the 2016 WY.

Date	Type*	Comments
9/23/2015	SI	Monitoring equipment installed and tested, station offline.
10/1/2015	SI/MA	DTS replaced, station offline.
10/28/2015	MO	Station kept offline.
11/2/2015	MO	Station kept offline.
11/9/2015	MO	Station kept offline.
11/15/2015	MO/MA	Station online.
11/18/2015	MO	Discharge measured.
11/23/2015	MO/MA	Discharge measured, 9V harness replaced.
12/2/2015	MO	Discharge measured.
12/4/2015	MO/MA	Discharge measured, DTS adjusted.
12/9/2015	MO/MA	Discharge measured, DTS adjusted.
12/11/2015	MO/MA	Discharge measured, DTS adjusted.
12/14/2015	MO/MA	Discharge measured.
12/21/2015	MO	Could not access site due to high flows.
12/22/2015	MO	Could not access site due to high flows.
12/23/2015	MO/MA	ISCO internal tubing replaced, DTS adjusted, discharge measured.
12/28/2015	MO	Discharge measured.
1/4/2016	MO	Discharge measured.
1/13/2016	MO/MA	Discharge measured, DTS adjusted.
1/19/2016	MO/MA	Discharge measured, DTS adjusted.
1/25/2016	MO/MA	Discharge measured, DTS adjusted.
1/29/2016	MO/MA	Discharge not measured, DTS adjusted.
2/1/2016	MO/MA	Discharge measured, DTS adjusted.
2/8/2016	MO/MA	Discharge measured, DTS adjusted, stage offset re-calculated.
2/18/2016	MO/MA	Discharge measured, DTS adjusted.
2/22/2016	MO/MA	Discharge not measured, DTS adjusted.
2/29/2016	MO/MA	Discharge measured, DTS adjusted.
3/4/2016	MO	Discharge measured.
3/7/2016	MO/MA	Discharge measured, DTS adjusted.
3/11/2016	MO	Discharge measured.
3/15/2016	MO/MA	Discharge measured, adjusted datalogger clock.
3/22/2016	MO	Discharge measured.
3/28/2016	MO/MA	Discharge measured, DTS adjusted.
4/7/2016	MO/MA	Discharge measured, DTS adjusted, stage offset re-calculated.
4/14/2016	MO/MA	Discharge measured, stage offset re-calculated, ISCO volumes calibrated.
4/20/2016	MO/MA	Discharge measured, DTS adjusted, stage offset re-calculated, ISCO volumes calibrated.
4/25/2016	MO/MA	Discharge measured, ISCO volumes calibrated.
5/6/2016	MO	Discharge measured.
5/9/2016	MO	Discharge measured.
5/16/2016	MO/MA	Discharge measured, DTS adjusted.
5/23/2016	MO	Discharge measured.
5/31/2016	MO	Discharge measured.
6/6/2016	MO/MA	Discharge measured, DTS adjusted.
6/13/2016	MO	Discharge measured.
6/20/2016	MO	Discharge not measured.
6/29/2016	MO	Discharge not measured.
7/1/2016	SD	Discharge not measured, DTS and ISCO taken offline for the year.

*Type: MO = Monitoring (data dumps, flow measurements, and grab samples),
MA = Maintenance (sensor cleanings and site adjustments),SI = Site installation, and SD = site dismantle.

Table 3. Summary of site observations collected at the McCloud Creek TTS station during the 2016 WY.

Date	Comment
09/23/15	Monitoring equipment installed and tested. Station offline due to dry conditions, will turn on when conditions allow.
10/28/15	Site is dry after minor rain event. Station kept offline.
11/02/15	Site is dry after minor rain event. Isolated pool is present below stage plate. Station kept offline.
11/09/15	Site is dry after minor rain event. Isolated pool is present below stage plate. Station kept offline.
11/15/15	Channel is wetted but still hydrologically disconnected. Turned station online.
11/18/15	Channel is hydrologically connected.

2.2.3 Download Data Summary

The data logger at the TTS station was downloaded to a field PC at least weekly when the station was online. The files were then transferred to the GDRCo server and compiled into a proprietary SQL database. Editing and analysis were performed using this database, Forest Technology Systems StreamTrac© software, Aquatic Informatics' AQUARIUS Time-Series©, and Microsoft Excel. The output data file for this report is labeled as "Appendix_A _MC2_All_Data_2016WY.xls" and was submitted with this annual report in accordance with the NCRWQCB 2014 electronic document submission guidelines.

2.2.3.1 Stage-Discharge Relationship

During the 2016 WY, GDRCo personnel collected 34 velocity measurements, using a current meter, and associated stage readings on the staff plate. Using Aquatic Informatics' rating development tool (Aquarius, 2016), we used a composite fitting technique (McCuen and Synder, 1986) with a breakpoint selected at 1.04 feet of stage height to develop a rating curve for WY 2016 between discharge and stage (Figure 2). The rating curve is a compound curve consisting of two segments, one for low flow conditions (section control) which is controlled by small gravels that often move during storms and one for medium flows (channel control) which consists of a larger substrate that shifts less frequently. This breakpoint was selected because it is thought to be the division of the section and channel control. At stages ≤ 1.04 feet, most discharge measurements included verticals with measured velocities < 0.25 fps (n = 9), values at the low end of the rated measurement capacity of the USGS Pygmy (Model 6205) flowmeter. Measurements within this range displayed relatively high variance.

In addition, at stages ≤ 1.04 feet, discharge measurements appeared to shift from the base rating curve in the latter part of the water year. This is likely due to a change to the channel morphology at the monitoring site during or after a major storm event. It is difficult to identify the exact timing of the shift, as these low stage conditions only occurred during the beginning and end of the water year.

At stages > 1.04 feet, in the channel control, velocities measured within each discharge measurement were within the acceptable range of rated flowmeter measurement capacity. Measurements within this range display less variance and appear to fall onto the same rating curve throughout the water year. These composite cut points provided the best fit of data in each of the two segments.

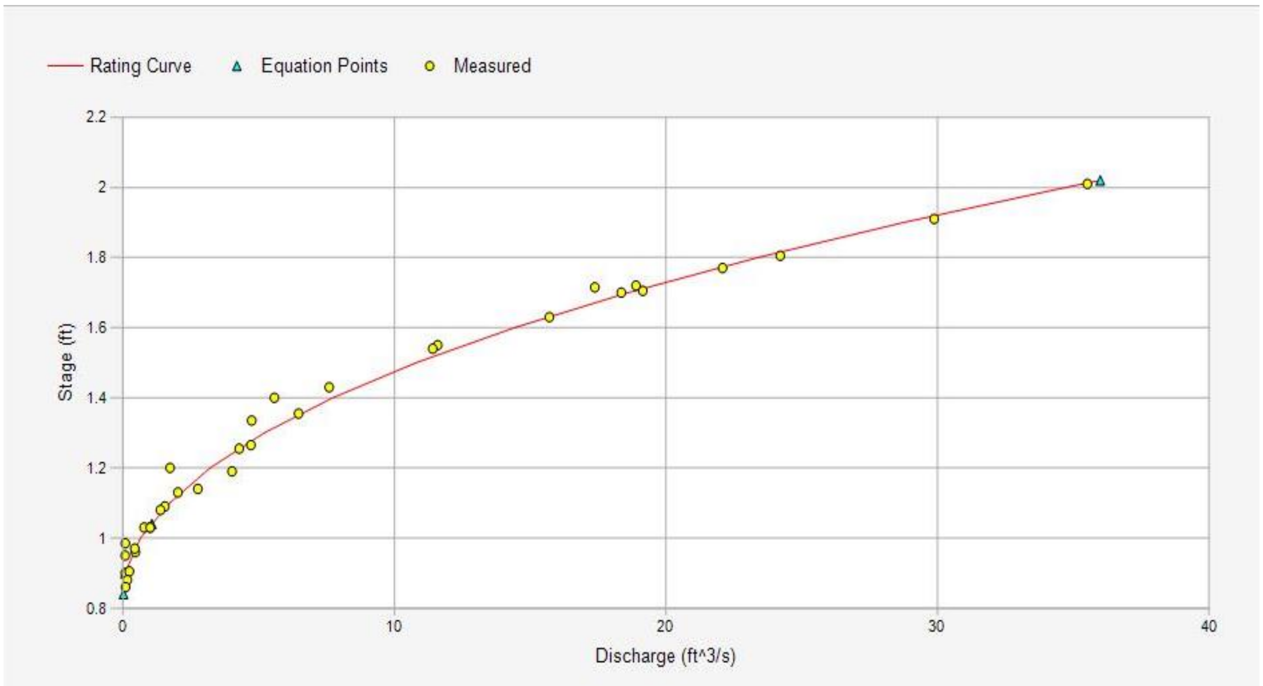

Figure 2. Discharge-stage relationship for WY 2016. This graph only includes the range of stage values that were measured in the field.

Discharge values estimated from stages greater than the maximum measured discharge (i.e., stage > 2.02 ft) for the 2016 WY were extrapolated using the Gauckler-Manning formula (Manning, 1891) and the rating curve to produce an expanded relationship between discharge and stage to include all continuous stage data (Figure 2.1). These data should be used and viewed with caution without empirical support. Efforts were made during this and previous WYs to obtain measurements at higher stages but site access was prohibited at these times because access required wading across SF Elk River, which was unsafe at high flows.

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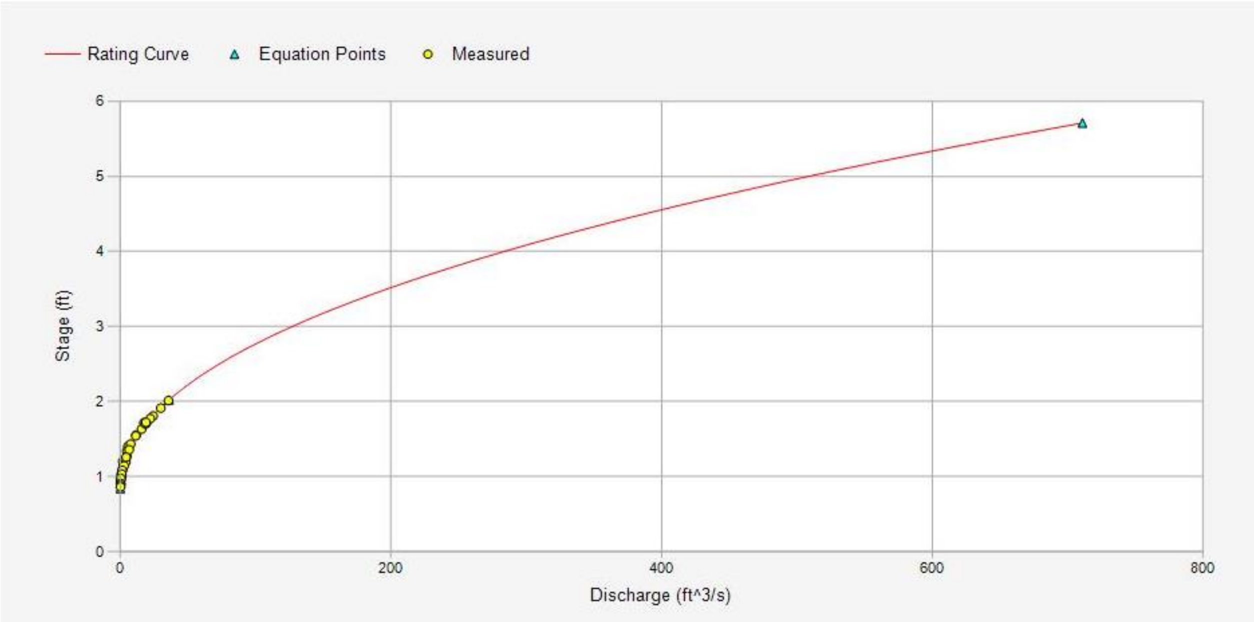

Figure 2.1. Discharge-stage relationship for WY 2016. This graph includes the range of stage values that were measured in the field (Yellow Circles) and an estimated maximum value based on the Gauckler-Manning formula (Blue Triangle).

2.2.3.2 Continuous Discharge

Continuous discharge for the 2016 WY (Figure 3) was estimated using the regressions calculated in AQUARIUS from the stage-discharge relationships that include extrapolated values (Figure 2.1). The estimated peak discharge for McCloud Creek during the 2016 WY occurred on January 17 and was ≈ 592 cfs (stage = 5.35 ft). Due to the safety limitations involved in wading across SF Elk River during storm events, discharge measurements at the McCloud TTS site were not taken at stages > 2.02 feet (≈ 36 cfs) during the 2016 WY. Despite this limitation, 95.8% of the stage measurements recorded during the 2016 WY were within the range of measured discharges and considering the strong relationship between stage and discharge, extrapolated discharges within this range have high confidence. The extrapolated discharge values that exceed the range of empirical values have a high uncertainty given the lack of discharge measurements for stages greater than 2.02 ft.

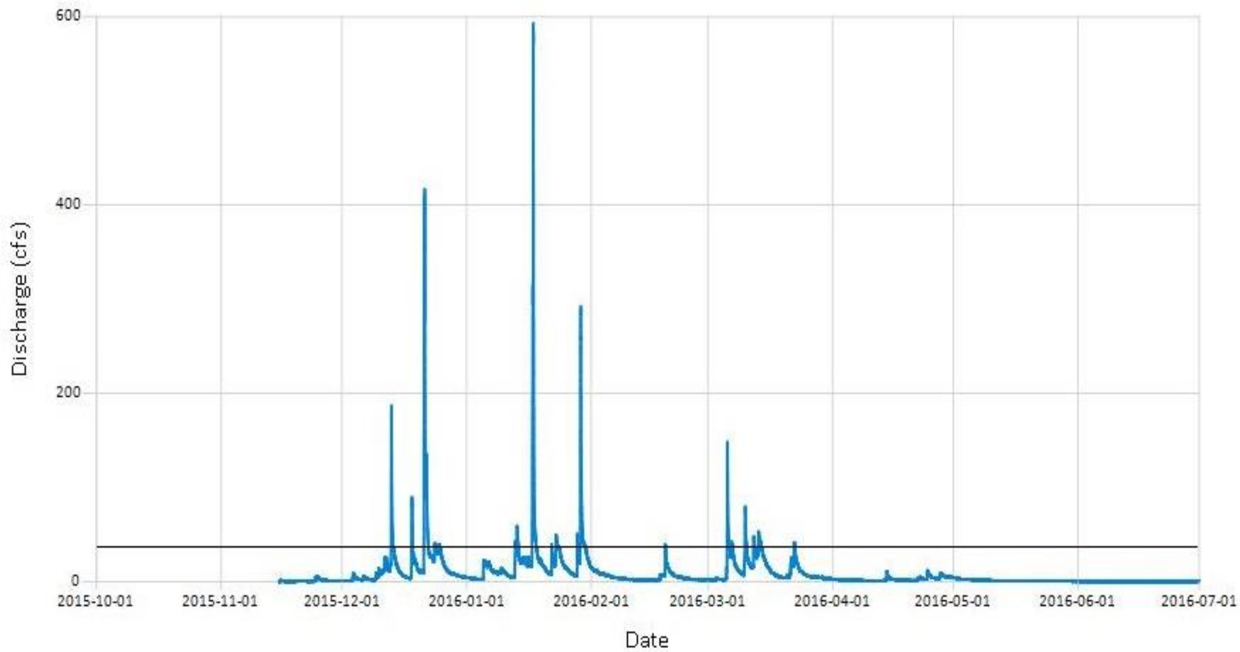

Figure 3. Continuous estimated discharge at the McCloud Creek TTS station during the 2016 WY. Values below the black line have empirical support whereas those above do not. The reach was dry between 10/1/15 and 11/15/15 and station was offline.

2.2.3.3 Turbidity

Turbidity was measured simultaneously using two methodologies at the McCloud Creek TTS station during the 2016 WY. A DTS-12 turbidity sensor (Forest Technology Systems, LTD., Victoria, B.C., Canada) was used to measure water turbidity (Formazin Nephelometric Units [FNU]) in the field. Coincident water samples were collected using an ISCO water sampler (Teledyne ISCO, Lincoln, Nebraska) during each field visit and automatically based on established turbidity thresholds.

During the 2016 WY, 347 water samples were collected for measuring turbidity. Most water samples (89%) were collected by automated turbidity threshold sampling (n = 309) and the remainder were collected manually during site visits (n = 38). Water samples were brought to the laboratory and a Hach 2100N turbidimeter (Hach Company, Loveland, Colorado) was used to measure turbidity (Nephelometric Turbidity-Ratio Units [NTRU]).

Among the water samples collected, three were identified as outliers and were excluded from analysis. Each of these suspicious values was a manually collected grab sample, and may have been inaccurately processed, or more likely, mixed up with another sample during lab processing. Their paired control samples, collected immediately afterwards, have turbidity close to what is assumed to be accurate representations of the actual environmental conditions.

The relationship between the two turbidity measurements was analyzed to develop a regression equation (Figure 4). A nonlinear relationship between turbidity readings from these two sensors was expected (Lewis et al. 2007) and a second-order polynomial relationship was found to be the best fit for the data collected during the 2016 WY.

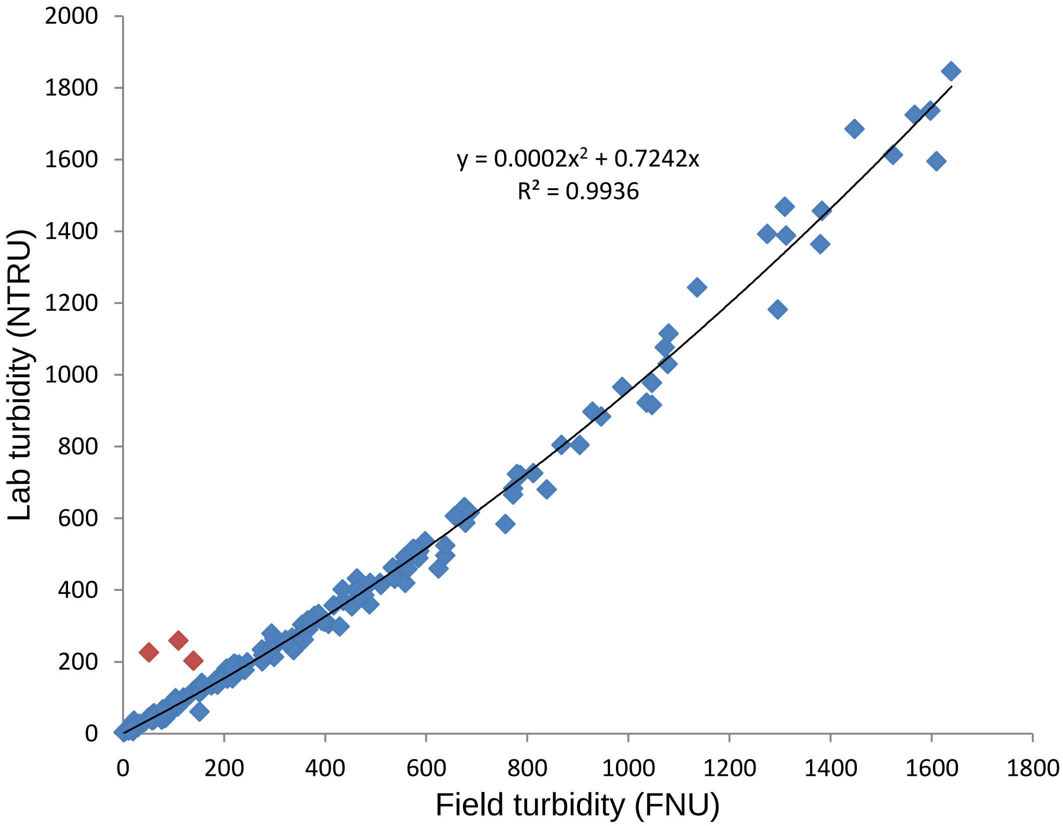

Figure 4. Relationships between coincident field turbidity measurements (FNU) and lab turbidity measurements (NTRU) collected at the McCloud Creek TTS station during the 2016 WY. The solid line is a second order polynomial model. The blue diamonds represent lab samples; the three red diamonds represent the outliers.

2.2.3.4 Continuous Turbidity

A DTS-12 sensor was used to measure continuous turbidity (FNU) at 10-minute intervals throughout the 2016 WY (Figure 5). These field measurements were converted to NTRU's using the regression equation in Figure 4, and a graph of continuous estimated turbidity was generated for the 2016 WY (Figure 5.1). Where turbidity values were missing or erroneous due to equipment failure, measurable range exceedance, or stochastic events, values were estimated using the stage-based regressions, values derived from ISCO samples (when possible), or interpolated using adjacent valid data. The type of estimates used for missing or erroneous data was noted and can be found in the electronic data file (Appendix A).

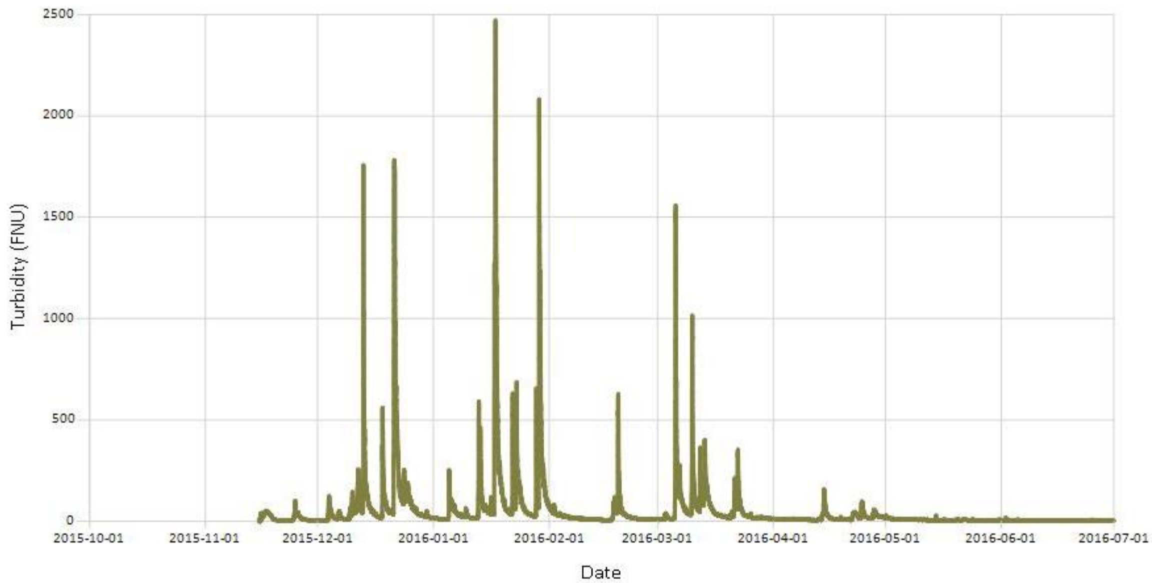

Figure 5. Continuous *in situ* FNU turbidity at the McCloud Creek TTS site during the 2016 WY.

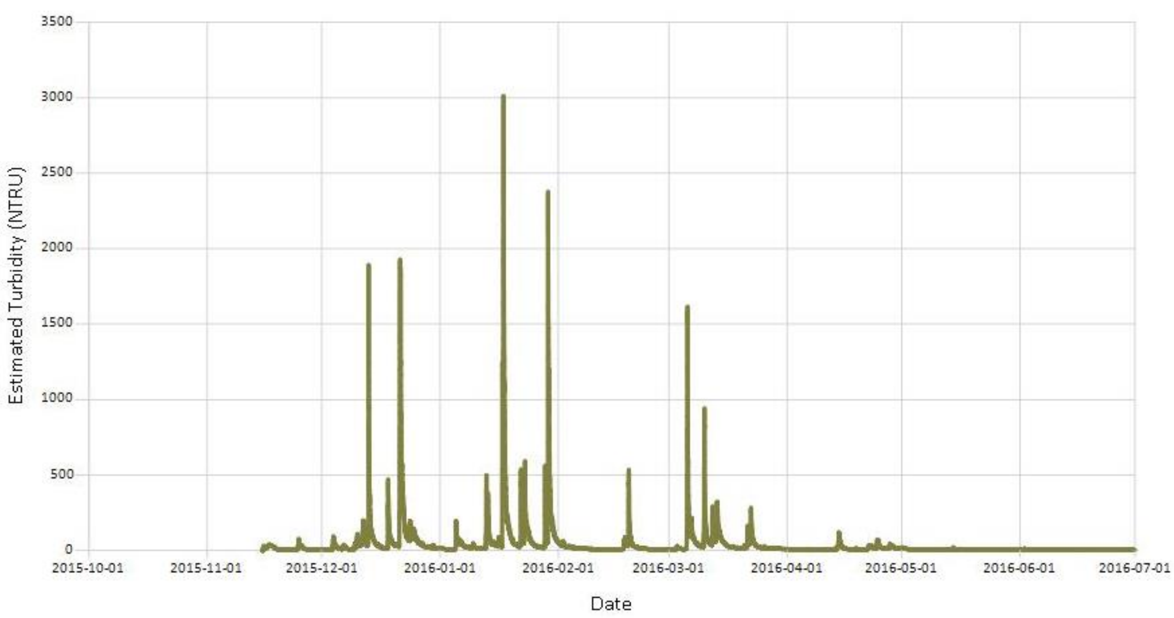

Figure 5.1. Continuous estimated NTRU turbidity at the McCloud Creek TTS site during the 2016 WY.

2.2.3.5 Grab Sample Data Summary

A total of 347 water samples were collected (38 manual and 309 automated) during the 2016 WY. Grab samples were usually taken during each site visit. These were collected using the ISCO sampler with a manual override, and were primarily used as laboratory quality control samples. The collection times for manual and automated (i.e., turbidity threshold) grab samples were compiled and overlaid on the continuous turbidity estimate for the 2016 WY (Figure 6).

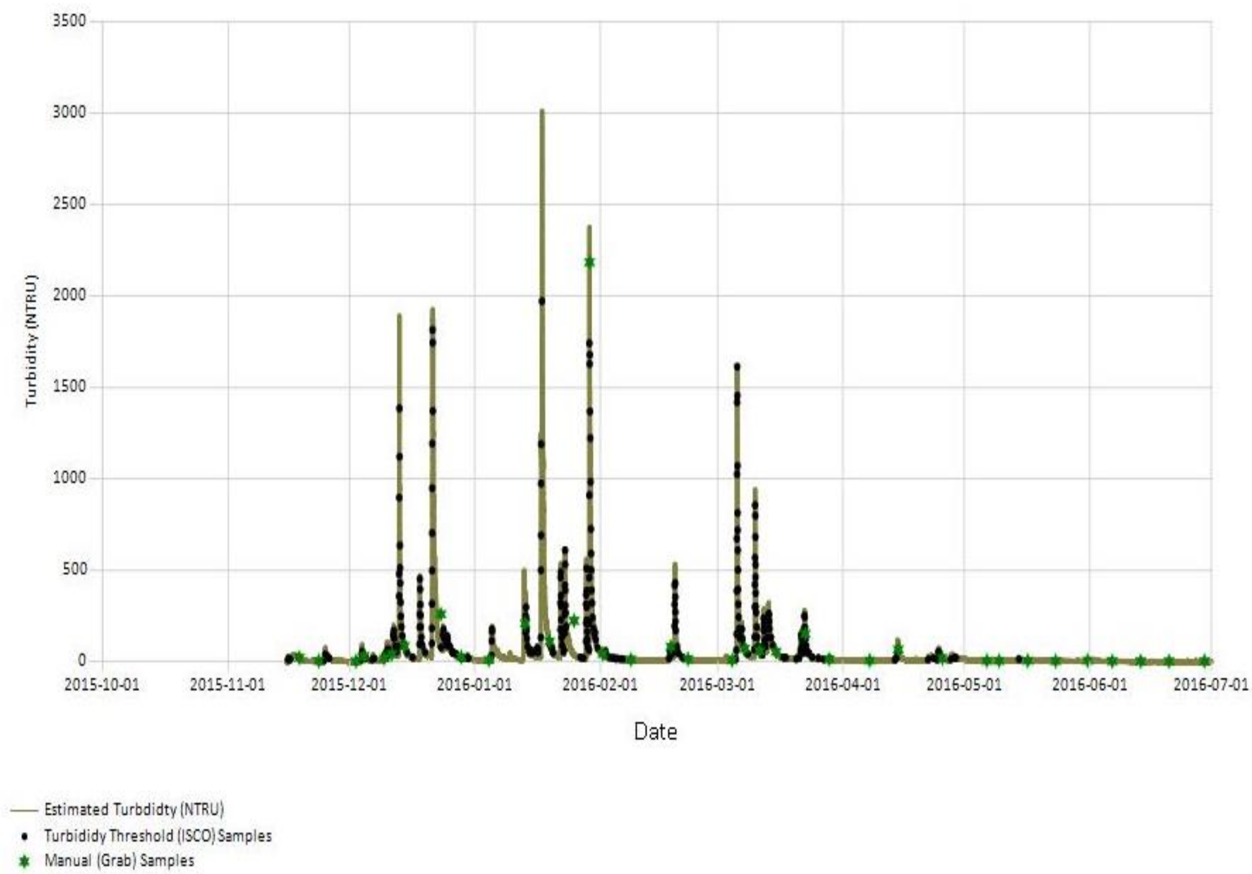

Figure 6. Continuous estimated turbidity (brown line) and timing of turbidity threshold ISCO samples (black circles) and manual ISCO samples (green stars) collected at the McCloud Creek TTS station during the 2016 WY.

2.2.3.6 Suspended Sediment Concentrations

The relationship between suspended sediment concentration (SSC) (mg/L) and turbidity (FNU) from manual and turbidity-threshold ISCO samples for the 2016 WY was established (Figure 7). Our assessment of this relationship was relatively simplistic and a better fit of these data may be possible through an assessment for additional relationships.

Though generally linear, the relationship between SSC and turbidity can change over the course of the year either between or within storm events (Lewis 1996). In order to establish stronger relationships we analyzed different ranges of turbidity, individual storm events, and between rising and falling limbs of the hydrograph. These rating relationships were broken into twelve different ratings (Table 4) with linear relationships that directly relate turbidity, in FNU, to SSC. We decided to analyze SSC with FNU, rather than NTRU to avoid having to convert the entire FNU data-set into NTRU before deriving a continuous SSC data-set. An analysis of these data is recommended to estimate the most accurate annual sediment load.

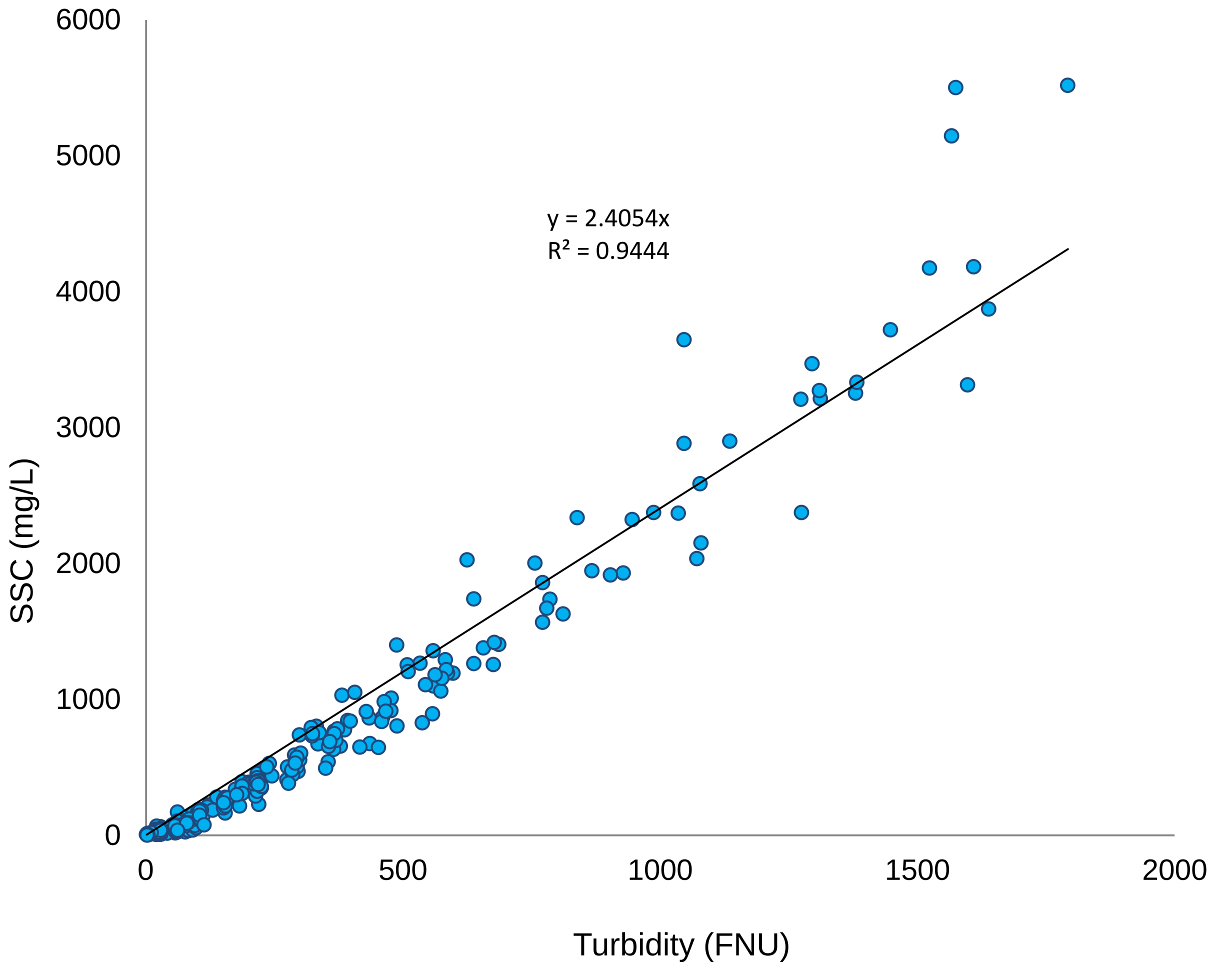

Figure 7. Relationships between turbidity and SSC for the McCloud Creek TTS station during the 2016 WY.

We have seen from our data (Figure 7) that the relationship between field turbidity (FNU) and the coincident laboratory suspended sediment concentration (SSC) is dynamic. In 2016, Green Diamond purchased Aquatic Informatics' Aquarius Time-Series software to better analyze this relationship, as well as for other data-management goals. Using this software, we identified twelve different turbidity-SSC relationships (Table 4), which when extrapolated over time provide us with a continuous data-set of derived SSC. The single, simplified linear relationship provided in this report, and years prior, should be used with caution if deriving a sediment load.

Table 4. Rating table for 12 relationships between turbidity (FNU) and SSC for the McCloud Creek TTS station during the 2016 WY. Note Y is SSC and X is turbidity.

Rating #	From:	To:	Turbdity (FNU)	SSC (mg/L)	Equation (Y=SSC)
1	10/1/2015 0:00	12/18/2015 9:30	0	0	-----
			1278	2391	Y = 0.325 + 1.871 * X
			2000	3745	Y = -4.716 + 1.875 * X
2	12/18/2015 9:30	1/17/2016 5:40	0	0	-----
			394	858	Y = -0.063 + 2.175 * X
			1692	3934	Y = -77.105 + 2.371 * X
			1982	4623	Y = -83.821 + 2.375 * X
3	1/17/2016 5:40	1/17/2016 12:50	0	0	-----
			161	211	Y = 0.049 + 1.310 * X
			503	1487	Y = -389.731 + 3.731 * X
			699	2216	Y = -386.671 + 3.725 * X
4	1/17/2016 12:50	1/17/2016 17:00	0	0	-----
	1/29/2016 4:30	1/29/2016 8:50	1607	5580	Y = 0.241 + 3.473 * X
			2610	8752	Y = 503.268 + 3.160 * X
5	1/17/2016 17:00	1/22/2016 1:30	0	0	-----
	1/29/2016 8:50	2/8/2016 13:30	801	1681	Y = 0.165 + 2.098 * X
			1649	4282	Y = -777.936 + 3.069 * X
			2476	6827	Y = -787.738 + 3.075 * X
6	1/22/2016 1:30	1/22/2016 5:30	0	0	-----
	1/23/2016 0:00	1/23/2016 6:50	624	1268	Y = -0.059 + 2.031 * X
			794	1840	Y = -843.677 + 3.382 * X
7	1/22/2016 5:30	1/23/2016 0:00	0	0	-----
			575	913	Y = 0.155 + 1.588 * X
			754	1200	Y = -6.736 + 1.600 * X
8	1/23/2016 6:50	1/28/2016 9:50	0	0	-----
	1/28/2016 13:30	1/29/2016 4:30	740	1477	Y = 0.162 + 1.995 * X
			894	1785	Y = -3.540 + 2.000 * X
9	1/28/2016 9:50	1/28/2016 13:30	0	0	-----
			161	211	Y = 0.049 + 1.310 * X
			503	1487	Y = -389.731 + 3.731 * X
			699	2216	Y = -386.671 + 3.725 * X
10	2/8/2016 13:30	2/19/2016 11:30	0	0	-----
			541	1217	Y = -0.135 + 2.250 * X
			764	1718	Y = -0.130 + 2.250 * X
11	2/19/2016 11:30	3/5/2016 14:10	0	0	-----
			581	825	Y = -0.089 + 1.420 * X
			838	1192	Y = -2.993 + 1.425 * X
	3/9/2016 22:00	3/10/2016 6:50	1415	3371	Y = -0.054 + 2.383 * X
			1551	4301	Y = -6280.821 + 6.823 * X
			1649	4968	Y = -6283.918 + 6.825 * X
12	3/5/2016 20:40	3/9/2016 22:00	0	0	-----
	3/10/2016 6:50	7/1/2016 0:00	1090	2155	Y = 0.495 + 1.977 * X
			1313	3388	Y = -3855.210 + 5.515 * X
			1649	5240	Y = -3868.426 + 5.525 * X

3.0 Problems Encountered and Resolutions

A summary of problems encountered and resolutions were compiled for the 2016 WY (Table 5). Typical problems encountered included but were not limited to: site access limitations, Druck offset adjustments, DTS adjustments, difficulty reading the stage plate, missed ISCO samples, over or under-filled ISCO samples, water observed in the ISCO base due to leaking, and equipment damage, repair, or maintenance.

Small leaks resulted in water collecting in the ISCO sampler base several times throughout WY 2016. Sources of these leaks include improper alignment of the distributor tubing of the sampler and the receiving sample bottle, improper pressure from the distributor, and a degraded silicone tube in the pump which can crack and leak. Whenever these problems were observed in the field, steps were taken to mitigate the problem (i.e. realign the distributor tubing, or replacement of the silicone tube) and tests were performed to ensure the sampler was left in good operating condition. At the end of the water year, the ISCO sampler was tested and appeared to function OK, but given the repetition of these minor issues, it will be replaced by a newly serviced unit in WY 2017.

DTS adjustments were made throughout the WY in response to the present or anticipated water depth (stage). It is in Green Diamond's standard operating procedures to position the DTS-12 at 6/10 water depth, but this can be challenging when access is restricted or when the stage is rapidly rising or falling. This will be an ongoing issue at this site.

During stages with fast flows, the stage plate can be difficult to read with certainty. This was noted seven times during the 2016 WY and the margin of error was recorded to be between 0.03 – 0.05 ft. during these observations. In these circumstances, the electronic stage was assumed to be the true "observed stage" as long as it fell within the margin of error and was previously tracking accurately. Given the lack of obstructions in McCloud Creek that would provide relief from turbulence, it may be impractical to re-locate the stage plate.

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Table 5. Summary of problems encountered and resolutions at the McCloud Creek TTS station during the 2015 WY.

Start Date	Problem	Resolution	Resolution Date
09/23/15	DTS (serial #51881) did not function during site installation.	Replaced malfunctioning DTS with a newly calibrated DTS (serial #8875).	10/01/15
11/18/15	Channel is hydrologically connected, but discharge is too low to measure at established cross-section.	Measured discharge 5 ft. downstream of established cross-section.	11/18/15
11/18/15	Data-logger program values (Dump count, stage multiplier) revert to default values during 12v swap.	Replaced 9V harness and tested without main battery supply.	11/23/15
12/02/15	Station is hydrologically connected but streamflow is too low to obtain a valid discharge measurement. Measurable velocity at only 5 verticals at stage plate reading of 1.00'.	Will monitor and measure discharge as streamflow increases.	12/02/15
12/04/15	DTS is sitting too low in the water column.	Raised DTS so that sensor is at standard 6/10' depth.	12/04/15
12/09/15	Slight amount of water (approximately 50 mL) observed in ISCO base.	OK sample volumes observed in ISCO slots 1-6 and in manual Grab and Controls samples of DD #5. Checked tube in ISCO distributor arm and length was appropriate. Will monitor and adjust ISCO settings if necessary.	12/09/15
12/09/15	Stage plate difficult to read in fast flows.	Observed stage plate measurement is an approximation (+/- 0.03'). Will monitor future stage plate measurements and edit if necessary.	12/09/15
12/09/15	DTS is sitting too low in the water column for anticipated flows.	Raised DTS so that sensor will be at standard 6/10' depth as stage rises.	12/09/15
12/09/15	Stage plate difficult to read in fast flows.	Observed stage plate measurement is an approximation (+/-0.03'). Will monitor future stage plate measurements and edit if necessary.	12/09/15
12/11/15	E-stage does not match observed stage measurement, is off by +/- 0.03'.	Will monitor and re-calculate stage offset if necessary.	12/09/15
12/11/15	ISCO desiccant requires replacement.	Replaced ISCO desiccant.	12/28/15
12/11/15	DTS is sitting too low in the water column for anticipated flows.	Raised DTS so that sensor will be at standard 6/10' depth as stage rises.	12/11/15

Table 5 Continued.

Start Date	Problem	Resolution	Resolution Date
12/11/15	Slight amount of water (approximately 40 mL) observed in ISCO base.	OK sample volumes observed in ISCO slots 1-5 and in manual Grab and Controls samples of DD #6. Checked tube in ISCO distributor arm and length was appropriate. Will monitor and adjust ISCO settings if necessary.	12/11/15
12/14/15	Stage plate difficult to read in fast flows.	Observed stage plate measurement is an approximation (+/-0.05'). Will monitor future stage plate measurements and edit if necessary.	12/14/15
12/14/15	Backstay that stabilizes DTS downrigger not attached upon arrival to site. DTS was submerged and vertical upon arrival to site.	Attached backstay to DTS downrigger so that sensor is stabilized in flow.	12/14/15
12/14/15	Water observed in ISCO base. OK volumes observed in ISCO slots 1-11 and 14-23 of DD #7 and slots 12-13 were empty.	Checked distributor arm tubing and re-seated round. Did not adjust sample volumes.	12/14/15
12/14/15	Empty samples observed in ISCO slots 12-13 of DD #7.	Generated generic BID #'s 9998-9999 in TTS.NET and changed data exception type to "NULL". Erratic FNU values from 650 -750 on 12/13/15 suggests that DTS was likely out of the water due to the backstay not being attached.	12/13/15
12/21/15	Could not access site due to high flows on the S.F. Elk river as well as flooding on Elk River rd.	Returned 12/23/15 when flows dropped to allow safe access to site.	12/23/15
12/22/15	Could not access site due to high flows on the S.F. Elk river as well as flooding on Elk River rd.	Returned 12/23/15 when flows dropped to allow safe access to site.	12/23/15
12/23/15	Empty sample observed in ISCO slot 3 of DD #8.	Unsure of reason for missed sample. Changed data exception type to "NULL" in TTS.Net.	12/23/15
12/23/15	ISCO full upon arrival to site. Datalogger reads "Next bottle = 38". 13 missed samples.	Collected all samples and reset ISCO. Generated generic BID #'s 9999-9986 in TTS.NET and changed data exception type to "NULL". Advanced data dump count. Both ISCO and datalogger read "next bottle = 1".	12/23/15

Table 5 Continued.

Start Date	Problem	Resolution	Resolution Date
12/23/15	Organic debris observed to be built up around Druck sensor and stage plate upon arrival to the site.	Removed debris that had built up around sensor and stage plate. Stage was observed to increase. Documented occurrence in StreamTrac hydrograph.	12/23/15
12/23/15	Internal ISCO tubing that leads to distributor arm requires replacement. Internal ISCO tubing was cracked, resulting in inadequate pressure during sampling which led to slightly low sample volumes. Could not take manual samples until replaced.	Replaced internal ISCO tubing. Tested with manual samples and no internal leaking was observed. Sample volumes were OK and consistent across slots.	12/23/15
12/23/15	E-stage does not match observed stage measurement, is off by 0.08'.	After debris was cleared from around sensor and stage plate, e-stage accurately matches observed stage.	12/23/15
12/23/15	DTS is sitting too high in the water column for anticipated stage.	Lowered DTS so that sensor will be at standard 6/10' depth as stage drops.	12/23/15
12/28/15	150 mL of water observed in ISCO base.	Closed 1/8" gap between distributor tubing and bottle. No spillage was observed post fix.	12/28/15
12/28/15	High samples observed in ISCO slots 4-6, 8-9. Low samples in slot 12 and grab and control samples of DD #9.	Closed 1/8" gap between distributor tubing and bottle. Even, acceptable sample volumes observed across samples post fix.	12/28/15
01/13/16	ISCO was off upon arrival. 12V battery was dead. 21 missed samples. Battery failure occurred on 1/5/16 between 550 and 940.	Replaced 12V battery, tested and decommissioned bad battery.	01/13/16
01/19/16	DTS observed to be out of the water and pinned to left bank upon arrival to site.	Lowered DTS back in stream at standard 6/10' depth. Replace para-cord backstay with string so that back stay breaks when struck with debris moving downstream.	01/19/16
01/19/16	Empty samples observed in ISCO slots 22-24 of DD #12.	DTS was out of the water upon arrival to site and was likely the problem. Generated generic BID #'s9999-9997 in TTS.NET and changed data exception type to "NULL".	01/19/16

Table 5 Continued.

Start Date	Problem	Resolution	Resolution Date
01/19/16	ISCO full upon arrival to site. Datalogger reads "Next bottle = 47". 11 missed samples.	Collected all samples and reset ISCO. Advanced data dump count. Both ISCO and datalogger read "next bottle = 1". Was likely due to false triggers from when DTS was out of the water. Assigned generic BID#s 9996-9975 in TTS.NET and changed data exception type to "NULL."	01/19/16
01/25/16	Stage plate difficult to read in fast flows. Low flow stage plate is leaning forward and oriented in such a way that it makes readings difficult and less accurate.	Observed stage plate measurement is an approximation (+/-0.04'). Will monitor future stage plate measurements and use e-stage for observed stage.	01/25/16
01/25/16	ISCO full upon arrival to site. Datalogger reads "Next bottle = 30". 5 missed samples.	Collected all samples and reset ISCO. Advanced data dump count. Both ISCO and datalogger read "next bottle = 1". Assigned BID#s 9999-9995 for slots 25-29 in TTS.NET and changed data exception type to NULL.	01/25/16
01/25/16	Water (approximately 100 mL) observed in ISCO base.	OK sample volumes observed in ISCO slots 2-24 and in manual Grab and Controls samples of DD #13. Checked tube in ISCO distributor arm and adjusted length. Will monitor and adjust ISCO settings if necessary.	01/25/16
01/25/16	DTS is sitting too high in the water column.	Lowered DTS so that sensor is at standard 6/10' depth.	01/25/16
01/29/16	DTS is sitting too low in the water column.	Raised DTS so that sensor is at standard 6/10' depth.	01/29/16
01/29/16	High sample volumes observed in ISCO slot 18 and manual grab and control of DD #14.	Will monitor and adjust sample volumes in ISCO settings if necessary.	01/29/16
01/29/16	Stage plate unable to be accurately read in fast flows and is across the river.	Used e-stage value as observed stage measurement due to difficulty reading stage plate.	01/29/16
02/01/16	Empty samples observed in ISCO slots 17-18 of DD #15.	DTS was observed near the surface of the water and ISCO tubing that is attached to the housing was out of the water. DTS was lowered to standard 6/10' depth. Generated generic BID #'s 9999-9998 in TTS.NET and changed data exception type to "NULL".	02/01/16

Table 5 Continued.

Start Date	Problem	Resolution	Resolution Date
02/01/16	DTS is sitting too high in the water column.	Lowered DTS so that sensor is at standard 6/10' depth.	02/01/16
02/01/16	Water (approximately 100 mL) observed in ISCO base.	OK sample volumes observed in ISCO slots 1-16 and in manual Grab and Controls samples of DD #15. Checked tube in ISCO distributor arm and length was appropriate. Will monitor and adjust ISCO settings if necessary.	02/01/16
02/08/16	E-stage does not match observed stage measurement, is off by -0.045'.	Re-calculated stage offset so that e-stage matches observed stage measurement.	02/08/16
02/08/16	DTS is sitting too high in the water column.	Lowered DTS so that sensor is at standard 6/10' depth.	02/08/16
02/08/16	Slight amount of water (approximately 25 mL) observed in ISCO base.	OK sample volumes and in manual Grab and Controls samples of DD #16. Checked tube in ISCO distributor arm and length was appropriate. Will monitor and adjust ISCO settings if necessary.	02/08/16
02/18/16	DTS is sitting too low in the water column.	Raised DTS so that sensor is at standard 6/10' depth.	02/18/16
02/22/16	DTS is sitting too high in the water column for anticipated drop in stage.	Raised DTS so that sensor will be at standard 6/10' depth as stage drops.	02/22/16
02/29/16	DTS is sitting too high in the water column.	Lowered DTS so that sensor is at standard 6/10' depth.	02/29/16
03/04/16	Empty samples observed in ISCO slots 1-2 of DD #20.	ISCO sampler had dead battery. Generated generic BID #s 9999-9998 in TTS.NET and changed data exception type to "NULL". Battery was decommissioned.	03/04/16
03/04/16	Discharge measured using flowmeter that did not calibrate fully.	Discharge record is suspect, measured discharge after cleaning and calibrating flow meter the following site visit.	03/07/16
03/07/16	DTS is sitting too low in the water column.	Raised DTS so that sensor is at standard 6/10' depth.	03/07/16

Table 5 Continued.

Start Date	Problem	Resolution	Resolution Date
03/11/16	Stage plate difficult to read in fast flows.	Observed stage plate measurement is an approximation (+/- 0.04'). Will monitor future stage plate measurements and edit if necessary.	03/11/16
03/11/16	Water (approximately 50 mL) observed in ISCO base.	OK sample volumes in all ISCO slots and in manual Grab and Controls samples of DD #22. Checked tube in ISCO distributor arm and length was appropriate. Will monitor and adjust ISCO settings if necessary.	03/11/16
03/13/16	Datalogger clock required update for daylight savings time.	Updated datalogger clock for daylight savings time, forward one hour.	03/15/16
03/15/16	Stage plate difficult to read in fast flows.	Observed stage plate measurement is an approximation (+/-0.02"). Will monitor future stage plate measurements and edit if necessary.	03/15/16
03/15/16	Water observed in ISCO base. Low volumes observed in ISCO slots 9-13 of DD #23.	Adjusted ISCO tubing in ISCO distributor arm and got OK volumes with no water in base.	03/15/16
03/22/16	Stage plate difficult to read in fast flows.	Observed stage plate measurement is an approximation (+/-0.05'). Will monitor future stage plate measurements and edit if necessary.	03/22/16
03/22/16	Water (approximately 30 - 100mL) observed in ISCO base.	OK sample volumes in all ISCO slots and in manual Grab and Controls samples of DD #24. Checked tube in ISCO distributor arm and length was appropriate. Noticed that end of pump tubing is jagged and may be leading to water spraying into base. Trimmed end of tubing so that it was smooth. Will monitor.	03/28/16
03/28/16	DTS is sitting too high in the water column.	Lowered DTS so that sensor is at standard 6/10' depth.	03/28/16
04/07/16	DTS is sitting too high in the water column.	Lowered DTS so that sensor is at standard 6/10' depth.	04/07/16
04/07/16	DTS is in danger of being exposed as flows drop.	Removed cobbles underneath DTS.	04/07/16

Table 5 Continued.

Start Date	Problem	Resolution	Resolution Date
04/07/16	E-stage does not match observed stage, is off by 0.03'.	Re-calculated stage offset so that e-stage matches observed stage measurement.	04/07/16
04/14/16	High samples observed in ISCO slots 1-3 and grab and control samples of DD #27.	Calibrated ISCO sample volumes.	04/14/16
04/14/16	E-stage does not match observed stage measurement, is off by 0.06'.	Re-calculated stage offset so that e-stage matches observed stage measurement.	04/14/16
04/20/16	Low sample volumes observed in ISCO slots 1-4 and grab and control samples of DD# 28.	Calibrated ISCO sample volumes.	04/20/16
04/20/16	E-stage does not match observed stage measurement, is off by 0.03'.	Re-calculated stage offset so that e-stage matches observed stage measurement.	04/20/16
04/20/16	DTS is sitting too high in the water column.	Lowered DTS so that sensor is at standard 6/10' depth.	04/20/16
05/23/16	E-stage has not match observed stage, has been off by .01- 0.03'.	Re-calculated stage offset so that e-stage matches observed stage measurement.	06/06/16
04/25/16	Stage plate difficult to read in fast flows.	Observed stage plate measurement is an approximation (+/-0.02'). Will monitor future stage plate measurements and edit if necessary.	04/25/16
04/25/16	Slight amount of water (approximately 40 mL) observed in ISCO base.	Low sample volumes observed in ISCO slots 2-6 of DD #29. Checked tube in ISCO distributor arm and it was short, lengthened tube. Rinse cycles had been disabled (liquid detector disabled) in a previous site visit. Enabled liquid detector and calibrated sample volume.	04/25/16

Table 5 Continued.

Start Date	Problem	Resolution	Resolution Date
05/06/16	ISCO full upon arrival to site. Datalogger reads "Next bottle = 42." 17 missed samples. Slots 1-24 of data dump #24 have suspect turbidity.	Collected all samples and reset ISCO. Generated generic BID #'s 9999-9984 in TTS.NET and changed data exception type to "NULL". Advanced data dump count. Both ISCO and datalogger read "next bottle = 1". Suspect turbidity verified with HACH, and changed data exception type to "NULL" in slots 4-24 of DD#30 in TTS.NET.	05/11/16
05/09/16	E-stage does not match observed stage measurement, is off by 0.02'.	Re-calculated stage offset so that e-stage matches observed stage measurement.	05/09/16
05/16/16	Suspect FNU turbidity in ISCO slot 1 of DD #32.	Increase in FNU over 40 minutes not associated with stage, may be due to animal or human crossing the channel. Turbidity verified with HACH and was not edited.	05/16/16
05/16/16	DTS is sitting too high in the water column.	Lowered DTS so that sensor is at standard 6/10' depth.	05/16/16
05/23/16	Slight amount of water (approximately 40 mL) observed in ISCO base.	OK sample volumes observed in manual Grab and Controls samples of DD #33. Adjusted ISCO distributor and got OK sample volumes.	05/23/16
06/06/16	DTS is sitting too high in the water column.	Lowered DTS so that sensor is at standard 6/10' depth.	06/06/16
06/20/16	Station is hydrologically connected but streamflow is too low to obtain a discharge measurement.	Did not measure discharge.	06/20/16
06/29/16	Station is hydrologically connected but streamflow is too low to obtain a discharge measurement.	Did not measure discharge.	06/29/16

4.0 QA Summary

Special training is required for all GDRCo staff involved in the implementation of this project. During the 2016 WY, ten individuals participated in some part of the implementation of field and lab standard operating procedures. All personnel were trained prior to performing assigned work tasks and responsibilities.

The Lead Watershed Technician was appointed by the Project Supervisor to perform the training and certification of the watershed staff during the 2016 WY (Table 6). Training was performed on all aspects of field work including: cleaning and adjusting equipment, downloading of data, exchanging ISCO samples, and taking discharge measurements. Training in the laboratory included: preparing filters, taking turbidity measurements, filtering and weighing of suspended sediment, and recording data. Data management training included: data entry, QA/QC, and updating files. The chain-of-custody for all phases of project implementation was tracked carefully.

Table 6. Summary of training dates for certifications completed by GDRCo staff involved in field and lab activities during the 2016 WY.

Personnel	Role	Lab Certification	Field Methods Certification	Data Management Certification
Ryan Bourque	Project Supervisor	12/15/11	11/02/11	12/15/11
Pat Righter	Technical Leader	12/15/11	11/02/11	12/15/11
Nick Hawthorne	Lead Watershed Technician	10/14/14	10/14/14	10/14/14
Melissa Reneski	Watershed Technician	10/01/15	10/01/15	10/01/15
Jonathan O'Connell	Watershed Technician	04/01/15	04/01/15	04/01/15
Charles Holt	Lab Assistant	N/A	10/14/2014	N/A
Matt Nannizzi	Lab Assistant	12/15/11	N/A	N/A
Matt Kluber	Lab Assistant	10/01/15	N/A	N/A
Michael Zontos	Lab Assistant	10/01/15	N/A	N/A
Jon Pini	Lab Assistant	10/01/15	10/1/2015	N/A

In order to evaluate the consistency of laboratory processing for turbidity and SSC, GDRCo performed a QA/QC test using paired grab and control water samples collected during site visits. A total of 38 paired water samples were collected during the 2016 WY. These samples were collected during each routine site visit, using the ISCO pump sampler. All paired water samples with a grab turbidity ≥ 40 NTRU were processed for turbidity and SSC. 13 paired water samples exceeded this turbidity threshold and were processed. An additional six samples (24% of the remaining paired samples) with a grab turbidity < 40 NTRU were randomly selected and also processed for turbidity and SSC.

The relationships between the paired samples for turbidity and SSC were established (Figures 8 and 9, respectively). Three outliers were observed in the dataset for both relationships and were excluded from this analysis. The specific reason for the deviation of these samples from the observed relationship is unclear. Furthermore, the processing at the end of the WY (control samples) appears to be much more consistent with the expected result. Given the huge difference in both turbidity and SSC for these samples, it seems likely that they were mixed up during initial laboratory processing rather than incorrectly measured. Green Diamond monitors eleven other TTS sites, so it is possible that these samples represent another location entirely. A high intensity of storms during the El Nino winter overwhelmed the laboratory and these samples appear to be erroneous. The relationships for both turbidity and SSC among the remaining 16 samples were linear and strong; indicating that laboratory processing produced nearly identical values between paired water samples. Efforts will be made to better manage the laboratory to ensure samples are properly labeled and processed accordingly.

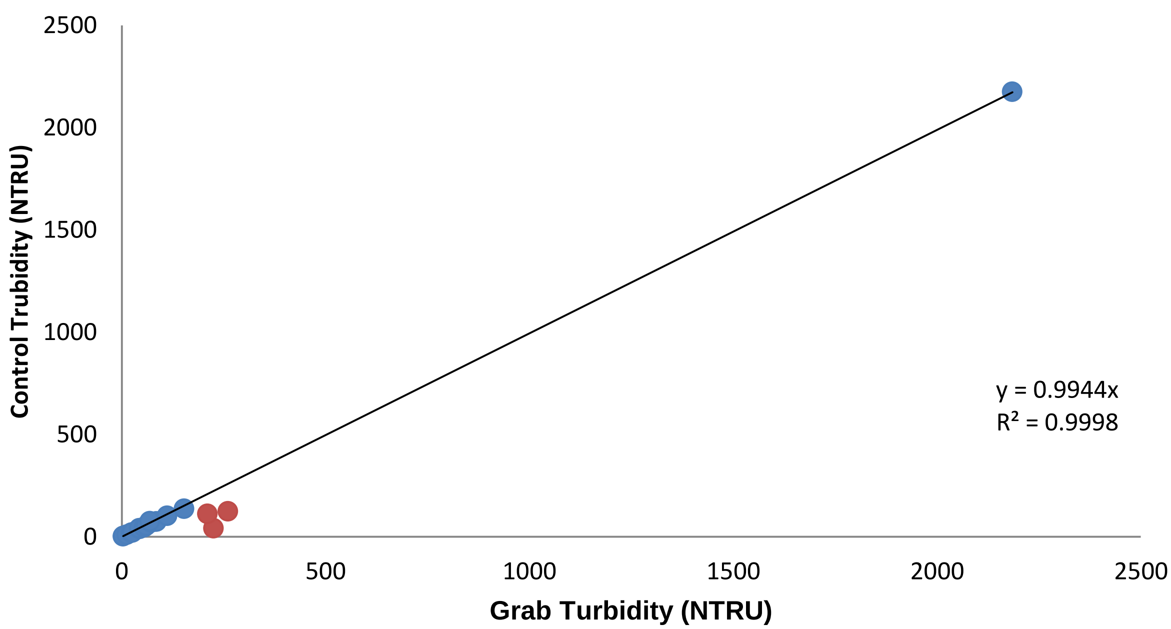

Figure 8. Relationship between water turbidity of paired control and grab samples (blue circles) collected at the McCloud Creek TTS station during the 2016 WY. The red circles represent outliers that were excluded from the analysis.

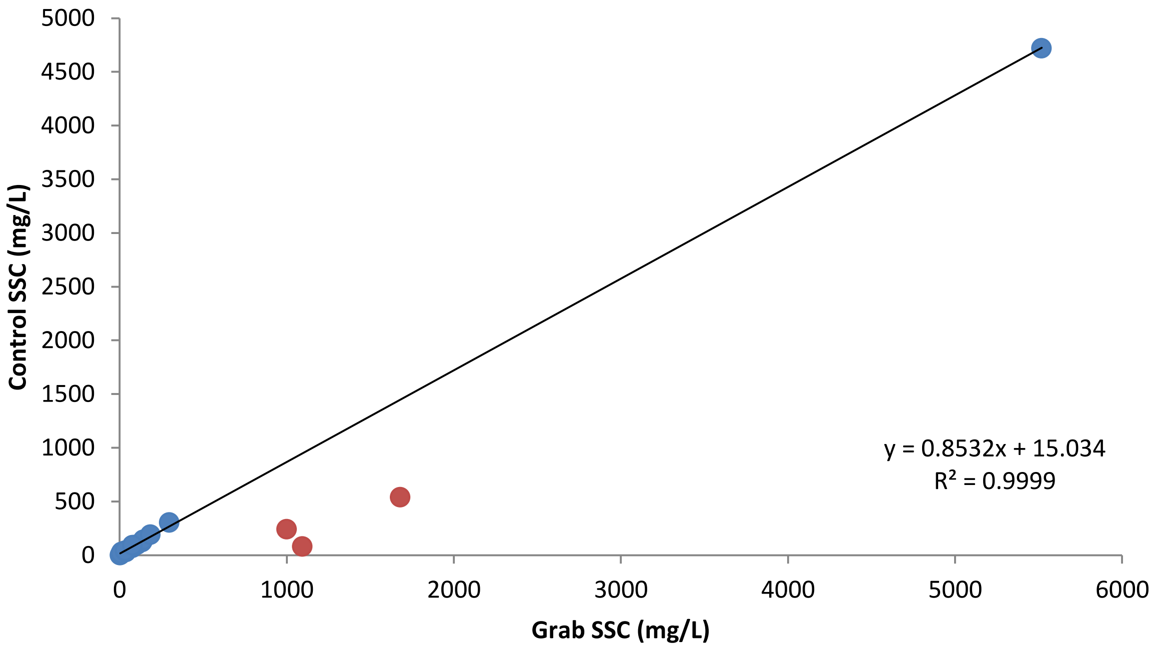

Figure 9. Relationship between suspended sediment concentration (SSC) of paired control and grab samples (blue circles) collected at the McCloud Creek TTS station during the 2016 WY. The red circles represent outliers that were removed from this analysis.

All equipment was maintained and calibrated within the frequency defined in Section B6 of the Turbidity Threshold Sampling QAPP submitted by GDRCo. The DTS-12 sensors were calibrated by FTS September 22, 2015 prior to deployment. The Hach 2100N was calibrated routinely prior to each use with Formazin StableCal® standards and weekly (33 times) during the monitoring season using the Gelex Secondary standards. The Druck pressure transducer was calibrated by the GDRCo watershed staff on July 14, 2015 to ensure proper operation prior to deployment. The CR10X datalogger was calibrated by Campbell Scientific on July 17, 2015. Finally, current meters used during the monitoring season received in-depth calibrations at least weekly and spin test calibration checks before each use.

At times there can be complication regarding the DTS-12 turbidity sensor, resulting in missing, or “noisy”, data. When this happened, the “cleaning” of the data was applied conservatively. In the case of missing data, values were generated using the methods described in Section 2.2.3.4 and are noted in the electronic data file (Appendix A).

Two different approaches were used to address “noisy” turbidity data where there was no association with fluctuations in stage. If the turbidity recordings prompted an ISCO sample that verified there was no increase in SSC, that turbidity value was interpolated from adjacent values. If there was no associated ISCO sample, which can happen when the turbidity increases didn't cross set thresholds, the value was left and no "cleaning" took place.

5.0 Other Problems Encountered

During larger storm events, it is often unsafe to cross SF Elk River, preventing access to the McCloud Creek TTS site. In WY 2016, two planned site visits were missed due to unsafe conditions. This can affect data quality with respect to discharge, turbidity, and SSC. The inability to obtain discharge measurements at higher stages is a limitation when estimating discharges above the measured values. Given that the channel geometry at the monitoring site is substantially different above the range of empirical discharge measurements, we assume that the actual relationship is likely different than that predicted here for discharges above this range.

Efforts were made in WY 2016 to better estimate discharge during larger storm events than we have done in years past. A careful assessment of the various Manning's roughness coefficients present in the discharge cross section, combined with a stage-area relationship and a channel slope estimate derived from a survey using a total-station provided us with the ability to make a prediction of high flow discharge. However, this projected value is an estimate and should only be used accordingly.

When GDRCo staff cannot access the site during high flow events to exchange ISCO bottles, it leads to missed water samples during these prolonged storm events. Thirteen samples were missed in 2016 for this reason. These events are usually associated with higher sediment loads, and calculation of discharge and sediment load require extrapolation from relationships established at low to medium flow conditions, resulting in low confidence in the sediment load estimates. This has been and will continue to be an ongoing challenge throughout the duration of the monitoring project.

The storm event on February 6, where stage peaked at 5.35 ft., resulted in stream turbidity values that exceeded the measurable range of the DTS-12 turbidimeter (1800 FNU) for 120 minutes. This resulted in a turbidity data gap and missed ISCO water samples when environmental conditions were above 1800 FNU. Without empirical data to validate the estimated turbidity during the peak of this storm, there is uncertainty for values above 1800 FNU.

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Appendix A

Electronic copy (file name = Appendix_A_MC2_All_Data_WY2016.xls) of data collected at the McCloud TTS site during the 2016 WY. This file was submitted as an email attachment to the NCRQCB in accordance with the 2014 electronic document submission guidelines.