Seasonal Progress Report #3

SR431 Treatment Vault Effectiveness Monitoring

Agreement Number: P423-13-019

Submitted by: Tahoe Resource Conservation District

Submitted to: Nevada Department of Transportation

Period: Summer Season, June 1 – September 30, 2016

Submission Date: October 31, 2016

Two stormwater treatment vaults, a Contech MFS and a Jellyfish, were installed by the Nevada Department of Transportation (NDOT) on State Highway 431 (SR431) above Incline Village, Nevada. Monitoring equipment was installed at the inflows and outflows of these two vaults. The Tahoe Resource Conservation District (Tahoe RCD) took over effectiveness monitoring at the four monitoring stations on May 1, 2015 and will continue to monitor through the end of water year 2016 (September 30, 2016). The Tahoe RCD follows sampling protocols outlined in the Regional Stormwater Monitoring Program Framework and Implementation Guidance document (RSWMP FIG, Tahoe RCD et al 2015).

The Tahoe RCD appreciates the opportunity to provide these water quality monitoring services for NDOT and looks forward to continuing the partnership.

Tasks and subtasks associated with this project and a summary of work completed to date are described below. Table 1 provides due dates and percent completion to date for each task.

Task 1: Project Administration

1. Invoices

    Six invoices will be submitted for this project covering the following periods:
    #1: May 1, 2015 – September 30, 2015
    #2: October 1, 2015 – December 31, 2015
    #3: January 1, 2016 – March 31, 2016
    #4: April 1, 2016 – June 30, 2016
    #5: July 1, 2016 – September 30, 2016
    #6: October 1, 2017 – December 31, 2016

2. Progress Reports

    Progress reports will not be concurrent with quarterly invoices. Three seasonal progress reports for water year 2016 will be submitted for this project covering the following periods:
    #1: Fall/winter – October 1, 2015 – February 29, 2016
    #2: Spring – March 1, 2016 – May 31, 2016
    #3: Summer – June 1, 2016 – September 30, 2016
    (Note that the period from May 1, 2015 to September 30, 2015 was covered by DRI.)

Please accept this report as seasonal progress report #3.

Task 2: Stormwater Monitoring

1. Maintain four stormwater monitoring stations to collect continous flow and turbidity data.
   All four stormwater monitoring stations have been dependably collecting continuous flow and turbididty data since the Tahoe RCD took over the project on May 1, 2015 and through the rain event that began March 4, 2016. After this event, it was discovered that accumulated sediment was prohibiting monitoring equipment from collecting reliable continuous turbidity data and samples. Turbidity readings in February, March, and April may be compromised. NDOT was notified that the vaults needed to be cleaned out via email on March 6, 2016. On March 8, 2016, NDOT responded that vactor trucks could come up the following week if weather permitted. During a site visit on March 16, 2016, visual inspections were made and sediment depth measurements were taken in various places throughout the system. The vault that should reliably split incoming flows equally between the Contech MFS and the Jellyfish filters had 1.85 feet of accumulated sediment in it, causing the flow to preferentially enter the Jellyfish. The pipes between the splitter vault and the inflow flumes where flow is measured and samples are taken were one third to one half full of sediment. The inflow flumes were full of sediment and the continuous turbidimeters were completely buried. The Contech MFS had about 0.58 ft. of sediment accumulated in the bottom of the vault, and the Jellyfish had about 1.17 feet. Fortunately, the outflow flumes were relatively clear of sediment but dirty snowmelt was entering through the gap around the outside of the manhole cover and raining down on the flumes giving false outflow data. On March 17, 2016, Tahoe RCD was made aware that the NDOT vactor truck was out for repairs. It was decided that Tahoe RCD would refrain from taking water quality samples during events, but would continue collecting continous flow and turbidity data even though it may not be accurate. NDOT vactored out the splitter vault and flushed the pipes between the splitter vault and the inflow flumes on April 15, 2016 (see photos below). Approximately two weeks later it was discovered that the inflow flumes and instrumentation were still covered in sediment so on May 4, 2016 the NDOT vactor truck came out and flushed the system again. A thunderstorm that occurred on May 5, 2016 was successfully sampled.

Vactor truck cleanout on 4/15/16 at SR431 (left). Note accumulated sediment along the curb. Sediment filled flume prior to cleanout (right).

Looking forward to the summer season, Tahoe RCD staff measured the depth of accumulated sediment in the Contech MFS vault at 0.75 feet on June 3, 2016. NDOT was notified immediately. On June 21 and 22, 2016 the NDOT maintenance crew was scheduled to:

- Vactor sediment from both treatment vaults
- Replace the cartridges in the Contech MFS
- Remove and clean the filters on the Jellyfish or remove and replace with the clean ones

However, Tahoe RCD staff was notified on the morning of June 21 that due to confined space issues the above described maintenance was on hold until further notice. Maintenance was rescheduled for August 3, 2016 at which time the crew cleaned out the Contech MFS vault and replaced the cartridges. The rest of the maintenance had to be postponed again due to a malfunction of the vactor truck. Event sampling for the summer season did not resume because the completion of the maintenance on the system did not occur during the summer season. The maintenance described above (with the exception of vactoring sediment from the Contech MFS and replacing the cartridges) has been scheduled for October 20, 2016, after which the instrumentation will be checked and recalibrated within a week of maintenance and event sampling will resume.

2. <u>Collect stormwater runoff samples at four monitoring sites during eight runoff events per year.</u>
   Tahoe RCD successfully collected samples at all four monitoring sites during four fall/winter runoff events: a thunderstorm on 10/1/15, rain on 11/1/15, rain on 12/10/15, and rain on snow on 1/29/16; and two spring runoff events: a rain event on 3/4/16 and a thunderstorm on 5/5/16. No events were sampled during the summer season due to sediment accumulation. Fortunately only 0.3 inches of rain fell during the whole summer season so it is expected that flows were minimal.

3. <u>If conditions allow for non-event snowmelt sampling, analyze a rising and a falling limb composite during three diurnals (counts as one of the eight events).</u>
   Due to accumulated sediment fouling sensors, and a lack of snowmelt after the system had been flushed on April 15 and 29, 2016, non-event snowmelt sampling did not occur during the spring season.

4. <u>Install a pressure transducer in each treatment vault to identify when there is bypass flow</u>.
   Pressure transducers installed in each of the vaults between September 30, 2015 and January 6, 2016 were removed so that data could be offloaded and analyzed. Data indicates that the Jellyfish never bypassed and the Contech MFS only bypassed slightly in three non-consecutive time intervals on October 1, 2015. New pressure transducers were provided to Tahoe RCD staff by NDOT in May 2016. They were installed in June 2016 and linked to the remote access data management system currently used at the SR431 monitoring site.

5. <u>Provide precipitation data to date</u>.
   Table 2 provides summary data for all 23 fall/winter precipitation events, 24 spring events, and 5 summer events that occurred during water year 2016 at the SR431 monitoring site including event start and end dates, total precipitation, peak precipitation, minimum and maximum temperature, and preciptation type. Events highlighted in pink were sampled for water quality (see task 2.2 above).

6. Provide hydrograph, continuous turbidity, and sample distribution graphs for each sampled event.

   See Figures 1-16 below for hydrographs, continous turbidity and sample distributions for each of the four events sampled in the fall/winter season and Figures 17-24 for each of the two events sampled in the spring season. As mentioned previously, no events were sampled during the summer season due to sediment accumulation on the sensors and intake tubes. Hydrographs at this site are generally very spikey, likely due to the high percentage of impervious area in the catchment. The high imperviousness causes sites to respond quickly to rapidly fluctuating precipitation intensity which causes the spikes in the flow data. In general, turbidity stays high for the duration of the event as opposed to peaking at the beginning of the event and tapering off. This is likely due to the fact that the dominant land use is primary road, which may be a constant source of sediment. It is interesting to note that during the 1/29/16 event, all sites did experience an initial pulse of turbidity that gradually tapered off. This could indicate that traction abrasives were applied to the highway for the icey conditions of January and were quickly washed off with the rain.

Task 3: Condition Assessments

1. Estimate Road RAM score prior to monitored runoff events.

   This task was not initiated until November 2015 following a meeting between the Tahoe RCD and NDOT where it was decided that determining a Road RAM score prior to runoff events was valuable. This procedure is expected to help establish a site-specific relationship between road condition and FSP concentration in runoff.

   Since November, six Road RAM scores have been determined; two prior to the 12/10/15 runoff event, one prior to the 1/29/16 event, one about a week prior to the 3/4/16 event, and two prior to the 5/5/16 event (one about a month prior and one a day prior). Roads are given a score from 0 to 5 based on how dirty they are with 0 being the dirtiest and 5 being the cleanest (dirtyness is determined by a series of tests measuring sediment). Road RAM scores correspond to an estimated FSP concentration range that can be expected in runoff events as outlined in the Road RAM Technical Document (2NDNATURE et al 2015).

   The scores below indicate that the roads were relatively dirty prior all runoff events, and fall within a range of 0.4 to 2.7. Between 12/2/15 and 12/8/15, there was an improvement in Road RAM scores (1.6 to 2.1) suggesting the roads may have been swept, but this has not been verified. The lowest score of 0.4 was determined in early April on 4/8/16. Though no events were sampled immediately afterwards, Tahoe RCD staff observed excessively dirty roads during this time and decided that determining a score was prudent. The exceptionally dirty roads observed in early April may be the reason the splitter vault, inflow flumes, and treatment vaults were inundated with excessive amounts of sediment which necessitated splitter vault and inflow pipe flushing in mid and late April, the clean-out of the Contech MFS vault and cartridge replacement in early August, and the full clean-out of the entire system and the Jellyfish scheduled for October 20, 2016.

Road RAM Date Time	Road Ram Score	Expected FSP Concentration Range* (mg/L)	Runoff Event Start Date Time	Number of Days Following Road RAM	Average Event Mean FSP Concentration (mg/L)	% Over Highest Expected FSP Concentration
12/2/15 15:30	1.6	291-679	12/10/15 4:22	8	723	6%
12/8/15 9:30	2.1	124-290	12/10/15 4:22	2	723	149%
1/28/15 8:10	1.7	291-679	1/29/16 6:10	1	1,118	65%
2/24/16 7:30	1.5	291-679	3/4/16 15:47	8	2,955	335%
4/8/16 12:00	0.4	680-1,592	na	na	na	
5/4/16 16:00	2.7	124-290	5/5/16 4:55	1	pending	pending

*Range of FSP concentrations expected with particular Road RAM score
(from the Road RAM Technical Document)

According to the Road RAM Technical Document scores greater than 1 and less than or equal to 2 fall into the “degraded” category. The range of FSP concentrations that can be expected in runoff from roads in this condition is 291-679 mg/L. However, the actual average inflow event mean FSP concentrations from runoff events were considerably higher than the Road RAM predictions. For the 12/10/15 event, average inflow FSP concentrations were 6% and 149% over the highest expected FSP concentration in the range predicted by the 12/2/15 and 12/8/15 scores respectively. The same is true for subsequent events (65% and 335% respectively). The 335% increase in actual concentration over predicted concentration may indicate that the road condition worsened significantly between the 2/24/16 score determination and the 3/4/16 runoff event. It is unknown if road abrasives were applied, but there was no precipitation or very cold temperatures that would indicate the need for large amounts of road abrasives during this time.

Road RAM scores greater than 2 and less than or equal to 3 fall into the “fair” category where the range of expected FSP concentrations in runoff is 124-290 mg/L. FSP concentrations that low were not measured during the 12/10/15 event so it is possible that the 12/8/15 score was overestimated slightly. Event mean FSP concentration is not yet available for the 5/5/16 event but it is expected to be relatively low with a score of 2.7 estimated the day prior to the runoff event and a maximum inflow turbidity of about 400 NTU.

2. <u>Measure depth of sediment in vaults after eight monitored runoff events.</u>
This task was not initiated until November 2015 following the meeting between Tahoe RCD and NDOT mentioned above where it was determined that post event sediment depth was valuable information. Thus, sediment depth was only measured one time during the fall/winter season. During the spring seasion it was measured four times in the Contech MFS and twice in the Jellyfish. The depths below represent the average depth in each vault in feet. These sediment depths indicate a gradual accumulation in the Contech this spring (with a small decrease between 4/15/16 and 4/22/16 following the system flush on 4/15/16 after the 4/15/16 measurement was taken) and a large increase in sediment accumulation between 4/22/16 and 6/3/16. The roads were relatively clean on 5/4/16 as indicated by a Road RAM score of 2.7, but a snow storm on 5/20/16-5/21/16 likely required road abrasive application that was later washed off in the thunderstorms that followed between 5/23/16 and 5/25/16. This could explain the 0.19 foot (2.28 inch) increase in sediment in the Contech MFS. Over a foot of sediment accumulated in the Jellyfish over the spring season. Sediment depth prior to Contech clean-out on August 3, 2016 was 1.10 feet. A measurement will be taken in the Jellyfish prior to clean-out on October 20, 2016.

Date Time	Contech MFS (ft)	Jellyfish (ft)
12/30/2015 10:30	0.33	na
3/16/2016 11:45	0.58	1.14
4/15/2016 10:00	0.61	na
4/22/2016 9:30	0.56	na
6/3/2016 10:00	0.75	2.17
8/3/16 10:00	1.10	na

Task 4: Final Report

1. Provide raw data.

   The task to develop a final report has not yet begun, but raw data can be provided at any time upon request.

2. Provide treatment effectiveness analysis following formats outlined in the RSWMP FIG.

   This task has not yet begun. The analysis will be provided in the final report.

3. Correlate Road RAM score to pollutant concentration and load.

   This task has not yet begun. The analysis will be provided in the final report.

4. Provide mass loading v. volume calculations for select events.

   Our findings under this task for Seasonal Progress Report #3 are based on events that occurred in the fall/winter and spring of water year 2016 (see Attachment A). Seasonal Progress Report #1 included a similar study based on four events that occurred in the late spring and early summer of water year 2015.

Table 1: Summary of tasks, due dates, and percent completion to date.

Task	Description	Due Date	% Of Work Complete	Date (s) Submitted
1	Project Administration			
1.1	Six Quarterly Invoices	10/31/15, 1/31/16, 4/30/16, 7/31/16, 10/31/16, 1/31/17	100%	10/31/15, 1/31/16, 4/30/16
1.2	Three Seasonal Progress Reports	3/31/16, 6/30/16, 10/31/16	100%	3/31/2016, 6/30/16, 10/31/16
2	Stormwater Monitoring			
2.1	Collect continuous flow and turbidity data at four monitoring stations	9/30/2016	100%	
2.2	Collect stormwater runoff samples during eight events per year	9/30/2016	75%*	*Incomplete due to sediment accumulation
2.3	Collect three diurnal non-event snowmelt events if conditions allow	5/31/2016	NA	
2.4	Collect flow bypass data in both vaults	9/30/2016	100%	
2.5	Provide precipitation data to date	9/30/2016	100%	3/31/16, 6/30/16, 10/31/16
2.6	Provide hydrograph, turbidity, and sample distribution graphs to date	9/30/2016	100%	3/31/16, 6/30/16, 10/31/16
3	Condition Assessments			
3.1	Estimate Road RAM score prior to eight sampled events	9/30/2016	75%*	3/31/16, 6/30/16
3.2	Measure depth of sediment in both vaults after sampled events	9/30/2016	100%	3/31/16, 6/30/16
4	Final Report			
4.1	Provide raw data	3/15/2017	0%	
4.2	Provide treatment effectiveness analysis	3/15/2017	0%	
4.3	Correlate Road RAM score to pollutant concentration and load	3/15/2017	0%	
4.4	Provide mass loading v. volume calculations for select events	3/15/2017	50%	3/31/16, 6/30/16

Table 2: Summary of water year 2016 precipitation events at SR431.

Station ID	Precip Event (#)	Precipitation event start (PST)	Event end (PST)	Event duration (hr:mm)	Interevent duration (hr:mm)	Event precipitation (inches)	Event peak precipitation (inch/10min)	Event minimum temp (°C)	Event maximum temp (°C)	Type of Precipitation
NDOT	NDOT-15-41	9/30/15 10:00	10/1/15 16:00	30:00	na	0.278	0.094	2	25	thunderstorm
NDOT	NDOT-16-01	10/3/15 20:15	10/4/15 4:20	8:05	52:15	0.068	0.008	4	6	rain
NDOT	NDOT-16-02	10/16/15 9:00	10/18/15 3:45	42:45	292:40	0.744	0.035	4	17	thunderstorm
NDOT		10/19/15 15:40	10/19/15 15:40	0:00	35:55	0.004	0.004	7	7	spurious
NDOT	NDOT-16-03	10/27/15 14:40	10/28/15 15:05	24:25	191:00	0.274	0.023	3	7	rain
NDOT	NDOT-16-04	11/1/15 11:25	11/3/15 23:45	60:20	92:20	1.325	0.027	-6	6	rain, snow
NDOT	NDOT-16-05	11/8/15 16:30	11/10/15 7:25	38:55	112:45	0.672	0.031	-6	1	snow
NDOT	NDOT-16-06	11/15/15 13:45	11/15/15 22:45	9:00	126:20	0.246	0.019	-7	-2	snow
NDOT	NDOT-16-07	11/24/15 11:35	11/26/15 5:45	42:10	204:50	0.396	0.016	-13	-3	snow
NDOT		11/29/15 11:15	11/29/15 11:15	0:00	77:30	0.004	0.004	0	0	spurious
NDOT	NDOT-16-08	12/3/15 16:25	12/4/15 13:55	21:30	101:10	0.260	0.016	-5	1	snow
NDOT	NDOT-16-09	12/10/15 0:55	12/11/15 11:05	34:10	131:00	1.439	0.023	-6	4	snow
NDOT	NDOT-16-10	12/13/15 1:25	12/14/15 0:25	23:00	38:20	1.159	0.019	-9	-1	snow
NDOT		12/15/15 13:45	12/15/15 13:45	0:00	37:20	0.004	0.004	-5	-5	spurious
NDOT		12/17/15 11:45	12/17/15 11:45	0:00	46:00	0.004	0.004	2	2	spurious
NDOT	NDOT-16-11	12/19/15 1:10	12/19/15 6:25	5:15	37:25	0.208	0.012	-3	-2	snow
NDOT	NDOT-16-12	12/20/15 13:20	12/25/15 11:45	118:25	30:55	2.436	0.016	-14	4	rain/snow
NDOT	NDOT-16-13	12/28/15 3:05	12/28/15 19:10	16:05	63:20	0.020	0.004	-8	-3	snow
NDOT	NDOT-16-14	12/30/15 6:35	12/30/15 11:30	4:55	35:25	0.012	0.008	-8	-1	snow
NDOT	NDOT-16-15	1/4/16 15:00	1/7/16 11:30	68:30	123:30	1.097	0.023	-9	0	snow
NDOT	NDOT-16-16	1/9/16 2:05	1/9/16 13:15	11:10	38:35	0.028	0.008	-6	2	snow
NDOT	NDOT-16-17	1/13/16 6:00	1/16/16 17:30	83:30	88:45	1.711	0.019	-9	4	snow, rain
NDOT	NDOT-16-18	1/17/16 18:35	1/19/16 17:40	47:05	25:05	0.592	0.016	-3	4	rain/snow
NDOT	NDOT-16-19	1/22/16 11:55	1/25/16 10:45	70:50	66:15	0.388	0.016	-8	3	rain/snow
NDOT	NDOT-16-20	1/29/16 5:35	2/1/16 9:20	75:45	90:50	0.120	0.004	-15	4	rain/snow
NDOT	NDOT-16-21	2/2/16 10:15	2/2/16 11:45	1:30	24:55	0.012	0.008	-7	-5	snow
NDOT	NDOT-16-22	2/17/16 9:20	2/20/16 9:30	72:10	357:35	0.580	0.020	22	49	rain, snow
NDOT	NDOT-16-23	2/25/16 19:25	2/26/16 0:00	4:35	129:55	0.016	0.004	-1	13	rain
NDOT	NDOT-16-24	3/4/16 15:20	3/5/2016 1:10	9:50	183:20	0.420	0.040	35	48	rain
NDOT	NDOT-16-25	3/5/16 19:10	3/7/16 8:50	37:40	18:00	0.970	0.040	28	42	rain
NDOT		3/11/16 15:50	3/11/16 15:50	0:00	103:00	0.010	0.010	35	35	rain
NDOT	NDOT-16-26	3/12/16 18:50	3/13/16 23:00	28:10	27:00	1.140	0.030	33	38	snow
NDOT	NDOT-16-27	3/20/16 17:10	3/22/16 10:40	41:30	162:10	0.630	0.020	25	42	rain/snow
NDOT	NDOT-16-28	3/28/16 4:30	3/28/16 15:30	11:00	137:50	0.470	0.030	26	34	snow
NDOT	NDOT-16-29	4/9/16 10:10	4/11/16 17:25	55:15	282:40	0.881	0.055	-1	10	rain
NDOT	NDOT-16-30	4/14/16 3:20	4/14/16 5:15	1:55	57:55	0.088	0.012	-5	-4	snow
NDOT	NDOT-16-31	4/22/16 10:10	4/23/16 9:20	23:10	196:55	0.894	0.023	-5	2	rain/snow
NDOT	NDOT-16-32	4/25/16 9:15	4/25/16 10:05	0:50	47:55	0.012	0.004	-4	-1	snow
NDOT	NDOT-16-33	4/27/16 0:35	4/28/16 4:55	28:20	38:30	0.131	0.019	-2	7	rain
NDOT	NDOT-16-34	4/29/16 18:30	4/29/16 22:00	3:30	37:35	0.185	0.023	-1	2	rain
NDOT		5/1/16 19:00	5/1/16 19:00	0:00	45:00	0.004	0.004	6	6	rain
NDOT	NDOT-16-35	5/4/2016 14:25	5/4/2016 14:30	0:05	67:25	0.016	0.012	10	11	thunderstorm
NDOT	NDOT-16-36	5/5/2016 4:25	5/5/2016 8:40	4:15	13:55	0.366	0.019	1	5	thunderstorm
NDOT	NDOT-16-37	5/5/2016 11:35	5/5/2016 22:35	11:00	2:55	0.558	0.019	1	5	thunderstorm
NDOT	NDOT-16-38	5/6/2016 0:45	5/6/2016 7:40	6:55	2:10	0.228	0.016	-1	2	thunderstorm
NDOT	NDOT-16-39	5/7/2016 6:35	5/7/2016 16:05	9:30	22:55	0.312	0.016	3	5	thunderstorm
NDOT	NDOT-16-40	5/8/2016 5:05	5/8/2016 6:10	1:05	13:00	0.064	0.012	4	4	thunderstorm
NDOT	NDOT-16-41	5/15/16 15:50	5/15/16 15:55	0:05	177:40	0.016	0.012	7	9	thunderstorm
NDOT	NDOT-16-42	5/16/16 20:55	5/17/16 7:30	10:35	29:00	0.02	0.004	3	7	thunderstorm
NDOT	NDOT-16-43	5/20/16 14:45	5/21/16 18:25	27:40	79:15	0.04	0.004	-3	4	snow
NDOT		5/23/16 16:45	5/23/16 16:45	0:00	46:20	0.004	0.004	4	4	thunderstorm
NDOT	NDOT-16-44	5/24/16 9:35	5/24/16 15:25	5:50	16:50	0.279	0.019	1	4	thunderstorm
NDOT	NDOT-16-45	5/25/16 13:20	5/25/16 17:00	3:40	21:55	0.175	0.039	4	8	thunderstorm
NDOT	NDOT-16-46	7/28/2016 20:55	7/28/2016 21:05	0:10	1539:55	0.035	0.023	17	22	thunderstorm
NDOT	NDOT-16-47	8/16/2016 15:35	8/16/2016 15:40	0:05	450:30	0.008	0.004	21	23	thunderstorm
NDOT	NDOT-16-48	8/22/2016 13:05	8/22/2016 13:35	0:30	2132:05	0.126	0.055	12	16	thunderstorm
NDOT	NDOT-16-49	9/13/2016 6:50	9/13/2016 17:50	11:00	521:15	0.059	0.019	6	12	thunderstorm
NDOT	NDOT-16-50	9/22/2016 13:15	9/22/2016 18:35	5:20	211:25	0.076	0.016	0	5	thunderstorm

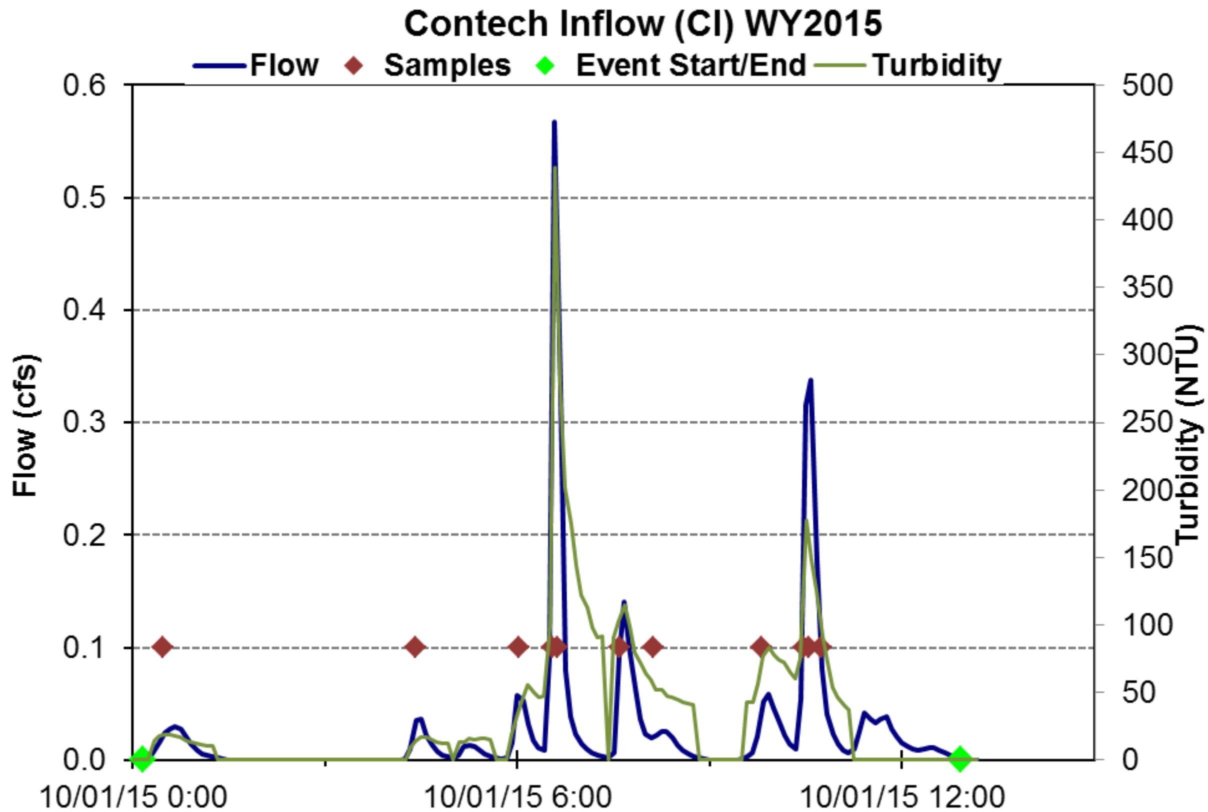

Figure 1: Hydrograph, continuous turbidity and sample distribution at the Contech MFS inflow for the 10/1/15 thunderstorm event.

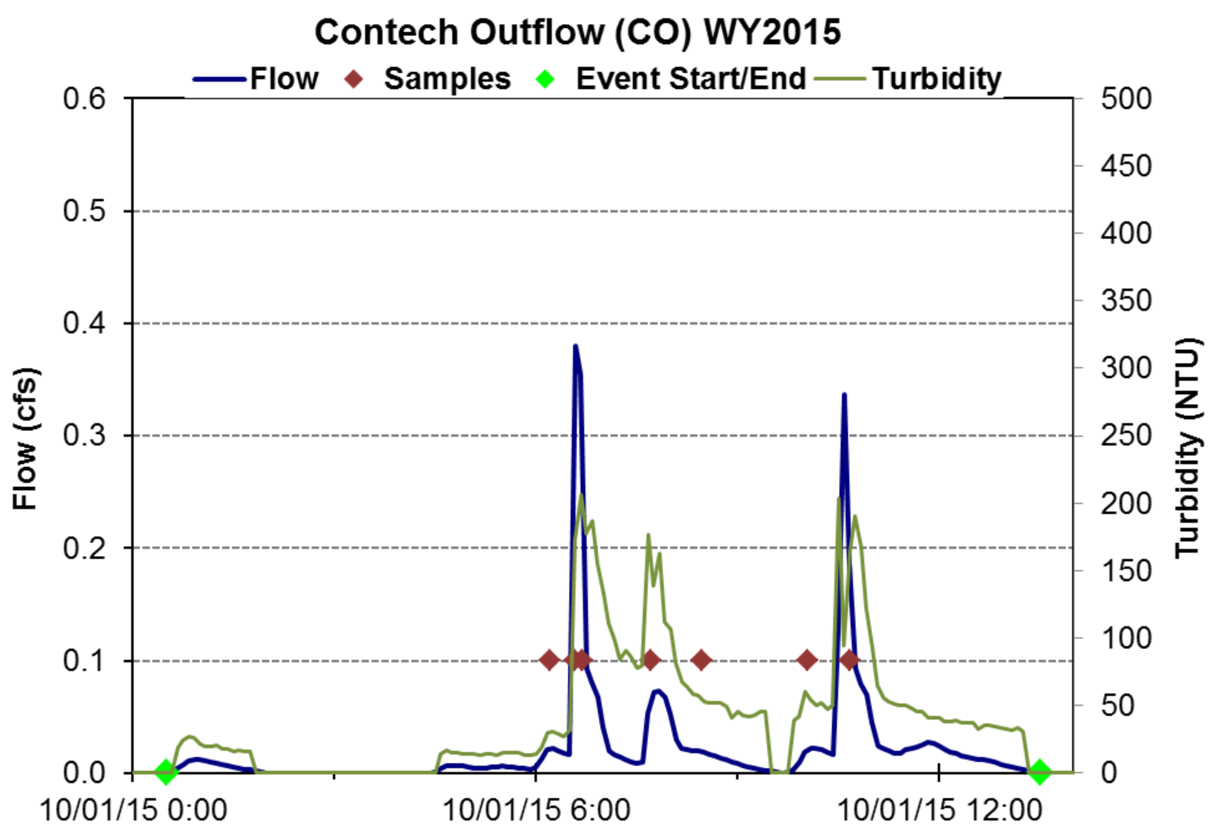

Figure 2: Hydrograph, continuous turbidity and sample distribution at the Contech MFS outflow for the 10/1/15 thunderstorm event.

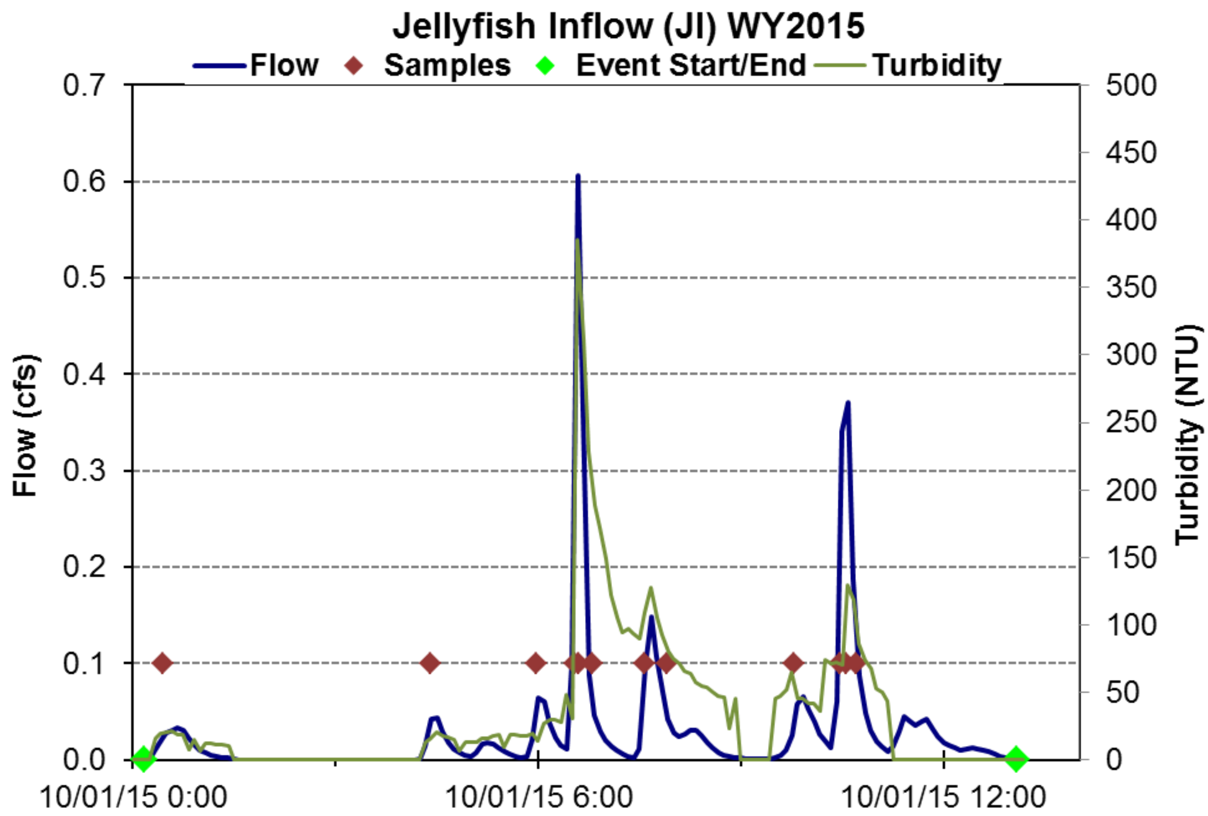

Figure 3: Hydrograph, continuous turbidity and sample distribution at the Jellyfish inflow for the 10/1/15 thunderstorm event.

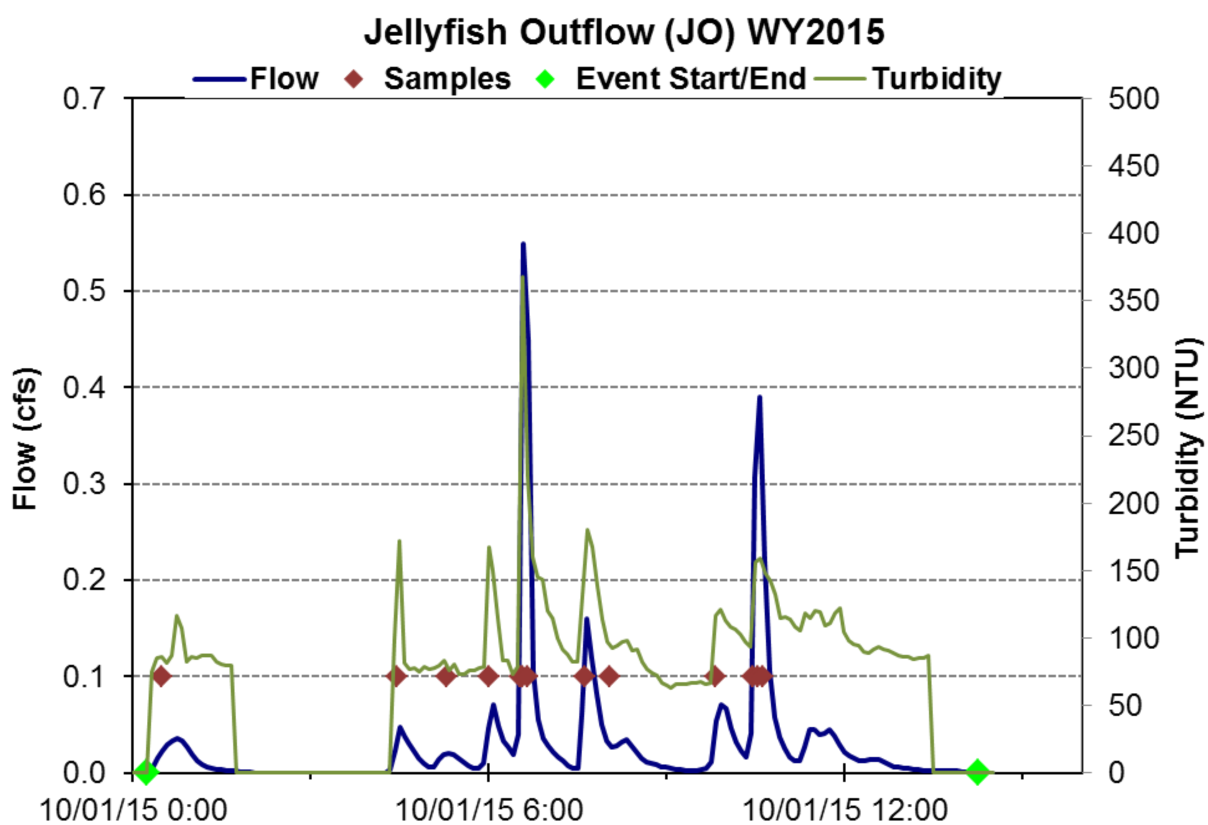

Figure 4: Hydrograph, continuous turbidity and sample distribution at the Jellyfish outflow for the 10/1/15 thunderstorm event.

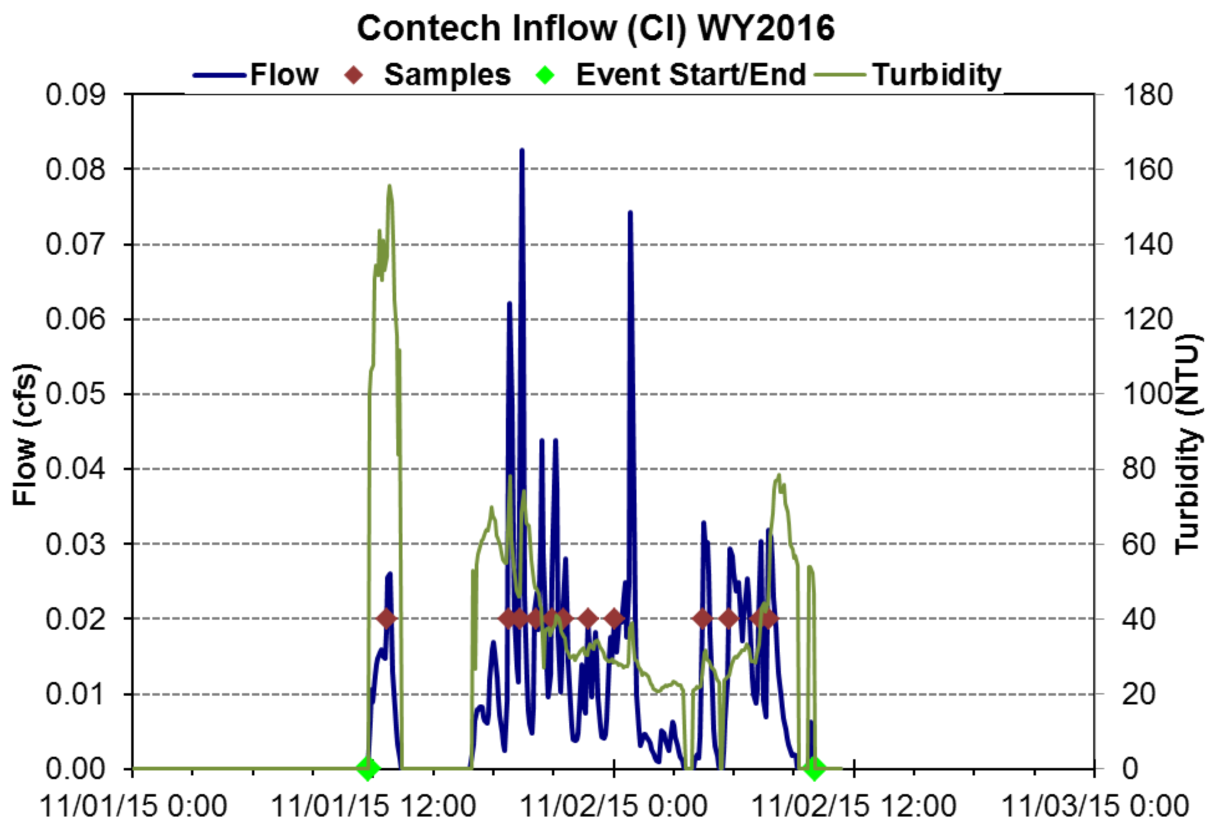

Figure 5: Hydrograph, continuous turbidity and sample distribution at the Contech MFS inflow for the 11/1/15 rain and snow event.

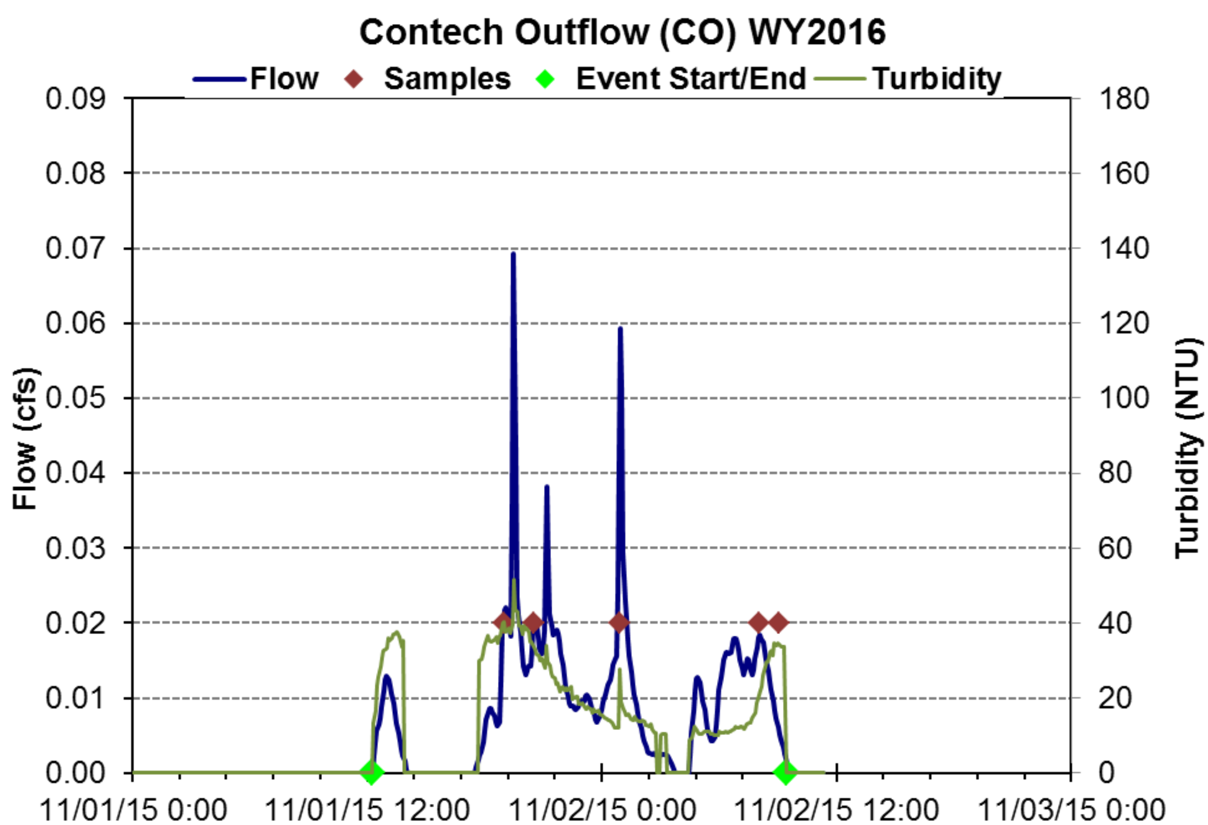

Figure 6: Hydrograph, continuous turbidity and sample distribution at the Contech MFS outflow for the 11/1/15 rain and snow event.

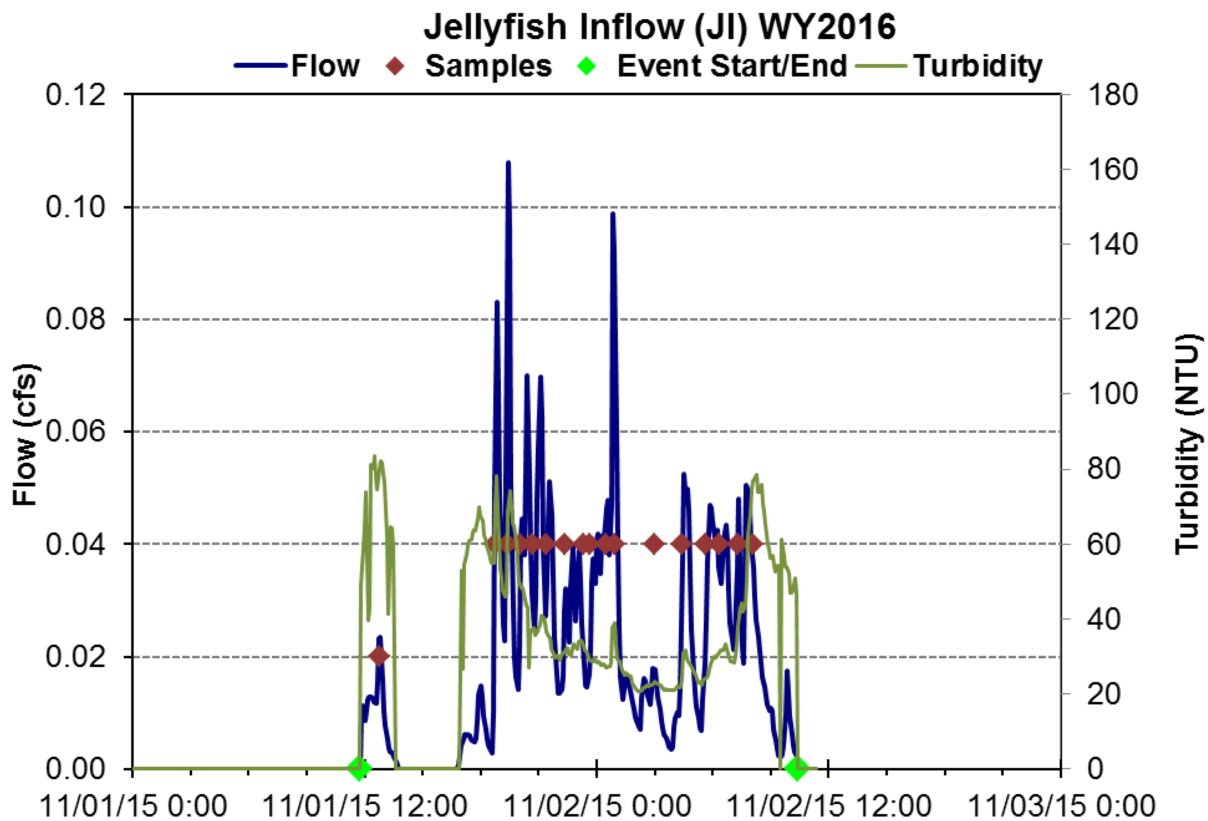

Figure 7: Hydrograph, continuous turbidity and sample distribution at the Jellyfish inflow for the 11/1/15 rain and snow event.

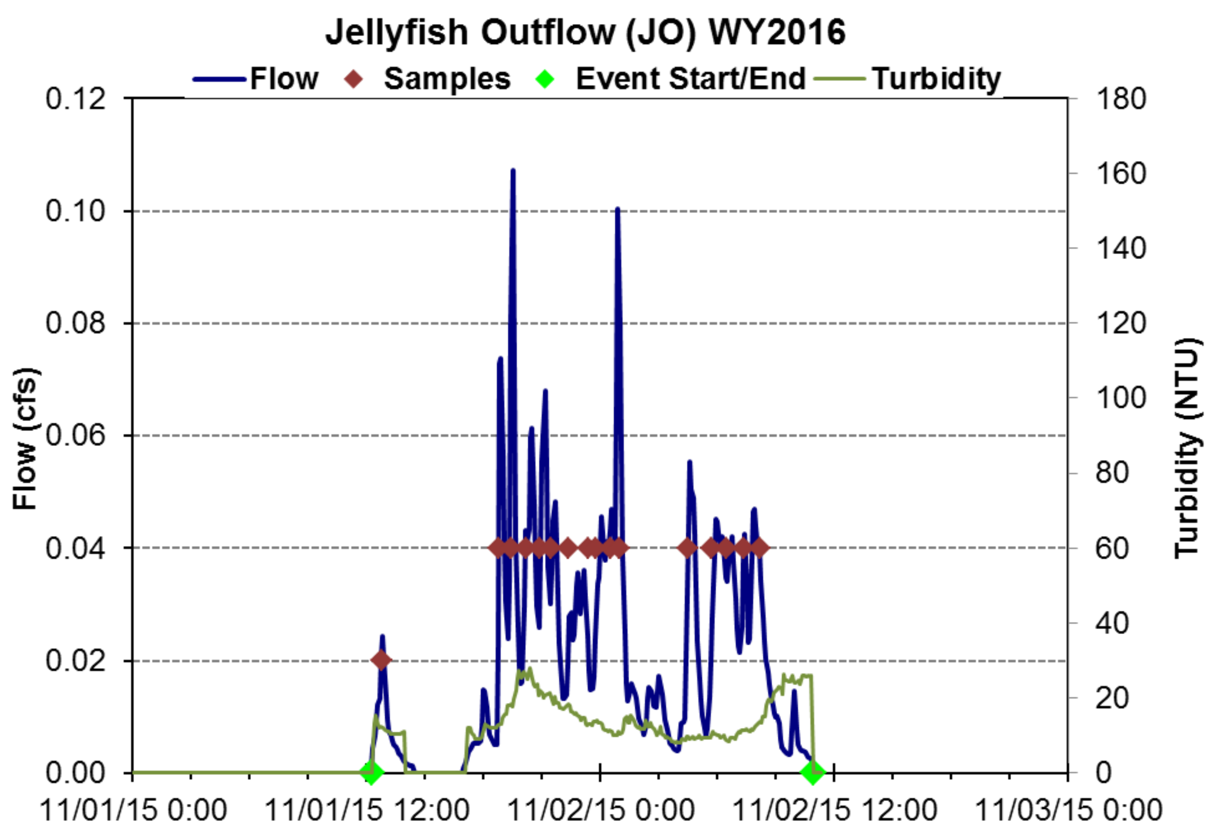

Figure 8: Hydrograph, continuous turbidity and sample distribution at the Jellyfish outflow for the 11/1/15 rain and snow event.

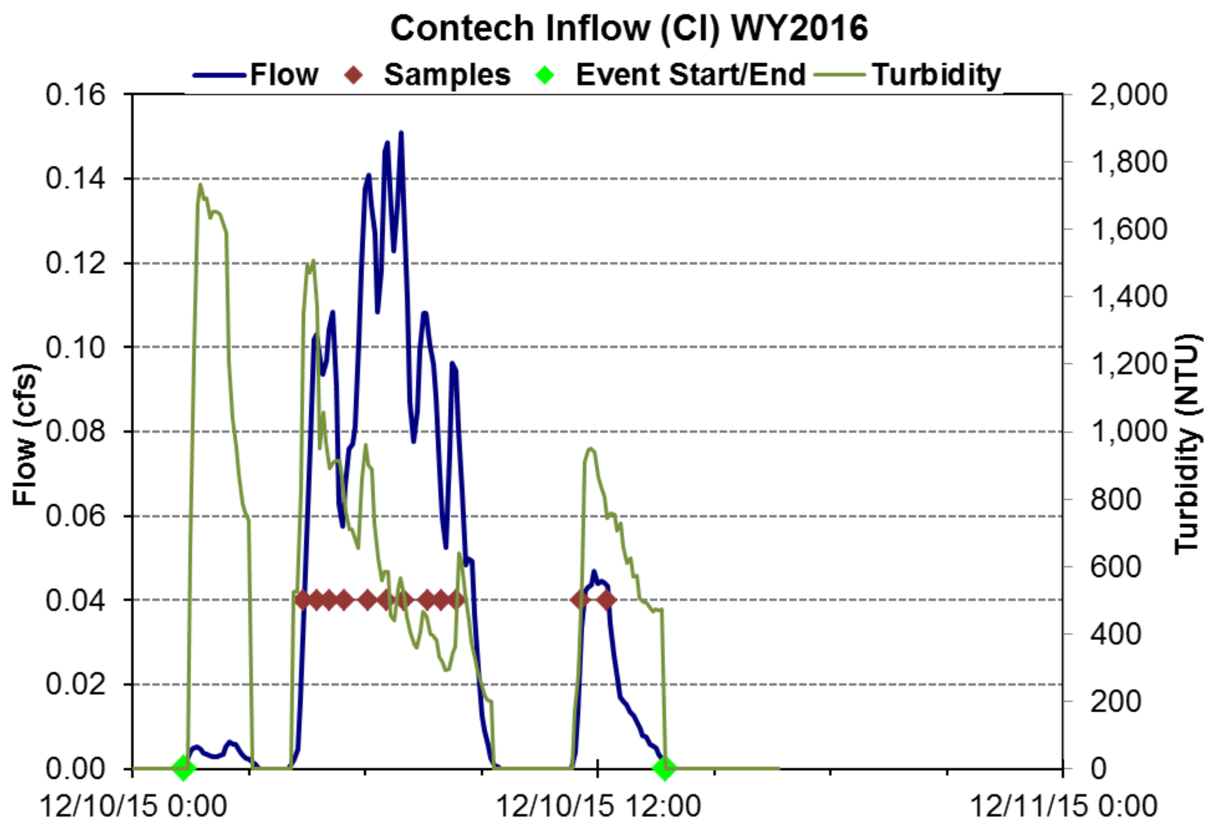

Figure 9: Hydrograph, continuous turbidity and sample distribution at the Contech MFS inflow for the 12/10/15 snow event.

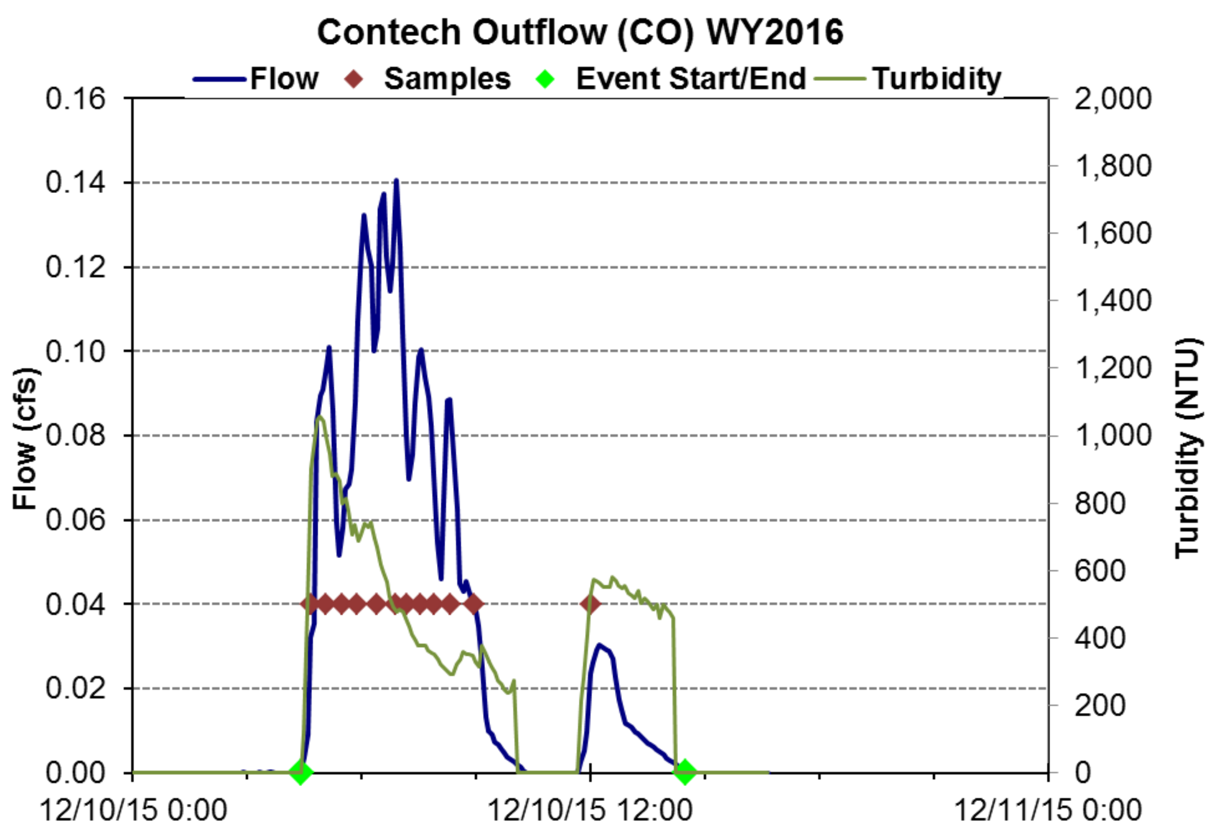

Figure 10: Hydrograph, continuous turbidity and sample distribution at the Contech MFS outflow for the 12/10/15 snow event.

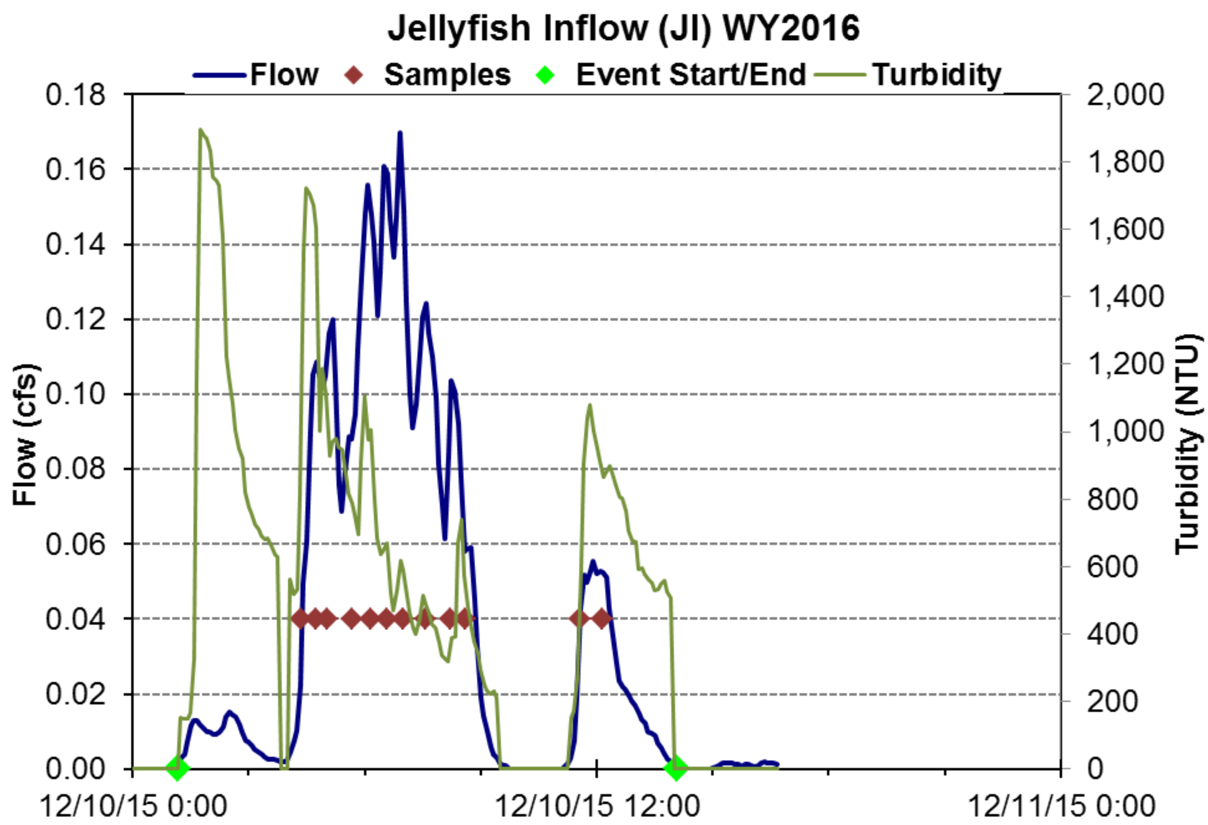

Figure 11: Hydrograph, continuous turbidity and sample distribution at the Jellyfish inflow for the 12/10/15 snow event.

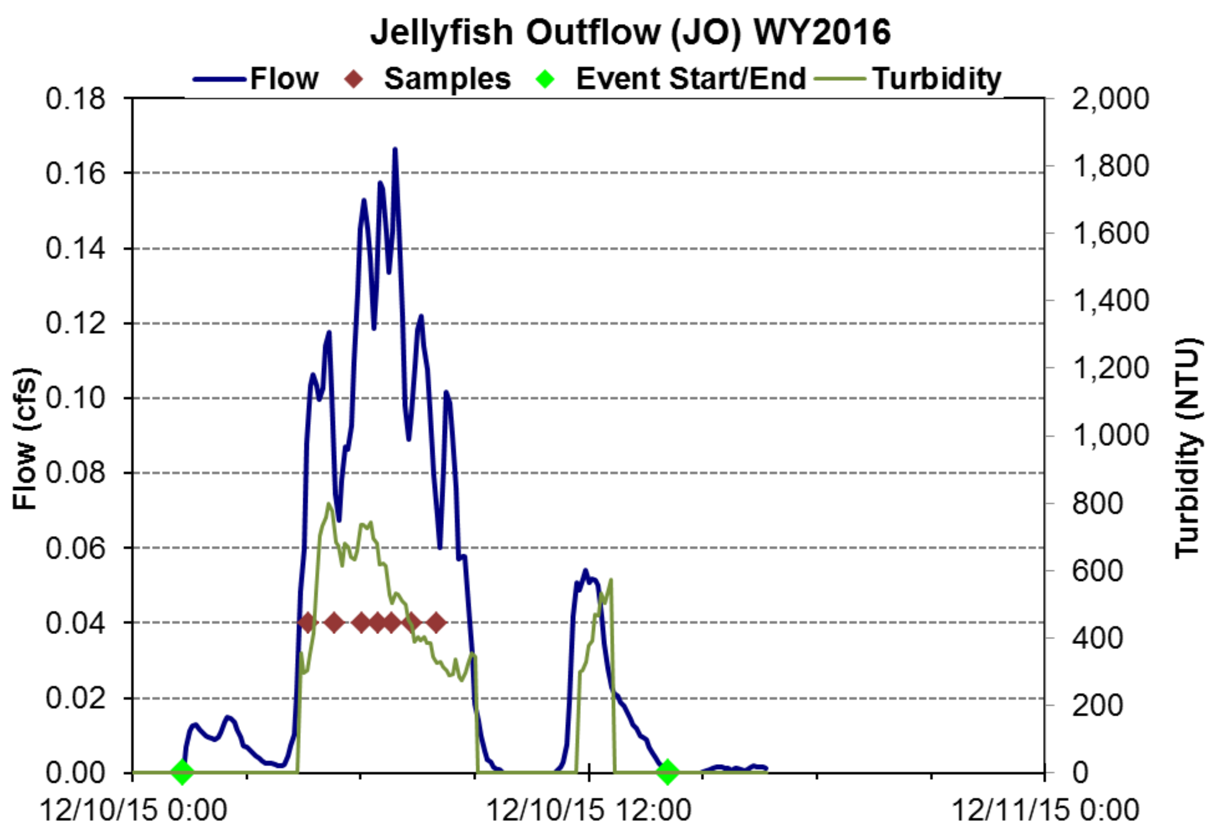

Figure 12: Hydrograph, continuous turbidity and sample distribution at the Jellyfish outflow for the 12/10/15 snow event.

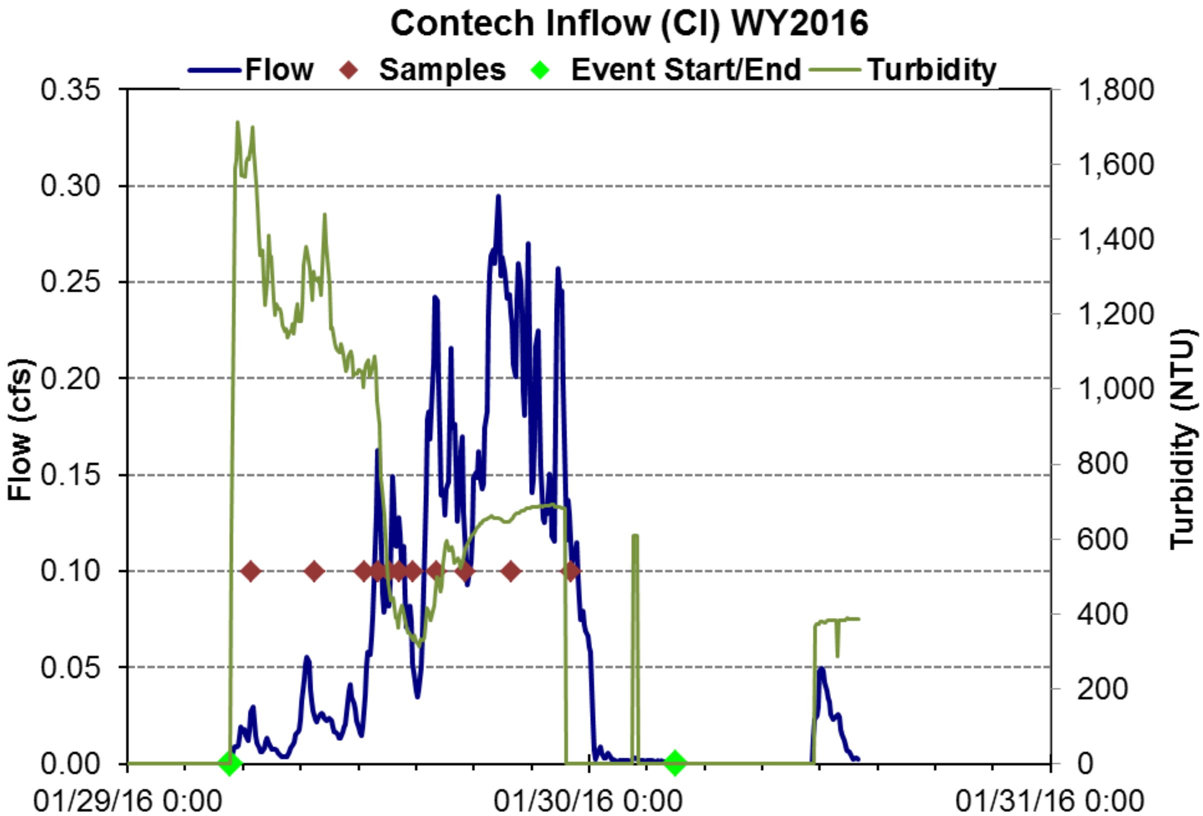

Figure 13: Hydrograph, continuous turbidity and sample distribution at the Contech MFS inflow for the 1/29/16 mixed rain and snow event.

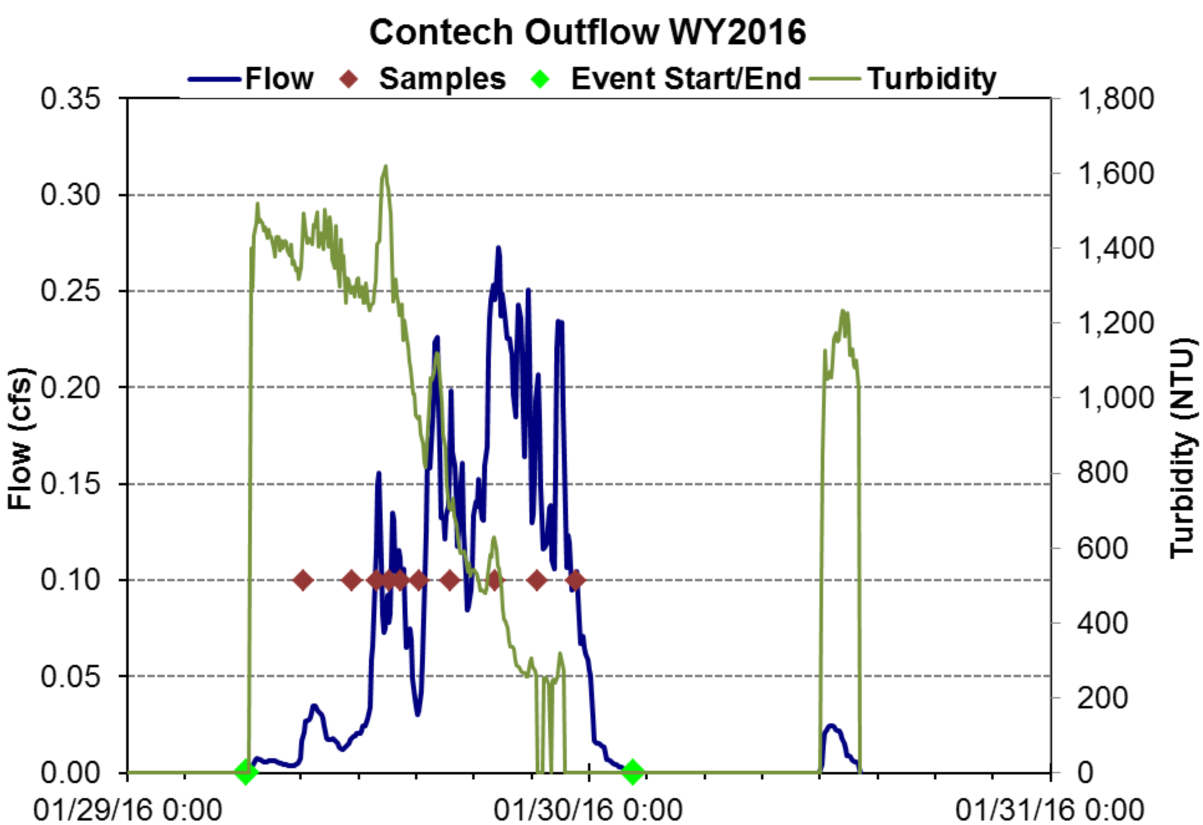

Figure 14: Hydrograph, continuous turbidity and sample distribution at the Contech MFS outflow for the 1/29/16 mixed rain and snow event.

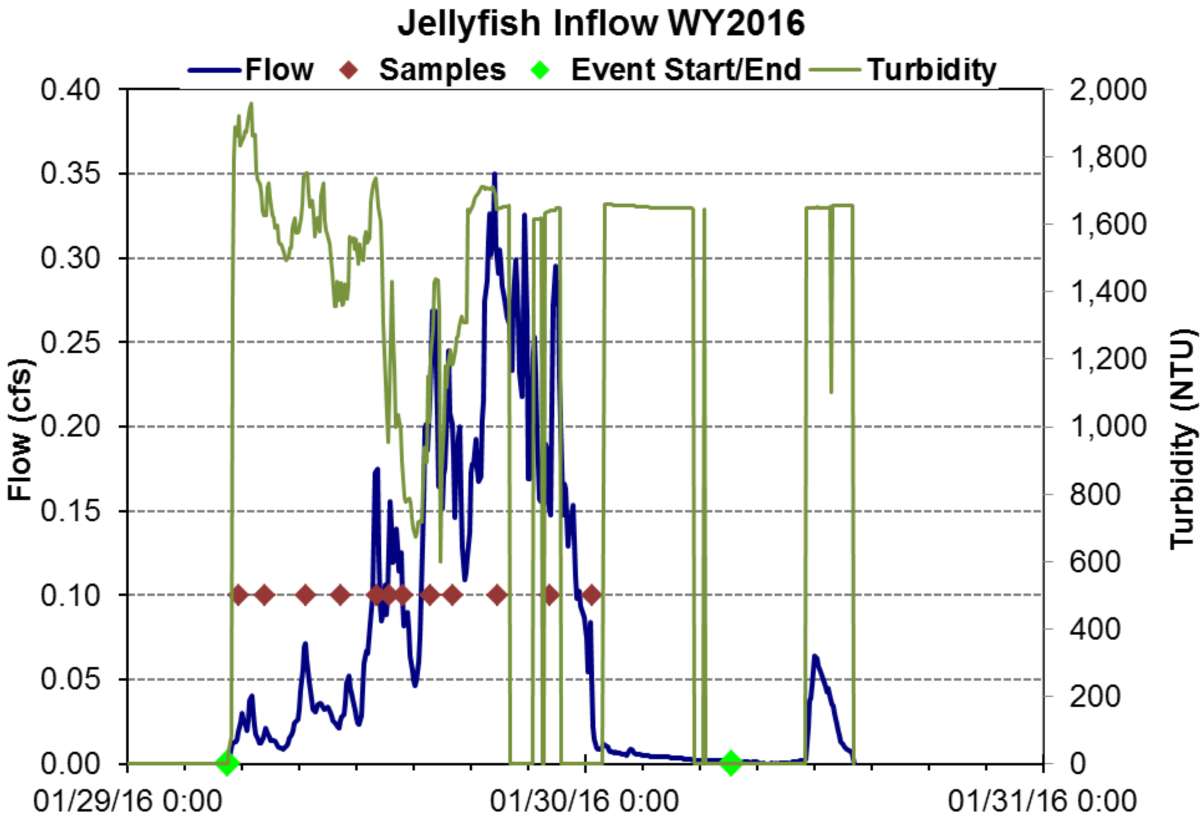

Figure 15: Hydrograph, continuous turbidity and sample distribution at the Jellyfish inflow for the 1/29/16 mixed rain and snow event.

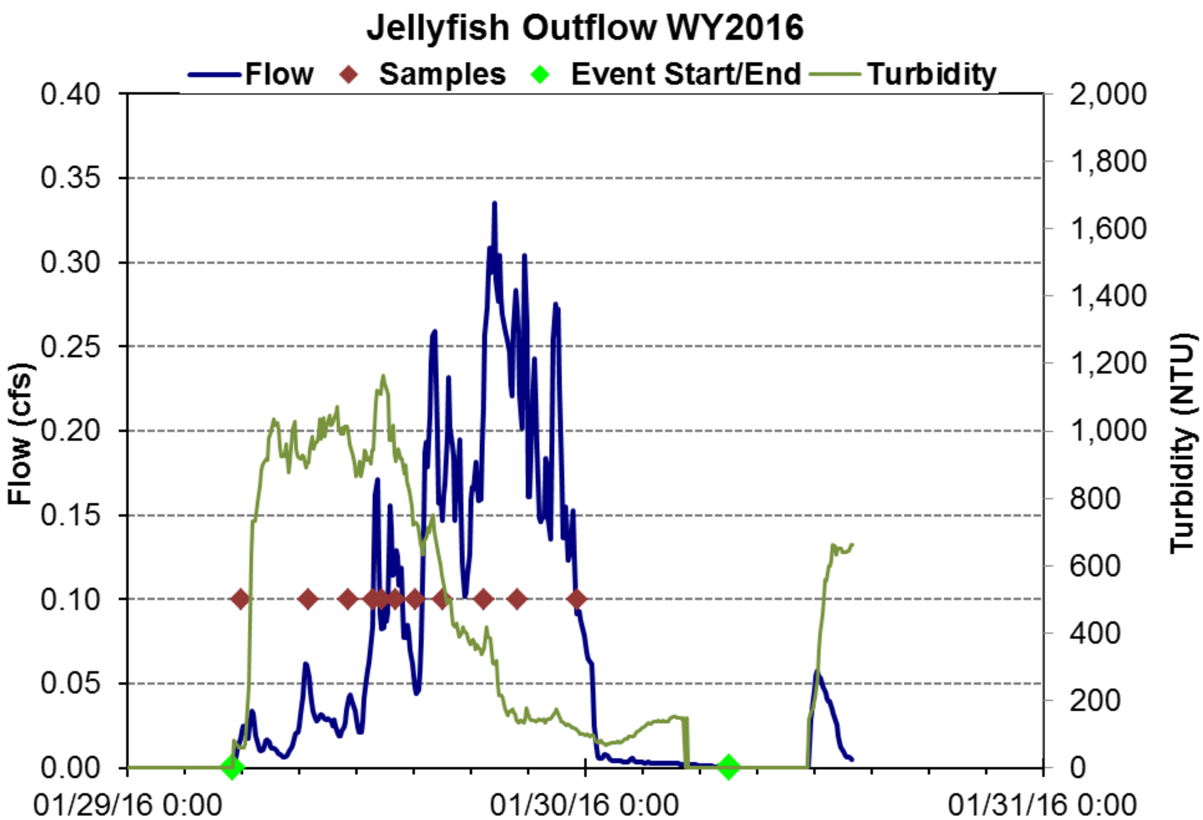

Figure 16: Hydrograph, continuous turbidity and sample distribution at the Jellyfish outflow for the 1/29/16 mixed rain and snow event.

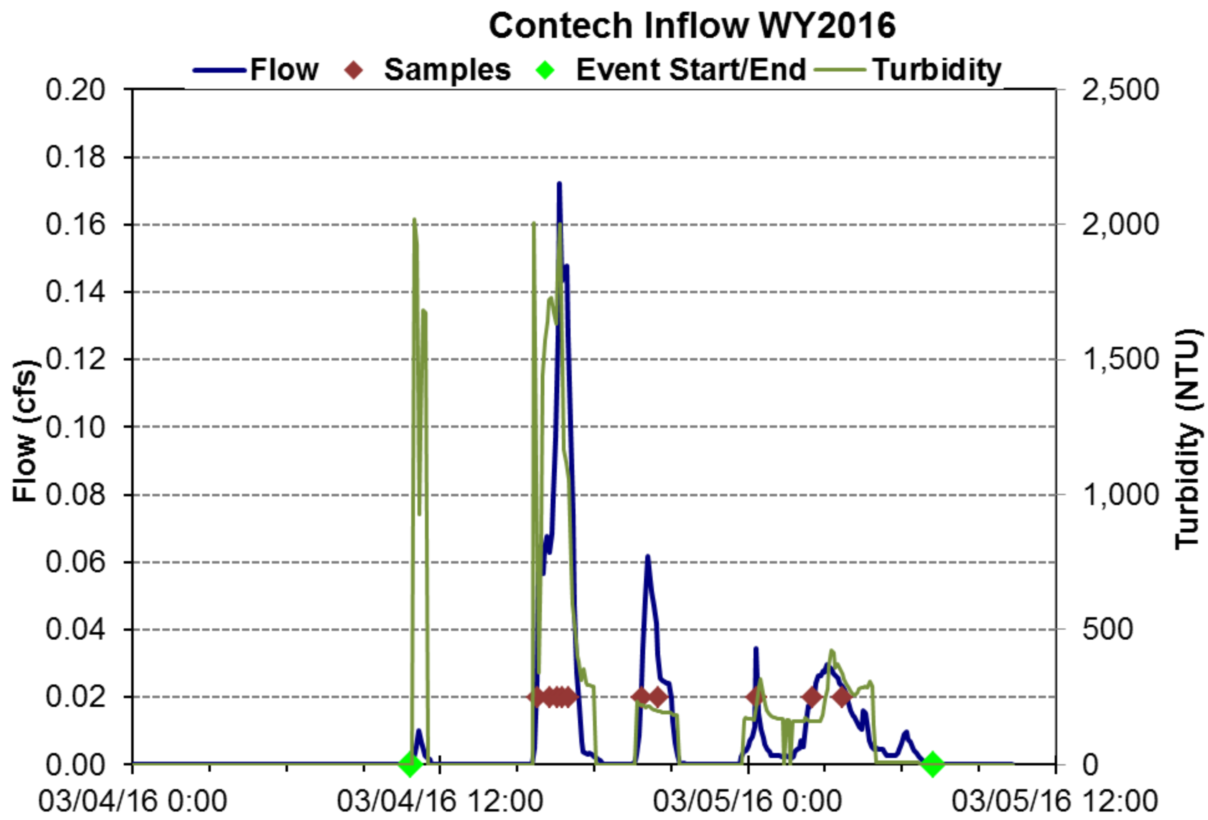

Figure 17: Hydrograph, continuous turbidity and sample distribution at the Contech MFS inflow for the 3/4/16 rain event.

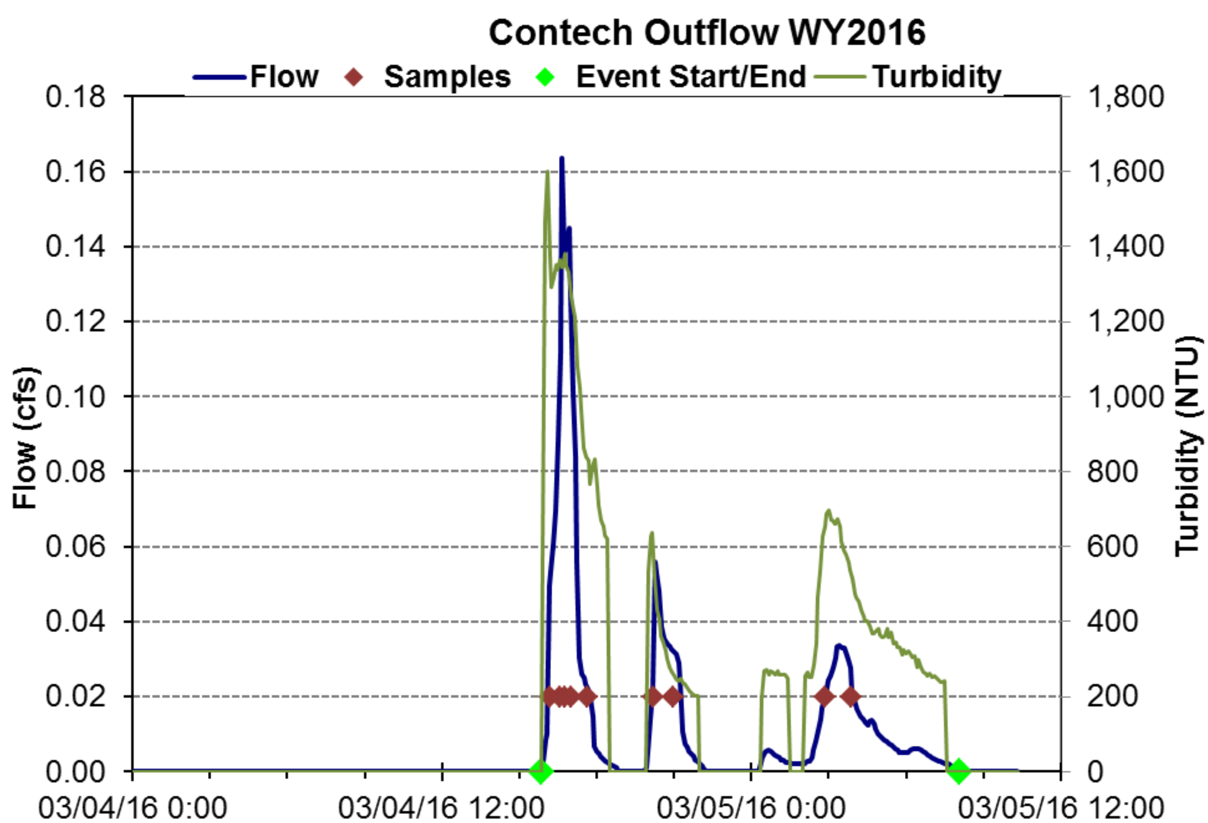

Figure 18: Hydrograph, continuous turbidity and sample distribution at the Contech MFS outflow for the 3/4/16 rain event.

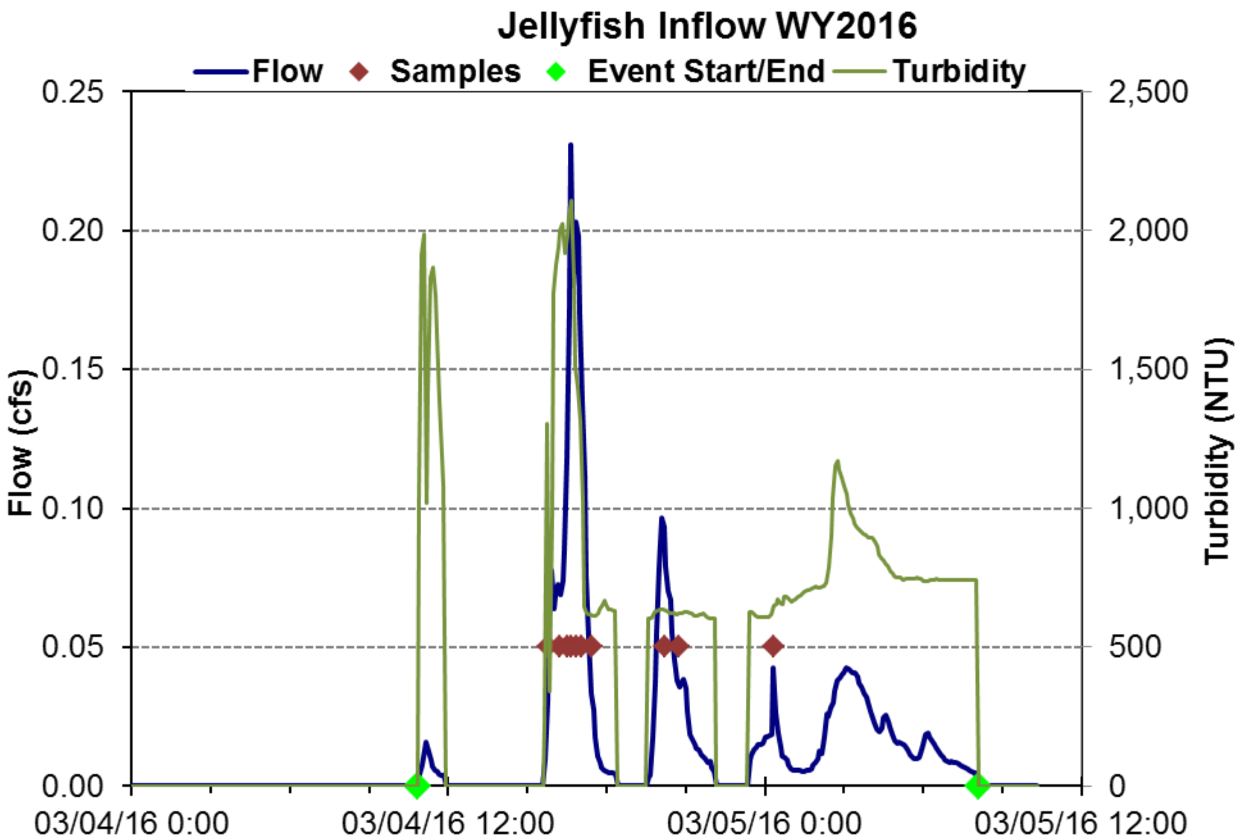

Figure 19: Hydrograph, continuous turbidity and sample distribution at the Jellyfish inflow for the 3/4/16 rain event.

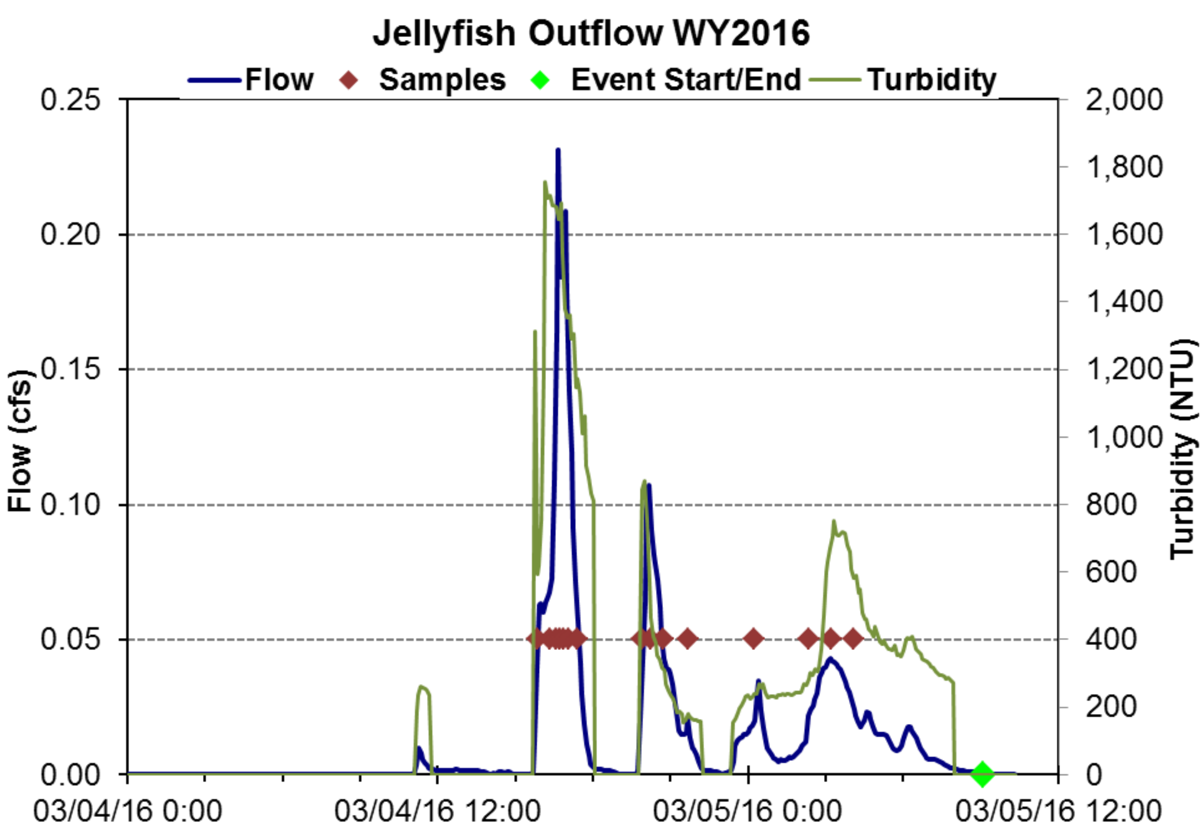

Figure 20: Hydrograph, continuous turbidity and sample distribution at the Jellyfish outflow for the 3/4/16 rain event.

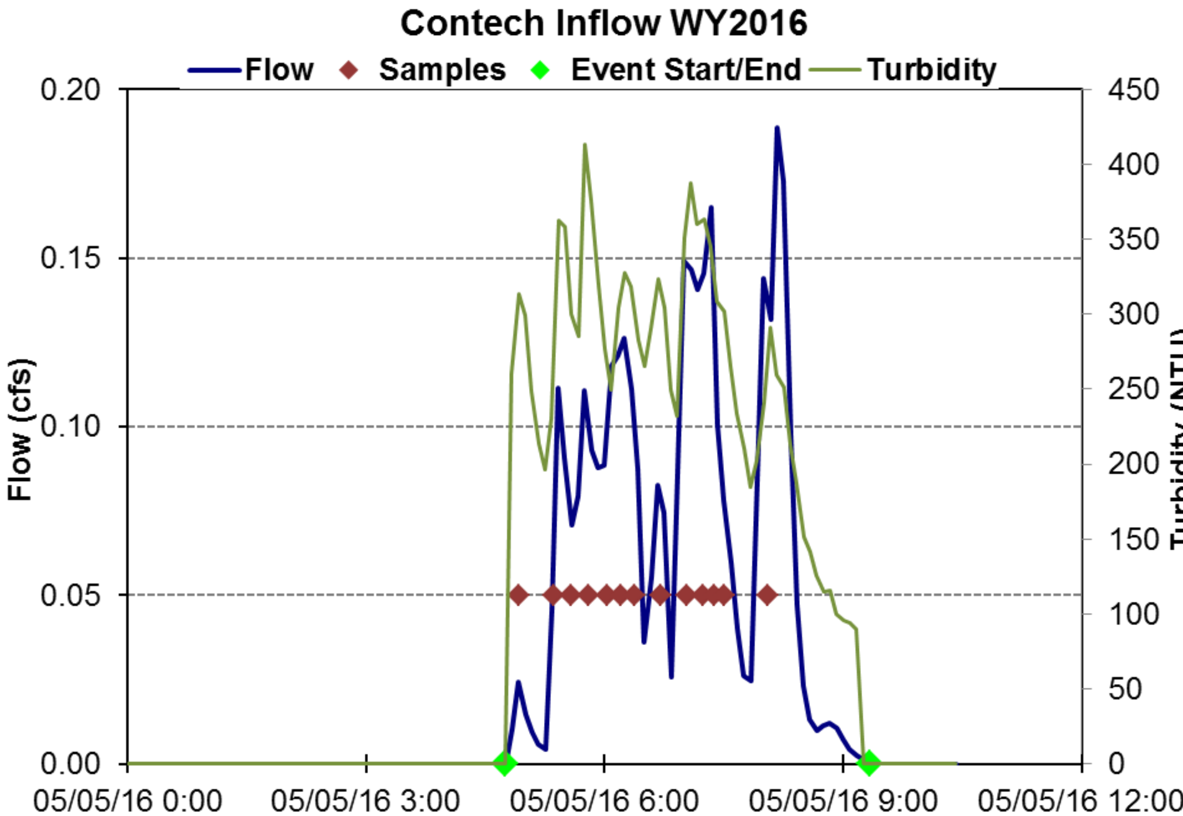

Figure 21: Hydrograph, continuous turbidity and sample distribution at the Contech MFS inflow for the 5/5/16 thunderstorm.

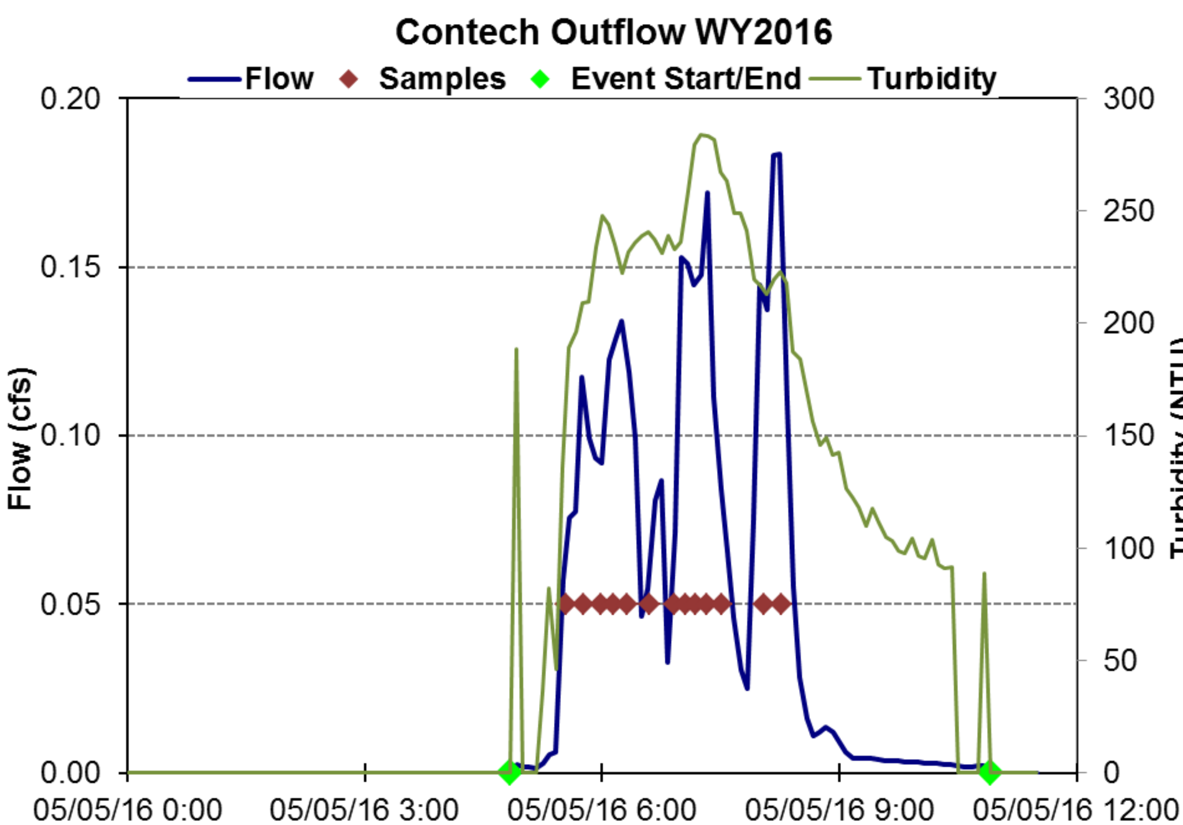

Figure 22: Hydrograph, continuous turbidity and sample distribution at the Contech MFS outflow for the 5/5/16 thunderstorm.

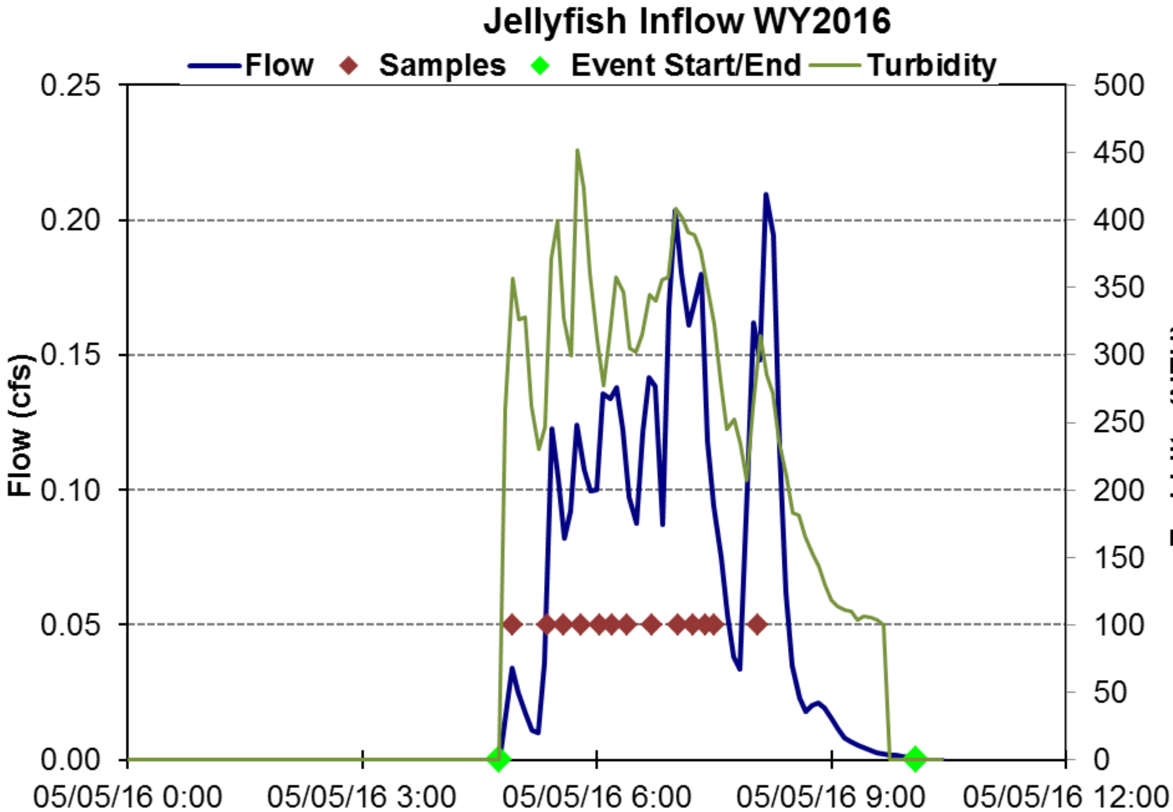

Figure 23: Hydrograph, continuous turbidity and sample distribution at the Jellyfish inflow for the 5/5/16 thunderstorm.

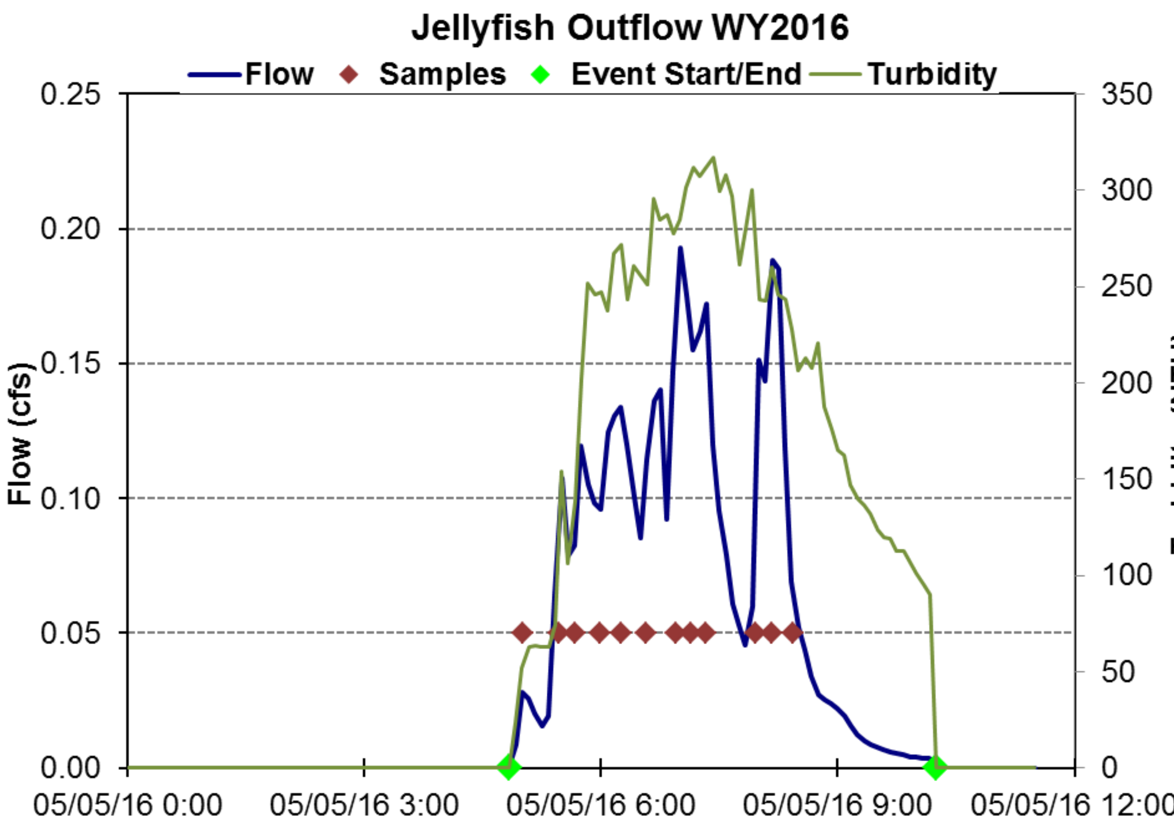

Figure 24: Hydrograph, continuous turbidity and sample distribution at the Jellyfish outflow for the 5/5/16 thunderstorm.

References

Tahoe Resource Conservation District, 2NDNATURE, Desert Research Institute, Northwest Hydraulic Consultants. 2015. *RSWMP Framework and Implementation Guidance Document*. Submitted the California State Water Board. March 30, 2015.

2NDNATURE LLC, Northwest Hydraulic Consultants, Environmental Incentives, 2015. *Road Rapid Assessment Methodology (Road RAM) User Manual v2, Tahoe Basin. Final Document*. Prepared for the Nevada Division of Environmental Protection and Lahontan Regional Water Quality Control Board. May 2015.

ATTACHMENT A

Seasonal Progress Report #2

SR431 Treatment Vault Effectiveness Monitoring

Temporal Delivery of TSS and FSP

Fall//Winter and Spring Season, October 1, 2015 – May 31, 2016

Introduction

Urban stormwater managers must often comply with a range of regulations and permit requirements to reduce pollutants discharged to local water bodies. As such, managers are constantly presented with the task of maximizing the effectiveness of stormwater Best Management Practices (BMPs). The task of efficiently reducing pollutant discharge is often challenged by a variety of constraints including available funding, site-specific physical restrictions, personnel availability, and BMP implementation and maintenance costs. With such considerations in mind, stormwater managers must focus on capturing pollutants in the most effective manner possible.

One option that has been proposed for its cost-efficiency is to capture and treat only the first flush. There are two types of first flush; a concentration first flush and a mass first flush. A concentration first flush occurs when the initial pulse of runoff contains high concentrations of pollutants relative to the runoff later in the storm event. As the precipitation event continues, the pollutant concentrations get progressively lower as the catchment area is “washed clean”. A mass first flush (pollutant concentration times flow rate) is flow dependent and occurs when both concentrations and the initial flow rates are high relative to concentrations and flow rates in the later runoff (Stenstrom et al 2005). As stormwater managers in the Tahoe Basin are primarily focused on reducing total pollutant load to Lake Tahoe, the focus of this study is on the mass first flush. In this report, mass and load are considered equivalent terms and used interchangeably, and mass first flush is henceforth referred to as simply “first flush”.

Different studies have suggested different thresholds for quantifying whether a mass first flush exists. Some studies suggest that the phenomenon exists if approximately 80% of the load is delivered in the first 20-40% of the total stormwater runoff volume, while others suggest that 30-50% must be delivered in the first 10-20% of the total stormwater runoff volume (Stenstrom et al 2005). In general, and for the purpose of this report, studies agree that the phenomenon of first flush exists if the majority of the pollutant load is delivered in the initial portion of the stormwater runoff.
The Tahoe Resource Conservation District (Tahoe RCD) has conducted an analysis of temporal pollutant load delivery at Nevada Department of Transportation (NDOT) State Route 431 (SR431) stormwater monitoring stations in order to determine if the mass first flush phenomenon exists at this site. The presence of a mass first flush would afford the opportunity to capture and treat only a given initial percentage of stormwater runoff, thereby maximizing the cost-efficiency of stormwater treatment.

Background

Stormwater runoff in this 1.35 acre catchment is generated primarily from the 96% impervious primary road. Stormwater enters a drop inlet and is conveyed by a 12-inch corrugated plastic pipe to a splitter vault that evenly splits and diverts incoming flow into two separate treatment BMPs. The Tahoe RCD actively manages stormwater monitoring equipment at four separate locations at the SR431 site; the inflows and outflows of the Contech MFS and Jellyfish treatment vaults (BMPs). Monitoring equipment at each of these locations measures continuous flow and turbidity and takes water quality samples on a flow-weighted basis.

Mathematical relationships have been developed between turbidity and fine sediment particles (FSP) and total suspended sediment (TSS) with the intent of using continuous turbidity data as a proxy for continuous FSP and TSS data (Heyvaert et al 2015). These relationships are advantageous to stormwater managers because they enable a cost-effective method for estimating annual pollutant loading based on readily-available continuous turbidity data, rather than costly lab analysis for individual stormwater samples. Using linear fit relationships derived from data collected at the SR431 sites during 2014 and 2015, researchers at the Desert Research Institute developed the following site-specific log-linear relationships between turbidity (measured in Nephelometric Turbidity Units (NTU)) and FSP and TSS estimated in milligrams per liter (mg/l):

$$\mathbf{Log(FSP\ (mg/L)) = -3.325219 + 0.921735 * Log(Turbidity\ (NTU))}$$

$$\mathbf{Log(TSS\ (mg/L)) = 0.3573445 + 1.0081966 * Log(Turbidity\ (NTU))}$$

These equations were applied to continuous turbidity measurements (collected every 5 minutes) to estimate FSP and TSS concentrations at 5 minute intervals. The instantaneous pollutant concentration multiplied by the instantaneous flow rate multiplied by 5 minutes results in a pollutant mass generated every 5 minutes. Similarly, the flow rate can be multiplied by 5 minutes to result in a runoff volume every 5 minutes. Pollutant mass and runoff volume are then aggregated to determine cumulative pollutant load and cumulative runoff volume throughout the duration of stormwater runoff.

Analysis

The calculations described above were applied to runoff events occurring between October 1, 2015 and May 31, 2016. Only runoff events with reliable turbidity data were included and they were divided by runoff type: rain, snowmelt, and thunderstorm to assess if there was variability in temporal pollutant load delivery between different runoff types. All events from February and March and most from April were eliminated due to faulty turbidimeter readings resulting from excessive amounts of accumulated sediment covering monitoring instruments.

The percentages presented in Table 1 represent the average of all the rain, snowmelt, or thunderstorm events that occurred during this time at each of the two monitored inflow sites. (Both FSP and TSS have very similar numbers as they are both derived from sediment and based on continuous turbidity readings.) For example, for rain events, 28% of the total TSS and FSP loads were delivered in the first 30% of the runoff volume. Also for these events, percent load is not greater than percent volume until the 90% volume interval. For thunderstorms, the percent load is slightly greater than percent volume at the 30% volume interval (37% and 36% for FSP and TSS respectively). For snowmelt events, percent load is just 1% greater (41% for FSP and TSS) than percent volume at the 40% volume interval. To demonstrate a first flush phenomenon at this site, closer to 80% of the load should be delivered in the first 20-40% of the runoff volume. Therefore, the first flush phenomenon cannot be confirmed at the SR431 site for any runoff event type.
Figures 1-3 illustrate the data from Table 1 visually and indicate that the relationship between runoff volume and pollutant load is virtually linear for both pollutants across all event types. These linear relationships, with very high R^2 values, confirm the absence of a first flush phenomenon for all event types at the SR431 inflow sites during the fall/winter and spring seasons. Had there been a mass first flush, the curves in Figures 1-3 would have risen quickly in the first 30-50% of the runoff volume and tapered off to almost flat in the later part of the storm. The linear relationships indicate that pollutants

are being delivered consistently throughout the entire runoff event, generally in direct proportion to the flow rate, and imply that there is a constant source of sediment at the SR431 inflow sites. The constant source of sediment may be from the highway (SR431) or it may be internal to the treatment system.

If the source is the highway, either there is a consistent source of pollutants that does not get washed clean or these storms did not generate enough runoff to wash the road clean. In both cases, there is little to no opportunity to treat only the initial pulse of stormwater runoff to get a relatively large load reduction. Thus, filters such as the Contech MFS and Jellyfish may be an effective way to reduce pollutants at this site as they theoretically treat runoff continuously throughout the event. If the source is internal to the treatment system, the excessive amounts of sediment that have built up in the splitter vault and the pipes between the splitter vault and the inflow flumes may be the culprit. It is reasonable to assume that each time runoff flows through the splitter and connecting pipes sediment is being remobilized and measured by the inflow turbidimeters. During a vactor truck cleanout event on April 15, 2016 it was visually confirmed that a large amount of sediment was present throughout the underground flow system as well as the SR431 pullout (see photos below).

A mass first flush analysis will be conducted again on events that follow the projected clean-out of the treatment system, hopefully in July 2016, which will help determine whether the consistent source of pollutants is the highway or internal to the treatment system.


Vactor truck cleanout on April 15, 2016 at SR431 (left). Note accumulated sediment along the curb.
Sediment filled flume prior to cleanout. Bottom of flume is filled with sediment. (right).

Table 1: Percent of total cumulative FSP and TSS loads presented at 10% runoff volume intervals for rain, snowmelt and thunderstorm event types. Percent of total pollutant load is an average of events occurring between October 1, 2015 and May 31, 2016 at the two inflow sites to the treatment vaults.

Rain			Snowmelt			Thunderstorm		
% of total volume	**% of total FSP**	**% of total TSS**	**% of total volume**	**% of total FSP**	**% of total TSS**	**% of total volume**	**% of total FSP**	**% of total TSS**
0%	0%	0%	**0%**	0%	0%	**0%**	0%	0%
10%	8%	8%	**10%**	5%	5%	**10%**	9%	9%
20%	20%	19%	**20%**	15%	15%	**20%**	17%	16%
30%	28%	28%	**30%**	27%	27%	**30%**	37%	36%
40%	35%	35%	**40%**	41%	41%	**40%**	49%	48%
50%	44%	44%	**50%**	53%	53%	**50%**	58%	57%
60%	57%	57%	**60%**	66%	65%	**60%**	67%	66%
70%	65%	65%	**70%**	78%	78%	**70%**	76%	75%
80%	78%	78%	**80%**	86%	86%	**80%**	83%	83%
90%	93%	92%	**90%**	95%	95%	**90%**	90%	90%
100%	100%	100%	**100%**	100%	100%	**100%**	100%	100%

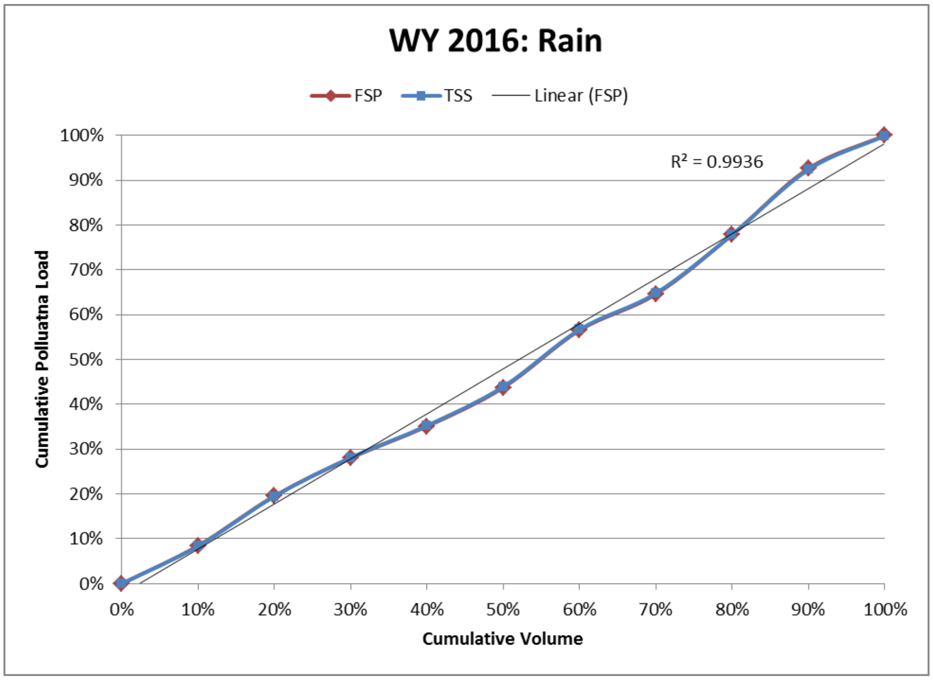

Figure 1: Percent of total cumulative FSP and TSS loads presented at 10% runoff volume intervals for rain events. The relationship is very nearly linear for both pollutants as indicated by an R^2 value of 0.9936 for FSP. Percent totals are an average of rain events occurring between October 1, 2015 and May 31, 2016.

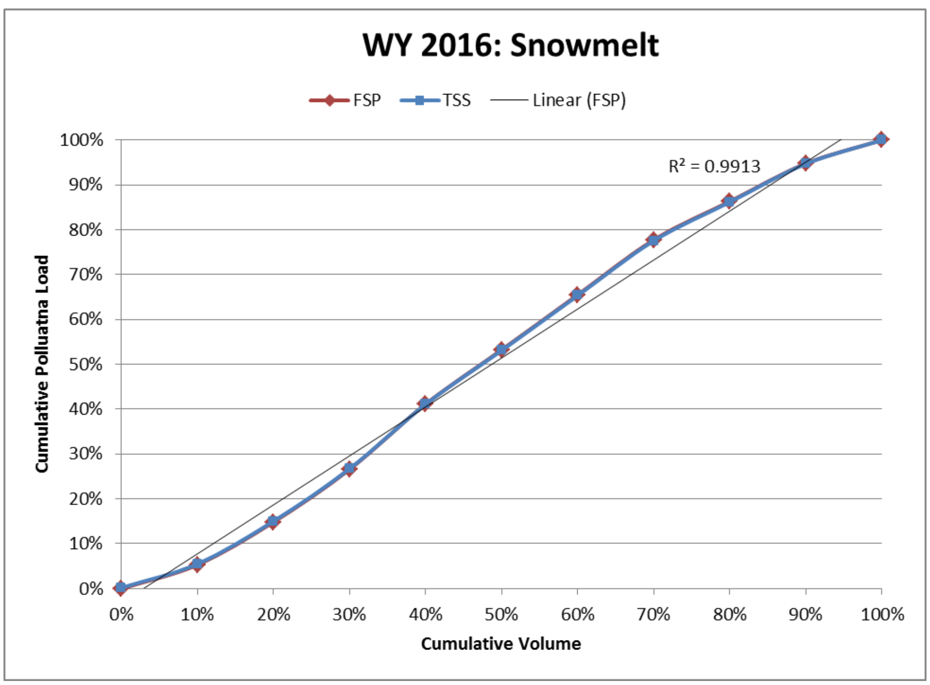

Figure 2: Percent of total cumulative FSP and TSS loads presented at 10% runoff volume intervals for snowmelt. The relationship is very nearly linear for both pollutants as indicated by an R^2 value of 0.9913 for FSP. Percent totals are an average of snowmelt occurring between October 1, 2015 and May 31, 2016.

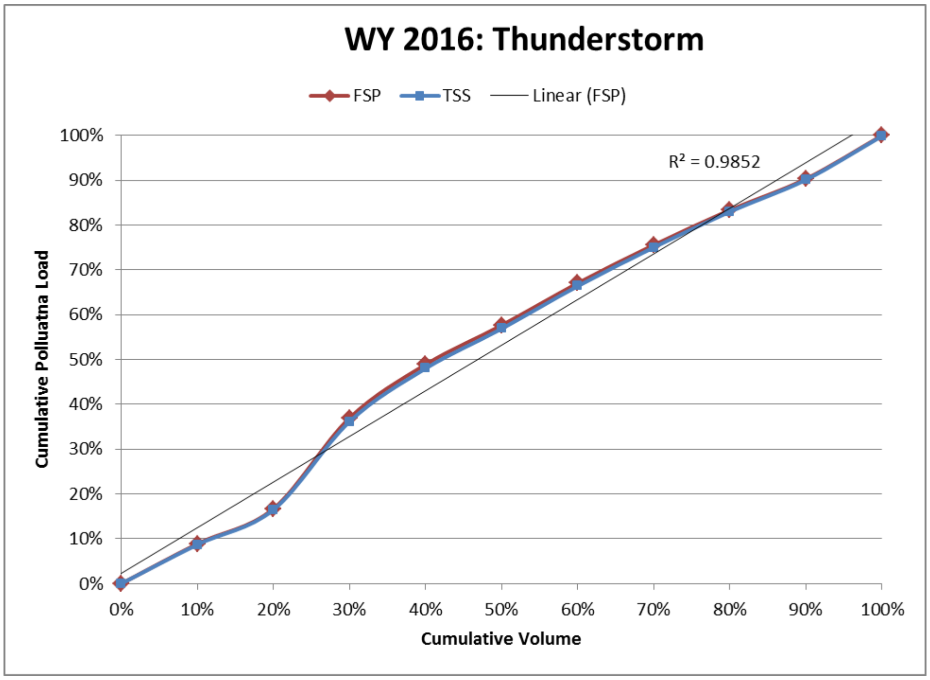

Figure 3: Percent of total cumulative FSP and TSS loads presented at 10% runoff volume intervals for thunderstorms. The relationship is very nearly linear for both pollutants as indicated by an R^2 value of 0.9852 for FSP. Percent totals are an average of thunderstorms occurring between October 1, 2015 and May 31, 2016.

References

Heyvaert, Alan C., Richard B. Susfalk, Brian Fitzgerald, and Andrea Buxton. *Performance Evaluation of Two Stormwater Draft: Filtration Treatment Devices Installed by the Nevada Department of Transportation*. Rep. N.p.: n.p., 2015.

Stenstrom, Michael K., and Masoud Kayhanian. *First Flush Phenomenon Characterization*. Sacramento, CA: California Department of Transportation Division of Environmental Analysis, 2005. Web. 3 Mar. 2016.