TETRA TECH

MEMORANDUM

TO: Jim Well, Ducks Unlimited

FROM: Mike Harvey, Ph.D., P.G.

SUBJECT: **June 7-9, 2011 Resurvey of M&T/Llano Seco Pumping Plant and City of Chico Outfall Reach of the Sacramento River**

DATE: July 11, 2011

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 inundated 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 tons 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.

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 Inc. (Tt) in January 2010. 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). Because of observed aggradation during low-flow conditions in the vicinity of the pump inlets following the 2010 survey (Tetra Tech, 2010) preparations for further gravel removal were commenced in late 2010. Unlike the previous gravel removal operations that were conducted in the "dry," the location of the sediment build-up dictated a below-water dredge operation. To determine the necessity of dredging and to quantify the volume (tonnage) of material, a further hydrographic survey was commissioned by Ducks Unlimited. The hydrographic survey was conducted by Tt between June 7-9, 2011 when the flows at the Hamilton City gage varied between 25,000 and 19,300 cfs as a result of Bureau of Reclamation releases from Shasta Dam. The survey was conducted with an Odum Hydrotrac Echosounder (±0.2-foot resolution) coupled with a Leica Vista RTK-GPS system that were mounted on Tt'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 in the river (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 resurveyed in May 2006, and this survey is used as the baseline condition for the following discussion.

Figure 1 presents the changes in elevation of the bed of the river within the M&T/Llano Seco reach between the 2010 survey and the 2006 survey. 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 2** presents the changes in bed elevation between the 2011 survey and the 2006 survey. It is apparent that the amount of aggradation in the vicinity of the pumping plant has been reduced following the high flows in early 2011 (peak flow at Hamilton City was about 102,000 cfs), but there is still some aggradation when compared to the 2006 survey. **Figure 3** presents the differences in elevation of the bed of the river between the 2010 and 2011 surveys.

In order to determine how much material had to be dredged 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 the 2006 and 2010 surveys was determined (**Figure 4**). The volume of material that had accumulated between the two surveys was about 89,000 cu.yd. (~120,000 tons). The same calculation was made to determine the difference between the 2011 and 2006 surveys (**Figure 5**). The volume of material that has accumulated between the two surveys was reduced to about 54,400 cu.yd. (~73,400 tons). The computed difference between the 2010 and 2011 surveys was about 34,800 cu.yd. (~47,000 tons) (**Figure 6**).

4. ANALYSIS OF CHANGES

Aggradation and degradation within the M&T/Llano Seco reach appears to be tied to the peak flow hydrology (**Figure 7**). With the exception of WY2004, the peak flows in the 6 years prior to 2005 were less than the bankfull (~90,000 cfs) in the M&T/Llano Seco reach and this sequence of flows appears to be responsible for the aggradation in the channel (**Figure 8**). In WY2006, the peak flow was about 135,000 cfs and clearly there was some degradation in the reach,

especially in the vicinity of the fish screens and pump inlets (**Figure 9**). 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 10**), activating the concern about the need to dredge. 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 11**).

The general patterns of aggradation and degradation shown in Figures 8 through 11 are supported by comparative cross-section plots. The locations of the plotted cross sections are shown on **Figure 12**, with Cross Section 1 (XS1) being located at the newly 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 13**) the cross sections indicate that there was some aggradation on the left (east) side of the channel in 2005 but subsequent surveys show that the local aggradation has been removed. Given the similarity of the cross sections in the post-2005 period it is likely that the bench represents rock riprap, which is reinforced by the deeper channel to the right (west). At the location of the City's prior outfall (**Figure 14**), 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. At the location of the fish screens and pump inlets (**Figures 15,16,17**) 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. The same general trend is seen on the upper part of the migrating bar (**Figures 18 and 19**). Aggradation occurs during the lower peak flow years (2005, 2010) and there is scour in the higher peak flow years (2006, 2011). The comparative cross sections indicate that there has been little or no filling in the area that was dredged in 2007 (**Figure 20**).

5. CONCLUSIONS

Based on the response of the system over the four surveys, it appears that there is cyclic behavior within the M&T/Llano Seco reach with the less than bankfull flows delivering sediment to the reach from upstream and the higher than bankfull flows causing scour in the vicinity of the fish screens and pump inlets. The scour 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. A weaker helical flow cell prevents deposition at the fish screens and pump inlets at less than bankfull flows. At higher flows, the strength of the helical flow cell increases and this erodes previously deposited material. The 3-dimensional flow fields associated with the formation of the helical cells are not well represented in the 2-dimensional hydraulic modeling of the reach (MEI, 2005). 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**).

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 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 involve the City of Chico's recently relocated outfall and diffuser since the post-2005 survey data tend to indicate that there is potential for sedimentation in that location as well.

7. REFERENCES

Mussetter Engineering, Inc., 2005. Two-dimensional Modeling to Evaluate Potential River Training Works at M&T Pumping Plant, Sacramento, River, RFM 192.5. Submitted to Ducks Unlimited, Rancho Cordova, California, January, 52 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.

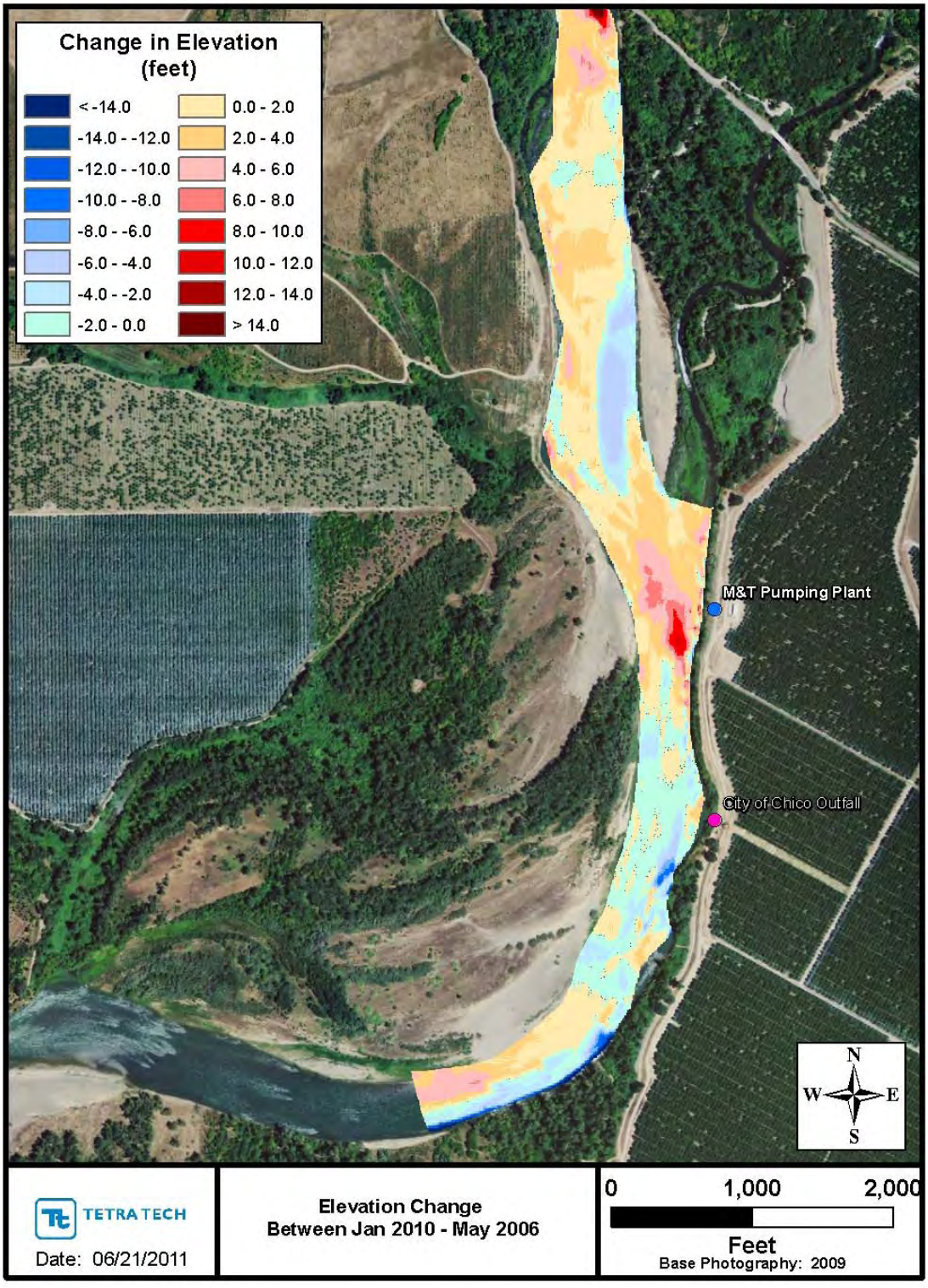


Figure 1. Elevation changes in the M&T/Llano Seco reach between the January 2010 and May 2006 surveys.

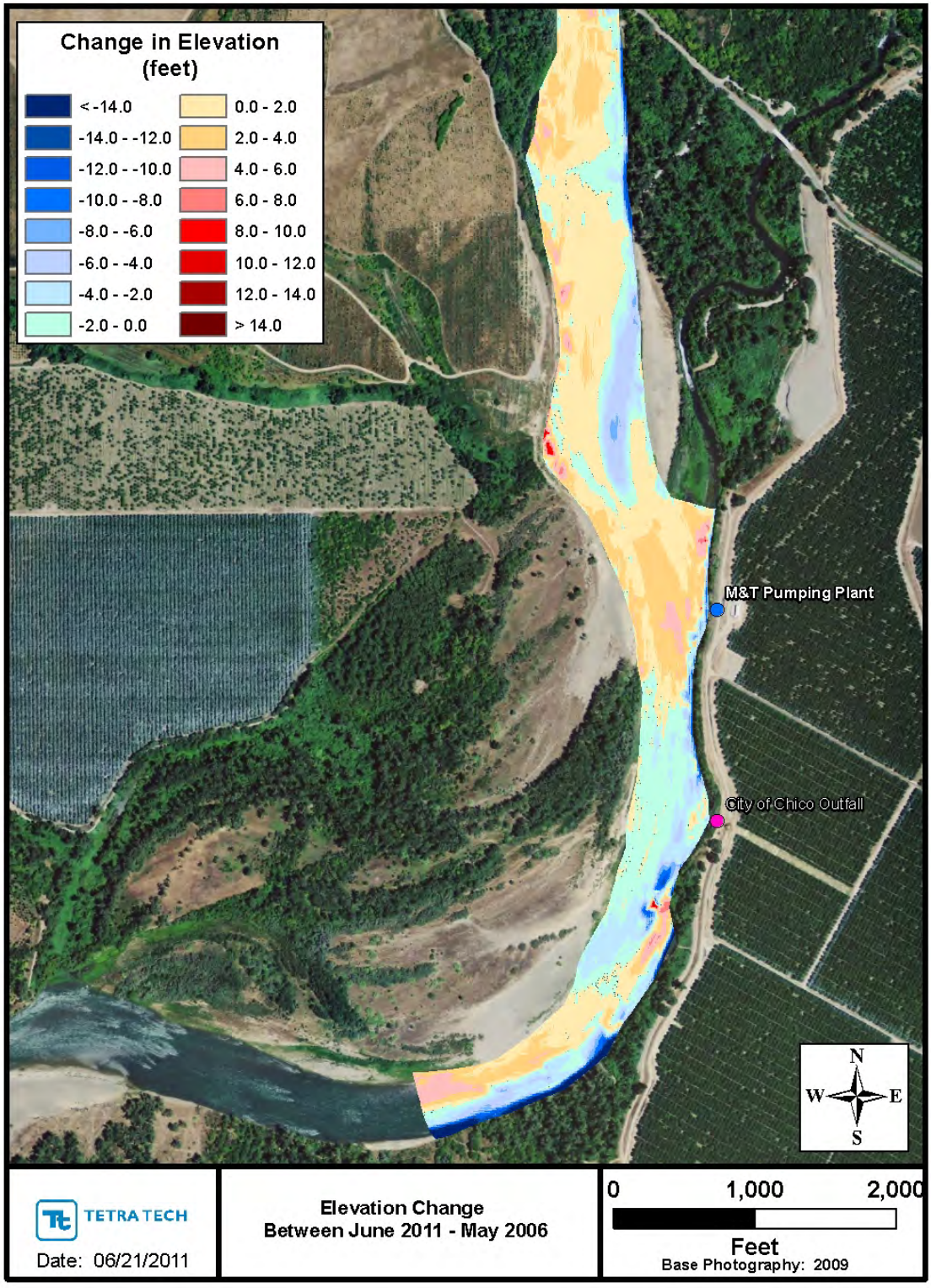


Figure 2. Elevation changes in the M&T/Llano Seco reach between the June 2011 and May 2006 surveys.

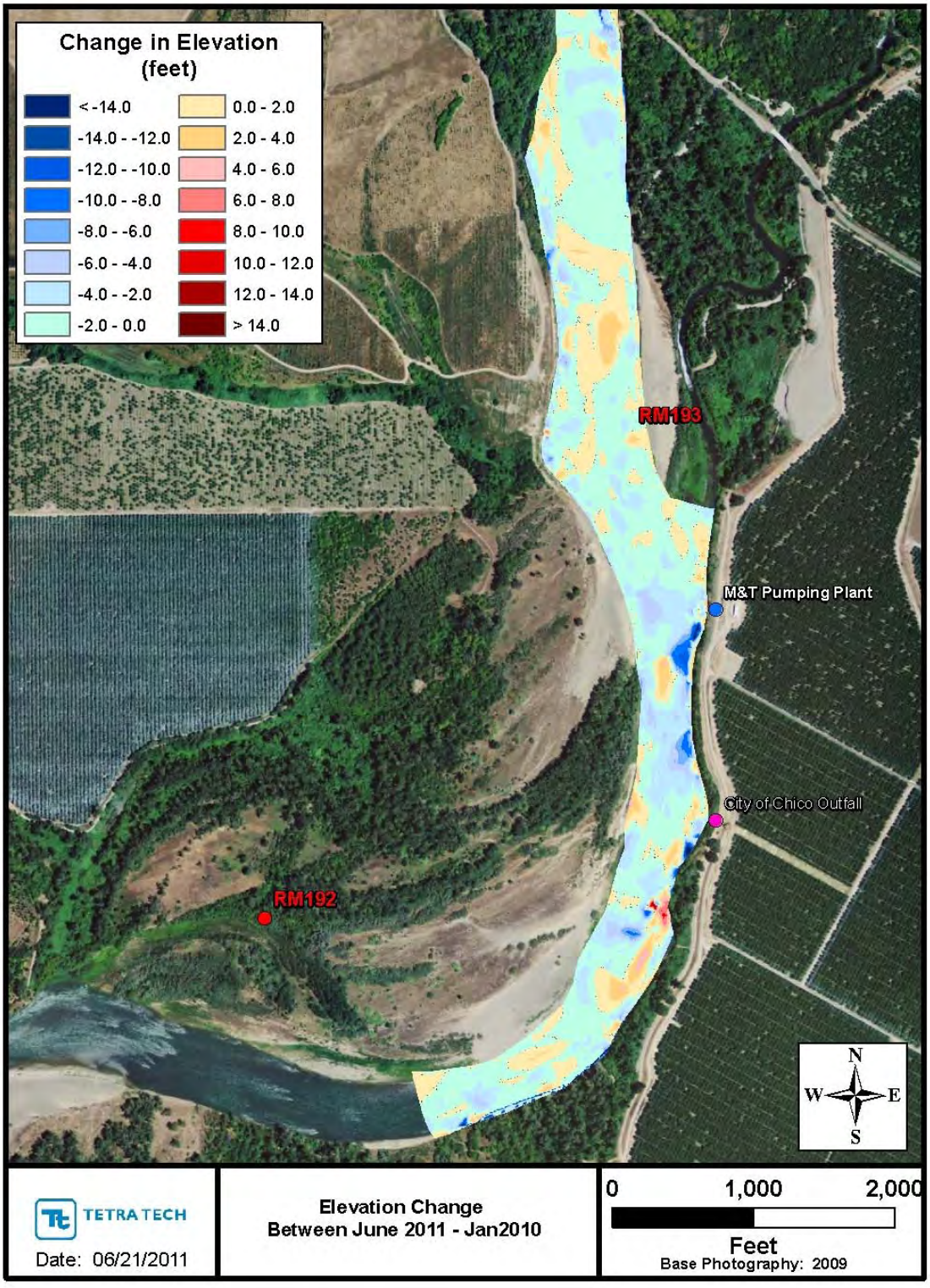


Figure 3. Elevation changes in the M&T/Llano Seco reach between the January 2010 and June 2011 surveys.

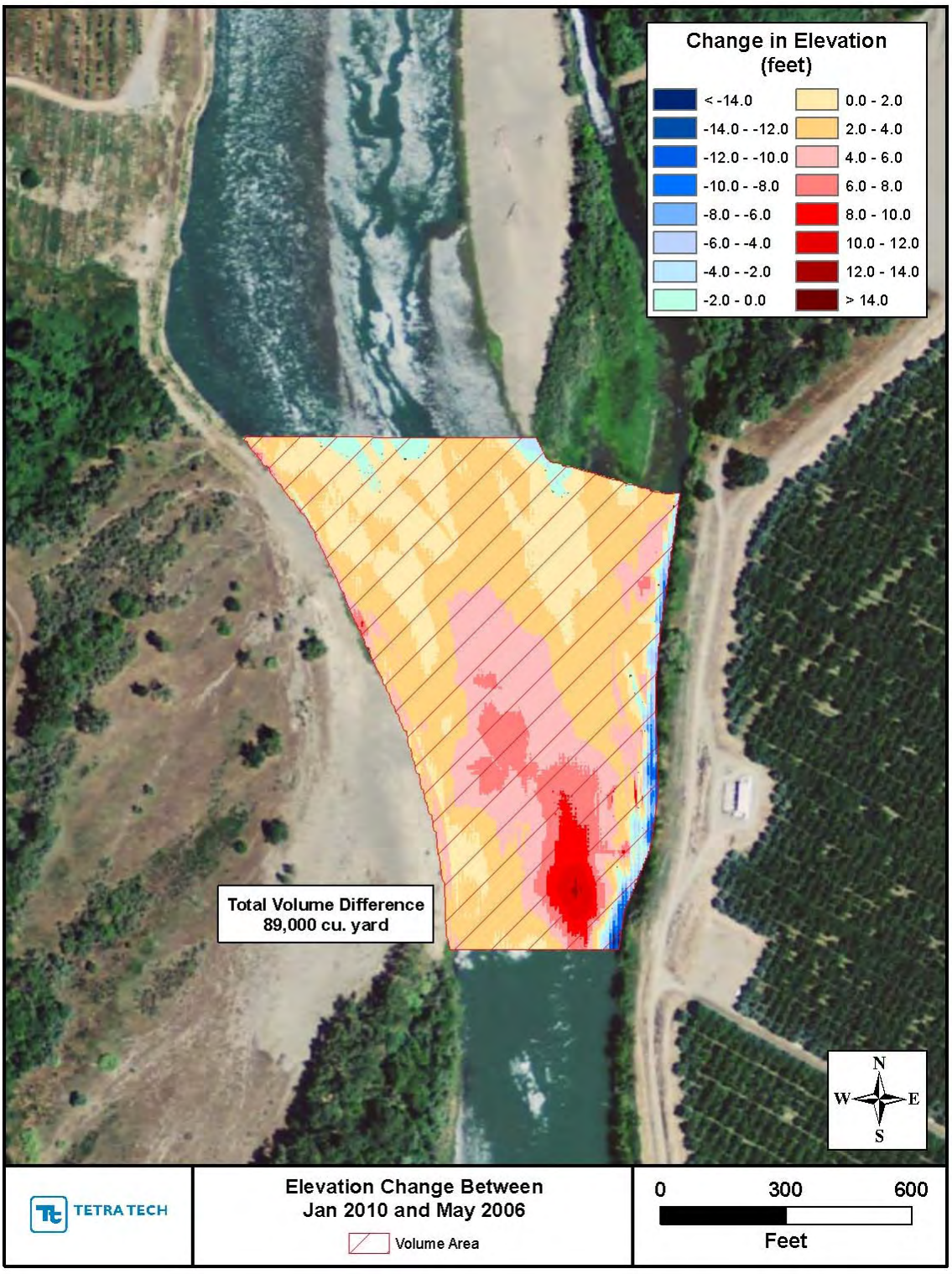


Figure 4. Volumetric calculation of the deposition in the 600 ft by 1200 ft segment in the vicinity of the fish screens and pump inlets between January 2010 and May 2006.

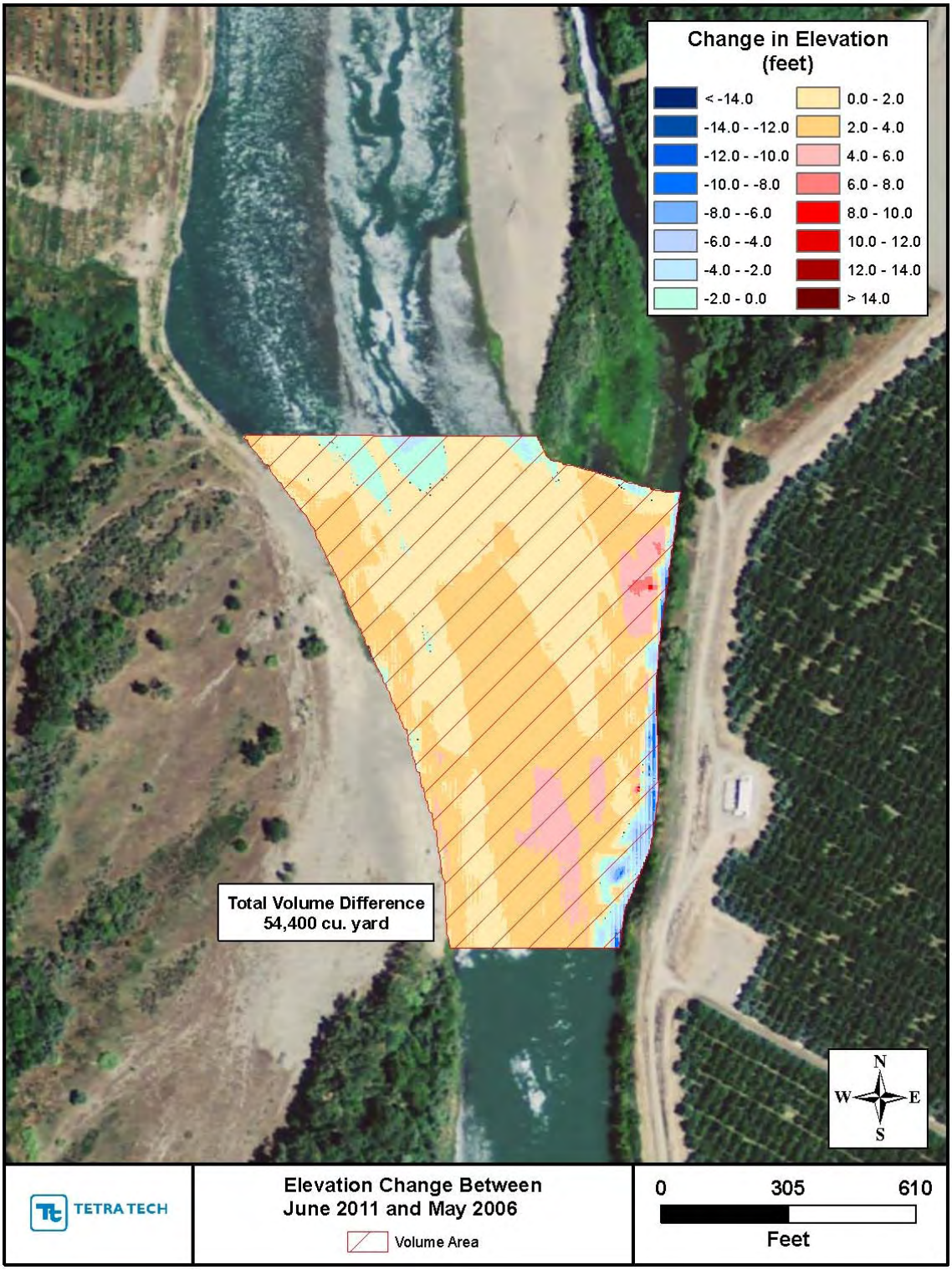


Figure 5. Volumetric calculation of the deposition in the 600- by 1,200-foot segment in the vicinity of the fish screens and pump inlets between June 2011 and May 2006.

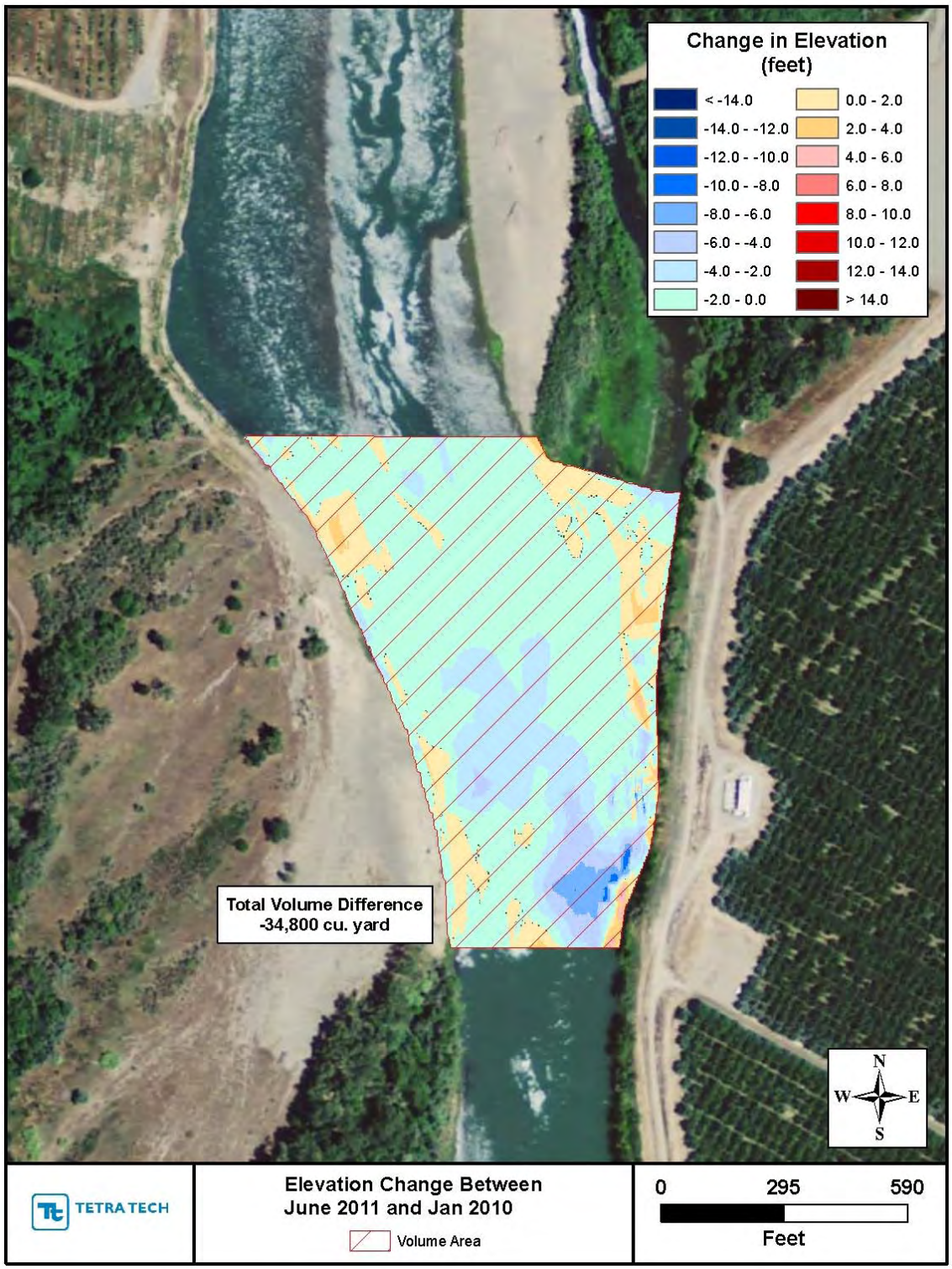


Figure 6. Volumetric calculation of the deposition in the 600- by 1,200-foot segment in the vicinity of the fish screens and pump inlets between January 2010 and June 2011.

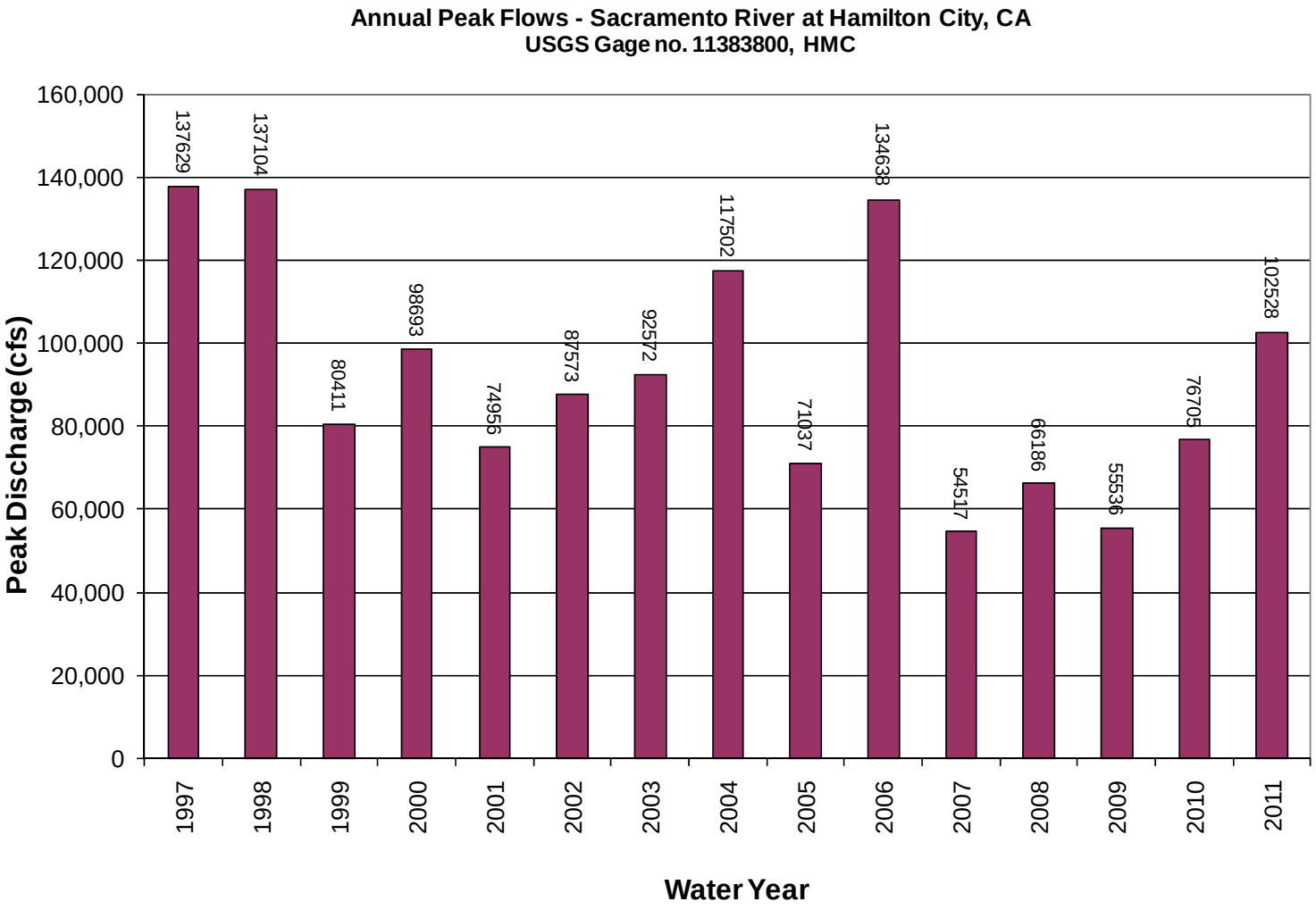


Figure 7. Peak annual flows at the Hamilton City gage between WY1997 and WY2011.

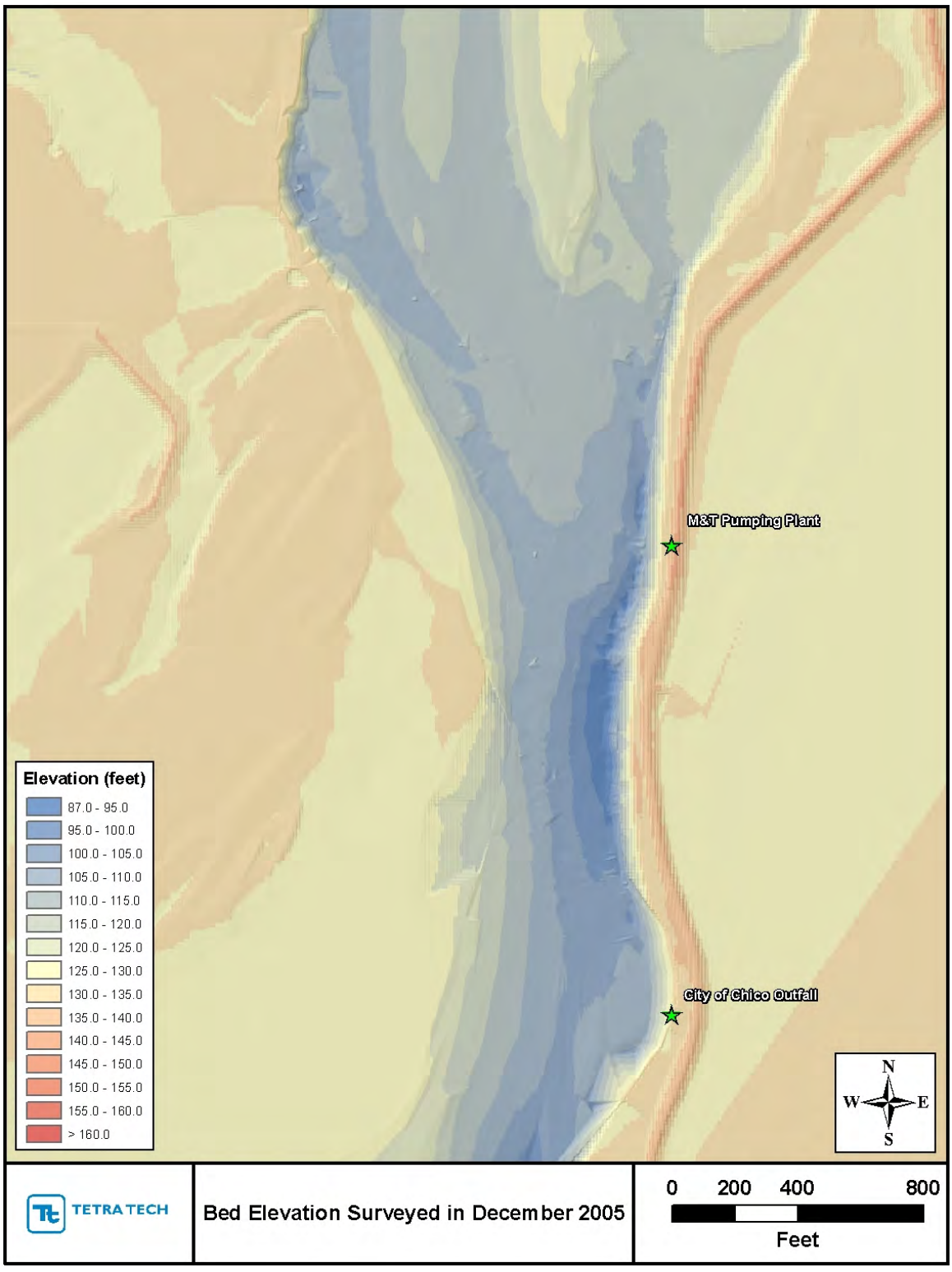


Figure 8. Color gradient plot showing the bed topography in the vicinity of the M&T/Llano Seco Pumping Plant and the relocated City of Chico Outfall in December 2005.

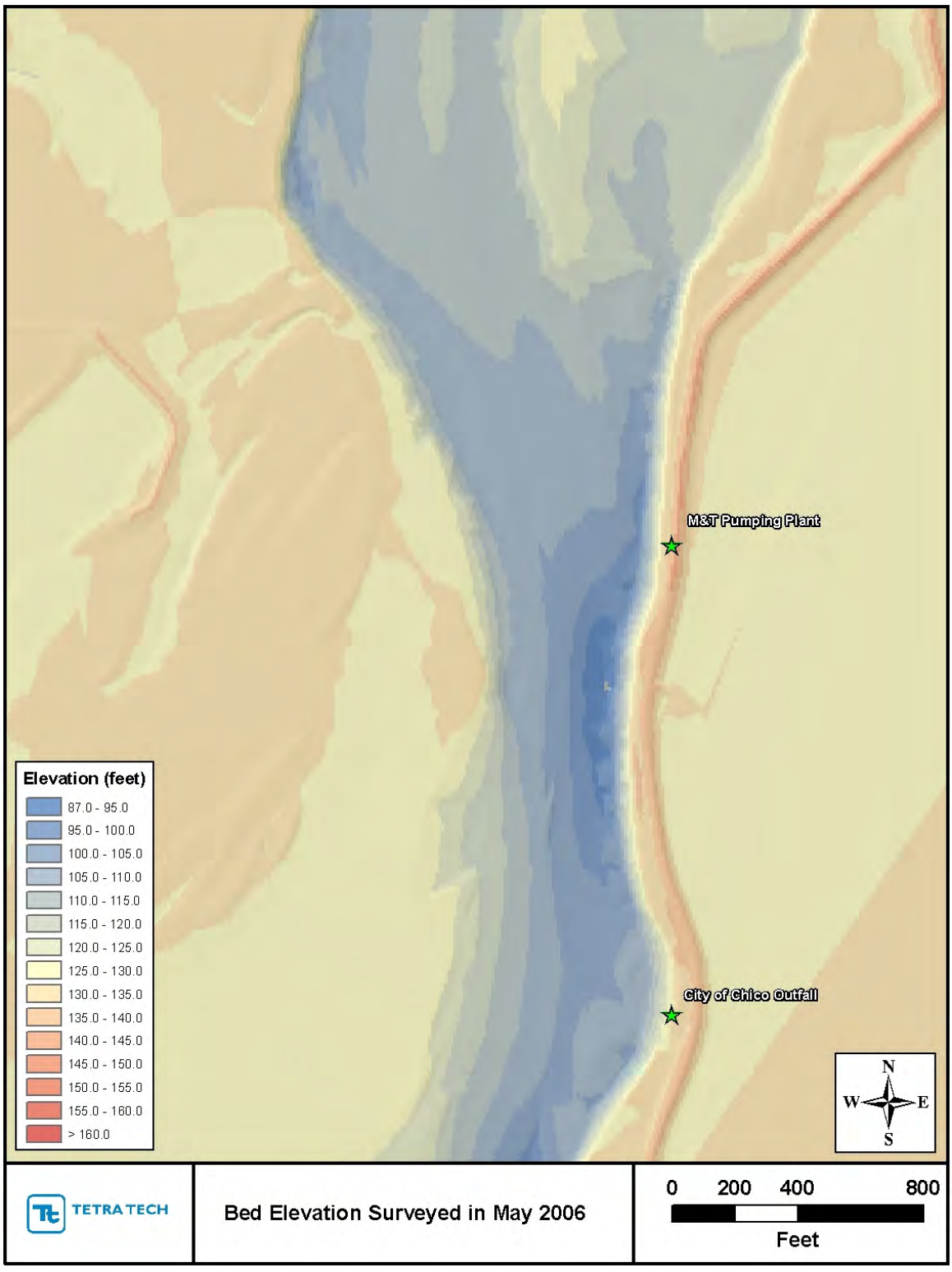


Figure 9. Color gradient plot showing the bed topography in the vicinity of the M&T/Llano Seco Pumping Plant and the relocated City of Chico Outfall in May 2006.

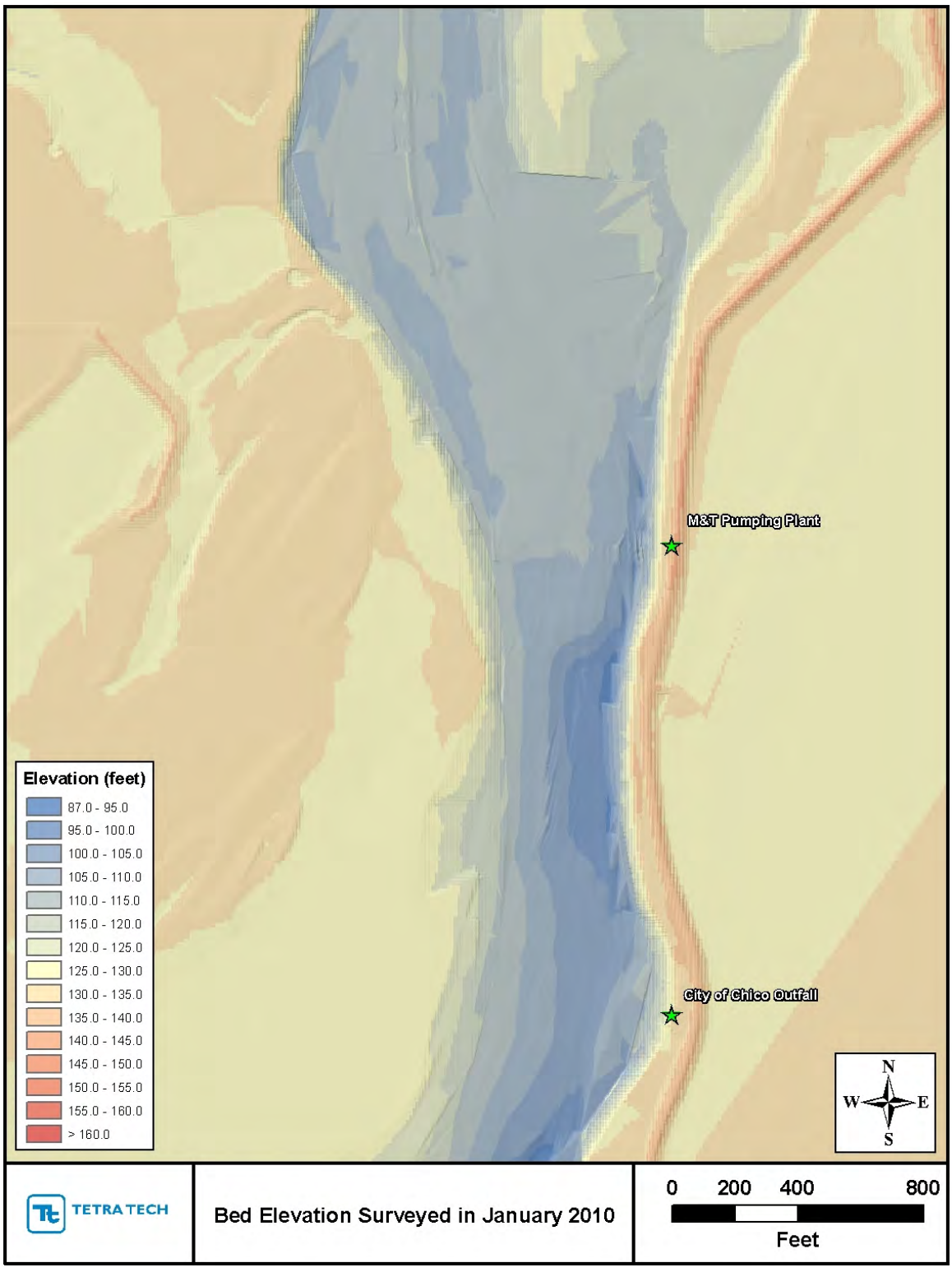


Figure 10. Color gradient plot showing the bed topography in the vicinity of the M&T/Llano Seco Pumping Plant and the relocated City of Chico Outfall in January 2010.

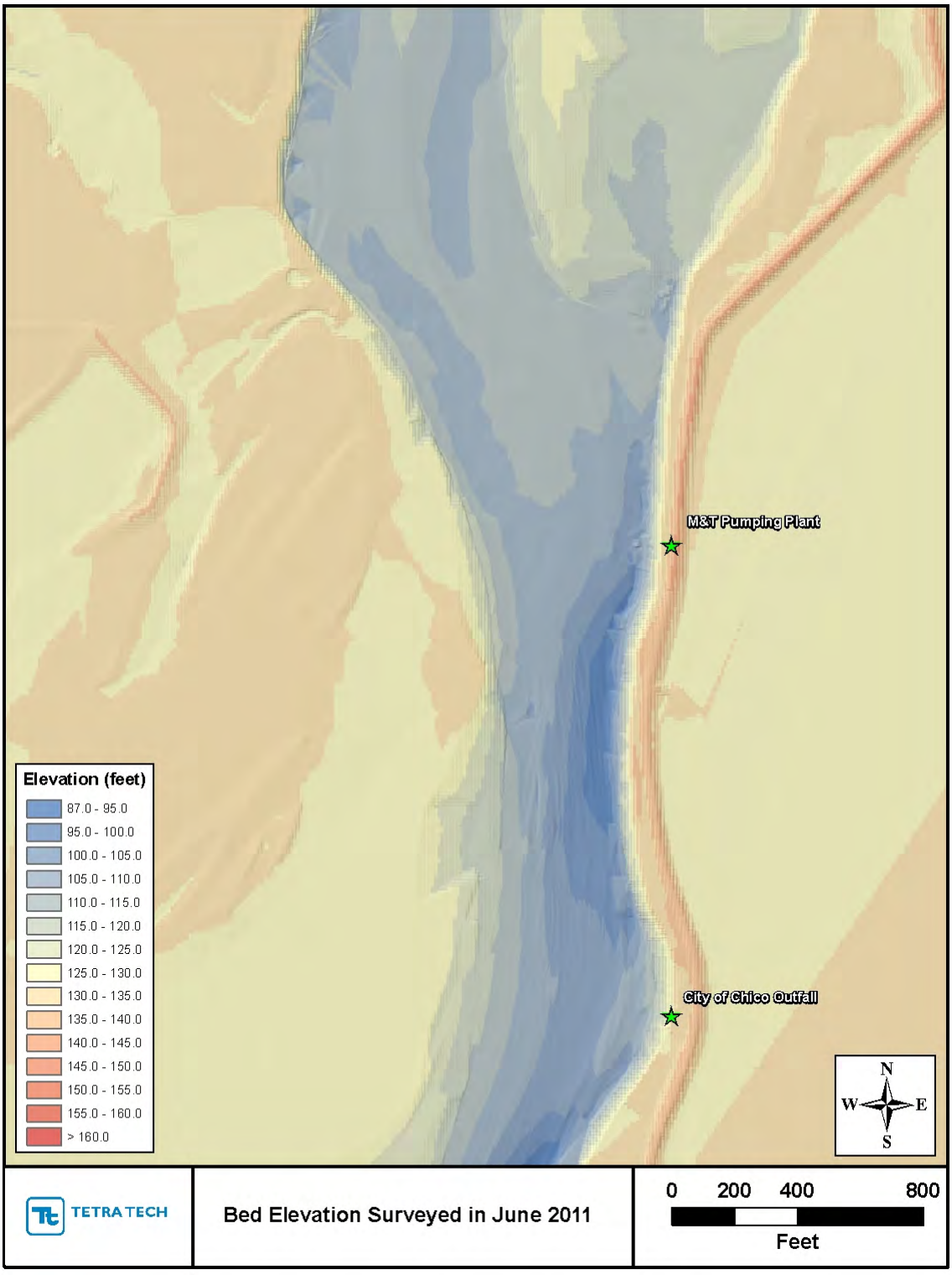


Figure 11. Color gradient plot showing the bed topography in the vicinity of the M&T/Llano Seco Pumping Plant and the relocated City of Chico Outfall in June 2011.

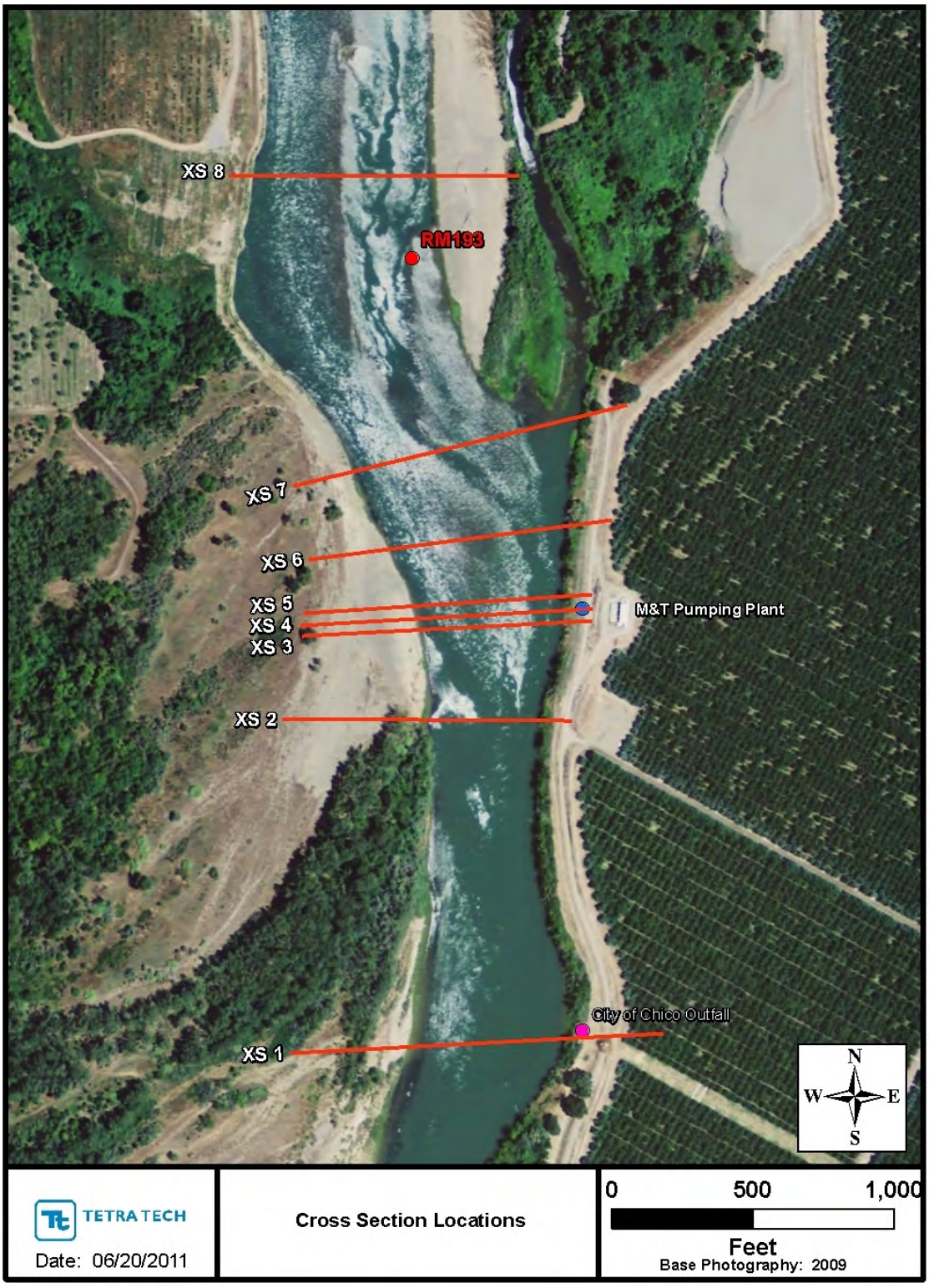


Figure 12. Locations of comparative cross sections discussed in the text.

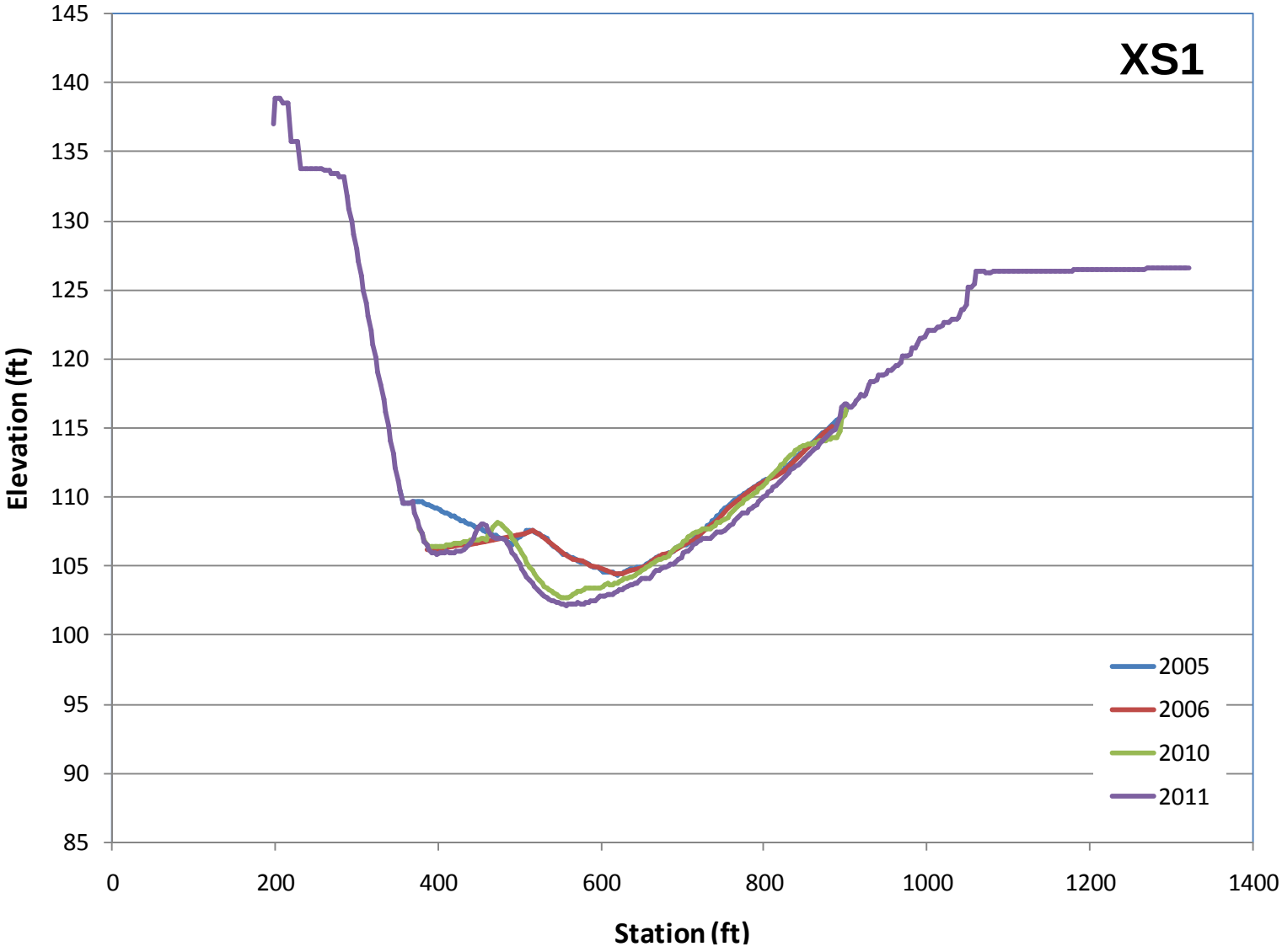


Figure 13. Comparative cross-section plots, 2005 to 2011 at the relocated City of Chico outfall.

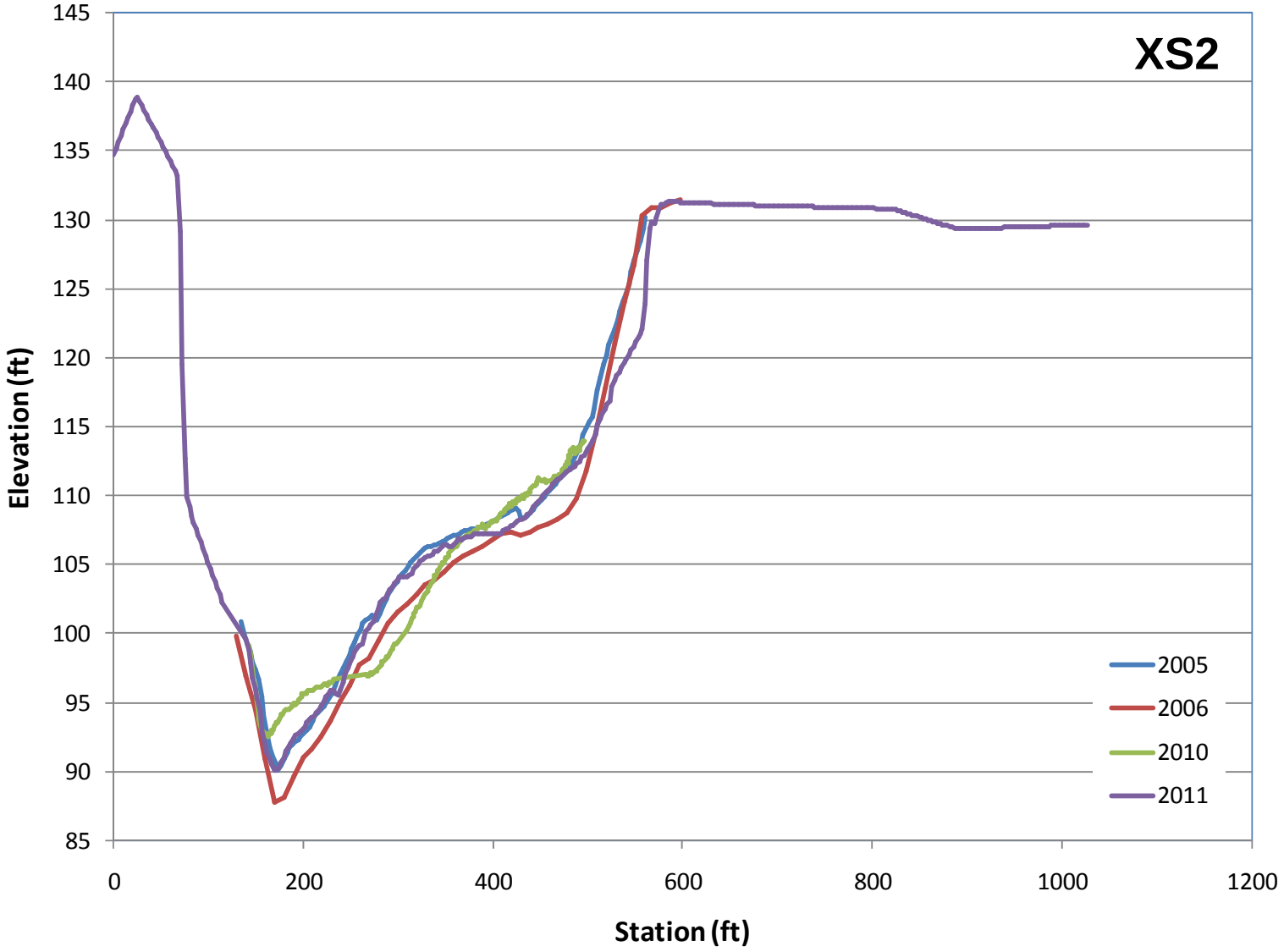


Figure 14. Comparative cross-section plots, 2005 to 2011 at the original City of Chico outfall.

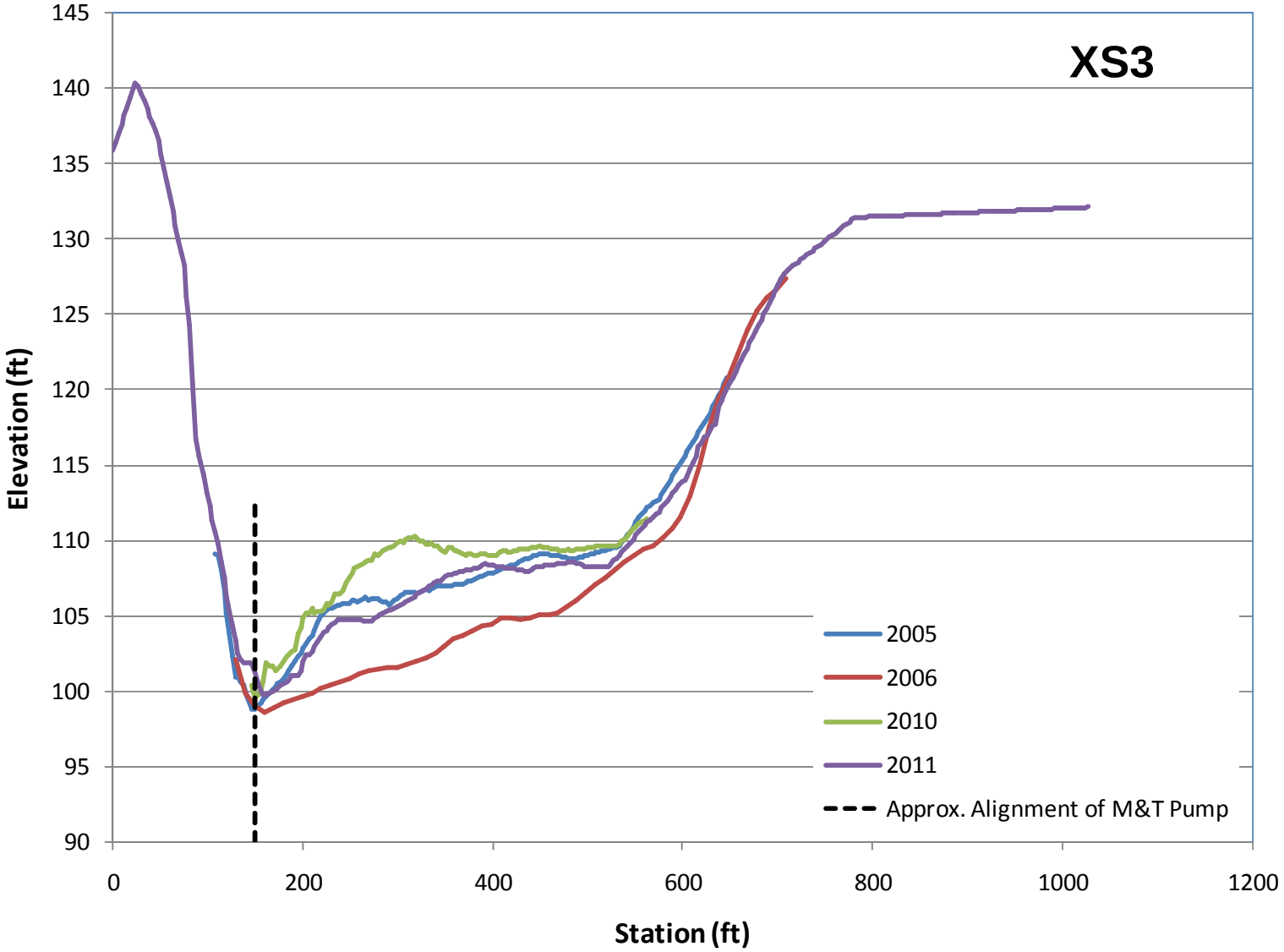


Figure 15. Comparative cross-section plots, 2005 to 2011 immediately downstream of the M&T/Llano Seco fish screens and pump inlets.

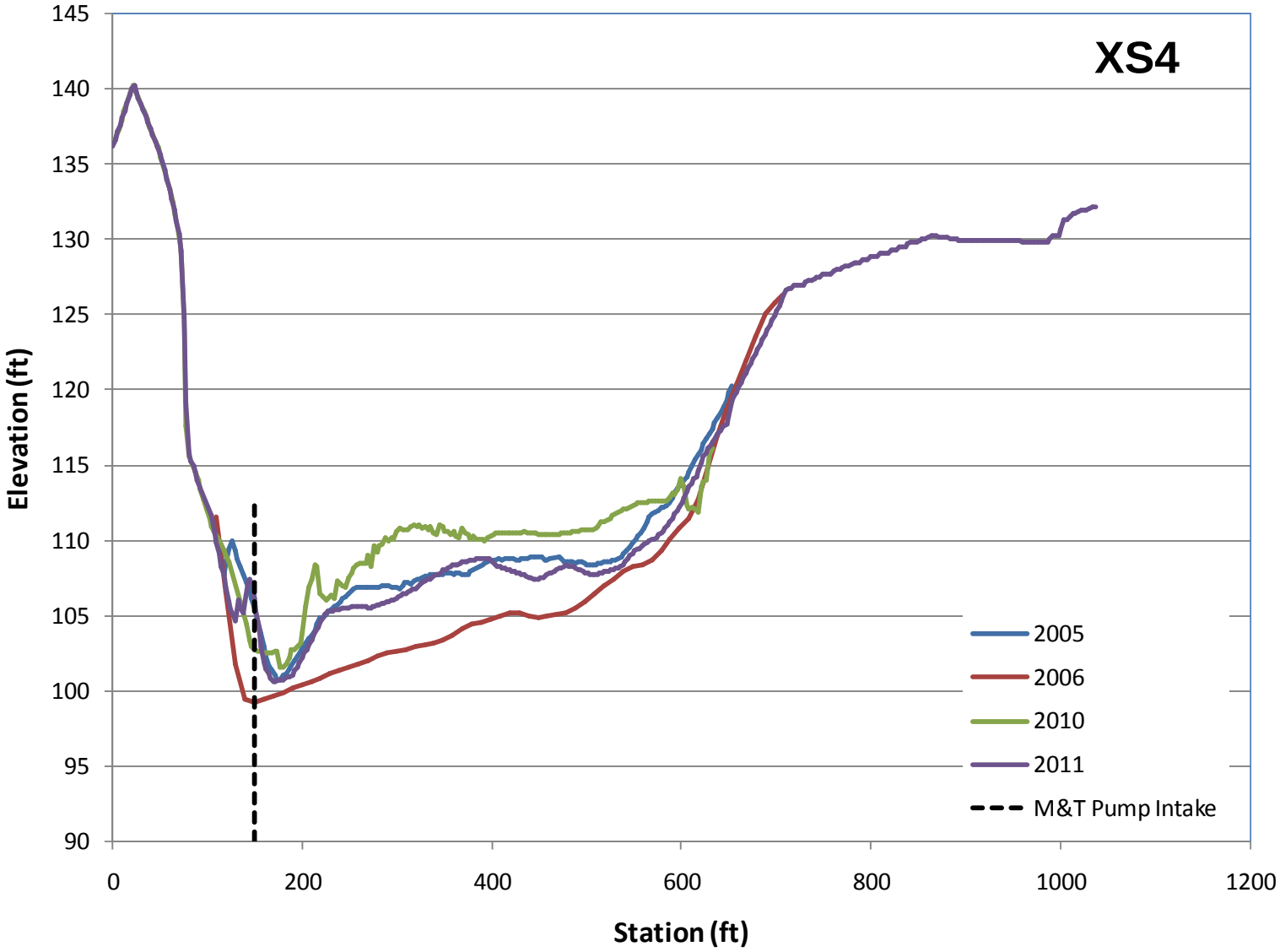


Figure 16. Comparative cross-section plots, 2005 to 2011 at the M&T/Llano Seco fish screens and pump inlets.

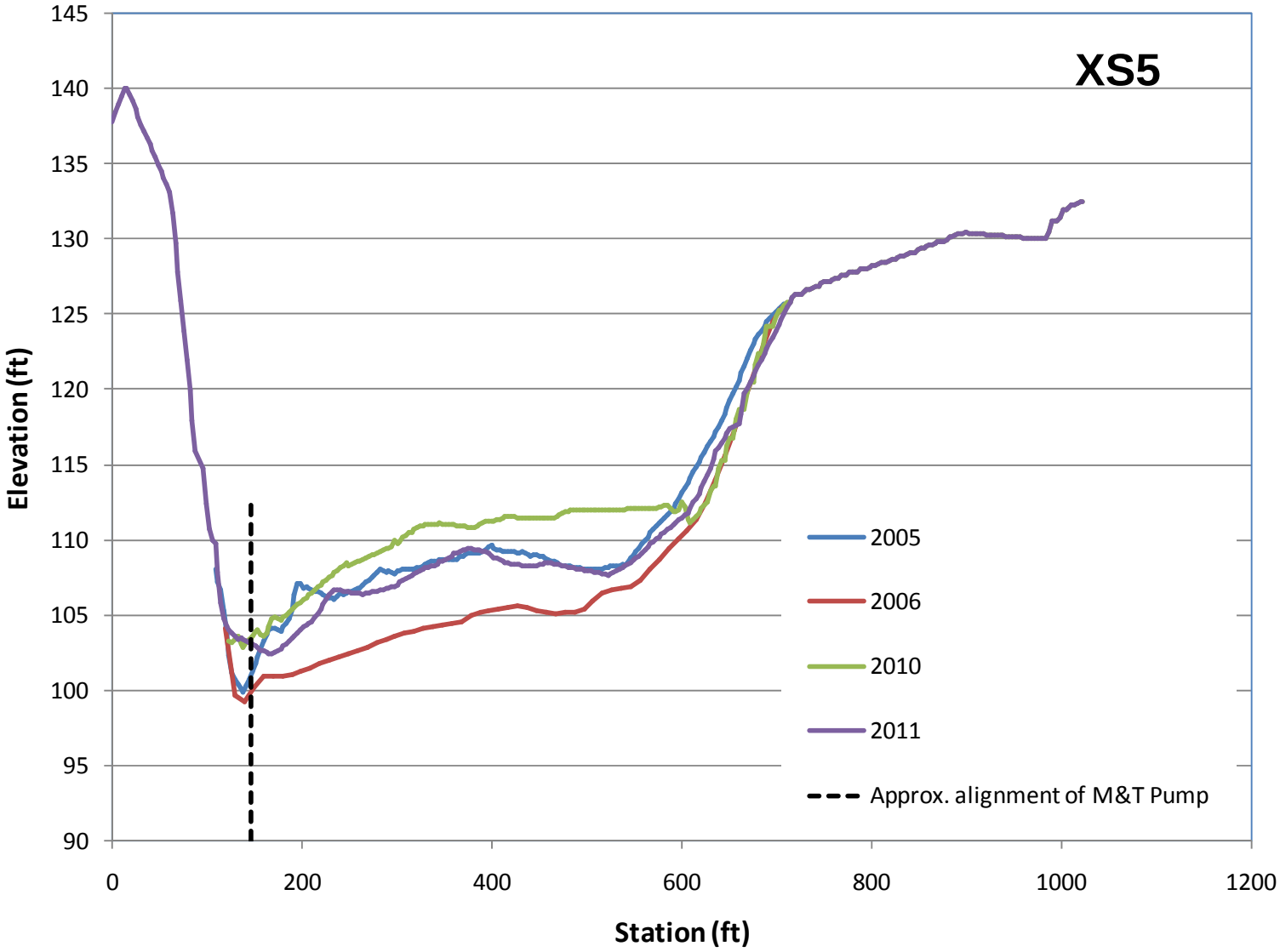


Figure 17. Comparative cross-section plots, 2005 to 2011 immediately upstream of the M&T/Llano Seco fish screens and pump inlets.

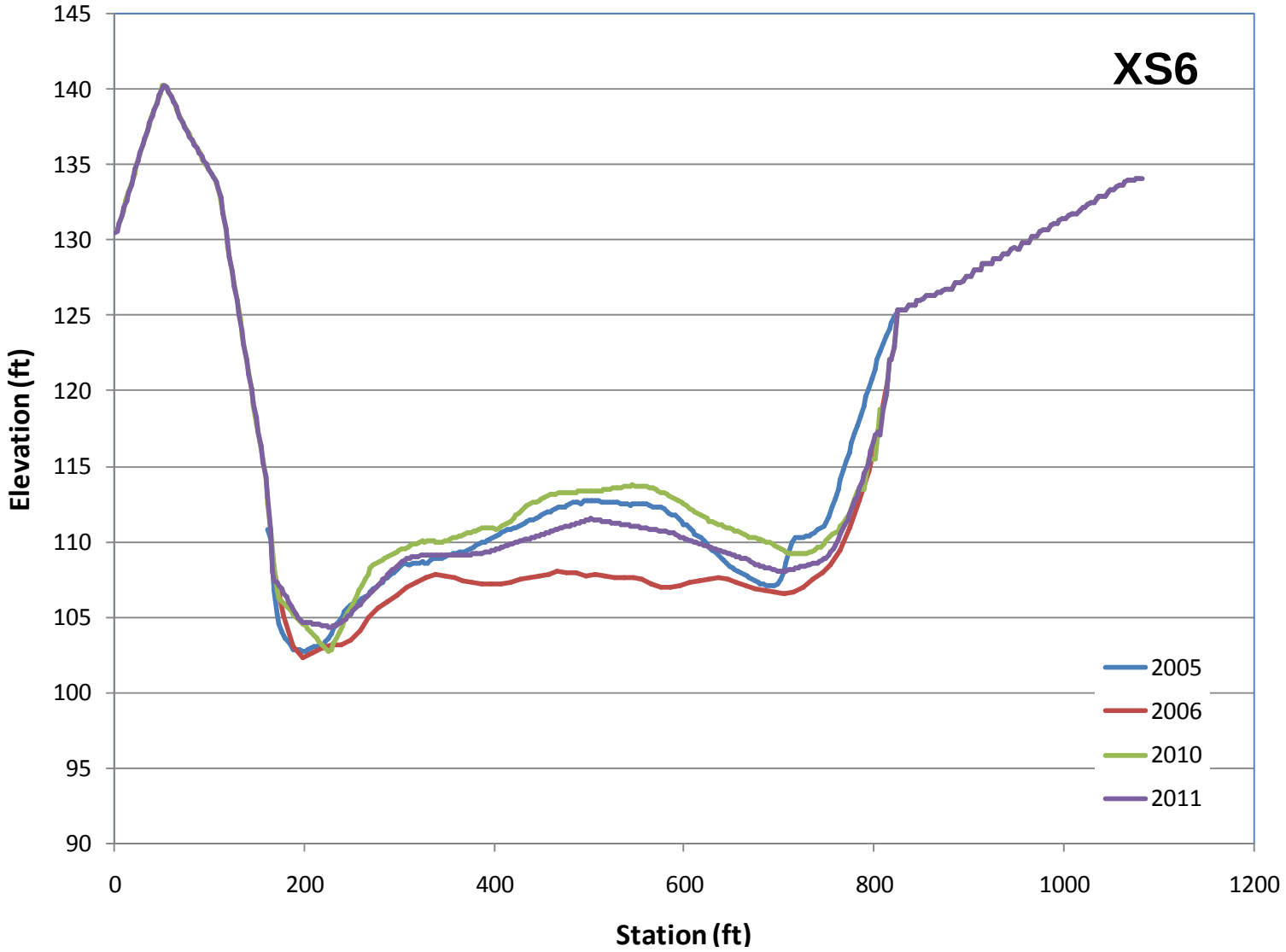


Figure 18. Comparative cross-section plots, 2005 to 2011 upstream of the M&T/Llano Seco fish screens and pump inlets on the lower part of the migrating bar.

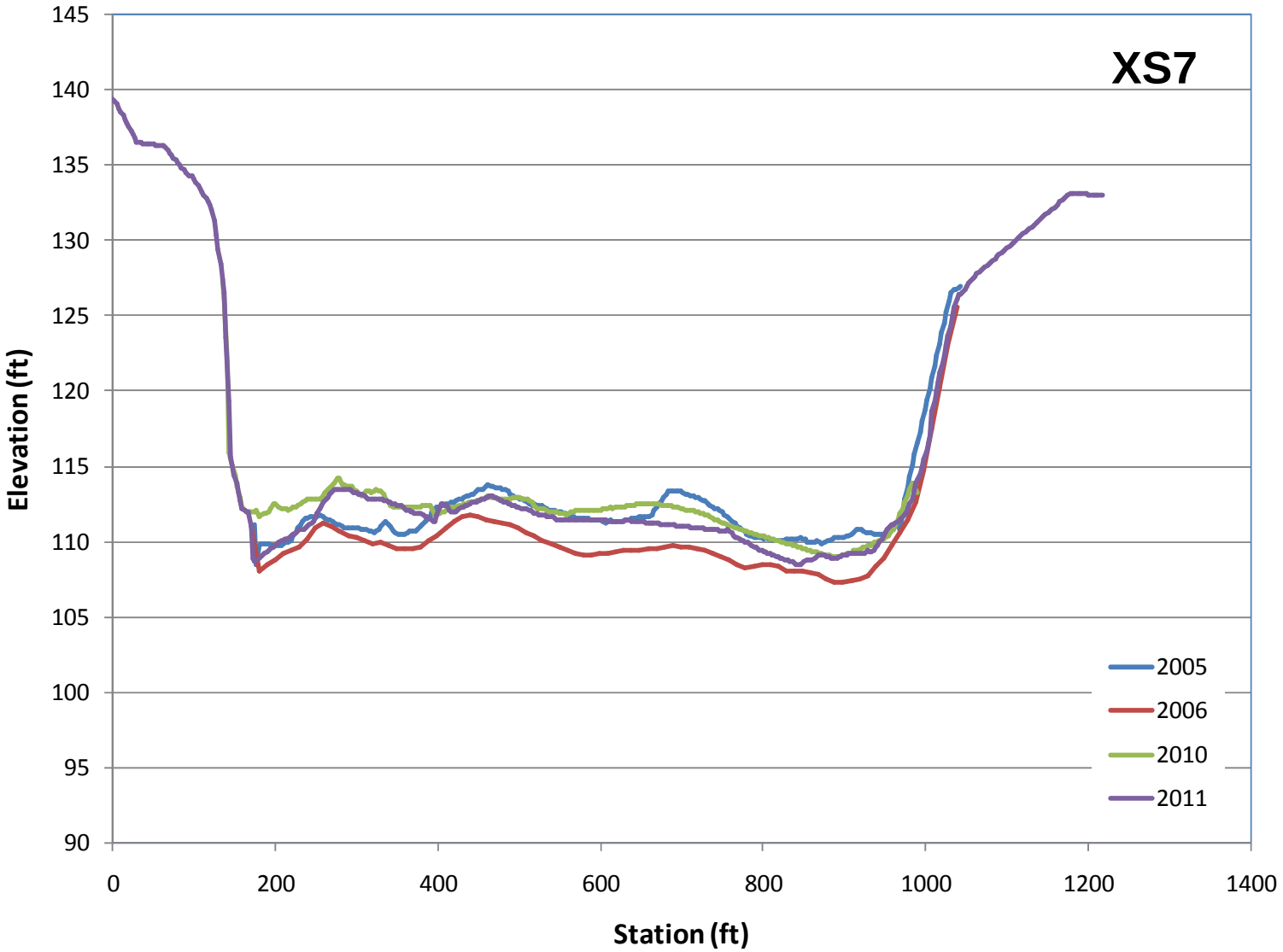


Figure 19. Comparative cross-section plots, 2005 to 2011 upstream of the M&T/Llano Seco fish screens and pump inlets on the upper part of the migrating bar.

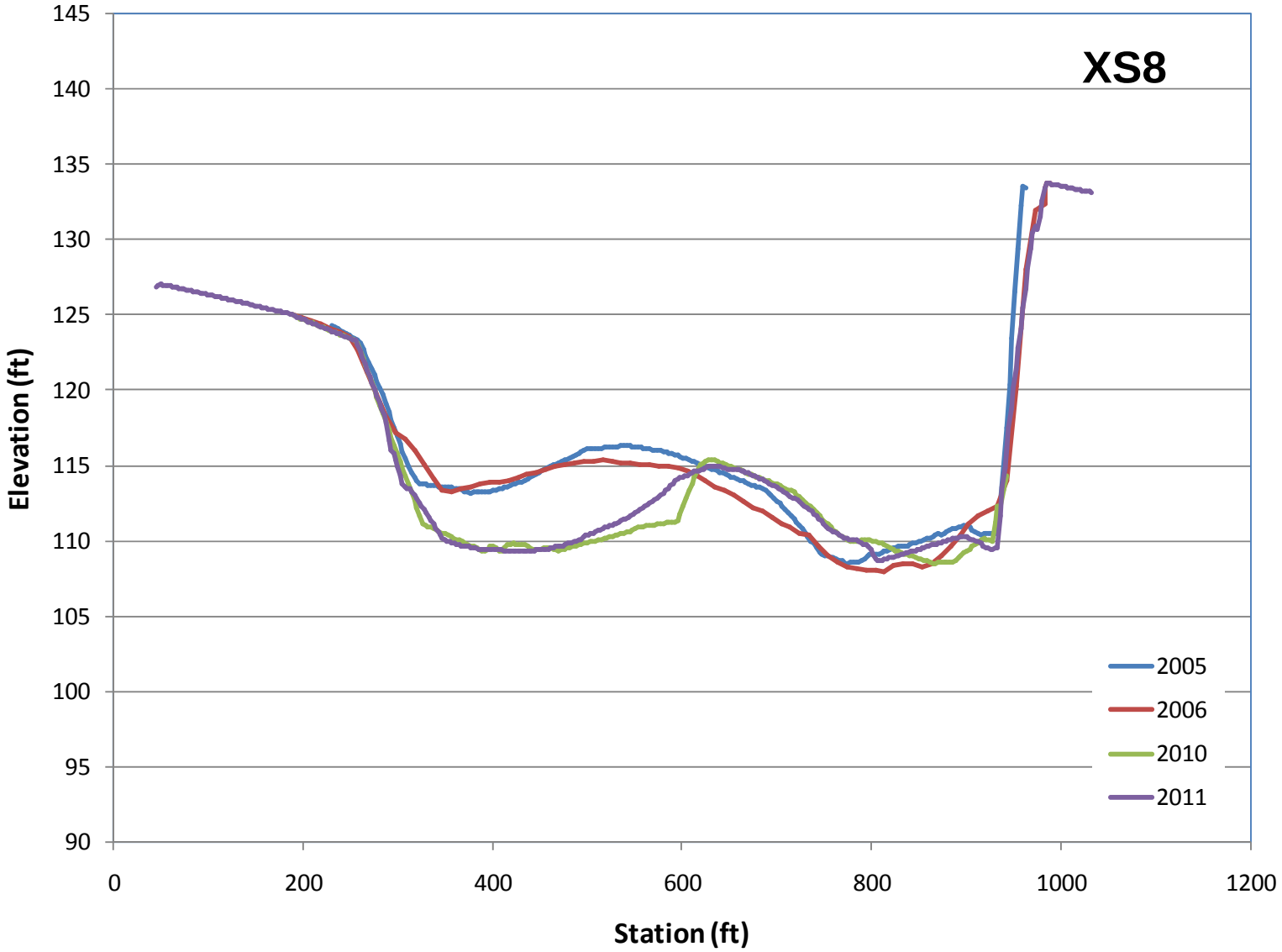


Figure 20. Comparative cross-section plots, 2005 to 2011 across the area that was dredged in 2007.

APPENDIX A
DIVE REPORTS

TETRA TECH

BIG VALLEY DIVERS, INC.

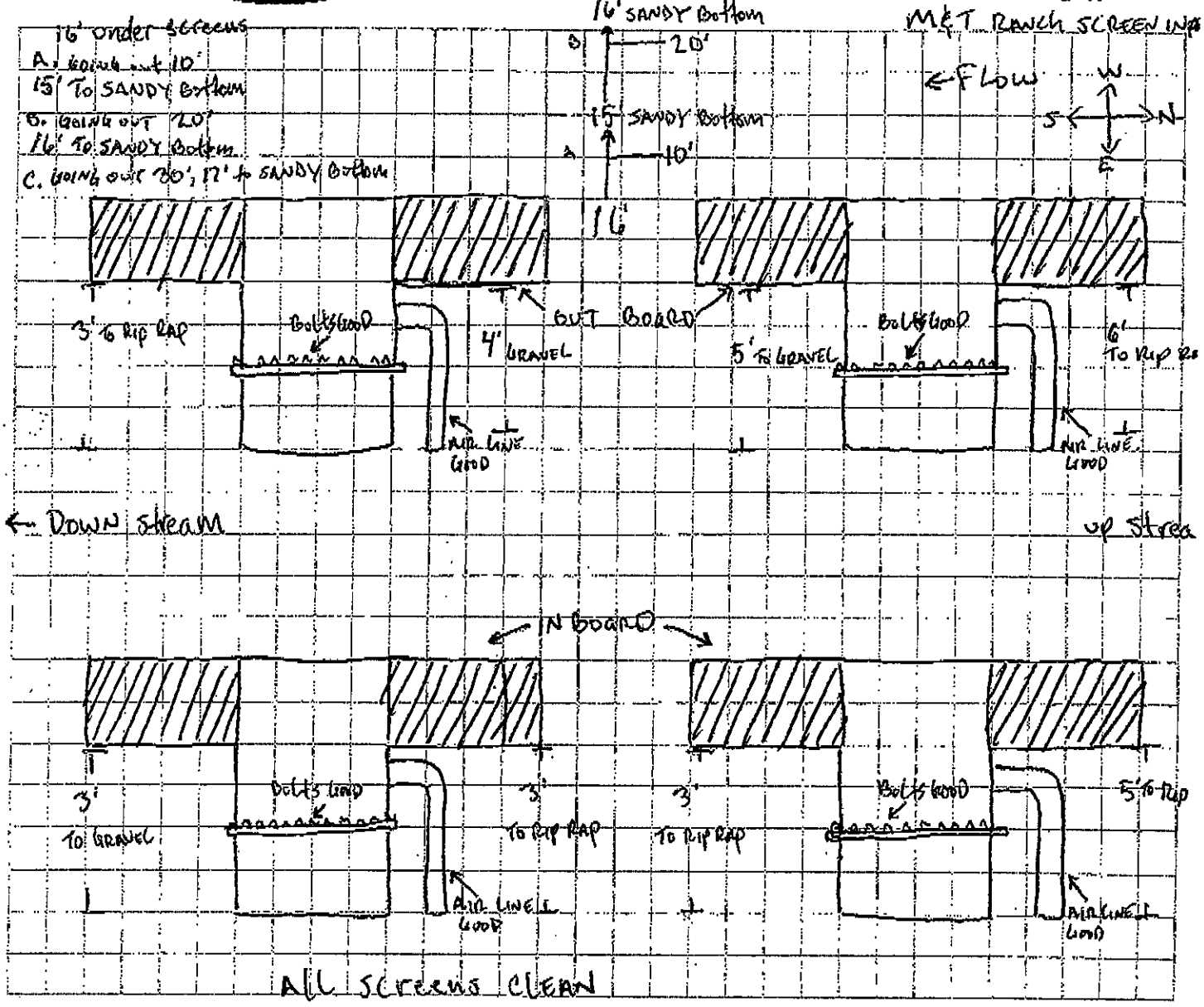
P.O. Box 3284 Chico, CA 95927 • Office (530) 898-1110

Cell (530) 521-0588 • Fax (530) 898-1110

CA Lic #757776 • ADCI Member

ads@sunset.net • www.bigvalleydivers.com

5-11-10



Commercial Divers Specializing in Northern & Central California Underwater Needs

Big Valley Divers, Inc. est. 1994, is made up of commercial divers, experienced in every aspect of inland diving operations. Commercial certifications are supported by yearly physicals, CPR, first aid, O2, and AED administration. The customer is always first with BVD.

- Irrigation Districts, Hydroelectric Maintenance and Repair, and Potable Water Service
- Lake & River Marina Maintenance
- Pump Stations, Fish Screens, Siphons
- Slide Gate and Hydraulic Install and Maintenance
- Underwater Video, R.O.V. Services
- Debris & Sediment Removal, Epoxy and Grout
- Fish Screen Cleaning Repair and Construction
- Aquatic Barrier Construction
- Dredging, Water Jetting & Pigging
- Underwater Welding & Cutting
- Salvage and Recovery
- Hydro-Brush Hull Cleaning

BIG VALLEY DIVERS, INC.

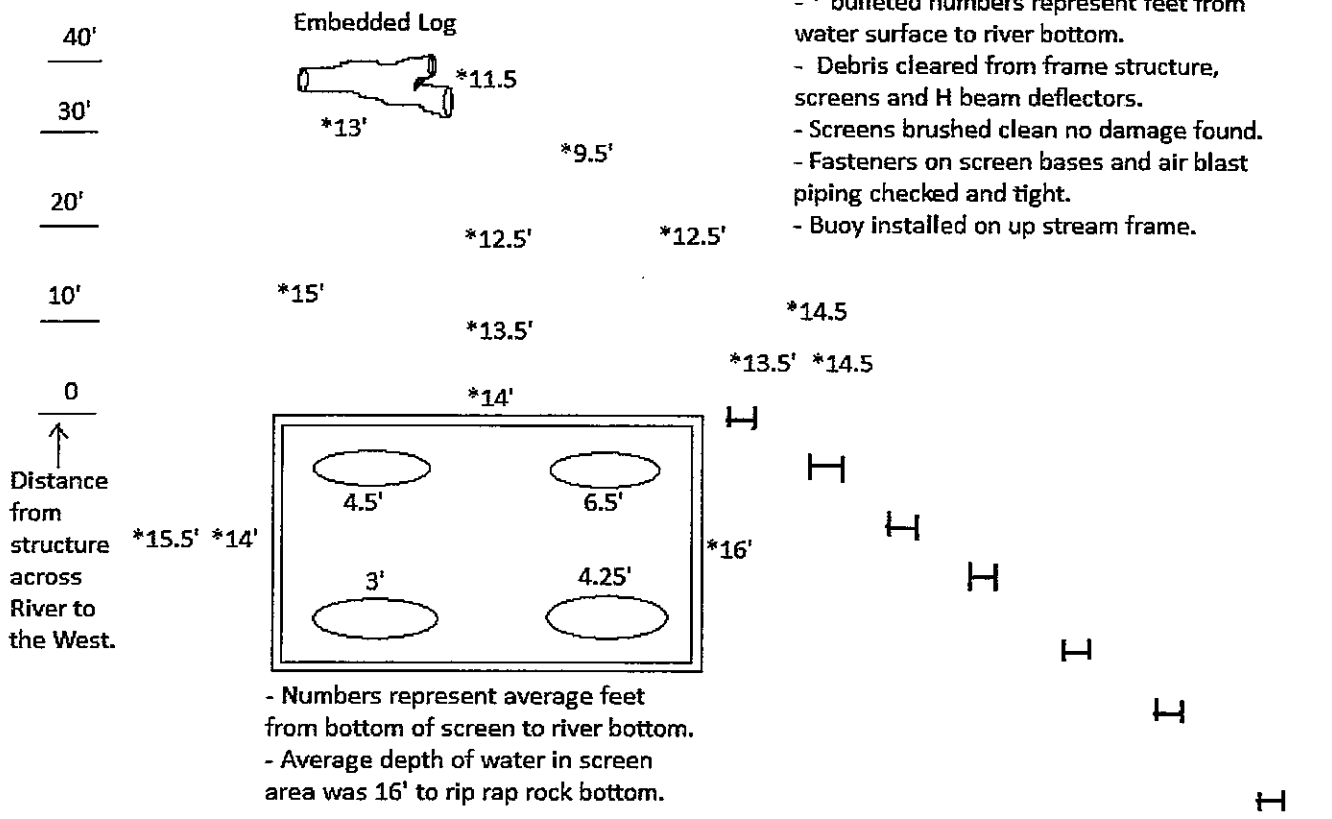
P.O. Box 3284
Chico, CA 95927
Office (530) 898-1110 Cell (530) 521-0588 Fax (530) 898-1110

4-9-09 Big Valley Divers Dive Inspection and Spring Cleaning of:

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

Ord Ferry Reading: 97.25

- * bulleted numbers represent feet from water surface to river bottom.
- Debris cleared from frame structure, screens and H beam deflectors.
- Screens brushed clean no damage found.
- Fasteners on screen bases and air blast piping checked and tight.
- Buoy installed on up stream frame.



- Numbers represent average feet from bottom of screen to river bottom.
- Average depth of water in screen area was 16' to rip rap rock bottom.

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

To: M&T RANCH – CHICO ORd Ferry River Stage 97.25'

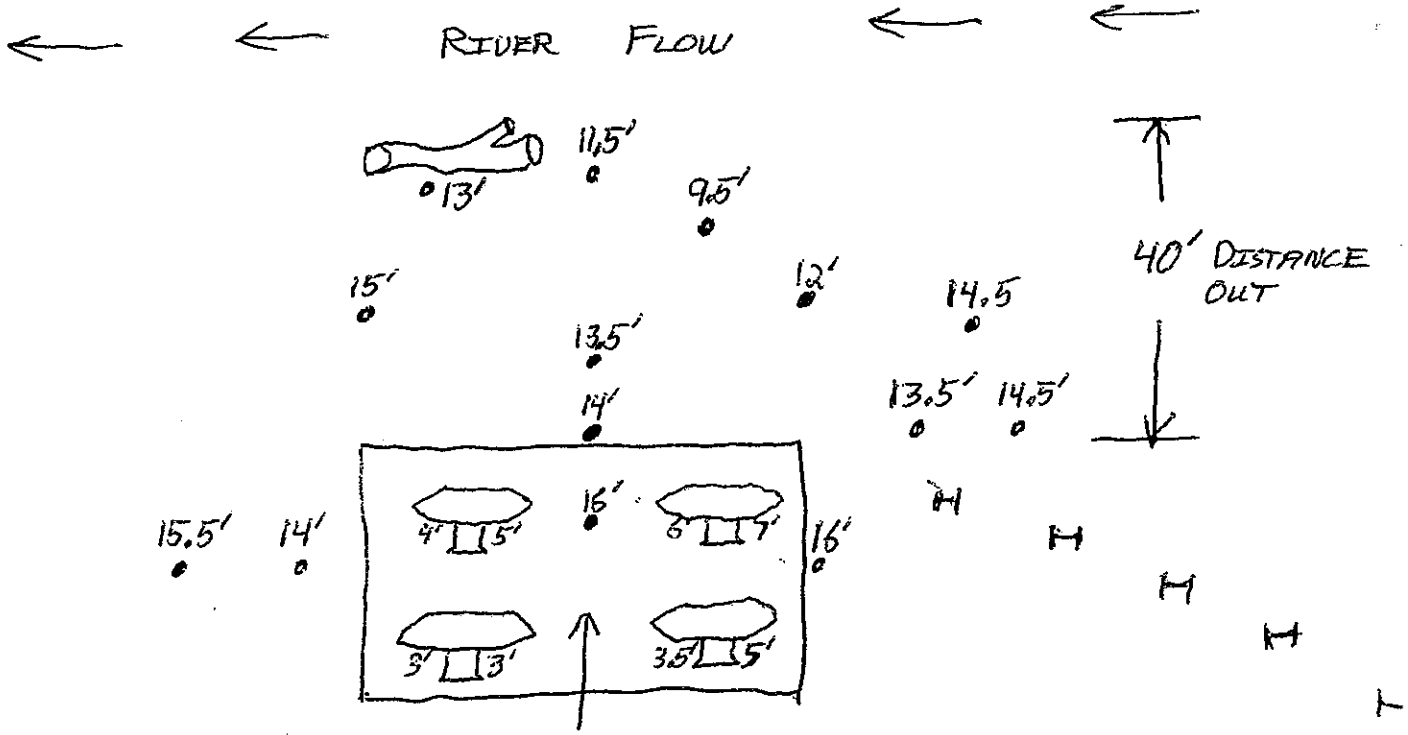
Rep: MIKE BOLIN
Re: 09 SPRING PUMP INSPECTION

DIVE REPORT

Date	4-9-09	Water Elevation	
Location	SAC. RIVER PUMPS	Depth	VARIED
		Water Temp.	55°
Requested By	MIKE BOLIN	Visibility	5'
Site Forman	MIKE	Current (fps)	2 FPS
Dive Supervisor	DOUG	Photos Y / N	N

Purpose of job: (Please note basic Tasks, Measurements (IE Before and After), and Drawings.

Readings Taken on 4-9-09



BIG VALLEY DIVERS, INC.

P.O. Box 3284
Chico, CA 95927
Office (530) 898-1110 Cell (530) 521-0588 Fax (530) 898-1110

INVOICE

CUSTOMER

NAME	M & T Ranch
ADDRESS	3964 Chico River Rd.
CITY	Chico CA.95928
PHONE	Of. (530) 342-2954 Cl. (530) 521-4464 Fx (530) 000-0000
REP	Les Heringer / Mike Bolin
Re	Install Bouys and Clean Fish Screens

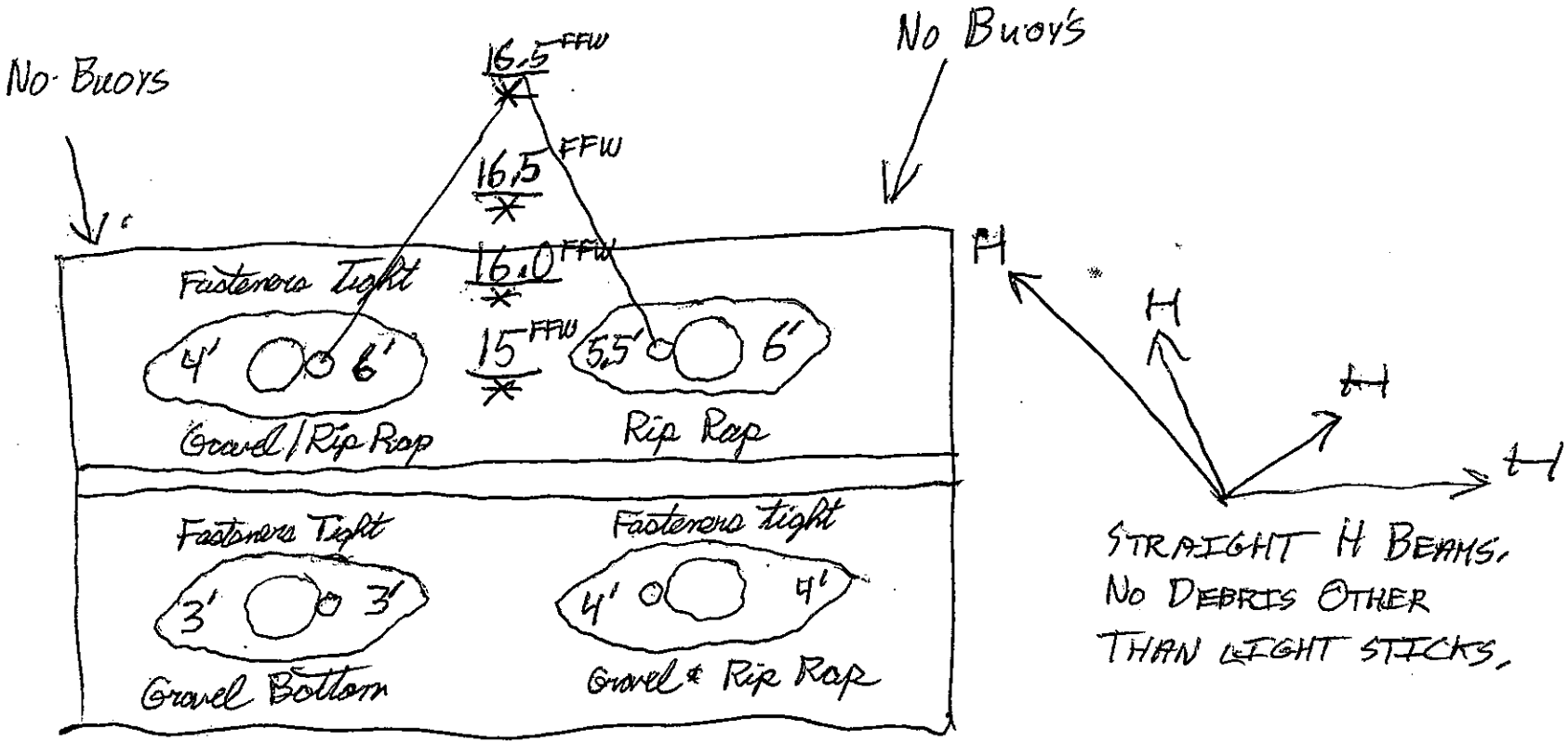
DATE	UNITS	DESCRIPTION	PER UNIT	TOTAL
6/5/2008	1	3 Person Dive Team, Heavy Gear, Full Comms.	1450	1450
	25	Mileage 1 Vehicles.	0.75	18.75
	1	Bouy	55	55
	1	Anchor Chains.	35	35
		1 - Anchors were attached with new chains.		0
		2 - Screens were cleaned.		0
		3 - Gravel encroachment is still held off as rip rap is around base of intakes.		0
				0
				0
				0
				0
				0
				0
				0
				0
				0
				0
				0
				0
				0
				0
				0
				0
TOTAL				1558.75

NOTES

Thank You For Using Big Valley Divers.
Doug.

← River Flow ←

Big Valley Divers
Doug @ 521-0588

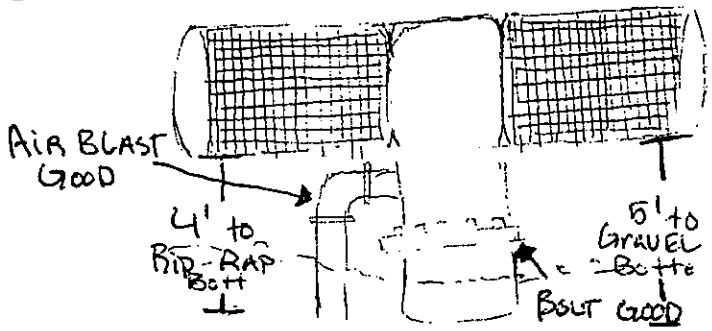


ORD FERRY EL = 97.7

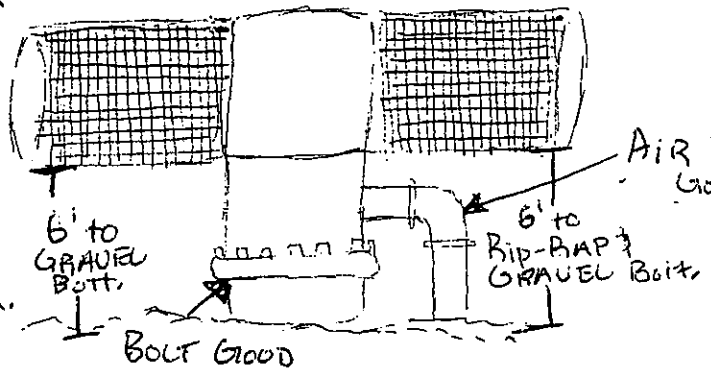
FLOW = 7,950

4-14-08
INSPECTION.

OUTER



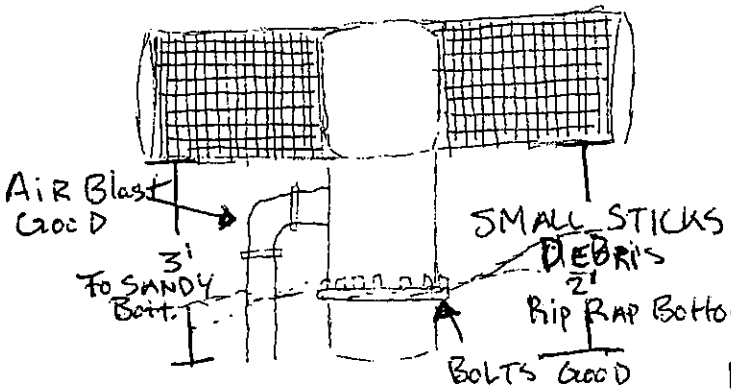
SIDE



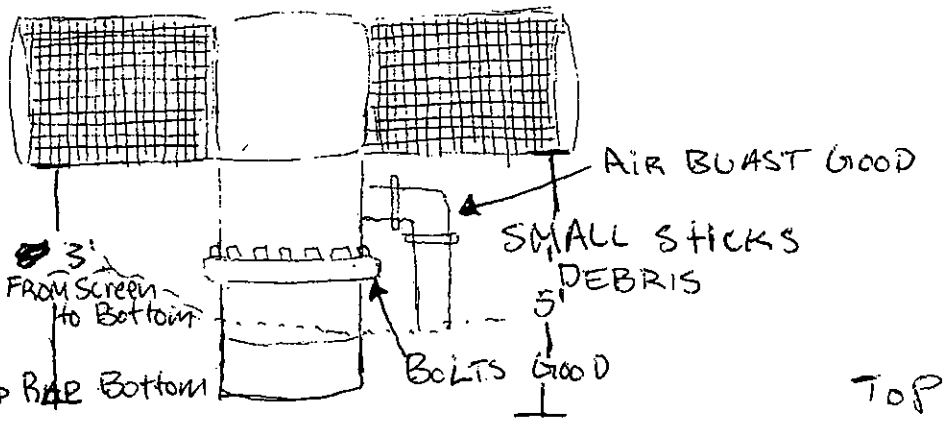
P.O. Box 3284
CA 95927

INER.

DOWN STREAM



UPSTREAM



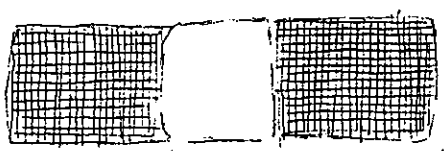
TOP

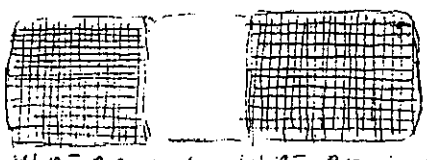
NOTES:
UPSTREAM-INER: UPST. 3' From SCREEN to Bottom
DOWN 5' From SCREEN TO Bottom
RipRAP Bottom
BOLTS GOOD/AIR BLAST Good

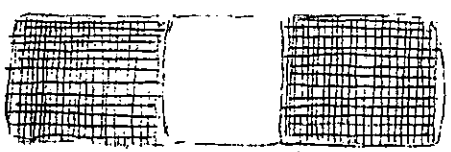
DOWN STREAM-INER: UPST. 2' to Rip RAP Bott.
Down. 3' to SANDY Bott.
BOLTS GOOD/AIR Blast Good

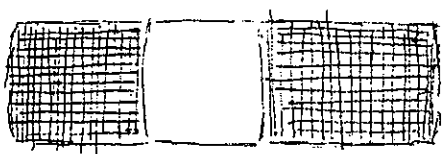
DOWN STREAM + Outter: UPST: 5' to GRAVEL Bott.
Down: 4' to Rip RAP Bott
Bolts GOOD/ AIR BLAST GOOD

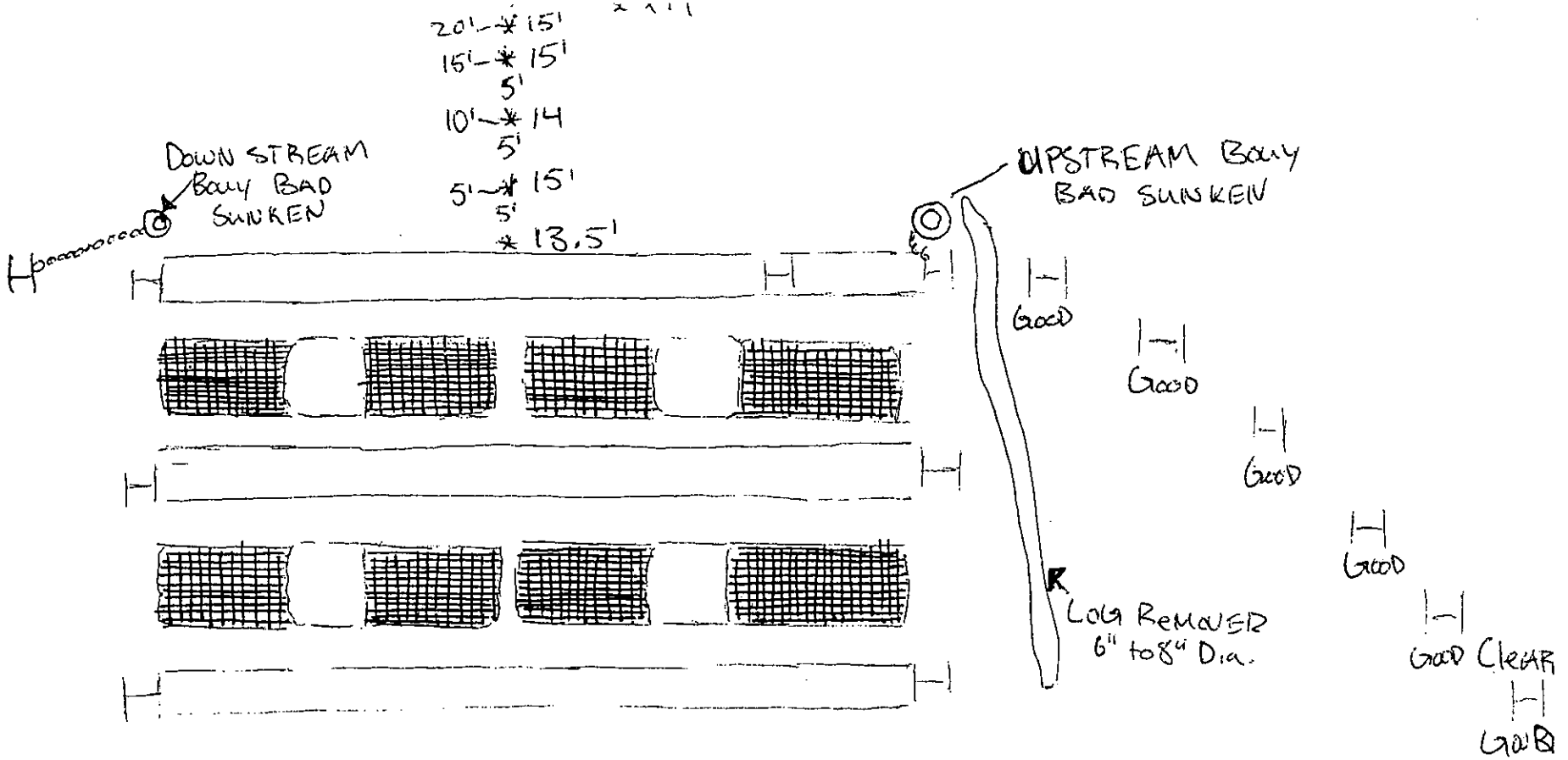
DOWNSTREAM-Outer: UPST: 6' TO Rip-RAP/Gravel Bott.
Down: 6' TO GRAVEL Bottom.
BOLTS GOOD/AIR BLAST GOOD











NOTES: *Depth READING STRAIGHT OUT From MIDDLE OF STRUCTURE
5' = 15' *PAST 30' SLOPES UP GRADUALY
10' = 14' * BOTH BOUY's SUNKEN
15' = 15' * REMOVED LOG FROM STRUCTURE
20' = 15' * ALL H-BEAMS GOOD
25' = 15'
30' = 14'

4-14-08 INSPECTION

P.O. Box 3254
Chico, CA 95927

BIG VALLEY DIVERS, INC.

P.O. Box 3284
Chico, CA 95927
Office (530) 898-1110 Cell (530) 521-0588 Fax (530) 898-1110

To: M & T Ranch
3964 Chico River Rd.
Chico Ca. 95928

Attn: Less Herringer, Mike Bolin

Re: 07 Pump Station Inspection.

DIVE REPORT

Date	3-26-07	Water Elevation	97.7 – Ord Ferry
Location	Main Pumping Plant.	Depth	17'
		Water Temp.	52
Requested By	Less Heringer	Visibility	3'
Site Forman	Mike Bolin	Current (fps)	1fps
Dive Supervisor	Doug Maxfield		

Purpose Of Job

1 – Check fish screen intake structure for winter damage and debris.
2 – Check clearances from bottom of fish screen to river bottom.
3 – Brush fish screens clean.
4 – Check fasteners and hardware.

Report

1 – No major winter damage was found. Screens and surrounding protective structures were found to be in tact. No holes were found and screen integrity was found to be intact.

2 – Screen #1 average clearance 4' to gravel and rip-rap bottom.
Screen #2 average clearance 3' to gravel bottom.
Screen #3 average clearance 5.5' to 6' to rip-rap bottom.
Screen #4 average clearance 5' to gravel and rip-rap bottom.

3 – Diver traveled West from fish screen structure. The encroaching gravel bar began a slight downward gradient continuing to the West. The bottom leveled off 20' West of the structure and about 1.5' lower than the screen structure bottom elevation. Diver reported that the bottom appeared to continue flat to the West.

BIG VALLEY DIVERS, INC.

P.O. Box 3284
Chico, CA 95927
Office (530) 898-1110 Cell (530) 521-0588 Fax (530) 898-1110

4 – Fish screens were brushed clean.

5 – Fasteners were checked and no loose hardware was found.

6 - Both buoys need to be replaced this year.

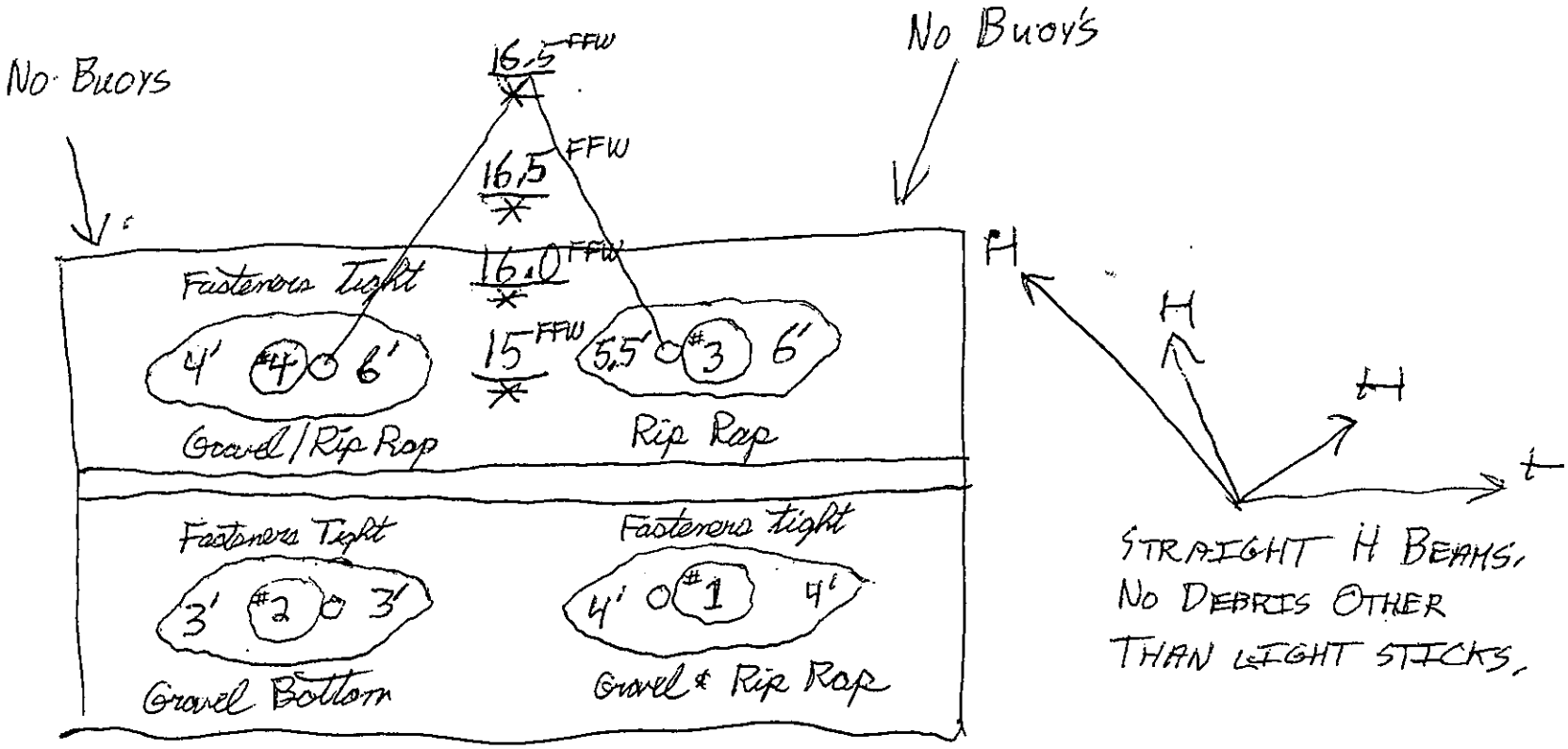
7 – The deflector H beam structure up-stream was cleared of minor debris and all beams were straight and structurally sound.

Report complete.

BIG VALLEY DIVERS, INC.
P.O. Box 3284
Chico, CA 95927

River Flow

BIG VALLEY DIVERS, INC.
Douglas R. Maxfield
Lic # 757776
"DIVING SAFE SINCE 1994"
OFF: (530) 898-1110
FAX: (530) 898-1110
CELL: (530) 521-0588
ads@sunset.net
- Commercial Divers Specializing in Northern & Central California Underwater Needs.
- Irrigation Districts, Powerhouse & Dam Maintenance and Repair, Clean Water.
- Pump Stations, Fish Screens, Siphons.
- Lake, Reservior, Pond.
- Underwater Video, Welding, R.O.V. services.
- Debris & Sediment Removal, Epoxy and Grout.
P.O. Box 3284, Chico, CA 95927



ORD FERRY EL. = 97.7

FLOW = 7,950

BIG VALLEY DIVERS, INC.

P.O. Box 3284 Chico, CA 95927 • Office (530) 898-1110

Cell (530) 521-0588 • Fax (530) 898-1110

CA Lic #757776 · ADCI Member

ads@sunset.net • www.bigvalleydivers.com

100' Old Ferry Co.

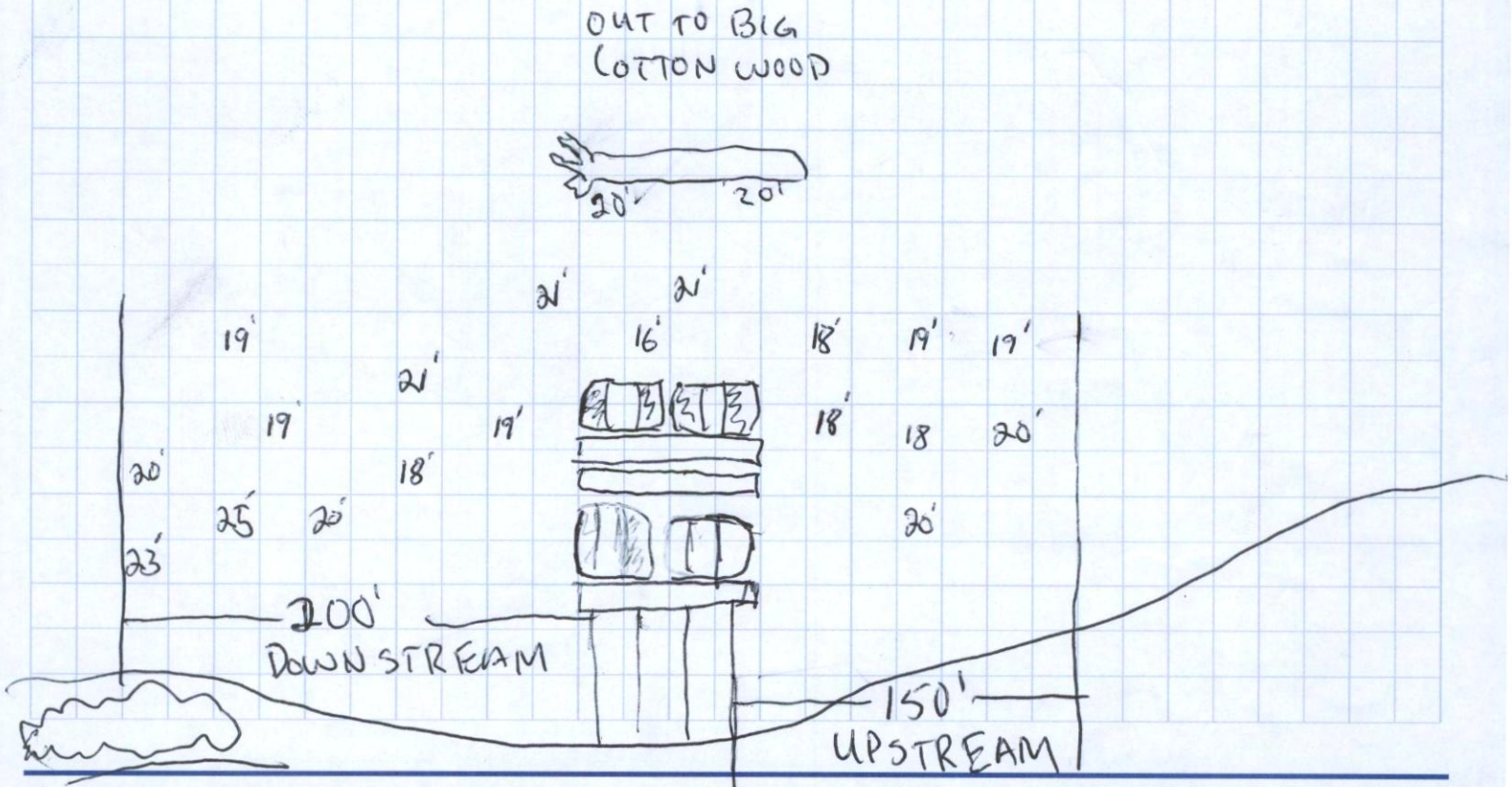
M & T RANCH ATTEN: LES

DEPTH SOUNDING

4-22-11

16,000 c.f.s. - Sac River

Area under screens clear to concrete/rip rap.



Commercial Divers Specializing in Northern & Central California Underwater Needs

Big Valley Divers, Inc. est. 1994, is made up of commercial divers, experienced in every aspect of inland diving operations. Commercial certifications are supported by yearly physicals, CPR, first aid, O2, and AED administration. The customer is always first with BVD.

- Irrigation Districts, Hydroelectric Maintenance and Repair, and Potable Water Service
- Lake & River Marina Maintenance
- Pump Stations, Fish Screens, Siphons
- Slide Gate and Hydraulic Install and Maintenance
- Underwater Video, R.O.V. Services
- Debris & Sediment Removal, Epoxy and Grout
- Fish Screen Cleaning Repair and Construction
- Aquatic Barrier Construction
- Dredging, Water Jetting & Pigging
- Underwater Welding & Cutting
- Salvage and Recovery
- Hydro-Brush Hull Cleaning