Appendix G:
2011 Exelon Conowingo Pond Bathymetric Survey Analysis

APPENDIX G: Introduction

This Assessment was computer-model intense and the models required data to estimate physical processes accurately. In October 2011, Exelon conducted bathymetric surveys of Conowingo Reservoir. This is the most recent bathymetric survey taken of Conowingo Reservoir; thus, representing the most current condition of the reservoir. Bathymetric surveys in Conowingo Reservoir have been conducted by U.S. Geological Survey (USGS) in the past. Exelon 2011 survey data and methods were evaluated by U.S. Geological Survey (USGS) who determined that the methods and collected data from this survey were appropriate and usable for this effort. The results of this survey are presented in this appendix.

GOMEZ AND SULLIVAN
Engineers, P.C.

Memo

To: Conowingo Relicensing Stakeholders

From: Gomez and Sullivan

Date: 8/3/2012

Re: Conowingo Pond Bathymetric Survey Analysis

Introduction

In September 2011, the Susquehanna River basin received heavy precipitation from Tropical Storm Lee[1]. Following the storm, the USGS estimated that Conowingo Dam's daily average flow peaked at 708,000 cfs with an instantaneous peak of 767,000 cfs (Personal Communication, Mike Langland [USGS], February 2012) – the Conowingo USGS gage's third highest recorded flow since it was established in October 1967. Given the opportunity to investigate how Conowingo Pond's sediment levels may have been affected by a major flood, Exelon decided to conduct a bathymetric survey of Conowingo Pond, with the following objectives:

1) Compare the 2011 results to the 2008 USGS bathymetry survey to determine whether Conowingo Pond experienced net deposition or scour.
2) Establish a physical "baseline" benchmark.
3) Provide the results for use as an input data set for the Lower Susquehanna River Watershed Assessment's Conowingo Pond modeling efforts.

This memo describes the background and analysis related to the bathymetric survey that Gomez and Sullivan conducted during the week of October 24, 2011.

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[1] Tropical Storm Irene preceded Tropical Storm Lee, and was responsible for the Susquehanna River's high base flow immediately prior to Tropical Storm Lee's arrival. This memo refers to the cumulative event as Tropical Storm Lee.

Methodology

Gomez and Sullivan collected bathymetric data at previously surveyed USGS transect locations, as well as at several additional transect locations in Conowingo Pond during the week of October 24, 2011 (Figure 1 and Figure 2). Data were collected from a 19-foot-long pontoon boat with a front-mounted echo-sounder and a real time kinematic global positioning system (RTK-GPS) placed directly above the echo-sounder.

The RTK-GPS utilized was a Sokkia GRX1 base and rover. A 35 W Pacific Crest repeater radio was used to extend the base-rover link distance to approximately 5 miles. When the GPS unit is in RTK mode, it has a horizontal accuracy of approximately ± 0.033 ft + 0.005 ft per mile from the base station. When in differential GPS (DGPS) mode, the unit has a horizontal accuracy of approximately ± 1.6 ft. GSE cross-sections 1 through 52 and all longitudinal profiles were collected in RTK mode. GSE cross-sections 53 through 59 were collected in DGPS mode. All position data were streamed to the bathymetric unit at a 10 Hz frequency (10 samples per second), where the position and timestamp were stored.

The bathymetric unit used was a Sontek RiverSurveyor M9. The RiverSurveyor M9 uses a vertical hydroacoustic beam to measure water depths between approximately 0.65 ft and 260 ft, with an approximately 0.003 ft resolution. The unit specifications state a depth accuracy of ±1% (e.g., ±0.5 ft at a 50-ft water depth), which was verified in the field during the survey through the use of a flat metal surface attached to a pre-measured rope length lowered into the water (Table 1). The RiverSurveyor also recorded water column velocities and a second water depth measurement through the use of eight angled hydroacoustic beams, only four of which are used at one time. The average water depth recorded by the velocity beams served as a secondary depth measurement to verify the primary (vertical beam) depth measurement. Water velocity and water depth measurements were continuously recorded in one-second intervals[2] throughout the entire study. The RiverSurveyor M9 recorded all data internally and also outputted to a USB-linked tablet computer for real-time data monitoring. Real-time data streamed to the tablet computer were redundantly saved on the tablet to prevent data loss.

Measured depth data were combined with water surface elevations (WSE) to calculate bed elevations, such that Bed Elevation = Water Surface Elevation – Water Depth[3]. WSEs were recorded at three locations along Conowingo Pond: Conowingo Dam, Peach Bottom Atomic Power Station (Peach Bottom), and Muddy Run. Though the surveyed portion of Conowingo Pond is primarily a backwater-type area from Conowingo Dam, a small but perceptible WSE gradient, typically less than

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[2] The unit measured bottom depths several times per second, and then recorded the average of all valid measurements made during the one-second interval.

[3] The bathymetry unit was placed approximately 8 inches (0.67 ft) deep in the water. The exact distance was measured and input into the RiverSurveyor's software every day prior to surveying. The RiverSurveyor's software automatically accounts for this in recorded depths.

0.25 ft, is measurable between Conowingo and Peach Bottom. To account for this WSE difference, the WSE gradient between Conowingo Dam and Peach Bottom was used to determine the WSE throughout Conowingo Pond. Muddy Run WSEs were not used because that area of Conowingo Pond is heavily influenced by Holtwood and Muddy Run operations. Thus, we determined that extrapolating the WSE gradient between Conowingo Dam and Peach Bottom to the most upstream cross-section (just downstream of Hennery Island) was the most appropriate WSE estimation method.

Several steps were taken to get Conowingo Pond's WSE gradient. First, WSEs at Conowingo (30-min interval) and Peach Bottom (~2.5-min interval) were interpolated over time to create a 1-min time series for both stations. Next, a WSE gradient (WSE change per river mile) was calculated between the two stations, for each 1-min interval. Then, for each depth measurement point, the linear distance upstream of Conowingo Dam was calculated, and the measurement point's time stamp (rounded to the nearest minute) was matched with a corresponding Conowingo Pond WSE gradient by matching 1-minute time stamps. The WSE at each measurement point was then calculated by multiplying the point's distance upstream of Conowingo Dam by the timestamp-matched WSE gradient. WSEs were then subtracted by the water depths to calculate bed elevations.

The Quality Assurance/Quality Control (QAQC) version of the 2008 Conowingo Pond bathymetry data set was provided by the USGS to Exelon. Data collection and analysis methodology for the 2008 data set are described in Langland (2009). The data set consists of spatially-georeferenced (latitude/longitude) depths from Conowingo Pond's normal water surface elevation of 109.2 ft NGVD 1929[4]. These data were used to compute bed elevation changes relative to historic bed elevations from fall 2008.

Our analysis followed the methodology described in Langland (2009), except that an additional method for calculating transects' average water depths from Normal Pool (109.2 ft NGVD 1929) was used. Langland (2009) calculated water volumes using the mid-point method, such that water volume equaled cross-sectional effective length multiplied by width between adjacent cross-sections multiplied by the cross-sectional average depth. The cross-section *width* was determined by calculating the distance between the first and last point of each cross-section. The cross-section *effective length* was calculated as half the distance to the next upstream cross-section plus half the distance to the next downstream cross-section. Langland (2009) calculated transects' *average depths* by taking the average of all points collected in each cross-section, normalized to Conowingo Pond's normal pool elevation, such that $D_{avg} = \frac{\sum_{i=1}^{n} d_i}{n}$, where D_{avg} is a transects' average depth, *n* is the number of points in a transect, and d_i is the depth from Normal Pool at point *i*. Our alternative method

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[4] The Langland (2009) data set was collected with reference to Conowingo Datum water surface elevations. All water depth data provided to Exelon were converted to bed elevation data in NGVD 1929. Conowingo Datum elevations are 0.7 ft below NGVD 1929 elevations, such that elevation 108.5 ft in Conowingo Datum equals elevation 109.2 ft in NGVD 1929.

was similar, except that it weighted depths by the distance, such that $D_{avg} = \frac{\sum_{i=1}^{n} d_i * w_i}{\sum_{i=1}^{n} w_i}$, where D_{avg} is a transects' average depth, n is the number of points in a transect, d_i is the depth from Normal Pool at point i, and w_i is the space between adjacent points in the same transect. Then, the total water volume was calculated for each cross-section as: $V_{water} = L_{eff} * W * D_{avg}$, where V_{water} is the cross-section's water volume, L_{eff} is the cross-section's effective length, W is the cross-section's width and D_{avg} is the cross-section's average depth.

Since the raw QAQC data available for the USGS 2008 survey had been adjusted for QAQC reasons during the initial steps of this analysis, cross-sectional average depths were re-calculated for this analysis, rather than using the volumes reported in Langland (2009). The cross-sectional widths and lengths were not changed from the Langland (2009) values, since those parameters have not appreciably changed since 2008. The Langland (2009) and recalculated total water volumes matched closely. When compared, Langland (2009) reported a total water volume of 162,398 acre-ft (the report had rounded to the nearest 1,000 acre-ft), while we computed a total 2008 water volume of 162,604 acre-ft using our recalculated unweighted average depths. Thus, the two calculations matched within 206 acre-ft.

As was done in Langland (2009), net sediment deposition was calculated as the change in water volumes between 2008 and 2011, such that any decrease in water volume was attributed to an equal increase in sediment volume (net deposition) and any increase in water volume was attributed to an equal decrease in sediment volume (net scour[5]). A normalized dry density of 67.8 lb/ft^3 was used to calculate sediment weight from sediment volumes. Sediment weights were reported in tons, where 1 ton equals 2,000 pounds. Once the individual cross-section sediment changes were computed, an aggregated Conowingo Pond water volume and sediment change was calculated as the sum of all cross-sections' net volume and sediment volume/weight change.

Results

The data were compiled and combined with other near-shore elevation data to create an updated Conowingo Pond bed elevation map (Figure 3). Bed elevations from the 2008 and 2011 surveys were compared at all 26 historic USGS cross-sections (Appendix A: Historic Cross-Section Comparison). All 59 transects collected in 2011 are shown in Appendix B: 2011 Cross-Section Plots.

The results showed that there were three distinguishable sections within Conowingo Pond. The upper Pond (USGS XC 1 – USGS XC 10) was shallow, with average channel depths of 17 feet or less[6]. The

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[5] In the context of a particular cross-section, "scour" refers to a net sediment removal between 2008 and 2011, only implying that the sediment has moved out of that particular cross-section. In the context of the entire Conowingo Pond, "net scour" refers to the Pond's overall sediment flux across all cross-sections, meaning that the total amount of sediment in Conowingo Pond has changed.

[6] The depths and changes in depths cited in this section refer to the weighted average depth calculations.

upper Pond generally had small amounts of net scour (< 1 ft avg.) between the 2008 and 2011 survey, such as in USGS XC 6 (Figure 4). The middle of the Pond (USGS XC 11 – USGS XC 18) was moderately shallow, with average channel depths between 14 and 22 feet. The middle Pond experienced small to negligible amounts of net deposition, with average bed elevations rising between 0.0 and 0.6 ft. Though the middle Pond experienced little net change, there were local areas of scour and deposition that were roughly balanced, such as in USGS XC 16 (Figure 5). The lower end of the Pond (USGS XC 19 – USGS XC 26) had increasingly deeper cross-sections, with average depths ranging from just over 21 feet to nearly 50 feet. The lower Pond transects had relatively large amounts of net deposition, with between 1 and 3.5 feet of average bed elevation increase between the 2008 and 2011 surveys. The only exception to this in the Lower Pond was at USGS XC 21, which only experienced a 0.38 ft average bed elevation increase between the 2008 and 2011 survey[7].

Deposition and scour occurred in predicable locations. Deposition was generally most noticeable along the river's edges or shallower areas. Conversely, there was typically little to no deposition (or occasionally scour) near the river's thalweg (the deepest point in the transect, or area where the majority of the flow travels through). This pattern emerged in the middle pond, and became more apparent in farther downstream transects (Figure 6).

Aggregated cross-section data were plotted in longitudinal profiles to compare 2008 and 2011 average bed elevations (Figure 7 and Figure 8) and changes in average bed elevation (Figure 9 and Figure 10), using both average depth methodologies. The profiles support the hypothesis that the upper and middle pond are in dynamic equilibrium. It also confirms that the lower pond is still experiencing substantial deposition, with the amount of deposition increasing closer to Conowingo Dam.

The sediment volume change for each cross-section was calculated using the weighted and unweighted water volume methodologies. Water volume and sediment results for each cross-section are shown for the unweighted methodology in Table 2 and for the weighted methodology in Table 3. Between 2008 and 2011, the net Conowingo Pond water volume decrease was between 2,940 acre-ft (using the unweighted methodology) and 3,434 acre-ft (using the weighted methodology). This corresponds to a sediment volume [weight] increase between 2,940 acre-ft [4.34 million tons] and 3,434 acre-ft [5.07 million tons] from fall 2008 to October 2011. Averaged over the approximately 3 years between the 2008 and 2011 survey, the data show a Conowingo Pond sediment deposition rate of approximately 980 acre-ft per year to 1,145 acre-ft per year, or 1.45 million tons per year to 1.69 million tons per year for the 2008-2011 period.

Using data from Langland (2009), an analysis was done comparing the pond's estimated remaining sediment capacity over time. Conowingo Pond's remaining sediment capacity calculated by subtracting the Pond's total water volume by Langland (2009)'s Conowingo Pond steady state water

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[7] The cross-section plot of USGS XC 21 shows several "spikes" in the 2008 data set that were not picked up in the 2011 survey. These spikes raised the 2008 average cross-section depth, explaining why USGS XC 21 appeared to experience less deposition than the surrounding cross-sections. These spikes may be due to logs, debris, or localized bedrock features.

volume estimation of 142,000 acre-ft. Figure 11a and Figure 11b show the plot of remaining sediment capacity over time next to a similar plot originally shown in Academy of Natural Sciences (1994). An exponential trendline was fitted to Figure 11b to show a similar line as the Academy of Natural Sciences (1994) figure. A sensitivity analysis for several steady-state water volumes showed that the trendline's general shape was maintained for a wide range of steady state volumes. A second sensitivity analysis showed that the trendline's general shape was insensitive to removing any of the individual points from the best-fit plot, including the 2011 results.

Discussion

A comparison of the 2008 and 2011 data sets provide great insight into the sediment transport processes occurring in Conowingo Pond. But, while these two surveys were taken within a relatively short period of time, these comparisons are not the same as a before and after comparison isolating a single event. Historic data have shown there is a considerable amount of deposition that occurs in Conowingo Pond on an annual basis, as the average Conowingo Pond sediment inflow between 1996 and 2008 was approximately 1.5 million tons/year, with a long-term (1959–2008) average deposition of approximately 2 million tons per year (Langland 2009). These historic deposition rates are comparable to the 2008-2011 deposition rates calculated in this study 1.45 to 1.69 million tons per year).

When viewing the individual cross-section plots, it is apparent that the magnitude and location of riverbed changes varied longitudinally along the Pond. In the upper and middle Pond (USGS XC 1 to USGS XC 18) there is little net change between 2008 and 2011, though some cross-sections experienced channel "shifting" or redistribution, such that the deposition and scour areas were roughly equal. This indicates that a large portion of the Pond is likely in "dynamic equilibrium". This is consistent with other USGS findings, which had concluded that the Pond has been in equilibrium at or above USGS XC 16 since 1959. It also shows that the proportion of the Pond in equilibrium is increasing. Beginning around USGS XC 19, three phenomena are apparent:

1) Within each cross-section, the amount of deposition begins to clearly outweigh the amount of scour, resulting in net deposition. The longitudinal profile comparison (Figure 7) further supports the first observation, generally showing between 1 and 3.5 feet of deposition averaged across the cross-section at USGS XC 19 and farther downstream.

2) The cross-sections generally experienced some scour along the river's thalweg or main channel, accompanied by larger amounts of deposition along the banks. Deposition was only observed along one bank when the thalweg was located adjacent to one of the river banks (e.g., USGS XC 20-23). The disparity was most obvious in the farthest downstream cross-sections (Figure 6). It is logical that local scour would occur at a cross-section's thalweg, as one would expect re-suspension to occur where the highest flows, and thus velocities, are found. It is not clear from this data set where the scoured sediment was transported to (e.g., downstream cross-sections, out of the Pond). It would be reasonable to assume that at least

some of the sediment scoured from the farthest downstream comparable cross-section (USGS XC 26) passed over the Conowingo Dam spillway.

3) Between 2008 and 2011, the river thalweg appeared to shift towards the center of the dam, where the spillway is located. This was likely a result of flows following Tropical Storm Lee, during which the Conowingo powerhouse was shut down to protect the turbines. As a result, all flow was passed through the Conowingo spillway, which had a large number of its crest gates (42 of 50) opened at one point.

While 2011 cross-section data were collected closer to the dam than at USGS XC 2008, no previous data sets exist in these areas. Thus, no scour/deposition comparison could be completed for Conowingo Pond downstream of USGS XC 26 at this time. These cross-sections may serve as a reference point for future surveys.

The Academy of Natural Sciences (1994) figure shows equilibrium as a condition where net deposition never permanently stops, though it does occur at reduced rates, and stored sediment never permanently remains at the non-flood steady-state level. It shows that storm events mobilize and remove previously deposited sediment, pushing the system back below a non-flood steady state condition, starting the net deposition cycle again.

The comparison in Figure 11 between the Academy of Natural Sciences (1994) figure and Conowingo Pond's estimated remaining sediment capacity shows a clear trend of Conowingo Pond filling over time in a manner consistent with the Academy of Natural Sciences (1994) figure. It shows that Conowingo Pond, on the whole, is on the rising limb of the curve, but is at a point where the rate of net deposition is reduced and net scour may begin to influence the reservoir's position above or below the long-term mean. The trendline's insensitivity to steady state water volume estimates and removal of individual data points further support this statement. It is unclear at this point whether Conowingo Pond has reached its long-term mean sediment storage level.

In summary, the Academy of Natural Sciences (1994) figure shows that 1) a reservoir's long-term equilibrium sediment volume is less than its true steady-state volume, due to periodic scouring events; and 2) as a reservoir approaches its steady state capacity, it fills increasingly slower, such that a true steady-state volume is rarely, if ever, reached. The Conowingo Pond data show that Conowingo Pond has experienced diminishing sedimentation over time, as the Pond approaches a non-flood steady state capacity. It also shows a scour event (1996), though no immediate pre-storm bathymetric sample was available to show the actual pre and post-storm sediment volumes. The similarity between the Conowingo Pond data and the Academy of Natural Sciences (1994) figure show that Academy of Natural Sciences's (1994) figure likely serves as a good template for predicting Conowingo Pond's future behavior.

Conclusions

Several important points were addressed through analysis of the 2011 bathymetric survey.

First, the survey results support the previous USGS hypothesis that the upper and middle portions of Conowingo Pond have reached dynamic equilibrium, where long term sediment inflow approximately equals long term sediment outflow. It also appears that the zone of dynamic equilibrium has expanded farther downstream than in previous surveys, perhaps extending to USGS XC 18, which is approximately 3.7 miles upstream of Conowingo Dam.

Secondly, 2008-2011 cross-section comparisons indicate that there was local scour (re-suspension) in portions of the Pond's lower cross-sections. The amount of deposition, however, generally exceeded the amount of scour. It was not clear where the re-suspended sediment was transported to.

Thirdly, given that the deposition prior to Tropical Storm Lee is unknown, the flood's sediment profile impacts cannot be directly assessed. Using two different methods, we calculated that the Conowingo Pond water volume decreased (due to a sediment volume increase) between 2,940 acre-ft and 3,434 acre-ft from 2008 to 2011, or between 980 acre-ft per year and 1,145 acre-ft per year. This corresponds to a total sediment deposition of 4.34 million tons to 5.07 million tons, or a rate of 1.45 million tons per year to 1.69 million tons per year, which matches historic deposition rates well.

Finally, the Conowingo Pond data compare well to a typical reservoir sedimentation profile over time. This was true in sensitivity analyses testing various steady state water volumes and excluding individual data points throughout the fitted curve. Thus, it appears the Academy of Natural Sciences (1994) curve likely serves as a reasonable template for how Conowingo Pond will continue to accumulate and scour over time. It is unclear at this point whether Conowingo Pond has reached its long-term mean sediment storage levels as shown in the Academy of Natural Sciences (1994) figure.

References

Langland, M.J., 2009. Bathymetry and Sediment-storage Capacity Change in Three Reservoirs on the Lower Susquehanna River, 1996-2008. United States Geological Survey Scientific Investigations Report 2009-5110. 21p.

Langland, M.J. and R.A. Hainly, 1997. Changes in Bottom-Surface Elevations in Three Reservoir on the Lower Susquehanna River, Pennsylvania and Maryland, Following the January 1996 Flood – Implications for Nutrient and Sediment Loads to Chesapeake Bay. United States Geological Survey Water-Resources Investigations Report 97-4138. 34p with plates.

Academy of Natural Sciences. Issues Regarding Estimated Impacts of the Lower Susquehanna River Reservoir System on Sediment and Nutrient Discharge to Chesapeake Bay. The Academy of Natural Sciences of Philadelphia, Division of Environmental Research. Report No. 94-20. 6 September, 1994.

Table 1: Observed versus measured water depths, from the bathymetric unit verification.

Observed Depth (ft)	Bathymetric Unit Measured Depth (ft)	Difference (ft)	Difference (%)
7.0	6.99	-0.01	-0.14
12.0	11.91	-0.09	-0.75
17.0	17.03	0.03	0.17
22.0	22.09	0.09	0.41
27.0	26.89	-0.11	-0.41

Table 2: Conowingo Pond cross-section sediment calculations, using unweighted average depths. Red numbers in parentheses are negative.

USGS Cross-Section Number	Distance US of Dam (ft)	Effective Length (ft)	Cross-Section Width (ft)	Unweighted Average Depth at Normal Pool [109.2 ft NGVD 1929] (ft)			Water Volume at Normal Pool (acre-ft)			Sediment Accumulation (acre-ft)	Sediment Accumulation (tons)
				2008	2011	Difference	2008	2011	2008-2011		
1	60,000	2,200	4,880	12.20	12.51	0.31	3,084	3,006	77	77	114,340
2	57,700	2,250	6,400	14.37	14.15	(0.22)	4,678	4,751	(72)	(72)	(106,770)
3	56,600	2,350	6,200	15.21	15.53	0.32	5,194	5,088	106	106	156,012
4	54,800	2,150	6,310	16.42	16.19	(0.24)	5,041	5,115	(74)	(74)	(108,849)
5	52,900	1,800	5,900	15.64	15.49	(0.15)	3,777	3,813	(36)	(36)	(52,948)
6	49,800	2,600	6,810	14.87	14.95	0.07	6,075	6,046	30	30	44,137
7	47,010	2,775	6,350	14.96	17.04	2.08	6,895	6,053	842	842	1,243,557
8	44,250	2,430	6,900	15.09	14.14	(0.95)	5,442	5,808	(365)	(365)	(539,555)
9	42,150	2,130	6,540	16.20	15.88	(0.32)	5,080	5,182	(102)	(102)	(150,747)
10	39,990	1,400	7,000	15.26	15.09	(0.17)	3,394	3,432	(38)	(38)	(55,922)
11	37,500	1,900	7,710	12.93	14.53	1.60	4,885	4,347	538	538	794,504
12	35,800	3,420	6,510	15.94	16.17	0.23	8,263	8,146	116	116	171,981
13	33,150	3,175	4,700	20.13	20.32	0.19	6,961	6,896	65	65	96,682
14	29,450	3,150	4,710	20.68	21.09	0.41	7,183	7,043	140	140	206,816
15	26,850	2,530	5,050	20.92	20.70	(0.21)	6,073	6,135	(62)	(62)	(92,147)
16	24,400	2,570	5,300	19.24	19.49	0.26	6,095	6,015	81	81	118,977
17	21,700	2,550	6,180	20.45	20.74	0.29	7,503	7,399	104	104	153,158
18	19,300	2,525	5,000	21.74	21.73	(0.01)	6,299	6,302	(4)	(4)	(5,276)
19	16,650	2,625	5,240	21.64	21.93	0.29	6,926	6,833	93	93	137,103
20	14,050	2,187	3,560	28.66	29.28	0.62	5,233	5,122	111	111	163,832
21	12,275	2,085	3,350	30.28	28.62	(1.66)	4,589	4,856	(267)	(267)	(394,202)
22	9,880	2,162	3,380	30.50	31.15	0.65	5,226	5,116	110	110	161,778
23	7,950	2,175	3,520	32.96	34.06	1.09	5,986	5,793	192	192	284,131
24	5,530	2,400	4,450	37.78	40.50	2.71	9,929	9,263	665	665	982,556
25	3,150	1,915	4,610	45.28	47.23	1.96	9,572	9,176	396	396	585,159
26	1,700	2,425	4,750	48.89	50.00	1.11	13,222	12,929	293	293	432,539
Total	-	-	-	-	-	-	**162,604**	**159,664**	**2,940**	**2,476**	**4,340,848**

Table 3: Conowingo Pond cross-section sediment calculations, using weighted average depths. Red numbers in parentheses are negative.

USGS Cross-Section Number	Distance US of Dam (ft)	Effective Length (ft)	Cross-Section Width (ft)	Weighted Average Depth at Normal Pool [109.2 ft NGVD 1929] (ft)			Water Volume at Normal Pool (acre-ft)			Sediment Accumulation (acre-ft)	Sediment Accumulation (tons)
				2008	2011	Difference	2008	2011	2008-2011		
1	60,000	2,200	4,880	12.60	12.54	0.06	3,106	3,090	16	16	23,337
2	57,700	2,250	6,400	14.26	14.42	(0.16)	4,715	4,769	(53)	(53)	(78,452)
3	56,600	2,350	6,200	15.96	15.98	(0.02)	5,339	5,345	(5)	(5)	(7,591)
4	54,800	2,150	6,310	16.66	16.96	(0.31)	5,188	5,284	(95)	(95)	(140,737)
5	52,900	1,800	5,900	15.65	15.66	(0.01)	3,817	3,819	(2)	(2)	(3,007)
6	49,800	2,600	6,810	15.09	15.40	(0.30)	6,135	6,259	(124)	(124)	(183,005)
7	47,010	2,775	6,350	16.49	16.80	(0.30)	6,671	6,794	(123)	(123)	(181,706)
8	44,250	2,430	6,900	14.82	15.78	(0.96)	5,704	6,074	(370)	(370)	(545,906)
9	42,150	2,130	6,540	16.37	16.61	(0.25)	5,234	5,313	(79)	(79)	(116,491)
10	39,990	1,400	7,000	15.31	16.05	(0.74)	3,444	3,611	(167)	(167)	(246,907)
11	37,500	1,900	7,710	15.01	14.48	0.52	5,047	4,871	176	176	259,516
12	35,800	3,420	6,510	16.43	16.24	0.19	8,398	8,303	96	96	141,080
13	33,150	3,175	4,700	20.87	20.57	0.30	7,150	7,047	102	102	151,068
14	29,450	3,150	4,710	20.86	20.86	0.00	7,106	7,104	2	2	2,347
15	26,850	2,530	5,050	21.64	21.36	0.28	6,347	6,264	83	83	123,021
16	24,400	2,570	5,300	20.27	19.72	0.55	6,338	6,166	172	172	253,873
17	21,700	2,550	6,180	20.87	20.62	0.25	7,550	7,460	90	90	133,167
18	19,300	2,525	5,000	22.04	21.77	0.28	6,388	6,308	80	80	117,718
19	16,650	2,625	5,240	22.62	21.63	0.99	7,143	6,829	314	314	463,741
20	14,050	2,187	3,560	30.16	28.60	1.56	5,391	5,112	279	279	411,278
21	12,275	2,085	3,350	31.13	30.73	0.40	4,992	4,927	64	64	94,812
22	9,880	2,162	3,380	33.43	31.79	1.64	5,608	5,333	274	274	405,053
23	7,950	2,175	3,520	35.94	33.58	2.36	6,317	5,903	414	414	611,712
24	5,530	2,400	4,450	41.64	38.61	3.04	10,210	9,465	745	745	1,100,243
25	3,150	1,915	4,610	49.07	45.61	3.46	9,946	9,244	702	702	1,036,292
26	1,700	2,425	4,750	52.75	49.56	3.19	13,949	13,105	844	844	1,246,207
Total	-	-	-	-	-	-	**167,234**	**163,800**	**3,434**	**3,434**	**5,070,661**

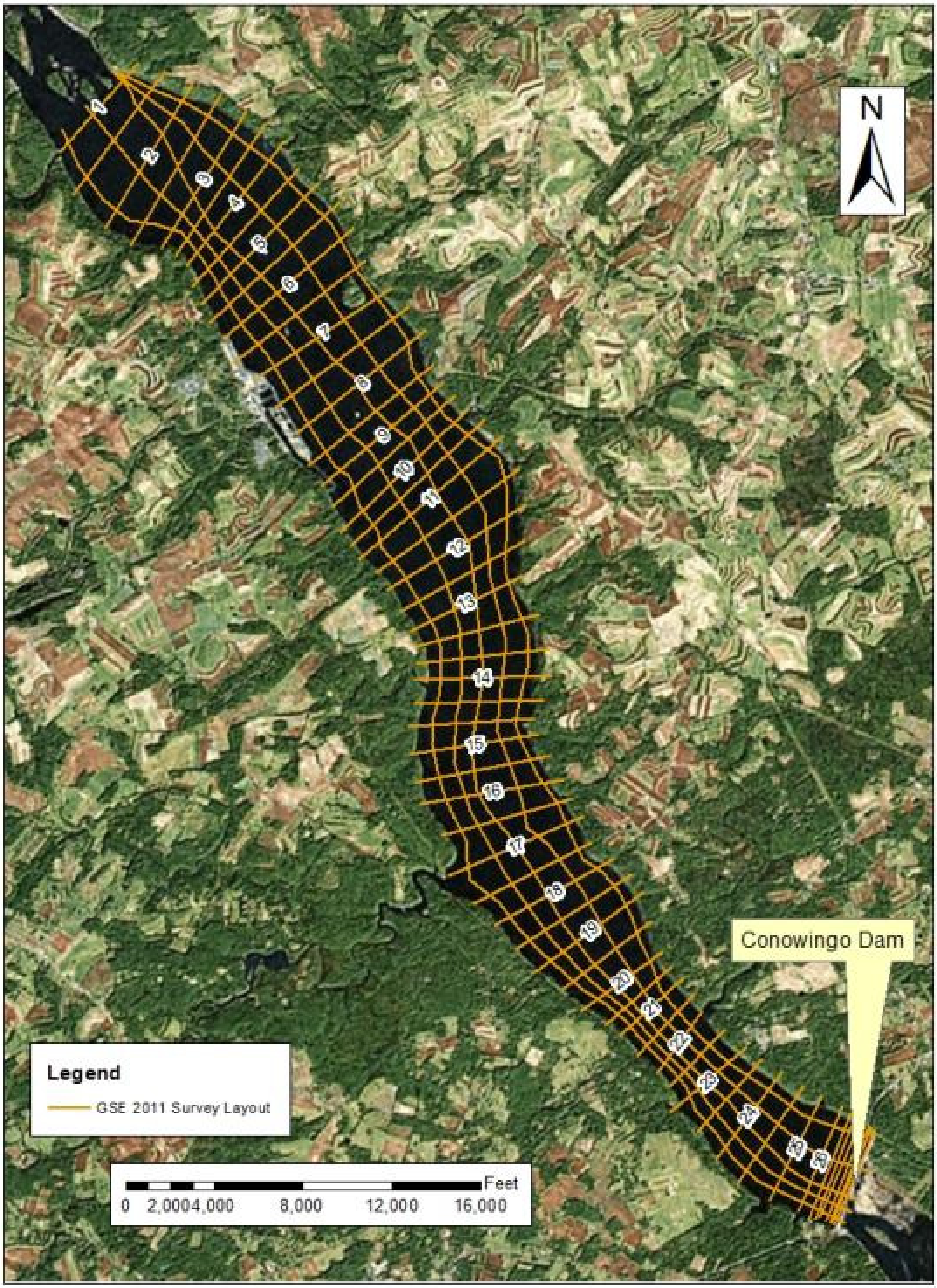


Figure 1: GSE 2011 data collection transects. Numbers shown are USGS 2008 XC numbers.

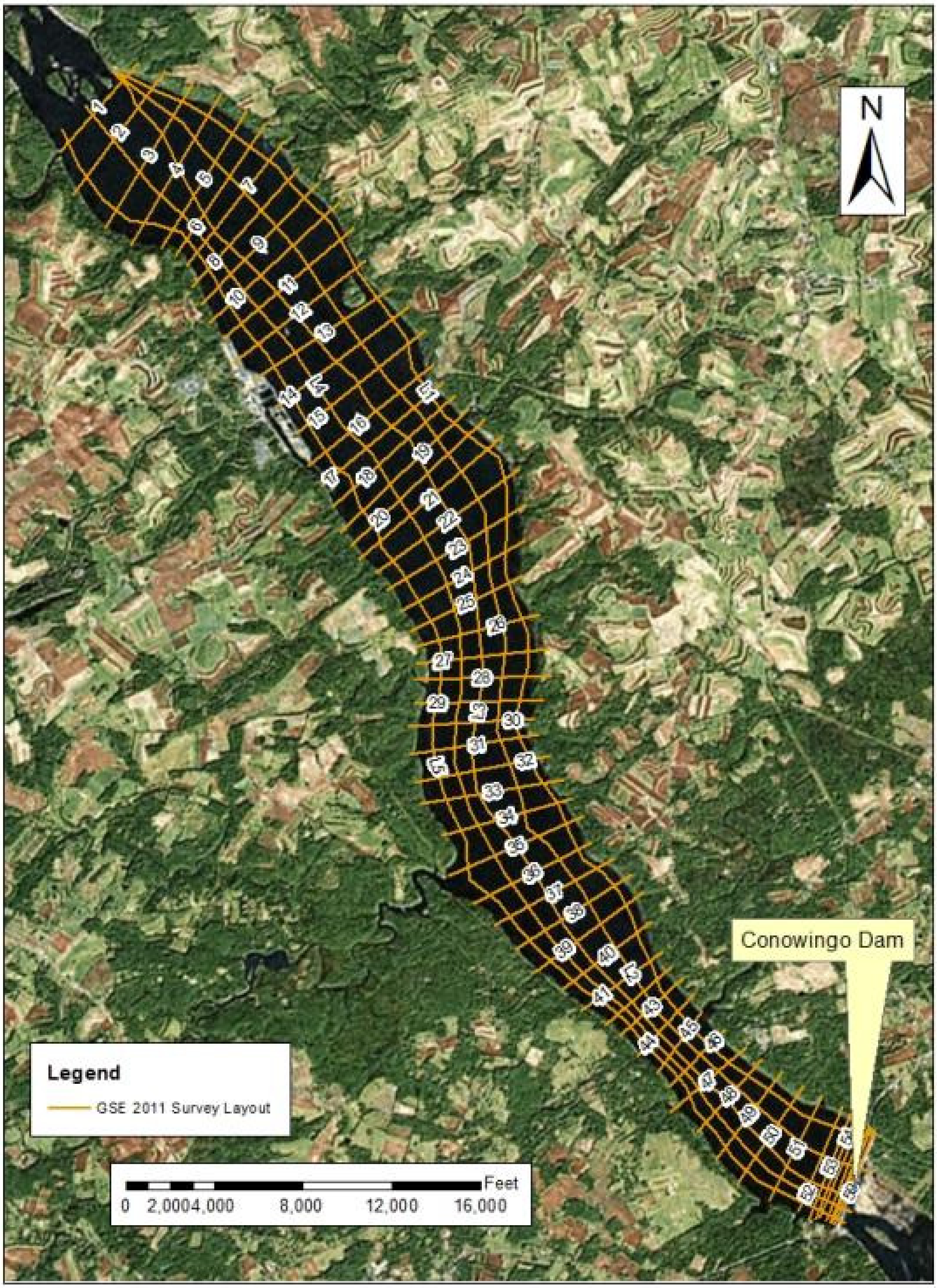


Figure 2: GSE 2011 data collection transects, with GSE 2011 transect numbers.

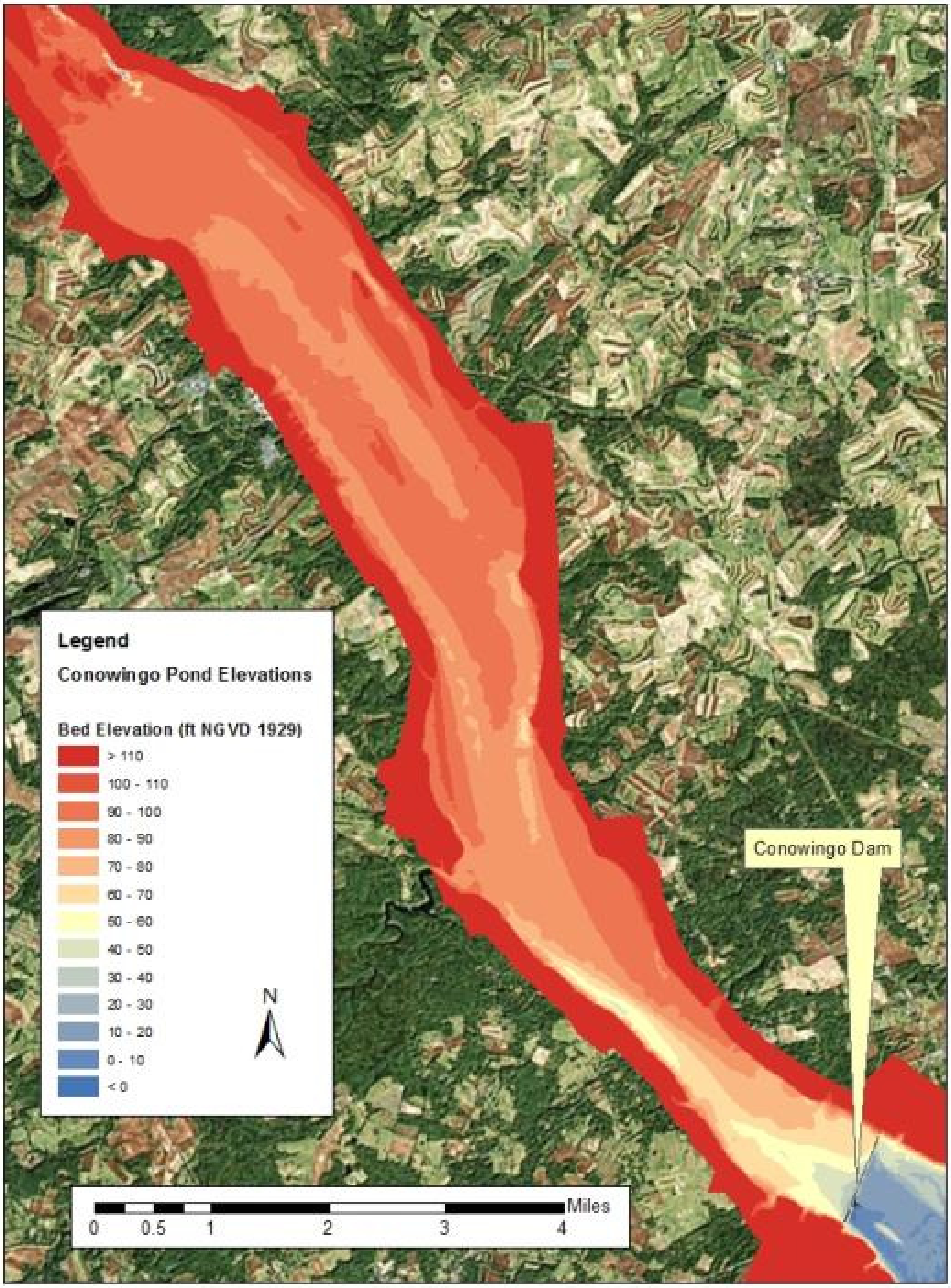


Figure 3: Composite elevation data set including 2011 Conowingo Pond data.

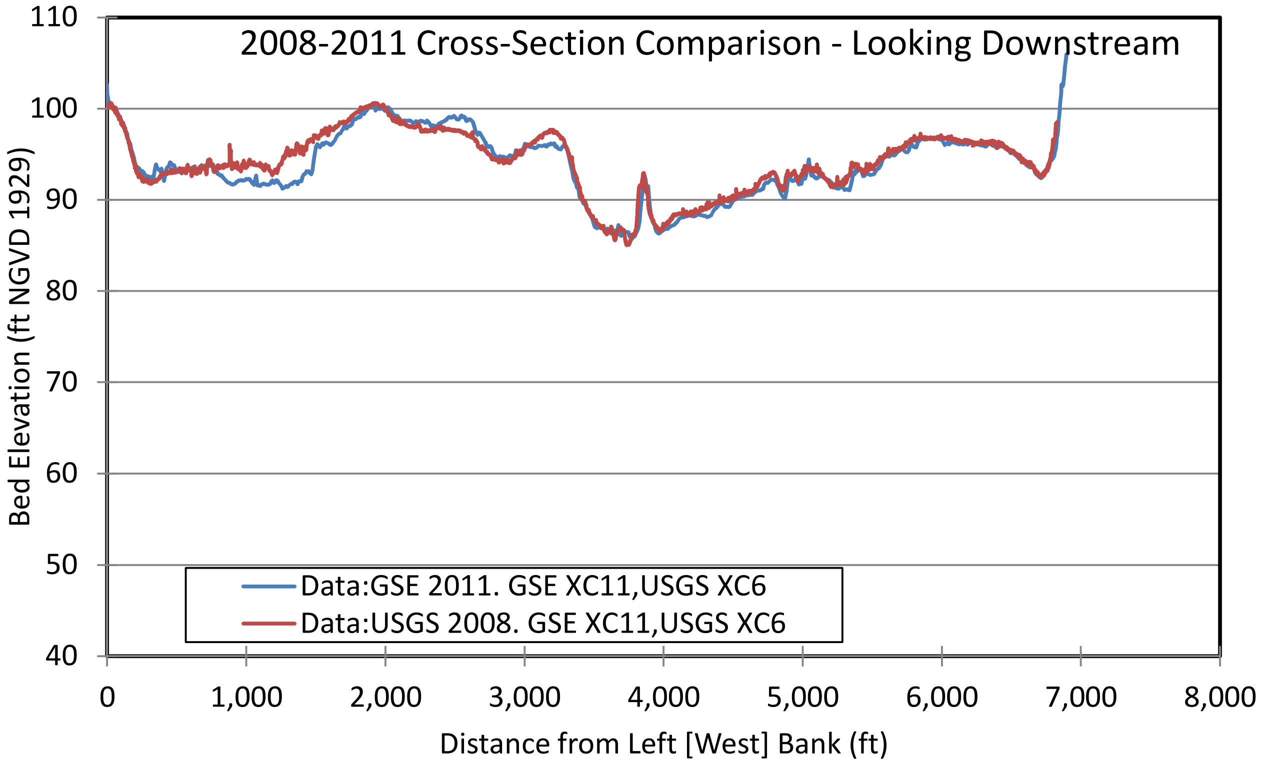


Figure 4: Plot comparing USGS 2008 and GSE 2011 cross-sections at USGS XC 2, located approximately 11.3 miles upstream of Conowingo Dam.

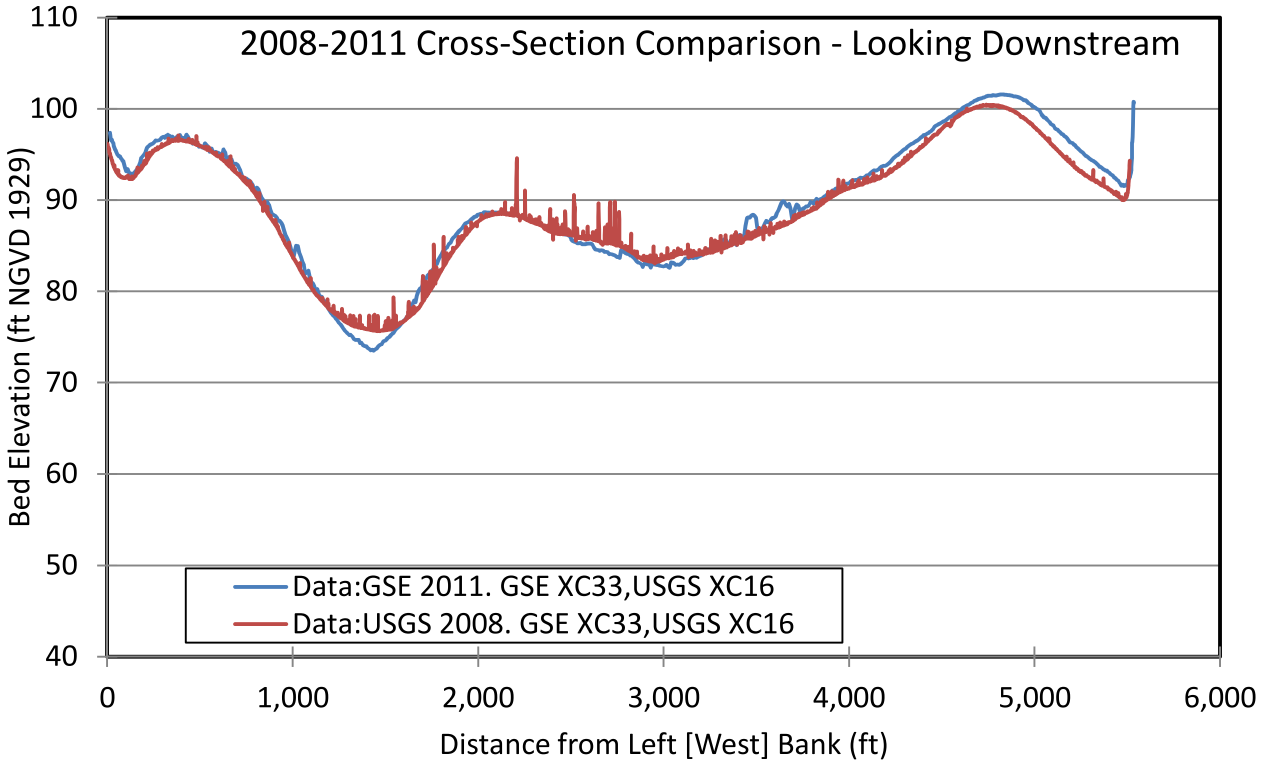
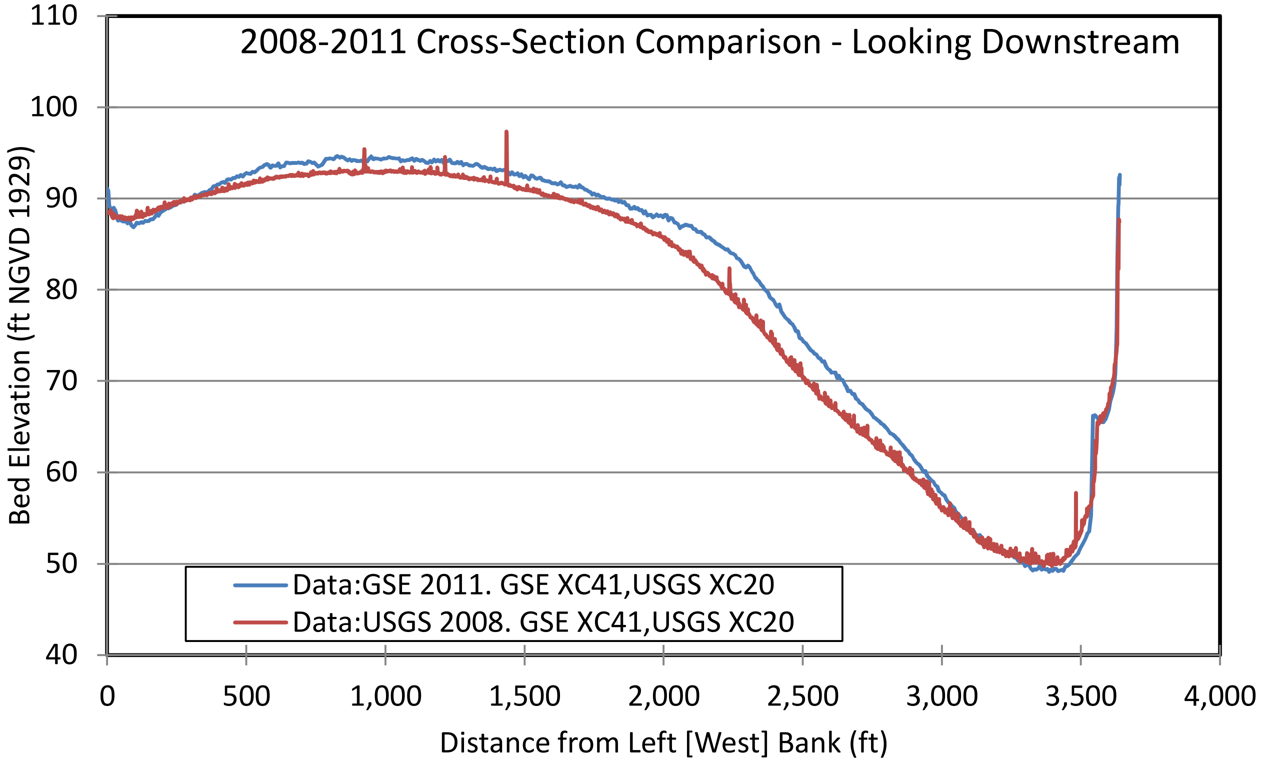


Figure 5: Plot comparing USGS 2008 and GSE 2011 cross-sections at USGS XC 16, located approximately 4.7 miles upstream of Conowingo Dam.



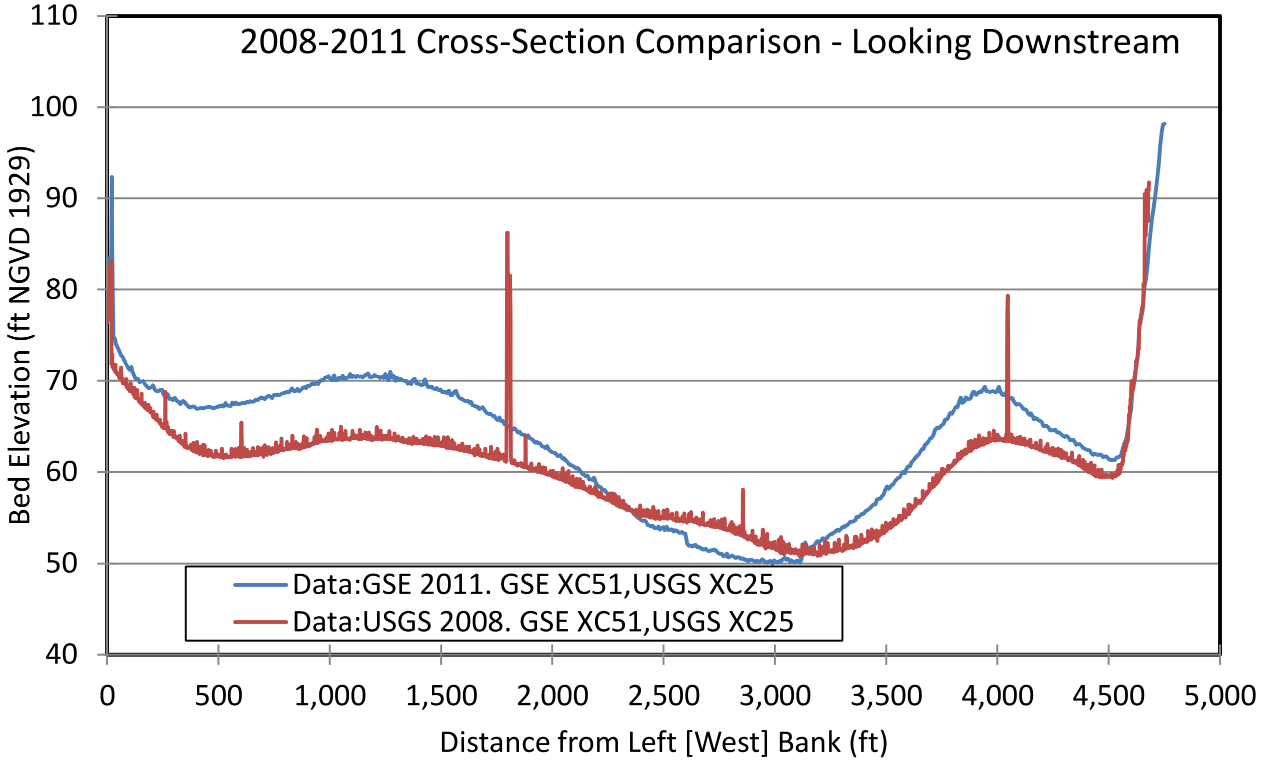


Figure 6: Comparison of two lower Pond transects. USGS XC 20 and 25 located 2.7 and 0.6 miles upstream of Conowingo Dam, respectively.

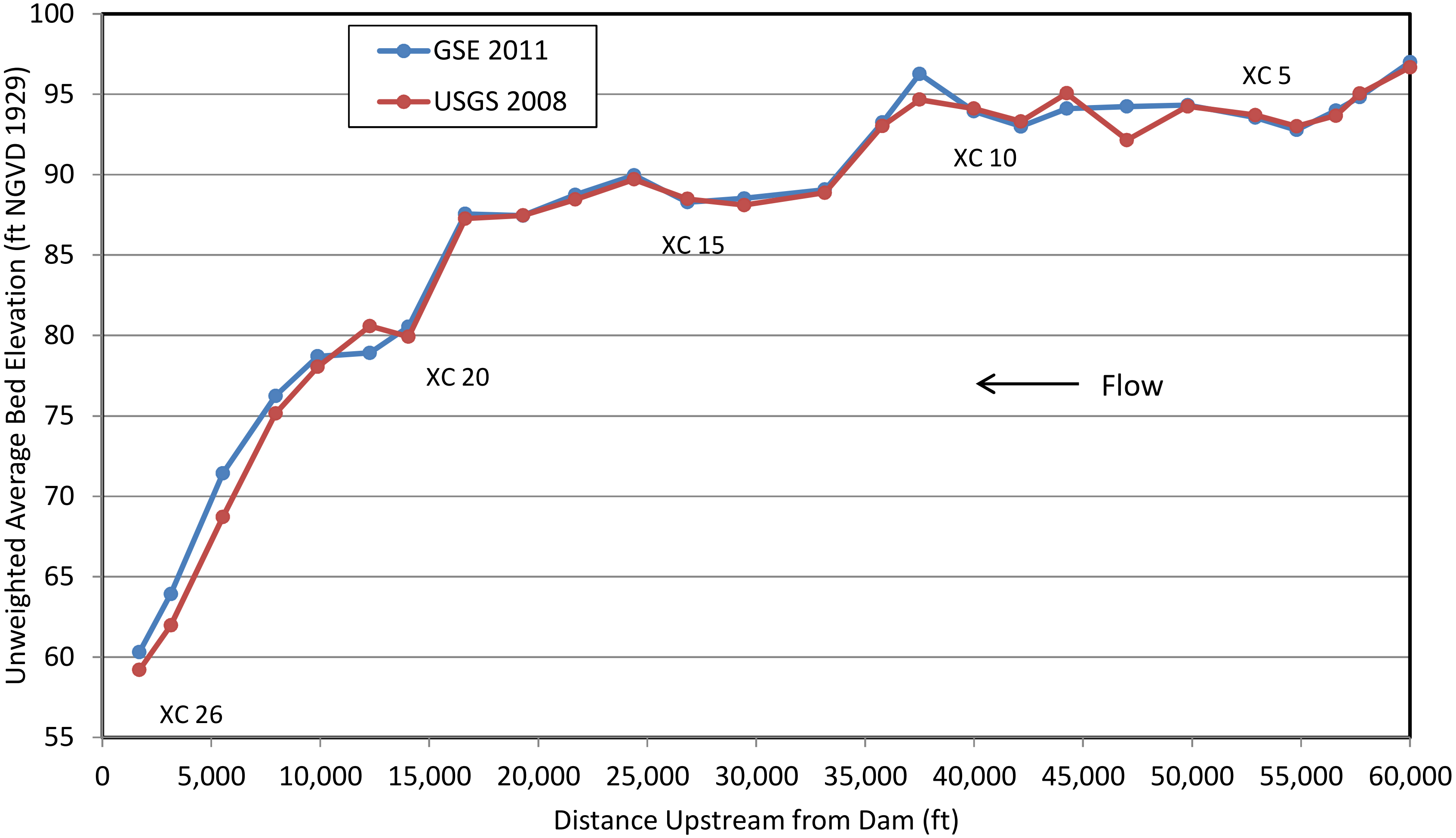


Figure 7: Unweighted average transect bed elevation versus distance upstream from Conowingo Dam.

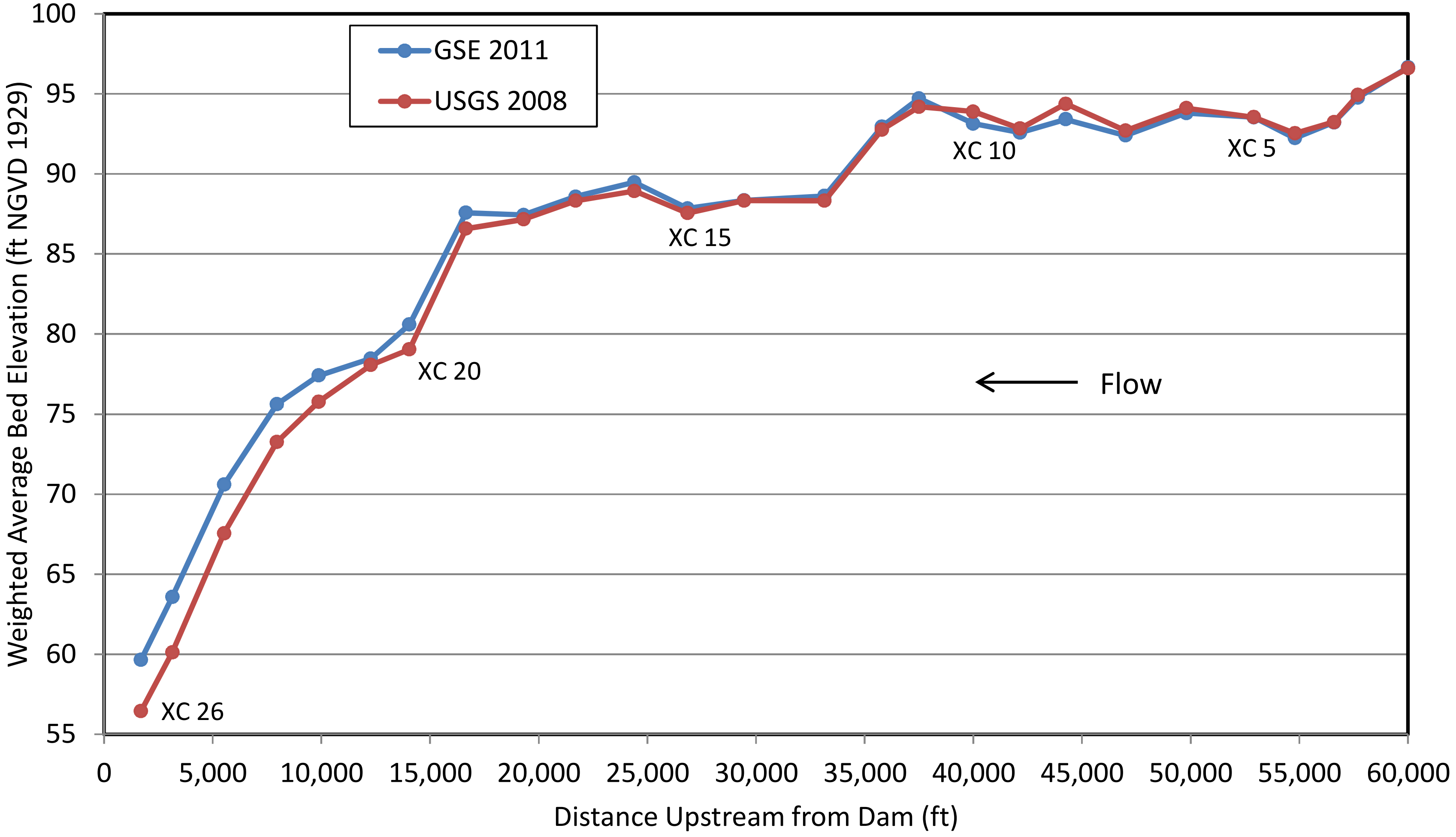


Figure 8: Weighted average transect bed elevation versus distance upstream from Conowingo Dam.

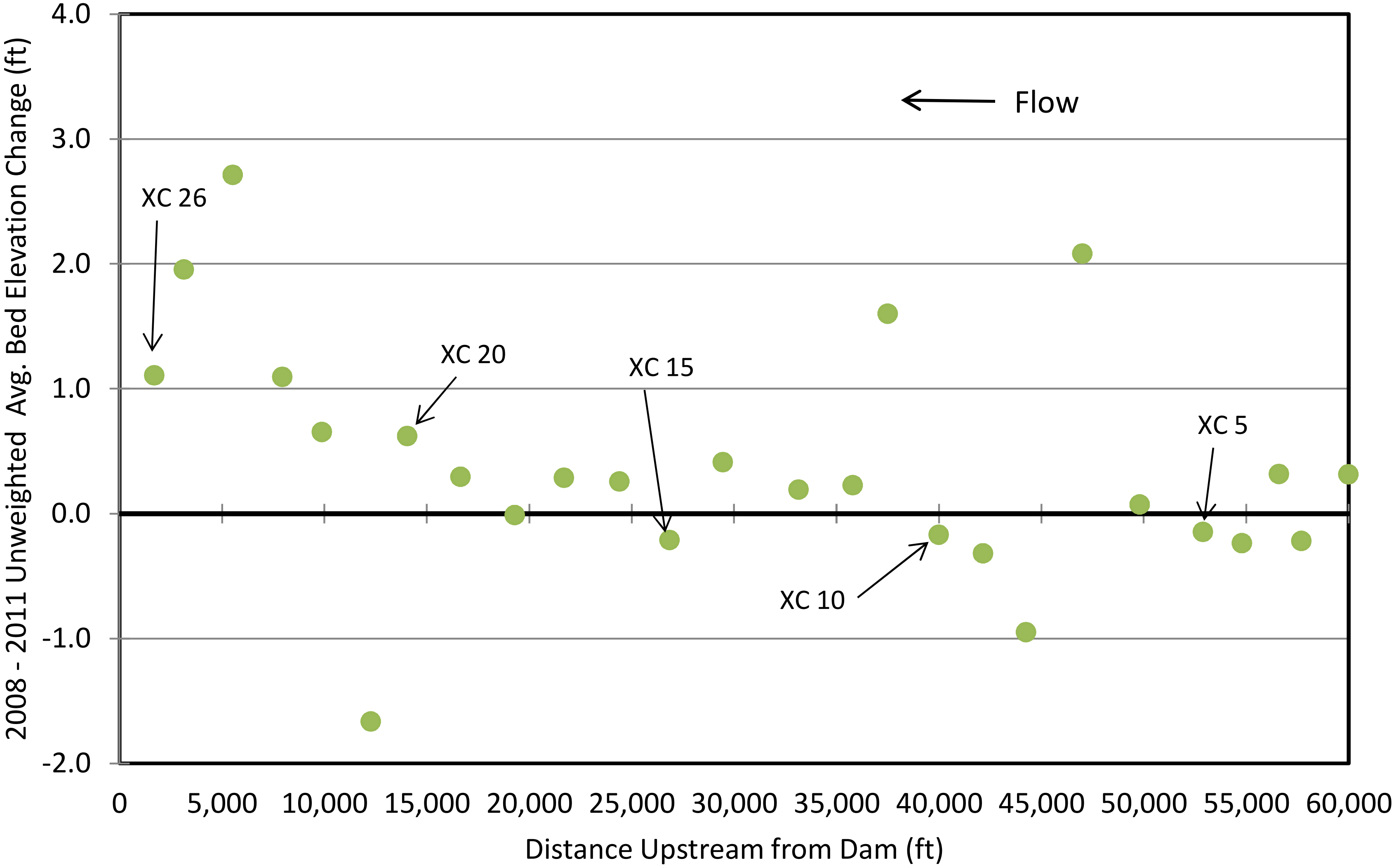


Figure 9: Unweighted average bed elevation change longitudinal profile, showing net deposition (positive values) and net scour (negative values).

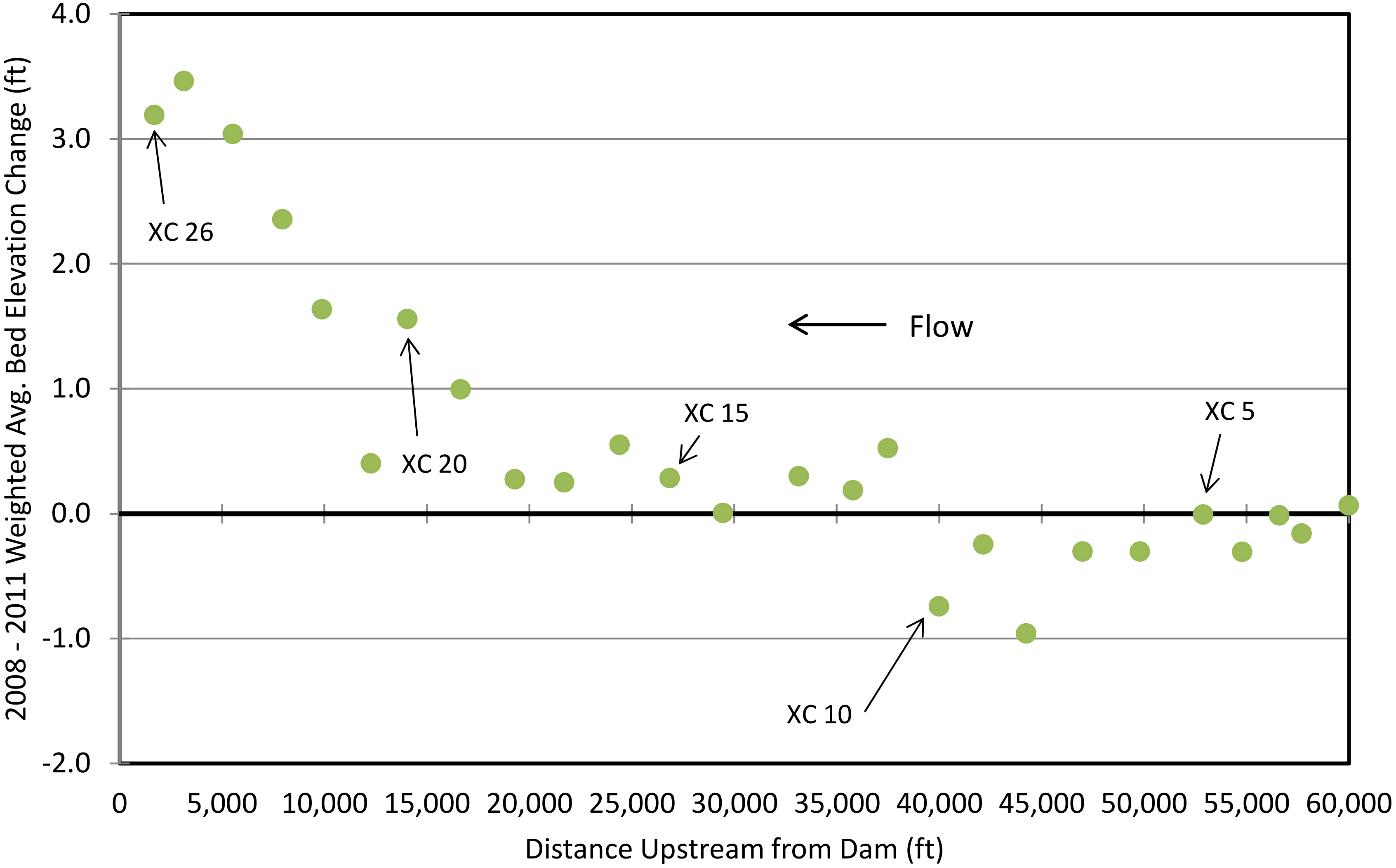
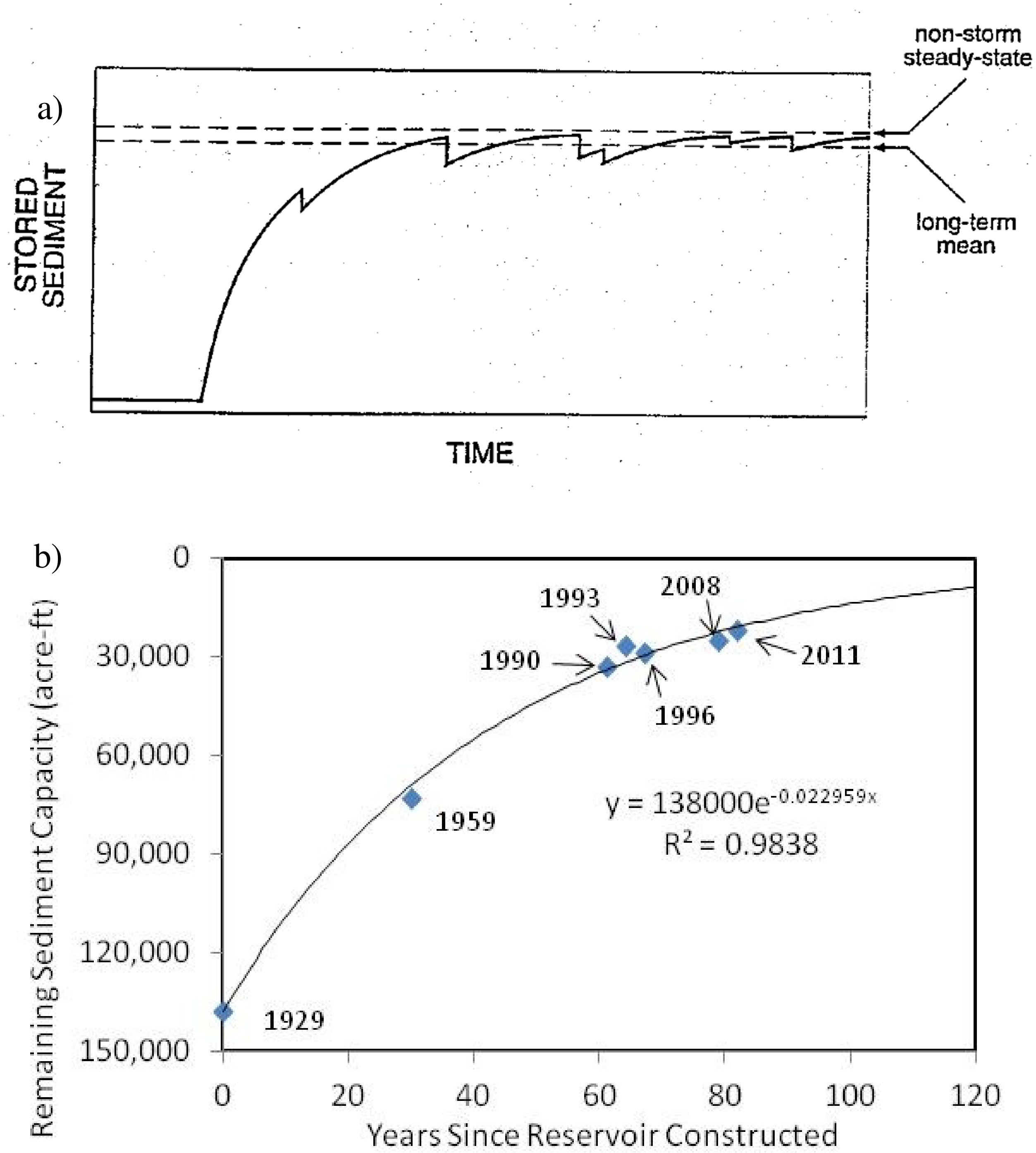


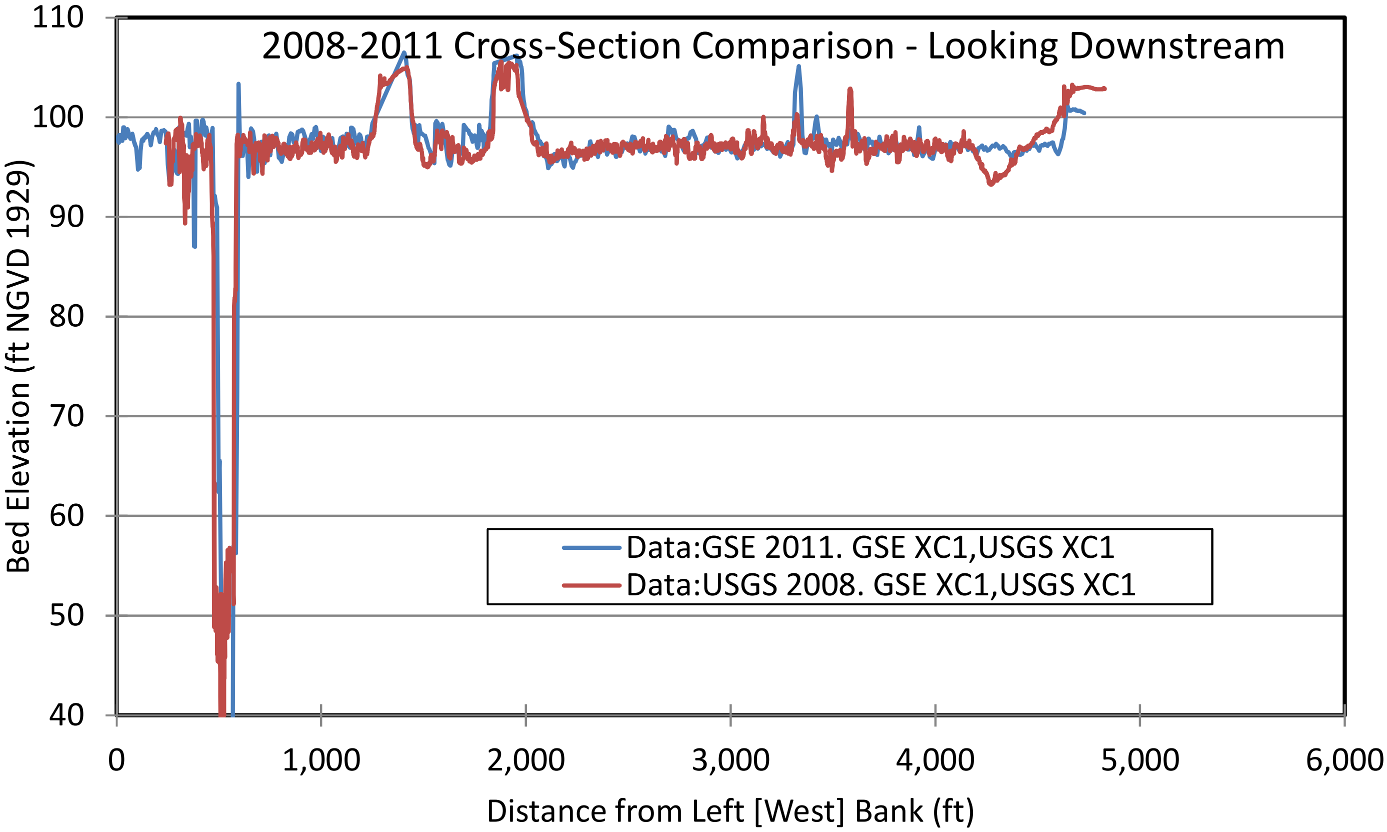
Figure 10: Weighted average bed elevation change longitudinal profile, showing net deposition (positive values) and net scour (negative values).

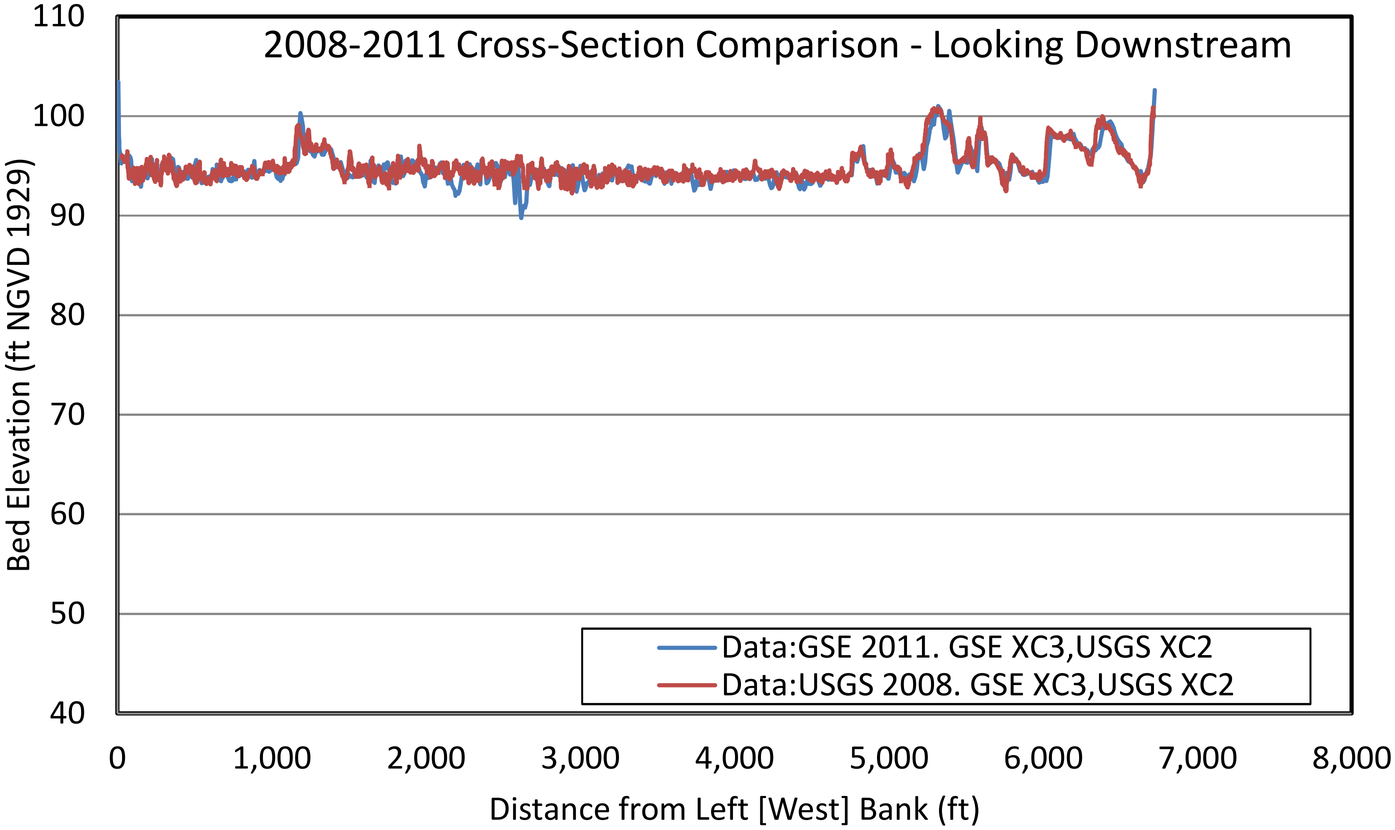


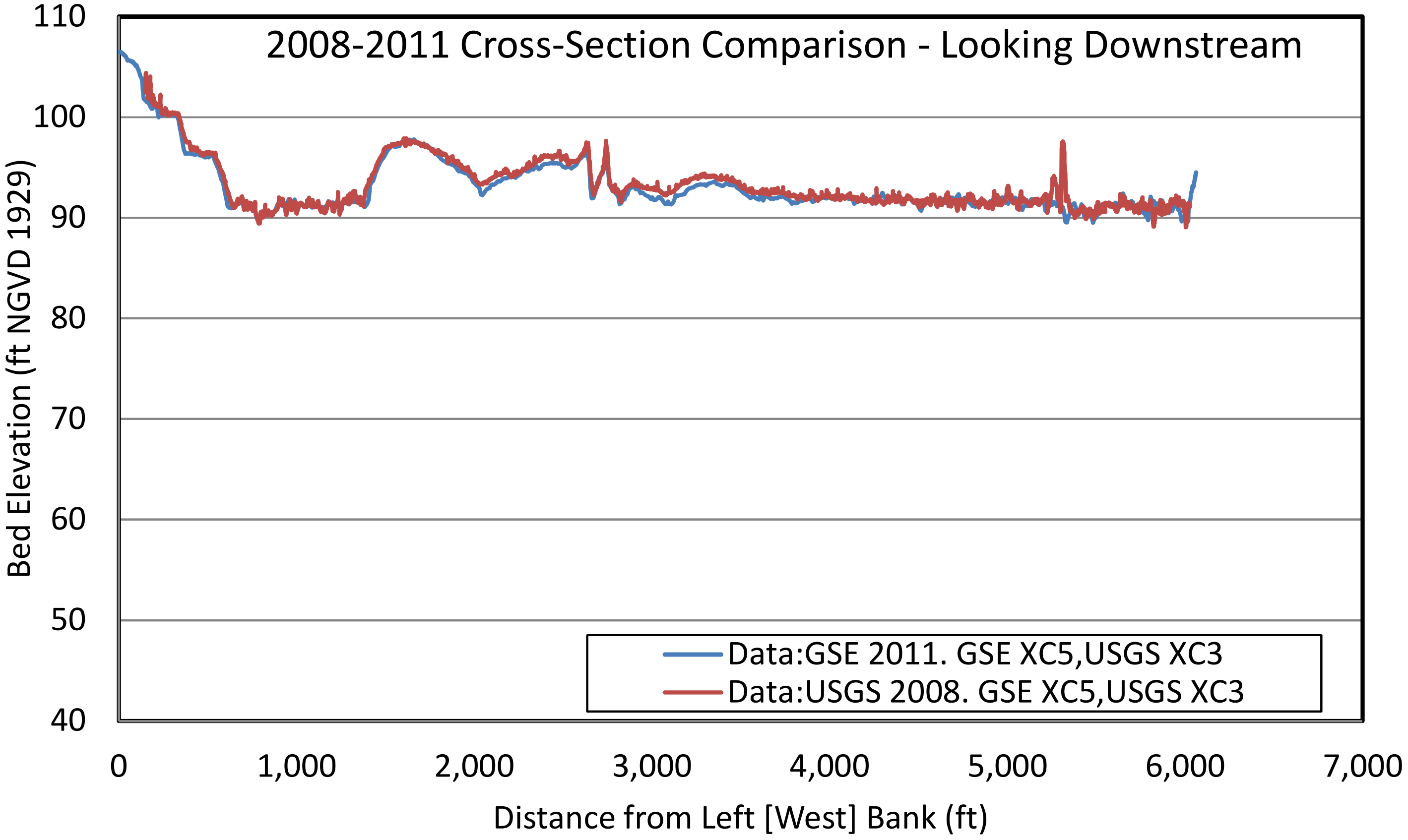
*Calculations assume the steady state reservoir water volume is 142,000 acre-ft

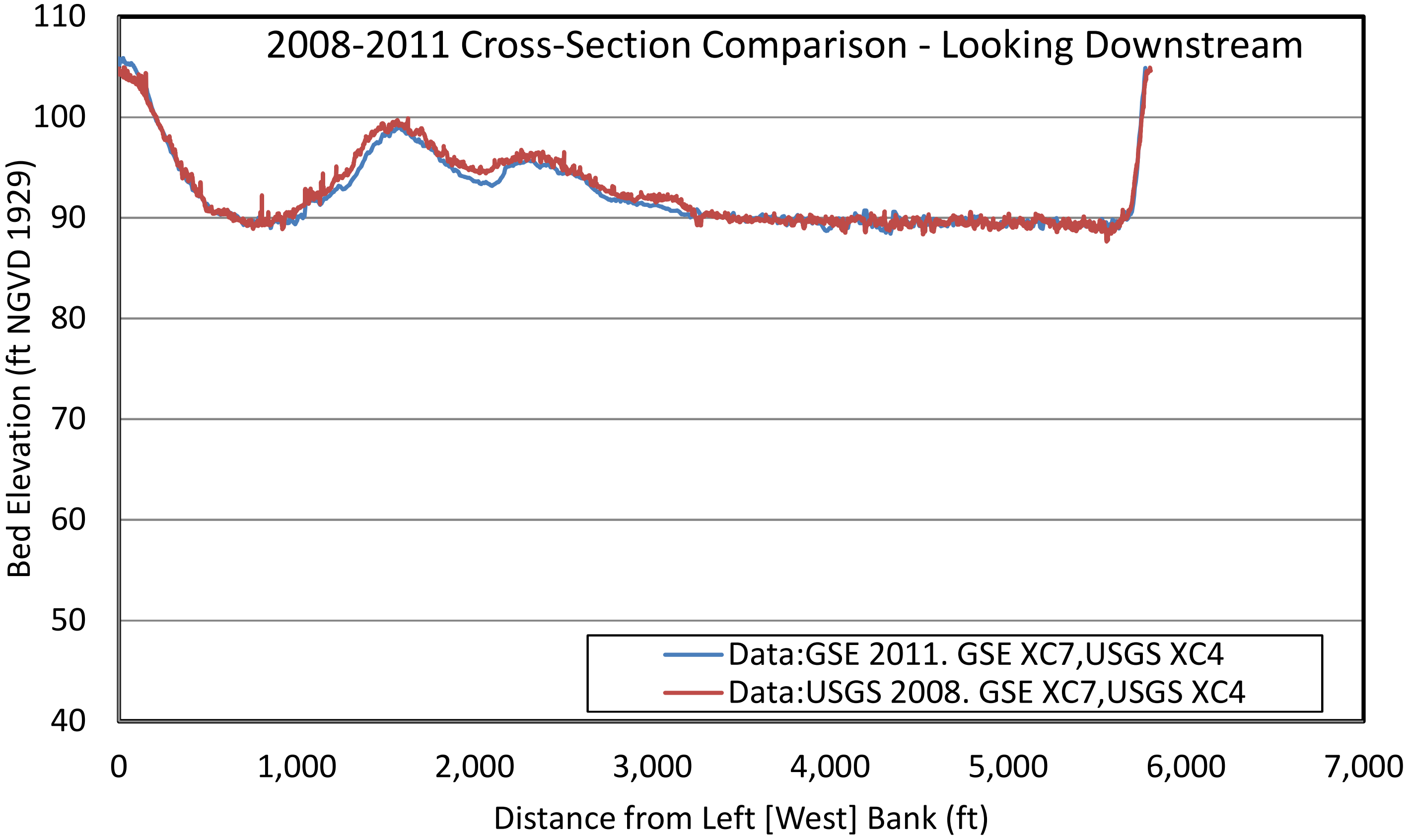
Figure 11: Comparison of a) sediment stored versus time for a general reservoir, taken from Academy of Natural Sciences (1994); and b) Conowingo Pond's estimated remaining sediment capacity versus time since the reservoir was constructed.

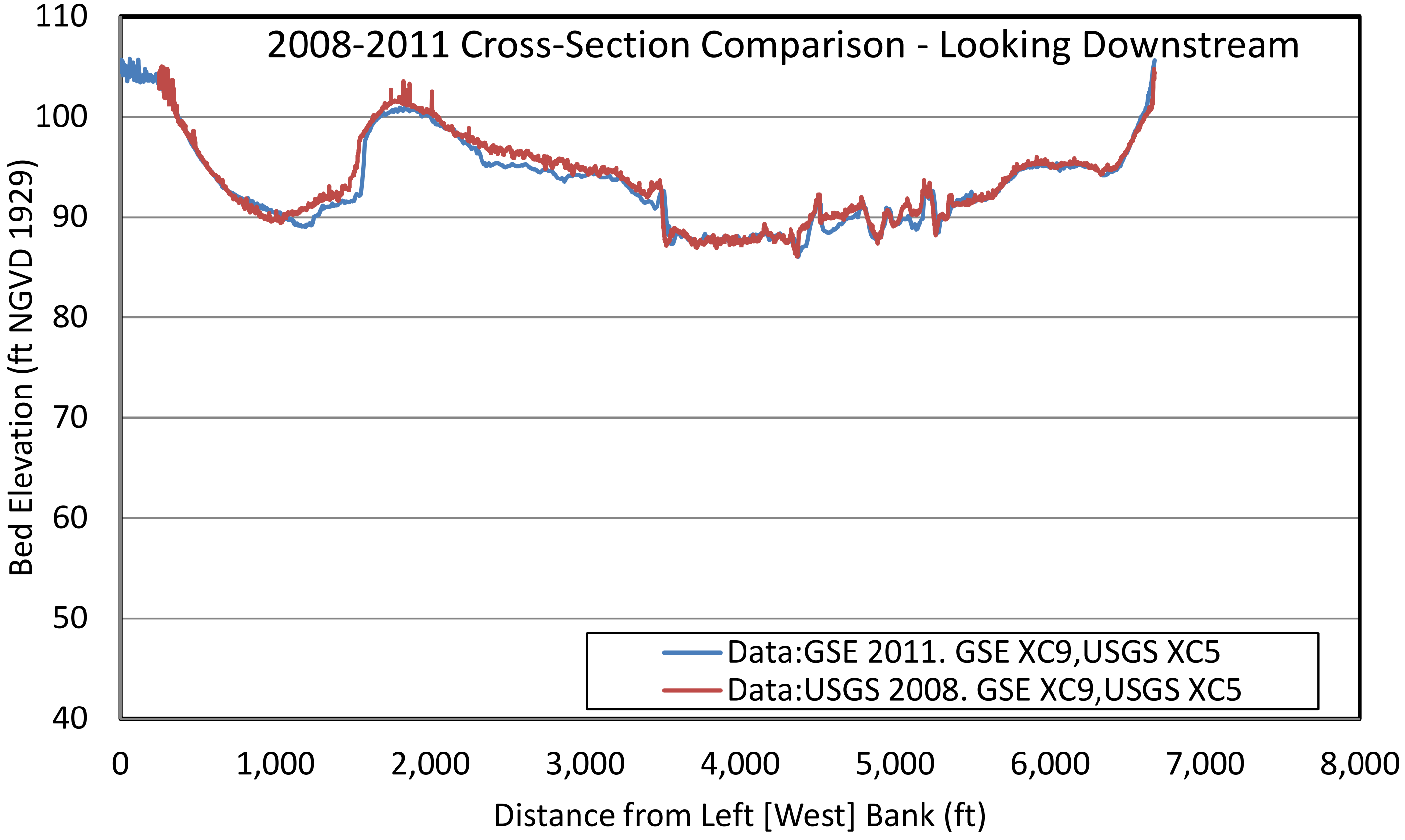
Appendix A: Historic Cross-Section Comparison

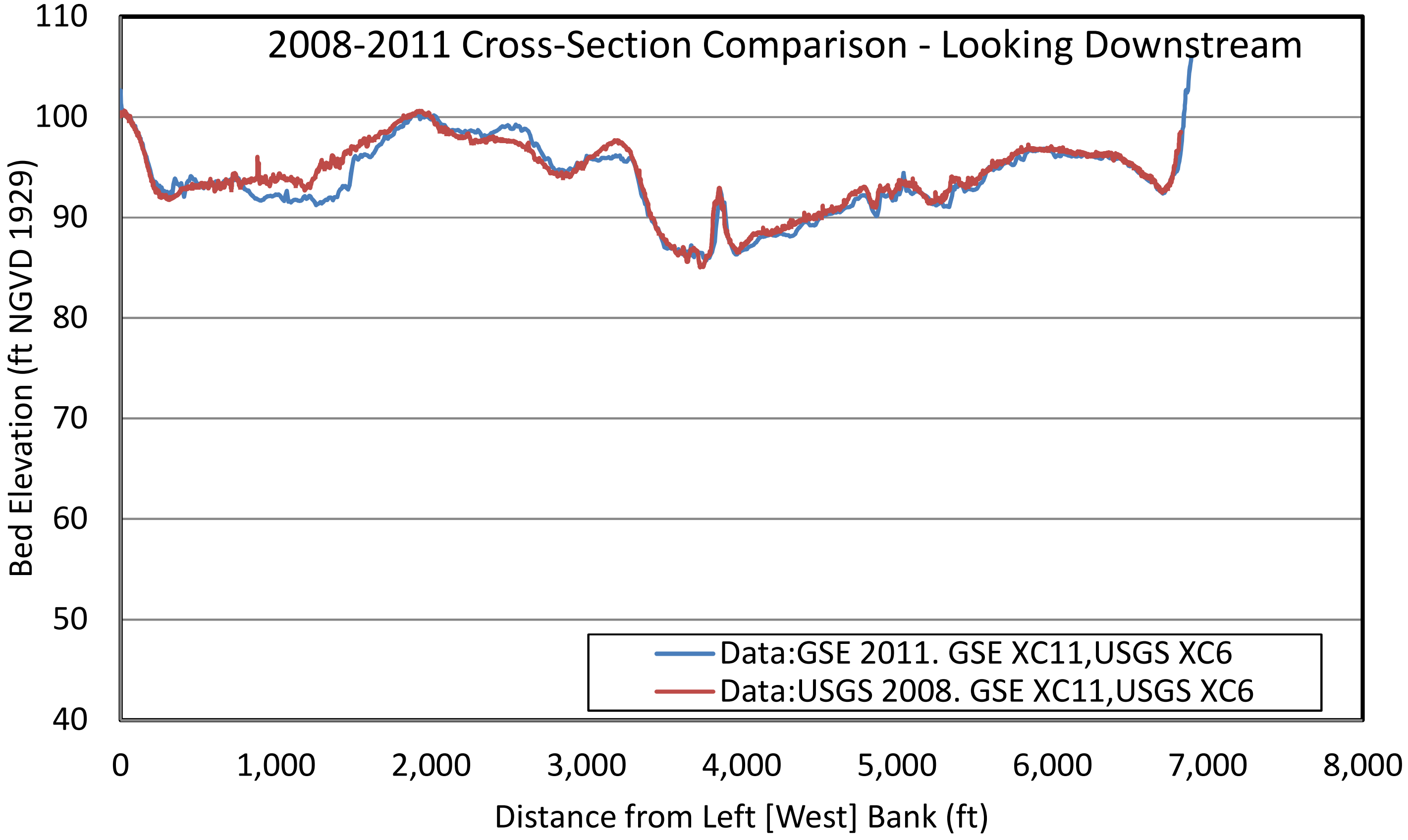


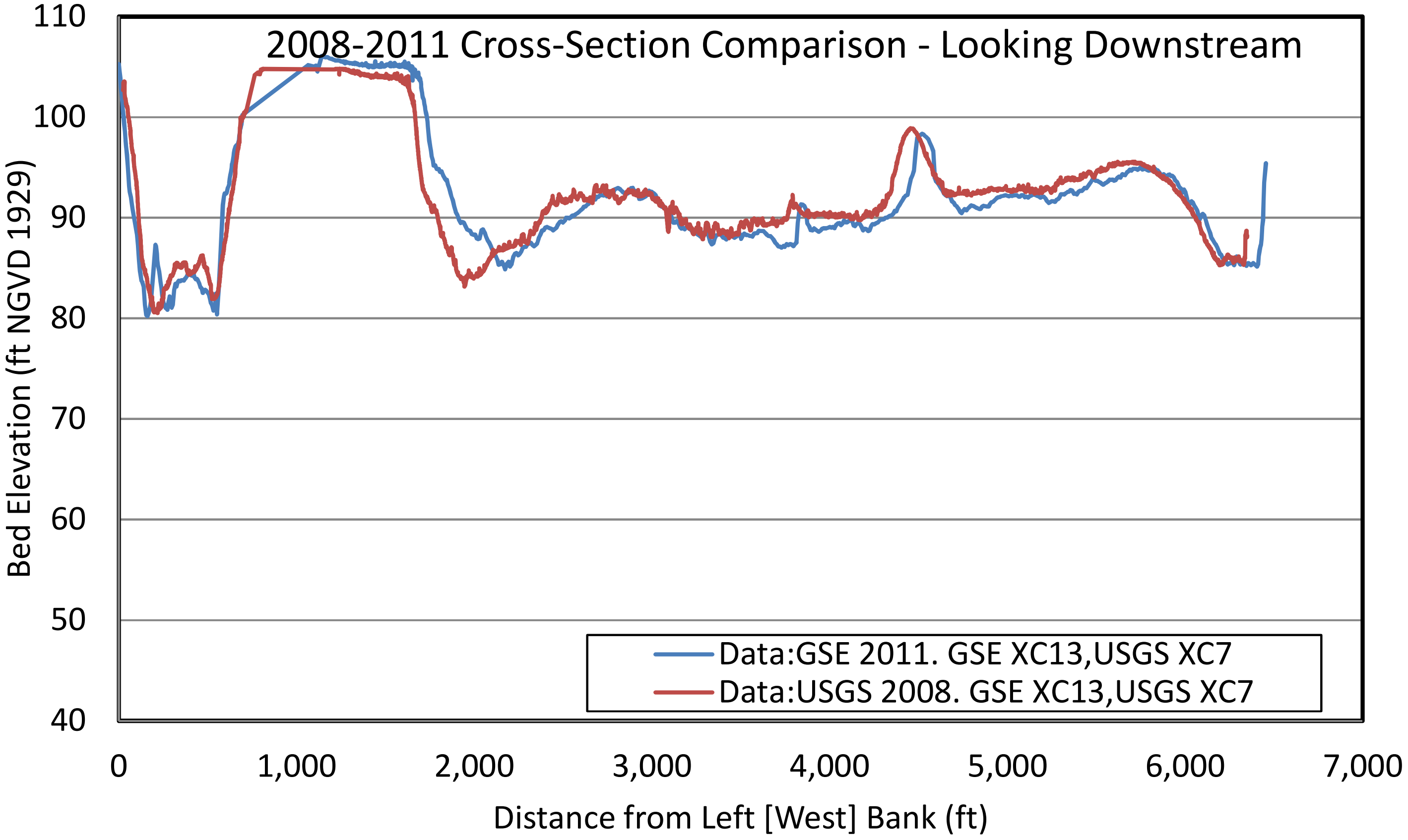


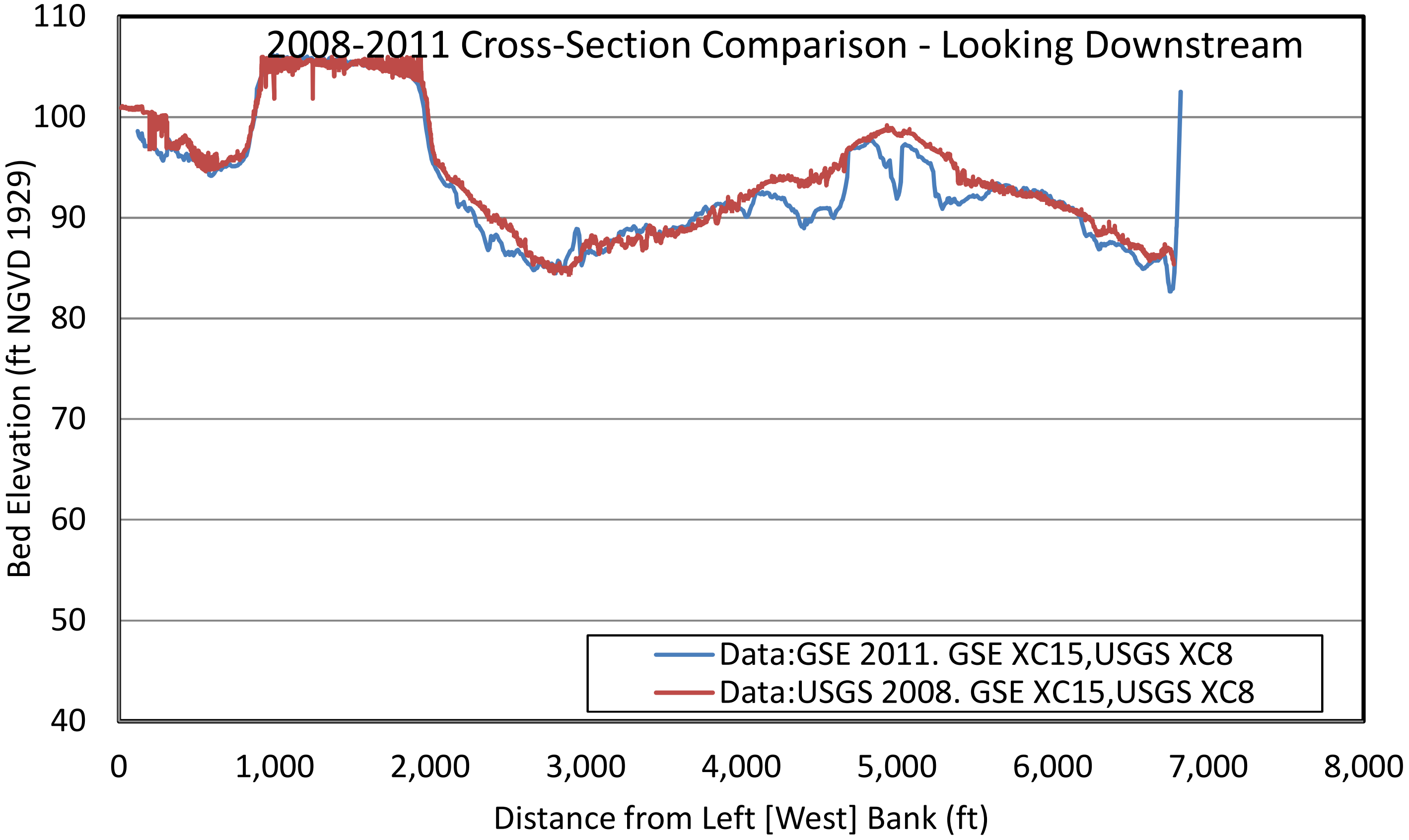

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC5,USGS XC3
Data:USGS 2008. GSE XC5,USGS XC3

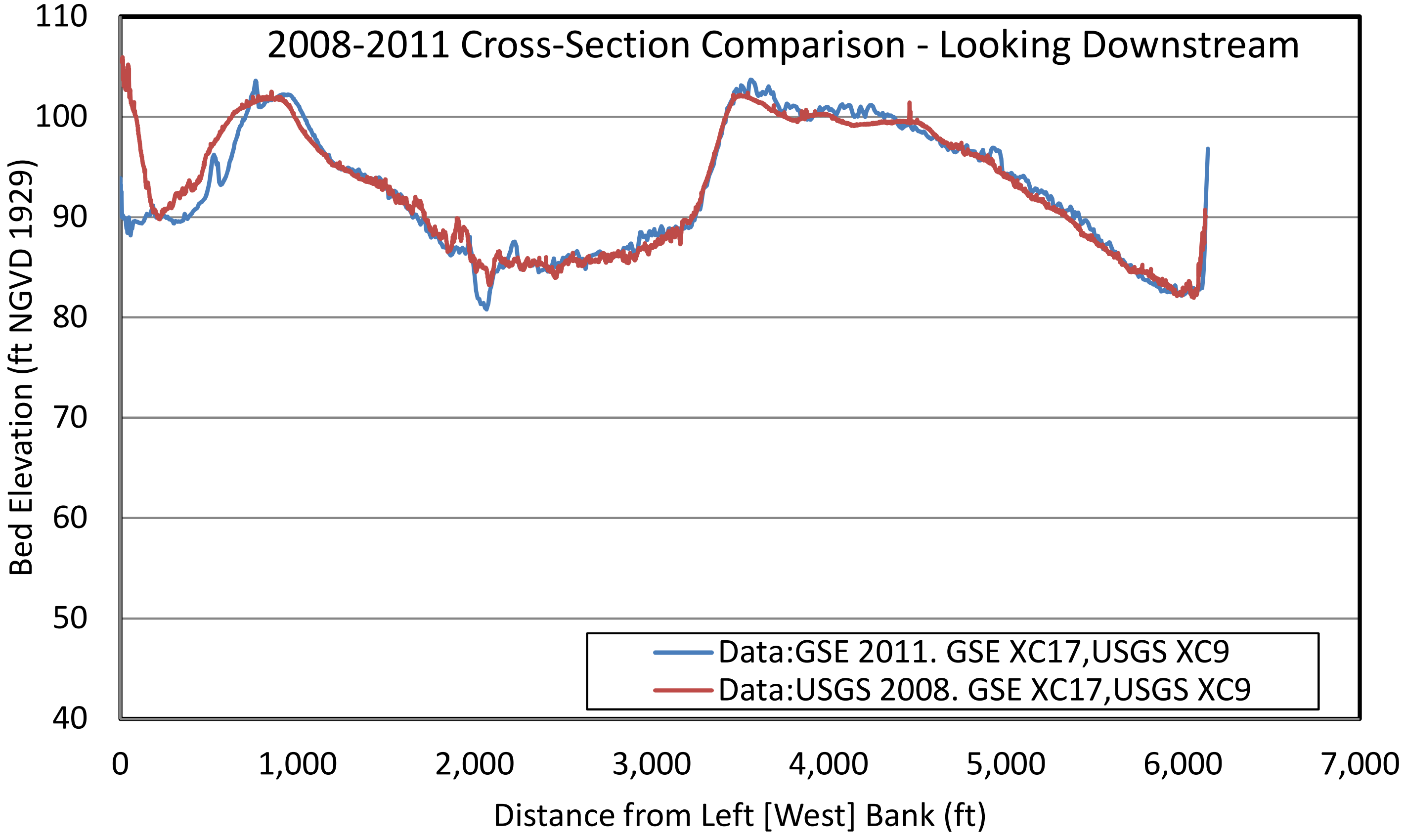

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC7,USGS XC4
Data:USGS 2008. GSE XC7,USGS XC4

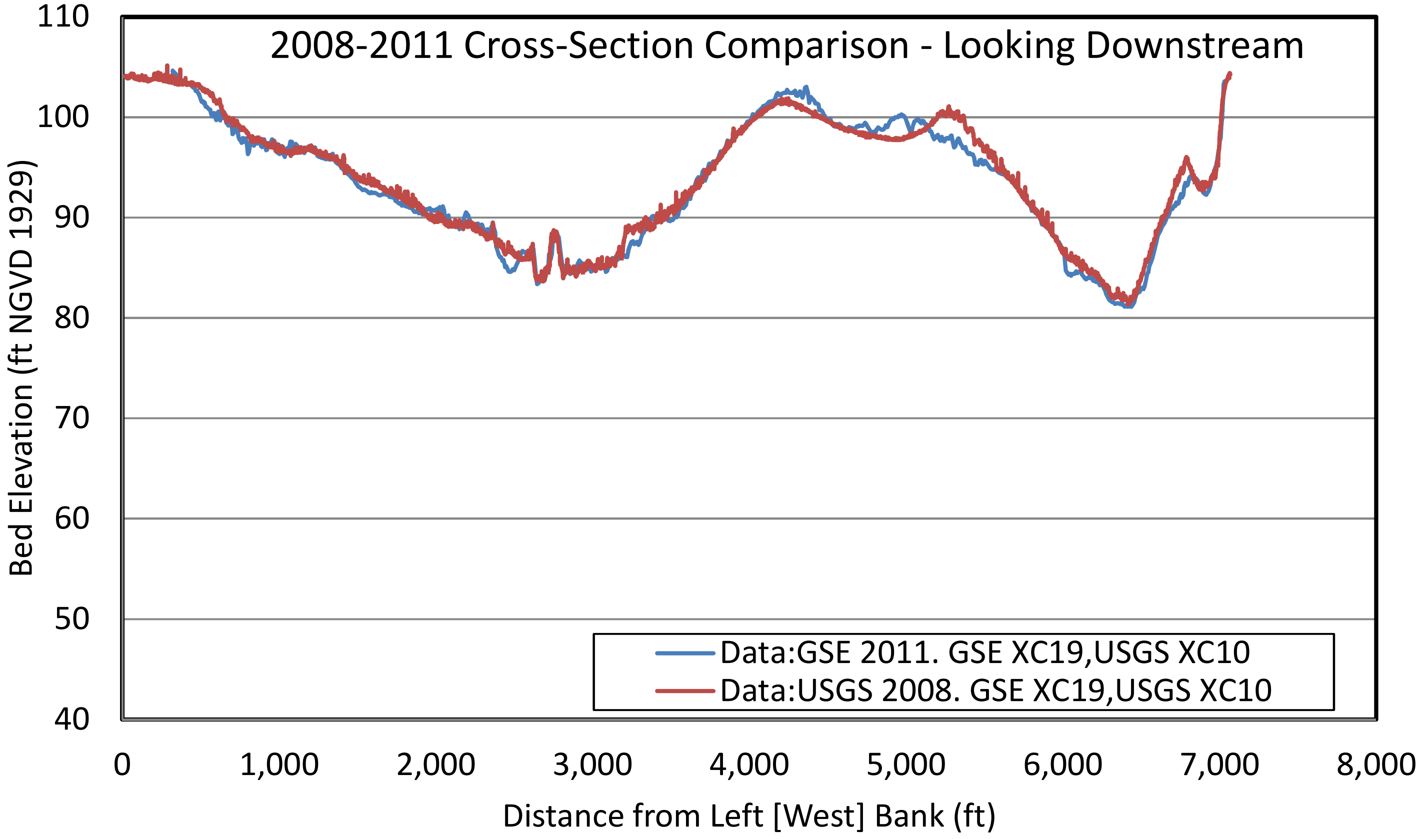

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC9,USGS XC5
Data:USGS 2008. GSE XC9,USGS XC5

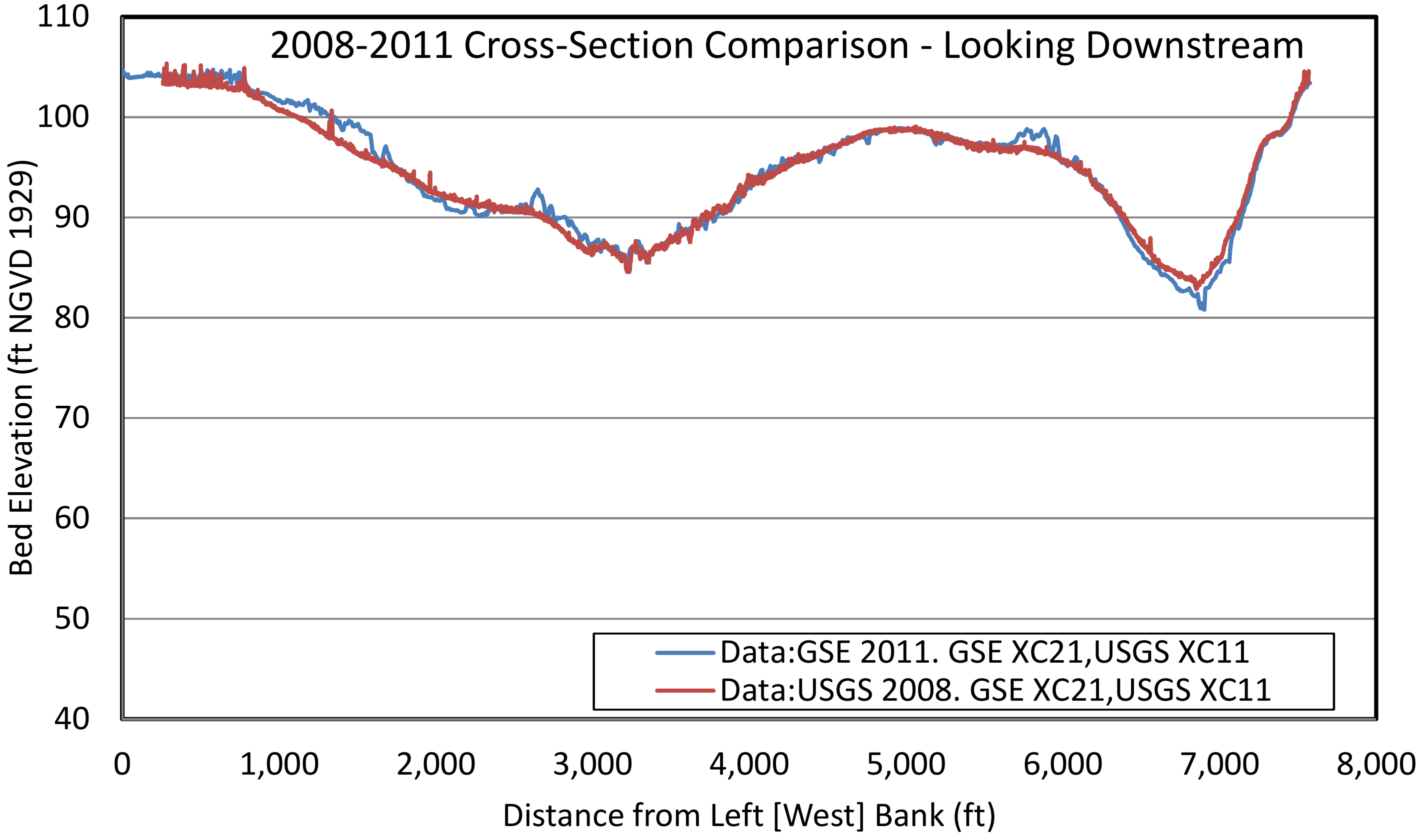

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC11,USGS XC6
Data:USGS 2008. GSE XC11,USGS XC6

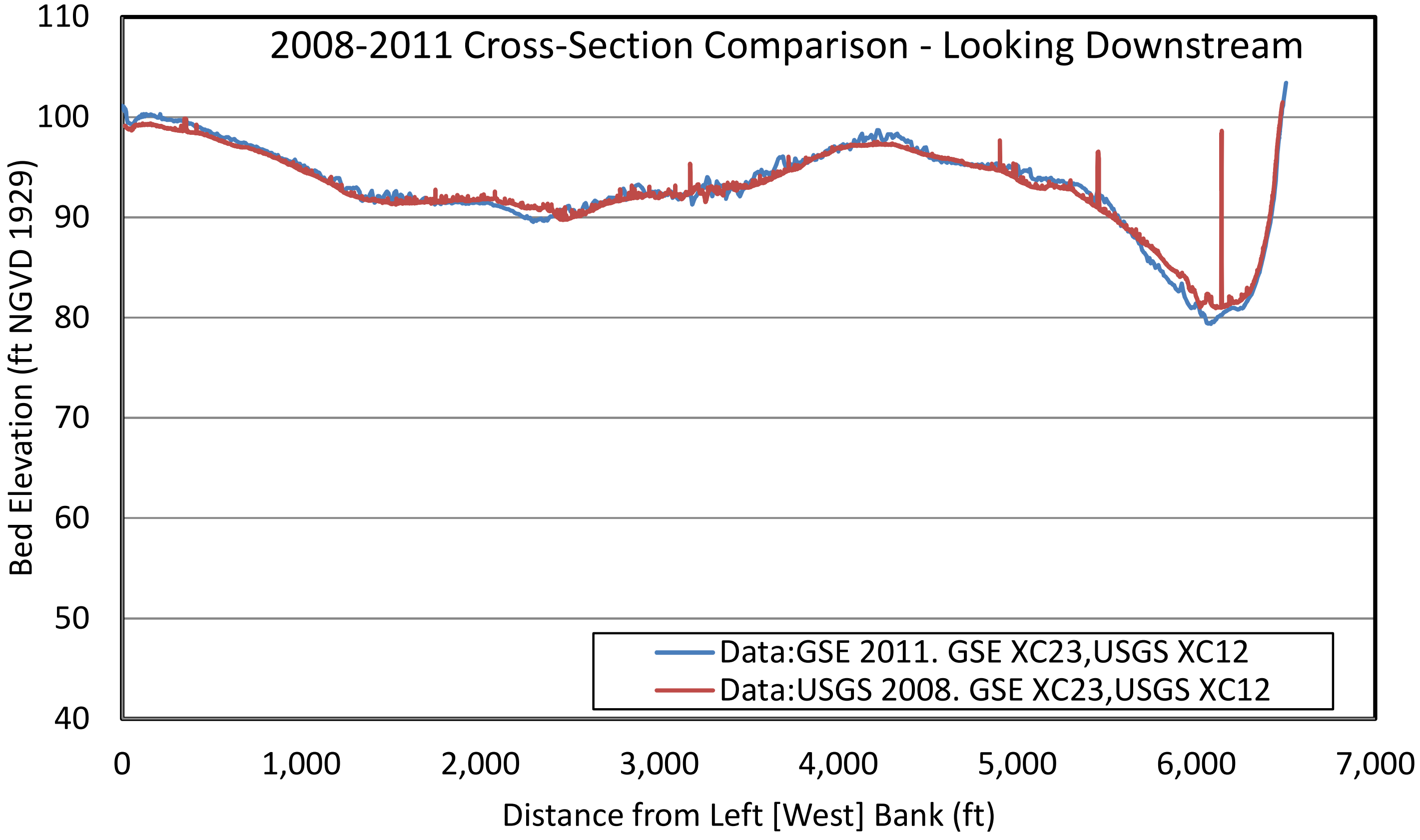

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC13,USGS XC7
Data:USGS 2008. GSE XC13,USGS XC7

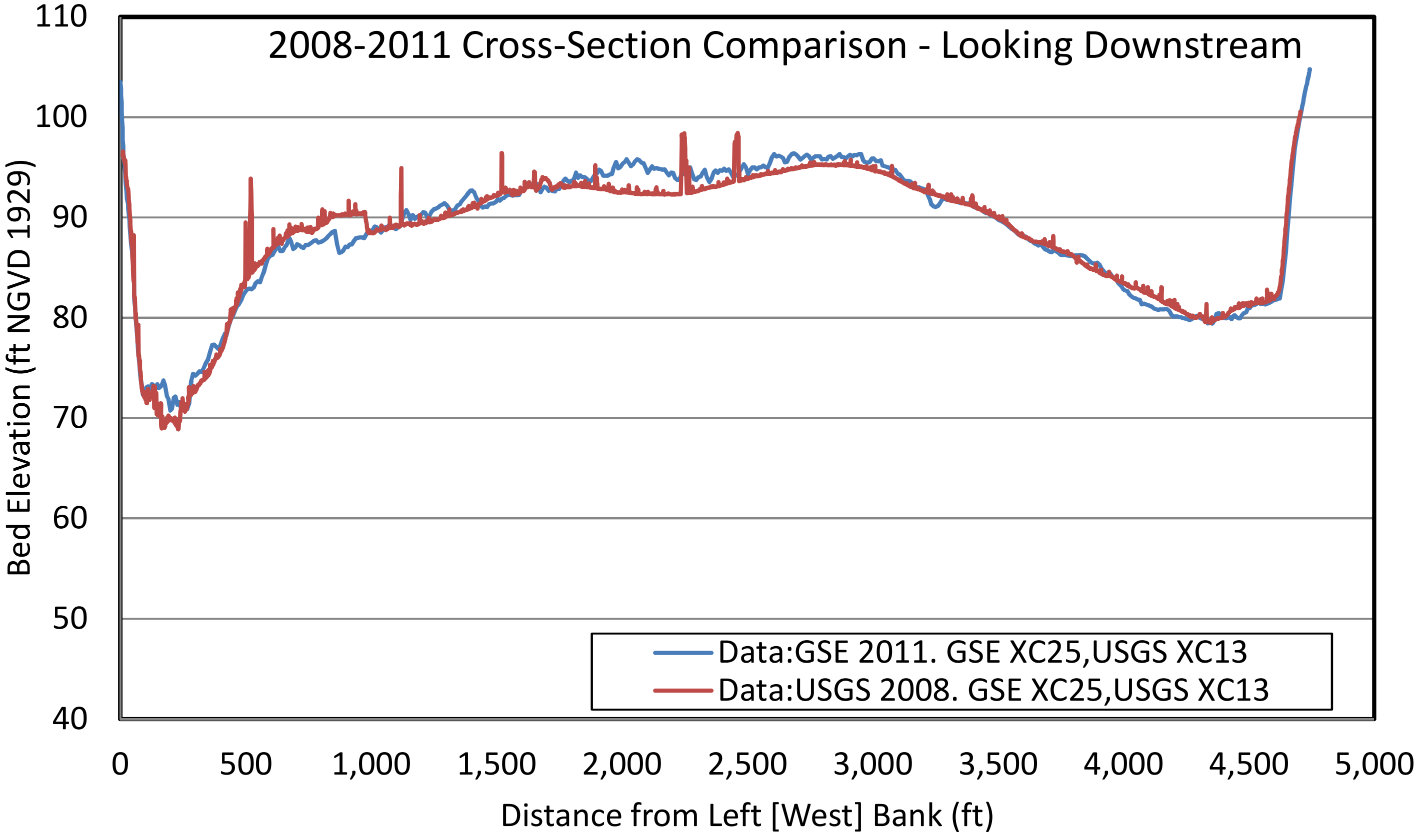

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC15,USGS XC8
Data:USGS 2008. GSE XC15,USGS XC8

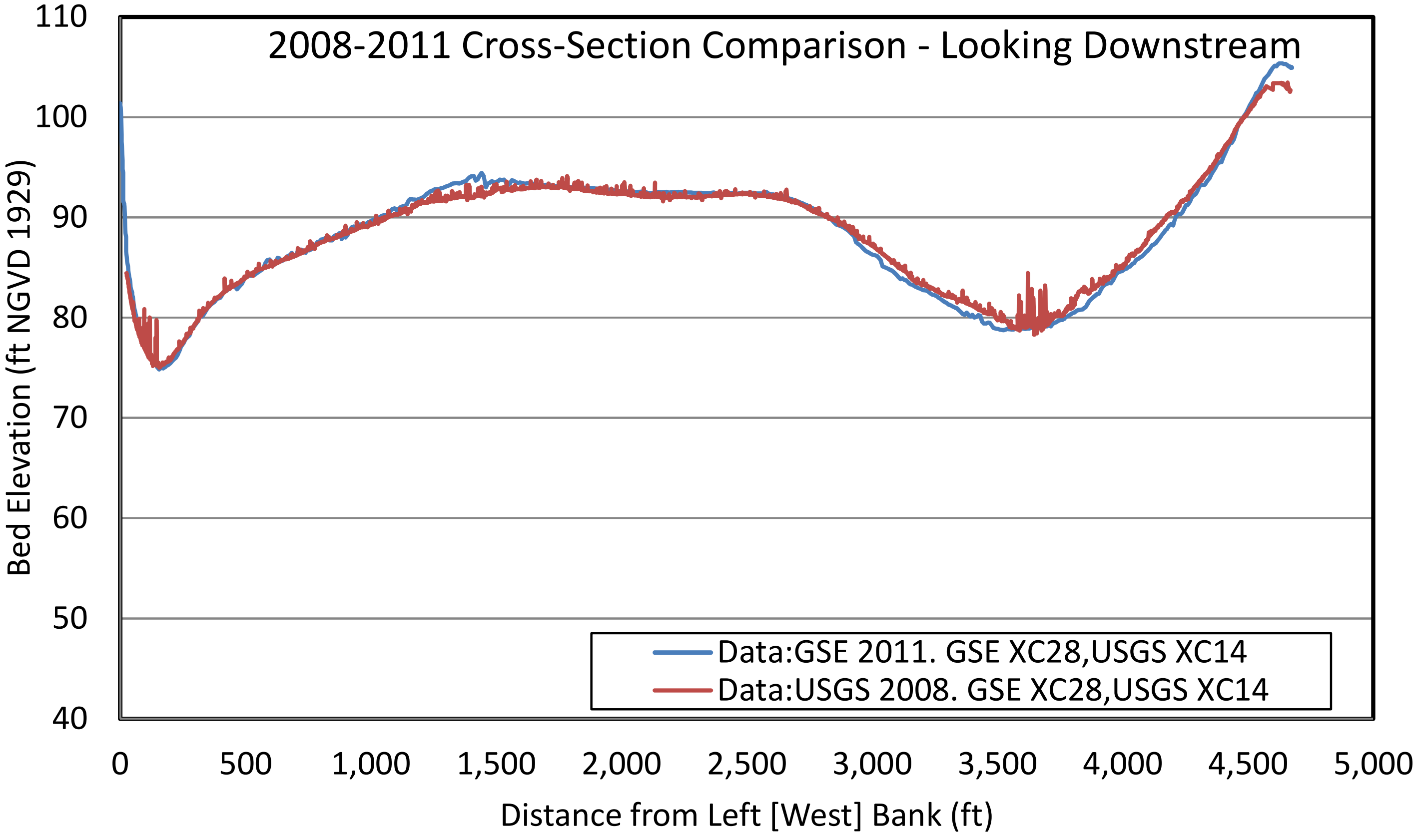

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC17,USGS XC9
Data:USGS 2008. GSE XC17,USGS XC9

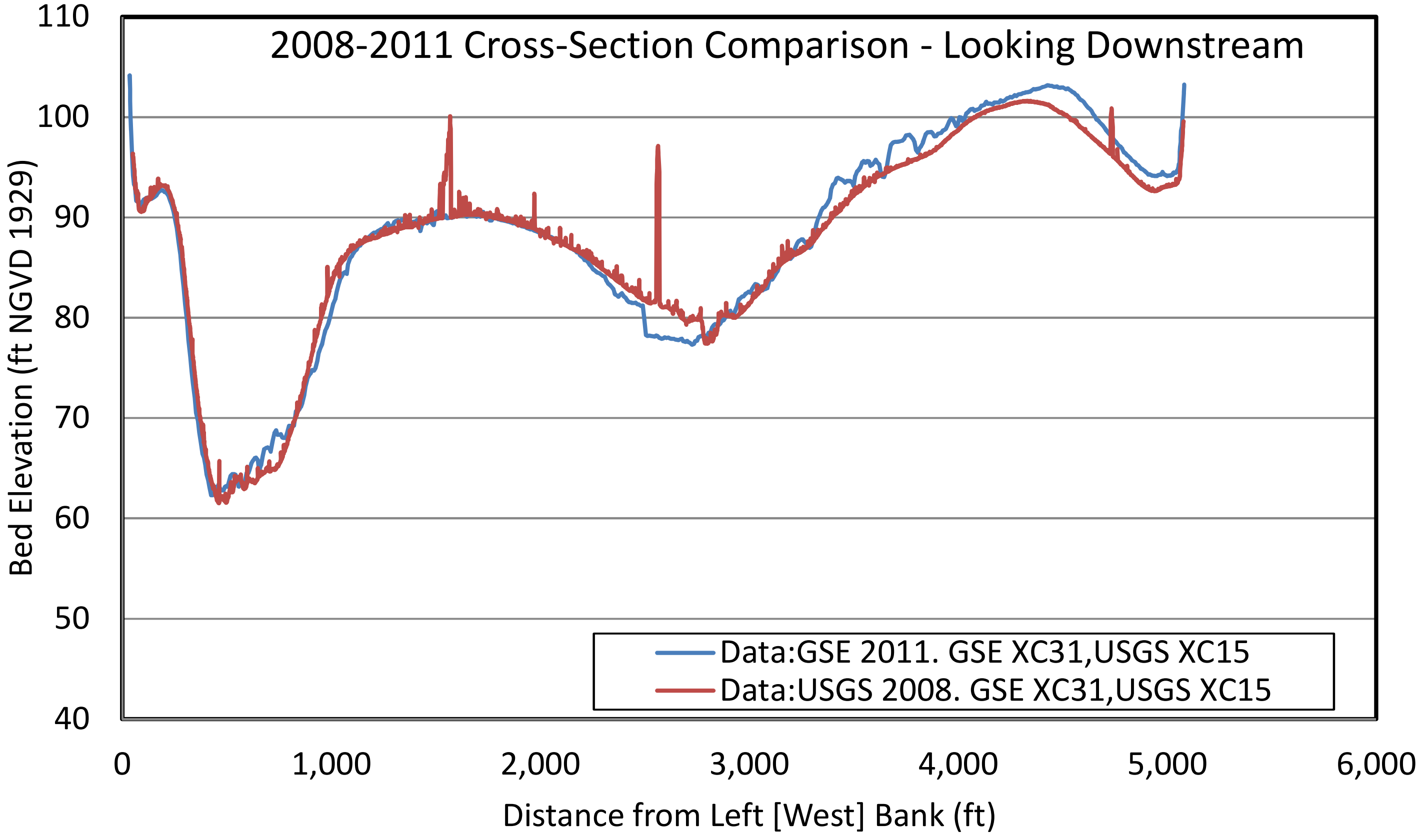

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC19,USGS XC10
Data:USGS 2008. GSE XC19,USGS XC10

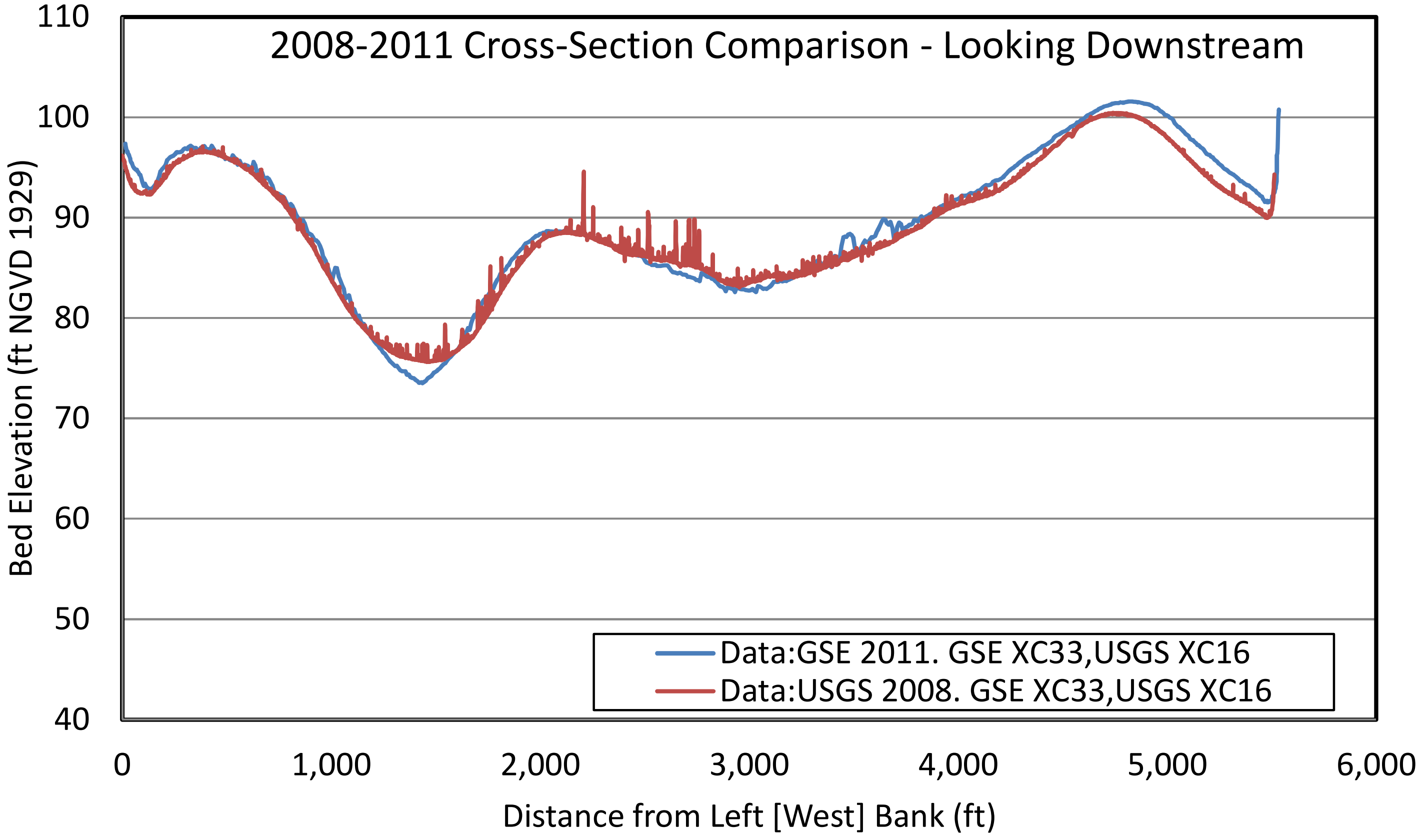

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC21,USGS XC11
Data:USGS 2008. GSE XC21,USGS XC11

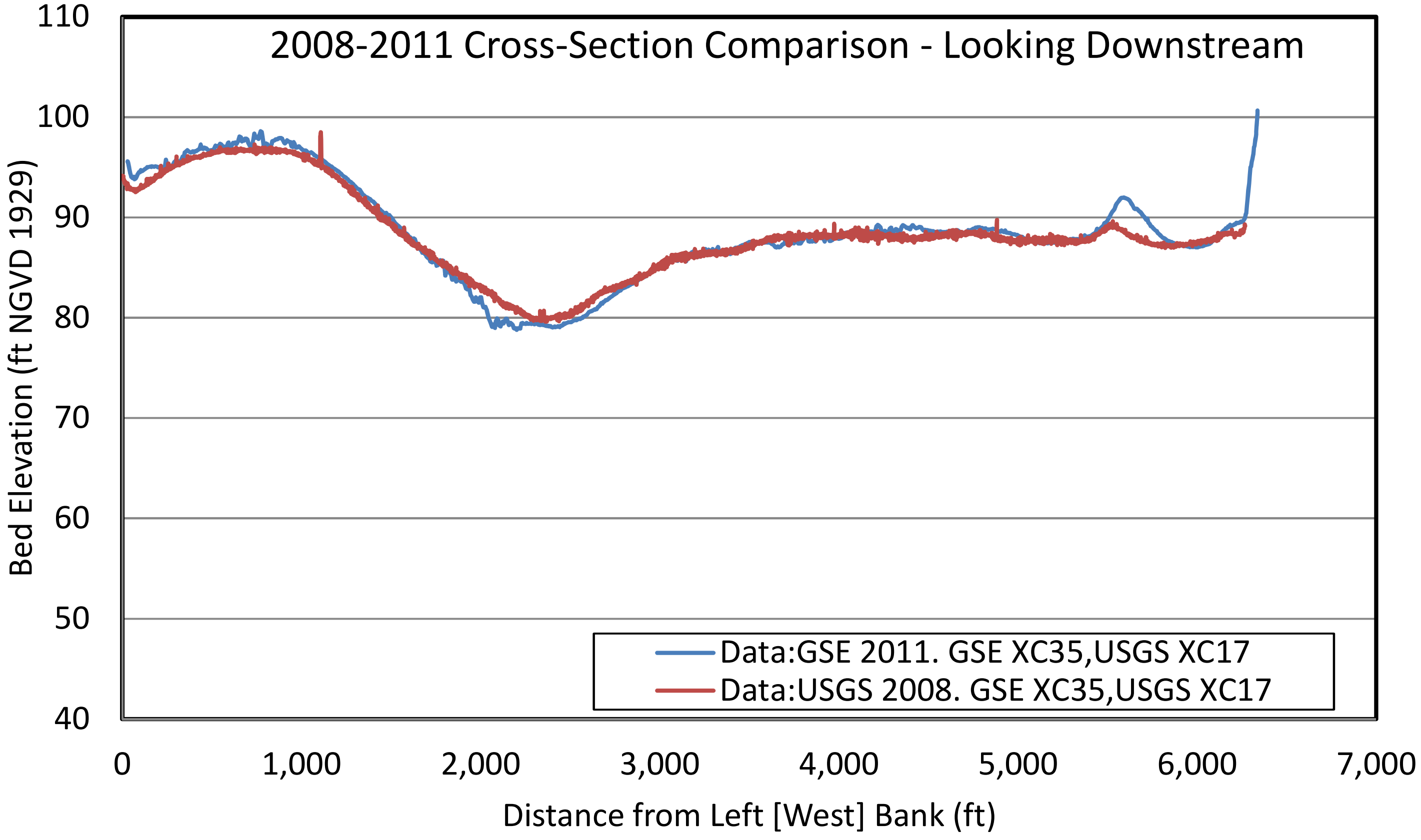

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC23,USGS XC12
Data:USGS 2008. GSE XC23,USGS XC12

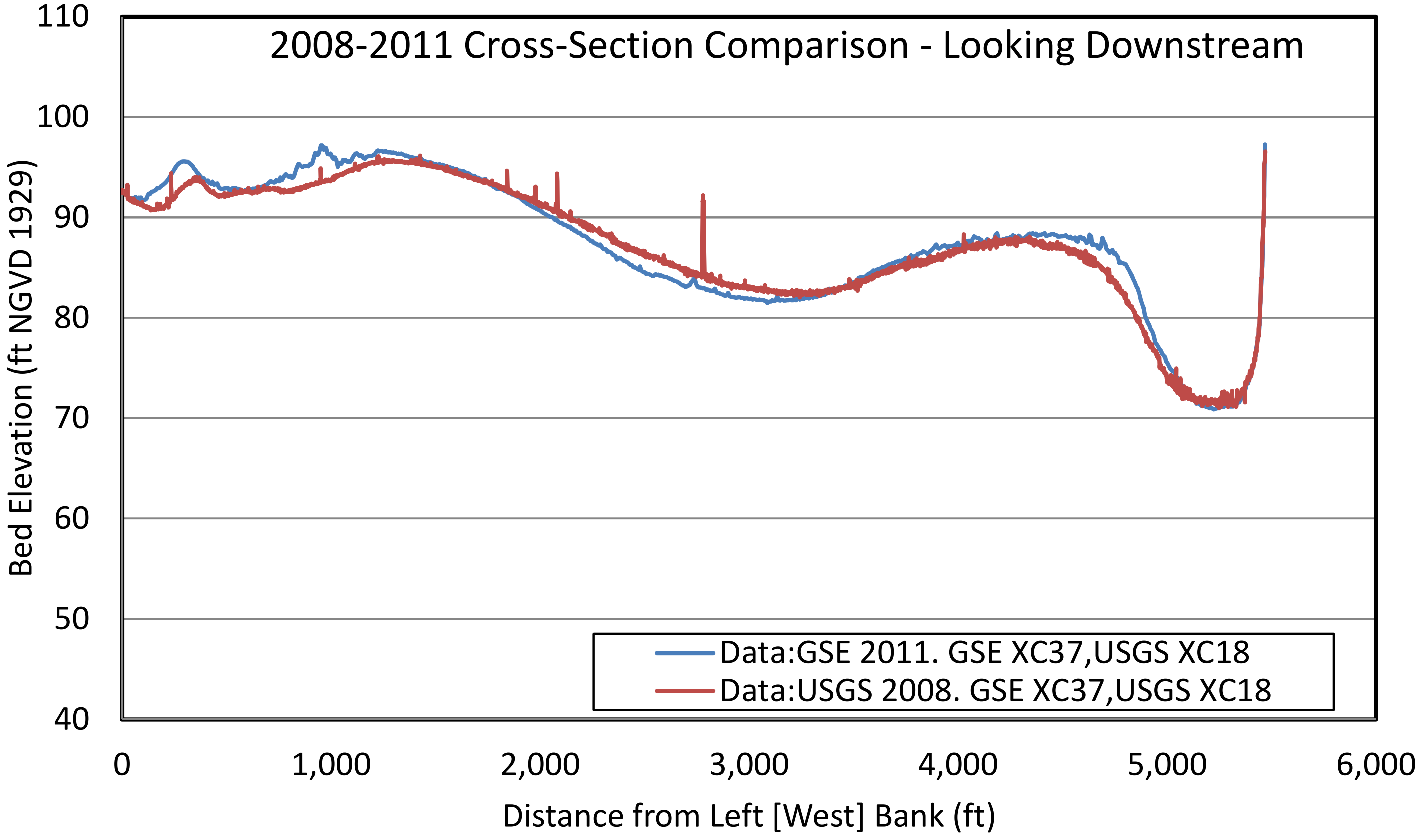

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC25,USGS XC13
Data:USGS 2008. GSE XC25,USGS XC13

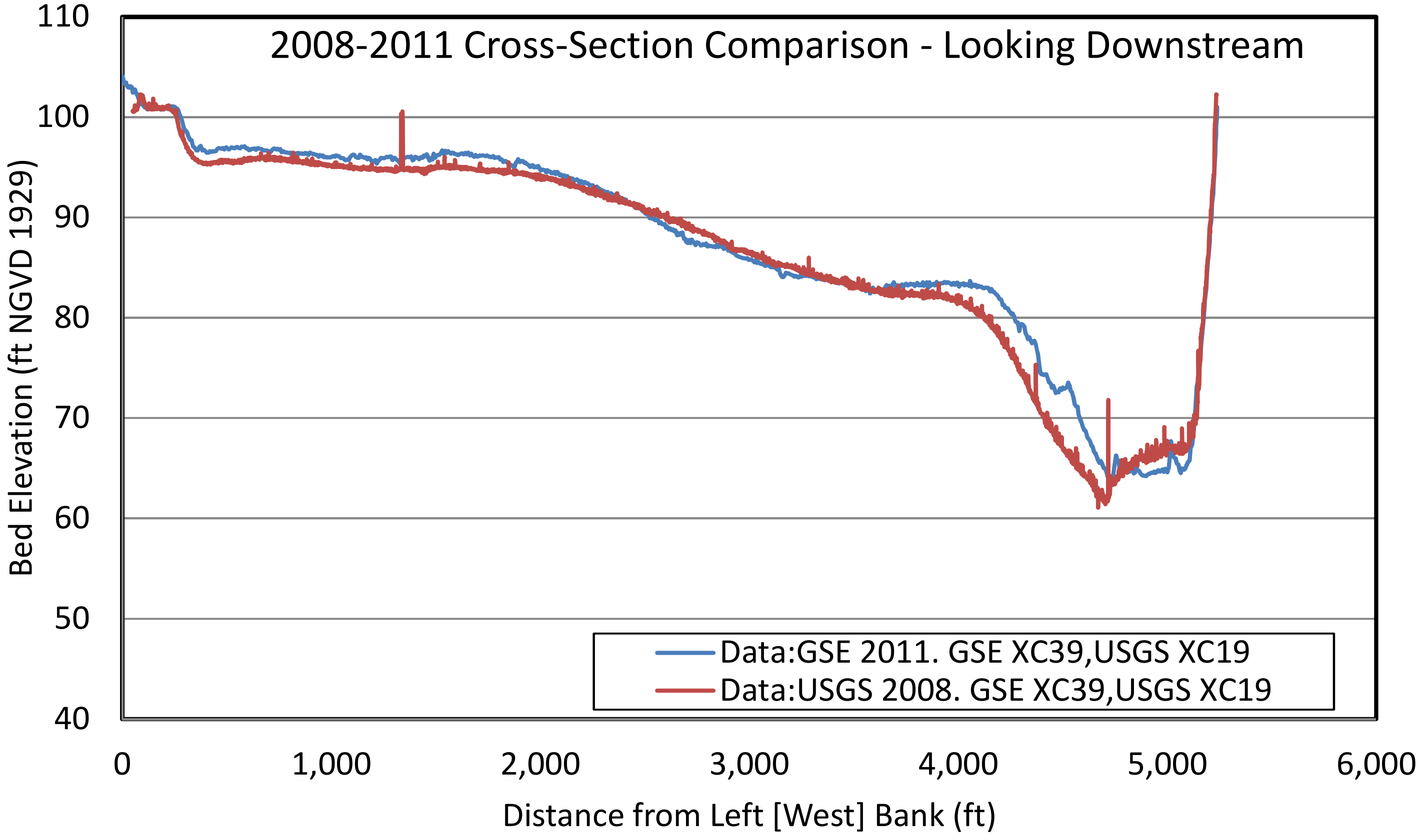

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC28,USGS XC14
Data:USGS 2008. GSE XC28,USGS XC14


2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC31,USGS XC15
Data:USGS 2008. GSE XC31,USGS XC15

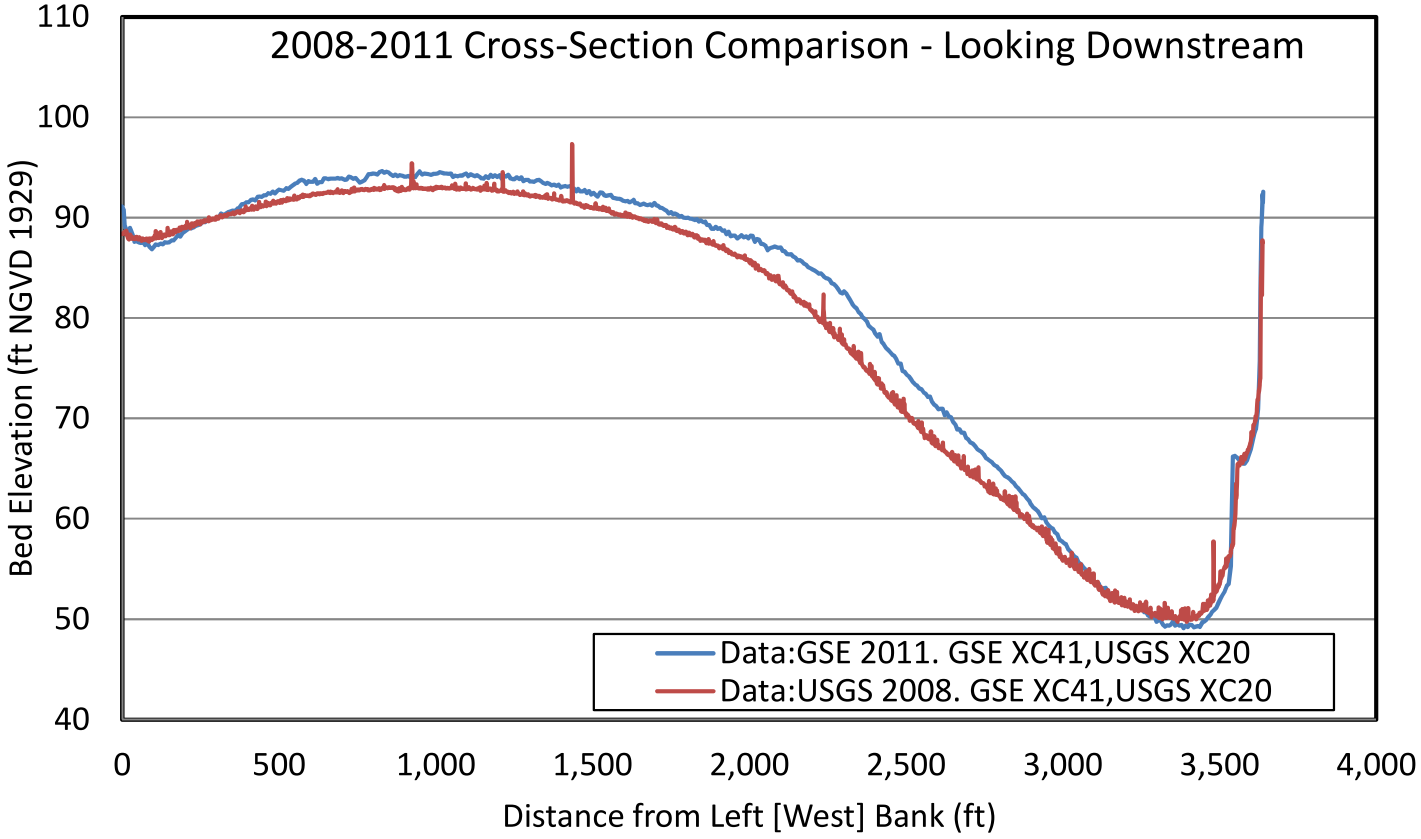

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC33,USGS XC16
Data:USGS 2008. GSE XC33,USGS XC16


2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC35,USGS XC17
Data:USGS 2008. GSE XC35,USGS XC17

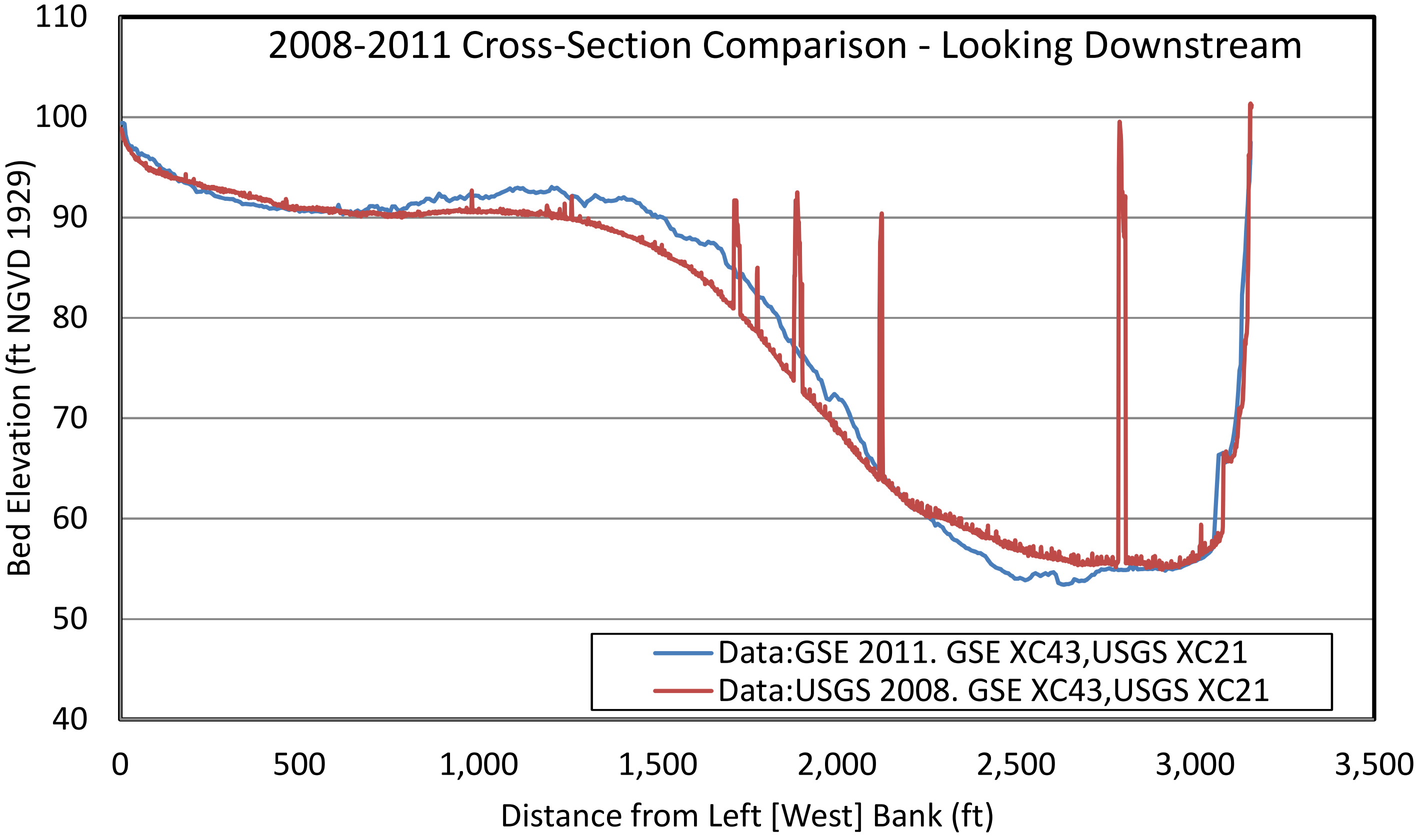

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC37,USGS XC18
Data:USGS 2008. GSE XC37,USGS XC18

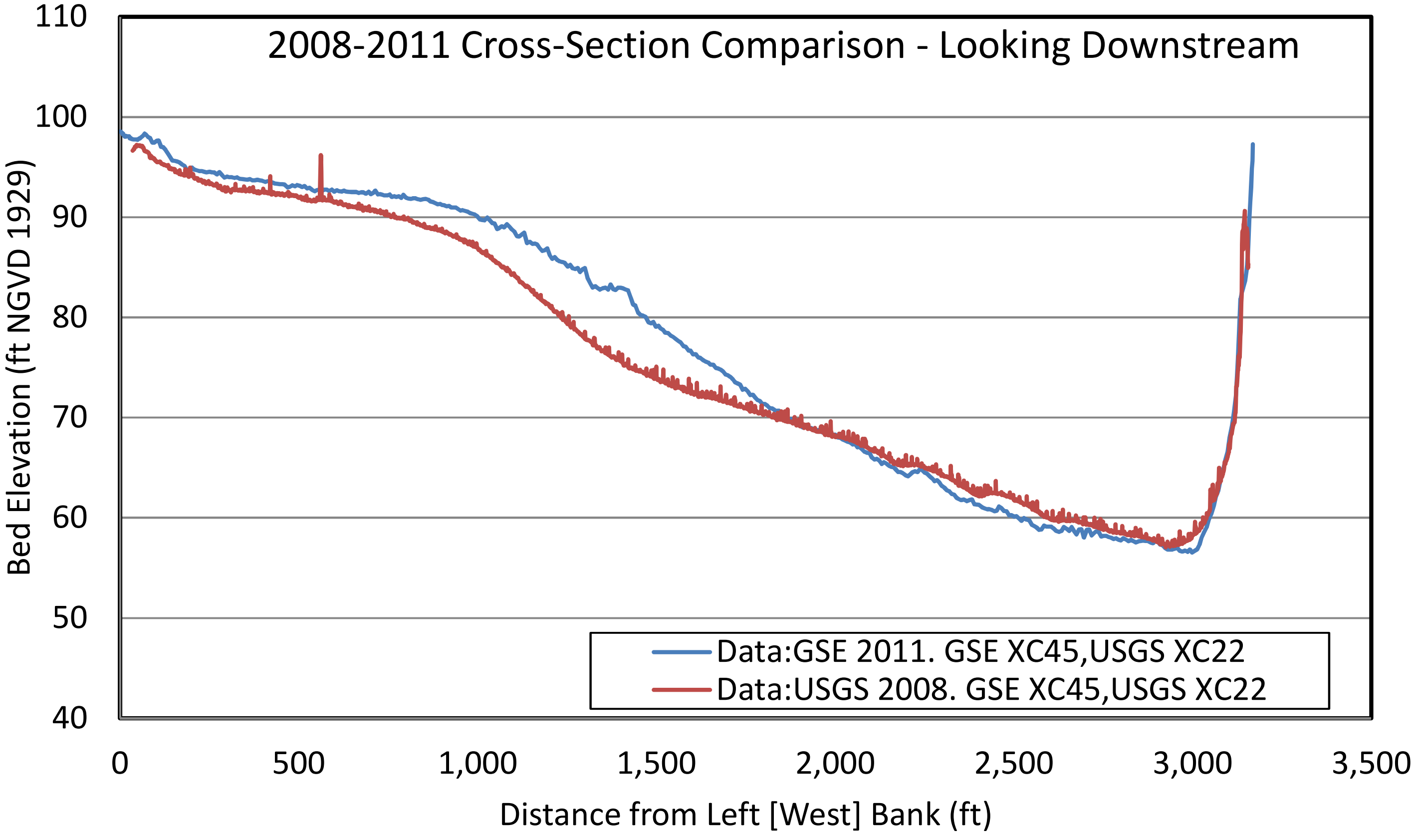


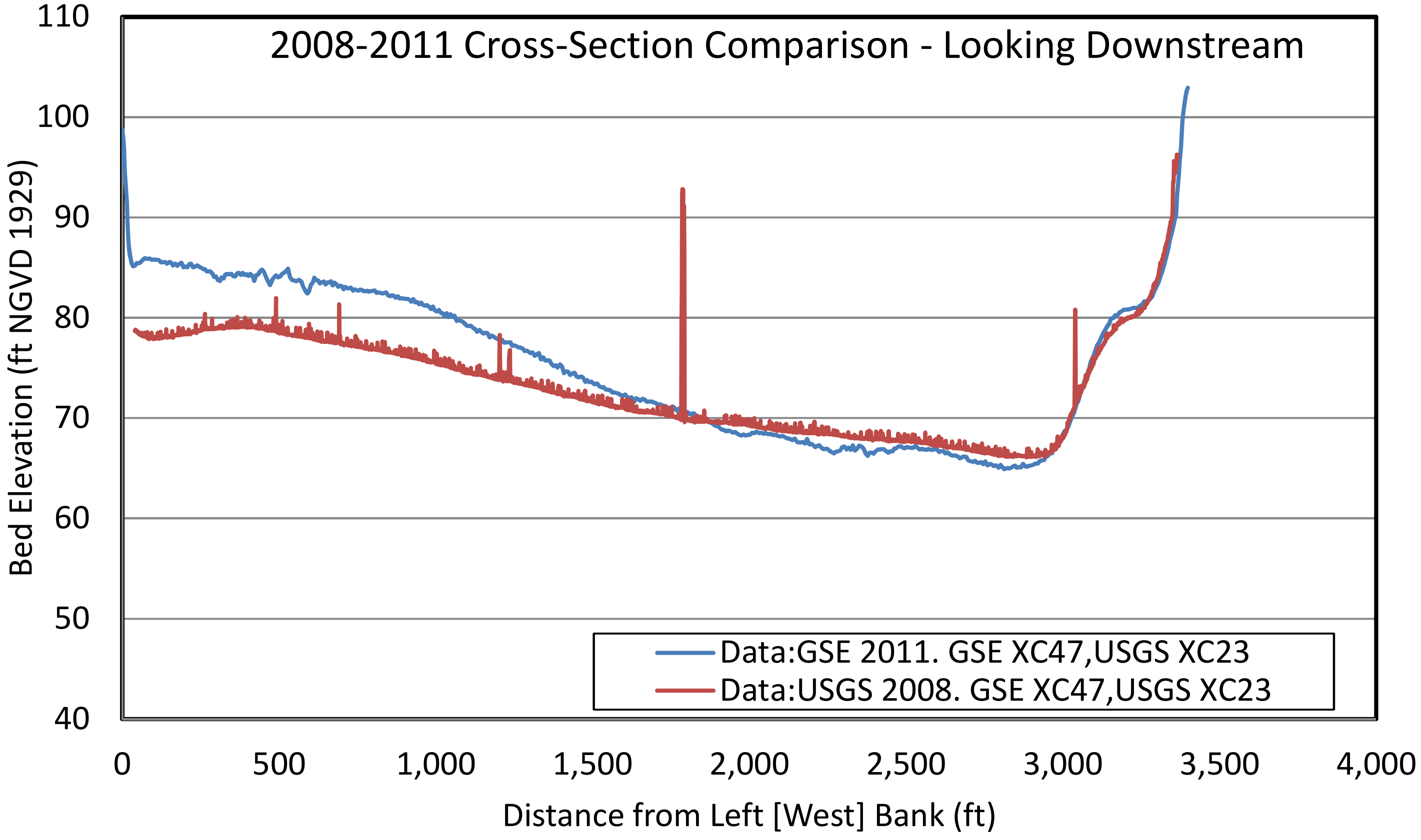
2008-2011 Cross-Section Comparison - Looking Downstream
110
100
90
80
70
60
50
40
Bed Elevation (ft NGVD 1929)
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC39,USGS XC19
Data:USGS 2008. GSE XC39,USGS XC19

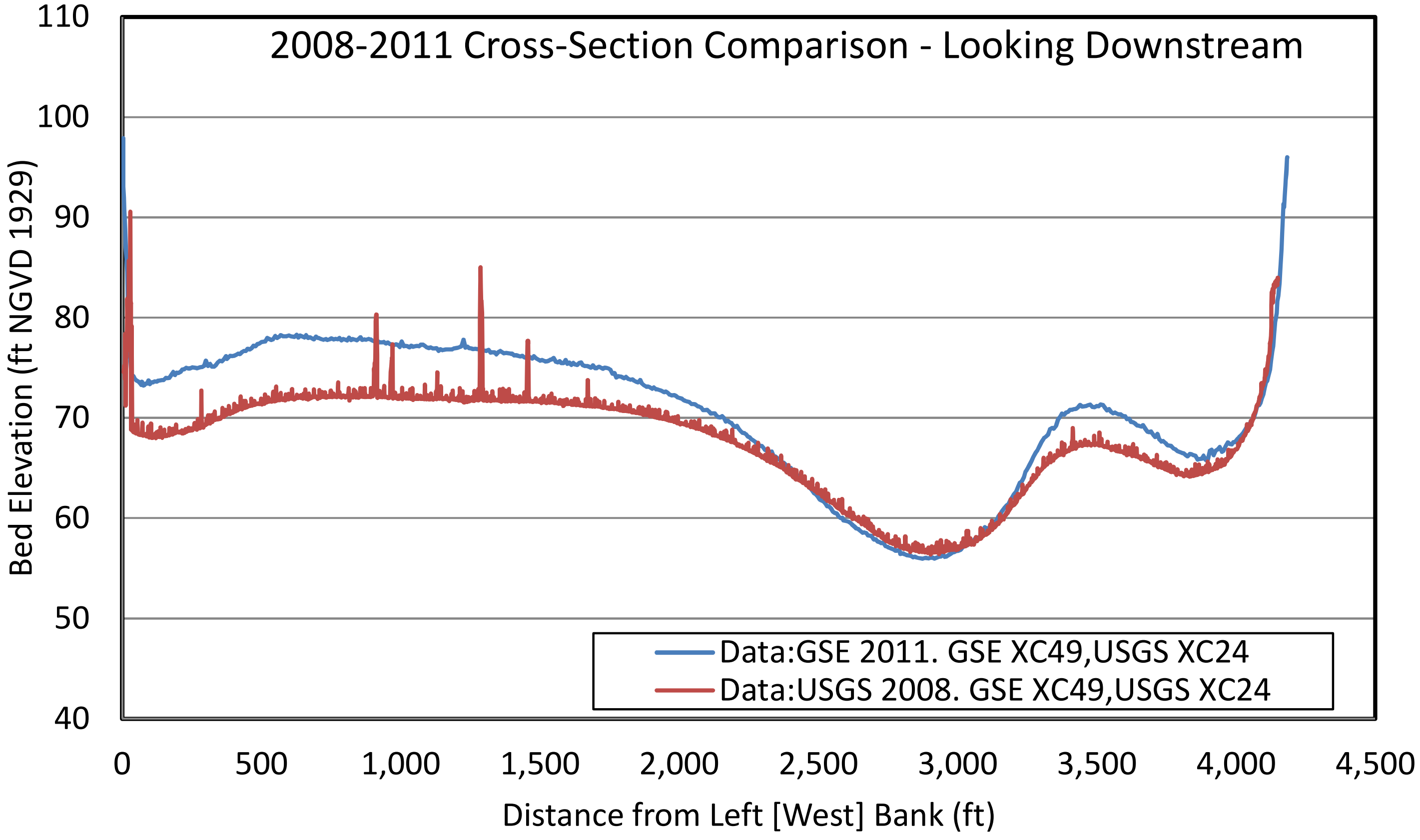


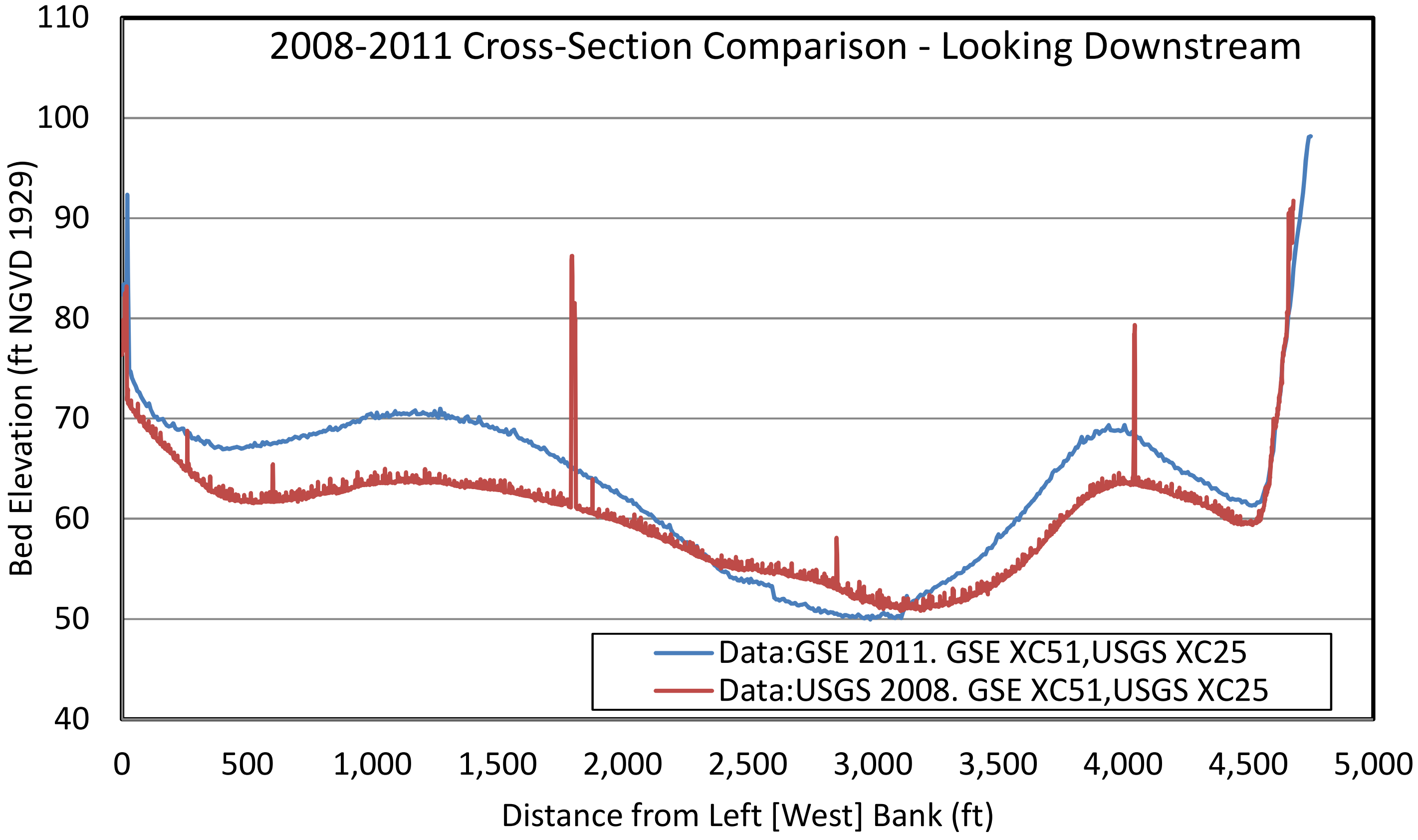
2008-2011 Cross-Section Comparison - Looking Downstream
110
100
90
80
70
60
50
40
Bed Elevation (ft NGVD 1929)
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC41,USGS XC20
Data:USGS 2008. GSE XC41,USGS XC20

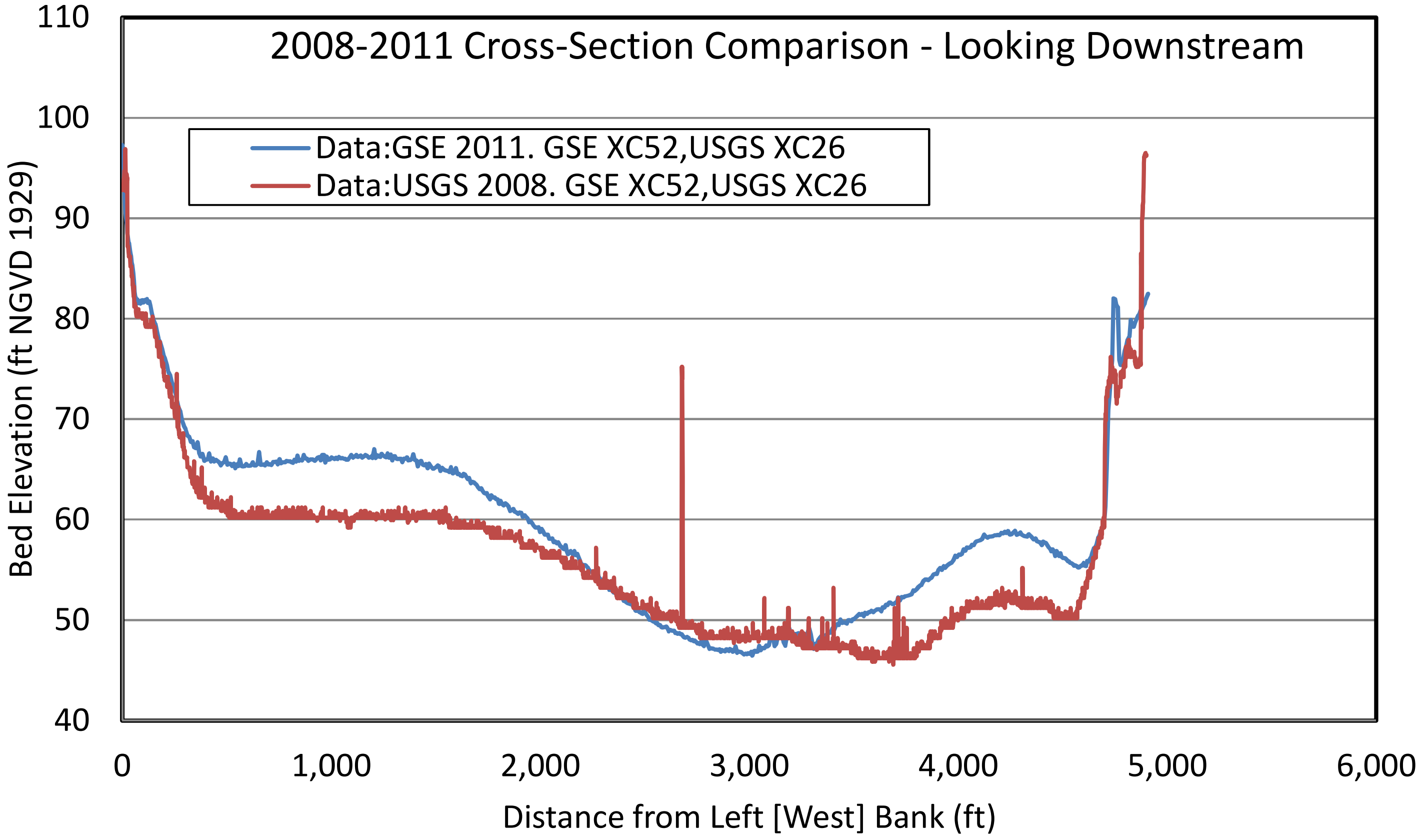

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC43,USGS XC21
Data:USGS 2008. GSE XC43,USGS XC21


2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC45,USGS XC22
Data:USGS 2008. GSE XC45,USGS XC22

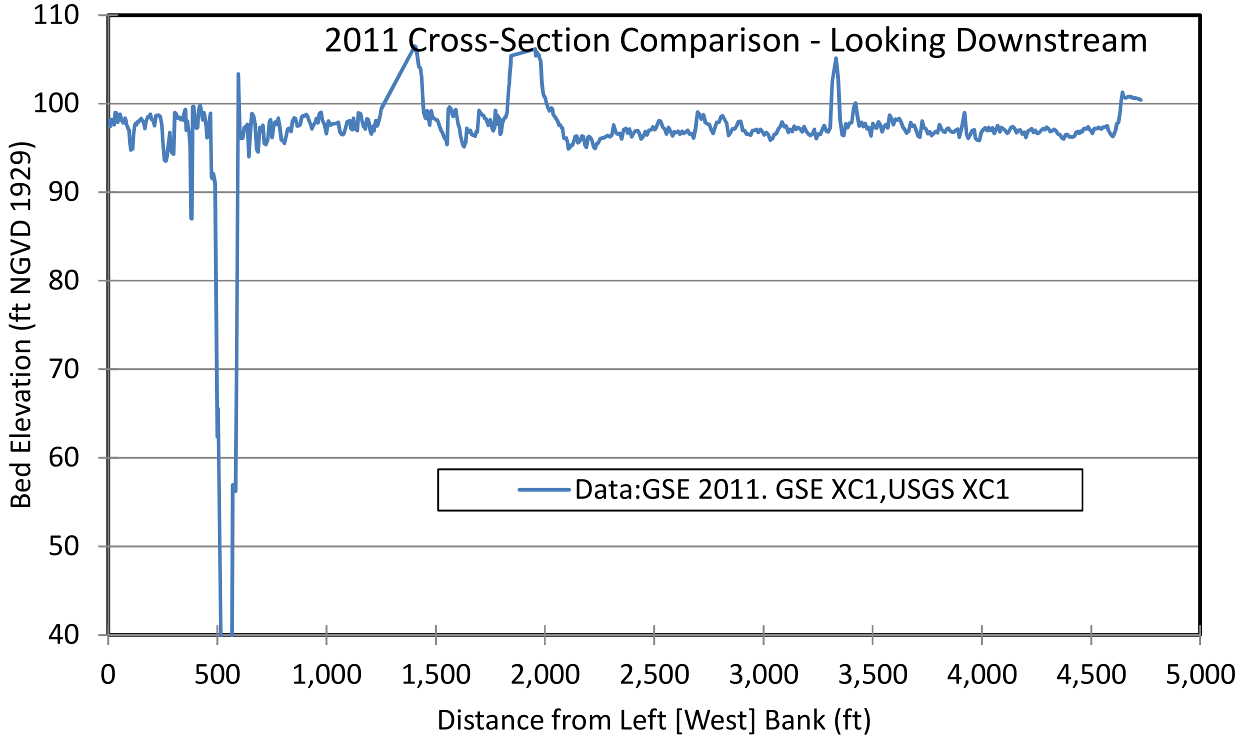

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC47,USGS XC23
Data:USGS 2008. GSE XC47,USGS XC23

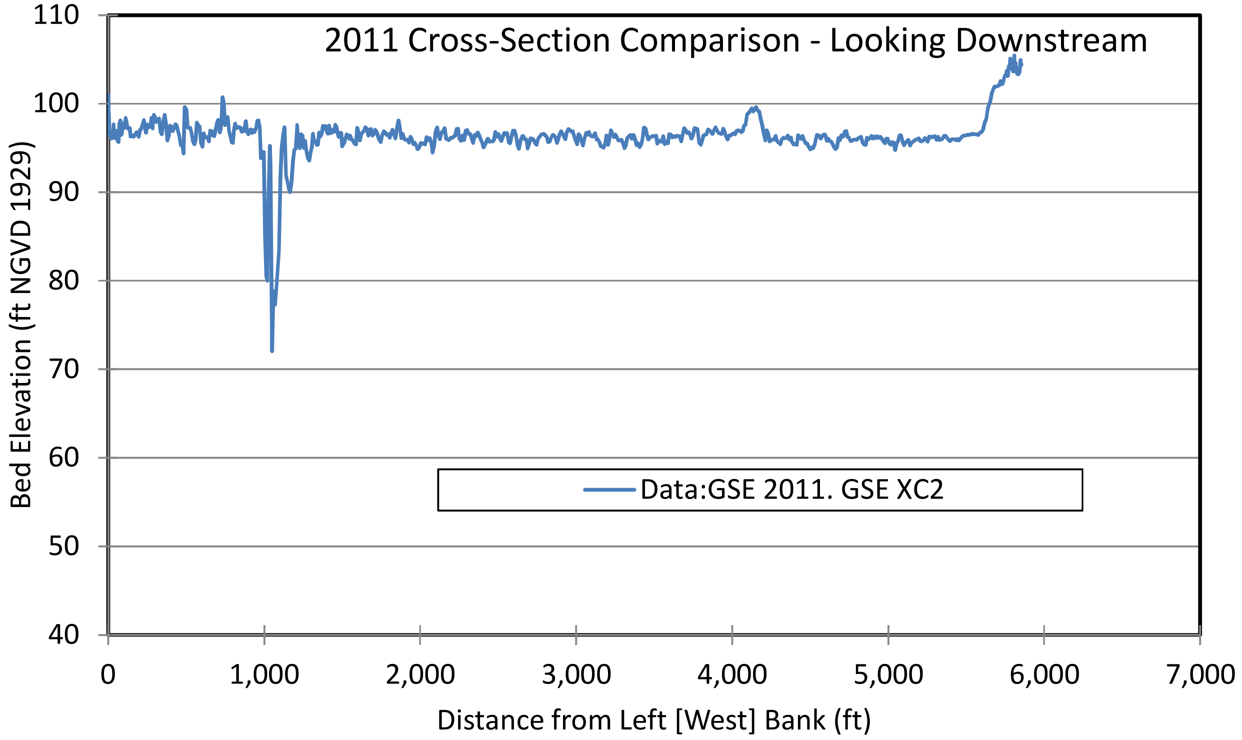

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC49,USGS XC24
Data:USGS 2008. GSE XC49,USGS XC24


2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC51,USGS XC25
Data:USGS 2008. GSE XC51,USGS XC25


2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC52,USGS XC26
Data:USGS 2008. GSE XC52,USGS XC26

Appendix B: 2011 Cross-Section Plots[8]





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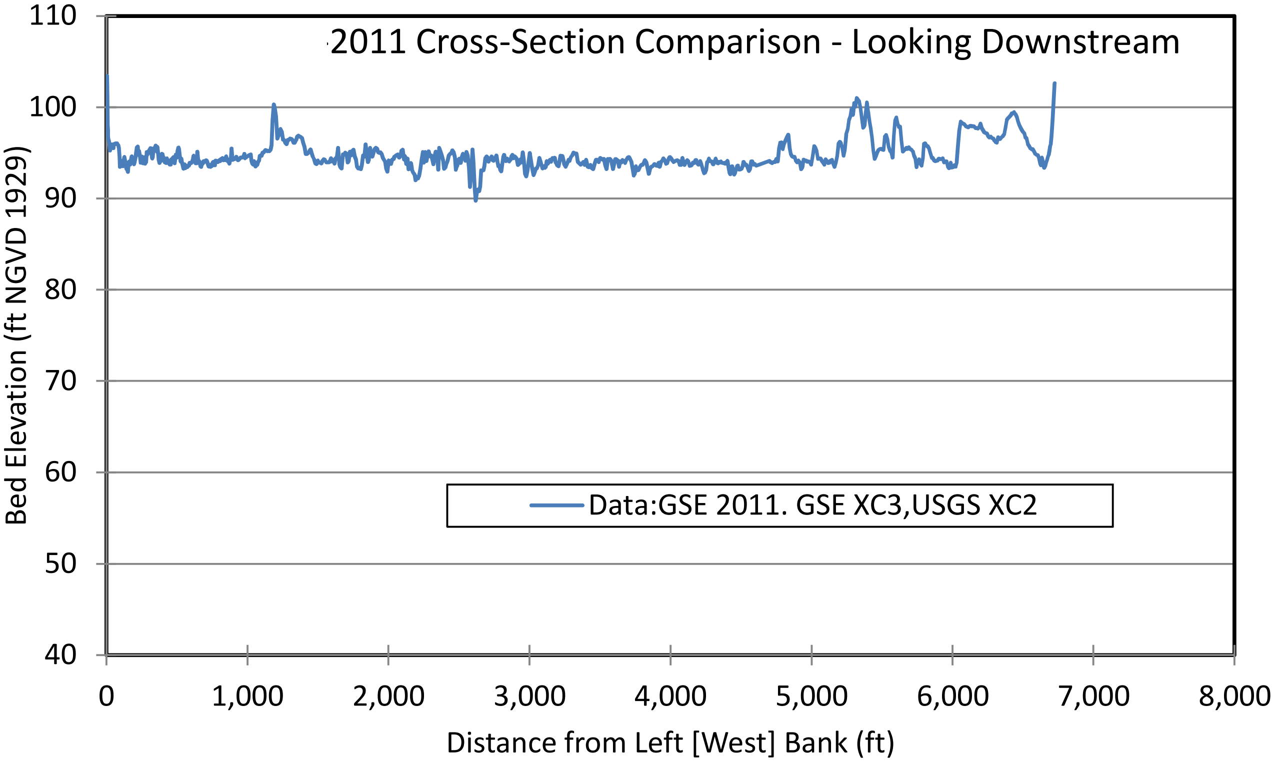
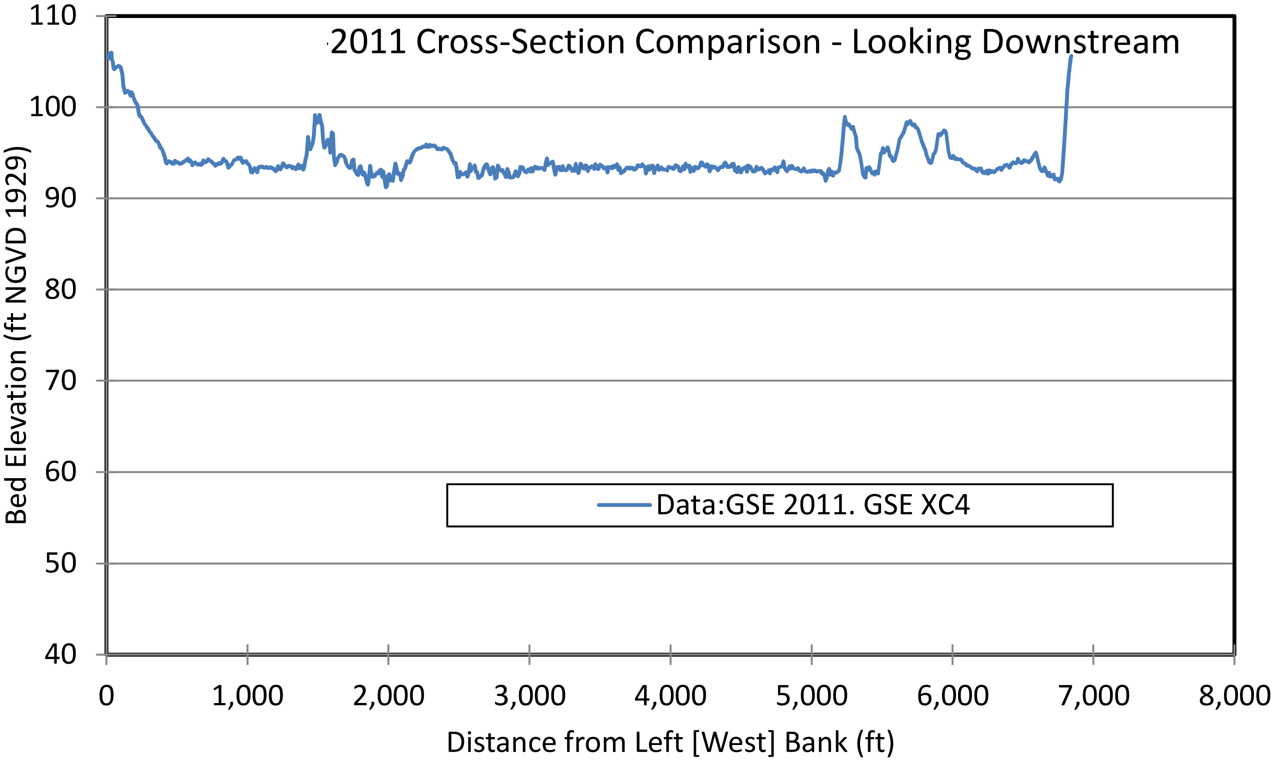
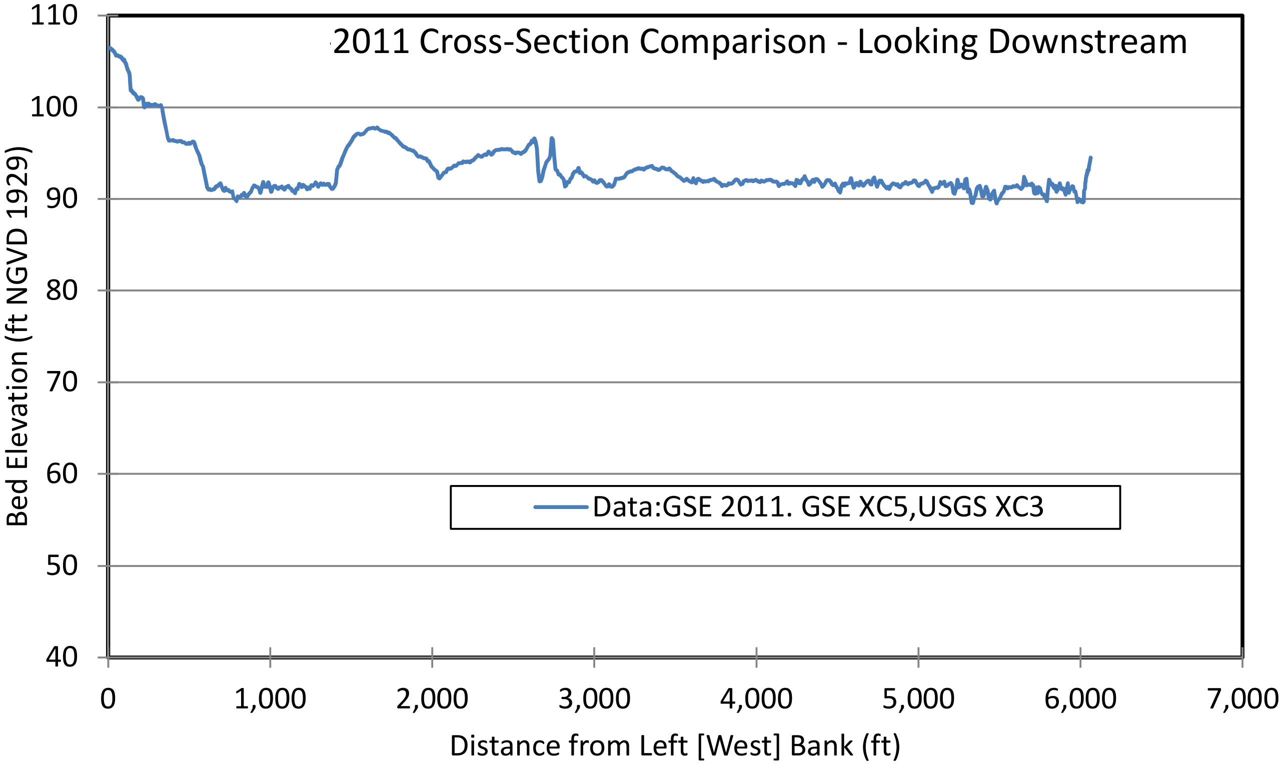
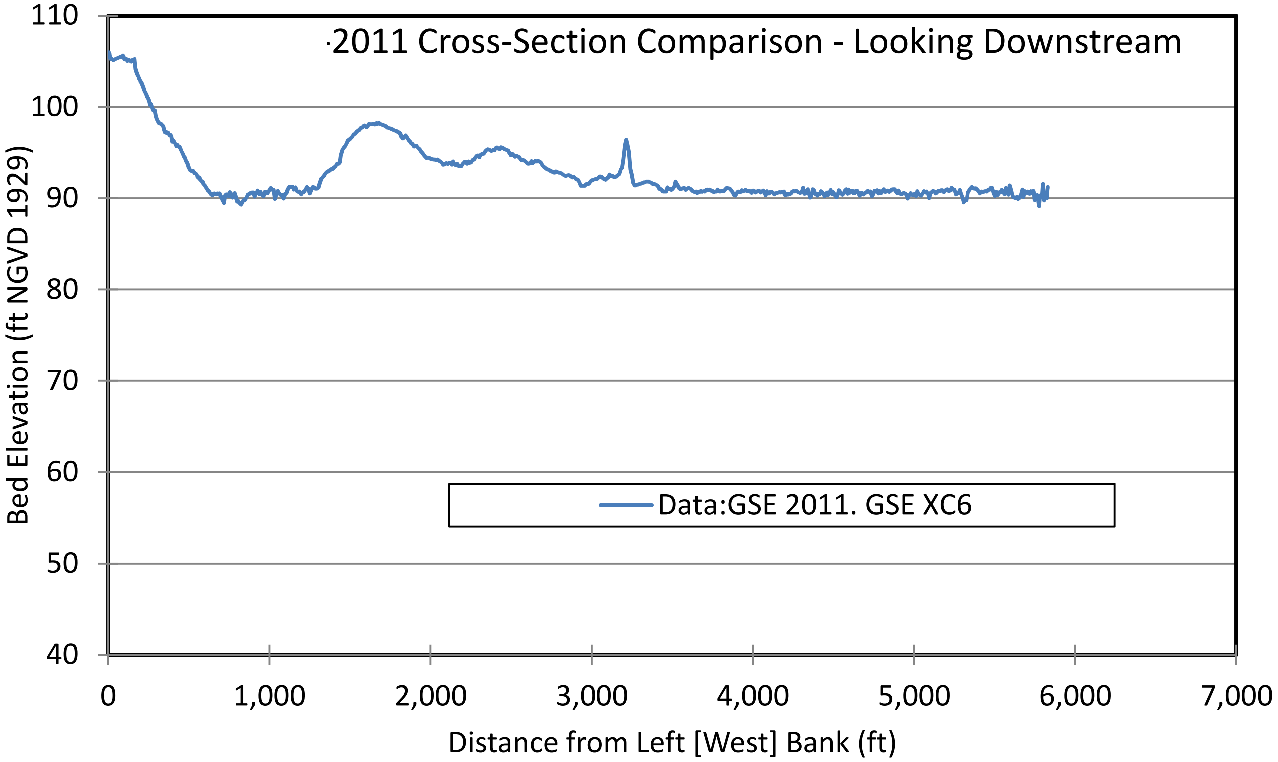
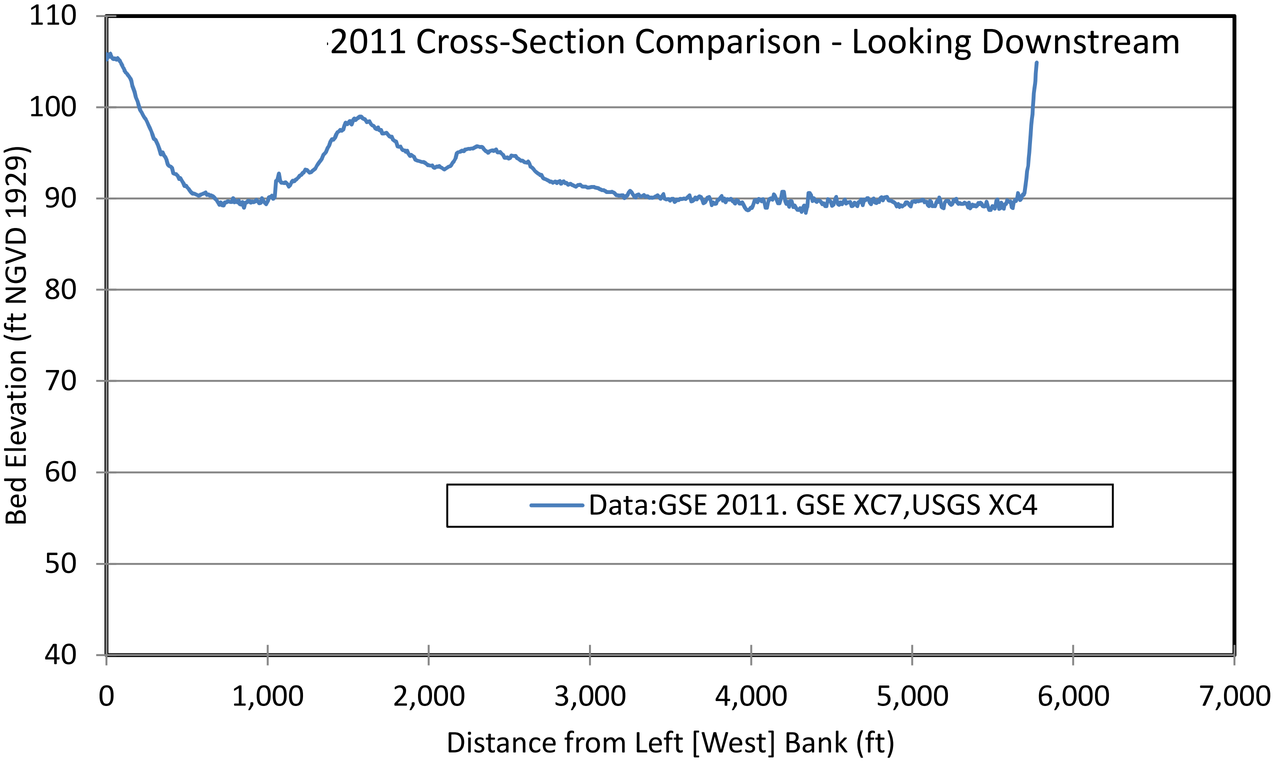
[8] Only 2011 cross-sections are shown in this appendix, but XC numbering for both surveys (2008 and 2011) are shown. Where GSE cross-sections overlapped with USGS cross-sections, both cross-section numbers are included. Appendix A compares overlapping cross-sections.

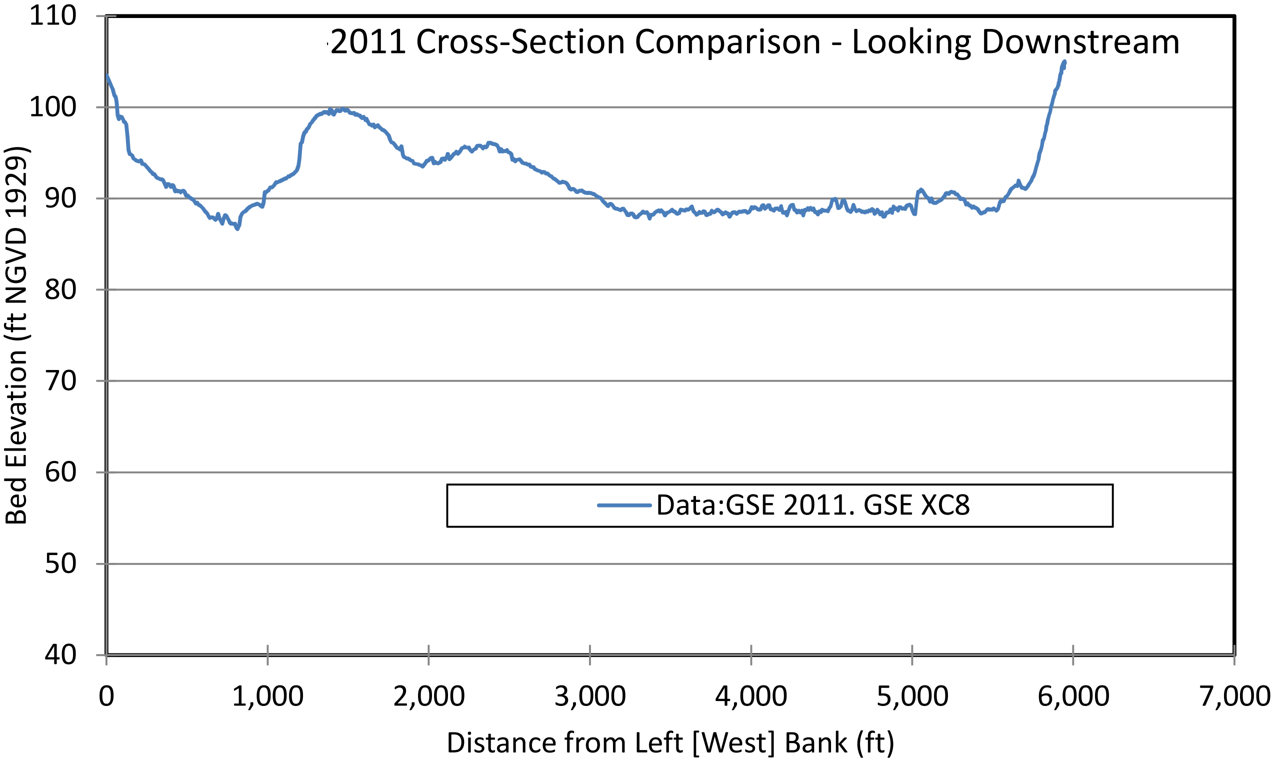

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC3,USGS XC2

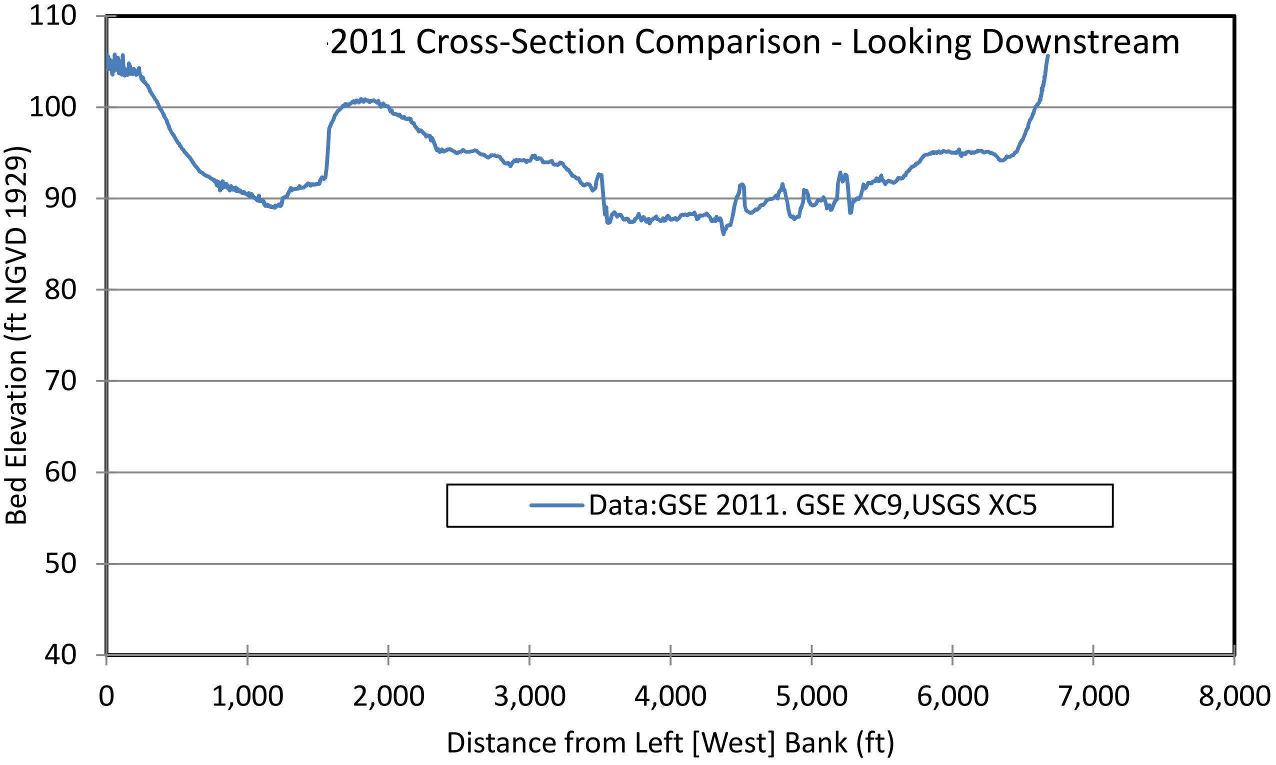

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC4

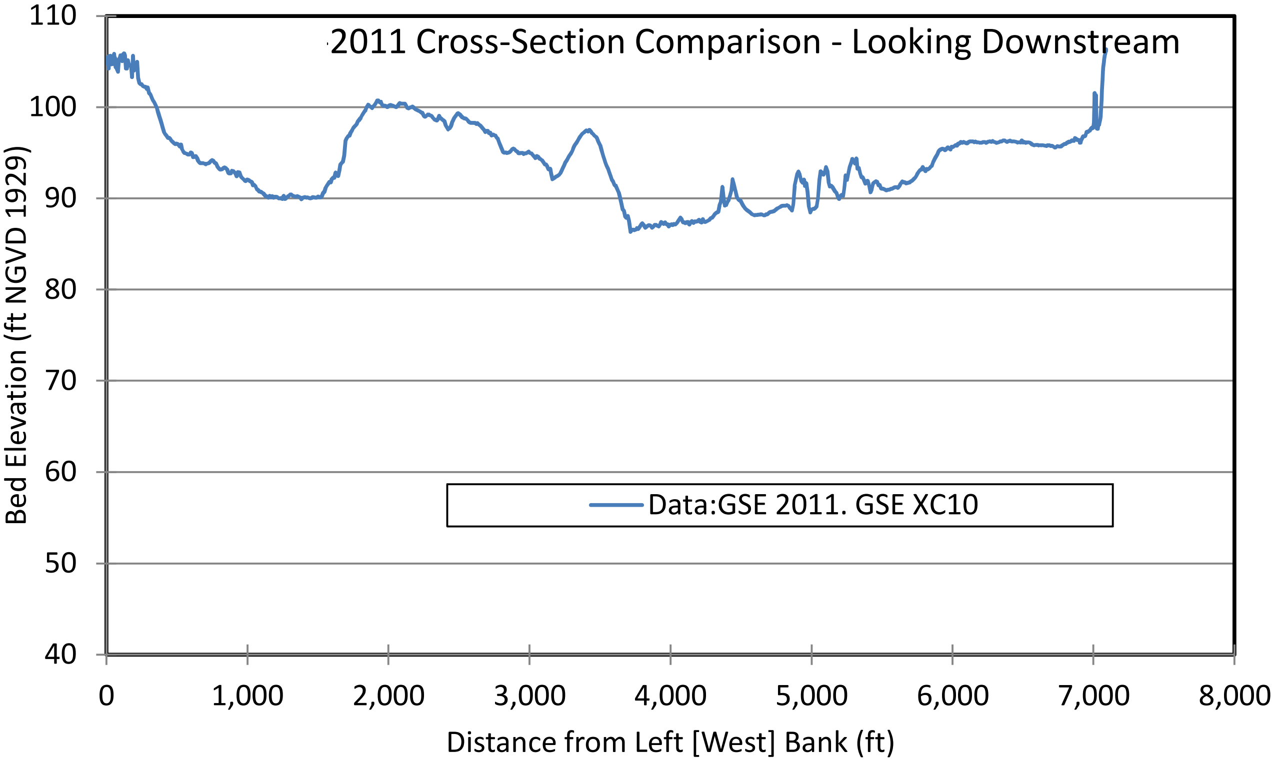

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC5,USGS XC3

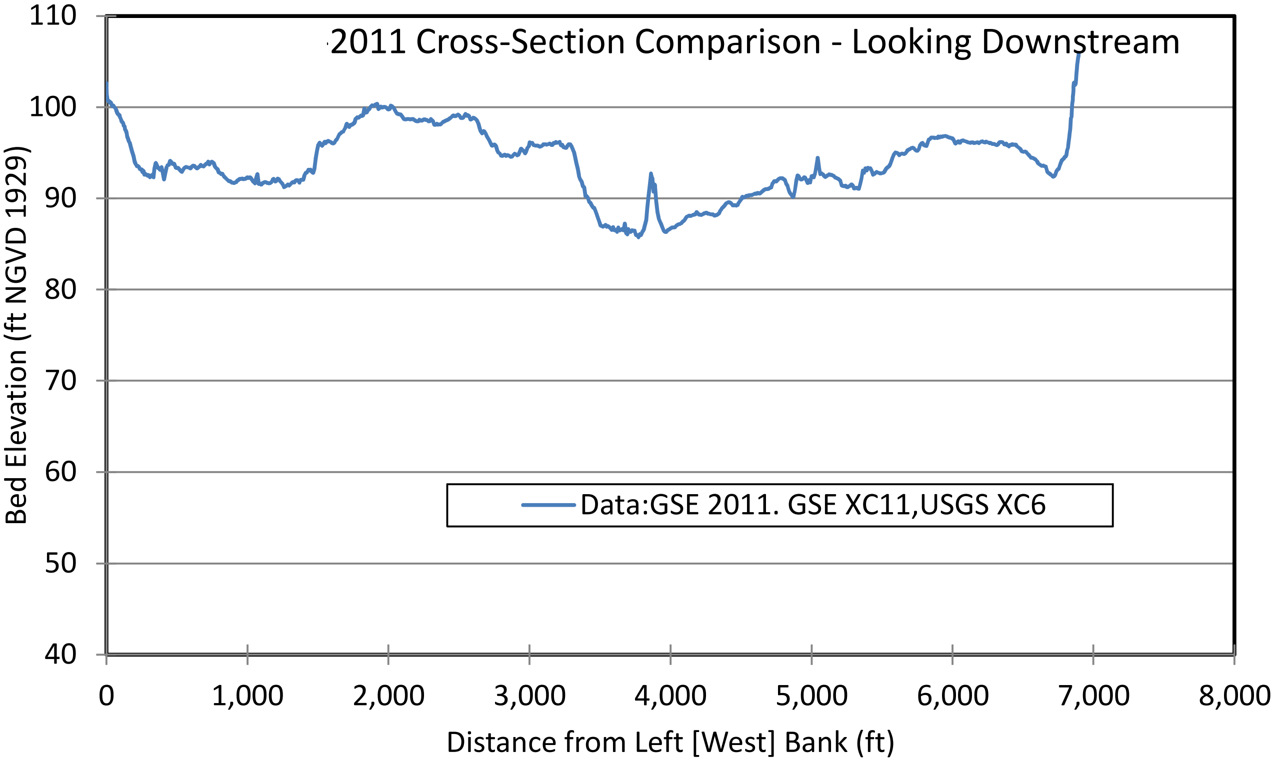

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC6

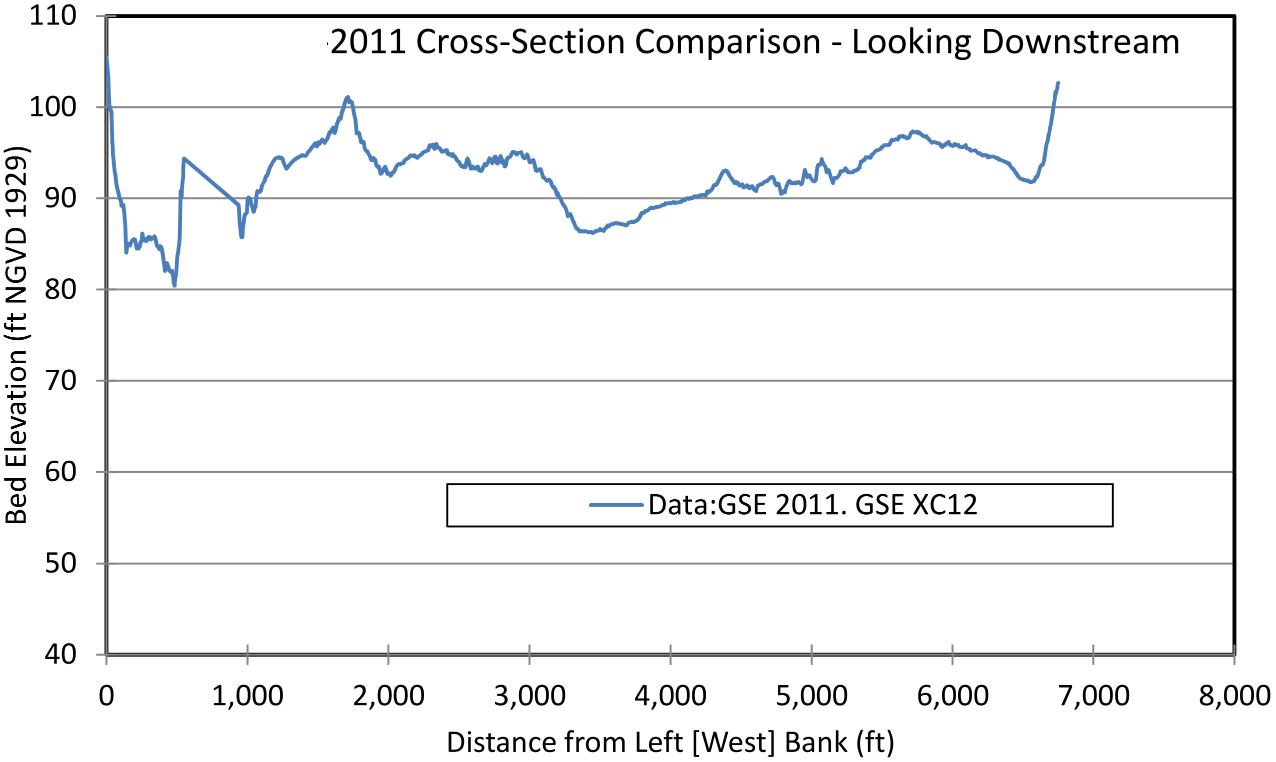

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC7,USGS XC4

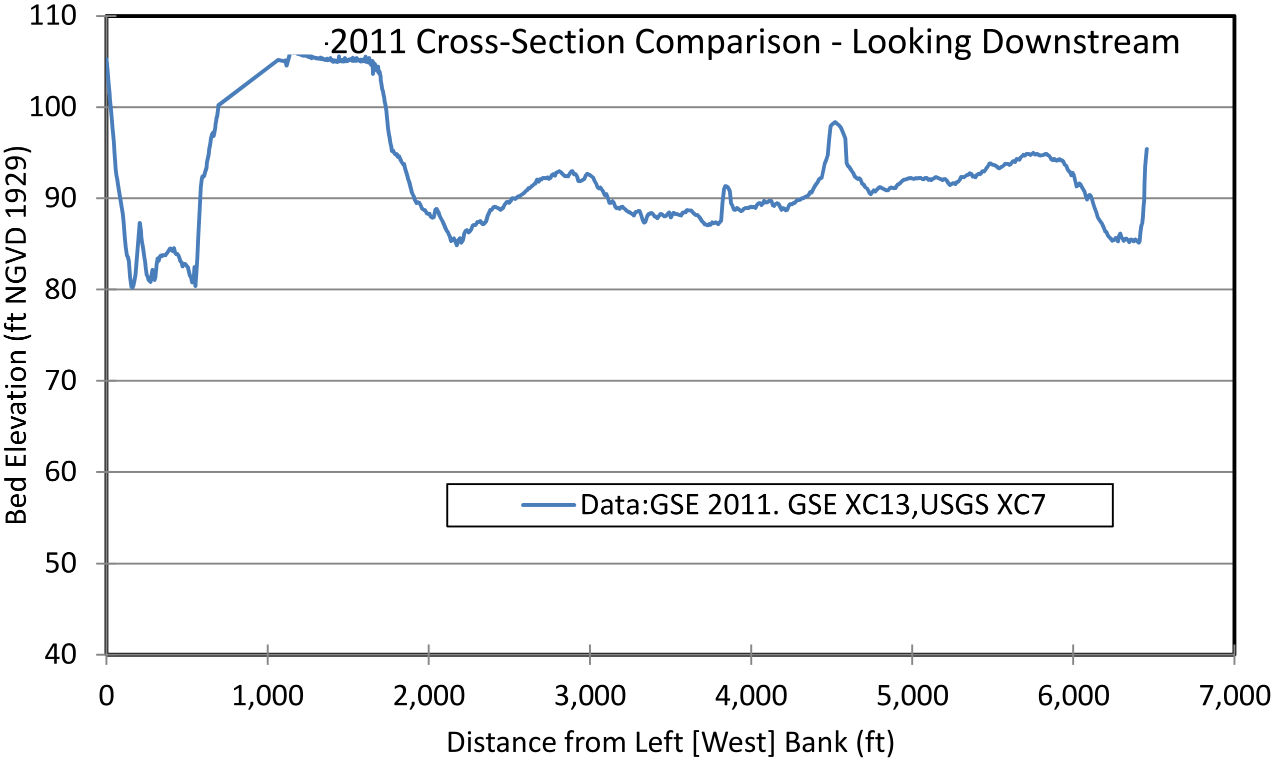

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC8

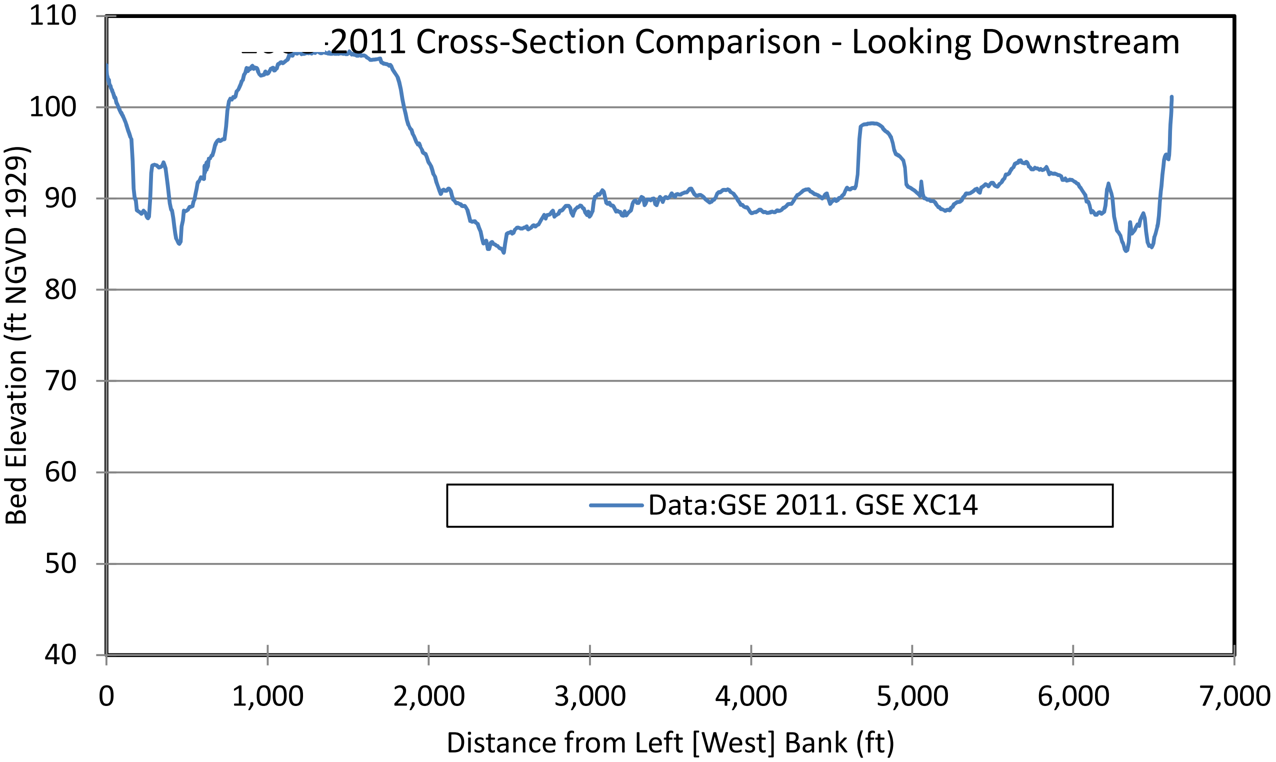

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC9,USGS XC5

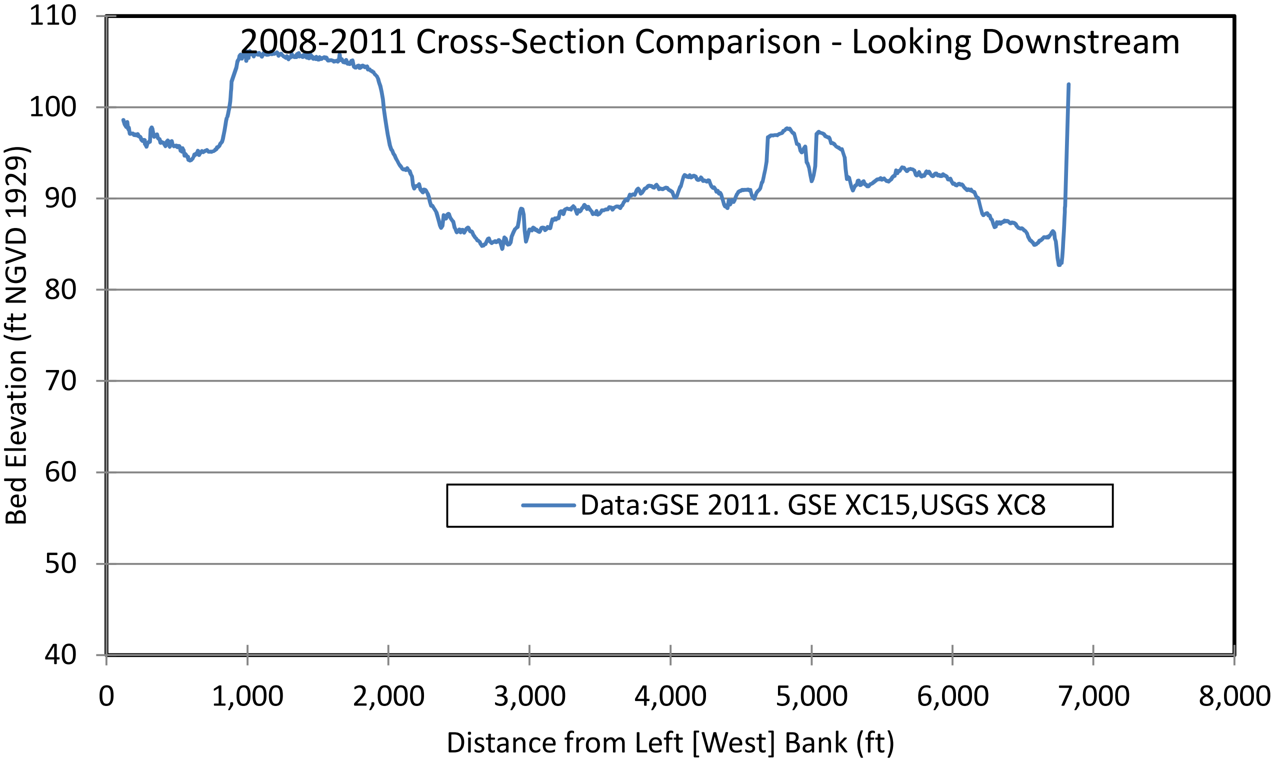

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC10

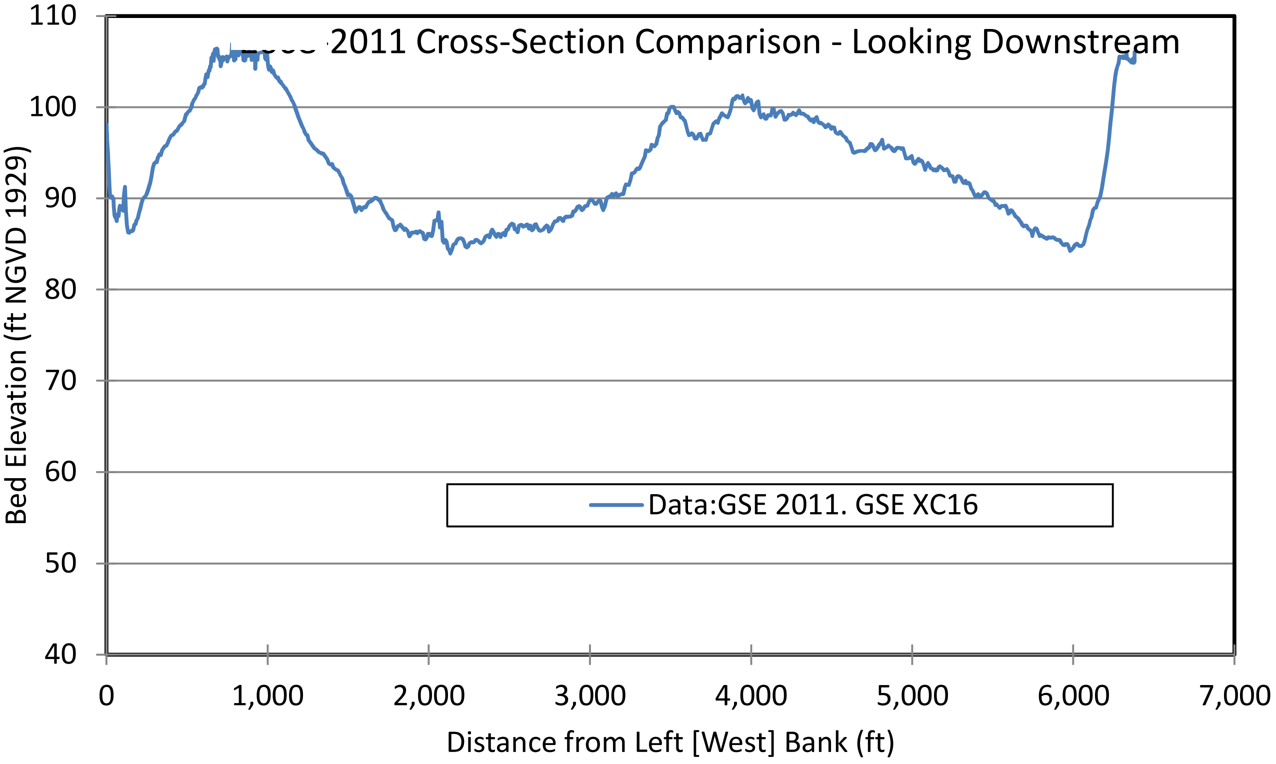

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC11,USGS XC6

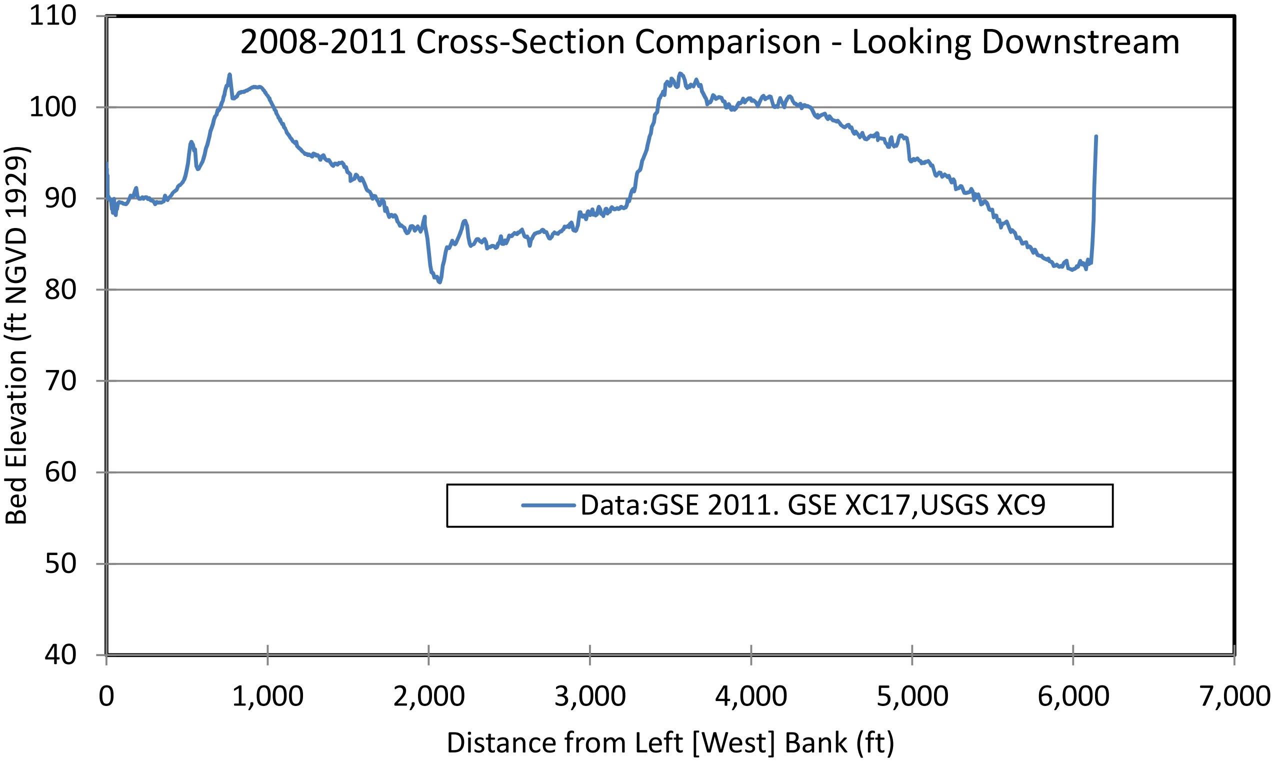

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC12


2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC13,USGS XC7
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)

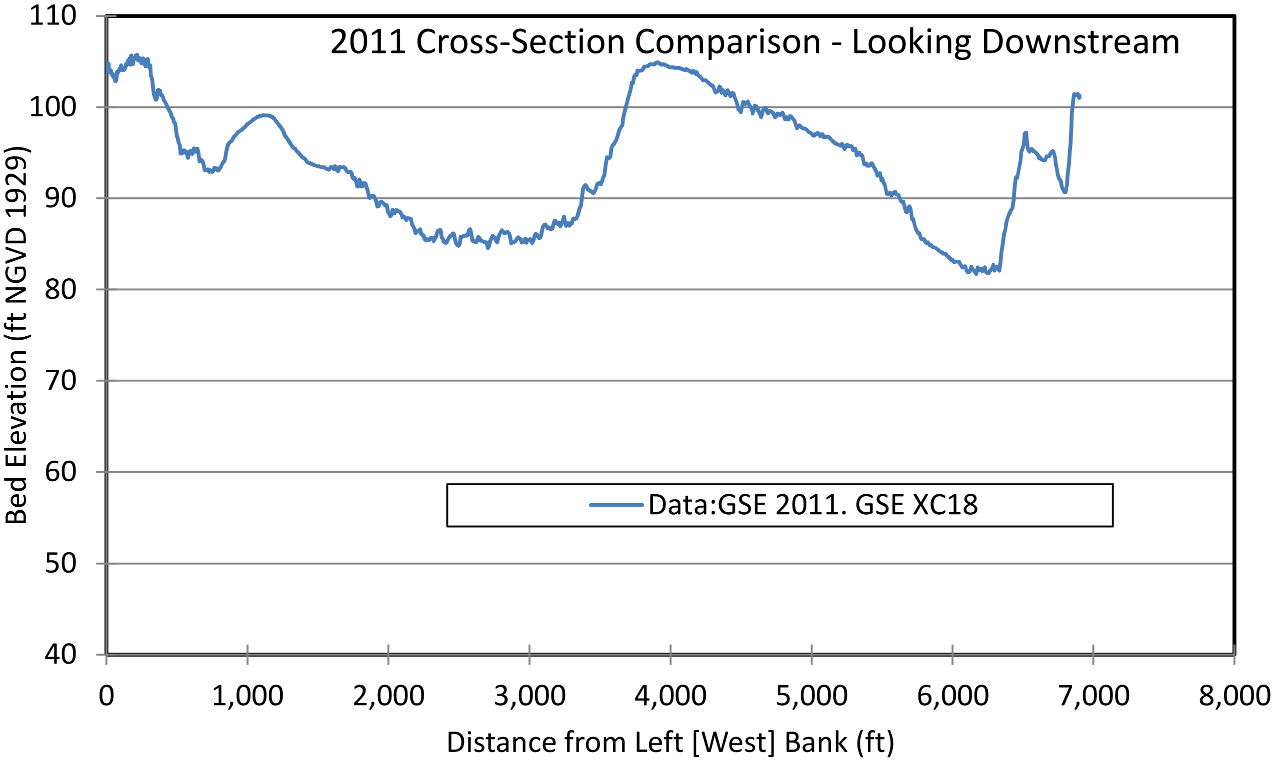

2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC14
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)


2008-2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC15,USGS XC8
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)

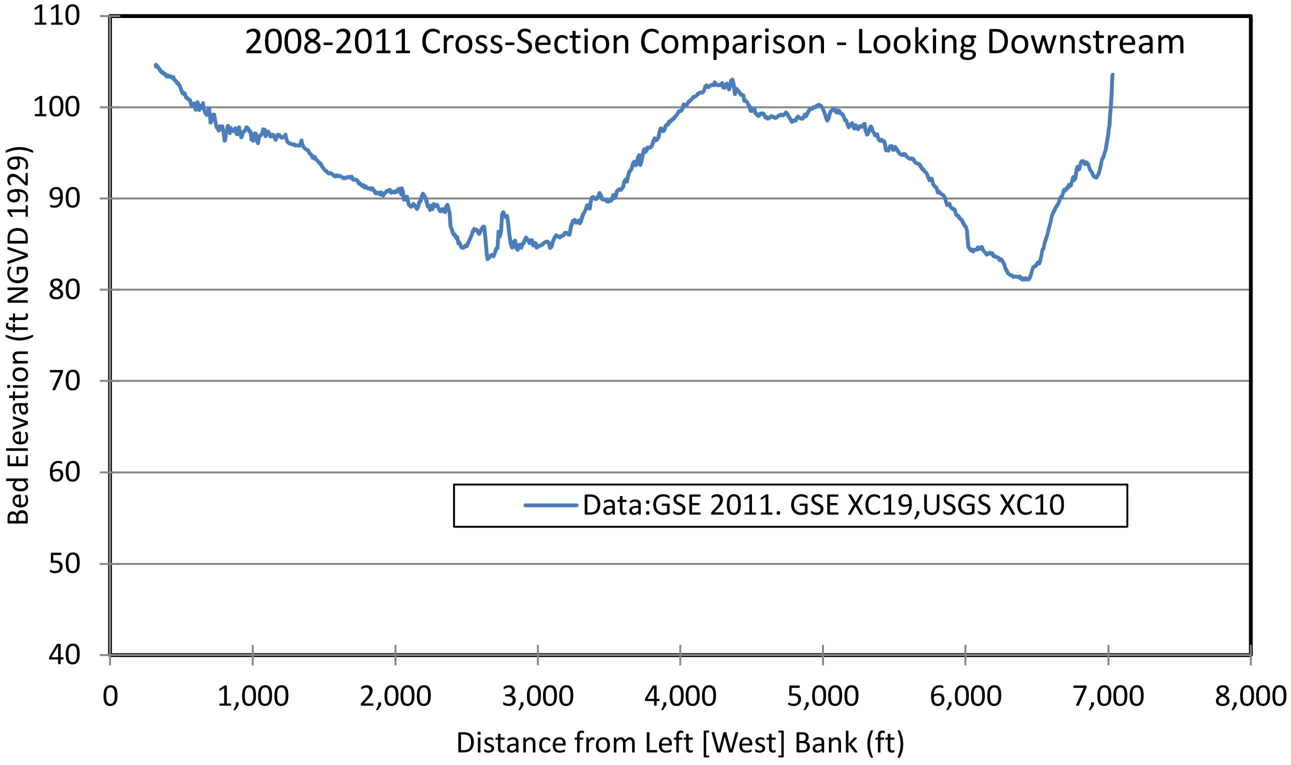

2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC16
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)

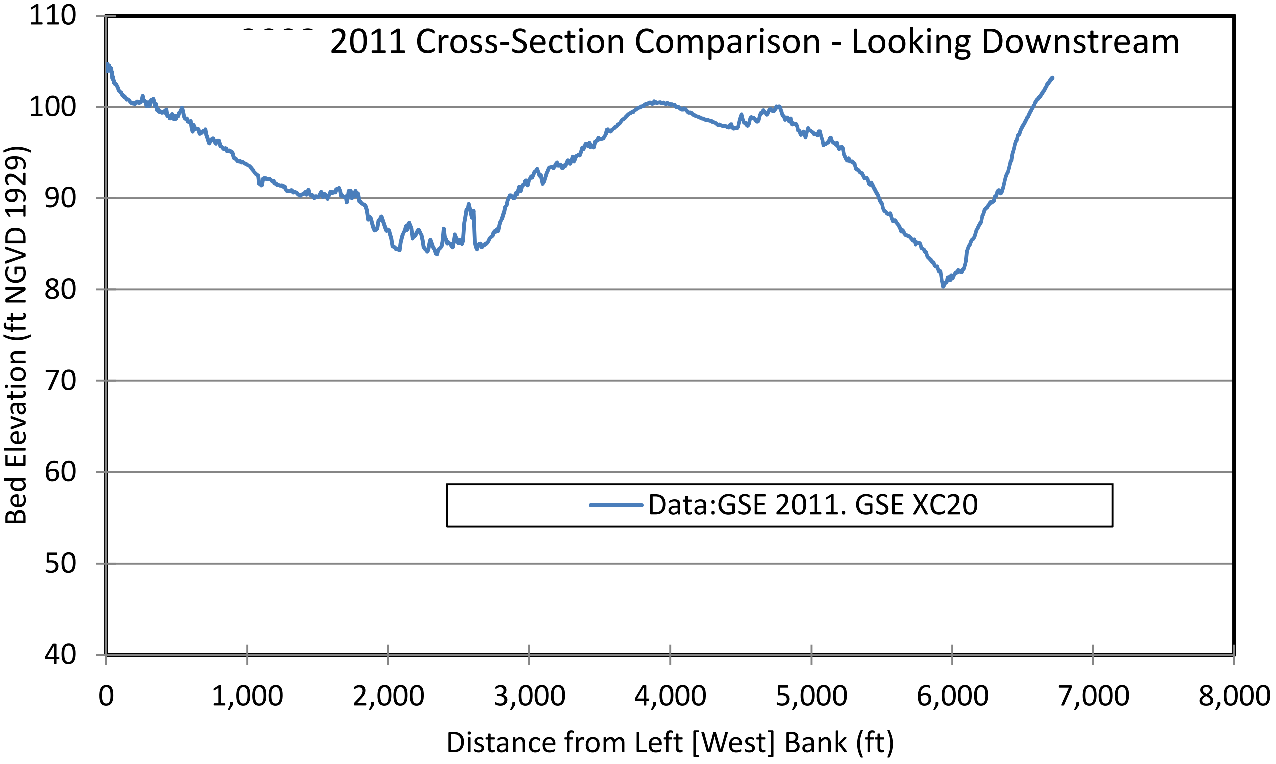


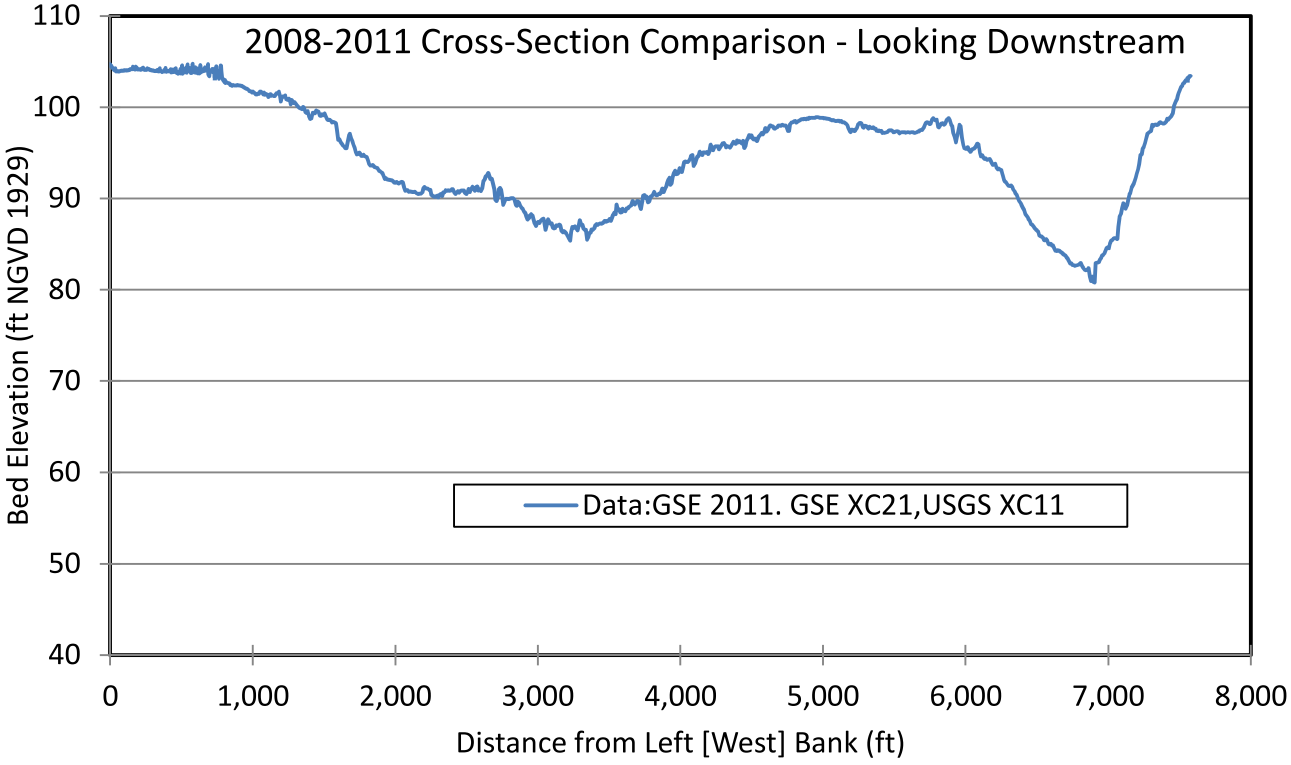
2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC17,USGS XC9

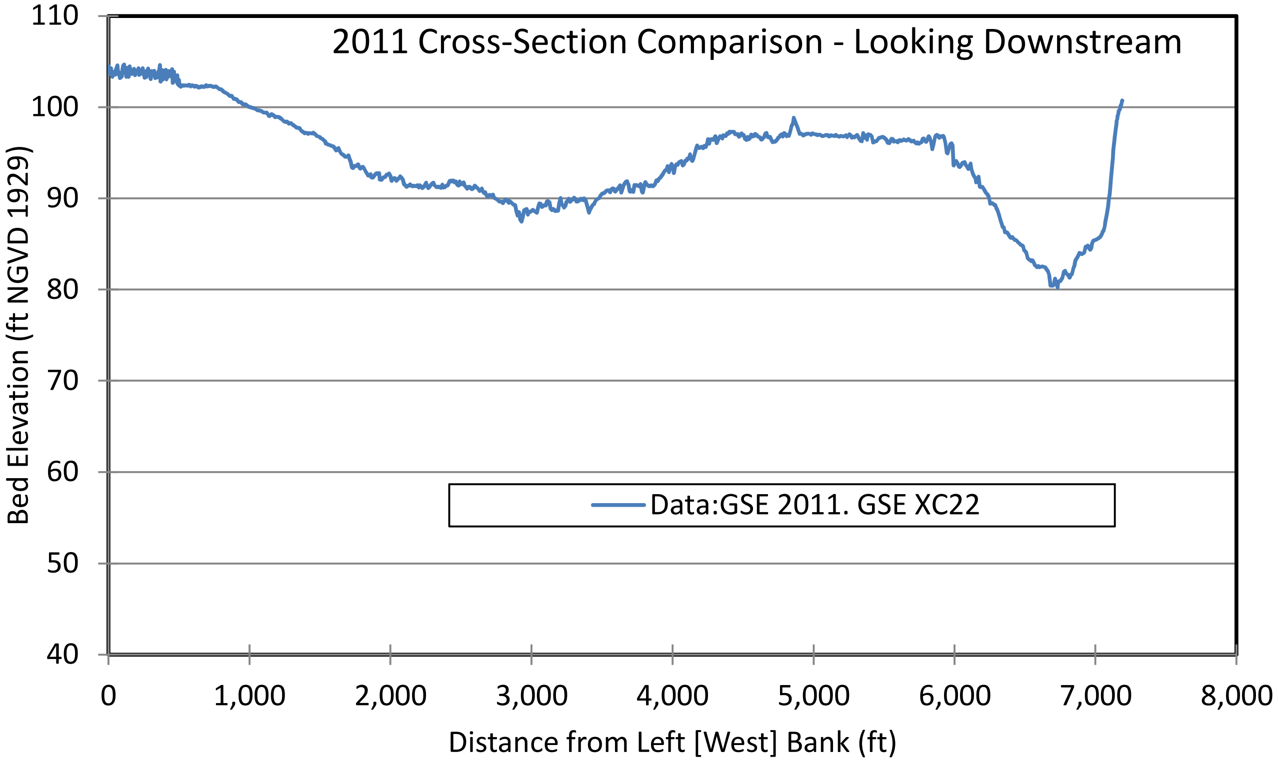


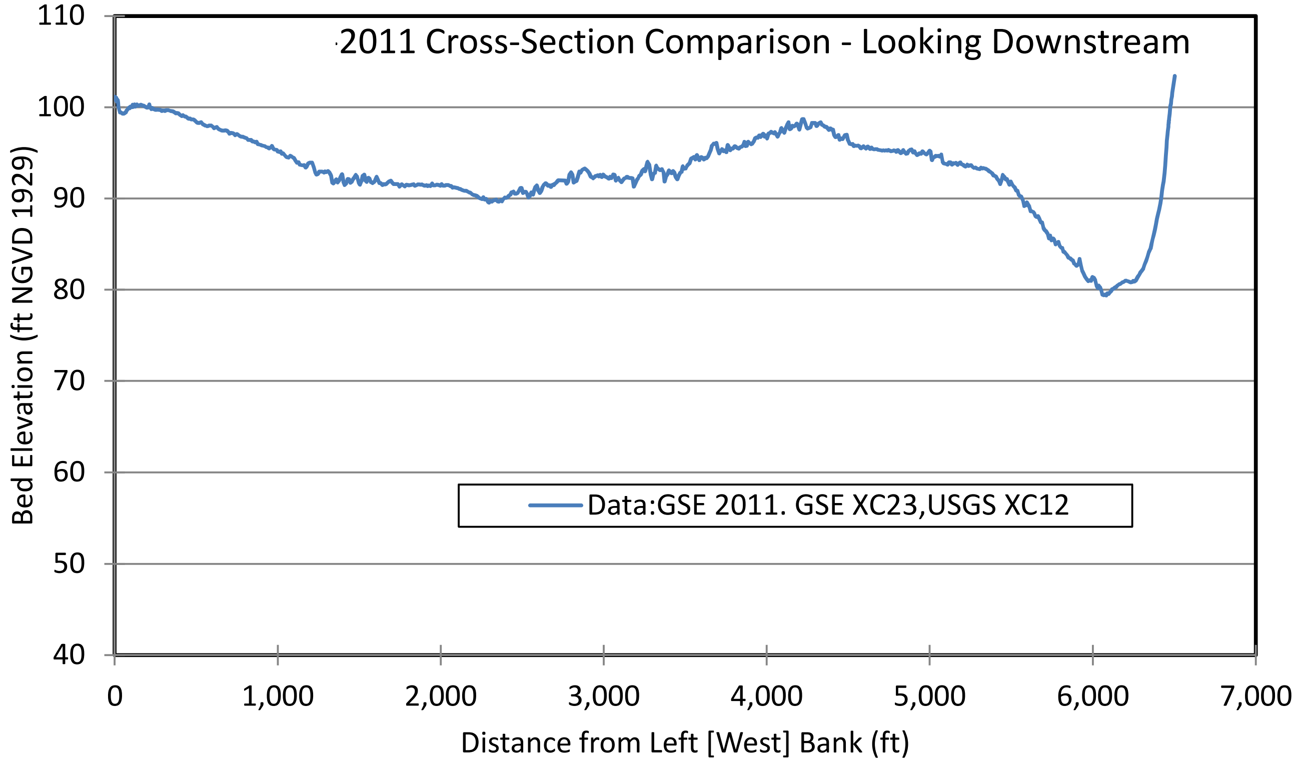
2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC18

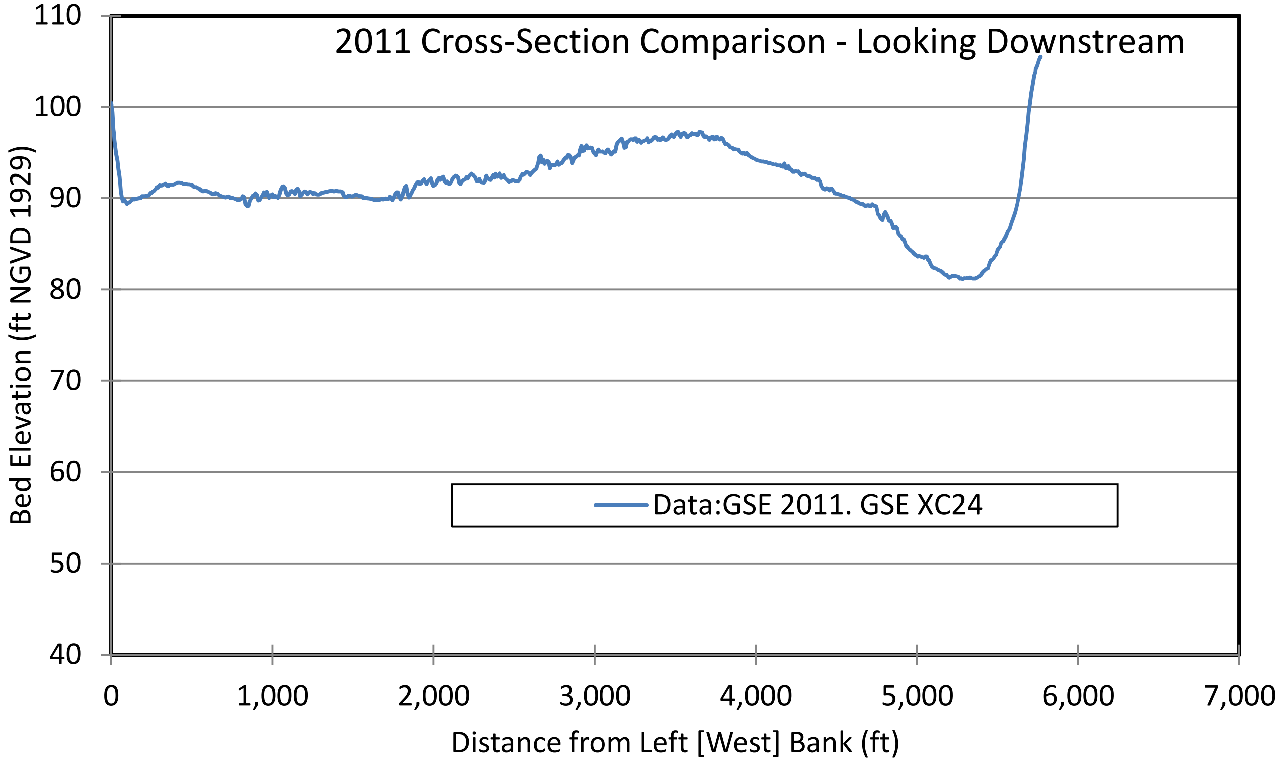

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC19,USGS XC10

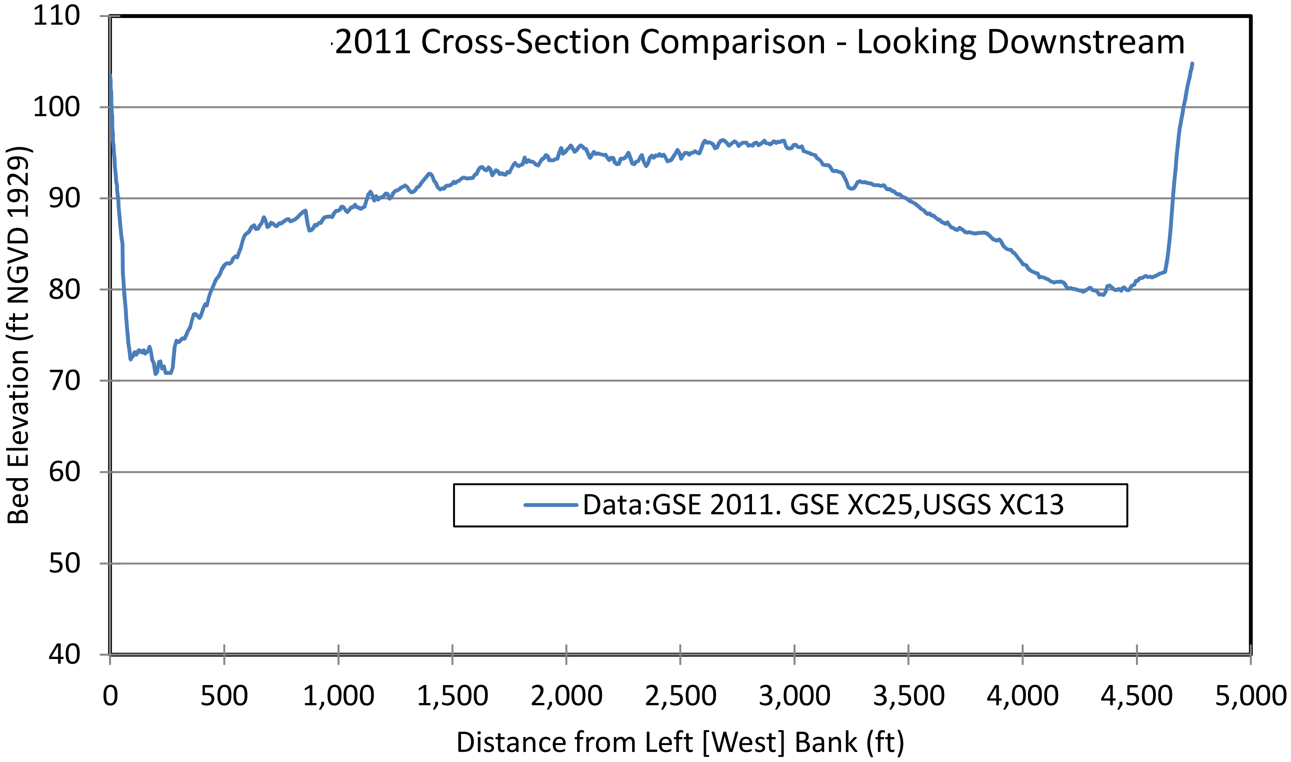

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC20

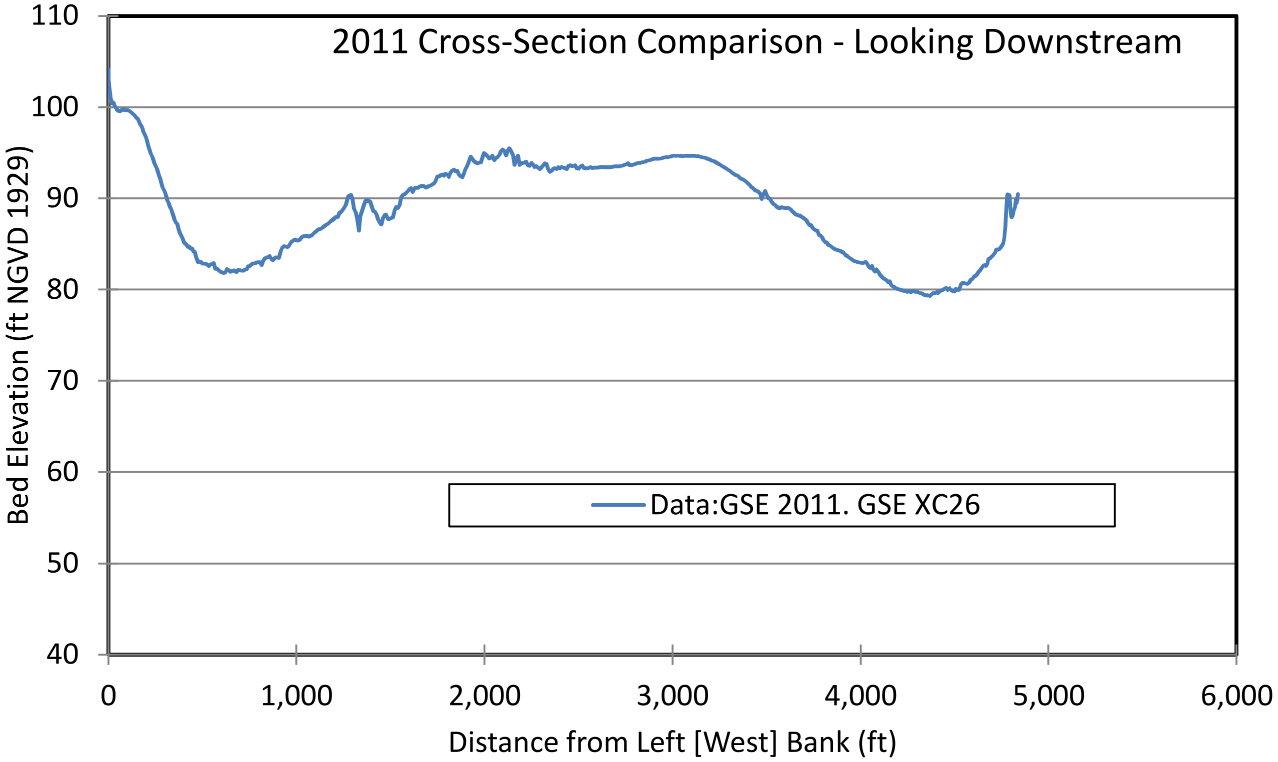

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC21,USGS XC11

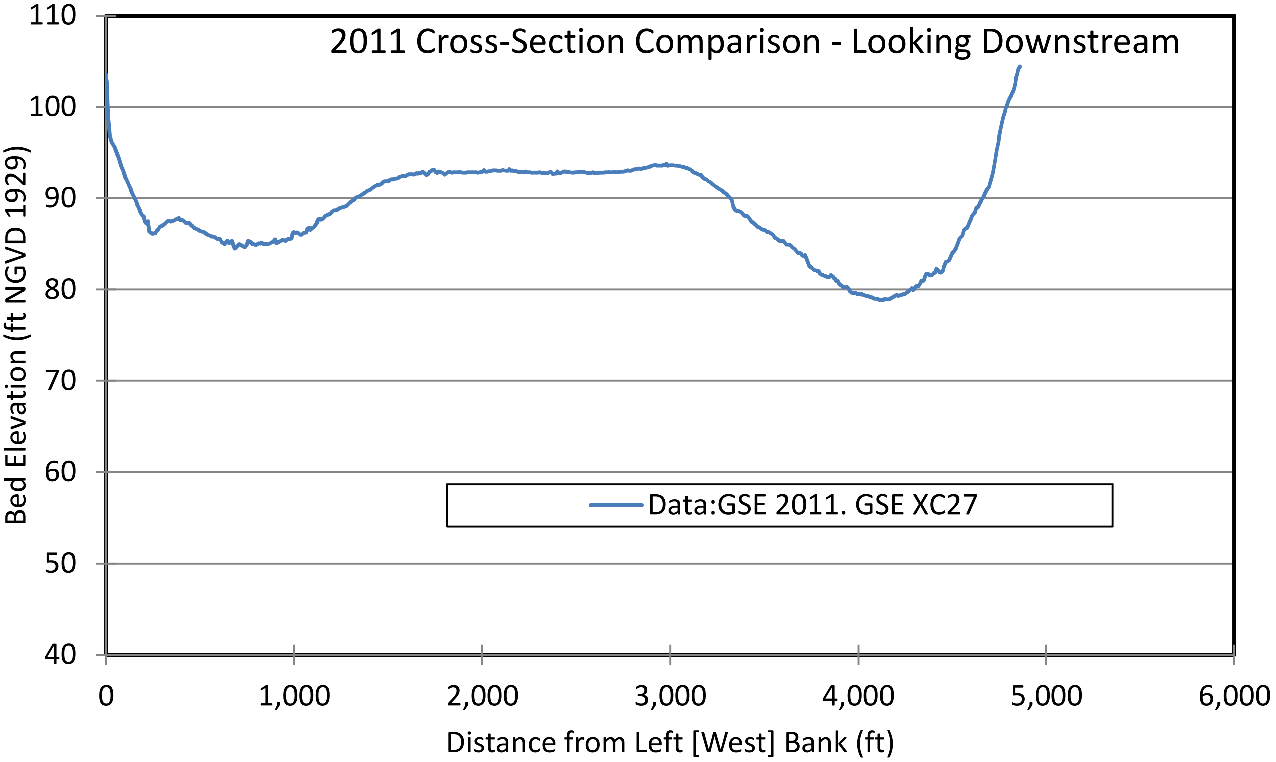

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC22

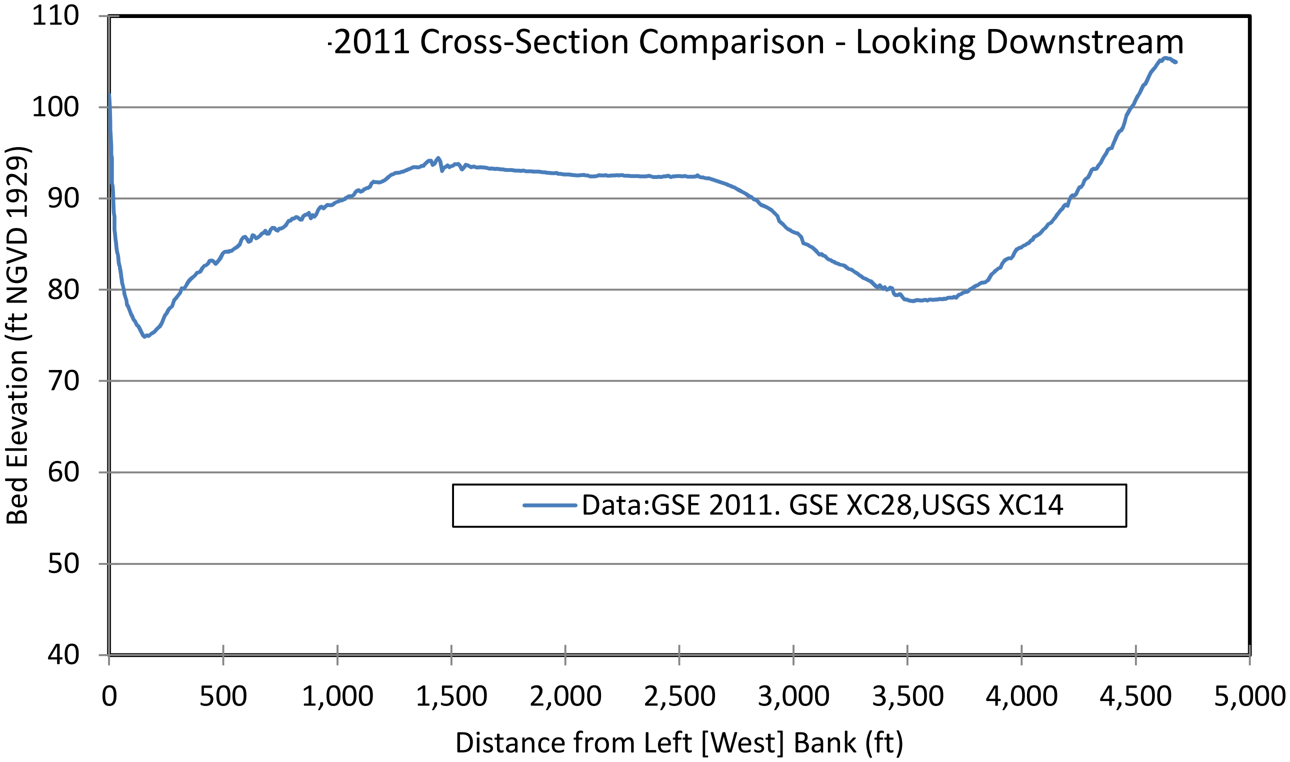

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC23,USGS XC12

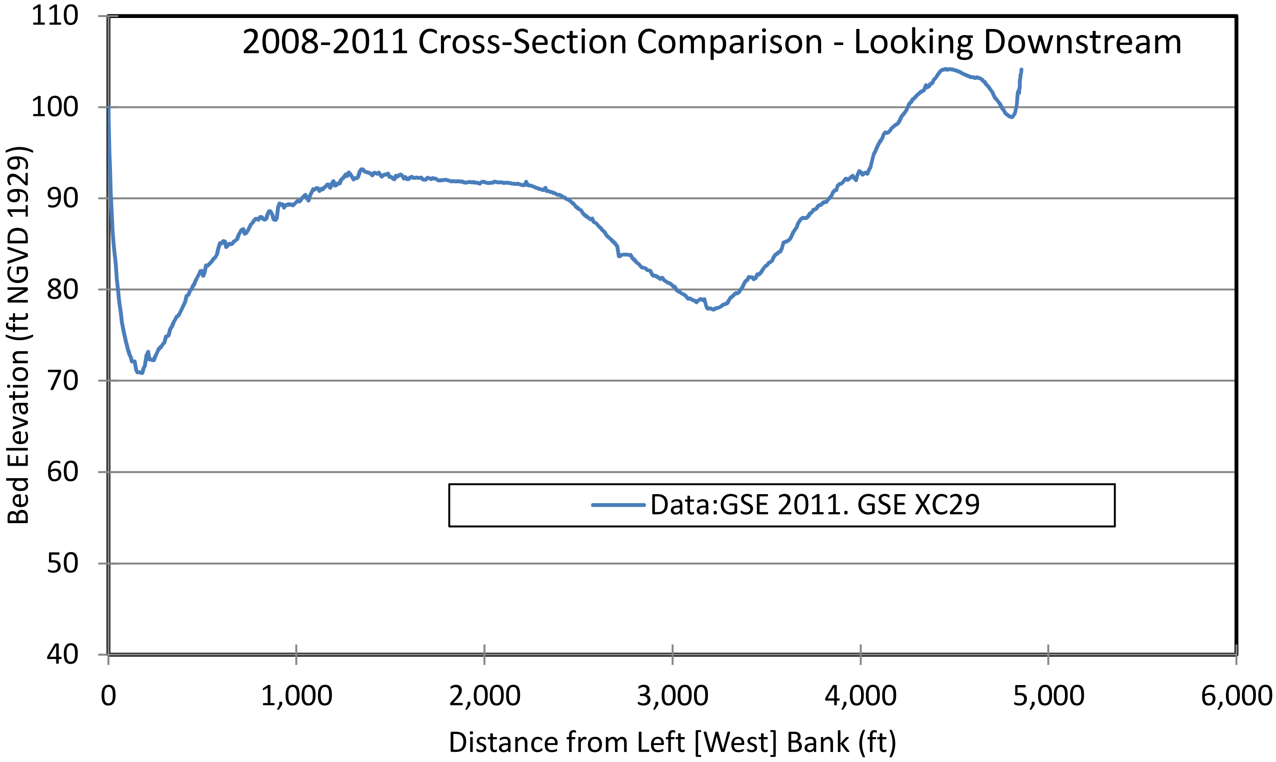

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC24

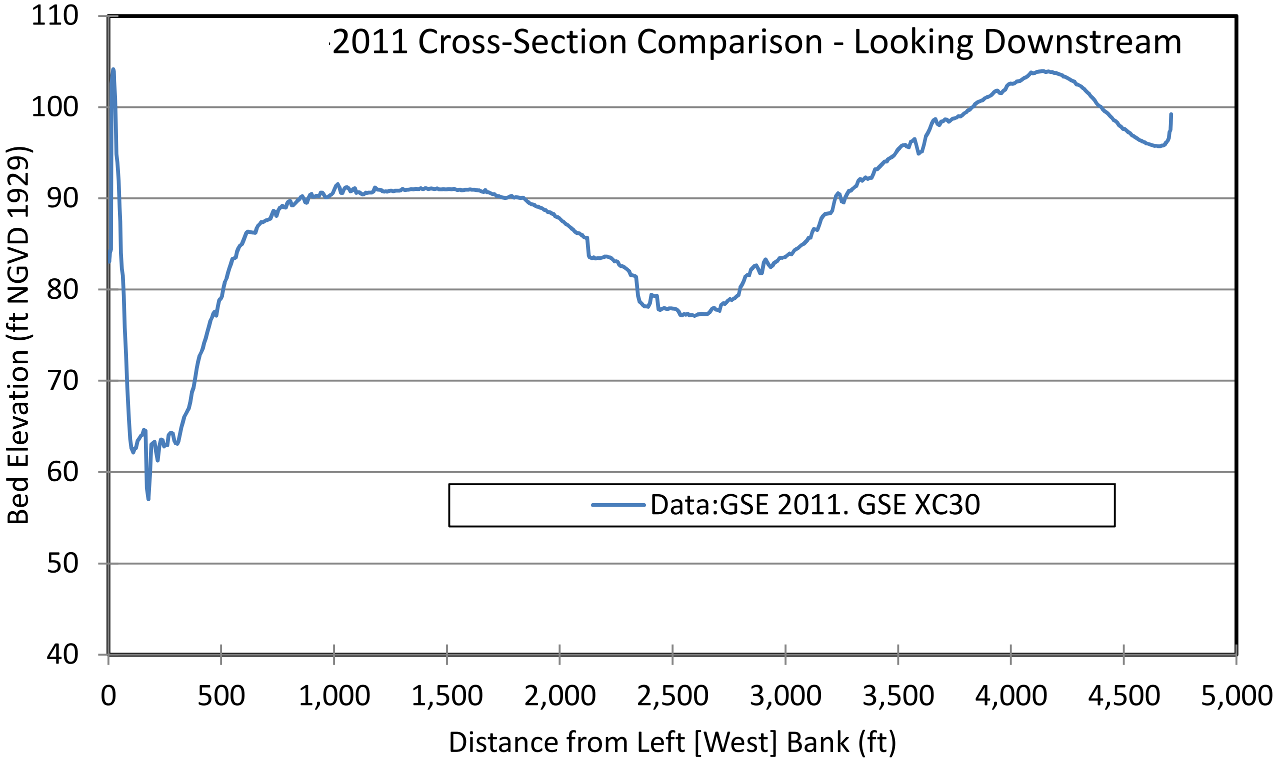

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC25,USGS XC13

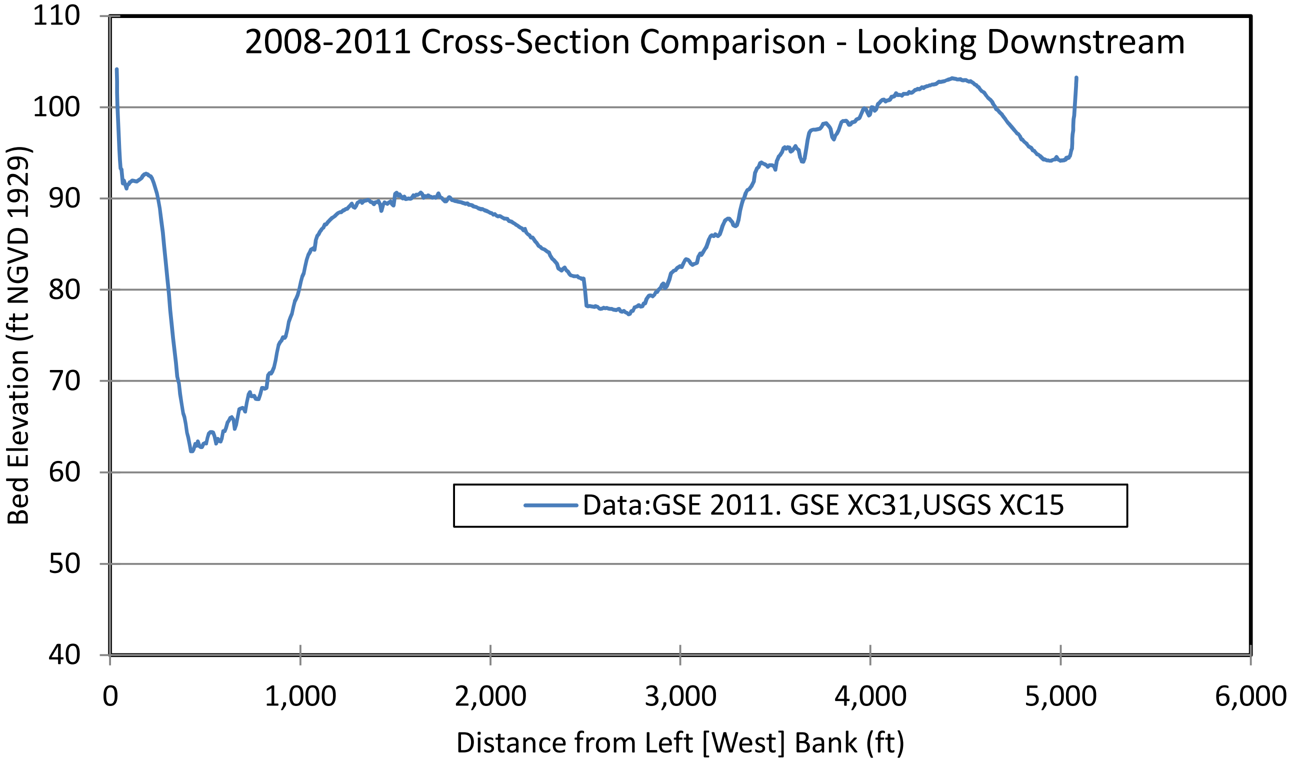

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC26

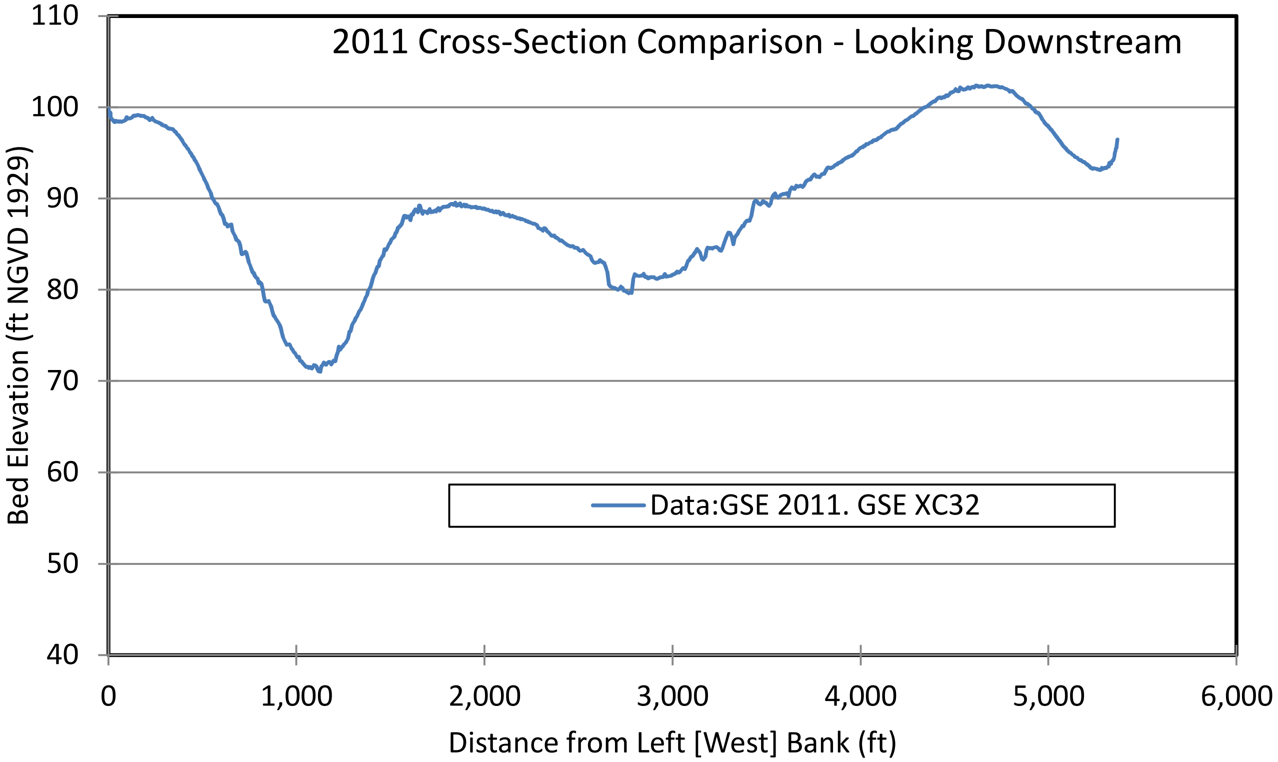

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC27

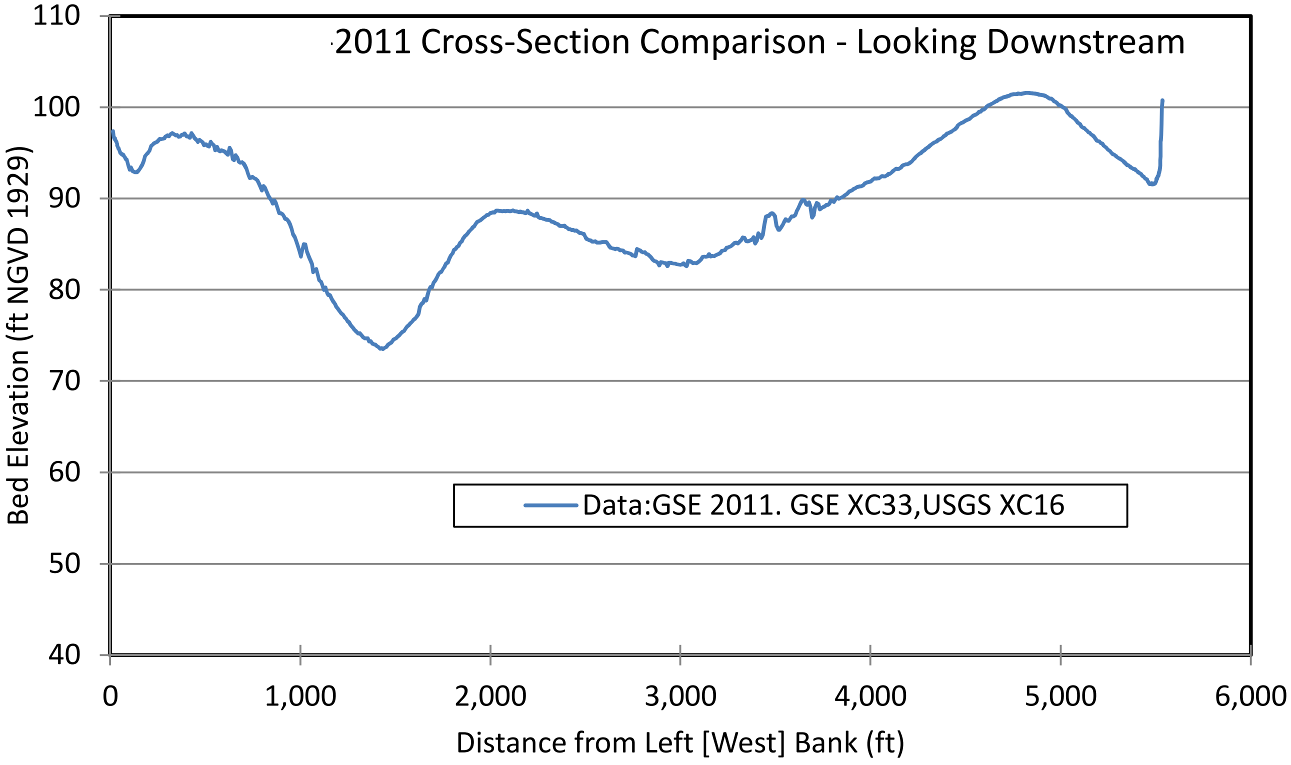

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC28,USGS XC14

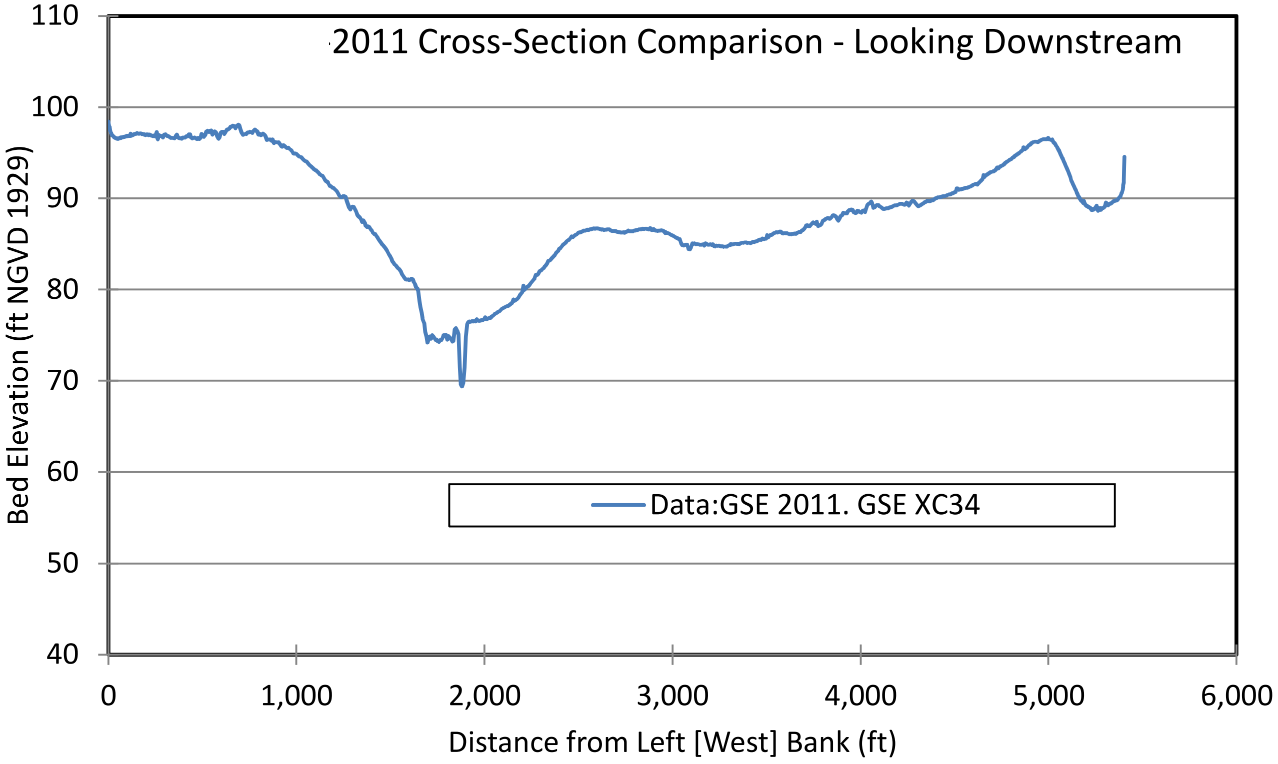

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC29

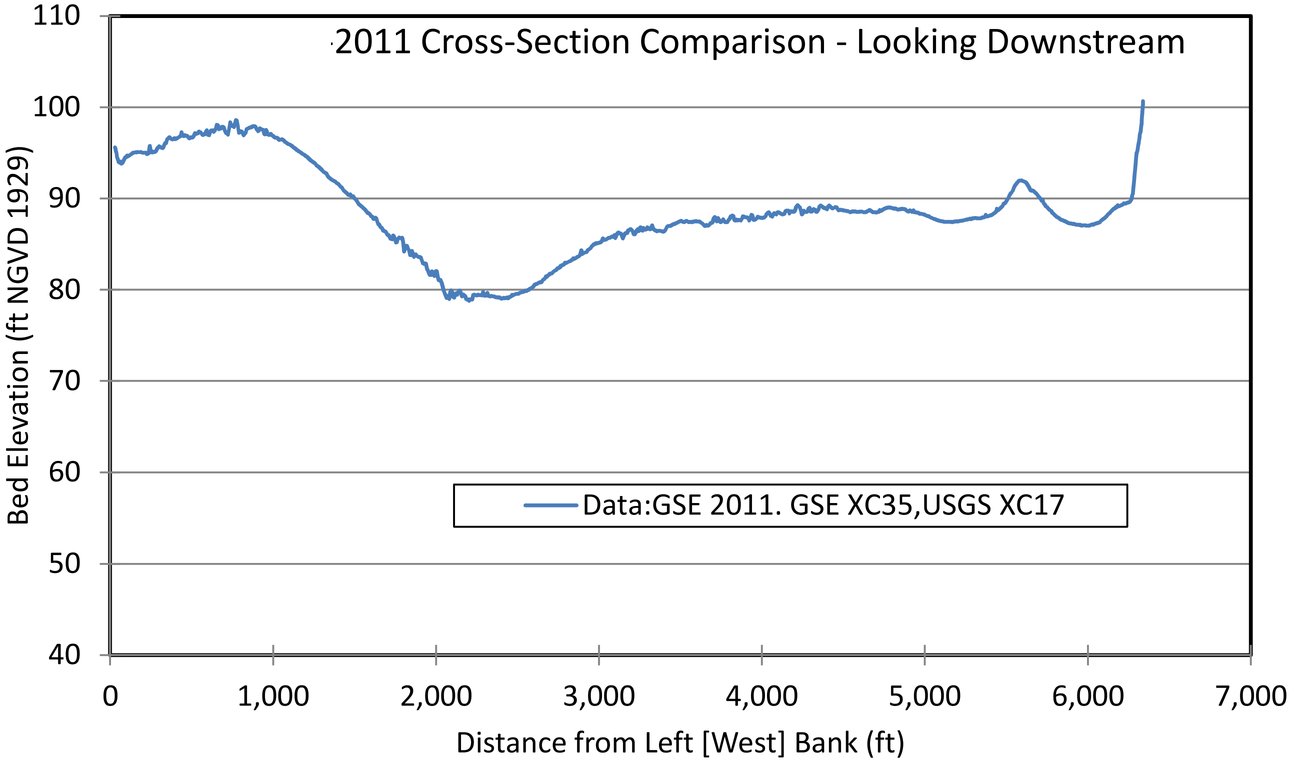

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC30

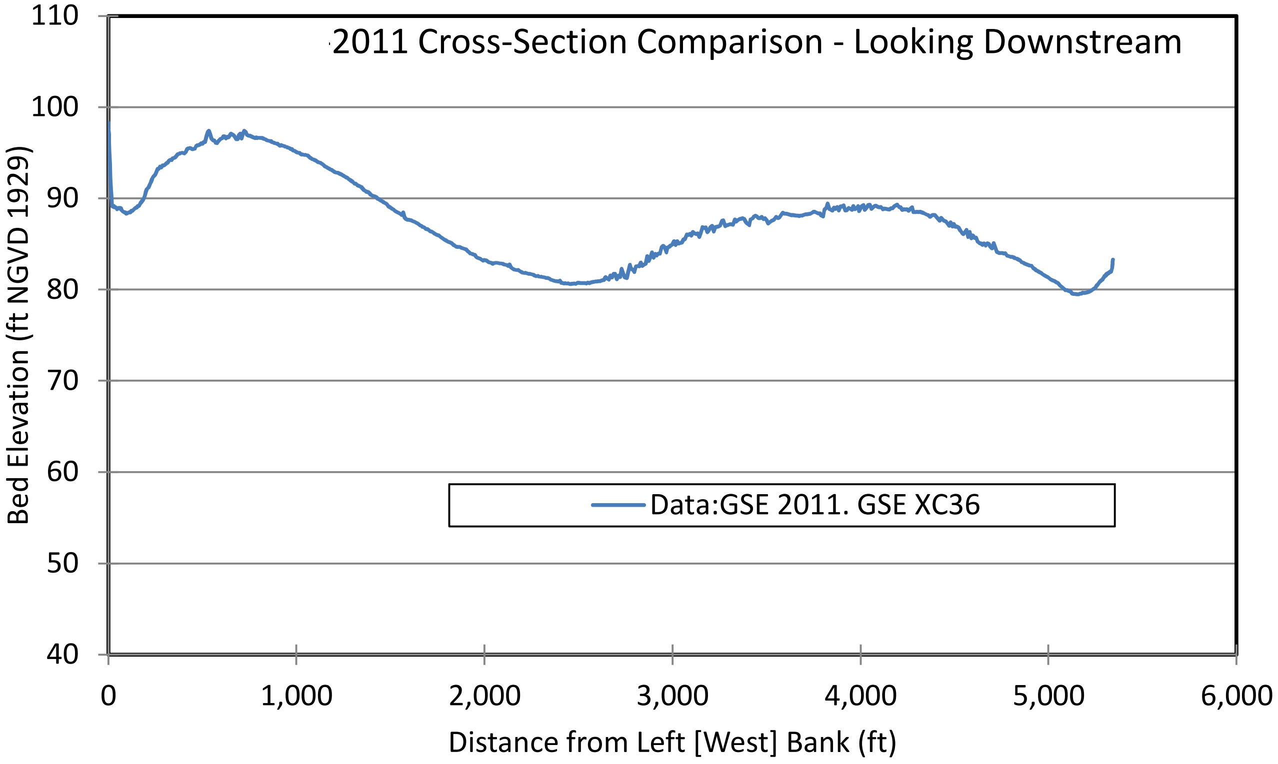

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC31,USGS XC15

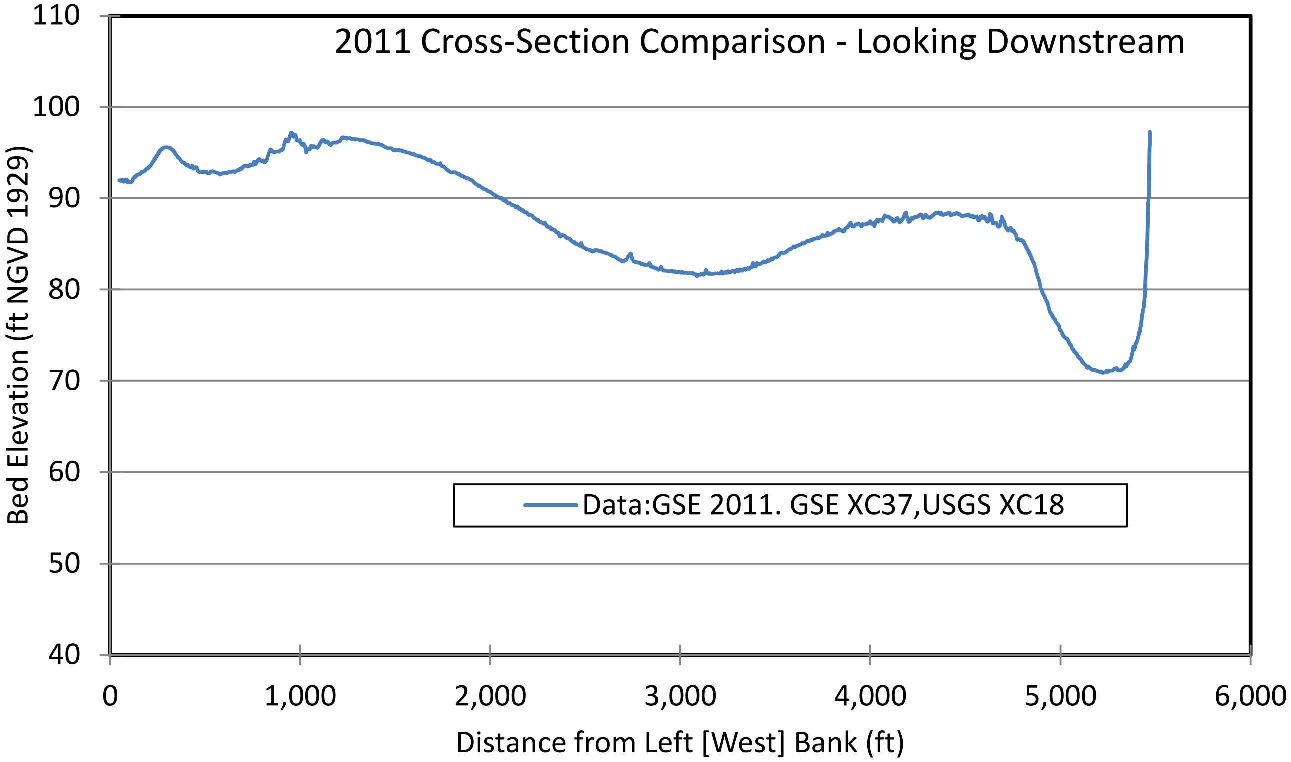

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC32

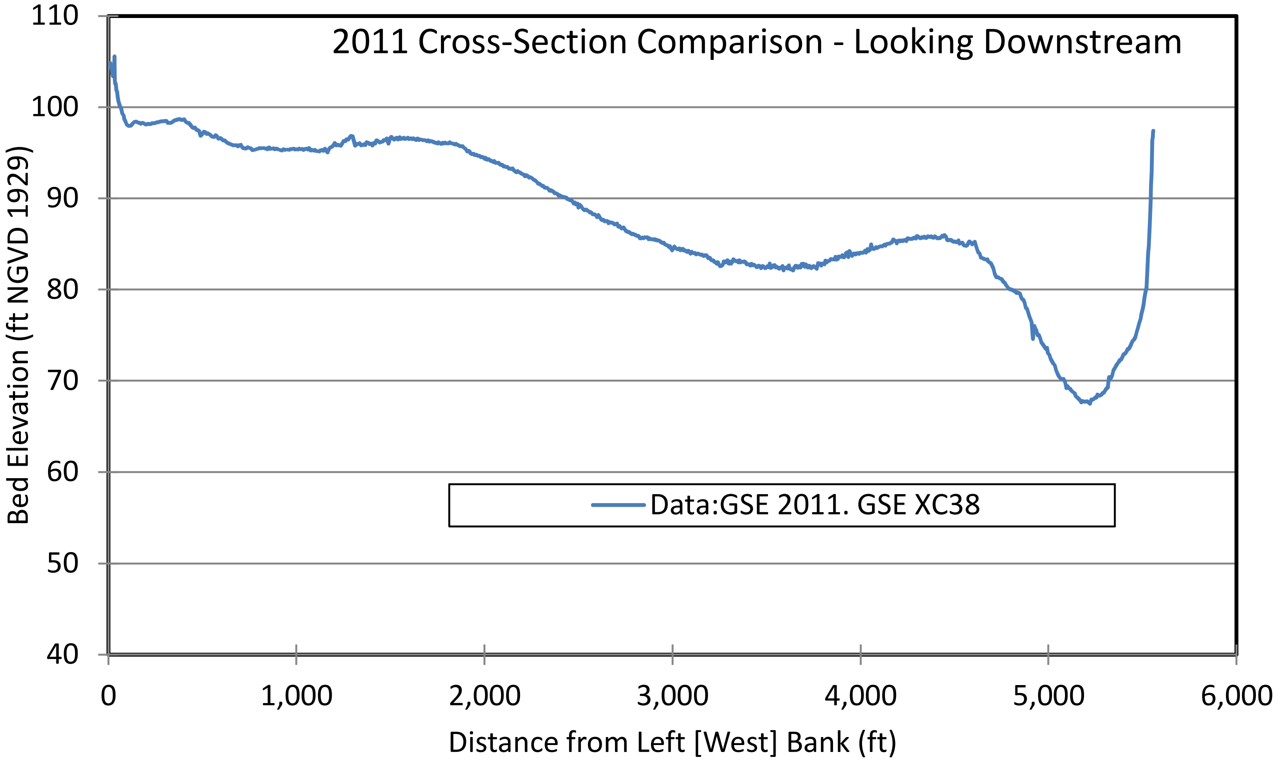

2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC33,USGS XC16
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)

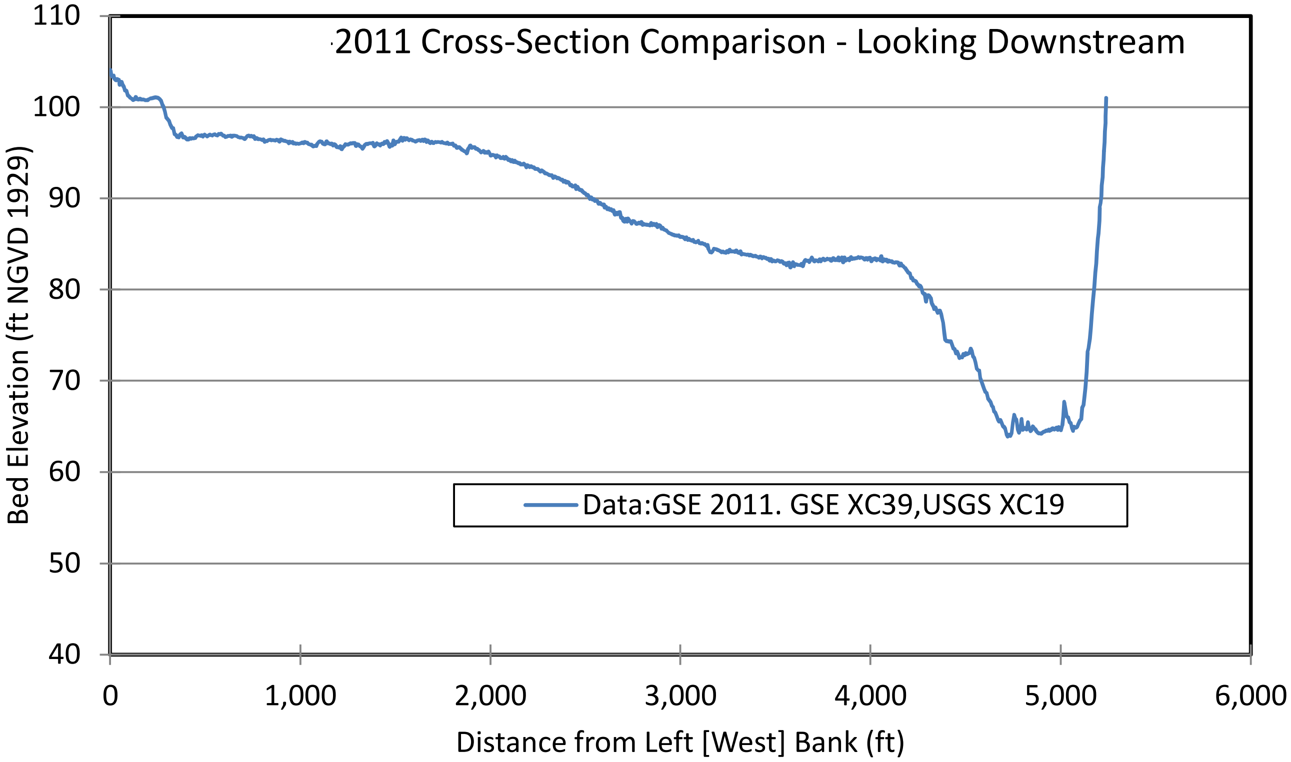

2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC34
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)

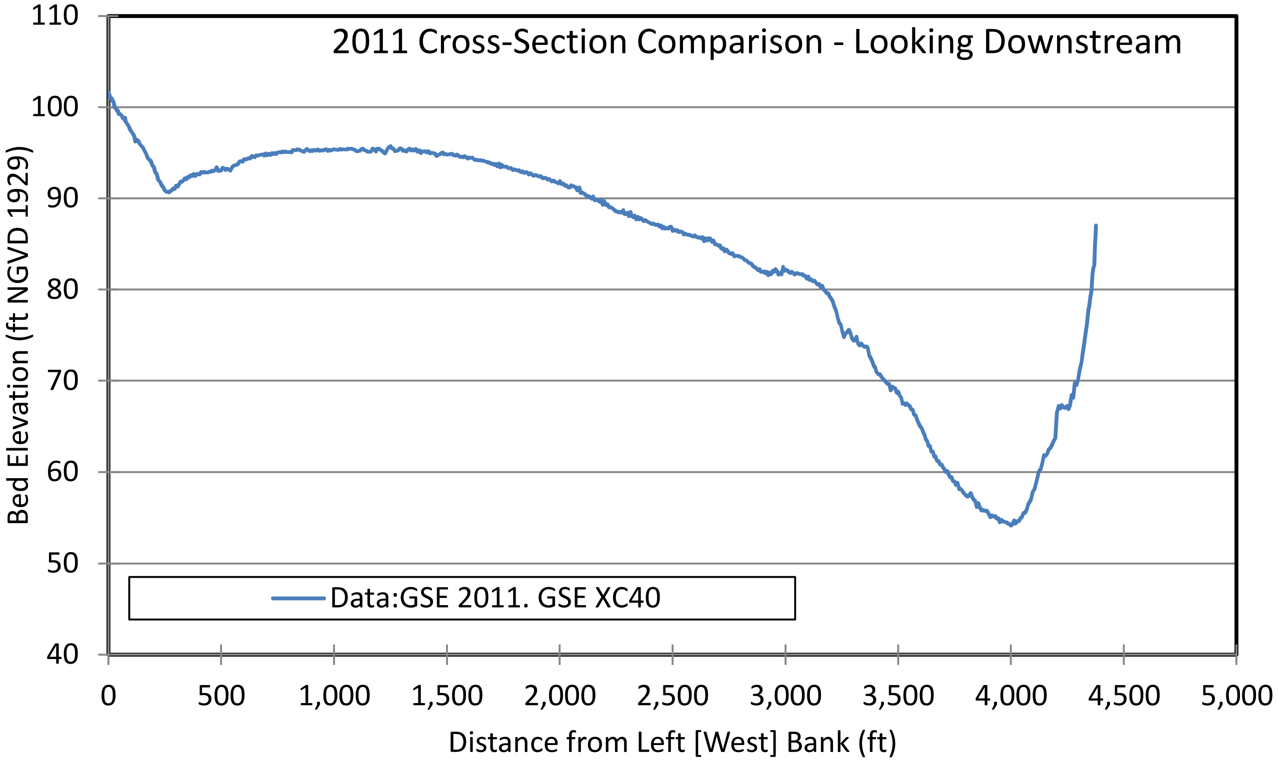

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC35,USGS XC17
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)

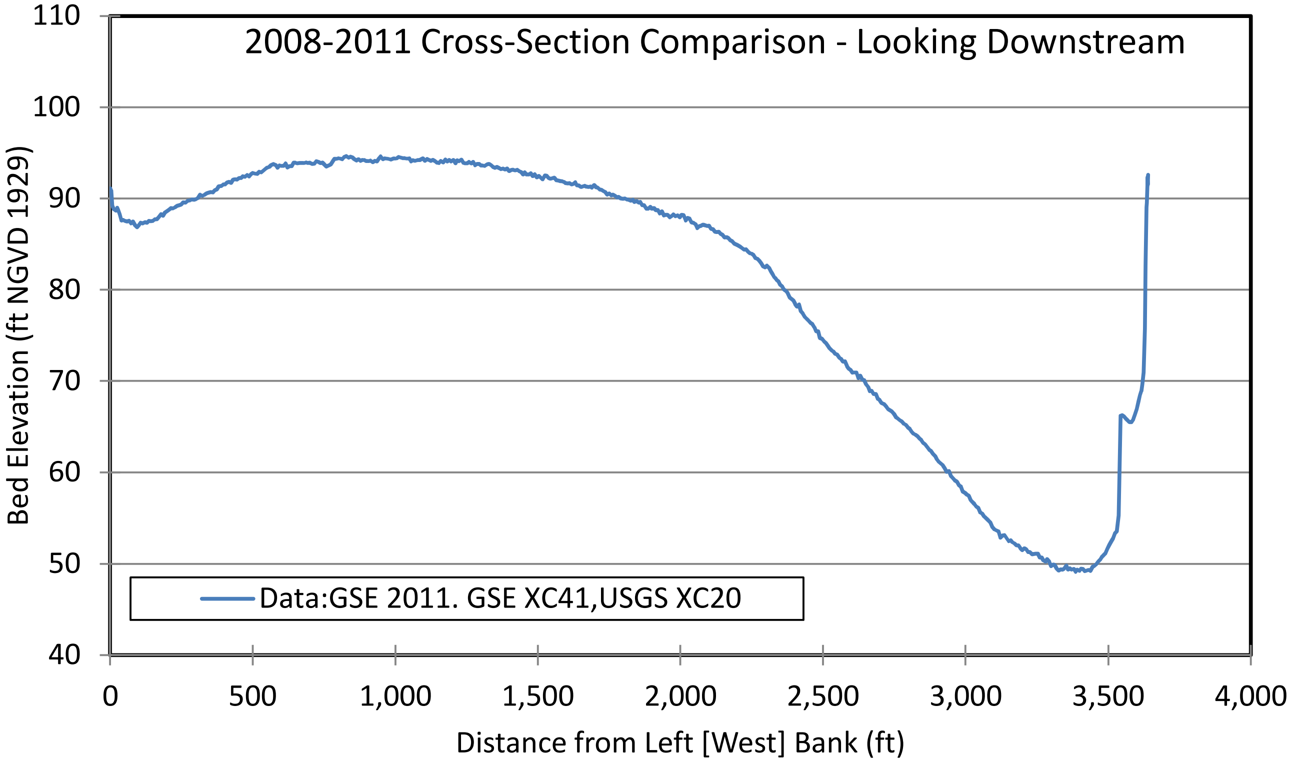

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC36
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)

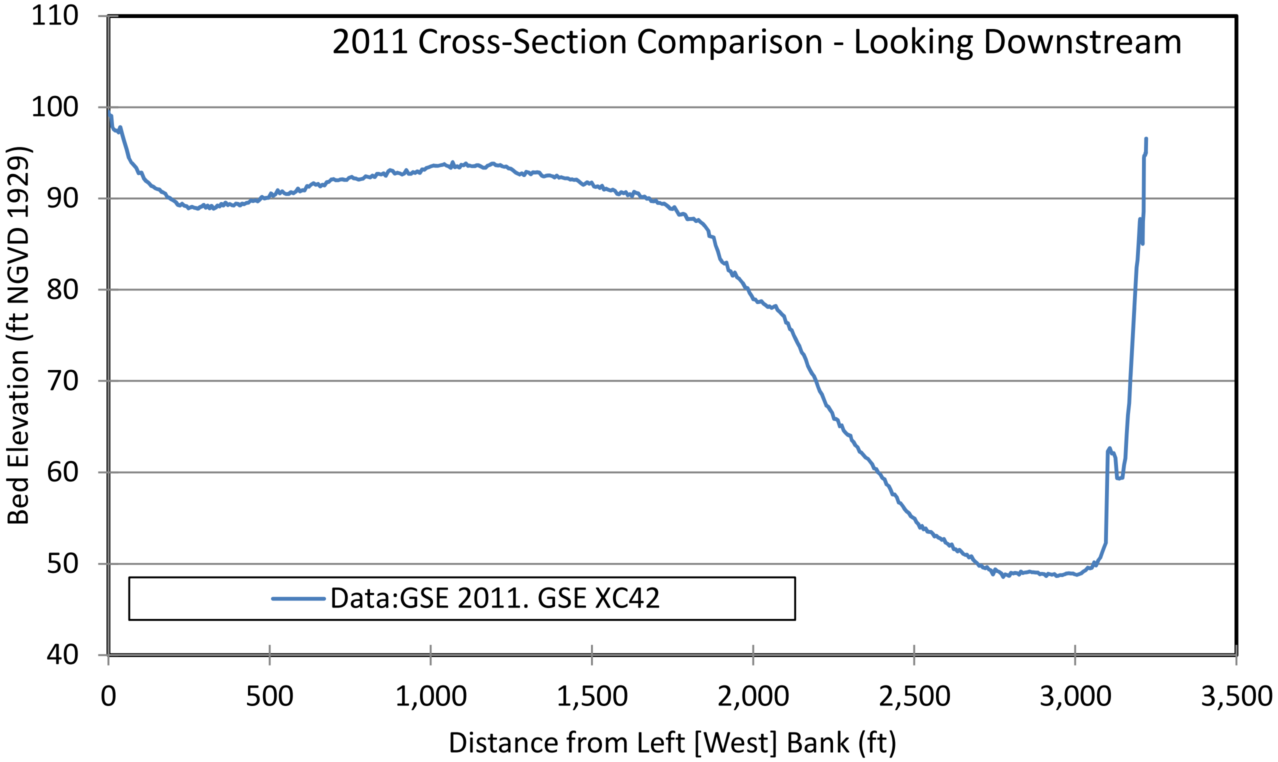

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC37,USGS XC18

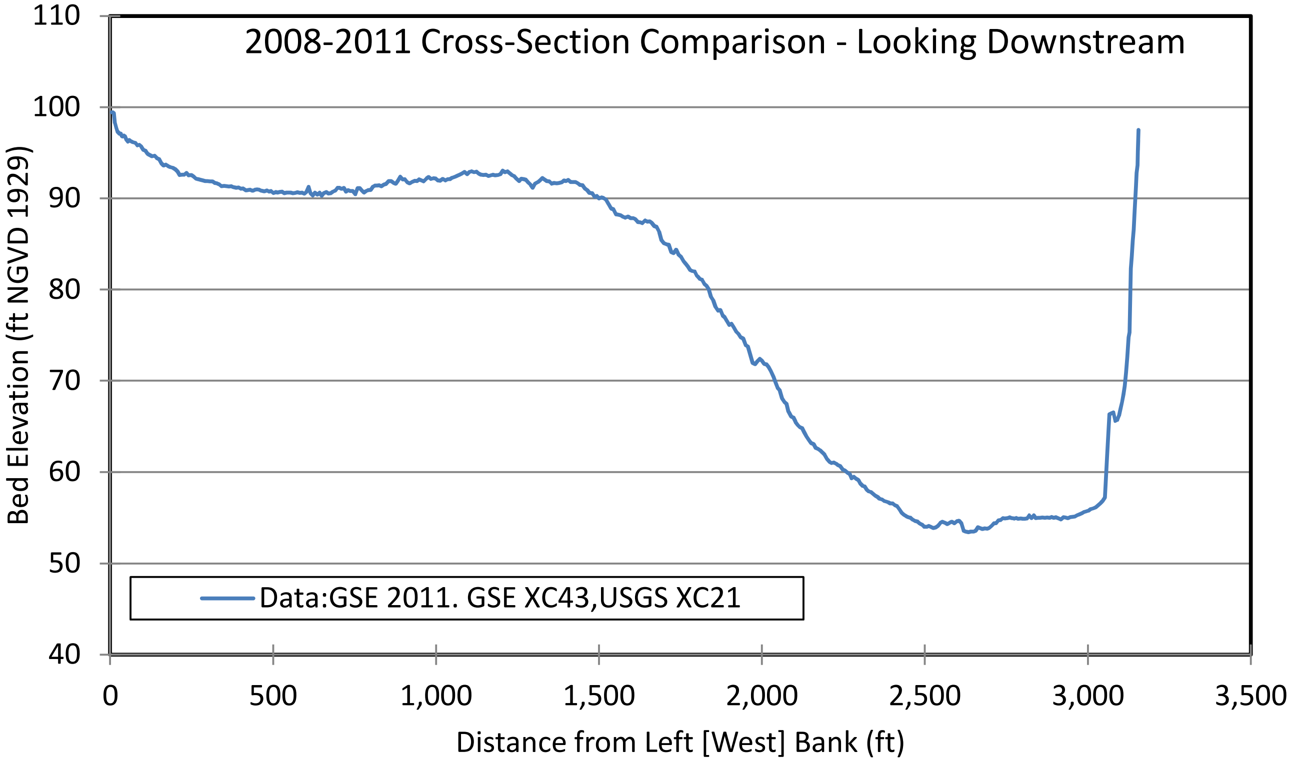

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC38

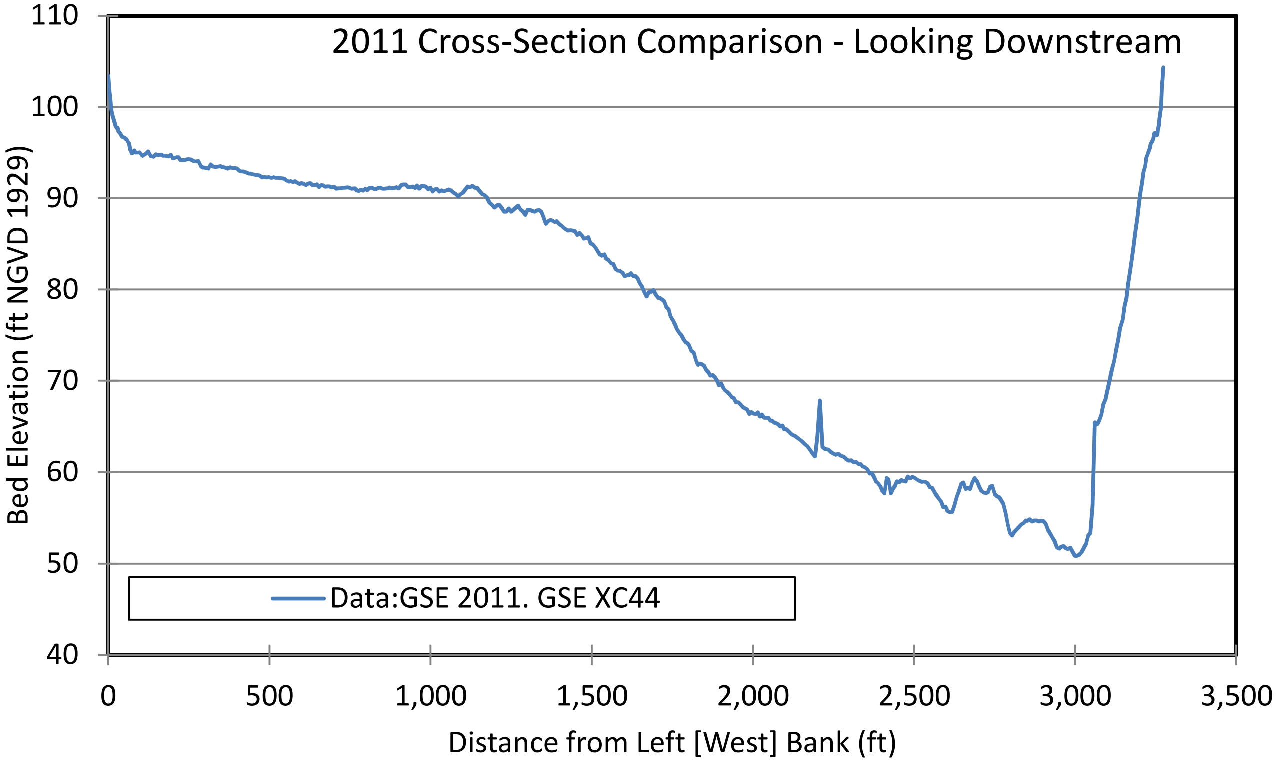

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC39,USGS XC19

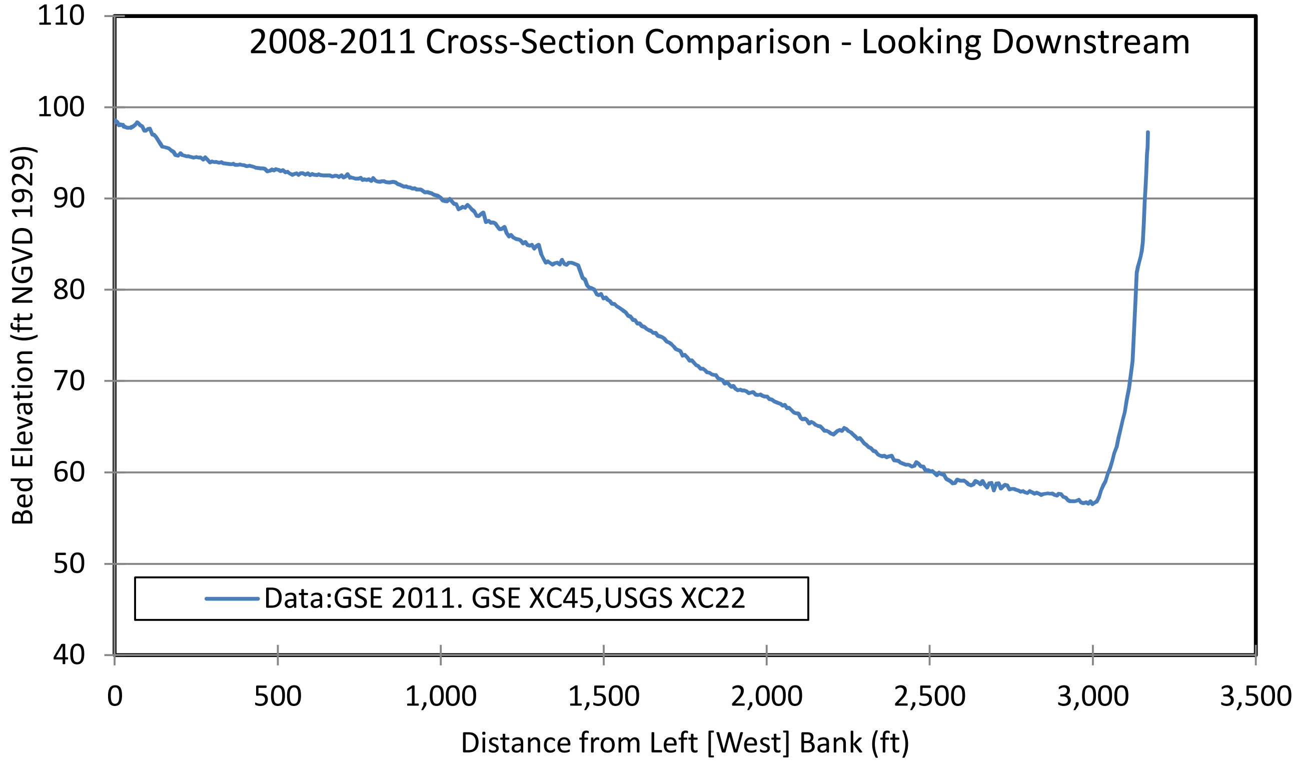

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC40

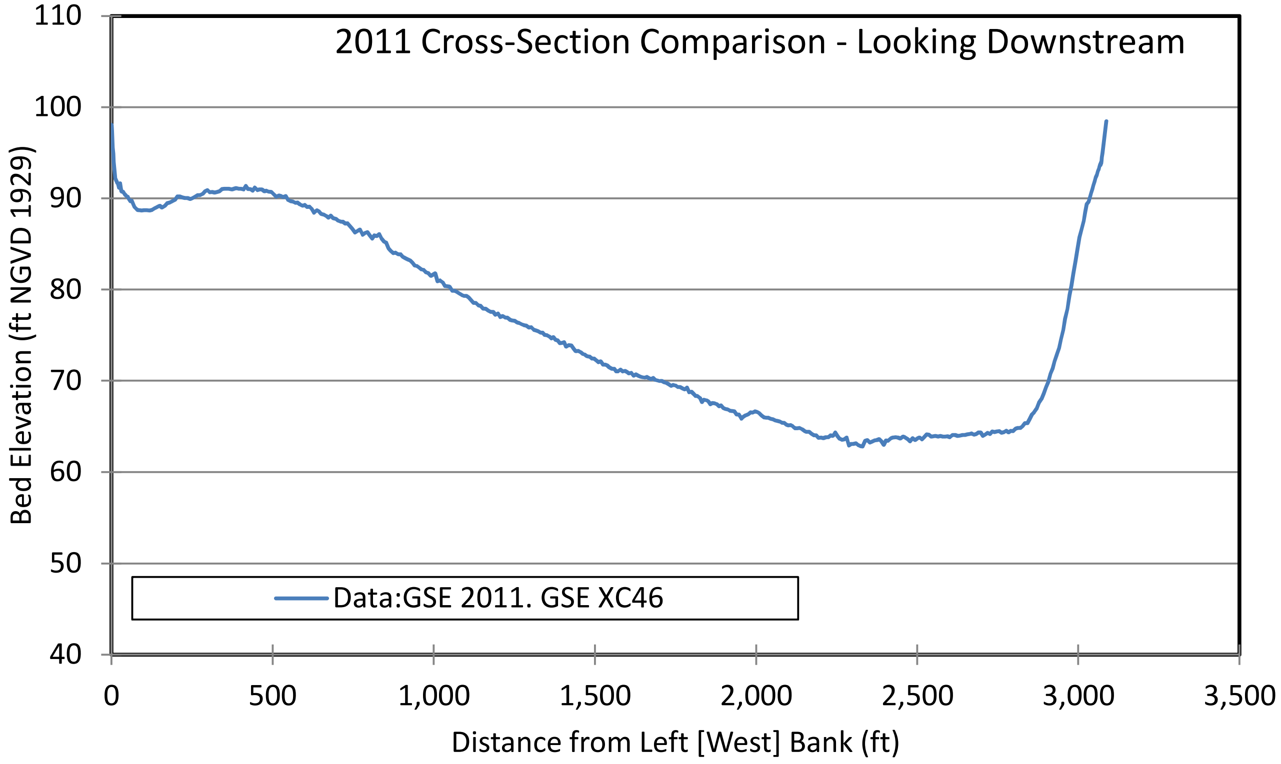

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC41,USGS XC20
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
Distance from Left [West] Bank (ft)

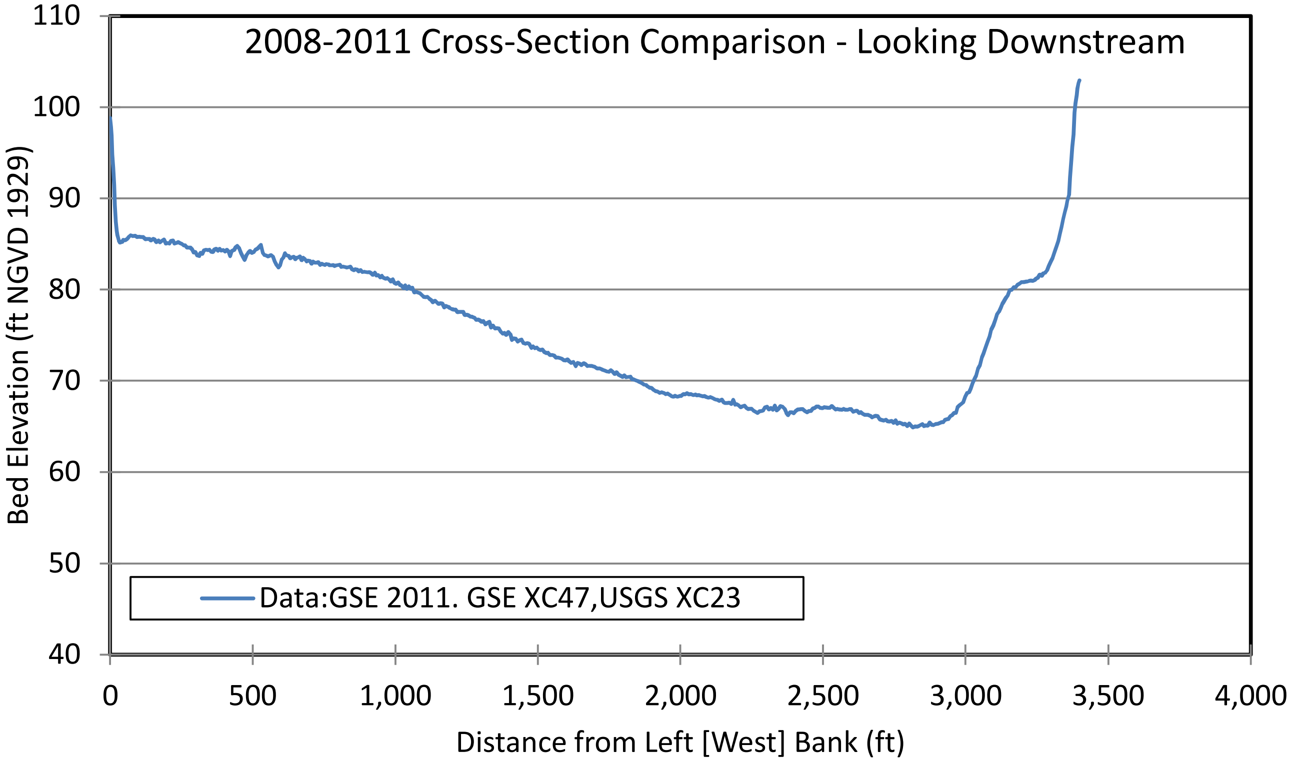

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC42
0
500
1,000
1,500
2,000
2,500
3,000
3,500
Distance from Left [West] Bank (ft)

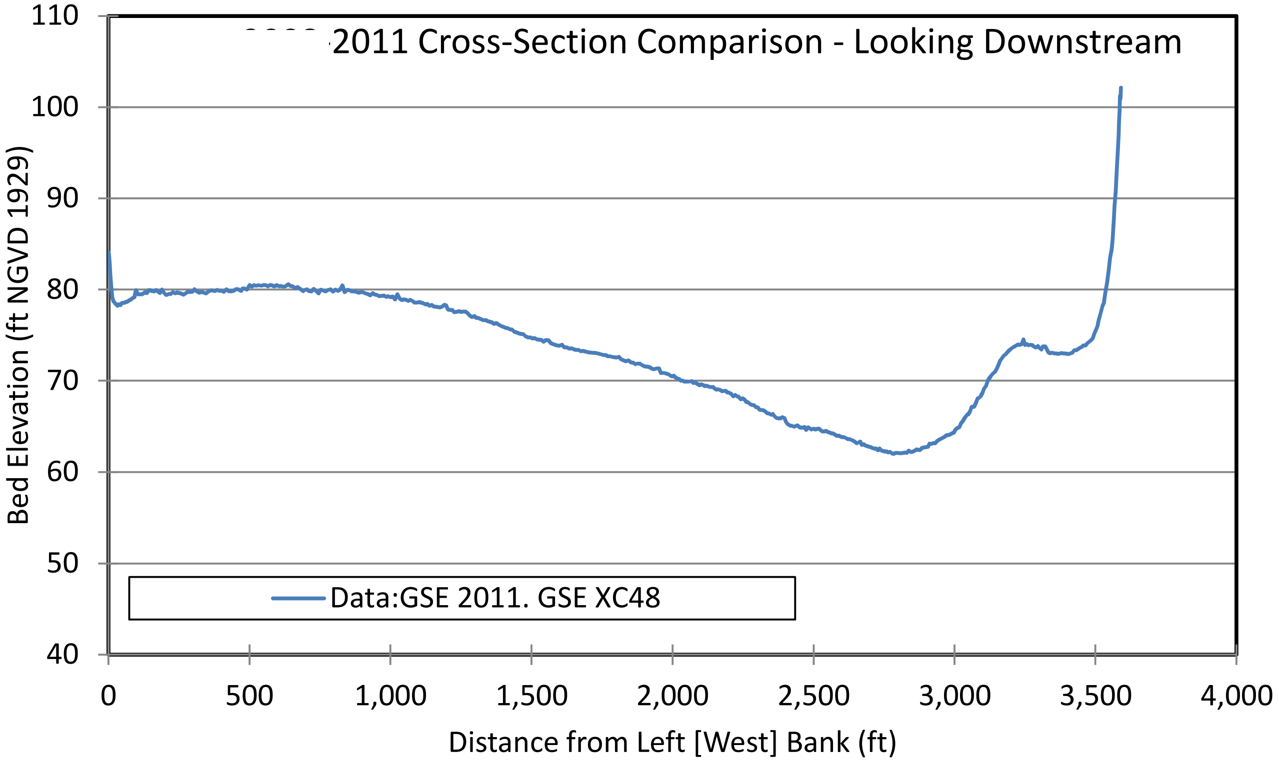

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
Data:GSE 2011. GSE XC43,USGS XC21

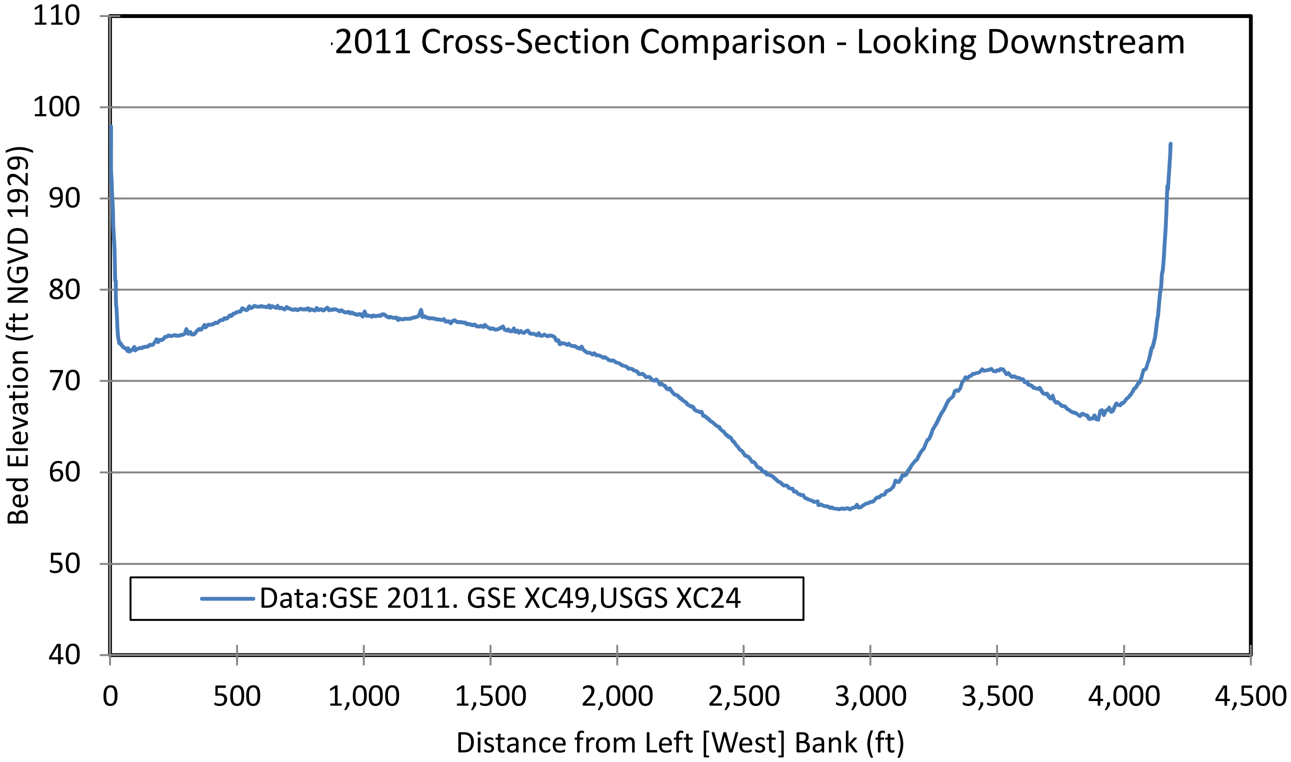

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
Data:GSE 2011. GSE XC44


2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC45,USGS XC22

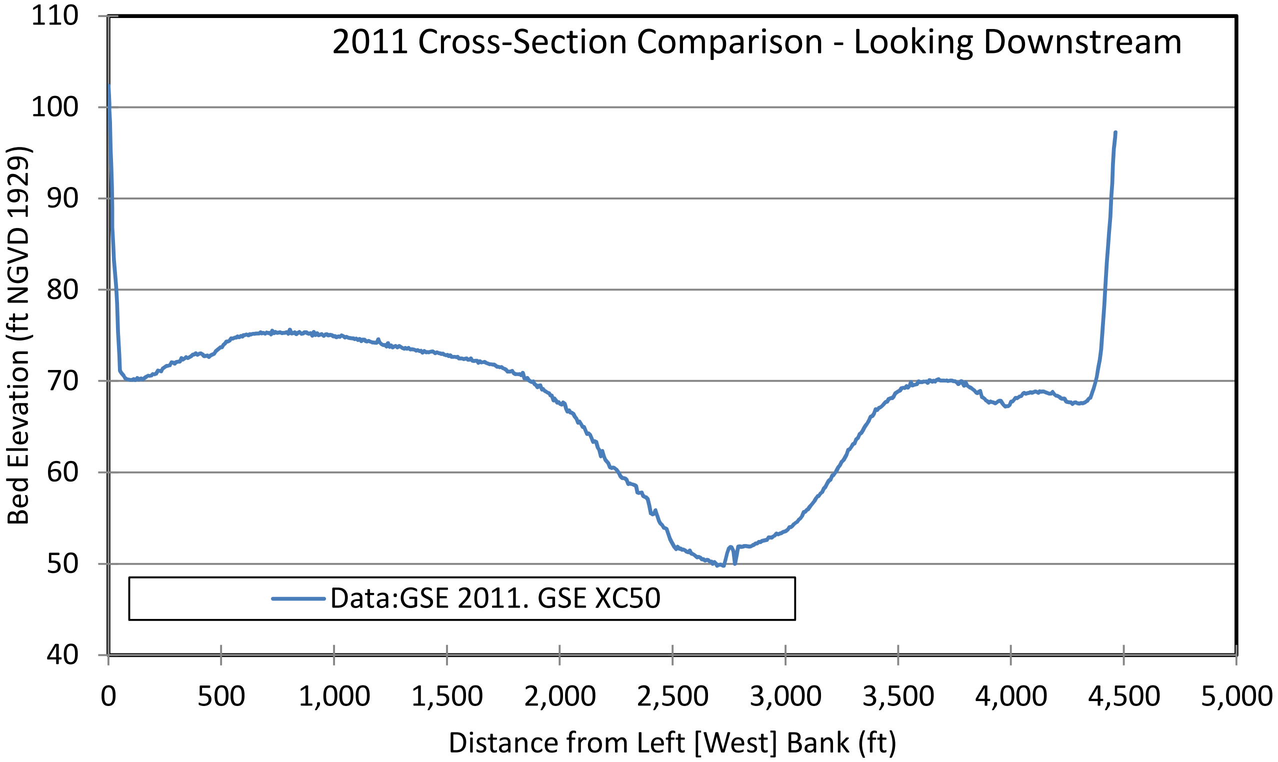

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC46


2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC47,USGS XC23

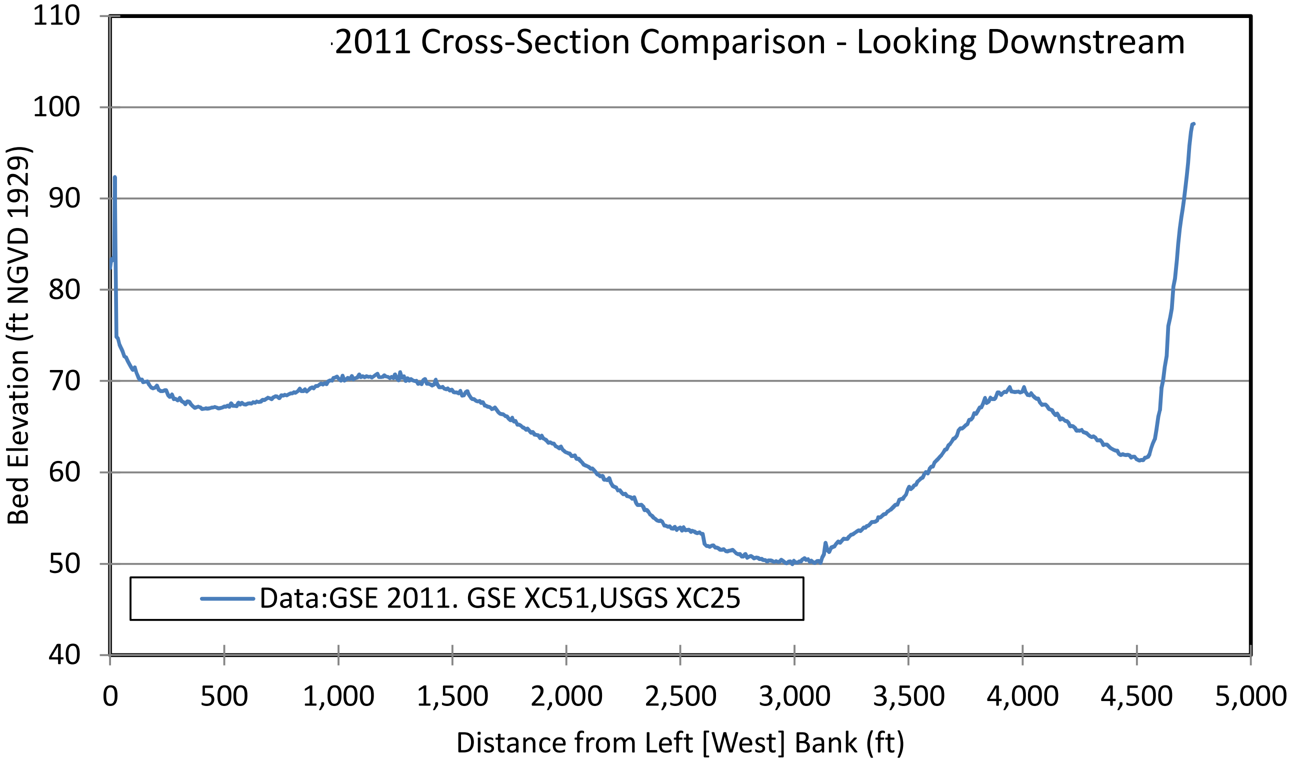

-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC48

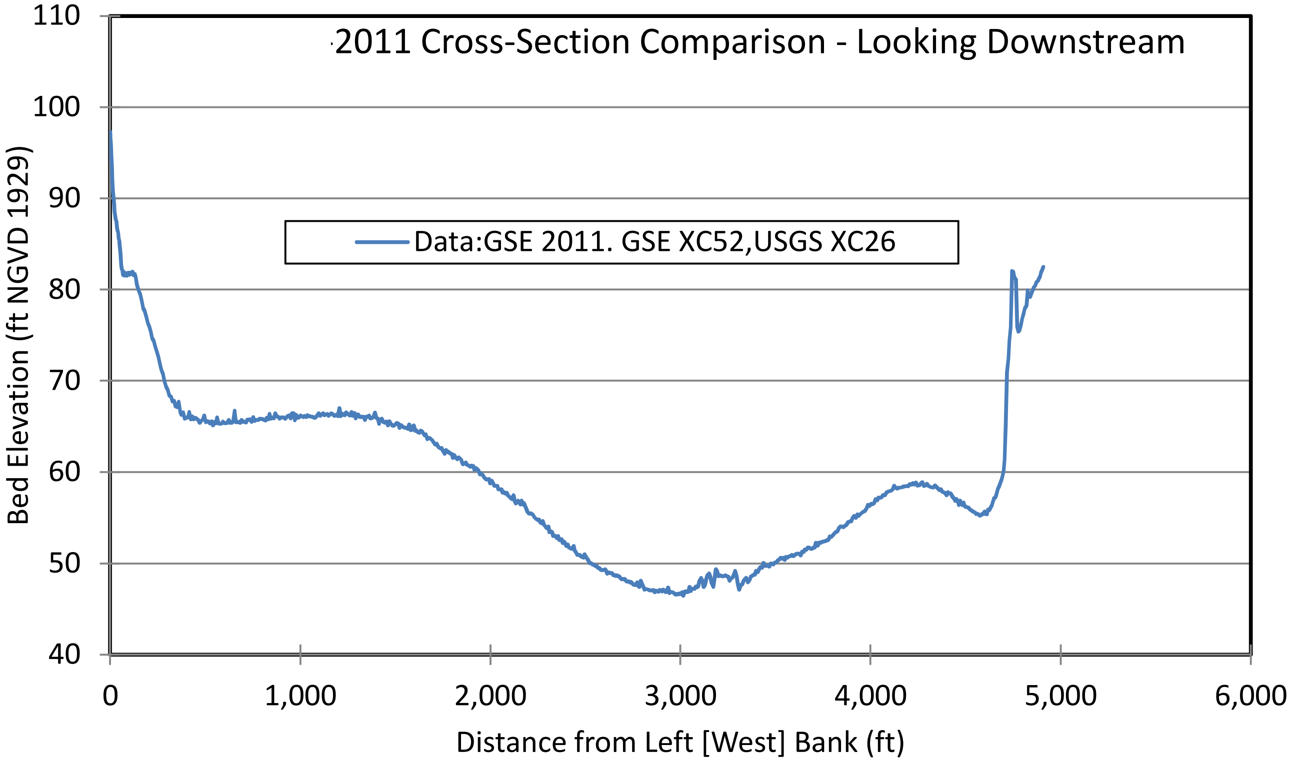


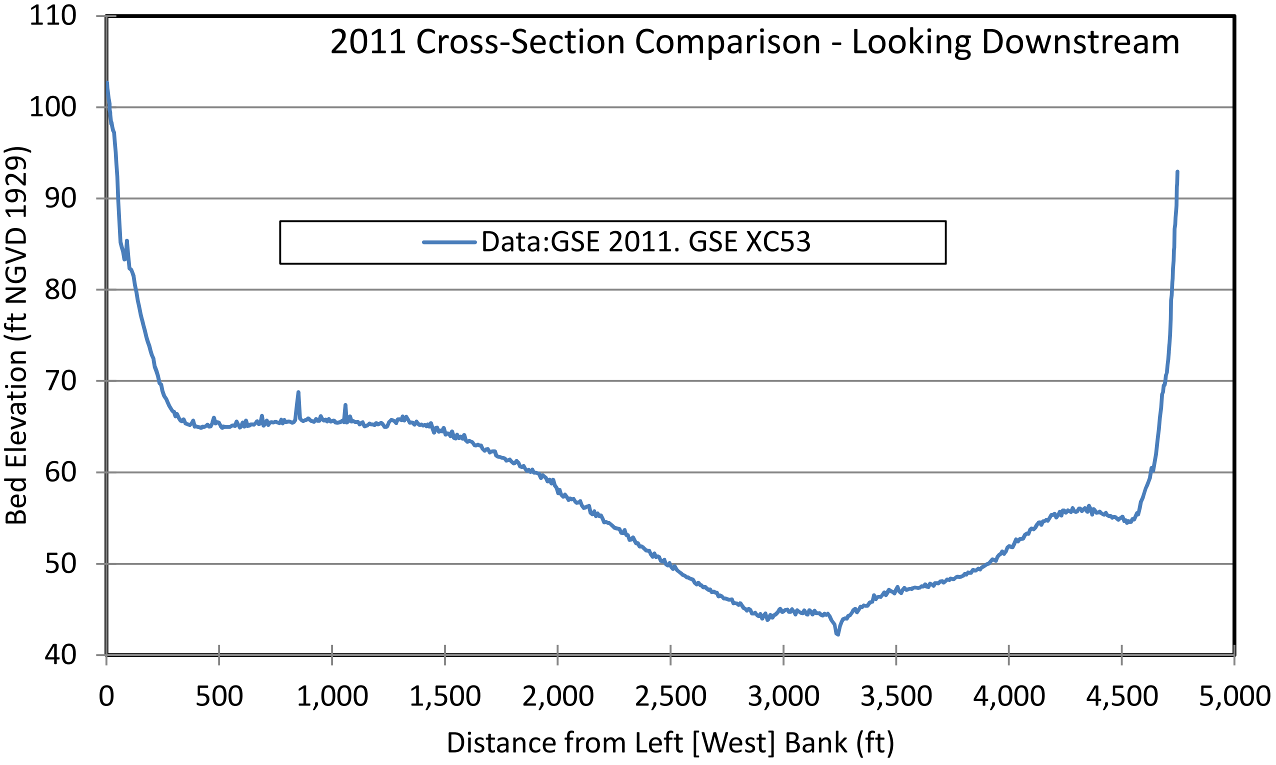
2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC49,USGS XC24
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
Distance from Left [West] Bank (ft)

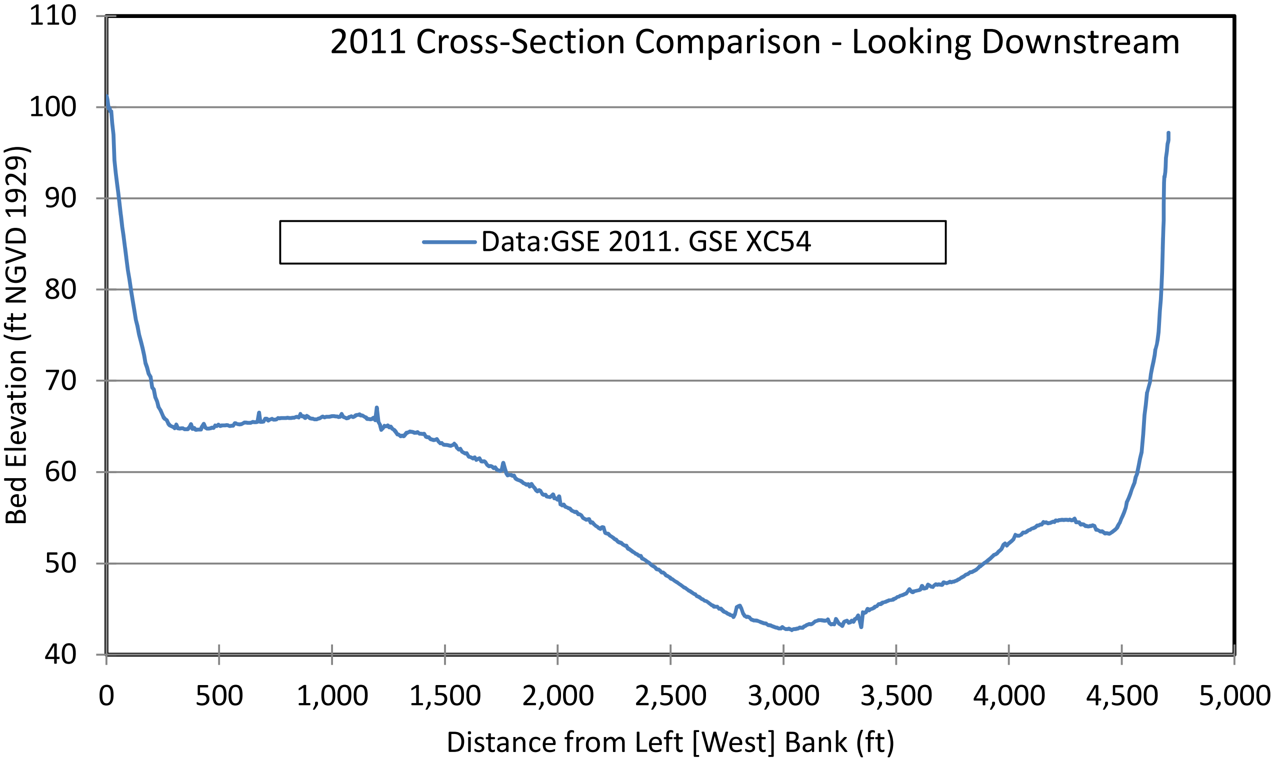


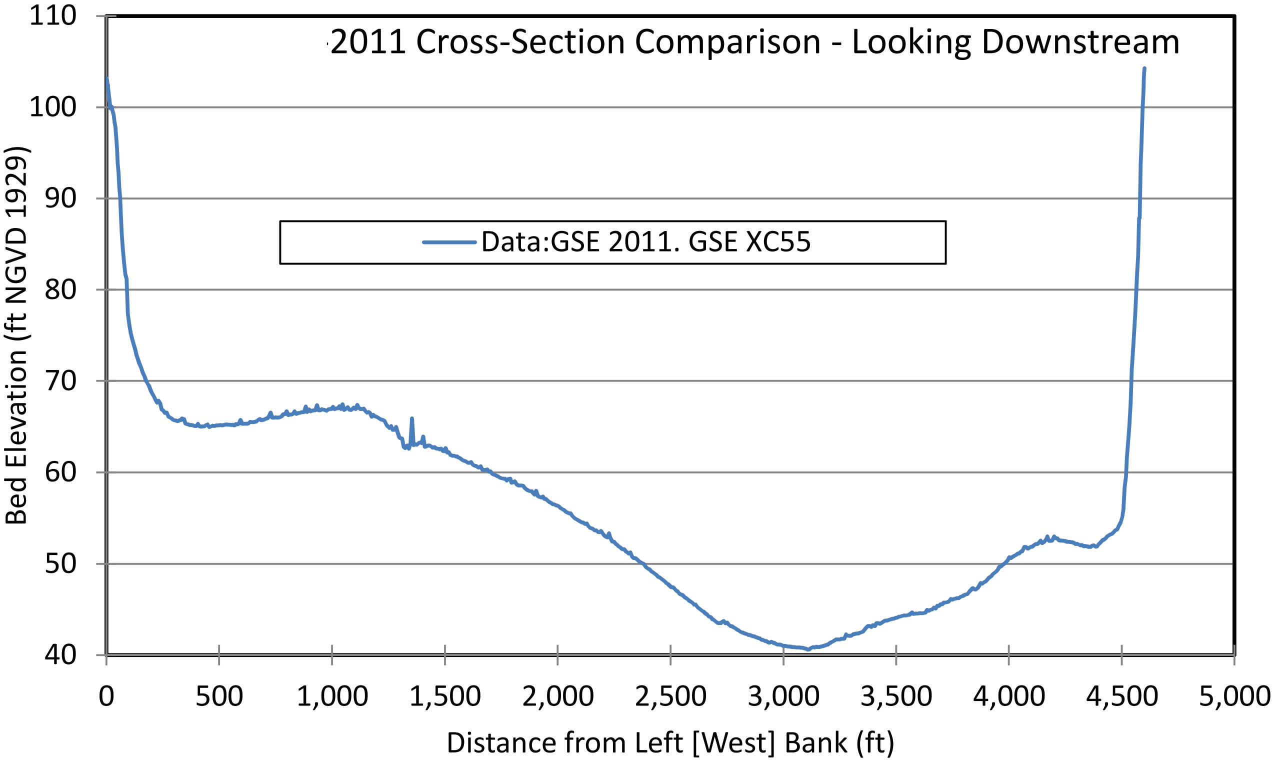
2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC50
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)


2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC51,USGS XC25
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)

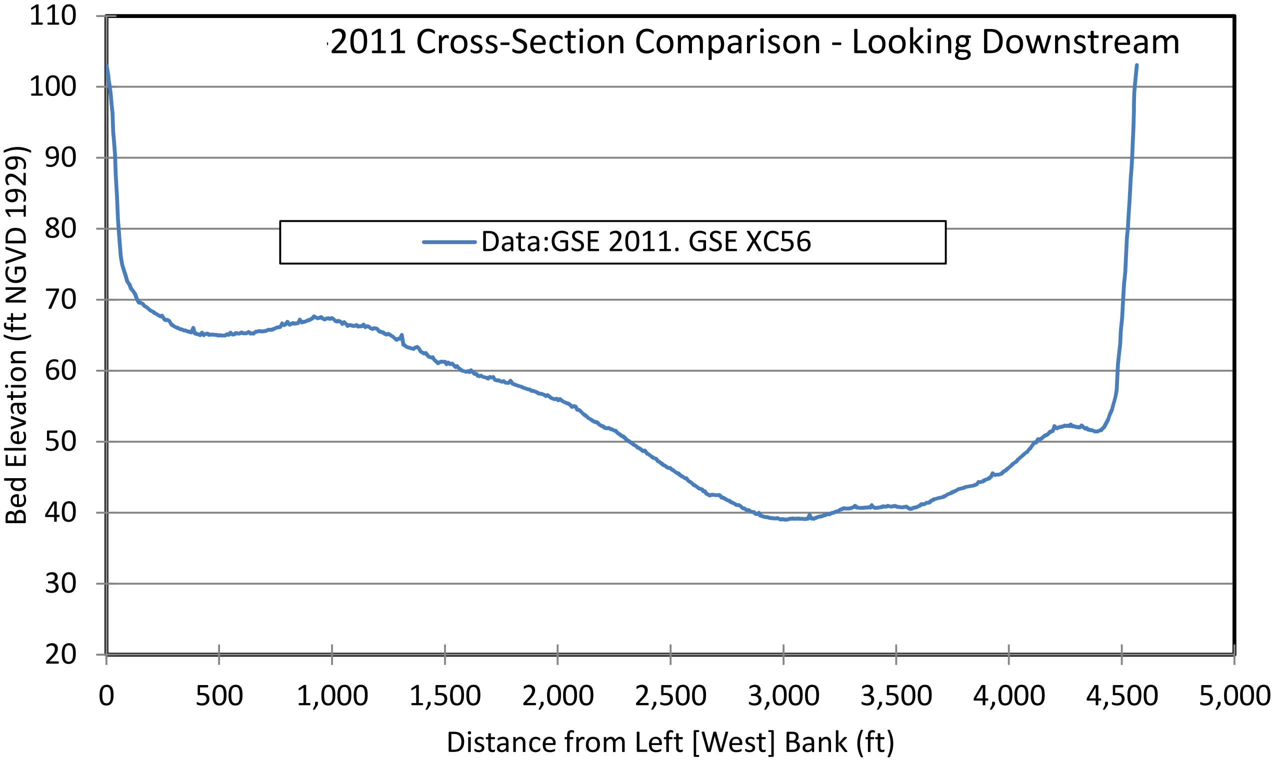

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC52,USGS XC26
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)


2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC53
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)

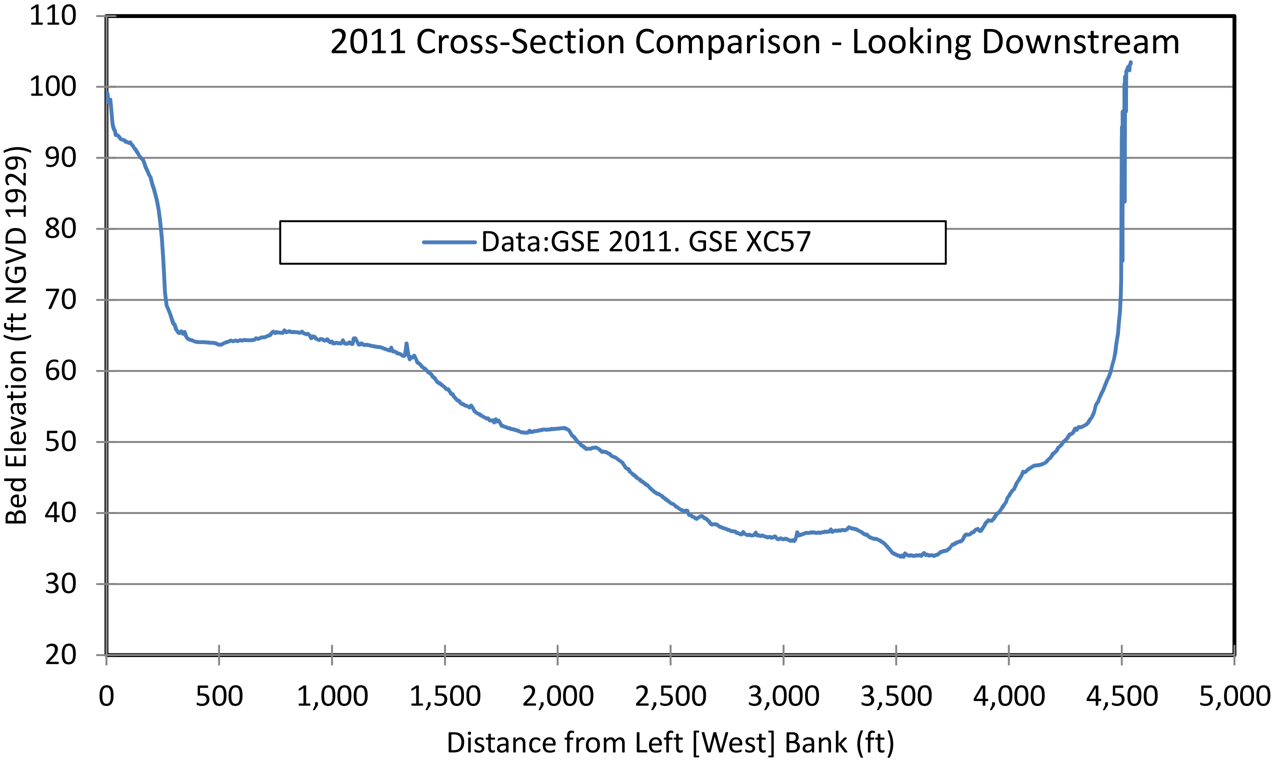

2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC54
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)

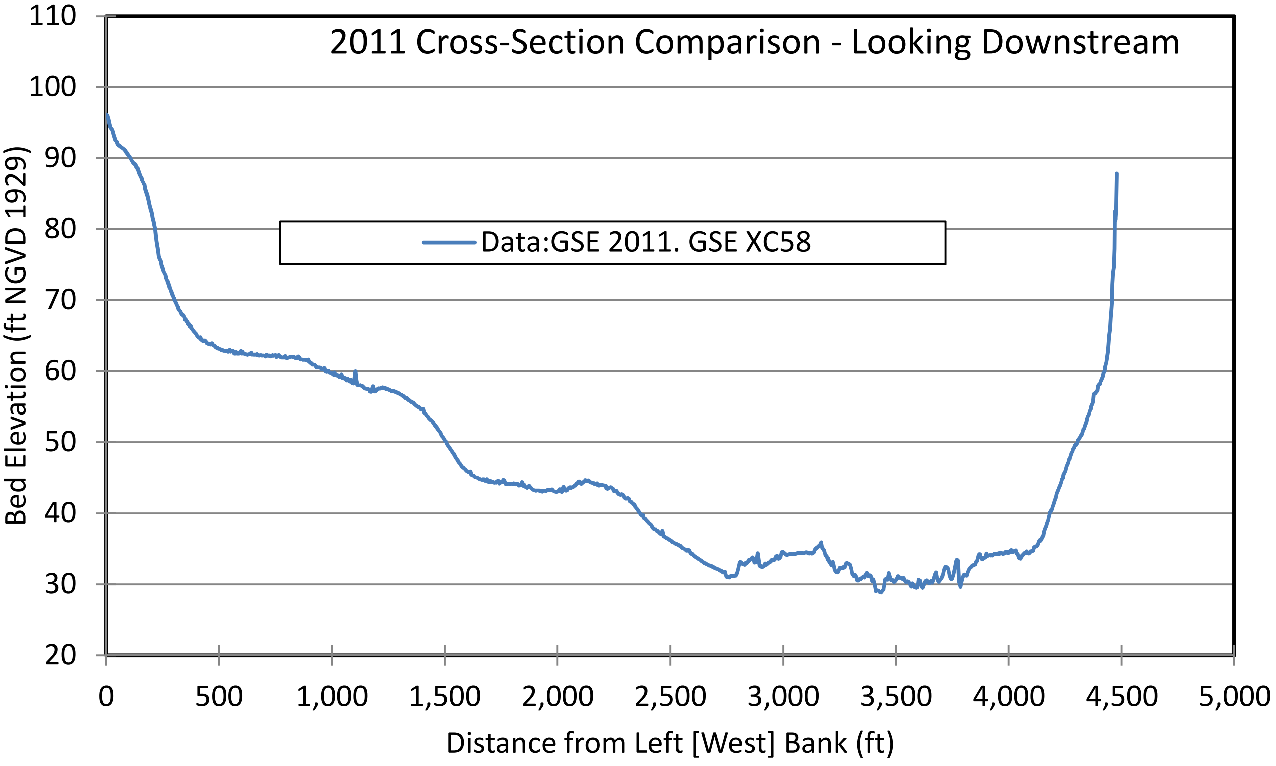


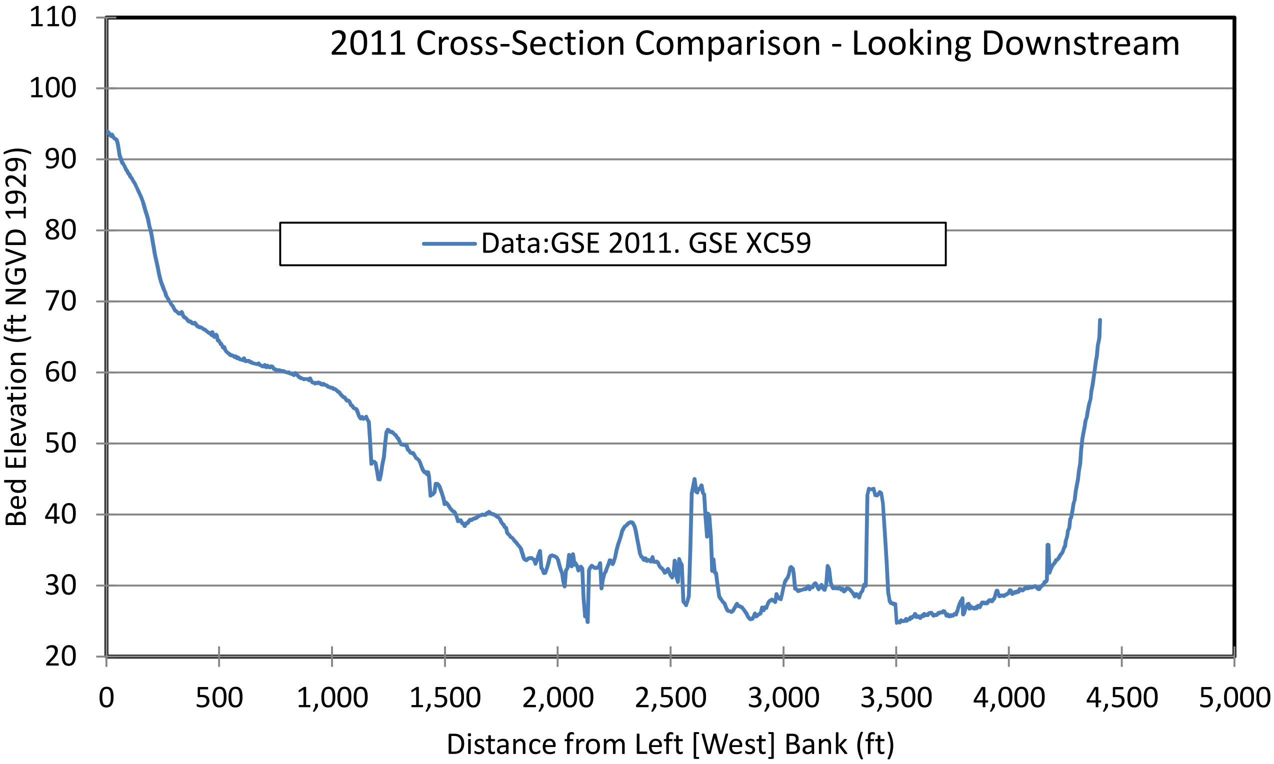
2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC55
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)



2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC56
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
30
20
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)


2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC57
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
30
20
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)


2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC58
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
30
20
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)


2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC59
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
30
20
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)