Final Report
Assessment of Geomorphic Impacts of Vegetation Removal on the Colorado River 2013/14 Grant

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Introduction

The introduction of tamarisk (*Tamarix* spp.) to the riparian zones adjacent to the Colorado River and many of its tributaries in the southwestern US has contributed to increased stability of the river channels (Graf 1978). The increased stabilization and salinization of riparian zones and increased total water consumption of tamarisk stands create a significant impact in the Colorado River drainage basin on the main stem and many tributaries. Tamarisk impacts on the Colorado River and its tributaries have led to removal efforts and the release of the tamarisk leaf beetle (*Diorhabda carinulata*) as a biological control agent. Bank erosion following high flows in 2011 in Grand Junction, CO, in areas where vegetation removal had occurred suggests that recent efforts at removal of tamarisk could contribute to increased bank erosion and increased channel mobility. Studies of the relationship between channel erosion and tamarisk control have shown that in some cases, erosion increases with tamarisk removal (Vincent et al. 2009) and in other cases, large-scale bank destabilization does not occur (Jaeger and Wohl 2011). The purpose of this study is to assess changes in channel mobility following tamarisk removal via GIS analysis of repeat aerial photos of the channel and side channels in areas where removal has been accomplished and field surveying of cross sections in reaches of the Colorado River where tamarisk removal is planned with the intention of continued annual monitoring to measure cross-section geometry changes.

During the summer of 2013 the initial field surveying of the river channel was accomplished at the two field sites identified for tamarisk and Russian olive (TRO) removal during the winter 2013/14: Franklin Island, near Corn Lake State Park and Walker State Wildlife Area (Walker SWA). A total of ten cross sections were surveyed at the two sites with survey-grade GPS to map the pre-removal channel bathymetry. TRO removal was not accomplished during the 2013/14 winter, so the riparian areas were not surveyed as part of this project.

The GIS analysis of the 51-km reach from DeBeque Canyon to Loma, CO, including the main channel and side channels, is intended to assess channel mobility in removal and non-removal areas via measurement of changes in the non-vegetated active channel from pre-removal and post-removal aerial photos. The "active channel" of the Colorado River is defined as the area of no or sparse woody vegetation that is cleared regularly by the river, and does not include vegetated islands or mechanically cleared areas. The GIS channel change analysis has been completed for the north bank of the channel between 2007 and 2012. Areas of significant channel change were identified and classified as removal areas, non-removal areas, or adjacent to removal areas based on GIS data from the Tamarisk Coalition (2013). Initial results do not indicate significant difference in sizes of eroded areas between removal or non-removal sites.

Field Surveying

Field Surveying Methods

Preliminary site visits were made to both the Franklin Island site and Walker SWA site to establish locations of cross sections to be surveyed. At the Franklin Island site an effort was made to set the new cross sections at the same location as Colorado Division of Wildlife's (CDOW) (Anderson 2002) sections. In 1999, Anderson (2002) surveyed the Corn Lake and Franklin Island areas with survey-grade GPS and sonar. They extracted more than 50 cross sections from the digital elevation model for use in flow modeling for understanding fish habitat. We established six cross sections (CL-1 through CL-6, CL = Corn Lake) at locations matching six of CDOW sections in the river channel and extended across the island for surveying of the riparian area pre and post vegetation removal (Figure 1).

At the Walker SWA site four cross-section (WW-1 through WW-4, WW = Walter Walker) locations were established (Figure 2). Locations were selected to include areas where tamarisk removal would occur close to the river channel and bank. Also, downstream location was constrained by private property on the left bank. The last section is just upstream of private property. At both sites, the endpoint locations were mapped with a mapping-grade (< one meter accuracy) GPS. T-posts were installed to note the location of the endpoints.

Both sites were re-visited and cross section topography was surveyed with survey-grade GPS (Trimble R8 with a TSC3 survey controller) using Mesa County's Real-Time Virtual Reference Network (RTVRN) with estimated sub-centimeter accuracy for horizontal location. We used the stake-out feature to stay "on-line" between endpoints. Points were surveyed at any change in grade (toes and tops of slopes), at regular intervals across the wetted perimeter and at the water surface. An effort was made to find the thalweg when possible. The current of the river made keeping the boat or wader stable in the water difficult, so some of the river points drifted off of the established cross section line. Low streamflows made it impossible to use a boat with a motor, so we were either paddling a duckie, rowing a raft or wading the river (Table 1). The GPS data were then imported to AutoCad for plotting, to GIS for mapping, and to Excel for comparison with Anderson's (2002) data.

For points surveyed in the river where depth was measured with a surveyor's rod, the bottom elevation was determined by subtracting the measured depth from the average water surface elevation between the right and left banks.

At Franklin Island, we used RTVRN GPS to locate the endpoints of the CDOW cross sections. When possible, we extended the cross sections beyond the endpoints of the CDOW cross sections. As a result, the "surveyed length" of some cross sections is different from the endpoint to endpoint length. Also at Franklin Island, cross-section endpoints and midpoints were set for future surveying of the riparian area, so these sections are much longer than the surveyed length. The summer 2013 survey effort focused on the river channel.

Table 1 – Colorado River Daily Mean Discharge on field survey dates

Survey Date	Daily Mean Discharge at Franklin Island* (cfs)	Daily Mean Discharge at Walker SWA** (cfs)		
25-Jul-13	172			
29-Jul-13		3600		
7-Aug-13	935			
8-Aug-13		3390		
9-Aug-13	839			
*USGS - COLO RIVER BELOW GRAND VALLEY DIV NR PALISADE, CO				
**USGS - COLORADO RIVER NEAR COLORADO-UTAH STATE LINE				

Field Survey Results

The total reach length at Franklin Island is 850 meters and the surveyed cross sections at Franklin Island averaged 76 meters in length (Appendix 1, Table 1 and Table 2). The Franklin Island cross-sections were also plotted with the CDOW cross sections to determine if major channel change had occurred since this survey. Given the uncertainty in tying down our new cross sections to the CDOW sections, we decided to pin the left endpoint to the CDOW cross section left endpoint. The left bank of the channel in this reach is in bedrock and it's unlikely that the elevation of the left bank changed significantly since the CDOW survey. The average difference between the water surface elevations measured at the left and right banks was five centimeters (Table 2)

Some of the differences between the CDOW surveyed cross sections and the 2013 survey were evident in the field. At CL-3 and CL-4 the right bank had eroded and the CDOW right bank endpoints were in the water and the current bank had retreated (Figure 3 and Figure 4). At cross sections CL-5 and CL-6 there was evidence in the field of deposition on the right bank, which is clear in the surveys as well (Figure 5 and Figure 6).

The total reach length at Walker SWA is 711 meters and the surveyed cross sections averaged 101 meters in length (Appendix 2, Table 2 and Table 4).

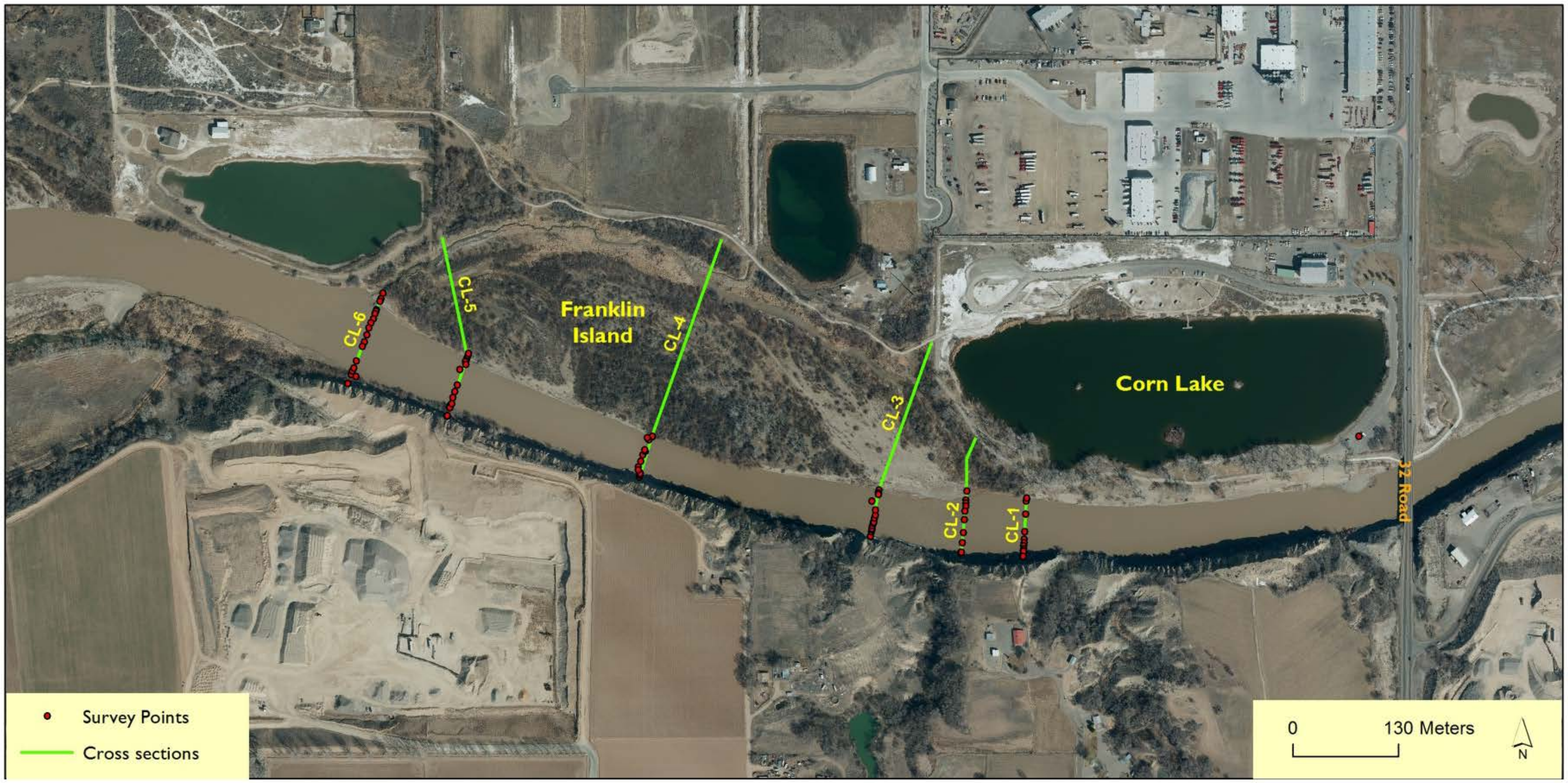


Figure 1 – Franklin Island study site with locations of surveyed cross sections and proposed extended section lines (Background image Mesa County 2012 aerial photo).

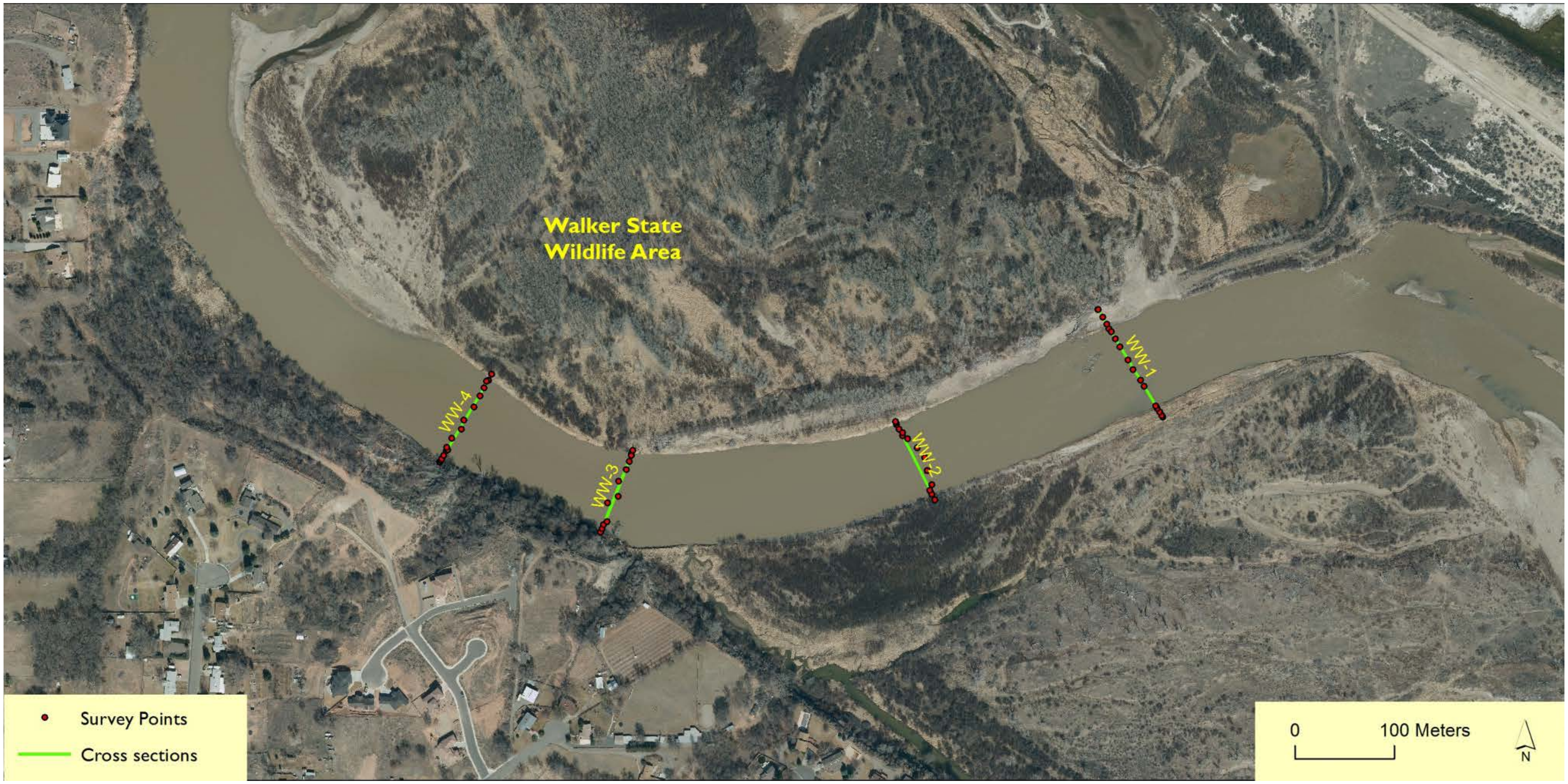


Figure 2 – Walker SWA study site with locations of August 2013 survey points (Background image Mesa County 2012 aerial photo).

Table 2 – Reach data

	Walker SWA	Franklin Island
Reach Length (m)	711	850
Average section length (m)	101	76
Average distance between cross sections (m)	237	170

Table 3 – Cross-section data for Franklin Island. The cross-sections were identified as CL for Corn Lake because the sections begin at the Corn Lake State Park.

Cross Section	Surveyed Length (m)	Length Endpoint to Endpoint (m)	Distance downstream to next cross section (m)	Difference between water surface elevations measured at right and left banks (m)
CL-1	71.5	68	75.3	
CL-2	76.2	143.8	110.4	0.093
CL-3	55.8	250.5	289.8	0.017
CL-4	52.4	309.2	247.9	0.033
CL-5	81.6	212.9	126.4	0.027
CL-6	119.6	107.7		0.07

Table 4 – Cross-section data for Walker SWA

Cross Section	Surveyed Length (m)	Length Endpoint to Endpoint (m)	Distance downstream to next cross section (m)
WW-1	126.5	126.5	237.8
WW-2	87.9	87.9	304.6
WW-3	88.4	88.4	168.9
WW-4	102.8	102.8	

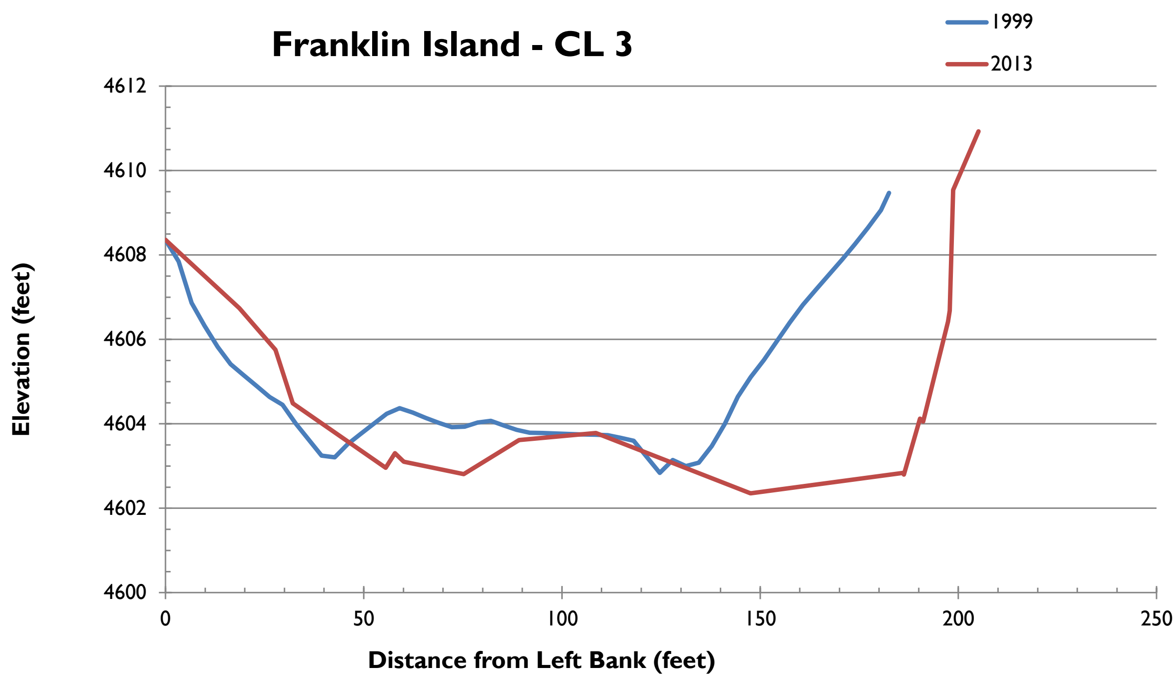


Figure 3 – Cross section surveys of CL-3 at Franklin Island

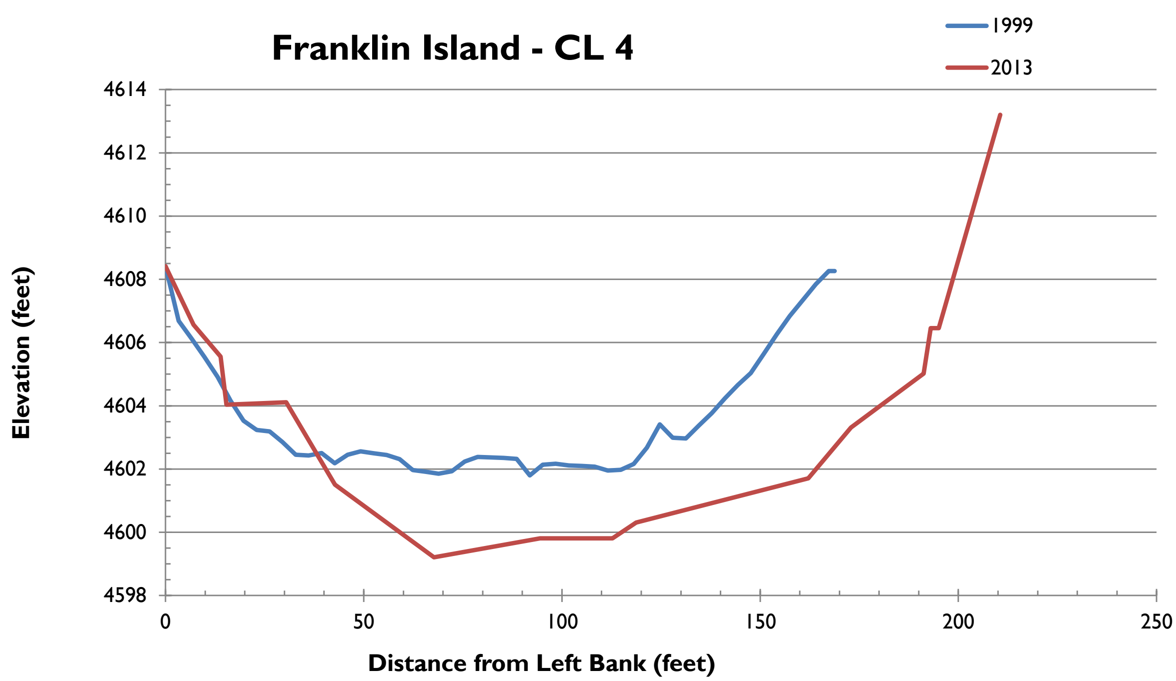


Figure 4 – Cross section surveys of CL-4 at Franklin Island

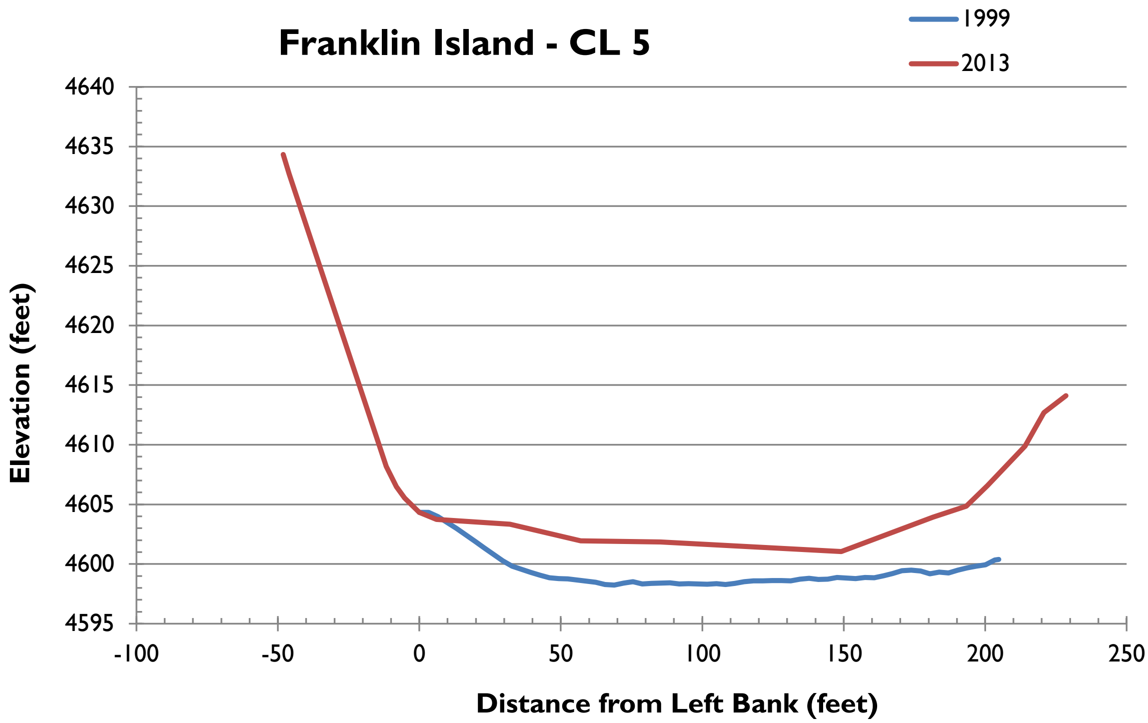


Figure 5 - Cross section surveys of CL-5 at Franklin Island

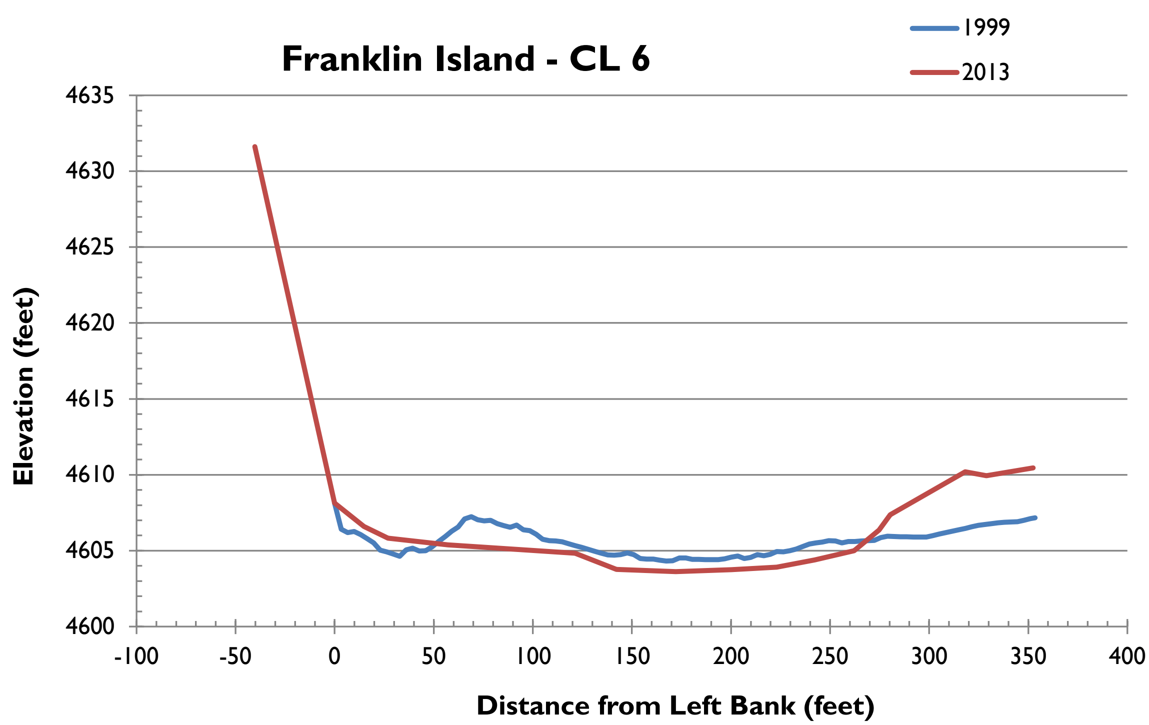


Figure 6 - Cross section surveys of CL-6 at Franklin Island

GIS Analysis

The purpose of this analysis is to create maps of the "active channel" of the Colorado River from Debeque Canyon to Loma, CO digitized from aerial photos pre- and post-vegetation removal to measure channel changes in areas where tamarisk and Russian olive has been removed compared with areas where no removal has occurred, and to compare pre-removal channel change with post-removal channel change. The "active channel" of the Colorado River is defined as the area of no or sparse woody vegetation cleared by the river, and does not include vegetated islands or mechanically cleared areas.

TetraTech previously digitized the channel centerline and water surface from 1937 and 2007 aerial photos. While comparison of the digitized water surfaces does illustrate dramatic channel changes, the outlined area will vary as discharge varies. As a result, unless the aerial photos were taken at about the same discharge, a quantitative analysis of channel change cannot be accomplished using water surface polygons. An example of the difference between outlining the water surface versus the active channel is shown in Figure 8 where the green polygon shows an example of area that would be included in the active channel, but is not included in the water surface outline.

Figure 7 – Example comparison of water surface outline versus the non-vegetated active channel. The polygon outlined in green would be considered active channel, but would not be included if just the water surface were outlined.

Completed tasks and methodology:

- Digitized the 2012 water surface and centerline for comparison with the analysis performed by TetraTech which compared the 1937 and 2007 water surfaces and channel centerlines.
- Digitized the north and south banks of the active channel from the March 2012, 6-in resolution full-color orthophotos (Mesa County) using the following "rules" for determining what to include as active channel:
    - Active channel included area where the woody vegetation is cleared by regular flooding of the river. The active channel may include grassy vegetation.
    - Where thick tree foliage lines the banks, the edge of the bankline was estimated as best as possible under the edge of the foliage.
    - When bankline is riprapped, used the top of the riprap as the bankline
    - Did not include any tributaries or roads or boat ramps as active channel. Drew the bankline straight across those areas
    - In areas where it's unclear what was active channel, tried to delineate areas that have clearly been inundated
    - In areas where TRO were removed and it looks like gravel mining or other manmade disturbance took place, digitized the bankline around the area as if the disturbed area were NOT active channel.
    - Where the bank is vertical, the shadow can be helpful in determining where the top of bank is depending on the sun angle in the photo. If there is a deep shadow, then it can be assumed that there is a tall vertical bank and so the top of bank was used as the active channel bankline.
- Digitized the north bank of the active channel from the April 2007, 6-in resolution full-color orthophotos (Mesa County) using the rules above. Also, I flipped back and forth between the 2007 and 2012 photos and banklines to ensure that the same "rules" were followed for what was included in the active channel.
- Clipped the north banklines (2007 and 2012) to create erosion site polygons (Figure 7) using the following procedure:
    - Used the Symmetrical Difference tool with a 3-meter tolerance, so that polygons are created where the two banklines are more than three meters apart.
    - Individually looked at each polygon created by the tool and bookmarked the sites where the bankline had clearly moved.
    - At each erosion site, the polygons were edited and redrawn when necessary to clearly outline the area of channel change.
- Measured the size of each erosion site: area (Figure 10), length (Figure 11), maximum width (Figure 12) and average width (Figure 13).
    - Used the measure tool to measure the length of the area eroded and the maximum width eroded.
    - Used calculate geometry to compute the area eroded for each polygon
    - Exported the attribute table to Excel and computed the average width of the eroded area by dividing the area by the length.

  - A bookmark was created in ArcGIS for each erosion site and the bookmark number was included in the spreadsheet.
- Identified vegetation removal areas, dates of removal and removal methods and added this information to attribute table in GIS.
  - Identified each removal polygon as: pre-2001, 2001-Apr 2007, Apr 2007-Mar 2012, and Post Mar 2012.
  - Identified each eroded area polygon as being associated with vegetation removal or not. If TRO removal was accomplished in the polygon or directly adjacent during the appropriate time frame, then the eroded area was considered to be associated with vegetation removal
- Compared erosion in vegetation removal areas with erosion in non-removal areas.

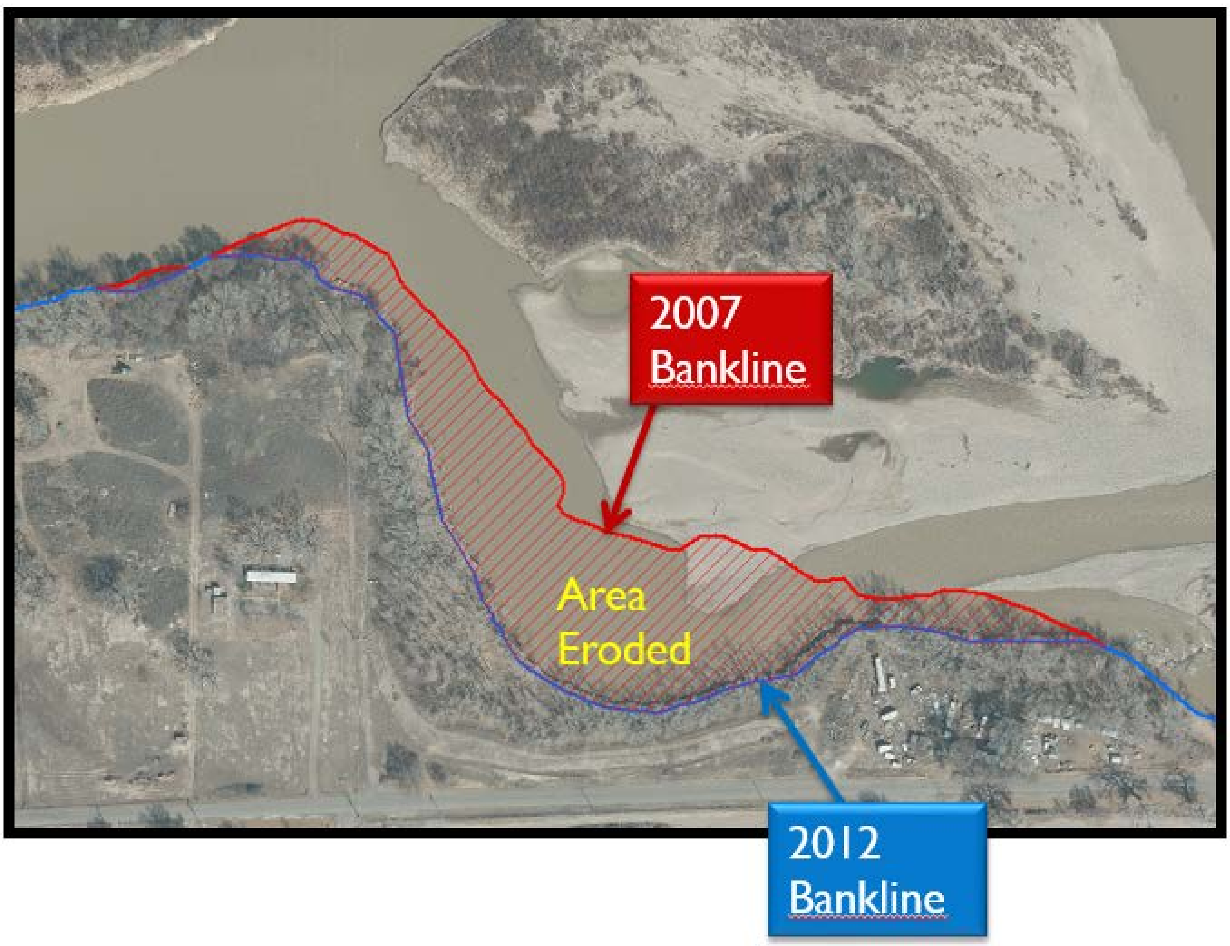


Figure 8. Example of an erosion site polygon.

GIS Analysis Preliminary Results

A total of 36 eroded areas were identified and measured (Tables 5 & 6), with only 8 being in areas where vegetation removal had been performed prior to 2012 (Table 5, Figure 9). The size and length of individual eroded areas did not differ significantly between sites with and without vegetation removal (Figures 10 and 11), but eroded sites without vegetation removal were slightly larger and longer. Individual sites where vegetation removal was performed exhibited very slightly wider eroded areas than sites where vegetation removal was not performed (Figures 12 and 13).

Summary of Work Completed

Several of the goals for this grant were accomplished:

- Ten cross sections were established at Franklin Island and Walker SWA
- Baseline survey of channel bathymetry was accomplished at the ten cross sections
- Established methodology for measuring channel change from aerial photos in GIS
- Measured channel change of north bank of Colorado River from DeBeque Canyon to Loma between 2007 and 2012.

The riparian areas at Franklin Island and Walker SWA were not surveyed because the tamarisk and Russian olive removal work on the CPW properties was not completed in 2013 as initially scheduled due to issues with contracting at the state level. This work is now underway and will be completed in early 2015. Clearing at Walter Walker was completed in December 2014, with work scheduled to begin at Franklin Island and Colorado River Island shortly. The remainder of the baseline field survey work and GIS analysis will be accomplished under the 2014/15 Grant.

Table 5 – Eroded area (2007-2012 north bank) associated with vegetation removal

Bookmarked Area ID	Area (sq m)	Length (m)	Maximum width (m)	Average width (m)
20	177	48	6	4
143	2,077	123	22	17
142	3,861	134	39	29
141	476	41	14	12
13	1,286	208	10	6
12	407	71	14	6
12	202	24	10	8
30	6,561	476	26	14
Total	15,046	1,125		
Maximum	6,561	476	39	29
Minimum	177	24	6	4
Average	1,881	141	18	12

Table 6 – Eroded areas (2007-2012 north bank) not associated with vegetation removal

Bookmarked Area ID	Area (sq m)	Length (m)	Maximum width (m)	Average width (m)
3	8,144	768	18	11
151	180	87	7	2
152	74	26	6	3
16	471	153	6	3
17	188	50	6	4
19	196	45	6	4
211	1,719	384	8	4
212	46	26	6	2
22	478	79	8	6
23	2,388	204	22	12
24	853	216	6	4
25	4,112	297	23	14
11	269	41	9	7
26	1,178	222	7	5
12	287	84	8	3
27	262	43	9	6
10	970	199	7	5
29	390	133	8	3
9	919	70	17	13
8	3,439	284	21	12
31	524	232	4	2
7	2,929	278	16	11
6	833	223	6	4
5	583	89	9	7
4	794	124	10	6
2	2,459	313	16	8
1	2,007	206	18	10
18	15,501	645	36	24
Total	52,195	5,521		
Maximum	15,501	768	36	24
Minimum	46	26	4	2
Avg	1,864	197	12	7

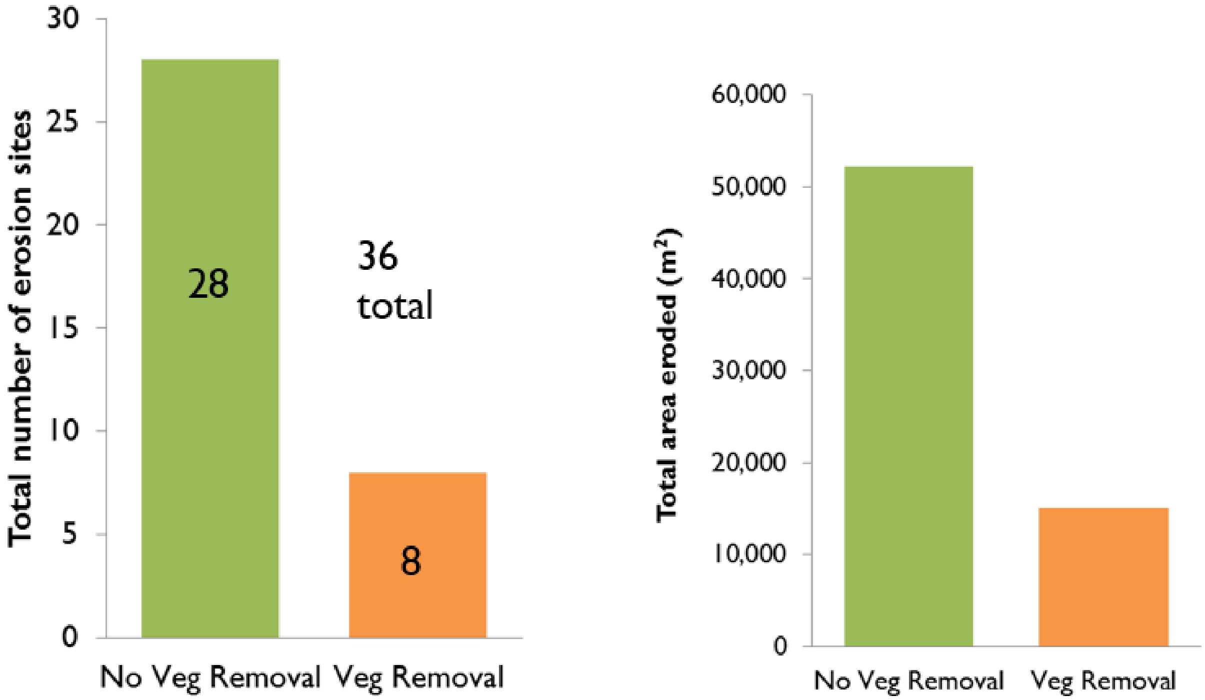


Figure 9. Distribution of erosion sites and comparison of total area eroded in vegetation removal sites vs. non-removal sites.

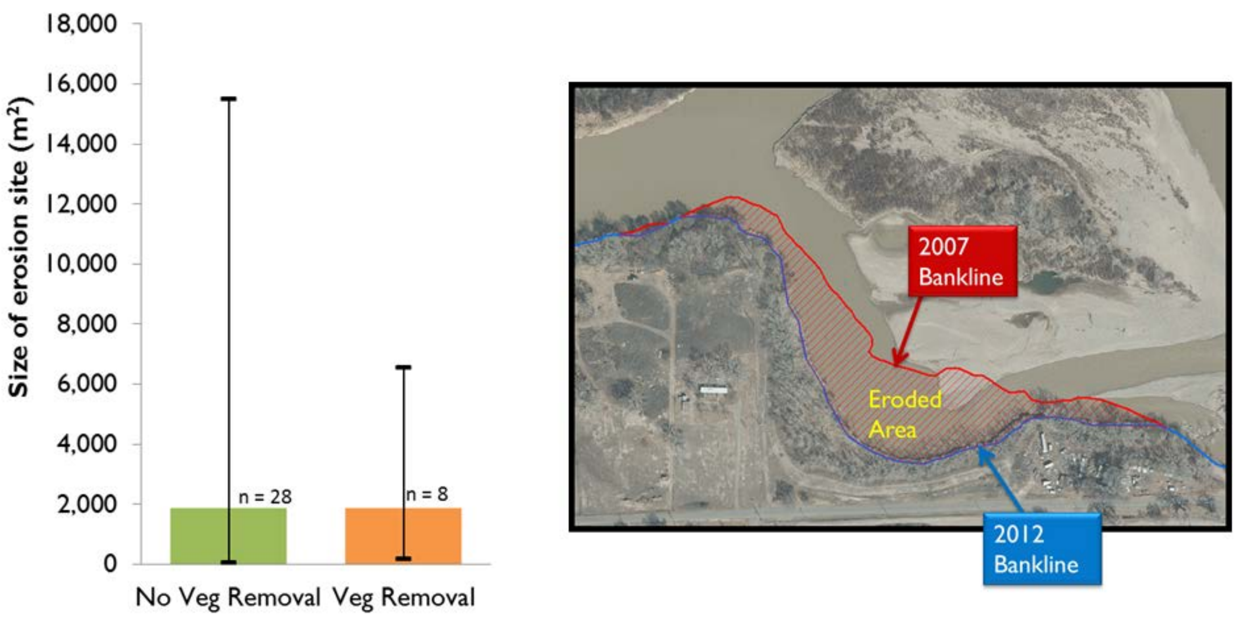


Figure 10. Comparison of area of individual erosion sites.

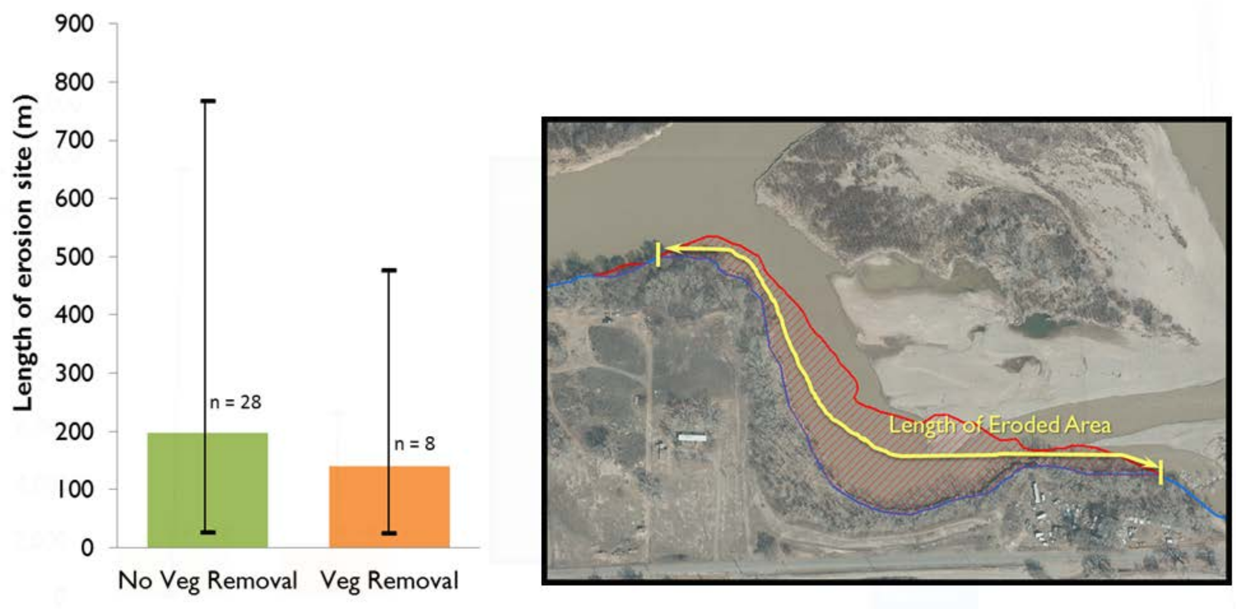


Figure 11. Comparison of length of individual erosion sites.

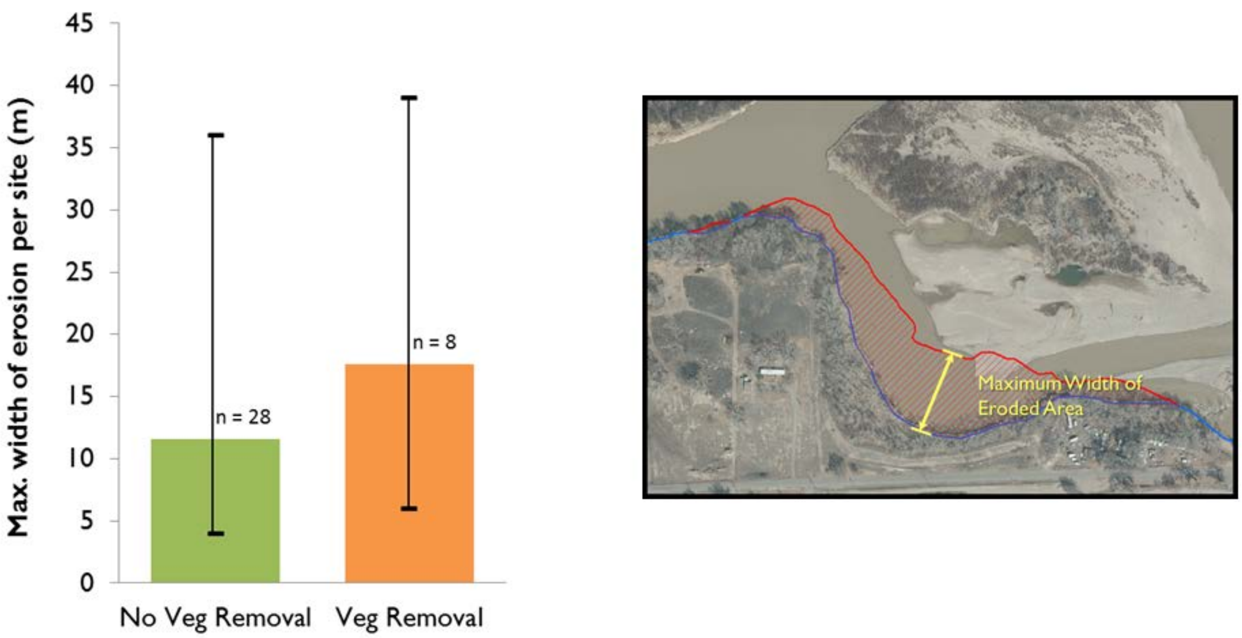


Figure 12. Comparison of maximum width of individual erosion sites.

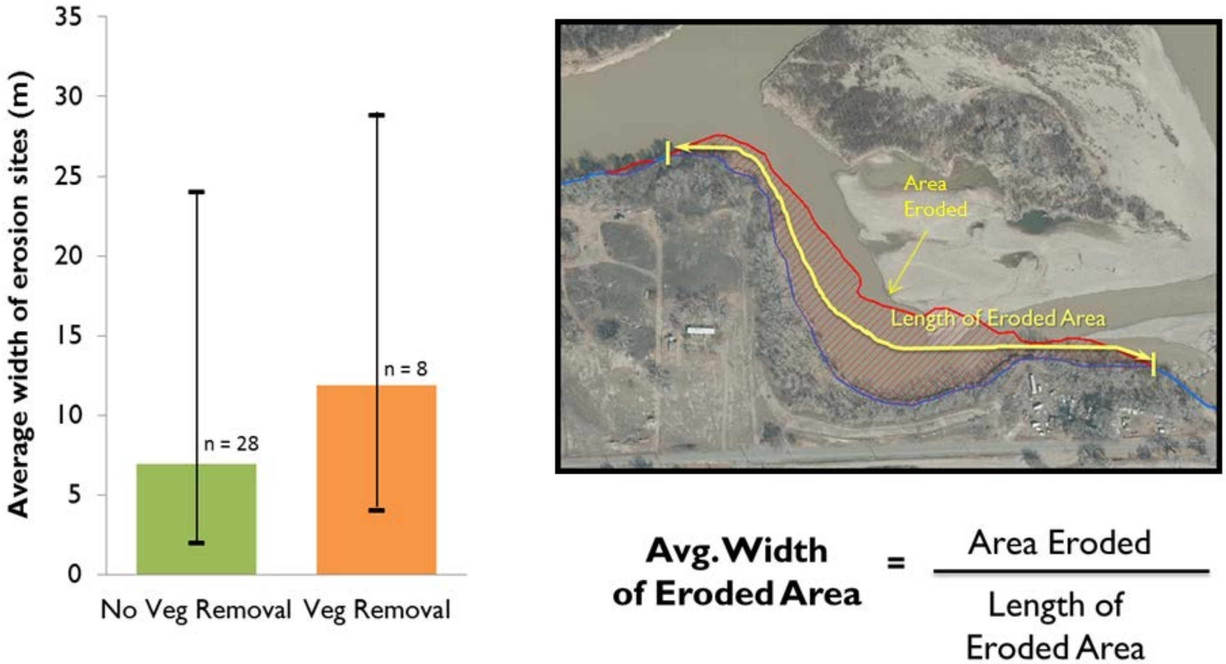


Figure 13. Comparison of average width of individual erosion sites.

References

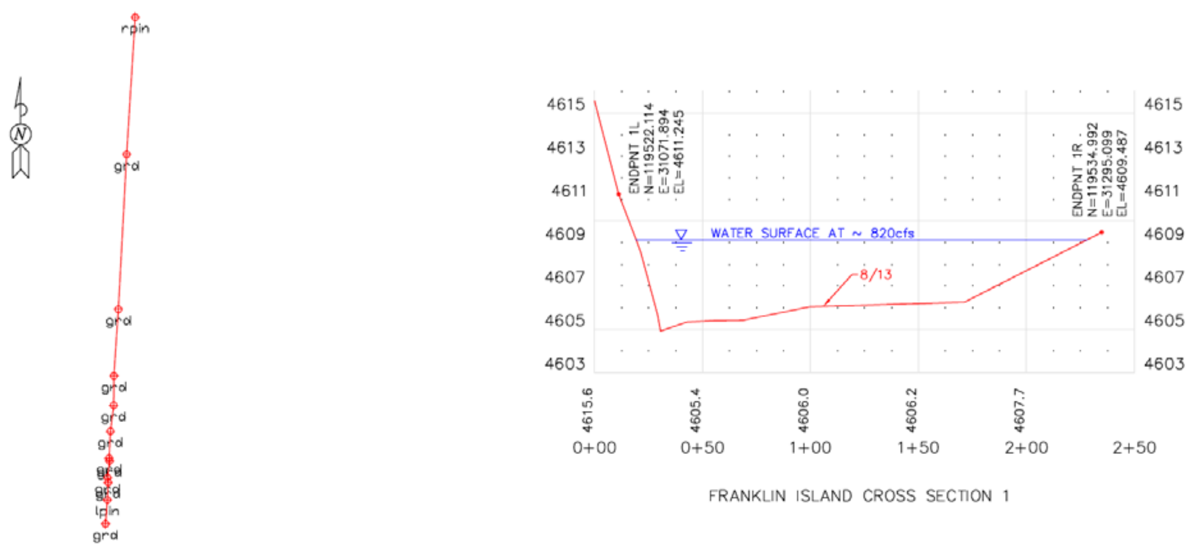
Anderson, R. 2002. *Riverine Fish Flow Investigations, Federal Aid Project F-289-R5*. Colorado Division of Wildlife, Fort Collins, CO.

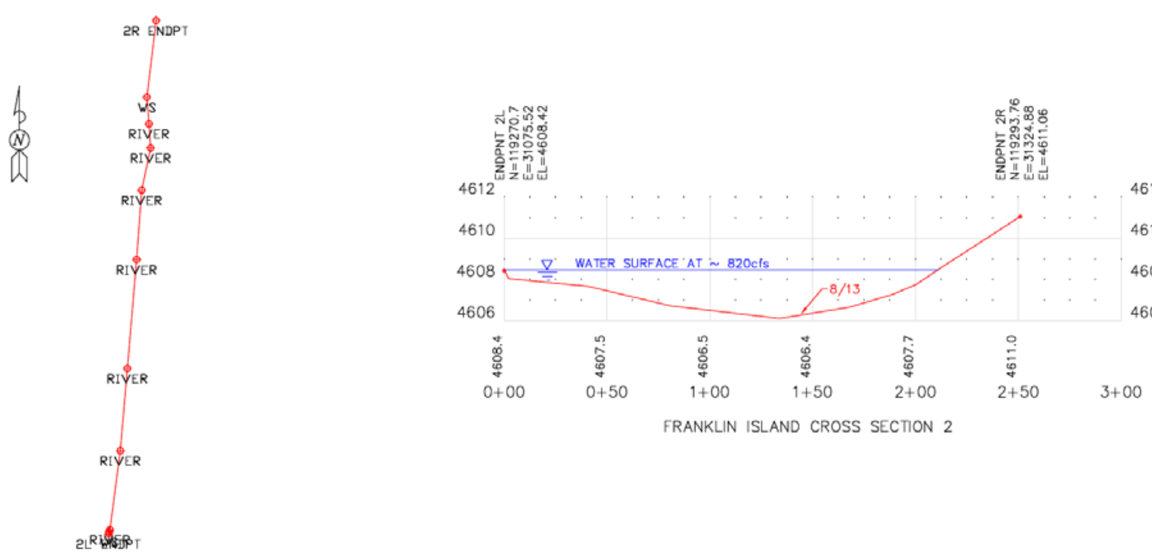
Graf, W.L. 1978, Fluvial adjustments to the spread of tamarisk in the Colorado Plateau region, *Geological Society of America Bulletin*, 89, 1491-1511.

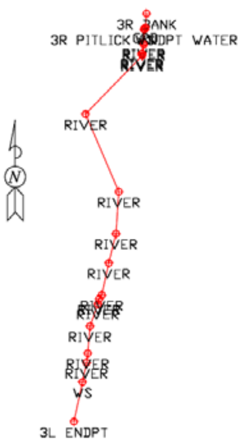
Jaeger, K.L. and E. Wohl, 2011, Channel response in a semiarid stream to removal of tamarisk and Russian olive, *Water Resources Research*, vol. 47, W02536, doi:10.1029/2009WR008741.

Vincent, K.R., J.M. Friedman and E.R. Griffin, 2009, Erosional Consequences of Saltcedar Control, *Environmental Management*, 44(2) 218-227.

Appendix I – Franklin Island (CL = Corn Lake) Cross Sections



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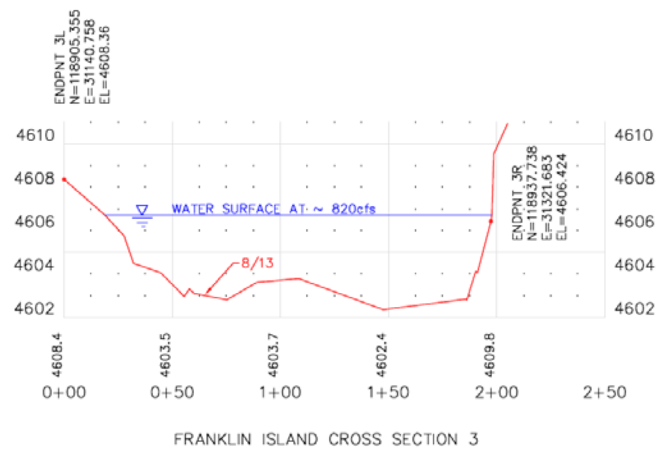
3R PITLICK
ENDPT WATER
RIVER
WS
3L ENDPT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8/13
ENDPNT 3R
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E=31321.683
EL=4606.424
4610
4608
4606
4604
4602
4608.4
4603.5
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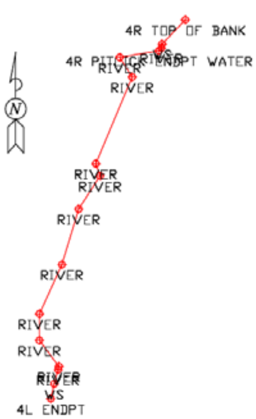
2+50
FRANKLIN ISLAND CROSS SECTION 3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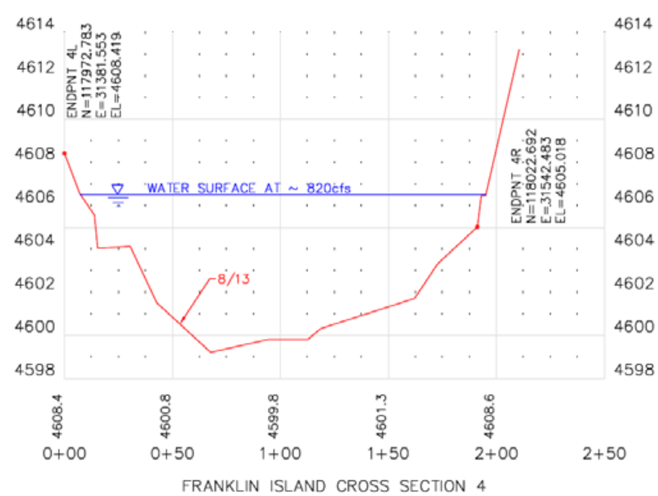
4R PIT
ENDPT WATER
RIVER
WS
4L ENDPT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WATER SURFACE AT ~ 820cfs
8/13
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E=31542.483
EL=4605.018
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4612
4610
4608
4606
4604
4602
4600
4598
4608.4
4600.8
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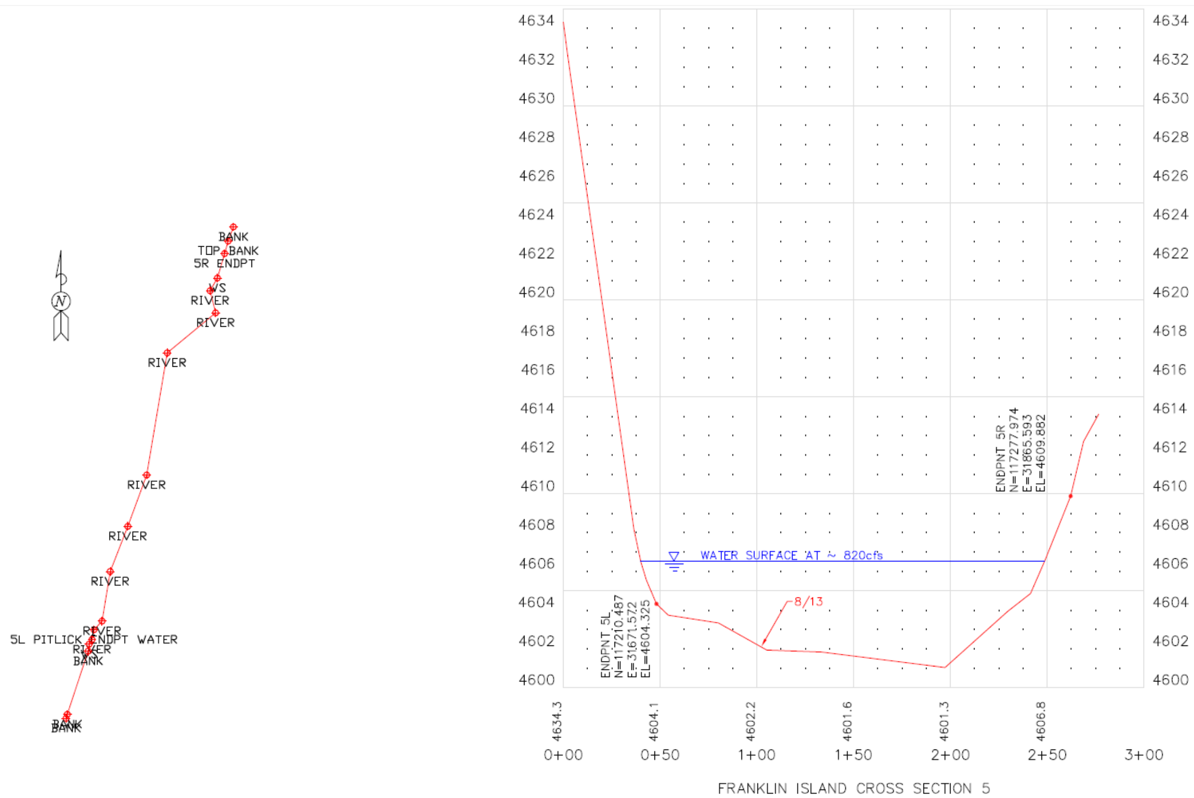
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WS
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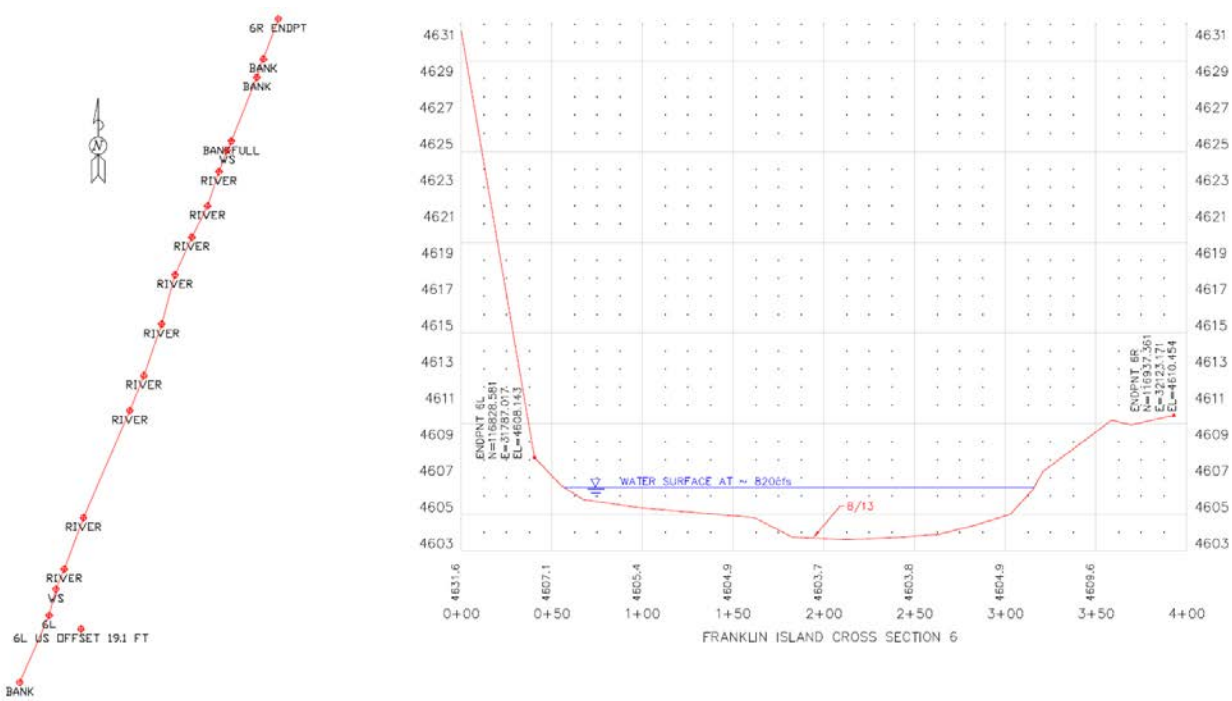
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BANK
BANK
BANKFULL
WS
RIVER
RIVER
RIVER
RIVER
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RIVER
RIVER
RIVER
RIVER
WS
6L
6L US OFFSET 19.1 FT
BANK
N
WATER SURFACE AT ~ 820cfs
8/13
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E=31787.017
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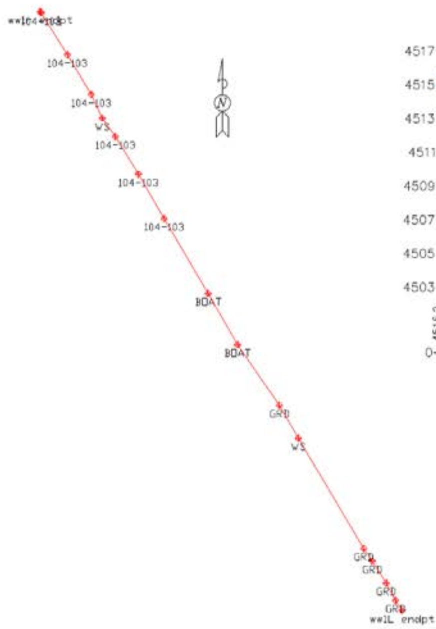
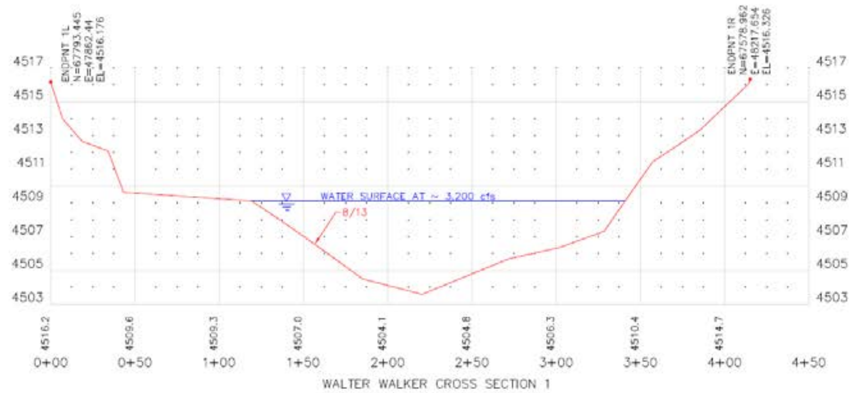
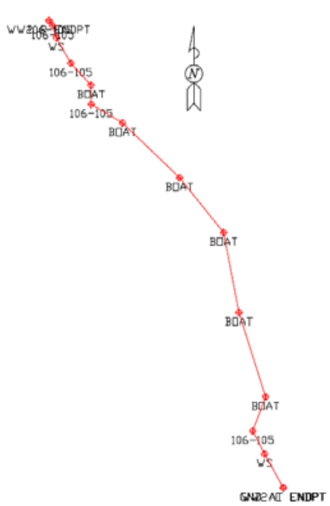
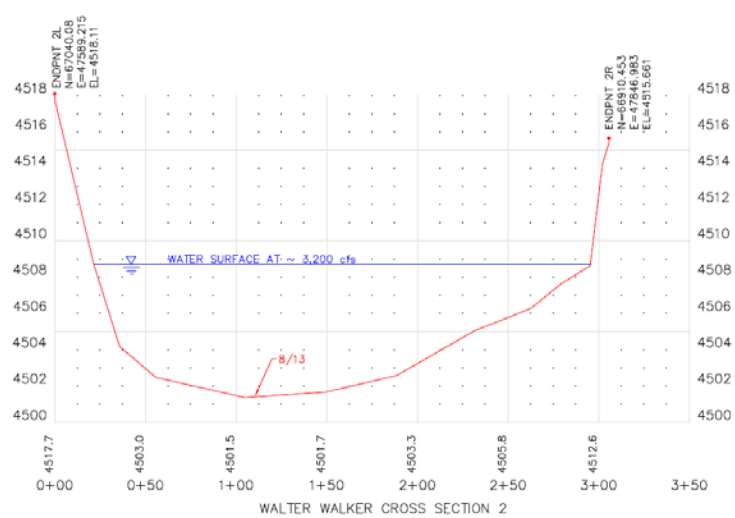
FRANKLIN ISLAND CROSS SECTION 6

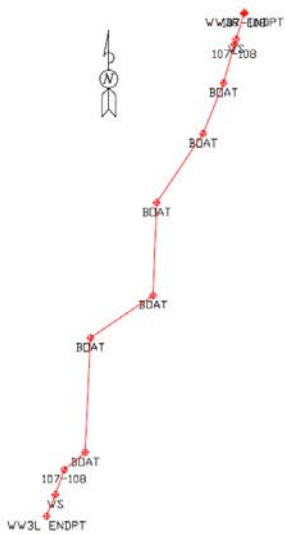
Appendix 2 – Walker SWA Cross Sections

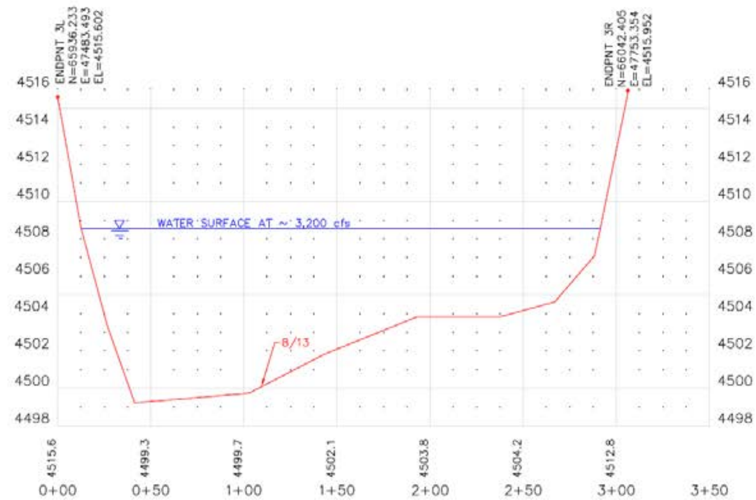




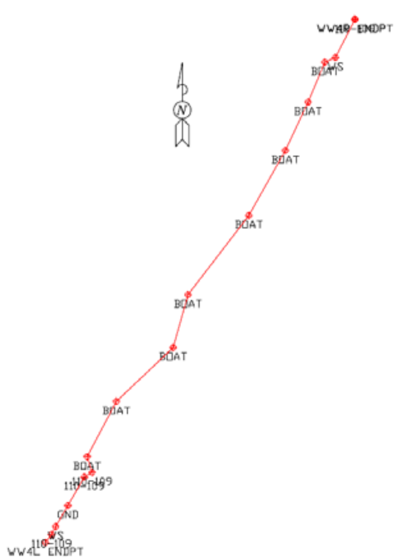


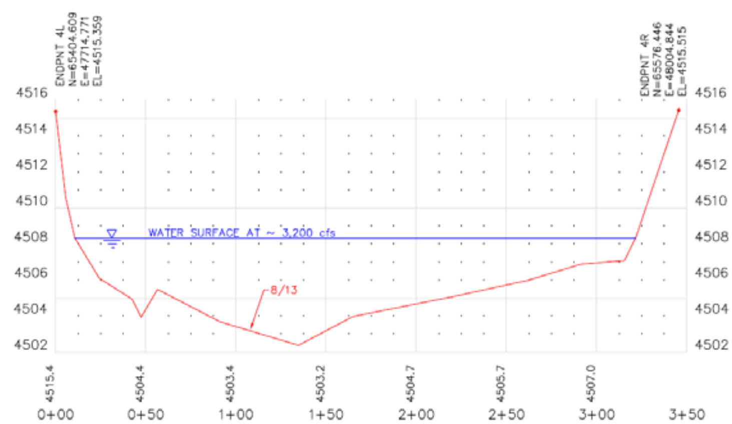






WALTER WALKER CROSS SECTION 3





WALTER WALKER CROSS SECTION 4