Appendix D

Reach 2A Sedimentation Evaluation (2011)

April 2012

SAN JOAQUIN RIVER
RESTORATION PROGRAM

Reach 2A Sedimentation Evaluation (2011)

April 17, 2012

1. INTRODUCTION

The Settlement Agreement calls for changes in the flow regime and restoration designs in the San Joaquin River between Friant Dam and the confluence with the Merced River necessary to help meet the overall objective of restoring and maintaining fish populations (**Figure 1**). To better understand impacts associated with implementation of the project, Tetra Tech dba Mussetter Engineering, Inc. (Tt-MEI) has performed various analyses to evaluate existing channel and levee capacities along the entire river, as well as sediment transport characteristics under existing and project conditions in Reach 2A (MEI, 2008; Tt-MEI, 2010a and 2010b).

Interim restoration flow and flood releases have been made from Friant Dam at varying magnitudes and durations during the past two years (**Figure 2**). Concerns about sediment deposition in the river upstream from the Chowchilla Bypass Bifurcation Structure (CBBS) have been expressed, and it has been suggested that the deposition may be related to the restoration flows. In late-2010, Tt-MEI was requested by California Department of Water Resources (DWR) to collect the necessary data to evaluate bed changes, conduct a preliminary evaluation of the potential for sedimentation, and predict the potential impacts on channel and levee capacity in Reach 2A and operation of the CBBS. To support this effort, field surveys were conducted by Provost and Prichard on November 16 and 17, 2010, and the results of the investigation that included 1-dimensional (1-D) modeling with 2010 cross sections, were reported in a memorandum dated December 3, 2010 (Tt-MEI, 2010c). The surveys and analysis were recently repeated to assess the effects of the 2011 interim flow releases. This memorandum summarizes the collected data and results of the updated evaluation.

2. CHANGES IN CHANNEL BED PROFILE

To evaluate changes in the channel bed topography since the 2010 surveys, the downstream portion (approximately 2.7 miles) of the river channel in Reach 2A was re-surveyed on November 7 and 8, 2011, at the locations of the 27 existing HEC-RAS hydraulic model cross sections, the same locations that were surveyed for the 2010 evaluation (**Figure 3**).

Cross-section plots from the 2011 survey data were compared with cross sections cut from the 2008 LiDAR mapping and the November 2010 surveyed cross sections to evaluate changes in channel shape and aggradation/degradation trends (**Appendix A**). In general, the 2011 data show that the overall channel shape and width along the reach did not change significantly as a result of the 2011 high flows. Significant changes in the thalweg elevations and low-flow channel did, however, occur at several locations[1]. For example, the thalweg/low-flow channel downcut by a noticeable amount at Cross Sections (XS) 515,130, just upstream from the CBBS, at XS 518,453, XS 519,908, XS 522,881, and XS 525,918 in the middle of the reach, and most significantly at XS 528,030, near the upstream end of the reach, where the 2011 thalweg is over 5 feet lower than in either 2008 or 2011. In a few locations where significant changes in thalweg and low-flow channel elevation occurred between 2008 and 2010, the channel adjusted back to near the 2008 condition during the 2011 high flows. For example, the thalweg aggraded significantly at XS 515,424 between 2008 and 2010, but degraded back to essentially the 2008 condition in 2011. The opposite trend occurred at the next upstream XS 515,986. At XS 523,952, the thalweg and right side of the low flow channel appears to have degraded by about 1 foot between 2008 and 2010, but these areas backfilled to near their 2008 condition in 2011. A mid-channel bar that formed at XS 527,444 between 2008 and 2010 was eroded back to near the 2008 condition during the 2011 high flows.

To further quantify aggradation/degradation trends along the reach, minimum bed (i.e., thalweg) and mean bed elevation profiles were developed from each survey and compared (**Figures 4 and 5, respectively**). Changes in thalweg elevation from 2008 to 2010 ranged from about 2.3 feet of degradation (XS 515,986, about 400 feet upstream from the CBBS) to 2.2 feet of aggradation (XS 515,130, about 100 feet upstream from the CBBS), with an overall average change of -0.1 feet. The thalweg lowered at 13 of the cross sections, raised at nine and did not change at five (Figure 4)[2]. From November 2010 to November 2011, the thalweg lowered by an average of approximately 0.4 feet over the reach, with a decrease in elevation at 14 cross sections, an increase at nine cross sections and little or no change at three cross sections. Over the entire period from 2008 through 2011, the thalweg lowered by an average of 0.5 feet, with 16 of the cross sections lowering, nine raising and three having little or no change.

The mean bed elevation was computed by subtracting the hydraulic depth for a common reference elevation at each cross section from the reference elevation. In some cases, it was not possible to resurvey a portion of the cross section where the thalweg was located at the base of an eroding bank due to safety issues. With two exceptions, it was assumed that the missing part of the cross section was the same as the 2008 LiDAR survey. Although there is obviously uncertainty in this assumption, the general shape of the surveyed part of the cross section was similar to the earlier profile; thus, the assumption is believed to be reasonable. The two exceptions occurred in the November 2011 surveys at XS 517,754 and XS 521,884. At XS 517,754, the toe of the left bank appears to have eroded laterally and the thalweg lowered by about 0.5 feet from 2008 (**Figure 6**). At XS 521,884, it is clear from the 2011 data that the low-flow channel filled in, raising the thalweg by over 2 feet (**Figure 7**). In both cases, the missing part of the 2011 cross-section profile was estimated based on the shape of the remainder of the cross sections.

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[1] The thalweg at each cross section was identified as the lowest elevation of the individual surveyed points. The typical spacing of the points is in the range of 15 to 20 feet, and the vertical accuracy of the RTK-GPS measurements is typically in the 2 to 3 centimeter range (i.e., ~1 inch). Considering the uncertainty associated with placement of the survey rod on the actual bed surface, particularly in the saturated sand in Reach 2A, the thalweg point elevations should be accurate to within about 0.2 to 0.3 feet. The LiDAR data used to identify the 2008 thalweg were collected to meet FEMA map accuracy standards, cross-referenced to the National Standards for Spatial Data Accuracy (NSSDA) developed by the Federal Geographic Data Committee (FGDC), for a 1-foot contour interval map. In general, these standards require the individual points to be within +/-0.3' RMSE of coincident points independently surveyed using higher accuracy methods, with a 95% confidence interval of +/-0.6'.

[2] The changes in thalweg elevation between 2008 and 2010 at 9 of the cross sections are within the 0.3' RMSE accuracy standard for the LiDAR data and within the +/-0.6' 95% confidence bands at 14 of the cross sections. The potential vertical error in the surveyed points is believed to be of similar magnitude; thus, the indicated changes are significant at one-half to two-thirds of the cross sections.

While the thalweg analysis quantifies the change in elevation of the deepest part of the channel, this is not necessarily a good indication of the overall aggradation/degradation tendency at each location because other parts of a particular cross section can build or degrade in the opposite direction from the thalweg change. Based on the mean bed elevations, net degradation occurred at 17 of the 27 cross sections between 2008 and 2010 and net aggradation occurred at eight cross sections, with the changes ranging from -0.5 to 1.3 feet, and averaging -0.2 feet (Figure 5). Between the 2010 and 2011 surveys, net degradation occurred at 14 of the cross sections, aggradation occurred at nine and three had little or no changes. For the overall period from 2008 to 2011, 16 cross sections degraded and nine aggraded, with an average change in bed elevation of about -0.2 feet over the entire reach.

3. AGGRADATION/DEGRADATION TRENDS

The overall aggradation/degradation response of the surveyed reach was quantified by computing the change in cross-sectional area between successive data sets and then using the average-end-area method to estimate the change in sediment volume based on the distances between the cross sections (**Figure 8**). These results indicate that approximately 10.2 ac-ft of sediment was removed from the channel bed (i.e., the reach degraded) between 2008 and the November 2010, and an additional 15.1 ac-ft of sediment was removed between November 2010 and November 2011, for a total degradation volume of about 25.3 ac-ft over the approximately 3-year period. Between 2008 and 2010, net degradation occurred over approximately 80 percent of the reach, with aggradation occurring in the approximately 900-foot reach immediately upstream from the CBBS, in the bend between XS 525918 and XS 526457. Net aggradation also occurred at XS 527444, where a mid-channel bar formed. The bulk of the degradation (~14.0 ac-ft) occurred in the approximately 1.7-mile reach beginning about 900 feet upstream from the CBBS. The remaining upstream portion of the surveyed reach remained approximately in balance during the period.

The magnitudes of the changes at the individual cross sections tended to be greater between the 2010 and 2011 surveys than during the 2008 to 2010 period, we assume due primarily to the high spring flows in Spring 2011. The most significant degradation during the latter period (~10.3 ac-ft) occurred in the approximately 4,000-foot reach between XS 517148 and XS 520510, and significant degradation also occurred at two specific locations in the middle to upstream portion of the reach (XS 522881 and XS 528030). Moderate degradation also occurred between XS 524,925 and XS 526,981 in the upstream portion of the reach. Significant aggradation occurred at XS 515886, near the downstream end of the reach and XS 522366, near the middle of the reach.

In spite of the general degradational tendency within the overall reach, about 2 ac-ft of sediment accumulated in approximately 900-foot reach upstream from the CBBS between 2008 and 2010. Based on the cross-section surveys, which may not completely describe the changes in the reach, this material appears to have been removed between the 2010 and 2011 surveys, but about 4.9 ac-ft of sediment accumulated in the approximately 0.9-mile reach just upstream. Although this cannot be confirmed with the available data, it appears that the relatively high flows passing into the Chowchilla Bypass may have relieved the aggradational tendency immediately upstream from the structure. Whether this condition will persist under restoration flows when all of the flow is passing through the river control structure into Reach 2B is uncertain, and will depend on the presence and extent of backwater due to gate operations and/or debris blockage of the trash rack on the upstream side of the structure.

4. CHANNEL AND LEVEE CAPACITY

The survey data collected in November 2011 was used to update the cross-sectional geometry in the existing conditions HEC-RAS hydraulic model, and the updated model was used to evaluate potential changes in the water-surface elevations over the range of restoration flows. Calibration of the updated model was checked by estimating the discharge associated with each measured point, running the model for the range of flows in the reach during the survey period, and comparing the estimated and measured water-surface elevations.

During the survey period on November 7, the discharge at the Gravelly Ford (GRF) gage, as reported on the California Data Exchange (CDEC) website, averaged about 270 cfs and declined slightly from about 275 cfs during the early part of the workday to 261 cfs at the end of the workday (**Figure 9**). The flows during this time-period at the below Bifurcation Structure (SJB) gage increased slightly from 169 to 177 cfs, and averaged 174 cfs. During the survey period on November 8, the discharge at the Gravelly Ford gage declined steadily from 214 cfs at the beginning of the workday to 195 cfs at the end of the workday, averaging about 205 cfs. At the below Bifurcation Structure gage, the flows on November 8 declined steadily from 161 to 147 cfs, and averaged about 154 cfs. This information was used to estimate the discharge associated with each of the water-surface elevation measurements by linearly interpolating between the reported flows at the two gages both along the reach and through time using time-stamp from the survey data logger. A total of 58 measurements were made on November 7 that covered essentially the entire survey reach. These were collected from up- to downstream through the day at discharges ranging from approximately 196 cfs at the upstream end of the reach to approximately 169 cfs at the downstream end (**Figure 10**).

The updated model was executed for discharges of 170 and 200 cfs, with the downstream boundary condition at the CBBS established using normal depth with energy gradient of 0.000063, which produces a water-surface elevation of 163.3 feet at 170 cfs, approximately the same as the measured elevations on November 7, With the exception of a relatively short segment of the reach between Station 523,000 and Station 524,000, the predicted water-surface profiles at discharges of 170 and 200 cfs agree very well with the measured data. The discrepancy in this area appears to be caused by the very constricted low flow channel in the 2011 cross section that causes the modeled energy gradient to be unreasonably steep; thus, over-predicting the water-surface elevation at the next upstream cross section. This issue could probably be corrected by interpolating, and inserting into the model, cross sections between the two surveyed cross sections. Since the problem does not appear to affect the predicted water-surface elevations at the higher flows that are of most interest in this analysis, the interpolation was not done.

After completion of the calibration check the model was executed for a range of flows up to 4,000 cfs and the predicted water-surface profiles were compared with the profiles developed using the 2008 LiDAR data and the 2010 survey data (**Figures 11 and 12**). Comparison of the three sets of profiles indicates that the predicted water surface in the approximately 1,500-foot reach just upstream from the CBBS is up to 0.3 feet higher at 1,000 cfs using the 2010 model than with the 2008 model, but is about the same as 2008 using the 2011 model. In the middle and upstream portions of the reach, the 1,000-cfs water surface is 0.1 to 0.2 feet lower with the 2010 model than with the 2008 model. The 1,000-cfs water surface in this part of the reach lowers even farther with the 2011 model, with differences from the 2008 model of up to 0.5 feet in the middle portion of the reach between about Sta 519,000 and Sta 524,000. Similar trends occur at the two higher discharges of 2,000 and 4,000 cfs, but the differences from the 2008 model decrease with increasing discharge. At 4,000 cfs, the water-surface elevations from the 2010 model in the portion of the reach upstream from Sta 519,000 are very consistent with those from the 2008 model, averaging less than 0.01 feet lower with a maximum difference of less than 0.1 feet.[3] The difference is somewhat larger, but still relatively small between the 2011 and 2008 models, averaging about 0.12 feet lower with a maximum difference of about 0.16 feet. These results suggest that the degradation in Reach 2A has tended to lower the water-surface elevations by a small amount at high flows, and this trend can be expected to continue with continued degradation.

5. SUMMARY

The results of this analysis indicate that most of the approximately 3.0-mile portion of Reach 2A upstream from the CBBS is degradational under flow conditions that have occurred over the past three years. Between March/April 2008, when the LiDAR data were collected, and the November 2010 survey, about 10.2 ac-ft of sediment was evacuated from the reach, and an additional approximately 16.3 ac-ft of material was evacuated between November 2010 and November 2011. The total degradation volume in this portion of Reach 2A was, thus, about 26.5 ac-ft over the entire period. With the exception of the approximately 400-foot reach immediately upstream from the CBBS and a few local areas scattered through the reach, both the thalweg and mean bed elevations generally lowered during the period as a result of the sediment evacuation. Based on the thalweg data in Figure 4a, deepening of the pools may be occurring as part of the degradational process.

The depositional tendency in the area immediately upstream from the CBBS is related to the effects of the structure on the upstream water-surface profiles and associated hydraulic conditions. It appears that the gate setting during the late-2009 and 2010 interim restoration flow releases, when all of the flow passed through the river-control structure into Reach 2B, caused localized backwater and deposition upstream from the structure. During the 2011 interim restoration flow and flood releases, when significant flow was diverted into the Chowchilla Bypass, the approximately 400-foot reach immediately upstream from the structure that was depositional in 2010 was roughly in sediment balance to slightly degradational, but a significant depositional tendency occurred in the next approximately 1,000 feet upstream. These results suggest that operation of the gates at the structure and the tendency for debris accumulation on the trash rack on the river-control structure have a significant influence on the sediment balance in the area immediately upstream from the CBBS and amount of sediment that passes into Reach 2B under restoration flows, and into both the Reach 2B and the Chowchilla Bypass during flood releases.

Based on results from hydraulic models using each of the three sets of data, the water-surface at low to intermediate flows appears to have decreased during the period encompassed by the surveys, but these changes have a relatively insignificant effect at the higher range of restoration releases and even higher flood releases. Continued degradation may eventually result in more significant changes at the higher flows.

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[3] Considering the accuracy of the survey data and limitations of the modeling, changes of 0.1 feet or less are probably not significant.

6. NEXT STEPS

The conclusions developed for this memorandum are based primarily on November 2010 and November 2011 surveys data. Additional data are available to help assess the overall response of this portion of Reach 2A to the interim flow releases, and these data are currently being evaluated. These evaluations include the following:

1. DWR performed detailed topographic patch surveys at the previously established riparian vegetation monitoring sites in January 2009, June 2010, October 2010, February 2011 and August 2012. The data from these surveys (particularly Sites M-11, 12 and 13 that are within or very close to the survey area for the above analysis) is being processed to assess bed changes and aggradation/degradation trends at these locations.
2. DWR also collected a suite of sediment samples at each of the patch survey sites in conjunction with the patch surveys. These data are being analyzed to assess whether systematic changes in bed material gradation occurred during the period encompassed by the surveys.
3. The USGS collected suspended sediment data at Gravelly Ford and below the CBBS, and possibly at a site within the study reach for this project, in 2010 and 2011. These data will be obtained and evaluated to assess whether systematic changes in the suspended sediment versus discharge rating curve occurred during the period.
4. Tt-MEI is currently developing and calibrating an SRH 2-D sediment transport model for the downstream portion of the study area. A key purpose for the model is to assess the movement of bed material to and through the CBBS. Once the calibration is complete, model runs will be made for a range of conditions that will be define, in part by the findings from the above tasks, to assess the likely future response of the river in the vicinity of the CBBS and the sediment load to Reach 2B during future interim flow releases.
5. A technical memorandum will be developed that summarizes all of the available data relative to sedimentation processes in the downstream portion of Reach 2A and the conclusions that can be drawn from those data.

7. REFERENCES

Mussetter Engineering, Inc., 2008. Evaluation of Existing Non-damaging Flow Capacities in Reaches 2A, 2B, 3, 4A, and 4B of the San Joaquin River. Draft technical memorandum prepared for California Dept. of Water Resources, Fresno, California, July 1.

Tetra Tech (dba Mussetter Engineering, Inc.), 2010a. Sediment-transport Capacity and Continuity Analysis for Existing and Proposed Levee Setbacks in Reaches 2A and 2B of the San Joaquin River. Draft technical memorandum prepared for California Dept. of Water Resources, Fresno, California, May 11, 13 p.

Tetra Tech (dba Mussetter Engineering, Inc.), 2010b. Evaluation of Potential Erosion and Stability Impacts on Existing Levees under Proposed Restoration Program. Draft technical memorandum prepared for California Dept. of Water Resources, Fresno, California, September 17, 48 p.

Tetra Tech (dba Mussetter Engineering, Inc.), 2010c. Reach 2A Sedimentation Evaluation. Draft technical memorandum prepared for California Dept. of Water Resources, Fresno, California, December 3, 14 p.

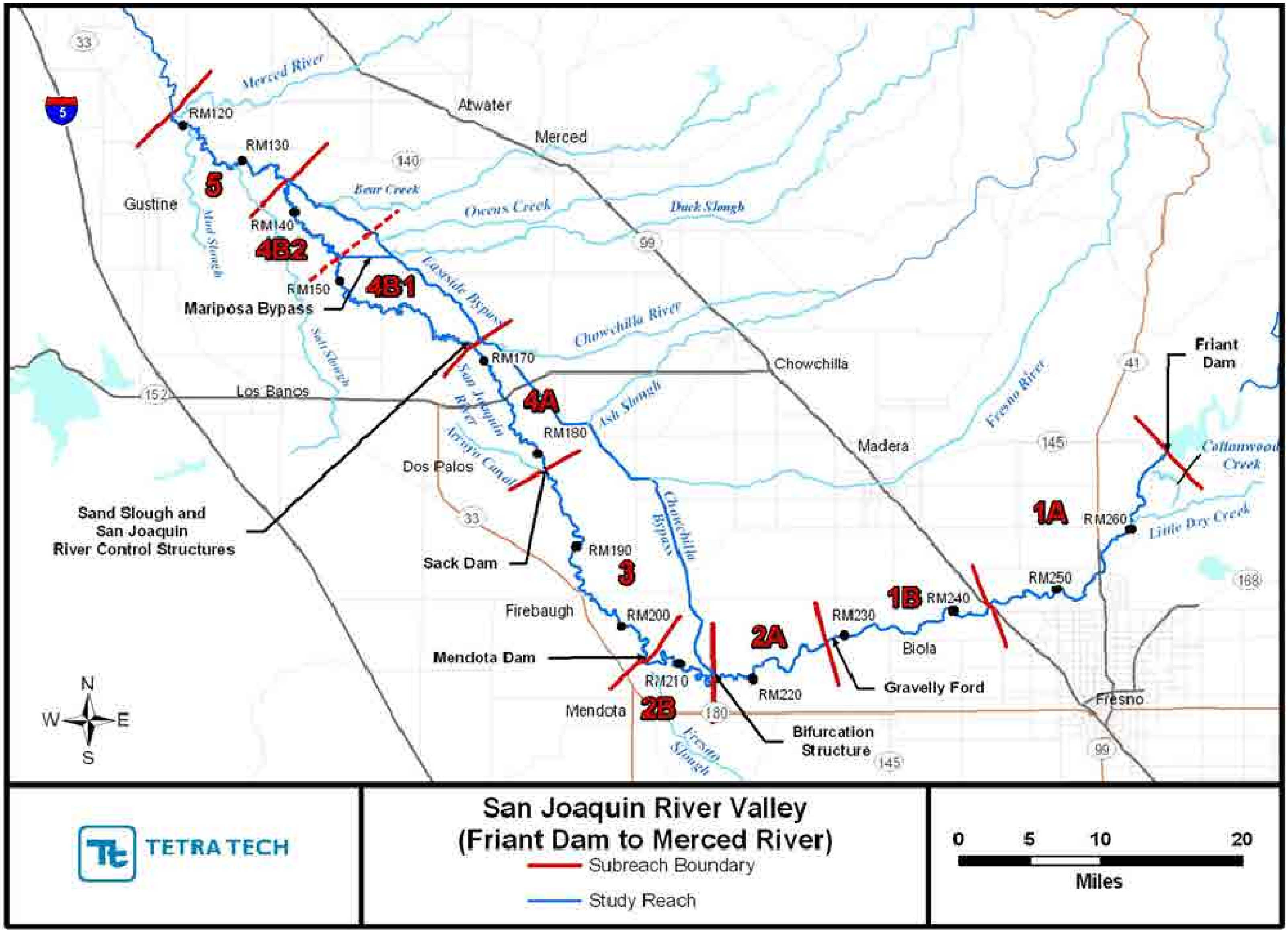


Figure 1. Map of the San Joaquin River Restoration Project Reach showing the subreach boundaries.

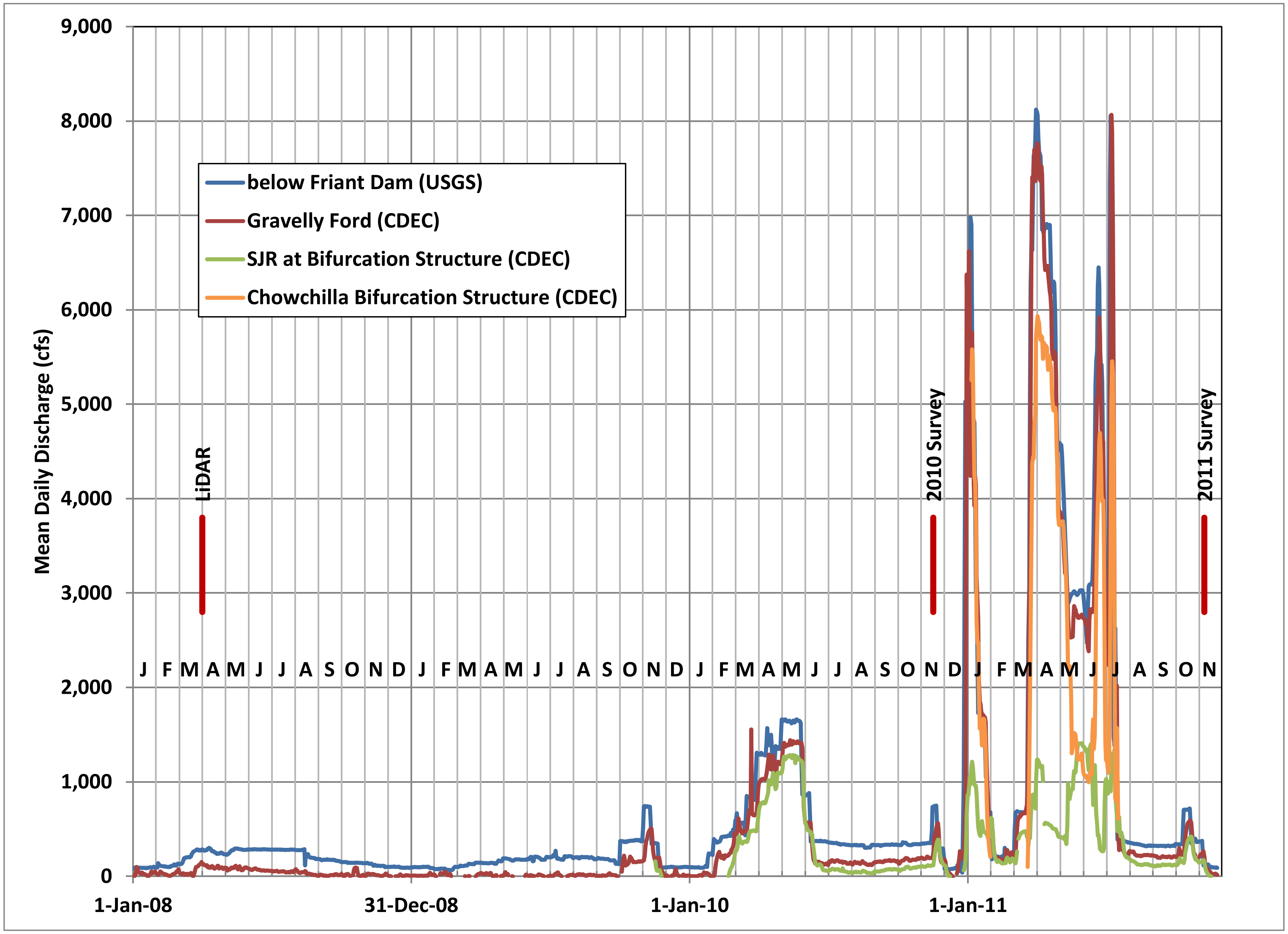


Figure 2. Reported mean daily discharges during the period encompassed by the LiDAR and field surveys at the USGS below Friant Dam gage and the CDEC Gravelly Ford (GRF), San Joaquin River below Bifurcation (SJB), and Chowchilla Bypass (CBP) gages.

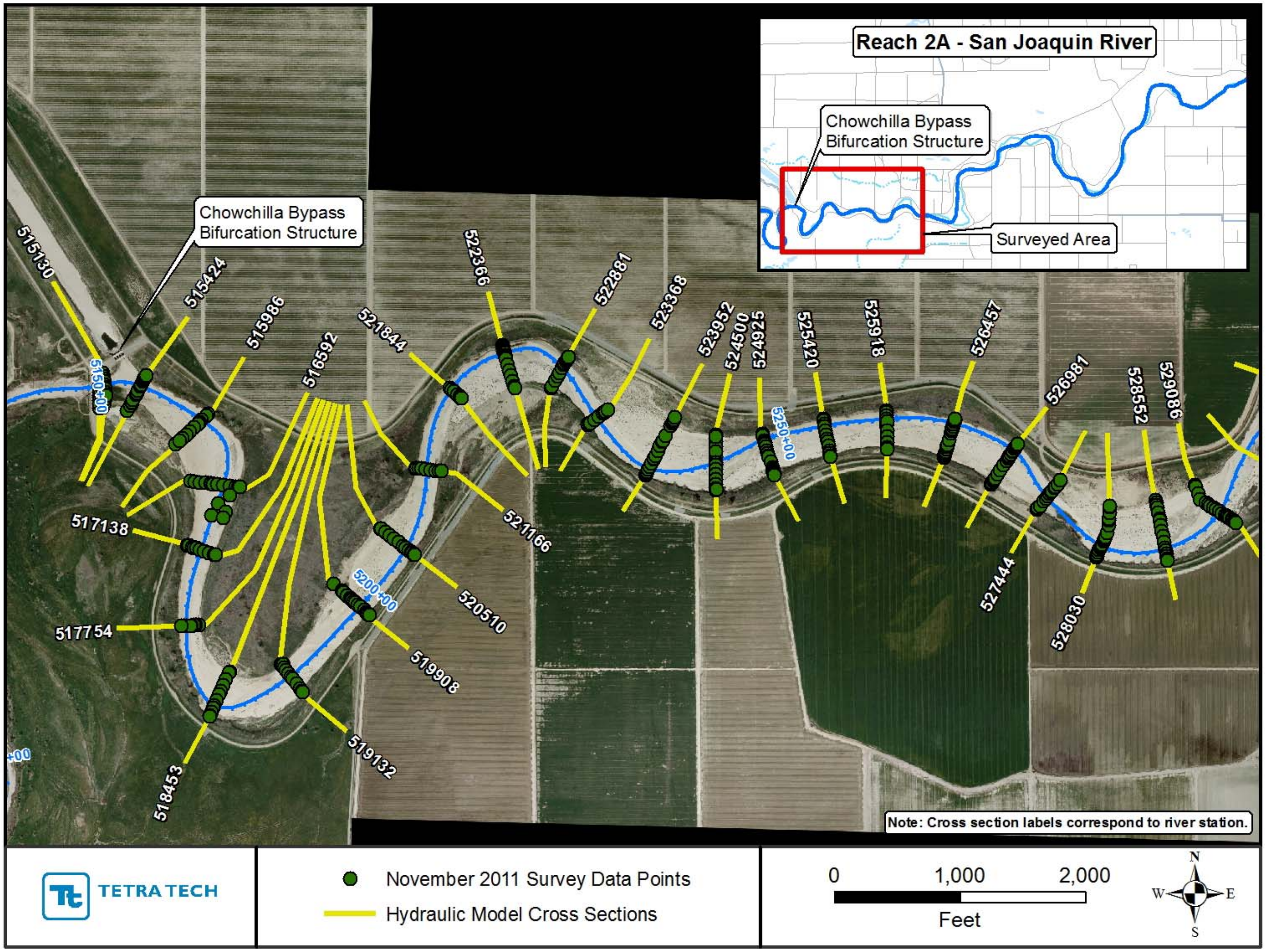


Figure 3. Map of lower portion of Reach 2A showing the locations of survey data collected during November 2011.

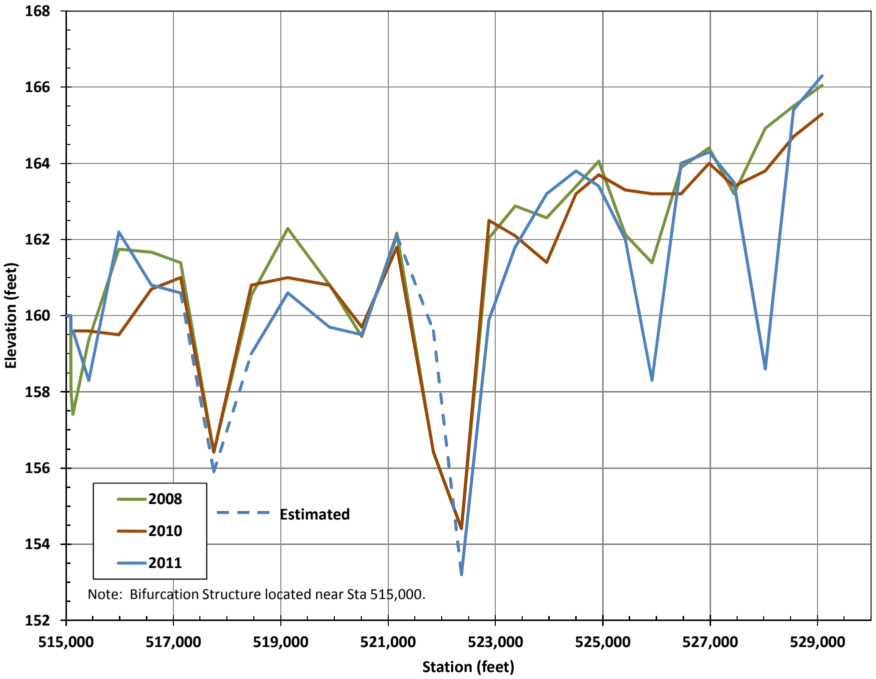


Figure 4a. Thalweg profiles for the downstream three miles of Reach 2A based on the 2008 LiDAR mapping, and the November 2010 and November 2011 cross-section surveys.

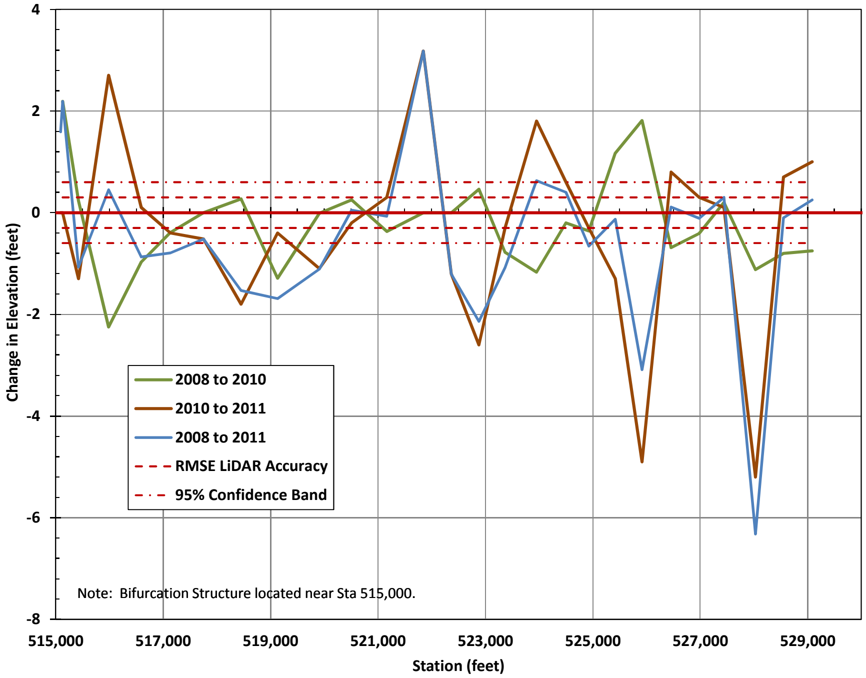


Figure 4b. Change in thalweg elevations in the downstream three miles of Reach 2A based on the 2008 LiDAR mapping, and the November 2010 and November 2011 cross-section surveys. RMSE and 95% Confidence Bands from LiDAR map accuracy standards are also shown. Error in surveyed cross section points is believed to be of similar magnitude.

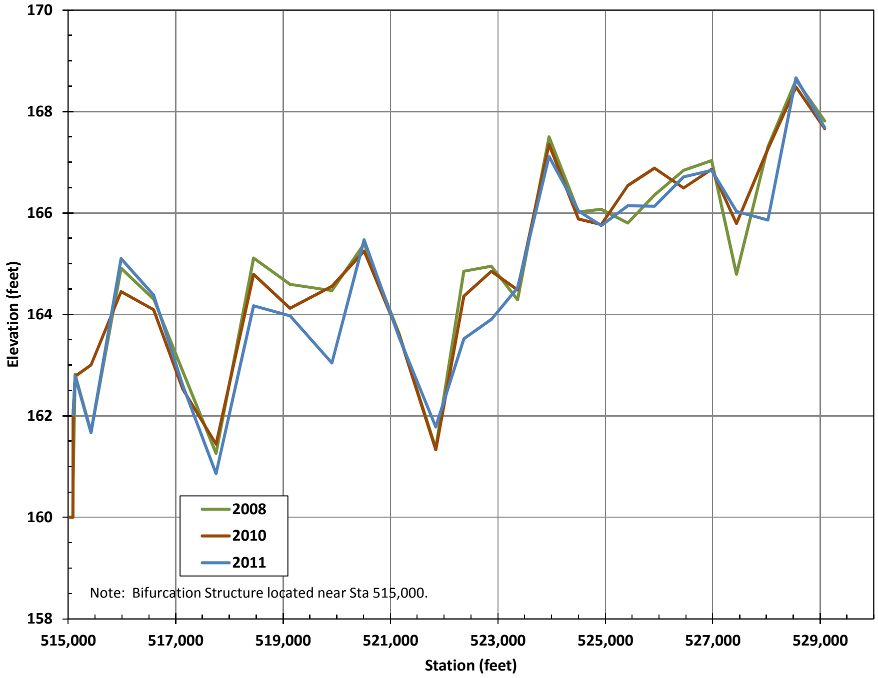


Figure 5a. Mean bed elevation profiles for the downstream three miles of Reach 2A based on the 2008 LiDAR mapping, and the November 2010 and November 2011 cross-section surveys.

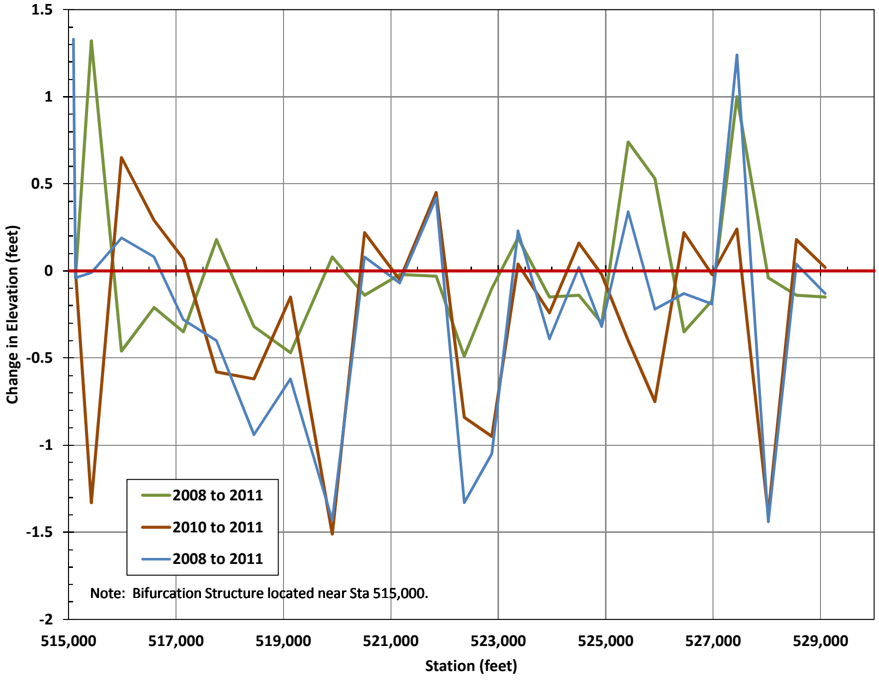


Figure 5b. Change in mean bed elevations in the downstream three miles of Reach 2A based on the 2008 LiDAR mapping, and the November 2010 and November 2011 cross-section surveys.

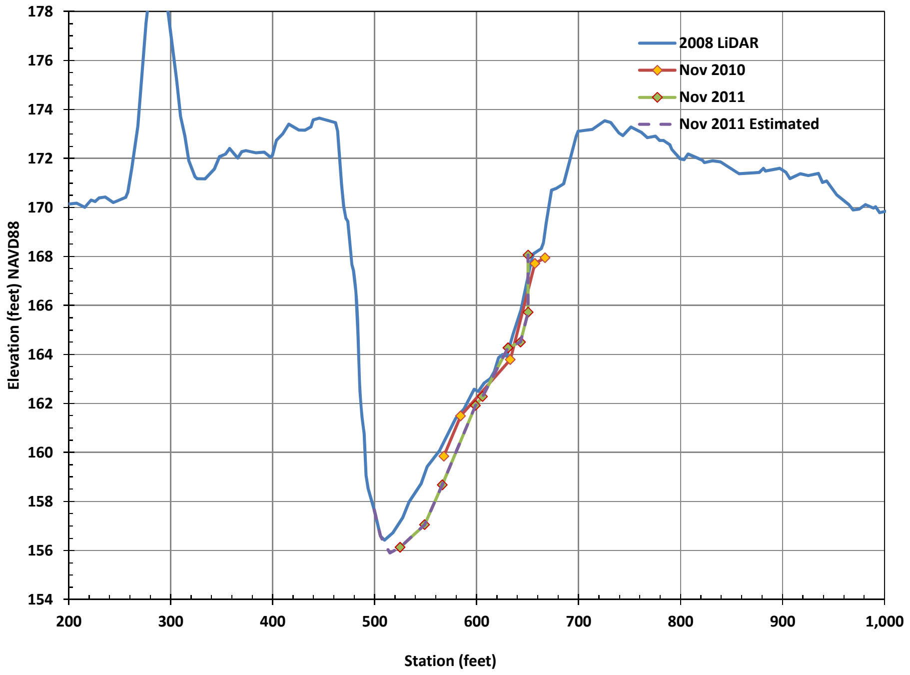


Figure 6. Profiles for XS 517,754 from the 2008 LiDAR and the November 2010 and November 2011 surveys. Also shown is the estimated profile for the missing portion of the 2011 profile used to compare thalweg and mean bed elevations.

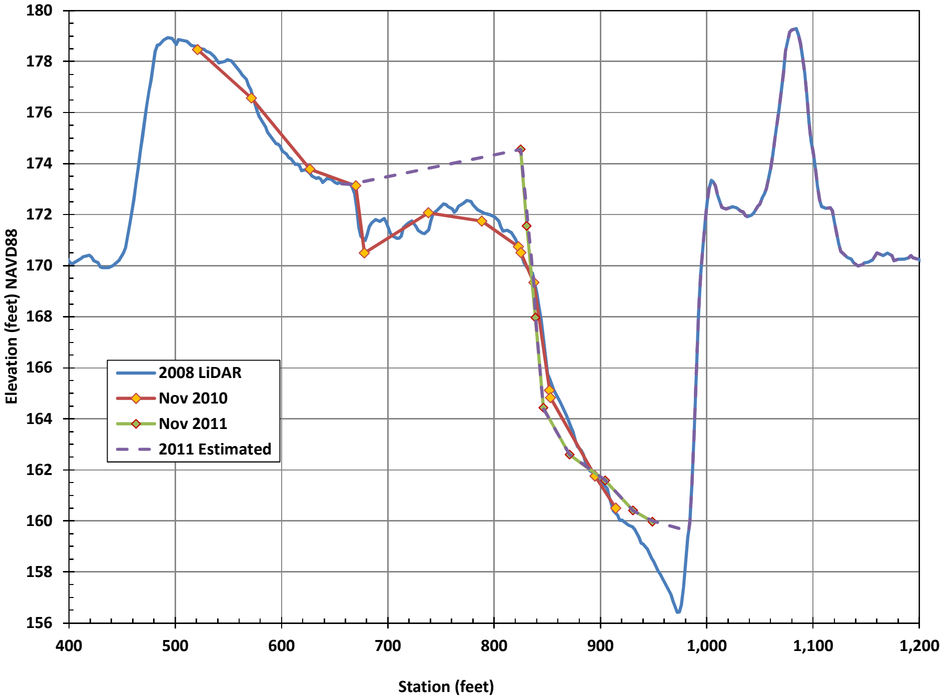


Figure 7. Profiles for XS 521,844 from the 2008 LiDAR and the November 2010 and November 2011 surveys. Also shown is the estimated profile for the missing portion of the 2011 profile used to compare thalweg and mean bed elevations.

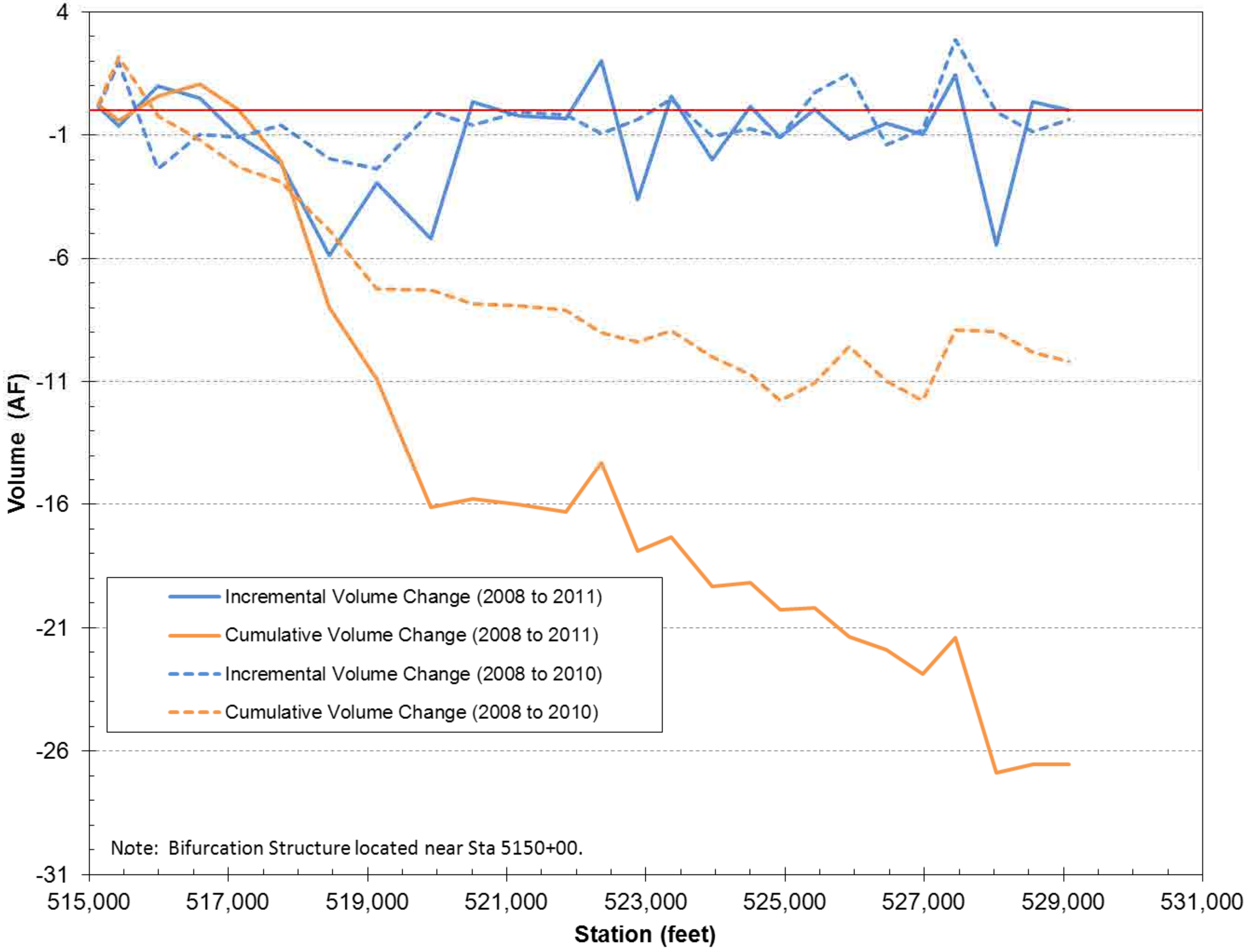


Figure 8. Profile plot of downstream three miles of Reach 2A, showing incremental and cumulative changes in sediment volume between 2008, November 2010, and November 2011.

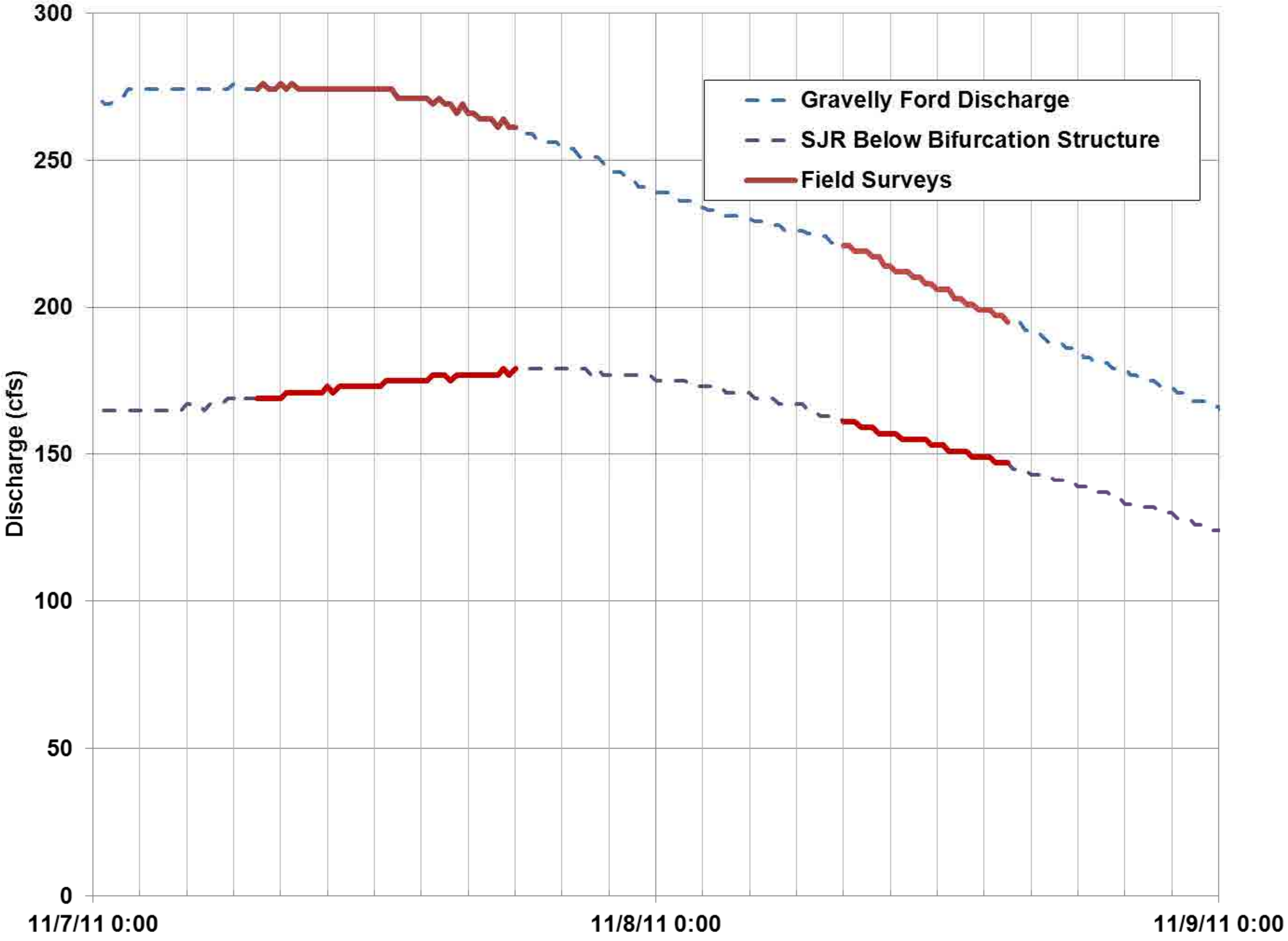


Figure 9. Discharge hydrograph during the November 2011 survey period at the Gravelly Ford (GRF) and below Bifurcation Structure (SJB) gages based on data from the CDEC website. **(Note that these discharges are provisional and subject to change upon review of the gage rating curves.)**

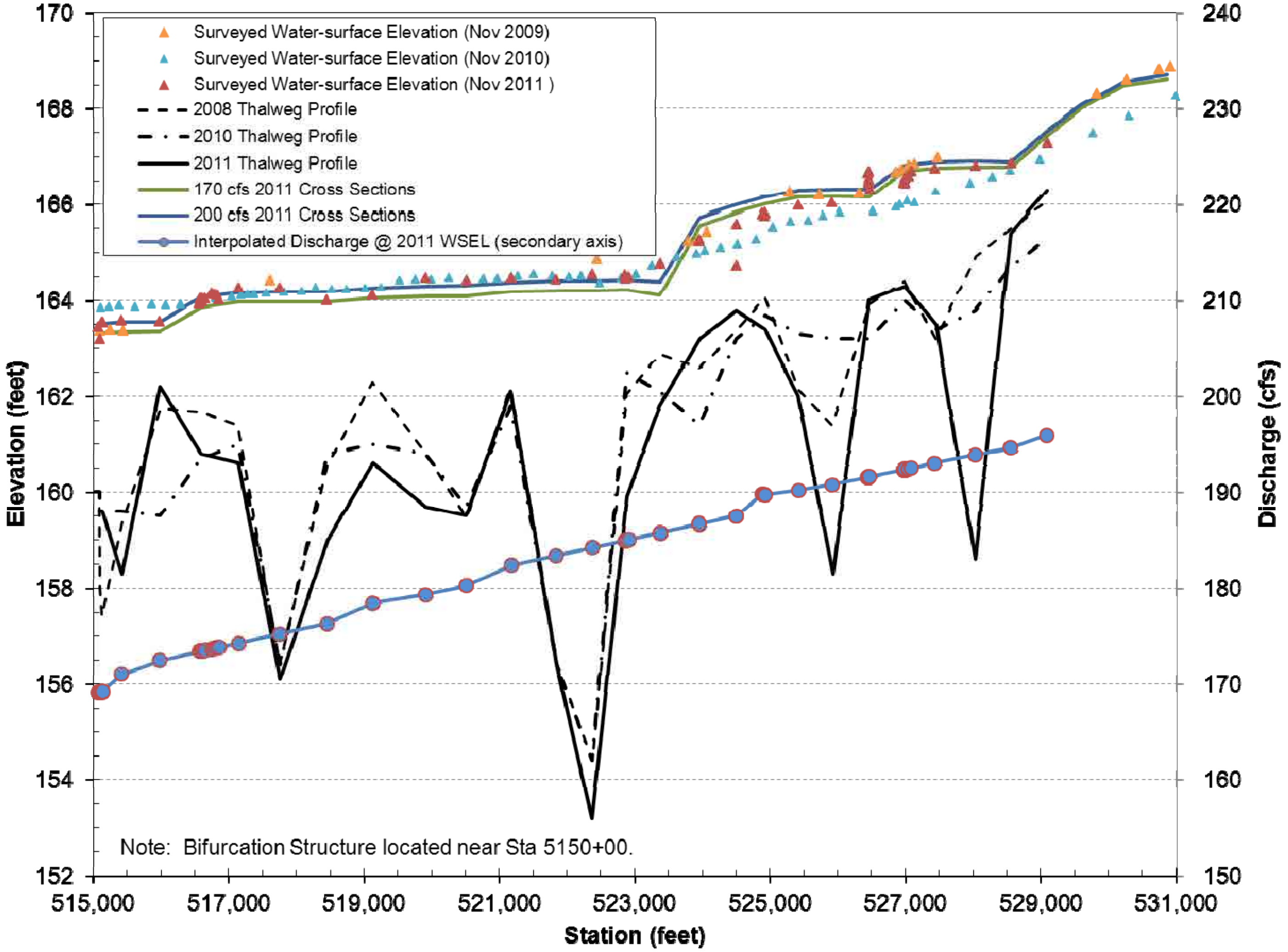


Figure 10. Water-surface elevations in the downstream three miles of Reach 2A from November 2009, when the discharge was in the range of 275 to 180 cfs, November 2010, when the discharge was in the range of 250 to 230 cfs, and November 2011 when the discharge was in the range of 170 to 200 cfs. Also shown are the water-surface profiles at discharges of 170 and 200 cfs predicted by the HEC-RAS model updated with the 2011 cross sections.

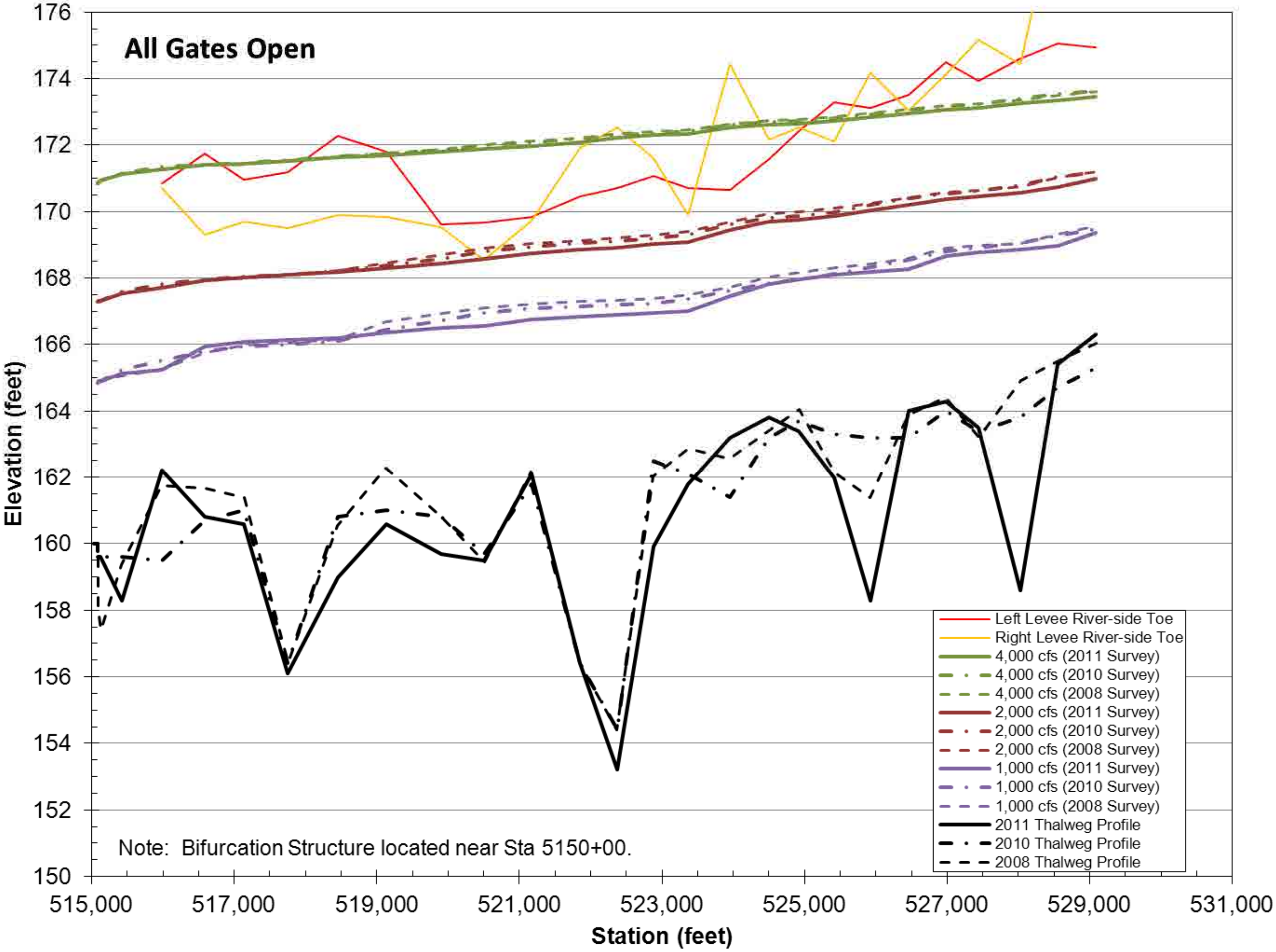


Figure 11. Water-surface profiles for discharges of 1,000, 2,000 and 4,000 cfs predicted by the HEC-RAS models with the 2008 LiDAR cross sections, November 2010 cross sections and November 2011 cross sections.

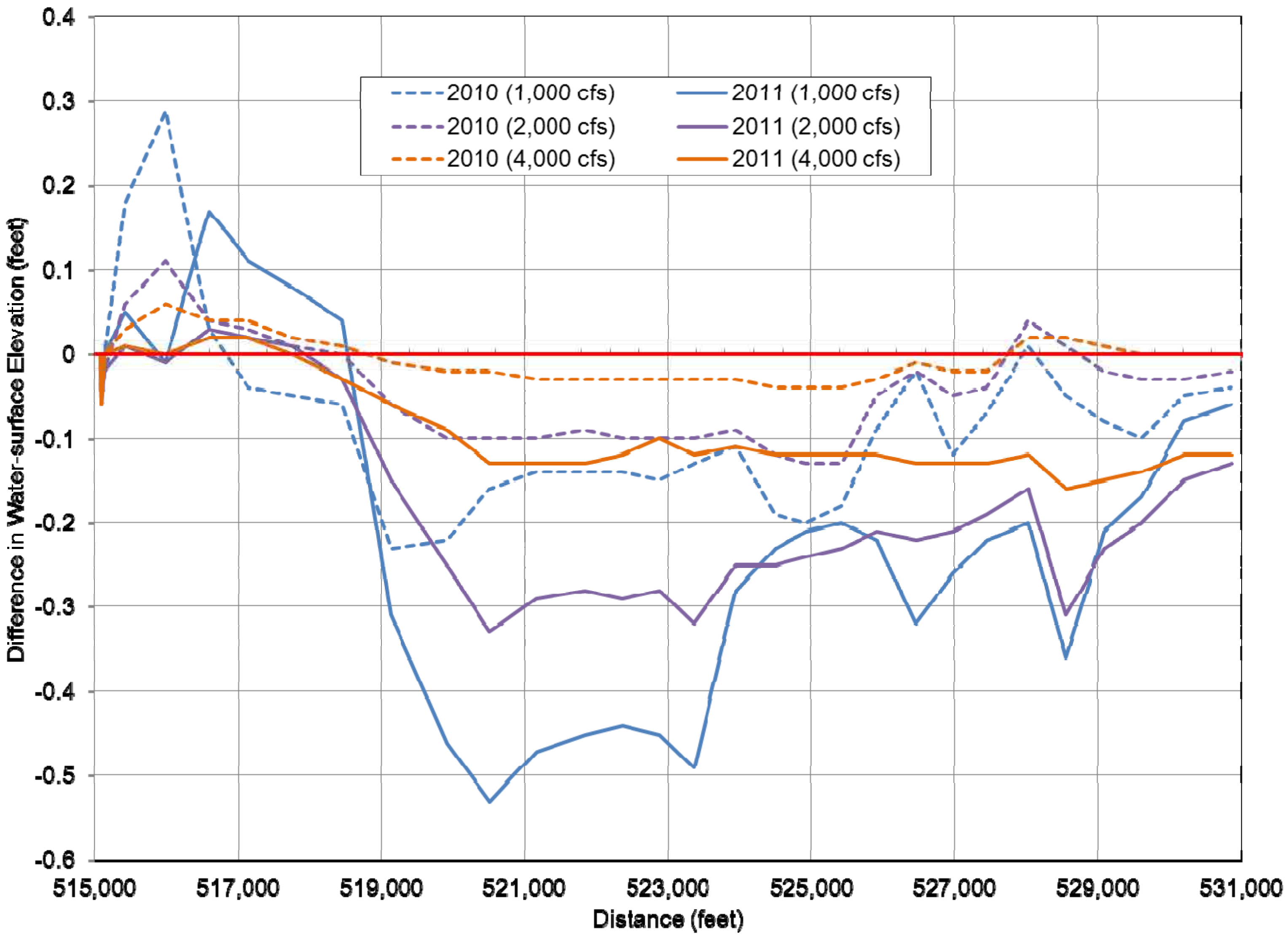
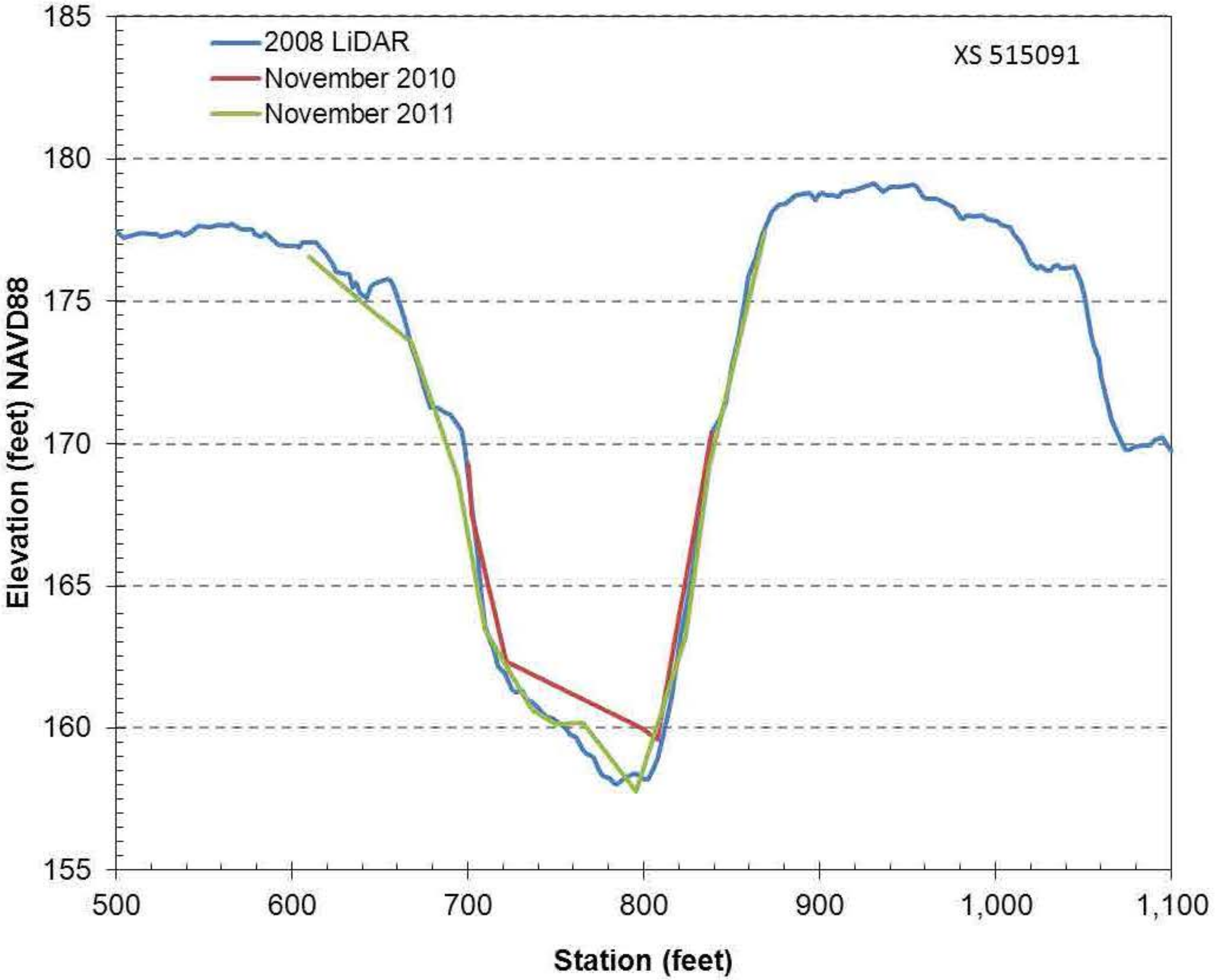


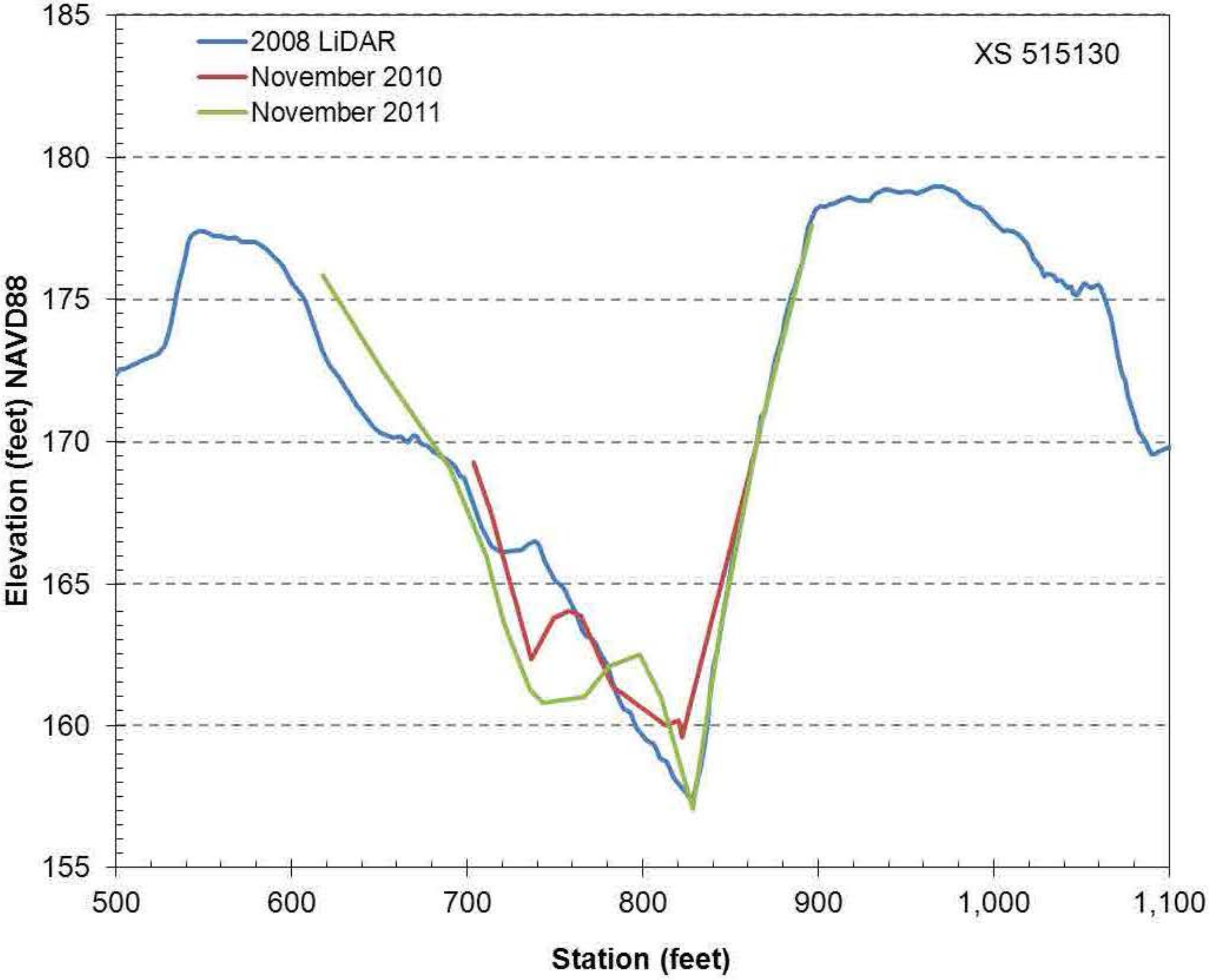
Figure 12. Difference in water-surface elevations for discharges of 1,000, 2,000 and 4,000 cfs predicted by the HEC-RAS models with the 2008 LiDAR cross sections, November 2010 cross sections and November 2011 cross sections.

APPENDIX A

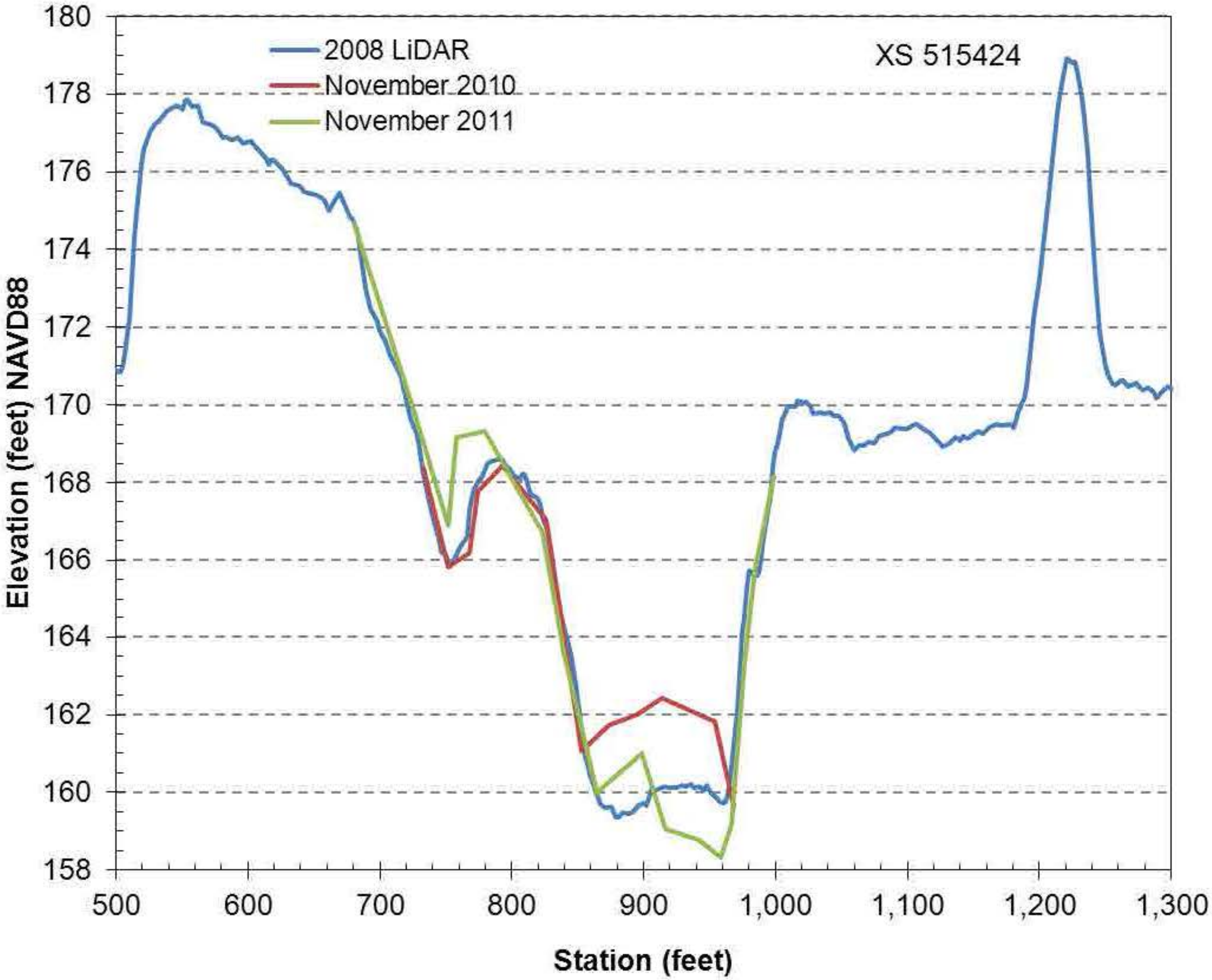
Reach 2A 2011 Survey Cross Section Comparisons

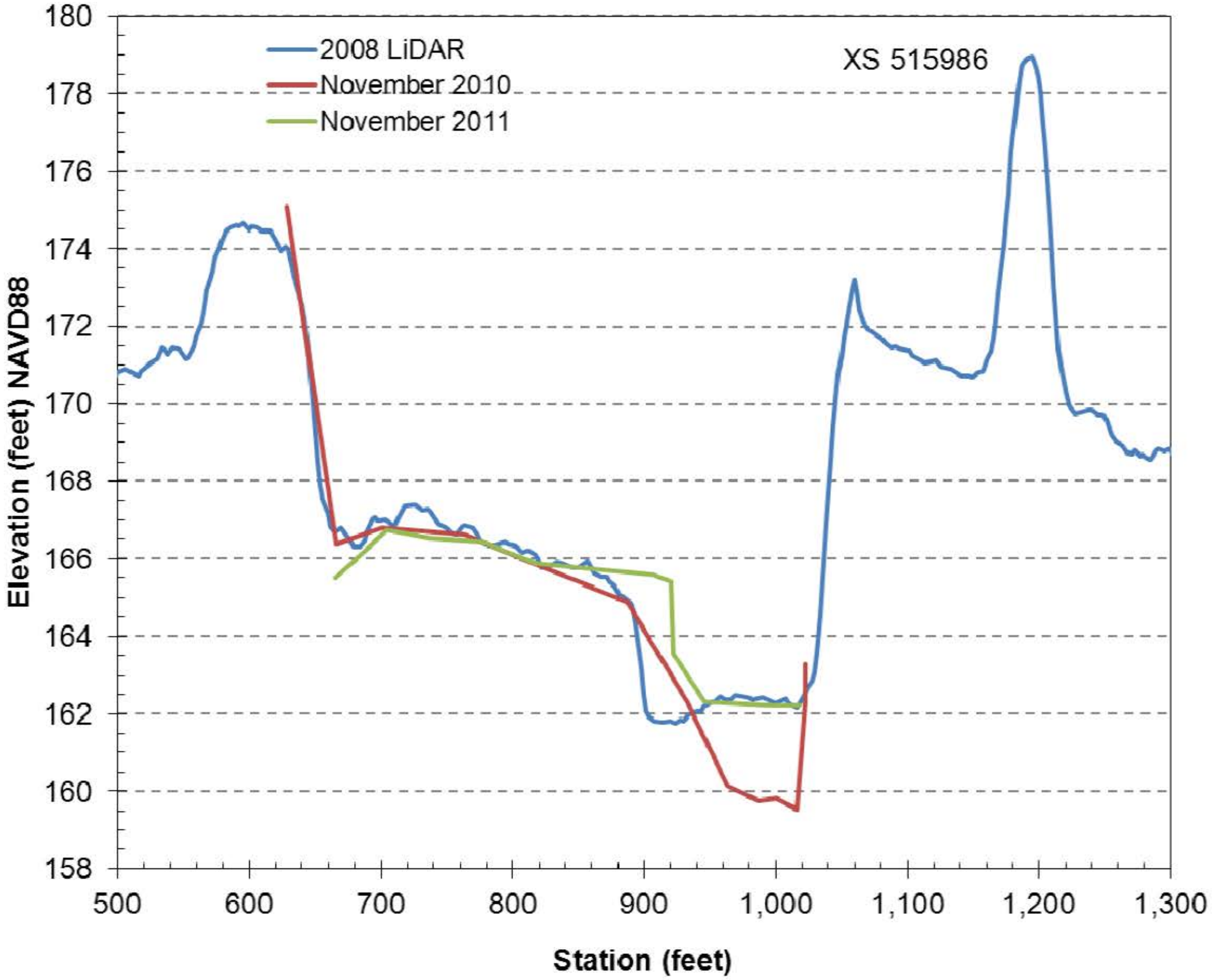


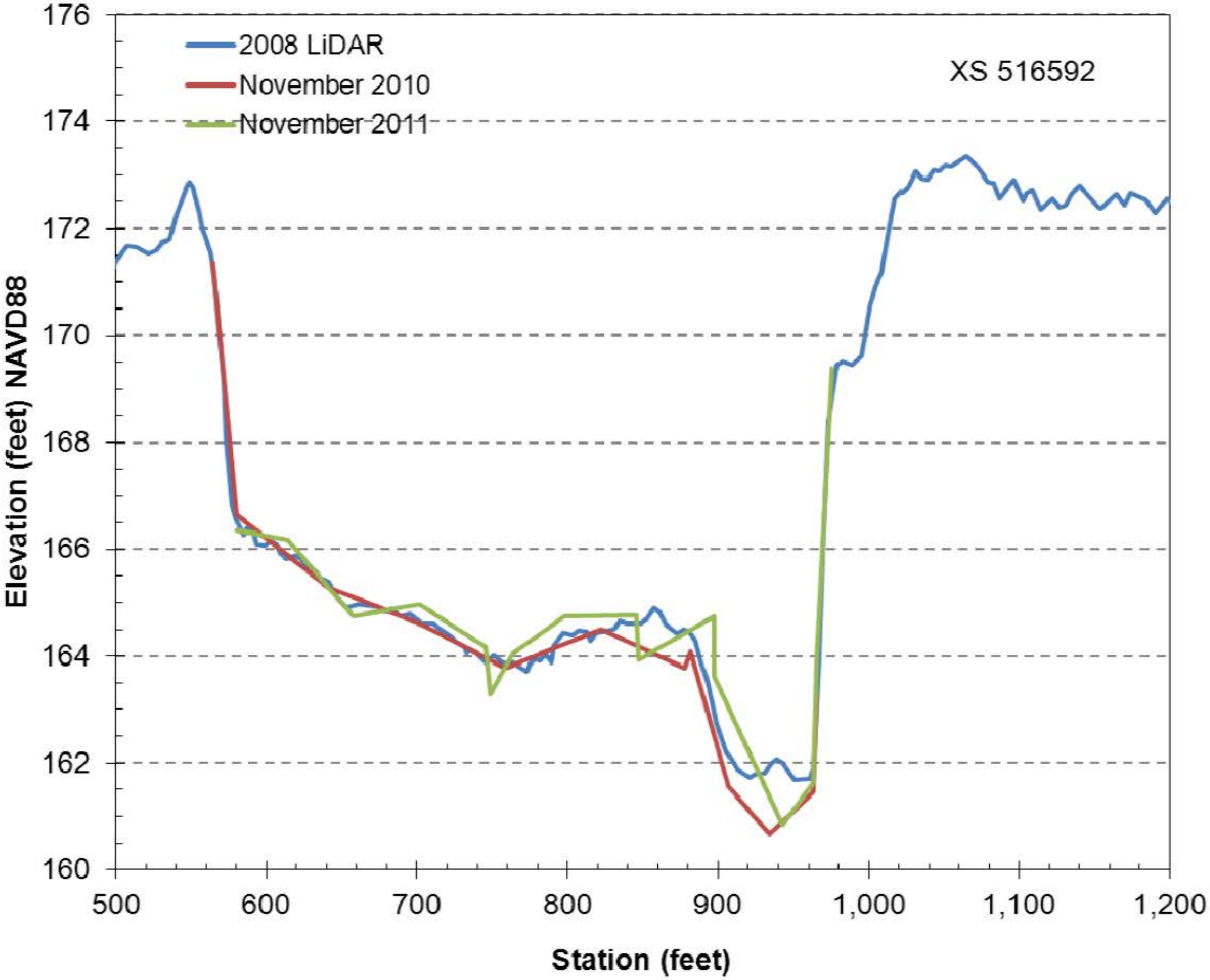
2008 LiDAR
November 2010
November 2011
XS 515091
Elevation (feet) NAVD88
185
180
175
170
165
160
155
500
600
700
800
900
1,000
1,100
Station (feet)

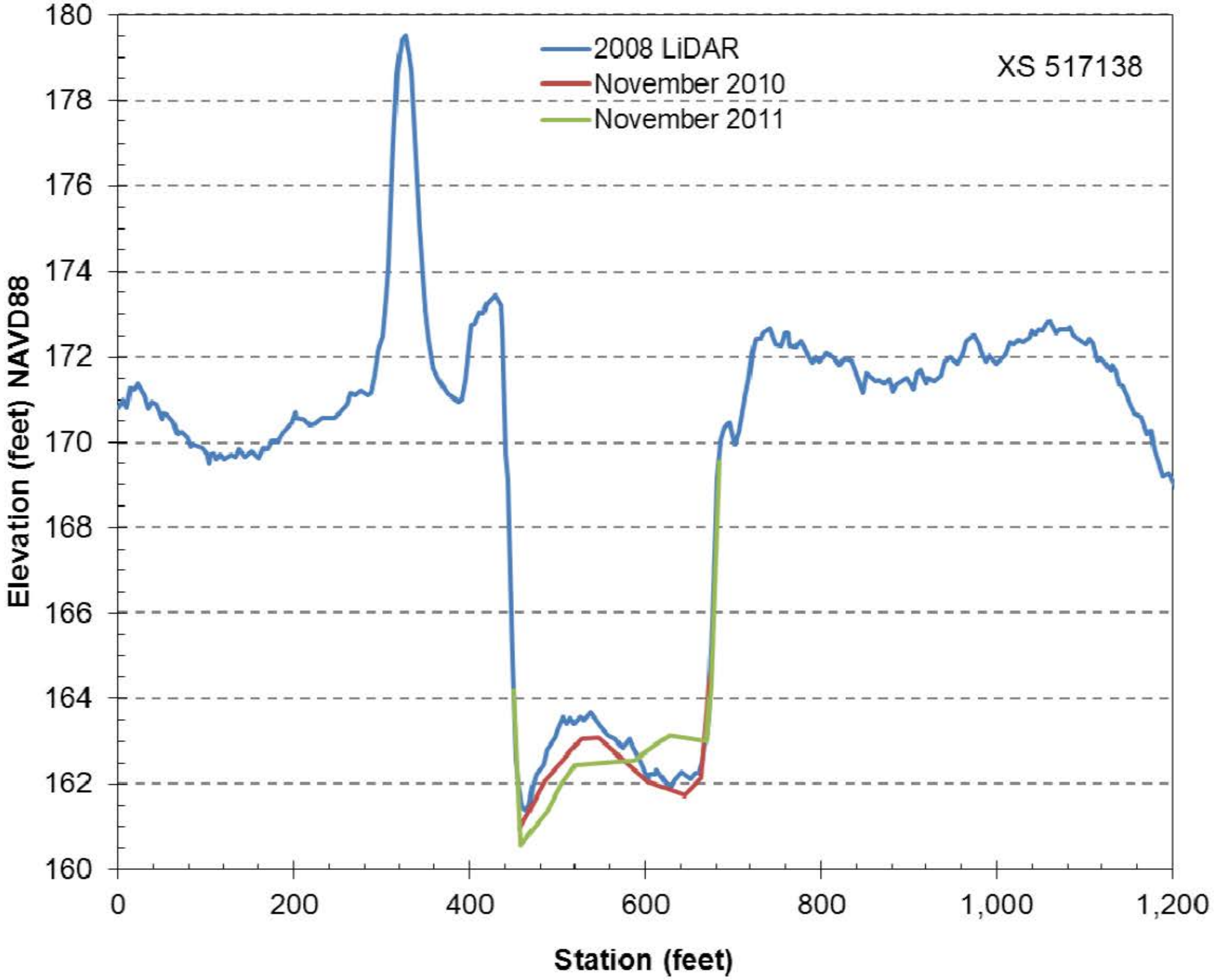


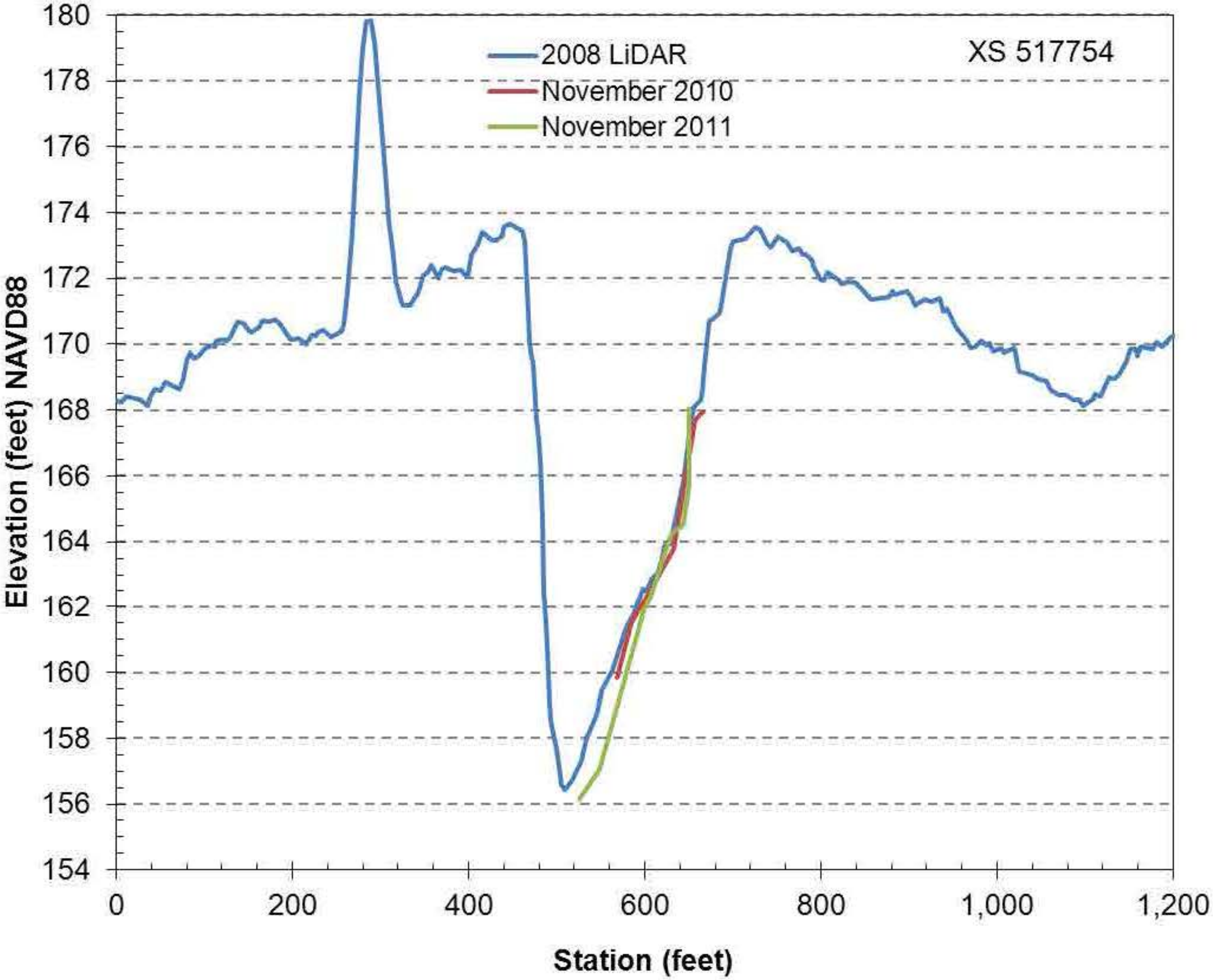
2008 LiDAR
November 2010
November 2011
XS 515130
185
180
175
170
165
160
155
Elevation (feet) NAVD88
500
600
700
800
900
1,000
1,100
Station (feet)

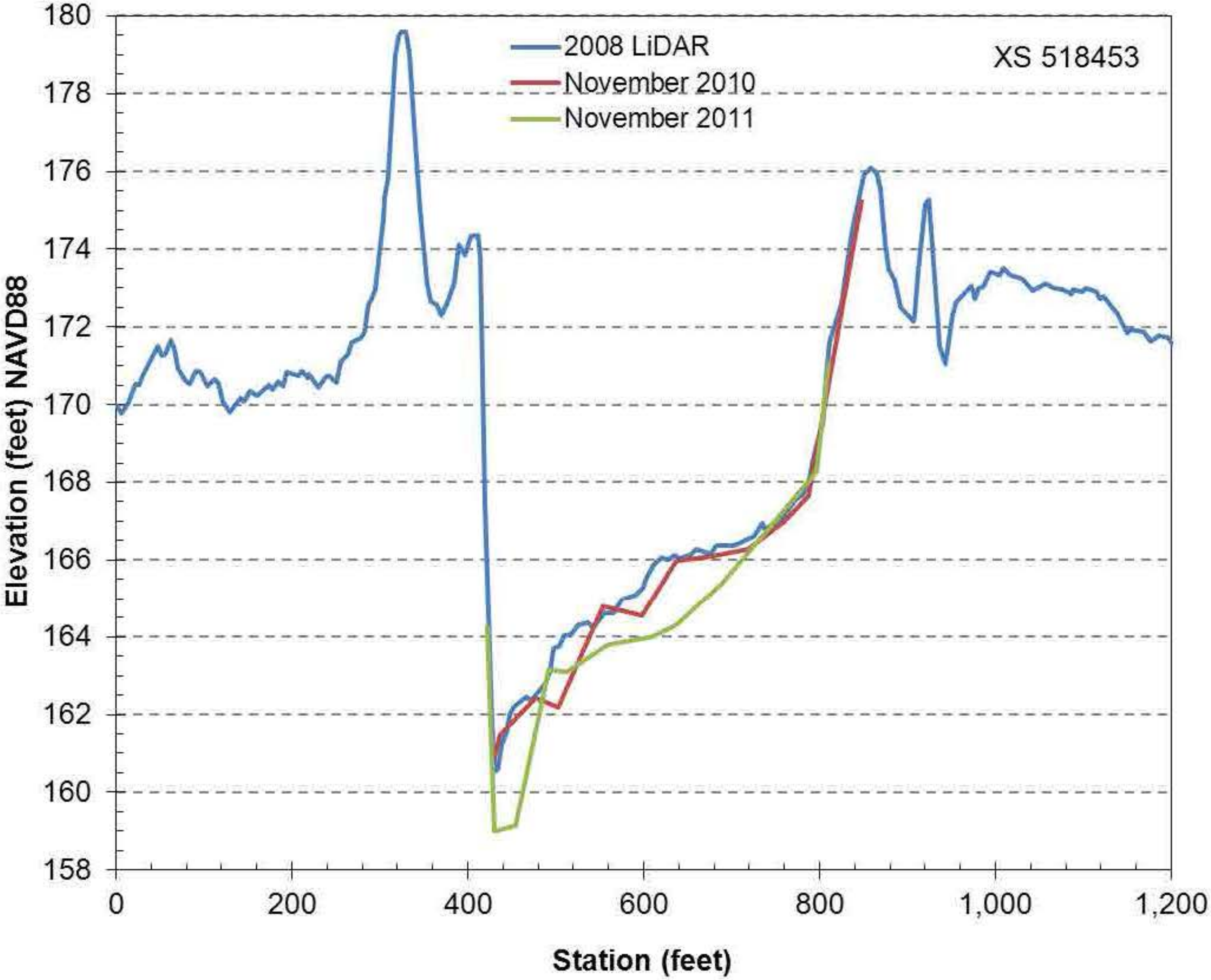

XS 515424
2008 LiDAR
November 2010
November 2011
Elevation (feet) NAVD88
Station (feet)
180
178
176
174
172
170
168
166
164
162
160
158
500
600
700
800
900
1,000
1,100
1,200
1,300

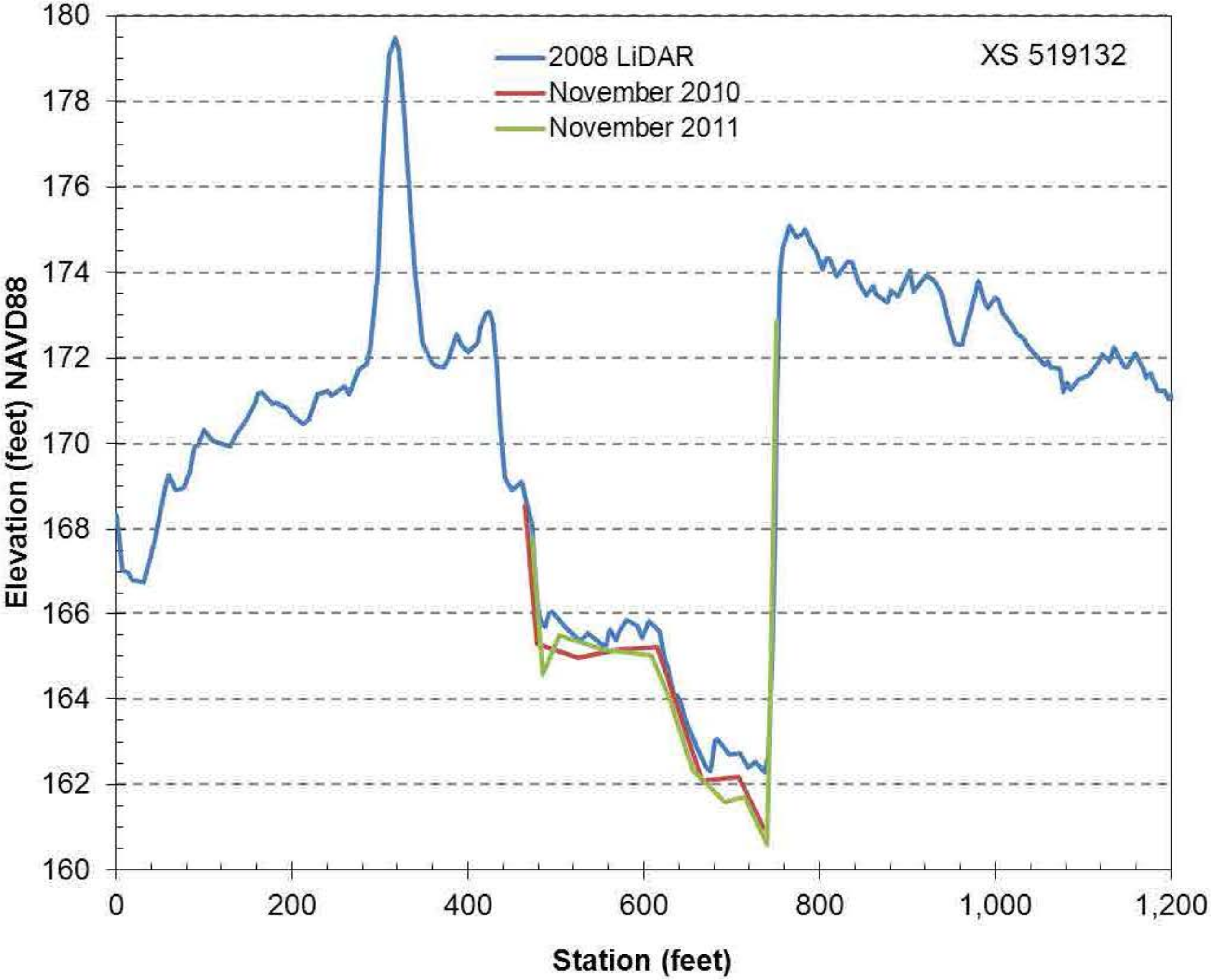

2008 LiDAR
November 2010
November 2011
XS 515986
Elevation (feet) NAVD88
180
178
176
174
172
170
168
166
164
162
160
158
500
600
700
800
900
1,000
1,100
1,200
1,300
Station (feet)

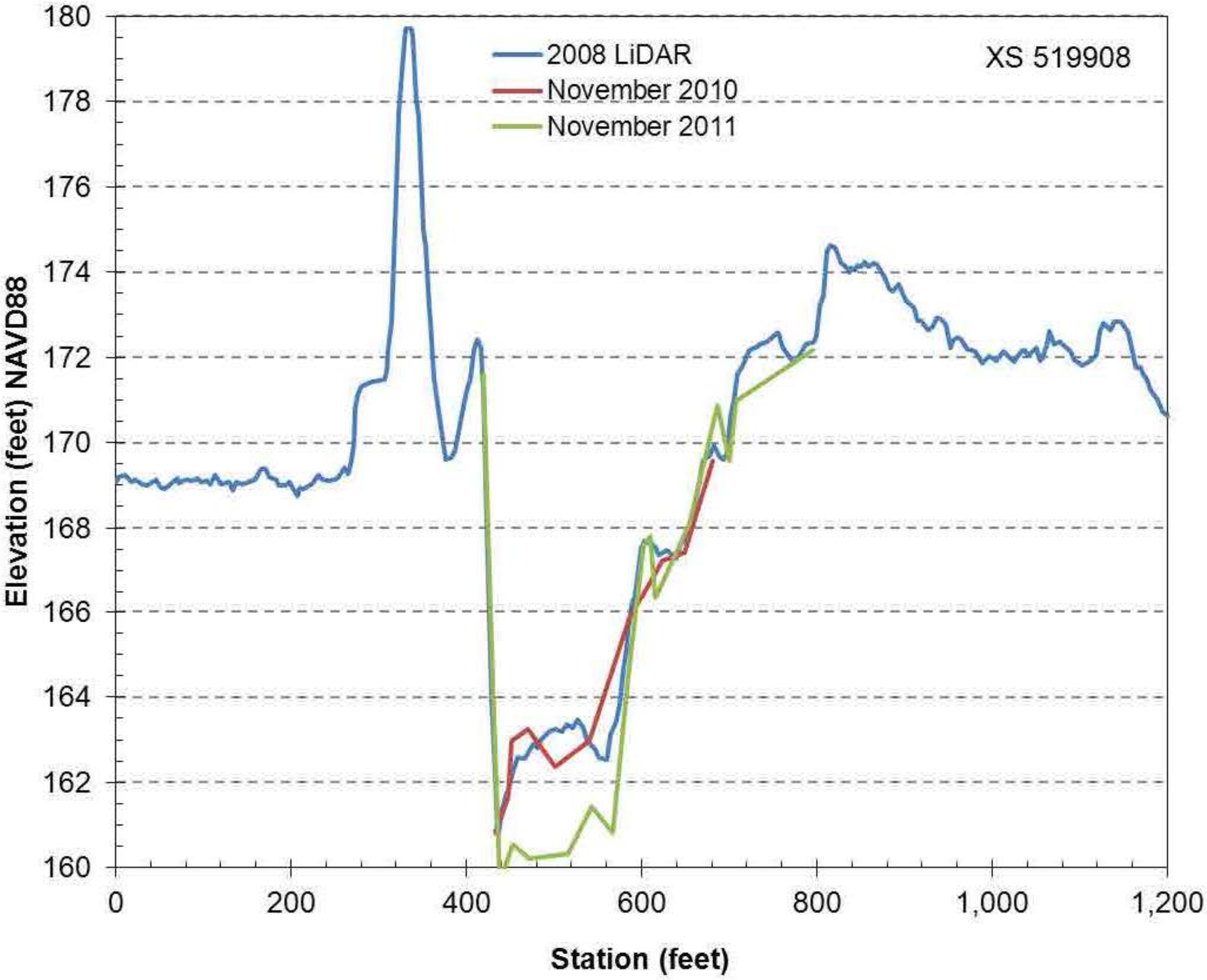

2008 LiDAR
November 2010
November 2011
XS 516592
Elevation (feet) NAVD88
Station (feet)
176
174
172
170
168
166
164
162
160
500
600
700
800
900
1,000
1,100
1,200


2008 LiDAR
November 2010
November 2011
XS 517138
Elevation (feet) NAVD88
180
178
176
174
172
170
168
166
164
162
160
0
200
400
600
800
1,000
1,200
Station (feet)

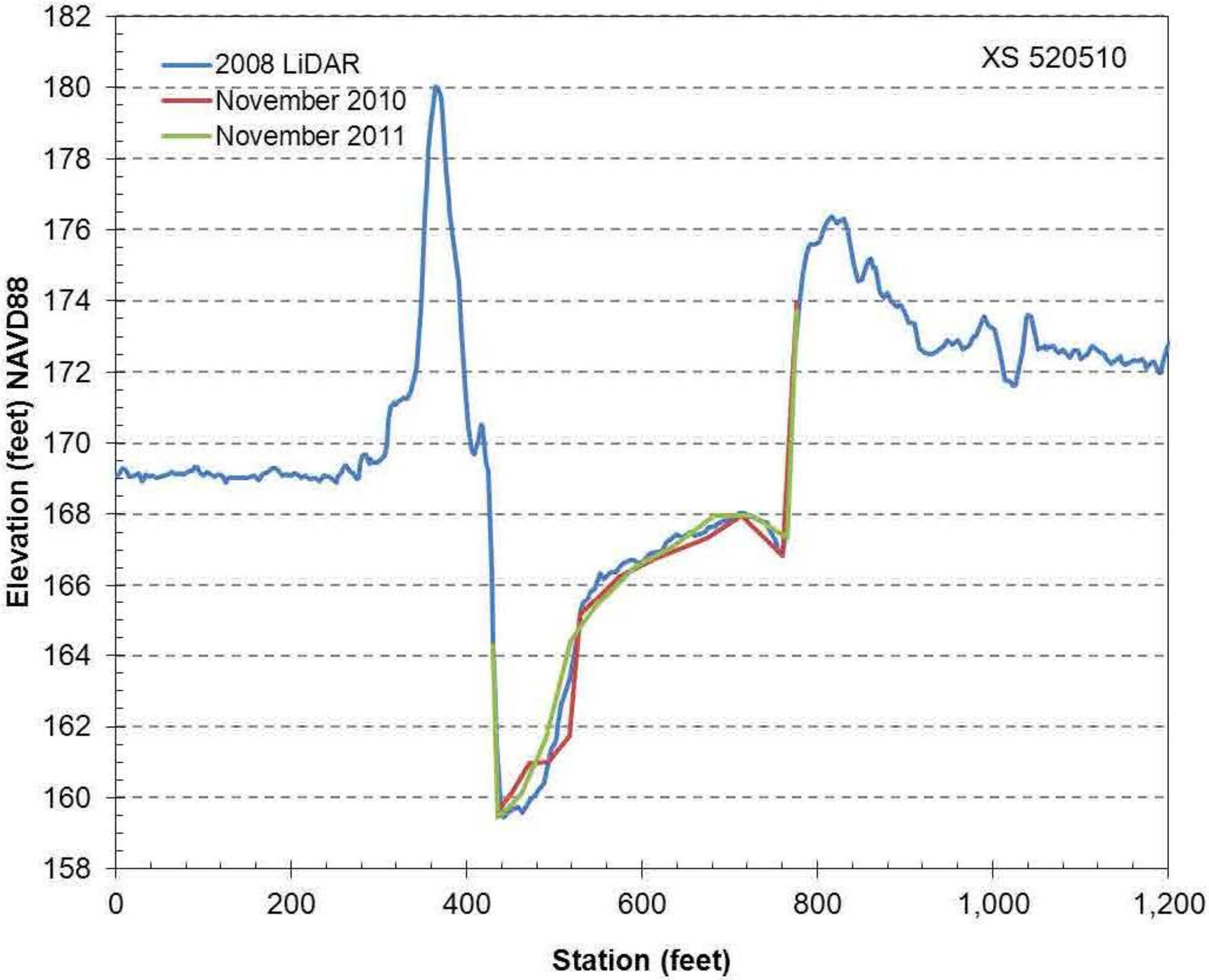

XS 517754
2008 LiDAR
November 2010
November 2011
Elevation (feet) NAVD88
Station (feet)
180
178
176
174
172
170
168
166
164
162
160
158
156
154
0
200
400
600
800
1,000
1,200


2008 LiDAR
November 2010
November 2011
XS 518453
Elevation (feet) NAVD88
180
178
176
174
172
170
168
166
164
162
160
158
Station (feet)
0
200
400
600
800
1,000
1,200

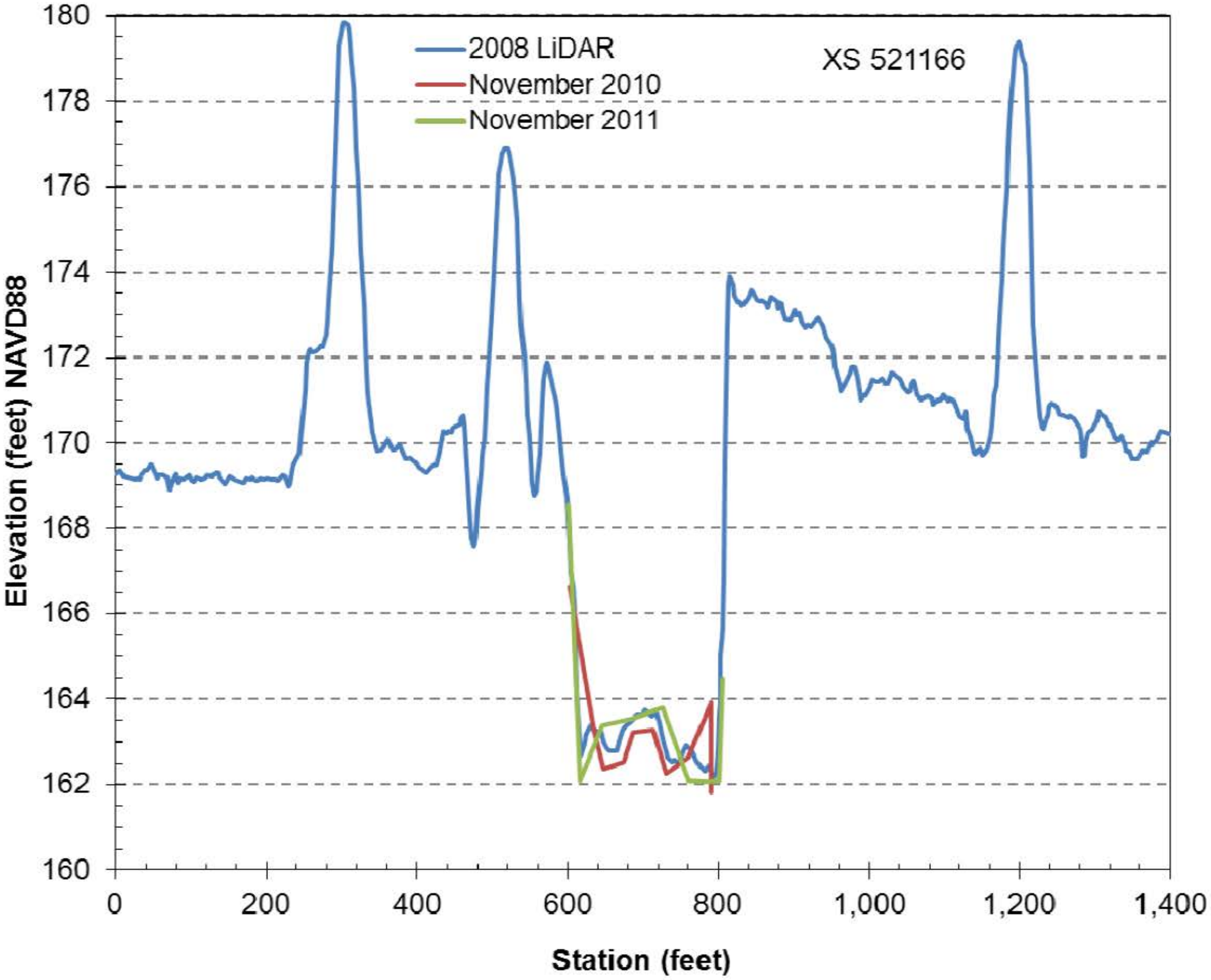

180
178
176
174
172
170
168
166
164
162
160
Elevation (feet) NAVD88
0
200
400
600
800
1,000
1,200
Station (feet)
2008 LiDAR
November 2010
November 2011
XS 519132

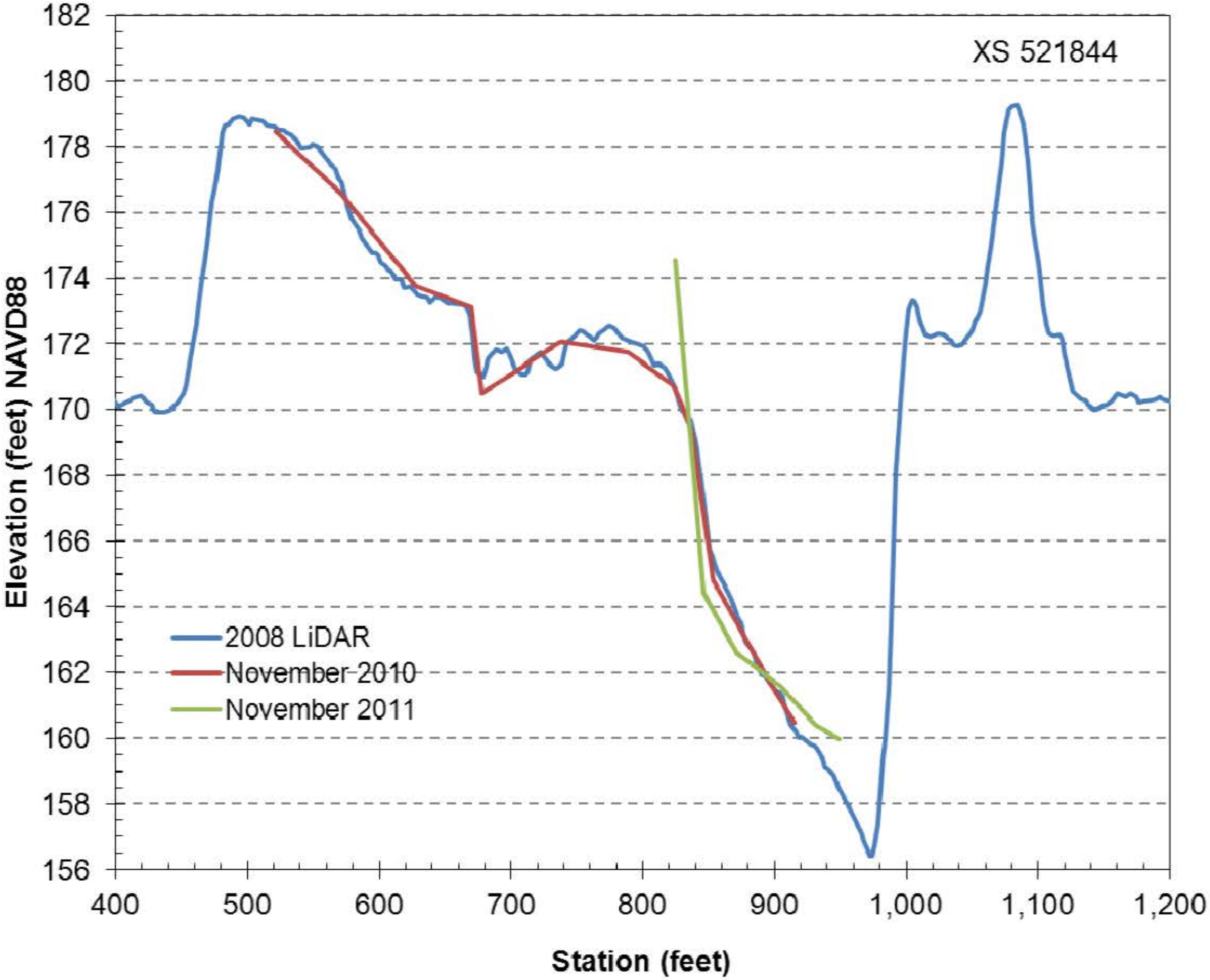


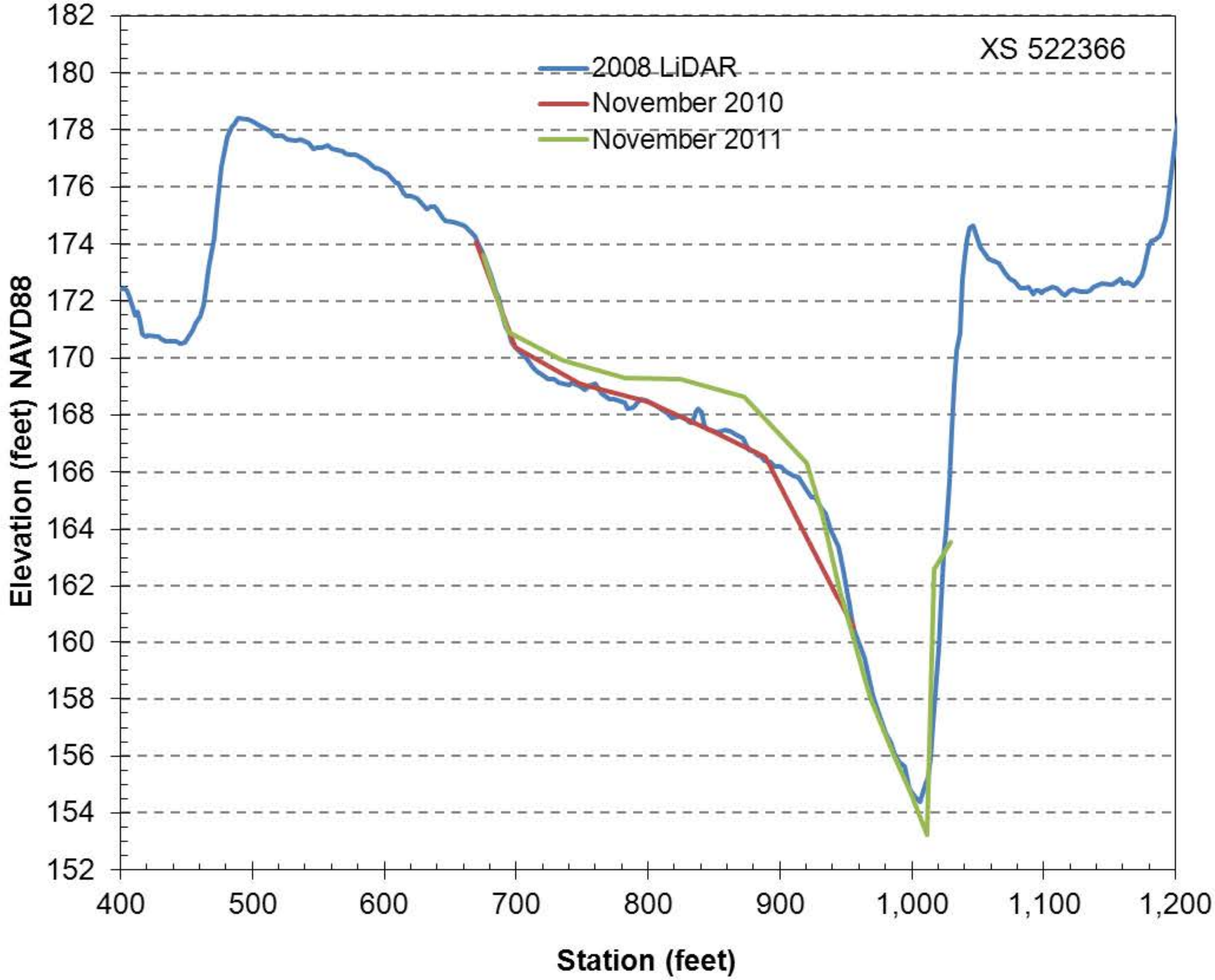
XS 519908
2008 LiDAR
November 2010
November 2011
Elevation (feet) NAVD88
180
178
176
174
172
170
168
166
164
162
160
Station (feet)
0
200
400
600
800
1,000
1,200

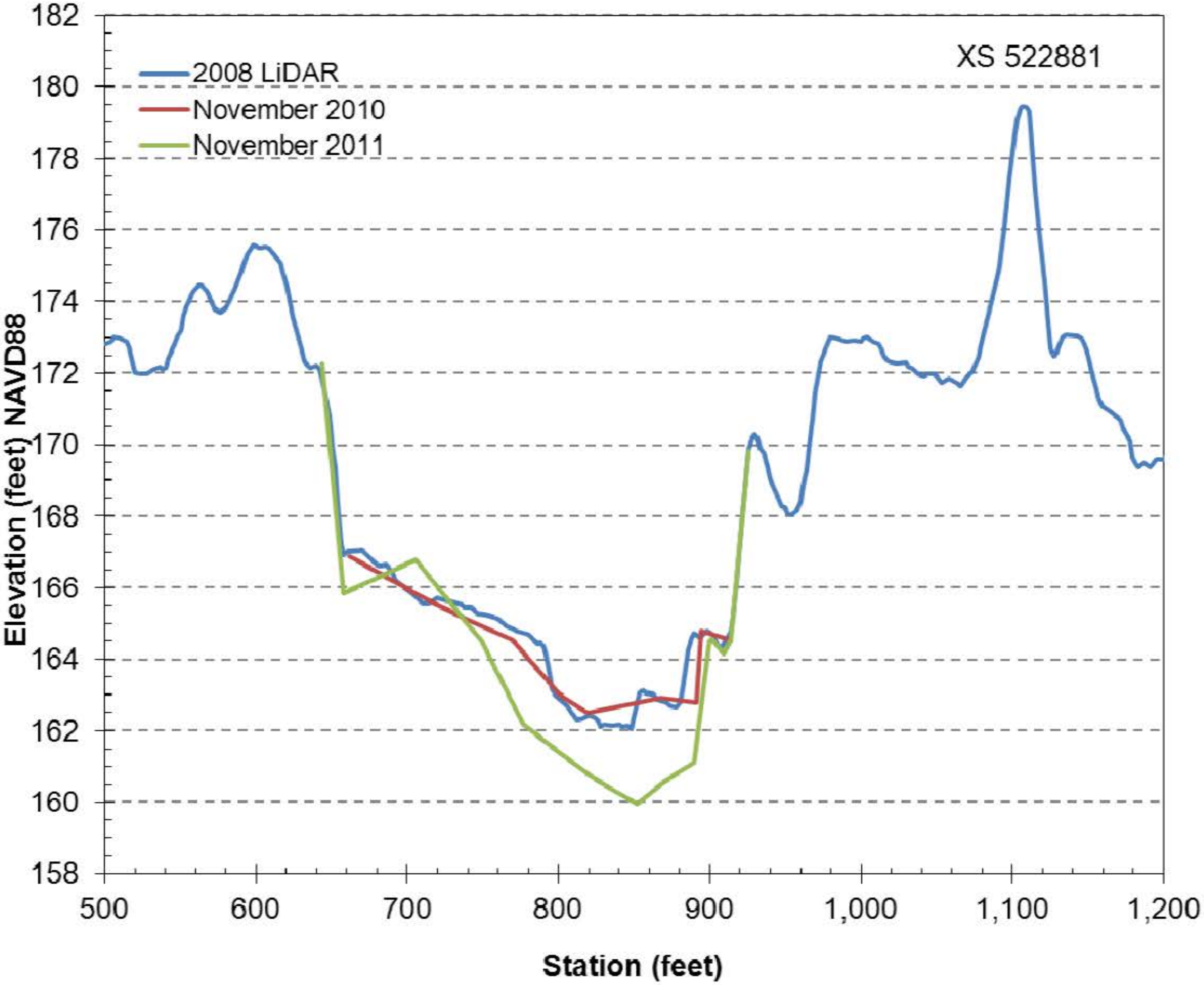


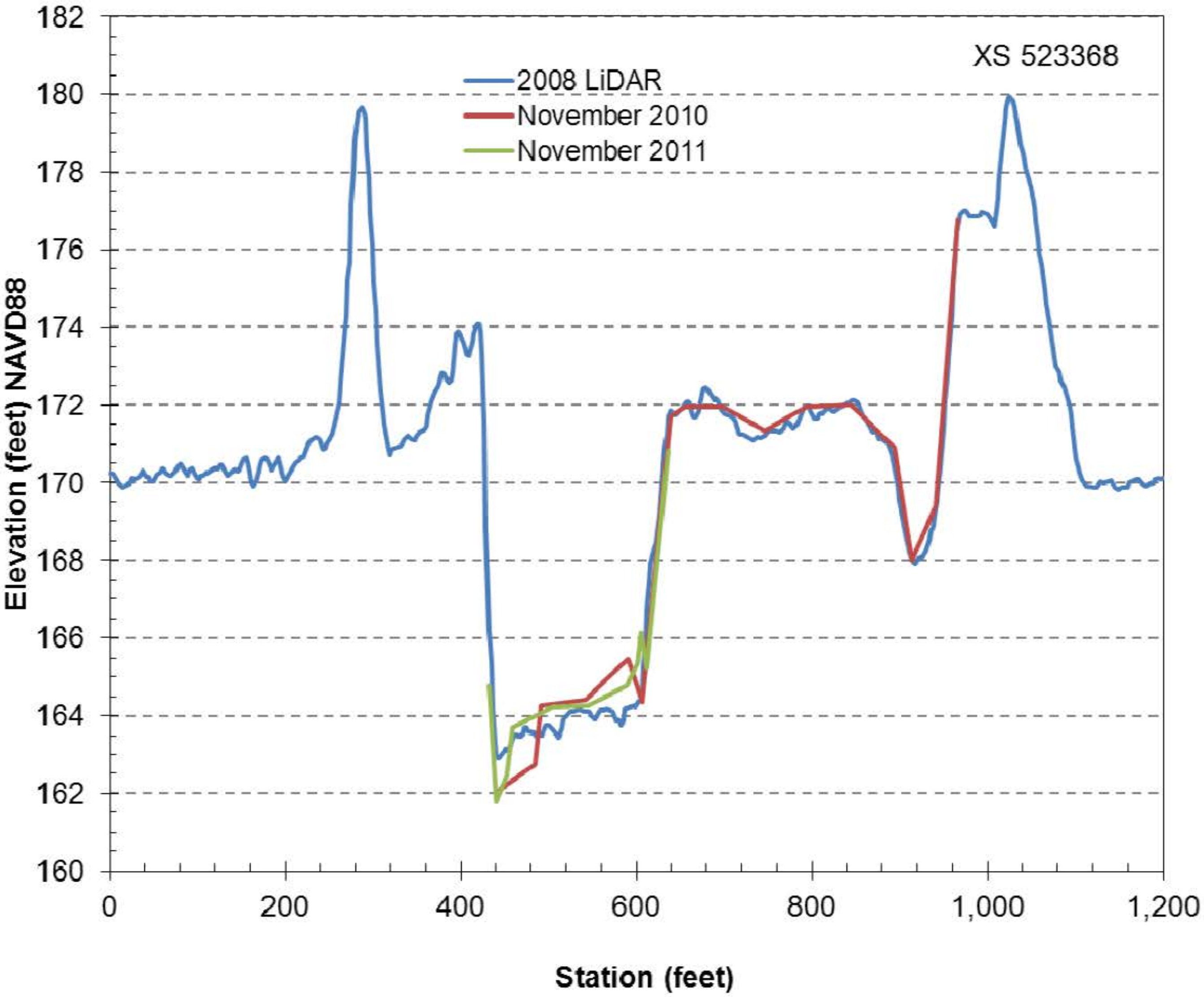
XS 520510
2008 LiDAR
November 2010
November 2011
Elevation (feet) NAVD88
182
180
178
176
174
172
170
168
166
164
162
160
158
0
200
400
600
800
1,000
1,200
Station (feet)

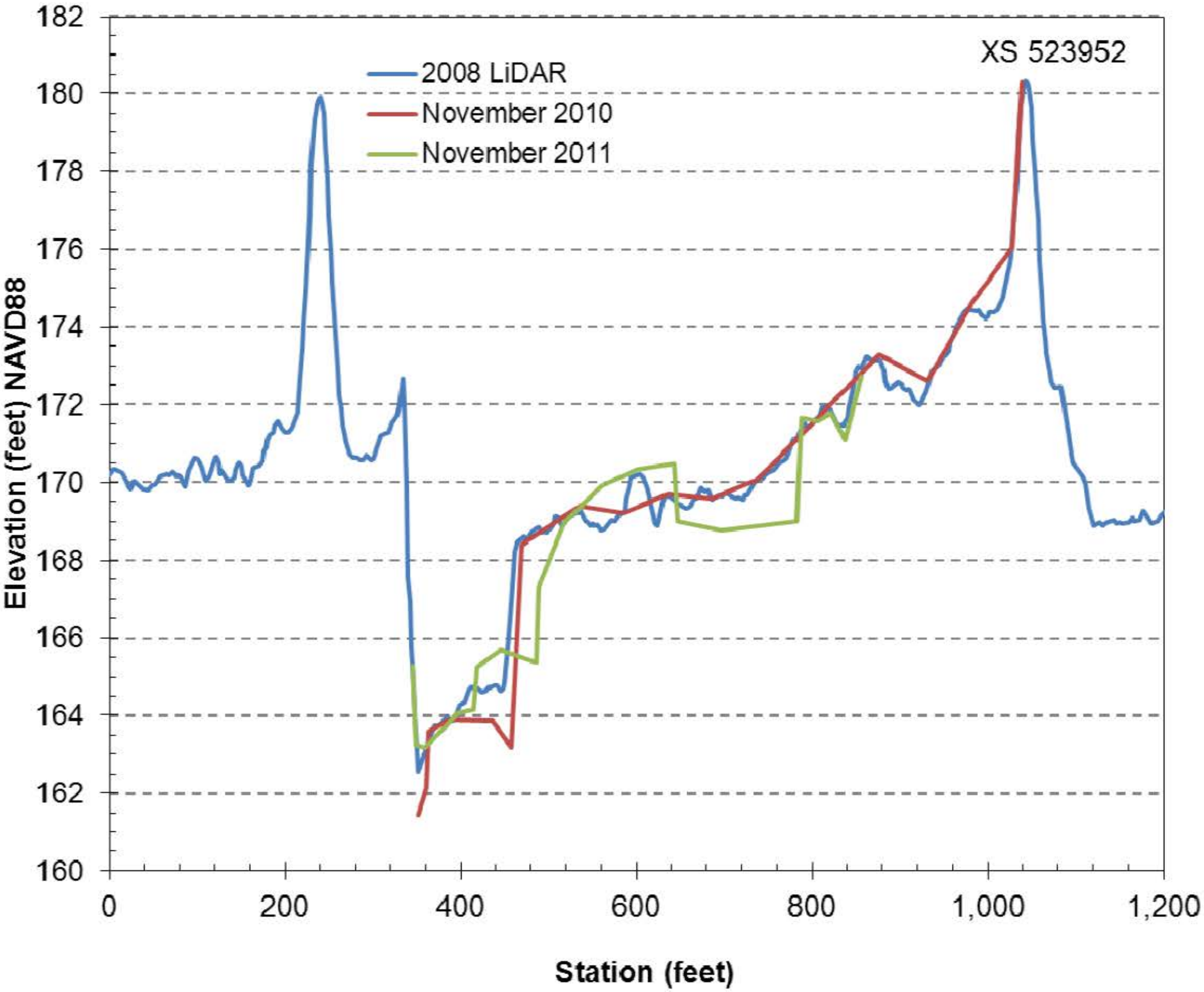

2008 LiDAR
November 2010
November 2011
XS 521166
Elevation (feet) NAVD88
180
178
176
174
172
170
168
166
164
162
160
0
200
400
600
800
1,000
1,200
1,400
Station (feet)

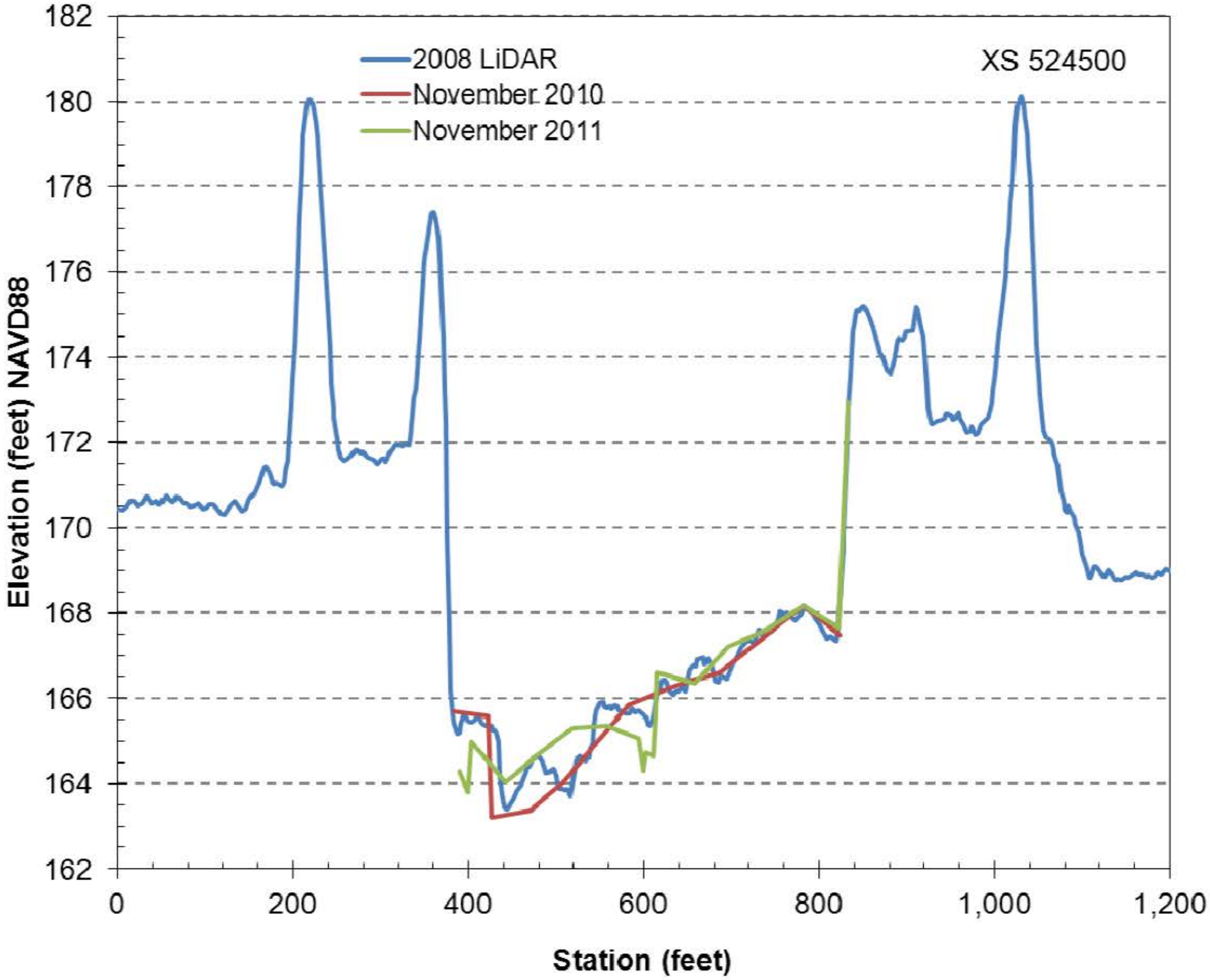

XS 521844
Elevation (feet) NAVD88
Station (feet)
182
180
178
176
174
172
170
168
166
164
162
160
158
156
400
500
600
700
800
900
1,000
1,100
1,200
2008 LiDAR
November 2010
November 2011


XS 522366
2008 LiDAR
November 2010
November 2011
Elevation (feet) NAVD88
182
180
178
176
174
172
170
168
166
164
162
160
158
156
154
152
Station (feet)
400
500
600
700
800
900
1,000
1,100
1,200


XS 522881
2008 LiDAR
November 2010
November 2011
Elevation (feet) NAVD88
182
180
178
176
174
172
170
168
166
164
162
160
158
Station (feet)
500
600
700
800
900
1,000
1,100
1,200


XS 523368
2008 LiDAR
November 2010
November 2011
Elevation (feet) NAVD88
182
180
178
176
174
172
170
168
166
164
162
160
0
200
400
600
800
1,000
1,200
Station (feet)


XS 523952
2008 LiDAR
November 2010
November 2011
Elevation (feet) NAVD88
182
180
178
176
174
172
170
168
166
164
162
160
Station (feet)
0
200
400
600
800
1,000
1,200


XS 524500
2008 LiDAR
November 2010
November 2011
Elevation (feet) NAVD88
Station (feet)
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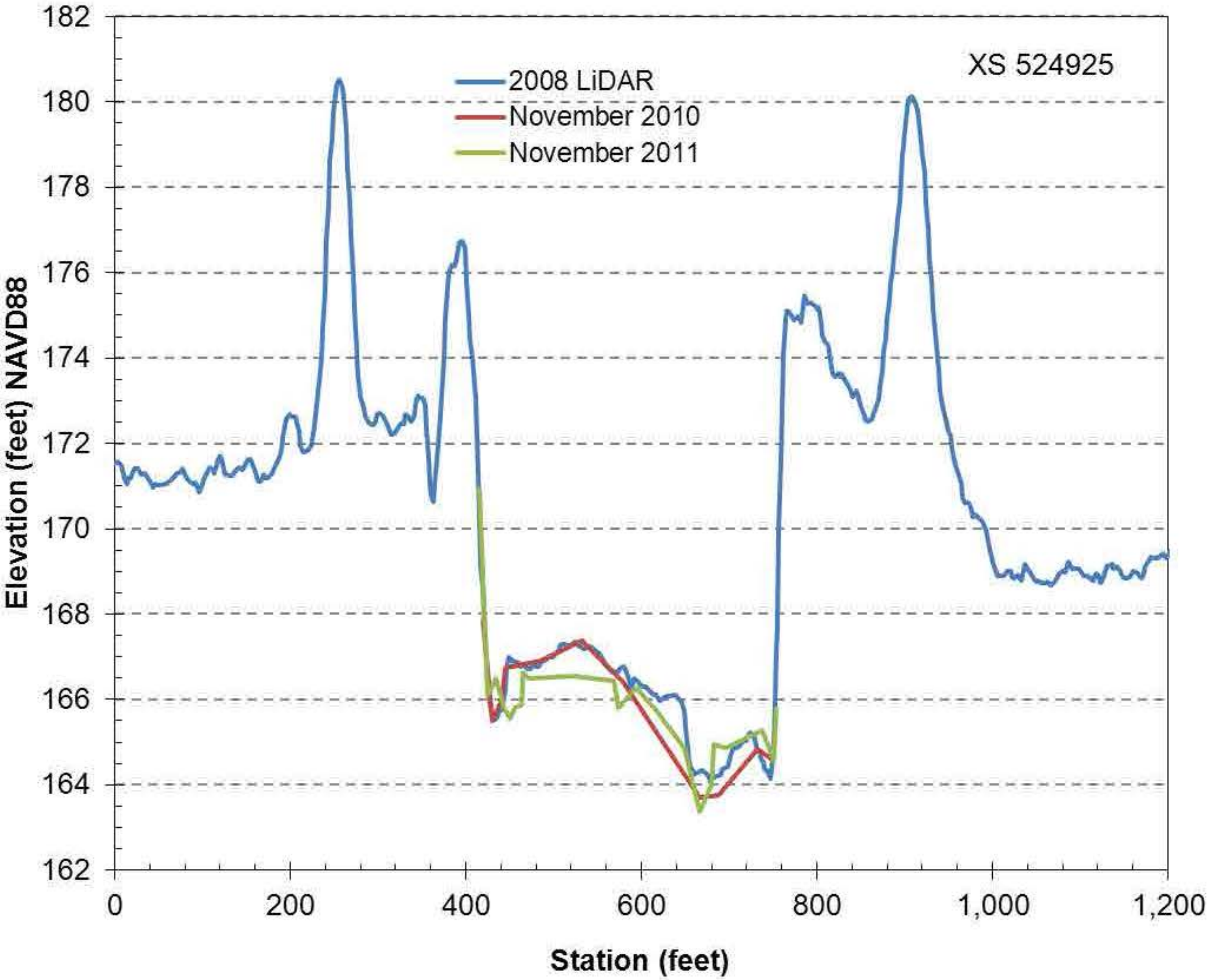
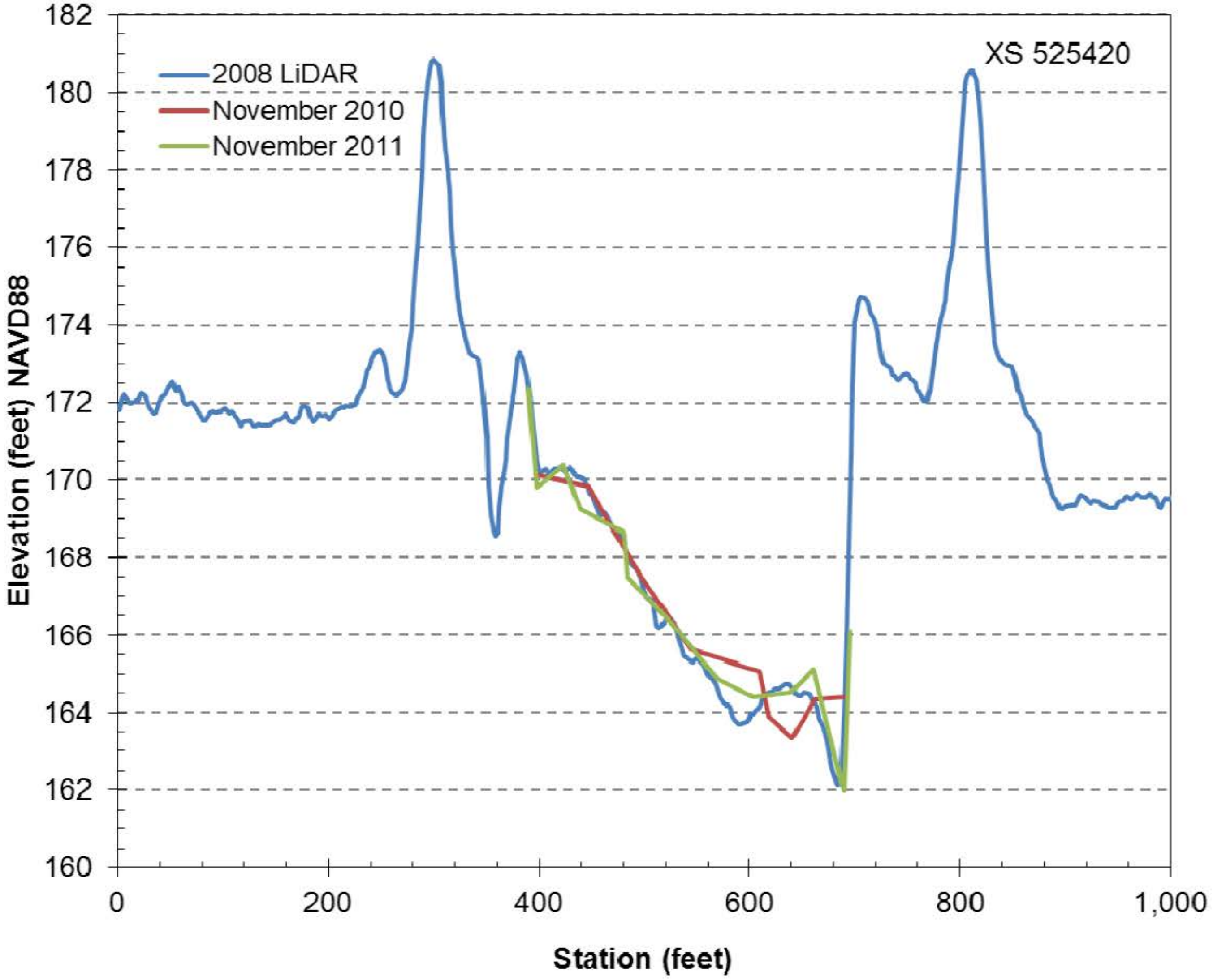
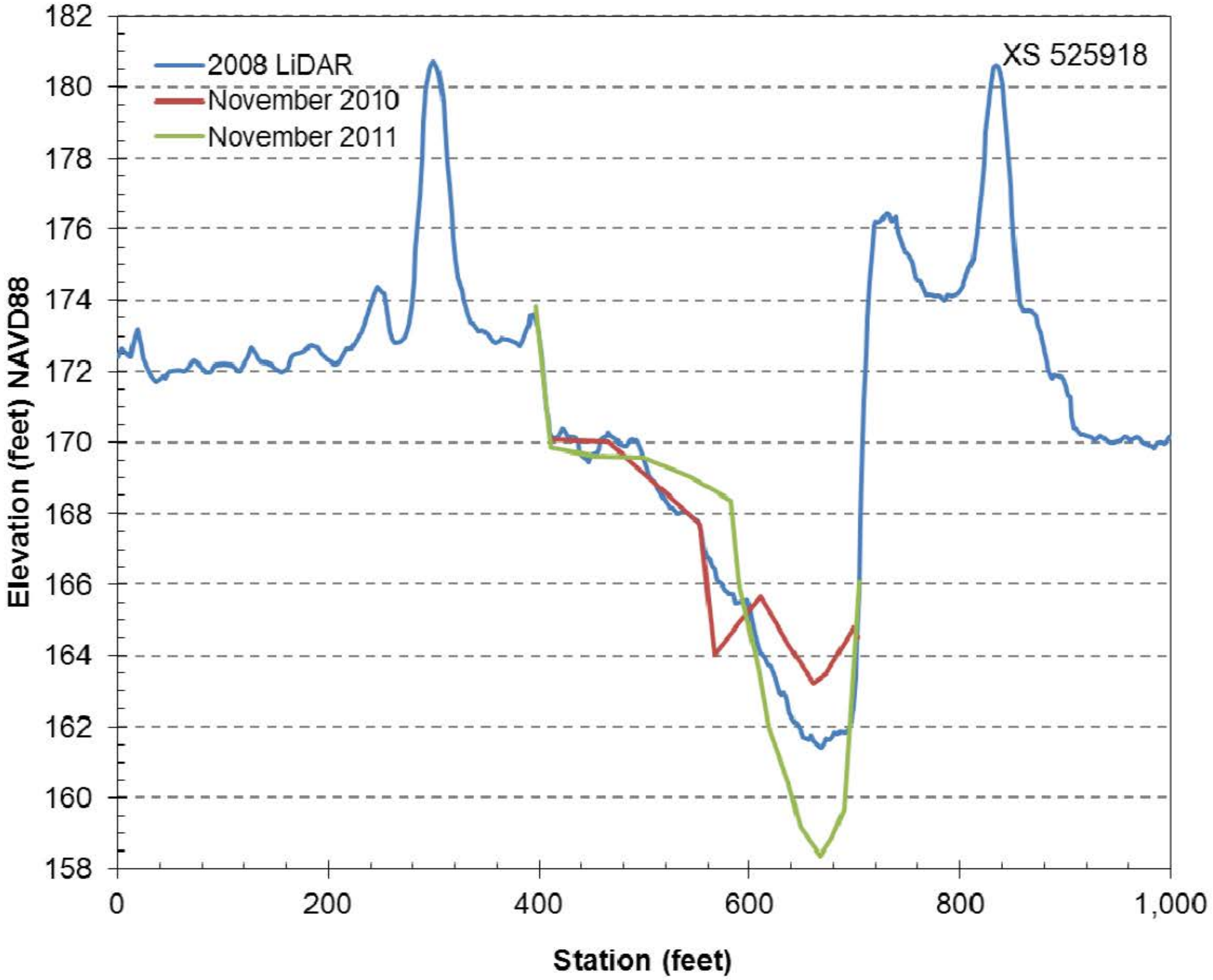
180
178
176
174
172
170
168
166
164
162
0
200
400
600
800
1,000
1,200


XS 524925
2008 LiDAR
November 2010
November 2011
Elevation (feet) NAVD88
182
180
178
176
174
172
170
168
166
164
162
Station (feet)
0
200
400
600
800
1,000
1,200


182
180
178
176
174
172
170
168
166
164
162
160
Elevation (feet) NAVD88
2008 LiDAR
November 2010
November 2011
XS 525420
0
200
400
600
800
1,000
Station (feet)


XS 525918
2008 LiDAR
November 2010
November 2011
Elevation (feet) NAVD88
Station (feet)
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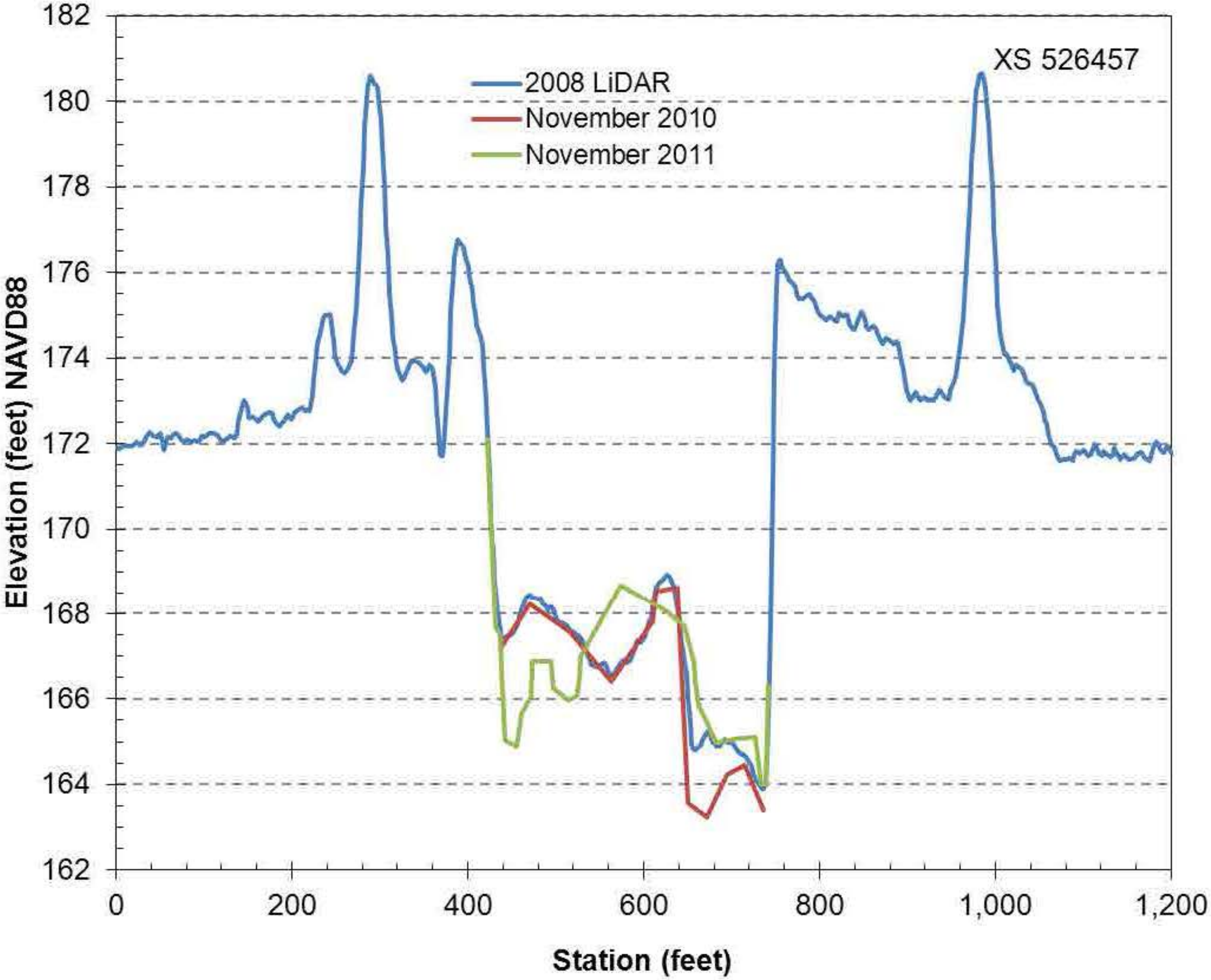
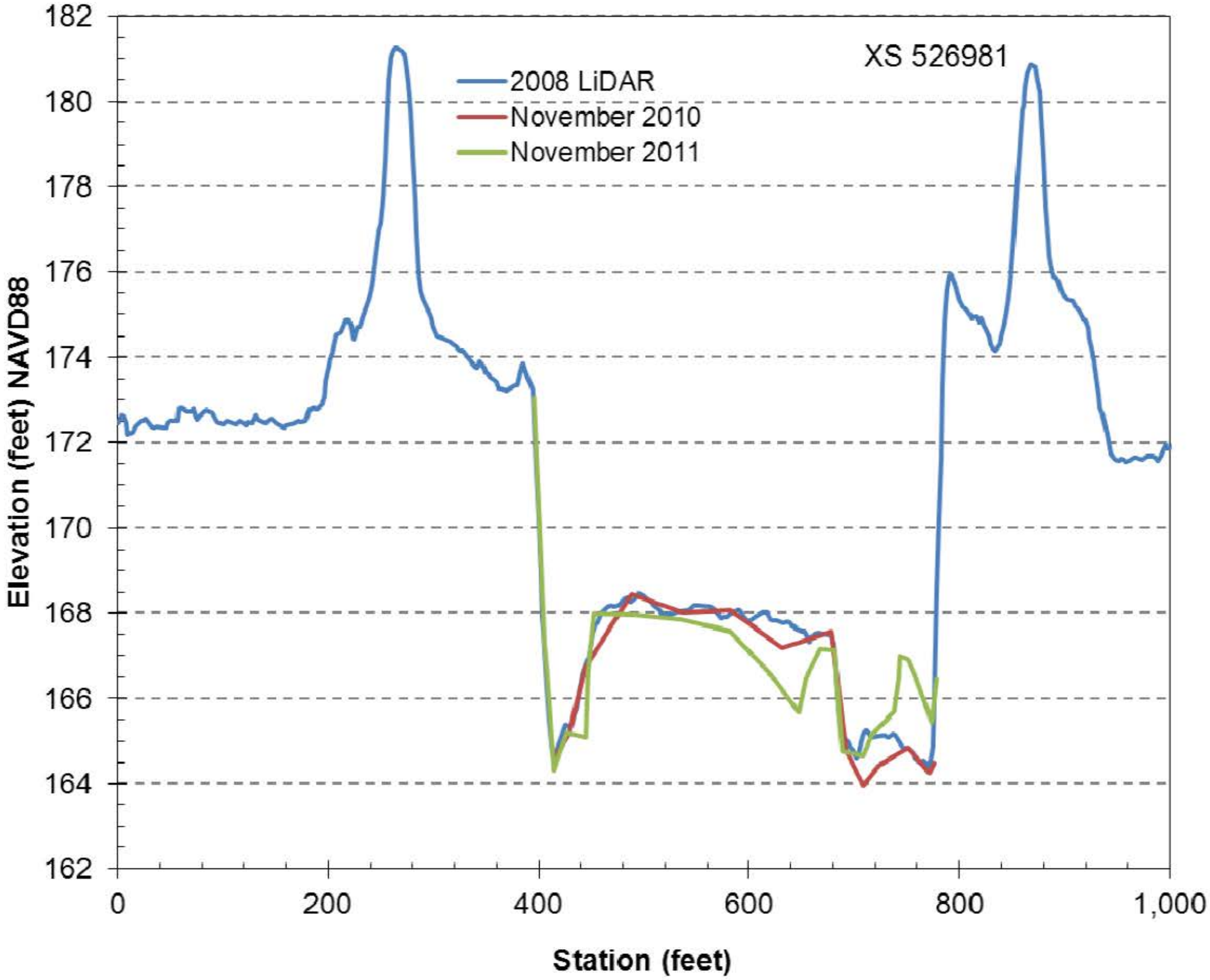
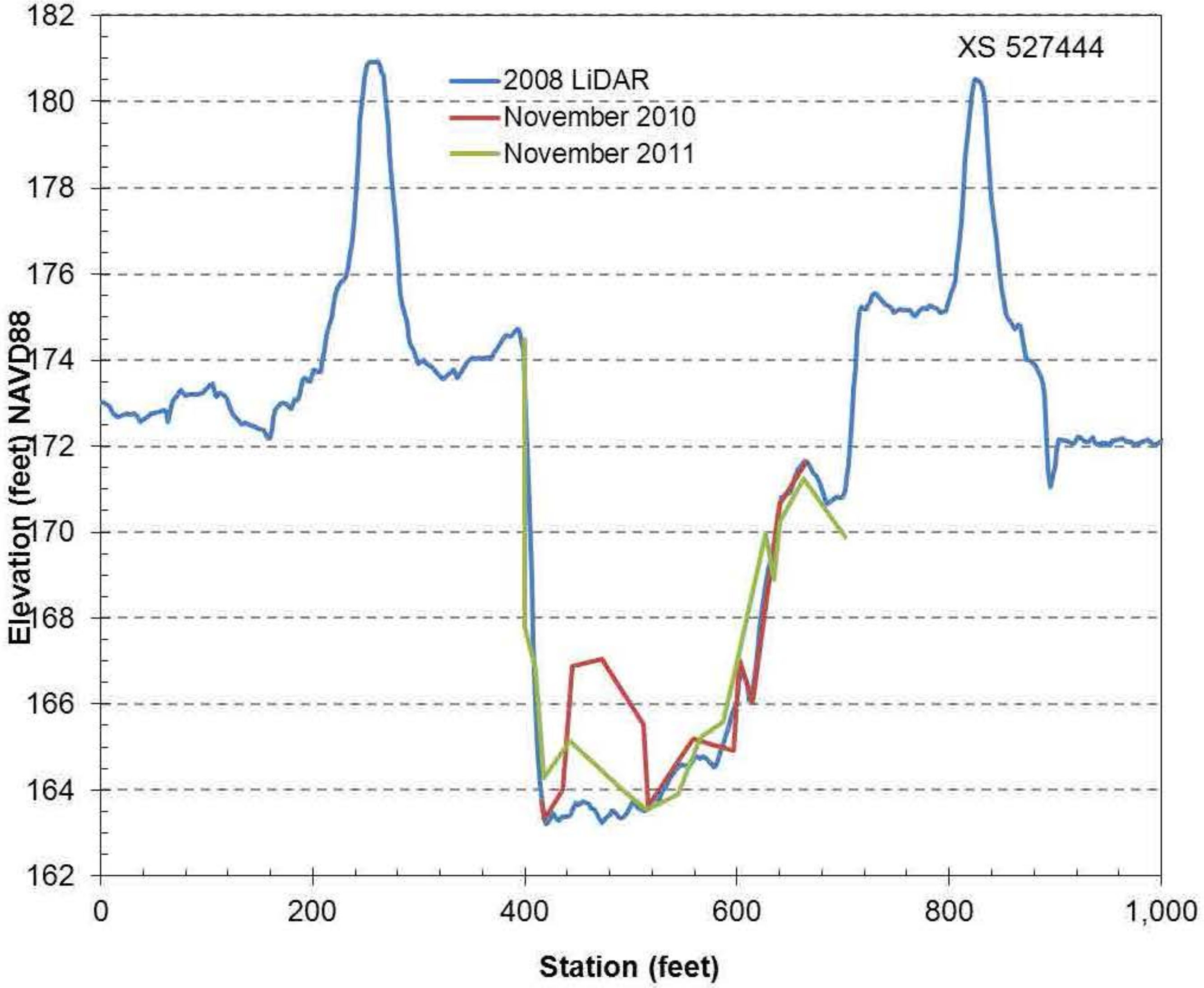
180
178
176
174
172
170
168
166
164
162
160
158
0
200
400
600
800
1,000


XS 526457
2008 LiDAR
November 2010
November 2011
Elevation (feet) NAVD88
182
180
178
176
174
172
170
168
166
164
162
Station (feet)
0
200
400
600
800
1,000
1,200


XS 526981
2008 LiDAR
November 2010
November 2011
Elevation (feet) NAVD88
Station (feet)
182
180
178
176
174
172
170
168
166
164
162
0
200
400
600
800
1,000


XS 527444
2008 LiDAR
November 2010
November 2011
Elevation (feet) NAVD88
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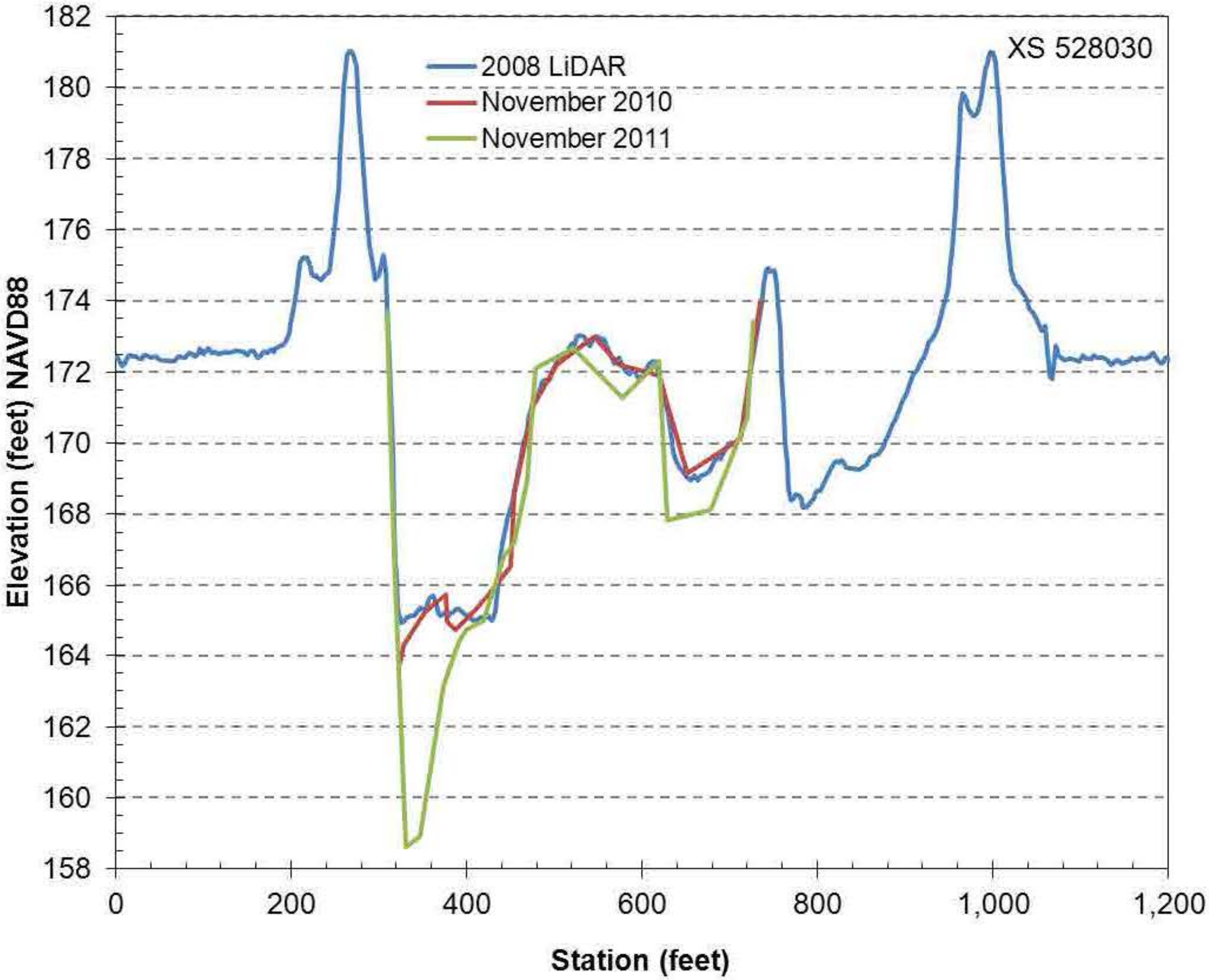
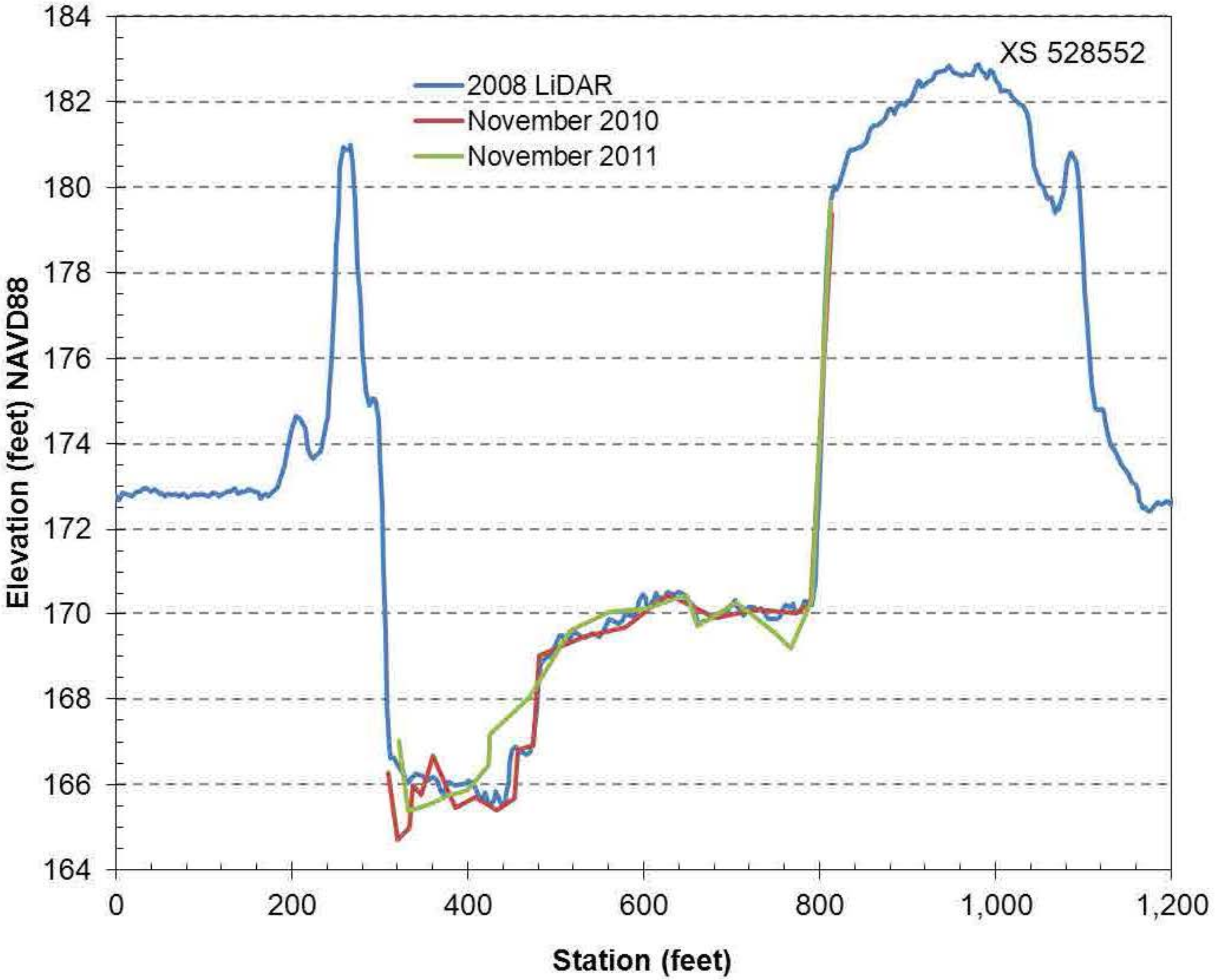
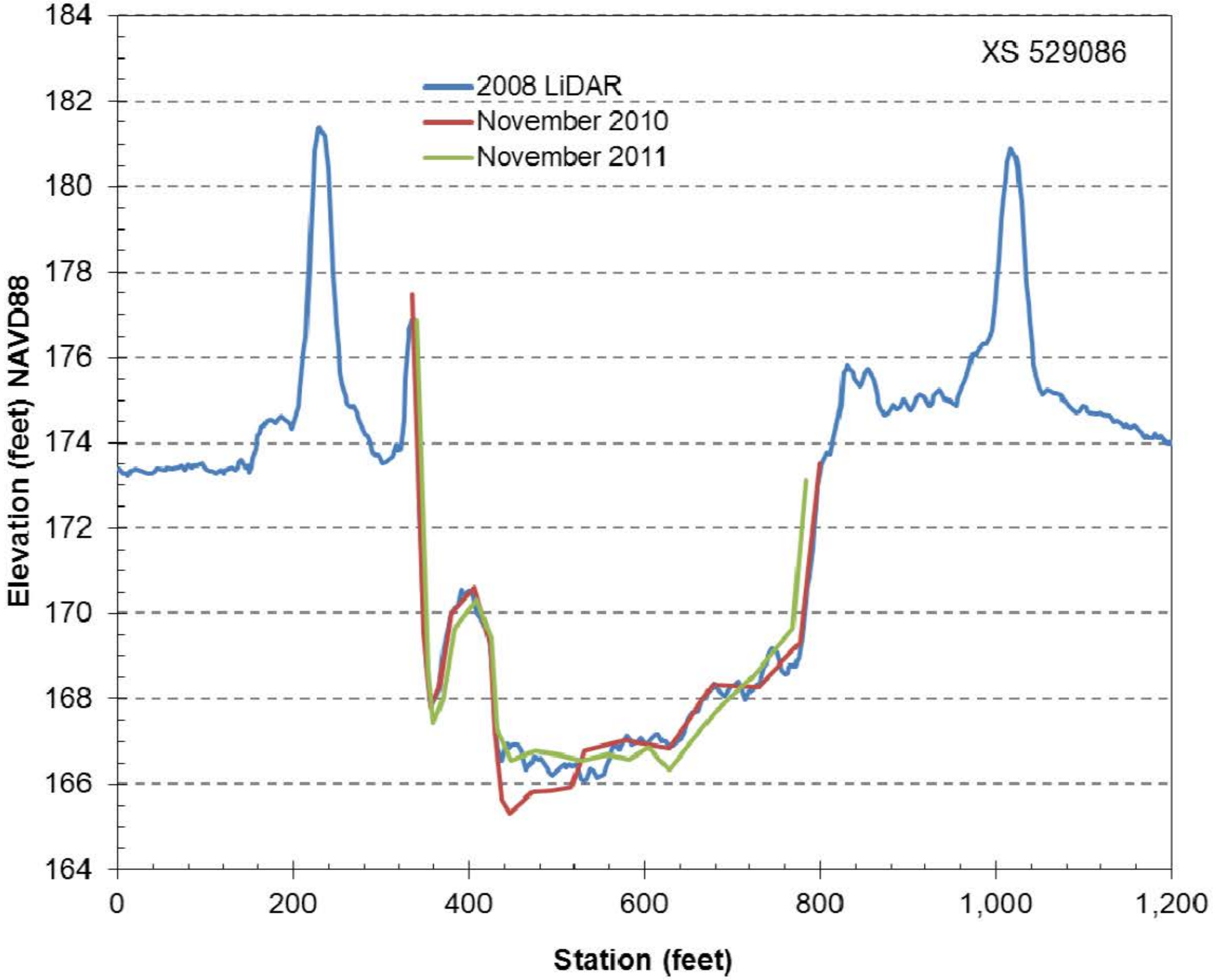
180
178
176
174
172
170
168
166
164
162
0
200
400
600
800
1,000
Station (feet)


XS 528030
2008 LiDAR
November 2010
November 2011
Elevation (feet) NAVD88
Station (feet)
182
180
178
176
174
172
170
168
166
164
162
160
158
0
200
400
600
800
1,000
1,200


XS 528552
2008 LiDAR
November 2010
November 2011
Elevation (feet) NAVD88
Station (feet)
184
182
180
178
176
174
172
170
168
166
164
0
200
400
600
800
1,000
1,200


XS 529086
2008 LiDAR
November 2010
November 2011
184
182
180
178
176
174
172
170
168
166
164
Elevation (feet) NAVD88
0
200
400
600
800
1,000
1,200
Station (feet)