P-6 Comparison Tests—A Point-Integrating Suspended Sediment Sampler Comparison

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Introduction

Federal Interagency Sedimentation Project (FISP) Memo 2011.01 introduced the US P-6 point-integrating suspended-sediment sampler (in 100 and 200 lb. versions yclept P-6 100 and P-6 200, respectively) as the next-generation replacement for the P-61, P-63, and P-72 series point-integrating samplers (FISP 2011). The memo describes the new sampler and provides details of flume and tow-tank hydraulic efficiency testing that verified nozzle hydraulic efficiencies within a range of 0.93 to 1.12. The tests showed a nozzle hydraulic efficiency of near 1.0 at 3.5 ft/sec flume flow velocity. Tow tank tests showed hydraulic efficiency varying from approximately 1.10 at 1.5 ft/sec to 0.95 at about 5.5 ft/sec, then remaining in a range between 0.93 to 0.96 up to 16 ft/sec. These results fall within the acceptable range of 0.9 to 1.1. The memo describes field testing performed by the U.S. Army Corps of Engineers' Coastal and Hydraulics Laboratory but lists only sampled ranges of flow velocity and depth, as well as total number of samples and sample frequency time. Field comparison sampling with a different point sampler is not mentioned. An important consideration of long-term time series sample data is to document potential bias due to changes in sampling equipment. Such sampler comparison tests were made between earlier versions of FISP-issued (and other) suspended-sediment samplers (FISP 1944). Notes from a Spring 2012 FISP meeting (FISP 2012) include a remark about acquiring side-by-side sampler testing, but subsequent testing was of limited value due to a very low amount of suspended sediment (Jim Selegean, USACE written communication 2018). Additional comparison testing between a P-6 200 and a P-63 was completed in 2015, but those data have not been published with narrative description (Lane Simmons, USGS written communication 2018). Presented here are results of field comparison sampling using a P-6 100 (hereinafter P-6) and a US-P-61-A1 (hereinafter P-61) under different conditions on two rivers near Mount St. Helens, Washington, during 2018. Sample analyses focused on suspended-sediment concentration (SSC) and particle size.

Study sites

Samples for this study were collected at two USGS gage sites in Southwest Washington state, Toutle River at Tower Road near Silver Lake, WA (USGS station number 14242580—USGS 2019a), and Cowlitz River at Castle Rock, WA (USGS station number 14243000—USGS 2019b). Both sites are on rivers that transport sediment derived mostly from the debris avalanche that resulted from the 1980 eruption of Mount St. Helens. Sampling at both sites was done from a bridge at the gage station (downstream side at Tower Road, upstream side at Castle Rock).

Methods

Comparison sampling can be done various ways, but no method under field conditions can achieve perfect comparison due to temporal and spatial variation in SSC, particle size distribution, and streamflow velocity. Due to limited resources for this study, sampling was conducted at a single station on a bridge, so all depth-integrated (DI) samples used the same vertical, and all fixed-point (FP, or point) samples used the same point, or points (with the exception that during the March 5 sampling at Castle Rock, bed elevation change due to dune migration engendered a 0.5-ft raise in the bottom three sampled depths, in an attempt to maintain relative distance above bed). This method limited spatial variation at the cost of accentuated temporal variation. The alternate approach of collecting samples side-by-side to constrain temporal variation at the expense of spatial variation was rejected as it would have required more people to operate two sampling rigs simultaneously. Samplers were deployed from a bridge crane using an E-reel with one-eighth inch copper-core steel suspension cable. and a Hydrologic Instrumentation Facility (HIF) variable speed reel drive unit. Limited velocity data was collected with a Price meter or an Acoustic Doppler Current Profiler (ADCP) but is not presented here due to large uncertainty in its applicability for computing nozzle intake efficiencies. Prior to sampling, dry bottle tests were performed by lowering the sampler with bottle into the stream for a short time with the nozzle closed, then retrieving it to inspect for leakage. Quart glass sample bottles were used for both samplers. Next, a series of samples, either DI or point, were collected using a P-61. Then, the P-61 was swapped for a P-6, and a second series of samples was collected with that sampler, at the same transit rate, depths, and nozzle open times. Generally, samples were collected using the same transit rate (for DI samples) and the same nozzle open times (for point samples). Exceptions to this were the first two P-61 point samples collected on March 5, when subsequent nozzle-open times were altered to optimize sample volume; one DI sample collected on March 5, transit rate for which was not noted; and the first P-61 point sample on December 19, when subsequent nozzle-open time was reduced to optimize sample volume. Throughout the four separate days of sampling at both sites, the sequence of sampling, and the number of samples collected varied. All samples were analyzed at the Cascades Volcano Observatory sediment lab for sand fine split and concentration.

Data

Samples were collected on February 27 and March 5 at USGS station 14243000 Cowlitz River at Castle Rock, WA; on December 19 at USGS station 14242580 Toutle River at Tower Road near Silver Lake, WA; and on December 21, again at Cowlitz River at Castle Rock.

Samples collected on February 27 (Table 1) consisted of five fixed-point samples from each sampler at a depth of 10 feet, and nozzle-open time of 20 seconds, at station 234 ft on the upstream side of the bridge (this and subsequent references to bridge station are distance in feet from the river-left end of the bridge).

On March 5, 30 fixed-point samples and two depth-integrated samples were collected at a single vertical at station 350, off the upstream side of the bridge in Castle Rock, WA (Table 2). Sampled depths were 10, 9, 8, 5, and 1 ft below the water surface (but the bottom P-6 samples were adjusted upward 0.5 ft to adjust for gradual rise in bed elevation). Twenty-one consecutive P-61 samples were collected at the various depths and nozzle-open times in a repeating fashion. Then the sampler was changed to the P-6 and another 9 samples were similarly collected with that sampler.

On December 19, sequential comparison samples were collected at station 200 off the downstream side of the Tower Road bridge over the Toutle River (Table 3). Six DI samples were collected with a P-61, followed by six point samples with the same sampler. Then,

Table 1. P-6 and P-61 sample metadata and lab results, February 27, 2018. [%finer; percent finer than 0.0625 mm]

Date/Time (PST)	Sampler		Sample Type		Transit rate (ft/s)	Transit length (ft)	Depth below water surface (ft)	Nozzle-open time interval (sec)	Lab Results	
	P-61	P-6	DI	FP					SSC (mg/L)	%finer
2/27/18 @1301	X			X			10	20	33	18.7
2/27/18 @1305	X			X			10	20	39	18.8
2/27/18 @1310	X			X			10	20	40	17.2
2/27/18 @1314	X			X			10	20	39	19.3
2/27/18 @1316	X			X			10	20	34	18.7
2/27/18 @1334		X		X			10	20	42	18.4
2/27/18 @1336		X		X			10	20	36	18.1
2/27/18 @1339		X		X			10	20	34	18.6
2/27/18 @1342		X		X			10	20	33	15.8
2/27/18 @1345		X		X			10	20	40	19.0

Table 2. P-6 and P-61 sample metadata and lab results, March 5, 2018. [%finer; percent finer than 0.0625 mm]

Date/Time (PST)	Sampler		Sample Type		Transit rate (ft/s)	Transit length (ft)	Depth below water surface (ft)	Nozzle-open time interval (sec)	Lab Results	
	P-61	P-6	DI	FP					SSC (mg/L)	%finer
3/05/18 @1347	X			X			10	30	41	23.0
3/05/18 @1351	X			X			9	45	26	27.4
3/05/18 @1353	X			X			8	40	25	26.1
3/05/18 @1356	X			X			5	30	21	34.0
3/05/18 @1358	X			X			1	25	18	39.1
3/05/18 @1420	X			X			10	45	29	25.9
3/05/18 @1421	X			X			9	35	23	31.3
3/05/18 @1433	X			X			8	30	20	33.0
3/05/18 @1435	X			X			5	30	20	34.8
3/05/18 @1436	X			X			1	25	17	41.9
3/05/18 @1450	X			X			10	45	39	18.6
3/05/18 @1455	X			X			9	35	31	26.2
3/05/18 @1457	X			X			8	30	22	34.8
3/05/18 @1458	X			X			5	25	19	33.0
3/05/18 @1503	X			X			1	25	19	44.6
3/05/18 @1529	X			X			10	45	30	24.3
3/05/18 @1528	X			X			9	35	24	30.1
3/05/18 @1532	X			X			8	35	26	29.5
3/05/18 @1534	X			X			5	30	20	36.6
3/05/18 @1537	X			X			1	25	14	52.6
3/05/18 @1556	X			X			10	45	30	25.4
3/05/18 @1605		X		X			9	35	42	20.3
3/05/18 @1607		X		X			8	35	32	25.4
3/05/18 @1609		X		X			5	30	25	34.5
3/05/18 @1614		X		X			1	25	16	46.4
3/05/18 @1634		X		X			9.5	45	38	19.7
3/05/18 @1636		X		X			8.5	35	31	18.7
3/05/18 @1638		X		X			7.5	30	21	33.3
3/05/18 @1640		X		X			5	25	21	34.8
3/05/18 @1642		X		X			1	25	16	41.8
3/05/18 @1504	X		X		1.0	~10.5			23	38.5
3/05/18 @1559		X	X		Not noted	~10.5			23	34.8

six point samples were collected with a P-6 at the same depth and nozzle open time, followed by six depth-integrated samples using the same transit rate as used with the P-61.

On December 21, sequential comparison samples were collected at station 234 ft off the upstream side of the bridge over the Cowlitz River in Castle Rock, Washington (Table 4). As at the Toutle River site two days earlier, six depth-integrated samples were collected with a P-61, followed by six point samples with the same sampler. Then, six point samples were collected with a P-6 at the same depth and nozzle open time, followed by six depth-integrated samples using the same transit rate as used with the P-61.

Table 3. P-6 and P-61 sample metadata and lab results, December 19, 2018. [%finer; percent finer than 0.0625 mm]

Date/Time (PST)	Sampler		Sample Type		Transit rate (ft/s)	Transit length (ft)	Depth below water surface (ft)	Nozzle-open time interval (sec)	Lab Results	
	P-61	P-6	DI	FP					SSC (mg/L)	%finer
12/19/2018@1336	X		X		1.5	~11.8			2,300	15.5
12/19/2018@1340	X		X		1.5	~11.8			2,573	13.9
12/19/2018@1342	X		X		1.5	~11.8			2,679	13.4
12/19/2018@1344	X		X		1.5	~11.8			2,683	13.2
12/19/2018@1346	X		X		1.5	~11.8			2,143	16.3
12/19/2018@1348	X		X		1.5	~11.8			2,960	11.5
12/19/2018@1354	X			X			7	20	2,145	16.4
12/19/2018@1356	X			X			7	15	1,987	17.7
12/19/2018@1358	X			X			7	15	2,093	16.9
12/19/2018@1400	X			X			7	15	2,341	14.9
12/19/2018@1402	X			X			7	15	2,164	16.2
12/19/2018@1404	X			X			7	15	2,163	16.2
12/19/2018@1428		X		X			7	15	1,980	17.2
12/19/2018@1431		X		X			7	15	2,201	15.9
12/19/2018@1433		X		X			7	15	2,079	16.5
12/19/2018@1435		X		X			7	15	1,962	17.5
12/19/2018@1437		X		X			7	15	1,924	17.8
12/19/2018@1439		X		X			7	15	2,009	17.2
12/19/2018@1447		X	X		1.5	~12.5			1,790	18.8
12/19/2018@1449		X	X		1.5	~12.5			2,000	16.7
12/19/2018@1451		X	X		1.5	~12.5			2,186	15.4
12/19/2018@1453		X	X		1.5	~12.5			2,273	14.8
12/19/2018@1456		X	X		1.5	~12.5			2,197	15.2
12/19/2018@1458		X	X		1.5	~12.5			2,215	15.0

Discussion

Due to the small number of samples collected during each of the four comparison sampling events (maximum number of directly comparable samples was six), rigorous statistical analysis was not conducted for these data. Graphs are presented for the three more-complex data sets collected on March 5, December 19, and December 21 to visualize sample variation.

Streamflow during sampling at Castle Rock on February 27 was steady at 16,200 ft^3/s. As the previous substantial sediment-mobilizing peak was in late December 2017, river SSC was relatively low. P-61 sample SSC ranged from 33 to 40 mg/L (37 mg/L average), and percent finer than 0.0625 mm (%finer) from 17.2% to 19.3% (18.5% average). P-6 samples collected at the same station, depth, and nozzle-open time ranged from 33 to 42 mg/L (37 mg/L average), and %finer from 15.8% to 19.0% (18.0% average). Under these relatively low SSC and stable flow conditions, the two samplers produced nearly identical results.

One week later, on March 5, streamflow at Castle Rock had almost halved, and was slowly declining at about 8,300 ft^3/s. Much of the decline in flow between February 27 and March 5 was due to a series of dam-regulated flow reductions on the Cowlitz River above its confluence with the Toutle River. This significant reduction in clean-water flow from the upper Cowlitz River, combined with a small rise on the Toutle River on March 1, resulted in similar SSC for the two sample sets. March 5 samples were collected to document variation in SSC and particle size distribution with depth, and to show temporal variation. Figure 1 shows six series of five repetitive different-depth point samples progressing from near-bed to near-surface. Although the first one or two samples collected with the P-6 appear slightly high compared to the immediately preceding P-61 sample, these data points also show close similarity of SSC and %finer values. A possible contributing factor to the higher SSC values in the first two P-6 samples is that the river bed elevation appeared to have aggraded since sampling commenced, presumably due to dune migration, so the P-6 samples at times 1605 and 1607 may have been nearer the bed than previous same-depth samples. For the final set of samples with the P-6, sample locations were raised 0.5 ft to adjust for the change.

Table 4. P-6 and P-61 sample metadata and lab results, December 21, 2018. [%finer; percent finer than 0.0625 mm]

Date/Time (PST)	Sampler		Sample Type		Transit rate (ft/s)	Transit length (ft)	Depth below water surface (ft)	Open-nozzle time interval (sec)	Lab Results	
	P-61	P-6	DI	FP					SSC (mg/L)	%finer
12/21/2018@1335	X		X		1.0	~10.5			228	25.2
12/21/2018@1338	X		X		1.0	~10.5			217	25.7
12/21/2018@1341	X		X		1.0	~10.5			200	28.1
12/21/2018@1342	X		X		1.0	~10.5			227	23.9
12/21/2018@1344	X		X		1.0	~10.5			200	27.8
12/21/2018@1346	X		X		1.0	~10.5			237	23.7
12/21/2018@1349	X			X			7	17	244	22.5
12/21/2018@1350	X			X			7	17	232	25.5
12/21/2018@1352	X			X			7	17	265	22.3
12/21/2018@1354	X			X			7	17	224	26.1
12/21/2018@1356	X			X			7	17	231	24.3
12/21/2018@1357	X			X			7	17	261	22.2
12/21/2018@1413		X		X			7	17	275	20.3
12/21/2018@1415		X		X			7	17	248	22.8
12/21/2018@1417		X		X			7	17	212	27.3
12/21/2018@1418		X		X			7	17	244	22.8
12/21/2018@1420		X		X			7	17	239	23.6
12/21/2018@1422		X		X			7	17	207	27.2
12/21/2018@1424		X	X		1.0	~10.5			234	25.2
12/21/2018@1426		X	X		1.0	~10.5			209	27.3
12/21/2018@1428		X	X		1.0	~10.5			198	29.3
12/21/2018@1430		X	X		1.0	~10.5			270	21.3
12/21/2018@1431		X	X		1.0	~10.5			190	30.0
12/21/2018@1433		X	X		1.0	~10.5			225	25.6

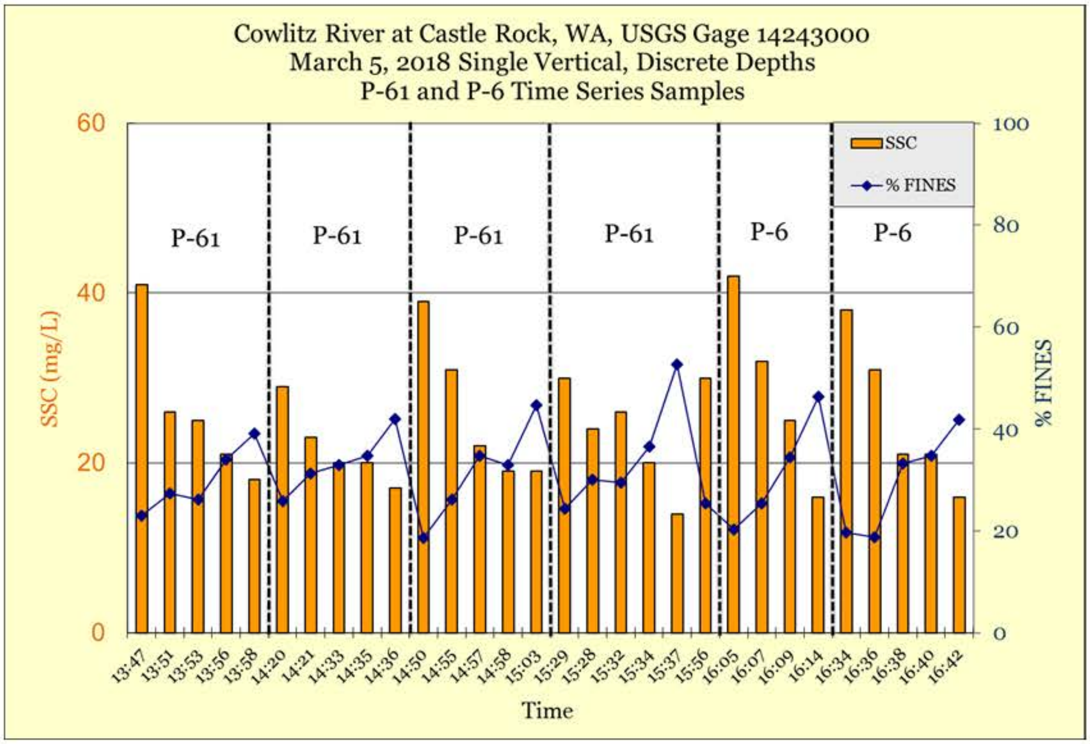

Figure 1. Cowlitz River at Castle Rock point sample SSC and %finer results. Samples taken successively at various depths, from near bed to near surface, repetitively.

Sample collection on December 19, at the Toutle River gage, occurred at streamflow of 5,800 ft^3/s during a slow recession from a peak about 24 hours previous (sharp rise in 14 hours from 2,000 ft^3/s to 10,000 ft^3/s). Figure 2 shows sample concentrations; 15-minute values of turbidity (scaled by multiplying raw value by 35) and discharge (both provisional) show a general declining trend in streamflow and SSC. Average values of the four sets of samples are plotted as well; these data show about 10% greater spread in SSC range for P-61 DI samples against later P-6 DI samples, and a 2% (on average) greater amount of sand in the P-6 samples. In the interval between P-61 DI and P-6 DI sampling, notes indicate stream depth increased approximately 0.7 ft (presumably a bed elevation change). Point samples show a tighter grouping for both samplers, with only about 3.5% difference from low to high SSC. Average %finer values between the two sets of point samples differed by less than one percent. Visual comparison shows that in context of declining streamflow and turbidity trends, the two samplers produced reasonably equivalent results.

Sample collection on December 21, at the Cowlitz River in Castle Rock gage, occurred at streamflow of about 14,800 ft^3/s during continued slow recession from the peak on December 18. Figure 3 shows sample SSC and 15-minute streamflow values that indicate a general declining trend. Average values of the four sets of samples are plotted as well. Opposite to data from two days previous, here the P-6 DI sample grouping is wider than the P-61 DI set (P-6 range about 20% greater than P-61 range). However, average SSC and %finer values for the two DI sample sets differed by only a percentage point. Point samples showed similar differences in range and average, with P-6 sample SSC having about 20% greater range, but close agreement with the P-61 in both mean SSC and mean %finer values.

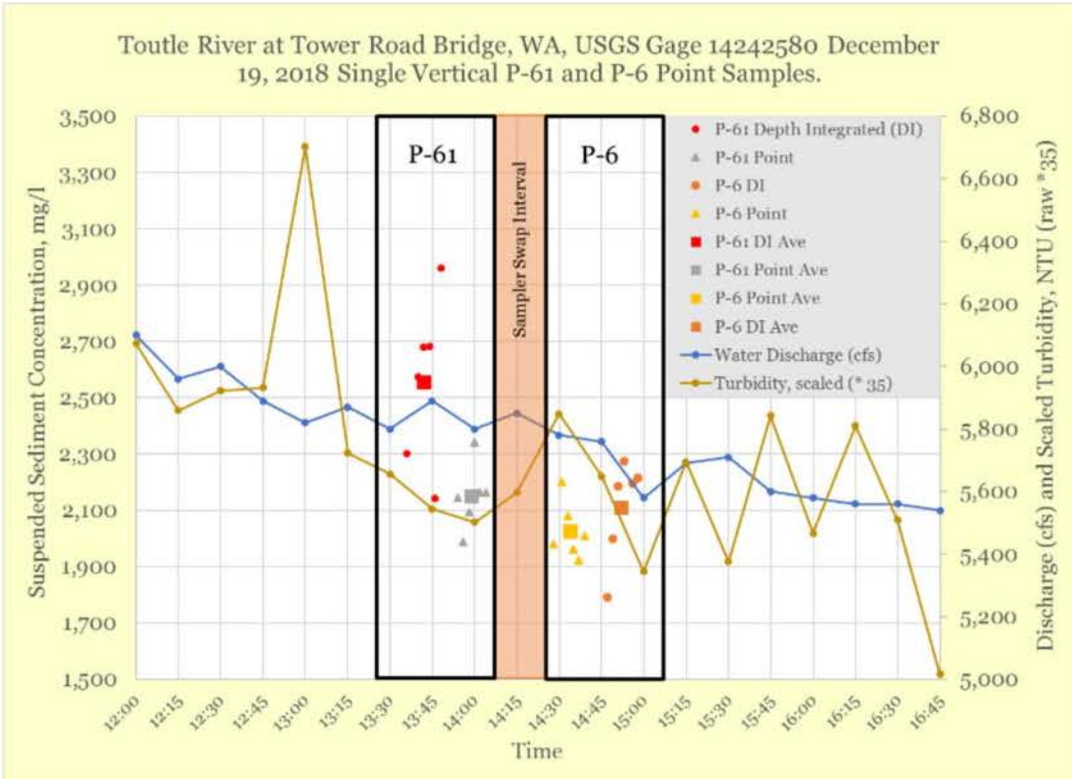

Figure 2. Toutle River at Tower Road DI and point sample SSC. Samples taken at same vertical and depths.

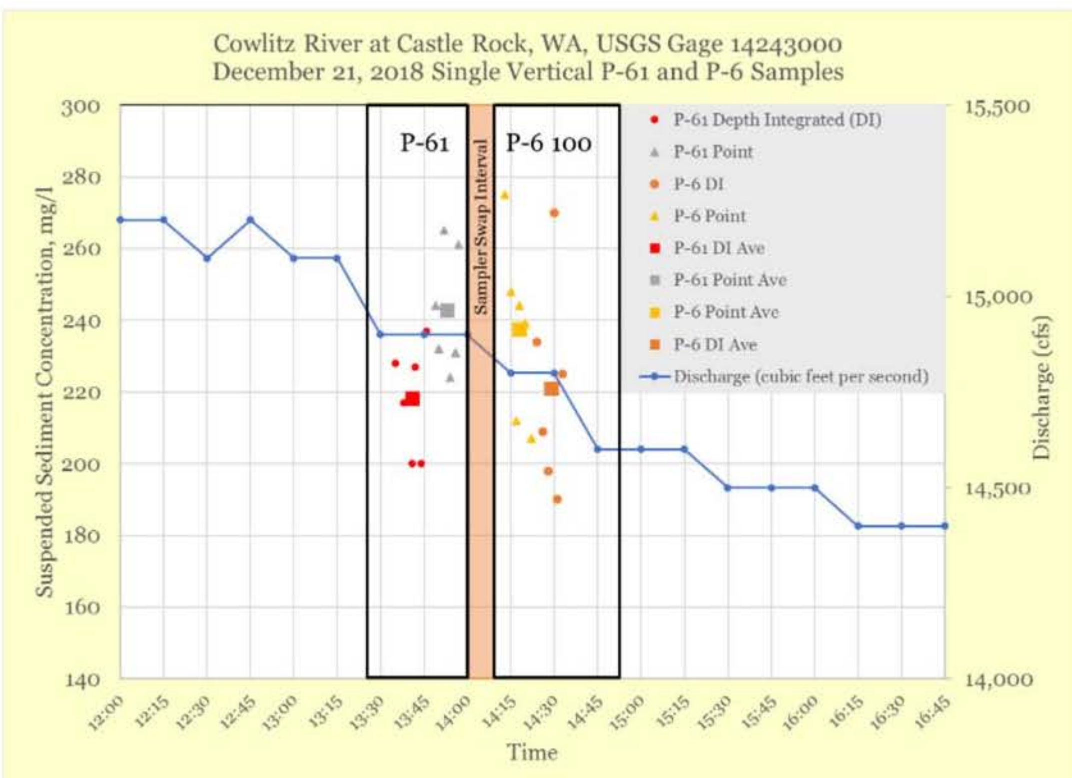

Figure 3. Cowlitz River at Castle Rock DI and point sample SSC. Samples taken at same vertical and depths.

Conclusions

Collectively, these sample sets show general agreement over a range of flow and concentration values. Despite the lack of perfect congruence in time and place, the results indicate that the two samplers produce reasonably consistent results. While this was the expected result of the study, these data document the compatibility of use between the two samplers and serve to bolster confidence that adoption of the P-6 will not introduce bias in any time series of samples collected with the P-61.

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