

2016 TRINITY RIVER SEDIMENT TRANSPORT MONITORING FINAL REPORT

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**TRINITY RIVER RESTORATION PROGRAM
 WY 2016 SEDIMENT TRANSPORT MONITORING
 FINAL REPORT**

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TRINITY RIVER RESTORATION PROJECT WY 2016 SEDIMENT TRANSPORT MONITORING FINAL REPORT

EXECUTIVE SUMMARY

This report presents the results of Water Year (WY) 2016 sediment transport monitoring efforts on the Trinity River near Weaverville, California. As part of an ongoing study for the Trinity River Restoration Program (TRRP), GMA Hydrology (GMA, formerly Graham Matthews and Associates) conducted bedload and suspended sediment sampling at four monitoring locations. Secondary hydrologic and geomorphic data such as water surface slope, streamflow measurements, cross section surveys, pebble counts and turbidity were collected as part of the study. WY2016 marks the 12th year (2004-2013, 2015-2016) of Trinity River sediment transport monitoring by GMA Hydrology for TRRP.

Historic impacts to the Trinity River and their effects on anadromous fish habitat are described in the Introduction (Section 1.0) of this report and are documented extensively elsewhere (McBain and Trush, 1997). In short, physical changes in the channel resulting from mining, increased sediment loads related to logging and flow reduction due to impoundment resulted in a severely degraded channel in the mainstem while the Trinity and Lewiston dams cut off anadromous salmonids from the upper 700 square miles of the watershed.

TRRP's restoration strategy involves a combination of Spring Flow Releases, fine and coarse sediment management, and mechanical channel rehabilitation. This 2016 study is conducted as part a sediment budget approach to understanding sediment-related habitat issues. We provide sediment load estimates at four locations along the river: at Lewiston (TRAL), near Grass Valley Creek (TRGV), at Limekiln Gulch (TRLG), and near Douglas City (TRDC). The sediment load estimates inform gravel injection strategies (locations and volumes) and hydrograph development for Spring Flow Releases.

Suspended sediment and bedload sampling were conducted from cataraft platforms attached to temporary cableways. Samplers (US D-74 for suspended sediment and TR-2 with 0.5mm mesh for bedload) are lowered and raised using cranes equipped with winches. Each station is located near a stream gage operated by either US Geological Survey (USGS) or GMA. Continuous turbidity was collected for use as a surrogate for suspended sediment concentration (SSC) at three sites. Cross section surveys and pebble counts were conducted before and after the 2016 Spring Flow Release.

GMA sampling crews collected measurements during nine consecutive days from May 8 to May 16, 2016. Crews collected two to 15 one-pass bedload samples and one suspended sediment sample each day. Bedload variability testing was performed once at each site by sampling repeatedly at one location along the cross section for at least 30 minutes. Water surface slope was measured each day. SSC samples were processed for three particle-size ranges (<0.063mm, 0.063 - <0.5mm and ≥0.5mm) and bedload samples were processed for total mass and grain size analysis. Sediment loads were computed using a variety of standard and modified methods (Sections 2.3.3, 2.3.4 and Appendix [Station Analyses]). Suspended sediment loads were computed for the three size classes mentioned and bedload was computed for 0.5 - <8mm (fine) and ≥8mm (coarse) loads. The computational period for sediment load estimates is April 1, 2016 to July 31, 2016.

WY2016 was determined to be a "Wet" water year (TRRP 2016). The approved release hydrograph included a 17 day rise to 4,000 cfs, followed by a steep rise to a one-day peak flow bench at 10,000 cfs. A two-day fall to 5,200 cfs was followed by a second rise to 10,000 cfs for two more days, then a sharp decline to 4,200 cfs. The tailout lasted until early August, with a return to 440 cfs. This "double peaked" hydrograph was the first of this type to be implemented for a Trinity River Spring Flow Release.

Suspended sediment loads for all size classes increased in the downstream direction, with one exception (<0.063mm at TRLG). Loads for all size classes are provided in Table 18 of the report. Total suspended load (the sum of <0.063, 0.063-0.5mm and ≥0.5mm) is provided here:

- TRAL: 1,890 tons

- TRGV: 5,210 tons
- TRLG: 6,300 tons
- TRDC: 16,600 tons

TRAL is located very near the dam and thus has very little channel length and only one small tributary to supply fine sediment. TRDC is at the downstream boundary and represents the combined contribution of all tributaries in the study reach.

Crews collected between 53 and 72 single-pass bedload samples during the 2016 Spring Flow Release. The fine (0.5 - <8mm) bedload for each station was:

- TRAL: 338 tons
- TRGV: 578 tons
- TRLG: 781 tons
- TRDC: 4,010 tons

The progressive downstream increase in fine bedload is presumably due to the contribution of more tributaries and more channel bank length in the downstream direction. Changes in transport capacity between sites (not evaluated here) can also influence sediment load magnitude.

Coarse bedload ($\geq 8\text{mm}$) is of particular interest as it is a critical geomorphic habitat component (e.g. spawning gravel, bar/riffle composition) and it represents the supply introduced by gravel injection. 2016 coarse bedload for each station was:

- TRAL: 1,800 tons
- TRGV: 3,110 tons
- TRLG: 2,040 tons
- TRDC: 7,850 tons

TRAL is located in a reach strongly influenced by gravel injection. At TRGV, gravel was actively injected a few hundred feet upstream of the sampling section while sampling occurred. TRLG and TRDC are less influenced by gravel injection.

Of particular interest in 2016, considering the unique double-peak hydrograph, is the question of how do the loads compare for each peak flow bench? We examined each site relative to its own hydrograph and summed the $\geq 8\text{mm}$ loads for each peak flow bench. Computational periods were defined as the time the hydrograph exceeded the low flow point between the two flow peaks (noted as “Q start” in Table 19, copied from Section 2.5.2.2). By this definition, the first peak was slightly longer than the second. For TRAL, the first peak transported 1,060 tons and the second transported 668 tons, 59 and 38 percent of the total $\geq 8\text{mm}$ load. At TRGV, the first peak transported 1,840 tons and the second transported 1,080 tons, 59 and 35 percent of the total 3,110 tons of $\geq 8\text{mm}$. TRLG transported 1,080 and 907 tons, 53 and 44 percent of the total 2,040 tons. TRDC transported 4,970 tons and 2,590 tons, 63 and 33 percent.

Table 19. $>8\text{mm}$ bedload totals for each peak flow bench, WY2016.

SEDIMENT MONITORING STATION	Q Start (cfs)	Peak #1			Peak #2		
		Bedload $>8\text{mm}$ (Tons)	# Hrs	Q Peak (cfs)	Bedload $>8\text{mm}$ (Tons)	# Hrs	Q Peak (cfs)
Trinity River at Lewiston (TRAL)	5,270	1,060	102.0	9,600	688	95.5	9,540
Trinity River above Grass Valley Creek (TRGV)	5,590	1,840	105.5	10,000	1,080	94.0	9,950
Trinity River below Limekiln Gulch (TRLG)	5,290	1,080	102.75	10,600	907	94.75	10,300
Trinity River near Douglas City (TRDC)	5,870	4,970	104.5	11,100	2,590	92.75	10,800

All values rounded using methods by Porterfield (1972)

The magnitude of Spring Flow Release sediment loads is dependent upon numerous factors, including: peak flow magnitude, hydrograph shape, sediment augmentation efforts, changes in transport capacity (e.g. from channel and floodplain restoration) and tributary sediment contributions. We examined potential trends in the coarse bedload ($\geq 8\text{mm}$) Spring Flow Release load totals from 2004 to 2016. In the previous 11 years of sediment sampling, there have been four “Dry” type releases (2007, 2009, 2013, 2015), five “Normal” releases (2004, 2005, 2008, 2010, and 2012), and two “Extremely Wet” releases (2006 and 2011). The distinction between water year type and Spring Flow release type is important because there were some variations (e.g. 2011 was a Wet water year type, but had an Extremely Wet release, 2004 was a wet year, but had a Normal Year release type). WY2016 was classified a Wet water year and had a modified Extremely Wet flow release and the double peak.

2006 and 2011 clearly dominated the relative bedload transport at all stations except TRGV where 2016 produced the second highest computed load. All stations exhibited an apparent downward trend in $\geq 8\text{mm}$ transport during Normal Release types. The trend among Dry Flow Release types is less clear (2007, 2009, 2013 and 2015), though 2015 clearly transported larger loads than the other three years. 2015 with its “Dry (modified)” release type (that is a dry year restoration total release [453,000 af] with an 8,500 cfs flow bench) showed an evident increase over preceding “Dry-type” flow releases at all stations. At TRGV, WY2015 exceeds some wet years and at TRAL and TRDC, WY2015 approximates the magnitude of “Normal” flow release types (Section 2.5.4).

Bedload sample particle-size distributions were compared to examine general variations in grain size, both between stations and between peak flow benches. TRAL showed little change between peaks while TRGV and TRLG show coarsening. Bedload at TRDC is noticeably finer for the second peak flow bench. TRAL presumably has a relatively homogenous source (supply is predominately injected gravel). The reason for the change in grain size for the other three sites is unknown.

At TRAL, the mean (cumulative) D50 (grain size for which 50 percent is smaller) appears to decrease over the initial rise to the first peak flow bench, then hold steady at around 45mm throughout the remainder of the hydrograph. At TRGV the trend appears to be an increase from approximately 50 to 60mm over the course of the hydrograph. At TRLG the mean D50 appears to hold at around 40mm for the entire release though the data exhibit more scatter than the previous two sites. Similarly, at TRDC the D50 appears to hold at roughly 25mm over the entire release and the data exhibit the least scatter of all the sites.

Bedload discharge is highly variable across a sampling section. Sample data reveal that two to three stations (locations) can transport most of the bedload along a sampling section (which generally contain 11-14 stations). Bedload discharge is also temporally variable. In 2016, we sampled the highest-transport location along the sampling section (at each site) repeatedly for at least 30 minutes yielding 10 to 13 samples. We examined variability in fine, coarse and total bedload discharge (total is the sum of fine and coarse) over the 30 minute period (though the units are transformed into tons per day).

At TRAL, fine bedload varied over a range of only 10 tons per day while the coarse load varied over a range of 90 tons per day. The relative contribution of the two size ranges varies considerably (one to 30 percent fine bedload). A few very coarse grains can make a large difference in the relative percentage. TRAL shows the highest coarse percentage (81 percent), which is likely due to the fact that only one small tributary (Deadwood Creek), enters between TRAL and the dam thus limiting the potential for fine bedload recruitment.

The effect of gravel injection on the grain size distribution appears clearly at TRGV. The fine fraction comprised only zero to five percent of the total bedload in the samples. The largest sample was nearly seven times as large as the smallest sample.

Unlike at TRAL and TRGV, TRLG reveals some heterogeneity with regard to the relative contribution of fine and coarse bedload. Two samples were >50 percent fine while the remaining eight are comprised primarily of coarse bedload.

At TRDC, fine sediment composes >50 percent of two samples. The data for TRDC are also more variable than for the other three. Since TRAL is starved of fines (located so close to the dam) and since both TRAL and

TRGV are so strongly influenced by coarse-gravel injection, TRLG and TRDC results are likely more representative of temporal variability in magnitude and composition of bedload transport in the Trinity River.

WY2016 crews reported most of the sediment load is typically generated at two to three stations. If we apply the spatial inference (most of the load is transported at a few stations) to the bedload variability study, then we can assume for example that at TRDC, a full cross section total load computed can vary greatly (>400 percent) from a load computed from a different sample time within the 30 minute window. While the variability study data are far from conclusive, they do suggest a need for more sampling at fewer stations (i.e., over a narrower width of the cross section where the most sediment load is being transported) in order to derive a more accurate estimate of average bedload discharge.

In an effort to improve future sediment transport monitoring efforts, we offer the following recommendations:

- The potential trend of reduced bedload transport in Normal and Dry Year type Spring Flow Releases, as discussed in Section 2.5.4, may warrant further investigation. Clearly, the modified Dry release hydrograph applied in WY2015 was successful in moving more sediment than was observed in other Dry water years. WY2016 was the first wet year in the study and the first to feature a double-peak hydrograph. At all sites except TRLG, the first peak transported far more (nearly double) coarse bedload than the second peak (Table 21). Future analyses should compare flow bench magnitude and duration versus loads transported by flow release type. This may have implications toward changing the scope of the sampling effort in such year types.
- Consider altering the bedload sampling protocols to use multiple occupations of single verticals along the same cross section, with the number of replicates based on the variability and magnitude of transport rates. At low transport rate verticals, a single long duration sample will provide a reasonable estimate of mean transport, while in high rate verticals, multiple samples would provide a more robust estimate of the mean. Such an approach will increase the accuracy of estimating a mean daily value to guide sedigraph development.
- GMA typically monitors bed texture of the same sub-section of the cross section each year (e.g. a transverse riffle that is shallow enough to sample and represents a significant portion of where transport occurs during high flow sampling). The boundaries of these areas shift with changes in bed evolution. If TRRP's desire is to represent the entire cross section with a single pebble count (as in to provide a roughness estimate for a hydraulic model), this should be discussed prior to future years' monitoring.
- The TRGV gaging location has been severely impacted by the collapse of a large cottonwood tree supporting the gage house. We suggest rebuilding the station for WY2017, as the existing stump appears unreliable.
- Water surface slope measurement at some stations (e.g. TRGV, TRLG) is strongly influenced by overbank flow slope reduction. The reported highest-flow slopes are really floodplain water surface slope. Presumably, analysts are more interested in the slope responsible for grain mobilization which is typically steeper than that measured on the floodplain. We suggest installing taller stage references at selected locations to improve the accuracy of water surface slope measures.
- At TRGV, turbidity induced by gravel injection renders the turbidity record ineffective for computing suspended sediment loads. Consider relocating the turbidity probe.

1.0 INTRODUCTION

The mainstem Trinity River drains a 2,036 square mile (mi²) watershed (excluding the South Fork Trinity) joining the Klamath River at Weitchpec, some 43 miles above the Klamath's entry into the Pacific Ocean. The Trinity River is the largest tributary to the Klamath River and historically produced large runs of Chinook salmon (*Oncorhynchus tshawytscha*), Coho salmon (*Oncorhynchus kisutch*), and steelhead trout (*Oncorhynchus mykiss*). Impacts from industrial gold mining and logging in the early to mid-1900s substantially changed the mainstem and tributary channels. Placer mining overturned the streambeds and washed hillslopes into stream channels; while logging of highly erosive watersheds, such as Grass Valley Creek, introduced considerable quantities of sand into the mainstem. Following the start of construction and resulting flow regulation in November 1960, the Trinity River Diversion Project (TRD) was fully completed in 1964 to increase water supplies to the Central Valley Irrigation Project. The TRD, which included both Trinity and Lewiston dams, blocked the upper 700 square miles of the watershed to fish passage, eliminated upstream large wood and sediment contributions, and severely reduced streamflow; in all, TRD diverted nearly 90 percent of the streamflow; however, downstream of the TRD, tributaries continued to remain largely unregulated, contributing streamflow, sediment, and wood at their natural (pre-TRD) rates. Constant low flow releases below Lewiston Dam failed to transport the tributary sediment contributions, and formed large deltas, commonly containing significant quantities of granitic sand. The low flows and large quantities of fine sediment provided the optimum conditions for riparian encroachment and berm development along the low-flow channel margin. Combined, these essentially eliminated channel migration, rendered the larger pre-dam alluvial features immobile, and greatly simplified stream channel geometry (e.g., continuous rectangular channel). The subsequent habitat loss and aquatic species decline were documented in numerous studies by the U.S. Fish and Wildlife Service, the Hoopa Valley Tribe, and other agencies e.g., Trinity River Maintenance Flow Study (McBain and Trush, 1997).

In an effort to restore the Trinity River fish and wildlife, the U.S. Secretary of the Interior directed the U.S. Fish and Wildlife Service to prepare the Trinity River Flow Evaluation Study in 1981 (TRFE, U.S. Fish and Wildlife Service and Hoopa Valley Tribe, 1999). The TRFE produced recommendations "to fulfill fish and wildlife mandates" of the Congressional Act authorizing the Trinity River Diversion. The study also provided the basis for the Trinity River Mainstem Fishery Restoration Environmental Impact Statement/Environmental Impact Report (U.S. Fish and Wildlife Service [USFWS], 2000) and the Record of Decision signed in 2000 (ROD, U.S. Dept. of Interior, 2000). The ROD established the Trinity River Restoration Program (TRRP), which included minimum water volume allocations based annually on water year type. The TRRP's purpose is to restore and maintain the natural production of fish and wildlife populations in the Trinity River, downstream of Lewiston Dam. To achieve this goal, the TRFE and ROD provide the scientific framework and management strategy to reestablish natural physical processes that promote a dynamic alluvial system which, in turn, are intended to enhance aquatic habitat conditions capable of restoring salmonid populations. Restoration efforts focus on the Trinity River mainstem from Lewiston Dam downstream to the confluence with the North Fork Trinity River (Figure 1). The restoration strategy requires a combination of Spring Flow Releases, fine and coarse sediment management, and mechanical channel rehabilitation. This monitoring report focuses on the sediment management component.

Managing dam releases to route fine and coarse sediment through a river system requires an accounting of the sediment inputs, outputs, and a change in stream channel storage (i.e., a sediment budget). The simplest form of a sediment budget is expressed by the mass balance relation:

$$\textit{Input} - \textit{Output} = \textit{Change in Storage}$$

On the Trinity River, sediment inputs downstream from Trinity and Lewiston dams are delivered naturally into each cell (Figure 2) by tributaries, and by managed coarse sediment injections, which are necessary to supplement lost upstream supplies or disconnected tributary supplies (i.e. Grass Valley Creek). Sediment outputs are simply the sediment transported by the mainstem at the downstream end of each sediment budget cell in Figure 2. The study reach and sub-reaches (cells, bounded by sampling stations) are further described in Section 2.1.

Several sediment budgets have been computed for the Trinity River between Lewiston Dam and Douglas City, including: the Trinity River Maintenance Flow Study (TRMFS, McBain & Trush, 1997); the Sediment Source Analysis for the Mainstem Trinity River (GMA, 2001); the Draft Sediment Budget and Monitoring Plan (SBMP, Wilcock, 2004); and the 2010 Bed-Material Sediment Budget Update (Gaeuman and Krause, 2011). Each sediment budget used the most current streamflow data, sediment transport measurements, tributary delta volumetric estimates, particle-size distribution measurements, and streamflow and sediment transport models to estimate the inputs and outputs.

The TRFE, ROD, and subsequent scientific contributions (Wilcock, 2004; Gaeuman and Krause, 2011), specify monitoring actions to address sediment budgeting related hypotheses and questions, and evaluate specific sediment management objectives. “A sediment budget provides a consistent and comprehensive framework within which the sediment objectives of the TRRP may be evaluated” (Wilcock, 2004). The central TRRP *sediment budgeting* objectives outlined in the TRFE are to:

- Reduce fine sediment storage in the mainstem;
- Increase and maintain coarse sediment storage in the mainstem Trinity River;
- Route coarse sediment supply through all reaches of the mainstem; and
- Reduce fine sediment inputs to the Trinity River.

Sediment transport monitoring is intended to estimate the inputs and outputs to mainstem sediment budget cells, which support flow scheduling (e.g., determining flow magnitude and duration) and other related sediment management efforts.

1.1 Sediment Management Objectives

The following section focuses on the flow-induced geomorphic processes and partially explains the flow evaluation process described in the TRMFS and TRFE. The magnitude, duration, frequency, timing, and rate of change of the ROD hydrographs were developed based on:

- thresholds required to initiate specific geomorphic processes (e.g., the flow magnitude necessary to scour a certain depth),

- the flow required to maintain a geomorphic process (e.g., flow duration required to transport various quantities of sediment), or
- historical attributes of the flow regime (e.g. historically, snowmelt flows occurred annually from April to June).

Previous monitoring on the Trinity River indicates sediment transport rates vary considerably over time and space, and can span up to several orders of magnitude; based on this, GMA (2006b) and Wilcock (2004) conclude direct measurement (as opposed to historical transport curves or mathematical models), provides the best method for estimating continuous sediment transport and annual loads. Sediment load computations inform gravel injection strategies, flow release hydrograph development, restoration design and other management decisions.

1.2 Report Organization

This report presents the results of WY2016 mainstem sediment transport monitoring efforts. The scope, scale and historical context of sediment sampling on the Trinity River are detailed in Section 2.0. WY2016 Methods and Results are described in their respective sections (2.3 and 2.4). Results are compared to those from previous years to examine general trends, which may be of use by Trinity River managers for predictive purposes and to assess management actions such as gravel augmentation and channel/floodplain restoration. Explanatory figures and tables are included in the text, whereas larger datasets are included as appendices. All data and seminal report files are included in a digital format. Less relevant documents (staff certification and SLQA compliance) are included with the digital files.

Definitions useful for this report:

“Site” and “Station” are used interchangeably to refer to the sediment monitoring locations. “Station” may also refer to a sampling location along a cross section – though in this case, we attempt to clarify in the associated text.

“Sediment discharge” is often used to describe both the instantaneous rate of sediment transport and/or the cumulated load over time. While others’ definitions may vary, in this report we attempt to distinguish between sediment discharge and sediment load as follows:

- (1) Sediment discharge: an instantaneous sediment transport rate, expressed in mass or volume per unit time (tons/day). For example, “a bedload discharge of 105 tons/day was measured on the Trinity River below Limekiln Gulch, sample measurement #7, on 5/6/12 at 13:15;” and
- (2) Sediment load: a mass or volume of sediment transported over a pre-defined unit of time (tons). This is the rate (sediment discharge) integrated over a period of time. For example, “674 tons of bedload were transported past the Trinity River below Limekiln Gulch monitoring station during the WY 2013 Spring Flow Release”.

In this report, *sediment discharge* describes sediment in transport, and *sediment load* describes the quantity that was accumulated over a longer time period. A useful comparison is with streamflow: discharge is the instantaneous rate (cfs, analogous to sediment discharge) and yield is the volume of water cumulated over time (acre feet, analogous to sediment load).

“Hysteresis” refers to varying concentration at a common discharge.

2.0 SEDIMENT TRANSPORT MONITORING

WY2016 marks the 12th year (2004-2013, 2015-2016) of mainstem Trinity River sediment transport monitoring by GMA Hydrology (GMA, formerly Graham Matthews and Associates) for TRRP. Sediment transport monitoring, in various forms, has periodically occurred at a range of sites in the TRRP study area during the last thirty years. For example, the U.S. Geological Survey (USGS) collected sediment data from 1976-1999 at the Grass Valley Creek at Fawn Lodge gaging station, and from 1981-1991 at the Trinity River below Limekiln Gulch gaging station. Most of these sediment monitoring efforts supported the TRFE process, or were conducted for watershed restoration and fine sediment reduction efforts occurring in tributary basins such as Grass Valley Creek. Previous results and data collection methods were described in detail in other reports, including the TRMFS; the Sediment Source Analysis for the Mainstem Trinity River Report (GMA, 2001); and the Annual Sediment Transport Monitoring Reports from WY 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2013, 2014 (GMA, 2003, 2006a, 2006b, 2007, 2008, 2009, 2010, 2013, 2014, 2015, 2016).

In WY 2002, following recommendations from the ROD and TRFE, the Trinity River Restoration Program began operating several tributary and mainstem streamflow and sediment monitoring stations. Subsequent recommendations laid out in the SBMP (2004) focused the sediment transport monitoring efforts on three major tributaries and four mainstem sites (Figure 1). Sediment monitoring on the tributaries was discontinued after WY 2006.

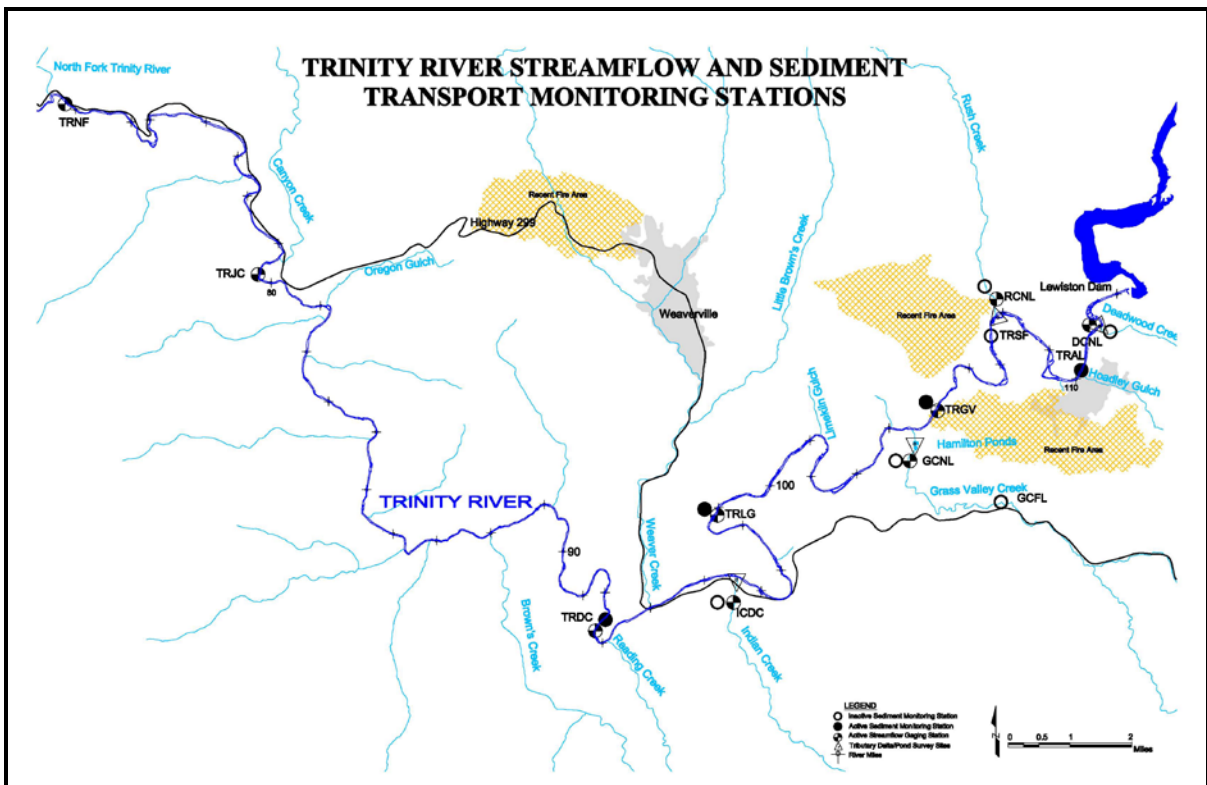


Figure 1. Location Map for the Trinity River Spring Flow Release Sediment Transport Monitoring. Black circles describe locations of the four mainstem sampling stations.

2.1 Sediment Transport Monitoring Locations

In WY 2016, sediment transport data were collected at four mainstem Trinity River monitoring stations during the Spring Flow Release: Trinity River at Lewiston (TRAL, USGS gage #11525500, approximate River Mile [distance upstream from confluence with Klamath River, RM] 109.95), Trinity River above Grass Valley Creek near Lewiston (TRGV, GMA gage #11525540, RM 104.5), Trinity River below Limekiln Gulch near Douglas City (TRLG, USGS gage #11525655, RM 98.7), and Trinity River at Douglas City (TRDC, USGS gage #11525670, RM 92.6) (Figure 1). These are the same stations used for previous annual GMA monitoring, with the exception of TRGV, which was relocated in 2006. The USGS operated the streamflow gages at the TRAL, TRLG, and TRDC stations. GMA operated the seasonal streamflow gaging station at TRGV.

The monitoring stations were designed to provide sediment flux data for the four mainstem sediment budget cells between Lewiston Dam and Douglas City (Figure 2). The larger tributaries (site name initials provided for reference in Figure 1), Deadwood (DCNL), Rush (RCNL), Grass Valley (GCFL, GCNL), Indian (ICDC), Weaver, and Reading Creeks, provide the majority of the natural sediment contributions for the mainstem within the study area. The downstream-most sediment budget boundary is located near Douglas City, where additional streamflow and sediment contributions (from Indian, Weaver, and Reading Creeks) significantly reduce the coarse sediment and streamflow deficits. Below Douglas City, dam releases and natural runoff events are generally capable of transporting sediment influxes (TRFE, 1999; GMA, 2007).

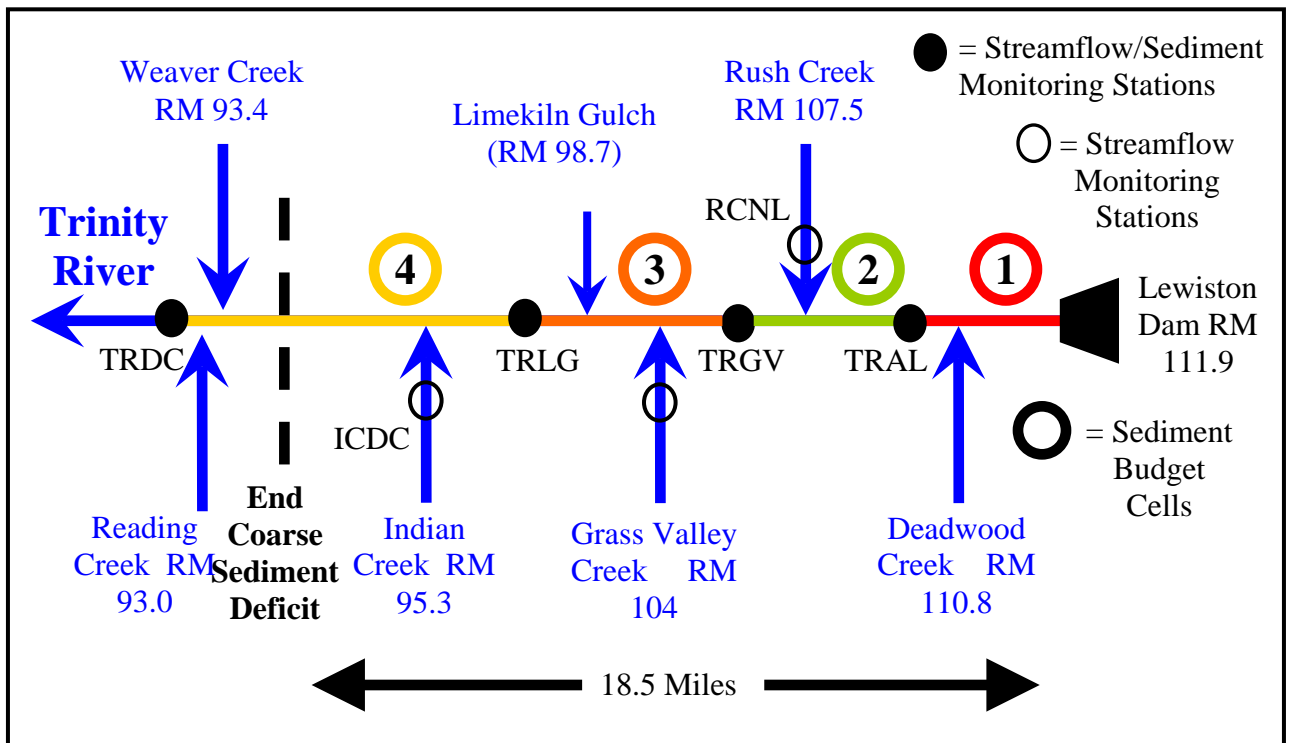


Figure 2. Schematic drawing of the Trinity River Sediment Budget, showing sediment sources and routing. The river has been divided into cells (1 through 4) bounded by stations, which are used for monitoring, measurement and analysis to compute sediment transport and storage.

2.2 Sediment Transport Monitoring: Objectives and Tasks

WY 2016 sediment transport monitoring occurred during the Spring Flow Release period. The overall WY 2016 objectives were to determine the rate, volume (load) and texture of total sediment load at the four monitoring locations.

Primary sediment monitoring tasks designed to accomplish these objectives included:

- Operating mainstem sediment transport monitoring stations at: the Old Lewiston Bridge (TRAL); above the Grass Valley Creek confluence (TRGV); at the USGS gaging station below Limekiln Gulch (TRLG); and just downstream of the USGS streamflow gaging station at the Bureau of Land Management (BLM) Douglas City Campground (TRDC);
- Collecting continuous turbidity at three of the four mainstem sampling stations TRGV, TRLG, TRDC;
- Collecting streamflow measurements and continuous stage data at TRGV during the Spring Flow Release period;
- Updating stage/discharge relationships and computing streamflow records for TRGV;
- Developing turbidity/suspended sediment concentration (SSC) relationships, SSC/discharge, and bedload/discharge relationships as required;
- Computing continuous bedload and suspended sediment discharge using sediment samples we collected and using methods developed by the USGS. Sediment sample analyses were performed to provide transport rates by size fraction: <0.063mm (suspended), 0.063-<0.5mm (suspended), ≥ 0.5 mm (suspended), 0.5-<8.0mm (bedload), and ≥ 8.0 mm (bedload); and
- Computing bedload and suspended sediment load estimates for these size classes for the Spring Flow release period.

Additional data were collected to support sediment transport computations, and subsequent sediment budgeting efforts, including: water surface slope measurements (during the flow release), bed-surface particle size distributions and cross section surveys at the sediment transport monitoring stations (pre- and post-flow release) (Appendices A, B, C, D). We also conducted experimental “bedload variability testing” (repeat sampling at one location) to assess the potential range in magnitude of bedload transport.

2.3 Sediment Transport Monitoring Methods

Sampling protocols and methods, lab analysis, data entry, quality assurance, and sediment computation methods are described in detail in previous reports (e.g., GMA, 2006b); thus the following section provides only the absolutely essential descriptions.

2.3.1 Streamflow Monitoring and Computational Methods at TRGV

Streamflow monitoring and continuous-discharge computation for the Trinity River above Grass Valley Creek was carried out using standard or modified USGS methods. Continuous stage was recorded using a Design Analysis H-310 pressure transducer. The H-310 has an accuracy of less than or equal to 0.025 percent of the full-scale output (FSO). Continuous stage readings were recorded in the data collection platform (DCP) at 15-minute intervals. Stage observations from staff plates were recorded on all site visits. All surface water data including electronic gage data, staff-height readings, the gage datum, and discharge measurements were entered and processed in the WISKI Suite (Water Information Management System Kisters), developed by KISTERS AG. WISKI is a Windows-based

time-series hydrological data management package, based on a relational database client-server platform such as Microsoft Sequel Server. The WISKI Suite is comprised of three components: WISKI, BIBER, and SKED. The main WISKI shell is the hydrologic workbench where all data are organized and where computations on time-series data are carried out. BIBER is used to evaluate and manage discharge measurements as well as track current meters and personnel using those meters. SKED is a rating curve editor that uses a graphical user interface to assist the hydrologist in developing, maintaining, and applying rating curves. The U.S. version of WISKI uses standard hydrologic computations and techniques as set forth by the USGS. Full details of computations can be found in the station analyses contained in Appendix B.

2.3.2 Mainstem Sediment Sampling

All sediment sampling was conducted from cataraft-based sampling platforms as in previous years. The catarafts were attached to tensioned cableways (temporary cableways of 3/8" galvanized wire rope) securely attached to trees or other anchors on either side of the channel. Various types of equipment were deployed from the cataraft platforms, including 12 inch wide TR-2 bedload samplers with 0.5mm mesh (Figure 3) and US D-74 suspended sediment samplers. This was the 10th year that TR-2 bedload samplers were utilized at all four stations. In previous years, 6 inch Helley-Smith samplers were utilized.

GMA personnel at each site consisted of two crew on the cataraft and one safety kayaker. All GMA staff have completed First Aid and CPR training and Swift Water Rescue Training courses. Crews collected up to 15 one-pass bedload samples, one two-pass suspended sediment sample, and one water surface slope measurements per day. On the first and last days of sampling, crews covered two sites per day, with the modified goal of collecting a one-pass bedload sample, one two-pass suspended sediment sample and one water surface slope measurement.

TRGV, TRLG, and TRDC were each fitted with a Forest Technology Systems DTS-12 in-situ turbidity probe and a Campbell CR200 data collection platform, set to record on 15-minute intervals. Articulating booms used in previous years were again used in 2016 to house the turbidity probes, whereas prior to 2011 the probes had been mounted in fixed locations. The articulated booms (Figure 4) allow turbidity probes to shed debris and produce much cleaner turbidity records.

Suspended sediment measurements were taken over a range of flows and at various positions on the hydrograph on nine consecutive days from May 8-16, 2016. Cross-sections were typically sampled at 11-15 verticals. Protocols followed standard USGS procedures (Edwards and Glysson, 1999) for Equal Width Increment (EWI) sampling. Information recorded for each sample included: time, date, site, stage, bottle #, pass #, method, equipment used, etc. All suspended sediment samples were transported to GMA's fine sediment laboratory in Placerville, CA, where they were processed and summarized for three particle-size ranges (<0.063mm, 0.063-<0.5mm or \geq 0.5mm).

Bedload measurements were collected daily for nine days within the release period. The sampling down-times (i.e., time the sampler rested on the bed actively collecting sediment) ranged from 30 to 240 seconds. Bedload samples were also transported to the GMA sediment lab in Placerville, CA where they were processed and the data were summarized (Figure 5).



Figure 3. A 200 lb twin-tube TR2 bedload sampler deployed from a cataraft, Sandy River, OR.



Figure 4. An articulating turbidity boom and gage house box deployed at TRGV in 2016.



Figure 5. GMA Coarse Sediment Laboratory, Placerville, CA.

Station Analyses, detailing sediment data collection and computational methods, were developed for each sampling station (Appendices A, B, C, D). Quality Assurance plans for both laboratories are available to interested parties.

2.3.3 Continuous Suspended Sediment Discharge and Load Computations

The computational period for the mainstem stations was April 1, 2016 00:00 to July 31, 2016 23:45. (encompassing the Spring Flow Release, as stipulated by TRRP). Computations were performed as follows. First, Suspended sediment transport curves were generated in order to develop estimates of continuous suspended sediment concentration (SSC). Next, the curves were analyzed to investigate whether streamflow and/or turbidity provided reasonable surrogate measures for predicting continuous suspended sediment concentration. Then, SSC data points were obtained from depth-integrated suspended sediment samples and the corresponding streamflow or turbidity values and transport curves were developed from these data. Once sedigraphs of continuous concentration were generated using the transport curves, the plotted traces were adjusted to pass through the depth-integrated sample data points. Finally, continuous concentration was transformed into continuous suspended sediment discharge (SSD) using the standard equation:

$$Q \text{ (cfs)} * SSC \text{ (mg/l)} * 0.002697 = SSD \text{ (tons/day)}$$

Continuous suspended sediment discharge was summed over the computational period to compute the load for the following size classes (partial loads): $< 0.063\text{mm}$, $0.063\text{mm} - < 0.5\text{mm}$, and $\geq 0.5\text{mm}$. Mainstem total suspended sediment load was computed by summing the partial loads. For detailed information on suspended sediment discharge computations see the individual Station Analyses in Appendices A, B, C, and D.

2.3.4 Continuous Bedload Discharge and Bedload Computations

The computational period for the mainstem stations was April 1, 2016 00:00 to July 31, 2016 23:45 (i.e. the Spring Flow Release, same as per the suspended sediment computations). Continuous partial-bedload discharge was computed for $0.5- < 8\text{mm}$ and $\geq 8\text{mm}$ size classes. Single (or multiple) sediment transport curves were fitted through distinct groupings of measured bedload vs stream discharge points. Continuous bedload sediment discharge was estimated as a function of stream discharge for the two size classes. Bedload sedigraphs (graphical depictions of continuous sediment discharge) were constructed and were manually fitted through the measured sediment discharge points. This employs a combined approach (utilizing multiple temporal transport curves and sedigraph fitting through measured data points) which is more accurate for assessing the transport variability on the Trinity River (observed during previous flow releases) than the application of a single, general transport curve for the entire release period. While comparisons between the combined and single-curve approaches have shown minor differences in computed bedload discharge totals (GMA 2006b; 2007), the combined method highlights short term trends which the single regression method does not. In WY2016 the single general equation and multiple equation approaches were applied as appropriate.

The TR-2 samplers were equipped with 0.5mm mesh sampler bags, which allowed an unknown portion of the $< 0.5\text{mm}$ size sediment particles to pass through the samplers. Therefore, continuous bedload discharge was not computed for the $< 0.5\text{mm}$ size fraction. For simplicity, the $0.5- < 8\text{mm}$ and $\geq 8\text{mm}$ size classes are hereafter referred to as “fine” and “coarse” bedload. Continuous total bedload discharge $\geq 0.5\text{mm}$ was computed by summing these partial bedload discharges. Bedload was estimated for the release period by summing the area under the respective sedigraph. For detailed information on bedload discharge and bedload computations see the individual Station Analyses in Appendices A, B, C, and D.

2.3.5 Cross Sections, Water Surface Slope and Pebble Counts

Water surface elevation (stage) monitoring was recorded at each station. Stage references consisted of posts or staff plates which had their elevation established using leveling methods detailed in Harrelson et al. (1994). The distance between posts was measured and stage measurements during peak flows facilitated calculation of water surface slope.

One cross section at each sediment monitoring site was surveyed pre- and post-Spring Flow Release. Cross sections were surveyed per standard methods (Harrelson et al. 1994) to assess topographic changes at the sampling section. Topographic change along cross sections was calculated in MS Excel by creating a common 1 foot stationing between sequential surveys and interpolating surveyed elevations to these stations, resulting in both surveys having elevations for the same stationing. Topographic change was computed incrementally, (elevation difference multiplied by a 1 foot width), and then summed, to create cut/fill tables and calculate total pre- and post-release cross section area change.

In addition, pebble counts (n=100+ particles) were collected along the cross sections to examine textural changes related to the flow release (Wolman 1954). Pebble count results are used to describe the texture of the dominant bedload transport feature (e.g. a transverse gravel bar).

2.4 Sediment Transport Monitoring Results

2.4.1 Hydrology and Streamflow

The following is a description of the Water Year 2016 hydrologic setting and the resulting flow release hydrograph. WY2016 was determined to be a “Wet” water year (TRRP 2016). The approved release hydrograph included a 17 day rise to 4,000 cfs, followed by a steep rise to a one-day peak flow bench at 10,000 cfs. A two-day fall to 5,200 cfs was followed by a second rise to 10,000 cfs for two more days, then a sharp decline to 4,200 cfs. The tailout lasted until early August, with a return to 440 cfs.

Examination of the 15 minute discharge data USGS gage near Lewiston (11525500, Figure 6) reveals the following.

Rising limb flow benches were relatively brief to nonexistent, with emphasis on steep rise-fall cycles within the overall rising limb period. The peak flow measured at the Lewiston gage was 9,600 cfs (May 9 at 13:45). The first peak flow bench (defined here as discharge >9,000 cfs) began at 10:30 on May 9 and remained over 9,000 cfs until 10:00 on May 10. Discharge fell to 5,280 cfs on May 12 at 17:30, then began increasing back to 9,480 cfs by 12:15 on May 13. The decline from the second peak flow bench began at 11:45 on May 14 and the river dropped to 4,320 cfs on May 17 at 10:00, coinciding with the last day of sediment sampling. The flow was ratcheted down with at least 10 short falling-limb discharge increases in the 200-400 cfs range. On July 11, the falling limb flattened out at 1,200 cfs through July 17 at 16:00, and then gradually declined to 700 cfs by July 22. By August 2, the river dropped to the summer base flow in the low-to-mid 400 cfs range.

2.4.2 Mainstem Sediment Transport Monitoring

GMA sampling crews collected suspended sediment and bedload measurements during nine consecutive days from May 8 to May 16, 2016. Crews collected two to 15 one-pass bedload samples and one suspended sediment sample each day. Table 1 summarizes the number of bedload and suspended sediment samples collect by station. For 2016, experimental bedload-variability testing (repeated sampling at a high-transport location) was conducted. Crews collected nine discharge measurements during the release period for computing continuous discharge at TRGV. Appendices A, B, C and D provide hydrographs displaying the timing of bedload and suspended sediment samples at each station.

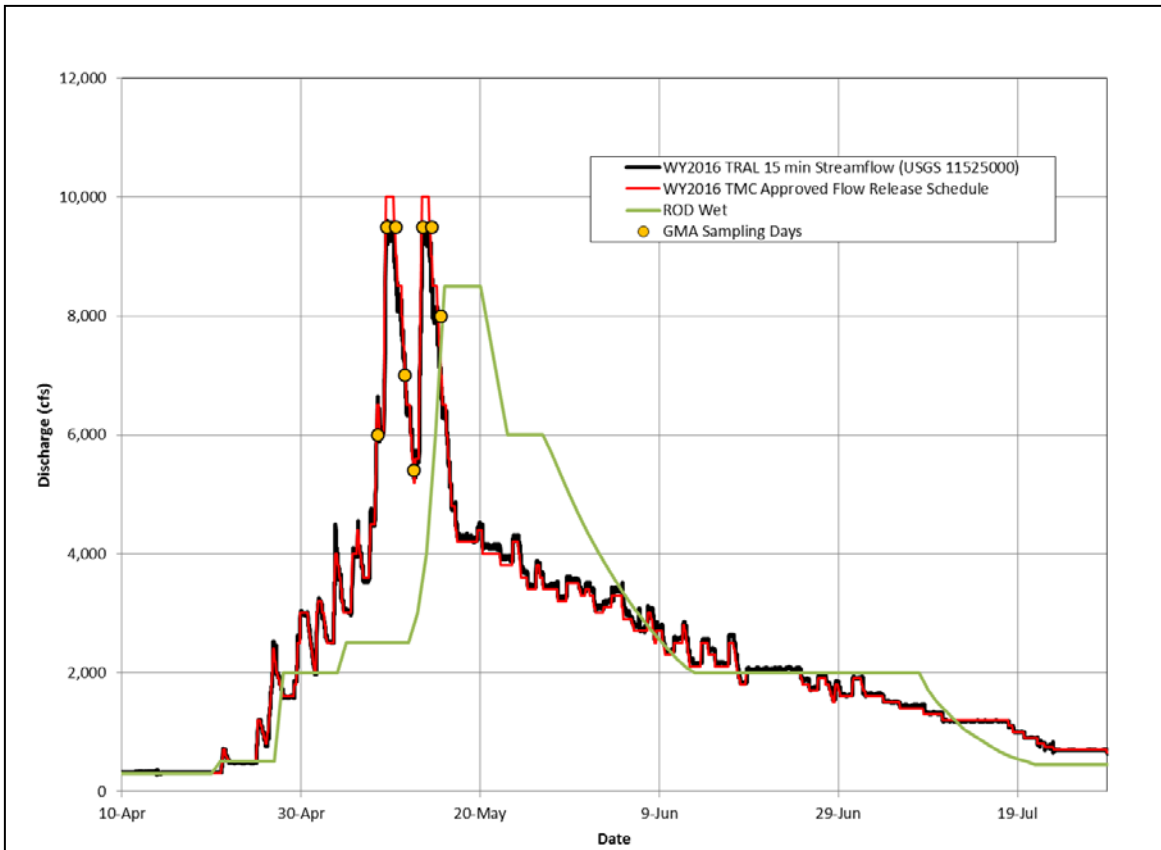


Figure 6. ROD Wet hydrograph, TMC Approved hydrograph, and recorded (actual) Streamflow for USGS Gage #11525500, Trinity River at Lewiston, CA for the WY2016 Spring Flow Release.

Table 1. WY 2016 Mainstem Sediment Sample Summary

SEDIMENT MONITORING STATION	SUSPENDED SEDIMENT SAMPLES (# collected)	BEDLOAD SAMPLES (# collected)
Trinity River at Lewiston (TRAL)	9	64
Trinity River above Grass Valley Creek (TRGV)	8	53
Trinity River below Limekiln Gulch (TRLG)	9	72
Trinity River near Douglas City (TRDC)	7	53

2.4.2.1 Trinity River at Lewiston

Station Description

The TRAL station defines the end of the first sediment budgeting cell which starts at Lewiston Dam (Figure 1, Figure 7). Since WY 2005, sediment transport monitoring has occurred directly beneath the old Lewiston Bridge. Previous sediment transport monitoring occurred 1,150 ft upstream, near the USGS Trinity River at Lewiston Gaging Station cableway. The USGS streamflow gaging station (#11525500) is located farther upstream, just below the old fish weir.

Suspended Sediment Transport Data

Nine suspended sediment discharge samples were collected at TRAL during the Spring Flow Release. All of the suspended sediment samples were two-pass samples. Sample concentrations ranged from 3 to 10 mg/l (Table 2), and the corresponding suspended sediment discharges ranged from 59 to 255 tons/day (Table 2, Figure 8).

The low concentrations and low turbidity at TRAL preclude the use of turbidity as a surrogate for SSC. Consequently, continuous suspended-sediment concentration is derived using measured concentrations and continuous discharge as a surrogate for SSC. The WY 2016 total suspended sediment discharge measurements were plotted in Figure 8 along with data from WY 2004-15. Appendix A-3 contains the transport curves used for the WY 2016 load computations.



Figure 7. Upstream view of TRAL Sampling Site, WY2016. Flow is approximately 8,500 cfs.

Table 2. Trinity River at Lewiston, CA -- USGS Gage #11525500, Suspended Sediment Sampling Summary -- WY2016

Sample Number	Date & Mean Time	Average Discharge (cfs)	Average SSC (mg/l)	Average SSD (tons/day)
TRAL-SSCT2016-01	5/8/2016 16:28	6,460	4	71
TRAL-SSCT2016-02	5/9/2016 17:25	9,320	10	255
TRAL-SSCT2016-03	5/10/2016 15:58	8,440	6	140
TRAL-SSCT2016-04	5/11/2016 16:00	6,790	3	59
TRAL-SSCT2016-05	5/12/2016 12:30	5,590	6	97
TRAL-SSCT2016-06	5/13/2016 15:27	9,350	6	160
TRAL-SSCT2016-07	5/14/2016 15:40	8,540	5	106
TRAL-SSCT2016-08	5/15/2016 13:45	7,090	7	130
TRAL-SSCT2016-09	5/16/2016 11:16	5,460	6	93

Values Rounded According to Porterfield (1972)

The SSC data for all size classes do not exhibit strong patterns of hysteresis (Appendix D-1), therefore single generalized transport curves were developed (Appendix A-3). Any hysteresis which was present was addressed by adjusting the continuous concentration to the individual sample data points using proportional and hydrograph-fitting techniques (Appendix A-1). Continuous suspended sediment discharge (SSD) was computed from continuous SSC, then

SSD was integrated over the release period to generate load. Computational methods and assumptions are detailed in the Station Analysis (Appendix A-1). The sedigraphs are presented in Appendix A-5.

The partial and total loads for the computational period were 1,510, 271, 113, and 1,890 tons (Table 3). Appendix A-8 contains the suspended sediment sample data (particle size distributions, summary tables, etc.) and the computations (daily and 15-min suspended sediment discharge and cumulative load values).

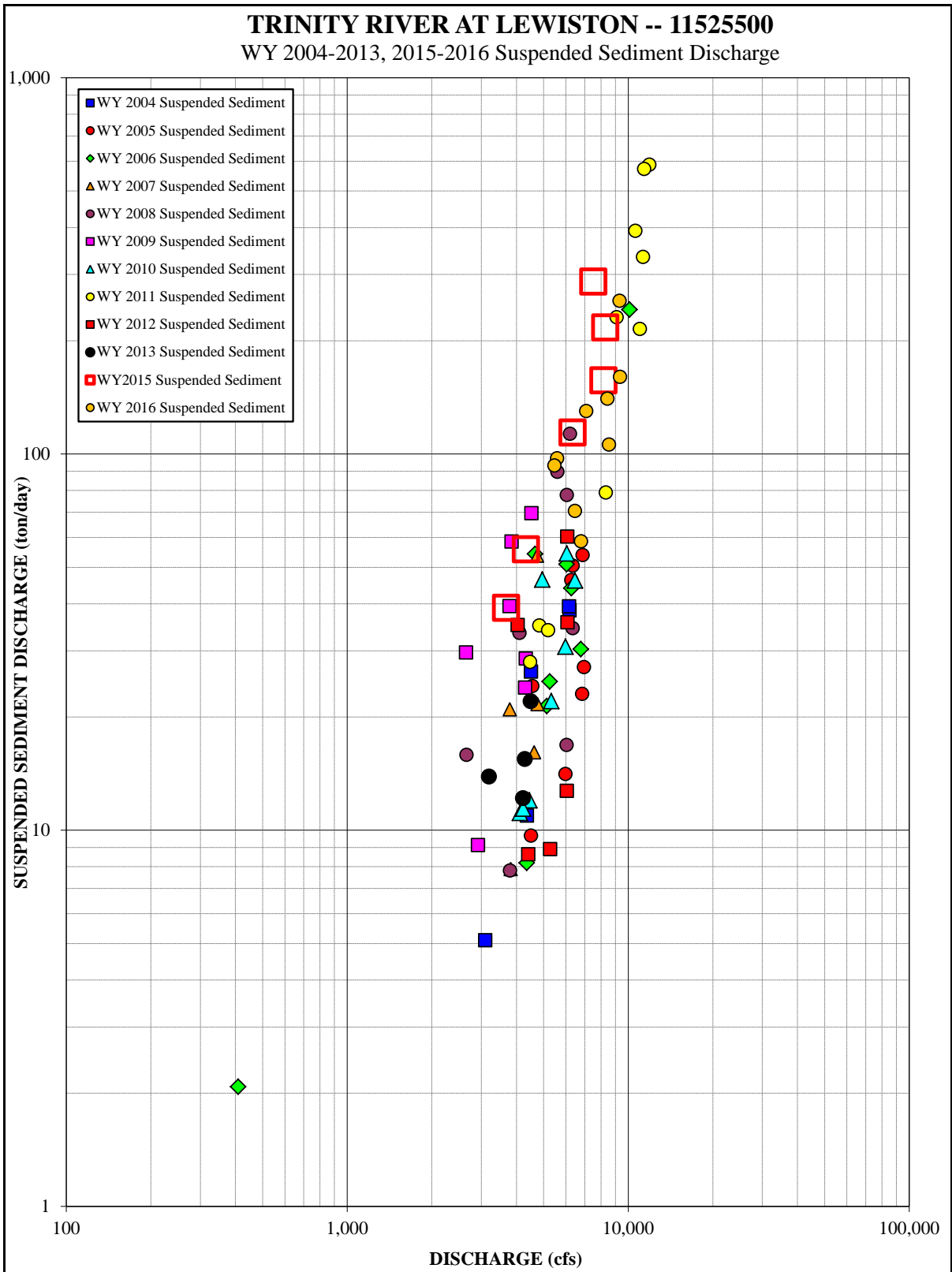


Figure 8. Suspended Sediment Discharge at TRAL 2004-2013, 2015-2016.

Table 3. Trinity River at Lewiston, CA -- USGS Gage #11525500, Suspended Sediment Loads -- WY2016

< 0.063 mm (tons)	0.063 mm-<0.50 mm (tons)	≥0.50 mm (tons)	Total Load (tons)
1,510	271	113	1,890

Values Rounded According to Porterfield (1972)

Bedload Data

Sixty-four bedload samples were collected at TRAL during the Spring Flow Release. All samples were one-pass samples. Bedload sample data are displayed in Table 4. Bedload sample times were plotted on the hydrographs in Appendix A-4 and displayed in the Bedload Summary in Appendix A-7. WY 2016 fine, coarse, and total bedload discharge points were plotted with historic data in Figures 9-11. Measured total bedload discharge (sum of fine and coarse bedload) ranged from a peak of 936 tons/day on May 10 to a minimum of 5.1 tons/day on May 16. The bedload transport curves used to compute continuous bedload discharge are located in Appendix A-2.

Table 4. Trinity River at Lewiston -- USGS #11525500, Bedload Sampling Summary -- WY2016

Table 1/2					
Sample Number	Date & Mean Time	Average Discharge (cfs)	Total Bedload Discharge (tons/day)	> 8mm Bedload Discharge (tons/day)	0.5-8 mm Bedload Discharge (tons/day)
TRAL-BLM2016-01	05/08/2016 11:12	6,020	265	251	14
TRAL-BLM2016-02	05/08/2016 11:54	5,930	80	75	4.2
TRAL-BLM2016-03	05/08/2016 12:36	6,650	225	216	8.9
TRAL-BLM2016-04	05/08/2016 13:04	6,390	123	111	12
TRAL-BLM2016-05	05/08/2016 14:06	6,370	182	153	28
TRAL-BLM2016-06	05/08/2016 14:32	6,400	214	201	13
TRAL-BLM2016-07	05/08/2016 15:04	6,340	71	61	9.2
TRAL-BLM2016-08	05/08/2016 15:32	6,430	180	169	11
TRAL-BLM2016-09	05/09/2016 08:48	7,770	594	577	15
TRAL-BLM2016-10	05/09/2016 09:28	7,700	488	447	36
TRAL-BLM2016-11	05/09/2016 10:10	8,420	662	615	45
TRAL-BLM2016-12	05/09/2016 10:39	9,120	931	797	129
TRAL-BLM2016-13	05/09/2016 12:52	9,520	660	551	106
TRAL-BLM2016-14	05/09/2016 13:30	9,520	568	461	104
TRAL-BLM2016-15	05/09/2016 14:42	9,340	515	456	58
TRAL-BLM2016-16	05/09/2016 15:12	9,420	861	775	83
TRAL-BLM2016-17	05/09/2016 15:58	9,290	522	446	75
TRAL-BLM2016-18	05/09/2016 16:27	9,300	474	392	79
TRAL-BLM2016-19	05/09/2016 18:02	9,350	639	564	72
TRAL-BLM2016-20	05/10/2016 09:27	9,540	424	352	74
TRAL-BLM2016-21	05/10/2016 09:54	9,340	264	206	57
TRAL-BLM2016-22	05/10/2016 10:33	8,870	445	346	98
TRAL-BLM2016-23	05/10/2016 11:05	8,900	936	828	106
TRAL-BLM2016-24	05/10/2016 12:29	9,050	676	585	89

Values Rounded According to Porterfield (1972)

Table 2/2

Sample Number	Date & Mean Time	Average Discharge (cfs)	Total Bedload Discharge (tons/day)	> 8mm Bedload Discharge (tons/day)	0.5-8 mm Bedload Discharge (tons/day)
TRAL-BLM2016-25	05/10/2016 13:03	8,800	313	221	91
TRAL-BLM2016-26	05/10/2016 14:48	8,610	439	370	70
TRAL-BLM2016-27	05/10/2016 15:13	8,590	418	392	26
TRAL-BLM2016-28	05/10/2016 16:30	8,370	248	222	25
TRAL-BLM2016-29	05/11/2016 09:04	7,660	135	76	59
TRAL-BLM2016-30	05/11/2016 09:31	7,690	95	69	26
TRAL-BLM2016-31	05/11/2016 10:20	7,360	160	123	38
TRAL-BLM2016-32	05/11/2016 10:48	7,330	169	127	42
TRAL-BLM2016-33	05/11/2016 13:01	7,190	112	56	55
TRAL-BLM2016-34	05/11/2016 13:26	7,270	66	49	18
TRAL-BLM2016-35	05/11/2016 14:48	7,100	109	81	28
TRAL-BLM2016-36	05/11/2016 15:16	6,730	70	47	22
TRAL-BLM2016-37	05/12/2016 09:00	6,010	54	44	10
TRAL-BLM2016-38	05/12/2016 09:40	6,050	48	39	10
TRAL-BLM2016-39	05/12/2016 10:32	5,730	42	27	15
TRAL-BLM2016-40	05/12/2016 11:10	5,640	13	6.9	5.9
TRAL-BLM2016-41	05/13/2016 09:32	7,790	281	246	35
TRAL-BLM2016-42	05/13/2016 09:57	7,760	142	100	41
TRAL-BLM2016-43	05/13/2016 10:52	8,560	396	342	54
TRAL-BLM2016-44	05/13/2016 11:20	8,590	222	179	43
TRAL-BLM2016-45	05/13/2016 12:50	9,370	337	296	41
TRAL-BLM2016-46	05/13/2016 13:25	9,290	374	307	65
TRAL-BLM2016-47	05/13/2016 13:57	9,230	457	369	87
TRAL-BLM2016-48	05/13/2016 14:30	9,280	190	128	61
TRAL-BLM2016-49	05/14/2016 09:22	9,010	719	603	115
TRAL-BLM2016-50	05/14/2016 09:50	9,140	778	602	174
TRAL-BLM2016-51	05/14/2016 10:35	9,050	469	404	65
TRAL-BLM2016-52	05/14/2016 11:00	9,240	489	371	116
TRAL-BLM2016-53	05/14/2016 13:10	8,470	391	345	45
TRAL-BLM2016-54	05/14/2016 13:34	8,400	333	272	60
TRAL-BLM2016-55	05/14/2016 16:26	7,990	417	370	46
TRAL-BLM2016-56	05/14/2016 16:50	8,060	476	374	102
TRAL-BLM2016-57	05/15/2016 09:07	7,590	126	75	50
TRAL-BLM2016-58	05/15/2016 09:31	7,590	54	28	25
TRAL-BLM2016-59	05/15/2016 10:57	7,130	43	26	17
TRAL-BLM2016-60	05/15/2016 11:37	7,140	19	11	7.7
TRAL-BLM2016-61	05/15/2016 13:06	7,110	71	64	7.0
TRAL-BLM2016-62	05/15/2016 15:00	6,720	59	46	12
TRAL-BLM2016-63	05/16/2016 09:15	5,880	5.1	3.3	1.8
TRAL-BLM2016-64	05/16/2016 10:23	5,720	11	7.1	3.4

Values Rounded According to Porterfield (1972)

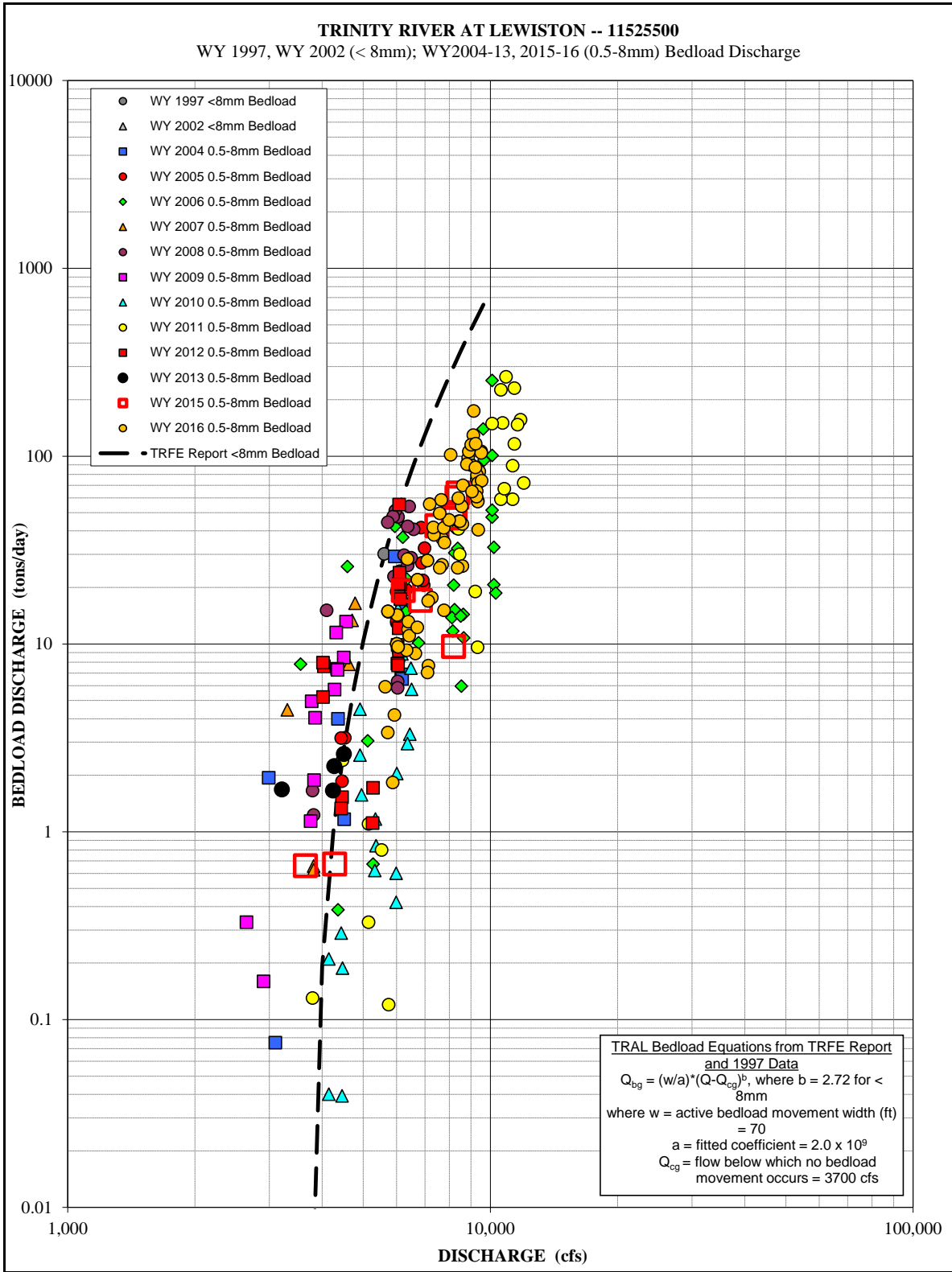


Figure 9. Fine Bedload Discharge (0.5-<8mm) at TRAL, WY1997-2016.

The 1999 TRFE bedload equations were used to develop flow recommendations based in part on bedload discharge predictions at TRAL and TRLG (shown in the inset box on chart). The equation is plotted and shown here as the dashed black line and is included for comparison with subsequent measured bedload transport rates.

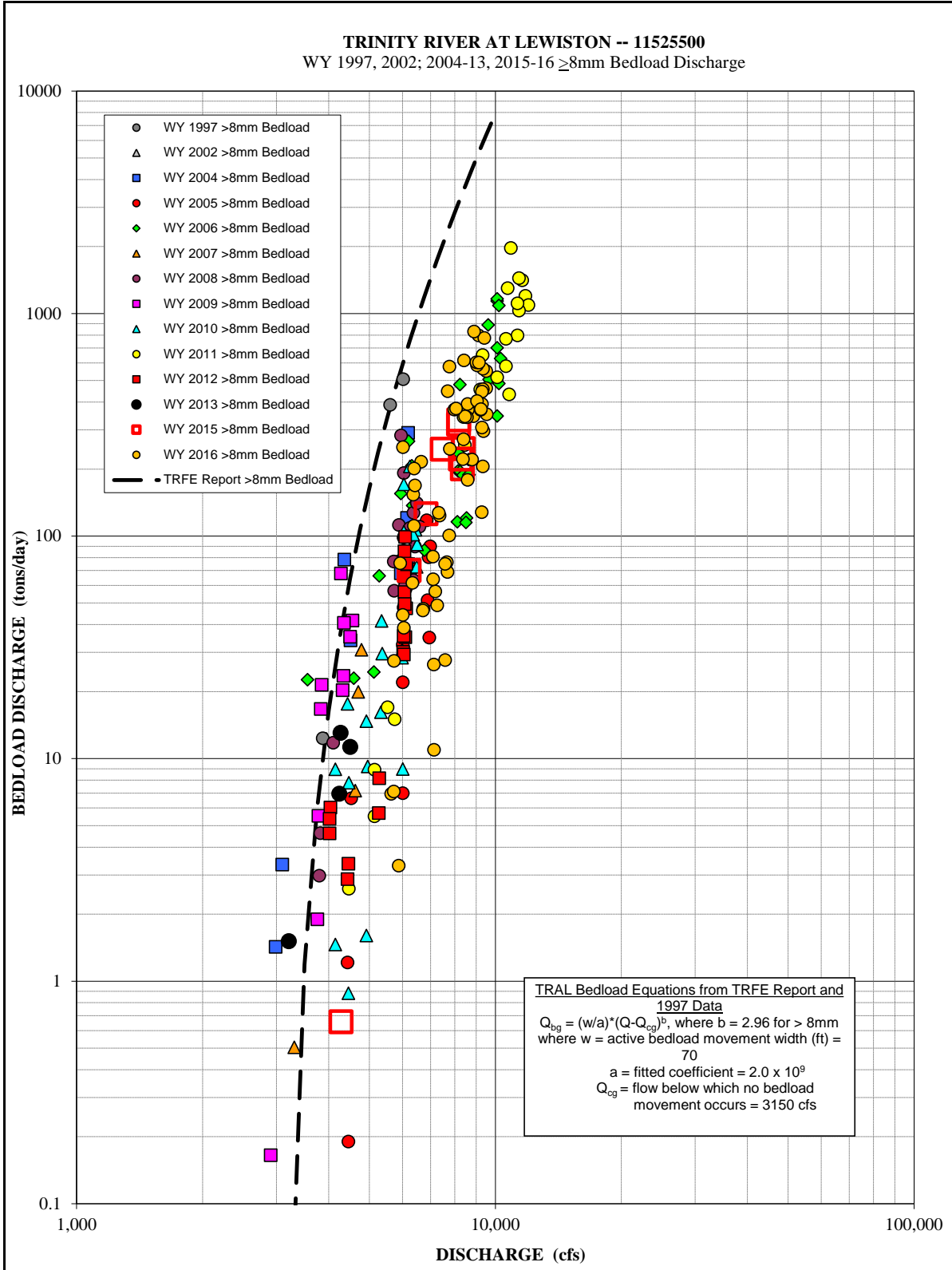


Figure 10. Coarse Bedload Discharge ($\geq 8\text{mm}$) at TRAL, WY1997-2016.

The 1999 TRFE bedload equations were used to develop flow recommendations based in part on bedload discharge predictions at TRAL and TRLG (shown in the inset box on chart). The equation is plotted and shown here as the dashed black line and is included for comparison with subsequent measured bedload transport rates.

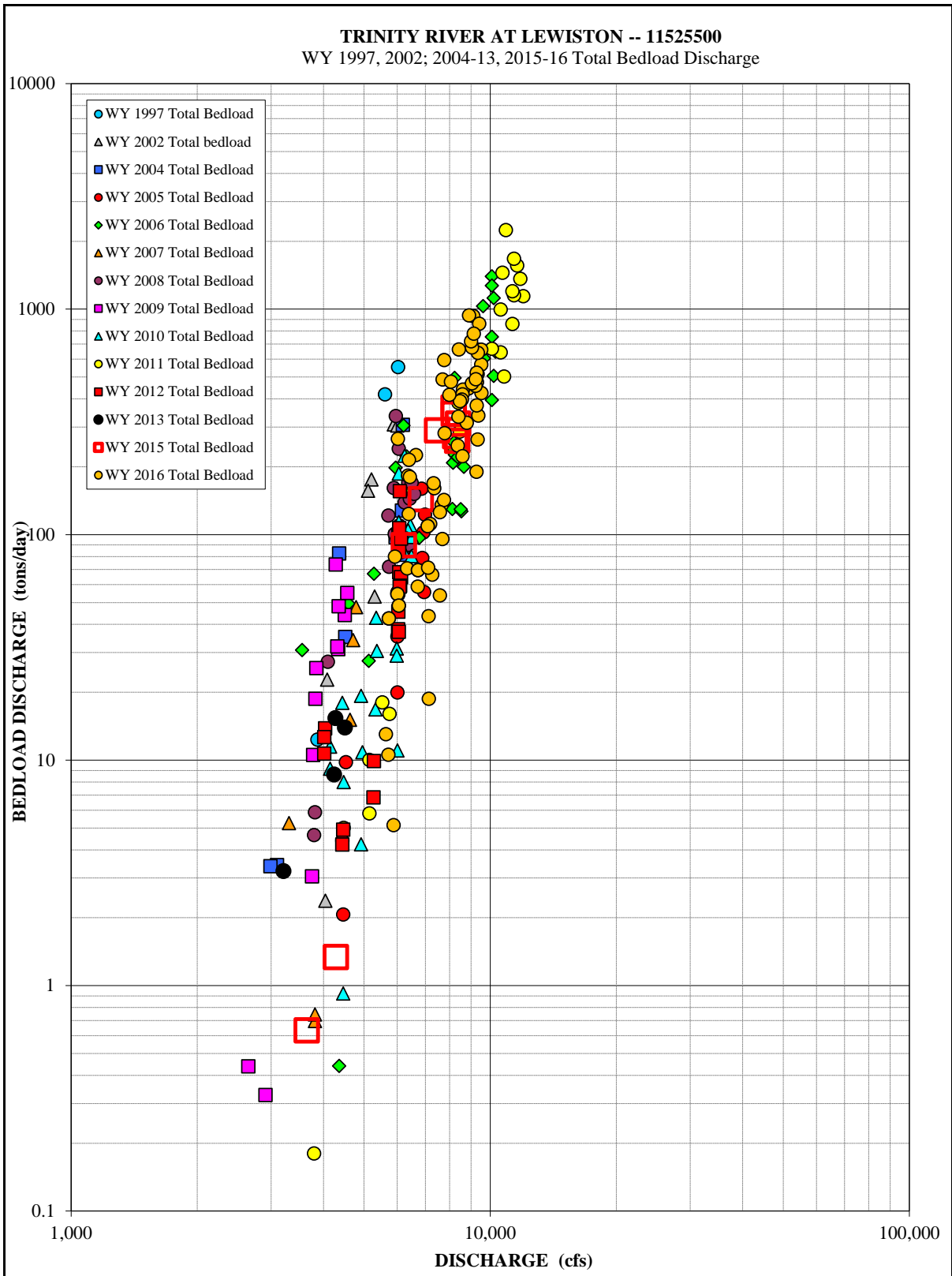


Figure 11. Total Bedload Discharge at TRAL, WY1997-2016.

Continuous bedload-discharge sedigraphs are displayed in Appendix A-4. Flow release estimates for fine, coarse, and total bedload in WY 2016 were 338, 1,800 and 2,140 tons, respectively (Table 5). Detailed explanations of the bedload discharge and load computations are provided in the Station Analysis (Appendix A-1). Appendix A-9 contains the particle size distributions, sample data, (e.g. sample times, weights, computed transport rates) and bedload computation values. As discussed in section 2.3.4, the <0.5mm fraction is omitted from bedload data and computations; however, this fraction is included for graphical comparisons with historic values (e.g. Figure 11).

Table 5. Trinity River at Lewiston, CA -- USGS Gage #11525500, Bedload -- WY2016

0.5-<8 mm (tons)	≥8 mm (tons)	Total Bedload (tons)
338	1,800	2,140

Values Rounded According to Porterfield (1972)

Water Surface Slope, Cross Section Changes and Pebble Count Changes

The WY2016 peak water surface slope through the reach was 0.0015. Surveyed changes in the cross section are presented in Figure 12. Below the 1,805 foot elevation, the channel cross section showed 15.9 ft² of scour and 2.9 ft² of fill for a net change of 13.1 ft² of scour.

The deeper, coarser left side of the channel is not included in the annual pebble count which represents the right half of the low flow channel. The particle size distribution derived from the pebble count data is provided in Figure 13. Most of the particle size distribution grew somewhat coarser, with the D50 (grain size for which 50 percent of the sample is smaller) increasing from 48 to 55mm. Above the 90th percentile, the distribution shows fining, and the D90 dropped from 91 to 84mm.

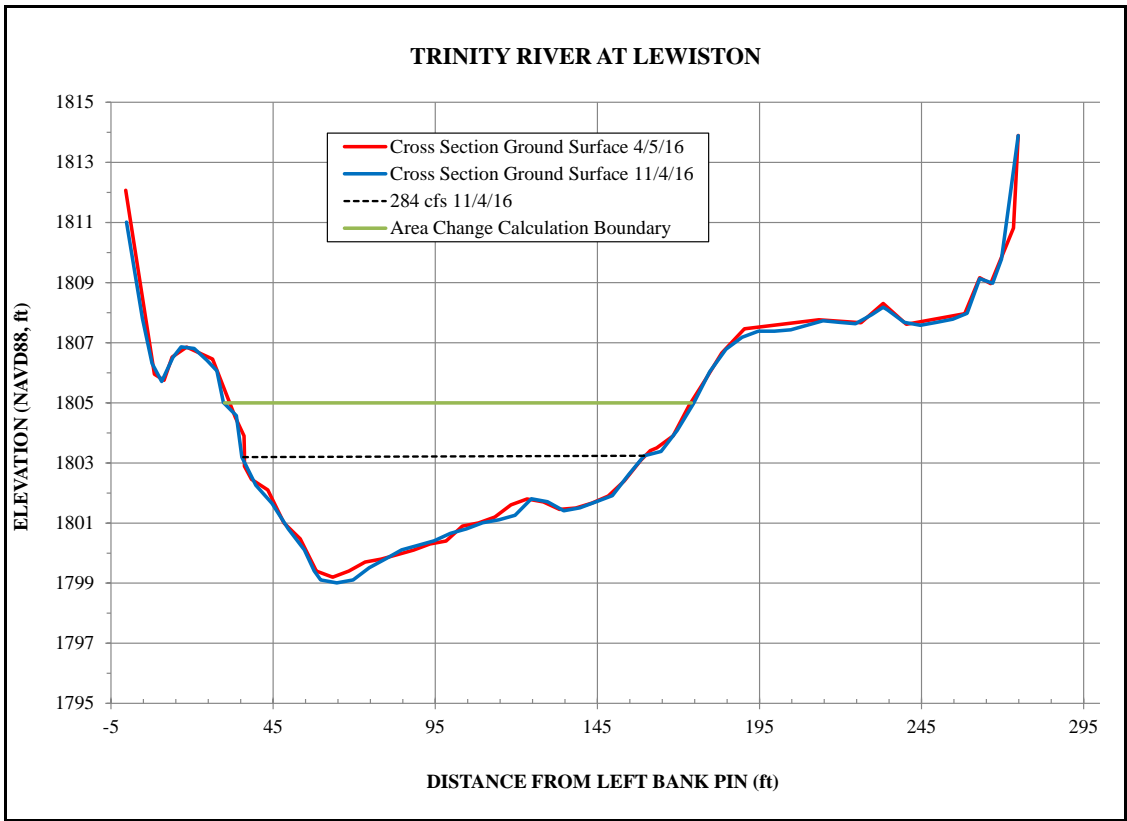


Figure 12. Cross Section changes at TRAL, pre/post Spring Flow Release 2016. Downstream view.

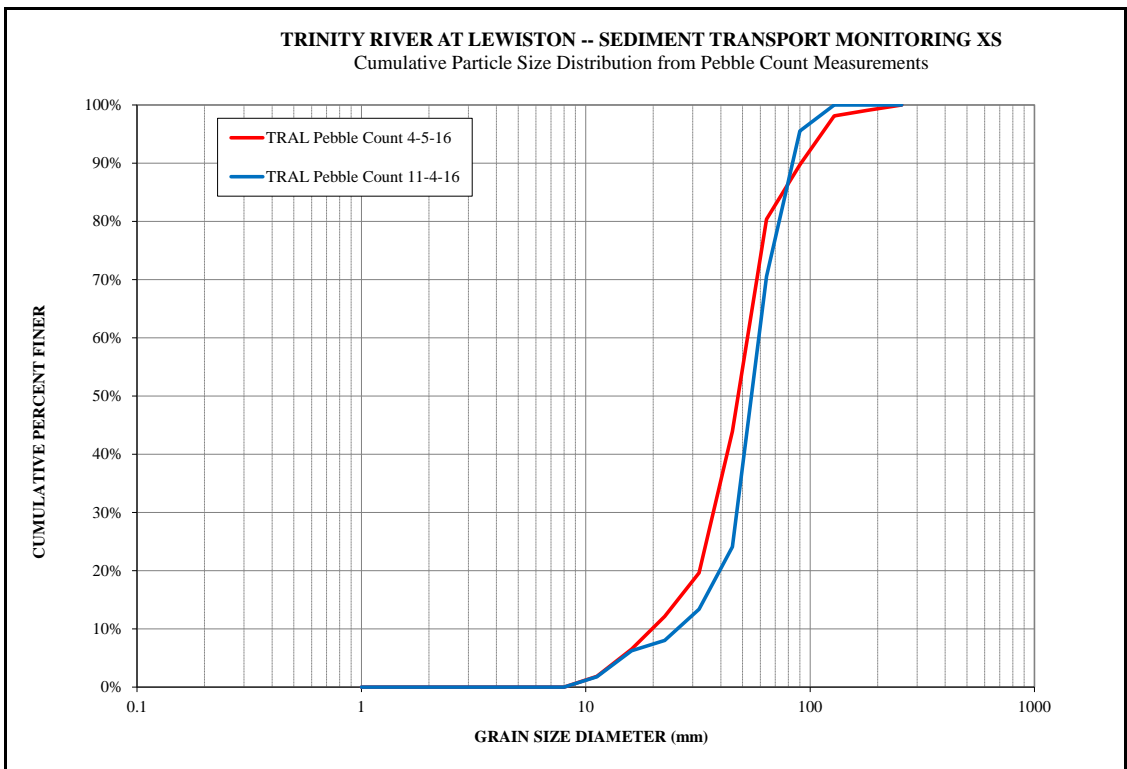


Figure 13. Changes in bed texture at TRAL, pre/post Spring Flow Release 2016.

2.4.2.2 Trinity River above Grass Valley Creek

Station Description

The TRGV sediment transport monitoring station is located approximately 1,800 feet upstream of the Grass Valley Creek confluence on the BLM Lowden Ranch property (Figure 1, Figure 14). A seasonal streamflow and turbidity gaging station was established at TRGV (Appendix B-1) just prior to the WY 2006 Spring Flow Release. The station was originally located in a relatively straight and uniformly-shaped low-gradient section of the Trinity River. The station was relocated about 200 feet downstream in WY 2011 as a result of restoration construction activities in 2010 which created a forced meander only a short distance upstream from the original gage site. Gravel injection frequently occurs just upstream of the sampling site during flow releases.

In WY 2016, the gage was operated from April 4 to July 31. Streamflow data from April 1 through April 4 was estimated by summing Trinity River at Lewiston and Rush Creek streamflow records. The TRGV gage defines the downstream end of the second sediment budget cell (Figures 1 and 2). A cable was strung between two large conifers above the active channel to allow cataraft sampling. High streamflow measurements were collected using an Acoustic Doppler Current Profiler or current meter with sounding weight, deployed from either a jet boat or cataraft. Low, wadeable flows, were measured using a 4-ft top-set rod, a Price AA meter, and an AquaCalc streamflow computer. The TRGV site presented few safety concerns and provided an excellent sediment sampling location and a fair streamflow gaging site, despite upstream gravel injection which causes deposition at the gaging site resulting in shifts in the stage-discharge relation.



Figure 14. Photograph of TRGV sampling crew, WY2012. View is downstream.

Streamflow Gaging

The relatively straight, uniform channel created by the riparian berms and old mining activities provided an ideal streamflow gaging reach for the 2006-2010 period. The reach was modified substantially during construction of the restoration project in 2010. Removal of the left bank riparian berm and tailing piles and construction of a floodplain resulted in a channel with a substantial floodplain flow component at the higher discharges. Continuous stage height readings were recorded from April 4 through August 3, but streamflow records were computed (or estimated) for the Spring Flow Release period (April 1 through July 31). Nine discharge measurements (Figure 15) were collected during the computation period (Appendix B-1; B-5). Measured discharge for the period ranged from 362 cfs to 9,266 cfs. Computed instantaneous discharge ranged from 362 cfs to 10,000 cfs.

The stage-discharge relationship, Rating 6.0, was established in WY 2016 to extend the low end of Rating 5.1 (Appendix B-2). Rating 6.0 was used during Water Year 2016 with a stage variable shift applied. A detailed explanation of the methods and assumptions used to compute the discharge record are provided in the Streamflow Station Analysis (Appendix B-1).

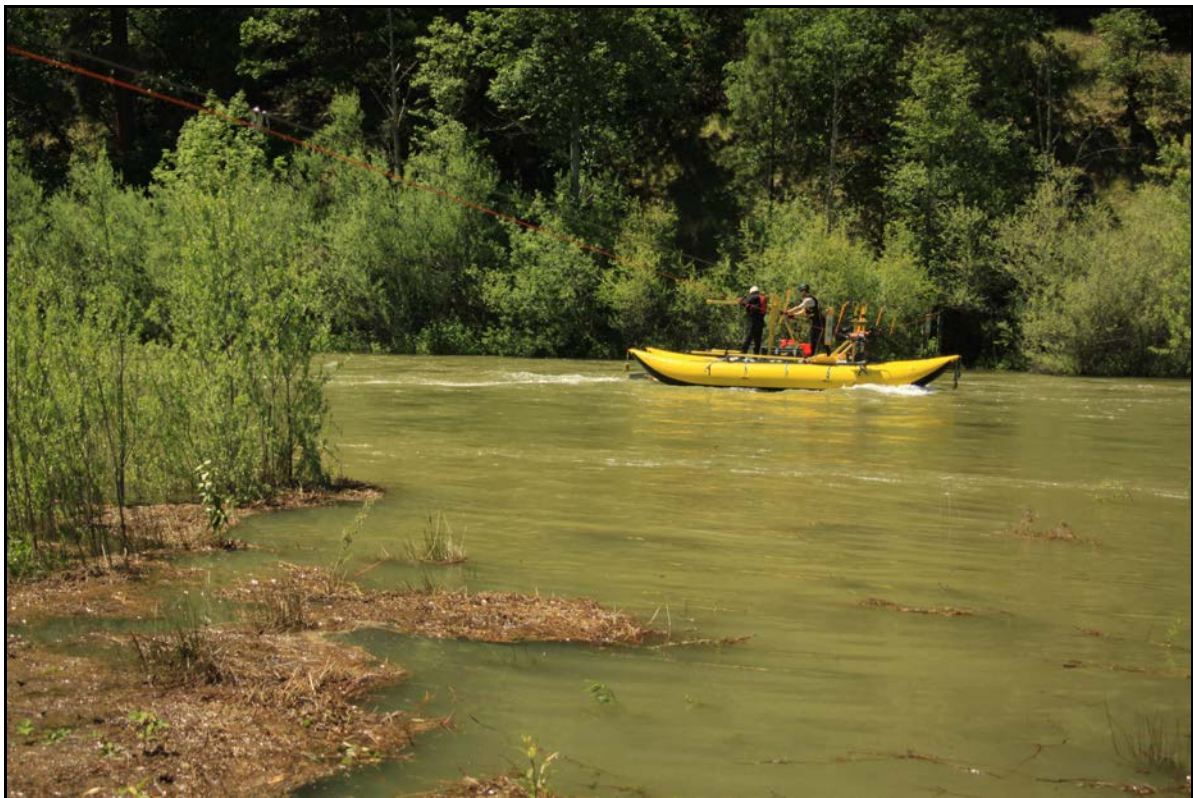


Figure 15. Photograph of sediment sampling crew on a cataraft at TRGV in 2016. Flow is right to left, approximately 6,500 cfs.

Suspended Sediment Transport Data

Eight two-pass suspended sediment samples were collected between May 8 and May 16, 2016 at TRGV (Table 6). Measured SSC fluctuated from a peak of 28 mg/l on May 14 at

9,610 cfs, to a low of 11 mg/l on May 12 at 5,990 cfs. The associated transport rates were 732 and 178 tons/day respectively. WY 2016 suspended sediment discharge values are plotted in Figure 16 along with sample data from WY 2006-2015.

Table 6. Trinity River above Grass Valley Creek -- GMA Gage #11525540, Suspended Sediment Sampling Summary -- WY2016

Sample Number	Date & Mean Time	Average Discharge (cfs)	Average SSC (mg/l)	Average SSD (tons/day)
TRGV-SSCT2016-01	5/8/2016 16:31	6,880	13	238
TRGV-SSCT2016-02	5/9/2016 8:33	7,170	13	258
TRGV-SSCT2016-03	5/11/2016 8:46	8,340	14	317
TRGV-SSCT2016-04	5/12/2016 12:46	5,990	11	178
TRGV-SSCT2016-05	5/13/2016 11:38	8,250	12	264
TRGV-SSCT2016-06	5/14/2016 12:49	9,610	28	732
TRGV-SSCT2016-07	5/15/2016 13:27	7,730	25	519
TRGV-SSCT2016-08	5/16/2016 14:47	5,790	12	190

Values Rounded According to Porterfield (1972)

Turbidity versus SSC showed poor relationships. A potential cause is gravel augmentation activities at the site during the flow release period effecting turbidity values at the turbidity probe, which is located along the left bank. Sampling crews observed a distinct turbidity plume several times near the probe. Sample data was collected along the entire cross section and did not relate to the increased turbidity seen only along the left bank. Continuous suspended sediment discharge for the three size classes was computed using discharge versus SSC relationships (Appendix B-1; B-4). Partial and total suspended sediment load for the Spring Flow Release were 2,850, 1,750, 612 and 5,210 tons for the <0.063mm, 0.063- <0.50mm, ≥0.50mm size classes and total load respectively (Table 7). The Sediment Station Analysis (Appendix B-1) details the relationships and periods of record for which the transport curves were applied. Appendix B-10 contains the sample data and SSC computations.

Table 7. Trinity River above Grass Valley Creek -- GMA Gage #11525540, Suspended Sediment Loads -- WY2016

< 0.063 mm (tons)	0.063 mm-<0.50 mm (tons)	≥0.50 mm (tons)	Total Load (tons)
2,850	1,750	612	5,210

Values Rounded According to Porterfield (1972)

TRINITY RIVER ABV GRASS VALLEY CREEK --11525540
WY 2006-2013, 2015-2016 Suspended Sediment Discharge

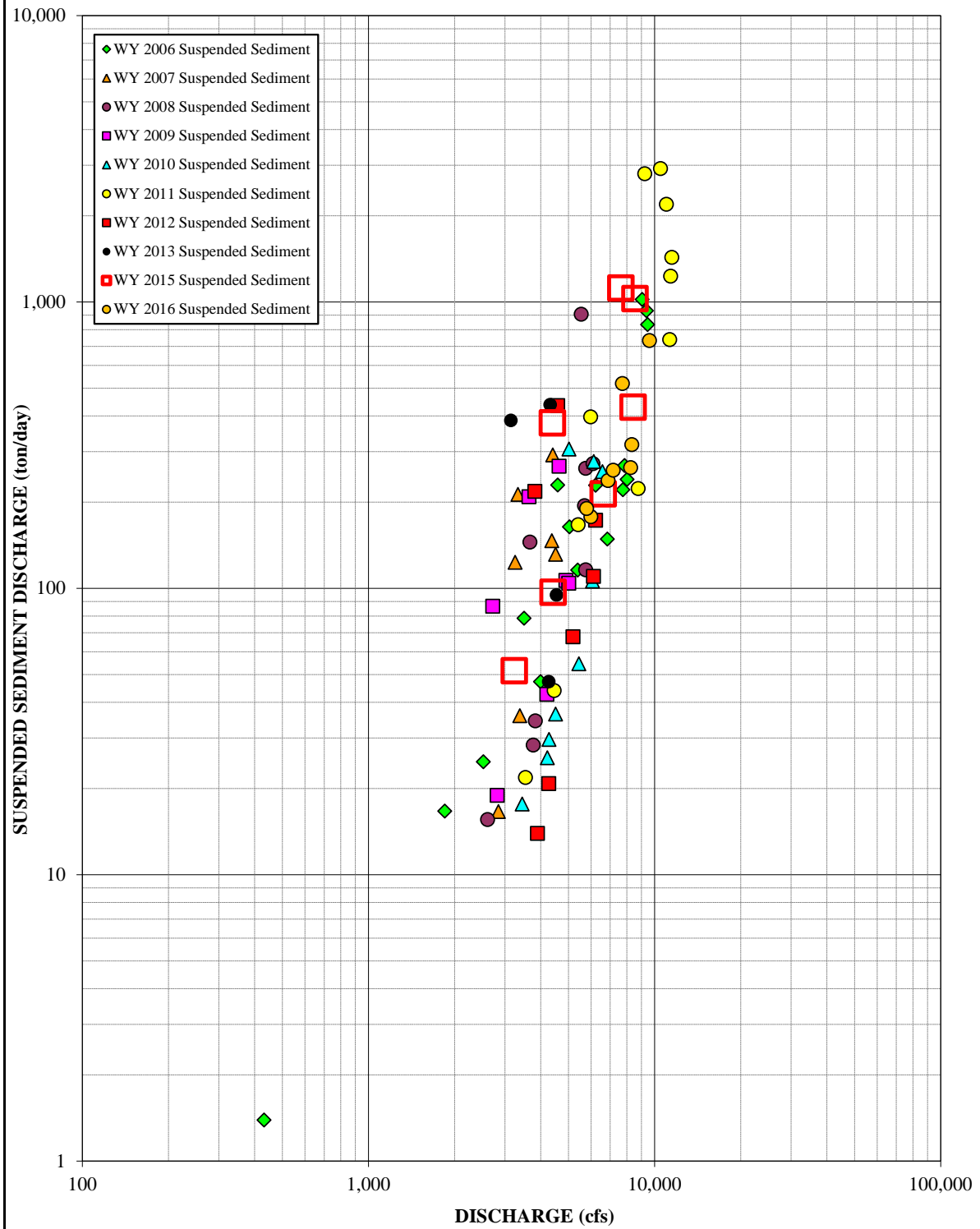


Figure 16. Suspended Sediment Discharge at TRGV, WY2006-2013, 2015-2016.

Bedload Data

Fifty three bedload samples were collected at TRGV between May 8 and May 16, 2016. Bedload sampling times were plotted on hydrographs in Appendix B-5. Bedload sample data and bedload discharge computations are summarized in Table 8. Fine, coarse, and total bedload discharge rates for WY 2006-16 are plotted in Figures 17-19 As discussed in section 2.3.4, the <0.5mm fraction is omitted from bedload data and computations; however, this fraction is included for graphical comparisons with historic values (e.g. Figure 11).

The measured (Total) transport rates started at 225 tons/day at 5,770 cfs on May 8, peaked at 2,610 tons/day at 9,880 cfs on May 9 and finished at 36 tons/day at 5,790 cfs on May 16, 2016. The Sediment Station Analysis (Appendix B-1) describes the development of the bedload transport curves and the periods of record over which each was applied. The transport curves and bedload measurements were used to compute continuous bedload discharge and load estimates (Appendix B-10). Appendix B-3 contains the bedload transport curves used to estimate continuous bedload discharge. Appendix B-6 contains the bedload sedigraphs for the Spring Flow Release Period. Fine, coarse, and total bedload estimates for the period April 1 to July 31, 2016 were 578, 3,110 and 3,690 tons (Table 9). Appendix B-9 contains the sample data (weights and computed transport rates) and bedload computation values.

Table 8. Trinity River above Grass Valley Creek -- GMA Gage #11525540, Bedload Sediment Sampling Summary -- WY2016

Table 1/2					
Sample Number	Date & Mean Time	Average Discharge (cfs)	Total Bedload Discharge (tons/day)	> 8mm Bedload Discharge (tons/day)	0.5-8 mm Bedload Discharge (tons/day)
TRGV-BLM2016-01	05/08/2016 10:50	5,770	225	159	63
TRGV-BLM2016-02	05/08/2016 11:58	6,090	164	88	71
TRGV-BLM2016-03	05/08/2016 13:15	6,350	134	63	68
TRGV-BLM2016-04	05/08/2016 14:02	6,500	110	66	42
TRGV-BLM2016-05	05/08/2016 14:49	6,850	205	110	90
TRGV-BLM2016-06	05/08/2016 15:34	6,920	205	125	77
TRGV-BLM2016-07	05/09/2016 09:20	7,340	312	222	87
TRGV-BLM2016-08	05/09/2016 10:26	7,980	633	529	98
TRGV-BLM2016-09	05/09/2016 11:17	8,270	441	349	88
TRGV-BLM2016-10	05/09/2016 13:16	9,510	793	608	176
TRGV-BLM2016-11	05/09/2016 13:57	9,850	2,210	1,970	224
TRGV-BLM2016-12	05/09/2016 14:58	9,830	1,360	1,040	304
TRGV-BLM2016-13	05/09/2016 15:37	9,880	2,610	2,400	195
TRGV-BLM2016-14	05/09/2016 18:10	9,870	2,600	2,430	164
TRGV-BLM2016-15	05/10/2016 08:53	9,900	924	769	149
TRGV-BLM2016-16	05/10/2016 11:34	9,920	900	729	165
TRGV-BLM2016-17	05/10/2016 12:08	9,740	1,000	842	154
TRGV-BLM2016-18	05/10/2016 13:41	9,430	988	877	108
TRGV-BLM2016-19	05/10/2016 15:34	9,250	408	346	59

Values Rounded According to Porterfield (1972)

Table 2/2

Sample Number	Date & Mean Time	Average Discharge (cfs)	Total Bedload Discharge (tons/day)	> 8mm Bedload Discharge (tons/day)	0.5-8 mm Bedload Discharge (tons/day)
TRGV-BLM2016-20	05/10/2016 16:11	9,220	574	469	101
TRGV-BLM2016-21	05/11/2016 09:31	8,300	244	223	21
TRGV-BLM2016-22	05/11/2016 11:20	8,180	89	74	15
TRGV-BLM2016-23	05/11/2016 12:11	8,000	145	118	26
TRGV-BLM2016-24	05/11/2016 13:43	7,870	110	88	22
TRGV-BLM2016-25	05/11/2016 14:45	7,830	74	49	24
TRGV-BLM2016-26	05/11/2016 15:39	7,720	40	28	12
TRGV-BLM2016-27	05/12/2016 08:33	6,540	47	33	14
TRGV-BLM2016-28	05/12/2016 09:20	6,480	35	23	11
TRGV-BLM2016-29	05/12/2016 11:01	6,430	47	33	14
TRGV-BLM2016-30	05/12/2016 12:02	6,270	113	96	16
TRGV-BLM2016-31	05/13/2016 08:36	7,320	182	156	25
TRGV-BLM2016-32	05/13/2016 09:12	7,460	182	150	30
TRGV-BLM2016-33	05/13/2016 09:48	7,650	59	40	18
TRGV-BLM2016-34	05/13/2016 10:23	8,030	192	154	36
TRGV-BLM2016-35	05/13/2016 12:15	8,570	268	232	33
TRGV-BLM2016-36	05/13/2016 13:31	9,200	236	176	57
TRGV-BLM2016-37	05/13/2016 14:13	9,640	348	288	57
TRGV-BLM2016-38	05/13/2016 15:33	9,770	611	502	106
TRGV-BLM2016-39	05/13/2016 16:22	9,750	981	936	42
TRGV-BLM2016-40	05/14/2016 08:47	9,880	695	651	42
TRGV-BLM2016-41	05/14/2016 09:24	9,840	840	814	25
TRGV-BLM2016-42	05/14/2016 11:37	9,590	430	391	38
TRGV-BLM2016-43	05/14/2016 12:11	9,600	820	758	60
TRGV-BLM2016-44	05/14/2016 14:30	9,090	408	388	20
TRGV-BLM2016-45	05/14/2016 15:00	9,040	380	358	21
TRGV-BLM2016-46	05/15/2016 09:41	8,130	135	130	5.2
TRGV-BLM2016-47	05/15/2016 10:37	8,150	155	148	6.9
TRGV-BLM2016-48	05/15/2016 11:23	8,050	189	180	9.0
TRGV-BLM2016-49	05/15/2016 11:59	7,900	120	114	6.0
TRGV-BLM2016-50	05/15/2016 14:14	7,640	181	174	6.5
TRGV-BLM2016-51	05/15/2016 14:52	7,620	119	109	9.6
TRGV-BLM2016-52	05/16/2016 12:41	5,870	33	28	4.8
TRGV-BLM2016-53	05/16/2016 13:37	5,790	36	29	6.2

Values Rounded According to Porterfield (1972)

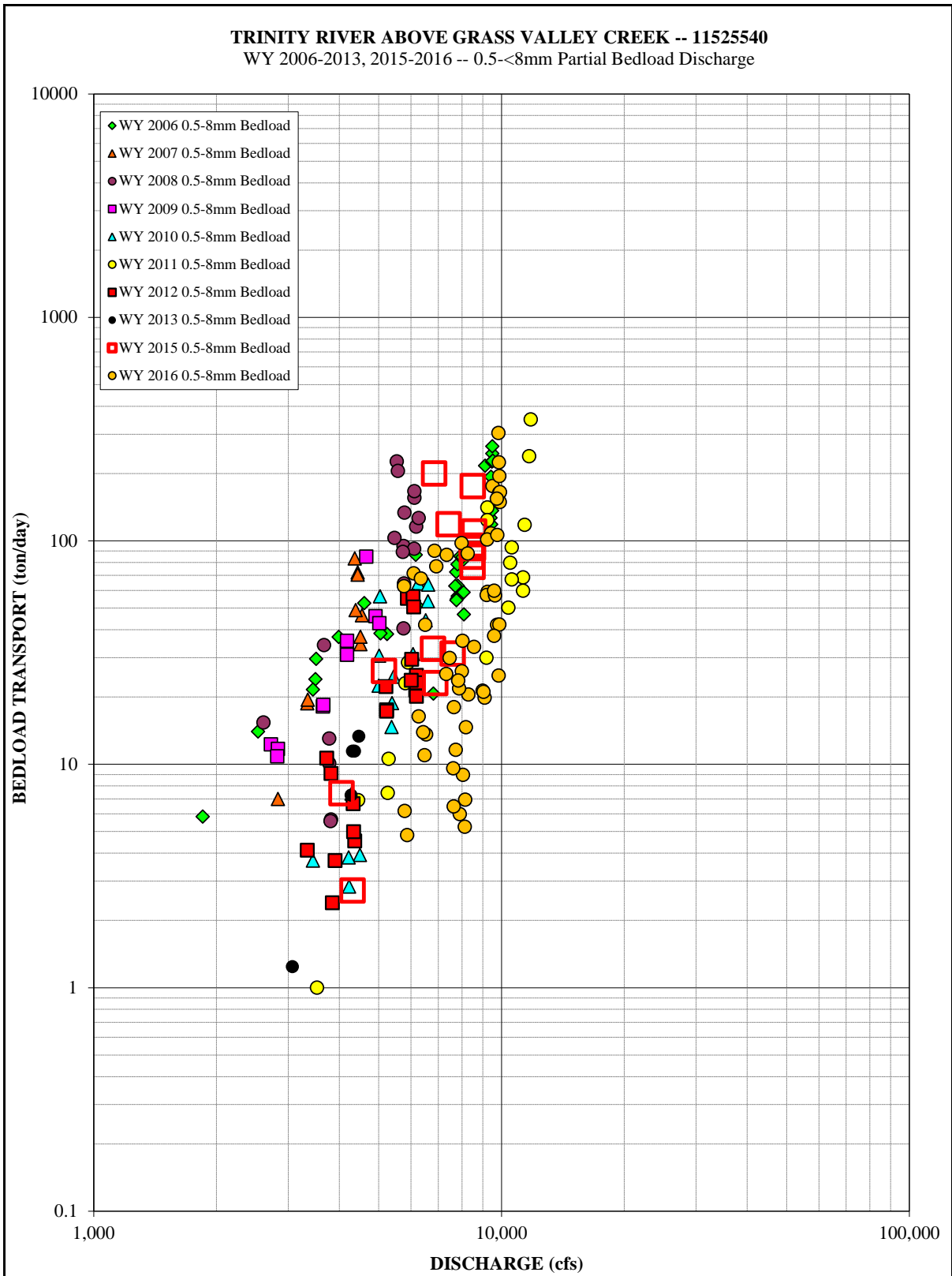


Figure 17. Fine Bedload Discharge (0.5-8mm) at TRGV, WY2006-2013, 2015-2016.

The 1999 TRFE bedload equations that were used to develop flow recommendations did not include this site. Thus, no transport curve is presented as was for Figure 9.

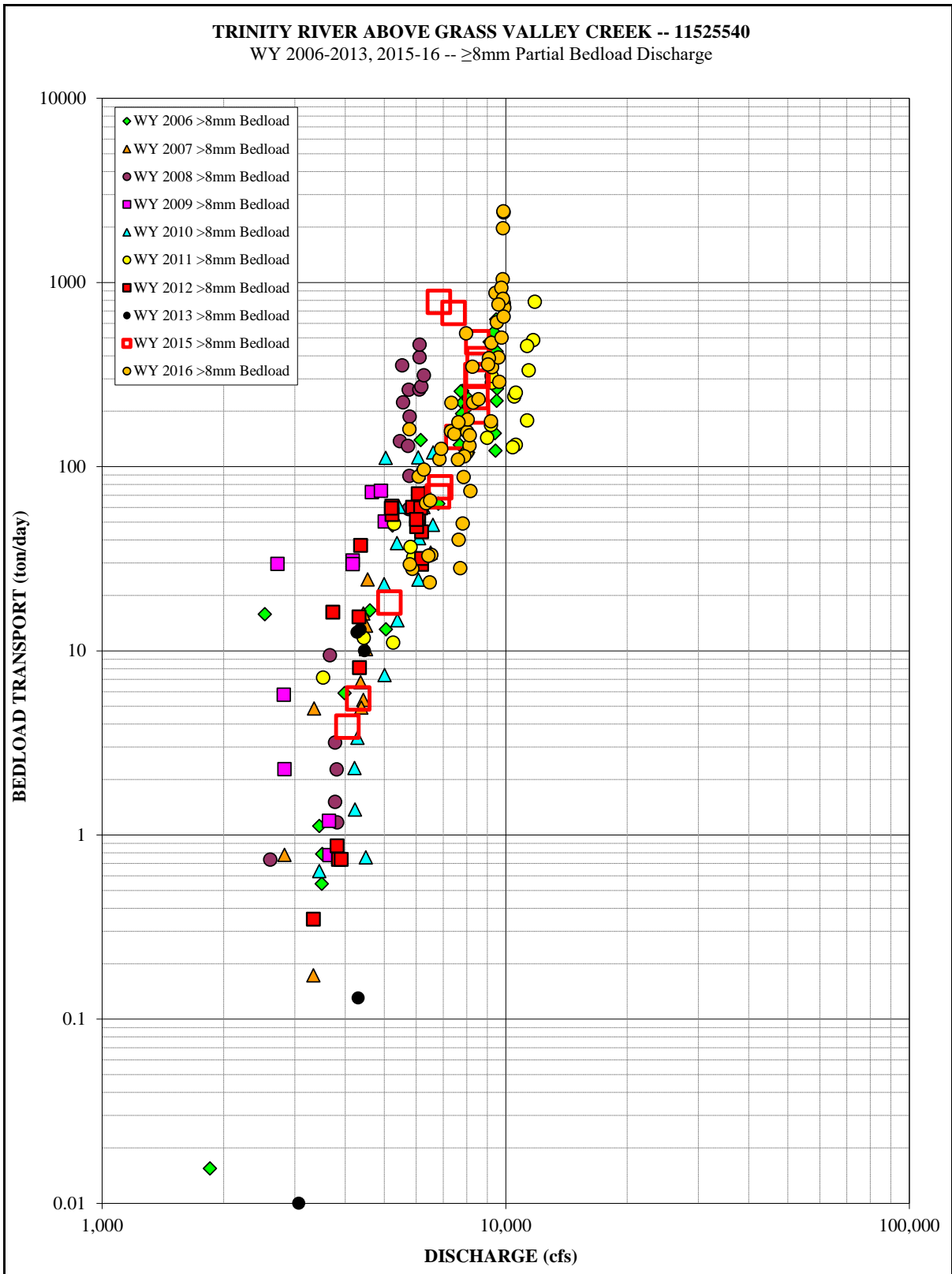


Figure 18. Coarse Bedload Discharge ($\geq 8\text{mm}$) at TRGV, WY2006-2013, 2015-2016.

The 1999 TRFE bedload equations that were used to develop flow recommendations did not include this site. Thus, no transport curve is presented as was for Figure 10.

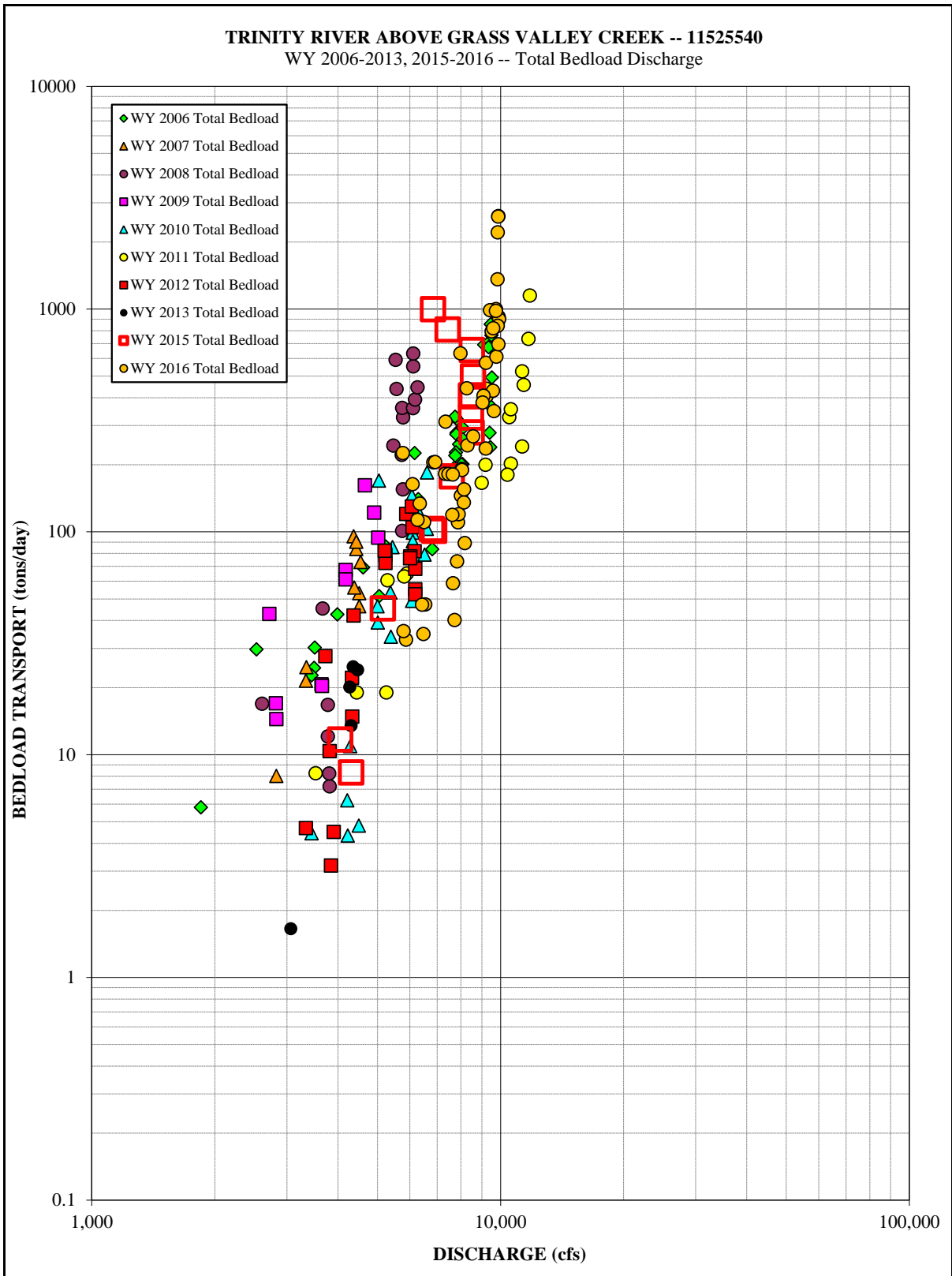


Figure 19. Total Bedload Discharge at TRGV, WY2006-2013, 2015-2016.

Table 9. Trinity River above Grass Valley Creek -- GMA Gage #11525540, Bedload -- WY2016

0.5-<8 mm (tons)	≥8 mm (tons)	Total Bedload (tons)
578	3,110	3,690

Values Rounded According to Porterfield (1972)

Water Surface Slope, Cross Section Changes and Pebble Count Changes

The 2016 water surface slope for 9,900 cfs was 0.0006. Cross section (Figure 20) and pebble count (Figure 21) data were collected at the TRGV sediment monitoring site pre- and post-Spring Flow Release to assess changes at the sampling section. The thalweg along the right side of the channel scoured up to 1.8 ft while the bar along the left side of the channel aggraded over a foot. Total computed scour was 44.8 ft², total fill was 35.8 ft² for a net change of 9.0 ft² scour.

The dominant transport feature through the sampling section appears to be a transverse bar which is developing in response to gravel injection. This bar extends from the injection site down to the low-flow hydraulic control (approximately 400 feet). Pebble counts characterize this transverse bar where it intersects the sampling section, though the rest of the section appears much coarser. The pebble count (n=100+ particles) grain-size distribution curve (Figure 21) shows fining for all but the lower end of the distribution. The D50 decreased from 54 to 32mm and the D90 decreased from 104 to 51mm.

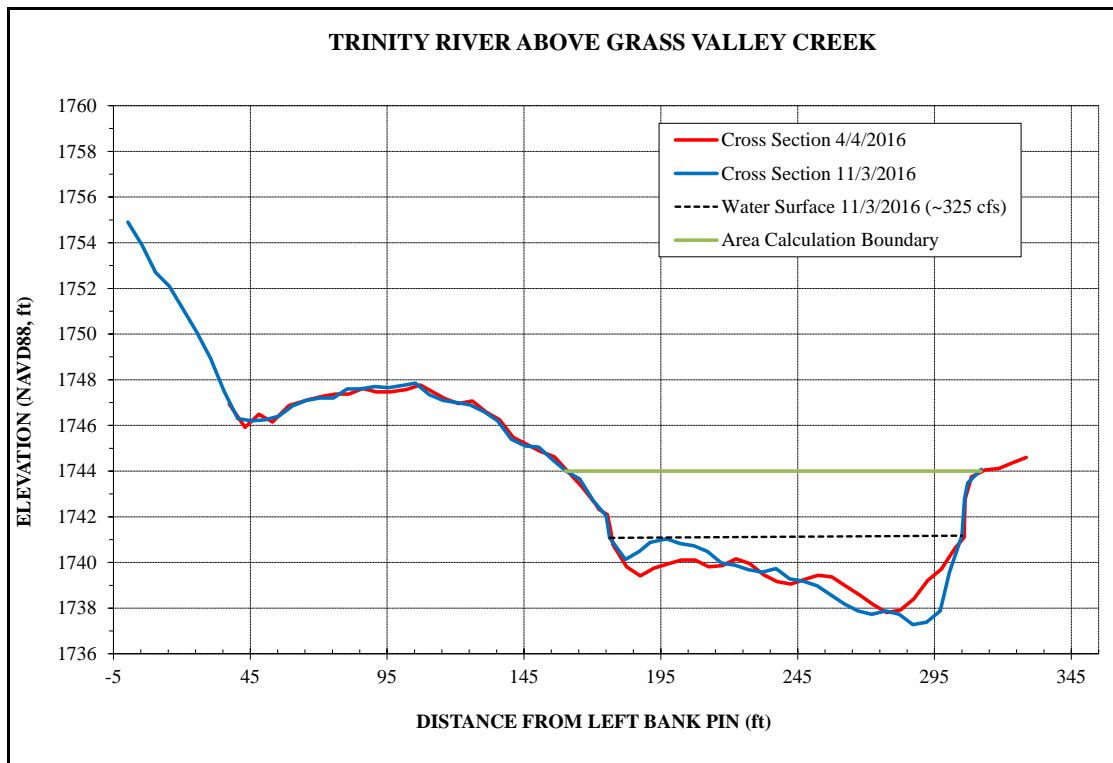


Figure 20. Cross Section Changes at TRGV, pre and post-Spring Flow Release 2016. Downstream view.

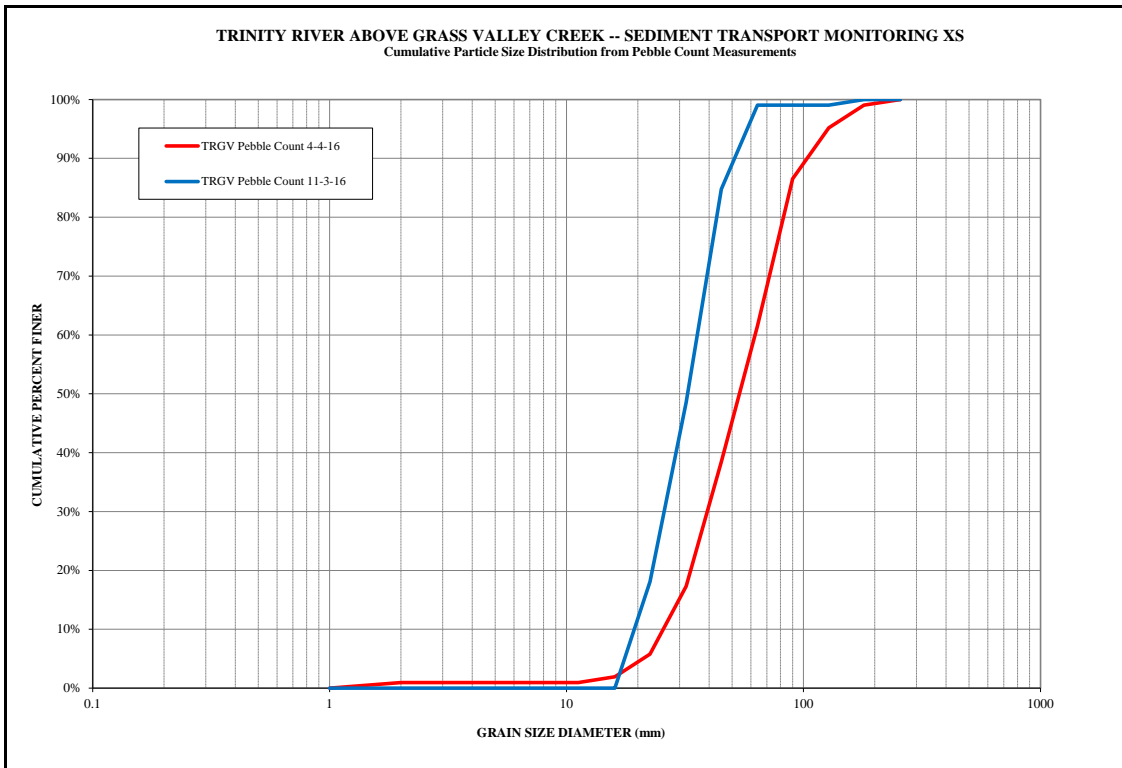


Figure 21. Changes in bed texture at TRGV, Spring Flow Release 2016.

2.4.2.3 Trinity River below Limekiln Gulch

Station Description

The station is located 60 feet downstream of the USGS streamflow gaging station (#11525655) and the 250 feet downstream of the GMA turbidimeter (Figure 22). Sampling has occurred at the current sampling location or approximately 30 ft upstream since WY 1998. A two-person cataraft crew collected 72 bedload and nine suspended sediment samples at TRLG during the 2016 Spring Flow Release.

Suspended Sediment Transport Data

Nine two-pass suspended sediment samples were collected during the Spring Flow Release (Table 10). Measured SSC ranged from a high of 60 mg/l during the first peak on May 9 to a low of 9 mg/l on May 12 (between, not after, the two peaks). The final measured concentration on May 16 was 13 mg/l. The computed suspended sediment discharges for the highest measurement was 1,690 tons/day at 10,500 cfs (Table 10). Computed suspended sediment loads for the Spring Flow Release are provided in Table 11.



Figure 22. Photograph: left bank view of TRLG sampling crew at 10,200 cfs.

Table 10. Trinity River below Limekiln Gulch -- USGS Gage #11525655, Suspended Sediment Sampling Summary -- WY2016

Sample Number	Date & Mean Time	Average Discharge (cfs)	Average SSC (mg/l)	Average SSD (tons/day)
TRLG-SSCT2016-01	5/8/2016 16:34	6,750	46	844
TRLG-SSCT2016-02	5/9/2016 17:28	10,500	60	1,690
TRLG-SSCT2016-03	5/10/2016 14:52	9,750	25	668
TRLG-SSCT2016-04	5/11/2016 14:42	7,630	23	463
TRLG-SSCT2016-05	5/12/2016 10:58	6,080	9	150
TRLG-SSCT2016-06	5/13/2016 15:06	9,380	33	822
TRLG-SSCT2016-07	5/14/2016 15:36	9,280	25	622
TRLG-SSCT2016-08	5/15/2016 13:22	7,590	14	282
TRLG-SSCT2016-09	5/16/2016 18:08	5,120	13	177

Values Rounded According to Porterfield (1972)

Table 11. Trinity River below Limekiln Gulch-- USGS Gage #11525655, Suspended Sediment Loads -- WY2015

< 0.063 mm (tons)	0.063 mm-<0.50 mm (tons)	≥0.50 mm (tons)	Total Load (tons)
2,800	2,410	1,090	6,300

Values Rounded According to Porterfield (1972)

Total suspended sediment discharge values were plotted in Figure 23 along with all historic transport data collected at TRLG, including the historic USGS data from multiple natural winter storm events. Hysteresis (changes in concentration at a common discharge) was evident during most Spring Flow Releases (Figure 24); suspended sediment concentrations rise rapidly with the rising flow and drop off quickly during the various flow benches. In Water Year 2016, hysteresis was less evident.

Continuous turbidity was collected through the Spring Flow Release (Appendix C-4). The turbidity versus SSC relationship for <0.063mm, 0.063mm-<0.5mm and ≥0.5mm proved adequate; therefore turbidity was used as a surrogate for SSC (Appendix C-3). Single generalized transport curves were developed for each size class. Partial discharges were computed for all three size classes and then summed to compute total SS discharge (Appendix C-1).

The continuous concentration traces show the initial increase in SSC with rising flow and the rapid drop-off in during the peak flow benches (Appendix C-6). As in previous years, turbidity, and consequently suspended sediment discharge, was highest during the largest increases in streamflow. Partial and total suspended sediment load for the Spring Flow Release were 2,800, 2,410, 1,090 and 6,300 tons for the <0.063mm, 0.063-<0.50mm, ≥0.50mm size classes and total load respectively (Table 11). The computational methods, assumptions, surrogate relationships, and period of records for which they were applied are described in detail in the Station Analysis (Appendix C-1). Appendix C-10 contains the sample data and SSC computations.

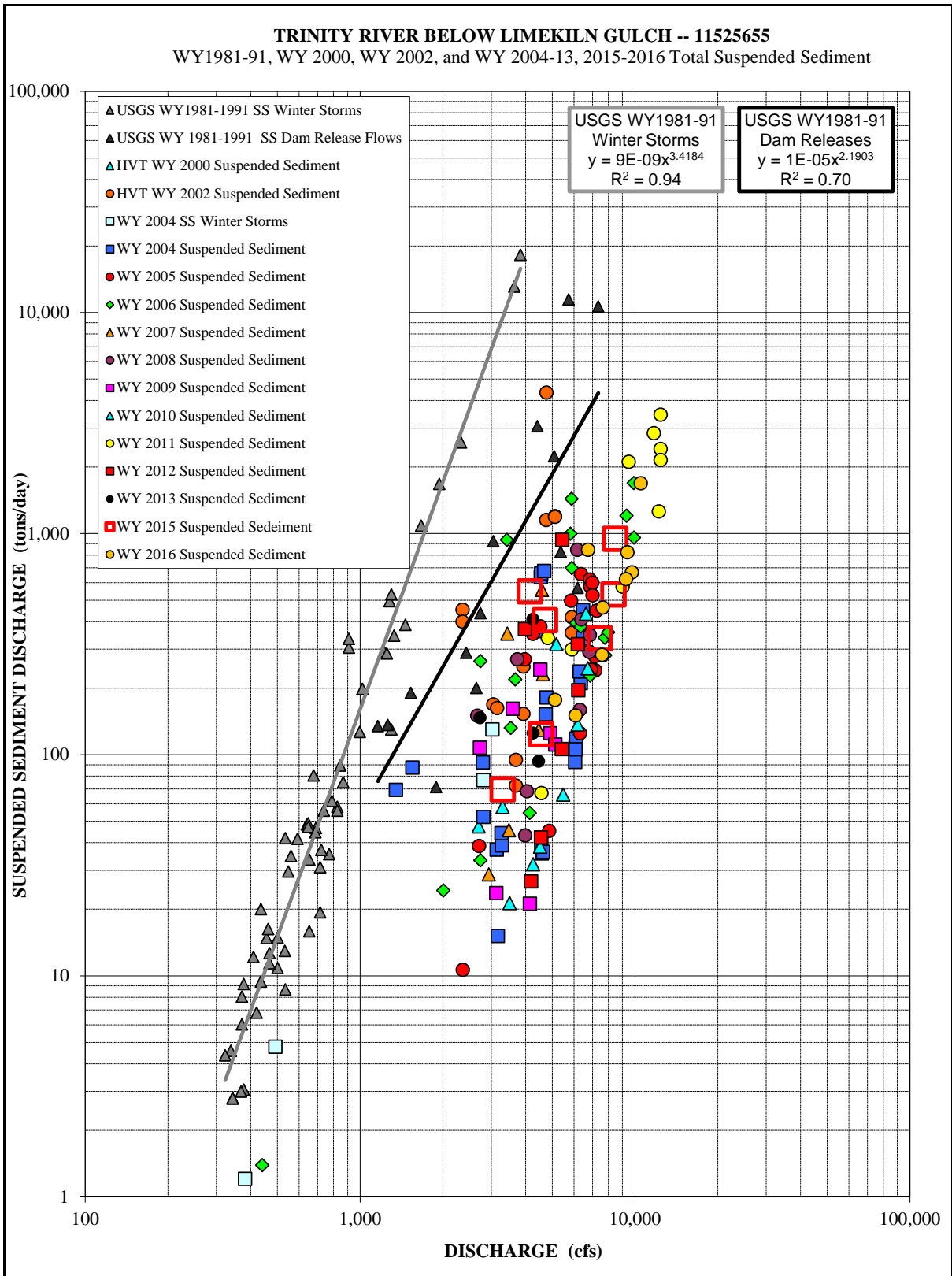


Figure 23. Suspended Sediment Discharge at TRLG, WY1981-1991, 2000, 2002, 2004-2013, 2015-2016.

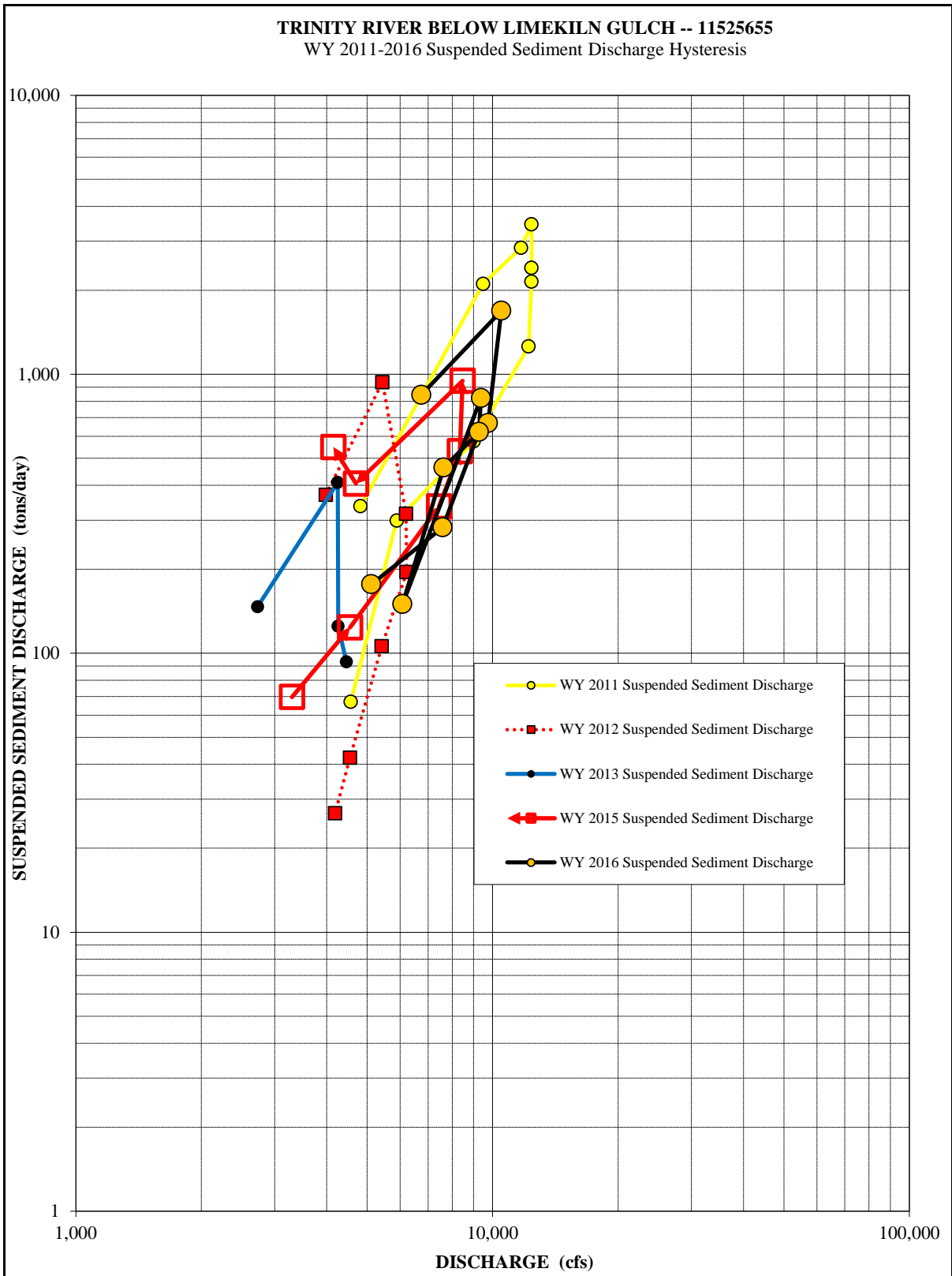


Figure 24. Suspended Sediment Discharge Hysteresis at TRLG, WY 2011-2016.

Bedload Transport Data

Seventy two one-pass bedload samples were collected during the Spring Flow Release (Table 12). Appendix C-5 displays the bedload sample collection times on the Spring Flow Release hydrograph. The highest bedload transport rate of 1,310 tons/day was measured at 10,400 cfs on May 9, while the lowest, 27.6 tons/day was measured at 5,240 cfs on May 16. All measured fine, coarse, and total bedload discharge rates were plotted in Figures 25-27 along with historic data from WY 1981-2015. Details regarding the samples and the sediment discharge computations are provided in the Station Analysis (Appendix C-1). Bedload transport curves were fit to the WY 2016 bedload discharge data in WISKI. No obvious patterns of hysteresis were observed in the coarse bedload data, therefore, a single piecewise transport curve was developed (Appendix C-2). For the fine fraction, hysteresis was present, however the pattern was too complicated to break out into multiple equations. A single transport curve was used and hysteresis was addressed during sedigraph development. The Sediment Station Analysis (Appendix C-1) describes the time periods over which the transport curves were used for estimating continuous bedload discharge.

Appendix C-5 displays the continuous fine, coarse, and total bedload discharge rates for the Spring Flow Release period. Detailed explanations of assumptions and relationships developed for computing continuous bedload discharge are provided in the Station Analysis (Appendix C-1). All bedload transport curves used to compute continuous sediment discharge are included in Appendix C-2. Appendix C-9 contains the sample data (e.g. weights and computed transport rates) and continuous bedload computation values.

The fine, coarse, and total bedload computed estimates for WY 2016 were 781, 2,040 and 2,820 tons, respectively (Table 13). As discussed in section 2.3.4, the <0.5mm fraction is omitted from bedload data and computations; however, this fraction is included for graphical comparisons with historic values (e.g. Figure 27). The <0.5mm fraction comprised an average of 3 percent of bedload sample masses in 2015.

Table 12. Trinity River below Limekiln Gulch -- USGS Gage #11525655, Bedload Sediment Sampling Summary -- WY2016

Table 1/2					
Sample Number	Date & Mean Time	Average Discharge (cfs)	Total Bedload Discharge (tons/day)	> 8mm Bedload Discharge (tons/day)	0.5-8 mm Bedload Discharge (tons/day)
TRLG-BLM2016-01	5/8/16 10:47	5,230	112	70	41
TRLG-BLM2016-02	5/8/16 11:56	5,550	72	17	54
TRLG-BLM2016-03	5/8/16 13:38	6,070	48	5	41
TRLG-BLM2016-04	5/8/16 14:34	6,240	108	60	46
TRLG-BLM2016-05	5/8/16 15:08	6,320	445	383	58
TRLG-BLM2016-06	5/8/16 15:20	6,450	168	76	89
TRLG-BLM2016-07	5/9/16 10:17	7,210	100	49	51
TRLG-BLM2016-08	5/9/16 10:53	7,350	284	233	50
TRLG-BLM2016-09	5/9/16 11:37	7,750	104	45	57
TRLG-BLM2016-10	5/9/16 12:12	8,080	340	252	86
TRLG-BLM2016-11	5/9/16 13:27	9,050	268	170	95
TRLG-BLM2016-12	5/9/16 14:48	10,100	136	35	98
TRLG-BLM2016-13	5/9/16 15:25	10,400	621	451	163
TRLG-BLM2016-14	5/9/16 16:24	10,400	1,310	1,140	159
TRLG-BLM2016-15	5/9/16 16:50	10,500	782	540	230

Values Rounded According to Porterfield (1972)

Table 2/2

Sample Number	Date & Mean Time	Average Discharge (cfs)	Total Bedload Discharge (tons/day)	> 8mm Bedload Discharge (tons/day)	0.5-8 mm Bedload Discharge (tons/day)
TRLG-BLM2016-16	5/9/16 17:57	10,500	942	791	144
TRLG-BLM2016-17	5/10/16 8:57	10,500	558	363	192
TRLG-BLM2016-18	5/10/16 9:23	10,500	455	289	163
TRLG-BLM2016-19	5/10/16 9:57	10,500	713	495	214
TRLG-BLM2016-20	5/10/16 10:35	10,400	824	671	150
TRLG-BLM2016-21	5/10/16 11:31	10,500	811	489	317
TRLG-BLM2016-22	5/10/16 12:06	10,500	431	207	222
TRLG-BLM2016-23	5/10/16 12:36	10,400	1010	753	252
TRLG-BLM2016-24	5/10/16 13:03	10,300	440	281	157
TRLG-BLM2016-25	5/10/16 14:17	9,880	579	401	177
TRLG-BLM2016-26	5/10/16 15:14	9,730	752	536	213
TRLG-BLM2016-27	5/10/16 15:53	9,750	502	333	166
TRLG-BLM2016-28	5/11/16 8:57	8,450	432	304	127
TRLG-BLM2016-29	5/11/16 9:23	8,320	465	334	130
TRLG-BLM2016-30	5/11/16 9:51	8,220	307	230	76
TRLG-BLM2016-31	5/11/16 10:13	8,170	242	155	86
TRLG-BLM2016-32	5/11/16 10:39	8,140	187	99	87
TRLG-BLM2016-33	5/11/16 10:58	8,090	217	155	61
TRLG-BLM2016-34	5/11/16 11:22	8,140	362	250	110
TRLG-BLM2016-35	5/11/16 11:46	8,160	324	234	88
TRLG-BLM2016-36	5/11/16 13:08	7,900	133	70	62
TRLG-BLM2016-37	5/11/16 13:26	7,840	139	53	85
TRLG-BLM2016-38	5/11/16 13:49	7,730	162	115	47
TRLG-BLM2016-39	5/11/16 14:11	7,730	478	362	114
TRLG-BLM2016-40	5/11/16 15:15	7,610	343	233	109
TRLG-BLM2016-41	5/11/16 15:40	7,580	158	76	81
TRLG-BLM2016-42	5/11/16 16:03	7,570	307	222	84
TRLG-BLM2016-43	5/12/16 9:42	6,200	74	51	23
TRLG-BLM2016-44	5/12/16 10:09	6,180	87	73	15
TRLG-BLM2016-45	5/12/16 11:29	6,140	69	36	33
TRLG-BLM2016-46	5/12/16 11:52	6,100	75	44	31
TRLG-BLM2016-47	5/13/16 9:38	6,840	168	108	59
TRLG-BLM2016-48	5/13/16 10:10	7,110	141	89	51
TRLG-BLM2016-49	5/13/16 11:15	7,500	160	110	49
TRLG-BLM2016-50	5/13/16 11:43	7,730	243	165	77
TRLG-BLM2016-51	5/13/16 12:25	7,970	327	244	82
TRLG-BLM2016-52	5/13/16 13:01	8,230	317	237	79
TRLG-BLM2016-53	5/13/16 13:34	8,460	224	175	48
TRLG-BLM2016-54	5/13/16 14:02	8,840	211	120	88
TRLG-BLM2016-55	5/13/16 15:44	9,760	432	336	93
TRLG-BLM2016-56	5/13/16 16:22	9,970	392	296	94
TRLG-BLM2016-57	5/13/16 16:56	10,100	565	414	148
TRLG-BLM2016-58	5/13/16 17:28	10,100	521	420	99
TRLG-BLM2016-59	5/13/16 17:52	10,100	776	639	133
TRLG-BLM2016-60	5/14/16 8:55	10,200	516	344	169
TRLG-BLM2016-61	5/14/16 9:23	10,200	463	332	128
TRLG-BLM2016-62	5/14/16 12:33	9,720	400	320	78
TRLG-BLM2016-63	5/14/16 12:56	9,760	435	315	117
TRLG-BLM2016-64	5/14/16 14:37	9,560	351	263	87
TRLG-BLM2016-65	5/14/16 15:01	9,470	184	108	73
TRLG-BLM2016-66	5/15/16 11:34	7,930	423	365	56
TRLG-BLM2016-67	5/15/16 11:58	7,920	279	229	49
TRLG-BLM2016-68	5/15/16 13:50	7,470	276	241	35
TRLG-BLM2016-69	5/15/16 14:13	7,420	225	174	49
TRLG-BLM2016-70	5/15/16 14:24	7,430	895	812	81
TRLG-BLM2016-71	5/16/16 16:34	5,380	45	22	22
TRLG-BLM2016-72	5/16/16 17:12	5,240	28	16	11

Values Rounded According to Porterfield (1972)

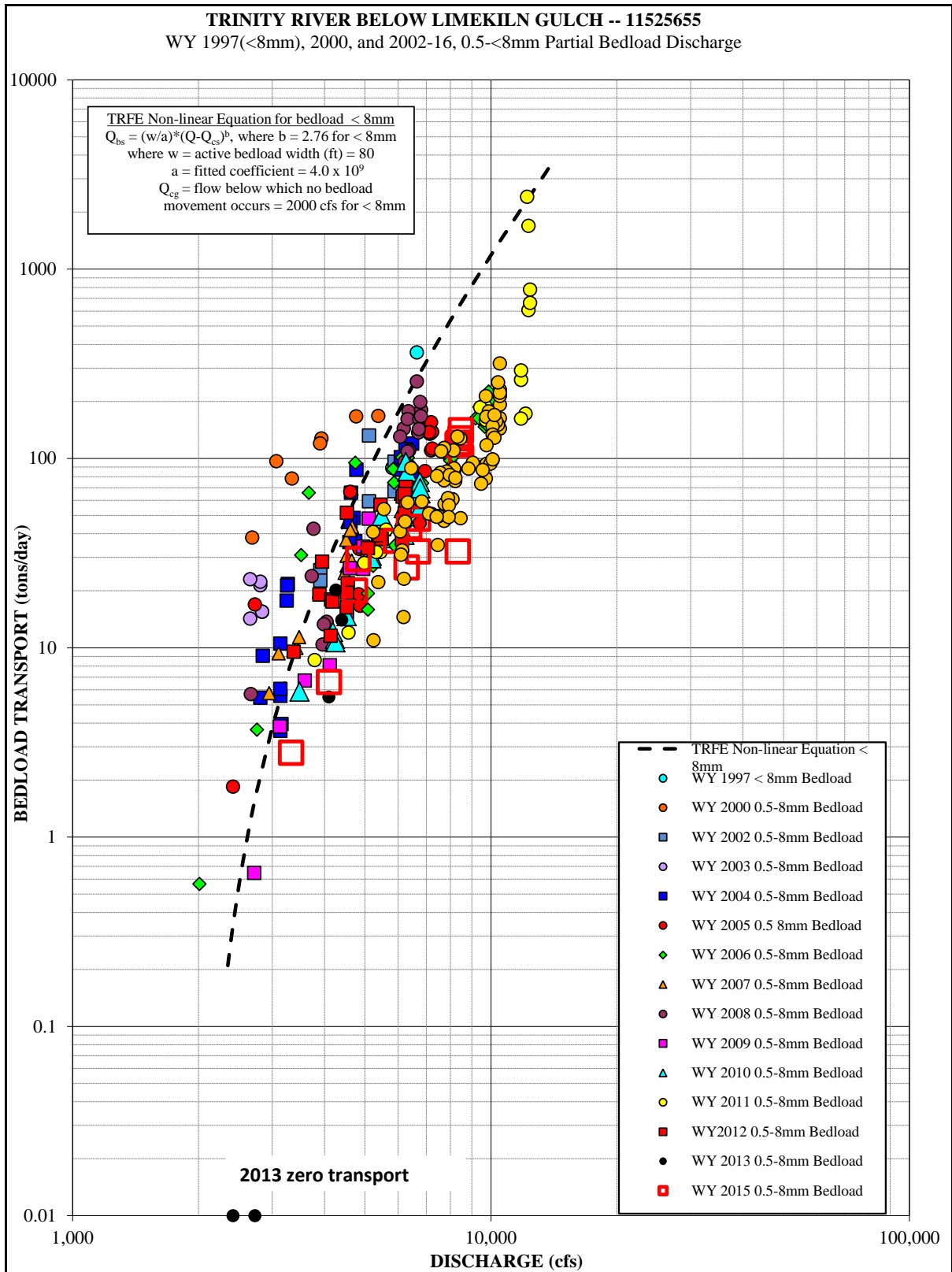


Figure 25. Fine Bedload Discharge (0.5-<8mm) at TRLG, WY1997-2013, 2015-2016.

The 1999 TRFE bedload equations were used to develop flow recommendations based in part on bedload discharge predictions at TRAL and TRLG (shown in the inset box on chart). The equation is plotted and shown here as the dashed black line and is included for comparison with subsequent measured bedload transport rates.

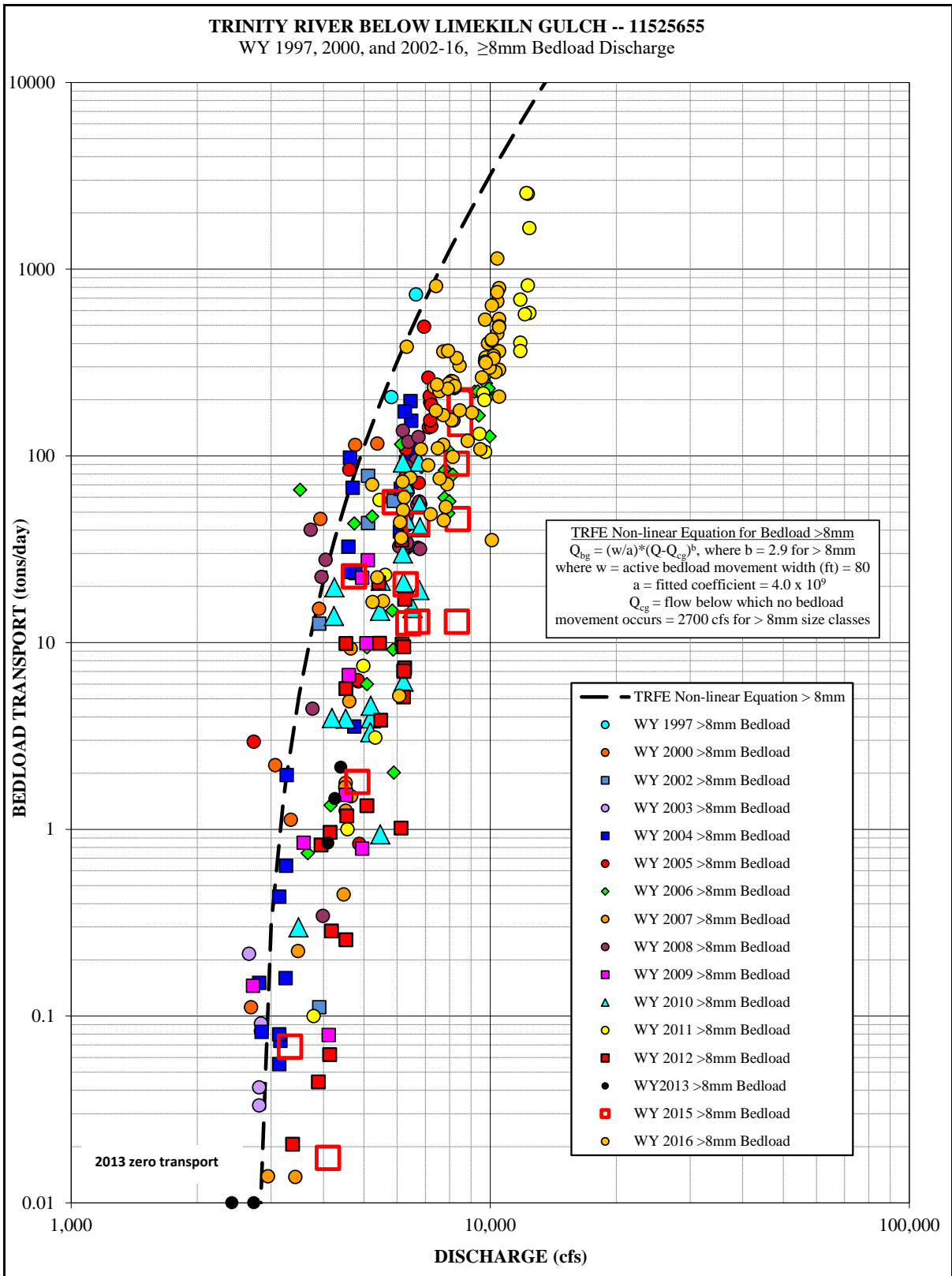


Figure 26. Coarse Bedload Discharge (≥8mm) at TRLG, WY1997-2013, 2015-2016.

The 1999 TRFE bedload equations were used to develop flow recommendations based in part on bedload discharge predictions at TRAL and TRLG (shown in the inset box on chart). The equation is plotted and shown here as the dashed black line and is included for comparison with subsequent measured bedload transport rates.

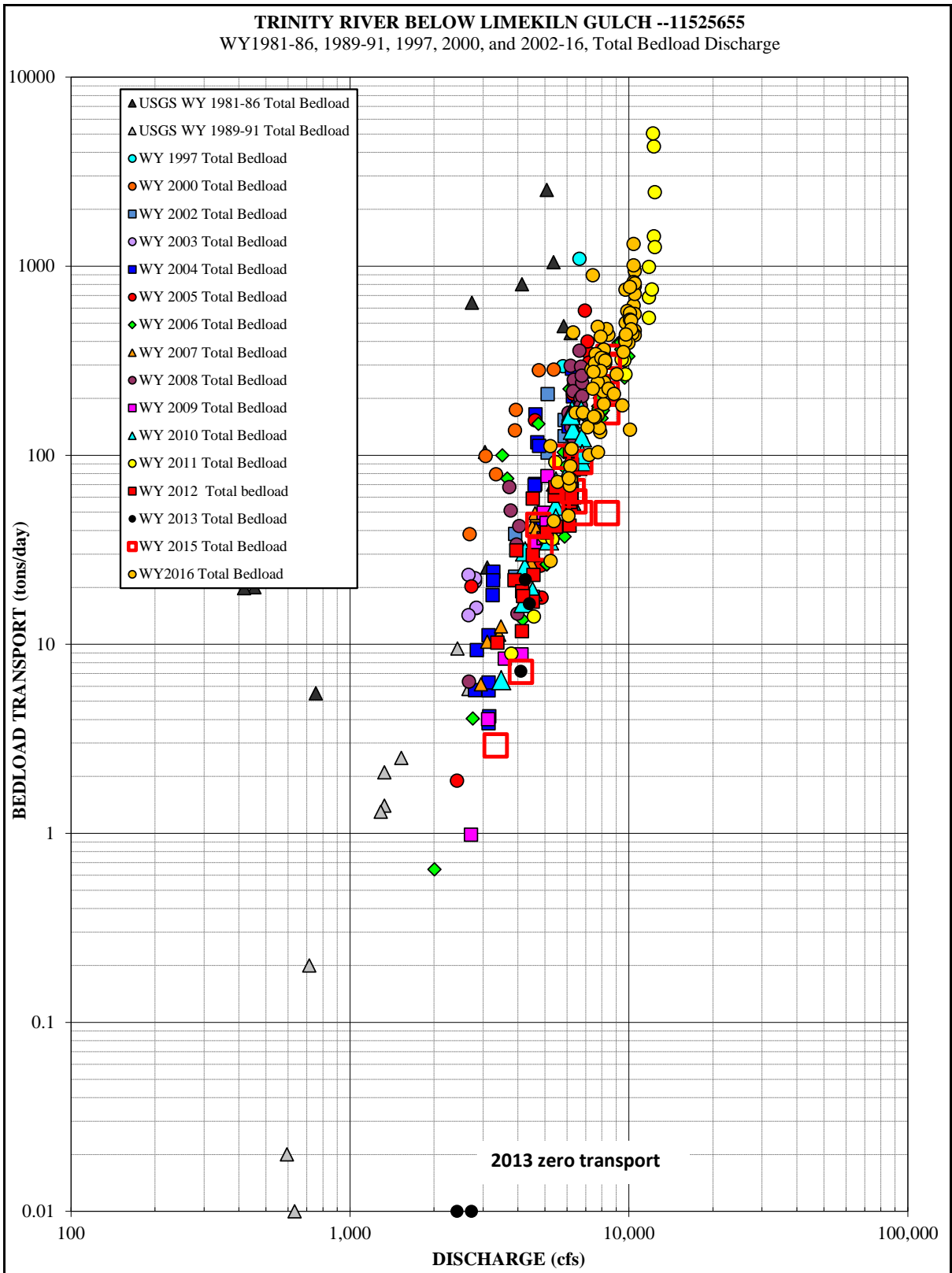


Figure 27. Total Bedload Discharge at TRLG, WY1997-2013, 2015-2016.

Table 13. Trinity River below Limekiln Gulch -- USGS Gage #11525655, Bedload -- WY2016

0.5-<8 mm (tons)	≥8 mm (tons)	Total Bedload (tons)
781	2,040	2,820

Values Rounded According to Porterfield (1972)

Water Surface Slope, Cross Section Changes and Pebble Count Changes

The 2016 water surface slope at 10,500 cfs was 0.0016. Cross section and pebble count data were collected at the TRLG sediment monitoring site pre- and post-Spring Flow Release to assess changes at the sampling section. Changes in the cross section and particle size distribution from the pebble count data are shown in Figures 28 and 29. The total computed scour at the sampling section was 14.1 ft², the total fill was 5.2 ft², for a net scour of 8.9 ft². The pebble count at this site describes the transverse riffle intersecting the right quarter (near station 200) of the sampling section. The left half of the section is deeper with bedrock fins and coarser boulder elements. The pebble count pre and post curves suggest fining which is more pronounced at the coarse end of the distribution where separation of the curves is greater (Figure 29). The D50 decreased from 59 to 47mm and the D90 decreased from 105 to 78mm.

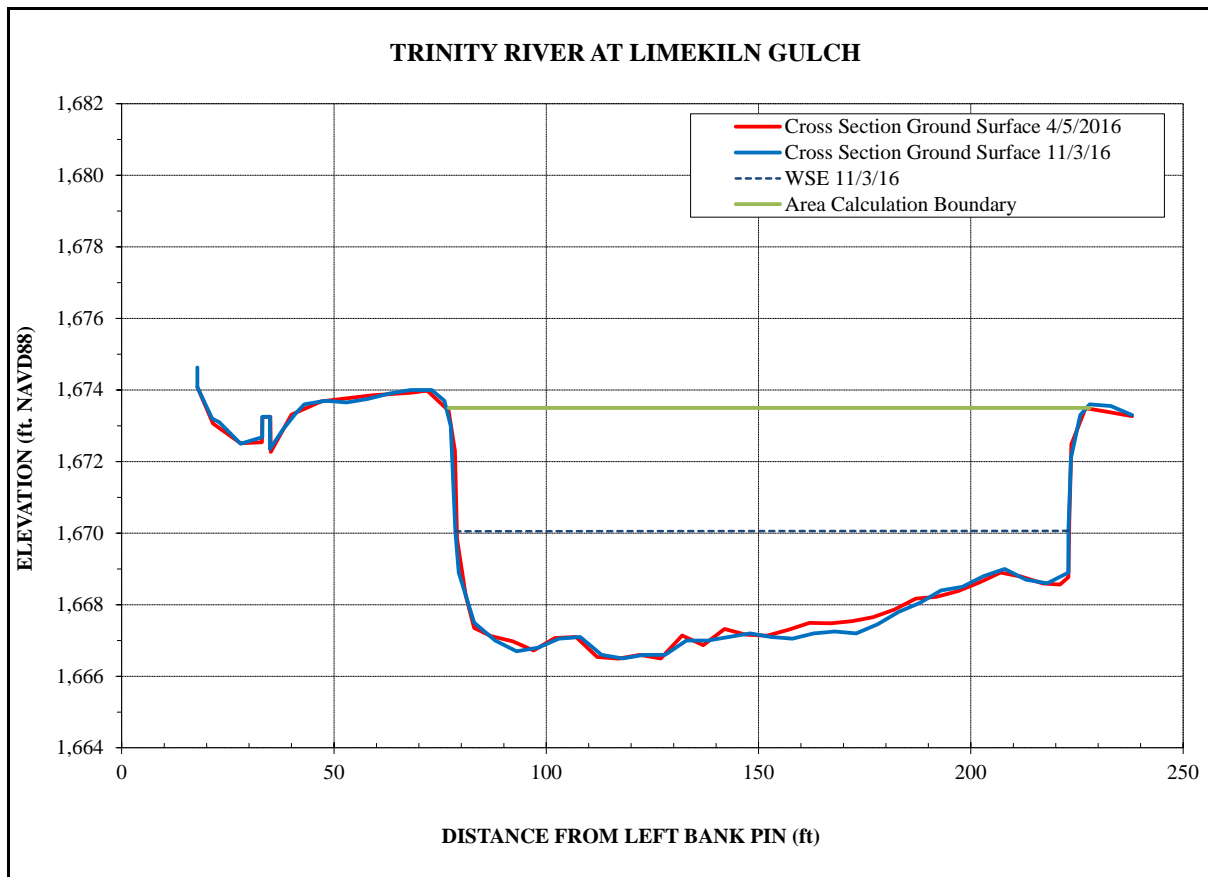


Figure 28. Cross Section Changes, pre and post-Spring Flow Release 2016.

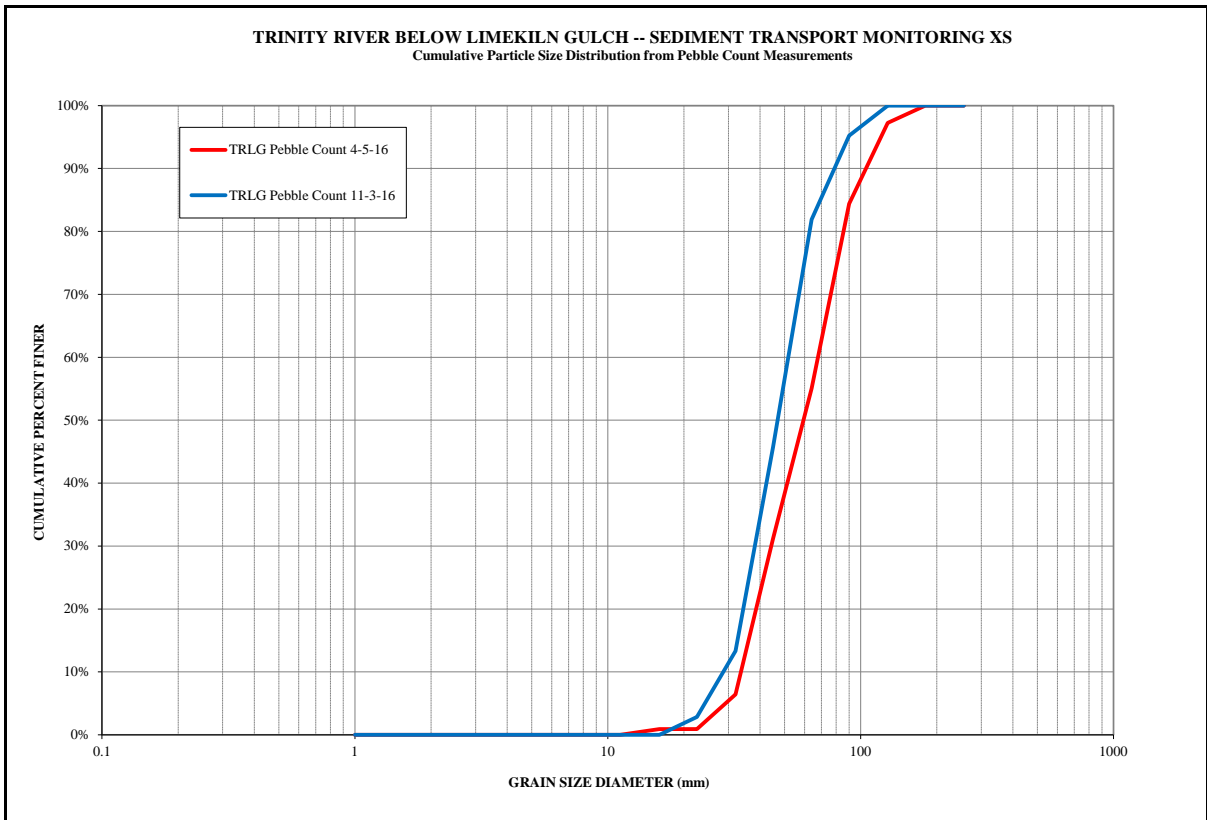


Figure 29. Changes in bed texture at TRLG, pre and post Spring Flow Release 2016.

2.4.2.4 Trinity River near Douglas City

Station Description

The TRDC sediment monitoring cross-section (Figure 30) was relocated approximately 200 feet downstream in 2012 from its 2011 location due to hydraulic complexity and bedrock elements at and upstream of the sampling section. The more favorable hydraulic conditions at the new sampling location facilitate more comprehensive sampling coverage and presumably results in higher quality sediment transport data. The water surface slope is the highest of all the mainstem stations at 0.003 (2016 at approximately 11,000 cfs). Sediment transport monitoring has occurred at TRDC since WY 2004. The USGS gaging station is now located at the very upstream end of the BLM Douglas City Campground, and the sediment transport monitoring station is located approximately two hundred and forty feet downstream of the gaging station.



Figure 30. Right bank downstream view of TRDC sampling site, WY2015. Discharge is 4,800 cfs.

Suspended Sediment Transport Data

All seven suspended sediment samples consisted of two pass samples. Measured SSC ranged from a high of 230 mg/l on May 8, to 17 mg/l on May 16, the last day of suspended sediment sampling. The associated computed suspended sediment discharges were 6,110 and 316 tons/day which were measured at 9,870 and 7,110 cfs (Table 14). Total suspended sediment discharge values are plotted in Figure 31, with transport data from WY 2004-2016.

Continuous turbidity was measured beginning April 5, 2016 at 19:15 (Appendix D-4). The turbidity versus SSC relationship proved adequate for all size classes and turbidity was used

as a surrogate for SSC (Appendix D-3). The three classes were then summed to compute the total suspended sediment discharge (Appendix D-6). The <0.063mm, 0.063-<0.5mm, and ≥0.5mm partial loads and total load were 3,780, 6,710, 6,060 and 16,600 tons (Table 15). Appendix D-10 contains the sample data and SSC computations.

Table 14. Trinity River at Douglas City-- USGS Gage #11525854, Suspended Sediment Sampling Summary -- WY2016

Sample Number	Date & Mean Time	Average Discharge (cfs)	Average SSC (mg/l)	Average SSD (tons/day)
TRDC-SSCT2016-01	5/9/2016 15:52	9,870	230	6,110
TRDC-SSCT2016-02	5/10/2016 13:07	10,900	103	3,030
TRDC-SSCT2016-03	5/11/2016 15:35	8,400	49	1,110
TRDC-SSCT2016-04	5/12/2016 9:49	7,040	25	465
TRDC-SSCT2016-05	5/13/2016 13:01	8,190	45	983
TRDC-SSCT2016-06	5/15/2016 16:21	8,080	40	872
TRDC-SSCT2016-07	5/16/2016 8:47	7,110	17	316

Values Rounded According to Porterfield (1972)

Table 15. Trinity River at Douglas City-- USGS Gage #11525854, Suspended Sediment Loads -- WY2016

< 0.063 mm (tons)	0.063 mm-<0.50 mm (tons)	≥0.50 mm (tons)	Total Load (tons)
3,780	6,710	6,060	16,600

Values Rounded According to Porterfield (1972)

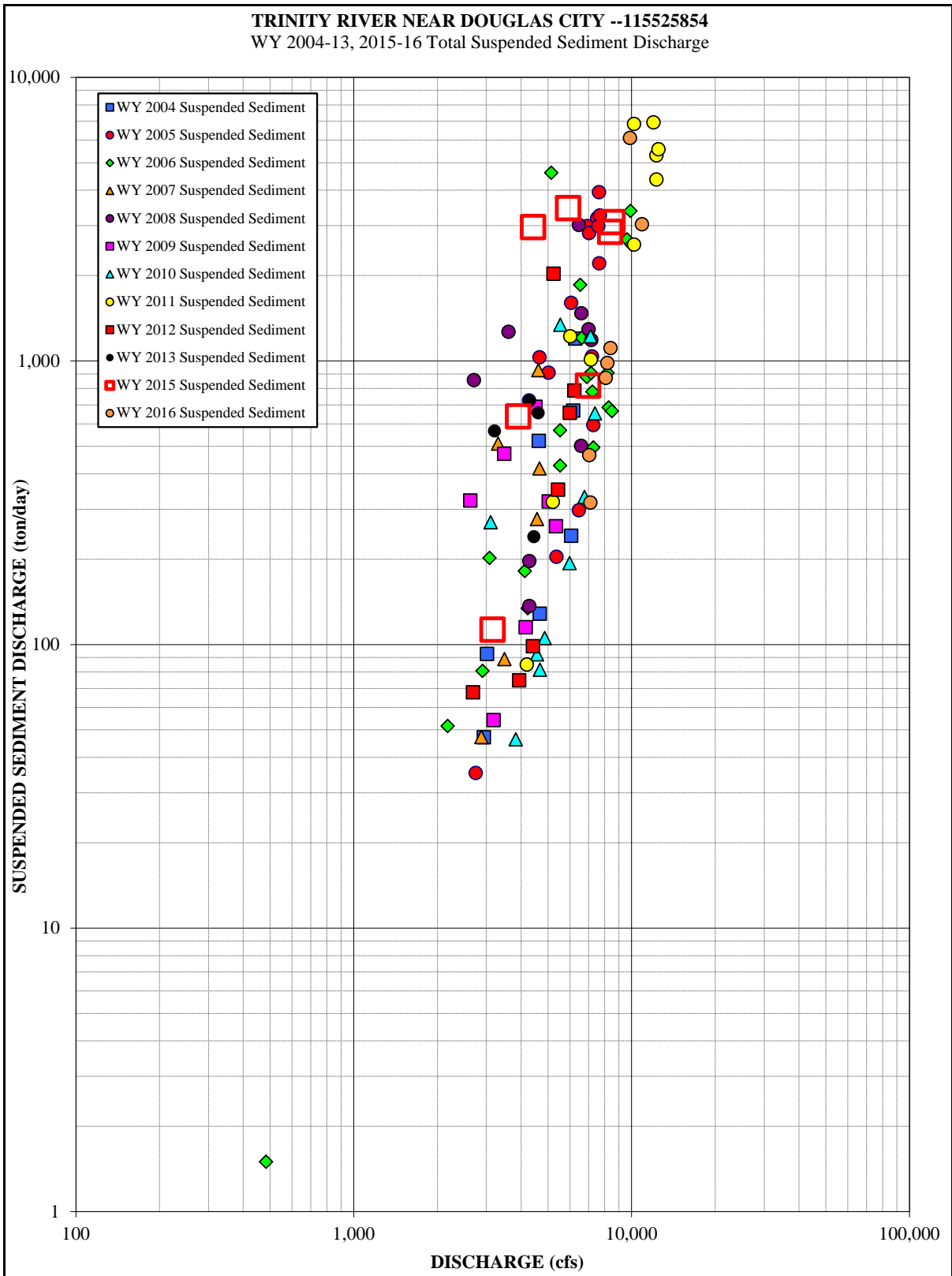


Figure 31. Total Suspended Sediment Discharge at TRDC, WY2004-2013, 2015-2016.

Bedload Transport Data

Fifty-three bedload samples were collected during the Spring Flow Release. Table 16 summarizes the sample bedload discharge data. Measured bedload discharge for Total bedload peaked on May 10 at 4,930 tons/day at 10,900 cfs (Table 16). Appendix D-9 contains the sample data (e.g. weights and computed transport rates) and bedload computation values. Bedload transport rates for fine and coarse sediment were computed using a single generalized equation developed from WY 2016 bedload samples (Appendix D-2). Fine, coarse, and total bedload estimates were 4,010, 7,850 and 11,900 tons, respectively (Table 17). As discussed in section 2.3.4, the <0.5mm fraction is omitted from bedload data and computations; however, this fraction is included for graphical comparisons with historic values (e.g. Figure 34).

Bedload discharge rates were plotted in Figures 32-34 with the previous nine years of data. The partial transport curves used to compute continuous bedload discharge are included in Appendix D-4. A complete explanation of assumptions and techniques employed in the continuous bedload discharge and load computation process is provided in the Station Analysis (Appendix D-1). The bedload sedigraphs are shown in Appendix D-2.

Table 16. Trinity River at Douglas City -- USGS Gage #11525854, Bedload Sediment Sampling Summary -- WY2016

Sample Number	Date & Mean Time	Average Discharge (cfs)	Total Bedload Discharge (tons/day)	> 8mm Bedload Discharge (tons/day)	0.5-8 mm Bedload Discharge (tons/day)
TRDC-BLM2016-01	05/08/2016 13:26	6,040	1,040	818	205
TRDC-BLM2016-02	05/08/2016 14:14	6,290	841	675	140
TRDC-BLM2016-03	05/08/2016 15:22	6,610	359	233	109
TRDC-BLM2016-04	05/08/2016 16:01	6,710	682	541	112
TRDC-BLM2016-05	05/08/2016 16:52	7,140	184	103	49
TRDC-BLM2016-06	05/08/2016 17:27	7,400	452	348	74
TRDC-BLM2016-07	05/09/2016 09:11	7,110	1,100	507	557
TRDC-BLM2016-08	05/09/2016 09:46	7,130	978	567	351
TRDC-BLM2016-09	05/09/2016 10:53	7,430	929	338	566
TRDC-BLM2016-10	05/09/2016 11:27	7,600	597	378	183
TRDC-BLM2016-11	05/09/2016 12:45	8,070	424	182	205
TRDC-BLM2016-12	05/09/2016 14:02	8,630	1,100	526	531
TRDC-BLM2016-13	05/09/2016 17:12	10,400	2,570	2,030	493
TRDC-BLM2016-14	05/09/2016 18:20	10,500	2,030	1,740	236
TRDC-BLM2016-15	05/10/2016 09:07	10,900	3,490	2,330	1,120
TRDC-BLM2016-16	05/10/2016 09:55	11,000	4,830	3,240	1,520
TRDC-BLM2016-17	05/10/2016 11:21	10,900	4,930	3,770	1,100
TRDC-BLM2016-18	05/10/2016 14:50	10,700	3,800	2,540	1,240
TRDC-BLM2016-19	05/10/2016 15:28	10,300	3,710	2,560	1,130
TRDC-BLM2016-20	05/10/2016 16:21	10,200	3,140	2,200	921
TRDC-BLM2016-21	05/11/2016 09:13	9,260	1,970	1,170	784
TRDC-BLM2016-22	05/11/2016 09:42	9,220	1,240	981	254
TRDC-BLM2016-23	05/11/2016 10:41	9,030	1,260	803	446
TRDC-BLM2016-24	05/11/2016 11:17	8,930	1,940	1,260	669
TRDC-BLM2016-25	05/11/2016 12:52	8,770	1,330	868	454
TRDC-BLM2016-26	05/11/2016 13:26	8,760	826	608	212
TRDC-BLM2016-27	05/11/2016 14:32	8,450	1,110	728	378
TRDC-BLM2016-28	05/12/2016 10:57	6,880	728	438	287
TRDC-BLM2016-29	05/12/2016 11:39	6,740	602	338	259
TRDC-BLM2016-30	05/12/2016 12:50	6,690	501	381	119
TRDC-BLM2016-31	05/12/2016 13:37	6,740	369	214	153
TRDC-BLM2016-32	05/13/2016 08:46	6,270	387	296	89
TRDC-BLM2016-33	05/13/2016 09:45	6,450	888	471	412
TRDC-BLM2016-34	05/13/2016 10:44	7,200	470	351	118
TRDC-BLM2016-35	05/13/2016 11:32	7,500	876	588	284
TRDC-BLM2016-36	05/13/2016 14:08	8,650	1,560	1,010	533
TRDC-BLM2016-37	05/13/2016 14:33	8,790	1,440	964	460
TRDC-BLM2016-38	05/13/2016 16:36	9,830	3,410	2,040	1,340
TRDC-BLM2016-39	05/13/2016 17:09	10,000	1,240	993	233
TRDC-BLM2016-40	05/14/2016 08:57	10,800	1,510	943	555
TRDC-BLM2016-41	05/14/2016 09:35	10,500	1,870	1,140	719
TRDC-BLM2016-42	05/14/2016 10:51	10,500	1,250	968	272
TRDC-BLM2016-43	05/14/2016 11:26	10,500	1,950	1,120	809
TRDC-BLM2016-44	05/14/2016 12:44	10,500	1,290	669	609
TRDC-BLM2016-45	05/14/2016 13:17	10,200	1,640	1,060	571
TRDC-BLM2016-46	05/15/2016 10:07	8,970	773	394	373
TRDC-BLM2016-47	05/15/2016 11:02	8,820	770	543	222
TRDC-BLM2016-48	05/15/2016 12:17	8,700	1,580	1,030	535
TRDC-BLM2016-49	05/15/2016 13:04	8,460	900	623	264
TRDC-BLM2016-50	05/15/2016 14:32	8,370	250	120	127
TRDC-BLM2016-51	05/15/2016 15:18	8,250	763	462	297
TRDC-BLM2016-52	05/16/2016 10:26	6,980	116	73	42
TRDC-BLM2016-53	05/16/2016 11:29	6,740	369	165	201

Values Rounded According to Porterfield (1972)

Table 17. Trinity River at Douglas City -- USGS Gage #11525854, Bedload -- WY2016

0.5-<8 mm (tons)	≥8 mm (tons)	Total Bedload (tons)
4,010	7,850	11,900

Values Rounded According to Porterfield (1972)

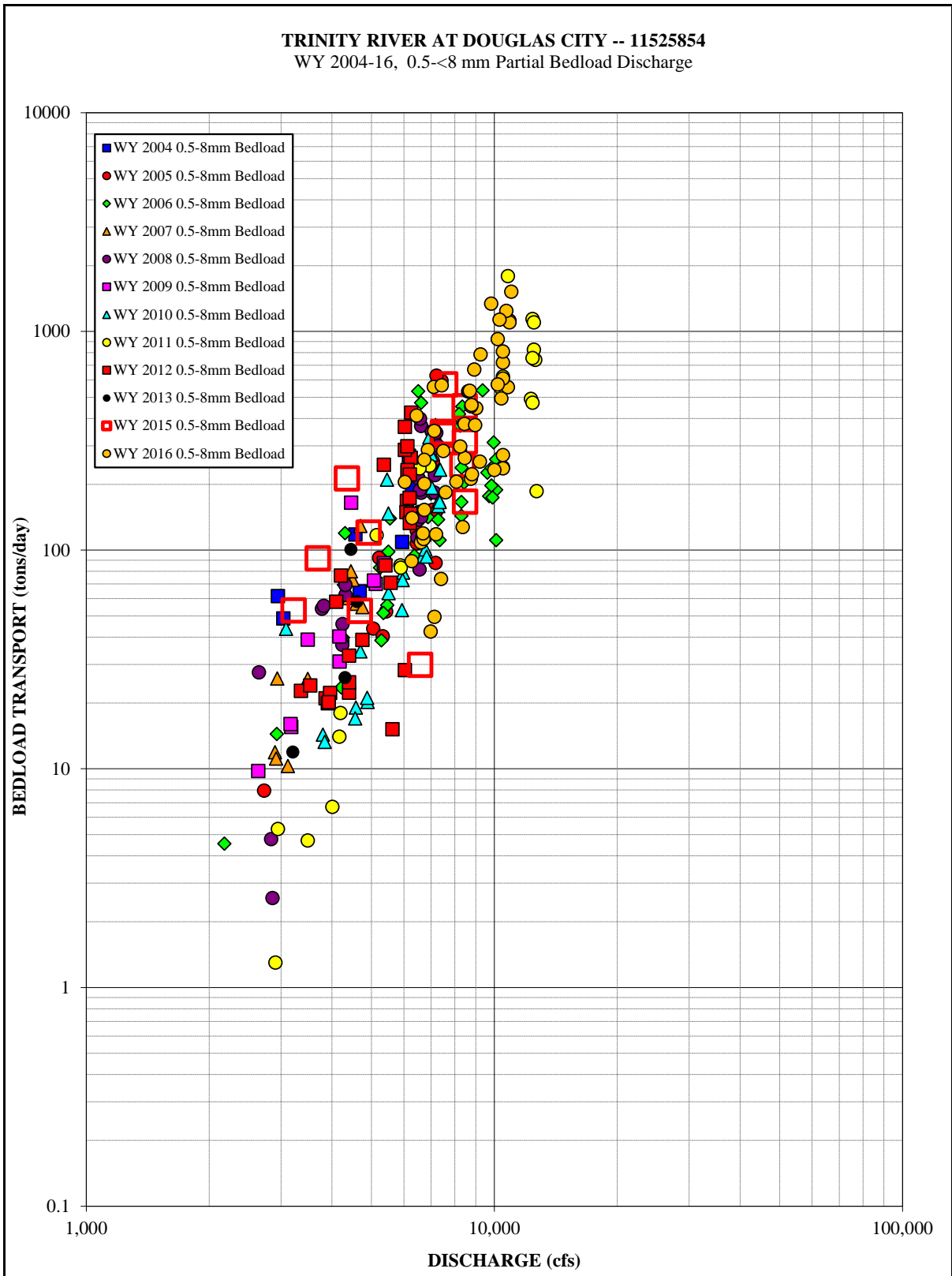


Figure 32. Fine Bedload Discharge at TRDC, WY2004-2013, 2015-2016.

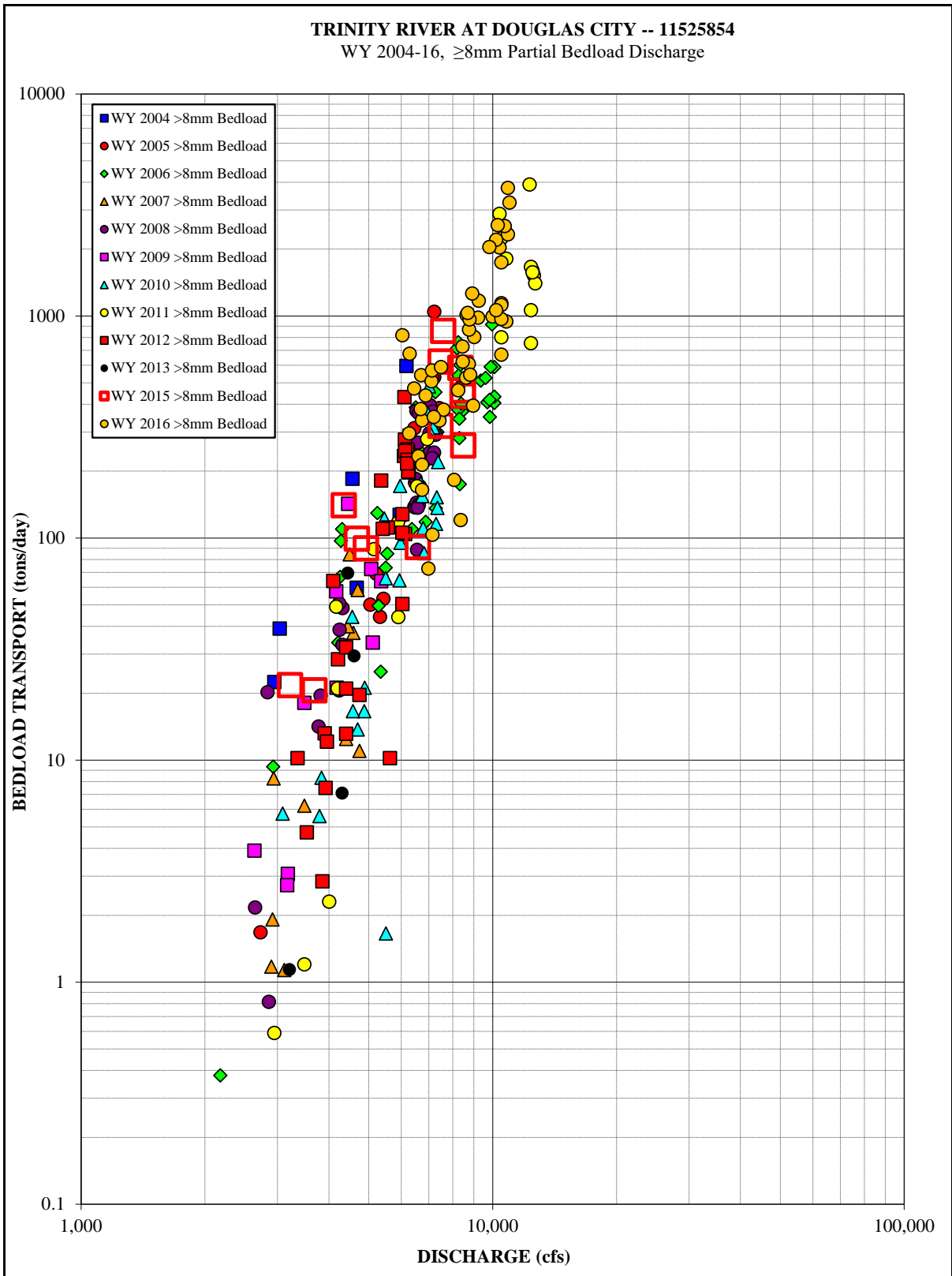


Figure 33. Coarse Bedload Discharge at TRDC, WY2004-2013, 2015-2016.

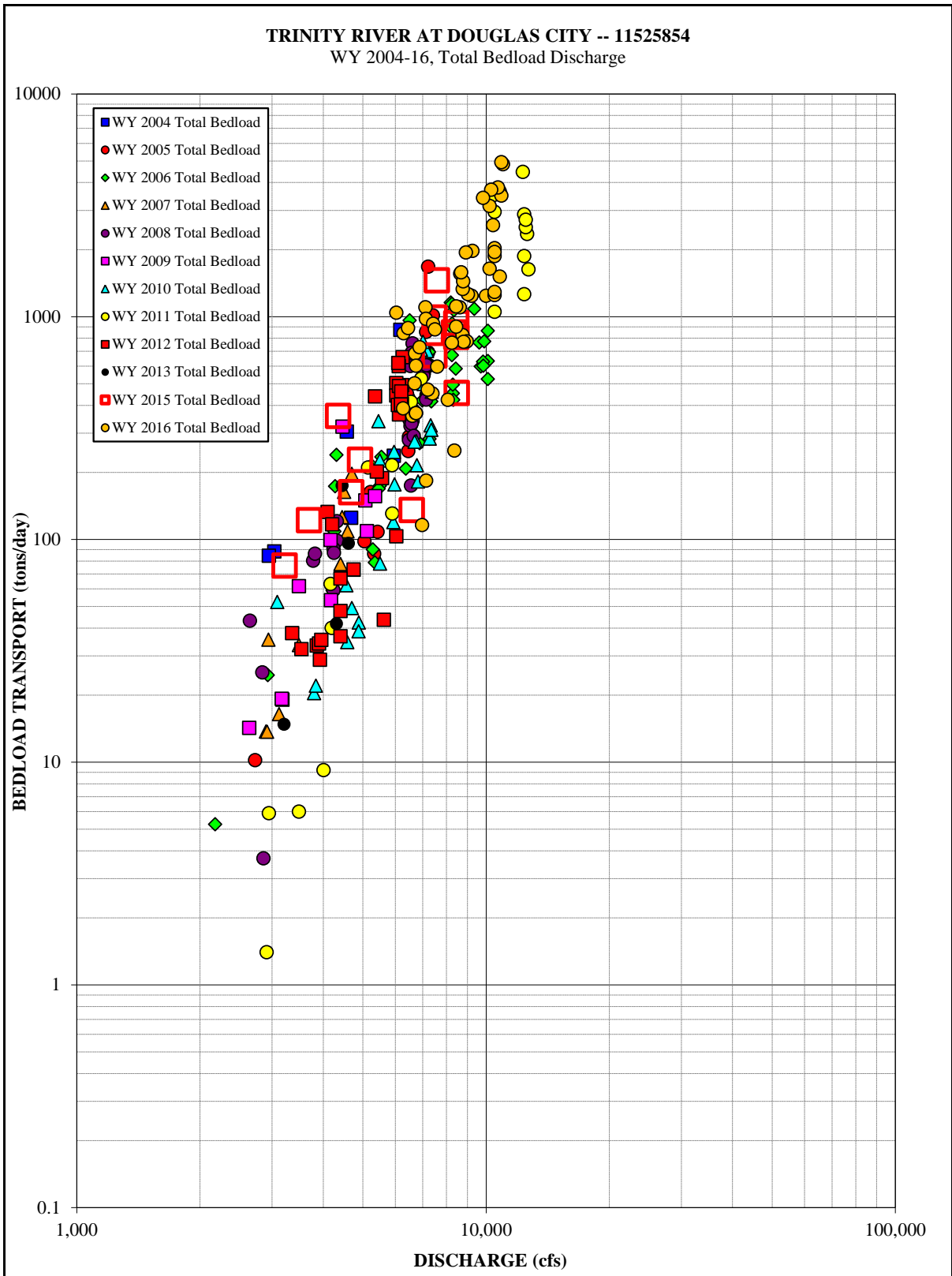


Figure 34. Total Bedload Discharge at TRDC, WY2004-2013, 2015-2016.

Water Surface Slope, Cross Section Changes and Pebble Count Changes

The 2016 11,000 cfs water surface slope was 0.003. Cross section and pebble count data were collected at the TRDC sediment monitoring station pre- and post-Spring Flow Release to assess changes at the sampling section. Changes in the cross section and particle size distribution are shown in Figures 35 and 36. The cross section showed over 1.8 feet of fill among the bedrock protrusions along the left side of the channel. The area change calculation for the cross section below the 1,604 foot elevation revealed 21.7 ft² of scour and 31.2 ft² of fill for a net change of 9.3 ft² fill. The pebble count describes the mid channel portion of the same transverse riffle. The pebble count showed coarsening across the distribution, with the D50 increasing from 50 to 70mm (Figure 36).

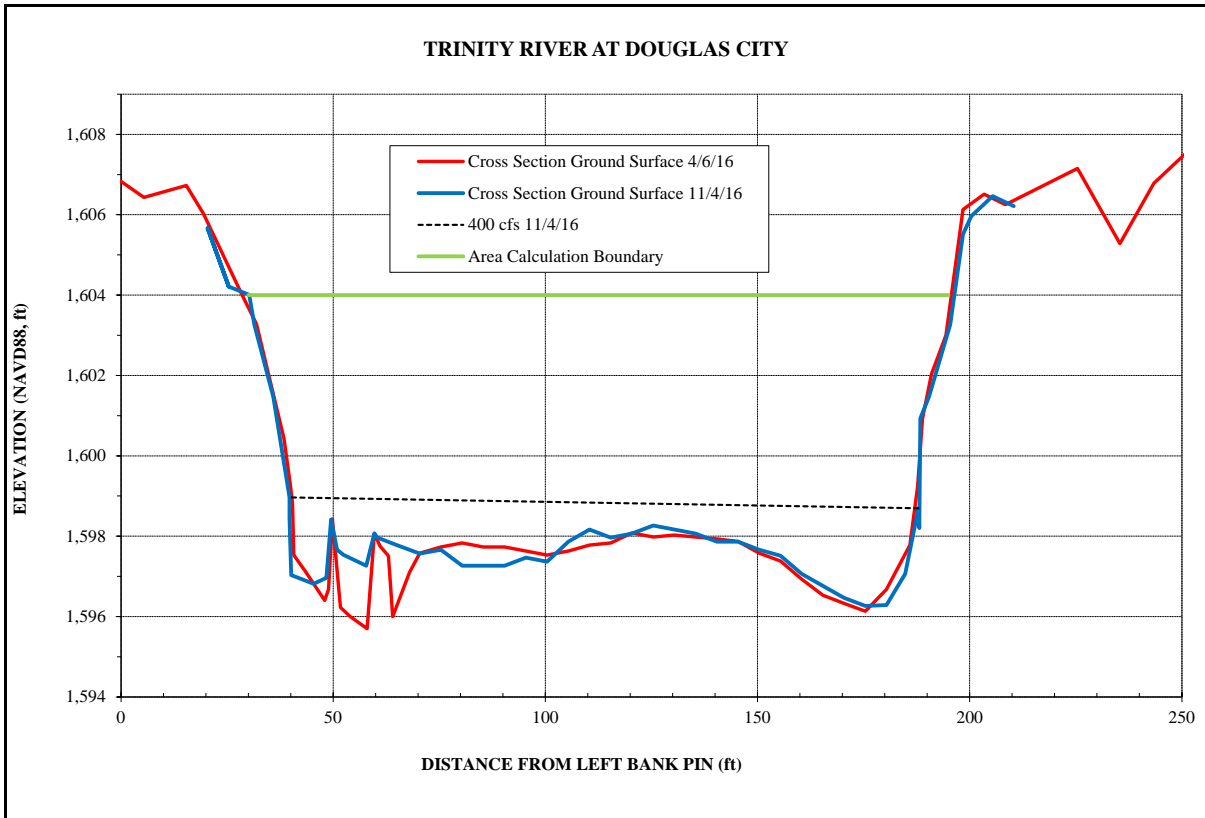


Figure 35. Cross section changes at TRDC, pre and post Spring Flow Release 2016.

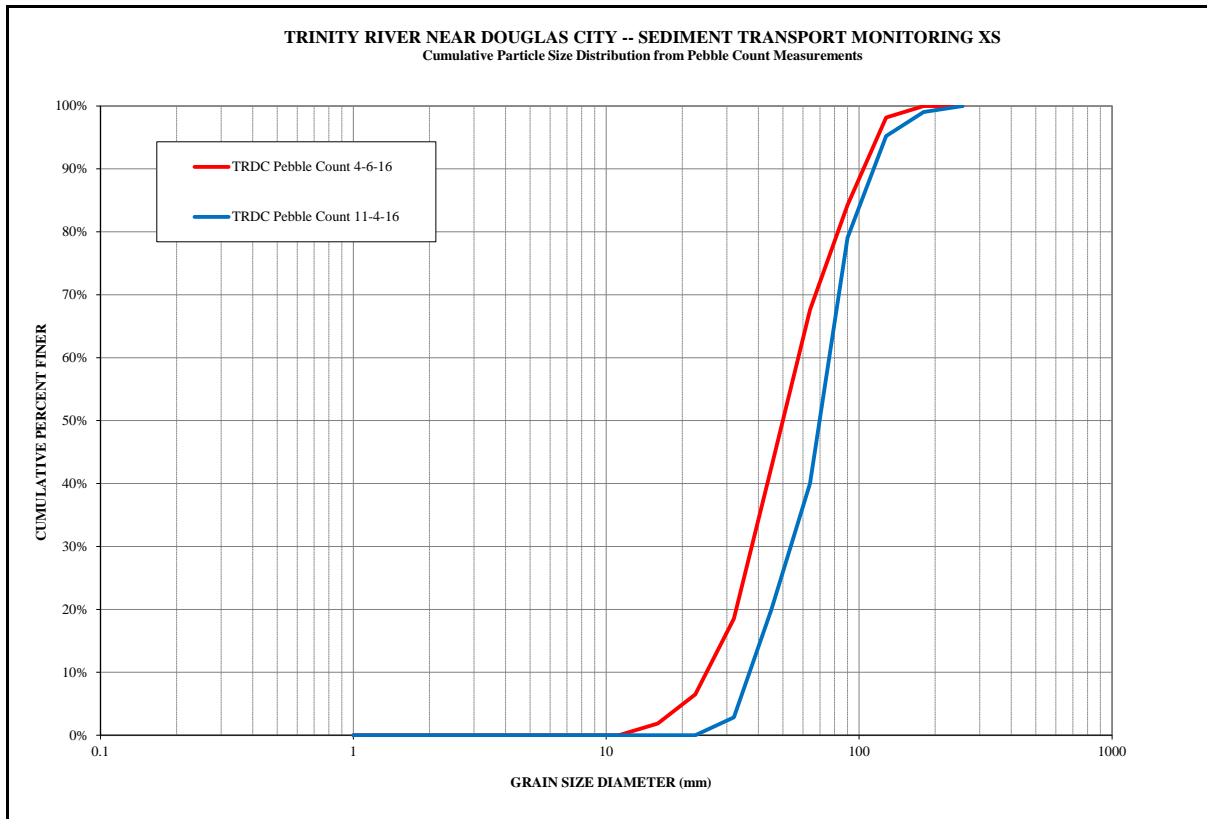


Figure 36. Changes in bed texture at TRDC, Spring Flow Release 2016.

2.5 Discussion

Sediment transport rates derived from field samples display considerable inter- and intra-annual variability. For example, the bedload transport rates at long-term sediment transport monitoring stations TRAL and TRLG show over an order of magnitude variation for a given discharge for a given year (Figures 9-11; 25-27). The suspended sediment data display less variation (Figures 8 and 23). The need to accurately estimate sediment transport rates for sediment load computations and to differentiate periods of higher or lower sediment transport (via transport curve comparison) provides the impetus for repeat annual sampling efforts.

The sediment budgeting objectives outlined in the TRFE and SBMP require an accounting of sediment inputs and outputs to sediment budget cells. These values are used to determine the dam release flow duration required to transport sediment, the sediment quantities, and the particle sizes needed to augment various reaches. Monitoring results which inform sediment budgets, and are ultimately used to help explain the linkages between management actions and desired restoration outcomes (e.g. as described in TRFE, 1999) include:

- Differences in sediment discharge (transport rates) between stations;
- Differences in sediment loads between stations;
- Differences in bedload sediment particle sizes;
- Changes in sediment loads at a station over time;
- Changes in sediment discharge (transport rates) at a station over time.

We focus on each of these topics in the following sections. We also explore uncertainty in some of the sediment load calculations as implied by temporal bedload discharge variation (also done previously in 2015); the results of this pilot study are presented in section 2.5.5.

Data evaluations in this section are based on visual estimates of data trends and no statistical analyses were performed (with exception of Sec 2.5.6 / Table 21). So although data may suggest clear trends, we do not provide statistical inference.

2.5.1 Differences in Sediment Discharge between Stations

2.5.1.1 Mainstem Suspended Sediment

WY 2016 suspended sediment discharge data for the four mainstem stations were plotted together (Figure 37) to highlight downstream transport variation. Mainstem suspended sediment transport rates increase (shift upward) with distance downstream from the dam. Assuming all stations are transporting below their potential SSD transport capacity, the progressive downstream increase in transport rate indicates that fine sediment supply increases with distance downstream. This is likely due to both tributary contributions and cumulative increase in channel bank (e.g. sandy lateral berms) available to recruit fine material. The USGS data from the 1981-1991 sits well to the left of the 2016 data, which suggests that the mainstem produced more fine sediment at TRLG than it does today (Figure 37).

Much of the scatter within each of the mainstem stations' data is attributed to hysteresis during the Spring Flow. While gravel was being introduced, increases in turbidity and suspended sediment were observed that were not associated with increases in discharge; this further contributed to the scatter observed at TRGV and to a lesser degree TRLG and TRDC (the injection-related turbidity pulse was observed at all three stations in 2015).

The WY 2016 sedigraphs for total and partial suspended sediment discharge were plotted with their respective site hydrographs to highlight sediment discharge variation across the hydrograph (at a station) and in the downstream direction (between stations) (Figures 38, 39). All stations (with minor exceptions) show an overall rapid rise in SSD with both peaks of the 2016 SFR hydrograph. With a limited supply reach above, TRAL barely registers the bumps on the initial rise and the trace for the second peak is noticeably smaller, approximately half as large, presumably because the reach above was depleted of fines by the first pulse. At TRGV, the sedigraph trace for the second peak is clearly higher and broader than for the first and this may be due to SSD increases related to gravel injection. At TRLG, the effects of the "ratcheting" on the rising limb become quite apparent as the sedigraph follows the hydrograph to the peak. After the initial peak and throughout the second peak, SSD drops off and the sedigraph doesn't mirror the hydrograph on the final decline as it did on the initial rise. TRDC follows the same pattern as TRLG, though the disparity between the peak SSD for each hydrograph peak is much greater (Figure 38). The hysteresis described above (for all but TRGV) is also illustrated in the shape of each sedigraph relative to the hydrograph shape; SSD drops off quickly after the steep rises to the peak benches, and SSD is smaller for the second peak of equal magnitude.

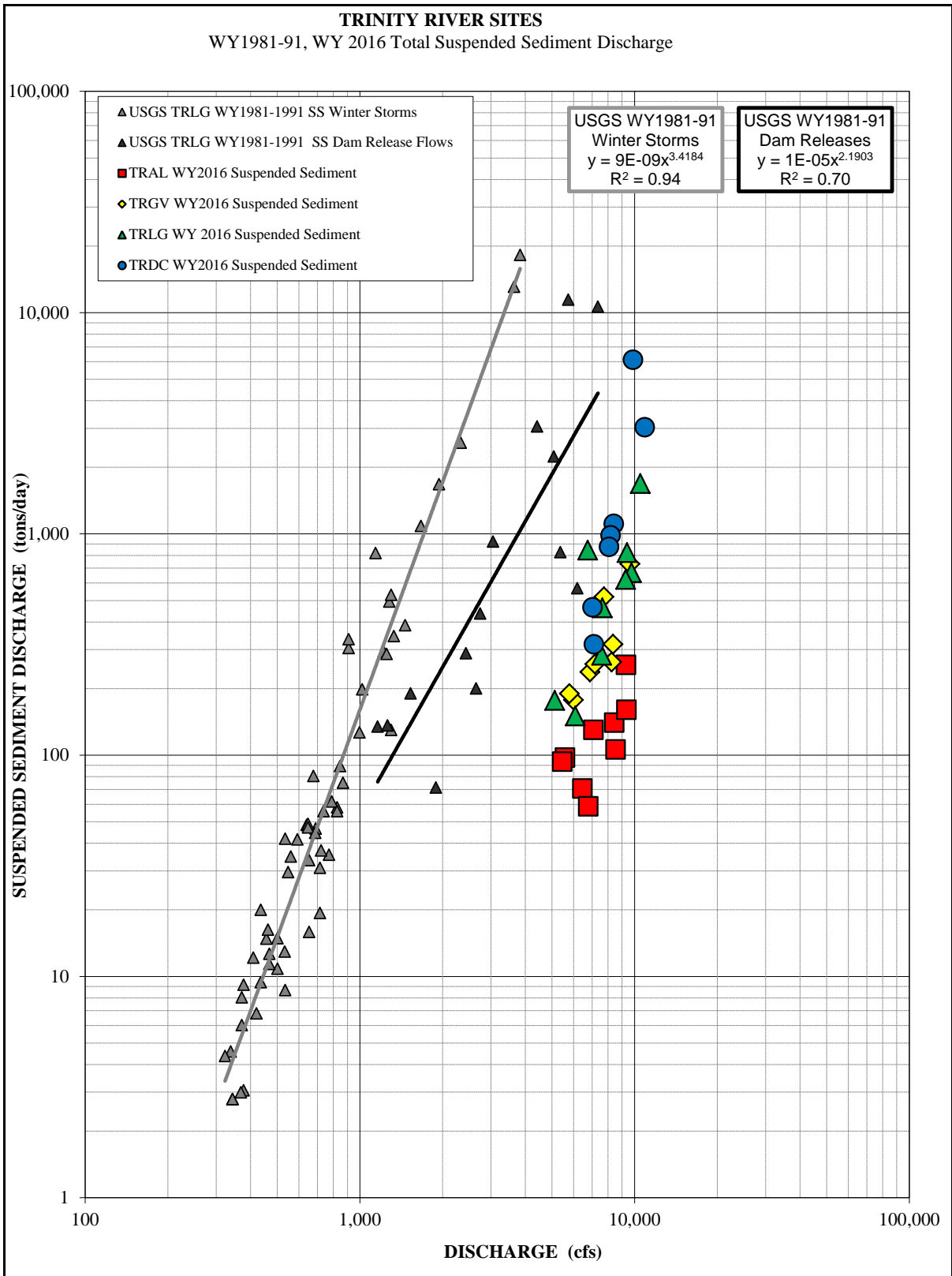
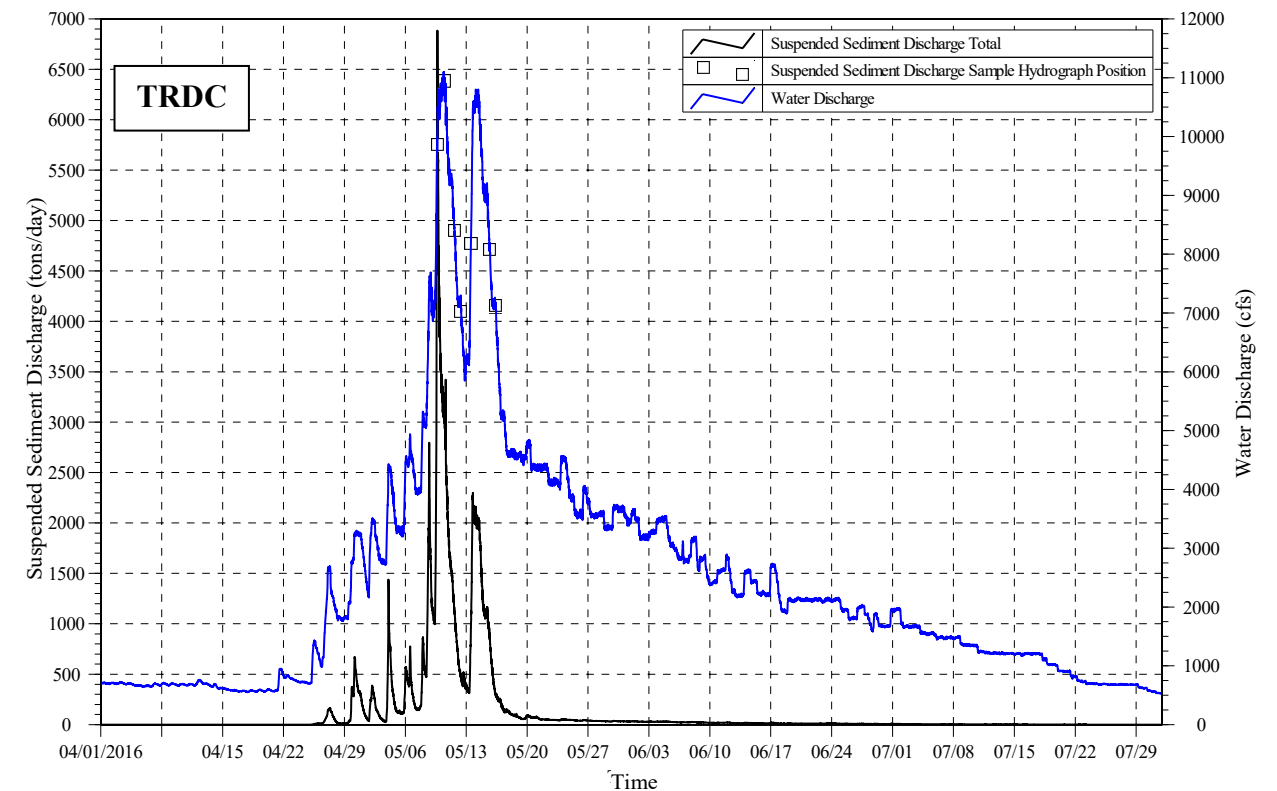
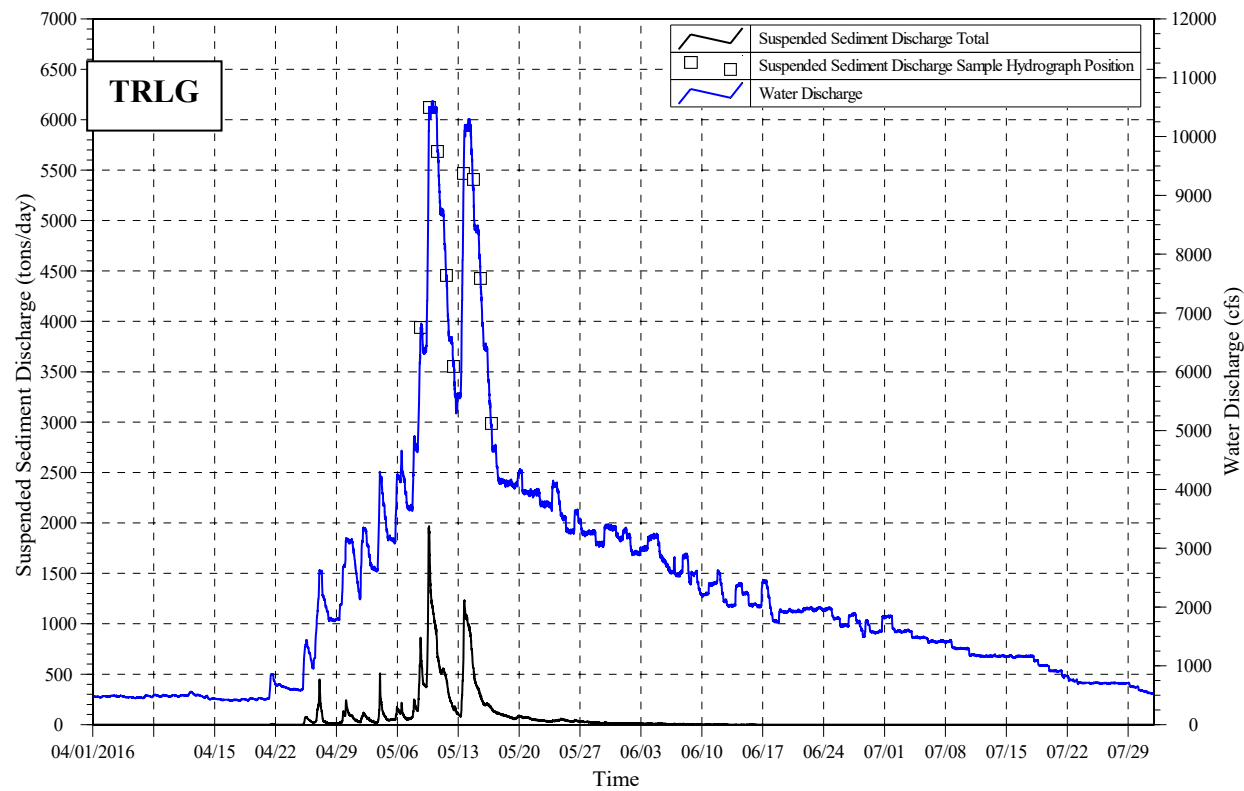
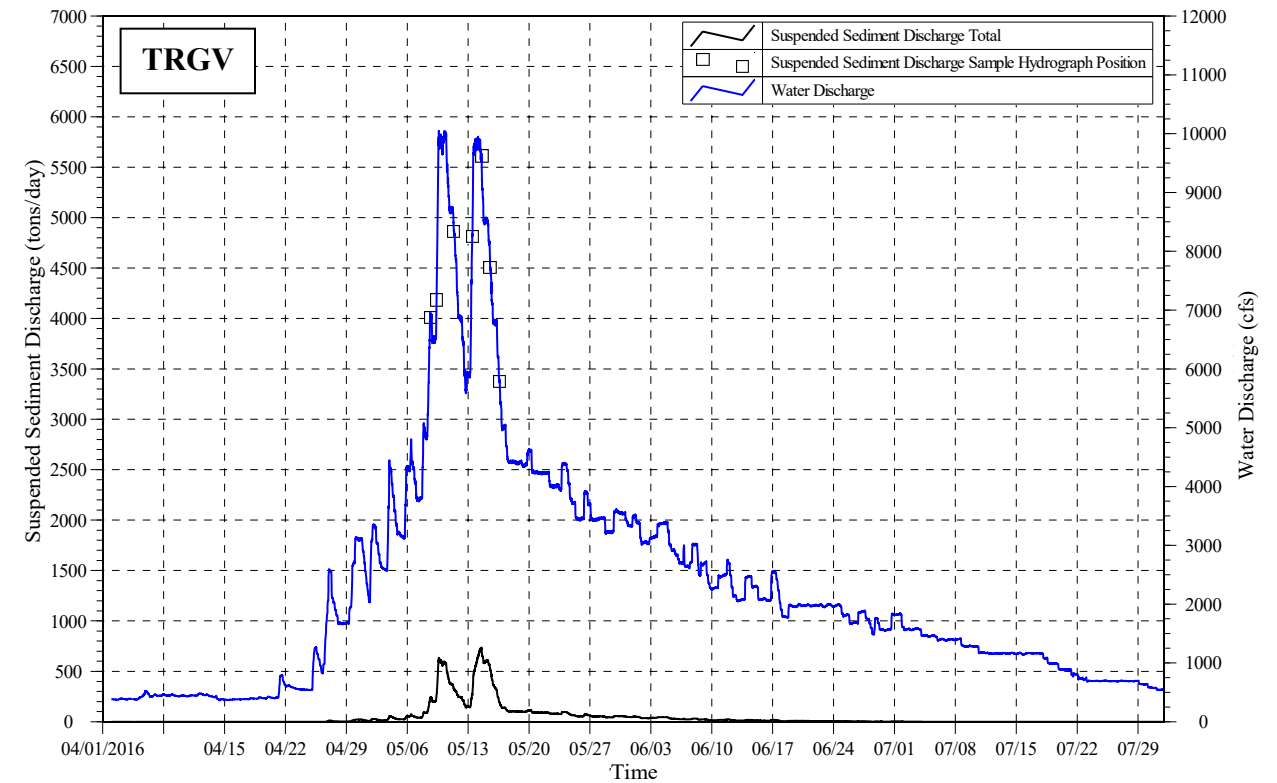
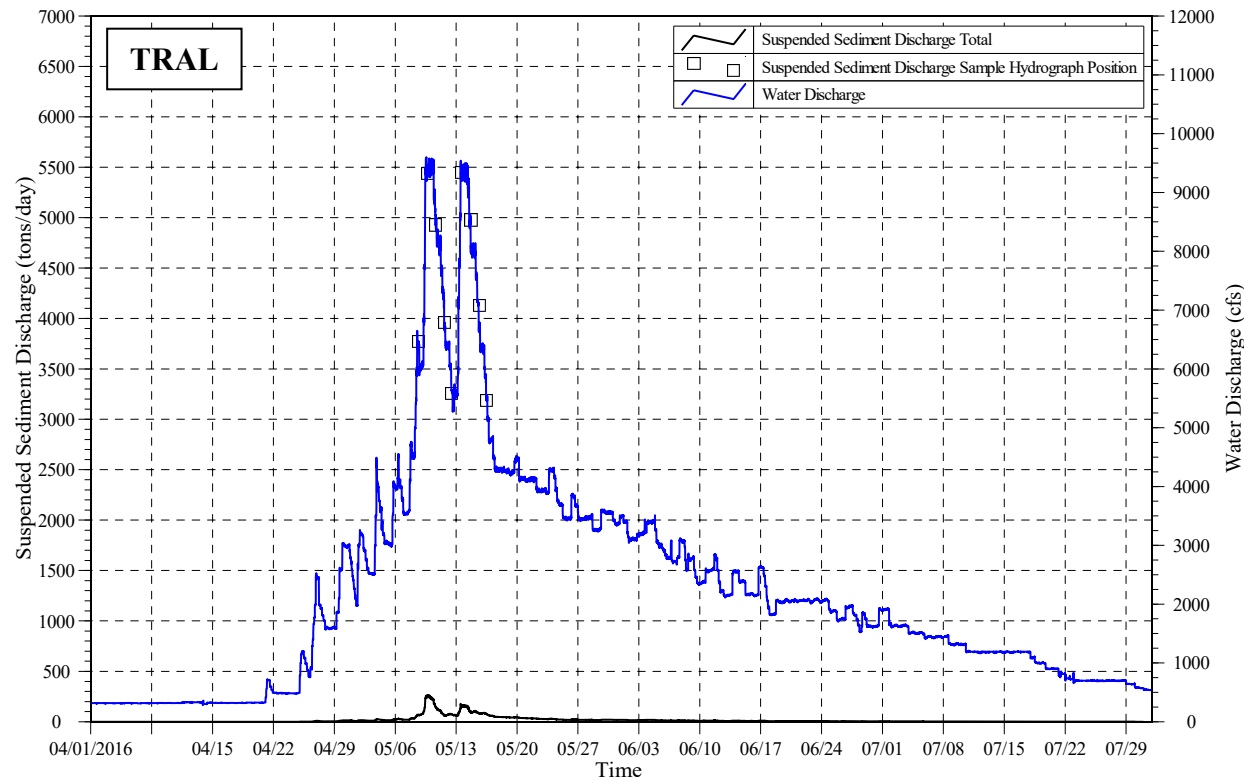


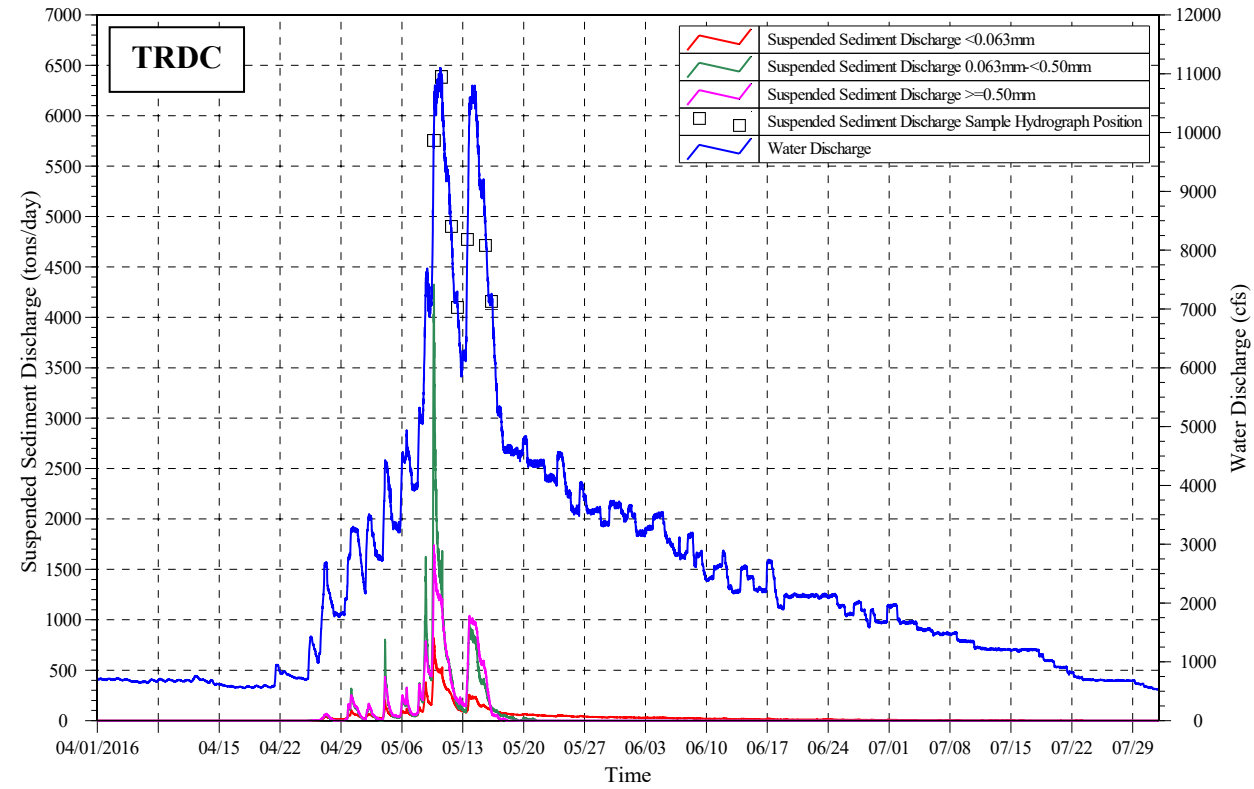
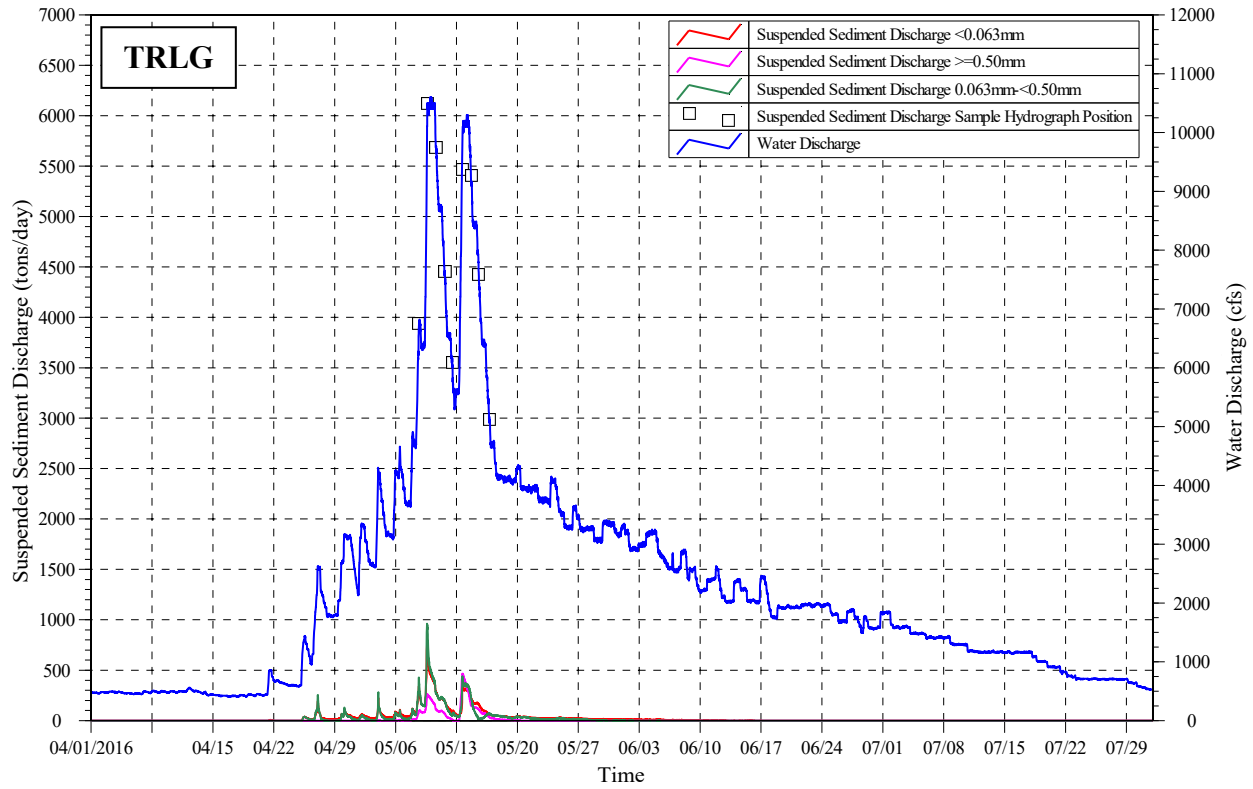
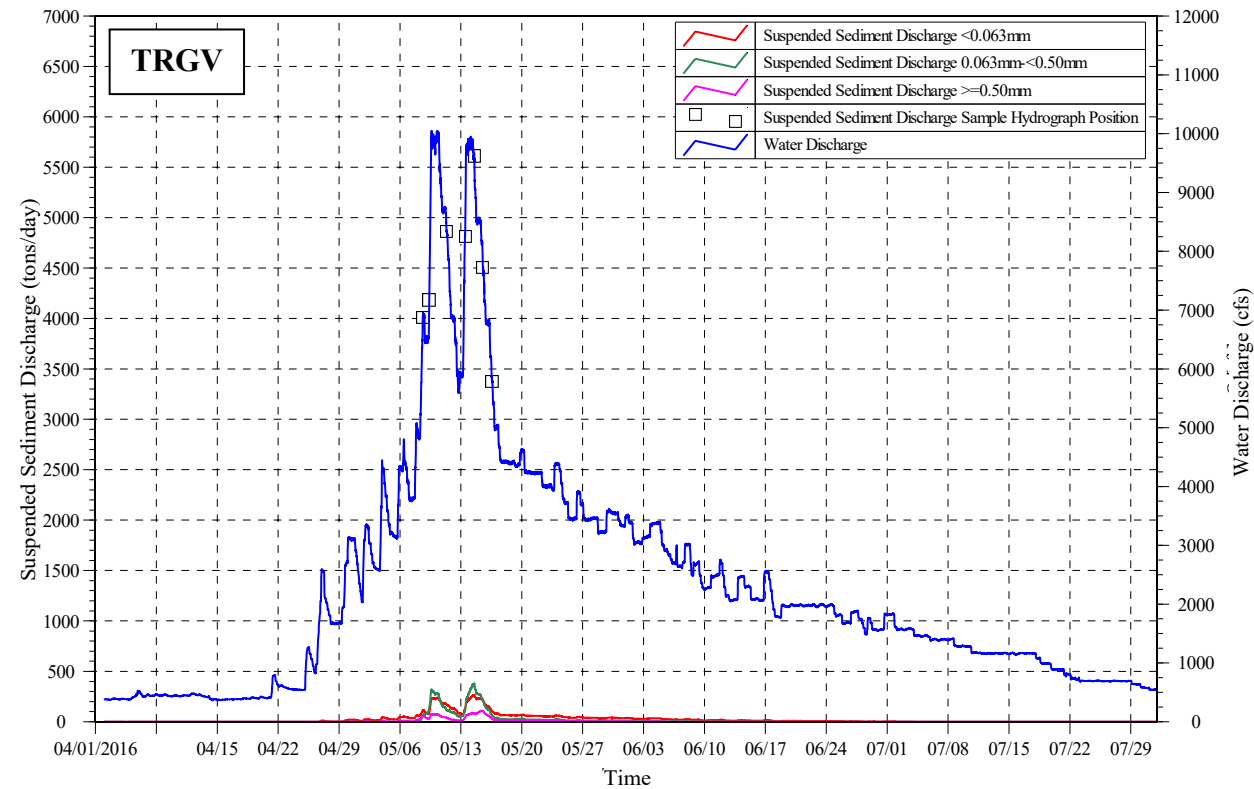
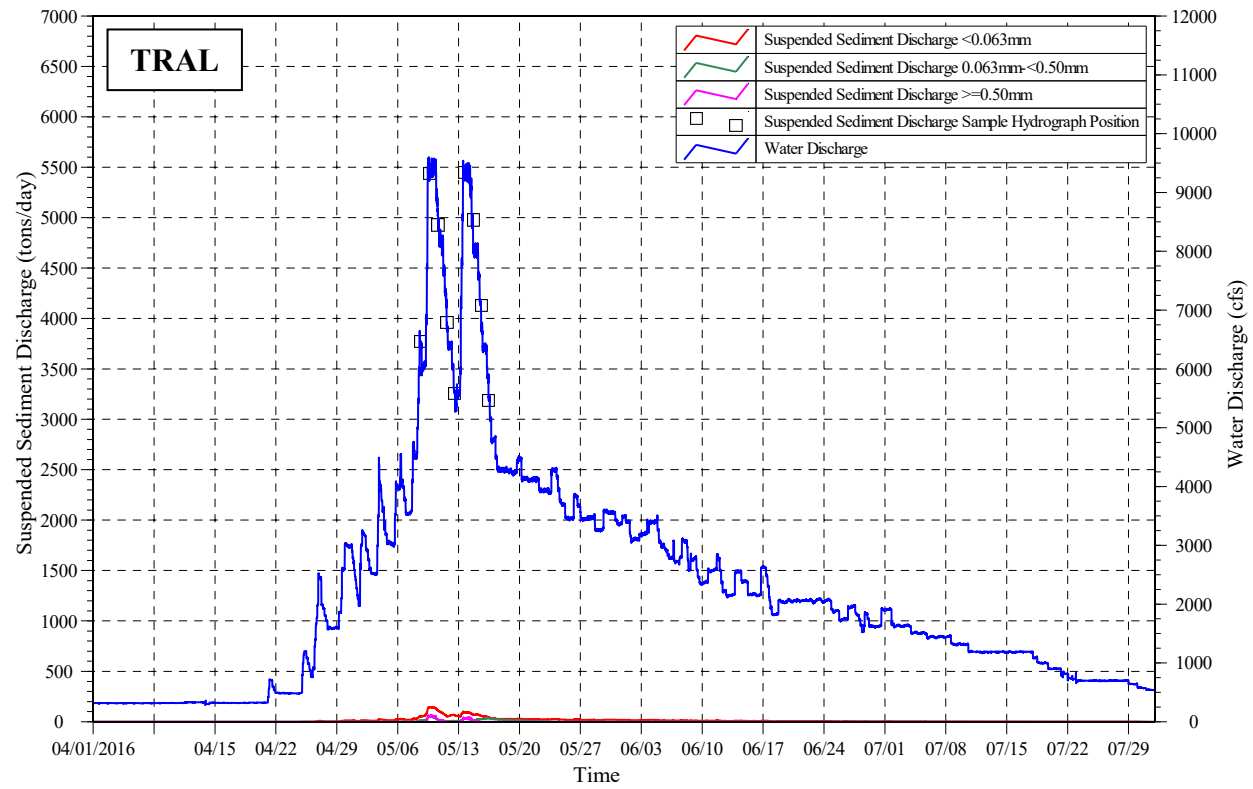
Figure 37. Suspended Sediment Discharge, Mainstem Trinity River Monitoring Stations, WY 2016 with TRLG Data from 1981-1991 for comparison.
See Figures 1 and 2 for sampling site locations.

TRINITY RIVER MAINSTEM STATIONS

Suspended Sediment Discharge -- Spring Flow Release WY 2016



TRINITY RIVER MAINSTEM STATIONS
Suspended Sediment Discharge -- Spring Flow Release WY 2016



2.5.1.2 Mainstem Bedload

The WY 2016 total bedload discharge measurements for all stations were plotted together in Figure 40. Trend lines were added strictly to aid in distinguishing relative trends. We attribute data-point scatter to: the hysteresis that often occurs across flow benches, the inherent variability in sample particle-size distributions (e.g. periodic large particles biasing the sample), and the inherent temporal variability in bedload transport.

TRAL bedload shows the highest rate of increase (exponent = 5.66 in the power function), though the exponent for TRGV is nearly the same at 5.42. TRAL, TRLG and TRGV generally plot together, though TRGV contains several samples which plot much higher than the others (at >2,000 tons/day, more than double the highest bedload discharge (BLD) measured at the other two sites). At TRDC, BLD magnitudes for individual samples clearly plot much higher than at the other three stations, though at 3.34, the rate of increase (exponent) in the equation is the lowest. TRLG shows a very similar exponent at 3.38 (Figure 40). TRDC clearly transports more bedload at all measured flows in 2016. This reflects the greater availability of sediment for transport towards the downstream end of the study area due to tributary inflows.

A higher sediment transport capacity may also contribute to higher bedload discharge rates at TRDC which has the steepest water surface slope of all the stations.

The four mainstem total bedload sedigraphs and sedigraphs for fine (0.5-<8mm) and coarse (≥ 8 mm) bedload size fraction (Figures 41, 42) illustrate bedload discharge variation across the Spring Flow Release hydrograph and in the downstream direction. All sites show higher transport on the first peak of the SFR hydrograph. TRDC shows the greatest response to the ratcheting of the rising limb and the effect is difficult to detect at the other three sites (Figure 41). At TRDC, the fine fraction of bedload comprises more of the total load than at the other three sites (Figure 42), again presumably due to its position lower in the watershed (fine sediment supply increases with distance downstream).

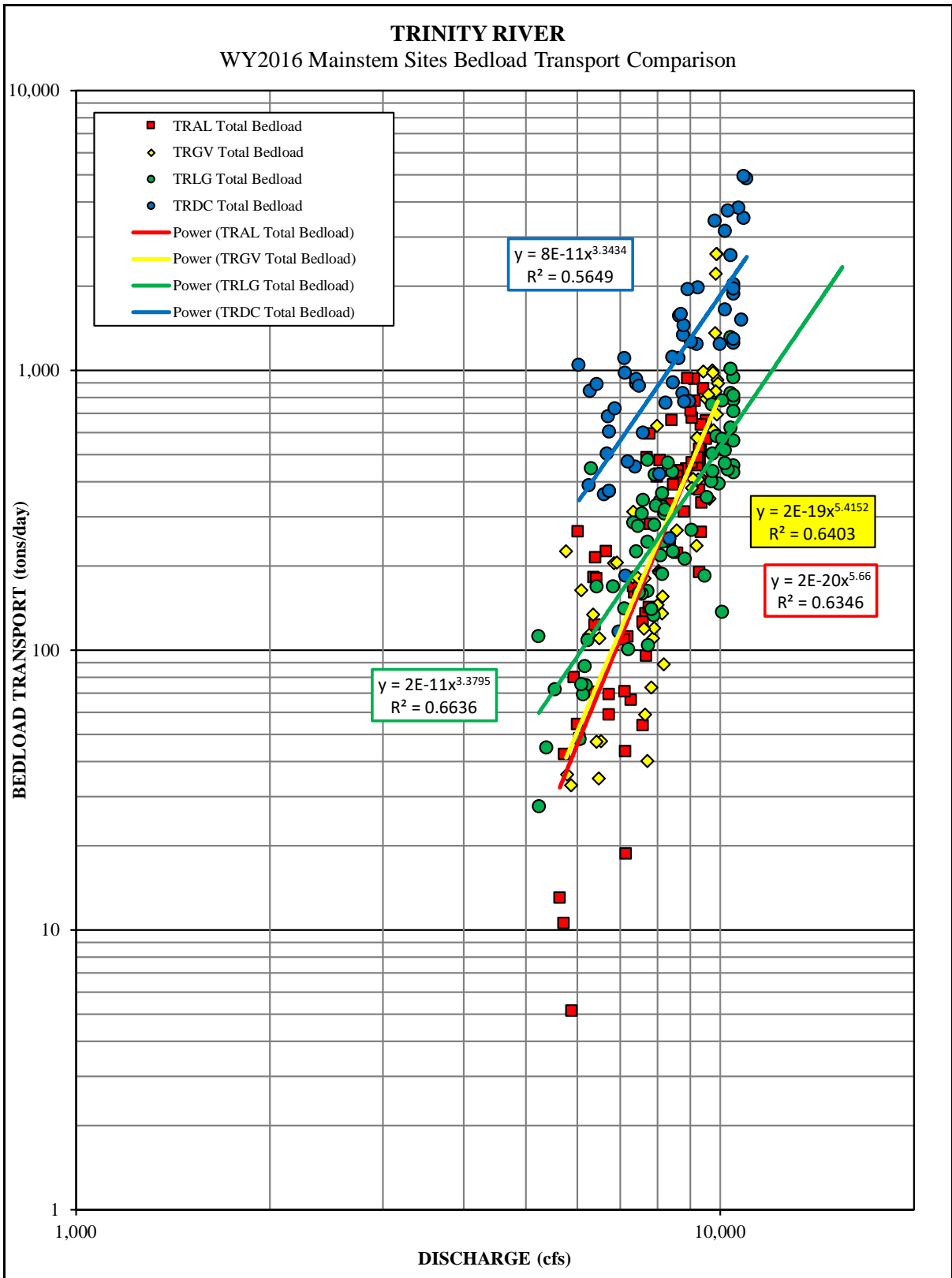
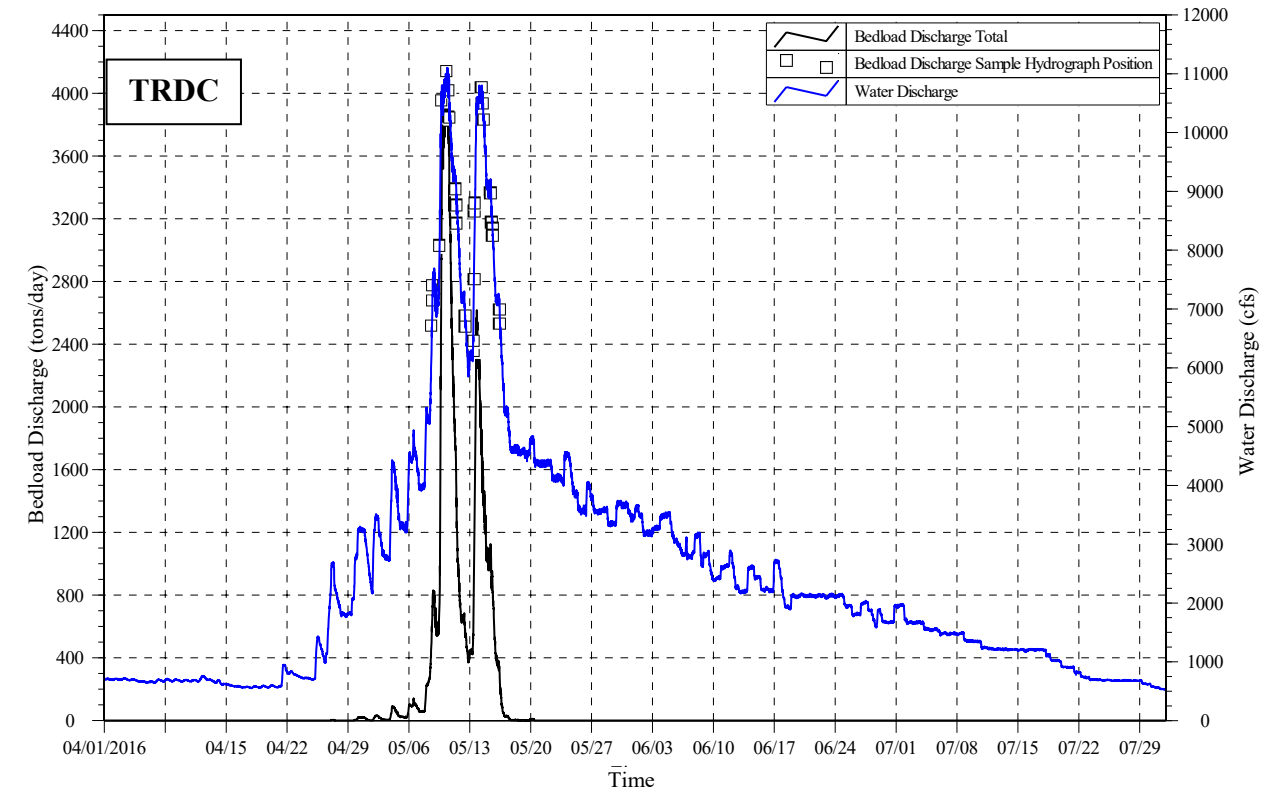
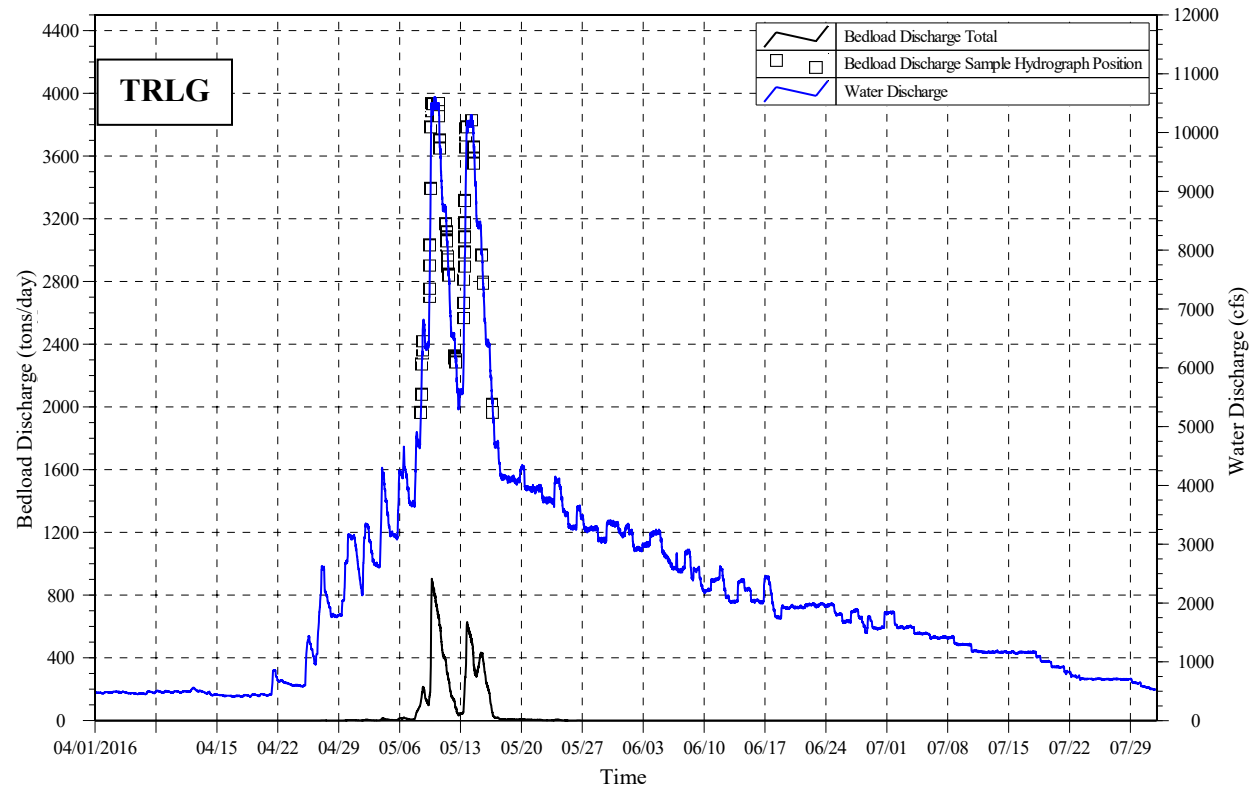
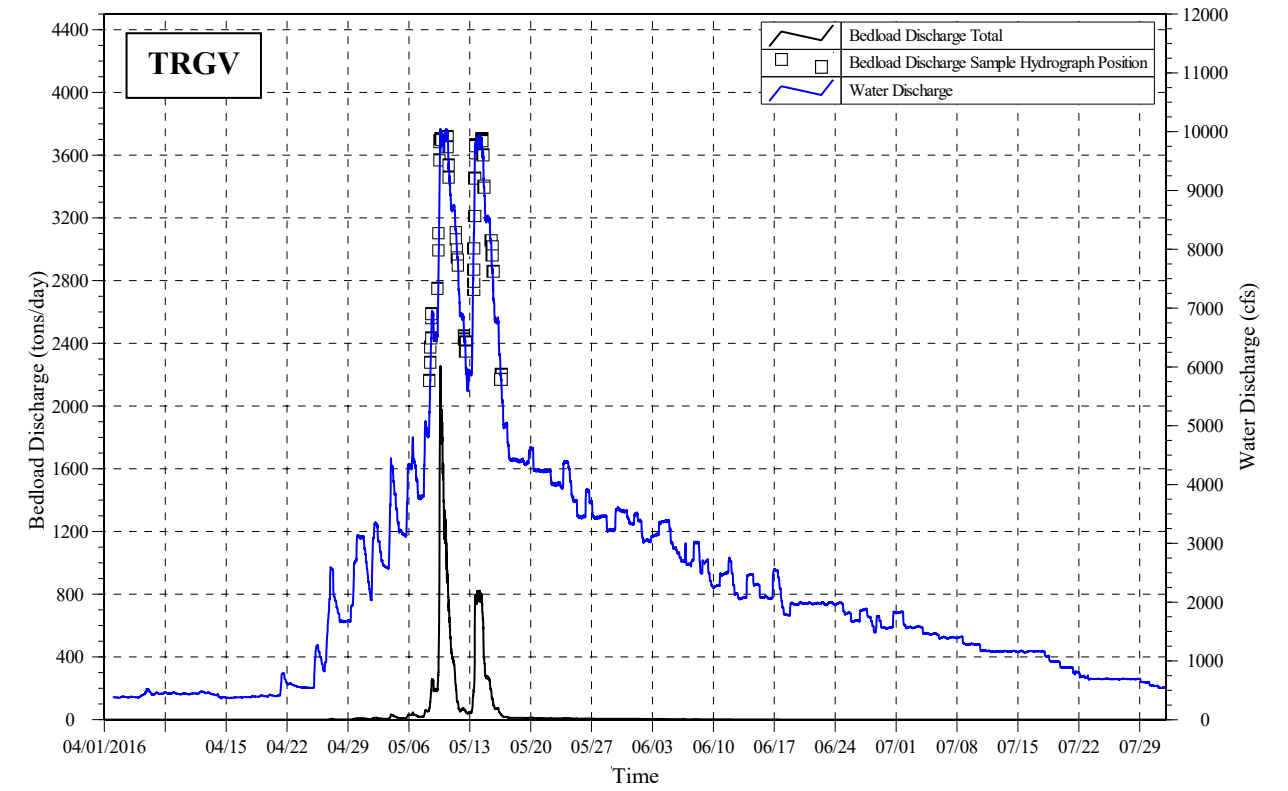
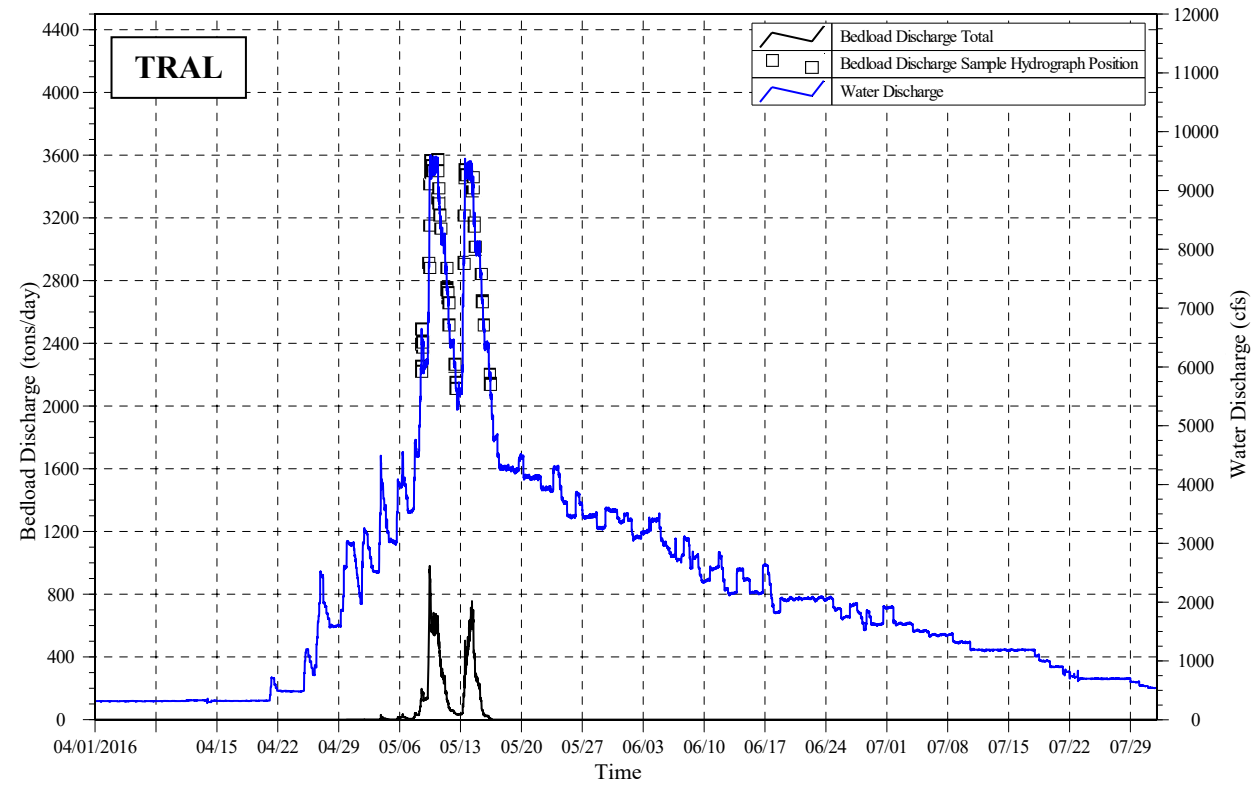
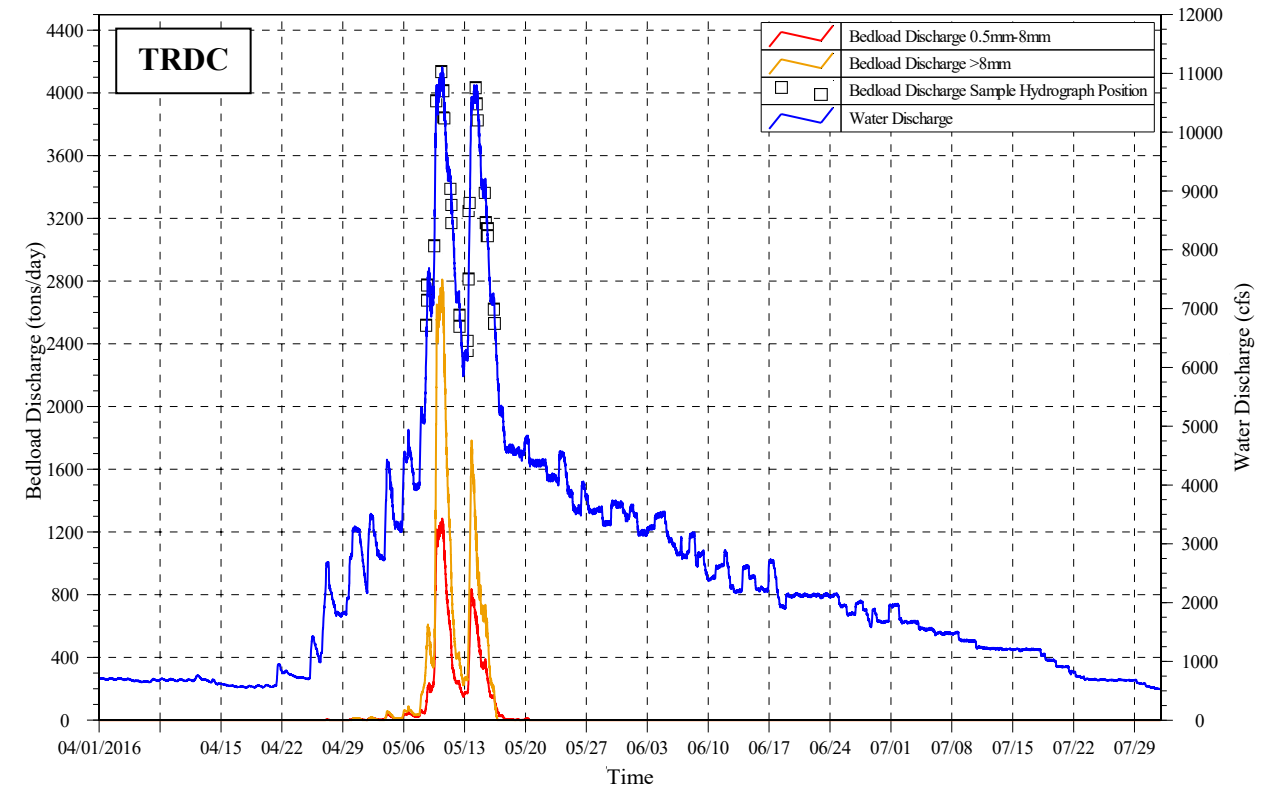
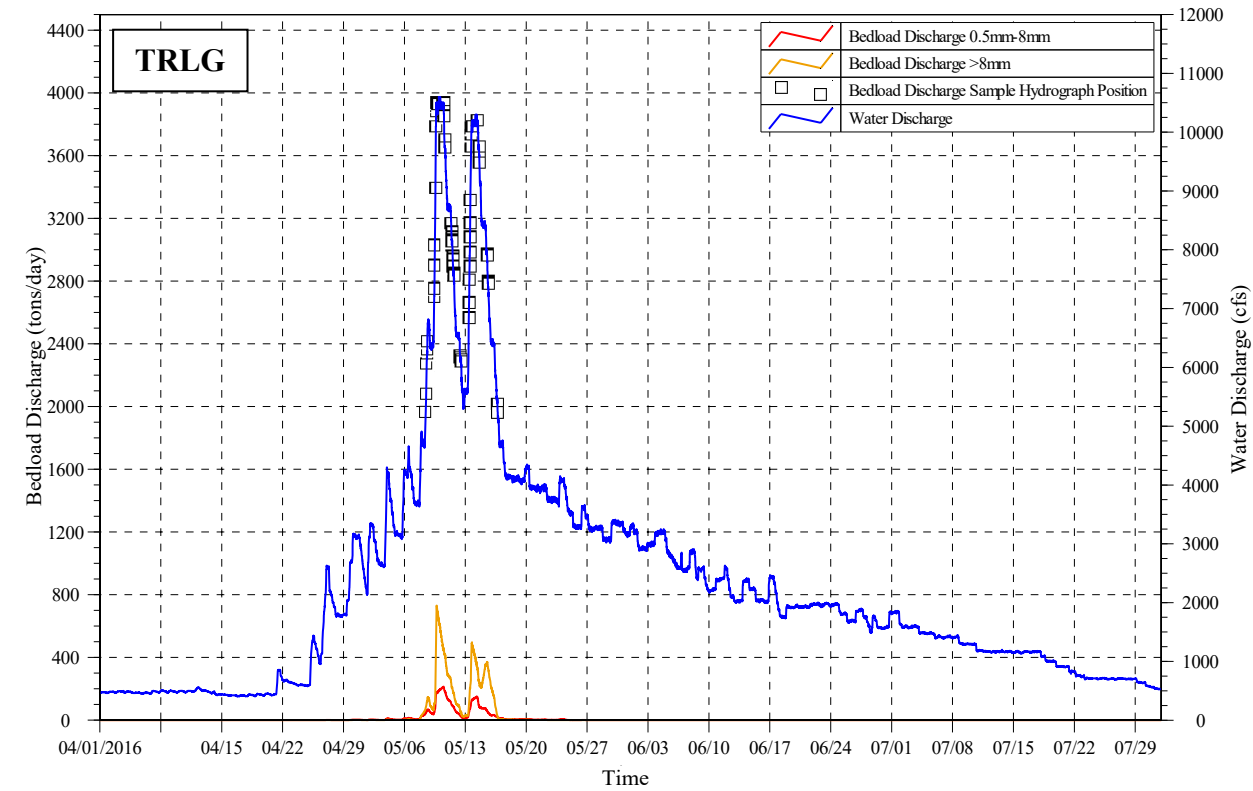
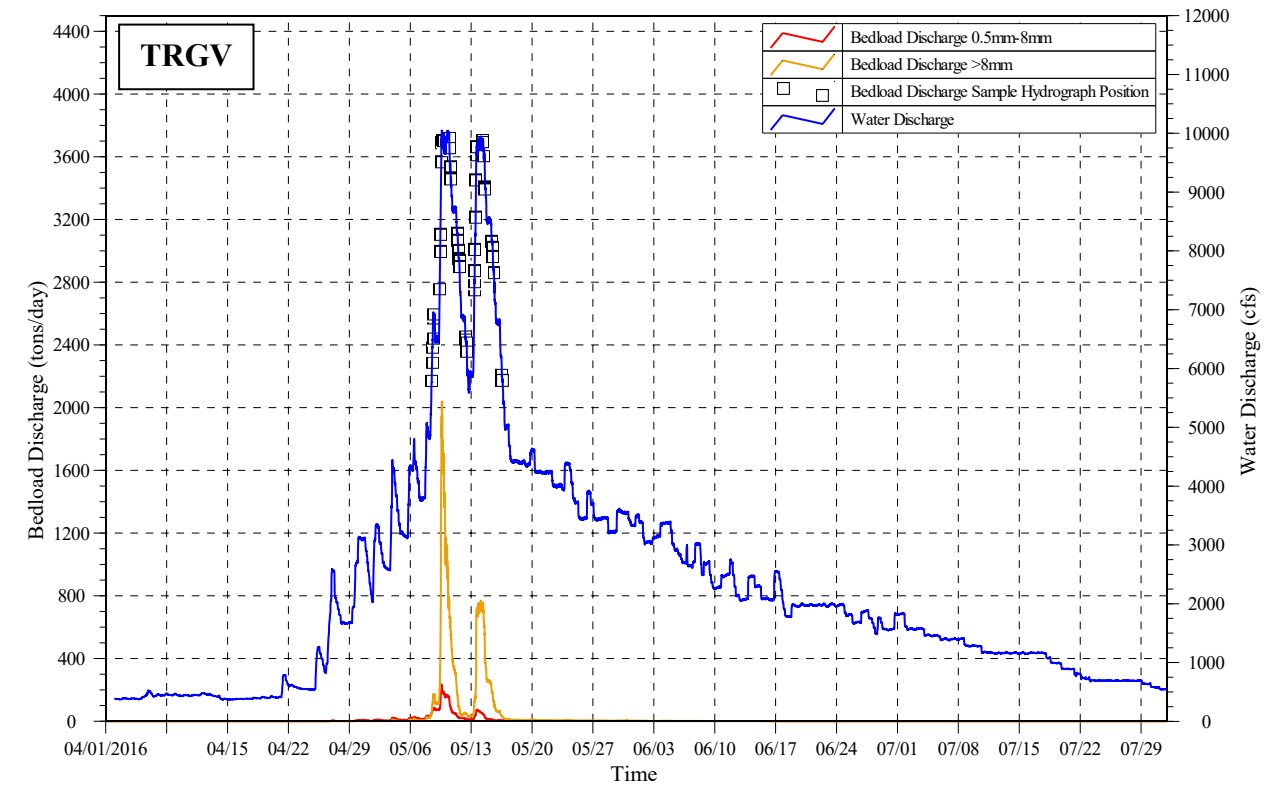
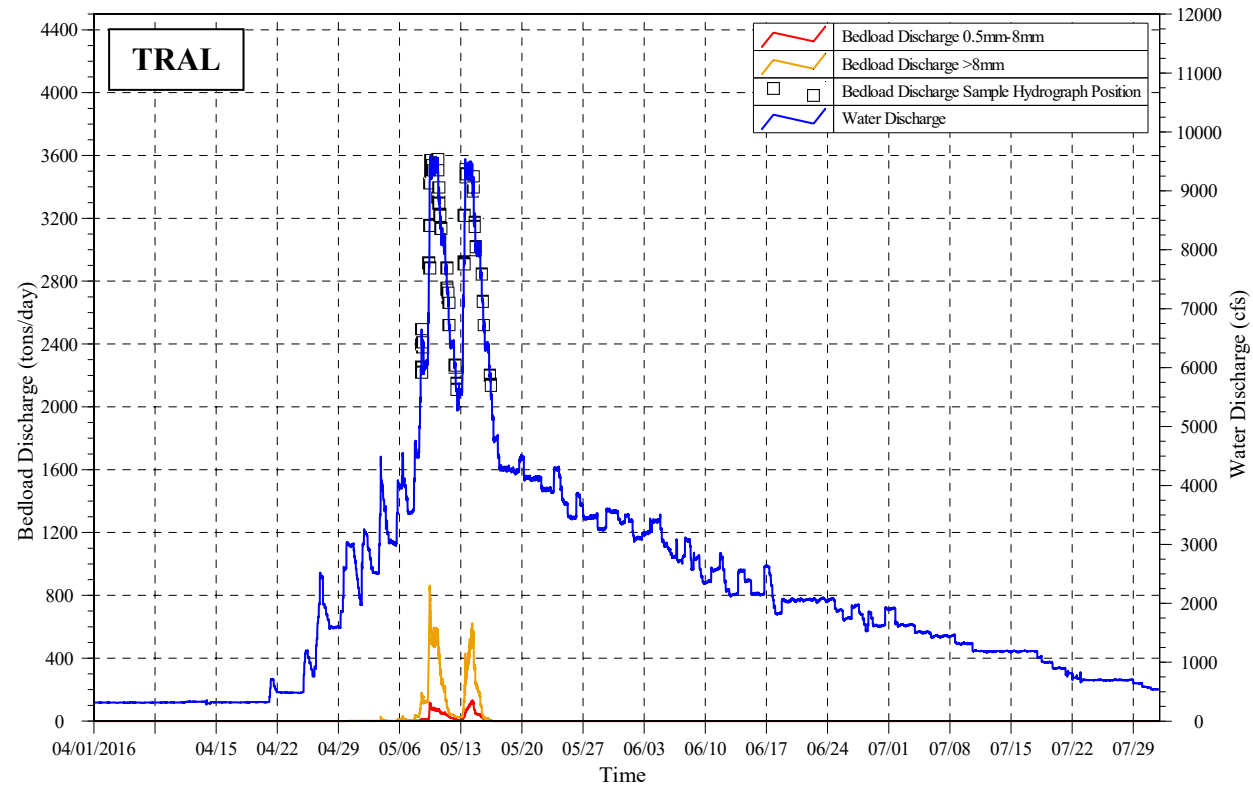


Figure 40. Total Bedload Discharge, Mainstem Trinity River Monitoring Stations, WY2016.
See Figures 1 and 2 for sampling station locations.

TRINITY RIVER MAINSTEM STATIONS
Bedload Discharge -- Spring Flow Release WY 2016



TRINITY RIVER MAINSTEM STATIONS
Bedload Discharge -- Spring Flow Release WY 2016



2.5.2 Differences in Sediment Load between Stations

2.5.2.1 Mainstem Suspended Sediment Loads

The computed partial and total suspended sediment loads for the WY2016 Spring Flow Release are presented in Table 18. Suspended sediment loads increased in the downstream direction: from 1,890 tons at TRAL, to 5,210 tons at TRGV, to 6,300 tons at TRLG, and 16,600 tons at TRDC.

2.5.2.2 Mainstem Bedload

Bedload does not show the same downstream increase as was observed for suspended load. Total bedload estimates for TRAL, TRGV, TRLG, and TRDC in WY2016 were 2,140, 3,690, 2,820 and 11,900 tons, respectively (Table 18). Gravel injection at the TRGV site during the flow release undoubtedly increases bedload measured at the sampling station.

Table 18. WY 2016 Mainstem Sediment Loads

SEDIMENT MONITORING STATION	Suspended Sediment				Bedload		
	SS <0.063 mm (tons)	SS 0.063 mm - <0.50 mm (tons)	SS ≥0.50 mm (tons)	SS Total (tons)	Bedload 0.50-<8 mm (tons)	Bedload ≥8 mm (tons)	Total Bedload (tons)
Trinity River at Lewiston (TRAL)	1,510	271	113	1,890	338	1,800	2,140
Trinity River above Grass Valley Creek (TRGV)	2,850	1,750	612	5,210	578	3,110	3,690
Trinity River below Limekiln Gulch (TRLG)	2,800	2,410	1,090	6,300	781	2,040	2,820
Trinity River near Douglas City (TRDC)	3,780	6,710	6,060	16,600	4,010	7,850	11,900

All values rounded using methods by Porterfield (1972)

The relative percentage of fine and coarse bedload varied between stations. TRAL and TRGV were each comprised of 16 percent fine bedload. TRLG bedload was composed of 28 percent fine bedload and TRDC was 34 percent. Comparison of the ratio of suspended load or bedload to total load at the various mainstem sites can provide additional insight into transport dynamics. TRAL generally has a much higher percentage of bedload versus total load compared to the other sites, with 53 percent in WY2016. TRGV bedload was 41 percent of the total and TRLG and TRDC were 31 and 42 percent.

Of particular interest in 2016, considering the unique double-peak hydrograph, is the question of how do the loads compare for each peak flow bench? We examined each site relative to its own hydrograph and summed the >8mm loads for each peak flow bench. Computational periods were defined as the time the hydrograph exceeded the low flow point between the two flow peaks (noted as “Q start” in Table 19). By this definition, the first peak was slightly longer than the second. For TRAL, the first peak transported 1,060 tons and the

second transported 668 tons, 59 and 38 percent of the total >8mm load for the entire computational period. At TRGV, the first peak transported 1,840 tons and the second transported 1,080 tons, 59 and 35 percent of the total 3,110 tons of >8mm. TRLG transported 1,080 and 907 tons, 53 and 44 percent of the total 2,040 tons. TRDC transported 4,970 tons and 2,590 tons, 63 and 33 percent.

Table 19. >8mm bedload totals for each peak flow bench, WY2016

SEDIMENT MONITORING STATION	Q Start (cfs)	Peak #1			Peak #2		
		Bedload >8mm (Tons)	# Hrs	Q Peak (cfs)	Bedload >8mm (Tons)	# Hrs	Q Peak (cfs)
Trinity River at Lewiston (TRAL)	5,270	1,060	102.0	9,600	688	95.5	9,540
Trinity River above Grass Valley Creek (TRGV)	5,590	1,840	105.5	10,000	1,080	94.0	9,950
Trinity River below Limekiln Gulch (TRLG)	5,290	1,080	102.75	10,600	907	94.75	10,300
Trinity River near Douglas City (TRDC)	5,870	4,970	104.5	11,100	2,590	92.75	10,800

All values rounded using methods by Porterfield (1972)

2.5.3 Differences in Bedload Sample Particle Size Distributions

The bedload sample particle-size distributions for the mainstem stations were compared to examine general variations in grain size, both between stations and between peak flow benches. Particle-size distributions were averaged for all samples collected during each 2016 peak flow bench (Figure 43). TRAL shows little change between peaks while TRGV and TRLG show coarsening. Bedload at TRDC is noticeably finer for the second peak flow bench. TRAL presumably has a relatively homogenous source (supply is predominately injected gravel). The reason for the change in grain size for the other three sites is unknown.

The D50 for each bedload sample collected during the 2016 SFR is provided by individual site-hydrograph in Figure 44. At TRAL, the mean (cumulative) D50 appears to decrease over the initial rise to the first peak flow bench, then hold steady at around 45mm throughout the remainder of the SFR hydrograph. At TRGV the trend appears to be an increase from approximately 50 to 60mm over the course of the hydrograph. At TRLG the mean D50 appears to hold at around 40mm for the entire release though the data exhibit more scatter than the previous two sites. Similarly, at TRDC the D50 appears to hold at roughly 25mm over the entire release and the data exhibit the least scatter of all the sites.

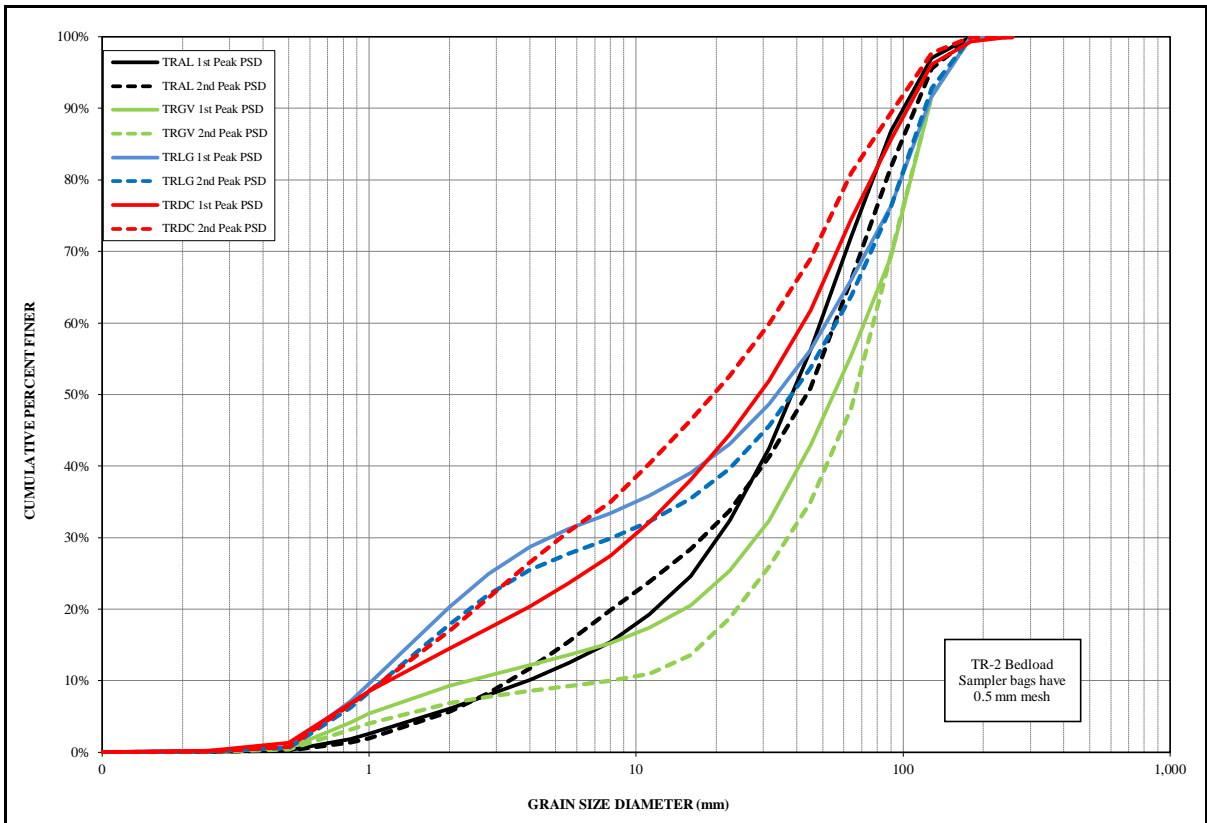
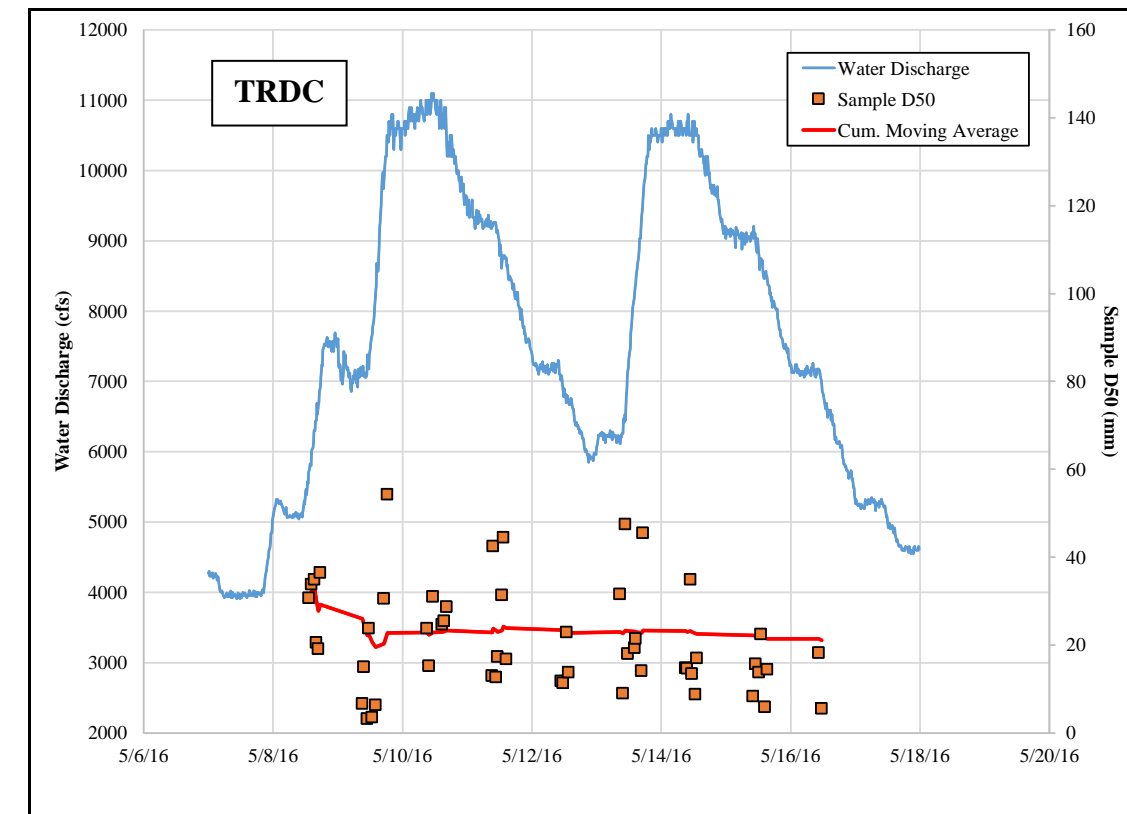
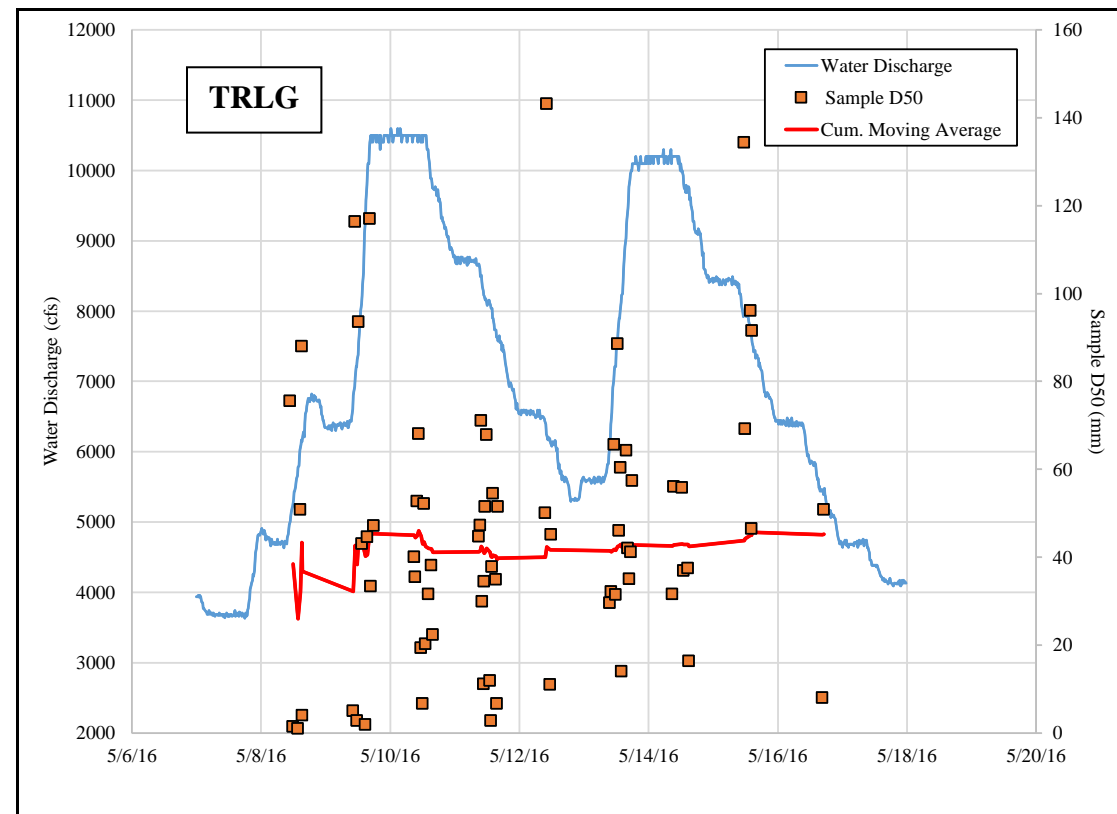
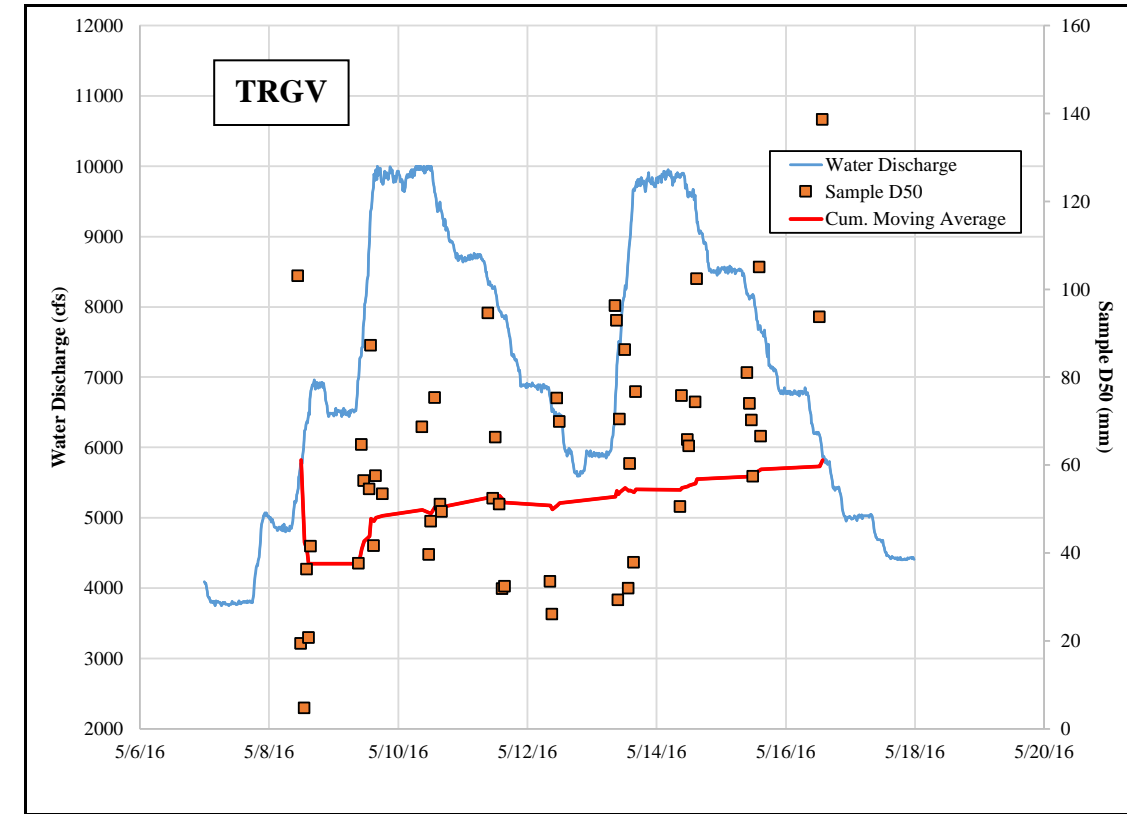
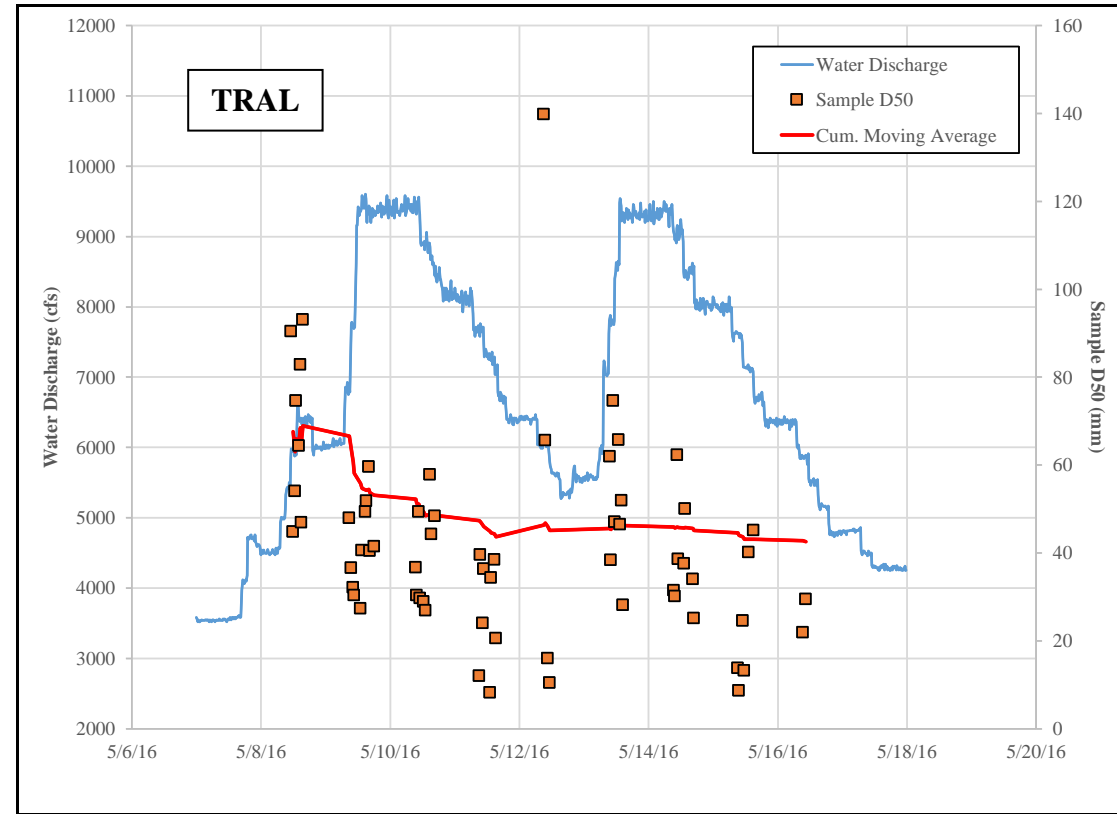


Figure 43. Peak Flow Bench Averaged Bedload Particle Size Distributions from the WY2016 Spring Flow Release.
 See Figures 1 and 2 for sampling station locations.

TRINITY RIVER MAINSTEM STATIONS
Bedload Sample D50 -- Spring Flow Release WY 2016



2.5.4 Changes in Sediment Loads Over Time

The magnitude of Spring Flow Release sediment loads is dependent upon numerous factors, including: peak flow magnitude, hydrograph shape, sediment augmentation efforts, changes in transport capacity (e.g. from channel and floodplain restoration) and tributary sediment contributions. Here, we examine potential trends in the coarse bedload ($\geq 8\text{mm}$) Spring Flow Release load totals from 2004 to 2016. Table 20 provides water year types, release volumes and peak flow magnitudes for WY2004-2016. In addition, Table 20 also provides the Spring Flow Release type (as described in the TRFE recommendations). In the previous 11 years of sediment sampling, there have been four “Dry” type releases (2007, 2009, 2013, 2015), five “Normal” releases (2004, 2005, 2008, 2010, and 2012), and two “Extremely Wet” releases (2006 and 2011). The distinction between water year type and Spring Flow release type is important because there were some variations (e.g. 2011 was a Wet water year type, but had an Extremely Wet release, 2004 was a wet year, but had a Normal Year release type). WY2016 was classified a Wet water year and had a modified Extremely Wet flow release.

Table 20. Water Year Types, Restoration Release Volumes, Flow Release Type and Peak Flow Release Magnitudes: 2004-2016 (source: TRRP 2016)

Water Year	Forecast Water Year Type	Actual Restoration Release (acre feet)	Spring Flow Release Type	Peak Release Magnitude (cfs)*
2004	Wet	651,000	Normal	6,200
2005	Normal	647,600	Normal	6,970
2006	Ex. Wet	809,900	Ex Wet	10,100
2007	Dry	453,700	Dry	4,750
2008	Normal	648,700	Normal	6,470
2009	Dry	445,500	Dry	4,410
2010	Normal	656,700	Normal	6,840
2011	Wet	721,800	Ex wet	11,600
2012	Normal	647,100	Normal	6,080
2013	Dry	451,900	Dry	4,420
2014	Crit. Dry	370,500	Crit. Dry	3,410
2015	Dry	450,700	Dry (modified)	8,500
2016	Wet	708,800	Ex Wet (modified)	10,000

**Mean daily discharge at Trinity River at Lewiston (USGS 11525500)*

Figures 45-48 compare the computed $\geq 8\text{mm}$ bedload at all stations for the 11 years of monitoring (nine years at TRGV). The $\geq 8\text{mm}$ component of bedload is of primary interest for creating beneficial channel and habitat characteristics (alternate bars, spawning riffles etc, TRRP 2011). Evaluating the $\geq 8\text{mm}$ component also removes much of the tributary influence, because the $< 8\text{mm}$ component is not included in gravel injections, and therefore it must be either delivered by tributaries, or derived from in-channel sources, adjacent banks or hillslopes.

2006 and 2011 clearly dominate the relative bedload transport at all stations except TRGV where 2016 produced the second highest computed load. All stations exhibit an apparent downward trend in $\geq 8\text{mm}$ transport during Normal Release types (Figures 48-51). The trend among Dry Flow Release types is less clear (2007, 2009, 2013 and 2015), though 2015 clearly transported larger loads than the other three years. 2015 with its “Dry (modified)” release type (that is a dry year restoration total release (453,000 af) with an 8,500 cfs flow bench) showed an evident increase over preceding “Dry-type” flow releases at all stations. At TRGV, WY2015 exceeds some wet years (Figure 49) and at TRAL and TRDC, WY2015 approximates the magnitude of “Normal” flow release types (Figures 47 and 48).

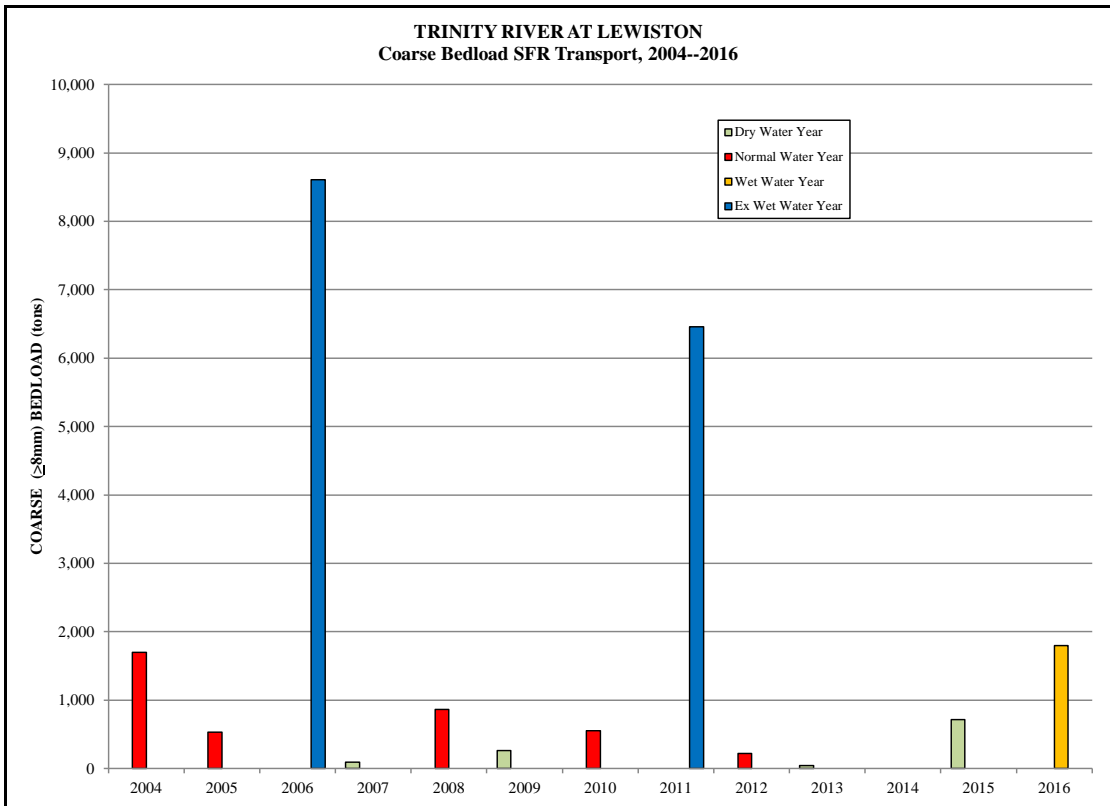


Figure 45. Trinity River at Lewiston, $\geq 8\text{mm}$ Bedload 2004-2013, 2015-2016.

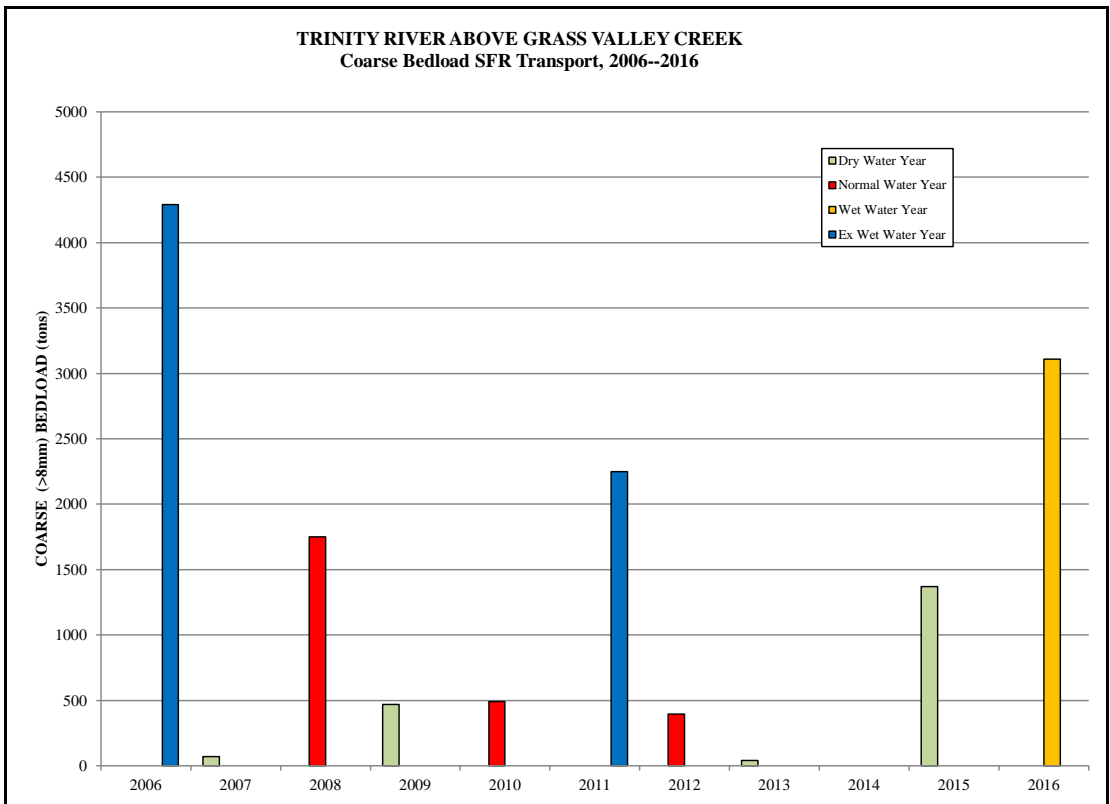


Figure 46. Trinity River above Grass Valley Creek, $\geq 8\text{mm}$ Bedload 2004-2013, 2015-2016.

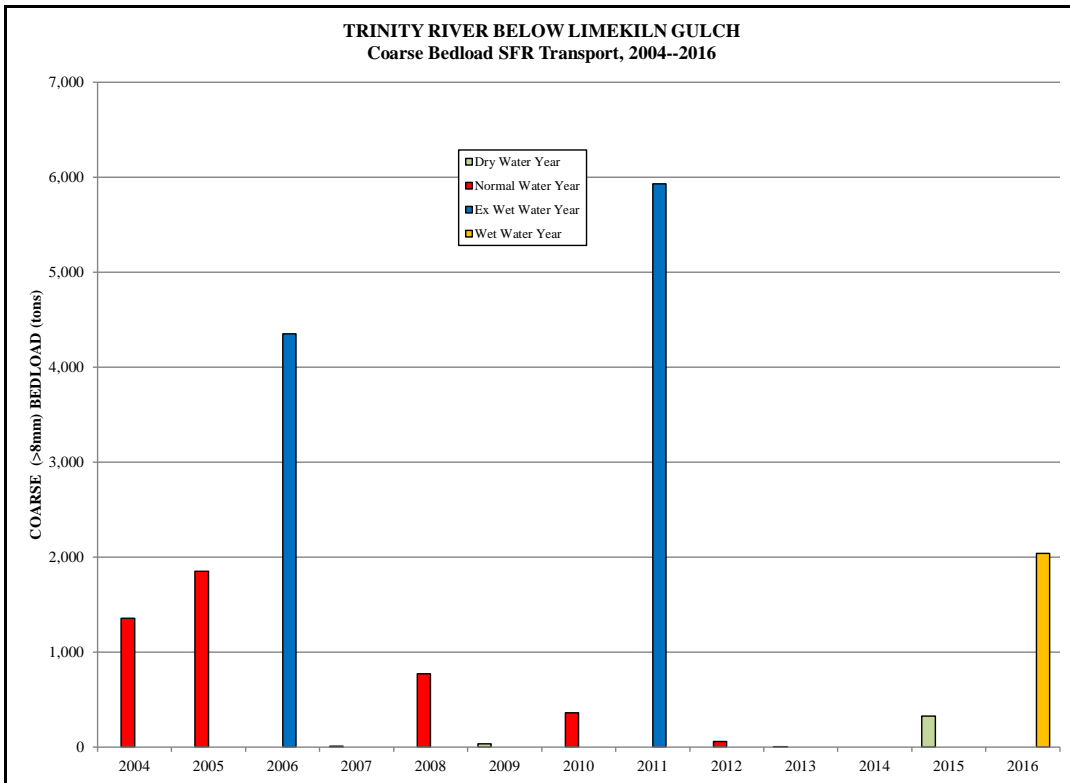


Figure 47. Trinity River below Limekiln Gulch, $\geq 8\text{mm}$ Bedload 2004-2013, 2015-2016.

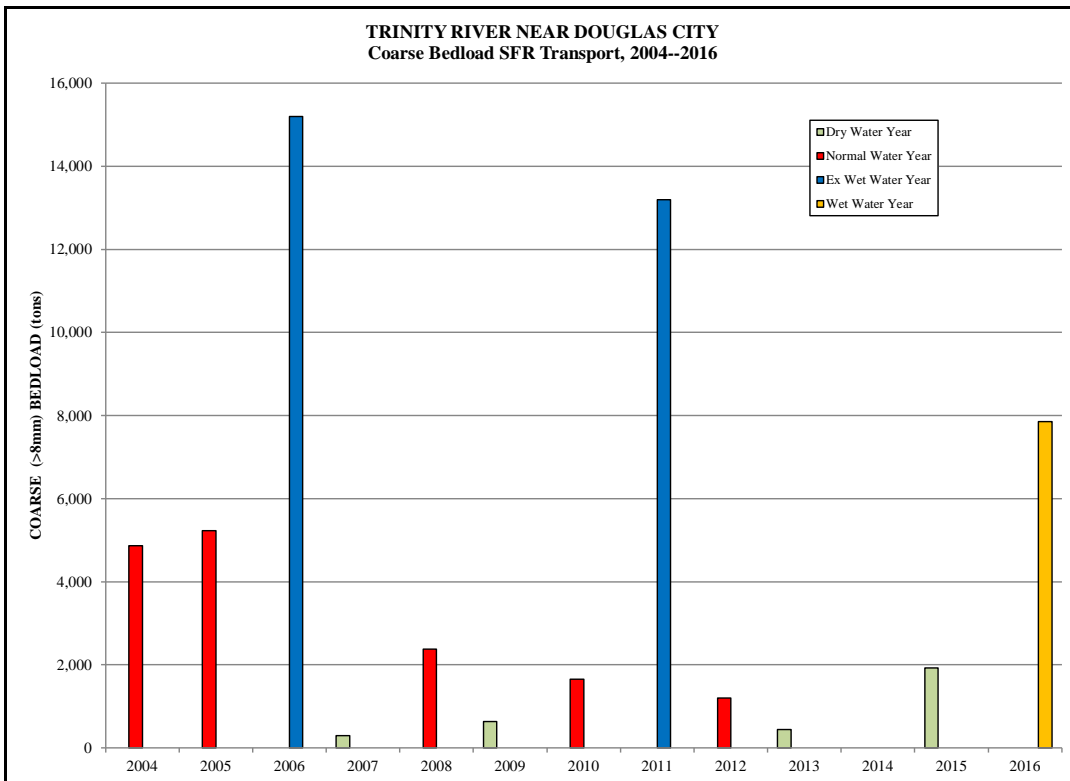


Figure 48. Trinity River below Limekiln Gulch, $\geq 8\text{mm}$ Bedload 2004-2013, 2015-2016.

2.5.5 Changes in Sediment Transport Rate Over Time

This discussion is limited to the long-term mainstem monitoring stations used in the TRFE to predict the fine and coarse fractions of bedload transport (TRAL and TRLG) and

2.5.4.1 Trinity River at Lewiston, CA

The total bedload transport rates for WY 1997, WY 2002, and WY 2004-16 appear in Figure 11. The WY2016 data plotted well within the overall cloud of points. Due to the wide range of variability within each year (e.g. WY2016 data spans a full order of magnitude), it is difficult to discern changes over time. Intra year comparisons are further compounded at TRAL by: changes in sampling location, the use of different types of samplers and winter storm samples lumped with flow release samples. The 2009 data sit to the left of the GMA data, suggesting total bedload transport rates were higher in that year.

For the 0.5-<8mm and ≥ 8 mm bedload classes (Figures 9 and 10), all of the TRAL 2016 data fell to the right of the TRFE curve, which suggests that today's measured transport rates are lower than those used in the TRFE.

2.5.4.2 Trinity River below Limekiln Gulch

Partial and total bedload discharge data are available for TRLG during WY 1981-86, WY 1989-91, WY 1997, WY 2000, and WY 2002-2016 (Figures 25-27). The WY 2016 ≥ 8 mm data fall generally within the cloud of historic data points but sit to the right of the TRFE curve (Figure 26). The 0.5-<8mm class follows the same pattern (Figure 25).

2.5.6 Spatial and Temporal Variation in Bedload Discharge

Variation across a sampling section

In 2006, between May 25 and June 12, at flows in the 5,000-10,000 cfs range, GMA conducted a number of experiments at the TRDC station (GMA 2007). Bedload samples were collected at 11 sampling locations (stations) along the cross section and were processed separately to examine the variability in bedload transport across the section (Figure 49). Samples are typically composited. These data clearly indicate where most of the transport is occurring (station 75 and from 105-125). Note that while, peak transport shifts among stations within the 105-125 range on different days, the peak always remains within this range. Figure 49 is intended to provide context for the next section, where samples are repeated at a high-transport location along a sampling section.

Variation over 30 minutes

In 2016, GMA assessed the potential temporal variation in bedload measurements by sampling repeatedly at a single vertical over period of at least 30 minutes (at each site). Crews were instructed to sample a high transport location on a high transport day. Downtimes were held constant (e.g. 60 seconds) and since sample handling time was relatively constant, the method allowed for a systematic sample over the 30 minute period, e.g. the sampler hits the streambed every 4 minutes. Bedload discharge was computed over a 10 foot width, equivalent to a single computational cell in the SEWI computational method. Total bedload is the sum of the fine and coarse loads. Sample sizes are relatively small (n=10-13) and only very basic summary statistics were computed from the data (Table 21).

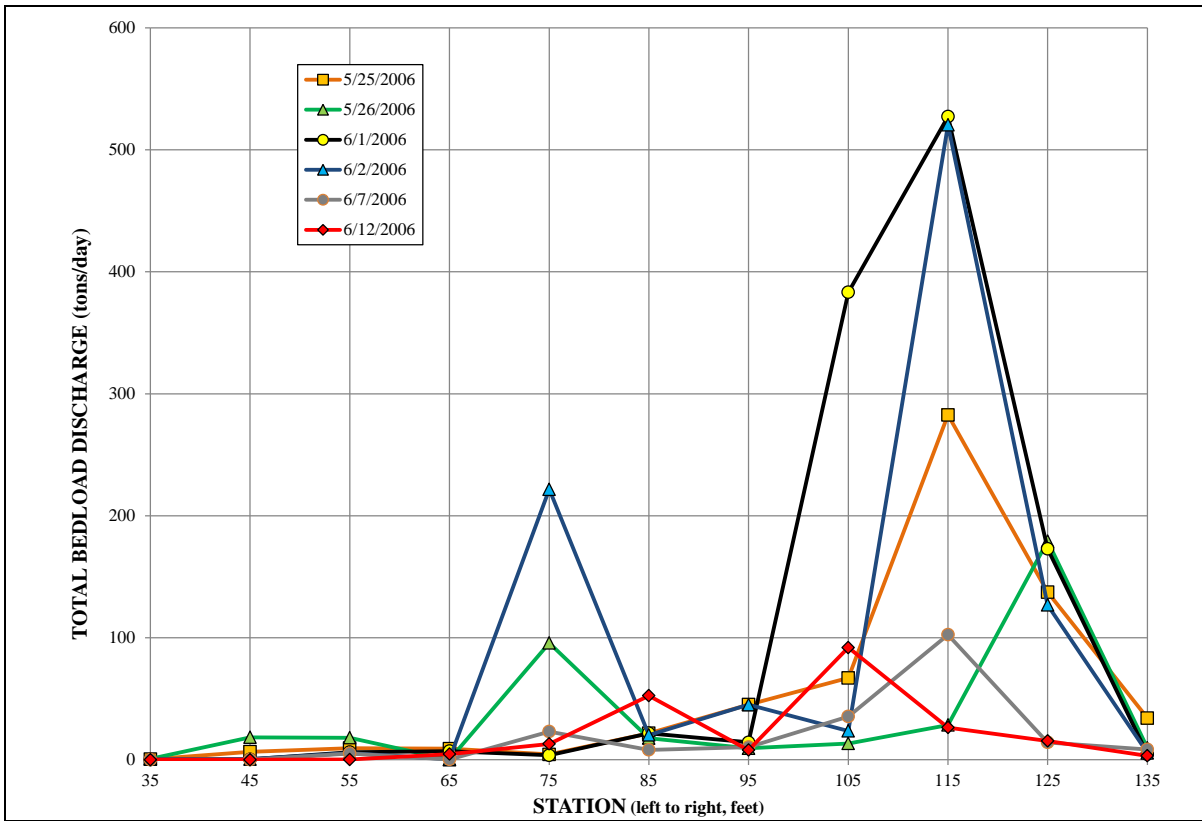


Figure 49. Spatial variation at a sampling section - total bedload discharge at TRDC in WY2006. Downstream view.

Table 21. Summary data for bedload variability sampling in 2016

Sample	TRAL			TRGV			TRLG			TRDC		
	Total Transport Rate (tons/day)	Transport ≥ 8 mm (tons/day)	Transport 0.5-8 mm (tons/day)	Total Transport Rate (tons/day)	Transport ≥ 8 mm (tons/day)	Transport 0.5-8 mm (tons/day)	Total Transport Rate (tons/day)	Transport ≥ 8 mm (tons/day)	Transport 0.5-8 mm (tons/day)	Total Transport Rate (tons/day)	Transport ≥ 8 mm (tons/day)	Transport 0.5-8 mm (tons/day)
#1	47.28	45.00	2.3	36.7	35.9	0.8	93.5	73.6	19.9	160.3	67.2	93.1
#2	58.41	56.47	1.9	94.5	94.2	0.3	100.5	67.3	33.2	95.8	80.8	14.9
#3	42.67	42.14	0.5	85.4	84.0	1.4	55.9	22.0	33.9	124.3	47.5	76.8
#4	40.84	40.09	0.7	246.6	243.5	3.1	95.4	71.6	23.8	316.8	100.9	216.0
#5	21.55	20.54	1.0	155.2	153.5	1.7	62.5	47.9	14.5	77.6	42.0	35.6
#6	19.17	18.30	0.9	237.6	234.2	3.3	202.9	143.9	58.9	135.0	50.3	84.7
#7	109.60	98.66	10.9	119.4	118.6	0.8	109.8	50.0	59.8	129.2	36.1	93.1
#8	12.08	8.46	3.6	181.6	180.5	1.2	117.2	63.7	53.5	68.7	30.5	38.2
#9	58.78	48.49	10.3	124.0	122.4	1.6	127.7	98.5	29.2	42.9	26.0	16.8
#10	27.69	23.51	4.2	174.5	165.9	8.6	74.7	58.1	16.6	65.2	32.8	32.5
#11										58.9	31.7	27.2
#12										48.1	14.7	33.4
#13										147.5	68.0	79.5
mean	43.8	40.2	3.6	145.6	143.3	2.3	104.0	69.7	34.3	113.1	48.3	64.7
SD	28.2	25.7	3.9	66.8	65.7	2.4	41.7	32.8	17.3	72.9	24.5	54.0
min	12.08	8.46	0.5	36.7	35.9	0.3	55.9	22.0	14.5	42.9	14.7	14.9
max	109.60	98.66	10.9	246.6	243.5	8.6	202.9	143.9	59.8	316.8	100.9	216.0
range	97.51	90.20	10.4	209.9	207.6	8.3	147.0	121.9	45.3	274.0	86.2	201.1

Values are not rounded as per Porterfield 1972

Figures 50-53 are provided as a visual representation of WY 2016 bedload variability for the study and Figure 54 portrays all four stations together.

At TRAL, the fine bedload varied over a range of only 10 tons per day while the coarse load varied over a range of 90 tons per day (Table 21). The relative contributions of the two size ranges varies considerably; note Sample 3 is composed of only 1 percent fine bedload while Sample 8 is 30 percent fine bedload (Table 21). A few very coarse grains can make a large difference in the relative percentage. Samples averaged 9 percent fine bedload.

TRAL shows the highest coarse percentage (81 percent), which is likely due to the fact that only one small tributary enters between TRAL and the dam (Deadwood Creek), thus limiting the potential for fine bedload recruitment.

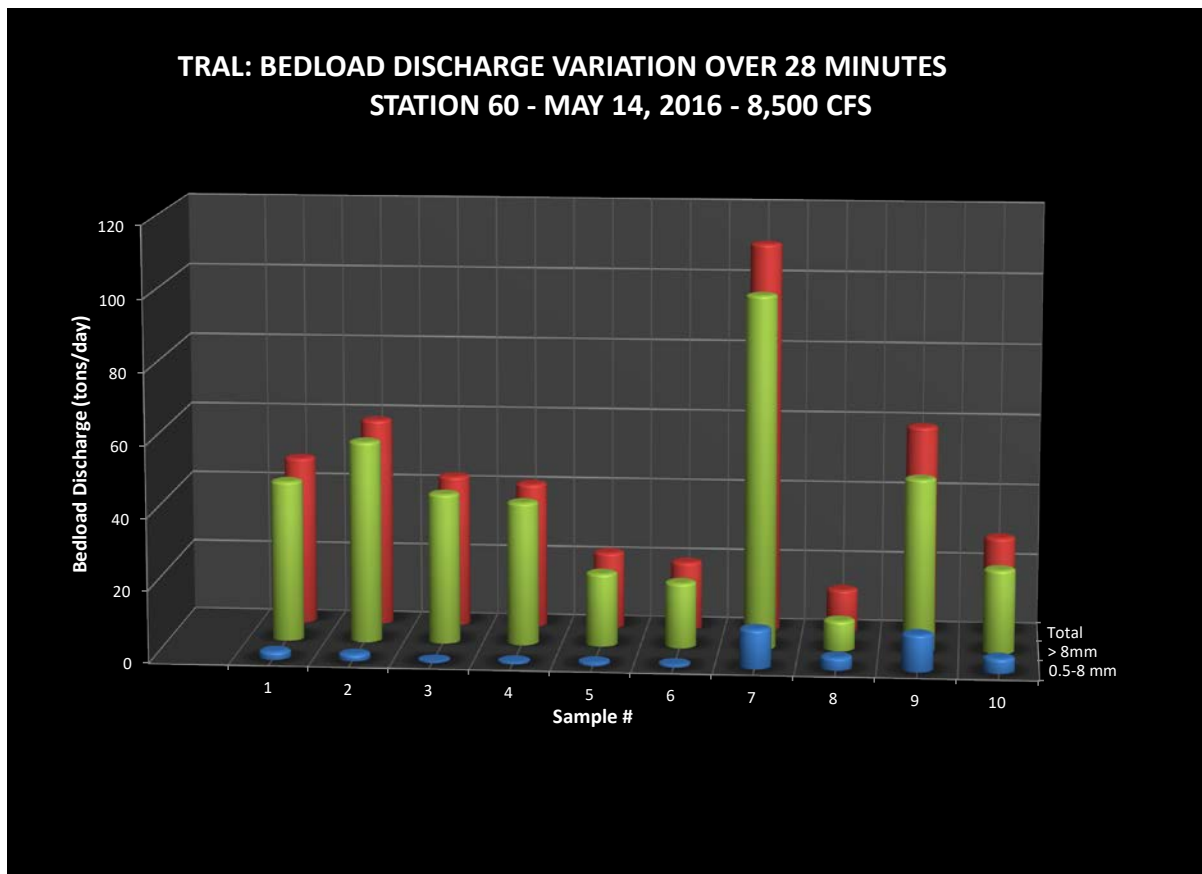


Figure 50. Bedload discharge at TRAL over 28 minutes at 120 second downtimes. (Total in red, coarse bedload in green, fine bedload in blue).

The effect of gravel injection on the grain size distribution appears clearly at TRGV (Figure 51). The fine fraction comprised zero to five percent of the total bedload in the samples. The largest sample (#4) was nearly seven times as large as the smallest sample (#1).

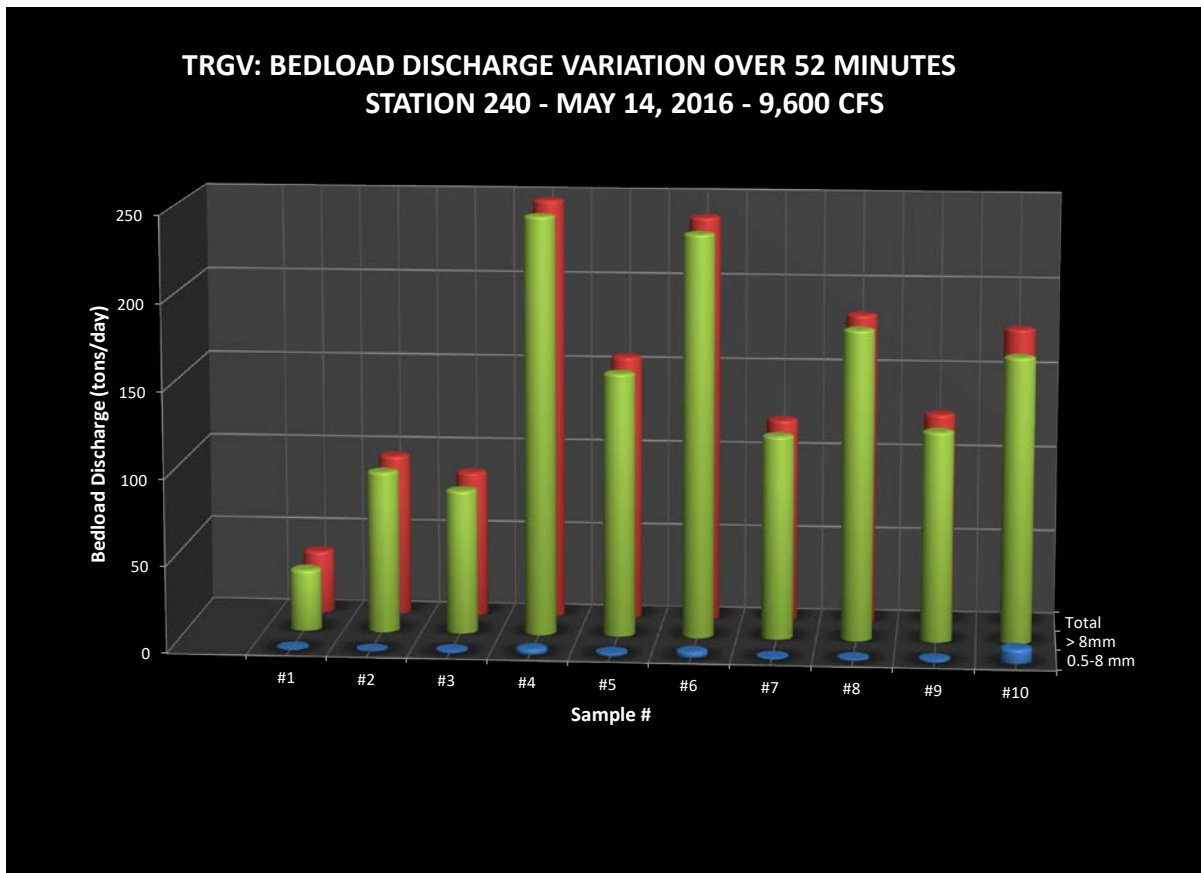


Figure 51. Bedload discharge at TRGV over 52 minutes at 120 second downtimes. (Total in red, coarse bedload in green, fine bedload in blue).

Unlike at TRAL and TRGV, TRLG reveals some heterogeneity with regard to the relative contribution of fine and coarse bedload. Samples 3 and 7 are >50 percent fine while the remaining eight are comprised primarily of coarse bedload.

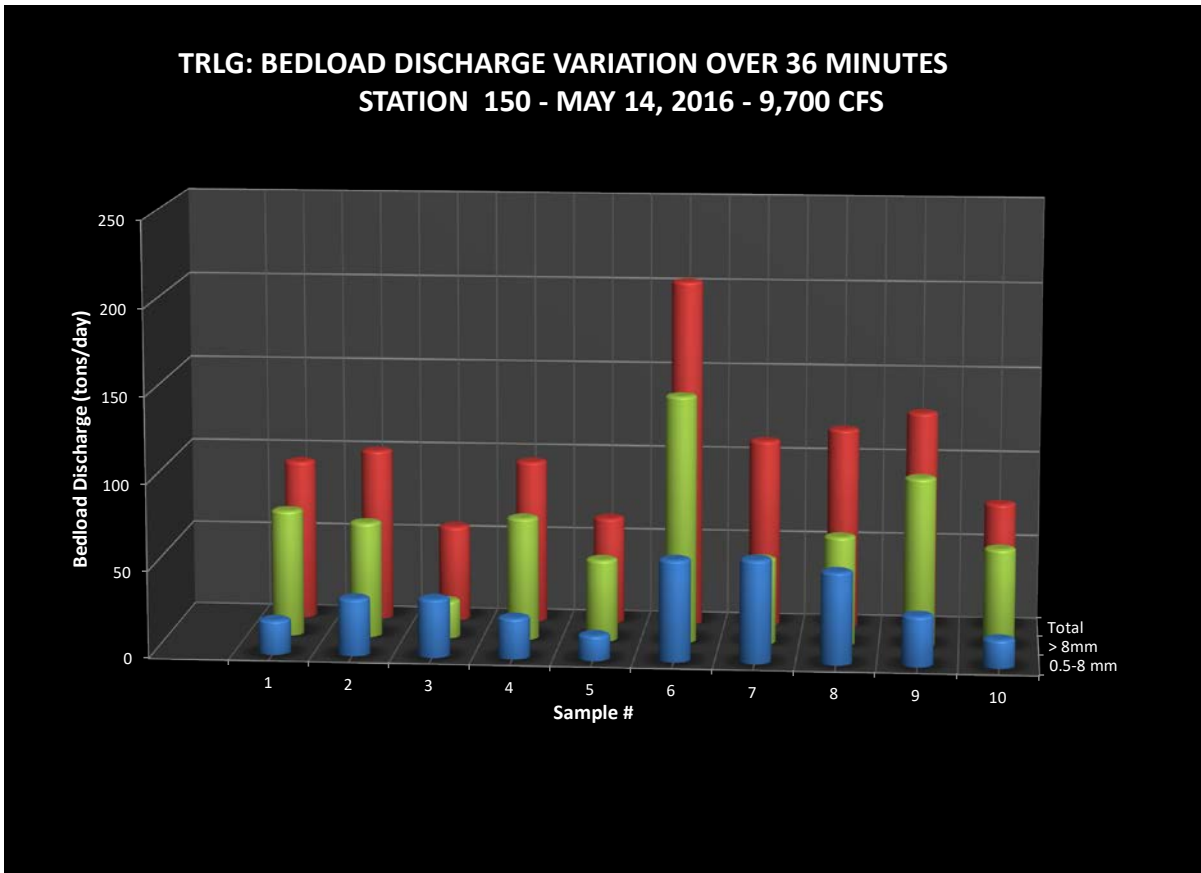


Figure 52. Bedload discharge at TRLG over a 36 minute period at 120 second downtimes. (Total in red, coarse bedload in green, fine bedload in blue).

At TRDC, fine sediment composes >50 percent of two samples (#3 and #7). The standard deviation (for Total bedload) is also the highest of all the sites at 72.9 (Table 21). This high value is primarily driven by Sample #6, which is much larger than the others.

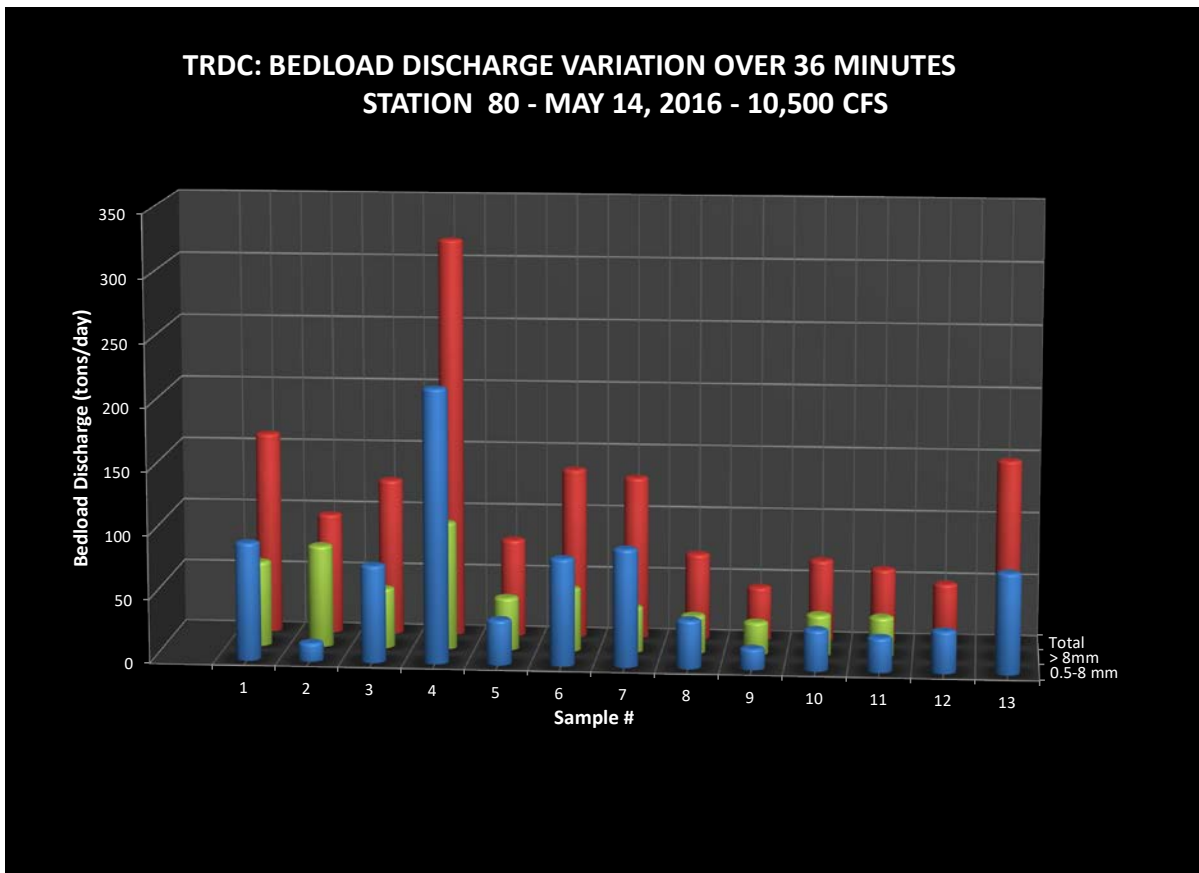


Figure 53. Bedload discharge at TRDC over a 36 minute period at 120 second downtimes. (Total in red, coarse bedload in green, fine bedload in blue).

Since TRAL is starved of fines (located so close to the dam) and since both TRAL and TRGV are so strongly influenced by coarse-gravel injection, TRLG and TRDC results are likely more representative of temporal variability in magnitude and composition of bedload transport in the Trinity River.

WY2016 crews reported most of the sediment load is typically generated at one to three stations. If we apply the 2006 spatial inference (most of the load is transported at 3 to 4 stations) to the bedload variability study, then we can assume that at TRDC, a full cross section total load computed from data collected at time #4 will differ greatly (>400 percent) from a load computed from time #9 (Figure 55). While the variability study data are far from conclusive, they do suggest a need for more sampling at fewer stations (i.e., over a narrower width of the cross section where the most sediment load is being transported) in order to derive a more accurate estimate of average bedload discharge.

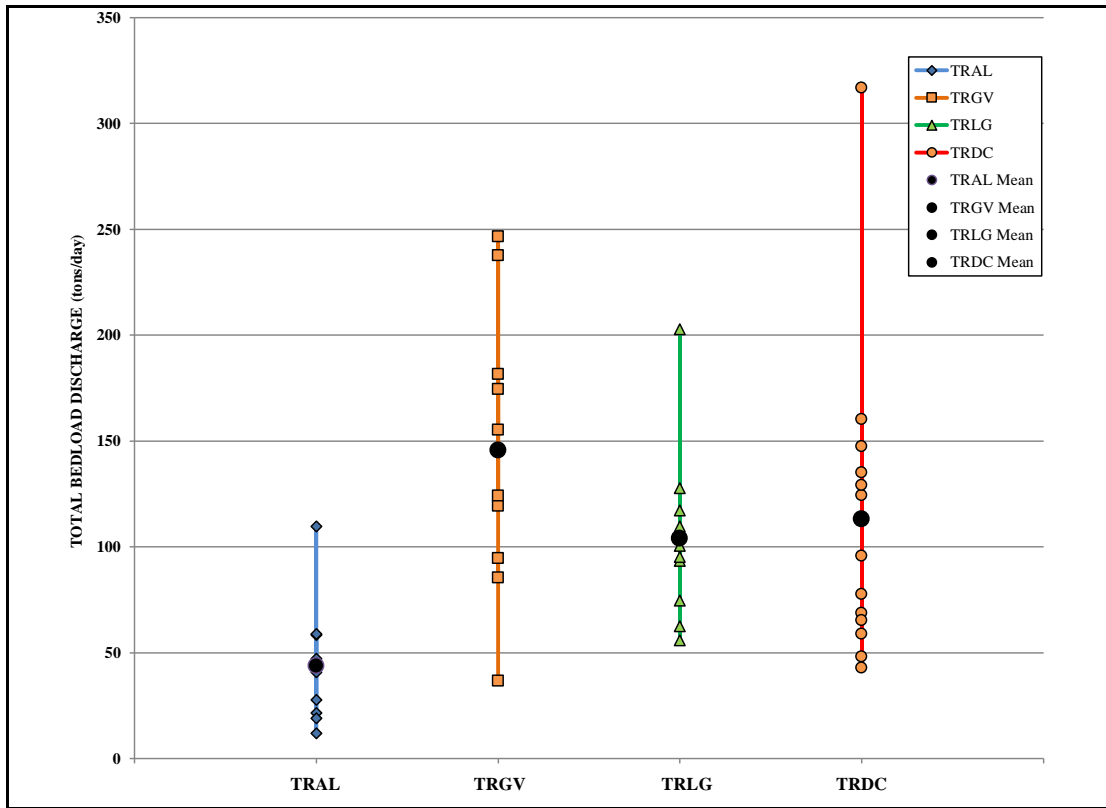


Figure 54. Total bedload discharge (range and mean values) during the variability pilot study at the four Trinity River sampling locations.

3.0 MONITORING RECOMMENDATIONS

In an effort to improve future sediment transport monitoring efforts, we offer the following recommendations:

- The potential trend of reduced bedload transport in Normal and Dry Year type Spring Flow Releases, as discussed in Section 2.5.4, may warrant further investigation. Clearly, the modified Dry release hydrograph applied in WY2015 was successful in moving more sediment than was observed in other Dry water years. WY2016 was the first wet year in the study and the first to feature a double-peak hydrograph. At all sites except TRLG, the first peak transported far more (nearly double) coarse bedload than the second peak (Table 21). Future analyses should compare flow bench magnitude and duration versus loads transported by flow release type. This may have implications toward changing the scope of the sampling effort in such year types.
- Consider altering the bedload sampling protocols to use multiple occupations of single verticals along the same cross section, with the number of replicates based on the variability and magnitude of transport rates. At low transport rate verticals, a single long duration sample will provide a reasonable estimate of mean transport, while in high rate verticals, multiple samples would provide a more robust estimate of the mean. Such an approach will increase the accuracy of estimating a mean daily value to guide sedigraph development.
- GMA typically monitors bed texture of the same sub-section of the cross section each year (e.g. a transverse riffle that is shallow enough to sample and represents a significant portion of where transport occurs during high flow sampling). The boundaries of these areas shift with changes in bed evolution. If TRRP's desire is to represent the entire cross section with a single pebble count (as in to provide a roughness estimate for a hydraulic model), this should be discussed prior to future years' monitoring.
- The TRGV gaging location has been severely impacted by the collapse of a large cottonwood tree supporting the gage house. We suggest rebuilding the station for WY2017, as the existing stump appears unreliable.
- Water surface slope measurement at some stations (e.g. TRGV, TRLG) is strongly influenced by overbank flow slope reduction. The reported highest-flow slopes are really floodplain water surface slope. Presumably, analysts are more interested in the slope responsible for grain mobilization which is typically steeper than that measured on the floodplain. We suggest installing taller stage references at selected locations to improve the accuracy of water surface slope measures.
- At TRGV, turbidity induced by gravel injection renders the turbidity record ineffective for computing suspended sediment loads. Consider relocating the turbidity probe.

4.0 REFERENCES

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2016 TRINITY RIVER SEDIMENT TRANSPORT MONITORING FINAL REPORT

TECHNICAL APPENDIXES

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*Hydrology – Geomorphology – Stream Restoration
Land and Hydrographic Surveys*

WY 2016 SEDIMENT TRANSPORT MONITORING REPORT			
SUMMARY OF DATA PRESENTED IN TECHNICAL APPENDICES A - F			
	Appendix		Description
Trinity River at Lewiston USGS Gage #11525500	A	1	Sediment Station Analysis
		2	Bedload Transport Curves
		3	Suspended Sediment Transport Curves
		4	Bedload Sedigraphs
		5	Suspended Sediment Sedigraphs
		6	15-min and Daily-Mean Streamflow Data (electronic files)
		7	Bedload Data and Computations (electronic files)
		8	Suspended Sediment Data and Computations (electronic files)
		9	Channel Geometry and Pebble Count Data (electronic files) and Water Surface Slopes
Trinity River above Grass Valley Creek USGS Gage #11525540	B	1	Streamflow and Sediment Station Analysis
		2	Discharge Rating Curves
		3	Bedload Transport Curves
		4	Suspended Sediment Transport Curves
		5	Turbidity and Streamflow Hydrograph Plot
		6	Bedload Sedigraphs
		7	Suspended Sediment Sedigraphs
		8	15-min and Daily-Mean Streamflow Data (electronic files)
		9	Turbidity (electronic files)
		10	Bedload Data and Computations (electronic files)
		11	Suspended Sediment Data and Computations (electronic files)
		12	Channel Geometry and Pebble Count Data (electronic files) and Water Surface Slopes
Trinity River below Limekiln Gulch USGS Gage #11525655	C	1	Sediment Station Analysis
		2	Bedload Transport Curves
		3	Suspended Sediment Transport Curves
		4	Turbidity and Streamflow Hydrograph Plot
		5	Bedload Sedigraphs
		6	Suspended Sediment Sedigraphs
		7	15-min and Daily-Mean Streamflow Data (electronic files)
		8	Turbidity (electronic files)
		9	Bedload Data and Computations (electronic files)
		10	Suspended Sediment Data and Computations (electronic files)
		11	Channel Geometry and Pebble Count Data (electronic files) and Water Surface Slopes
Trinity River at Douglas City USGS Gage #11525854	D	1	Sediment Station Analysis
		2	Bedload Transport Curves
		3	Suspended Sediment Transport Curves
		4	Turbidity and Streamflow Hydrograph Plot
		5	Bedload Sedigraphs
		6	Suspended Sediment Sedigraphs
		7	15-min and Daily-Mean Streamflow Data (electronic files)
		8	Turbidity (electronic files)
		9	Bedload Data and Computations (electronic files)
		10	Suspended Sediment Data and Computations (electronic files)
		11	Channel Geometry and Pebble Count Data (electronic files) and Water Surface Slopes
Sediment Lab Quality Assurance	E		Sediment Lab Quality Assurance Plans and Results
USGS Training Certificates	F		USGS Sediment Data Collection and Computation Training Certifications

Appendix A

Trinity River at Lewiston
USGS Gage # 11525500

11525500 Trinity River at Lewiston, CA

TOTAL LOAD SEDIMENT DISCHARGE RECORD

Spring Flow Release WY 2016: (April 1 to July 31)

Records collected at station.-- Daily streamflow has been collected continuously since 1911 and peak streamflow has been recorded since 1860. Various bedload and suspended-load data have been collected by the USGS and other entities since 1997. Instantaneous air and water temperature data have been collected since 1990. The purpose for collecting sediment data at this site is to quantify sediment discharge delivered from this portion of the mainstem, versus the discharge measured at sediment collection stations downstream. This effort is part of a long-term study of sediment transport in the Trinity River, under the Trinity River Restoration Program (TRRP), sponsored by the U.S. Department of Interior, Bureau of Reclamation. This station analysis describes (1) sampling efforts during and (2) records computed from the WY 2016 spring flow release by GMA Hydrology (GMA), under contract to the Trinity River Restoration Program.

Equipment.--Sampling equipment consists of a D-74 and DH-48 for suspended-sediment sampling, and a cable-deployed 12-inch x 6-inch Toutle River 2 bedload sampler (TR-2) with a 0.5mm mesh collection bag. The D-74 suspended-sediment sampler and the TR-2 sampler were deployed from a crane-mounted E-reel or B-reel. The E-reel was driven by a battery operated power-drive during periods of the release and the B-reel was operated by hand. Sampling was performed from a cataraft-based sampling platform attached to a temporary cableway. Stage references were installed near cableways. Photographs were taken with a digital camera.

Sampling program.--Total (flow release) load season for this site is from April 1 to July 31. The program consisted of 9 sampling days. A minimum of two bedload-discharge and one suspended-sediment discharge sample were collected on each of the sampling days. The sampling days and samples collected are as follows:

May 08	8 bedload discharge	1 suspended-sediment discharge
May 09	11 bedload discharge	1 suspended-sediment discharge
May 10	9 bedload discharge	1 suspended-sediment discharge
May 11	8 bedload discharge	1 suspended-sediment discharge
May 12	4 bedload discharge	1 suspended-sediment discharge
May 13	8 bedload discharge	1 suspended-sediment discharge
May 14	8 bedload discharge	1 suspended-sediment discharge
May 15	6 bedload discharge	1 suspended-sediment discharge
May 16	2 bedload discharge	1 suspended-sediment discharge

Sampling crews consisted of a safety kayaker, and two on-river personnel specifically trained in cataraft-based sediment data collection techniques. All samples were reviewed by the site technicians and individual analyses were standardized for suspended-sediment (concentration, particle size analysis) and bedload samples (total dry mass, particle size analysis). Sediment data were generally collected according to USGS protocols with the following exceptions: test-velocity ratings for sampler nozzles were occasionally exceeded. Suspended-sediment samples were analyzed at the GMA Suspended-Sediment Lab and bedload samples were sent to the GMA Coarse Sediment Lab, both located in Placerville, CA.

USGS Field Review. -- No USGS field review was conducted during the 2016 Spring Flow Release.

Data summary for WY 2016 spring flow release.--

Total number of samples:	
Suspended sets	9
Single pass suspended samples	0
Box sample sets	0
Single box samples	0
Bedload sets	0
Single pass bedload samples	64
Three pass bedload samples	0
Number of field turbidities measured	0
Number of suspended sediment size analysis samples:	
Particle size analysis	0
0.063mm break	9
0.50mm break	9
Number of bedload sediment size analysis samples:	
Particle size analysis	64
Number of suspended sediment discharge measurements	9
Number of bedload discharge measurements	64
Number of visits by Field Office	0
Maximum flow sampled by:	
GMA technicians, ft ³ /s	9,540
Range sampled by:	
GMA technicians, mg/l	3-10
GMA technicians, ton/d	5-936
Peak flow during flow release, ft ³ /s	9,600
Periods of faulty record	NA

Coefficients -- None Used

Total suspended sediment-discharge computations. -- Total suspended-sediment discharge was computed by summing the partial suspended-sediment discharge records.

Size analysis.-- 9 cross-sectional, depth-integrated samples were analyzed using a split at <0.063mm and ≥0.50mm.

Partial suspended sediment-discharge computations. – Discharge versus SSC transport curves were developed for use during the period. Generalized transport curves were developed using all samples collected during Water Year 2016. Sample data did not show signs of hysteresis, however this could be because samples were not collected at low enough streamflow to describe the phenomenon. No outliers were identified.

For the <0.063mm size class, the discharge versus SSC transport curve is defined by Eqn. (1)

$$SSC = 0.019 * Discharge^{0.589}, \quad r^2 = 0.49 \quad (1)$$

The transport curve is used between April 1 at 00:00 hours and July 31 at 00:00 hours. The transport curve has a validated range between 5,460 cfs and 9,350 cfs. Zero transport was estimated during sediment development, using previous years' low flow sample data, at 500 cfs. Samples did not indicate

hysteresis for this size class and the same zero transport threshold was used for both the rising and falling limb.

For the 0.063 - <0.5mm size class, the discharge versus SSC transport curve is defined by Eqn. (2)

$$SSC = 1.246e - 007 * Discharge^{1.76}, r^2 = 0.53 \quad (2)$$

The transport curve is used between April 1 at 00:00 hours and July 31 at 00:00 hours. The transport curve has a validated range between 5,460 cfs and 9,350 cfs. Zero transport was estimated during sedigraph development, using previous years' low flow sample data, at 4,000 cfs. Samples did not indicate hysteresis for this size class and the same zero transport threshold was used for both the rising and falling limb.

For the ≥ 0.5 mm size class, the discharge versus SSC transport curve is defined by Eqn. (3)

$$SSC = 1.021e - 031 * Discharge^{7.86}, r^2 = 0.96 \quad (3)$$

The transport curve is used between April 1 at 00:00 hours and July 31 at 00:00 hours. The transport curve has a validated range between 5,460 cfs and 9,350 cfs. Zero transport was estimated during sedigraph development. Samples 1, 4, 5, 8, and 9 were both below the laboratory detection limit and reported as 0 mg/l. The sedigraph was brought to zero at the beginning of the first rise in discharge following Sample 1, which occurs at 6,440 cfs and at Sample 8, which occurs at 7,090 cfs.

The transport curve was used to develop a continuous concentration trace for each size class during the computational period. Once the continuous concentration data had been developed, the sample data were used to adjust the continuous concentration trace by fitting or proportional fitting, so that it passed through all sample points. Proportional fitting calculates the ratio between two sequential sample values and then scales the appropriate time series (e.g. continuous SSC) by this ratio. When applied between sequential pairs of data, the ratio is decayed or increased linearly to match the end-points. Fitting and proportional fitting techniques recognize short-term correlations and address hysteresis effects by using subsets of data. When only a single sample exists on a flow bench, the proportional fitting technique assumes that the determined ratio applies for the duration of that flow bench. When SSC is not highly correlated with discharge or turbidity, it is not possible to evaluate this assumption and therefore it is a potential source of error.

Suspended-sediment discharge was computed directly from the continuous concentration once the continuous concentration data had been checked and its accuracy verified.

Bed material.-- None.

Bedload measurement. -- Sixty-four bedload discharge samples were collected during the computational period. All were single pass samples.

Bedload-discharge computations. -- The sample analysis contains the portion of sample <0.5mm but the total bedload discharge was determined by summing the partial discharges for the 0.5mm-<8mm and the ≥ 8 mm size fractions.

Partial Bedload-discharge computations -- Sediment transport curves were developed and partial bedload discharges were computed for the 0.5mm-8mm and ≥ 8 mm size classes. 2016 had a double peak hydrograph and sample data was analyzed for the entire year, with each peak broken out separately and for rise and fall patterns of hysteresis. No outliers were identified during analysis of either size class.

For the 0.5mm-<8mm size class, the transport curve is shown in Equation (4). No obvious pattern of hysteresis or difference between the first and second peak of the hydrograph were observed, so a single generalized equation was used for the entire time period.

$$BLD = 3.13e - 020 * Discharge^{5.40}, \quad r^2 = 0.87 \quad (4)$$

The transport curve was developed using samples 1-64. The transport curve is used from April 1 at 00:00 hrs until July 31 at 00:00 hours. Eqn. (4) has a validated range between 5,640 cfs and 9,540cfs. Zero transport for the rising limb was estimated using previous years' data at 2,000 cfs. For the falling limb, zero transport was determined by fitting the sedigraph to the average of sample 63 and 64 and occurs at approximately 5,200 cfs.

For the ≥0.8mm size class, the transport curves are defined by Eqn. (5), Eqn. (6) and Eqn. (7). The first hydrograph peak showed higher transport rates than the second for the ≥0.8mm size class, and was represented with a single generalized transport curve (Eqn. (7)).

$$BLD = 5.51e - 006 * (Discharge - 3000)^{2.11}, \quad r^2 = 0.85 \quad (5)$$

$$BLD = 1.46e - 012 * (Discharge - 3400)^{3.80}, \quad r^2 = 0.91 \quad (6)$$

$$BLD = 3.86e - 017 * (Discharge - 3200)^{5.03}, \quad r^2 = 0.89 \quad (7)$$

Eqn. (5) was developed using samples 1-19 and is valid from April 1, 2016 at 00:00 until May 9, 2016 at 18:00. Eqn. (6) was developed using samples 20-40 and is valid from May 9, 2016 at 18:15 through May 12, 2016 at 14:45. Eqn. (7) was developed using samples 21-64 and is valid from May 12, 2016 at 15:00 through July 31, 2016 at 23:45. Eqn. (5) has a validated range between 5,930 cfs and 9,520 cfs. Eqn. (6) has a validated range between 5,640 cfs and 9,540 cfs. Eqn. (7) has a validated range between 5,720 cfs and 9,370 cfs. Zero transport for the rising limb was estimated during transport curve development and occurs at 3,000 cfs. For the falling limb, zero transport was determined by fitting the sedigraph to the average of samples 63-64 and occurs at approximately 3,400 cfs.

Once the continuous bedload-discharge traces were developed using the above transport curves, they were adjusted to the sample values using the same techniques as was described for the partial suspended-sediment discharge computations. Due to the inherent high variability in bedload sampling, during flow benches, sample values were averaged on days where multiple samples were collected to produce average transport values. These average transport values were used to adjust the continuous bedload transport trace.

Remarks. – The suspended sediment discharge record is rated as follows:

April 1 (00:00) to May 7 (23:45)	Estimated
May 8 (00:00) to May 16 (23:45)	Good
May 17 (00:00) to July 31 (23:45)	Estimated

The bedload discharge record is rated as follows:

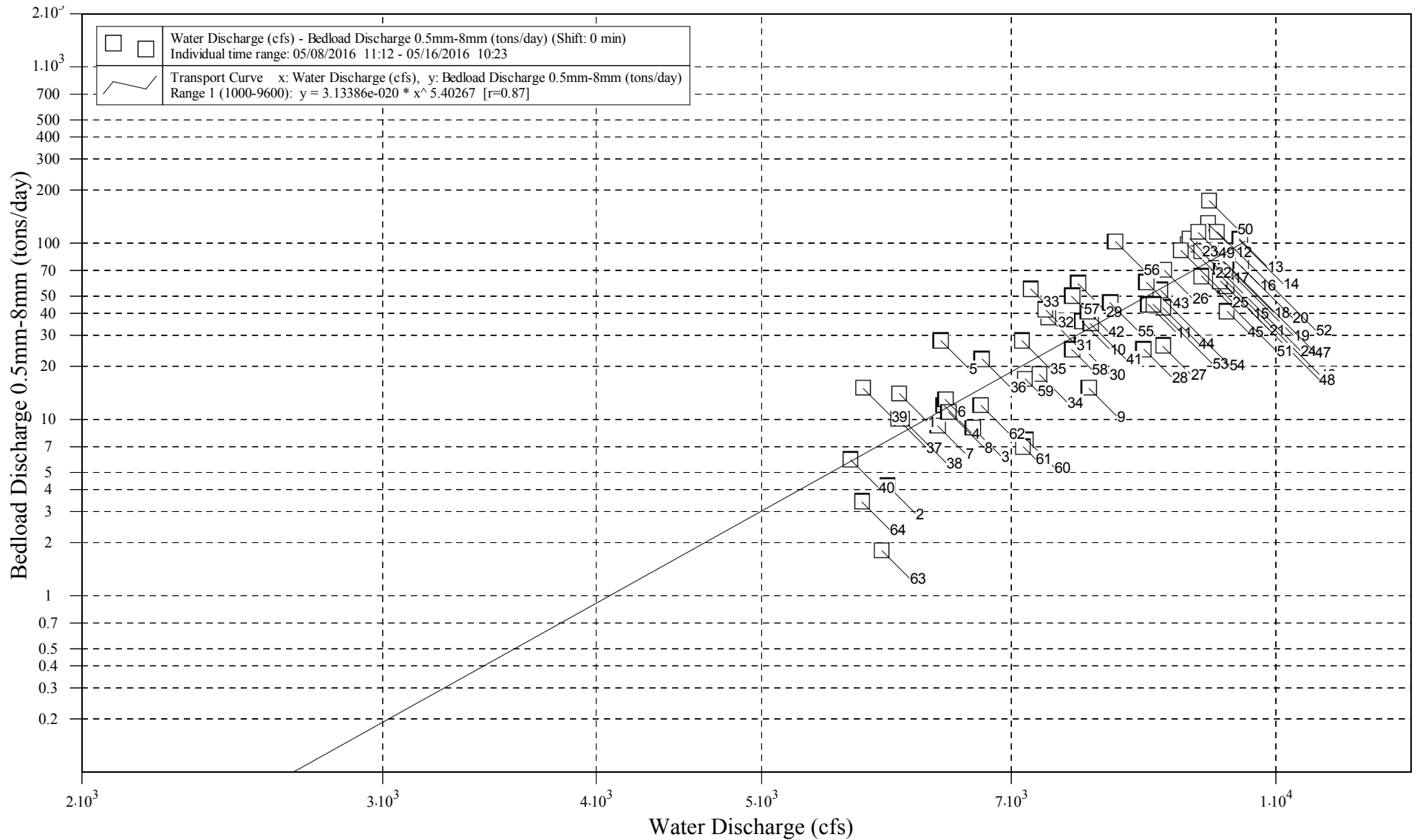
April 1 (00:00) to May 7 (23:45)	Estimated
May 8 (00:00) to May 16 (23:45)	Good
May 17 (00:00) to July 31 (23:45)	Estimated

Computed by: Brooke Pittman, December 2016

Reviewed by: Smokey Pittman, January 2017

TRINITY RIVER AT LEWISTON --11525500

Water Discharge (cfs) Versus Bedload Discharge 0.5mm-<8mm (tons/day): Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

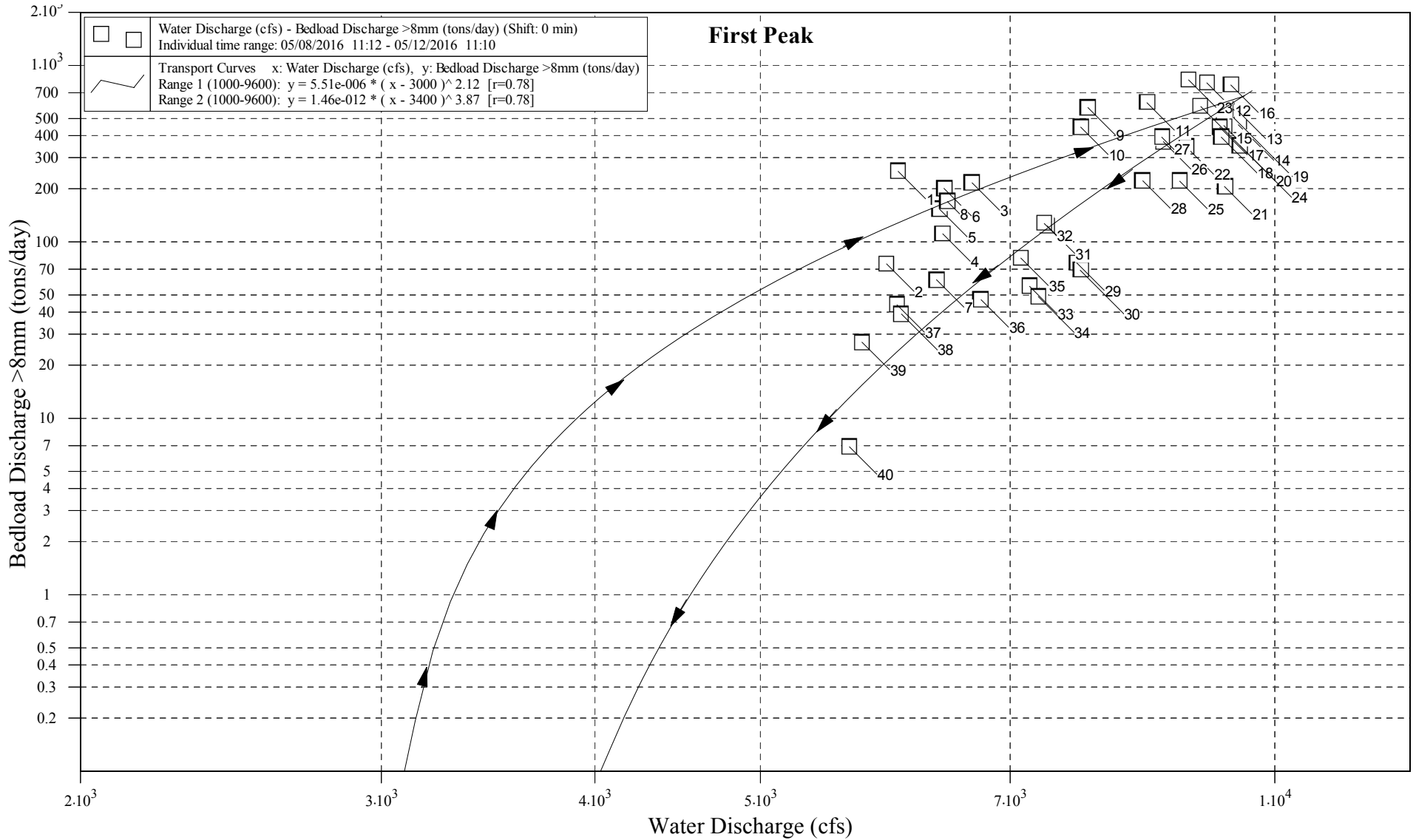


APPENDIX

A-2

TRINITY RIVER AT LEWISTON --11525500

Water Discharge (cfs) Versus Bedload Discharge $\geq 8\text{mm}$ (tons/day): Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

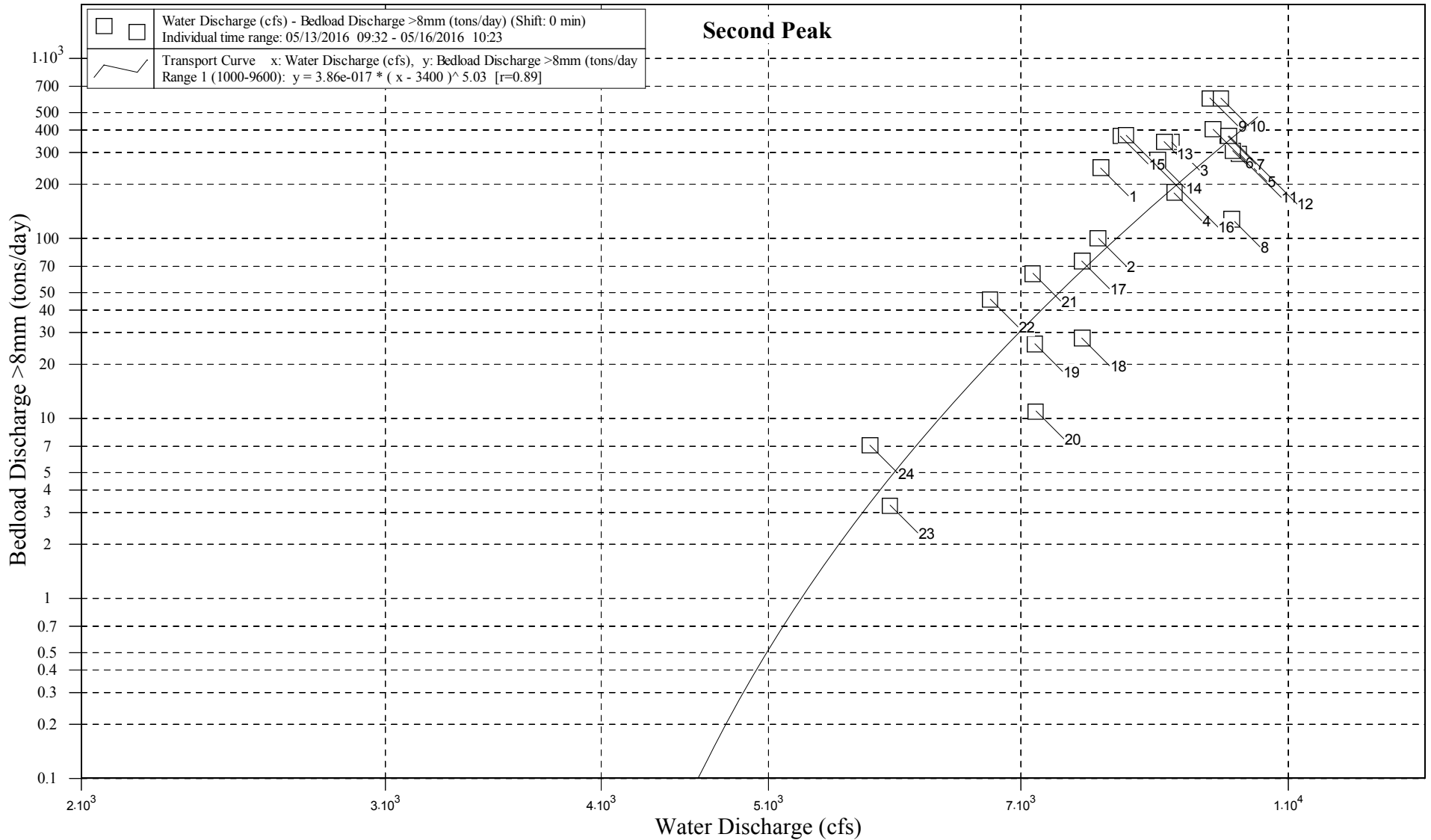


APPENDIX

A-2

TRINITY RIVER AT LEWISTON --11525500

Water Discharge (cfs) Versus Bedload Discharge $\geq 8\text{mm}$ (tons/day): Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

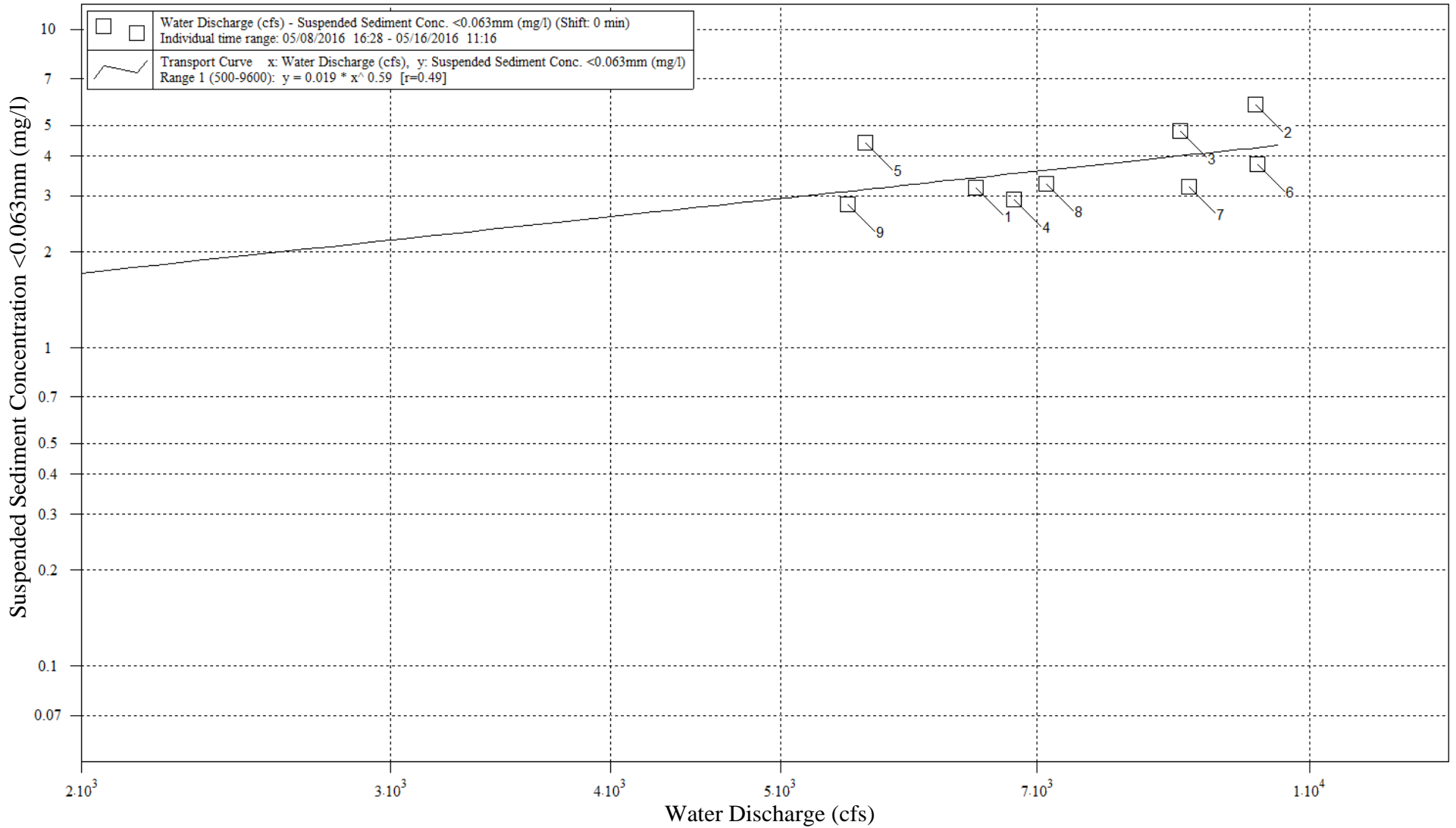


APPENDIX

A-2

TRINITY RIVER AT LEWISTON--11525500

Water Discharge (cfs) Versus Suspended Sediment Concentration <0.063mm (mg/l): Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

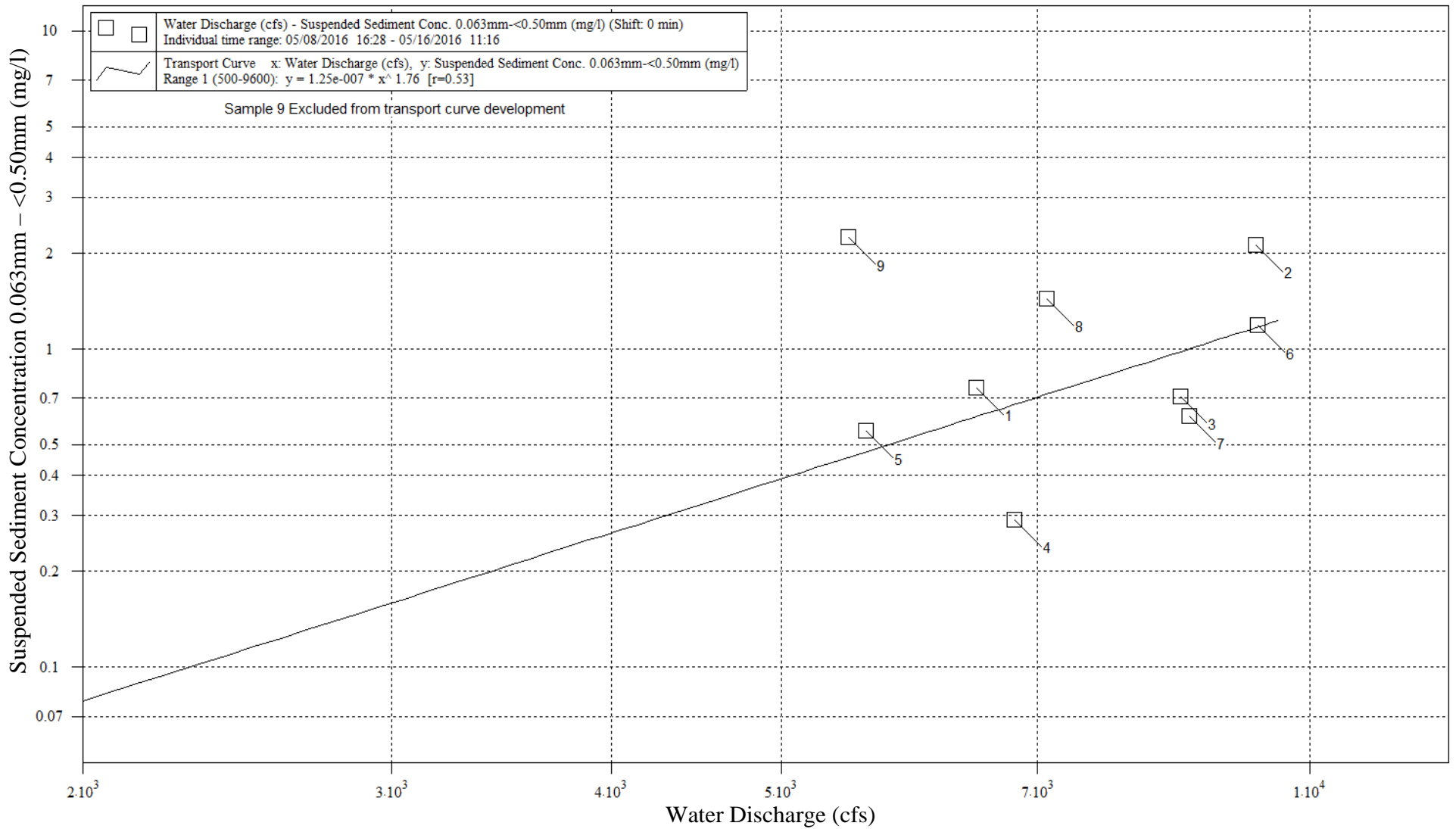


APPENDIX

A-3

TRINITY RIVER AT LEWISTON--11525500

Water Discharge (cfs) Versus Suspended Sediment Concentration 0.063mm - <0.5mm (mg/l): Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

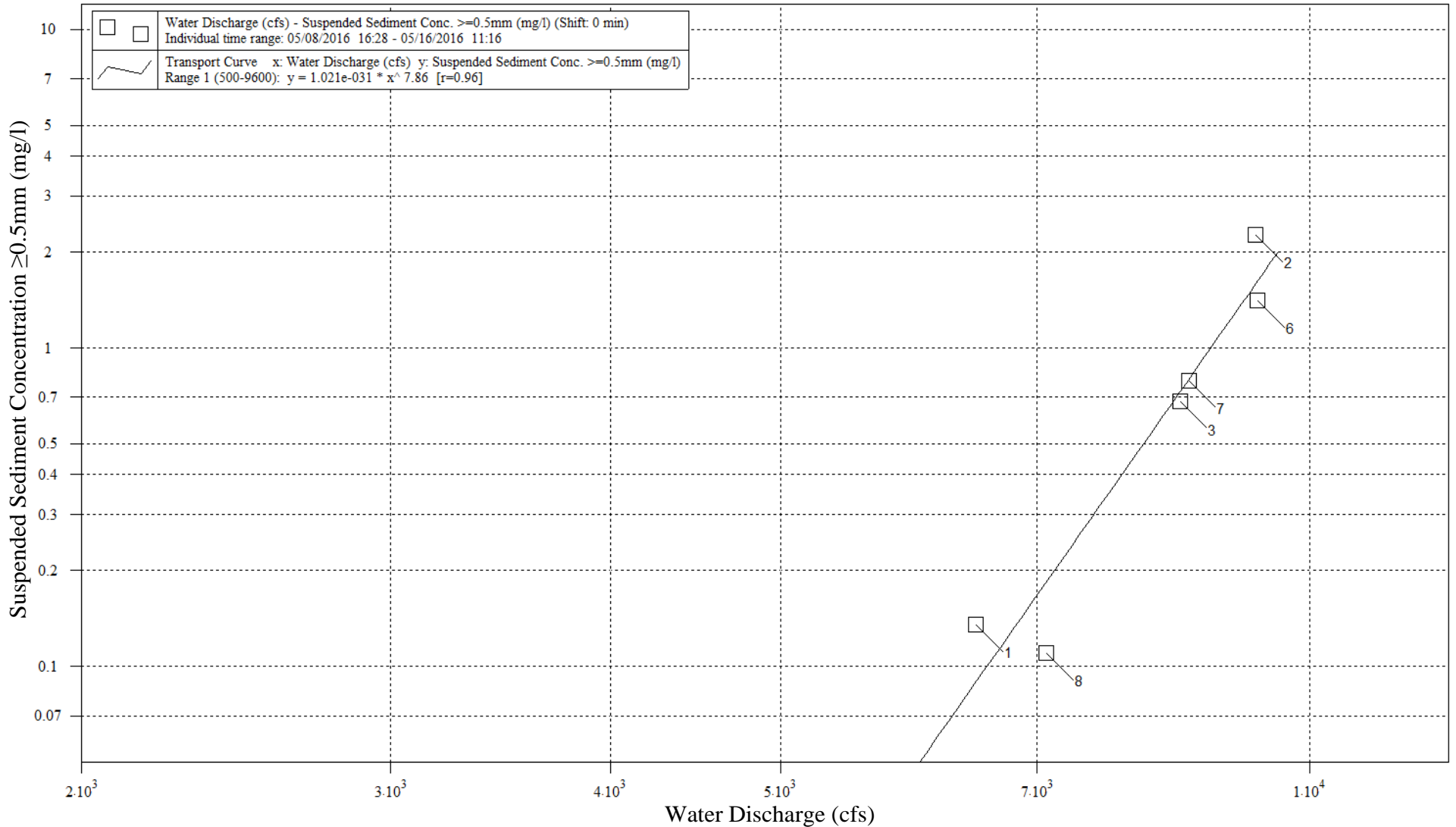


APPENDIX

A-3

TRINITY RIVER AT LEWISTON--11525500

Water Discharge (cfs) Versus Suspended Sediment Concentration $\geq 0.5\text{mm}$ (mg/l): Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

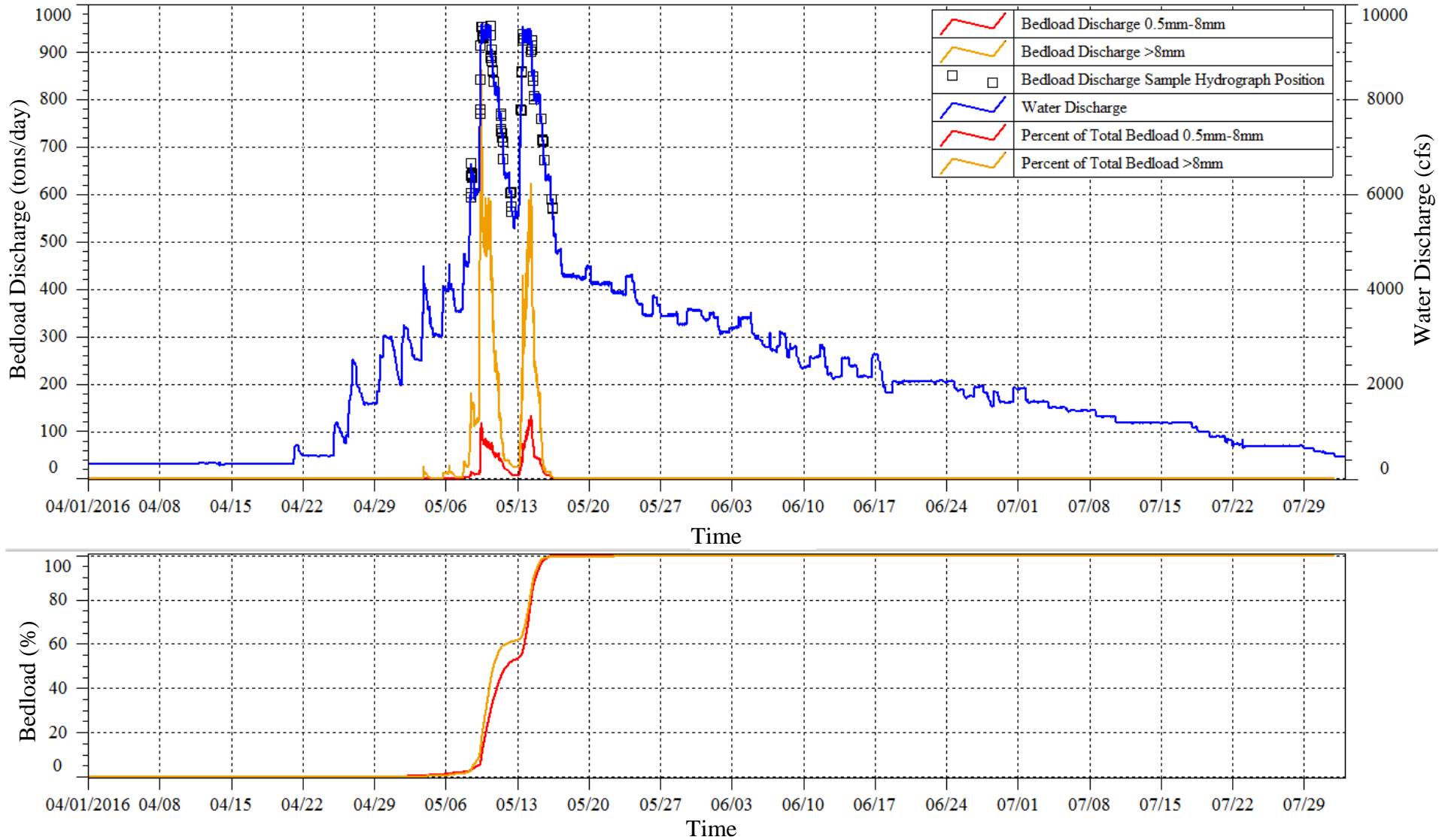


APPENDIX

A-3

TRINITY RIVER AT LEWISTON –11525500

Bedload Discharge – Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

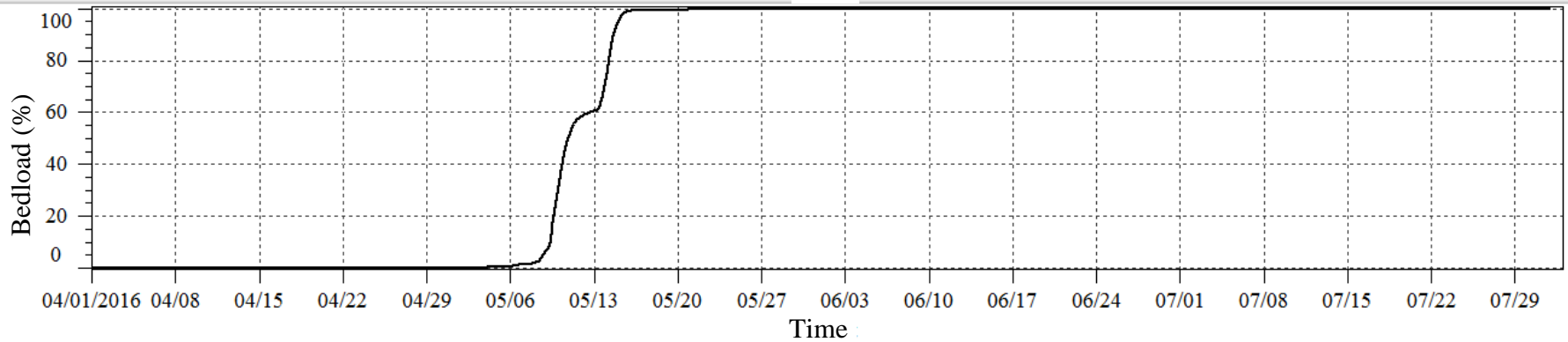
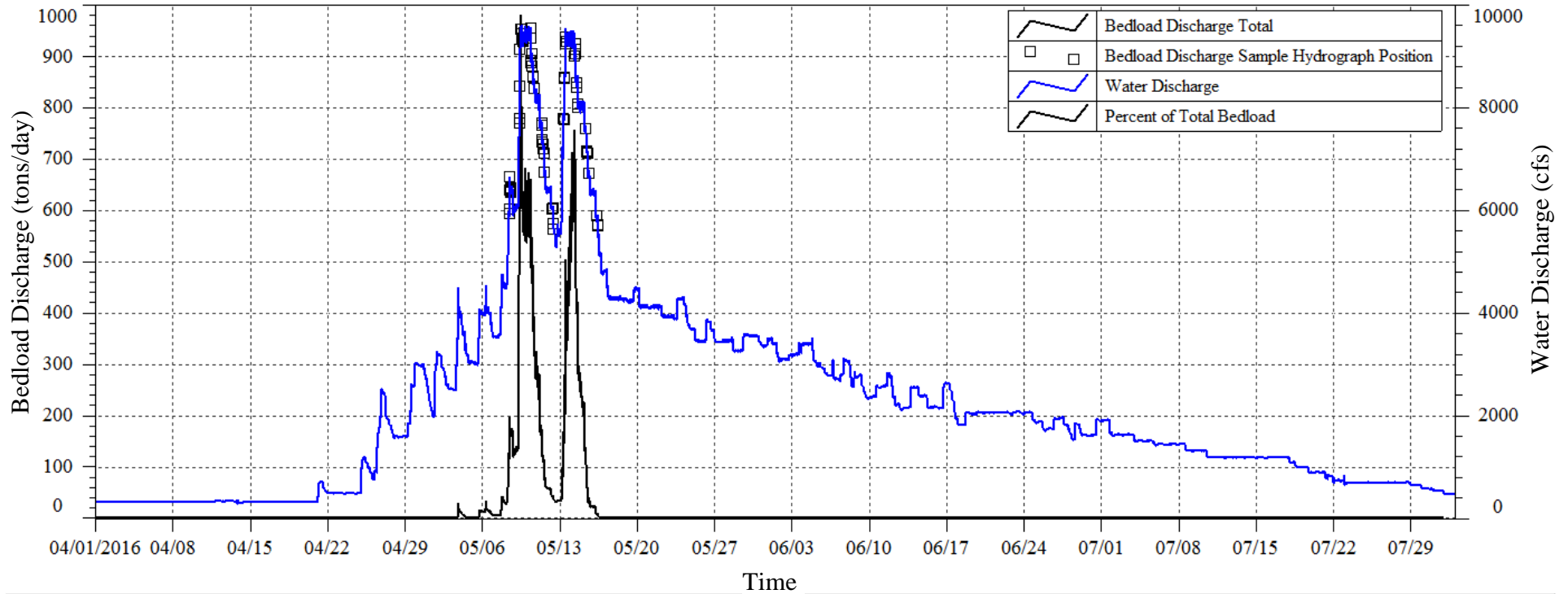


APPENDIX

A-4

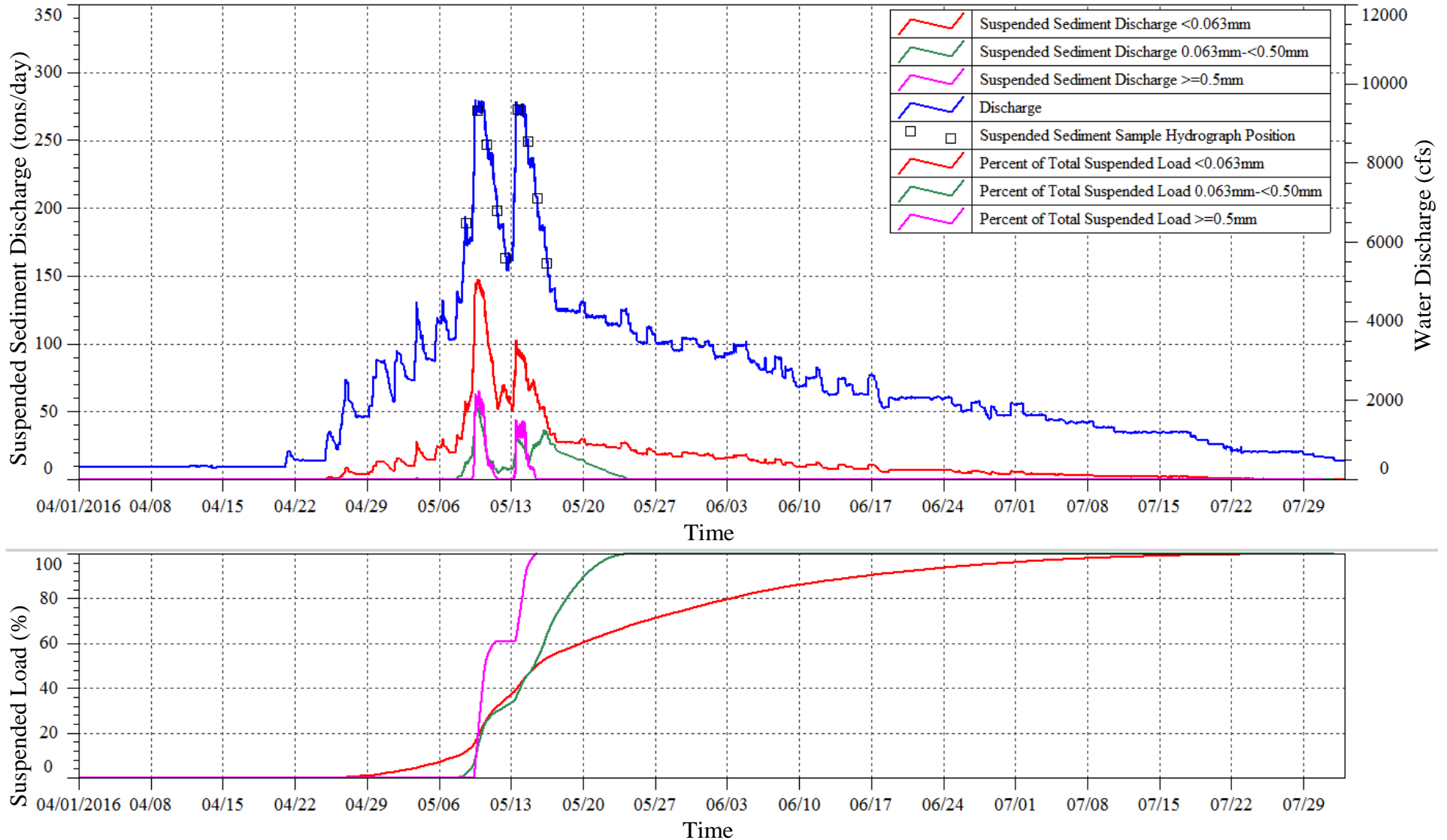
TRINITY RIVER AT LEWISTON –11525500

Bedload Discharge – Spring Flow Release WY 2016



TRINITY RIVER AT LEWISTON – 11525500

Suspended Sediment Discharge – Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

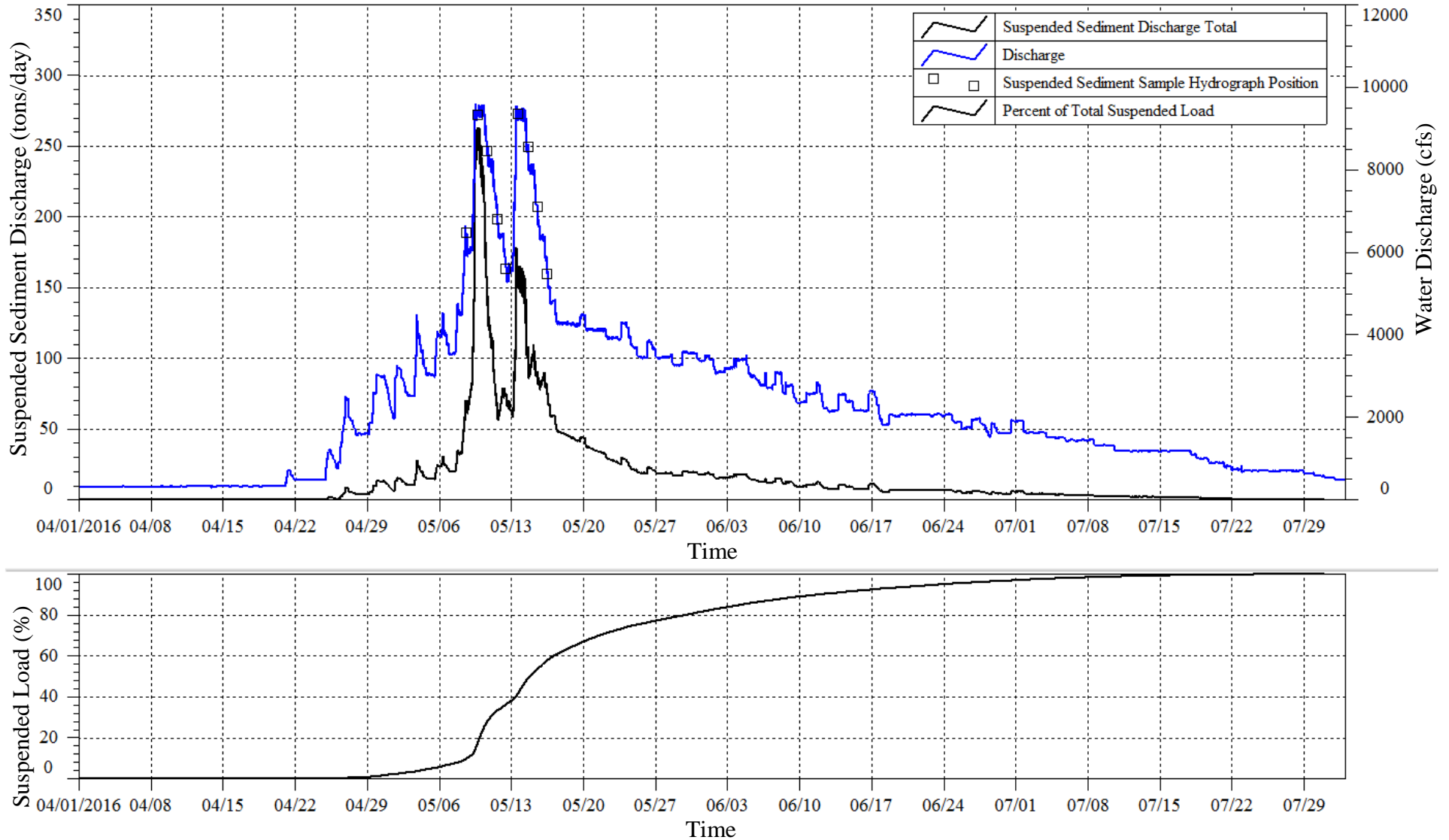


APPENDIX

A-5

TRINITY RIVER AT LEWISTON – 11525500

Suspended Sediment Discharge – Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

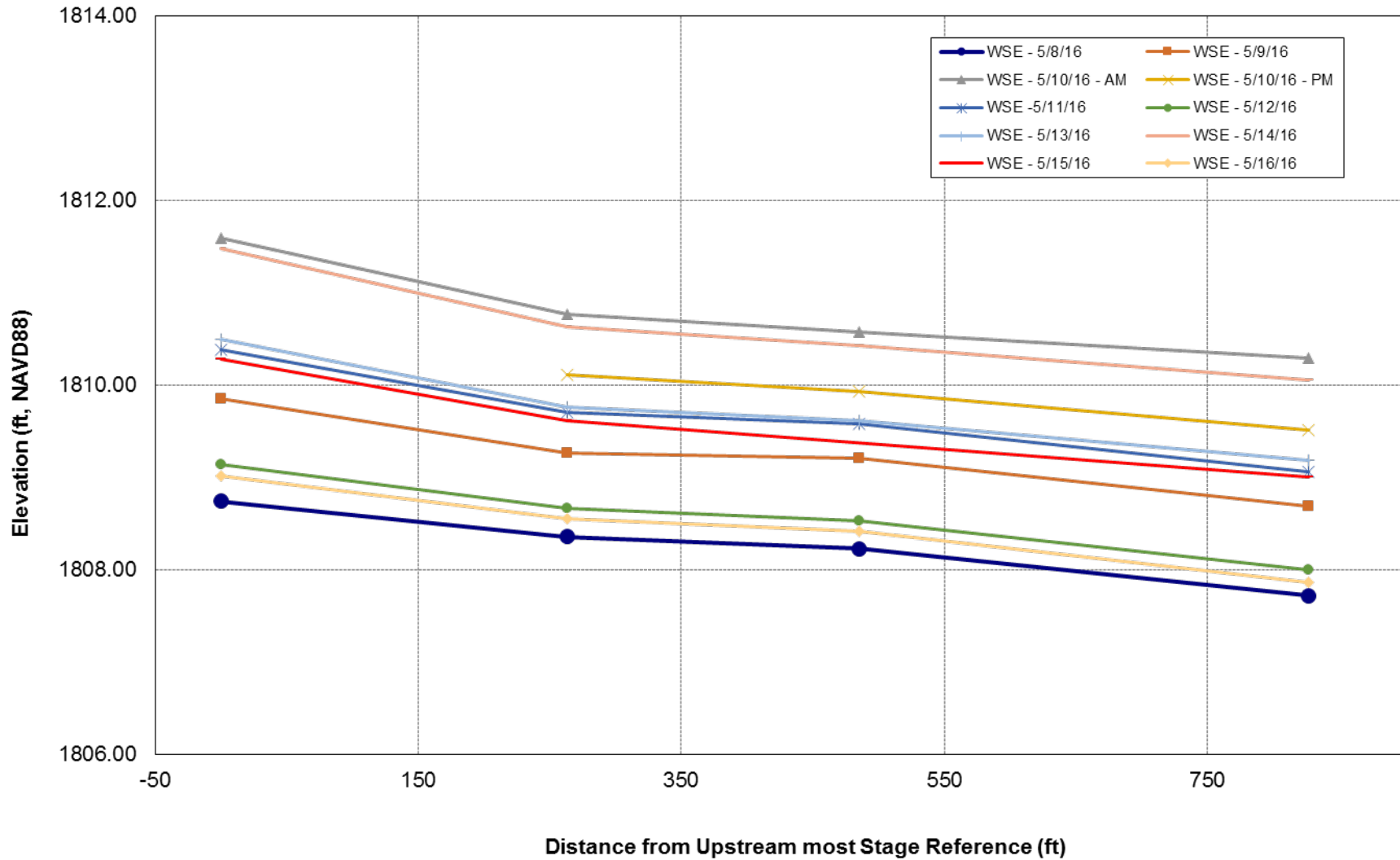
WY2016 SEDIMENT TRANSPORT MONITORING REPORT



APPENDIX

A-5

TRINITY RIVER AT LEWISTON
WY 2016 Water Surface Slopes



Appendix B

Trinity River above Grass Valley Creek
USGS Gage # 11525540

11525540 Trinity River Above Grass Valley Cr. near Lewiston

STATION ANALYSIS

SURFACE WATER RECORD

Spring Flow Release WY 2016: (April 1 to July 31)

LOCATION – Lat 40°41'51", long 122°,15'11" referenced to North American Datum of 1983

RECORDS – Surface Water. The purpose for collecting streamflow at this site is to provide accurate streamflow records for bedload and suspended sediment discharge computations. Potential flow increases from tributaries between the Trinity River at Lewiston streamflow gage (11525500) and the Trinity River above Grass Valley Creek Sediment Monitoring Station require the establishment of a seasonal streamflow gaging station. This effort is part of a long-term study of sediment transport in the Trinity River, under the Trinity River Restoration Program (TRRP), sponsored by the U.S. Department of Interior, Bureau of Reclamation. This station analysis describes (1) discharge measurement efforts during and (2) records computed for the WY 2016 Spring Flow Release by GMA, under contract to the TRRP. This gage is operated during the Spring Flow Release period.

Prior to the WY 2011 Spring Flow Release this station was located 166 ft upstream. During the summer of 2010 TRRP completed a channel and floodplain restoration project in the reach which required moving the surface water monitoring station.

EQUIPMENT – Graham Matthews & Associates re-established this site in April of Water Year 2011. A Campbell Scientific Inc. CR200 DCP, Design Analysis Associates Water Log H-310 pressure transducer, and a Forest Technology Systems DTS-12 are installed at the site.

Inside recording gage: Design Analysis H-310 (Accuracy to ± 0.007 ft)
Forest Technology Systems DTS-12 (Accuracy (0-499.99 NTU $\pm 2\%$ +0.2 NTU), (500.00 to 1600 NTU $\pm 4\%$))

Outside staff gage: Three enameled sections (0.00 ft – 9.99 ft).

GAGE HEIGHT RECORDS – Record is incomplete for the computational period. Small gaps in the record on April 4, 2016 at 10:15 to 11:30 and 17:00 to 17:45 were created during station maintenance. During the computational period the maximum gage height of 9.36 ft. occurred on May 9 at 15:15 hours. The minimum gage height for the computational period of 1.67 ft. occurred on April 14 at 10:45 hours.

Staff height readings were compared to recorded gage height values. Staff height readings made during the period indicated that corrections to the electronic gage data were necessary. When flow goes over bank and reaches the second staff plate, a back watering effect occurs. This causes the staff plate water surface elevation to be different

than the water surface elevation measured by the pressure transducer, which was moved farther out into the channel prior to Water Year 2012. Additionally, staff plate #3 is installed at the far edge of a large floodplain, which further accentuates the difference in electronic gage height and staff height. For this reason, very few readings were recorded from staff plate #3 during WY 2016. Even at the highest flows, water surface was measured from staff plate #2. The gage height correction was adjusted to staff height readings for staff plate #1 and #2.

A staff height observation on April 4, 2016 and May 16, 2016 show a 1.2' correction at the lowest staff plate which indicates that the pressure transducer did not drift during the spring flow release computational period. A gage height correction of 1.2' was used for the entire period. Gage height corrections were held constant and not increased with increasing stage as was done in previous years to account for backwatering on floodplain staff plates.

DATUM CORRECTIONS – No correction necessary. A level survey was performed on April 4, 2016 and November 4, 2016. The control, BM1 (3/8-inch capped rebar), for the station was set on April 14, 2011 and is located 20 ft upstream of the gage and roughly 140 ft to the east.

CONTROL – The low water control at the site is a downstream riffle. The low water control is prone to shifts. At high water channel control dominates. The high water channel was significantly altered during restoration activities in 2010. The floodplain was lowered and a significant amount of vegetation was removed from the left bank.

RATING – Nine discharge measurements (85-92) were made during the computational period. Measurements were made with an ADCP or with a Price AA meter and Aquacalc Pro suspended from a cataraft platform or wading rod. Measured discharge for the period ranged from 362 cfs to 9,270 cfs. Computed instantaneous discharges ranged from 362 cfs to 10,000 cfs.

Rating 6.0 was developed to extend the low end of Rating 5.1 and is used during the entire Water Year 2016 SFR. Stage variable shift SV15-01 was in use at the end of the previous computational period. Measurements were plotted and inspected for use during the period. Measurements 85 through 92 indicate that SV15-01 is still valid and it was renamed SV16-01 for use during Water Year 2016. Measurement 90 suggests a shift back to Rating 6.0, however it was a Poor measurement and hydrographic comparison with Trinity River at Lewiston and Trinity River below Limekiln Gulch indicate the SV16-01 is still valid.

Rating 6.0 has a validated range between 1.71 ft (366 cfs) and 10.1 ft (11,400 cfs).

RATING 6.0 WAS USED FROM 4/1/2016 TO 07/31/2016

DISCHARGE –Rating 6.0 is used as follows:

April 1 to Jul. 31 (23:45)

SV16-01 (1.92, 0.03; 5.50, 0.27; 8.00, 0.00)

SPECIAL COMPUTATIONS – Hydrographic comparison with discharge records from Trinity River near Lewiston (11525500) and Trinity River below Limekiln Gulch near Douglas City (11525655) were used to verify the accuracy of the computed record.

Prior to the gage being installed on the April 4, 2016, discharge records were estimated using the Trinity River at Lewiston, CA (TRAL, 11525500) and the Rush Cr near Lewiston, CA (RCNL, 11525530) gaging records.

REMARKS – The record should be considered **Fair** for the computational period. The record should be considered estimated from April 1, 2016 through April 4, 2016 when the record was estimated using TRAL and RCNL data.

Record Worked by: B. Pittman, November 2016

Proofed: S. Pittman, January 2017

11525540 Trinity River Above Grass Valley Cr. near Lewiston

TOTAL LOAD SEDIMENT DISCHARGE RECORD

Spring Flow Release WY 2016: (April 1 to July 31)

Records collected at station.— GMA Hydrology established this site in May of Water Year 2006. In April 2011 the electronic monitoring equipment was moved 166 feet downstream and the sampling cableway was moved roughly 300 feet downstream. Relocation of the station was necessary due to restoration activities that occurred during the summer of 2010. A Campbell Scientific Inc. CR200 data collection platform (DCP), Design Analysis Assoc. WaterLog H-310 pressure transducer, and a Forest Technology Systems DTS-12 are installed at the site. The purpose for collecting sediment data at this site is to quantify sediment discharge delivered from this portion of the mainstem. This effort is part of a long-term study of sediment transport in the Trinity River, under the Trinity River Restoration Program (TRRP), sponsored by the U.S. Department of Interior, Bureau of Reclamation. This station analysis describes (1) sampling efforts during and (2) records computed from the WY 2016 high flow release by GMA, under contract to the Trinity River Restoration Program (TRRP).

Equipment.-- Sampling equipment consists of a D-74 and DH-48 for suspended-sediment sampling, and a cable-deployed 12-inch x 6-inch Toutle River 2 bedload sampler (TR-2) with a 0.5mm mesh collection bag. The D-74 suspended-sediment sampler and the TR-2 bedload sampler were deployed from a crane-mounted E-reel or B-Reel. The E-reel was driven by a battery operated power-drive during periods of the release and the B-reel was operated by hand. Sediment sampling was performed from a cataraft-based platform attached to a temporary cableway. Stage references were installed near cableway at the streamflow gaging station. A Forest Technology Systems DTS-12 turbidimeter was installed on April 4, 2016 at 18:00 and operated until August 17, 2016 at 10:45. Photographs were taken with a digital camera.

Sampling program.-- Total (flow release) load season for this site is from April 1 to July 31. The program consisted of 9 sampling days. A minimum of three bedload-discharge and one suspended-sediment discharge sample were collected on each of the sampling days. The sampling days and samples collected are as follows:

May 08	6 bedload discharge	1 suspended-sediment discharge
May 09	8 bedload discharge	1 suspended-sediment discharge
May 10	6 bedload discharge	0 suspended-sediment discharge
May 11	6 bedload discharge	1 suspended-sediment discharge
May 12	4 bedload discharge	1 suspended-sediment discharge
May 13	9 bedload discharge	1 suspended-sediment discharge
May 14	6 bedload discharge	1 suspended-sediment discharge
May 15	6 bedload discharge	1 suspended-sediment discharge
May 16	2 bedload discharge	1 suspended-sediment discharge

Sampling crews consisted of a safety kayaker, and two on-river personnel specifically trained in cataraft-based sediment data collection techniques. All samples were reviewed by the site technicians and individual analyses were standardized for suspended sediment (concentration, particle size analysis) and bedload samples (total dry mass, particle size analysis). Sediment data were generally collected according to USGS protocols with the following exceptions: test-velocity ratings for sampler nozzles

were occasionally exceeded. Suspended-sediment samples were sent to the GMA Suspended-Sediment Lab and bedload samples were analyzed at the GMA Coarse Sediment Lab both located in Placerville, CA for analysis.

USGS Field Review. -- No USGS field review was conducted in during the 2016 spring flow release.

Data summary for WY 2016 spring flow release.--

Total number of samples:	
Suspended sediment sets	8
Single pass suspended sediment samples.....	0
Box sample sets	0
Single box samples	0
Bedload sets	0
Single pass bedload samples	53
Three pass bedload samples	0
Number of field turbidities measured	0
Number of suspended sediment size analysis samples:	
Particle size analysis	0
0.063mm break	8
0.500mm break	8
Number of bedload sediment size analysis samples:	
Particle size analysis	53
Number of suspended sediment discharge measurements	8
Number of bedload discharge measurements	53
Number of visits by Field Office	0
Maximum flow sampled by:	
GMA technicians, ft ³ /s	9,920
Range sampled by:	
GMA technicians, mg/l	11-28
GMA technicians, ton/d.....	33 -2,610
Peak flow during flow release, ft ³ /s	10,000
Periods of faulty record	
Turbidity	
April 4, 2016 at 18:00 – April 26, 2016 at 12:45	
May 17, 2016 at 16:00 – June 23, 2016 at 12:30	
June 28, 2016 at 15:45 – July 31, 2016 at 23:45	

Coefficients.-- None used.

Continuous Turbidity.-- The turbidity record is incomplete for the computational period. At the end of the previous computational period the DTS-12 turbidity probe, H-310 pressure transducer, and DCP were removed from the site. The equipment was re-installed on April 4 at 18:00 and operated until August 17 at 10:30.

The turbidity record is faulty from the time of installation until April 26, 2016 at 12:45 and from July 7, 2016 at 16:45 until the end of the period due to probe being out of the water. Additionally, the turbidity record was faulty from May 17, 2016 at 16:00 until June 23, 2016 at 12:30 and June 28, 2016 at 15:45 until July 7, 2016 at 16:30 for unknown reasons.

Several turbidity spikes were removed. Turbidity spikes are defined as short periods of time, 15-minutes to several hours, during which the optics of the probe were presumably fouled. After removing the turbidity spikes the gaps were filled using linear interpolation or the gaps were filled with a constant value if turbidity was not changing.

Once the turbidity record was cleaned, the record was inspected to see if application of a turbidity offset was necessary. Analysis indicated that an offset of -4.0 FNU was necessary during the period. Offsets are determined by averaging turbidity values at base flows when turbidity should be at or close to 0.0 FNU.

During the computational period the maximum turbidity was 39.7 FNU on May 8 at 14:30, and the minimum turbidity was 0.01 FNU, which occurred on May 28 at 12:15.

Total suspended sediment-discharge computations. -- Total suspended-sediment discharge was computed by summing the partial suspended-sediment discharges.

Size analysis. – Eight cross-sectional, depth-integrated samples were analyzed using a split at <0.063mm and ≥0.50mm. Prior to 2011 splits were made at 0.50mm.

Partial suspended sediment-discharge computations. – Turbidity versus SSC transport curves were analyzed for use during the computational period, however, WY2016 SSC sample data showed a very poor relation with turbidity. A potential cause is gravel augmentation activities at the site during the flow release period affecting turbidity values at the turbidity probe, which is located along the left bank. Sampling crews observed several times a distinct turbidity plume near the probe. Sample data was collected along the entire cross section and did not relate to the increased turbidity seen only along the left bank. Discharge versus SSC transport curves were developed for all three size classes. No outliers were identified.

For the <0.063mm size class, the discharge versus SSC transport curve is defined by Eqn.(1).

$$SSC = 0.0088 * (Discharge - 1500)^{0.75}, \quad r^2 = 0.47 \quad (1)$$

Eqn.(1) is used from April 1, 2016 through July 31, 2016 . The auto-generated shifted power function was determined to be the best fit even though it under-values the highest samples. This potential source of error is mitigated by using the sedigraph method. Eqn. (1) has a validated range between 5,790 cfs and 9,610 cfs. Because no samples were collected near zero transport on the rising and falling limbs it was necessary to estimate zero transport based on previous years' data. Zero transport was estimated during transport curve development, using previous years' low flow sample data, at 1,500 cfs. Samples did not indicate hysteresis for this size class and the same zero transport threshold was used for both the rising and falling limb.

For the 0.063mm-<0.50mm size class, the discharge versus SSC transport curve is defined by Eqn. (2).

$$SSC = 1.013 * (Discharge - 2000)^{1.54}, \quad r^2 = 0.70 \quad (2)$$

Eqn.(2) is used from April 1, 2016 through July 31, 2016 . Eqn. (1) has a validated range between 5,790 cfs and 9,610 cfs. Because no samples were collected near zero transport on the rising and falling limbs it was necessary to estimate zero transport based on previous years' data. Zero transport was estimated during transport curve development, using previous years' low flow sample data, at 2,000 cfs. Samples

did not indicate hysteresis for this size class and the same zero transport threshold was used for both the rising and falling limb.

For the $\geq 0.50\text{mm}$ size class, the discharge versus SSC transport curve is defined by Eqn. (3).

$$SSC = 0.001 * (Discharge - 3000)^{0.911}, \quad r^2 = 0.48 \quad (3)$$

Eqn.(3) is used from April 1, 2016 through July 31, 2016 . Eqn. (1) has a validated range between 5,790 cfs and 9,610 cfs. Because no samples were collected near zero transport on the rising and falling limbs it was necessary to estimate zero transport based on previous years' data. Zero transport was estimated during transport curve development, using previous years' low flow sample data, at 3,000 cfs. Samples did not indicate hysteresis for this size class and the same zero transport threshold was used for both the rising and falling limb.

The transport curves were used to develop continuous concentration curves for the $<0.063\text{mm}$, $0.063\text{mm}-<0.50\text{mm}$, and the $\geq 0.5\text{mm}$ size classes during the computational period. Once the continuous concentration data had been developed the sample data were used to adjust the continuous concentration curves so that they passed through all sample points. The continuous concentration curves were adjusted using fitting and proportional fitting techniques

Proportional fitting calculates the ratio between two sequential sample values and then scales the appropriate time series (e.g. continuous SSC) by this ratio. When applied between sequential pairs of data, the ratio is decayed or increased linearly to match the end-points. Fitting and proportional fitting techniques recognize short-term correlations and address hysteresis effects by using subsets of data. When only a single sample exists on a flow bench, the proportional fitting technique assumes that the determined ratio applies for the duration of that flow bench. When SSC is not highly correlated with discharge or turbidity, it is not possible to evaluate this assumption and therefore it is a potential source of error. Suspended-sediment discharge was computed directly from the continuous concentration once the continuous concentration data had been checked and its accuracy verified.

Bed material.-- None.

Bedload measurement. -- Fifty three bedload discharge samples were collected during the Spring Flow Release.

Bedload-discharge computations. -- The sample analysis contains the portion of sample $<0.5\text{mm}$ but the total bedload discharge was determined by summing the partial discharges for the $>0.5\text{mm}-8\text{mm}$ and the $\geq 8\text{mm}$ size fractions.

Partial bedload-discharge computations -- Sediment transport curves were developed and partial bedload discharges were computed for the $0.5\text{mm}-8\text{mm}$ and $\geq 8\text{mm}$ size classes. 2016 had a double peak hydrograph and sample data was analyzed with each peak broken out separately and for rise and fall patterns of hysteresis. No outliers were identified during analysis of either size class.

For the $0.5\text{mm}-<8\text{mm}$ size class, the transport curves are defined by Eqn. (4), Eqn. (5), Eqn. (6) and Eqn. (7). Each hydrograph peak showed patterns of hysteresis and the first peak had higher transport than the second.

$$BLD = 3.86e - 009 * Discharge^{2.69}, \quad r^2 = 0.89 \quad (4)$$

$$BLD = 1.70e - 022 * Discharge^{5.97}, \quad r^2 = 0.90 \quad (5)$$

$$BLD = 2.41e - 013 * Discharge^{3.62}, \quad r^2 = 0.82 \quad (6)$$

$$BLD = 1.80e - 015 * Discharge^{4.05}, \quad r^2 = 0.80 \quad (7)$$

Eqn. (4) was developed using samples 1-13 and is valid from April 1, 2016 at 00:00 until May 9, 2016 at 15:00. Eqn. (5) was developed using samples 14-30 and is valid from May 9, 2016 at 15:15 through May 13, 2016 at 05:00. Eqn. (6) was developed using samples 31-39 and is valid from May 13, 2016 at 05:15 through May 13, 2016 at 16:30. Eqn. (7) was developed using samples 40-53 and is valid from May 13, 2016 at 16:45 through July 31, 2016 at 23:45. Eqn. (4) has a validated range between 5,930 cfs and 9,880 cfs. Eqn. (5) has a validated range between 6,270 cfs and 9,900 cfs. Eqn. (6) has a validated range between 7,320 cfs and 9,770 cfs. Eqn. (7) has a validated range between 5,790 cfs and 9,880 cfs. Zero transport was estimated using previous years' data and field observations and was 1,500 cfs on the rising limb and 1,800 cfs for the falling limb.

For the $\geq 0.8\text{mm}$ size class, the transport curves are defined by Eqn. (8), Eqn. (9) and Eqn. (10). The first hydrograph peak showed higher transport rates than the second for the $\geq 0.8\text{mm}$ size class. Additionally, the first peak showed a strong pattern of hysteresis and was broken into a relationship for the rising limb (Eqn. (8)) and a relationship for the falling limb (Eqn. (9)). The second peak had no obvious trend of hysteresis and was represented with a single generalized transport curve (Eqn. (10)).

$$BLD = 4.44e - 022 * Discharge^{6.14}, \quad r^2 = 0.93 \quad (8)$$

$$BLD = 7.96e - 027 * Discharge^{7.23}, \quad r^2 = 0.89 \quad (9)$$

$$BLD = 1.67e - 021 * Discharge^{5.89}, \quad r^2 = 0.91 \quad (10)$$

Eqn. (8) was developed using samples 1-14 and is valid from April 1, 2016 at 00:00 until May 9, 2016 at 19:00. Eqn. (9) was developed using samples 15-30 and is valid from May 9, 2016 at 19:15 through May 13, 2016 at 05:00. Eqn. (10) was developed using samples 31-53 and is valid from May 13, 2016 at 05:15 through July 31, 2016 at 23:45. Eqn. (8) has a validated range between 5,770 cfs and 9,880 cfs. Eqn. (9) has a validated range between 6,270 cfs and 9,900 cfs. Eqn. (10) has a validated range between 5,790 cfs and 9,880 cfs. Zero transport for the rising limb and falling limb were estimated during transport curve development and examining previous years' data; they occur at 2,000 cfs and 2,300 cfs for the rising and falling limb respectively.

Once the continuous bedload-discharge traces were developed using the above transport curves, they were adjusted to the sample values using the same techniques as was described for the partial suspended-sediment discharge computations. Due to the inherent high variability in bedload sampling, during flow benches, sample values were averaged on days where multiple samples were collected to produce average transport values. These average transport values were used to adjust the continuous bedload transport trace.

Remarks. – The suspended sediment discharge record is rated as follows:

April 1 (00:00) to May 7 (23:45)	Estimated
May 8 (00:00) to May 16 (23:45)	Good
May 17 (00:00) to July 31 (23:45)	Estimated

The bedload discharge record is rated as follows:

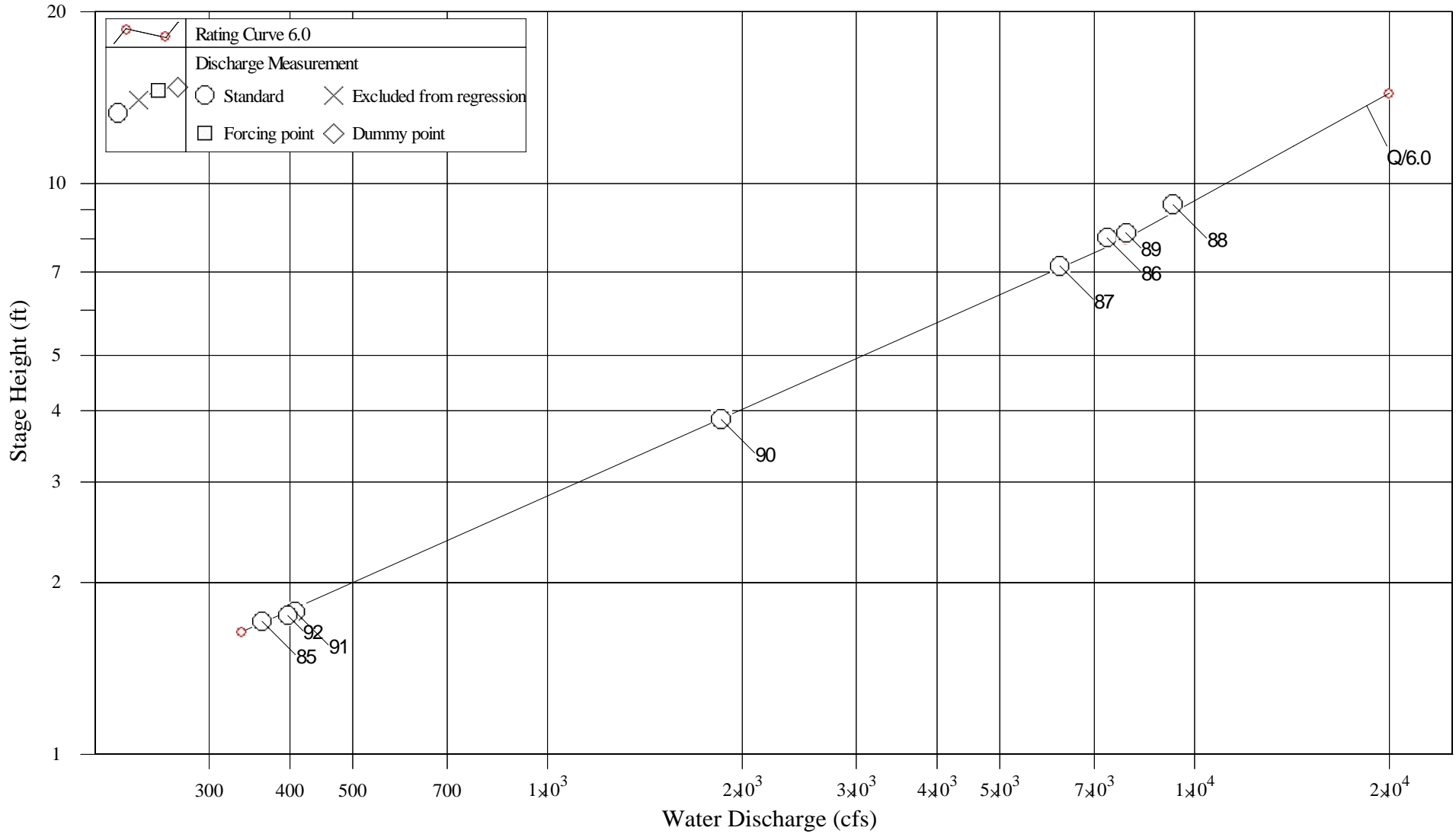
April 1 (00:00) to May 7 (23:45)	Estimated
May 8 (00:00) to May 16 (23:45)	Good
May 17 (00:00) to July 31 (23:45)	Estimated

Computed by: Brooke Pittman, December 2016

Reviewed by: Smokey Pittman, January 2017

TRINITY RIVER ABOVE GRASS VALLY NEAR LEWISTON --11525540

Discharge Rating Curve 6.0 – Valid From April 1, 2016 – Present



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

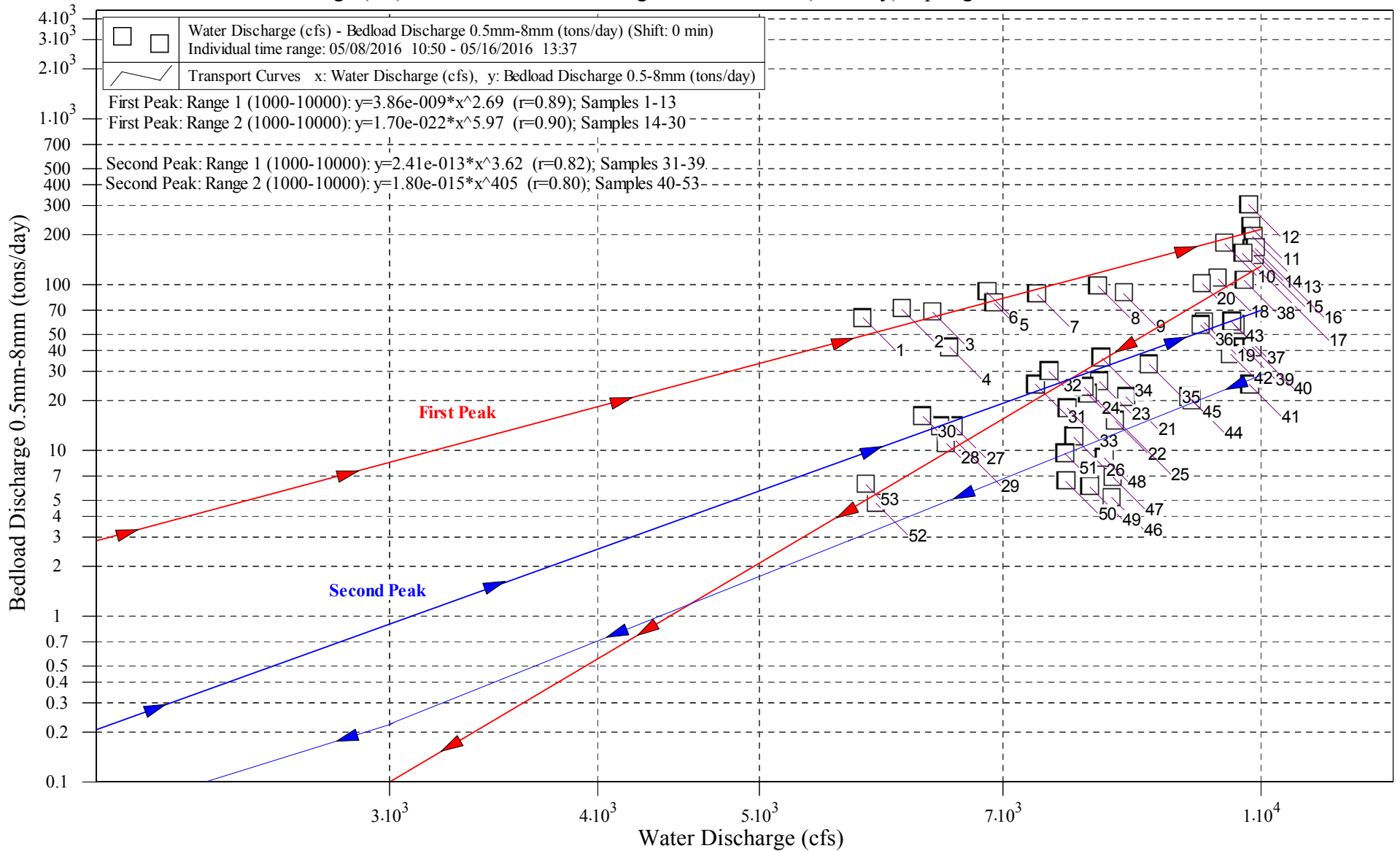


APPENDIX

B-2

TRINITY RIVER ABOVE GRASS VALLEY C. NEAR LEWISTON --11525540

Water Discharge (cfs) Versus Bedload Discharge 0.5mm-<8mm (tons/day): Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

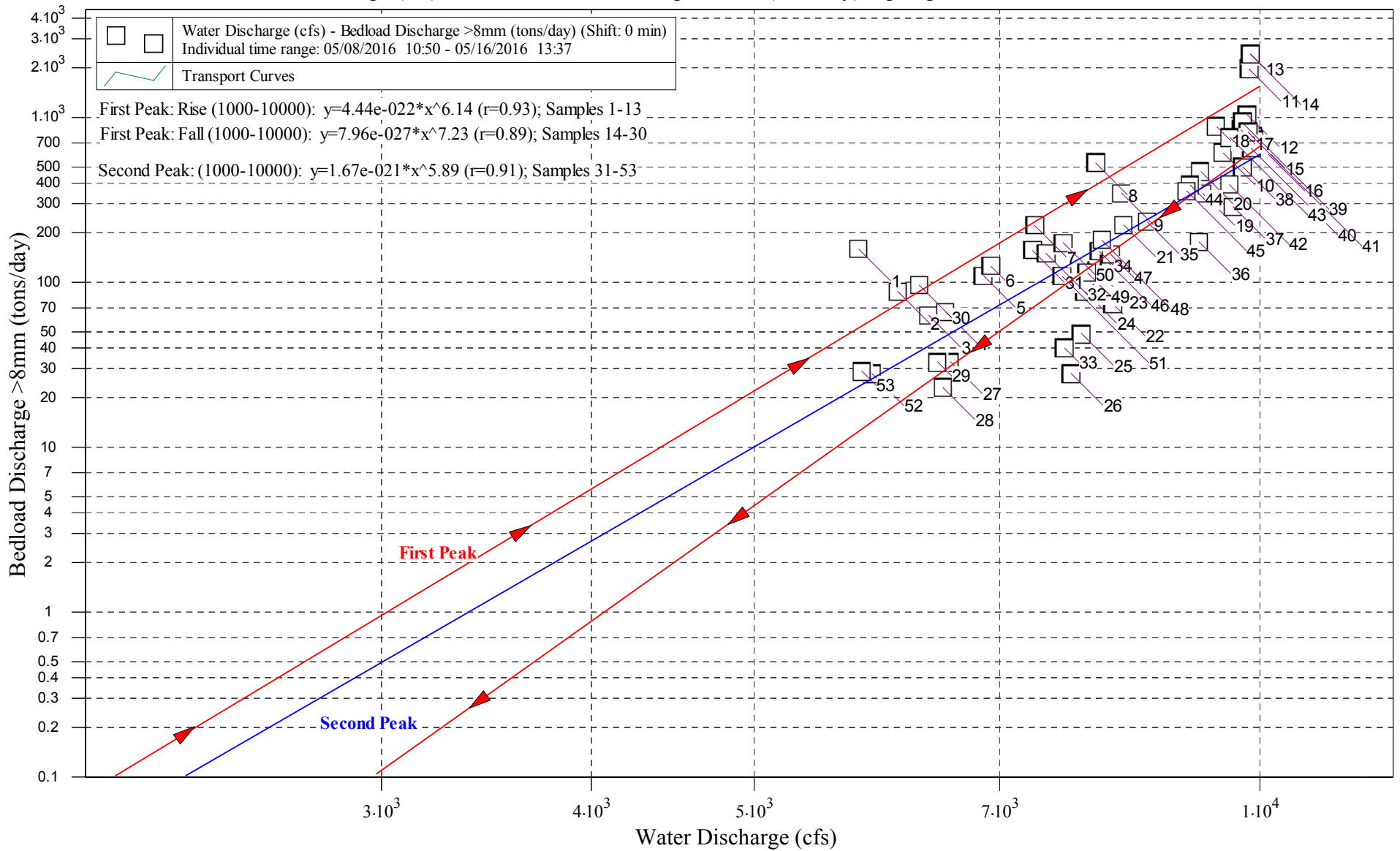


APPENDIX

B-3

TRINITY RIVER ABOVE GRASS VALLEY C. NEAR LEWISTON --11525540

Water Discharge (cfs) Versus Bedload Discharge $\geq 8\text{mm}$ (tons/day): Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

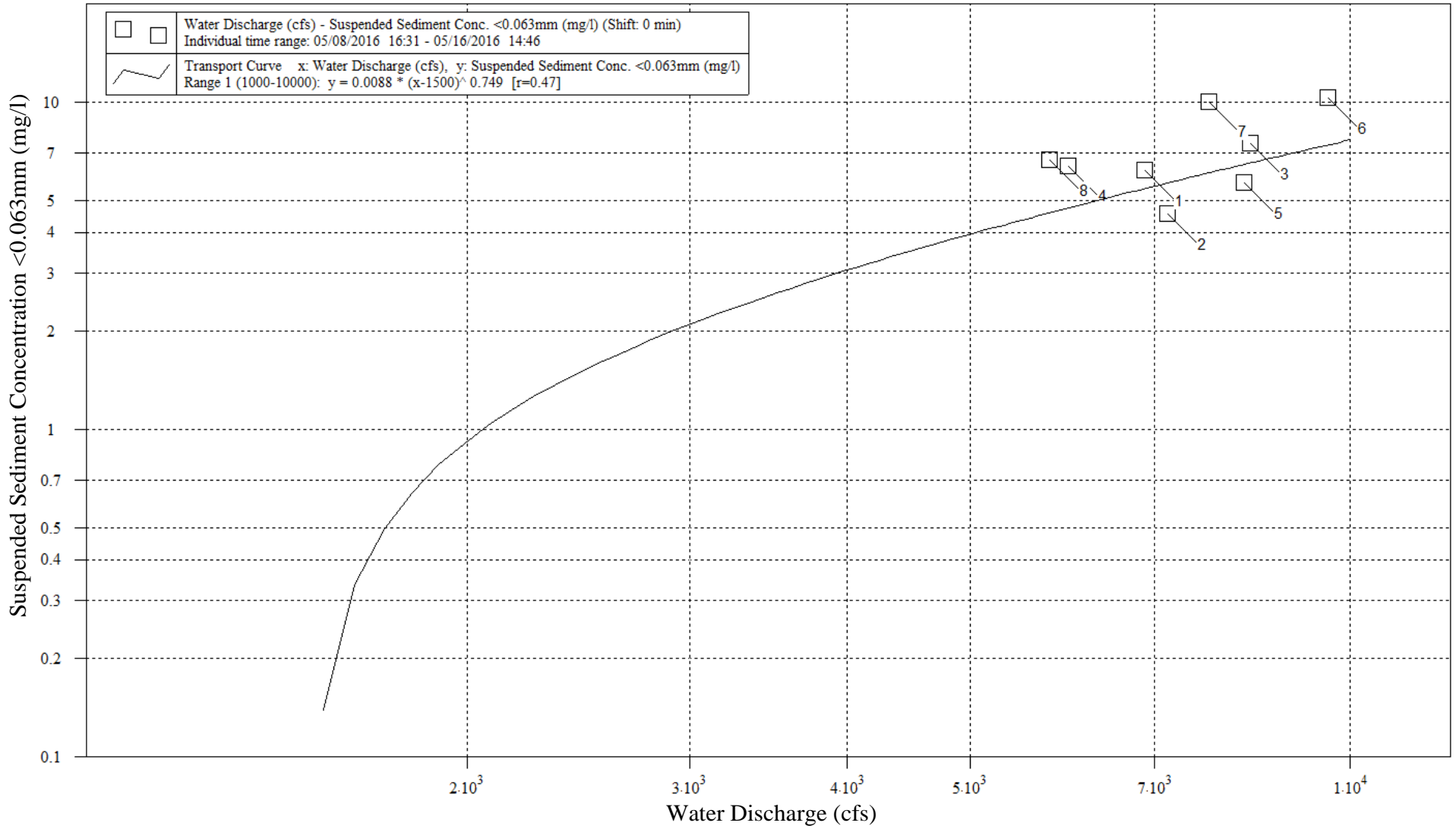


APPENDIX

B-3

TRINITY RIVER ABOVE GRASS VALLEY C. NEAR LEWISTON -- 11525540

Water Discharge (cfs) Versus Suspended Sediment Concentration <0.063mm (mg/l): Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

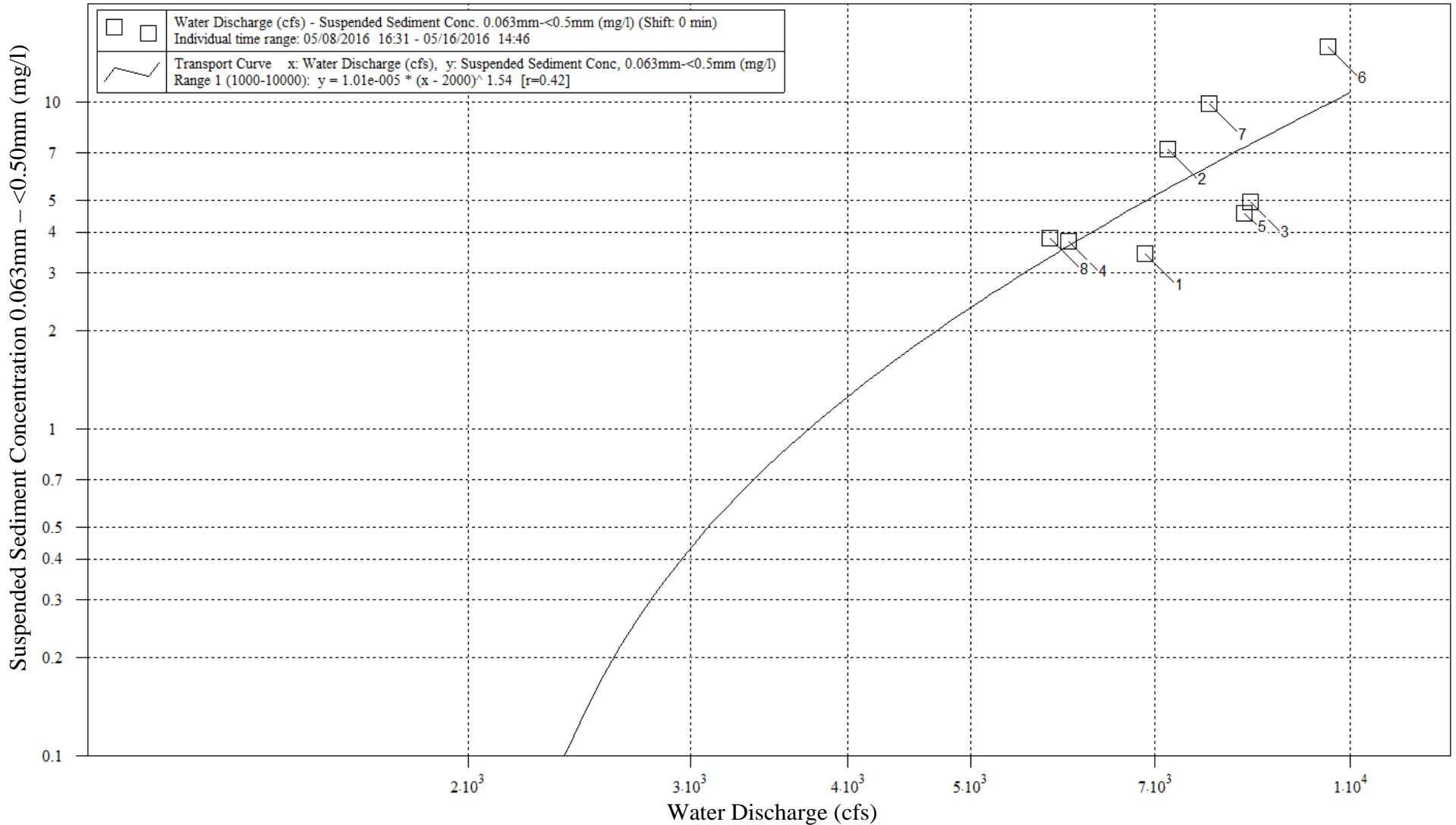


APPENDIX

B-4

TRINITY RIVER ABOVE GRASS VALLEY C. NEAR LEWISTON -- 11525540

Water Discharge (cfs) Versus Suspended Sediment Concentration 0.063mm - <0.5mm (mg/l): Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

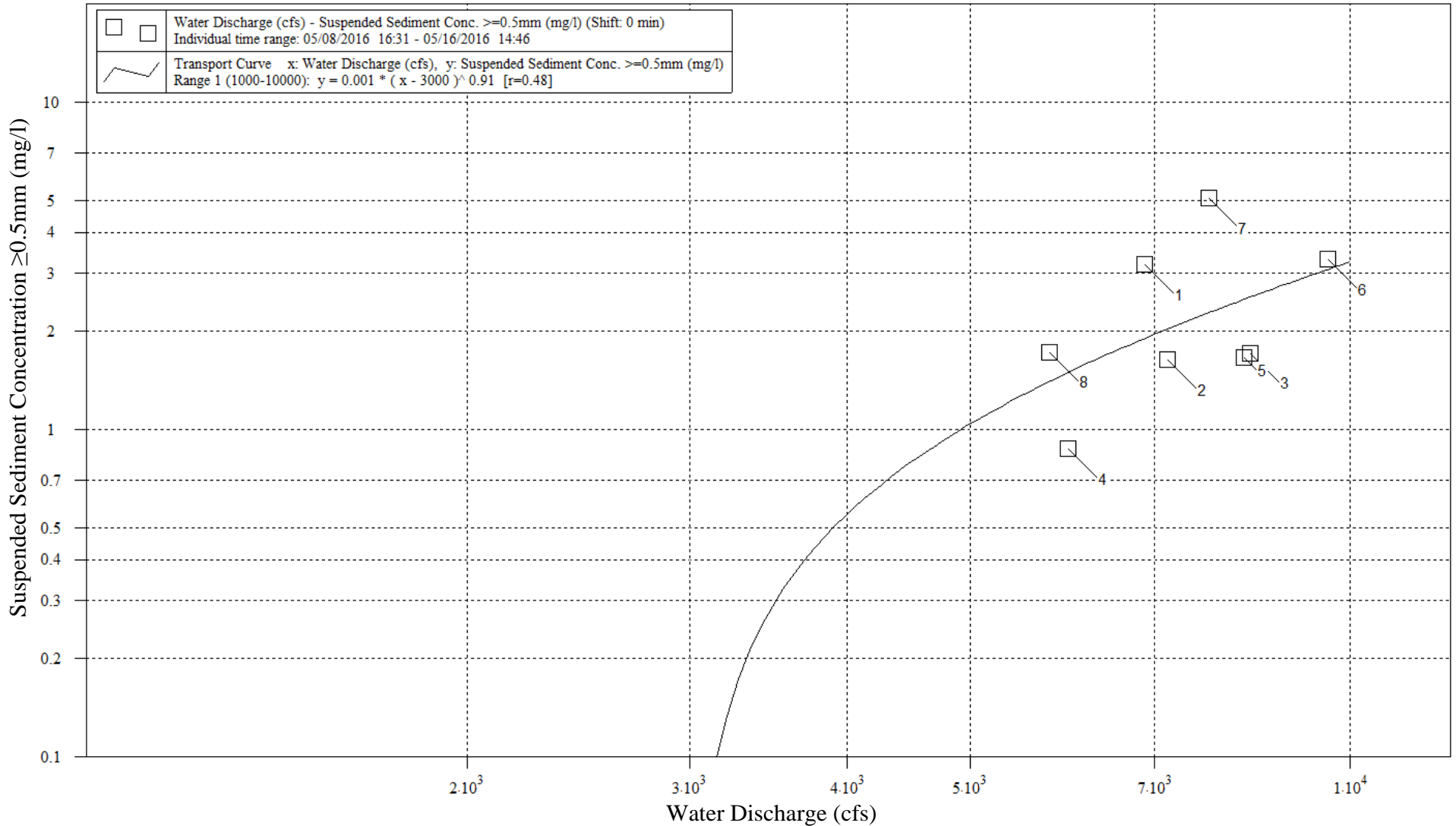


APPENDIX

B-4

TRINITY RIVER ABOVE GRASS VALLEY C. NEAR LEWISTON -- 11525540

Water Discharge (cfs) Versus Suspended Sediment Concentration $\geq 0.5\text{mm}$ (mg/l): Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

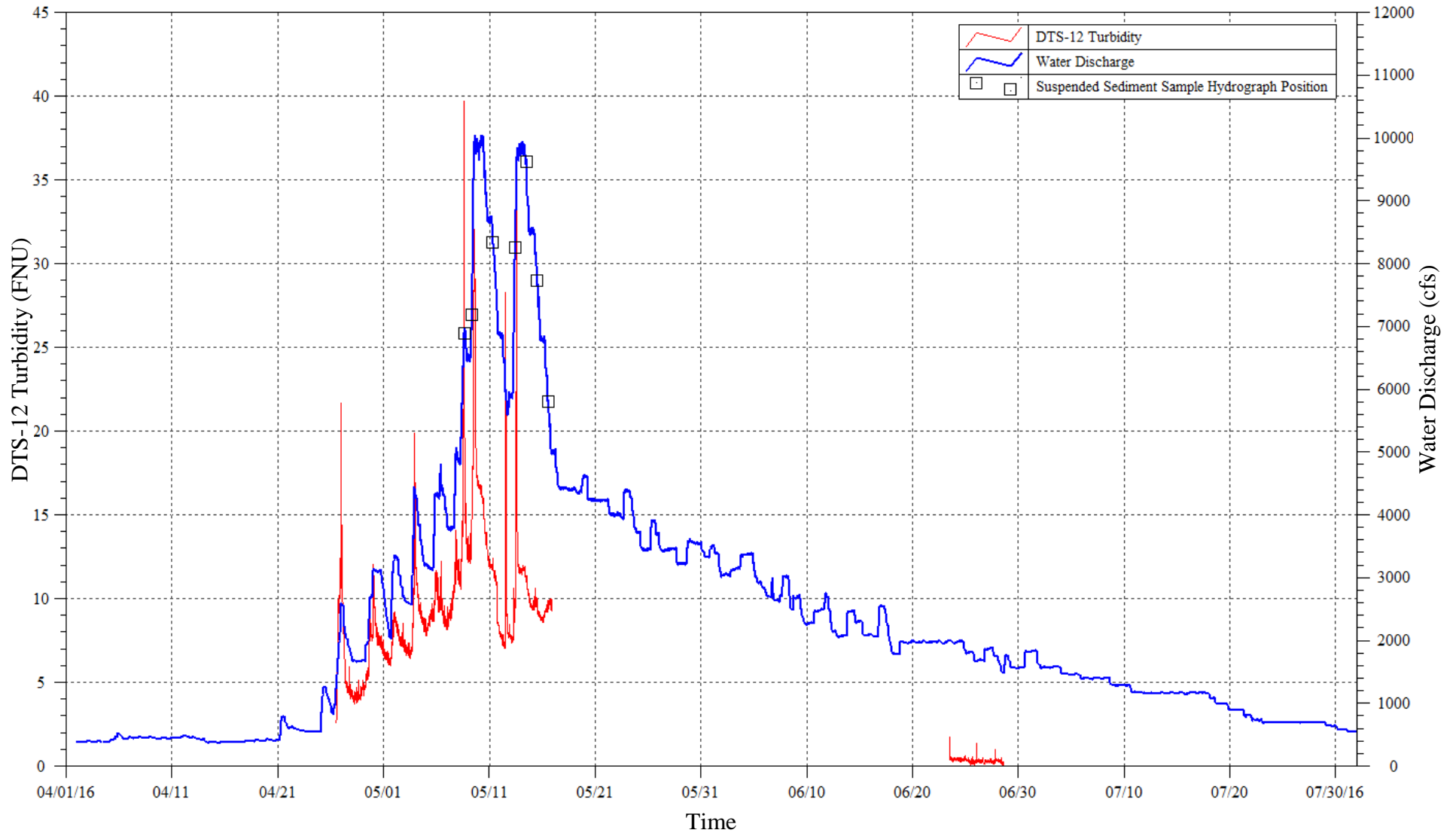


APPENDIX

B-4

TRINITY RIVER ABOVE GRASS VALLEY C. NEAR LEWISTON -11525540

DTS-12 Turbidity – Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

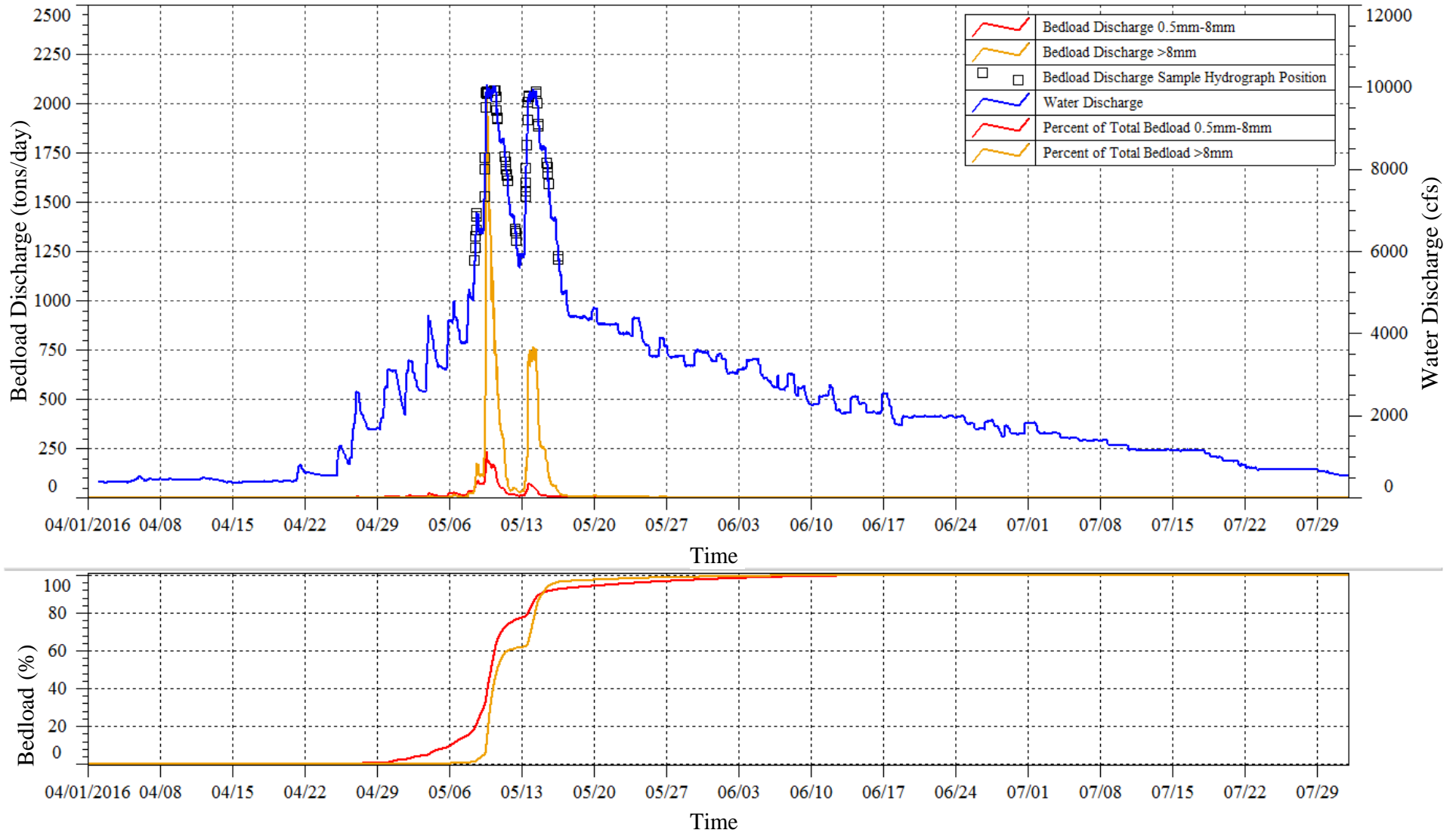


APPENDIX

B-5

TRINITY RIVER ABOVE GRASS VALLEY C. NEAR LEWISTON -11525540

Bedload Discharge – Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

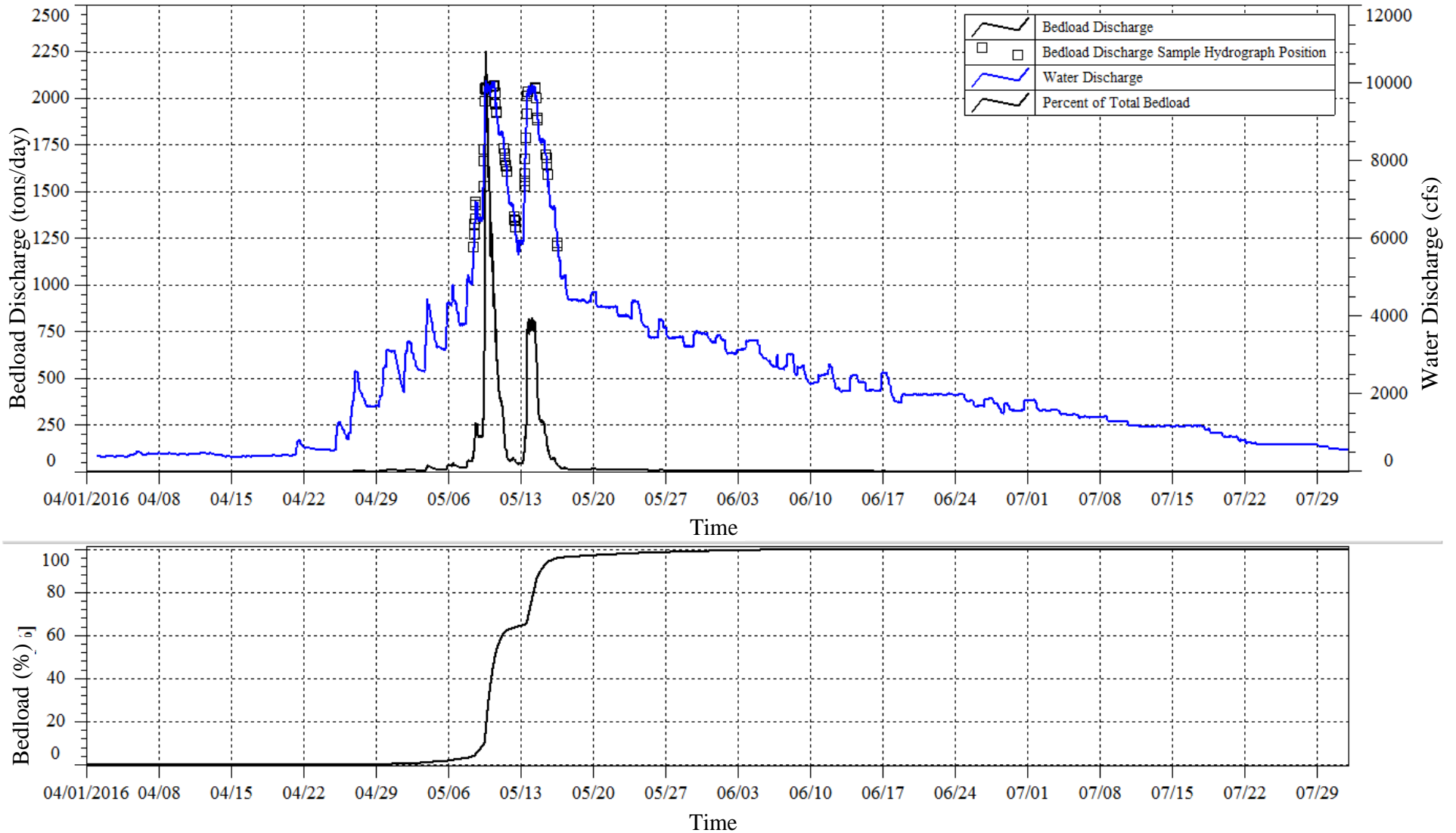


APPENDIX

B-6

TRINITY RIVER ABOVE GRASS VALLEY C. NEAR LEWISTON -11525540

Bedload Discharge – Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

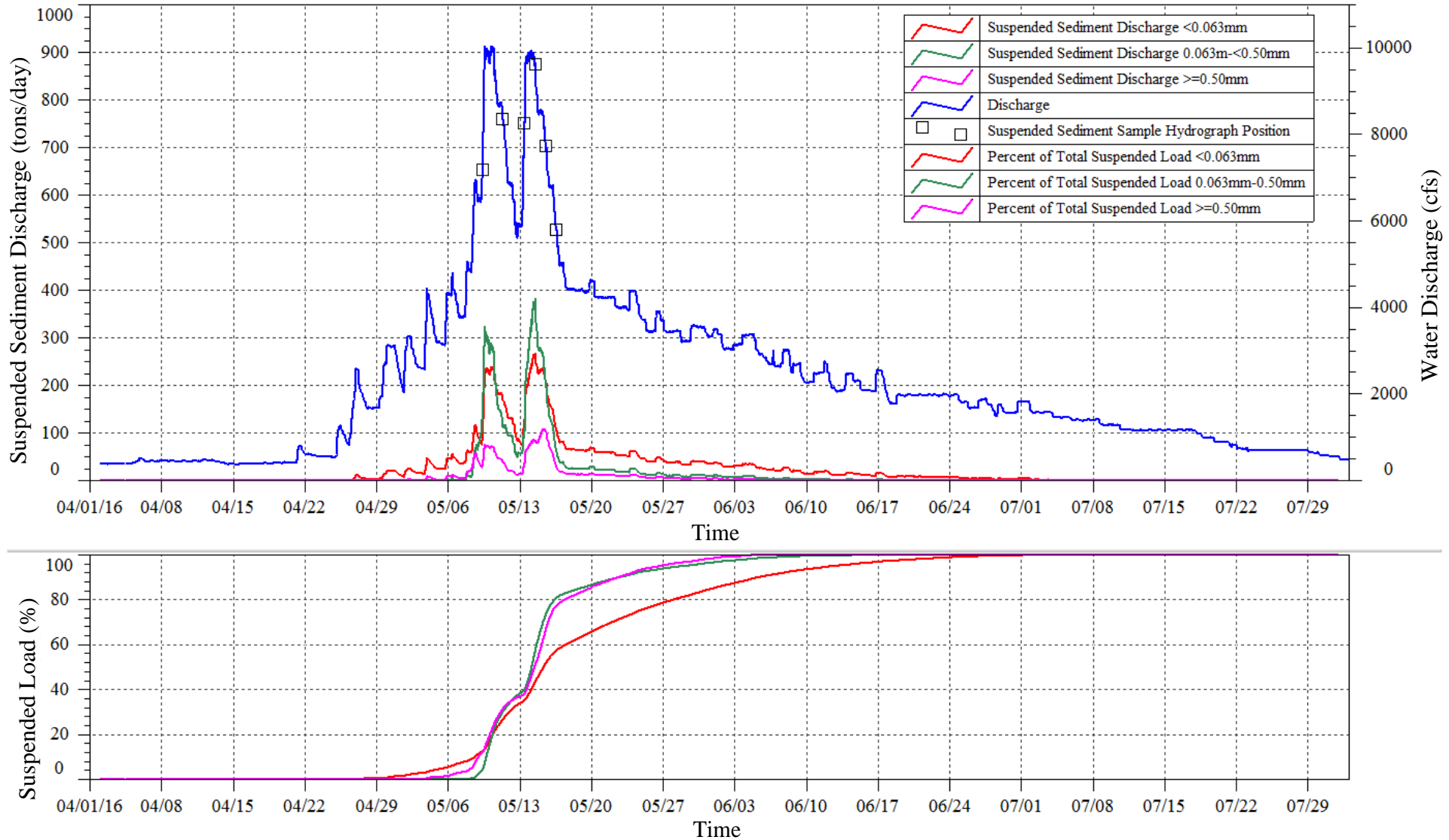


APPENDIX

B-6

TRINITY RIVER ABOVE GRASS VALLEY C. NEAR LEWISTON -11525540

Suspended Sediment Discharge – Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

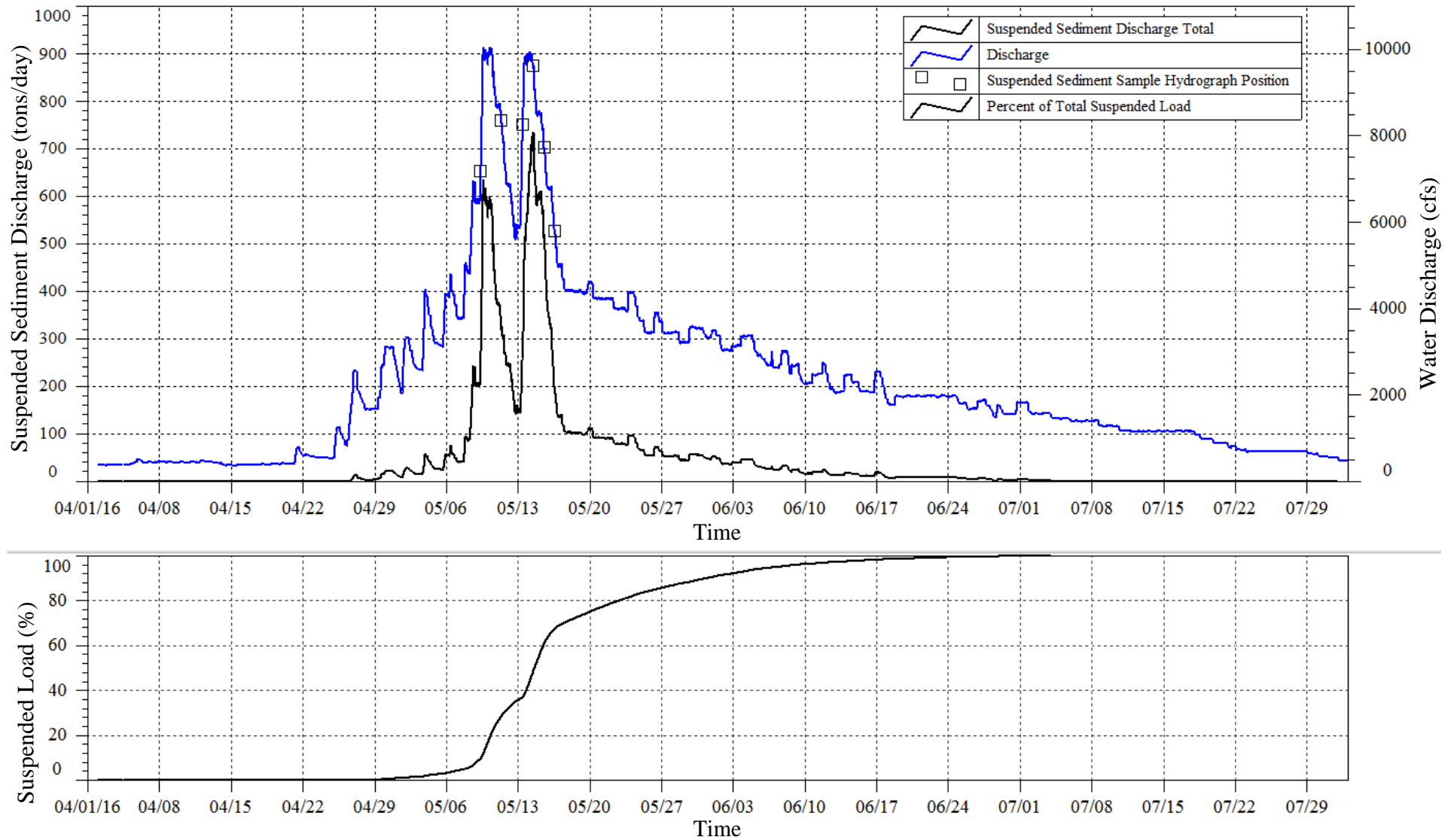


APPENDIX

B-7

TRINITY RIVER ABOVE GRASS VALLEY C. NEAR LEWISTON -11525540

Suspended Sediment Discharge – Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

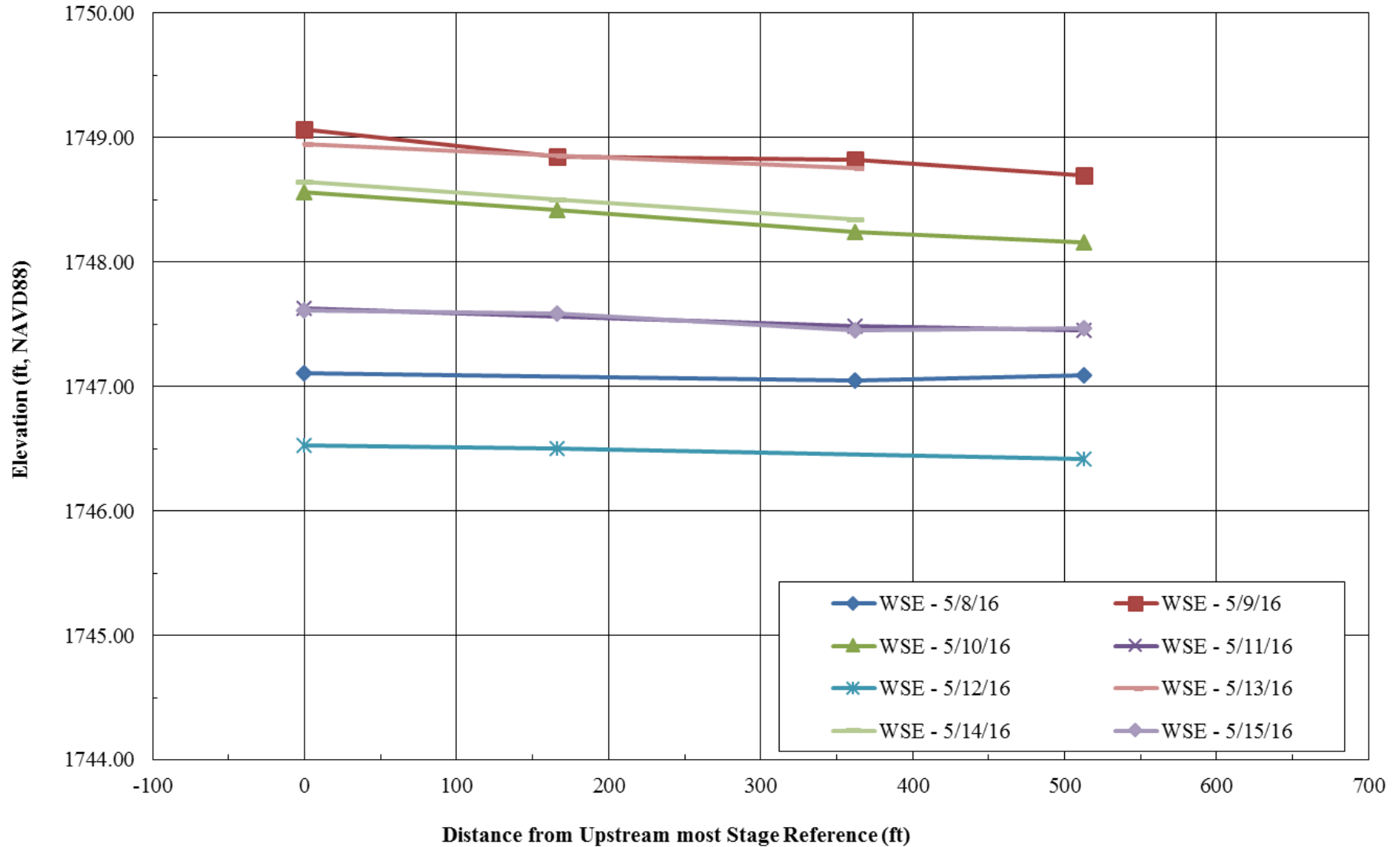
WY2016 SEDIMENT TRANSPORT MONITORING REPORT



APPENDIX

B-7

**TRINITY RIVER ABOVE GRASS VALLEY CREEK
WY 2016 Water Surface Slopes**



Appendix C

Trinity River below Limekiln Gulch
USGS Gage # 11525655

11525655 Trinity River Below Limekiln Gulch near Douglas City, CA

TOTAL LOAD SEDIMENT DISCHARGE RECORD

Spring Flow Release WY 2016: (April 1 to July 31)

Records collected at station.-- Daily streamflow has been collected for the following periods: WY1981-1991, WY1999-2004 by the Hoopa Valley Tribe and 2005-present by the USGS. This site was operated as a daily sediment station from 1981-1991. Sediment sampling (storm season and flow release) has occurred intermittently since 1998 by the Hoopa Valley Tribe. Sediment sampling (flow release) has occurred on a regular basis from 2004-15. Instantaneous water temperature data have been collected in conjunction with sampling and water discharge measurements since 1981. A turbidimeter recorded data during the WY 2015 spring flow release period: a Forest Technology Systems DTS-12 linked to a Campbell CR200 data collection platform (DCP), installed and operated by GMA Hydrology (GMA). The purpose of collecting sediment data at this site is to quantify sediment discharge transported through this portion of the mainstem, versus the sediment discharge measured at sediment collection stations either upstream or downstream: Trinity River at Lewiston (11525500), Trinity River above Grass Valley Creek near Lewiston (11525540), and Trinity River at Douglas City (11525854). This effort is part of a long-term study of sediment transport in the Trinity River, under the Trinity River Restoration Program (TRRP), sponsored by the U.S. Department of Interior, Bureau of Reclamation. This station analysis describes (1) sampling efforts during and (2) records computed from the WY 2016 spring flow release by GMA, under contract to the TRRP.

Equipment.-- Sampling equipment consists of a D-74 and DH-48 for suspended-sediment sampling, and a cable-deployed 12-inch x 6-inch Toutle River 2 bedload sampler (TR-2) with a 0.5 mm mesh collection bag. The D-74 suspended-sediment sampler and the TR-2 bedload sampler were deployed from a crane-mounted E-reel. The E-reel was driven by a battery operated power-drive during periods of the release and the B-reel was operated by hand. Sediment sampling was performed from a cataraft-based platform attached to a temporary cableway. Stage references were installed near the cableway at the streamflow gaging station. A Forest Technology Systems DTS-12 turbidimeter was installed and operated during the sediment sampling period. Photographs were taken with a digital camera.

Sampling program.-- Total (flow release) load season for this site is from April 1 to July 31. The program consisted of 9 sampling days. A minimum of three bedload-discharge sample and one suspended-sediment discharge sample was collected on each of the sampling days. The sampling days and samples collected are as follows:

May 08	6 bedload discharge	1 suspended-sediment discharge
May 09	10 bedload discharge	1 suspended-sediment discharge
May 10	11 bedload discharge	1 suspended-sediment discharge
May 11	15 bedload discharge	1 suspended-sediment discharge
May 12	4 bedload discharge	1 suspended-sediment discharge
May 13	13 bedload discharge	1 suspended-sediment discharge
May 14	6 bedload discharge	1 suspended-sediment discharge
May 15	5 bedload discharge	1 suspended-sediment discharge
May 16	2 bedload discharge	1 suspended-sediment discharge

Sampling crews consisted of two on-river personnel specifically trained in cataraft-based sediment data collection techniques, and a safety kayaker. All samples were reviewed by the site technicians and individual analyses were standardized for suspended sediment (concentration, particle size analysis) and bedload samples (total dry mass, particle size analysis). Sediment data were generally collected according to USGS protocols with the following exceptions: test-velocity ratings for sampler nozzles were occasionally exceeded. Suspended-sediment samples were sent to the GMA Suspended-Sediment Lab and bedload samples were sent to the GMA Coarse-Sediment Lab, both located in Placerville, CA for analysis.

USGS Field Review. -- No USGS field review was conducted during the 2016 spring flow release.

Data summary for WY 2016 spring flow release. --

Total number of samples:	
Suspended sets	9
Single pass suspended samples	0
Box sample sets	0
Single box samples	0
Bedload sets	0
Single pass bedload samples	72
Three pass bedload samples	0
Number of field turbidities measured	0
Number of suspended-sediment size analysis samples:	
Particle size analysis	0
0.063mm break	9
0.50mm break	9
Number of bedload sediment size analysis samples:	
Particle size analysis	72
Number of suspended-sediment discharge measurements	9
Number of bedload discharge measurements	72
Number of visits by Field Office	0
Maximum flow sampled by:	
GMA technicians, ft ³ /s	10,200
Range sampled by:	
GMA technicians, mg/l	9-60
GMA technicians, ton/d	28-1,311
Peak flow during flow release, ft ³ /s	10,600
Periods of faulty record	
Turbidity	
April 25, 2016 at 10:45 to April 26, 2016 at 15:00	
July 15, 2016 at 19:00 to July 15, 2016 at 22:15	
July 28, 2016 at 15:00 to August 17, 2016 at 14:45	

Coefficients.-- None used.

Continuous Turbidity.-- The turbidity record is incomplete for the computational period. The turbidity probe had been removed at the end of the previous computational period and was not re-installed until

April 5, 2016 at 18:15 hours. Additionally, the following periods of faulty turbidity data, caused by the probe being out of the water or debris fouling, were removed;

April 25, 2016 at 10:45 to April 26, 2016 at 15:00
July 15, 2016 at 19:00 to July 15, 2016 at 22:15
July 28, 2016 at 15:00 to August 17, 2016 at 14:45

Once the turbidity record was cleaned, the record was inspected to determine if a turbidity offset was necessary. Inspection of the record indicated that a shift of -1.5 FNU was necessary. Offsets are determined by averaging turbidity values at base flows when turbidity should be at or close to 0.0 FNU.

During the computational period, the maximum turbidity was 29.7 FNU on April 27 at 01:30, and the minimum turbidity was 0.3 FNU, which occurred on July 28, 2016 at 13:00.

Total suspended sediment-discharge computations. -- Total suspended-sediment discharge was computed by summing the partial suspended-sediment discharges.

Size analysis. -- Seven cross-sectional, depth-integrated samples were analyzed using a split at 0.063mm and 0.50mm.

Partial suspended sediment-discharge computations. -- Turbidity versus SSC transport curves were inspected for use during the period. For the <0.063mm and 0.063mm – 0.5mm size classes, relationships indicated that turbidity was a good surrogate for SSC. The ≥0.5mm size class did not show a reasonable relation with turbidity and a discharge versus SSC transport curve was developed. Generalized transport curves were developed using all samples collected during Water Year 2016. No outliers were identified.

For the <0.63mm size class, the turbidity versus SSC transport curve is defined by Eqn. (1).

$$SSC = 1.033 * Turbidity - 3.49, \quad r^2 = 0.91 \quad (1)$$

Eqn. (1) is used from April 5, 2016 at 18:15 through July 28, 2016 at 14:45, when the turbidity record was usable. Eqn. (1) has a validated range between 8.34 FNU and 24.5 FNU. Zero transport was determined by applying the transport curve to the turbidity record and occurs at 763 cfs on the rising limb and 2,460 cfs on the falling limb.

For the 0.063mm-<0.50mm size class, the turbidity versus SSC transport curve is defined by Eqn. (2).

$$SSC = 1.54 * Turbidity - 9.76, \quad r^2 = 0.95 \quad (2)$$

Eqn. (2) is used from April 5, 2016 at 18:15 through July 28, 2016 at 14:45, when the turbidity record was usable. Eqn. (2) has a validated range between 8.34 FNU and 24.5 FNU. Zero transport on the rising limb was determined by applying the transport curve to the turbidity record and occurs at 1,090 cfs. Zero transport on the falling limb was estimated by fitting the sedigraph to sample 9 and occurs at 3,320 cfs.

For the ≥0.5mm size class, both turbidity versus SSC and discharge versus SSC were analyzed. Discharge versus SSC was produced a better relationship for ≥0.5mm SSC at TRLG. The ≥0.5mm transport curve is defined by Eqn. (3).

$$SSC = 0.00069 * (Discharge - 4000)^{1.07}, \quad r^2 = 0.65 \quad (3)$$

The transport curve is used between April 1 at 00:00 hours and July 31 at 00:00 hours. The transport curve has a validated range between 5,120 cfs and 10,500 cfs. Zero transport of 4,000 cfs was estimated during transport curve development. Samples did not indicate hysteresis for this size class and the same zero transport threshold was used for both the rising and falling limb.

The transport curves were used to develop continuous concentration curves for the <0.063mm, ≥0.063mm-<0.50mm, and the ≥0.5mm size classes during the computational period. Once the continuous concentration data had been developed, the sample data were used to adjust the continuous concentration trace so that they passed through all sample points. The continuous concentration trace was adjusted using fitting and proportional fitting techniques.

Proportional fitting calculates the ratio between two sequential sample values and then scales the appropriate time series (e.g. continuous SSC) by this ratio. When applied between sequential pairs of data, the ratio is decayed or increased linearly to match the end-points. Fitting and proportional fitting techniques recognize short-term correlations and address hysteresis effects by using subsets of data. When only a single sample exists on a flow bench, the proportional fitting technique assumes that the determined ratio applies for the duration of that flow bench. When SSC is not highly correlated with discharge or turbidity, it is not possible to evaluate this assumption and therefore it is a potential source of error. Suspended-sediment discharge was computed directly from the continuous concentration once the continuous concentration data had been checked and its accuracy verified.

Bed material-- None.

Bedload measurement -- Seventy two bedload discharge samples were collected during the Spring Flow Release.

Bedload-discharge computations -- The sample analysis contains the portion of sample <0.5mm but the total bedload discharge was determined by summing the partial discharges for the ≥0.5mm-8mm and the ≥8mm size fractions.

Partial bedload-discharge computations -- Sediment transport curves were developed and partial bedload discharges were computed for the 0.5mm-8mm and ≥8mm size classes. 2016 had a double peak hydrograph and sample data was analyzed for the entire year, with each peak broken out separately and for rise and fall patterns of hysteresis.

For the 0.5mm-<8mm size class, no obvious patterns of hysteresis or changes in transport rates between the two peaks were observed so a single generalized transport curve was developed and is shown in Eqn. (4). No outliers were identified

$$BLD = 4.30e - 007 * (Discharge - 1800)^{2.18}, \quad r^2 = 0.85 \quad (4)$$

The transport curve was developed using samples 1-72. The transport curve is used from April 1 at 00:00 hrs until July 31 at 23:45 hours and has a validated range between 5,230 cfs and 10,500 cfs. Zero transport for the rising limb was estimated during transport curve development and occurs at 1,800 cfs. For the falling limb, zero transport was estimated by fitting the sedigraph to the average of sample 71-72 and occurs at 3,500 cfs.

For the $\geq 8\text{mm}$ size class, no obvious patterns of hysteresis or changes in transport rates between the two peaks were observed so a single generalized transport curve was developed and is shown in Eqn. (5) and Eqn. (6). Sample 1, 5, 70, 3 and 12 were identified as outliers for this size class. They were excluded from transport curve development, but were used when developing the sedigraph.

$$\text{Discharge} \geq 6,571 \text{ cfs} \quad BLD = 9.49e - 028 * \text{Discharge}^{7.58}, \quad r^2 = 0.94 \quad (5)$$

$$\text{Discharge} < 6,571 \text{ cfs} \quad BLD = 1.49e - 012 * \text{Discharge}^{3.6}, \quad r^2 = 0.70 \quad (6)$$

The transport curve defined by Eqn. (5) and Eqn. (6) was developed using samples 1-72, excluding previously identified outliers and is used from April 1, 2016 at 00:00 hours through July 31, 2016 at 23:45 hours and has a validated range between 5,230 cfs and 10,500 cfs. Zero transport for the rising limb was estimated during transport curve development and occurs at 1,850 cfs. For the falling limb, zero transport was estimated during sedigraph development at 3,800 cfs.

Once the continuous bedload-discharge traces were developed using the above transport curves, they were adjusted to the sample values using the same techniques as was described for the partial suspended-sediment discharge computations. Due to the inherent high variability in bedload sampling, during flow benches, sample values were averaged on days where multiple samples were collected to produce average transport values. These average transport values were used to adjust the continuous bedload transport trace.

Remarks. – The suspended sediment discharge record is rated as follows:

April 1 (00:00) to May 7 (23:45)	Estimated
May 8 (00:00) to May 16 (23:45)	Good
May 17 (00:00) to July 31 (23:45)	Estimated

The bedload discharge record is rated as follows:

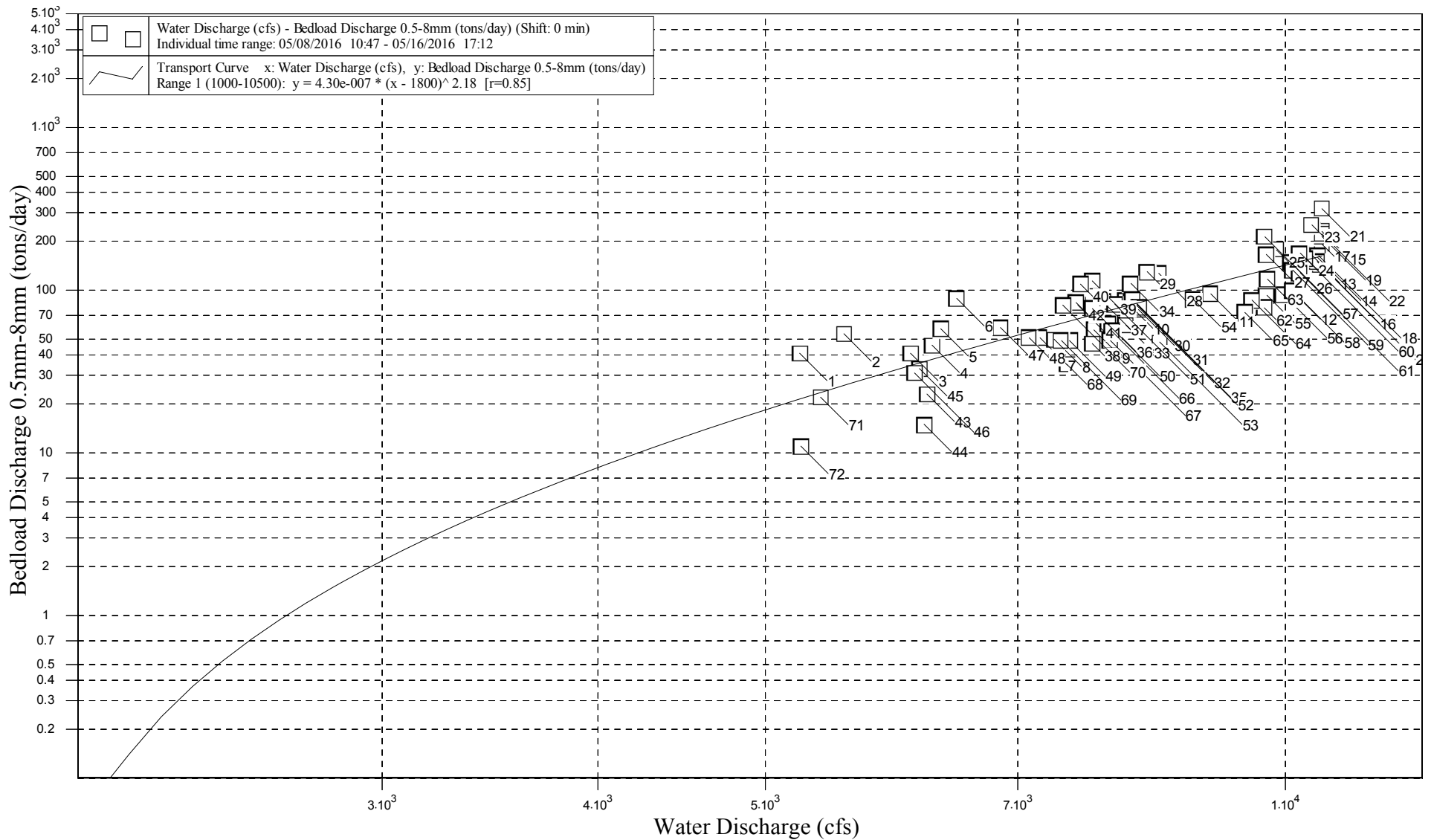
April 1 (00:00) to May 7 (23:45)	Estimated
May 8 (00:00) to May 16 (23:45)	Good
May 17 (00:00) to July 31 (23:45)	Estimated

Computed by: Brooke Pittman, December 2016

Reviewed by: Smokey Pittman, January 2017

TRINITY RIVER BELOW LIMEKILN GULCH NEAR DOUGLAS CITY --11525655

Water Discharge (cfs) Versus Bedload Discharge 0.5mm-<8mm (tons/day): Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

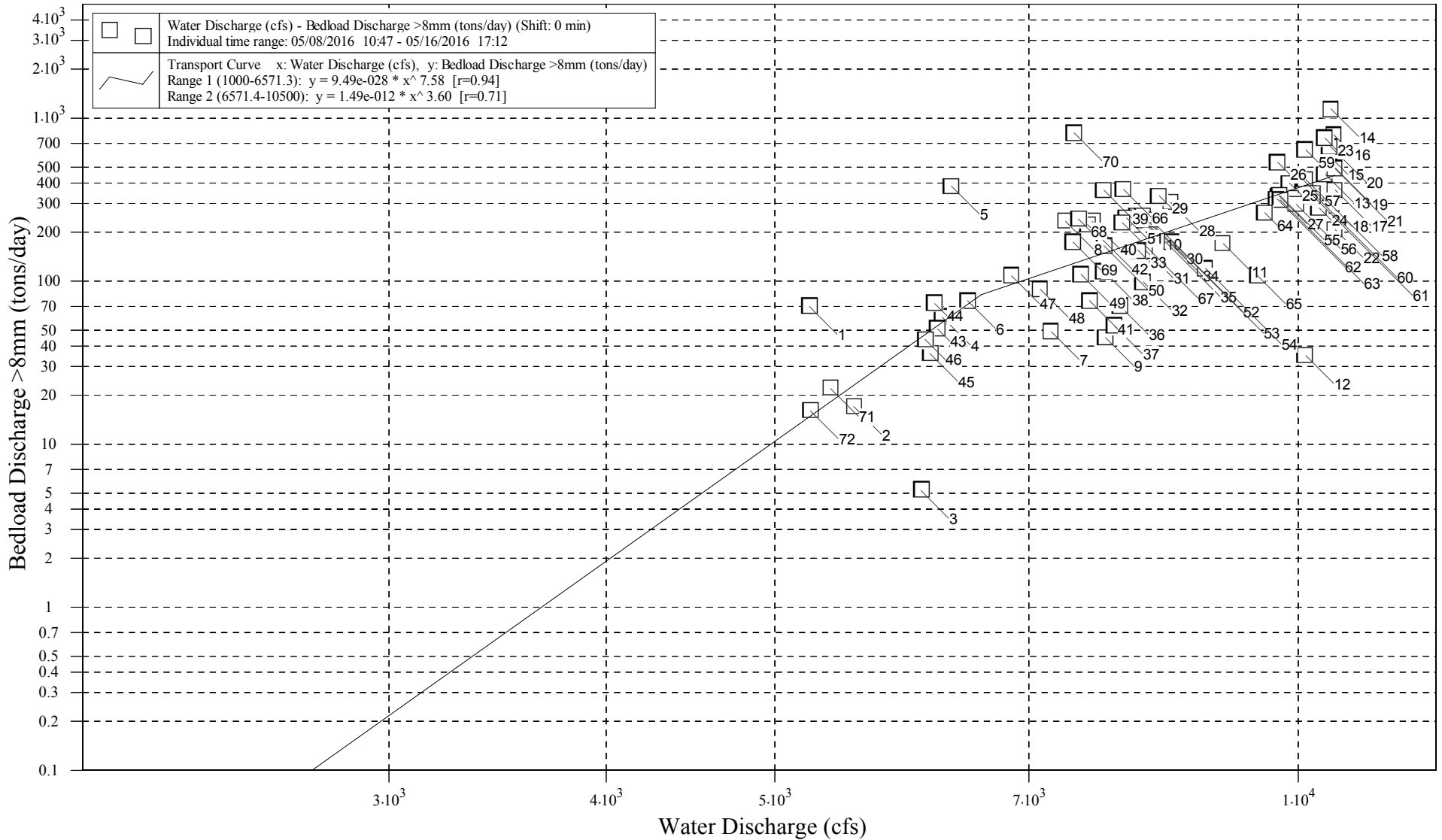


APPENDIX

C-2

TRINITY RIVER BELOW LIMEKILN GULCH NEAR DOUGLAS CITY --11525655

Water Discharge (cfs) Versus Bedload Discharge $\geq 8\text{mm}$ (tons/day): Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

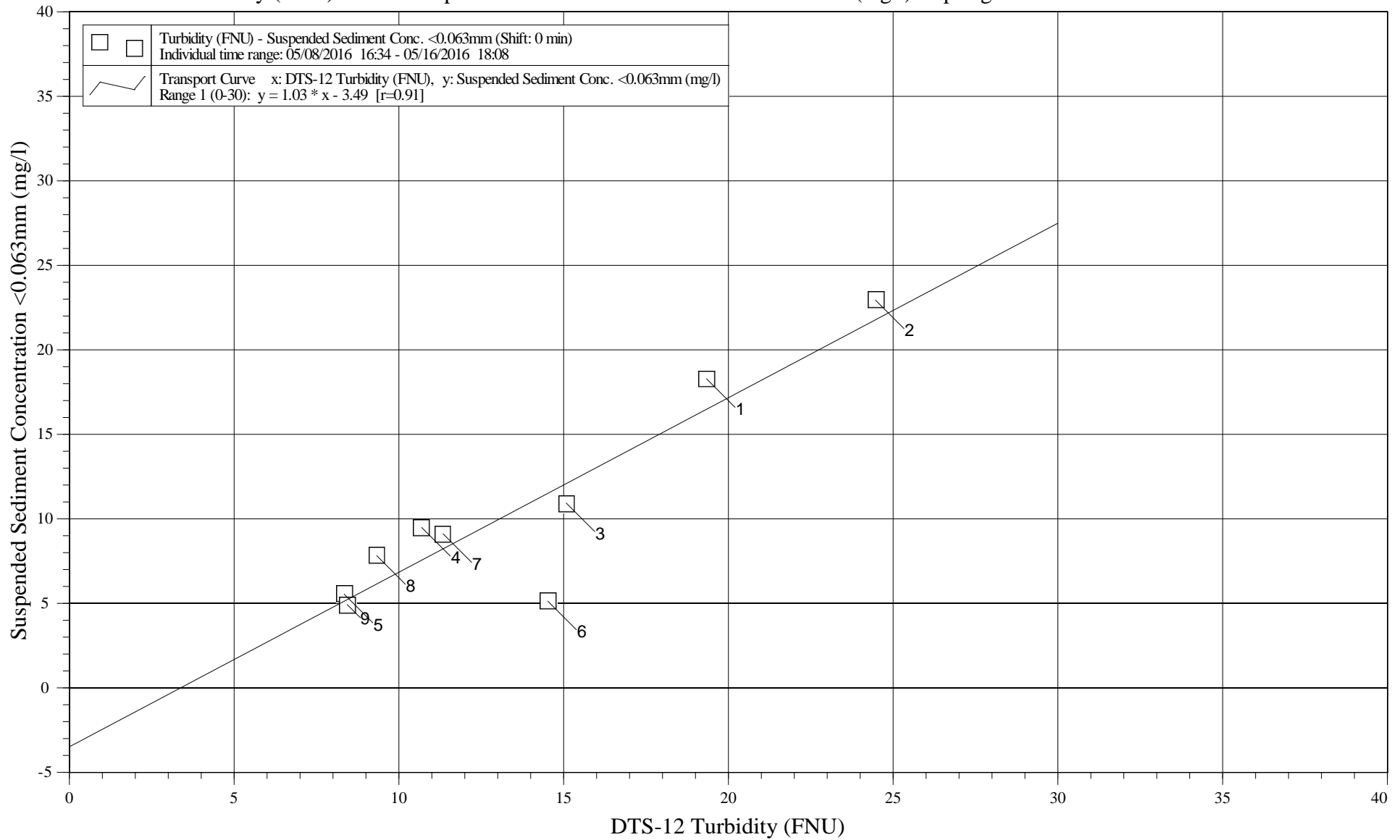


APPENDIX

C-2

TRINITY RIVER BELOW LIMEKILN GULCH NEAR DOUGLAS CITY --11525655

Turbidity (FNU) Versus Suspended Sediment Concentration <0.063mm (mg/l): Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

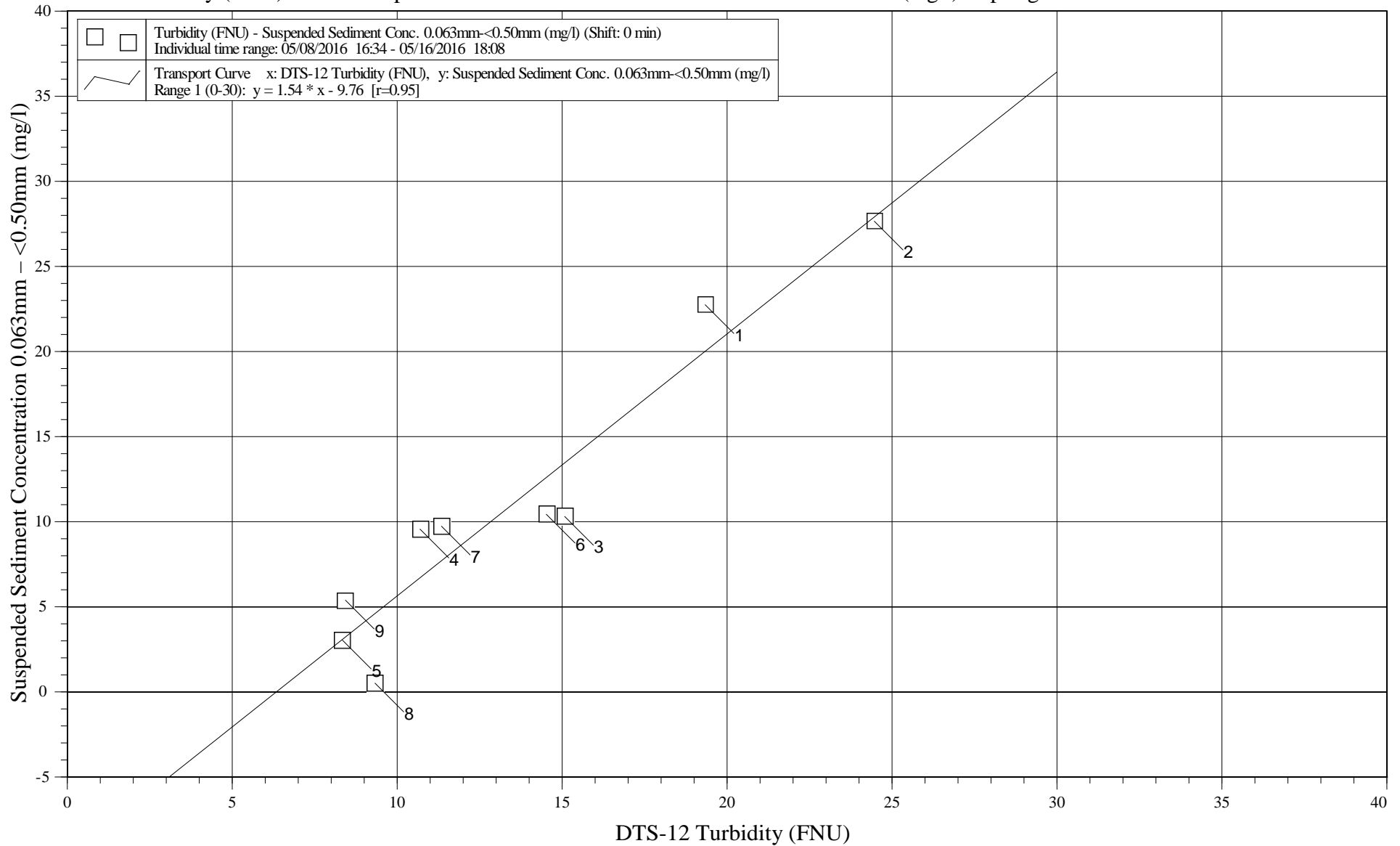


APPENDIX

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TRINITY RIVER BELOW LIMEKILN GULCH NEAR DOUGLAS CITY --11525655

Turbidity (FNU) Versus Suspended Sediment Concentration 0.063mm - <0.50mm (mg/l): Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

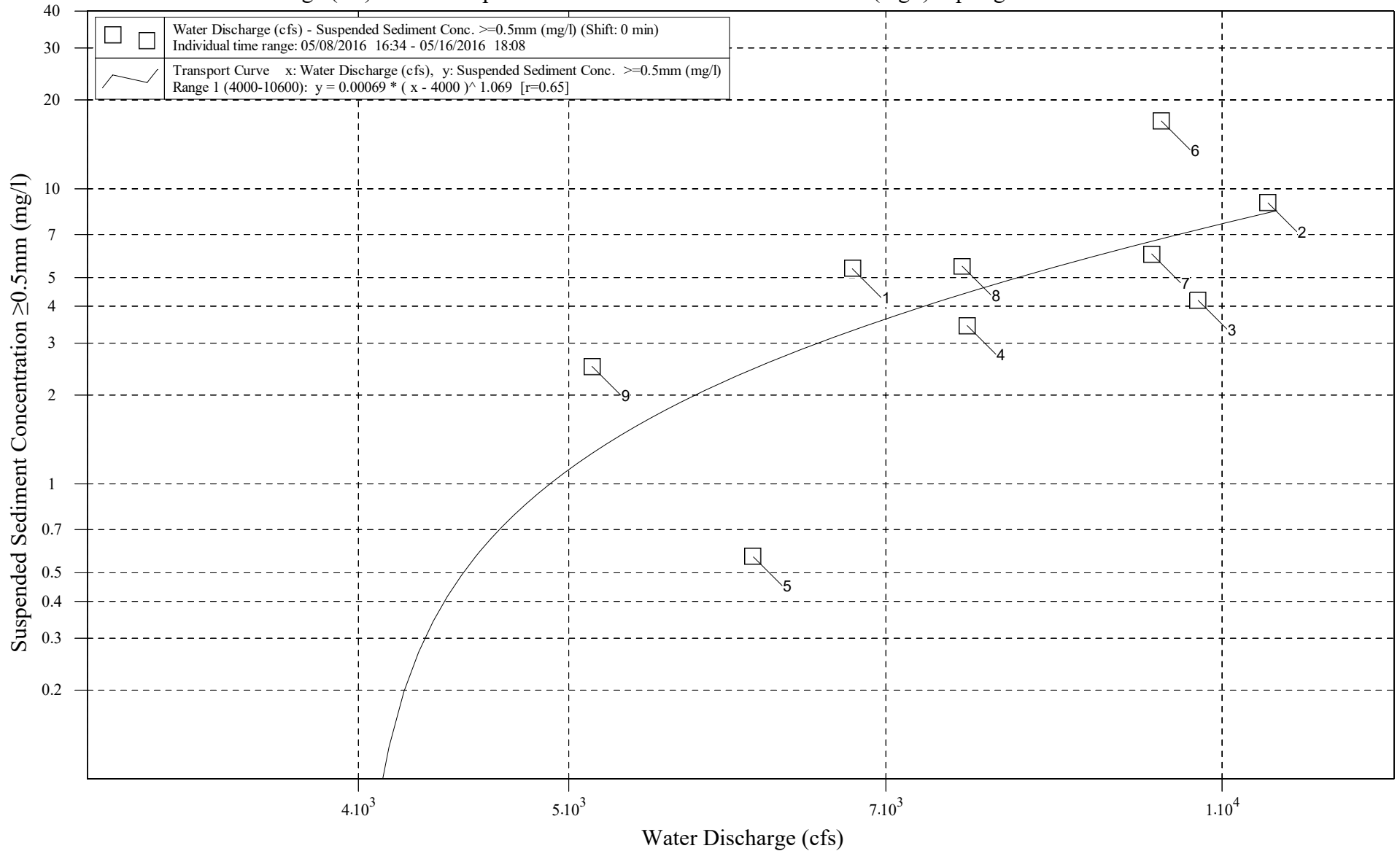


APPENDIX

C-3

TRINITY RIVER BELOW LIMEKILN GULCH NEAR DOUGLAS CITY --11525655

Water Discharge (cfs) Versus Suspended Sediment Concentration $\geq 0.5\text{mm}$ (mg/l): Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

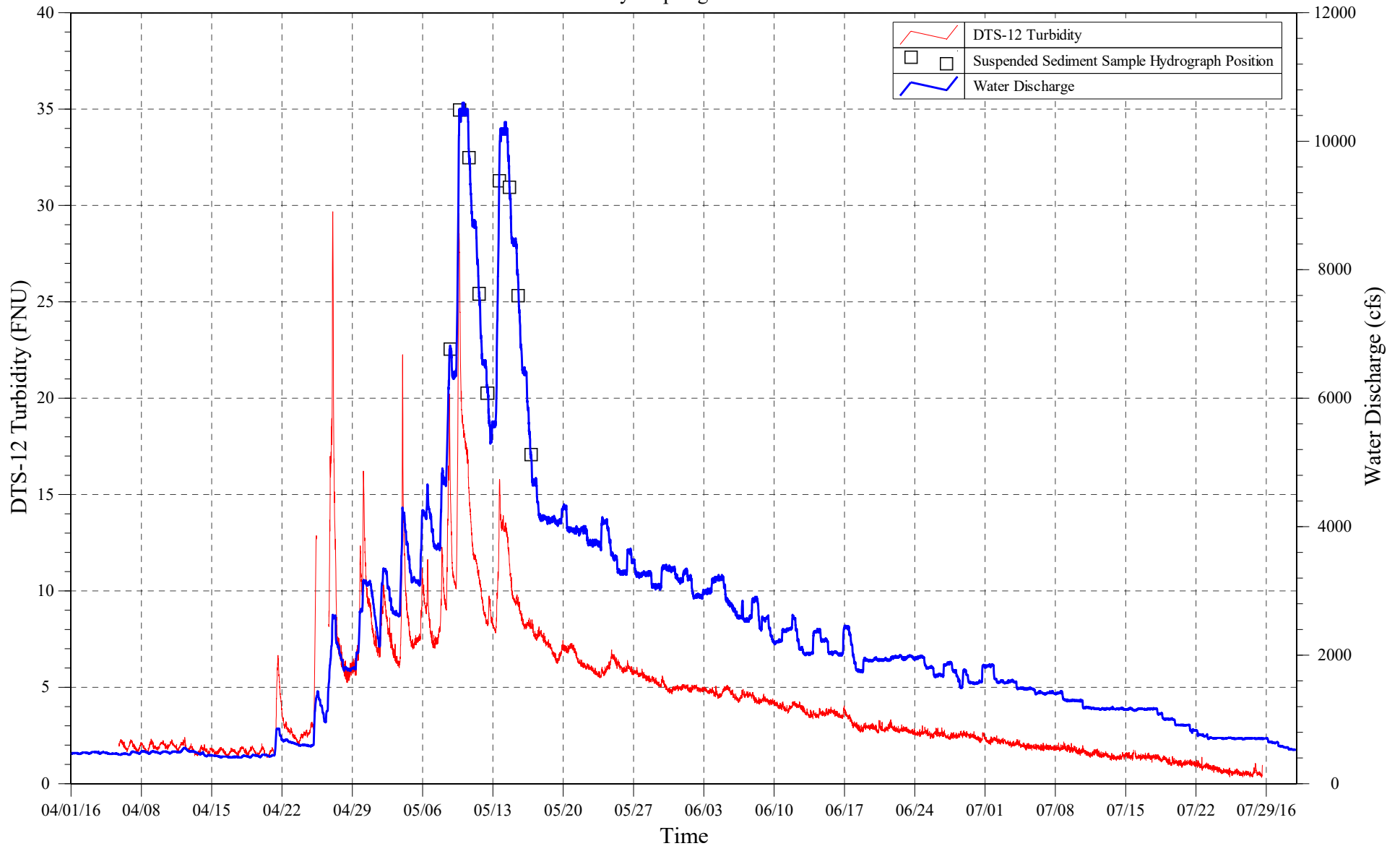


APPENDIX

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TRINITY RIVER BELOW LIMEKILN GULCH NEAR DOUGLAS CITY --11525655

DTS-12 Turbidity – Spring Flow Release WY 2016



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WY2016 SEDIMENT TRANSPORT MONITORING REPORT

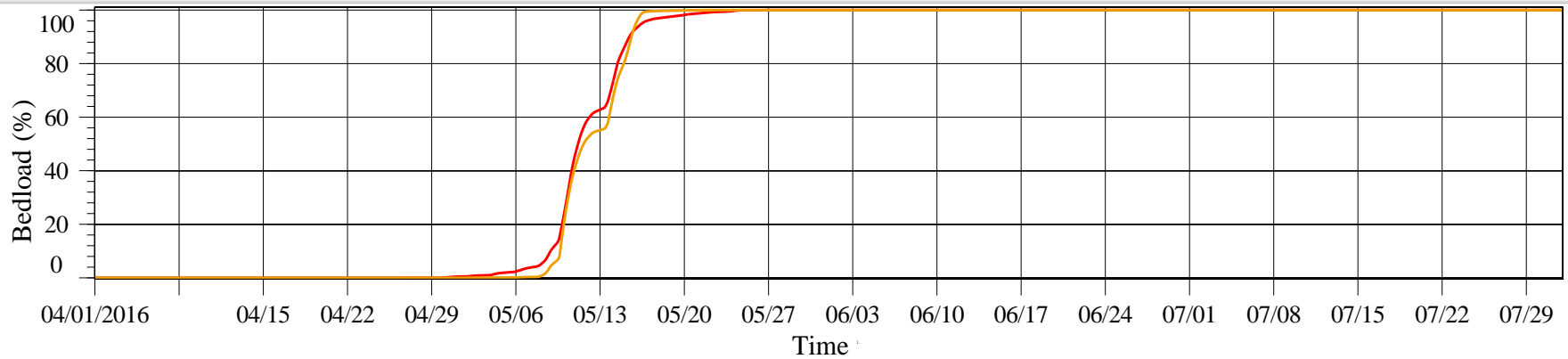
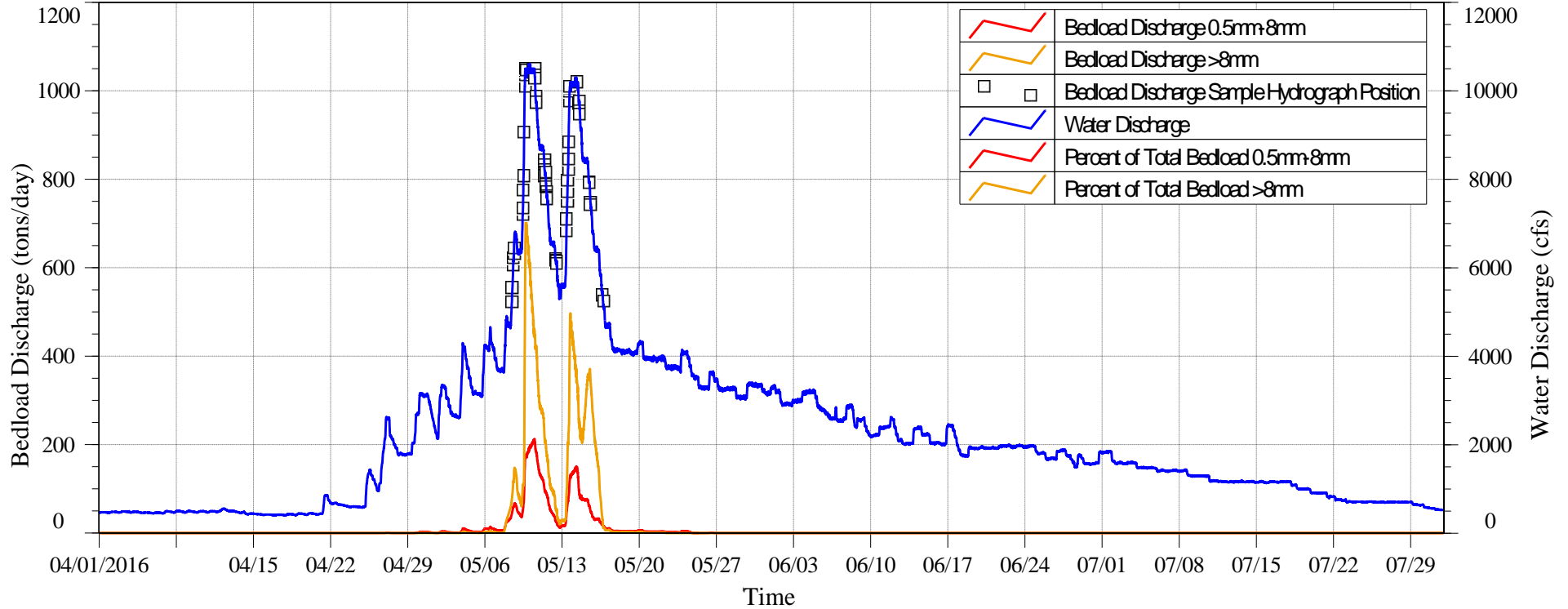


APPENDIX

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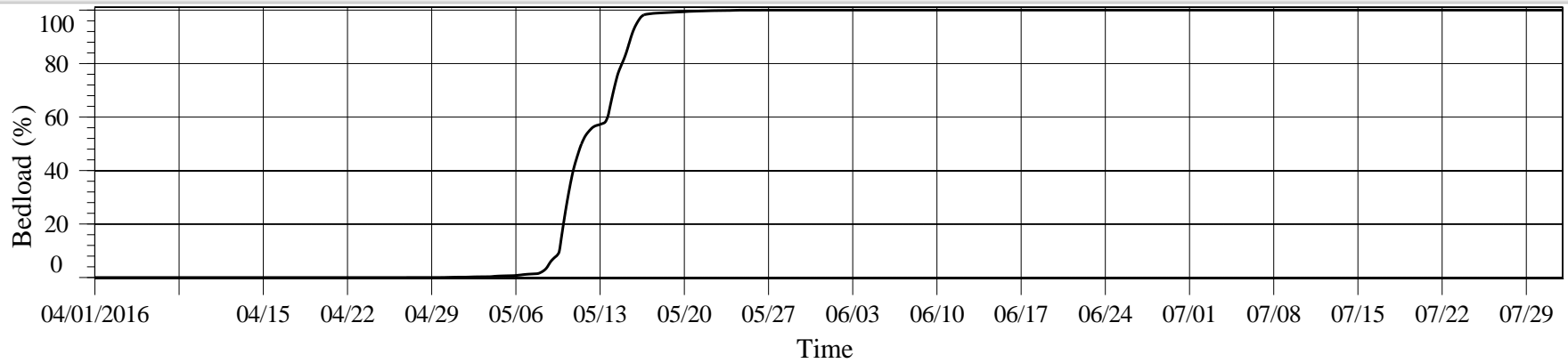
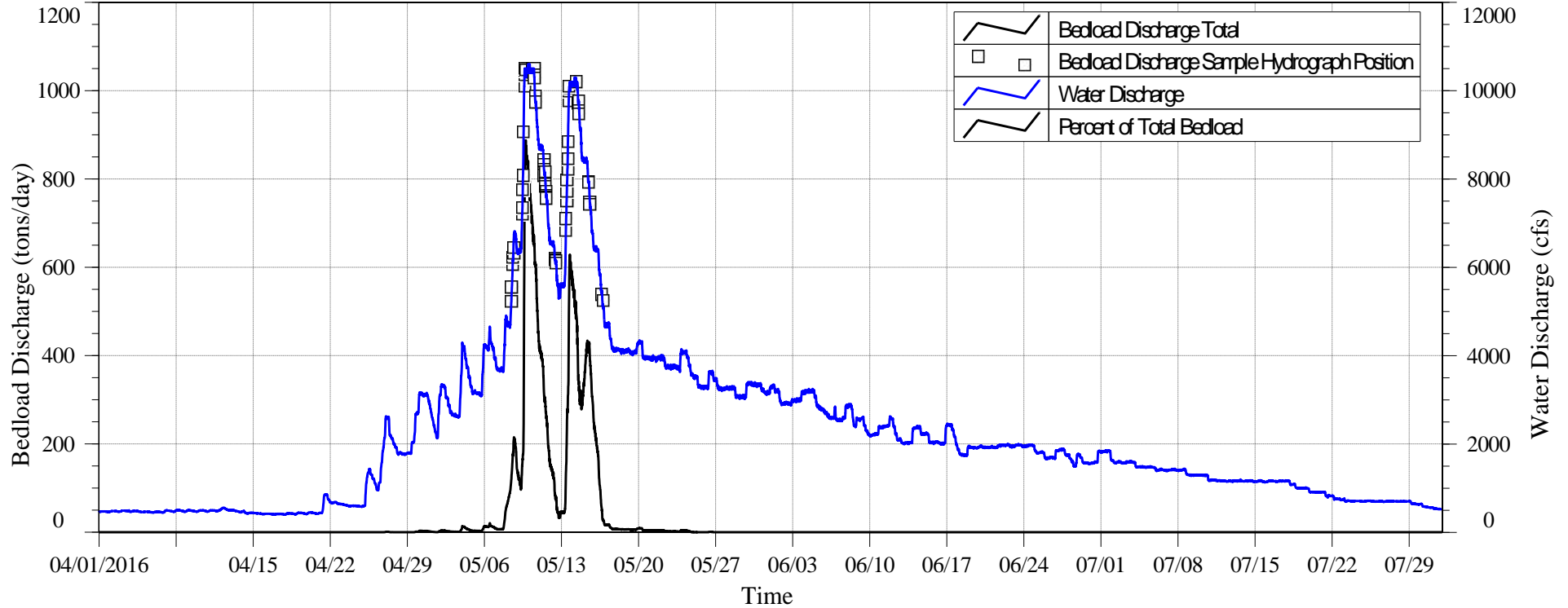
TRINITY RIVER BELOW LIMEKILN GULCH NEAR DOUGLAS CITY -11525655

Bedload Discharge – Spring Flow Release WY 2016



TRINITY RIVER BELOW LIMEKILN GULCH NEAR DOUGLAS CITY -11525655

Bedload Discharge – Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM
WY2016 SEDIMENT TRANSPORT MONITORING REPORT

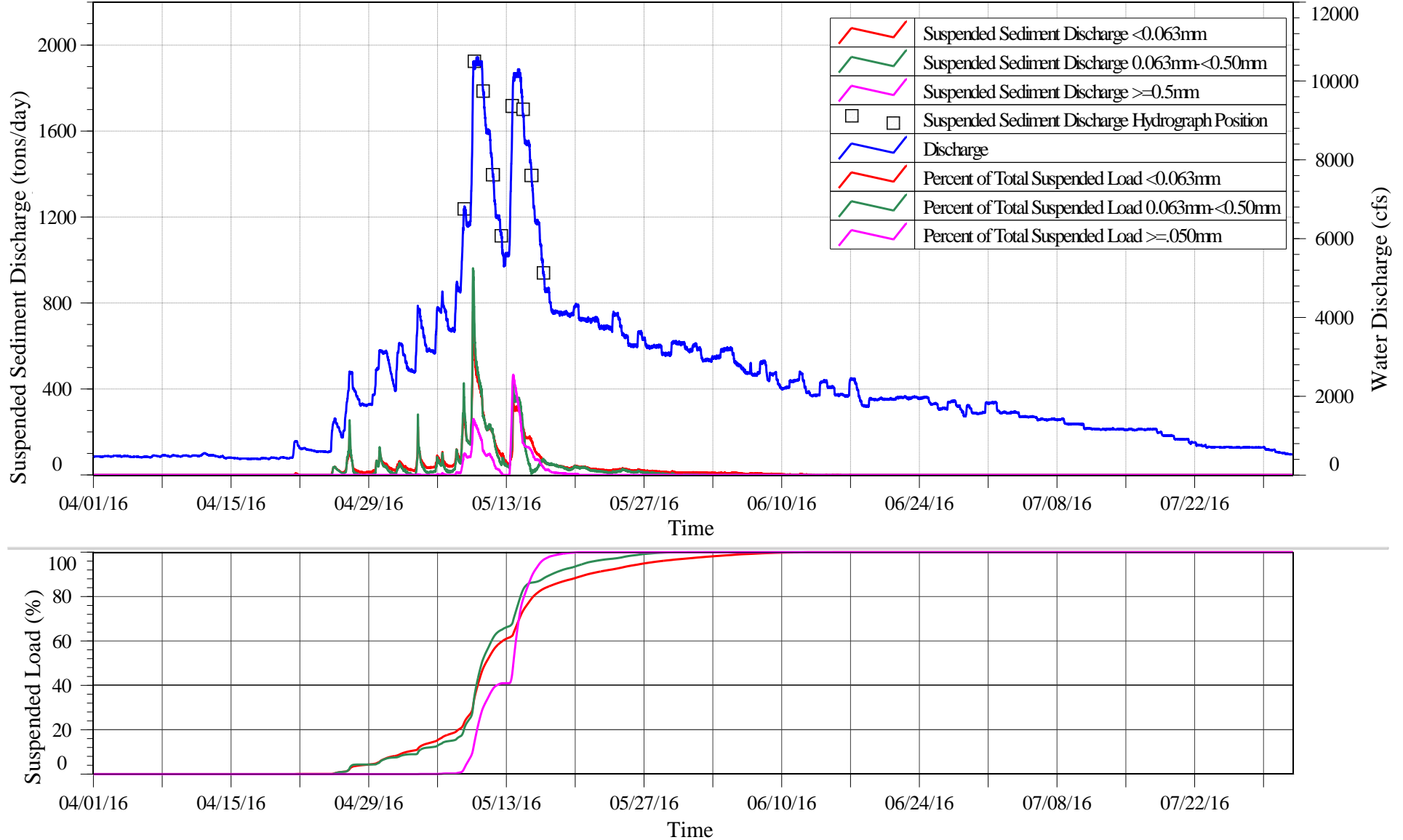


APPENDIX

C-5

TRINITY RIVER BELOW LIMEKILN GULCH NEAR DOUGLAS CITY -11525655

Suspended Sediment Discharge – Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

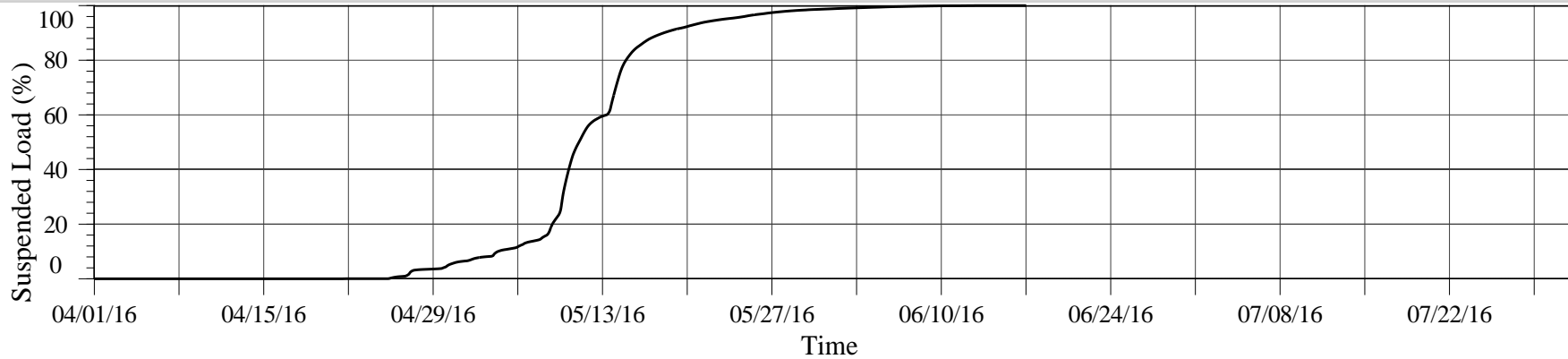
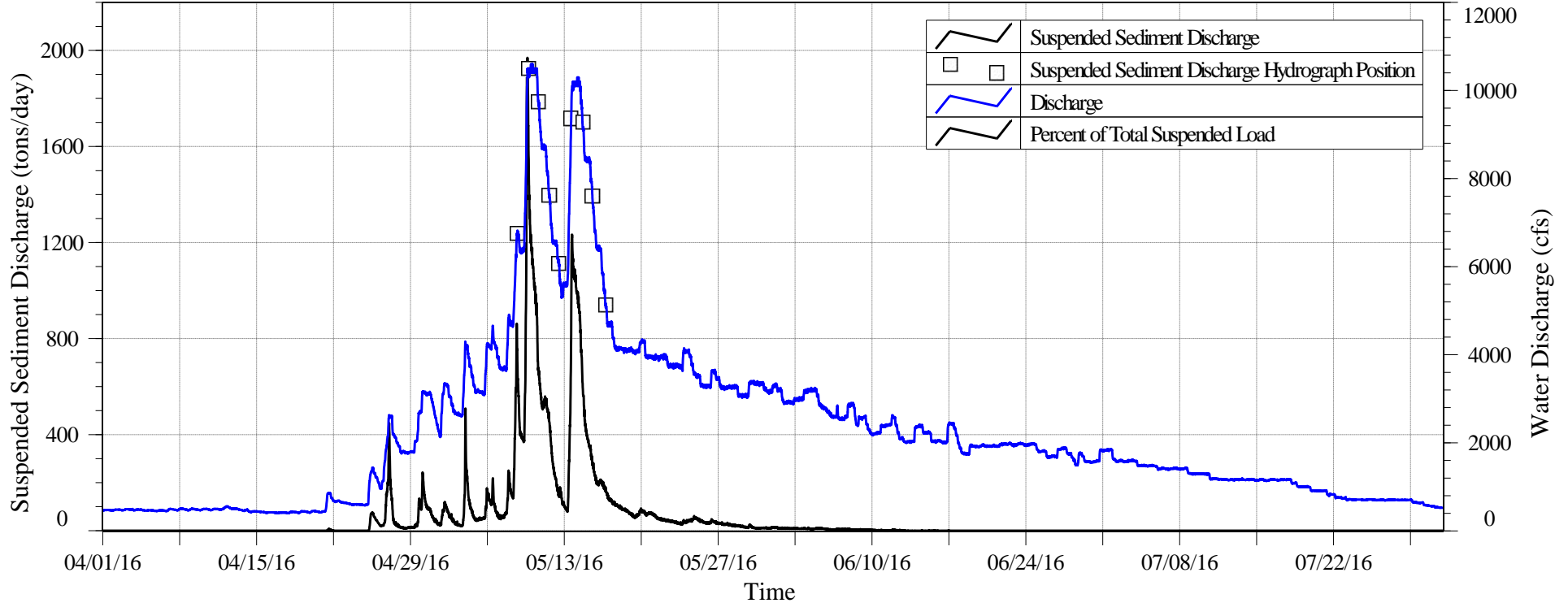


APPENDIX

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TRINITY RIVER BELOW LIMEKILN GULCH NEAR DOUGLAS CITY -11525655

Suspended Sediment Discharge – Spring Flow Release WY 2016



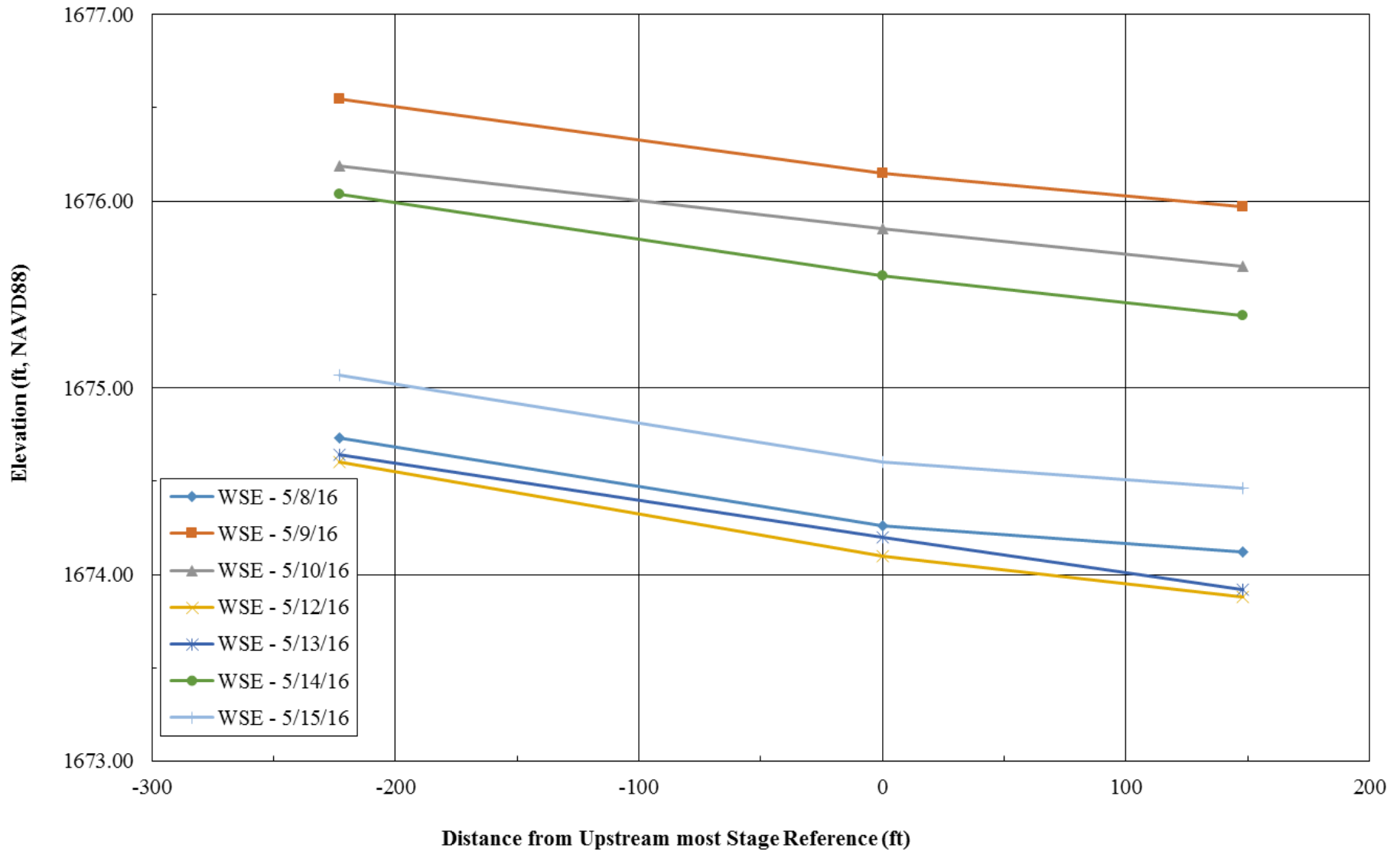
TRINITY RIVER RESTORATION PROGRAM
WY2016 SEDIMENT TRANSPORT MONITORING REPORT



APPENDIX

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**TRINITY RIVER BELOW LIMEKILN GULCH
WY 2016 Water Surface Slopes**



Appendix D

Trinity River near Douglas City
USGS Gage # 11525854

11525854 Trinity River at Douglas City, CA

TOTAL LOAD SEDIMENT DISCHARGE RECORD

Spring Flow Release WY 2016: (April 1 to July 31)

Records collected at station. -- Daily streamflow has been collected continuously since 1995 by the Hoopa Valley Tribe and since 2005 by USGS. Sediment sampling (flow release) has occurred in 2002 and 2004-13, 2015-16. Instantaneous water temperature data have been collected since 1992. A Forest Technology Systems DTS-12 turbidity probe collects continuous turbidity data during the spring flow release. The purpose for collecting sediment data at this site is to quantify sediment discharge delivered from this portion of the main stem, versus the sediment discharge measured at sediment collection stations upstream, notably Trinity River at Limekiln Gulch (11525655). This effort is part of a long-term study of sediment transport in the Trinity River, under the Trinity River Restoration Program (TRRP), sponsored by the U.S. Department of Interior, Bureau of Reclamation. This station analysis describes (1) sampling efforts during and (2) records computed from the WY 2016 spring flow release by GMA Hydrology (GMA), under contract to the TRRP.

Prior to the 2012 release, the section was moved to a location 225 ft downstream of the USGS gaging station. The Forest Technology Systems DTS-12 turbidity probe is now located at the USGS stream gage.

Equipment. -- Sampling equipment consists of a D-74 and DH-48 for suspended-sediment sampling, and a cable-deployed 12-inch x 6-inch Toutle River 2 bedload sampler (TR-2) with a 0.5mm mesh collection bag. The D-74 suspended-sediment sampler and the TR-2 sampler were deployed from a crane-mounted E-reel or B-Reel. Sampling was performed from a cataraft-based sampling platform attached to a temporary cableway. Stage references were installed near cableways. Photographs were taken with a digital camera.

Sampling program. -- Total (flow release) load season for this site is from April 1 to July 31. The program consisted of 9 sampling days. A minimum of three bedload-discharge sample and one suspended-sediment discharge sample was collected on each of the sampling days. The sampling days and samples collected are as follows:

May 08	6 bedload discharge	0 suspended-sediment discharge
May 09	8 bedload discharge	1 suspended-sediment discharge
May 10	6 bedload discharge	1 suspended-sediment discharge
May 11	7 bedload discharge	1 suspended-sediment discharge
May 12	4 bedload discharge	1 suspended-sediment discharge
May 13	8 bedload discharge	1 suspended-sediment discharge
May 14	6 bedload discharge	0 suspended-sediment discharge
May 15	6 bedload discharge	1 suspended-sediment discharge
May 16	2 bedload discharge	1 suspended-sediment discharge

Sampling crews consisted of two on-river personnel specifically trained in cataraft-based sediment data collection techniques and a safety kayaker. All samples were reviewed by the site technicians and individual analyses were standardized for suspended-sediment (concentration, particle size analysis) and bedload samples (total dry mass, particle size analysis). Sediment data were generally collected according to USGS protocols with the following exception: test-velocity ratings for sampler nozzles were occasionally exceeded. Suspended-sediment samples were sent to the GMA Suspended-Sediment Lab

and bedload samples were sent to the GMA Coarse-Sediment Lab, both located in Placerville, CA for analysis.

USGS Field Review. -- No USGS field review was conducted during the 2016 spring flow release.

Data summary for WY 2016 Spring Flow Release --

Total number of samples:	
Suspended sets	7
Single pass suspended samples	0
Box sample sets.....	0
Single box samples	0
Bedload sets	0
Single pass bedload samples	53
Three pass bedload samples	0
Number of field turbidities measured	0
Number of suspended sediment size analysis samples:	
Particle size analysis	0
0.063mm break	7
0.50mm break	7
Number of bedload sediment size analysis samples:	
Particle size analysis	53
Number of suspended sediment discharge measurements	7
Number of bedload discharge measurements	53
Number of visits by Field Office	0
Maximum flow sampled by:	
GMA technicians, ft ³ /s	11,000
Range of concentrations sampled by:	
GMA technicians, mg/l	17-230
GMA technicians, ton/d.....	116-4,930
Peak flow during flow release, ft ³ /s	11,100
Periods of faulty record	
Turbidity	
July 23, 2016 at 06:15 to August 17, 2016 at 17:15	

Coefficients -- None used.

Continuous Turbidity-- The turbidity record is incomplete for the computational period. At the end of the 2015 spring flow release the turbidity probe at the site was removed for calibration. The probe was reinstalled April 4, 2016, however vandalism was discovered at the site and a new probe wire was not installed until April 27, 2016 at 13:30. Additionally, erroneous turbidity data was removed from the record from July 23, 2016 at 06:15 to August 17, 2016 at 17:15, when the probe was out of the water.

Once the turbidity record was cleaned, the record was inspected to determine if a turbidity offset was necessary. An offset of -3.0 FNU was applied to the entire record.

During the computational period the maximum turbidity was 66.2 FNU on May 9 at 16:30, and the minimum turbidity was 0.00 FNU, which occurred on July 22, 2016 at 17:30.

Total suspended sediment-discharge computations -- Total suspended-sediment discharge was computed by summing the partial suspended-sediment discharges.

Size analysis -- Seven cross-sectional, depth-integrated samples were analyzed using a split at 0.063mm and ≥ 0.50 mm.

Partial suspended sediment-discharge computations -- Turbidity versus SSC and discharge versus SSC transport curves were inspected for use during the period. For all size classes, turbidity showed a good relation with SSC and was used for transport curve development. Generalized transport curves were developed using all samples collected during Water Year 2016. No outliers were identified.

For the <0.63 mm size class, the turbidity versus SSC transport curve is defined by Eqn. (1).

$$SSC = 0.449 * Turbidity + 0, \quad (1)$$

Eqn. (1) is used from April 27 at 13:30 hours to July 23 at 07:00 hours. Eqn. (1) has a validated range between 11.2 FNU and 63.4 FNU, and was forced through 0. The turbidity record doesn't reach 0.0 on the rising limb, so zero transport, for the <0.063 mm size class was estimated during sedigraph analysis at 710 cfs. For the falling limb, zero transport occurs at 0.0 FNU and was determined during transport curve development.

For the 0.063 mm- <0.50 mm size class, the turbidity versus SSC transport curve is defined by Eqn. (2) and Eqn. (3).

$$Turbidity < 31.1 \text{ FNU} \quad SSC = 1.96 * Turbidity - 14.9, \quad r^2 = 0.99 \quad (2)$$

$$Turbidity \geq 31.1 \text{ FNU} \quad SSC = 3.21 * Turbidity - 54.3, \quad r^2 = 1.0 \quad (3)$$

Eqn. (2) and Eqn. (3) were used from April 27 at 13:30 hours to July 23 at 07:00 hours and have a validated range between 11.2 FNU and 63.4 FNU. The turbidity record doesn't reach 0.0 on the rising limb, so zero transport was estimated during sedigraph analysis at 710 cfs. Zero transport for the falling limb was estimated by fitting the sedigraph to sample 2015-07 and occurs at 7.78 FNU.

For the ≥ 0.5 mm size class the turbidity versus SSC transport curve developed for the computational period is defined by Eqn. (4) and Eqn. (5).

$$Turbidity < 18.6 \text{ FNU} \quad SSC = 2.05 * Turbidity - 14.7, \quad r^2 = 0.76 \quad (4)$$

$$Turbidity \geq 18.6 \text{ FNU} \quad SSC = 0.67 * Turbidity + 11.2, \quad r^2 = 0.92 \quad (5)$$

Eqn. (4) and Eqn. (5) were used from April 27 at 13:30 hours to July 23 at 07:00 hours and have a validated range between 11.2 FNU and 63.4 FNU. The turbidity record doesn't reach 0.0 on the rising limb, so zero transport was estimated during sedigraph analysis at 710 cfs. Zero transport for the falling limb was estimated by fitting the sedigraph to sample 2015-07 and occurs at 9.40 FNU.

The transport curves were used to develop continuous concentration curves for the <0.063 mm, 0.063 mm- <0.50 mm, and the ≥ 0.5 mm size classes during the computational period. Once the continuous concentration data had been developed the sample data were used to adjust the continuous concentration curves so that they passed through all sample points. The continuous concentration curves were adjusted using fitting and proportional fitting techniques.

Proportional fitting calculates the ratio between two sequential sample values and then scales the appropriate time series (e.g. continuous SSC) by this ratio. When applied between sequential pairs of data, the ratio is decayed or increased linearly to match the end-points. Fitting and proportional fitting techniques recognize short-term correlations and address hysteresis effects by using subsets of data. When only a single sample exists on a flow bench, the proportional fitting technique assumes that the determined ratio applies for the duration of that flow bench. When SSC is not highly correlated with discharge or turbidity, it is not possible to evaluate this assumption and therefore it is a potential source of error

Suspended-sediment discharge was computed directly from the continuous concentration once the continuous concentration data had been checked and its accuracy verified.

Bed material -- None.

Bedload measurement – Fifty-three bedload samples were collected during the Spring Flow Release. All were single pass samples.

Bedload-discharge computations -- The sample analysis contains the portion of sample <0.5mm but the total bedload discharge was determined by summing the partial discharges for the ≥0.5mm-8mm and the ≥8mm size fractions.

Partial Bedload-discharge computations -- Sediment transport curves were developed and partial bedload discharges were computed for the 0.5mm-8mm and ≥8mm size classes. 2016 had a double peak hydrograph and sample data was analyzed for the entire year, with each peak broken out separately and for rise and fall patterns of hysteresis.

For the 0.5mm-<8mm size class, no obvious patterns of hysteresis or changes in transport rates between the two peaks were observed so a single generalized transport curve was developed and is shown in Eqn. (6). No outliers were identified

$$BLD = 4.74 * Discharge^{3.27}, \quad r^2 = 0.94 \quad (6)$$

The transport curve is used from April 1 at 00:00 hours through July 31 at 23:45 hours. The transport curve has a validated range between 6,040 cfs and 11,000 cfs. Zero transport for the rising limb was estimated during transport curve development and occurs at 2,200 cfs. The falling limb zero transport was determined by fitting the sedigraph to sample 53 and occurs at 4,510 cfs.

For the ≥8mm size class, the transport curve developed for use during the computational period is defined by Eqn. (7).

$$BLD = 1.31e - 011 * Discharge^{3.49}, \quad r^2 = 0.73 \quad (7)$$

The transport curve is used from April 1 at 00:00 hours through July 31 at 23:45 hours. The transport curve has a validated range between 6,040 cfs and 11,000 cfs. Zero transport for the rising limb was estimated during transport curve development and occurs at approximately 2,800 cfs. The falling limb zero transport was determined by fitting the sedigraph to sample 53 and occurs at 6,090 cfs.

Once the continuous bedload-discharge traces were developed using the above transport curves, they were adjusted using the sample values using the same techniques as was described for the partial suspended-sediment discharge computations. Due to the inherent high variability in bedload sampling, during flow benches, sample values were averaged on days where multiple samples were collected to

produce average transport values. These average transport values were used to adjust the continuous bedload transport trace.

Remarks. – The suspended sediment discharge record is rated as follows:

April 1 (00:00) to May 7 (23:45)	Estimated
May 8 (00:00) to May 16 (23:45)	Good
May 17 (00:00) to July 31 (23:45)	Estimated

The bedload discharge record is rated as follows:

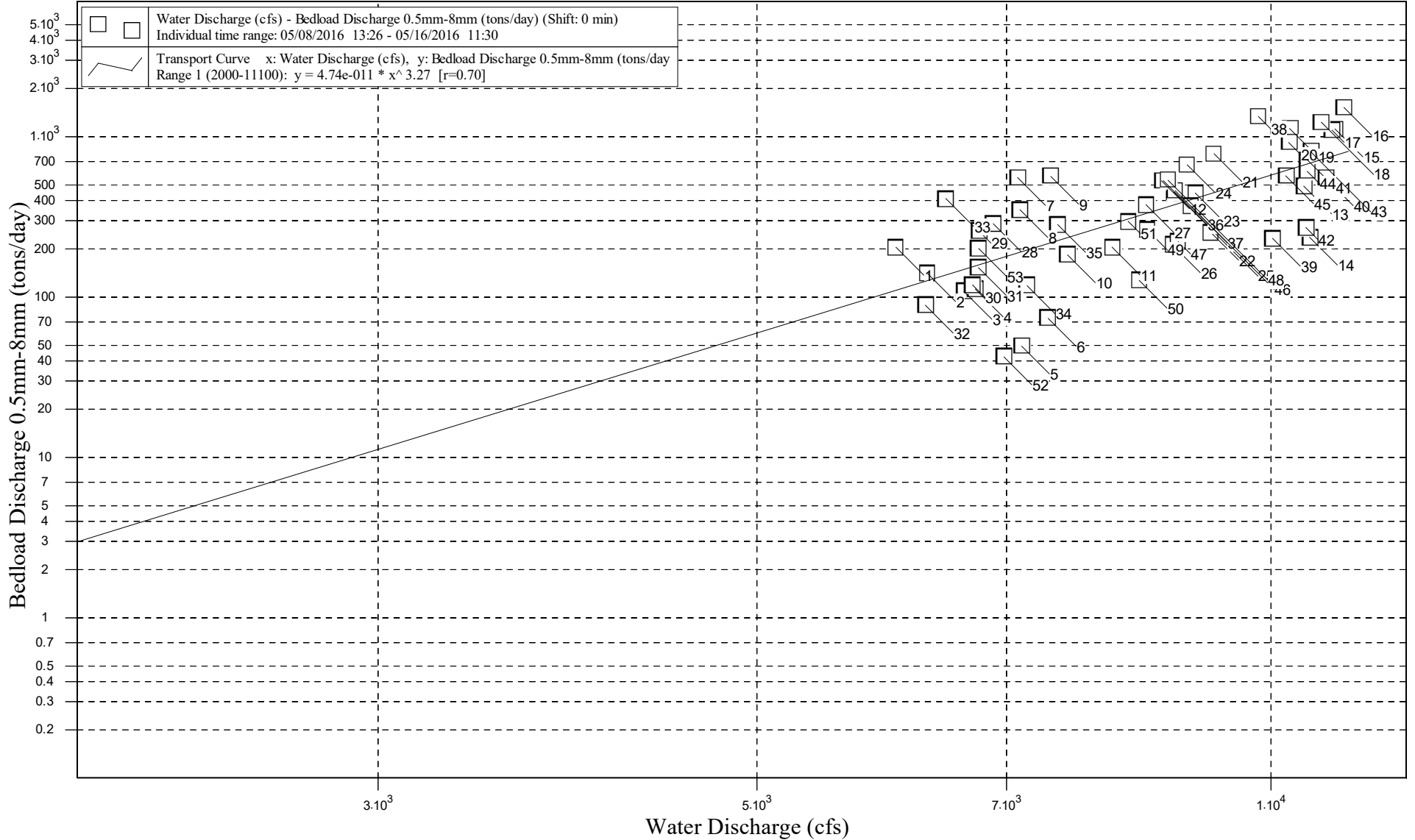
April 1 (00:00) to May 7 (23:45)	Estimated
May 8 (00:00) to May 16 (23:45)	Good
May 17 (00:00) to July 31 (23:45)	Estimated

Computed by: Brooke Pittman, December 2016

Reviewed by: Smokey Pittman, January 2017

TRINITY RIVER AT DOUGLAS CITY --11525854

Water Discharge (cfs) Versus Bedload Discharge 0.5mm-<8mm (tons/day): Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

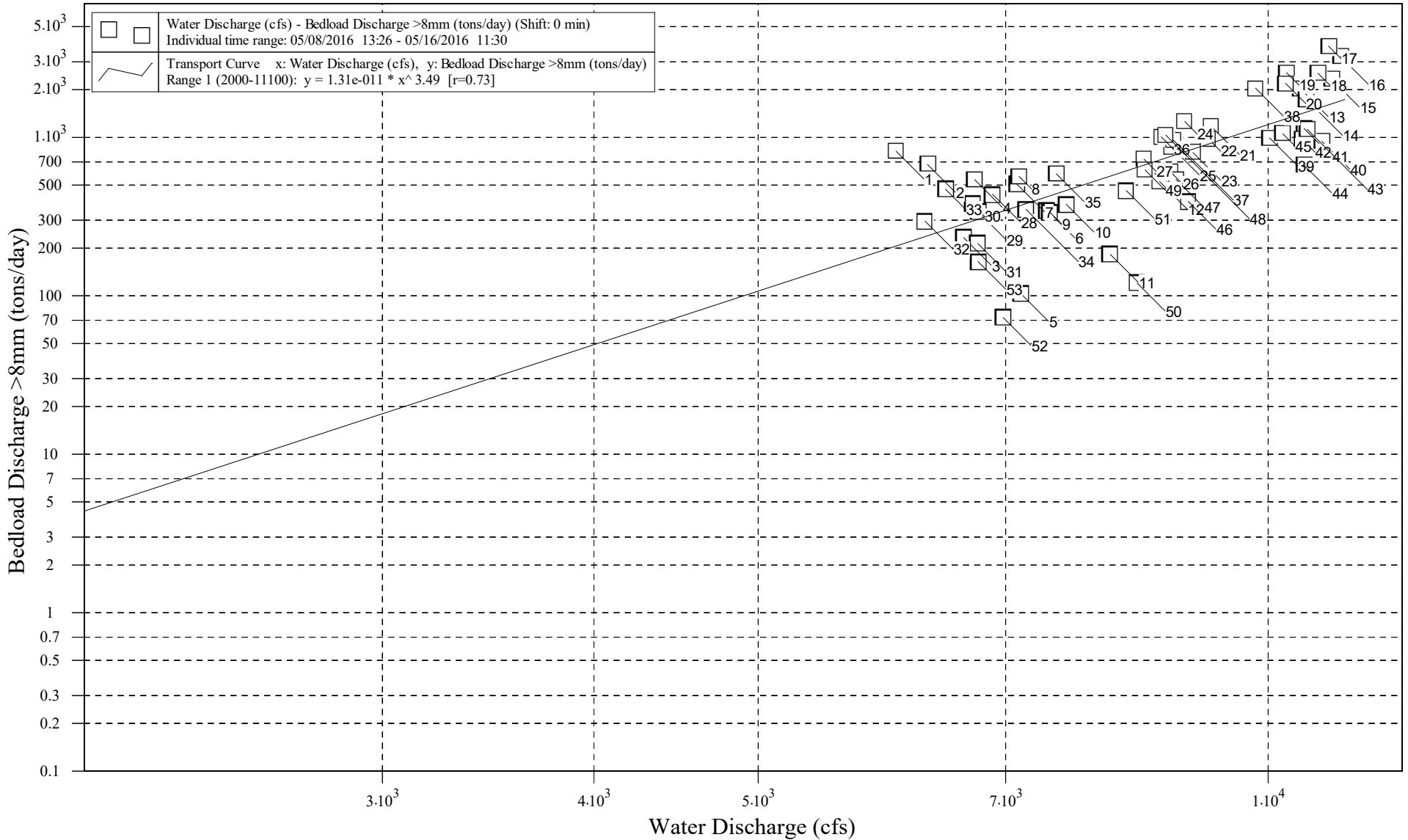


APPENDIX

D-2

TRINITY RIVER AT DOUGLAS CITY --11525854

Water Discharge (cfs) Versus Bedload Discharge $\geq 8\text{mm}$ (tons/day): Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

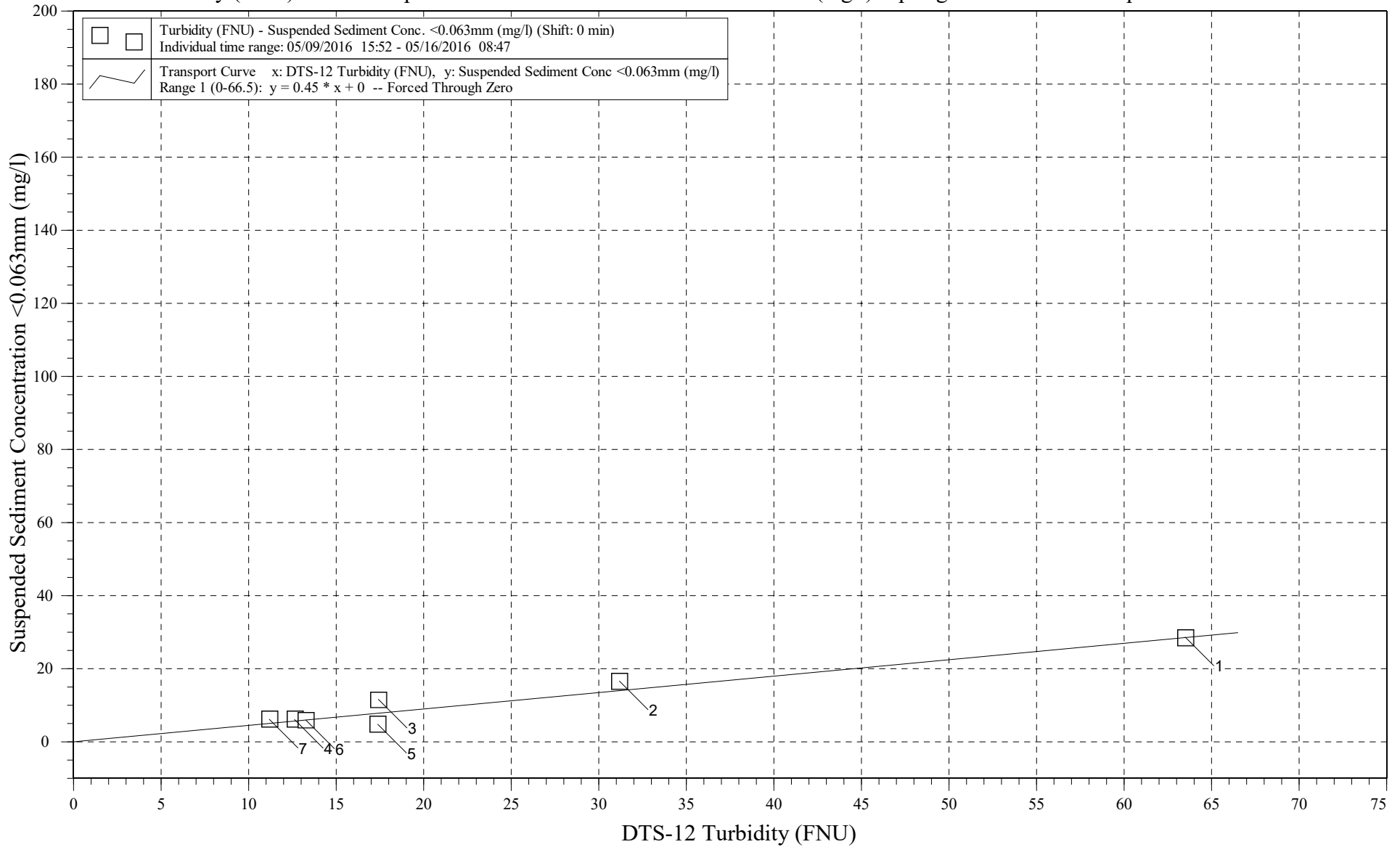


APPENDIX

D-2

TRINITY RIVER AT DOUGLAS CITY -115525854

Turbidity (FNU) Versus Suspended Sediment Concentration <0.063mm (mg/l): Spring Flow Release Samples WY2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

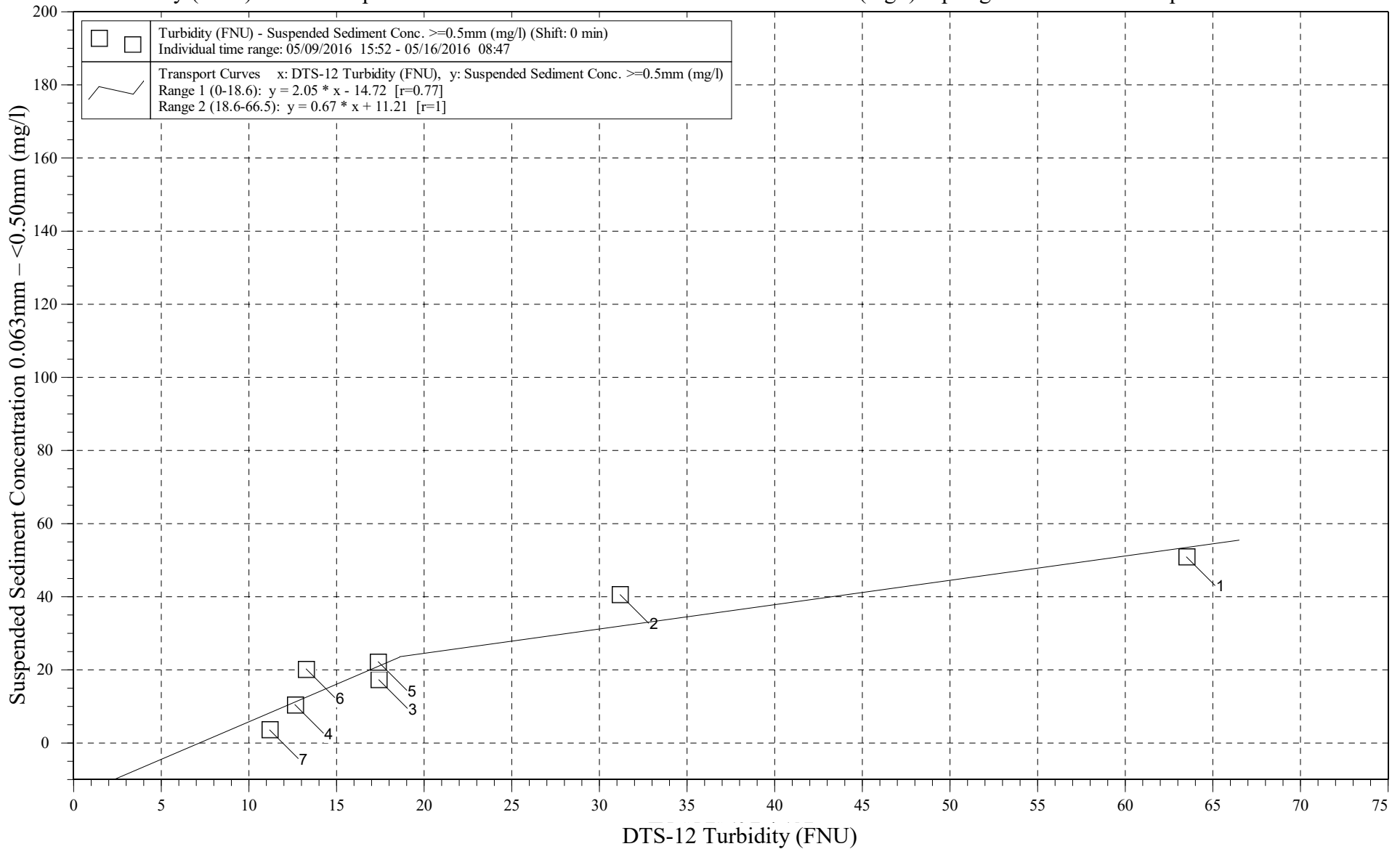


APPENDIX

D-3

TRINITY RIVER AT DOUGLAS CITY -115525854

Turbidity (FNU) Versus Suspended Sediment Concentration 0.063mm-<0.50mm (mg/l): Spring Flow Release Samples WY2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

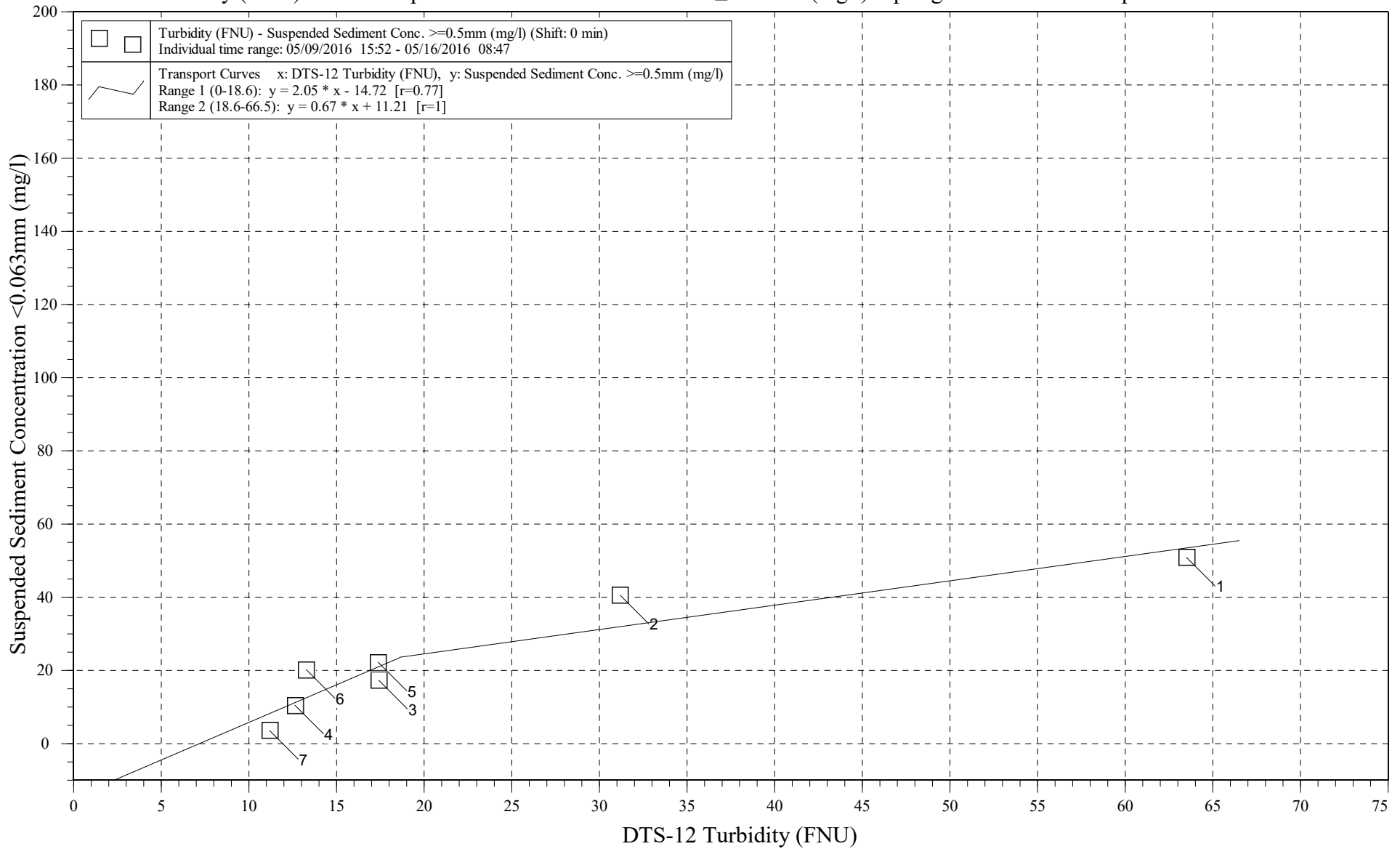


APPENDIX

D-3

TRINITY RIVER AT DOUGLAS CITY -115525854

Turbidity (FNU) Versus Suspended Sediment Concentration $\geq 0.50\text{mm}$ (mg/l): Spring Flow Release Samples WY2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

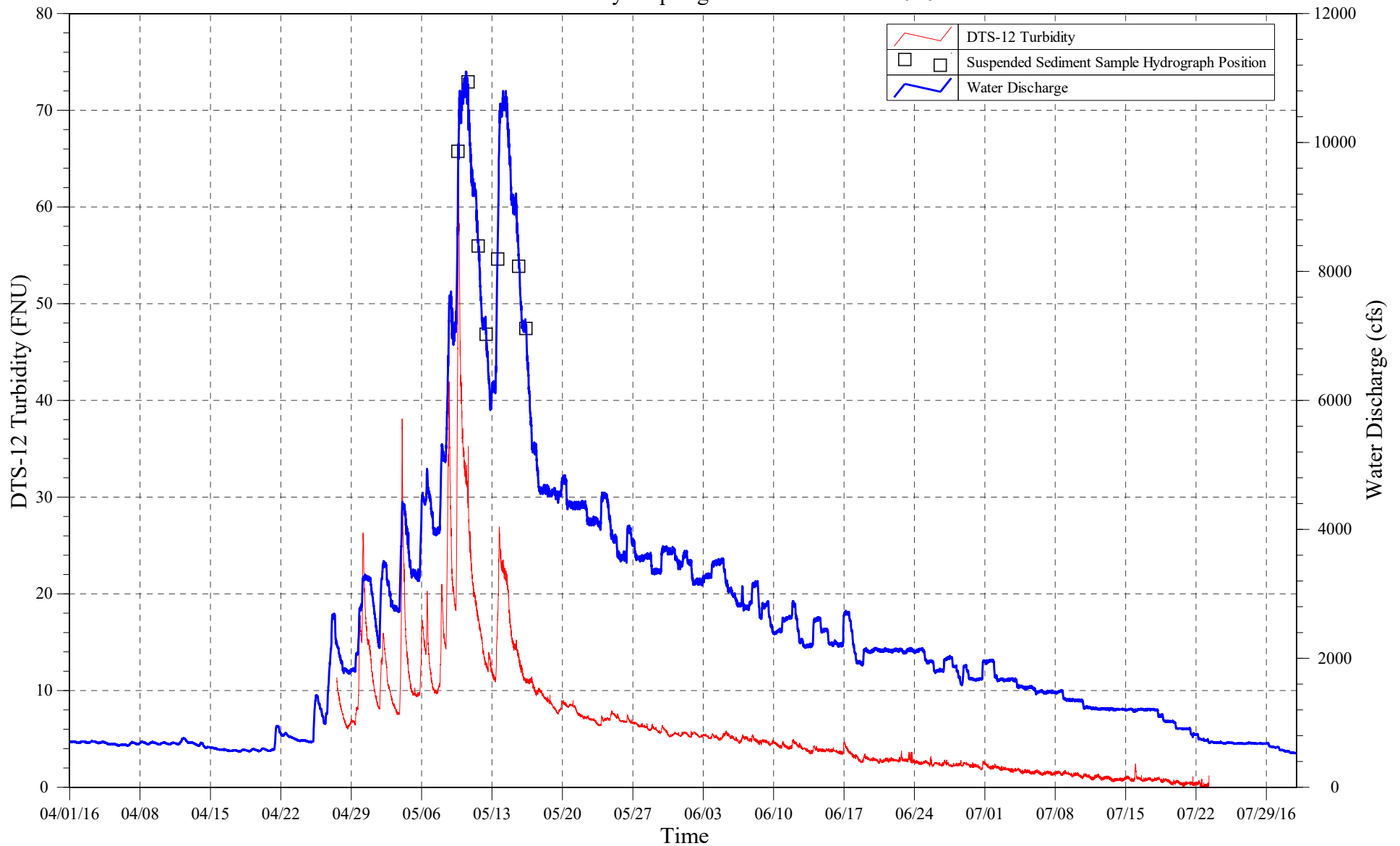


APPENDIX

D-3

TRINITY RIVER AT DOUGLAS CITY -115525854

DTS-12 Turbidity – Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

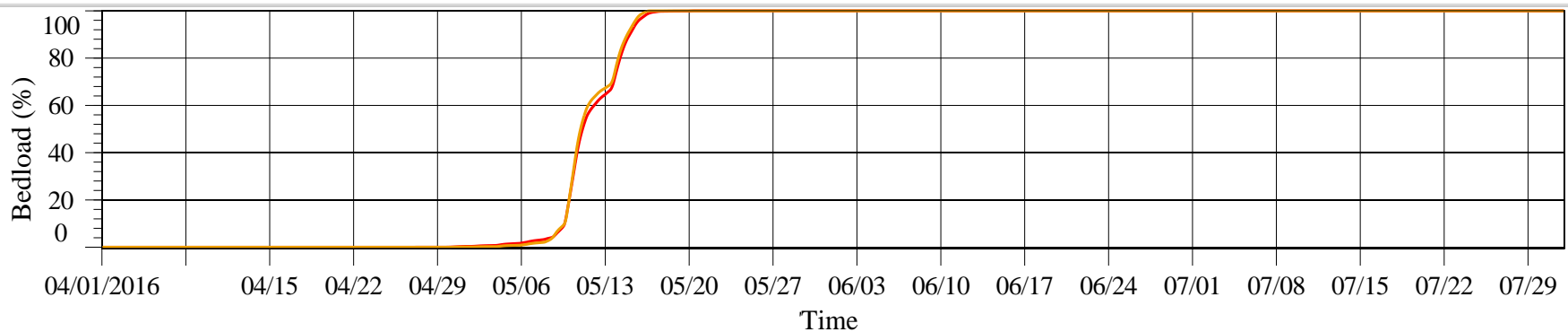
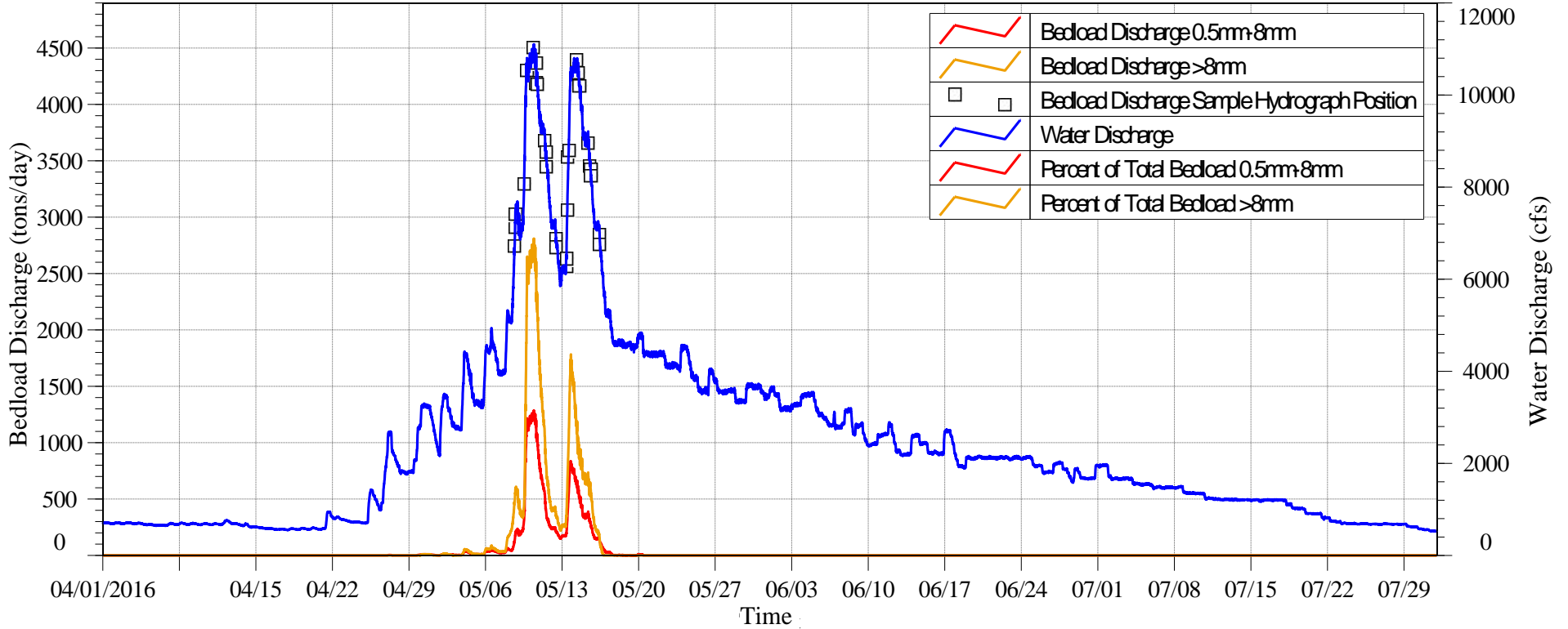


APPENDIX

D-4

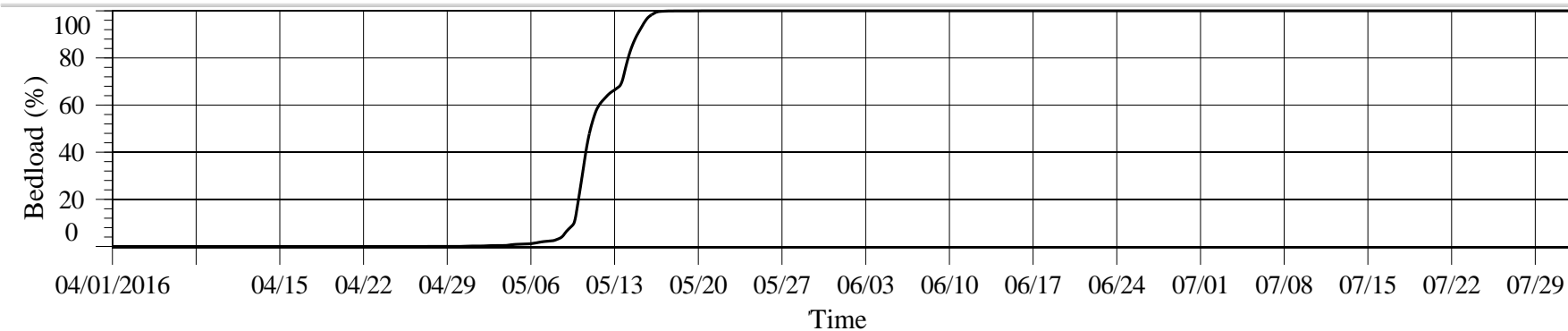
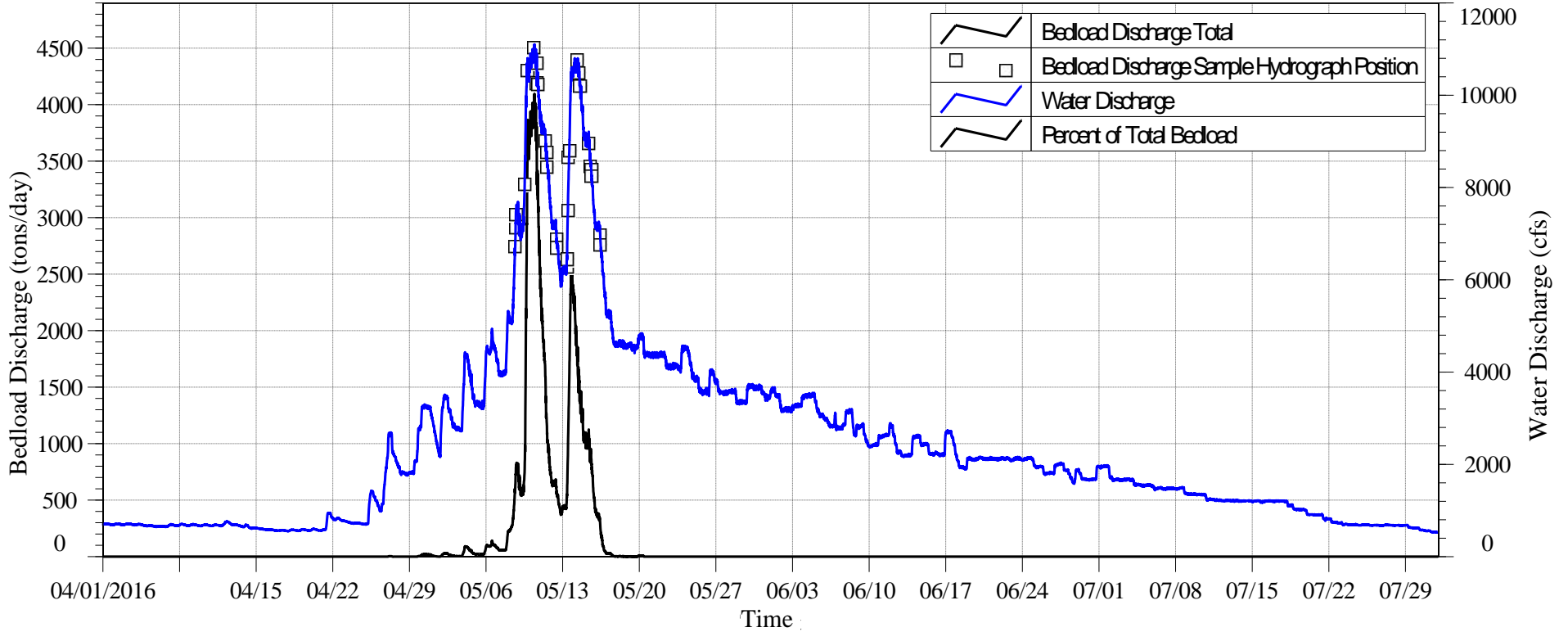
TRINITY RIVER AT DOUGLAS CITY -115525854

Bedload Discharge – Spring Flow Release WY 2016



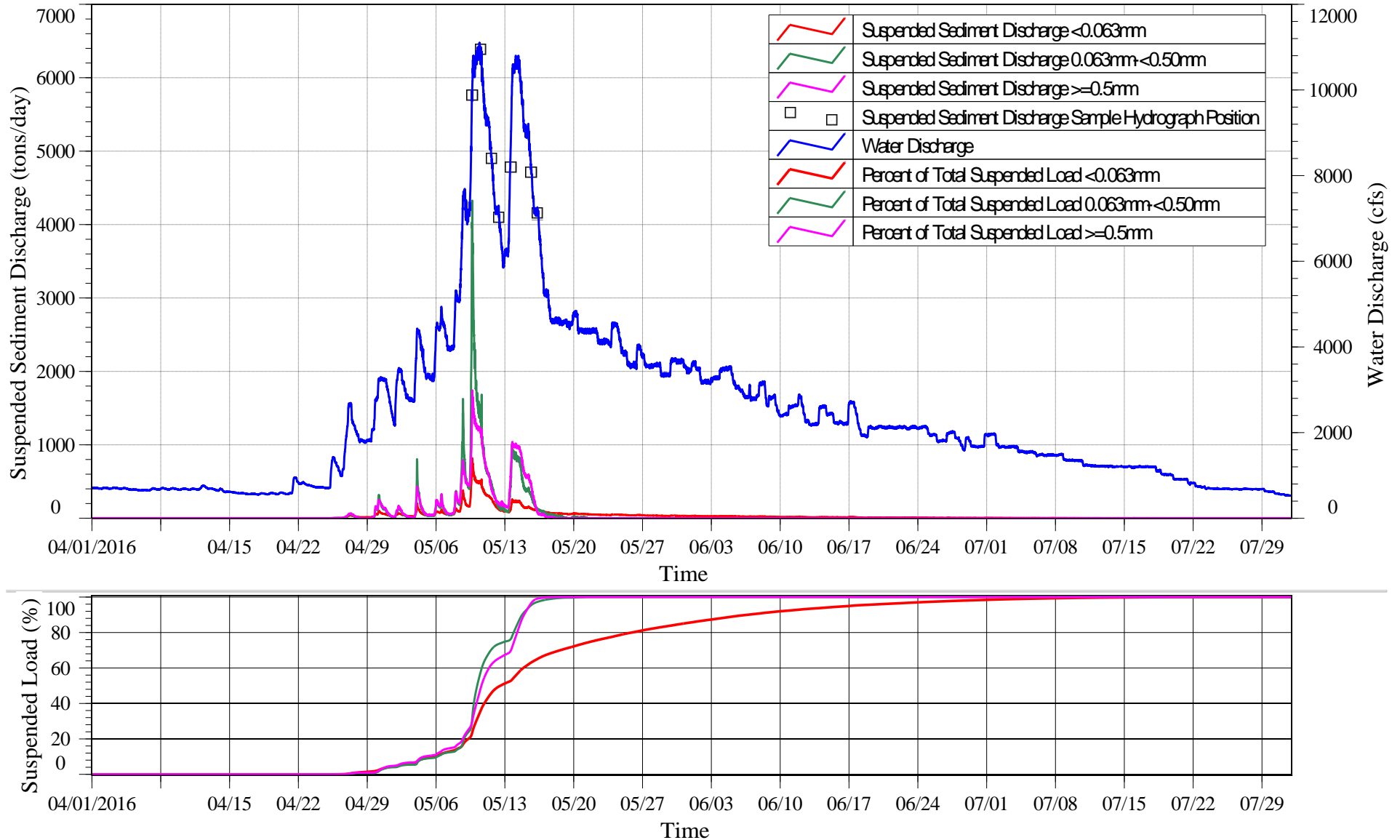
TRINITY RIVER AT DOUGLAS CITY -115525854

Bedload Discharge – Spring Flow Release WY 2016



TRINITY RIVER AT DOUGLAS CITY -115525854

Suspended Sediment Discharge – Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM

WY2016 SEDIMENT TRANSPORT MONITORING REPORT

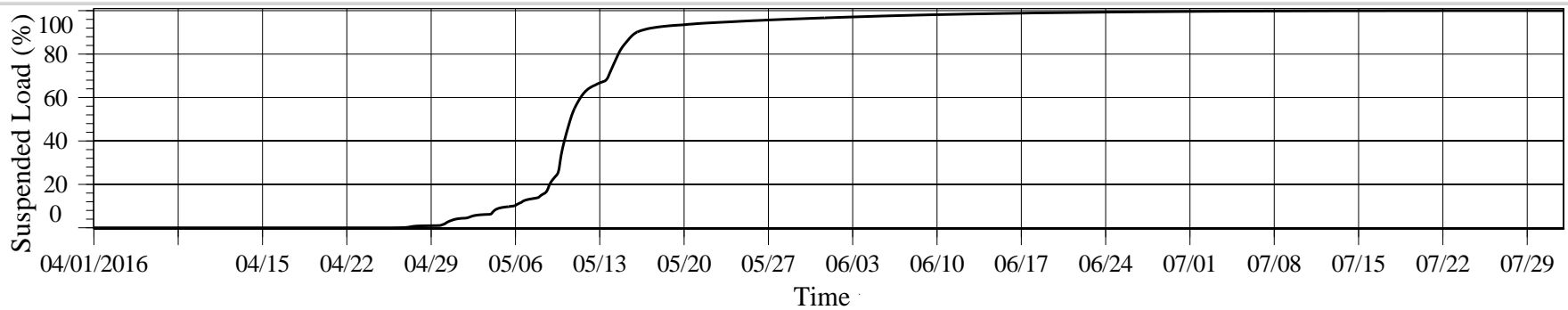
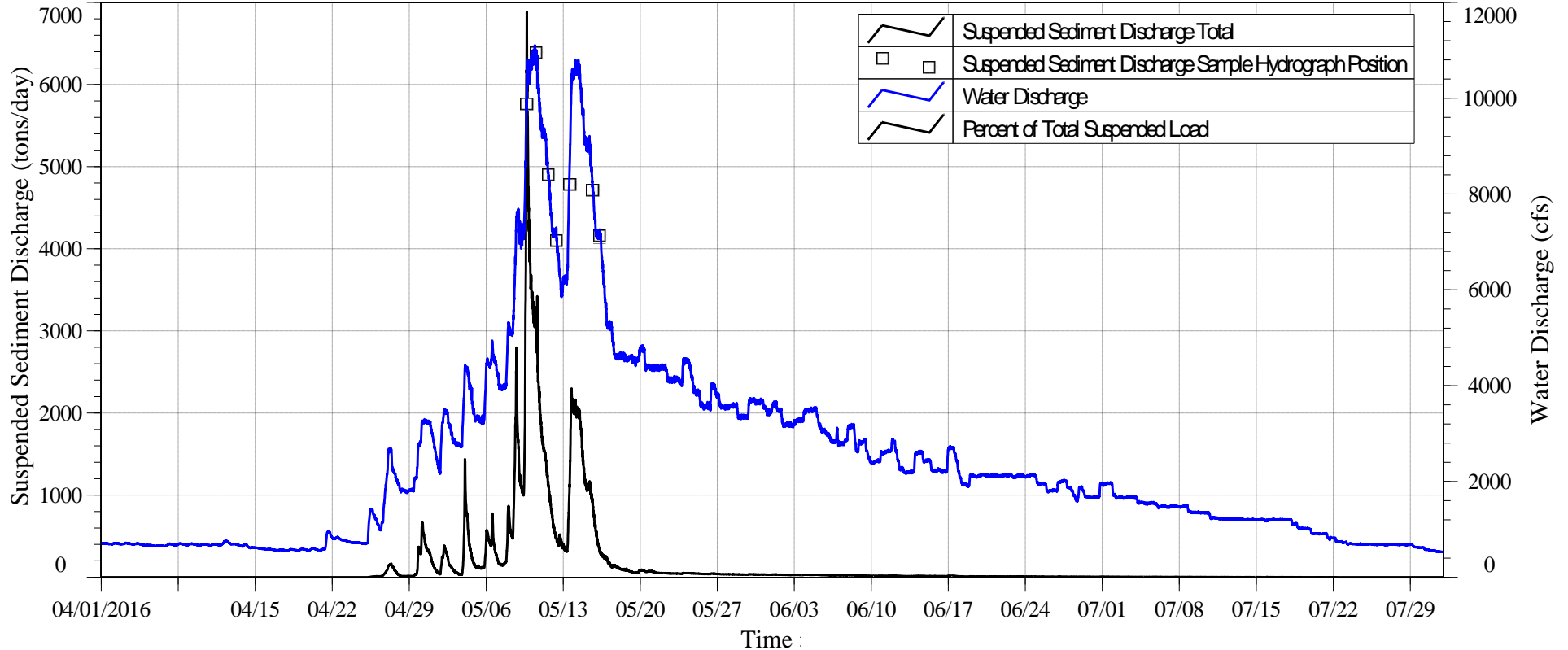


APPENDIX

D-6

TRINITY RIVER AT DOUGLAS CITY -115525854

Suspended Sediment Discharge – Spring Flow Release WY 2016



TRINITY RIVER RESTORATION PROGRAM
WY2016 SEDIMENT TRANSPORT MONITORING REPORT



APPENDIX

D-6

**TRINITY RIVER NEAR DOUGLAS CITY
WY 2016 Water Surface Slopes**

