MEMORANDUM

TO:	Jim Well, Ducks Unlimited
FROM:	Dai Thomas, PhD., PE, and Mike Harvey, PhD., PG
SUBJECT:	**June 2017 Resurvey of M&T/Llano Seco Pumping Plant and City of Chico Outfall Reach of the Sacramento River** **M&T/Llano Seco Fish Screen Facility Long-term Protection Project, Phase IV, Project No. US-CA-62-6**
DATE:	July 26, 2017

1. INTRODUCTION

As part of an effort to reduce the risk of mortality to native anadromous salmonids, including special-status species within the Sacramento River Basin, the M&T Chico Ranch/Llano Seco Rancho fish screen and pumping facility was redesigned, upgraded, and relocated from Big Chico Creek to the Sacramento River during 1997. Since its construction, local geomorphic changes including erosion and lateral migration of the west bank of the Sacramento River and related sediment deposition at the mouth of Big Chico Creek and in the vicinity of the fish screened intakes have posed a threat to the normal operation and fish protection function of the M&T Chico Ranch/Llano Seco Rancho diversion facility.

An upriver gravel bar adjacent to the Bidwell-Sacramento River State Park is migrating toward the vicinity of the fish-screened diversion. As a result of continued sediment deposition and increased river meander, the intake screens are progressively becoming threatened by encroaching sediment, which could cause a reduction in sweeping velocities across the screens (parallel to screen). A reduction in sweeping velocities would render the screens out of compliance with the National Oceanographic and Atmospheric Administration's National Marine Fisheries Service (NMFS) and the CDFG fish screen criteria. Periodic maintenance is required to reduce the size of the gravel bar and prevent interference with the diversion facility. In 2001 and 2007, 200,000 and 100,000 tons of material, respectively, were excavated from the gravel bar as a short-term solution to limit sedimentation impacts. Additionally in 2007, 1,500 feet of short-term, rock toe and brush bank protection was installed on the west side of the Sacramento River on the U.S. Fish and Wildlife Service's (USFWS) Capay Unit of the Sacramento River National Wildlife Refuge to prevent further channel meander.

As part of the long-term monitoring program, Ducks Unlimited commissioned Tetra Tech to perform annual bathymetric surveys to monitor sedimentation along the study reach and in particular, to determine the necessity of dredging and to quantify the volume (tonnage) of material. Unlike the previous gravel removal operations that were conducted in the "dry" during 2001 and 2007, future dredging will likely require a below-water dredge operation.

Technical Memorandums (Tetra Tech, 2010, 2011, 2012b, 2013) describing the bed elevation changes that occurred between 2006 and 2013 were provided to Ducks Unlimited following the 2010, 2011, 2012, and 2013 surveys. Surveys were not conducted from 2014 through 2016 due to the absence of sustained high flows. This Technical Memorandum was developed by updating the 2013 Technical Memorandum with inclusion of the June 2017 survey data and results.

2. HYDROGRAPHIC AND TOPOGRAPHIC SURVEYS

Hydrographic and topographic surveys of the M&T/Llano Seco reach of the Sacramento River between River Mile (RM) 192 and RM 193.5 have been used to monitor geomorphic changes in the reach, including aggradation of the bed as well as bank erosion and lateral migration of the river. Surveys were conducted by Mussetter Engineering Inc. (MEI) in December 2005 and May 2006 and by Tetra Tech in January 2010, June 2011, June 2012 and June 2017. The horizontal datum for the surveys is referenced to the State Plane Coordinate System, North American Datum of 1983 (NAD83) (California, Zone 2) and the vertical datum is the North American Vertical Datum of 1988 (NAVD88). Relatively little flow occurred during the drought years of 2013 (after the survey) and 2014, with the maximum discharge only reaching 32,950 cfs. The peak flow in 2015 was 124,360 cfs. This event had a very short duration with the flow above the bankfull discharge of approximately 90,000 cfs for less than 1 day.

In WY2017, there were four flood events that exceeded the bankfull discharge. The fourth high flow event was the largest with a peak flow of approximately 132,900 cfs, on February 19, 2017.During this event, the flow was greater than 80,000 cfs for approximately 23 days. The peak flow of 132,900 cfs was used as the provisional peak flow event for WY2017 (**Figure 1**).

The hydrographic survey was conducted by Tetra Tech between noon on June 7 and noon on June 9, 2017. Flow measured at the Hamilton City gage was 11,300 cfs on June 7, falling to 10,270 cfs by June 9 (**Figure 2**). The survey was conducted with an Ohmex SonarMite Echosounder (±0.1-foot resolution) coupled with a Leica Viva RTK-GPS system that were mounted on Tetra Tech's survey boat.

3. SURVEY RESULTS

The initial survey of the M&T/Llano Seco reach was conducted in December 2005, but in January 2006 there was a flow of 135,000 cfs (Hamilton City gage) which caused both lateral erosion of the west bank of the river and aggradation and degradation in the reach. As a result, the reach was re-surveyed in May 2006, and this survey is used as the baseline condition for the following discussion.

3.1. Aggradation and Degradation

Figure 3 presents the changes in elevation of the bed of the river within the M&T/Llano Seco reach between the 2010 and 2006 surveys. The comparison indicates that there had been significant aggradation (4 to 10 feet) in the vicinity of the pumps which was supported by observations of the river under low-flow conditions. The location of the 2007 gravel removal is clearly visible (-4 to -6 feet) along the left (east) bank of the river upstream of the pumping plant and adjacent to Bidwell State Park. **Figure 4** presents the changes in bed elevation between the 2011 survey and the 2006 survey. It is apparent that the amount of deposition in the vicinity of the pumping plant was reduced following the high flows in early 2011 (peak flow at Hamilton City was about 102,500 cfs), but there is still some aggradation when compared to the 2006 survey. **Figure 5** presents the differences in elevation of the bed of the river between the 2010 and 2011 surveys.

Figure 6 presents the changes in bed elevation between the 2011 survey and the 2012 surveys. The data indicate that there was some additional aggradation in the vicinity of the pump intake as compared to the 2011 survey, which was likely due to the lack of significant peak flows during the 2012 spring runoff period (peak flow at Hamilton City was about 44,000 cfs).

Figure 7 presents the changes in bed elevation between the 2012 survey and the 2013 surveys. The data indicate that there was very little change in bed elevation between the 2012 and 2013 surveys with the majority of the values in the -2 to 0 or the 0- to 2-foot categories. The range of these categories has been kept consistent with the previous survey report (Tetra Tech, 2012); in general, most of the values range between -0.5 and 0.5 feet, which represents little change in bed elevation. **Figure 8** presents the differences in elevation of the bed of the river between the 2013 and 2006 surveys, and demonstrates that the site was still net aggradational.

Figure 9 presents the changes in bed elevation between the 2013 survey and the 2017 survey. There was aggradation on the order of 2 to 4 feet on the downstream end of the gravel bar, and similar amounts of aggradation were observed in the left channel of the mid-channel bar. The aggradation occurred mainly in the area that was last dredged in 2007. **Figure 10** presents the differences in elevation of the bed of the river between the 2017 and 2006 surveys, and demonstrates that the site was still net aggradational.

Between the downstream end of the gravel bar to approximately opposite the pumps, approximately 2 to 4 feet of degradation occurred near the center of the channel. Field observations and survey data collected in 2013 indicated the eroded subsurface bar was comprised of sand and fine gravel. The channel near the left bank between the pumps and Big Chico Creek aggraded by up to 4 feet.

Approximately 2,500 feet downstream from the pumps, the high flows in early 2017 caused lateral migration of approximately 150 lineal feet of of the left bank. The bank retreat is beginning to encroach into the windrow revetment and the riprap is launching into the river along the toe of the bank.

3.2. Volumetric Changes

To further evaluate bed elevation changes between 2006 and 2013, and to determine the volume of dredge material in the vicinity of the fish screens and pump inlets, an approximately 600- by 1,200-foot area was designated and the difference in volume between surveys was determined. Between the 2006 and 2010 surveys, about 89,000 cu.yd. (~120,000 tons) of material accumulated (**Figure 11**). Between the 2011 and 2006 surveys, the volume of material that accumulated was reduced to about 54,400 cu.yd. (~72,900 tons) (**Figure 12**). Between 2010 and 2011, there was net loss of about 34,800 cu.yd. (~47,000 tons) of material (**Figure 13**). Between the 2012 and 2006 surveys, there was a net accumulation of about 61,300 cu.yd (~82,800 tons) (**Figure 14**). From 2011 to 2012, there was slight aggradation in the delineated area and a net gain of about 6,700 cu.yd (~9,000 tons) of material (**Figure 15**). Between the 2013 and 2006 surveys, there was a net accumulation of about 66,000 cu.yd (~89,100 tons) (**Figure 16**). From 2012 to 2013, there was slight aggradation in the delineated area and a net gain of about 3,600 cu.yd (~4,860 tons) of material (**Figure 17**). Between 2013 and 2017, there was a net loss of about 12,300 cu. yd (~16,600 tons) that was mostly due to the erosion of the downstream end of the subsurface bar (**Figure 18**). From 2006 to 2017, there has been a net gain of about 51,000 cu. yd. (~68,850 tons) (**Figure 19**).

4. ANALYSIS OF CHANGES

Aggradation and degradation within the M&T/Llano Seco reach appears to be tied to the peak flow hydrology. With the exception of WY2004, the peak flows in the six years prior to 2005 were less than the bankfull (~90,000 cfs) and this sequence of flows appears to be responsible for the aggradation in the channel (Figure 1). In WY2006, the peak flow was about 134,600 cfs and clearly there was some degradation in the reach, especially in the vicinity of the fish screens and pump inlets (**Figure 20**). Between WY2006 and WY2010, the peak flows were again less than the bankfull and aggradation occurred in the vicinity of the fish screens and pumps (Figure 11 and **Figure 21**). Peak flow in WY2011 was about 102,500 cfs and this flow appears to have caused degradation in the vicinity of the fish screens and pump inlets (Figure 13 and **Figure 22**). Between 2011 and 2012, the peak flows during the spring 2012 runoff period was about 44,000 cfs (approximately half of the bankfull flow) and there was a relatively small amount of deposition in the vicinity of the fish screens and pump inlets but the general trend of deposition during low flow years was observed (Figure 15 and **Figure 23**).

The peak flow between the 2012 and 2013 surveys was about 85,600 cfs, which is slightly less than the bankfull discharge of 90,000 cfs, and the duration of the peak flow event was less than one day. Between 2012 and 2013, there was a relatively small amount of deposition in the vicinity of the fish screens and pump inlets, but the general pattern of deposition at less than bankfull discharges was observed (Figure 17 and **Figure 24**). Between 2013 and 2017, peak flows exceeded the bankfull discharge on several occasions, but in general the period was relatively dry. There was slight degradation along and near the thalweg, and aggradation along the left bank of the channel and in the vicinity of the fish screens (Figure 19 and **Figure 25**).

The highest flows between the 2013 and 2017 surveys were 124,300 cfs in 2015 (for less than 1 day) and 132,900 cfs in 2017. The high flows resulted in net degradation of about 12,300 cu. yd between the surveys. In the vicinity of the pumps, the channel aggraded by approximately 2 feet between 2013 and 2017. It was likely that there was aggradation in the vicinity of the pumps during the low flow years of 2013, 2014, and 2016. There may have been aggradation after the 2013 survey and therefore the change between the 2013 and 2017 surveys is an underestimate of the amount moved out by the 2017 event.

A dive survey conducted in 2013 indicated the depth below the screens was approximately 3 to 4 feet (Appendix A). A NOAA dive survey in July 2016 indicated the depth under the screens was approximately 2 to 3 feet, indicating aggradation between 2013 and 2016. The 2016 dive survey also indicated that under low-flow conditions, the screens are located in an eddy and the sediment below the screens was mostly “fine sediments”. The May 2017 dive survey occurred following the peak flow of approximately 132,000 cfs and indicated the depth under the screens was approximately 2 to 2.5 feet. Based on the dive surveys, it appears there was approximately 1 foot of aggradation between 2013 and 2016, and possibly an additional 0.5 feet of aggradation between 2016 and 2017.

Based on the hydrographic survey results and the dive surveys, it appears the channel in the vicinity of the pumps did not degrade during the 2017 high flows, which is contrary to the historical trend where the channel degraded at flows greater than bankfull conditions. It is possible the channel in the vicinity of the pumps did degrade during the 2017 high flows, and has subsequently aggraded. Field observations and the 2017 survey results indicate that the degradation occurred near the center of the channel opposite the pumps. Under-low flow conditions, this appears to have moved the main flow path towards the center of the channel and increased the strength of the eddy at the pumps, which in turn causes deposition of the fine sediments at the pumps.

The general patterns of aggradation and degradation are supported by comparative cross-sectional plots. The locations of the plotted cross sections are shown on **Figure 26**, with Cross Section 1 (XS1) being located at the relocated City of Chico wastewater outfall and diffuser, XS2 is located near the City's previous outfall, XS3 through XS5, span the fish screens and pump inlets and XS6 and XS7 are located upstream and incorporate the migrating gravel bar. XS8 represents the area that was dredged in 2007.

At the City of Chico's outfall (**Figure 27**), the cross sections indicate that there was some aggradation on the left (east) side of the channel in 2005 but the 2006, 2010 and 2011 surveys show that the local aggradation was removed. The 2012 survey shows a small amount of aggradation near the left bank in the vicinity of Sta 440 and degradation in the vicinity of Sta 450. The 2013 survey shows slight degradation along the left side of the channel from near the left bank (east) to approximately Station 430. The 2013 survey also shows no change from the location of the thalweg (~Sta 560) to Sta 890 compared to the 2012 survey. In the 2017 survey, aggradation was observed near the left bank of the channel, while degradation was observed from about Sta 450 to Sta 750. The thalweg appears to have migrated towards channel left by about 75 feet since 2005.

At the location of the City's former outfall (**Figure 28**), it is apparent that the aggradation in 2010 was removed by the flows in 2011 and that the depth of scour probably depends on the magnitude of the high flows since the bed elevation in 2006 is the lowest. The 2012 survey shows there was very little change along the cross section compared to 2011 conditions. The 2013 survey shows approximately 1.5 feet of degradation at the channel thalweg (~Sta 170) compared to the 2012 survey. The 2013 survey also shows slight aggradation along the right side of the channel from Sta 290 to Sta 450. Only slight changes were observed at the cross-section between 2013 and 2017.

At the location of the fish screens and pump inlets (**Figures 29 through 31**) it is clear that during the lower peak flow years the deposition approaches the inlets and fish screens, and it is eroded during the higher-flow years. At XS3 (located slightly downstream from the fish screen), the 2017 survey shows that there was degradation of about 2 ft immediately adjacent to the bank, but that the thalweg became less defined and aggraded by 3 feet compared to the 2013 surveys. Degradation was observed on the right hand side of the channel from Sta 250 to Sta 600 (Figure 29). The section at the M&T intake (XS4) shows a similar trend between 2013 and 2017. There was aggradation in the thalweg near the pumps, and degradation of up to 3 feet between the thalweg and the right bank from Sta 225 to Sta 600 (Figure 30). At XS5, which is located slightly upstream of the M&T pump intakes, the 2017 survey shows slight aggradation (generally less than a foot) in the vicinity of the intakes; this is consistent with the dive survey observations. Degradation on the right side of the channel was less than in XS3 and XS4, but persisted from about Sta 350 to Sta 625 (Figure 31).

The same general trend is seen at the upper part of the migrating bar (**Figures 32 and 33**). Aggradation occurs during the lower peak flow years (2005, 2010, and 2012) and there is scour in the higher peak flow years (2006 and 2011). The 2017 survey shows there was aggradation of up to 5 feet near the left bank of XS6 and localized differences (aggradation and degradation) of up to 5 feet in the main channel, but in general, between Sta 450 and the right bank, the 2017 survey shows degradation, trending towards a return to the 2006 geometry (Figure 32). At XS7, the 2017 bathymetry is similar to the 2013 data, alternating between aggradation and degradation across the channel, with deviations generally less than two feet (Figure 33).

The comparative cross sections indicate that there has been significant aggradation in the left channel created by the gravel bar dredging. At XS8, the 2017 survey data show that the channel in this location has reverted to the pre-dredged geometry. The gravel bar itself may have aggraded by an additional three feet compared to the 2013 survey. The channel to the right of the gravel bar has remained stable since the 2013 survey. (**Figure 34**).

The results of the surveys conducted between 2006 and 2013, Acoustic Doppler Current Profiler (ADCP) measurements and 3-dimensional hydraulic modeling indicated that the scour occurring at higher flows is most likely due to the formation of a helical flow cell along the riprap that lines the east bank of the river in the vicinity of the fish screens and pump inlets because of downstream translation of flows that approach the riprap obliquely from upstream. ADCP measurements collected in June 2011 indicated the presence of a weak helical flow cell at approximately 19,500 cfs (Tetra Tech, 2012a). Three-dimensional hydraulic modeling (Alden, 2012) over a range of flows from 20,000 to 134,600 cfs, showed an increase in strength of the helical flow with increasing discharge, and thereby supported the hypothesis that at higher flows, a helical cell forms and with sufficient strength to erode previously deposited material.

This hypothesis of the cyclic behavior of the system depends on the general alignment of the river being maintained. If the west bank was to erode and migrate westward, it is likely that the flow alignments would change and it is unlikely that the helical flow cell would be maintained in the vicinity of the fish screens and pump inlets, which would probably cause them to be buried. Dive reports at the fish screens tend to support the results of the comparative surveys (**Appendix A**).

5. CONCLUSIONS

Based on the response of the system over the surveys conducted between 2006 and 2013, it was hypothesized that there was cyclic behavior within the M&T/Llano Seco reach with the less than bankfull flows delivering sediment to the reach from upstream and causing aggradation, and the higher than bankfull flows causing scour in the vicinity of the fish screens and pump inlets. The results of the 2017 survey indicated slight aggradation between 2013 and 2017 which appears to be contrary to the historic trend of the channel degrading in the vicinity of the pumps during high flow conditions.

The 2017 survey indicated deposition along the left side of the bar that was dredged in 2007 and deposition along the left side of the channel between the pumps and Big Chico Creek. Dredging of the mid-channel bar is not recommended at this time.

6. RECOMMENDATIONS

Until a long-term solution is developed and implemented at the M&T/Llano Seco pumping plant inlets and fish screens, it is recommended that geomorphic changes in the reach continue to be monitored. Monitoring should involve deposition/erosion in the vicinity of the inlets as well as any erosion of the west bank of the river downstream of the rock toe and brush revetment. In addition, monitoring should also continue at the City of Chico's relocated outfall and diffuser.

7. REFERENCES

Alden Research Laboratory, 2012. Three-Dimensional Numerical Flow Analysis of the M&T Pumps, Chico, California. 32 p.

Tetra Tech, Inc., 2010. Survey Report 1 (Subtask 13.2) for M&T/Llano Seco Fish Screen Facility Short-term/Long-term Protection Project (Project No. US-CA-62-2). Submitted to Ducks Unlimited, Rancho Cordova, California, March 18, 6 p.

Tetra Tech, Inc., 2011. June 7-9, 2011 Resurvey of M&T/Llano Seco Pumping Plant and City of Chico Outfall Reach of the Sacramento River. Submitted to Ducks Unlimited, Rancho Cordova, California, July 11, 24 p.

Tetra Tech, Inc., 2012a. Two-dimensional Sediment-transport Modeling of the M&T/Llano Seco Pumps Reach Submitted to Ducks Unlimited, Rancho Cordova, California, May 1, 42 p.

Tetra Tech, Inc., 2012b. Evaluation of ADCP Data Collected in June 2011 at the M&T/Llano Seco Pumps Reach (DRAFT). Submitted to Ducks Unlimited, Rancho Cordova, California, June 29, 11 p.

Tetra Tech, Inc., 2012c. June 26, 2012 Resurvey of M&T/Llano Seco Pumping Plant and City of Chico Outfall Reach of the Sacramento River. Submitted to Ducks Unlimited, Rancho Cordova, California, July 16, 29 p.

Tetra Tech, Inc., 2013. June 7, 2013 Resurvey of M&T/Llano Seco Pumping Plant and City of Chico Outfall Reach of the Sacramento River. Submitted to Ducks Unlimited, Rancho Cordova, California, June 7, 29 p.

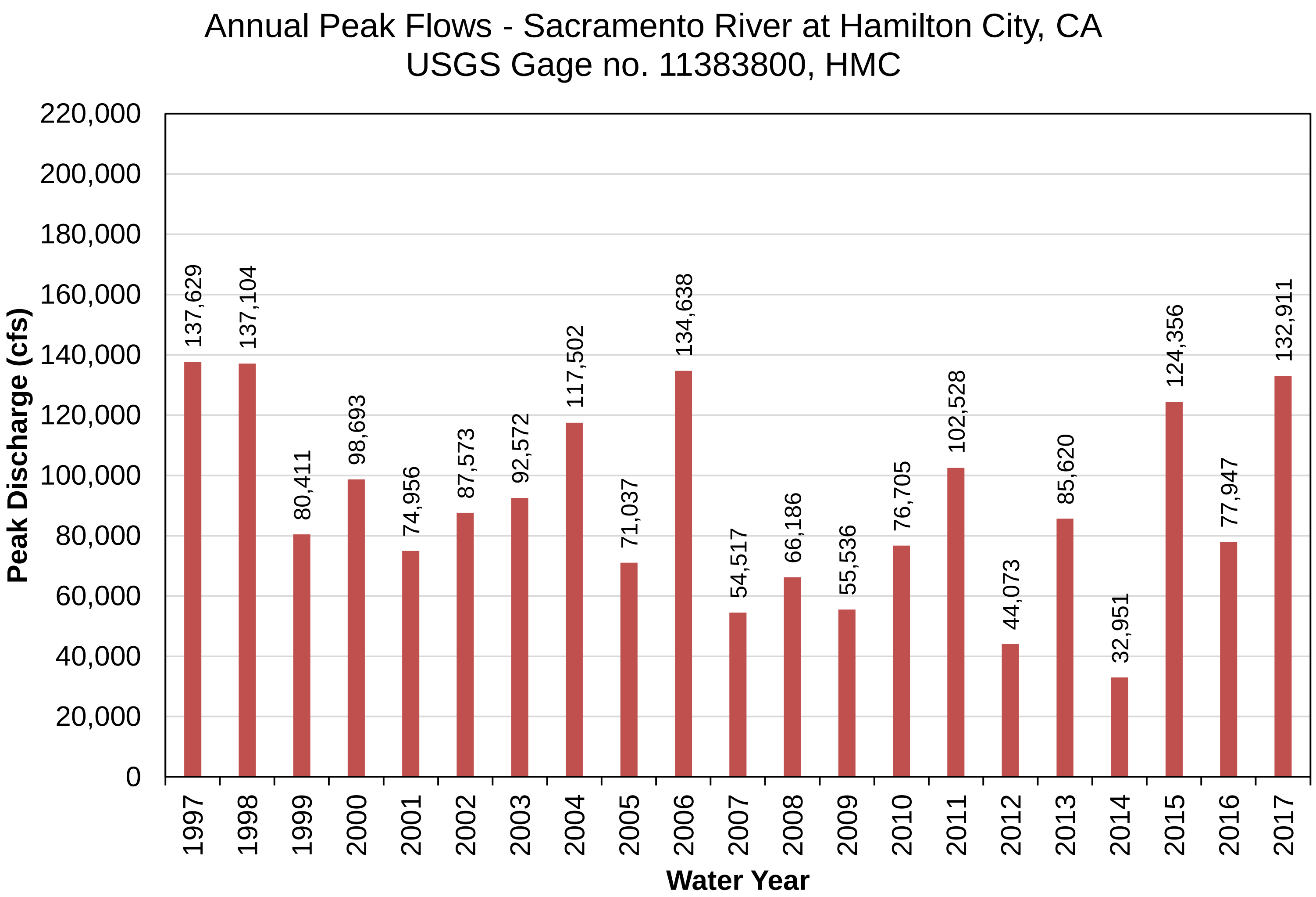


Figure 1. Peak annual flows at the Hamilton City gage between WY1997 and WY2017.

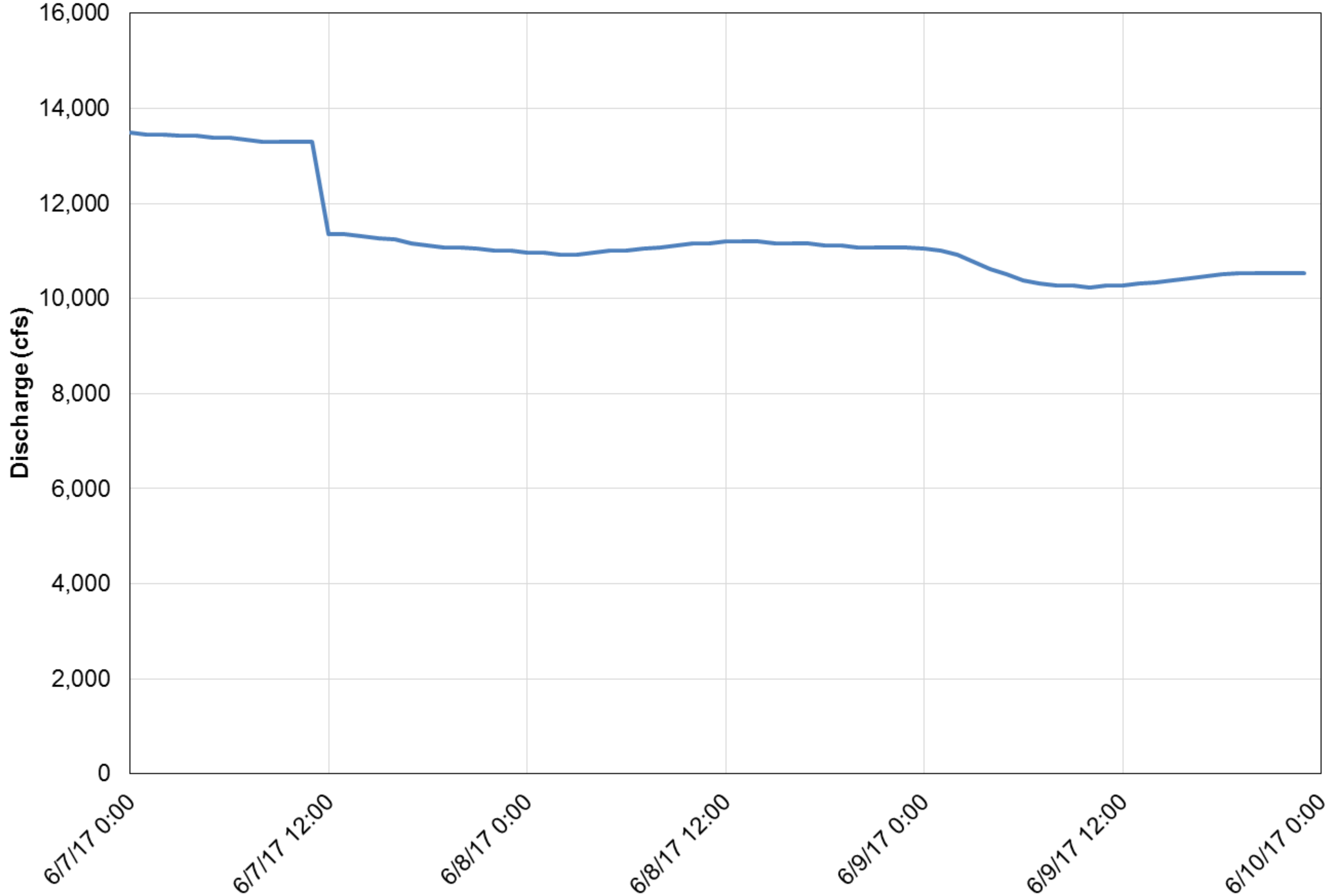


Figure 2. Flow measured at Hamilton City during the June 2017 survey.

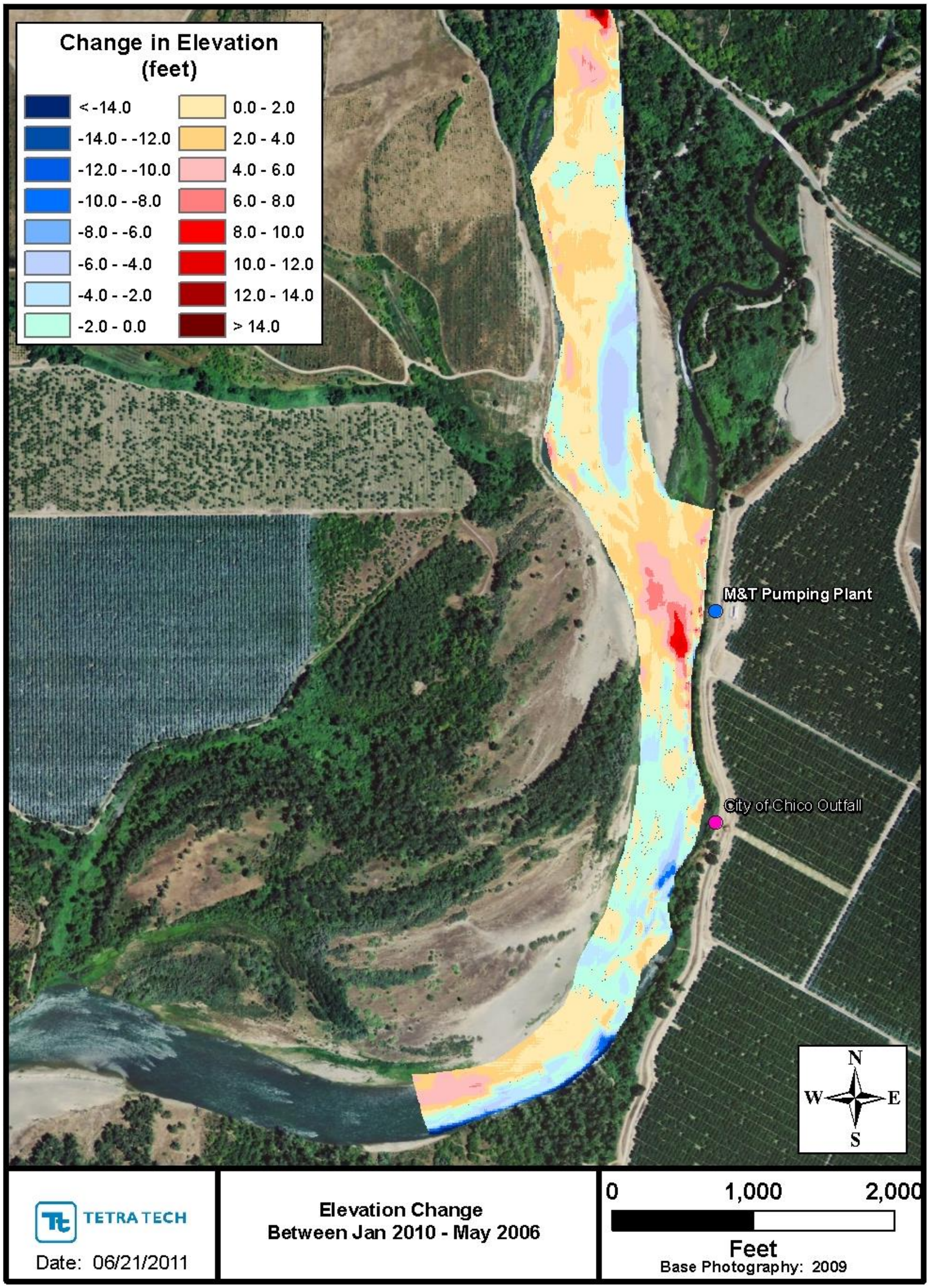


Figure 3. Elevation changes in the M&T/Llano Seco reach between the January 2010 and May 2006 surveys.

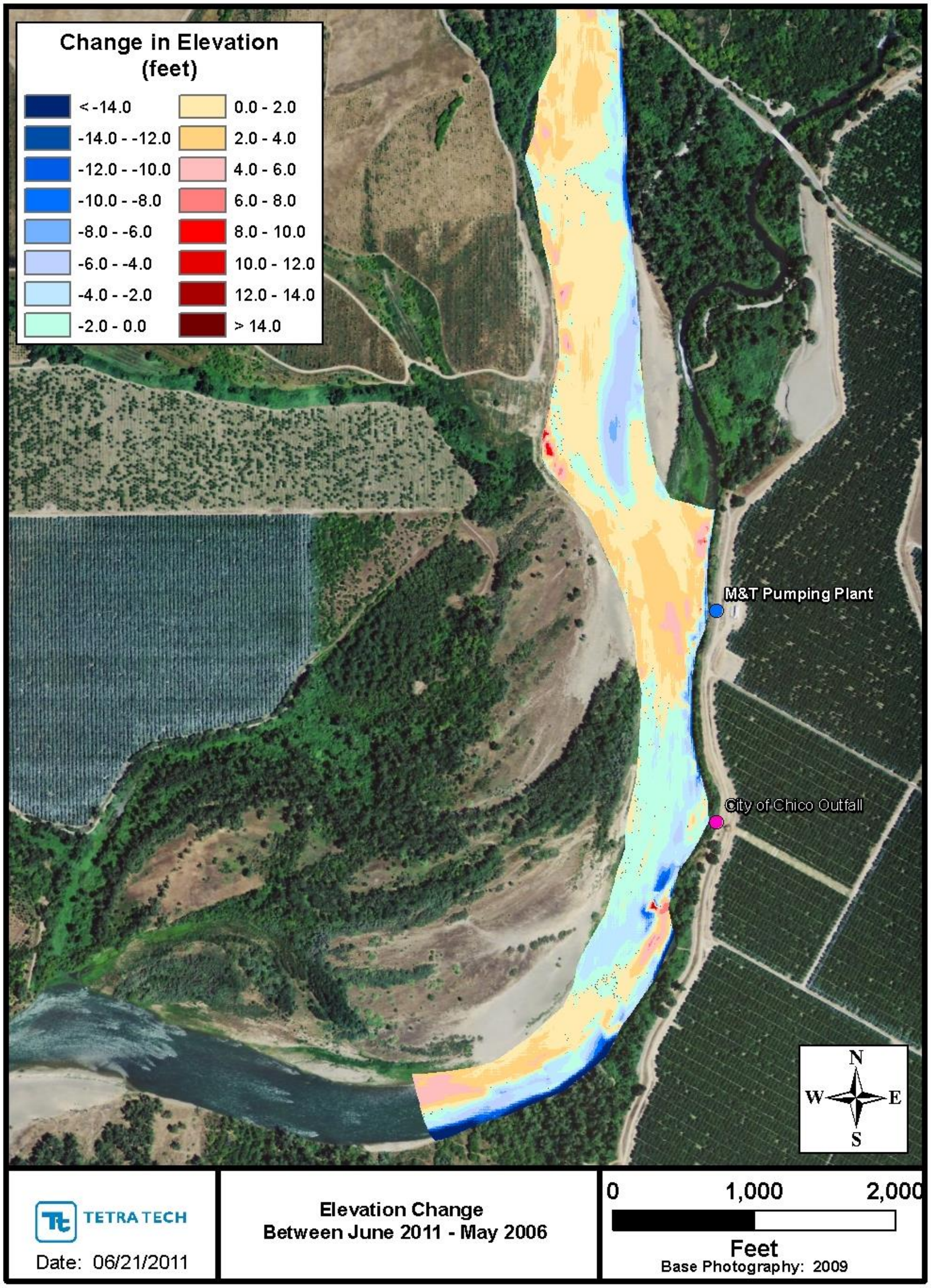


Figure 4. Elevation changes in the M&T/Llano Seco reach between the June 2011 and May 2006 surveys.

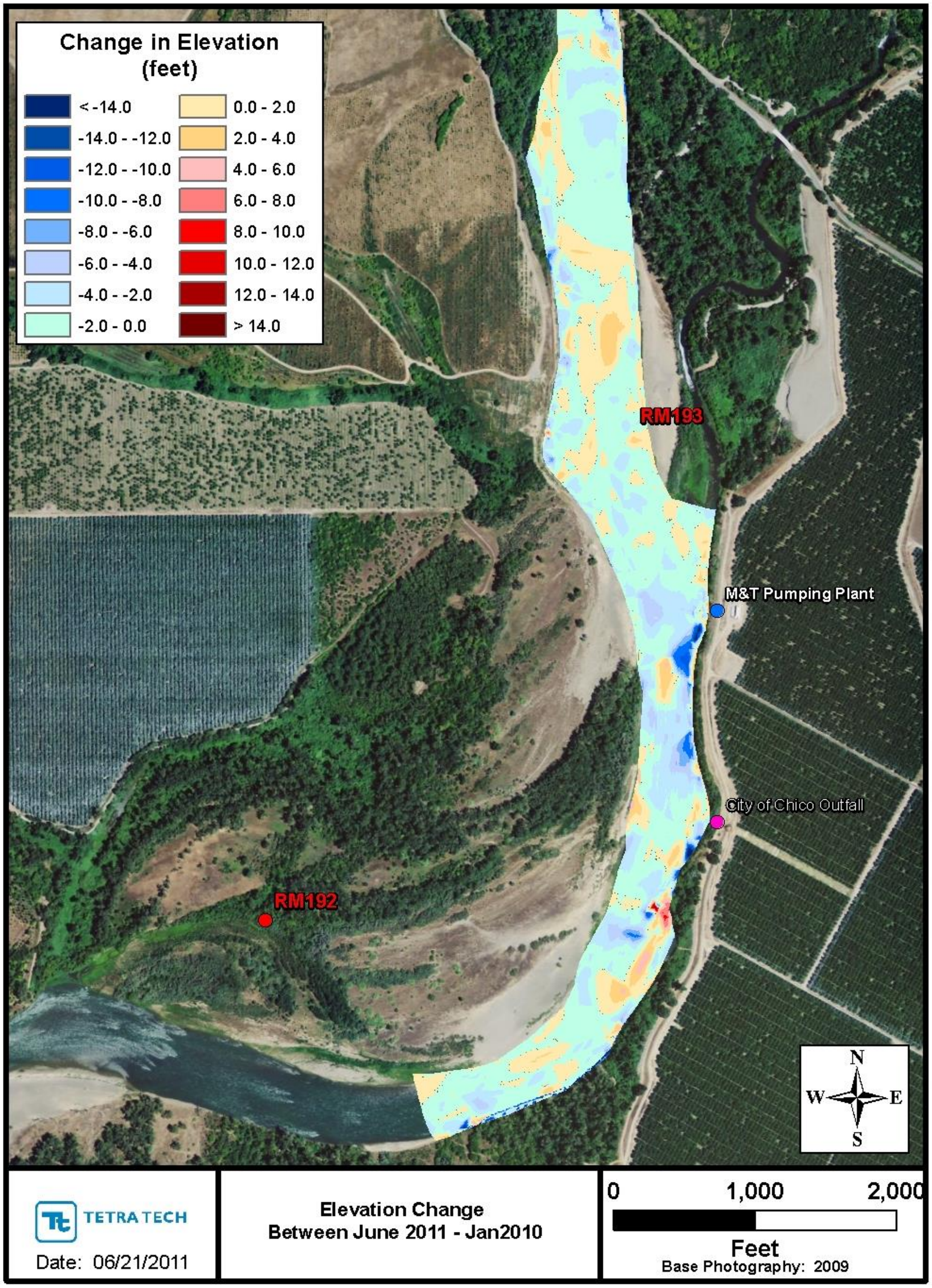


Figure 5. Elevation changes in the M&T/Llano Seco reach between the June 2011 and January 2010 surveys.

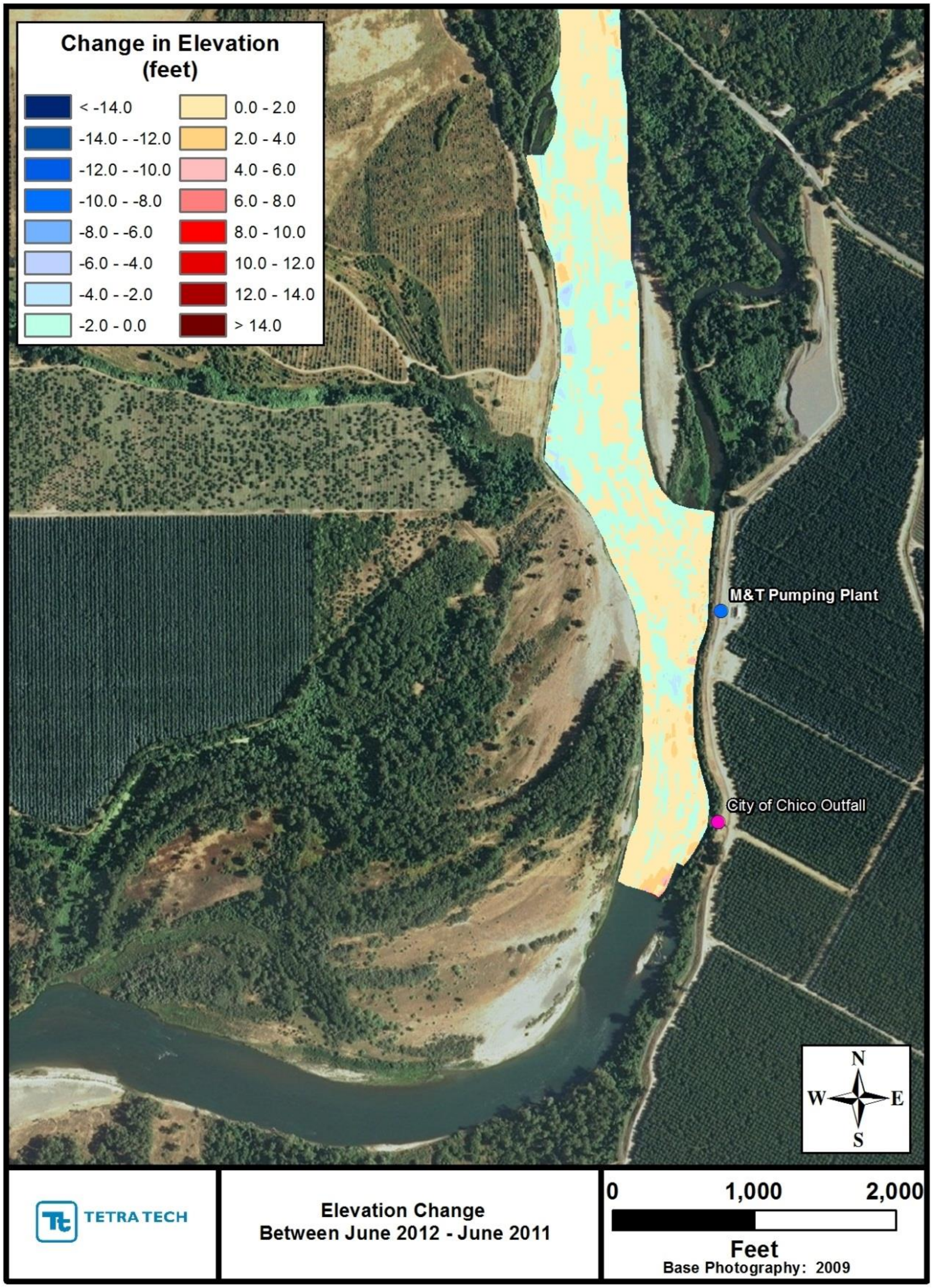


Figure 6. Elevation changes in the M&T/Llano Seco reach between the June 2012 and June 2011 surveys.

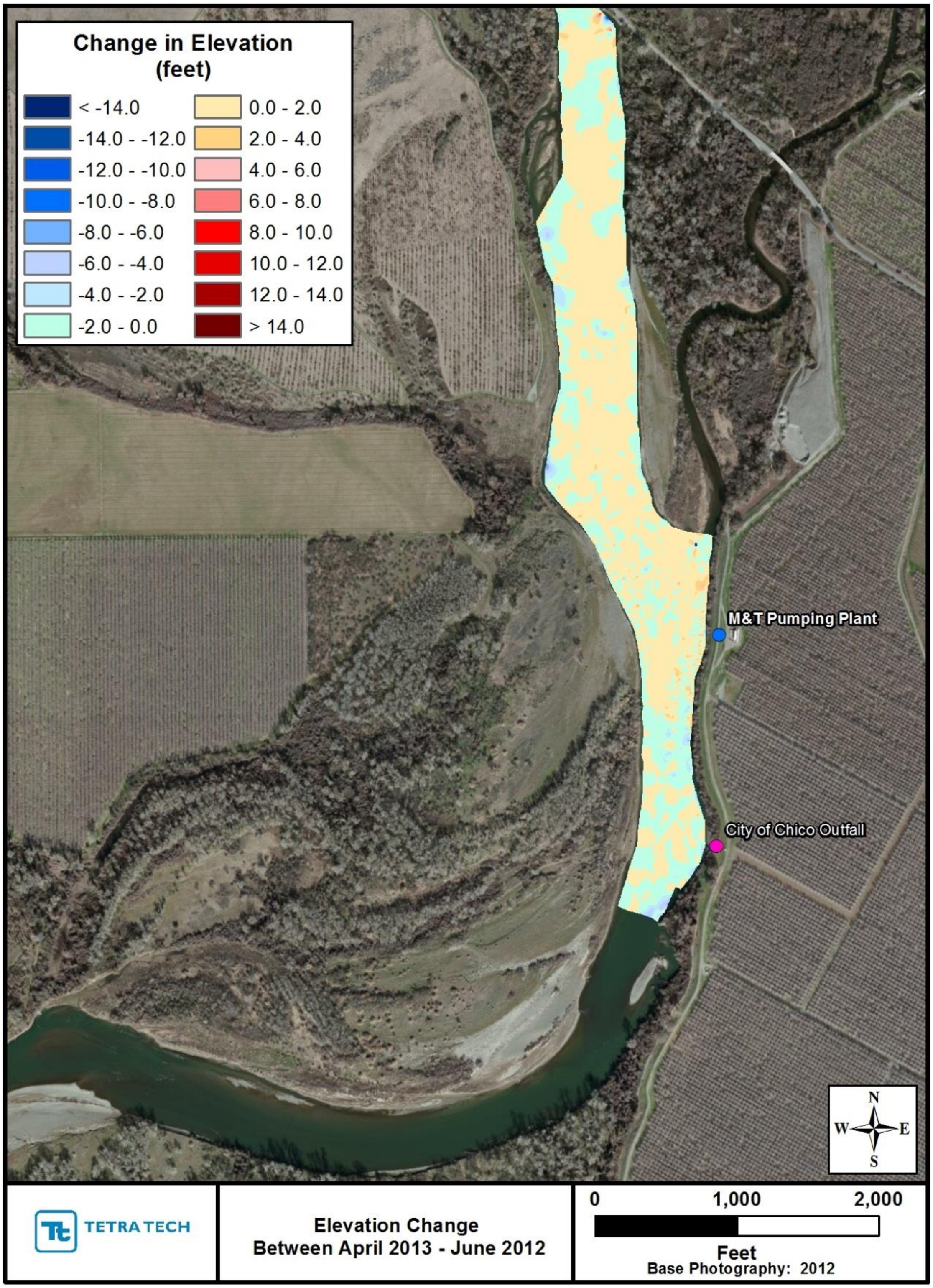


Figure 7. Elevation changes in the M&T/Llano Seco reach between the June 2012 and May 2013 surveys.

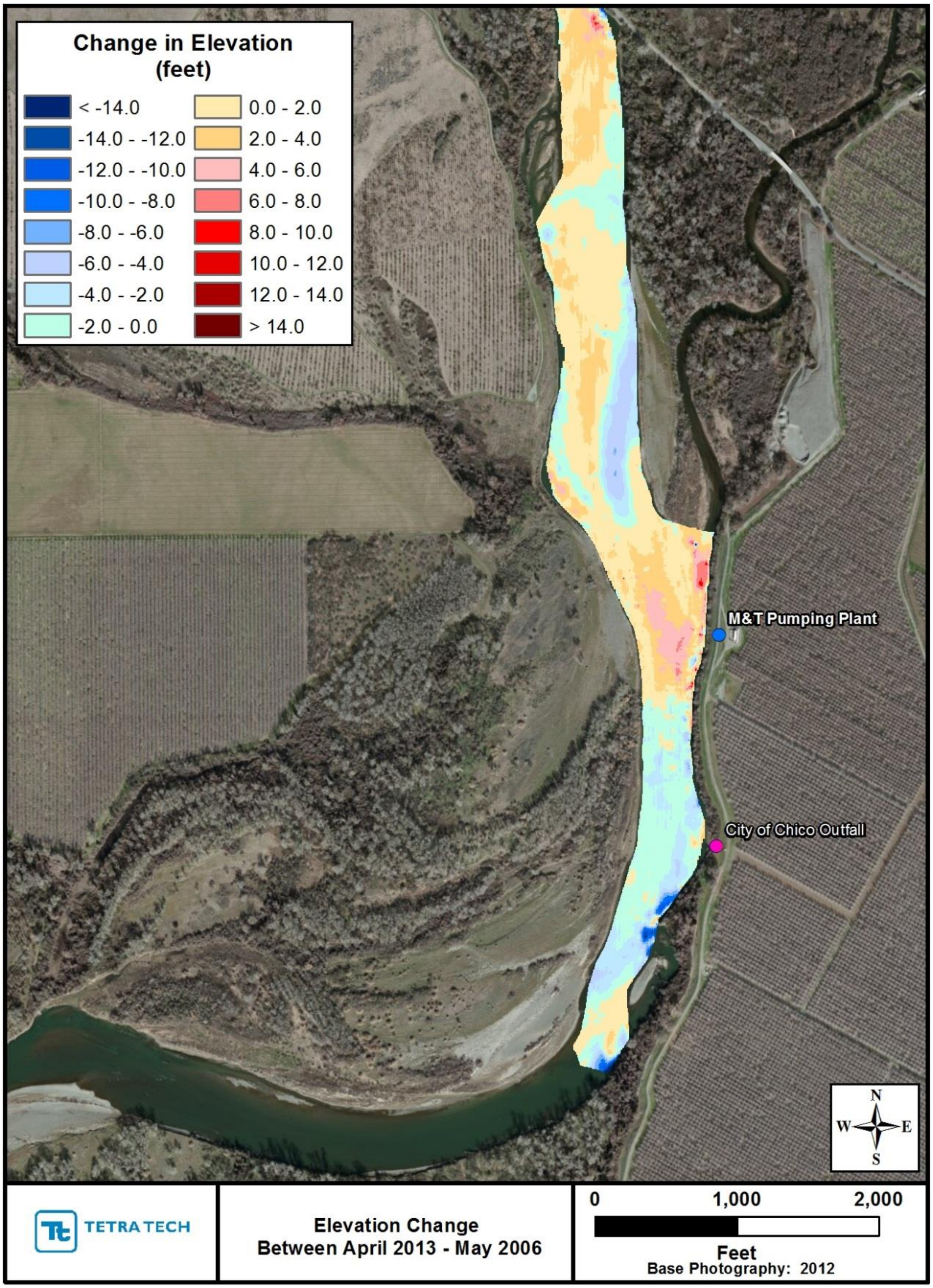


Figure 8. Elevation changes in the M&T/Llano Seco reach between the May 2013 and May 2006 surveys.

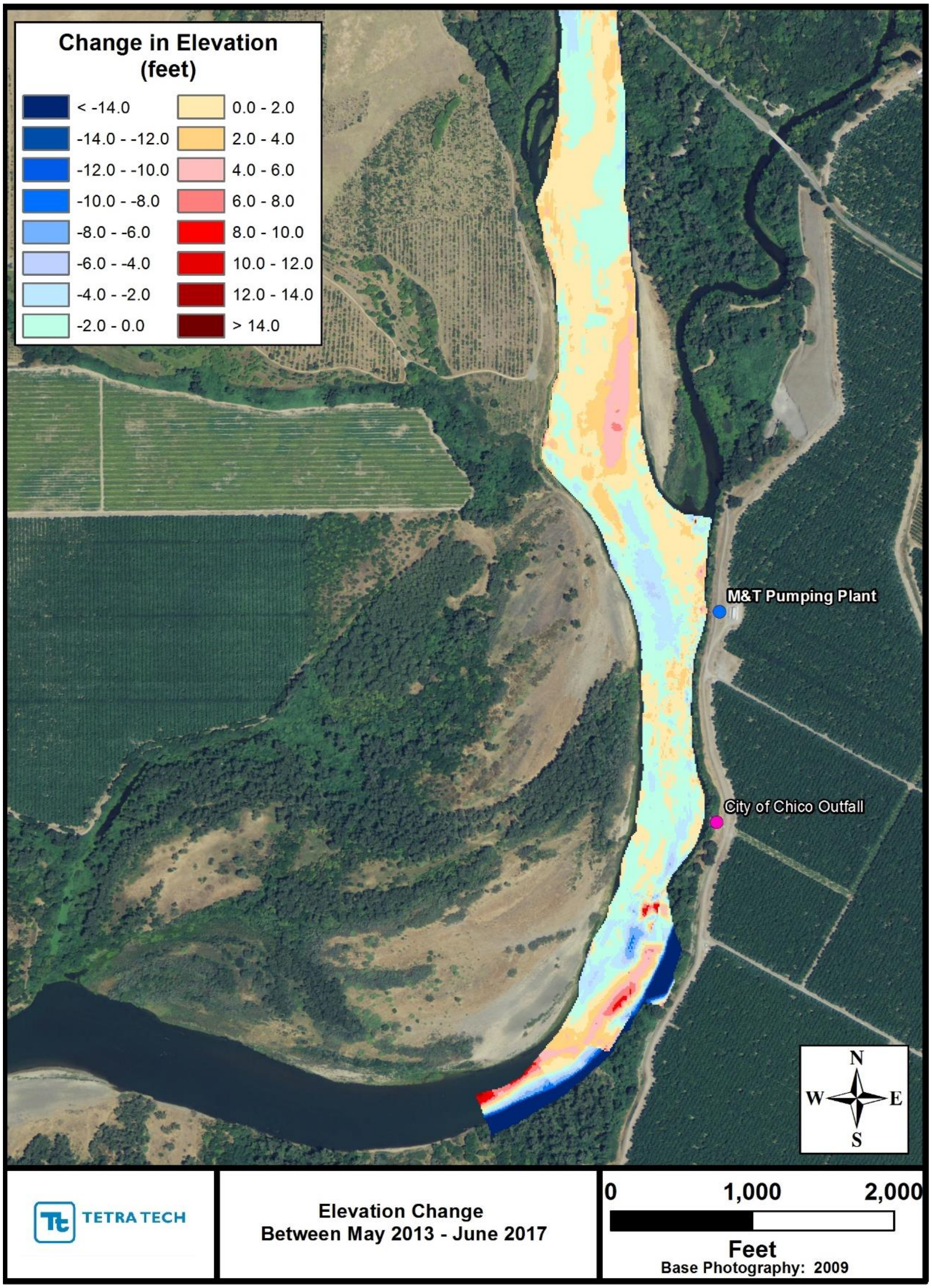


Figure 9. Elevation changes in the M&T/Llano Seco reach between the June 2017 and May 2013 surveys.

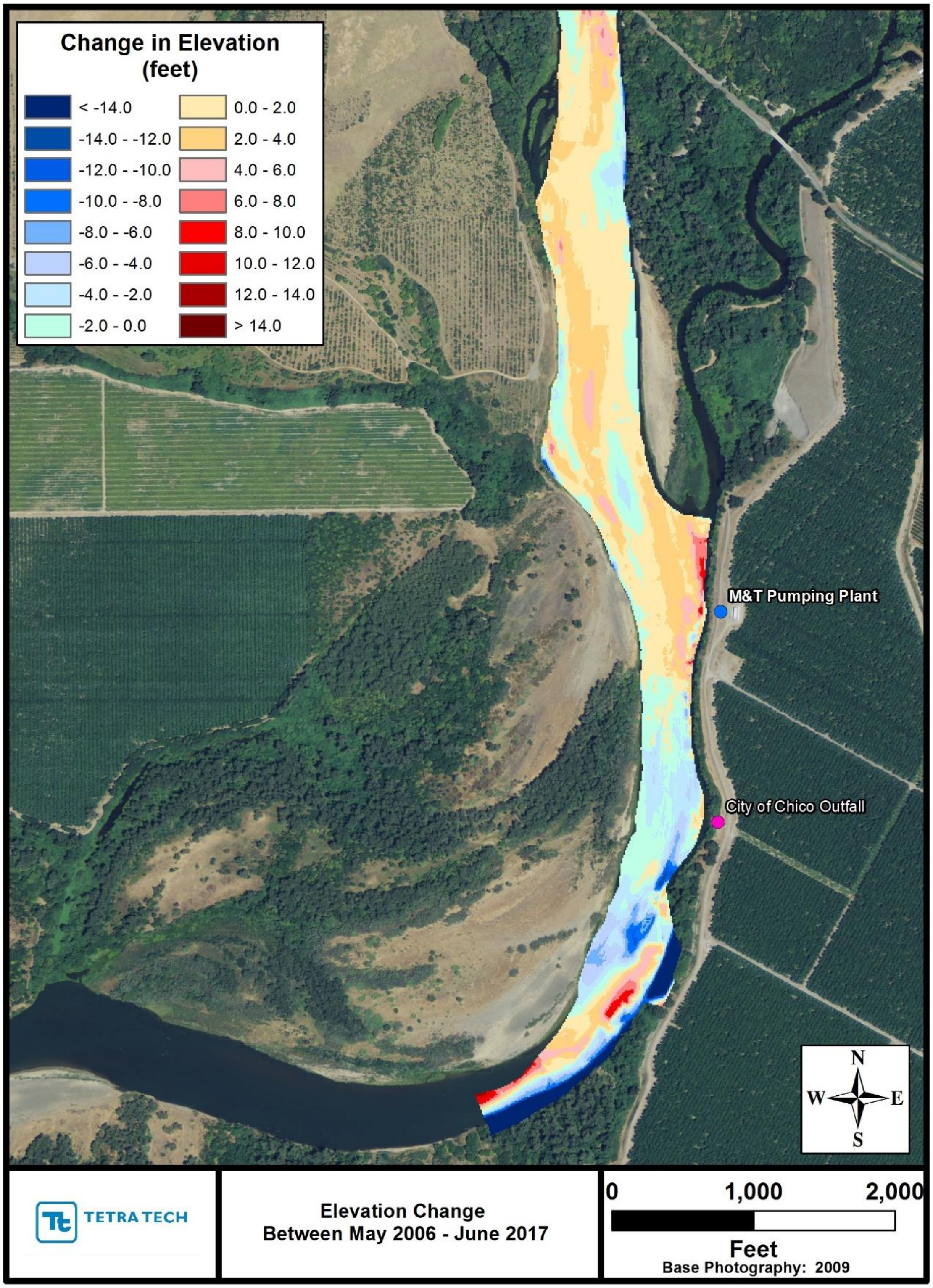


Figure 10. Elevation changes in the M&T/Llano Seco reach between the June 2017 and May 2006 surveys.

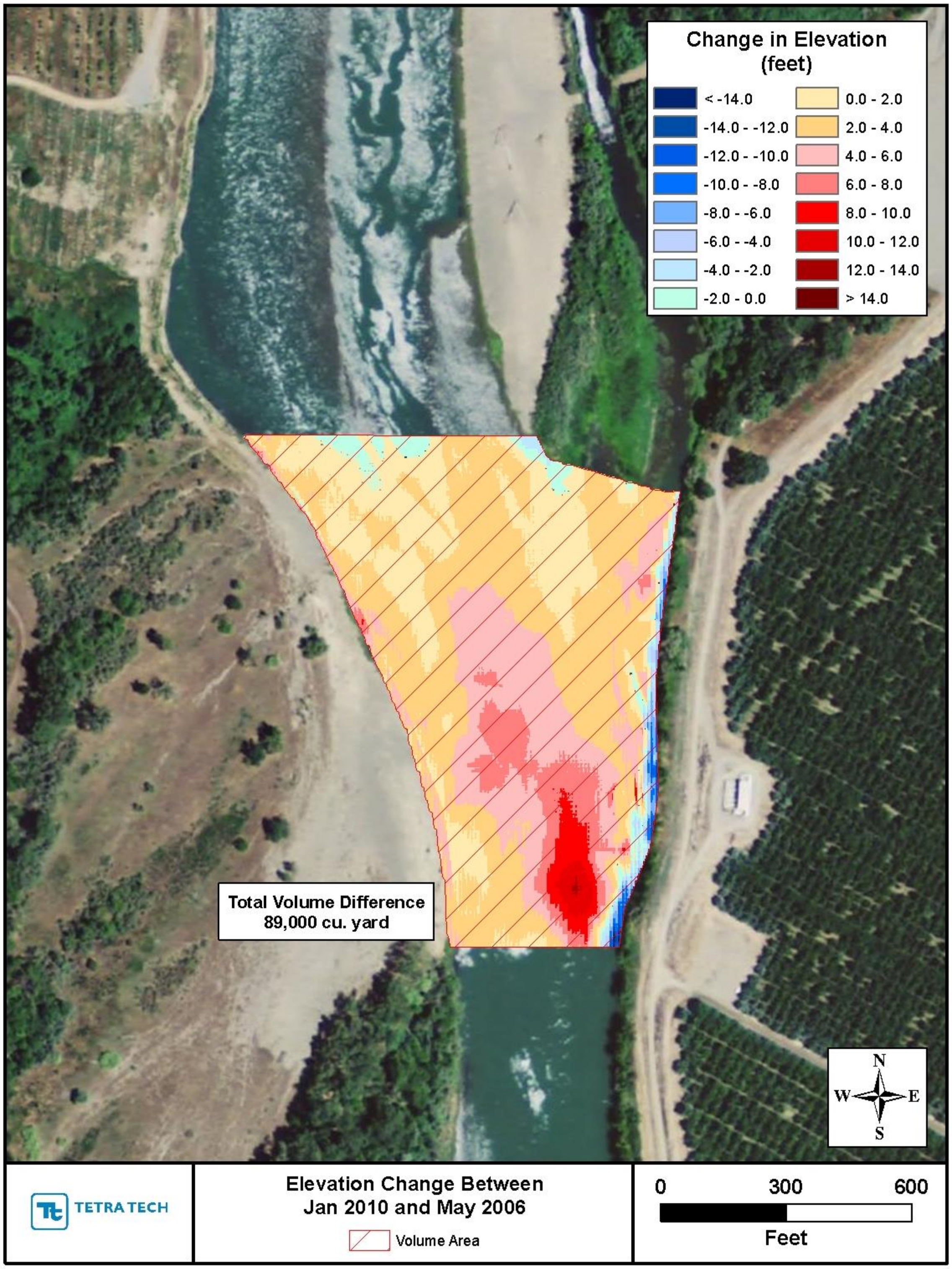


Figure 11. Volumetric calculation of the deposition in the 600- by 1,200-foot segment in the vicinity of the fish screens and pump inlets between the January 2010 and May 2006 surveys.

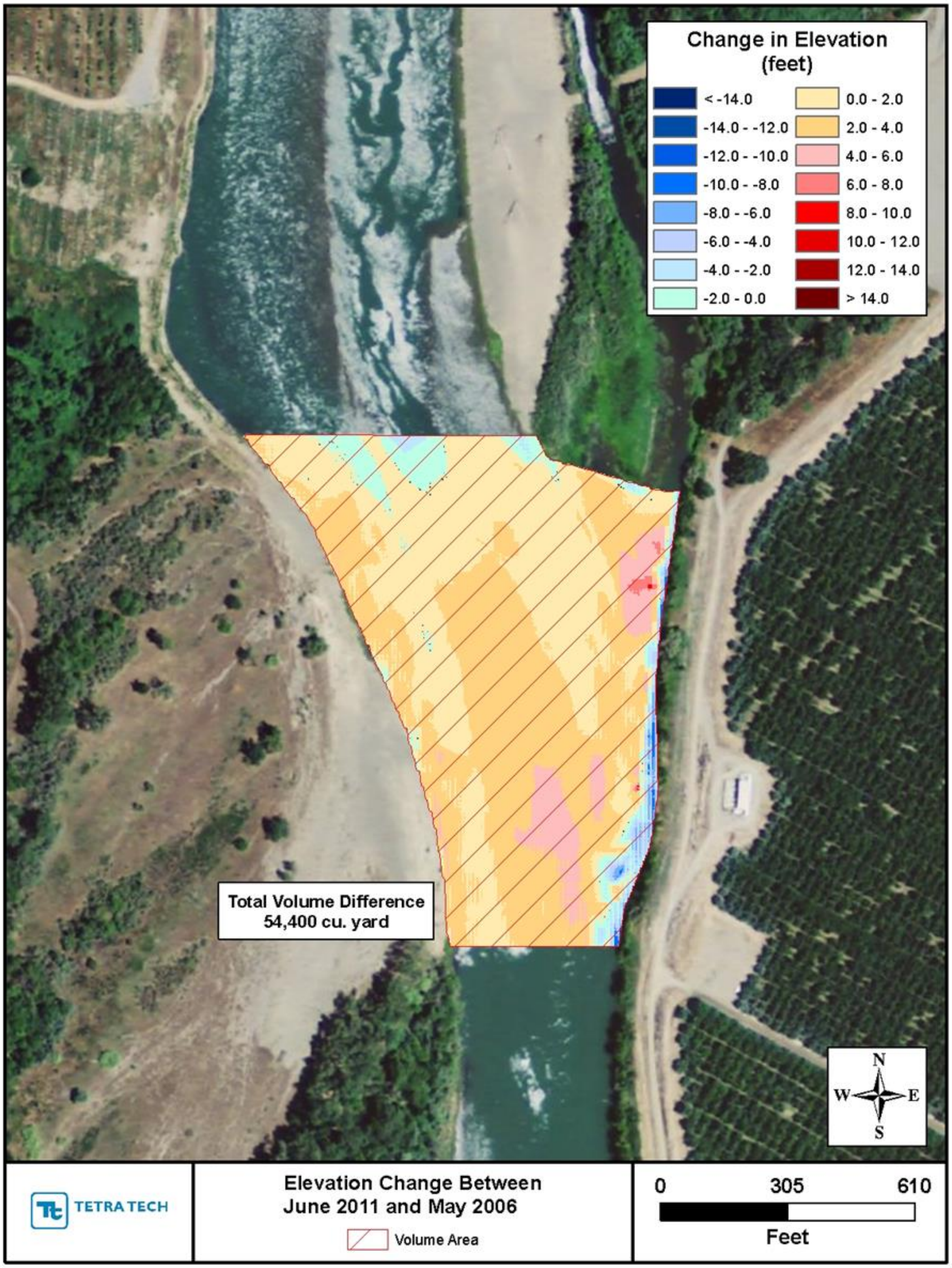


Figure 12. Volumetric calculation of the deposition in the 600 by 1,200-foot segment in the vicinity of the fish screens and pump inlets between the June 2011 and May 2006 surveys.

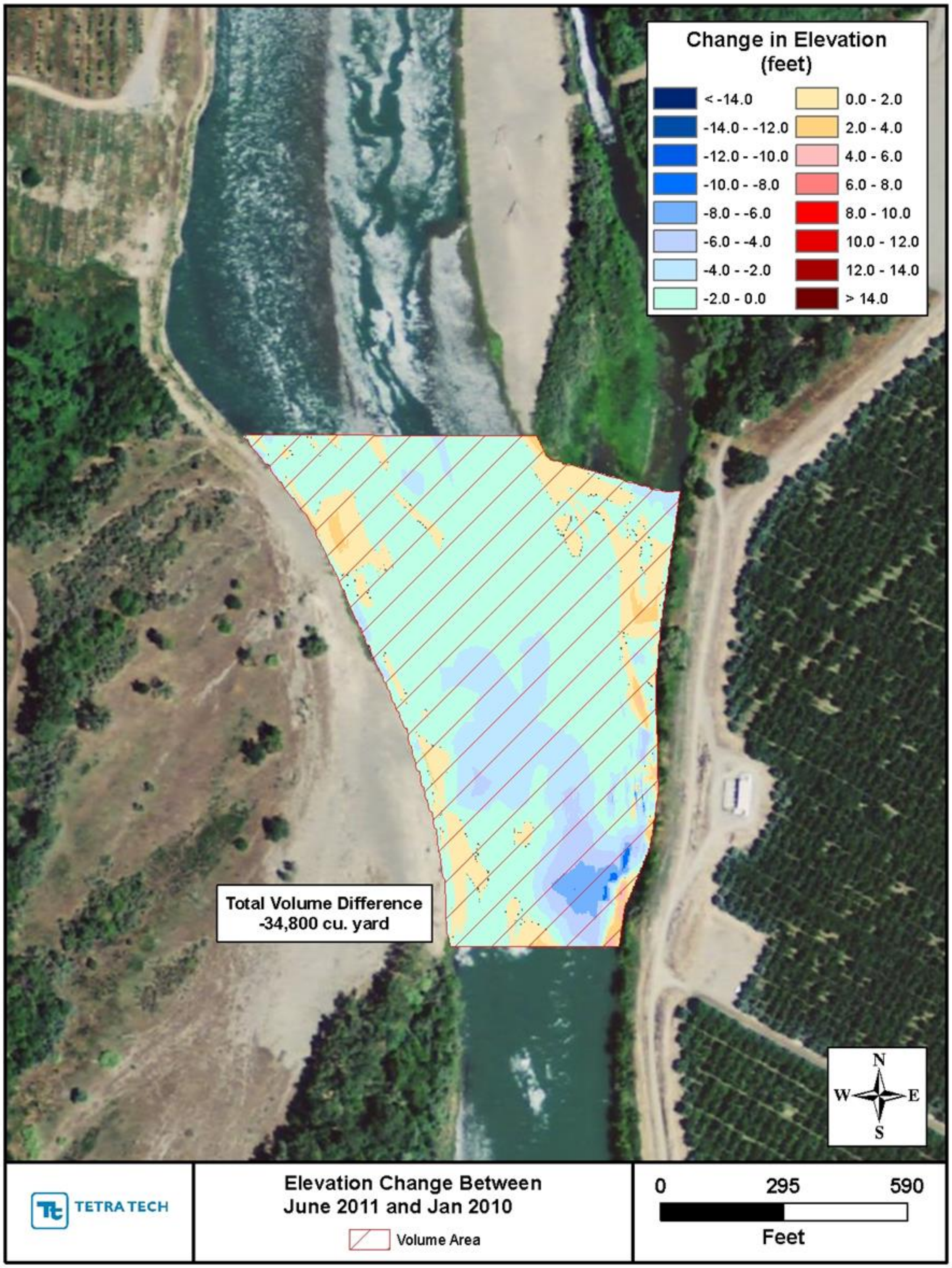


Figure 13. Volumetric calculation of the deposition in the 600- by 1,200-foot segment in the vicinity of the fish screens and pump inlets between the January 2010 and June 2011 surveys.

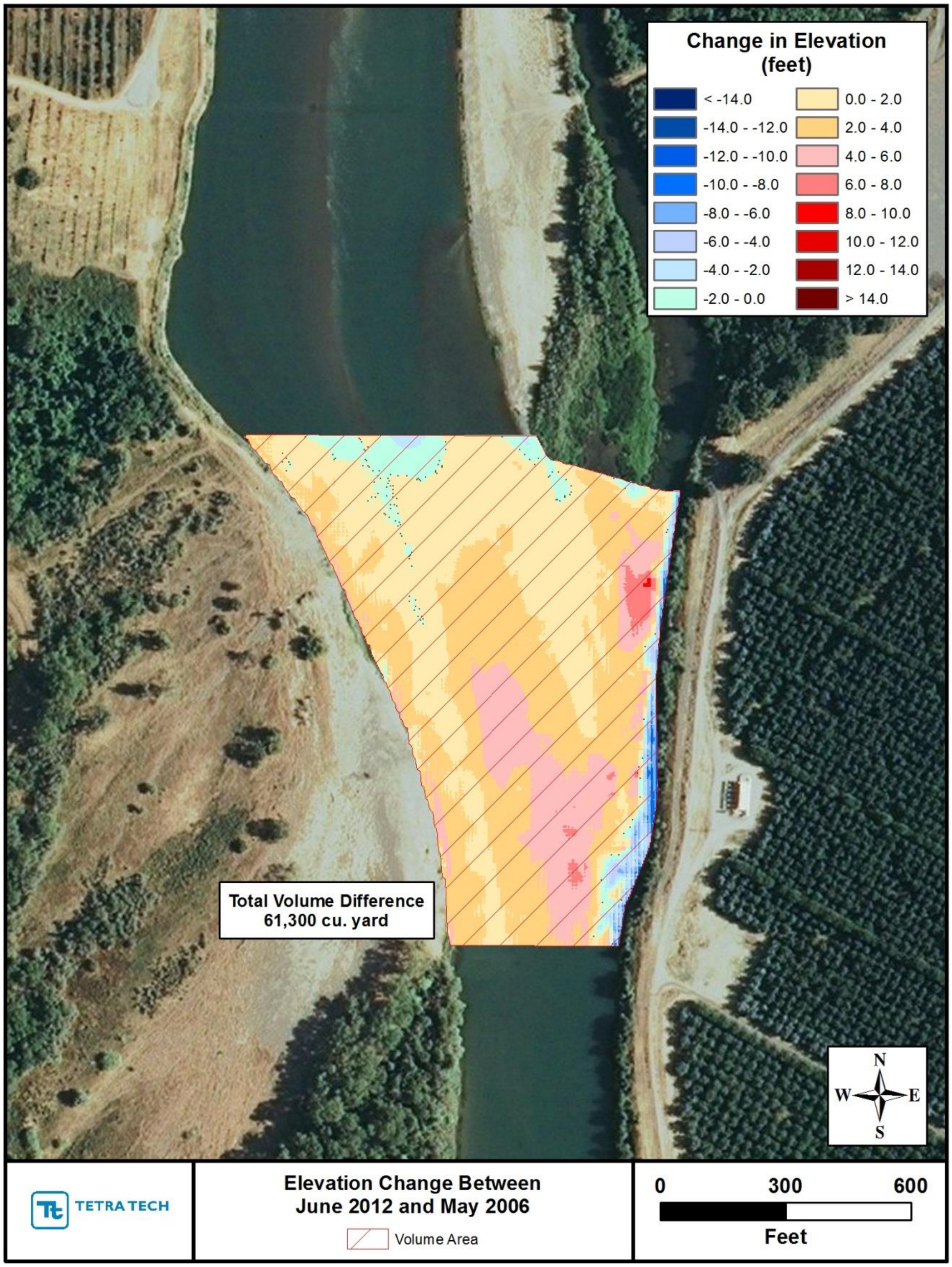


Figure 14. Volumetric calculation of the deposition in the 600- by 1,200-foot segment in the vicinity of the fish screens and pump inlets between the June 2012 and May 2006 surveys.

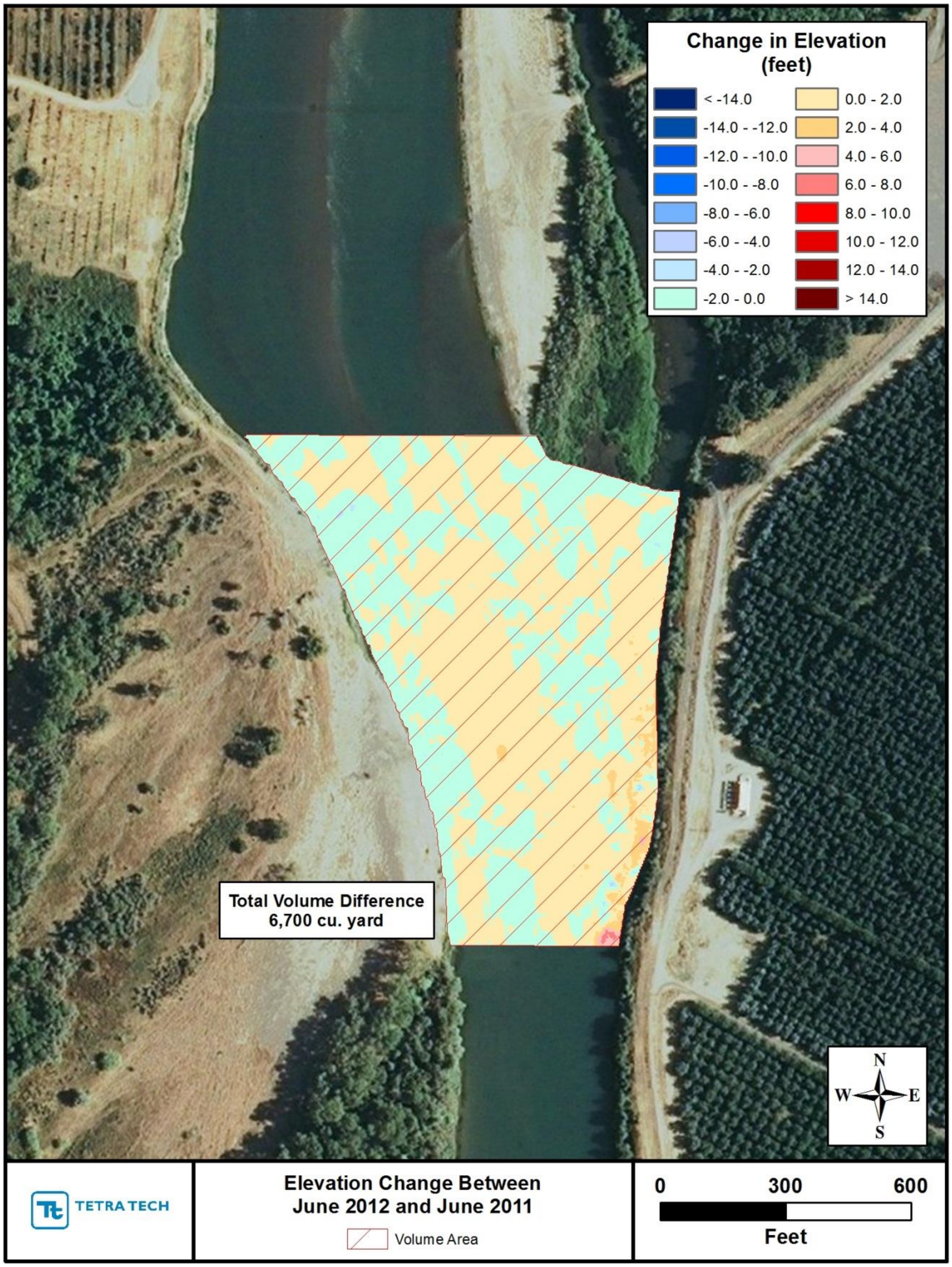


Figure 15. Volumetric calculation of the deposition in the 600- by 1,200-foot segment in the vicinity of the fish screens and pump inlets between the June 2011 and June 2012 surveys.

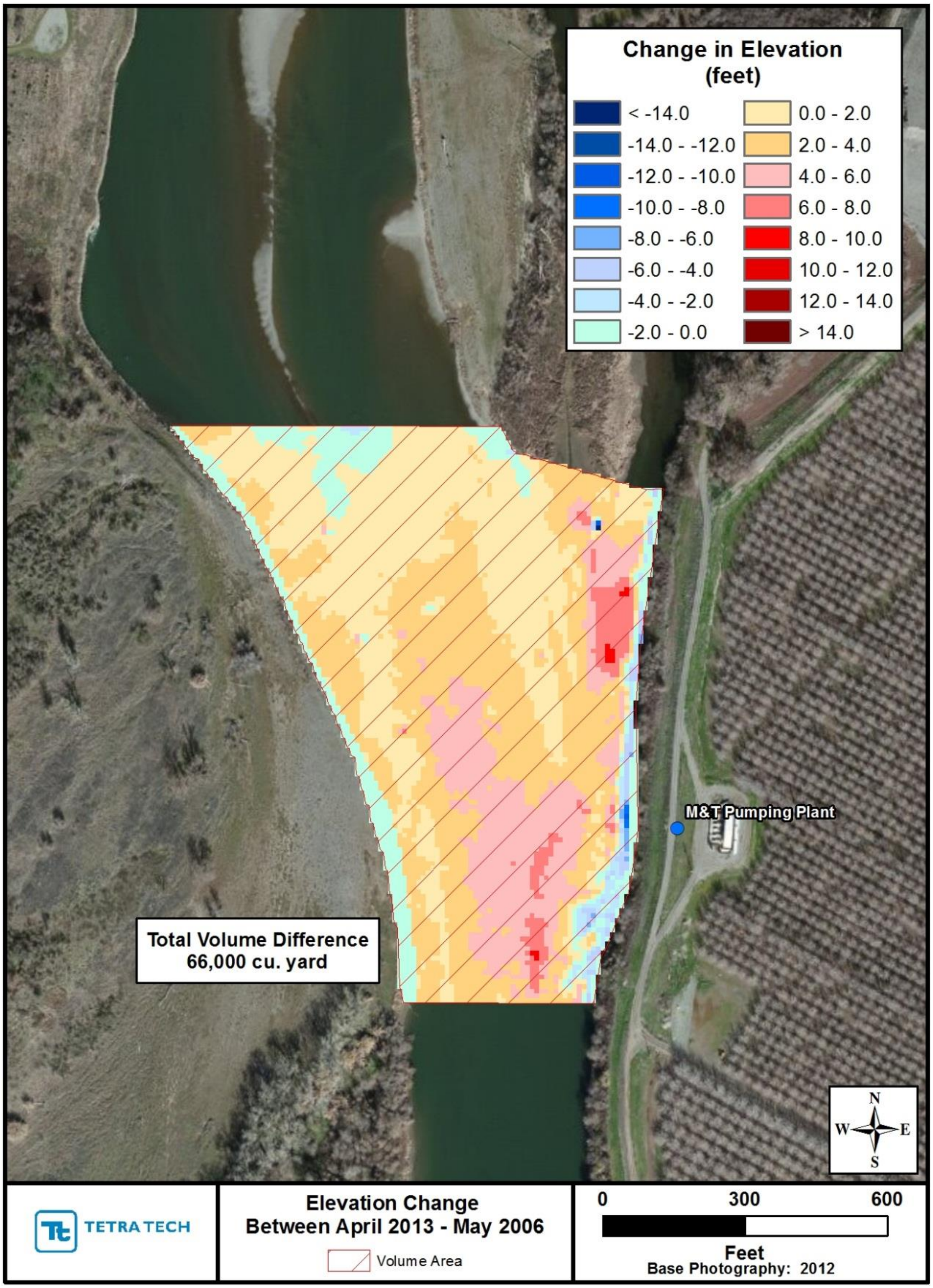


Figure 16. Volumetric calculation of the deposition in the 600 by 1,200-foot segment in the vicinity of the fish screens and pump inlets between the June 2013 and May 2006 surveys.

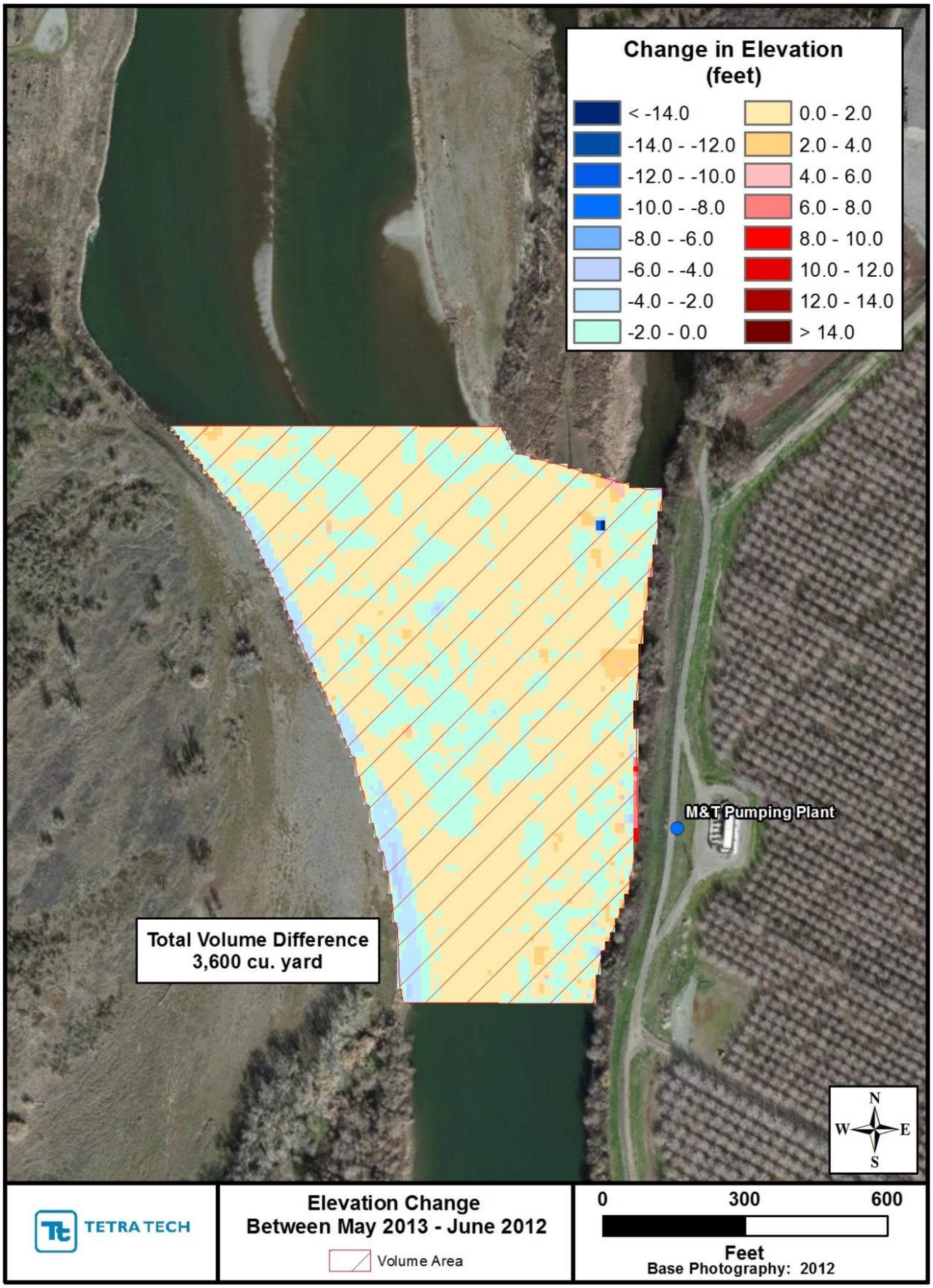


Figure 17. Volumetric calculation of the deposition in the 600- by 1,200-foot segment in the vicinity of the fish screens and pump inlets between the May 2013 and June 2012 surveys.

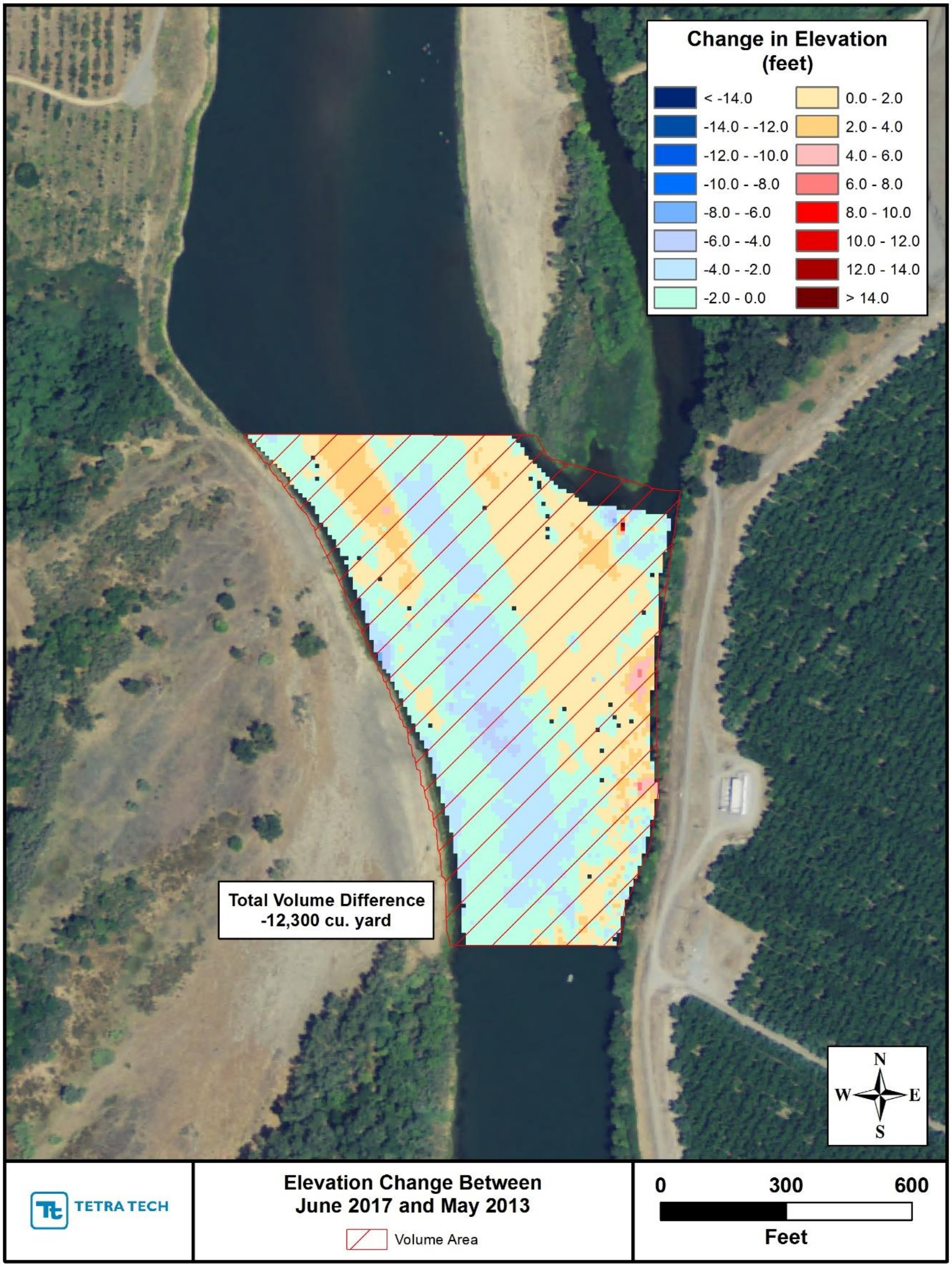


Figure 18. Volumetric calculation of the deposition in the 600- by 1,200-foot segment in the vicinity of the fish screens and pump inlets between the June 2017 and May 2013 surveys.

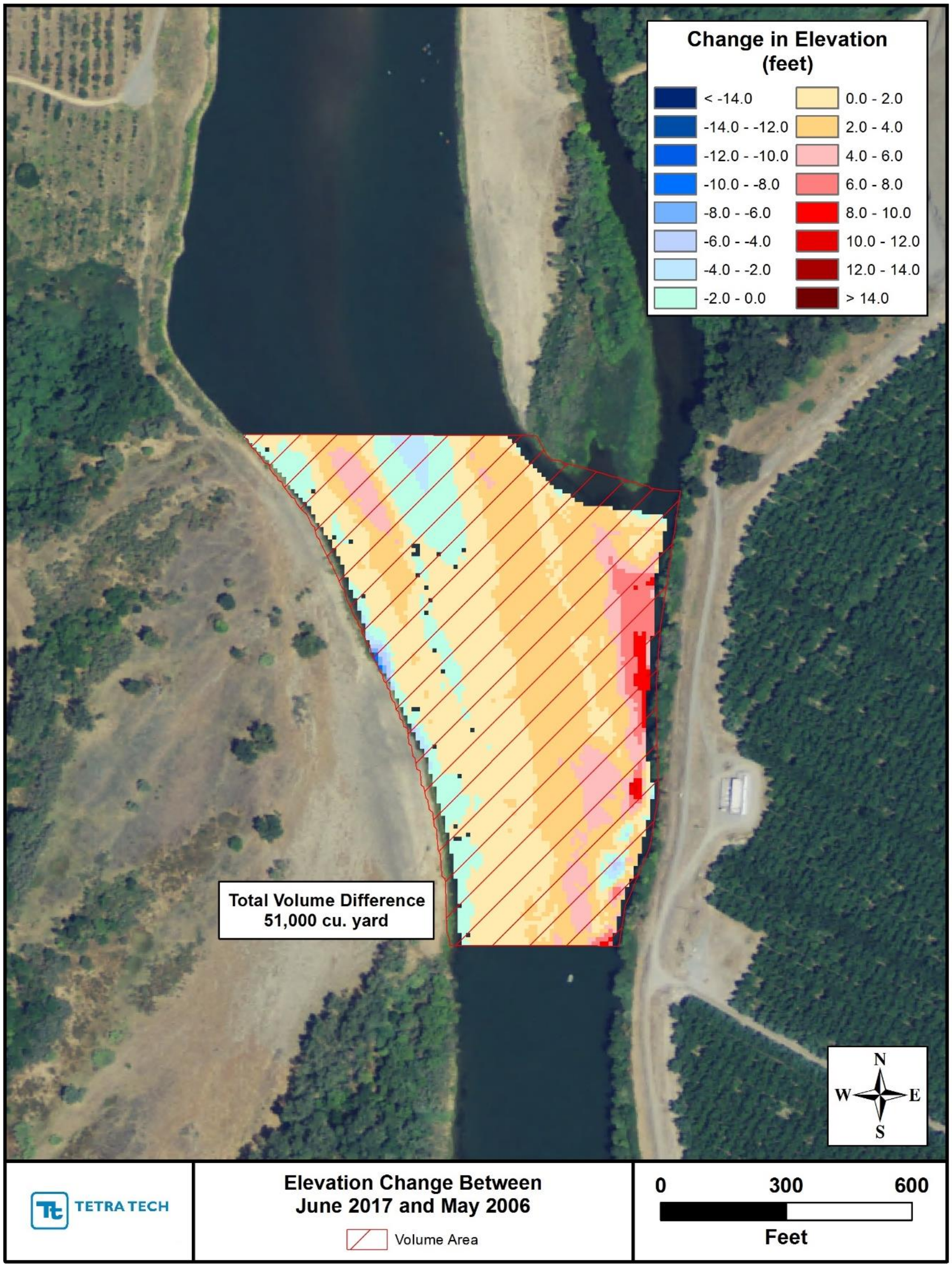


Figure 19. Volumetric calculation of the deposition in the 600- by 1,200-foot segment in the vicinity of the fish screens and pump inlets between the June 2017 and May 2006 surveys.

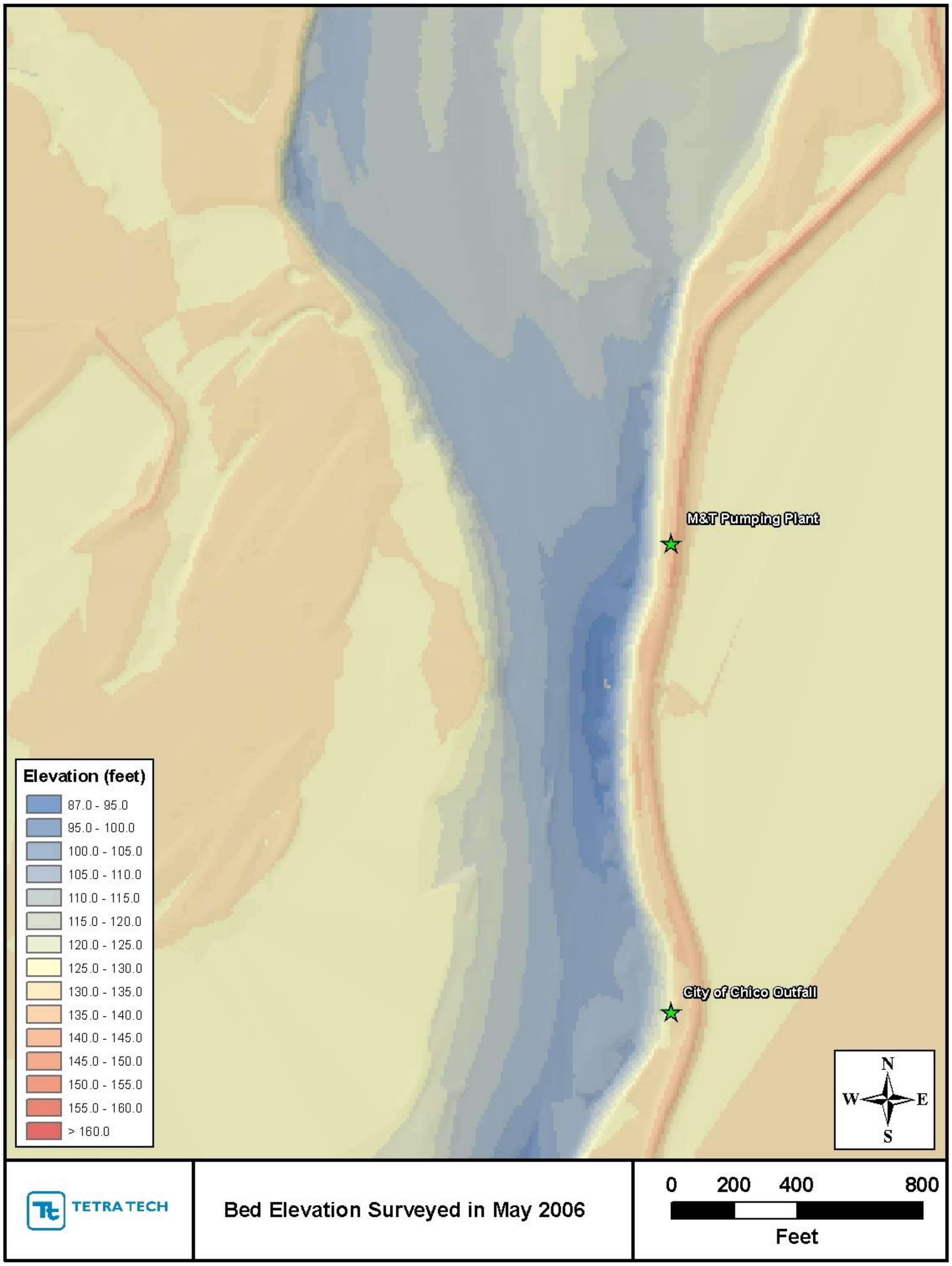


Figure 20. Color gradient plot showing the bed topography in the vicinity of the M&T/Llano Seco Pumping Plant and the relocated City of Chico Outfall in May 2006.

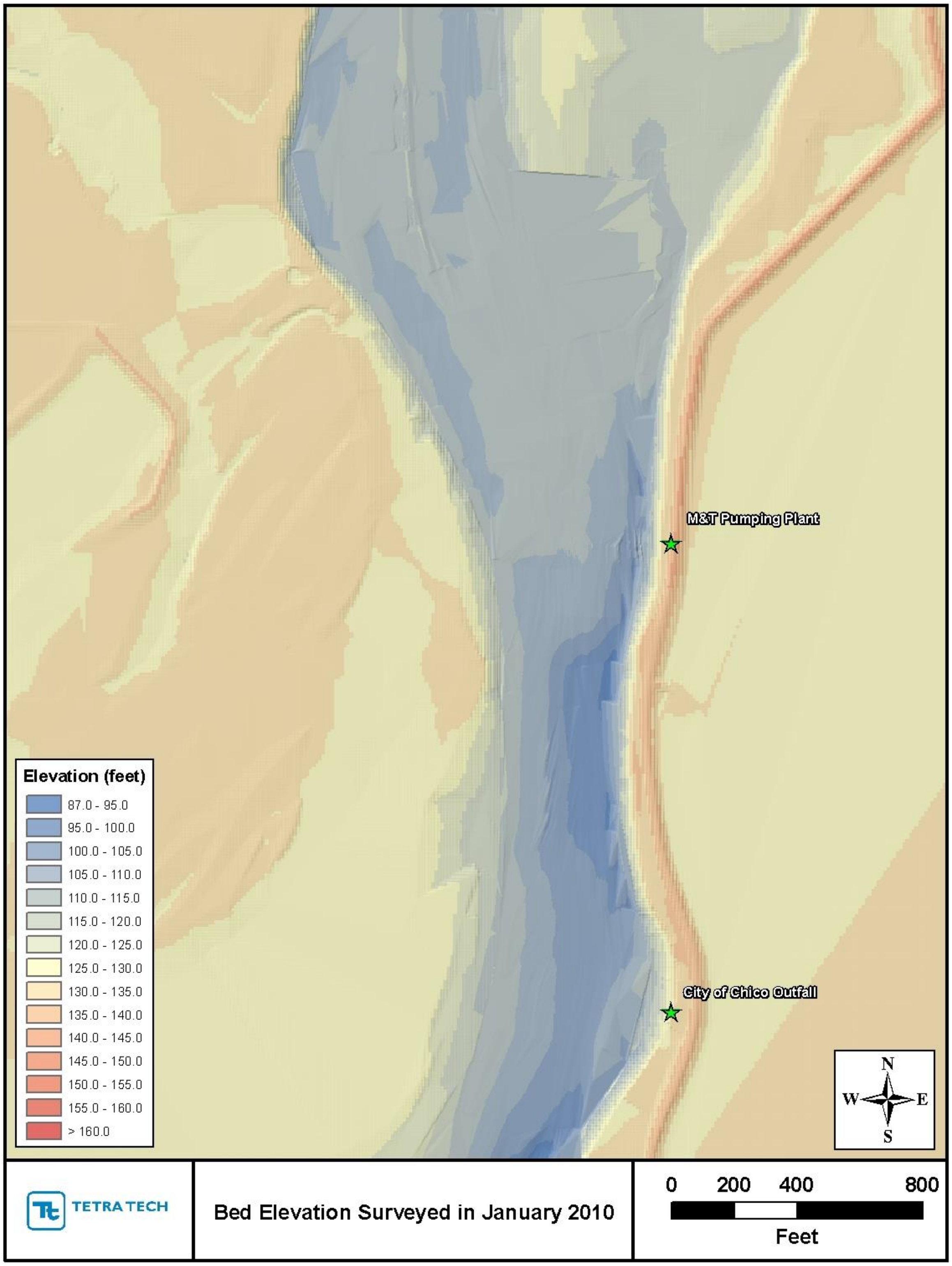


Figure 21. Color gradient plot showing the bed topography in the vicinity of the M&T/Llano Seco Pumping Plant and the relocated City of Chico Outfall in January 2010.

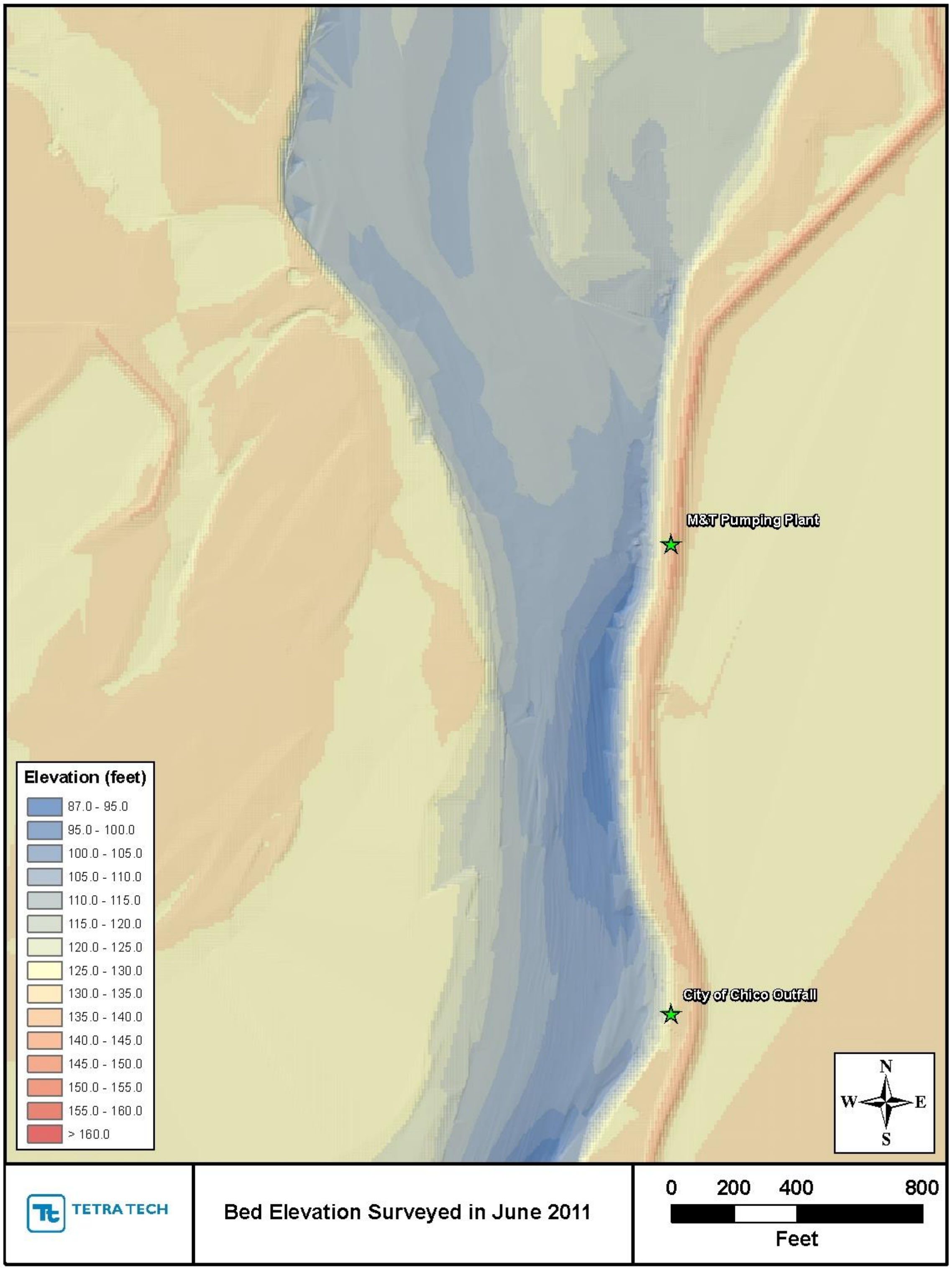


Figure 22. Color gradient plot showing the bed topography in the vicinity of the M&T/Llano Seco Pumping Plant and the relocated City of Chico Outfall in June 2011.

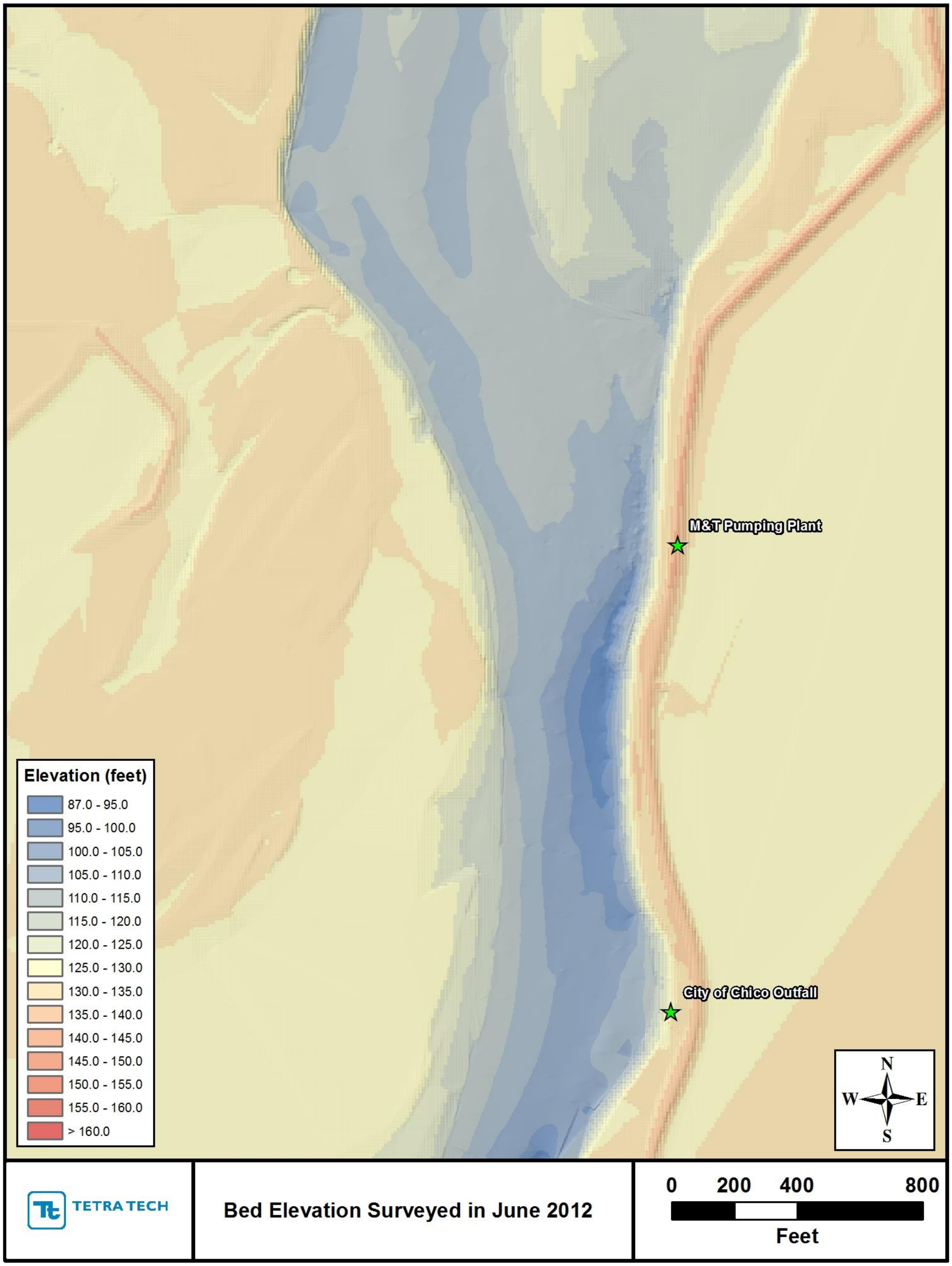


Figure 23. Color gradient plot showing the bed topography in the vicinity of the M&T/Llano Seco Pumping Plant and the relocated City of Chico Outfall in June 2012.

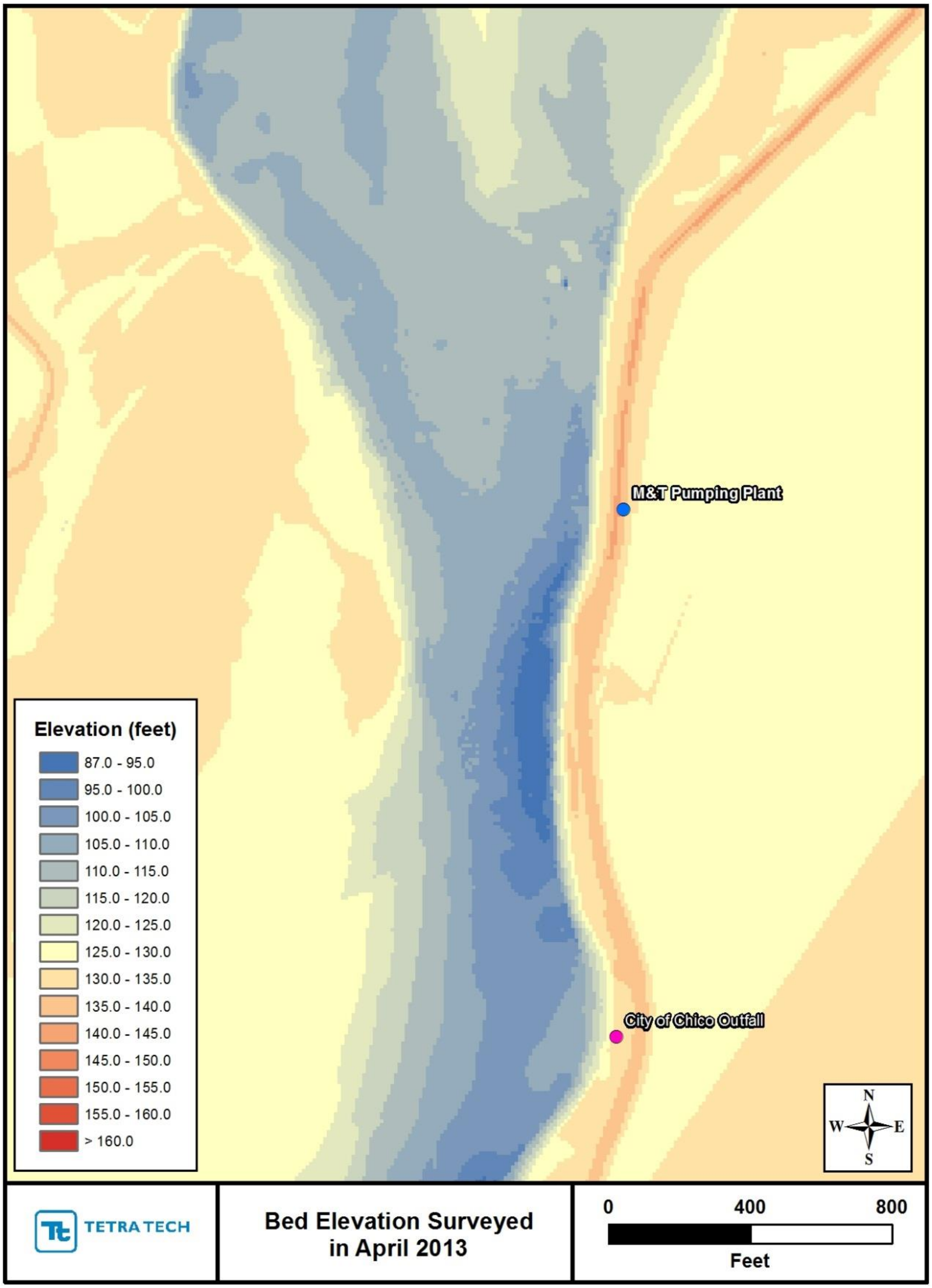


Figure 24. Color gradient plot showing the bed topography in the vicinity of the M&T/Llano Seco Pumping Plant and the relocated City of Chico Outfall in May 2013.

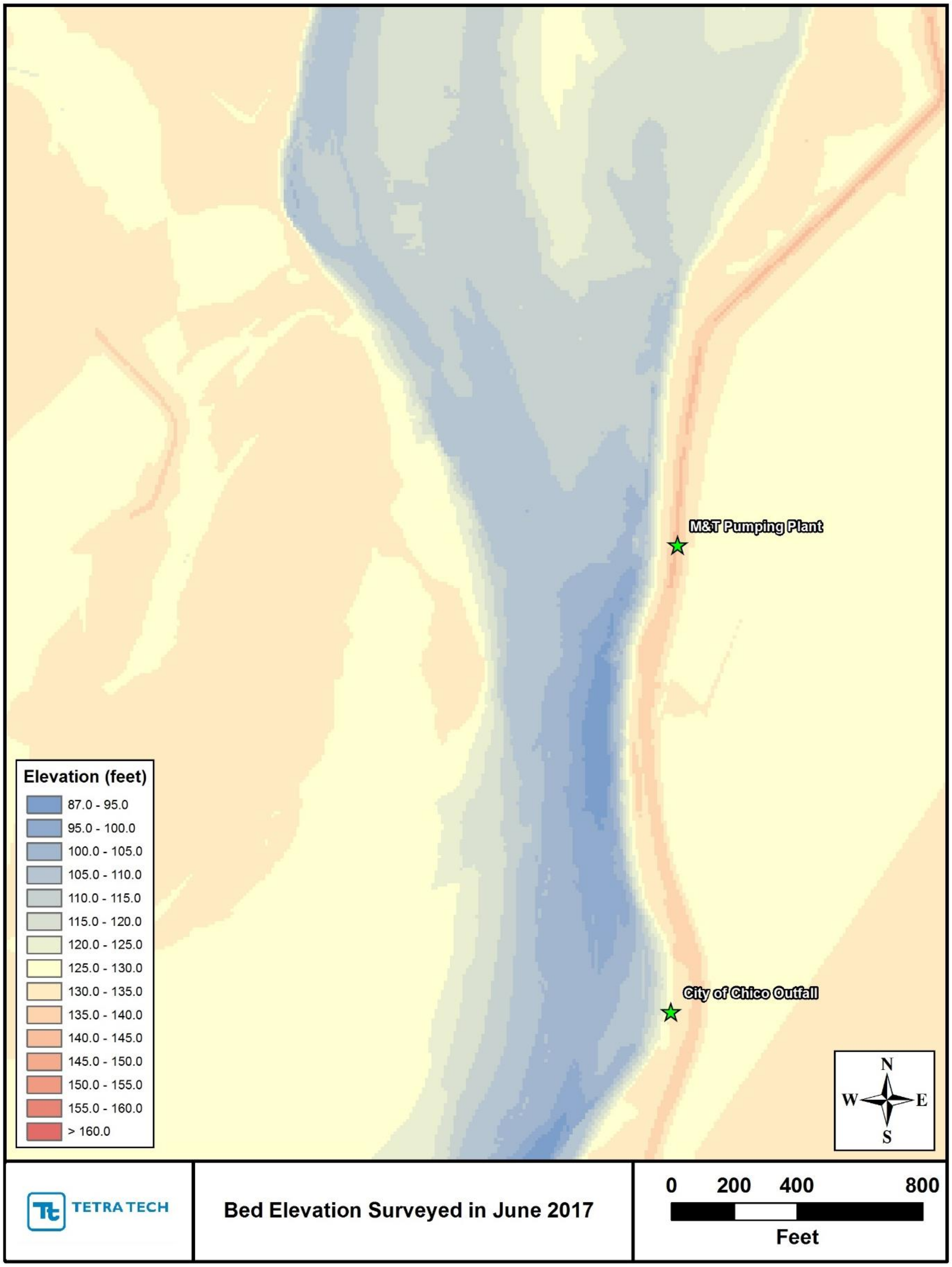


Figure 25. Color gradient plot showing the bed topography in the vicinity of the M&T/Llano Seco Pumping Plant and the relocated City of Chico Outfall in June 2017.

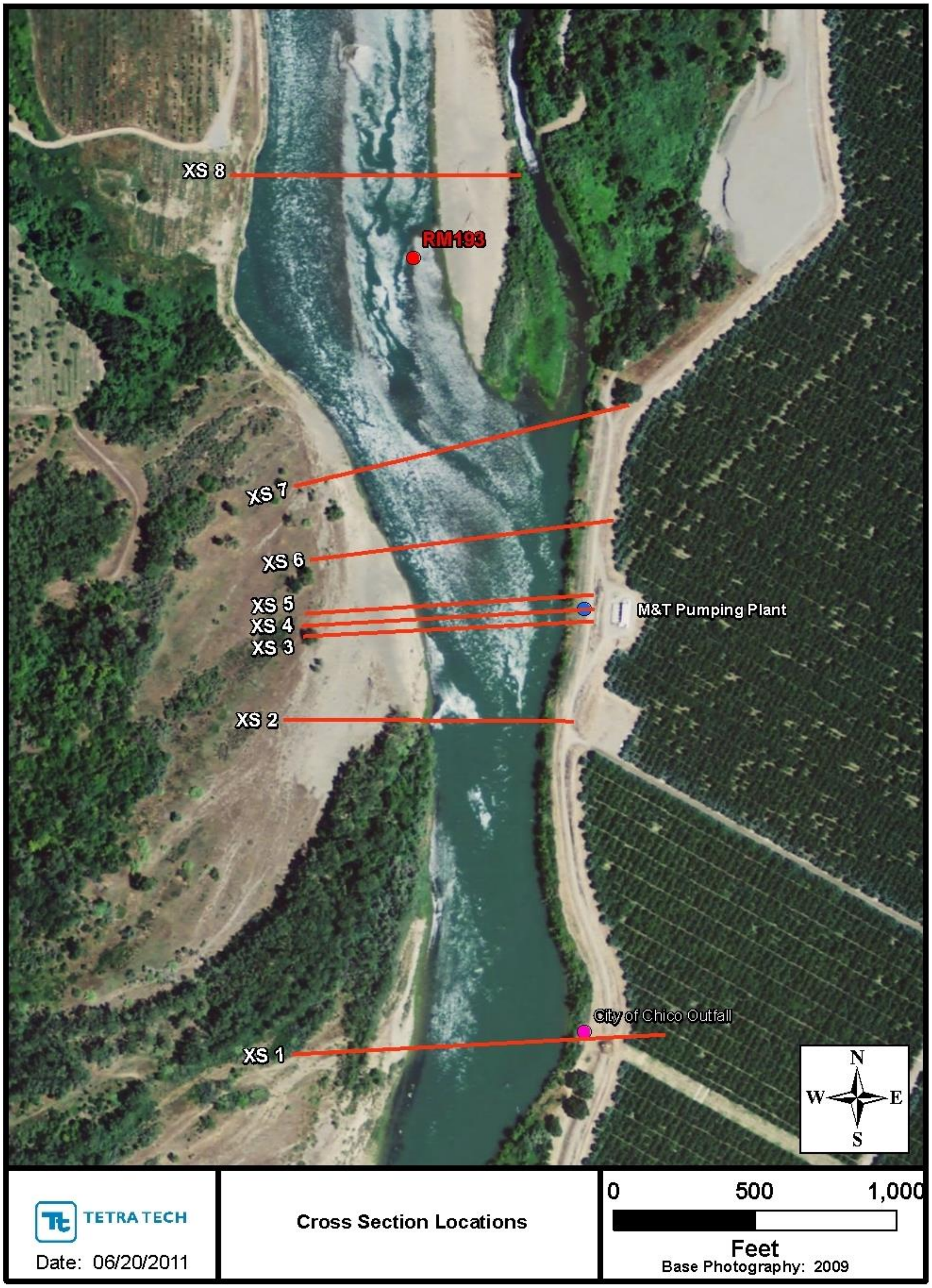


Figure 26. Locations of comparative cross sections discussed in the text.

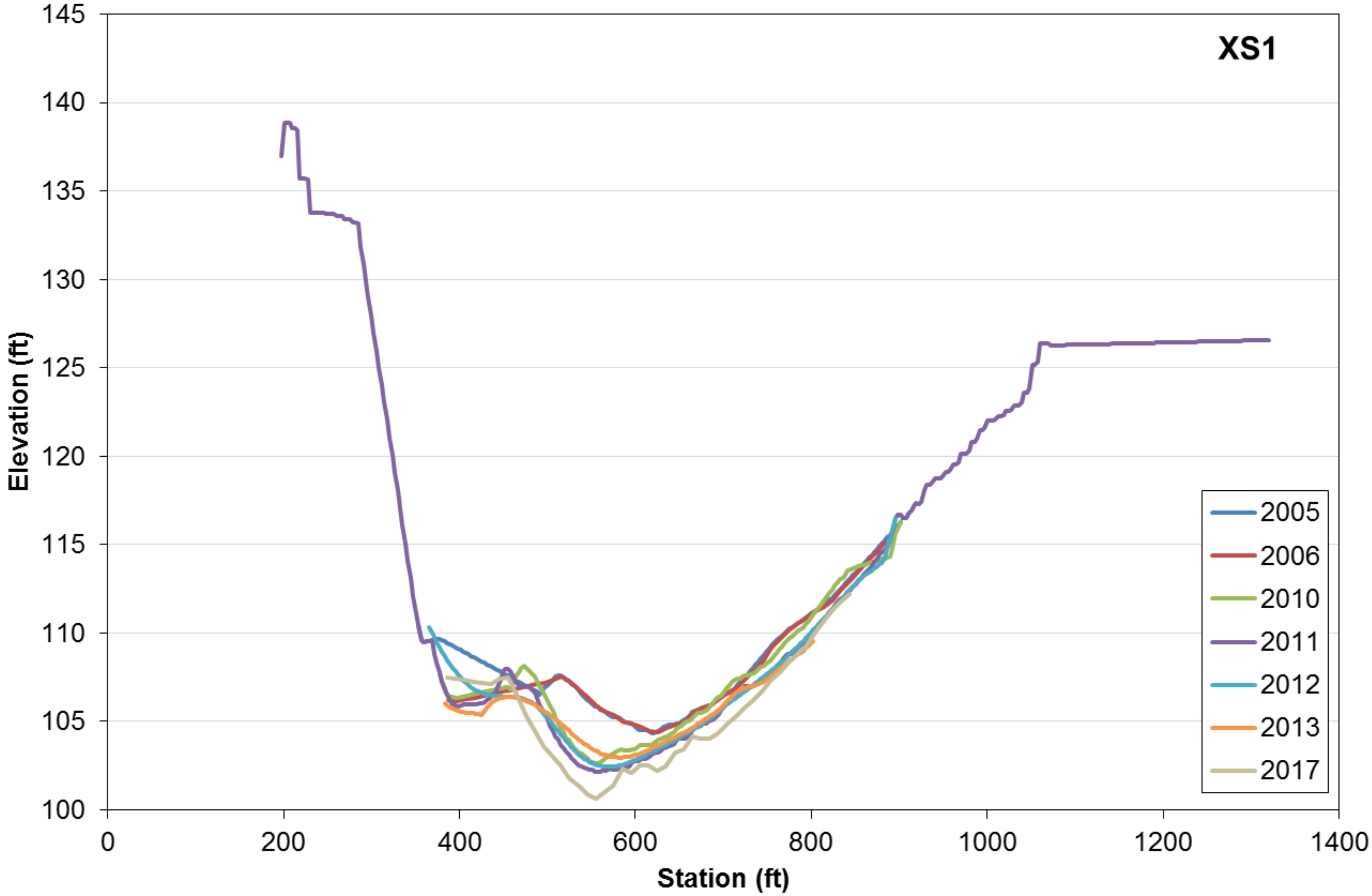


Figure 27. Comparative cross-section plots, 2005 to 2017 at the relocated City of Chico outfall.

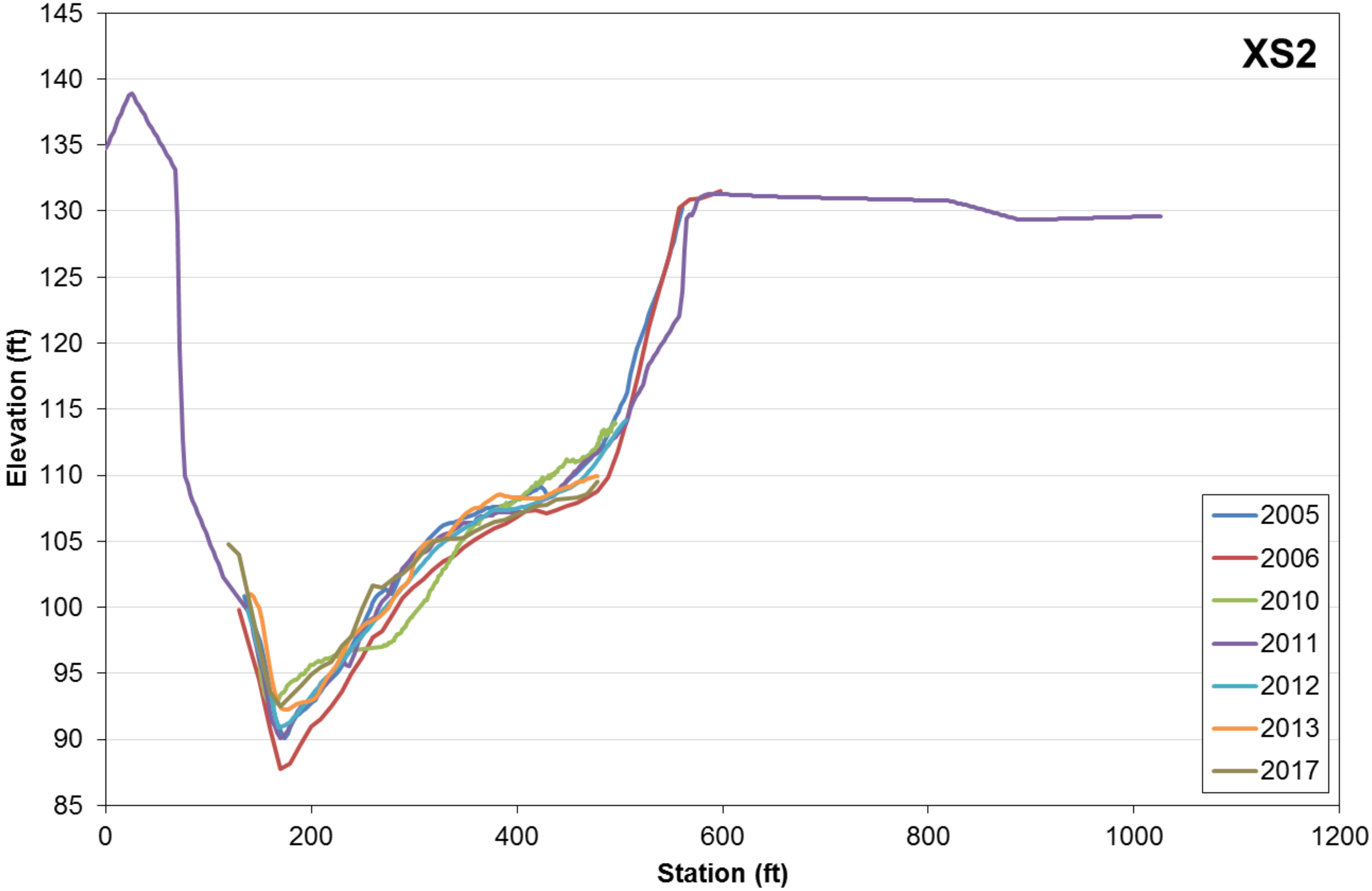


Figure 28. Comparative cross-section plots, 2005 to 2017 at the original City of Chico outfall.

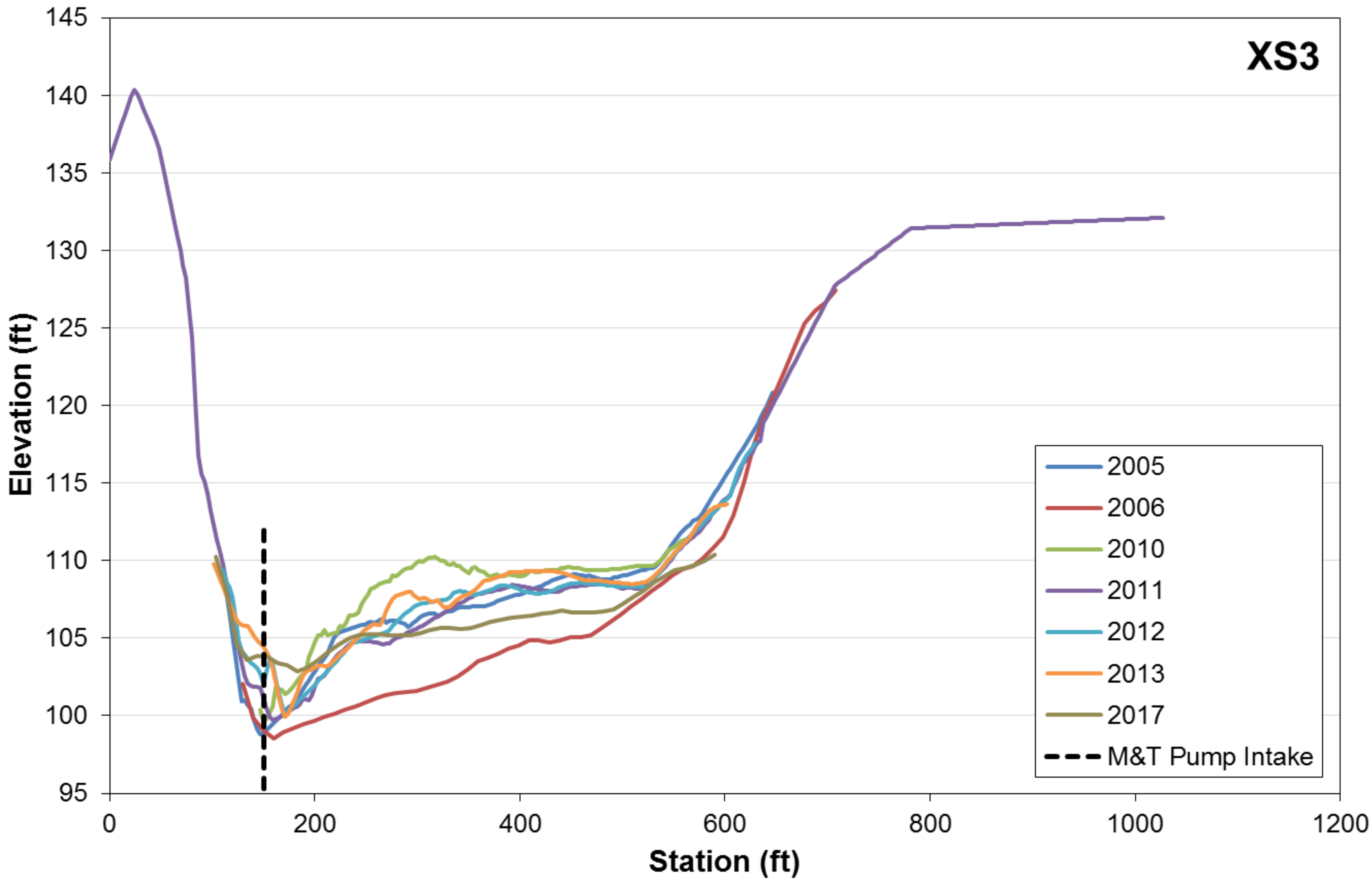


Figure 29. Comparative cross-section plots, 2005 to 2017 immediately downstream of the fish screens and pump inlets.

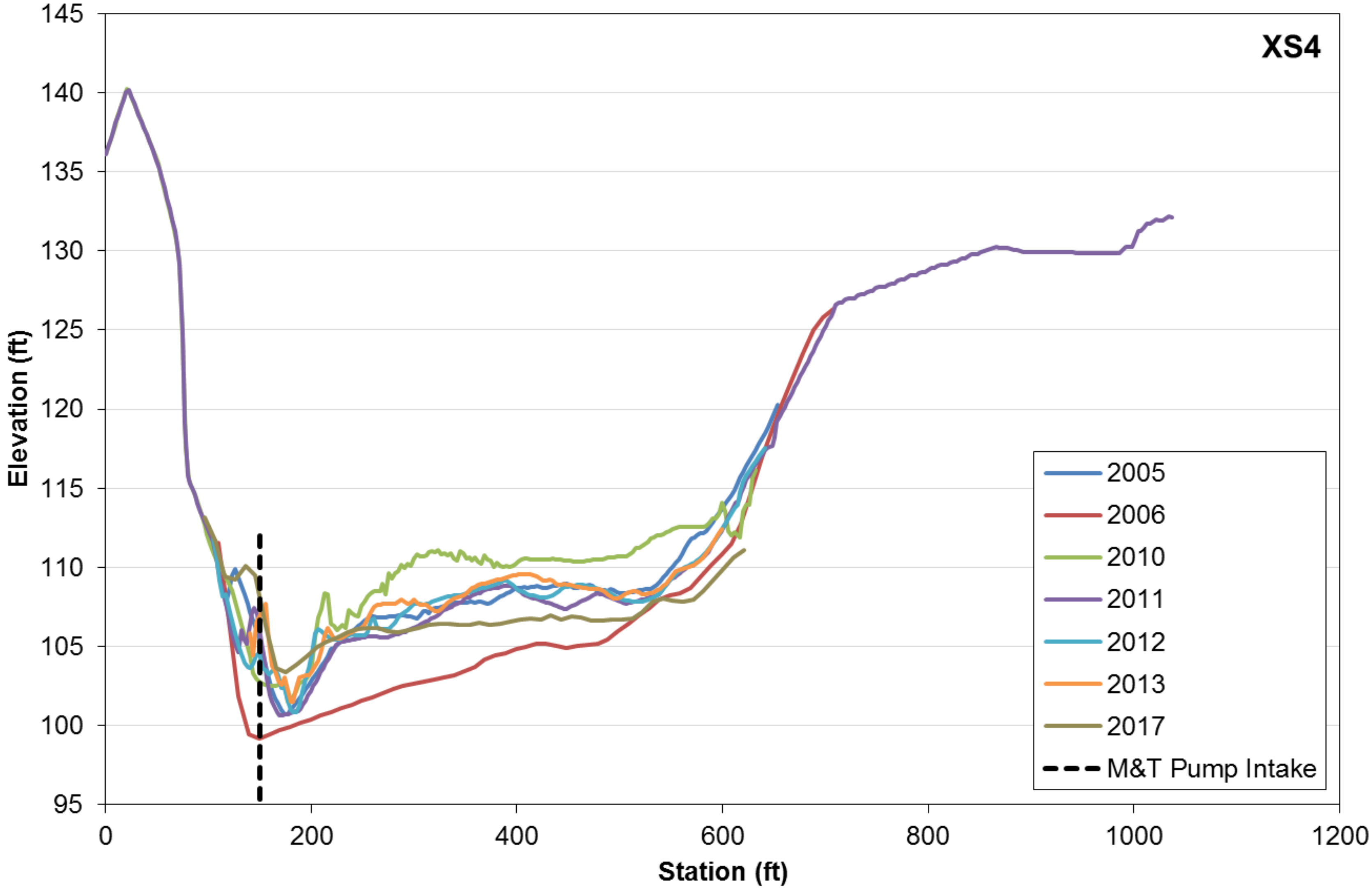


Figure 30. Comparative cross-section plots, 2005 to 2017 at the M&T/Llano Seco fish screens and pump inlets.

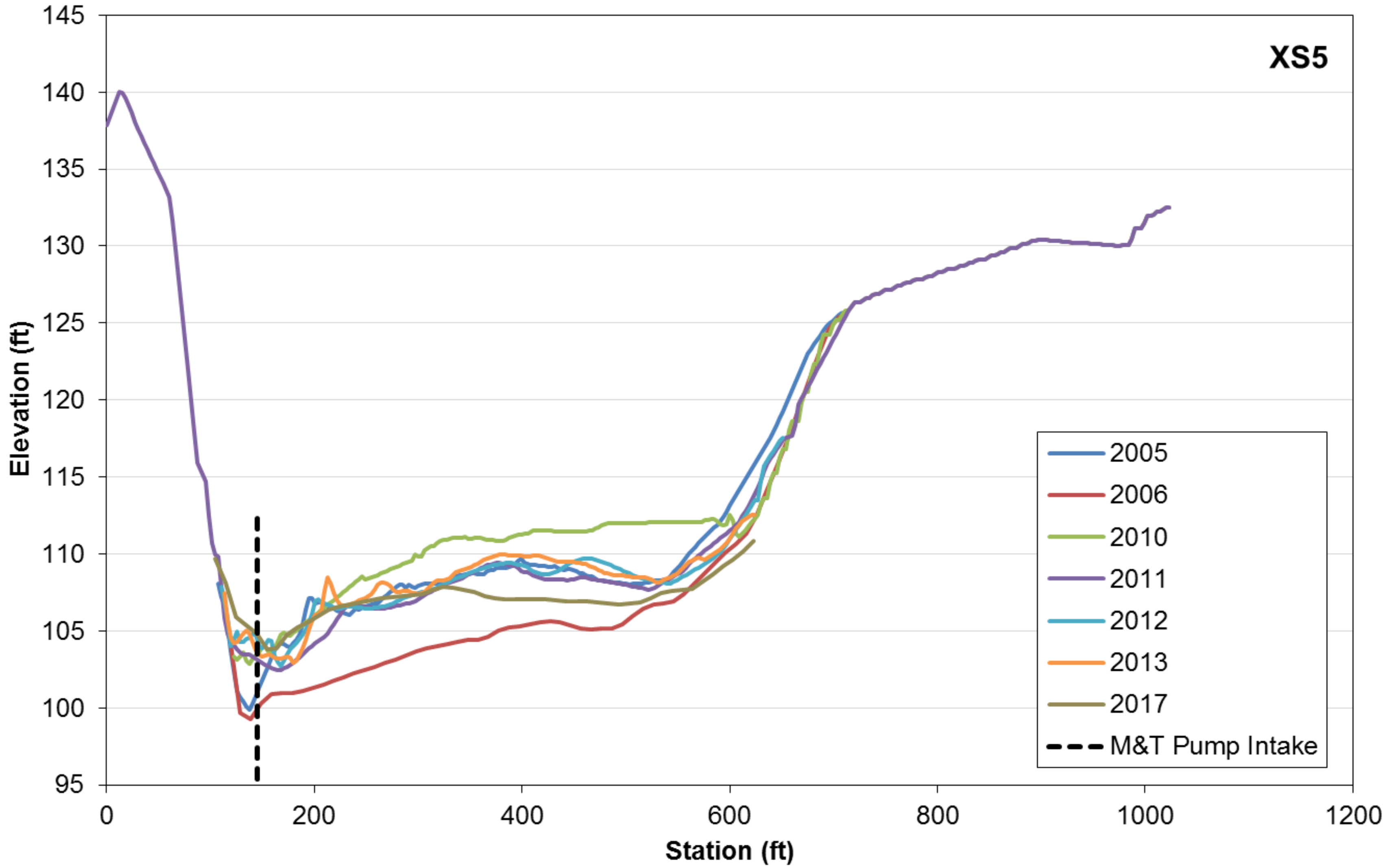


Figure 31. Comparative cross-section plots, 2005 to 2017 immediately upstream of the fish screens and pump inlets.

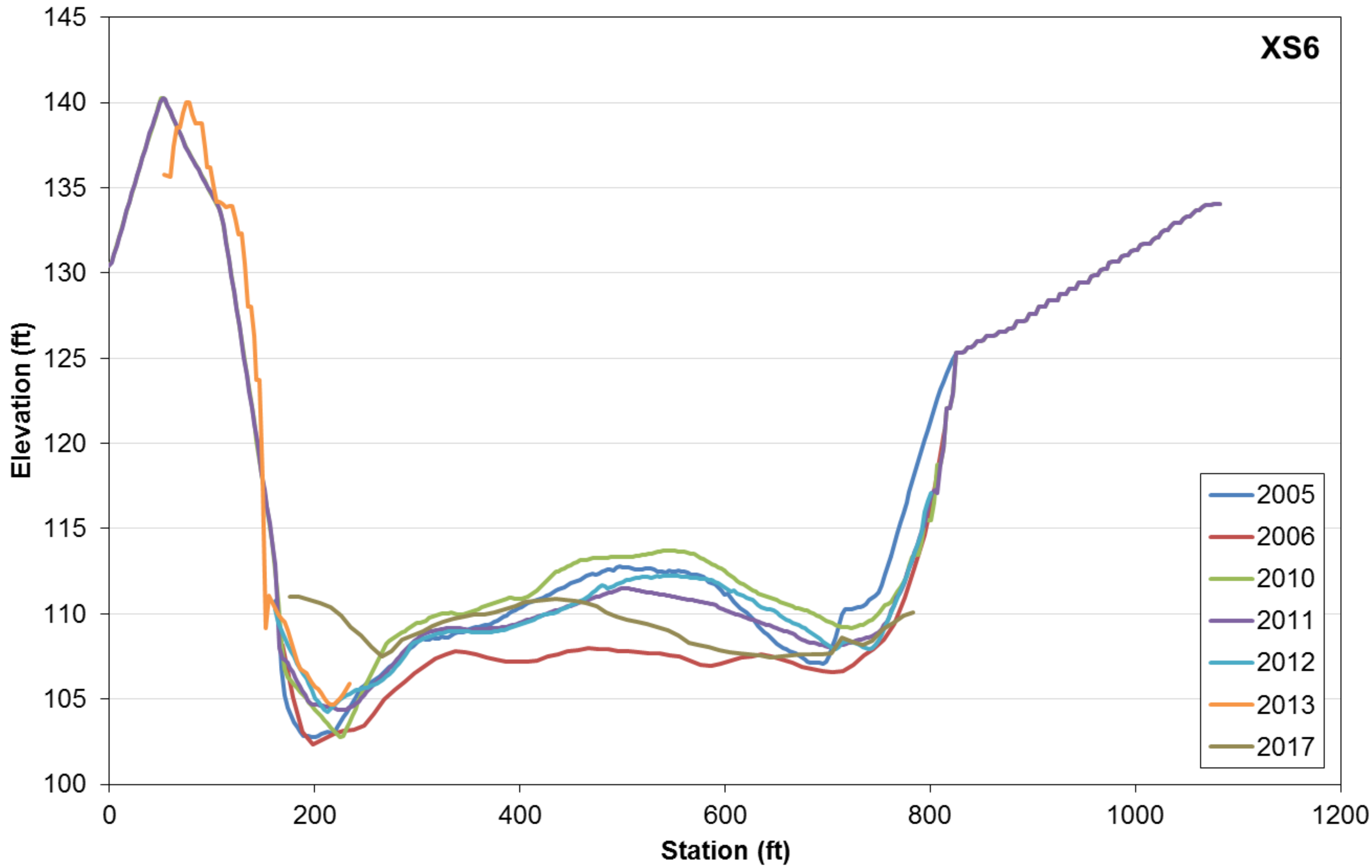


Figure 32. Comparative cross-section plots, 2005 to 2017 upstream of the fish screens and pump inlets on the lower part of the migrating bar.

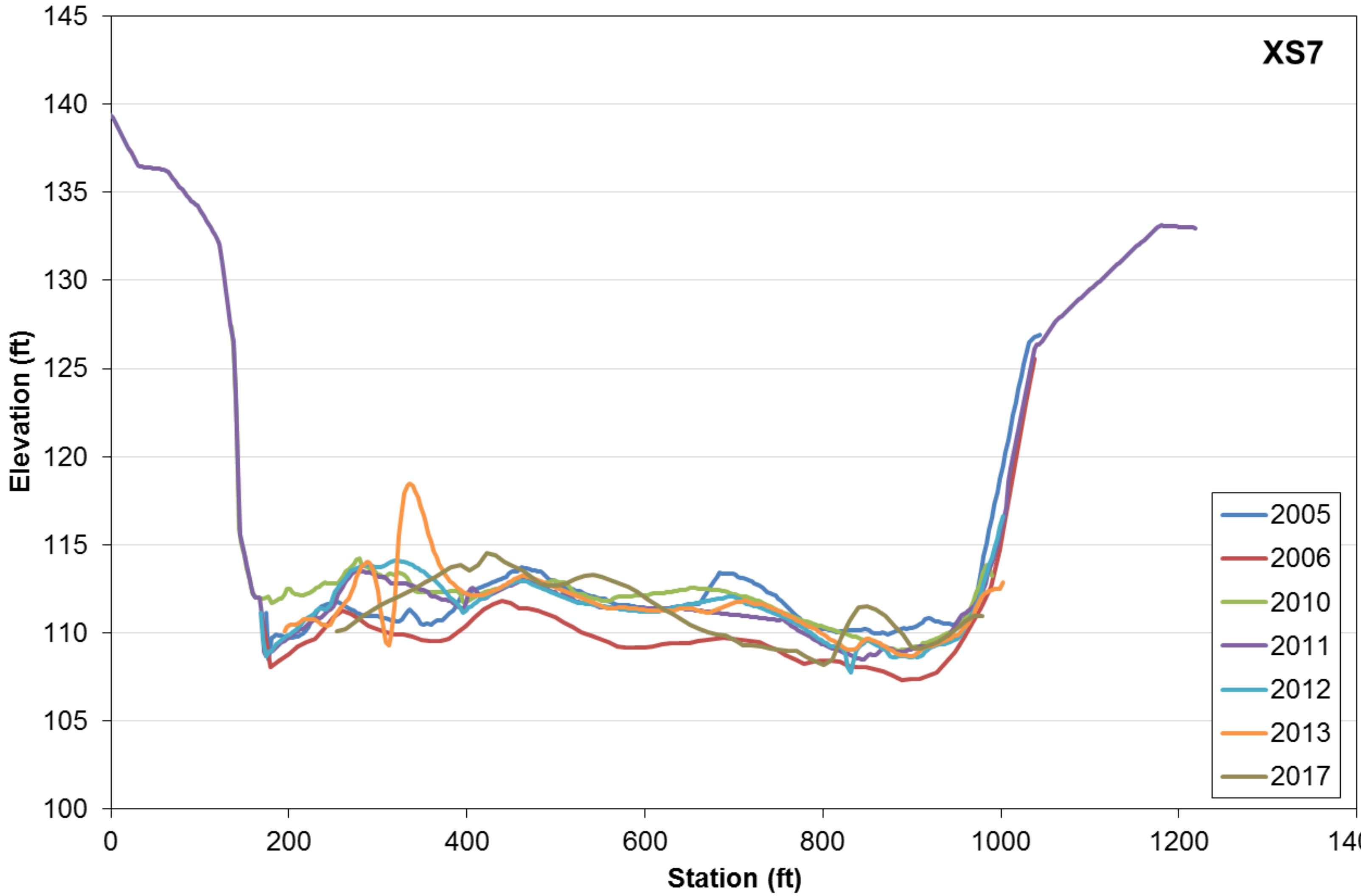


Figure 33. Comparative cross-section plots, 2005 to 2017 upstream of the fish screens and pump inlets on the upper part of the migrating bar.

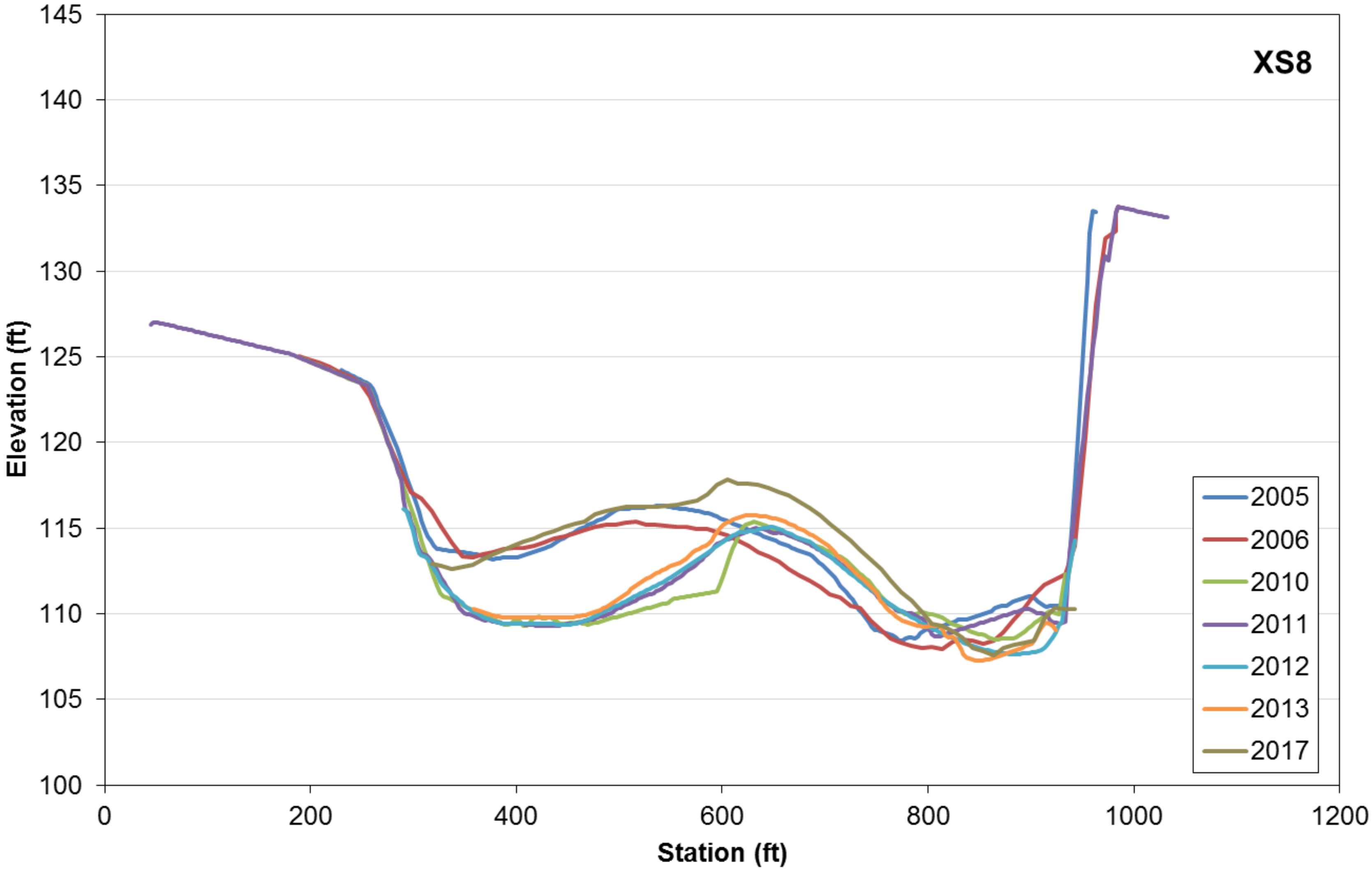


Figure 34. Comparative cross-section plots, 2005 to 2017 across the area that was dredged in 2007.

APPENDIX A

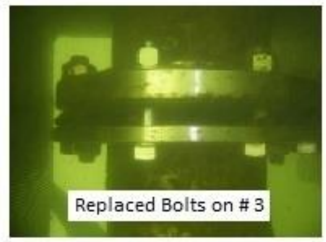
2012, 2013, 2016 and 2017 Dive Reports

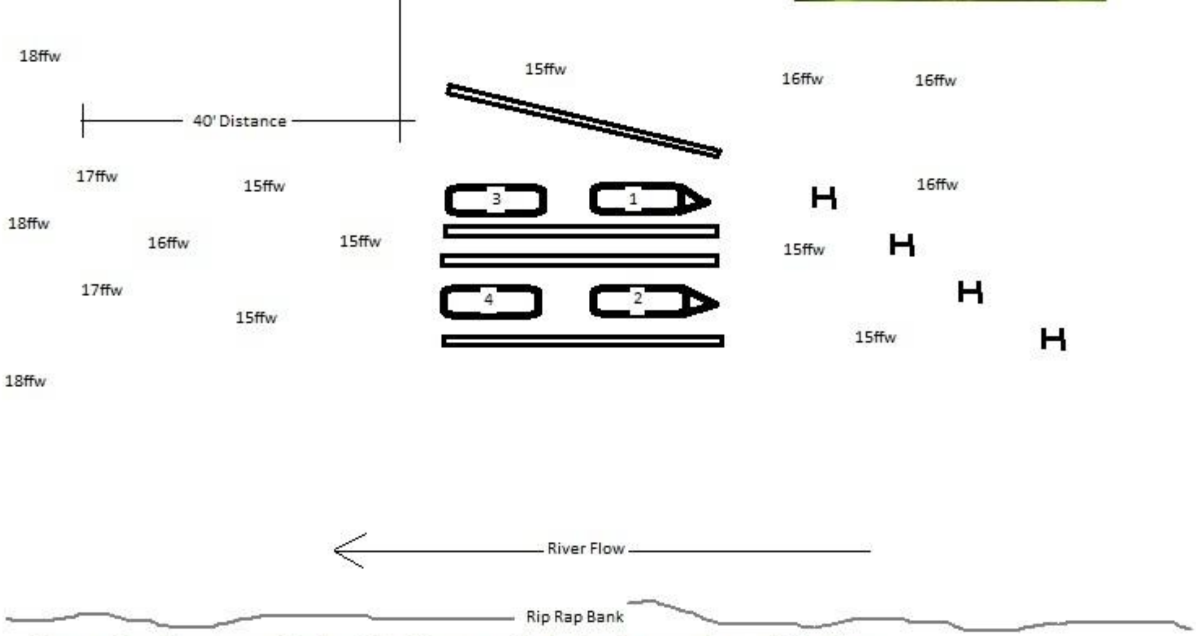
Big Valley Divers Inc.
P O Box 3284
Chico Ca. 95927
Off/Fax (530) 898-1110 Cl (530) 521-0588

5-18-12 - Big Valley Divers Inspection and Spring Cleaning Of:

M & T Ranch , Sacramento River Intake Station.
For: Les Heringer, Mike Bolen

Ord Ferry 5-17-12 River Stage 97.75





Screen #1 - Flanges and bolts tight. Air test = No leaks. Screen cleaned. No dents.
6' from bottom of screen to sandy bottom.

Screen #2 - Flanges and bolts tight. Air test = No leaks. Screen cleaned. No dents.
5' From bottom of screen to sandy bottom.

Screen #3 - Flanges and bolts checked. 2 Galled Stainless Steel bolts found. Bolts removed and replaced. Bolts tightened. Air test = Small leak at beginning of air burst. Determined leak is workable and not to be repaired but will monitor. Screen cleaned. Two dents found. Diver able to rebend wedge wire back to operational status and closed up small gap. 4' From bottom of screen to sandy bottom.

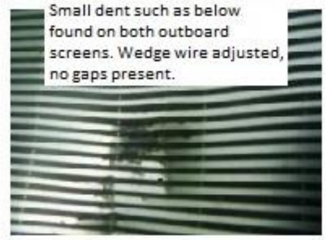
Screen #4 - Flanges and bolts tight. Air test = No leaks. Screen cleaned. No dents.
3' From bottom of screens to sandy bottom.

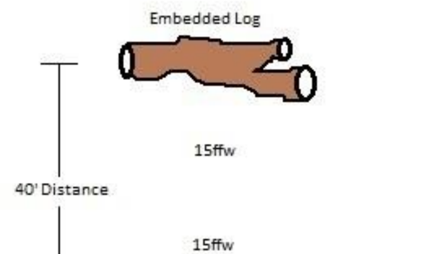
Big Valley Divers Inc.
P O Box 3284
Chico Ca. 95927
Off/Fax (530) 898-1110 Cl (530) 521-0588

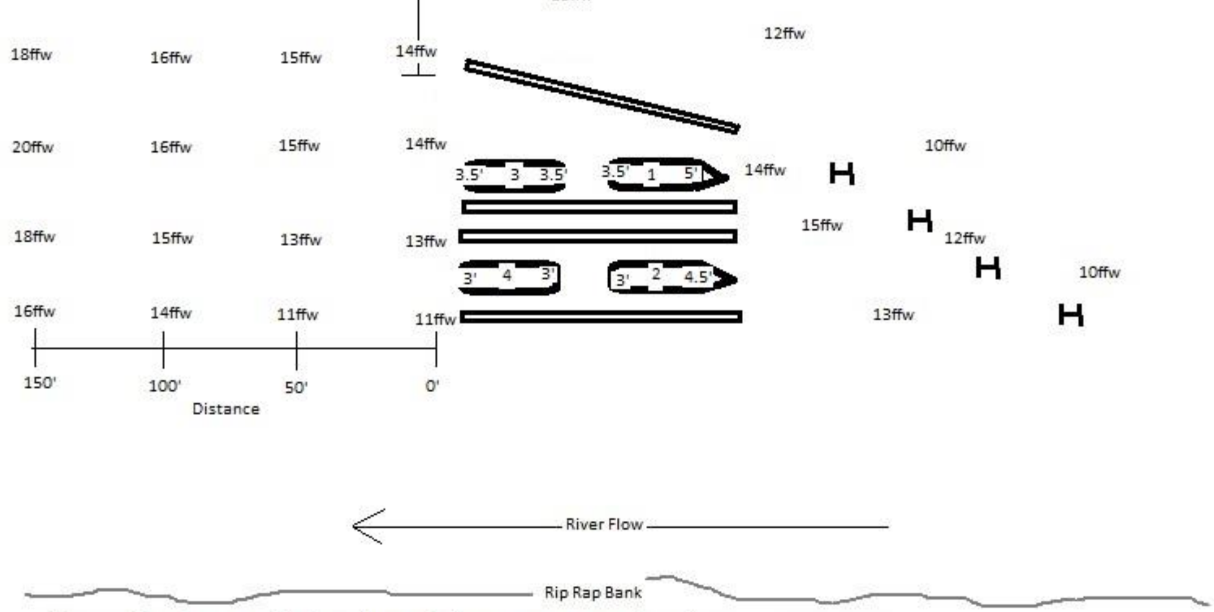
3-20-13 - Big Valley Divers Inspection and Spring Cleaning Of:

M & T Ranch , Sacramento River Intake Station.
For: Les Heringer, Mike Bolen

Ord Ferry 3-20-13 River Stage __ 97.1 _____







Screen #1 - Flanges and bolts tight. Small dent, no gap. Screen cleaned.
4.25' Average under screen to sand and gravel bottom.

Screen #2 - Flanges and bolts tight. No Damage. Screen cleaned.
3.75' Average under screen to sand and silt bottom.

Screen #3 - Flanges and bolts tight. Small dent, no gap. Screen cleaned.
3.5' Average under screen to sand and gravel bottom.

Screen #4 - Flanges and bolts tight. No Damage. Screen cleaned.
3' Average under screen to sand and silt bottom.

NOAA FISHERIES
West Coast Region
Environmental Services Branch

July 28, 2016

Dive Inspection Report

M&T Ranch fish screens, Sacramento River, Butte Count, California

Dive Location:	M&T Ranch pumping plant fish screen, Sacramento River, Butte County	
Lat/Long	39°41'43.62"N 121°56'28.44"W	
Dive Date:	July 15, 2016	
Purpose:	Observe fish habitat and fish behavior near the fish screen and note possible hazards to fish.	
Personnel:	Sean Luis, NOAA Corps Kasey Sims, NOAA Corps Steve Thomas, NMFS[1]	
River Conditions:	Stage	129.42 ft @ Hamilton City (HMC)
	Flow	6,423 cfs @ Hamilton City (HMC)
	Temperature	63 °F
	Visibility	4 feet

Site Description

The diversion is located on river-left of the Sacramento River at about river mile 193. The pumping plant is located on the land side of the levee as shown in Figure 1 and has a capacity of 150 cfs. The intake is approximately 500 feet downstream from the confluence of Big Chico Creek and the Sacramento River.

One conductor pipe connects the pumping plant to the intake which consists of four cylindrical Tee screens the closest of which is approximately twenty feet from shore. The Tee screens are arranged in two rows with "I" beams along either side of each row of screens which are just slightly higher than the tops of the fish screens (Figure 2). Four "I" beams are driven vertically upstream of the intake as debris deflectors. The screens are cleaned with an internal air burst or air sparge system to displace water and debris impinged on the surface of the screen but is not designed to remove attached growth like algae or sponges.

Over the past decade or more a gravel bar migrating downstream threatened to bury the screens. Twice gravel has been dredged from the area upstream of the screens.

[1] Dive master and POC for NMFS inland dive operations in California, steve.thomas@noaa.gov, (707) 575-6079.

Dive Description and Findings

Divers observed conditions from the surface prior to entering the water. Surface currents indicated the screens sit in an eddy where flow was moving downstream along the outer edges of the screen area and upstream closer to shore. The screens were visible from the surface and divers observed the air sparge system initiate on two of the four screen units.

Divers surveyed all surfaces of the screens and explored the vicinity upstream an outboard into the river. The upper surfaces of all screen cylinders were covered with algae (Figure 3). Divers did not observe any damage to the screens even though it is known that there was a depression in the top of one cylinder at the prior inspection in 2011 and personnel with M&T Ranch said the indentation had not been fixed. The indentation is slight and must have been camouflaged due to the algae growth.

The lower surfaces of the screens were partially occluded with leafy matter despite activation of the cleaning system less than 30 minutes prior to the inspection (Figure 4).

The substrate in the near vicinity of the screen was layered with fine sand and silt and light woody debris. It appeared as though light woody debris accumulated around the screen units at higher flows and sediment has settled on top of the debris during the lower flows. Under each cylinder was a depression approximately 2 – 3 feet deep.

Divers swam approximately 50 feet upstream and about 20 feet further west (into the river) from the screens to observe composition of the stream substrate in anticipation that gravel could be threatening to bury the screens. When divers were within the eddy current the substrate was consistently fine sediment with light and moderate sized woody debris. Further away from shore the stream current increased suddenly to 1-2 ft/s. Stream sediment there was larger gravel mostly hardened in place with finer material where the higher stream velocities exited.

Conclusions and Recommendations

The screens are in good shape. The amount of algae seen on upper surfaces is typical and not an issue if cleaned once or twice a year by professional divers. There was no evidence of a gravel bar moving towards the screens, although the scope of this inspection was limited in proximity to the screens. The air burst cleaning system appeared to be strong enough to keep light sediment clear of the bottoms of screen units, providing sufficient clearance between the screens and the substrate. The facility would benefit from having stronger currents to move leafy debris away from the screens after initiating a cleaning cycle. Since the screens are in an eddy at the existing river flow, the light sediment will continue to accumulate in that area. Flow patterns may change at higher flows to remove the light sediment and perhaps the light woody debris.

For more information please contact Steve Thomas at (707) 575-6079.

Figures

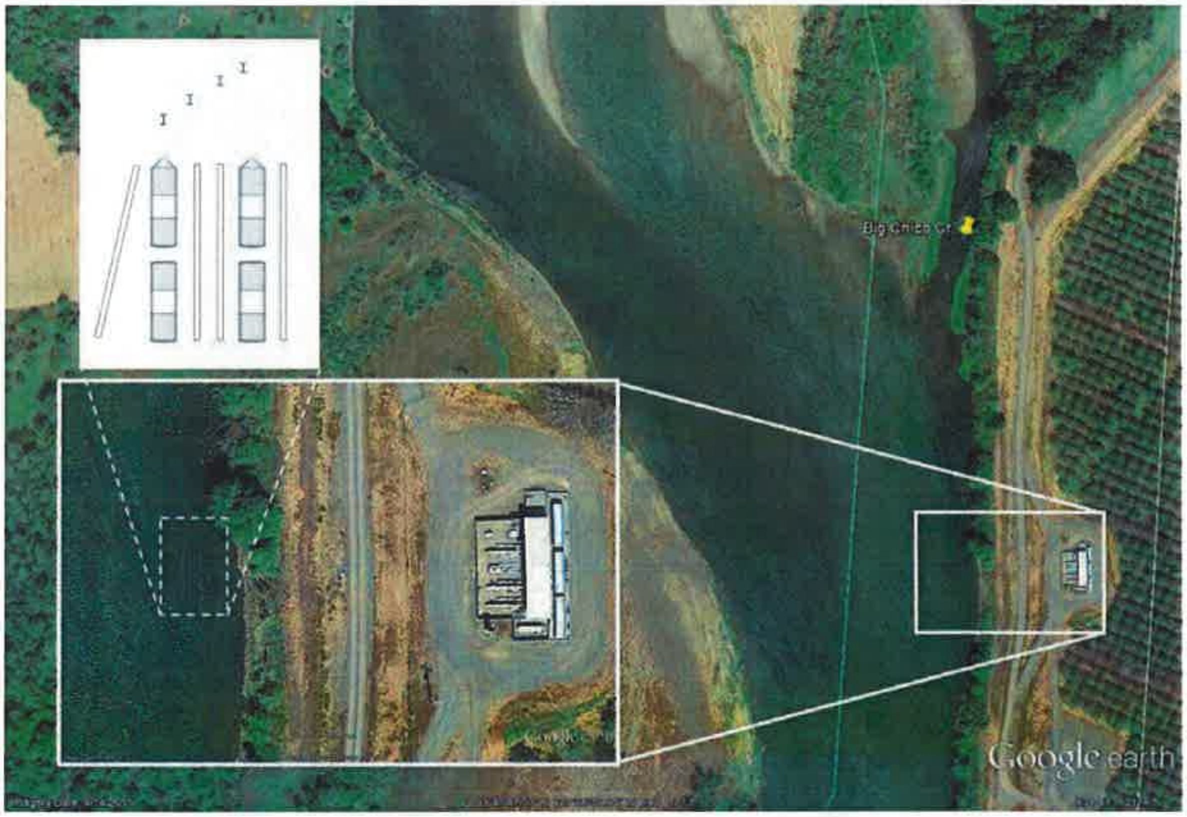


Figure 1. Location of the pumping plant and fish screen. Inset shows a plan view sketch of the screens and protective elements. The intake is on the Sacramento River immediately downstream from the confluence of Big Chico Creek. Stream flow is from top to bottom in the photos.

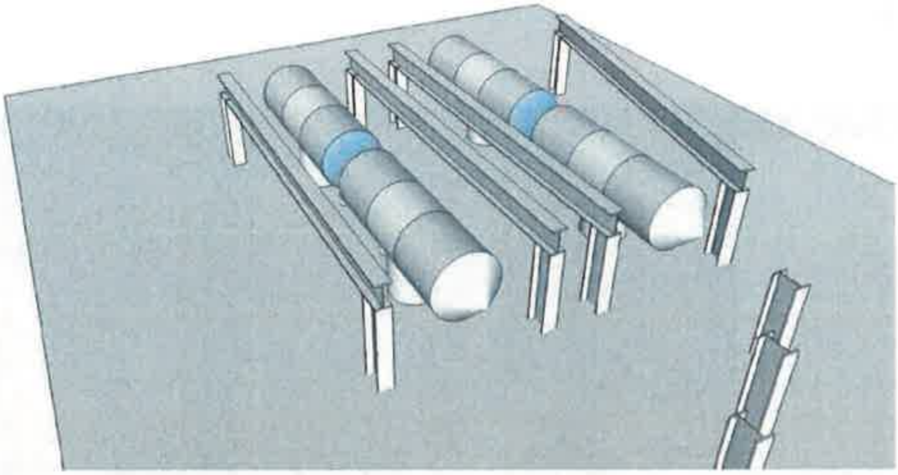


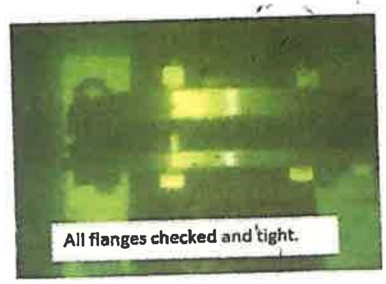
Figure 2. Isometric drawing of fish screens with debris protection elements.

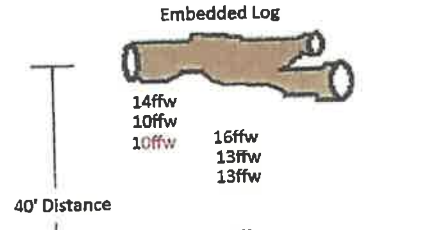
Figure 3. Algae on all upper surfaces of screen cylinders. The amount of algae observed is typical for a shallow screen on the Sacramento River and will not appreciably restrict water flow.

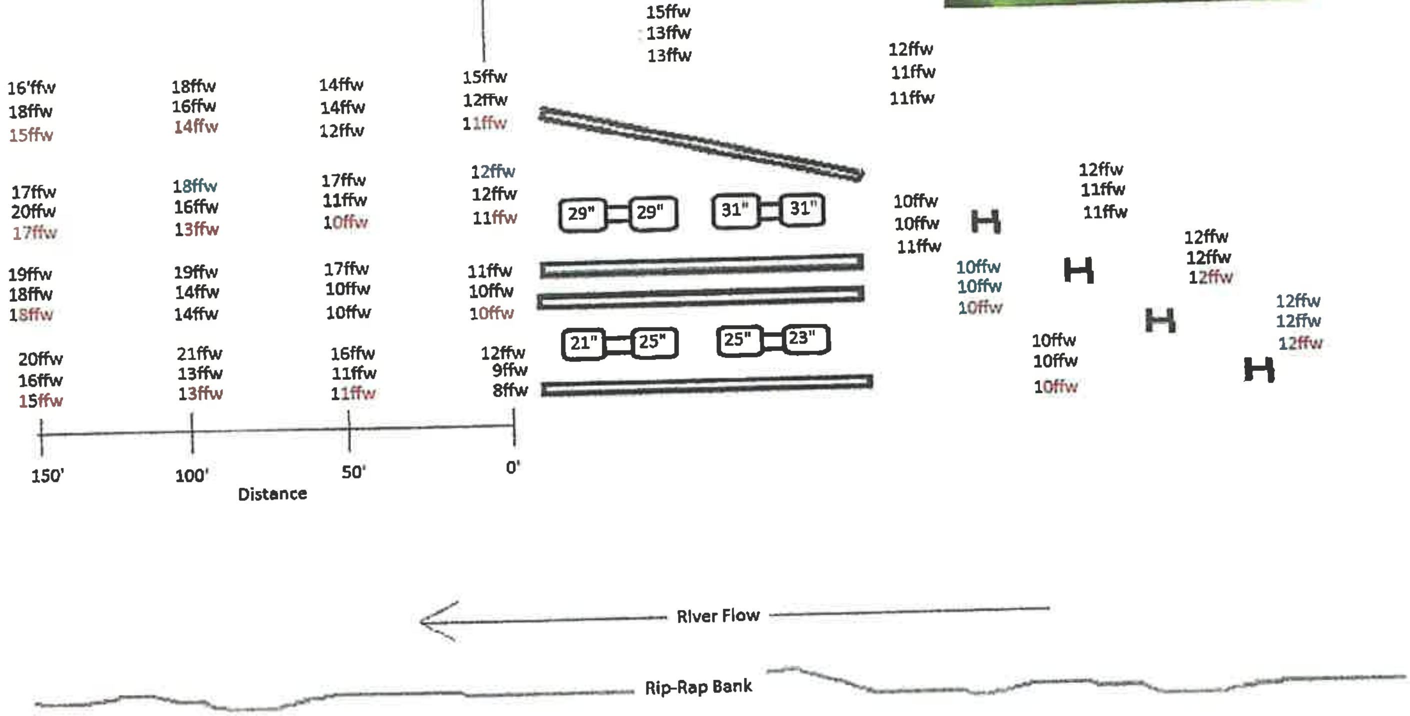
Big Valley Divers Inc.
PO Box 3284
Chico, CA 95927
Off: (530) 898-1110 Cell: (530) 570-8833

Date: 05-26-17 **Customer:** M & T Ranch
Location: M & T Ranch Sacramento River Intake Station
Job Scope: Spring Inspection & Cleaning
Rep: Les Heringer & Mike Bolen
Ord Ferry River Stage on 05-26-17: 98.9'
Ord Ferry River Stage on 05-27-16: 96.5'
Ord Ferry River Stage on 05-15-15: 96.4'

Key:
Blue is 2017 Water Depth
Black is 2016 Water Depth
Red is 2015 Water Depth







Screen # 1: Flanges and bolts tight. Small dent with no gaps. Screens Cleaned. 31"Average under screen to sand and gravel bottom.

Screen # 2: Flanges and bolts tight. No Damage. Screens Cleaned. 24"Average under screen to sand and silt bottom.

Screen # 3: Flanges and bolts tight. Small dent with no gaps. Screens Cleaned. 29"Average under screen to sand and gravel bottom.

Screen # 4: Flanges and bolts tight. No Damage. Screens Cleaned. 23"Average under screen to sand and silt bottom.