INITIAL ISLAND AND BAR GEOMORPHIC SURVEYS FOR THE RIVERINE HABITAT RESTORATION PROJECT IN THE ALBUQUERQUE REACH, MIDDLE RIO GRANDE, NEW MEXICO

Submitted to

NEW MEXICO INTERSTATE STREAM COMMISSION
121 Tijeras, Suite 2000
Albuquerque, New Mexico 87102
505-764-3880

Prepared by

Joseph Fluder, M.S.
Burt McAlpine

SWCA® ENVIRONMENTAL CONSULTANTS
7001 Prospect Place NE, Suite 100
Albuquerque, New Mexico 87110
Telephone: 505-254-1115; Facsimile 505-254-1116
www.swca.com

and

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

MUSSETTER ENGINEERING, INC.
1730 S. College Ave, Suite 100
Fort Collins, Colorado 80525
Telephone: 970-224-4612; Facsimile 970-472-6062

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1.0 INTRODUCTION

This report provides the New Mexico Interstate Stream Commission (NMISC) with a summary of Mussetter Engineering, Inc.'s (MEI) work on the Middle Rio Grande Riverine Habitat Restoration project that is being conducted on the Middle Rio Grande in the Albuquerque Reach by SWCA for the NMISC. In summary, MEI has completed all of the survey tasks, which included: (1) topographic surveys of five bank-attached bars and four mid-channel bars/islands in the South Diversion Channel (SDC) subreach; (2) topographic surveys of three bank-attached bars and four mid-channel bars/islands in the Central Avenue outfall subreach; and (3) topographic surveys of five mid-channel bars/islands in the North Diversion Channel (NDC) outfall subreach. Six mid-channel bars/islands and one bank-attached bar that were originally surveyed in the SDC and NDC subreaches in March 2005 were resurveyed in September 2005, and we have prepared maps identifying the changes that occurred as a result of the relatively high, long-duration flows that were experienced this year. Reduction of all of the survey data and preparation of 0.5-foot contour interval maps of the surveyed bank-attached and mid-channel bars/islands have been completed. An HEC-RAS hydraulic model of the Rio Grande that has been calibrated by MEI to the 2005 peak flow of 6,300 cfs has been used to identify water-surface elevations for a range of flows between 500 and 6,300 cfs at each of the surveyed sites. Classification of the bars/islands based on the bar classification scheme developed by MEI for the Endangered Species Act (ESA) Collaborative Program has been completed.

2.0 SURVEY DATA AND CLASSIFICATION

Surveys of the bank-attached bar and the mid-channel bars/islands (Figure 1) were conducted with a Leica Series 1200, RTK-GPS unit in three periods: between March 28 and April 1, 2005, when the flow in the Rio Grande was between 720 and 970 cfs at the Central Avenue USGS gaging station (Figure 2); between July 18 and 23, 2005, when the flow in the Rio Grande at the Central Avenue gage was between 412 and 660 cfs (Figure 3); and between September 12 and 17, 2005, when the flow in the Rio Grande at the Central Avenue gage was between 319 and 271 cfs (Figure 4). The surveys were conducted in the NAVD88 and New Mexico State Plane Central NAD83 coordinate systems.

The Bureau of Reclamation (BOR) CO 37 LEP monument provided control for the SDC subreach, checked against the BOR AQ 567 LEP and NMDOT 2500-5 monuments. Control for the NDC subreach was provided by the BOR CO 34 LEP (pipe) monument, checked against the BOR CR 413 EIP monument. The City of Albuquerque 15-J-12 monument provided control for the Interstate-40/Central Avenue subreach, checked against the City of Albuquerque 14-J-12 monument. Temporary benchmarks consisting of 0.5-inch rebar with blue plastic caps were set on the bars/islands to facilitate future resurveys.

2.1 MAPPING AND CROSS-SECTION SURVEYS

Topographic data from the mid-channel bars/islands and bank-attached bars were reduced to provide 0.5-foot contour interval maps, using the Microstation software. Contour maps for the four mid-channel bars/islands and five bank-attached bars in the SDC subreach are provided in Appendix A. Contour maps for the four mid-channel bars/islands and three bank-attached bars in the Interstate-40/Central Avenue subreach are provided in Appendix B. Contour maps for the five mid-channel bars/islands in the NDC subreach are provided in Appendix C. Contour maps for the resurveyed mid-channel bars/islands in the SDC and NDC subreaches are also included in Appendixes A and C, respectively.

The locations of cross-section profiles that were surveyed in the SDC subreach in March 2005 are shown on Figure 5. Cross-section numbers are related to the U.S. Army Corps of Engineers (USACE) HEC-RAS model and the BOR range line numbering system, and the cross sections are plotted looking downstream. Figure 6 shows the cross-section profile (XS567.5) through the downstream-most mid-channel bar/island. Figure 7 shows the cross-section profile (XS567) through the upstream-most mid-channel bar/island, and Figure 8 shows the cross-section profile (XS566) through the control mid-channel bar/island. Figure 9 shows the cross-section profile (XS564) through the lower portion of the bank-attached bar, and Figure 10 shows the cross-section profile (XS563) through the upper portion of the bank-attached bar.

The locations of the surveyed cross-section profiles for the NDC subreach are shown on Figure 11. Cross-section numbers are related to the USACE HEC-RAS model and the BOR range line numbering system, and the cross sections are plotted looking downstream. Figure 12 shows the cross-section profile (XS414.5) through the downstream-most mid-channel bar/island. Figure 13 shows the cross-section profile (XS405.5) through the downstream end of the upstream-most mid-channel bar/island. Figure 14 shows the cross-section profile (XS405) that crosses both the upstream end of the upstream-most mid-channel bar/island and the downstream end of the control mid-channel bar/island. Figure 15 shows the cross-section profile (XS404.5) through the control mid-channel bar/island.

2.2 HYDRAULIC ANALYSIS

An existing HEC-RAS hydraulic model of the Rio Grande developed by the Albuquerque District of the USACE was modified with the addition of surveyed cross sections of the river derived from a number of sources by MEI for the USACE, and calibrated to the high-water marks for the peak flow of 6,300 cfs developed by Tetra Tech Inc. (2005) for the USACE. NMISC requested hydraulic analysis only for the original three mid-channel bars/islands and one bank-attached bar in the SDC subreach.

Figures 16 and 17 show that the bank-attached bar (XS563 and XS564) should be overtopped at a flow of between 10,000 and 12,000 cfs, which is similar to the 5-year peak discharge (10,800 cfs) prior to construction of Cochiti Dam (MEI 2002). This discharge is somewhat higher than would be expected for the 2-year peak discharge (about 7,000 cfs) that probably correlated with the floodplain elevation of the Rio Grande prior to the construction of Cochiti Dam. Stage-discharge rating curves for the Central Avenue USGS gage indicate that the channel degraded about 2 feet between 1973 and 1987 (MEI 2002), and this probably explains the greater present channel capacity at the bank-attached bar.

Figure 18 shows that the highest portions of the control mid-channel bar/island (XS566) will be inundated at a discharge of about 10,000 cfs, whereas other parts of the bar will be inundated at discharges on the order of 5,000 to 6,000 cfs, which is what occurred during the May to June 2005 period of high flows. Figure 19 (XS567) shows that at the upstream-most of the restoration mid-channel bars/islands, the bar will be inundated at a discharge of between 5,000 and 6,500 cfs, which is what occurred in the May to June 2005 period of high flows. The downstream-most of the restoration mid-channel bars/islands (XS567.5) will be inundated at a discharge of between 4,500 and 5,500 cfs (Figure 20), which is what occurred in the May to June 2005 period of high flows. The 2-year peak discharge in the post–Cochiti Dam period is on the order of 5,400 cfs (MEI 2002), and this flow appears to correlate with the mid-channel bar/island surfaces fairly well, which suggests that the mid-channel bars/islands are now functionally equivalent to the present floodplain of the Rio Grande, and the former floodplain surfaces are now terraces that are inundated infrequently (20- to 50-year post–Cochiti Dam peak discharges) (MEI 2002).

Hydraulic analysis for the remainder of the mid-channel bars and islands was also conducted with the HEC-RAS model, since site-specific, stage-discharge and stage-duration and frequency information is required for the restoration planning process. Cross sections showing the water-surface elevations for flows between 500 and 6,300 cfs for each of the mid-channel bars/islands and bank-attached bars in the SDC, Interstate-40/Central Avenue, and NDC subreaches are provided in Appendix D.

2.3 BAR CLASSIFICATION

As part of the bar dynamics research project funded by the NMISC-ESA Collaborative Program, MEI has developed a bar classification for the Middle Rio Grande and has related the elevations of the various bar types to flow frequencies and flow durations (Harvey et al. 2004). Within the SDC subreach, all of the mid-channel bars/islands are classified as Level II mid-channel bars, but each of the bars has an LI mid-channel bar accreted to portions of the main bar (Figures 21 through 23). The bank-attached bar is classified as an LII bank-attached bar (Figure 24). Based on the flood-frequency and flow-duration analyses that were determined for the MEI Central Avenue site, the LII mid-channel bars are inundated on average by the 2-year peak flow, for about 4 percent of the time (about 15 days per year). The LII bank-attached bars are inundated on average by the 5-year peak flow, which has zero duration of inundation in the post–Cochiti Dam period.

Within the NDC subreach, the control mid-channel bar/island is classified as an LII mid-channel bar (Figure 25). About one-third of the upstream-most mid-channel bar/island is classified as an LII mid-channel bar, but the remainder of the bar is classified as an LI mid-channel bar that has accreted to the LII bar (Figure 26). Based on the Central Avenue site data, LI mid-channel bars are inundated on average by the 1.5-year peak flow, for about 5 percent of the time (about 18 days per year). The downstream-most of the mid-channel bars/islands is classified as an LI mid-channel bar (Figure 27).

Although the mid-channel bars/islands and bank-attached bars that were surveyed for the first time in July and September 2005 were not classified in the field, it is reasonable to conclude from the topographic maps (Appendixes A, B, and C) that the mid-channel bars/islands have LII cores with laterally accreted lower elevation LI surfaces. Bank-attached bars are classified generally as LII bank-attached bars. Inundation flow magnitudes and durations will be similar to those described above for the SDC and NDC initial survey (March 2005) bars/islands.

2.4 COMPARATIVE SURVEYS

In September 2005, following the spring runoff when flows in the river exceeded 5,000 cfs from May 12 to June 15 and the peak flow in the Albuquerque Reach was 6,300 cfs, three mid-channel bars/islands in the NDC subreach and three mid-channel bars/islands and one bank-attached bar in the SDC subreach that were originally surveyed in March 2005 were resurveyed (Tetra Tech 2005). Contour maps of the bars for the two surveys are provided in Appendix A (SDC) and Appendix C (NDC).

Figure 28 is a color-gradient map of the elevation changes at the control island in the SDC subreach. The bulk of the island was not inundated during the high flows between May 12 and June 15, 2005, and therefore there were few changes. Some bed scour took place at the head of the heavily vegetated and root-reinforced head of the bar/island (LII surface), but the remainder of the LI surface that was inundated experienced about 0.5 feet of vertical accretion. At the downstream end of the bar/island, the vertical accretion was closer to 1.5 feet.

Figure 29 is a color-gradient map of the elevation changes at the upstream-most restoration bar/island (No. 2) in the SDC subreach. Most of the island, with the exception of the LII core, was inundated during the high flows between May 12 and June 15, 2005, and therefore there was a significant amount of vertical accretion, from about 0.5 to 2 feet, on the LI surfaces. Degradation along the west (right) side of the bar/island was due to a channel change. Prior to the high flows, the main thread of the river was located to the east, but during the high flows, the main channel switched to the west side.

The generally lower elevation downstream-most restoration bar/island (No. 3) in the SDC subreach was subjected to considerable vertical accretion on the LI surface between May 12 and June 15, 2005 (Figure 30), from about 0.5 to 2.5 feet. Degradation on the east side was due to channel shift that resulted in a defined channel between bars/islands 2 and 3 following the high flows.

Figure 31 is a color-gradient map of the elevation changes at the Control (upstream) and Restoration No. 2 bars/islands in the NDC subreach. The bulk of the Control bar/island is an LII surface and was not inundated during the high flows between May 12 and June 15, 2005. The LI surface along the west (right) side of the bar/island shows vertical accretion of up to 1.5 feet. An active channel previously occupied the former channel between the Control and Restoration No. 2 bars/islands. During the high flows, this channel aggraded by up to 2 feet and was abandoned. Vertical accretion on the LI surface that constitutes the majority of the Restoration bar/island (No. 2) ranged from about 0.5 to 2 feet, but there was little if any deposition on the LII surface that forms the core of the bar.

Restoration bar/island No. 3 in the NDC subreach consists completely of an LI surface, and as such it experienced significant vertical accretion during the high flows (Figure 32). Vertical accretion on the west (right) side of the bar/island was high because of channel switching during the high-flow event. Prior to the high flows, the main channel was located on the west side of the bar/island, but it switched to the east side during the event, causing some degradation of the bed. On most of the bar/island, vertical accretion ranged from 0.5 to 1.5 feet.

Based on the comparative surveys, it can be concluded that in general the higher-elevation LII surfaces experienced very little if any vertical accretion during the high-flow period because they either were not inundated or were inundated to very shallow depths. In contrast, the perennially vegetated LI surfaces were inundated and experienced on average up to 1.5 feet of vertical accretion, increasing the magnitude of the flows that will be required to inundate them in the future. Root reinforcement over time of the predominantly sandy sediments that comprise the bars/islands has made them much more erosion-resistant, and the comparative surveys indicate that there was little lateral erosion of the bars/islands during the long-duration, high-magnitude flow event.

3.0 REFERENCES

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Mussetter Engineering, Inc. (MEI). 2002. Geomorphic and Sedimentologic Investigations of the Middle Rio Grande between Cochiti Dam and Elephant Butte Reservoir. Prepared for New Mexico Interstate Stream Commission, June.

Tetra Tech, Inc. 2005. Middle Rio Grande Hydrographic Data Collection Report, Overbank Monitoring of the 2005 High Flow Spring Release from Cochiti Dam. Prepared for ESA Collaborative Program through USACE Albuquerque District, July.

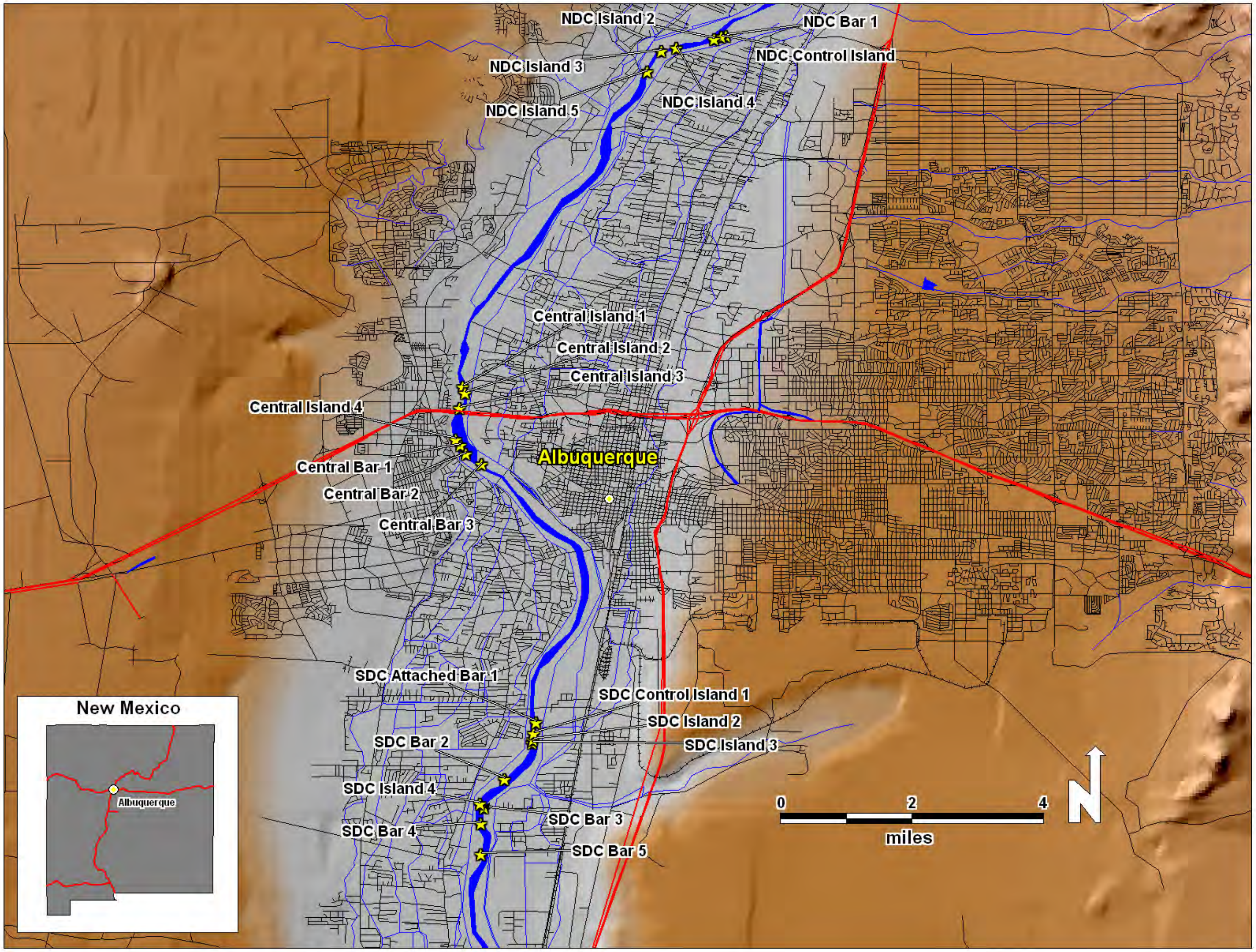


Figure 1. Map showing the locations of the bank-attached bar downstream of Rio Bravo Bridge and the mid-channel bars/islands in the South Diversion Channel and North Diversion Channel subreaches.

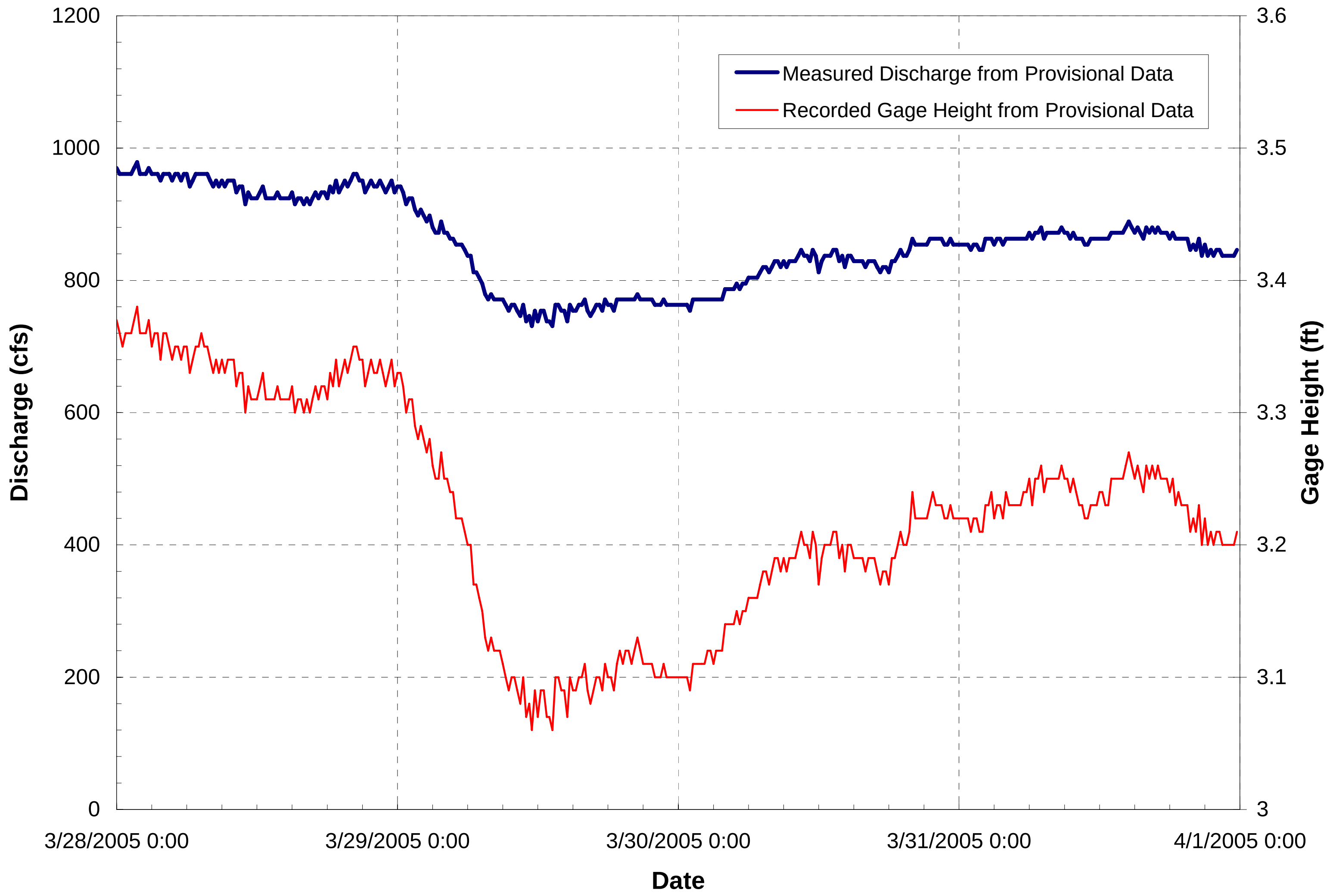


Figure 2. Stage and discharge data for the period between March 28 and April 1, 2005, at the Central Avenue USGS gaging station on the Rio Grande.

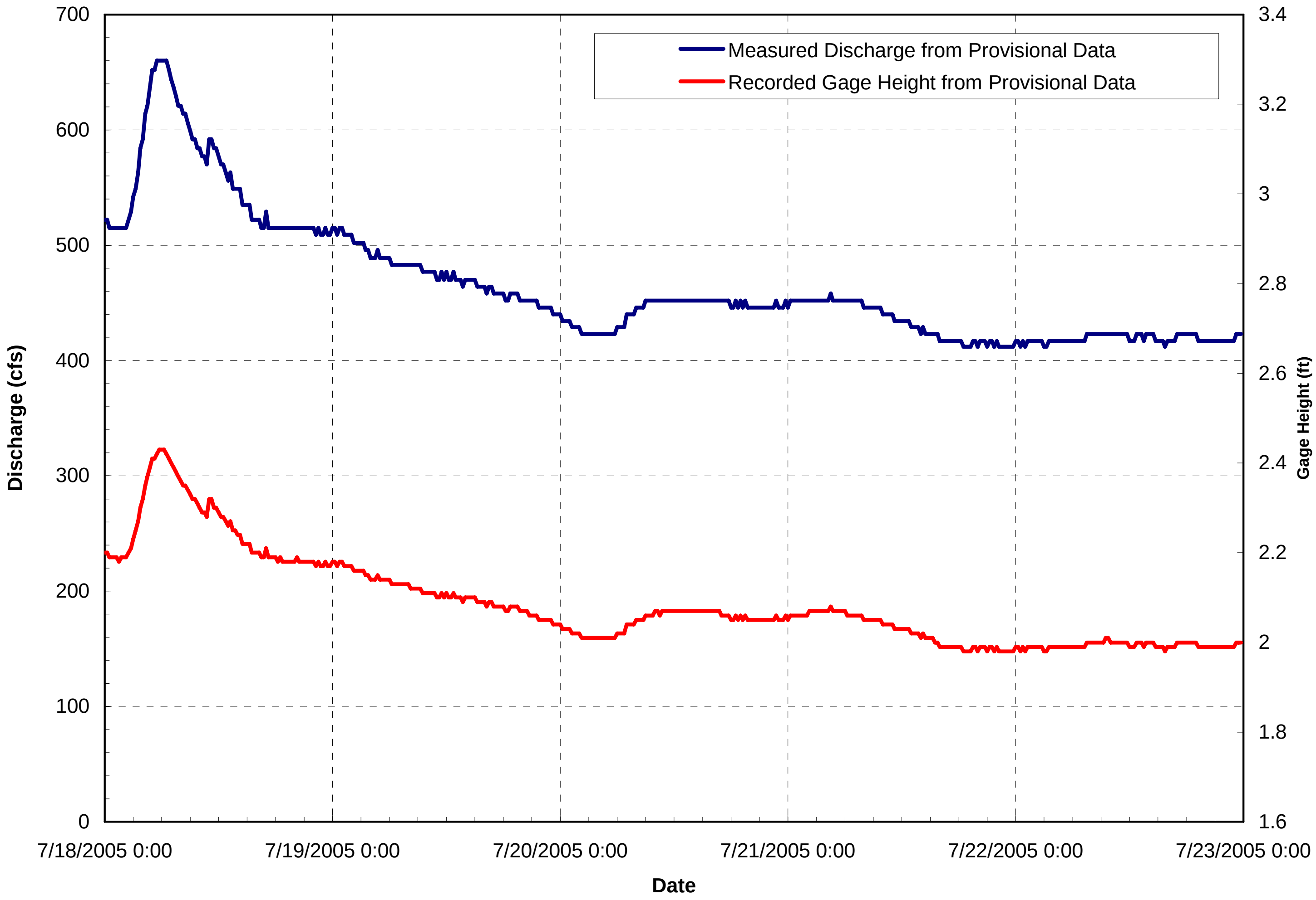


Figure 3. Stage and discharge data for the period July 18 through 23, 2005, at the Central Avenue USGS gaging station on the Rio Grande.

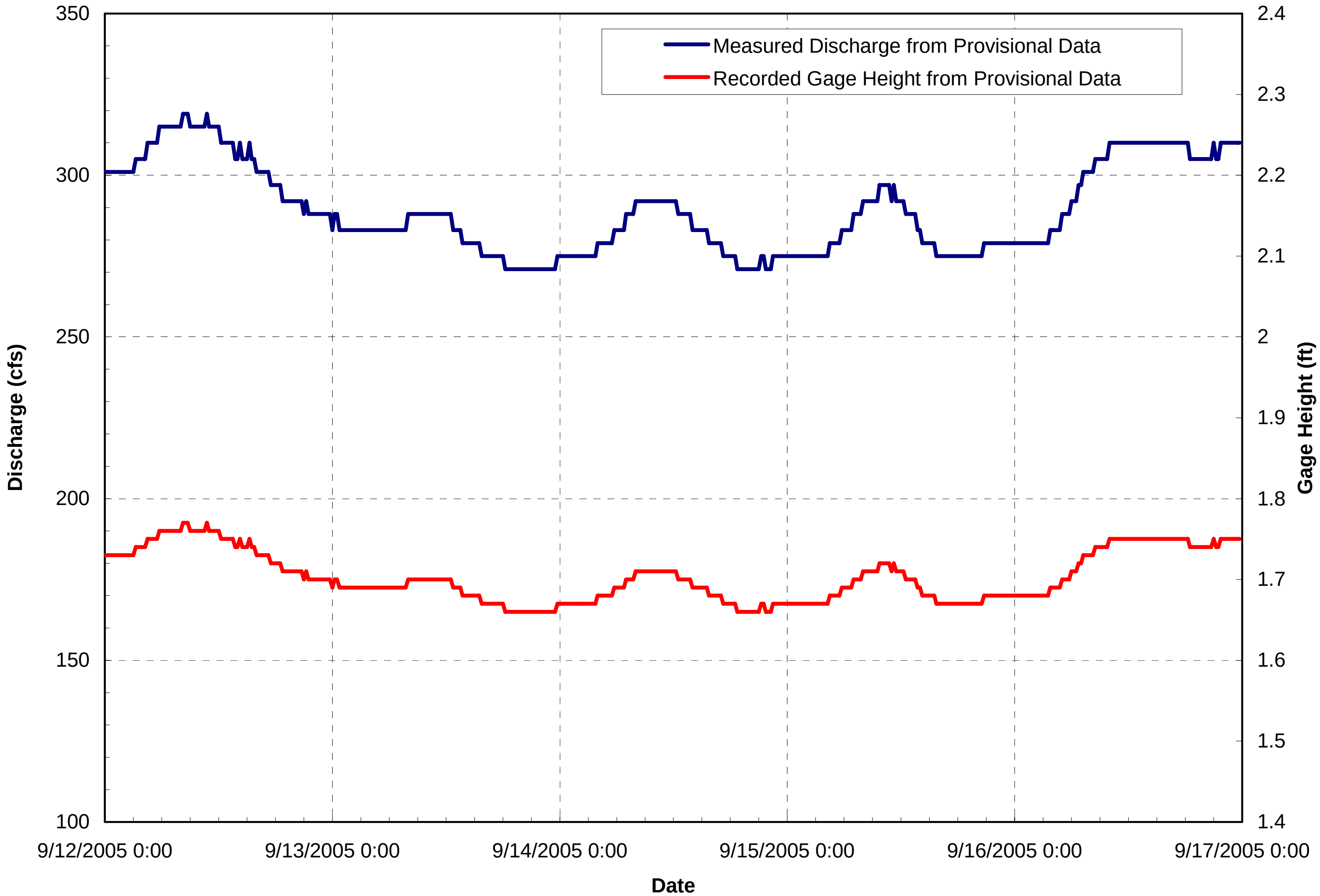


Figure 4. Stage and discharge data for the period September 12 through 17, 2005, at the Central Avenue USGS gaging station on the Rio Grande.

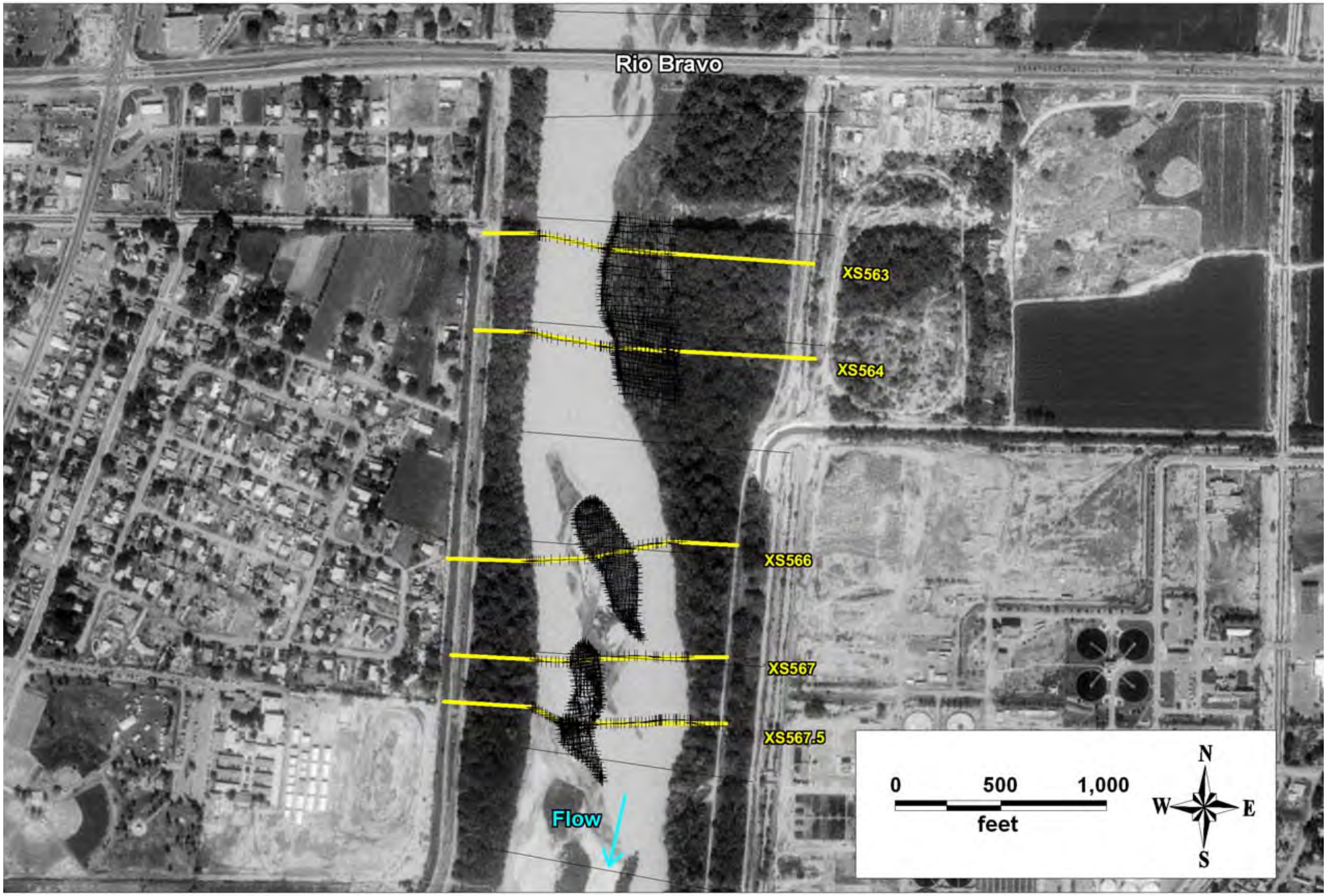


Figure 5. Aerial photograph showing the locations of the surveyed cross sections in the South Diversion Channel subreach.

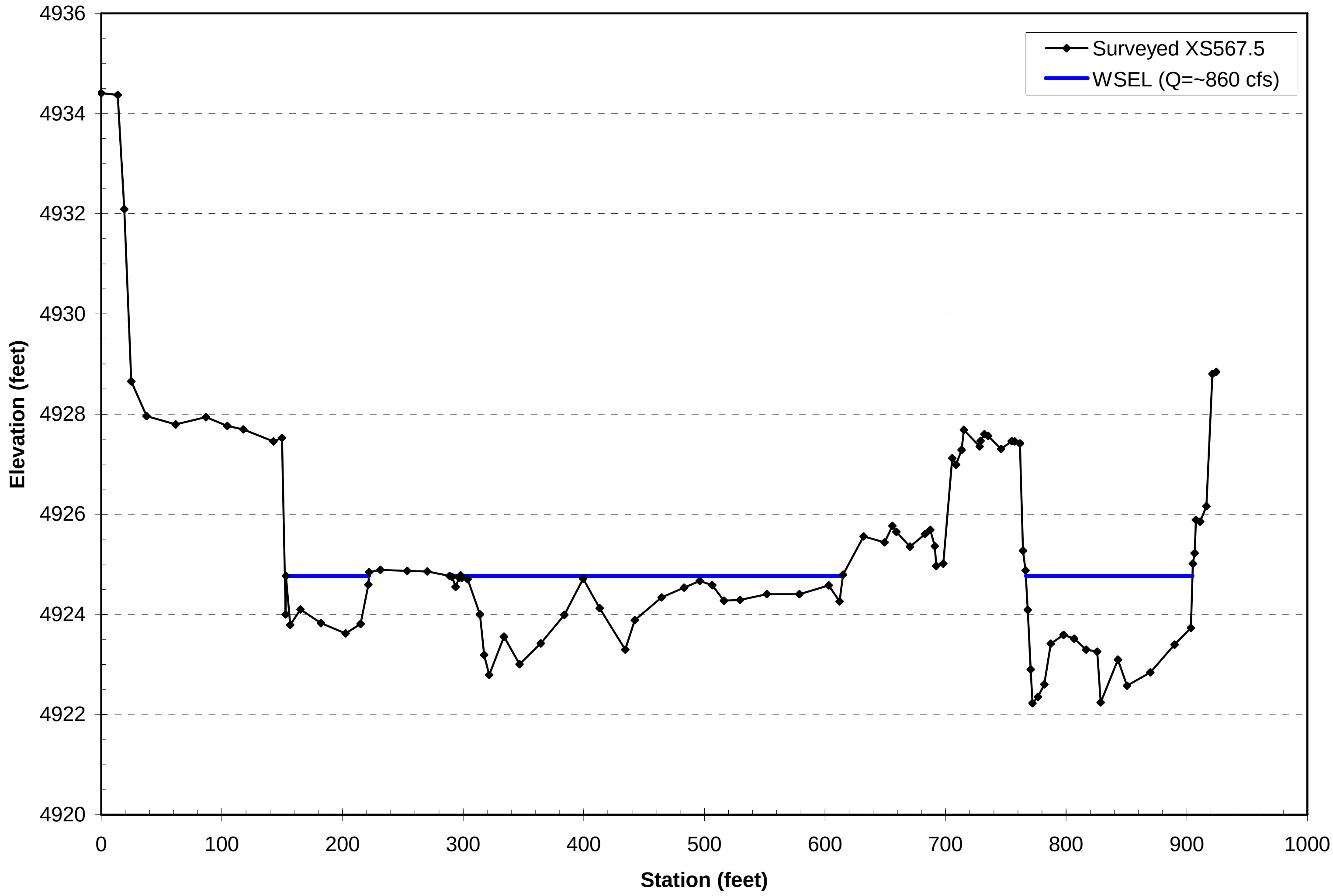


Figure 6. Cross-section profile for XS567.5 that crosses the downstream-most of the restoration mid-channel bars/islands in the South Diversion Channel subreach. The flow in the river was about 860 cfs.

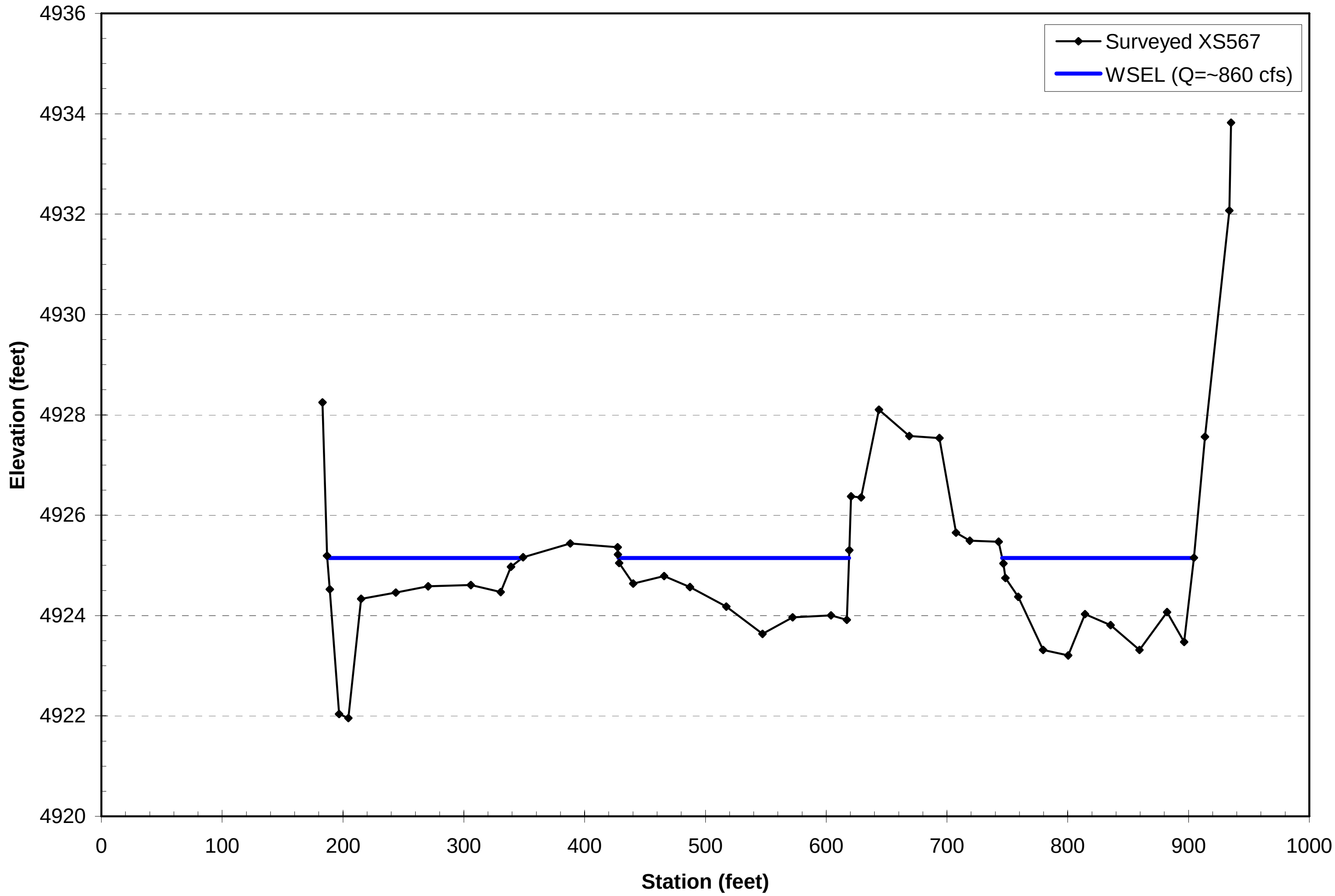


Figure 7. Cross-section profile for XS567 that crosses the upstream-most of the restoration mid-channel bars/islands in the South Diversion Channel subreach. The flow in the river was about 860 cfs.

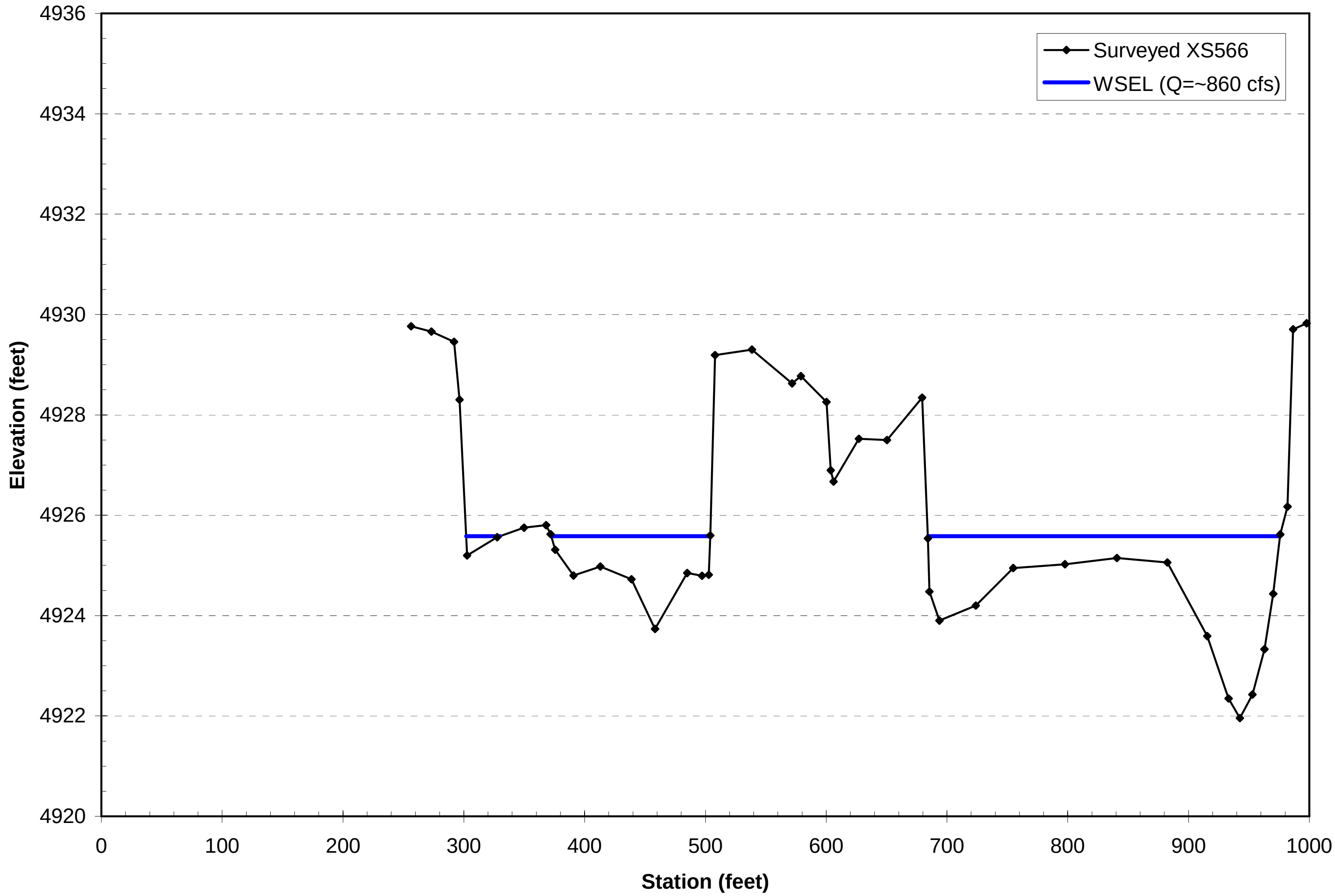


Figure 8. Cross-section profile for XS566 that crosses the control mid-channel bars/islands in the South Diversion Channel subreach. The flow in the river was about 860 cfs.

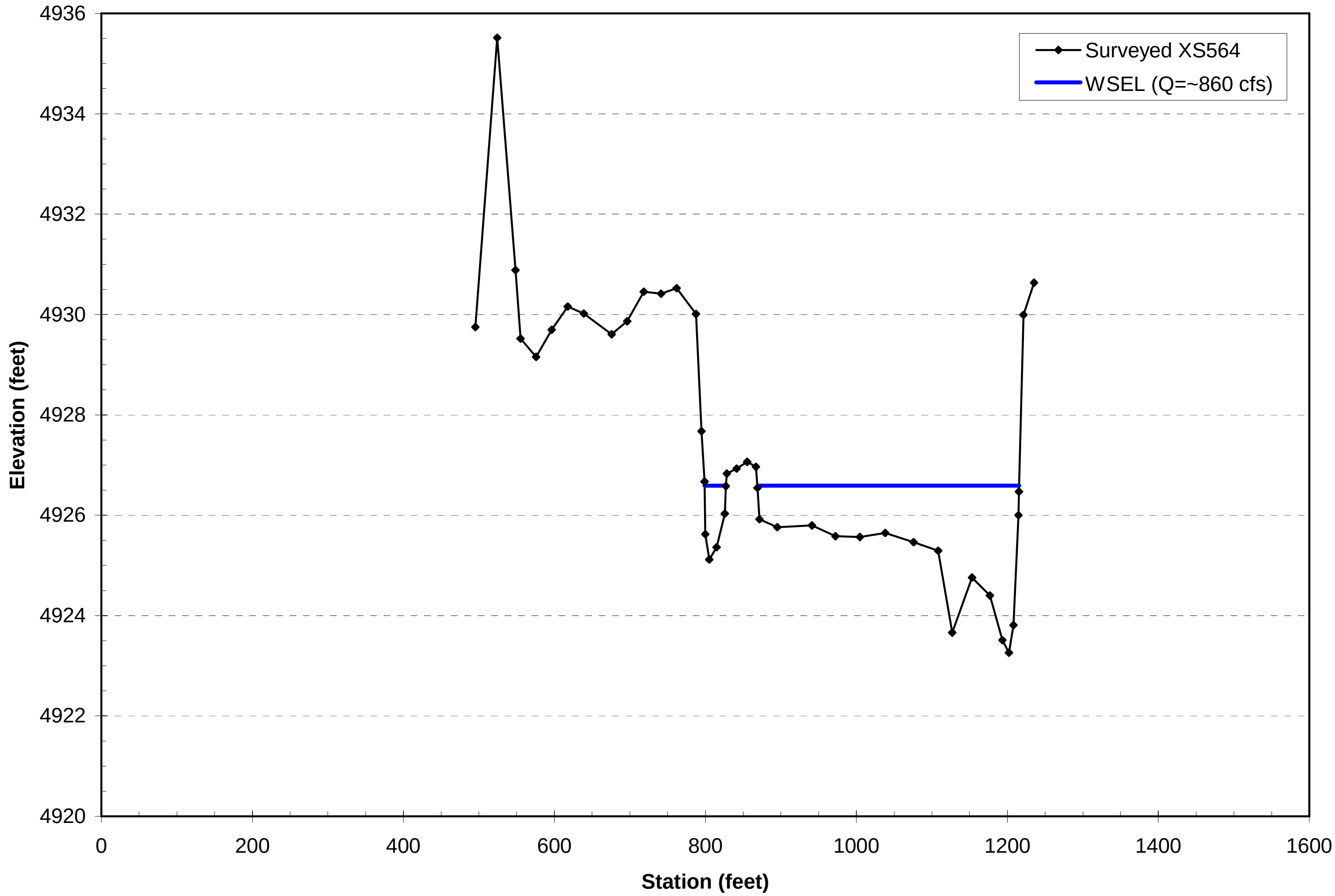


Figure 9. Cross-section profile for XS564 that crosses the lower portion of the bank-attached bar in the South Diversion Channel subreach. The flow in the river was about 860 cfs.

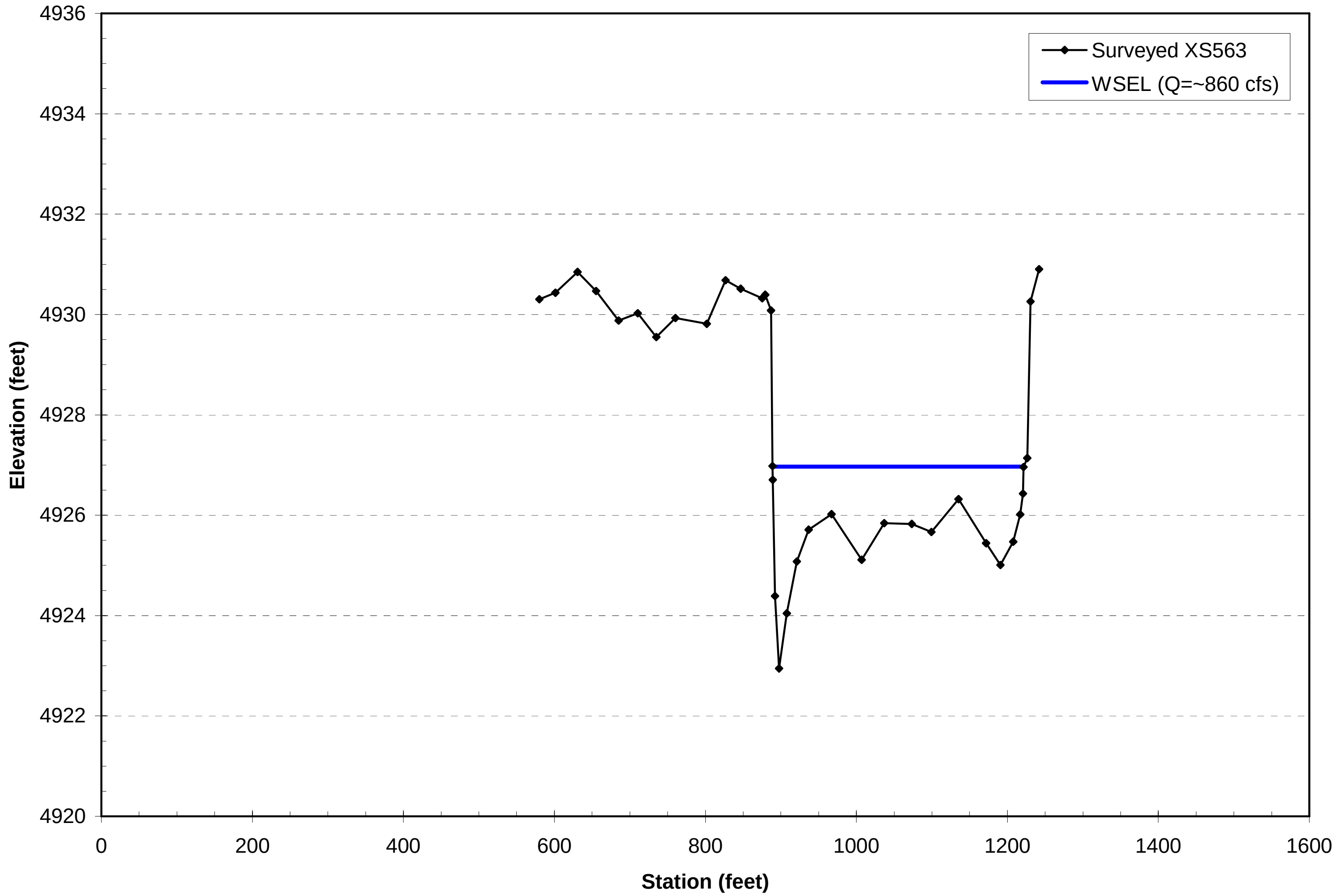


Figure 10. Cross-section profile for XS563 that crosses the upper portion of the bank-attached bar in the South Diversion Channel subreach. The flow in the river was about 860 cfs.

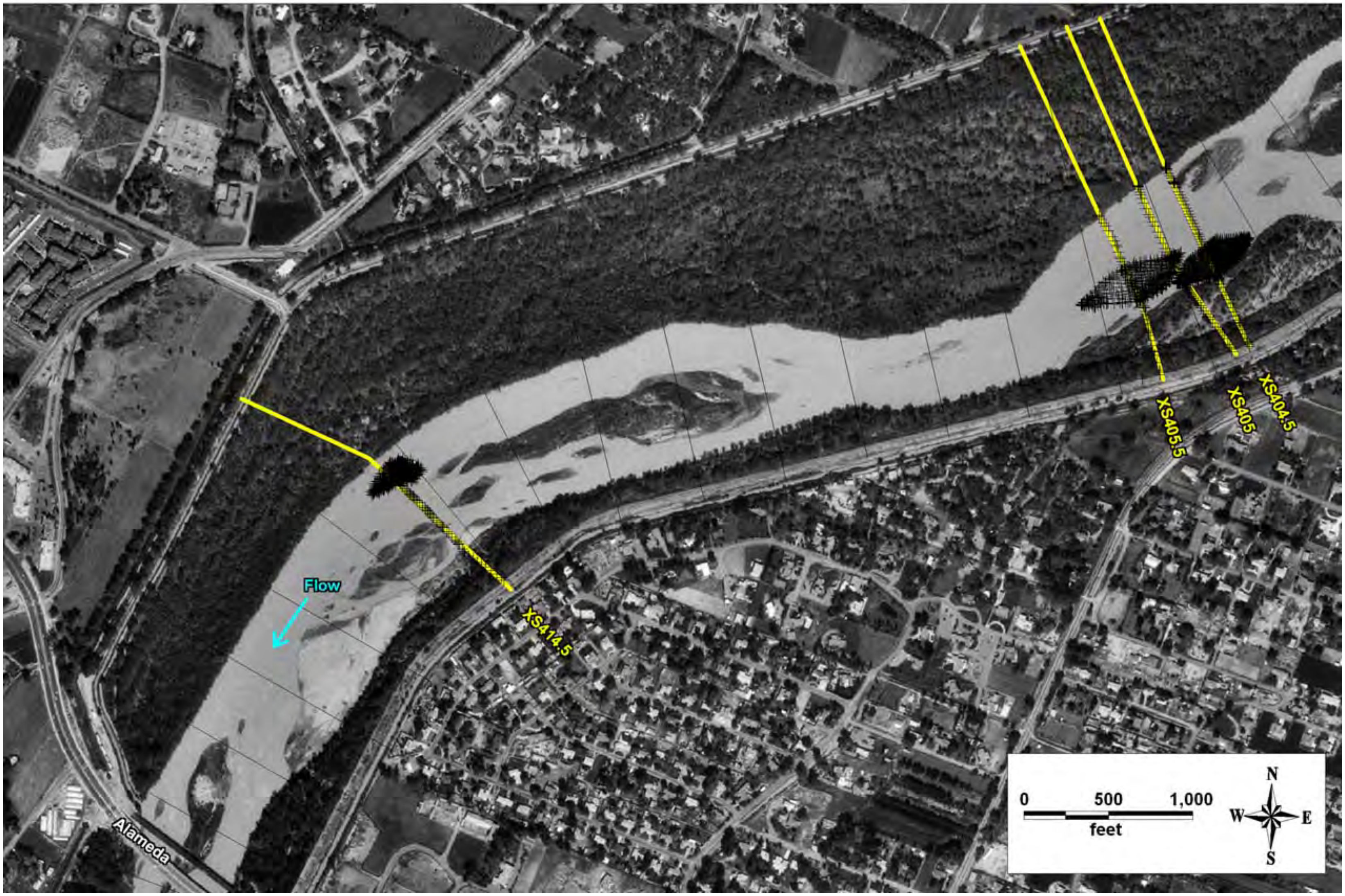


Figure 11. Aerial photograph showing the locations of the surveyed cross sections in the North Diversion Channel subreach.

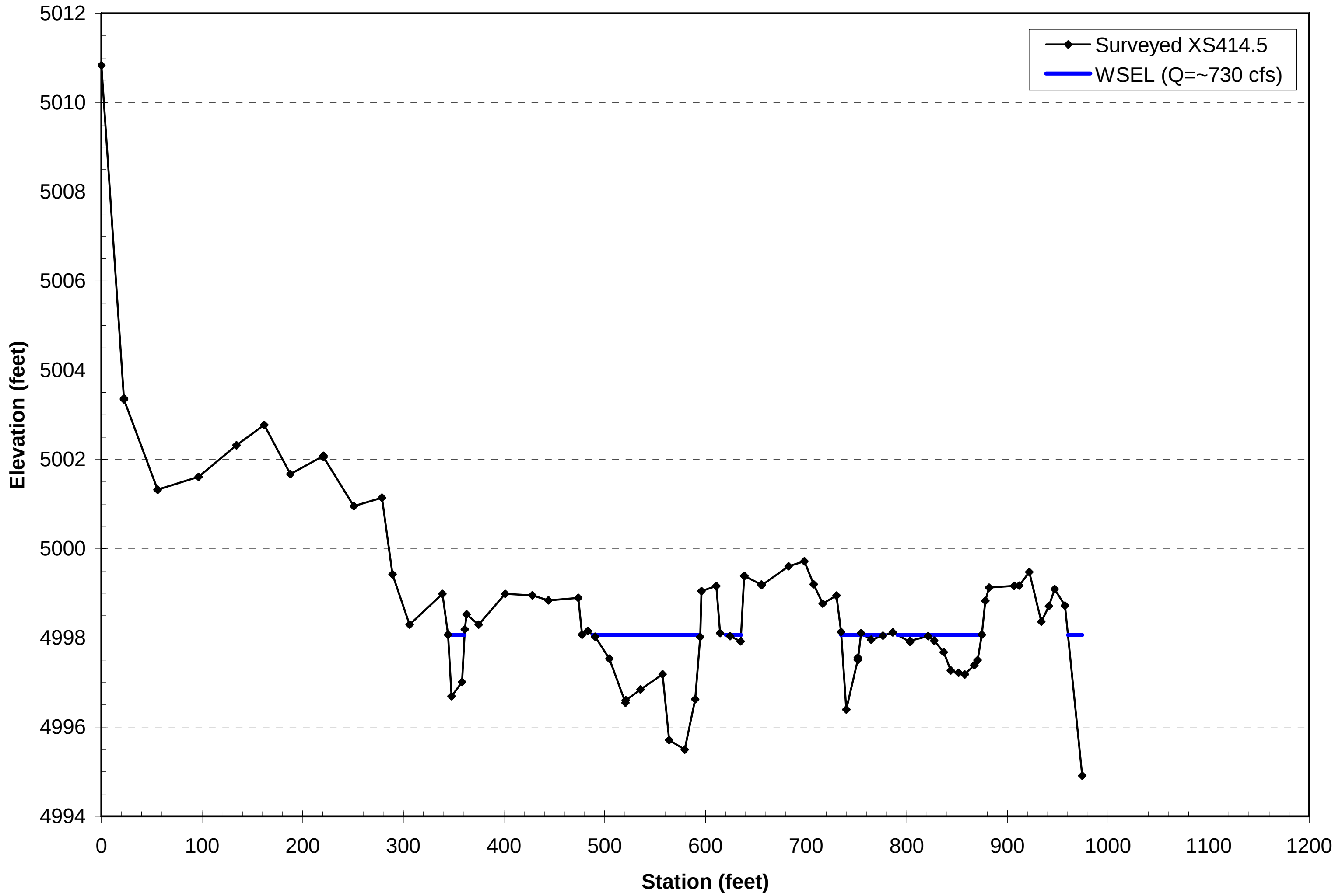


Figure 12. Cross-section profile for XS414.5 that crosses the downstream-most of the restoration mid-channel bars/islands in the North Diversion Channel subreach. The flow in the river was about 730 cfs.

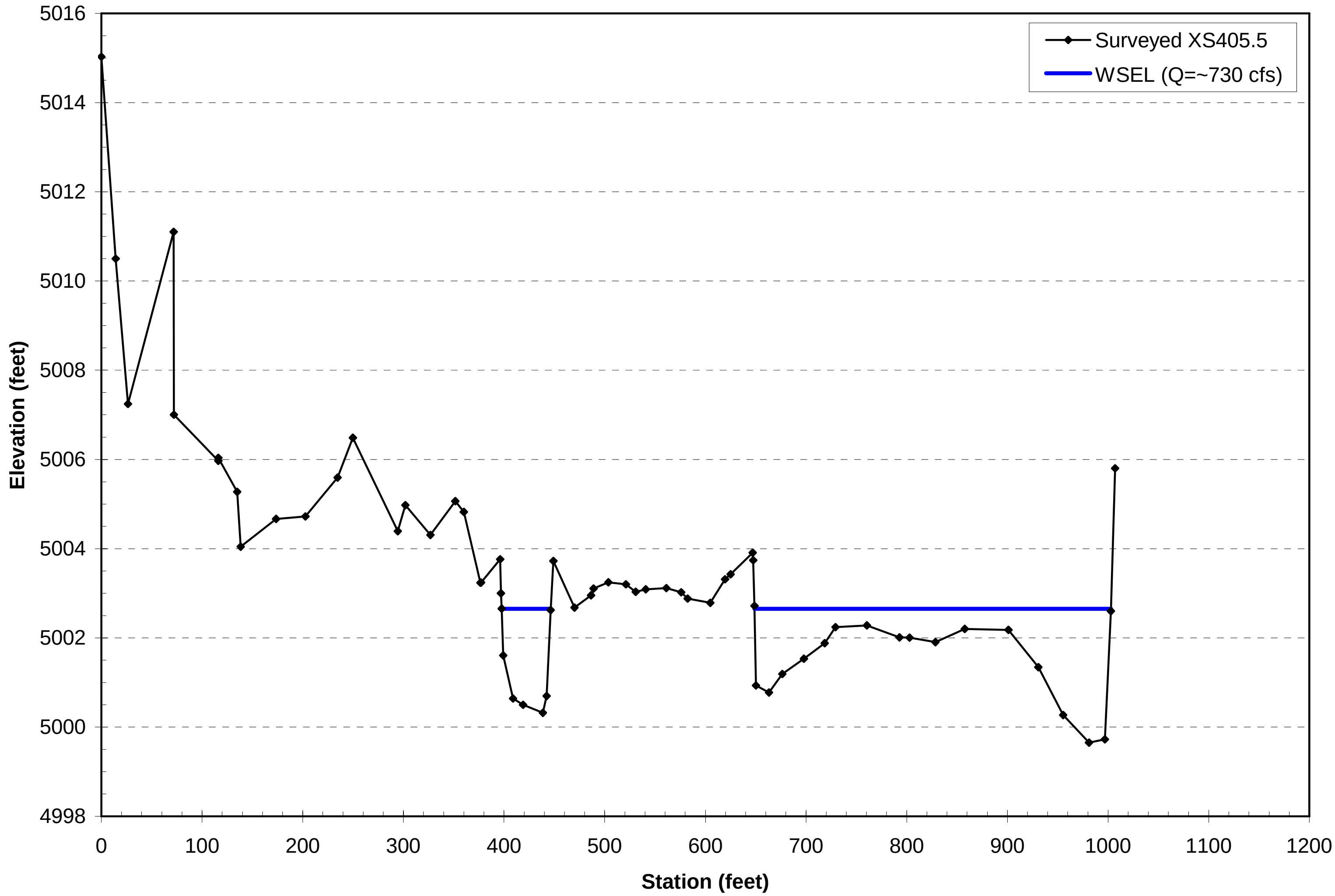


Figure 13. Cross-section profile for XS405.5 that crosses the downstream end of the downstream-most of the restoration mid-channel bars/islands in the North Diversion Channel subreach. The flow in the river was about 730 cfs.

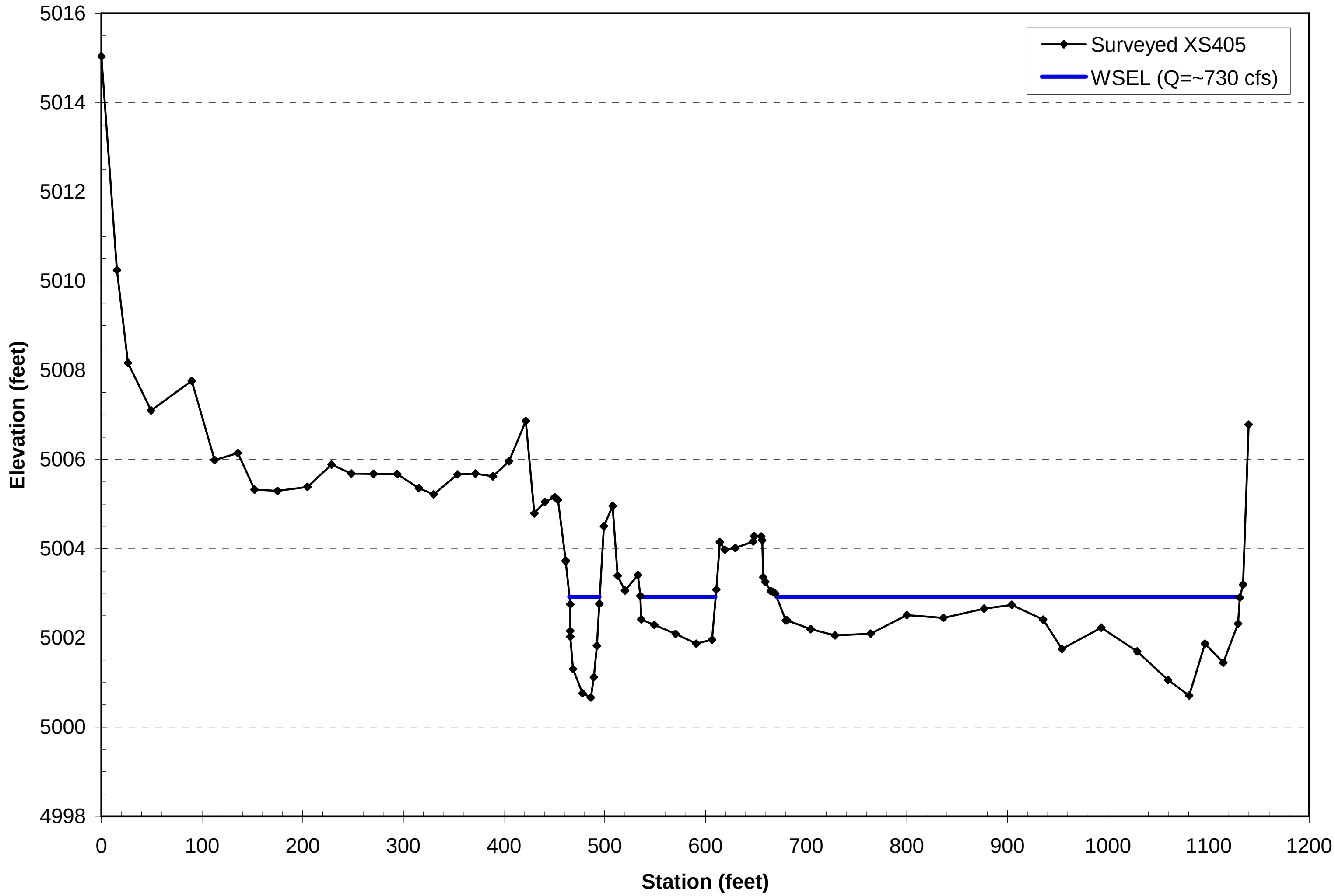


Figure 14. Cross-section profile for XS405 that crosses the upstream end of the upstream-most of the restoration mid-channel bars/islands and the downstream end of the control mid-channel bar/island in the North Diversion Channel subreach. The flow in the river was about 730 cfs.

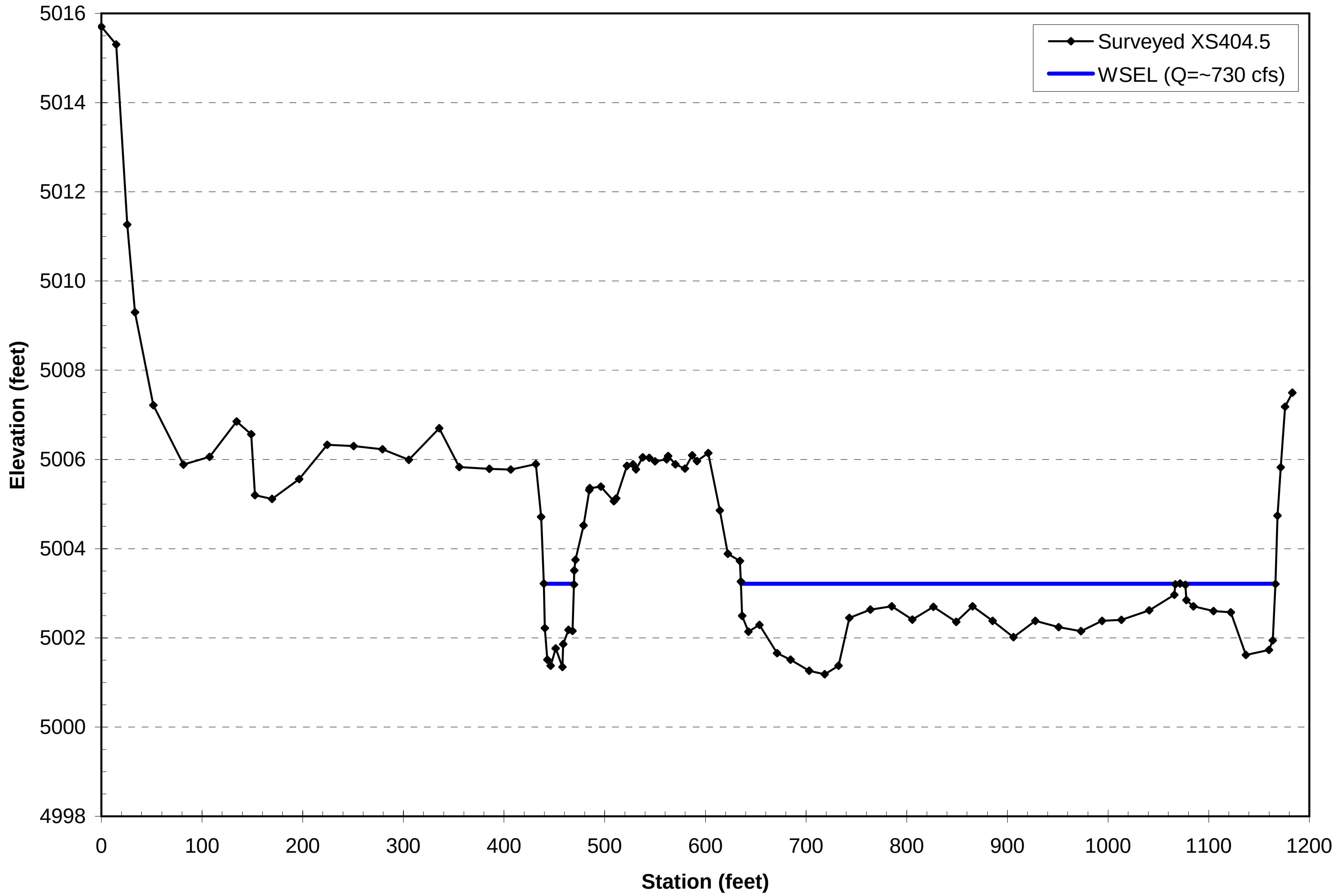


Figure 15. Cross-section profile for XS404.5 that crosses the control mid-channel bar/island in the North Diversion Channel subreach. The flow in the river was about 730 cfs.

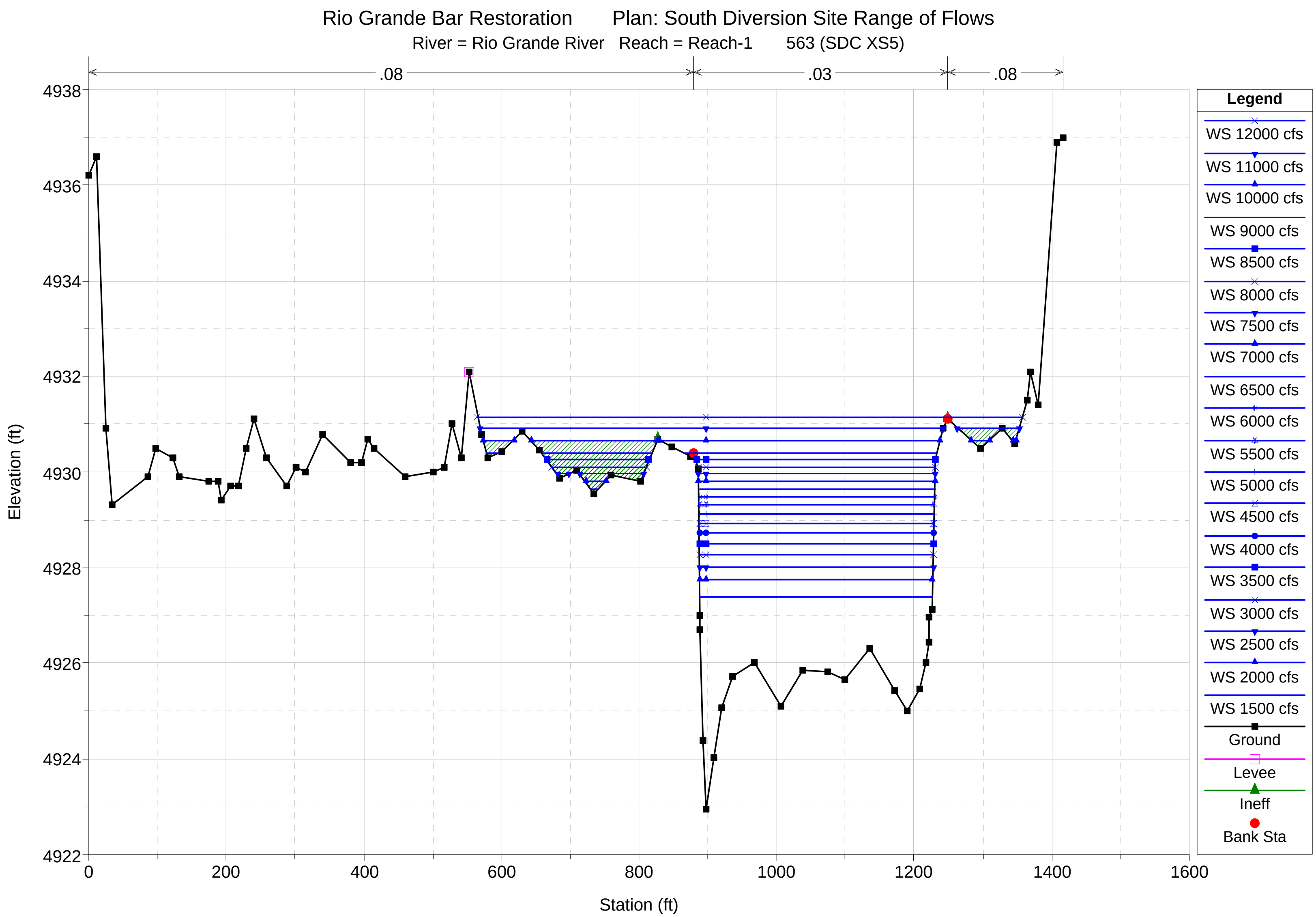


Figure 16. Cross Section 563 showing water-surface elevations for flows between 1,500 and 12,000 cfs at the upstream end of the bank-attached bar.

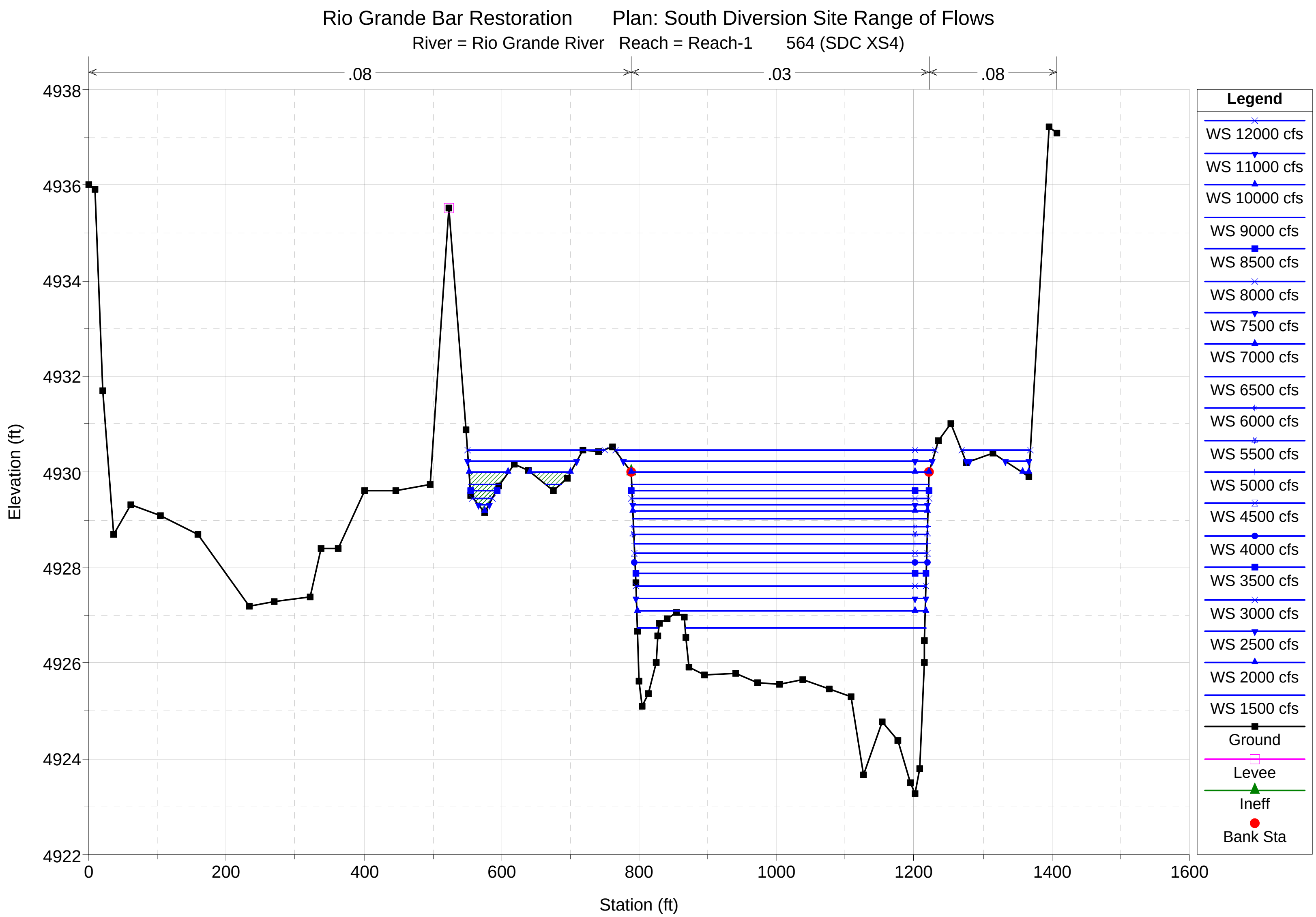


Figure 17. Cross Section 564 showing water-surface elevations for flows between 1,500 and 12,000 cfs at the downstream end of the bank-attached bar.

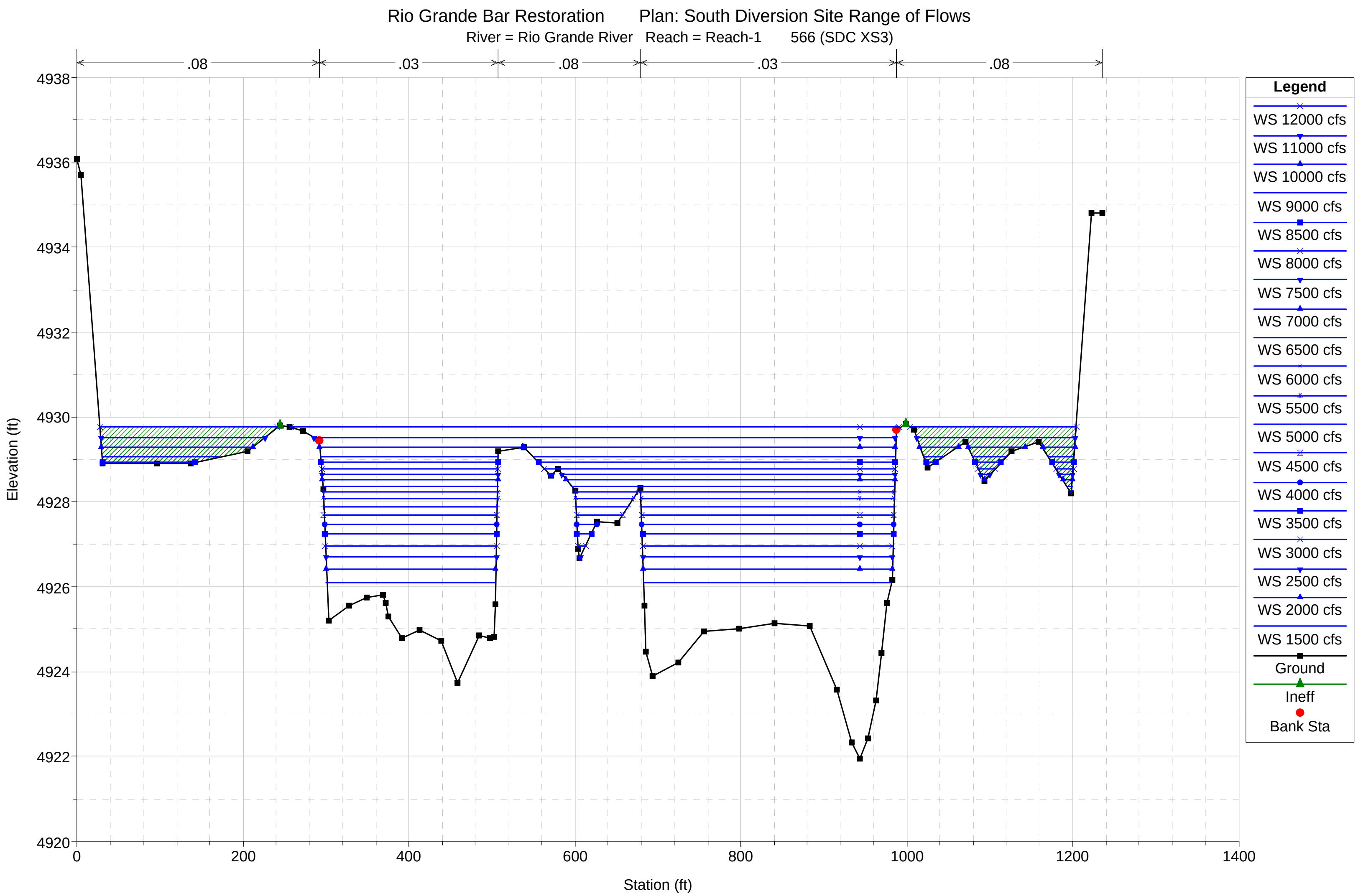


Figure 18. Cross Section 566 showing water-surface elevations for flows between 1,500 and 12,000 cfs at the control mid-channel bar/island.

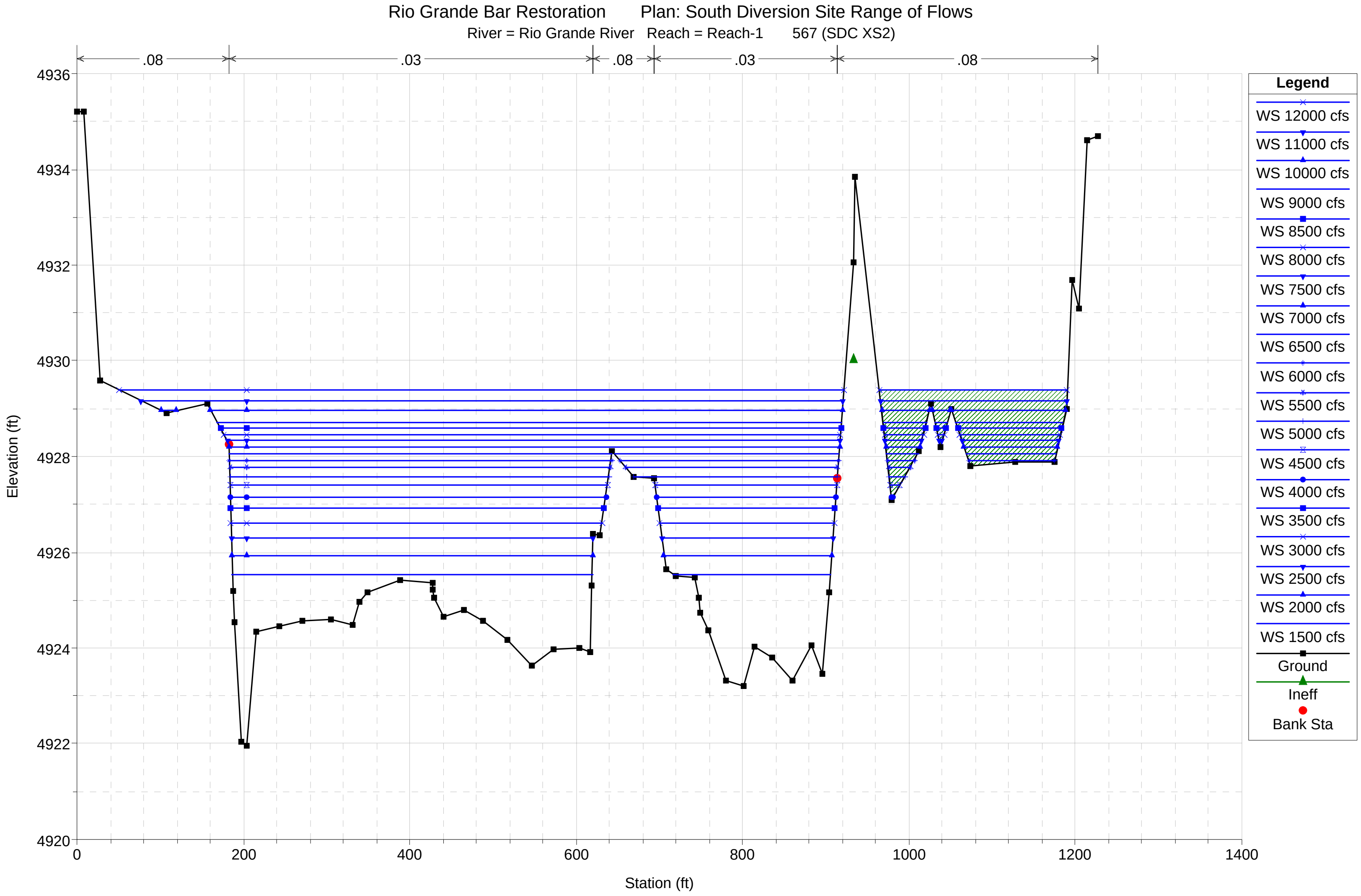


Figure 19. Cross Section 567 showing water-surface elevations for flows between 1,500 and 12,000 cfs at the upstream-most of the restoration mid-channel bars/islands.

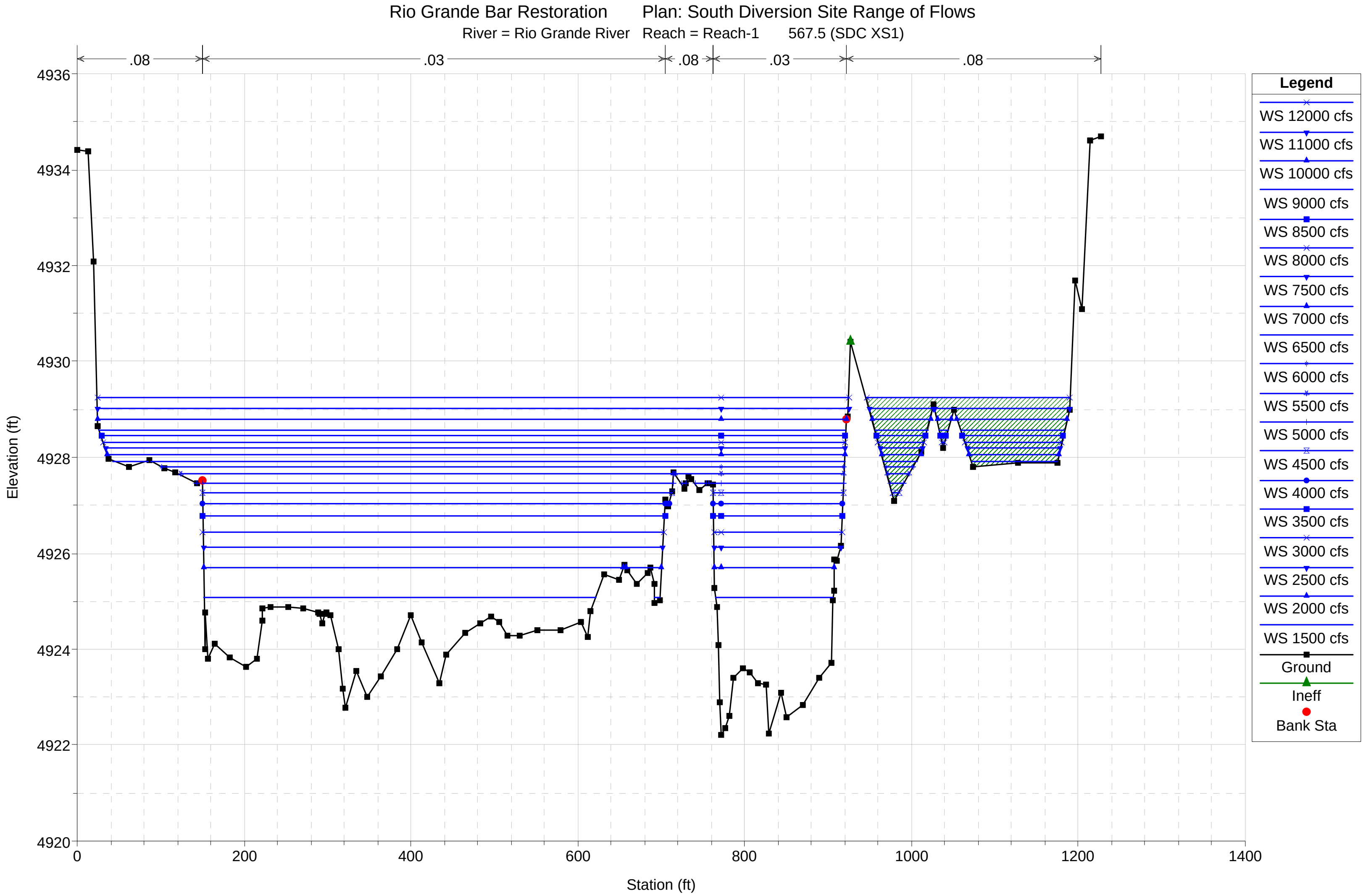


Figure 20. Cross Section 567.5 showing water-surface elevations for flows between 1,500 and 12,000 cfs at the downstream-most of the restoration mid-channel bars/islands.

Figure 21. View downstream of the head of the downstream-most mid-channel bar/island in the South Diversion Channel subreach. The low vegetation is on the LI surface, and the Russian olive trees are on the LII surface.

Figure 22. View upstream of the downstream end of the upstream-most of the mid-channel bars/islands in the South Diversion Channel subreach. The lower vegetation is on the LI surface, and the Russian olives are on the LII surface.

Figure 23. View downstream of the LII mid-channel bar that is the control for the South Diversion Channel subreach.

Figure 24. View upstream of the left bank of the bank-attached bar with the Rio Bravo Bridge in the background. The top of the bank represents an LII bank-attached bar.

Figure 25. View upstream of the LII mid-channel bar that is the control for the North Diversion Channel subreach. An LI surface is located along the right side of the higher-elevation LII bar.

Figure 26. View downstream of the upstream-most of the mid-channel bars/islands in the North Diversion Channel subreach. The right side of the picture shows the LI surface, and the left side shows the LII surface.

Figure 27. View upstream of the downstream-most mid-channel bar/island in the North Diversion Channel subreach. The entire bar is classified as an LI mid-channel bar.

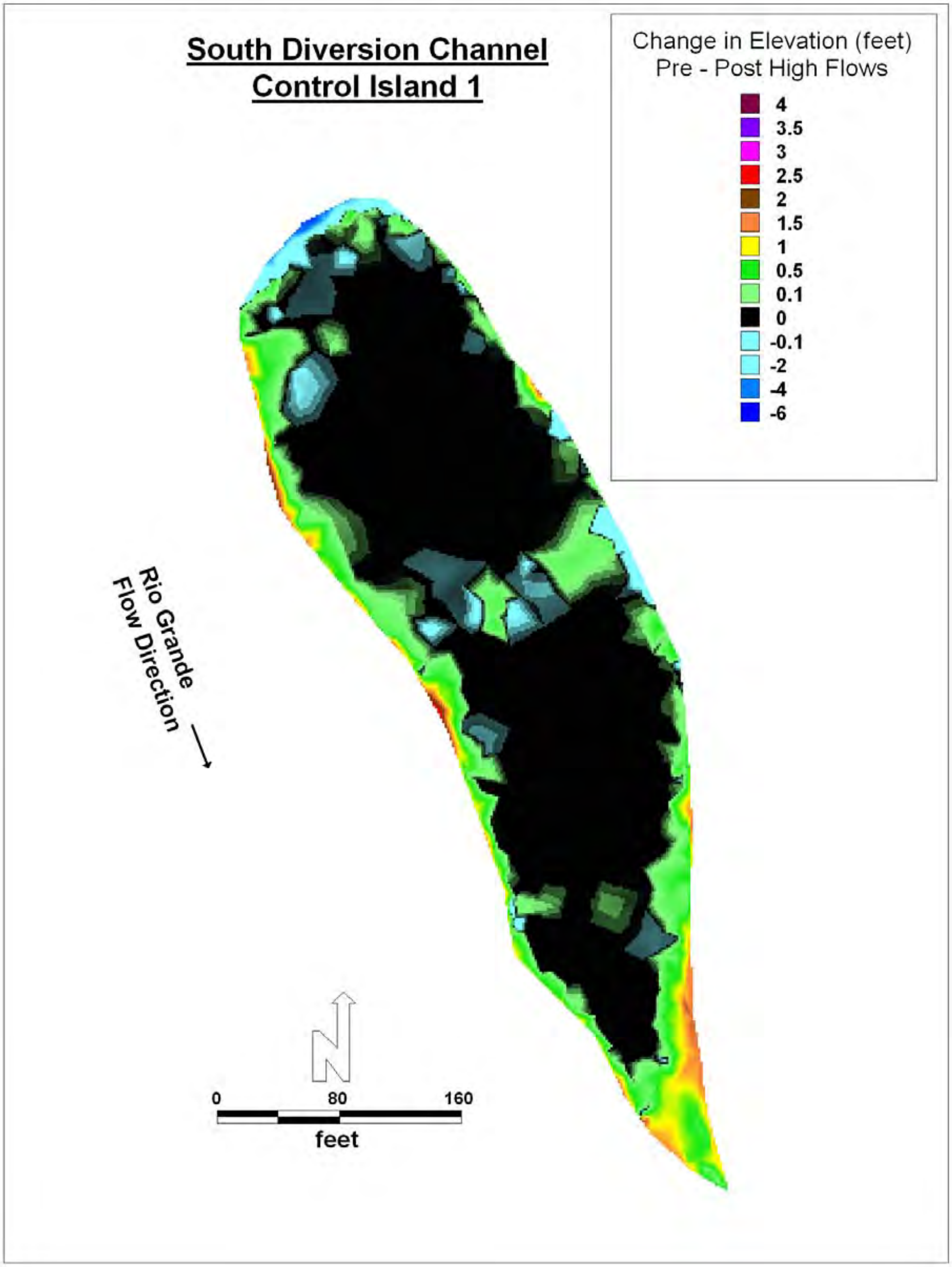


Figure 28. Color-gradient map of elevation changes between the March and September 2005 surveys at Control island/bar, SDC subreach.

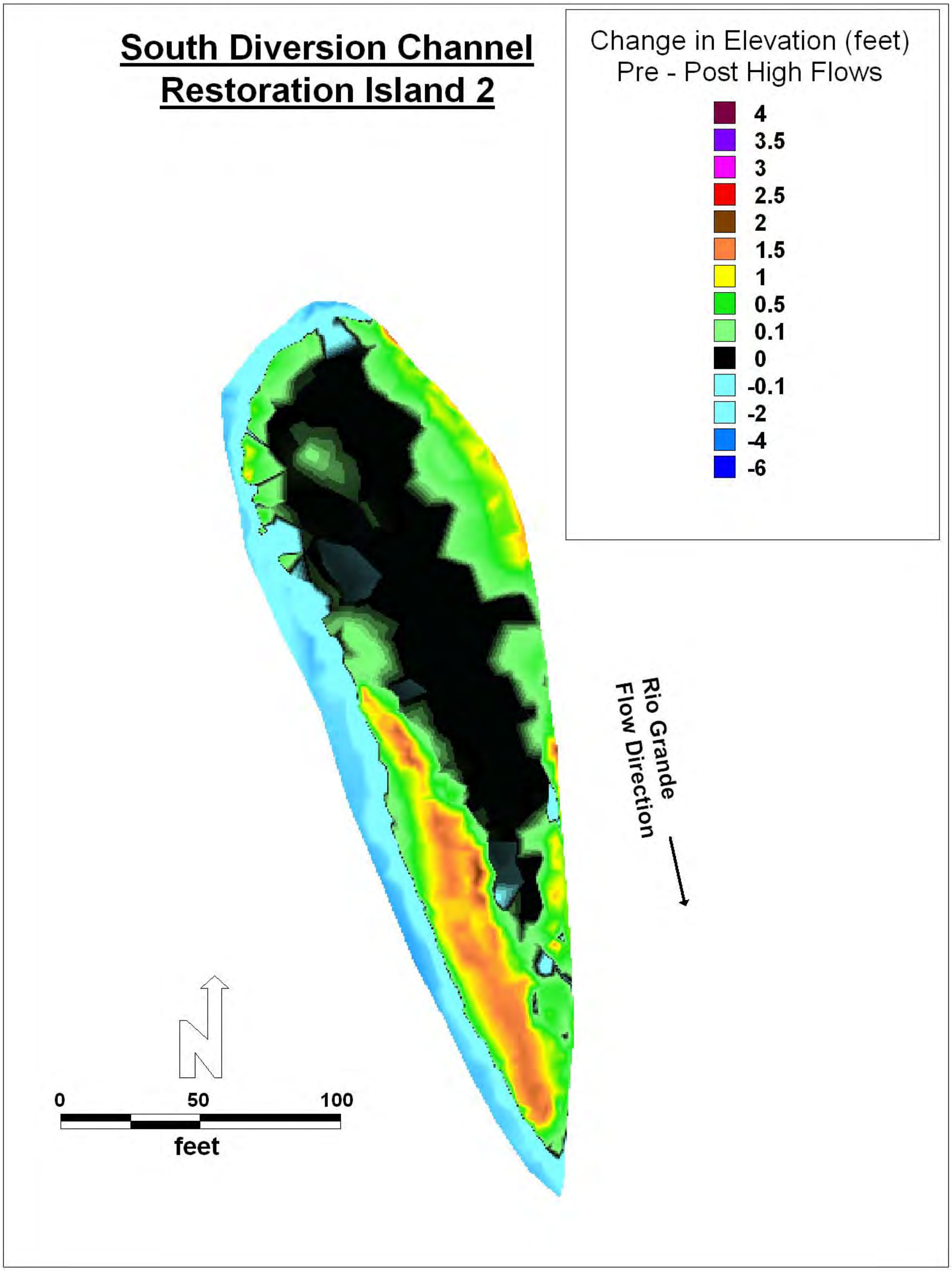


Figure 29. Color-gradient map of elevation changes between the March and September 2005 surveys at Restoration island/bar No. 2, SDC subreach.

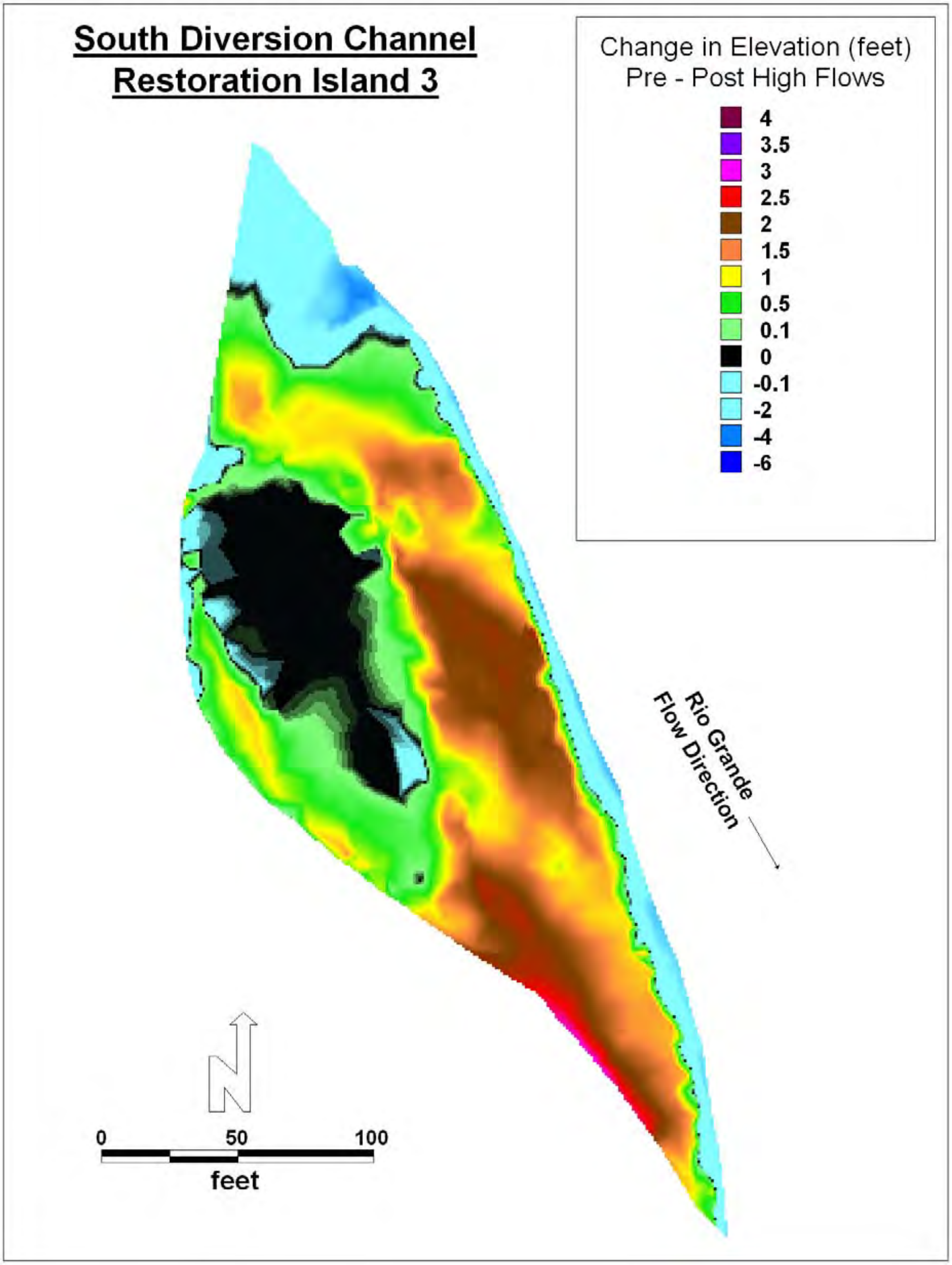


Figure 30. Color-gradient map of elevation changes between the March and September 2005 surveys at Restoration island/bar No. 3, SDC subreach.

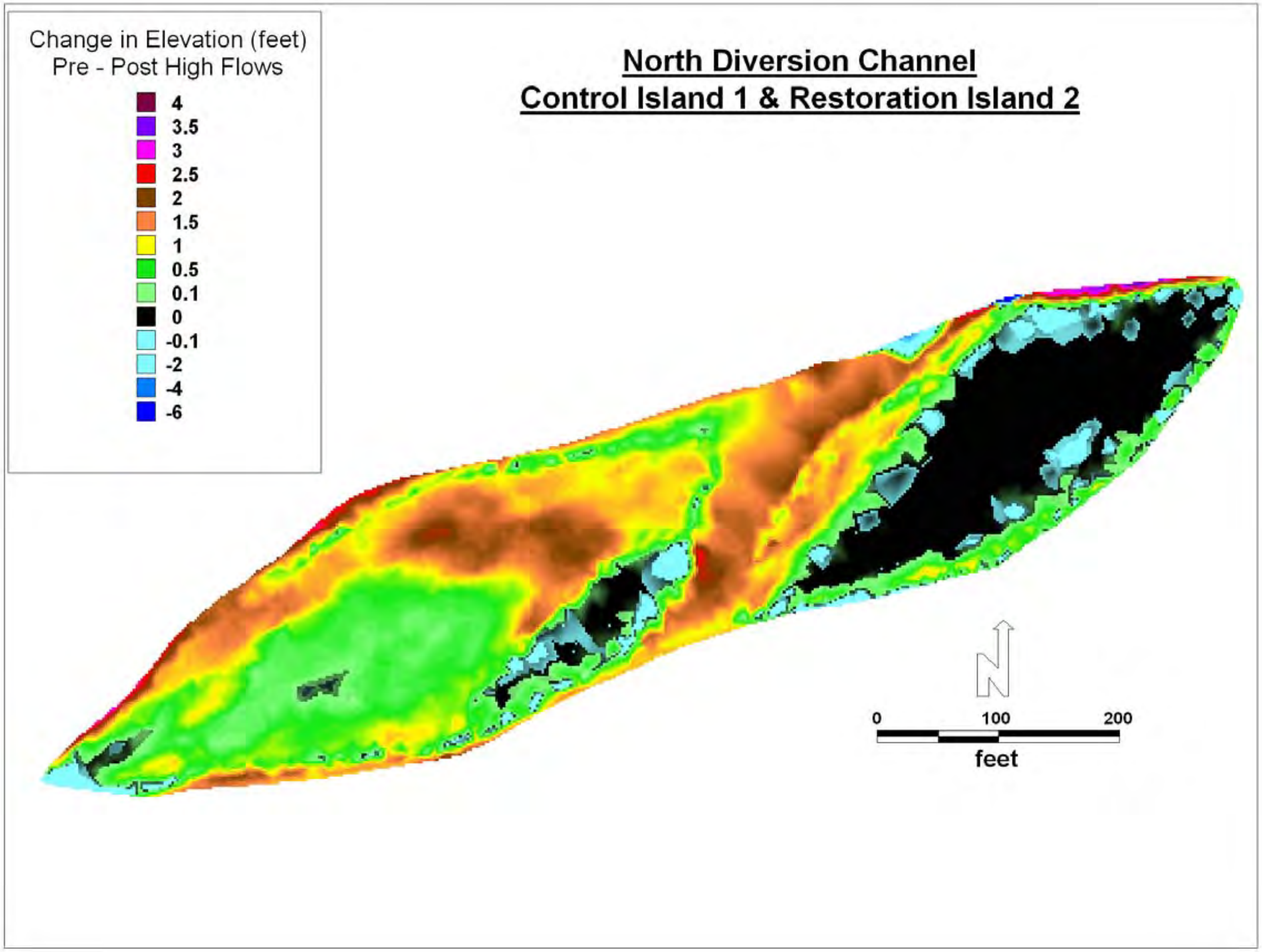


Figure 31. Color-gradient map of elevation changes between the March and September 2005 surveys at Control island/bar and Restoration island/bar No. 2, NDC subreach.

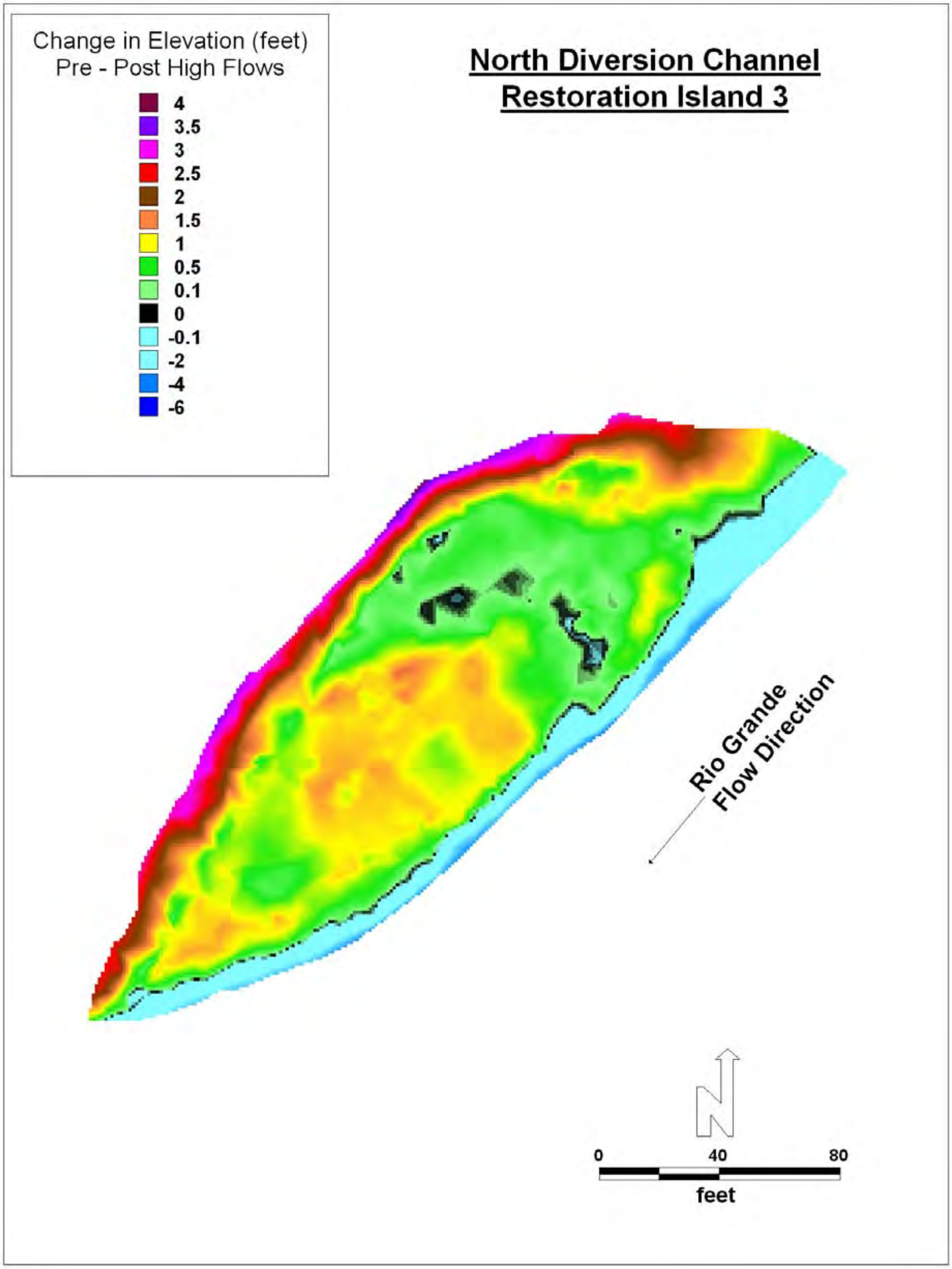
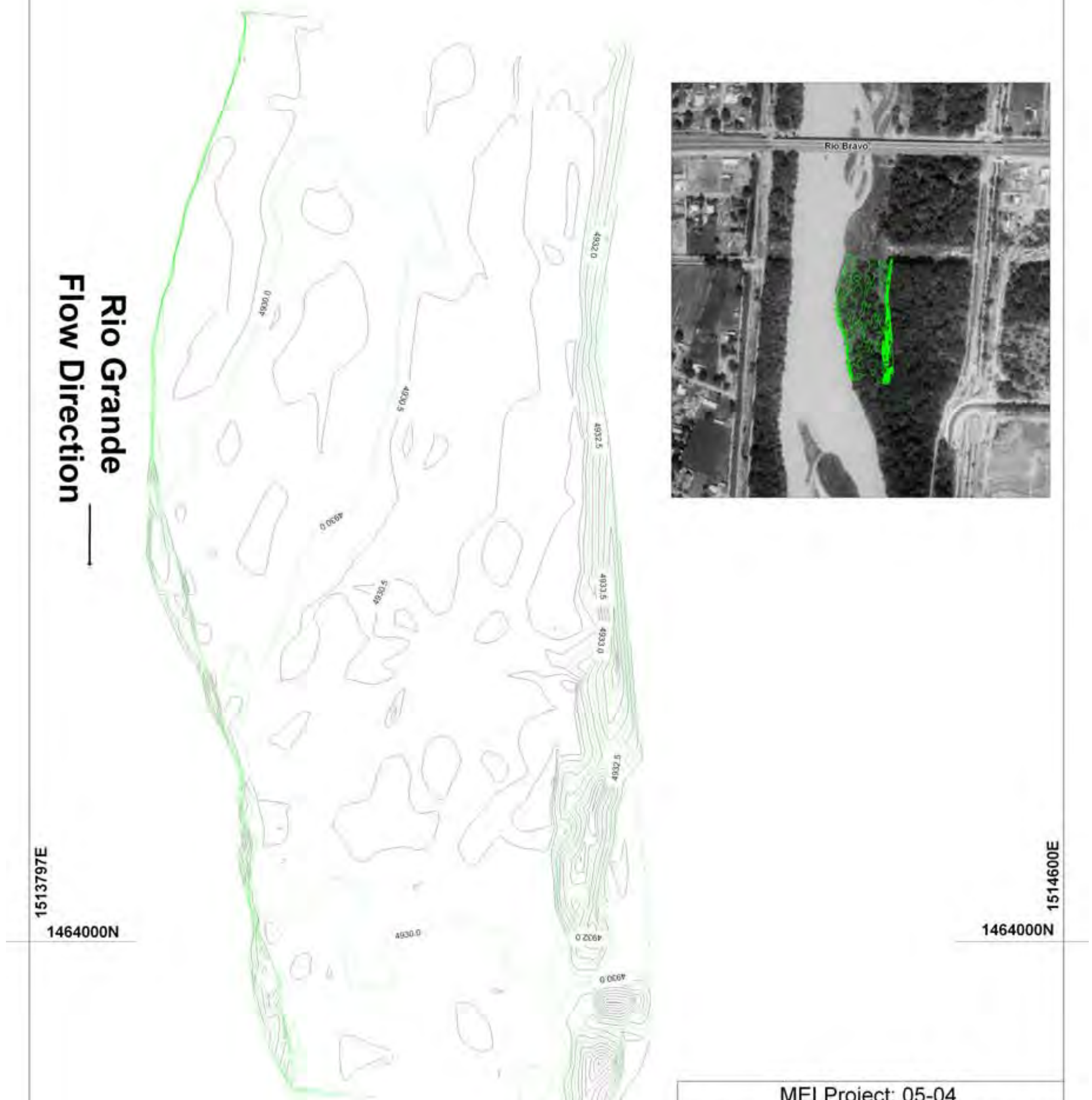


Figure 32. Color-gradient map of elevation changes between the March and September 2005 surveys at Restoration island/bar No. 3, NDC subreach.

APPENDIX A

SOUTH DIVERSION CHANNEL SUBREACH CONTOUR MAPS

South Diversion Channel
Attached Bar 1



0 80 160
feet

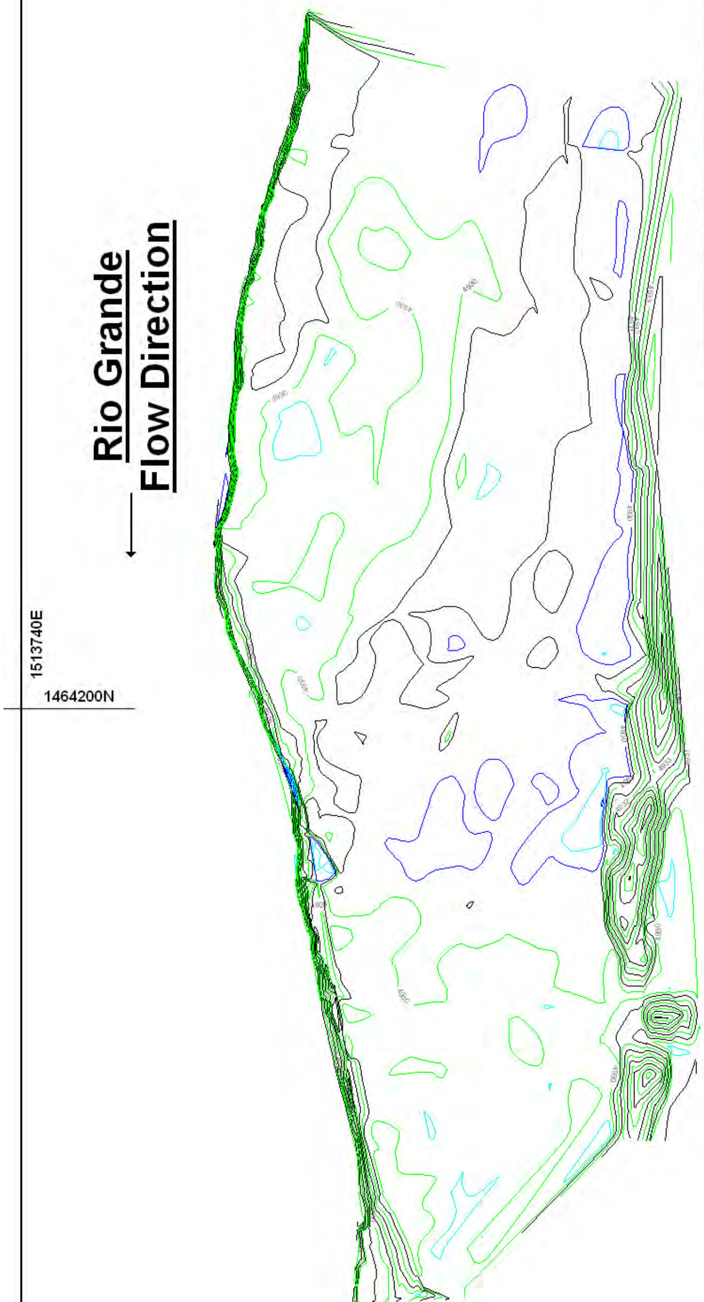
Contour Interval 0.5 ft.

MEI Project: 05-04
WTB Bar Habitat Resoration Project
March 2005

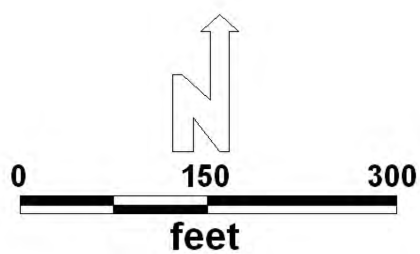
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525

Vertical Datum: NAVD88
Horzontal Datum: NAD 83
Drawn by: MCI; Checked by: MDH
Sheet 1 of 1

South Diversion Channel
Attached Bar 1



1514740E
1464200N

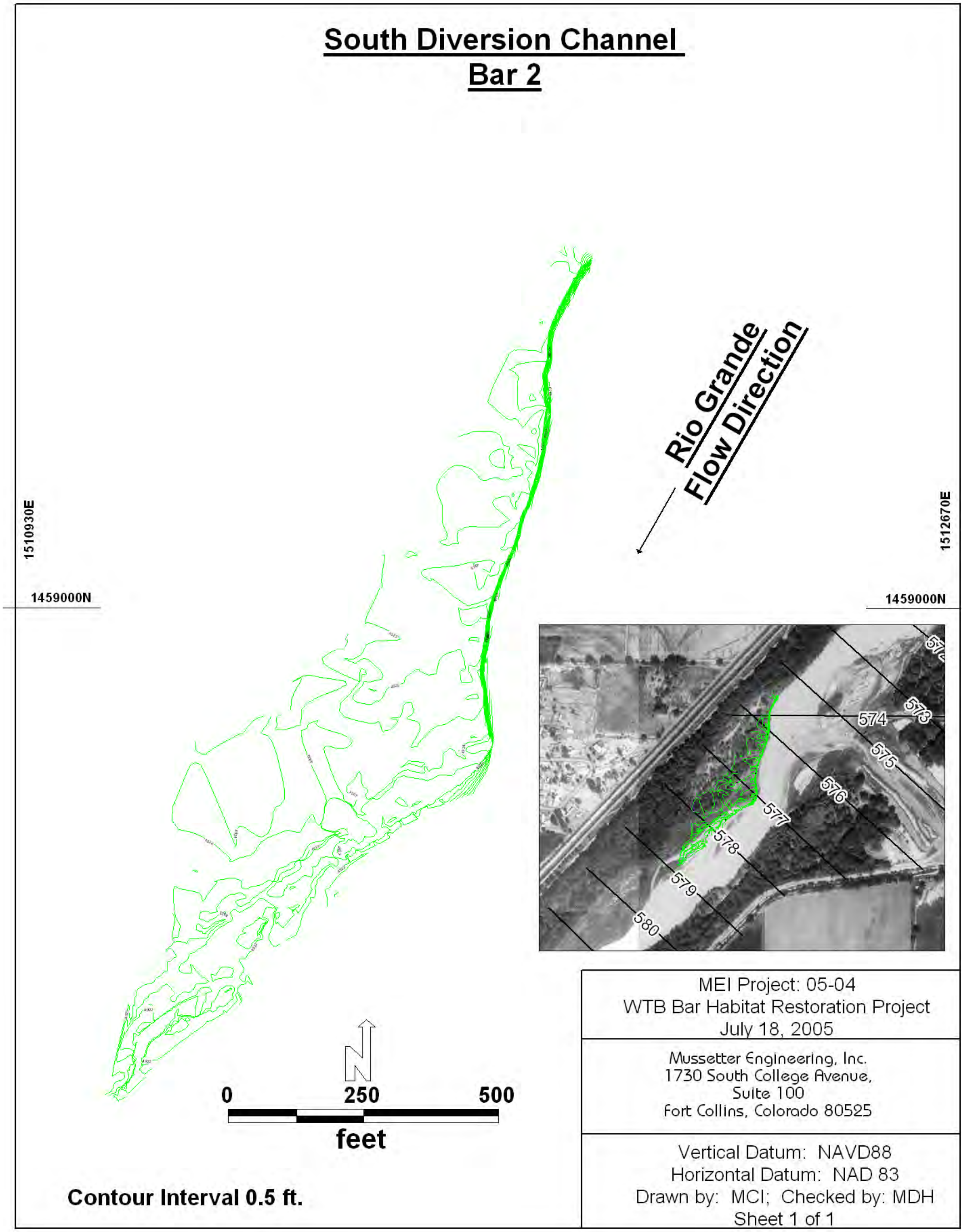


Contour Interval 0.5 ft.

MEI Project: 05-04
WTB Bar Habitat Restoration Project
September 12, 2005

Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525

Vertical Datum: NAVD88
Horizontal Datum: NAD 83
Drawn by: MCI; Checked by: MDH
Sheet 1 of 1


South Diversion Channel
Bar 2
Rio Grande
Flow Direction
1510930E
1512670E
1459000N
1459000N
574
573
575
576
577
578
579
580
0
250
500
feet
Contour Interval 0.5 ft.
MEI Project: 05-04
WTB Bar Habitat Restoration Project
July 18, 2005
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525
Vertical Datum: NAVD88
Horizontal Datum: NAD 83
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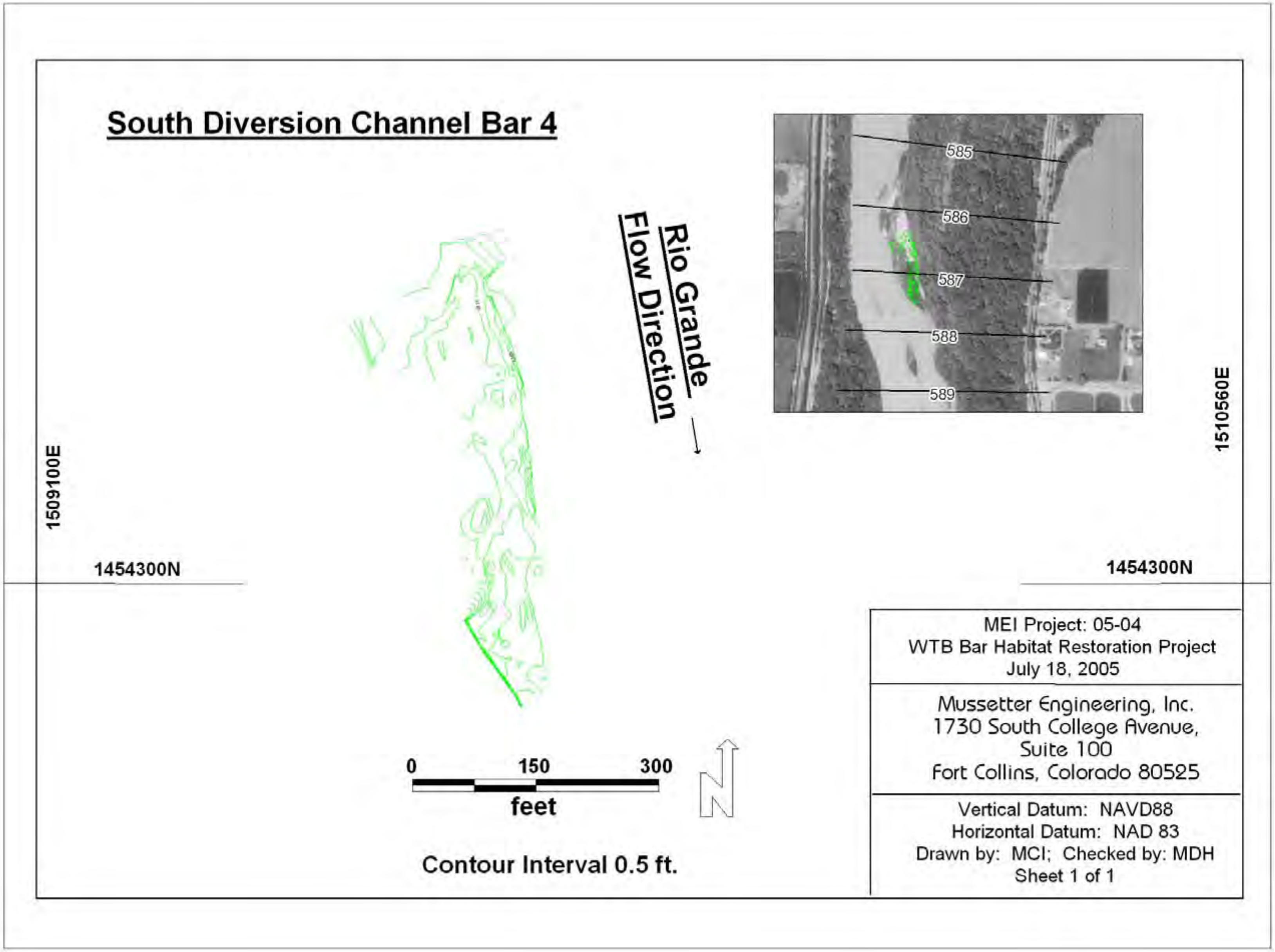
South Diversion Channel
Bar 3
582
583
584
585
1509540E
1456000N
1510650E
1456000N
Rio Grande
Flow Direction
0
150
300
feet
MEI Project: 05-04
WTB Bar Habitat Restoration Project
September 12, 2005
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525
Vertical Datum: NAVD88
Horizontal Datum: NAD 83
Drawn by: MCI; Checked by: MDH
Sheet 1 of 1
Contour Interval 0.5 ft.


South Diversion Channel Bar 4
Rio Grande
Flow Direction
585
586
587
588
589
1509100E
1510560E
1454300N
1454300N
0
150
300
feet
Contour Interval 0.5 ft.
MEI Project: 05-04
WTB Bar Habitat Restoration Project
July 18, 2005
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525
Vertical Datum: NAVD88
Horizontal Datum: NAD 83
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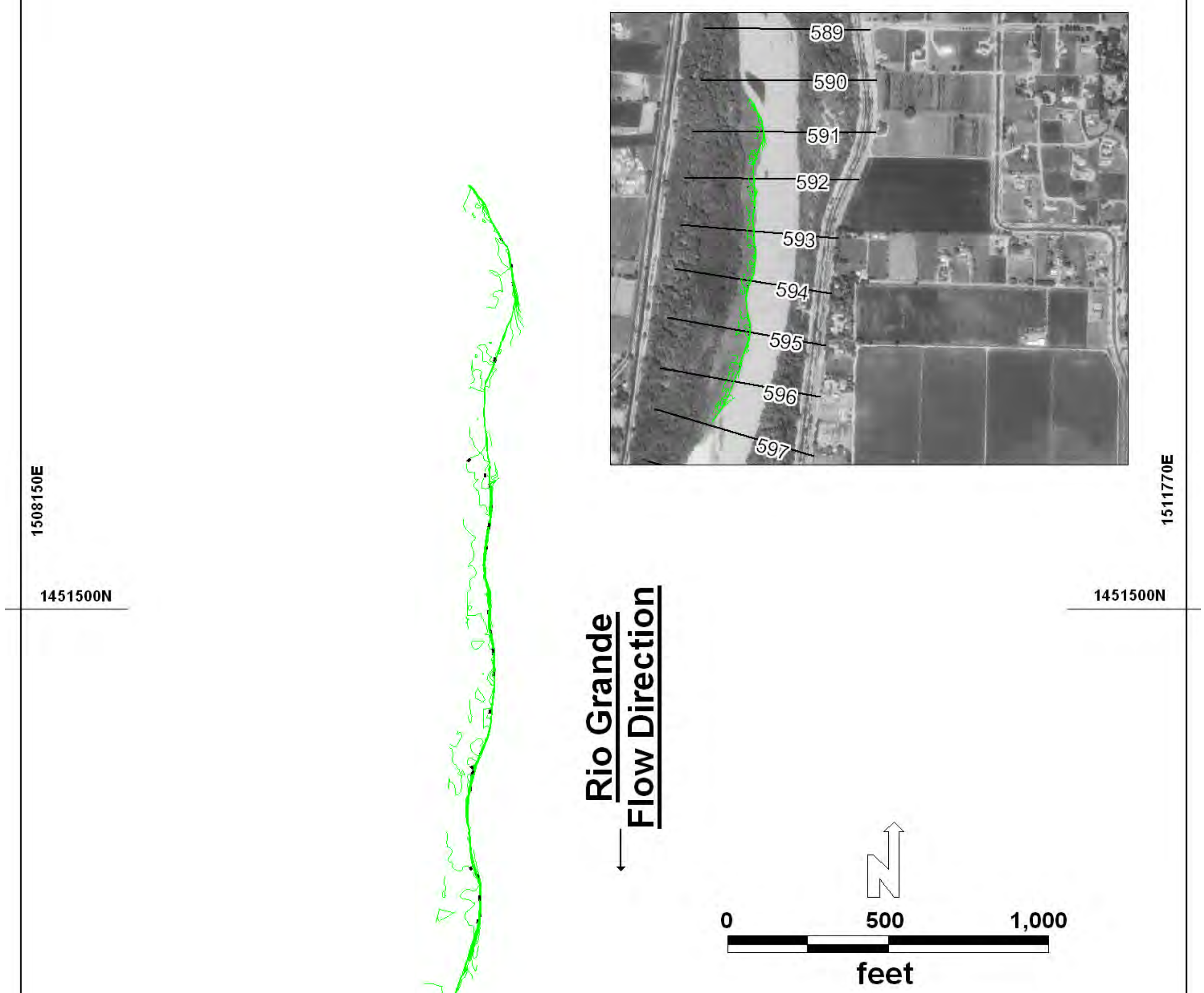
Sheet 1 of 1

South Diversion Channel
Bar 5

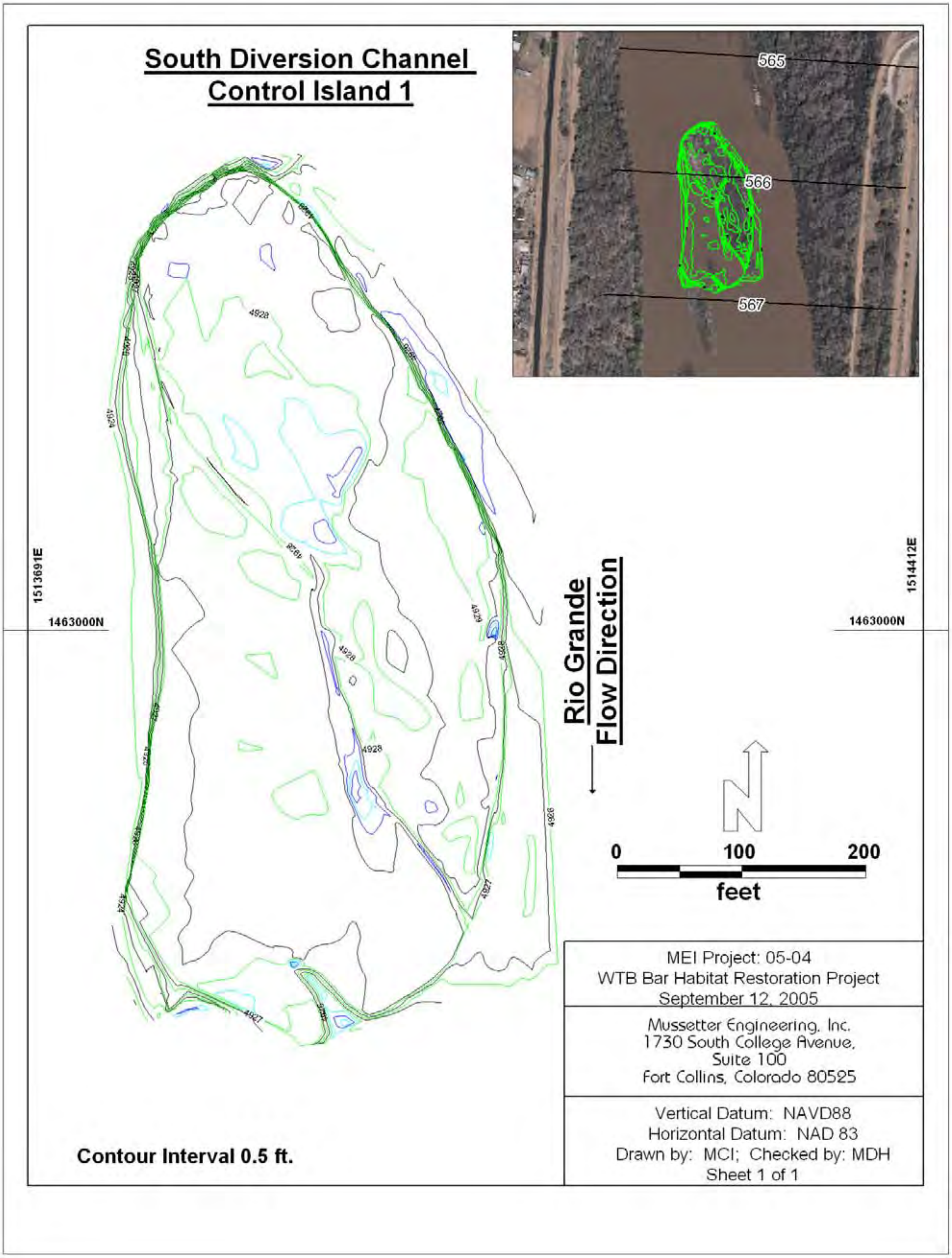


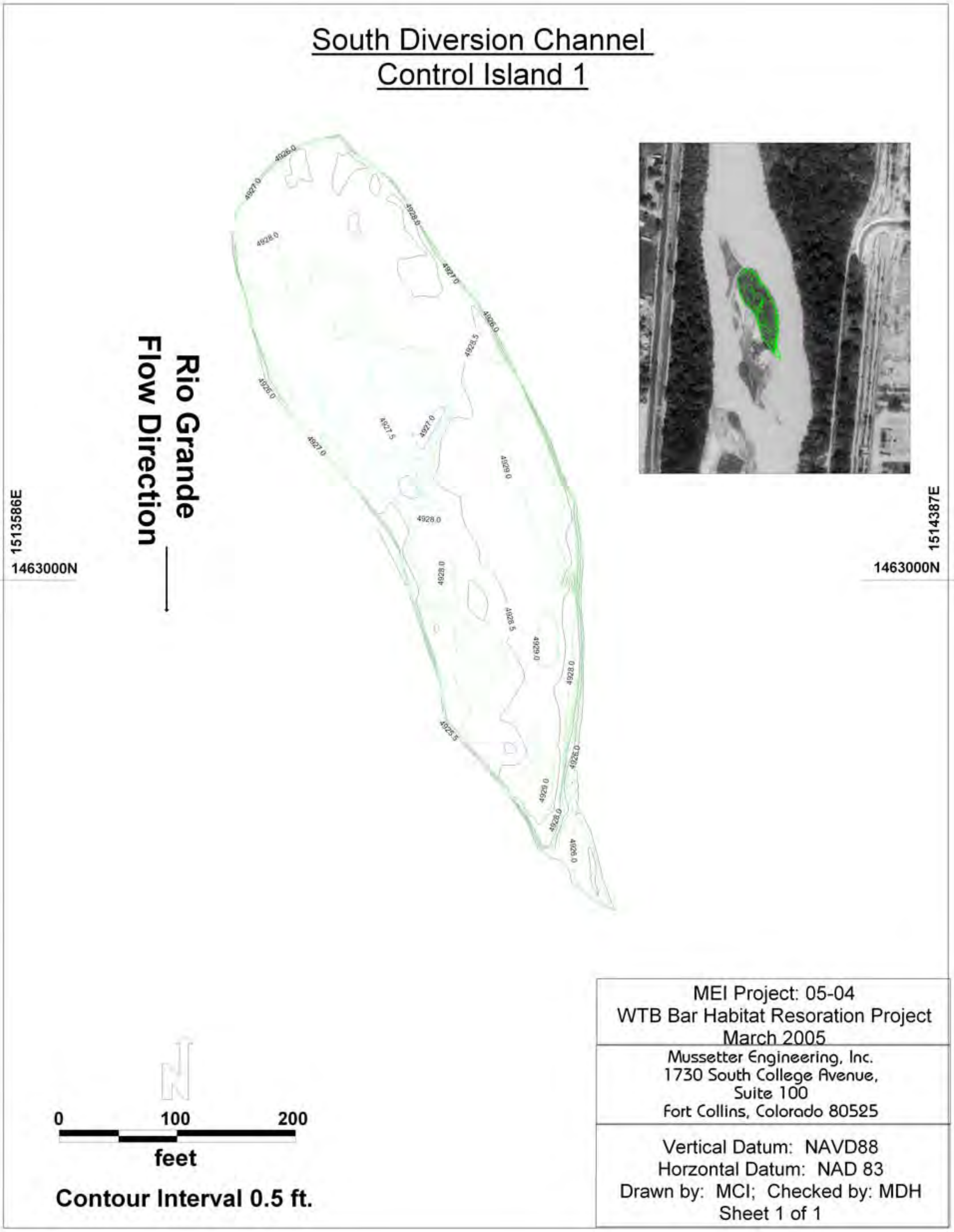
MEI Project: 05-04
WTB Bar Habitat Restoration Project
July 18, 2005

Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525

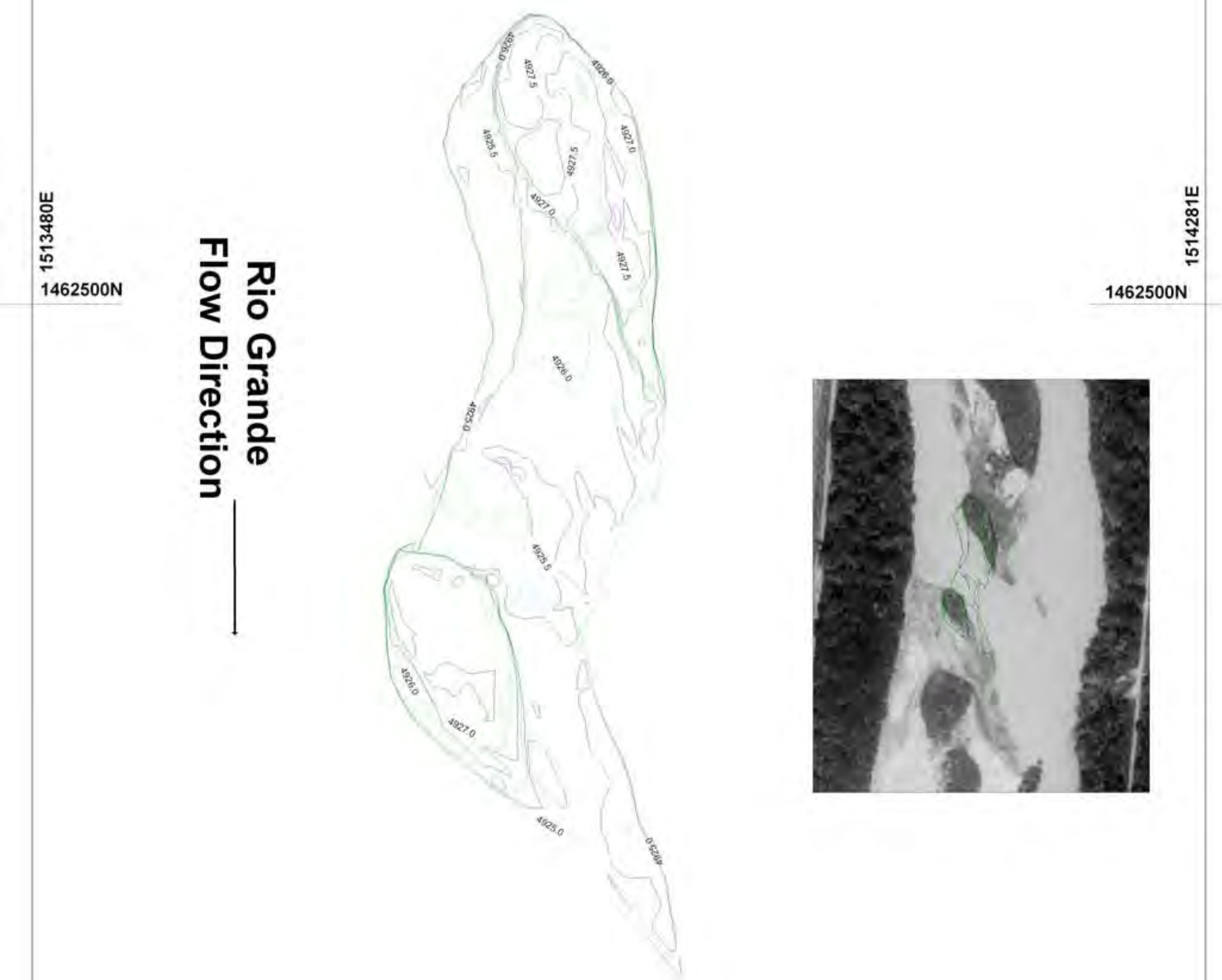
Vertical Datum: NAVD88
Horizontal Datum: NAD 83
Drawn by: MCI; Checked by: MDH
Sheet 1 of 1

Contour Interval 0.5 ft.


South Diversion Channel
Control Island 1
565
566
567
1513691E
1514412E
1463000N
1463000N
4928
4927
4926
4924
Rio Grande
Flow Direction
0
100
200
feet
MEI Project: 05-04
WTB Bar Habitat Restoration Project
September 12, 2005
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525
Vertical Datum: NAVD88
Horizontal Datum: NAD 83
Drawn by: MCI; Checked by: MDH
Sheet 1 of 1
Contour Interval 0.5 ft.


South Diversion Channel
Control Island 1
Rio Grande
Flow Direction
1513586E
1463000N
1514387E
1463000N
0
100
200
feet
Contour Interval 0.5 ft.
MEI Project: 05-04
WTB Bar Habitat Resoration Project
March 2005
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525
Vertical Datum: NAVD88
Horzontal Datum: NAD 83
Drawn by: MCI; Checked by: MDH
Sheet 1 of 1

South Diversion Channel Restoration Islands 2 and 3



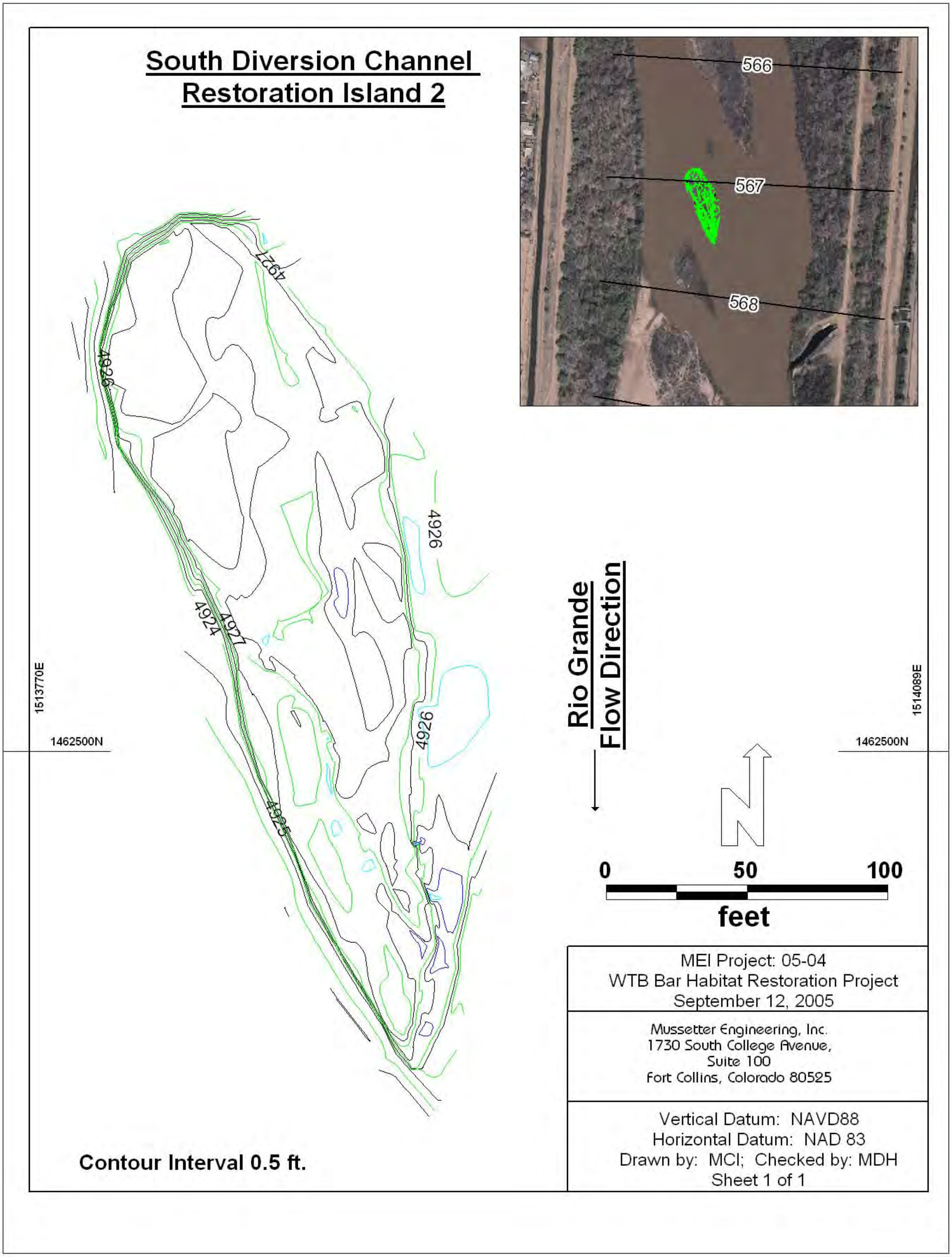
0 100 200
feet

Contour Interval 0.5 ft.

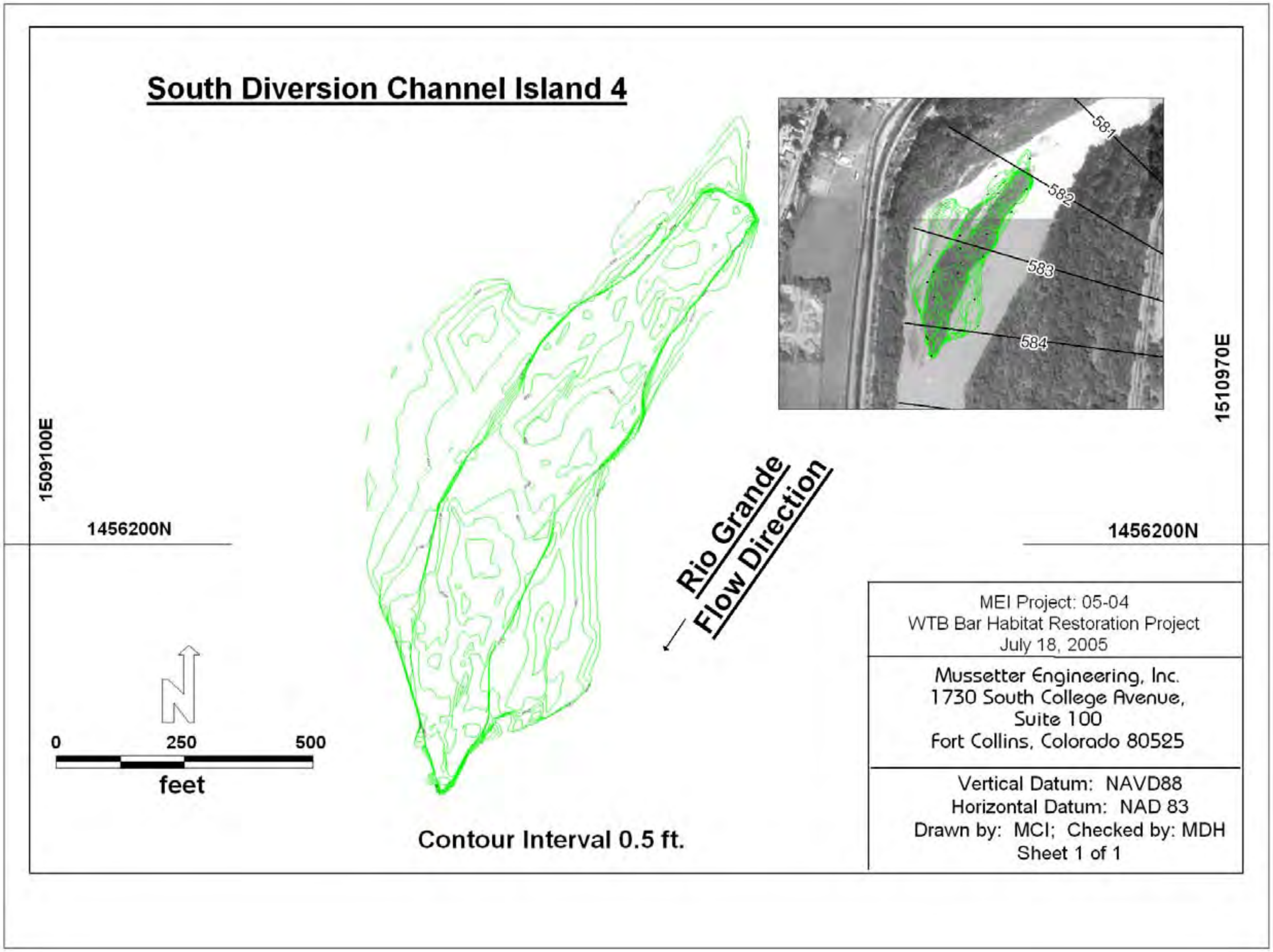
MEI Project: 05-04
WTB Bar Habitat Resoration Project
March 2005

Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525

Vertical Datum: NAVD88
Horzontal Datum: NAD 83
Drawn by: MCI; Checked by: MDH
Sheet 1 of 1

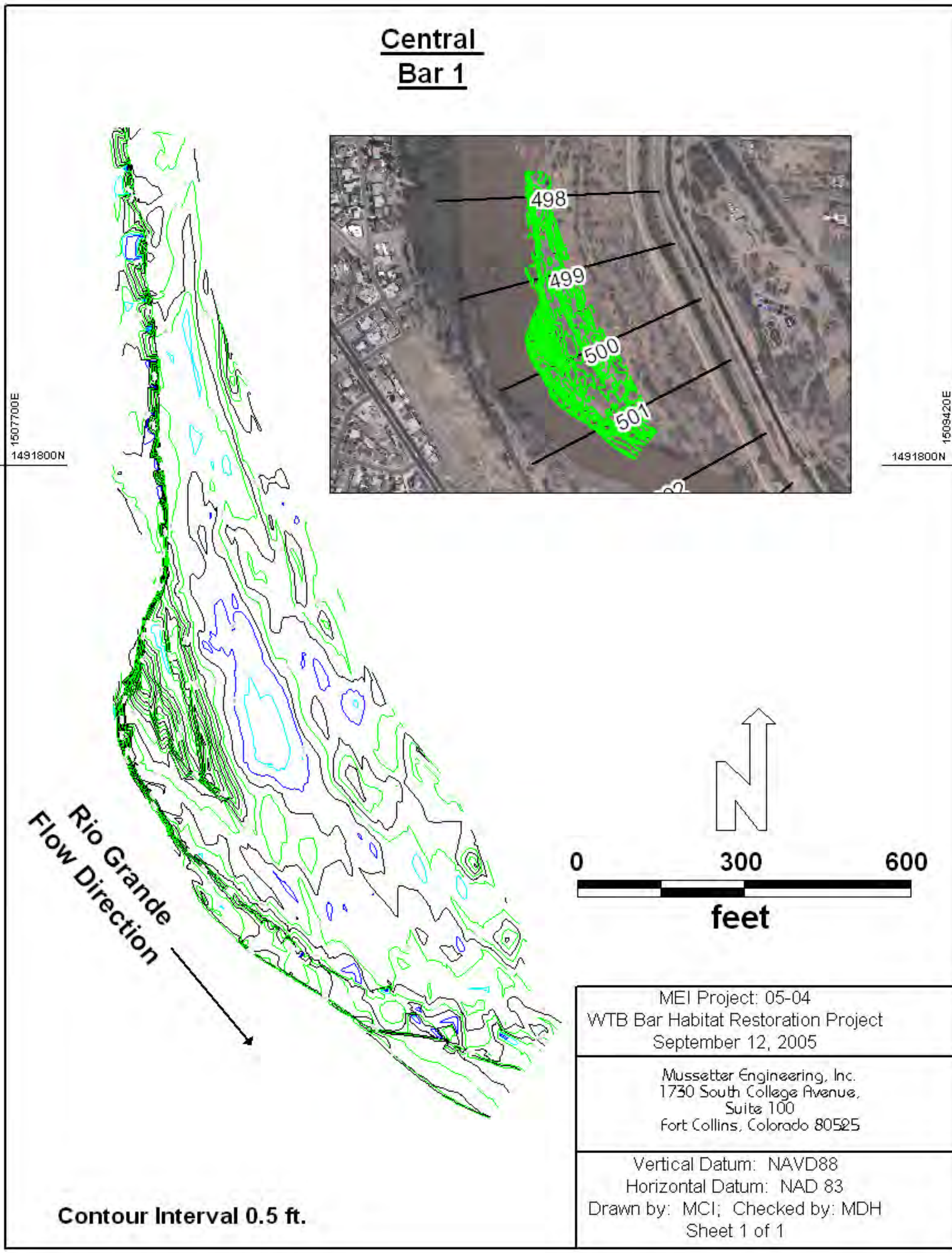

South Diversion Channel
Restoration Island 2
566
567
568
4927
4926
4924
4925
1513770E
1514089E
1462500N
1462500N
Rio Grande
Flow Direction
0
50
100
feet
MEI Project: 05-04
WTB Bar Habitat Restoration Project
September 12, 2005
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525
Vertical Datum: NAVD88
Horizontal Datum: NAD 83
Drawn by: MCI; Checked by: MDH
Sheet 1 of 1
Contour Interval 0.5 ft.

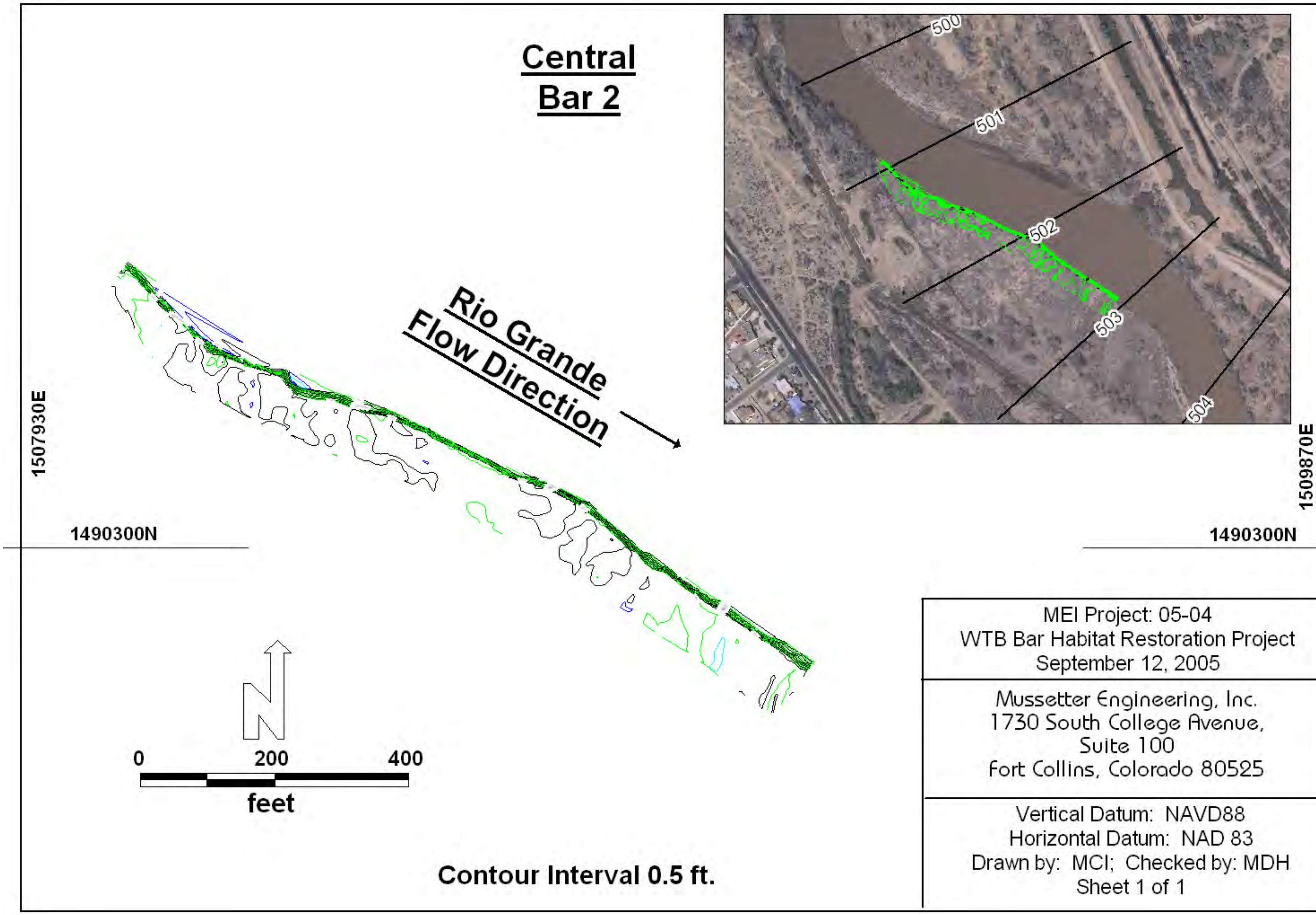

South Diversion Channel
Restoration Island 3
567
568
569
4924
4925
1513548E
1514260E
1462200N
1462200N
Rio Grande
Flow Direction
0
100
200
feet
MEI Project: 05-04
WTB Bar Habitat Restoration Project
September 12, 2005
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525
Vertical Datum: NAVD88
Horizontal Datum: NAD 83
Drawn by: MCI; Checked by: MDH
Sheet 1 of 1
Contour Interval 0.5 ft.

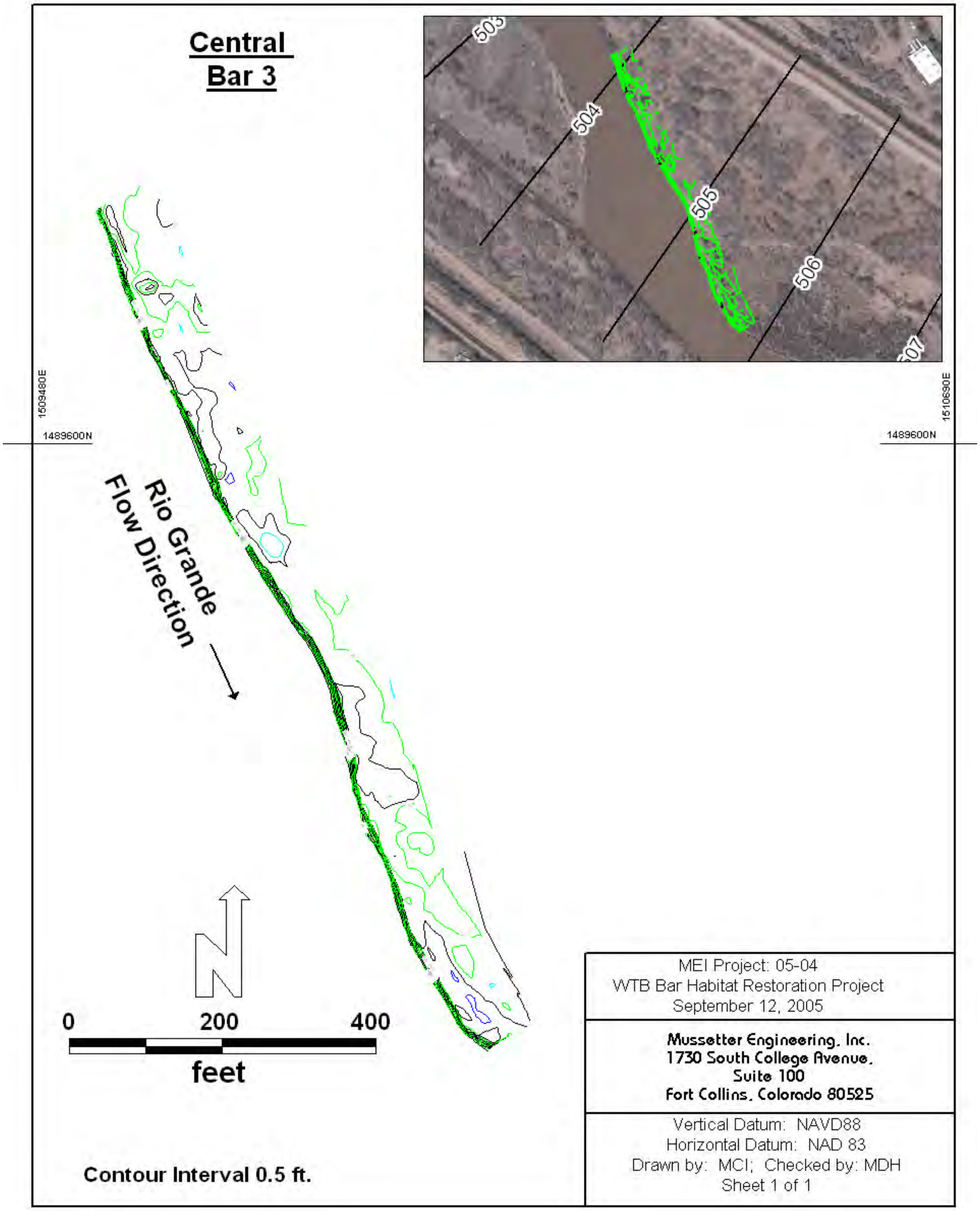

South Diversion Channel Island 4
581
582
583
584
1509100E
1510970E
1456200N
1456200N
Rio Grande
Flow Direction
0
250
500
feet
Contour Interval 0.5 ft.
MEI Project: 05-04
WTB Bar Habitat Restoration Project
July 18, 2005
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525
Vertical Datum: NAVD88
Horizontal Datum: NAD 83
Drawn by: MCI; Checked by: MDH
Sheet 1 of 1

APPENDIX B

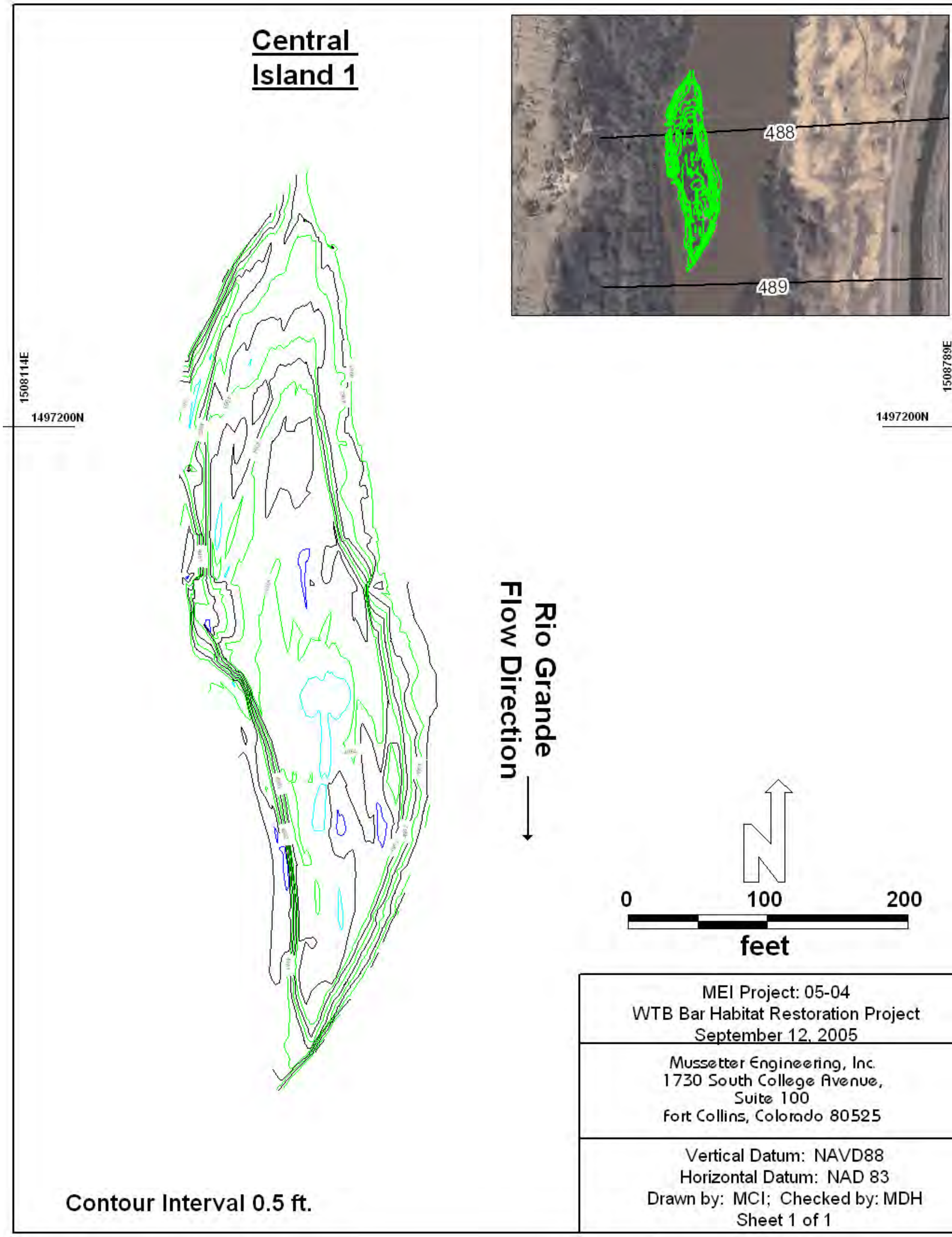
INTERSTATE-40/CENTRAL AVENUE SUBREACH CONTOUR MAPS

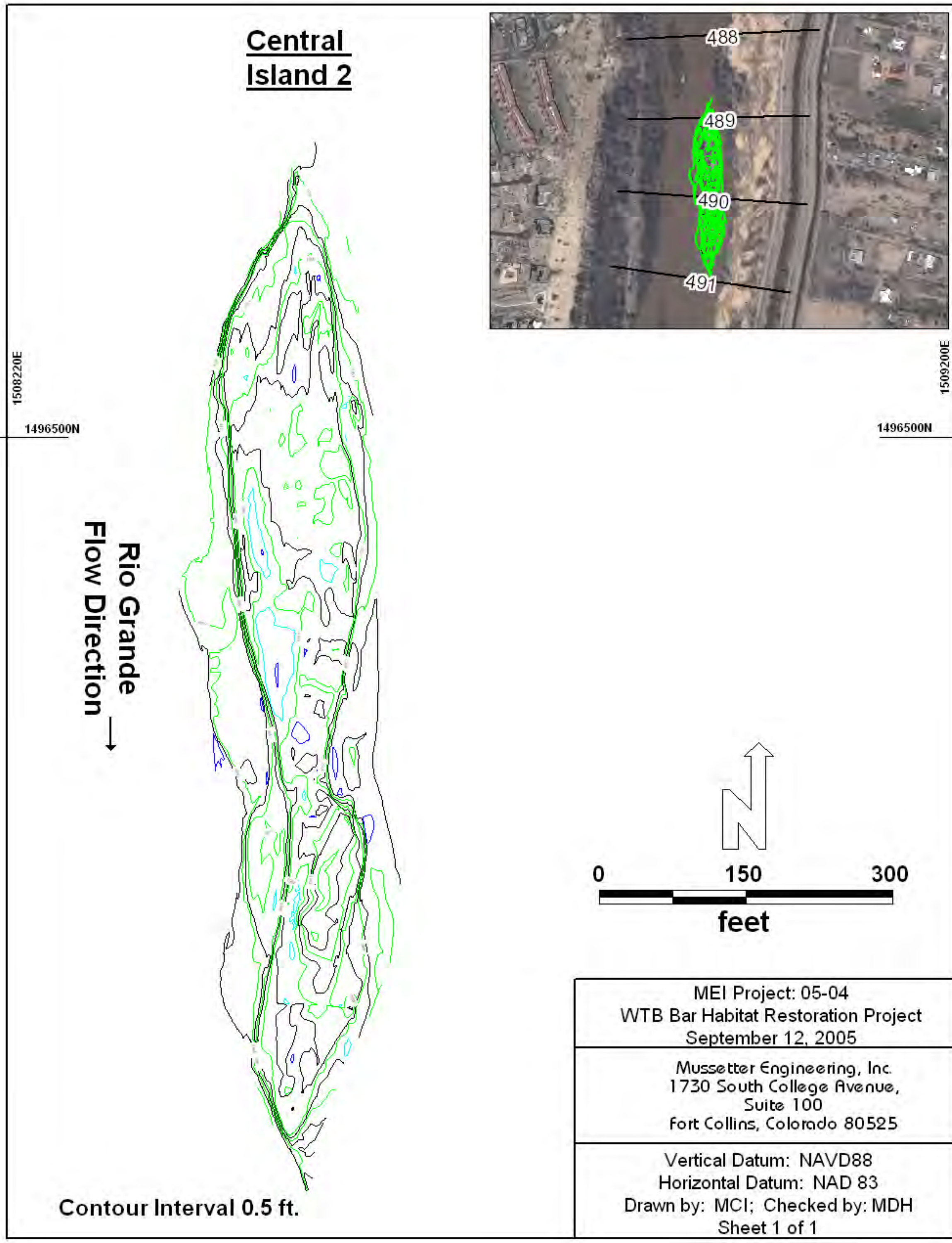

Central
Bar 1
498
499
500
501
1507700E
1491800N
1509420E
1491800N
Rio Grande
Flow Direction
0
300
600
feet
Contour Interval 0.5 ft.
MEI Project: 05-04
WTB Bar Habitat Restoration Project
September 12, 2005
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525
Vertical Datum: NAVD88
Horizontal Datum: NAD 83
Drawn by: MCI; Checked by: MDH
Sheet 1 of 1

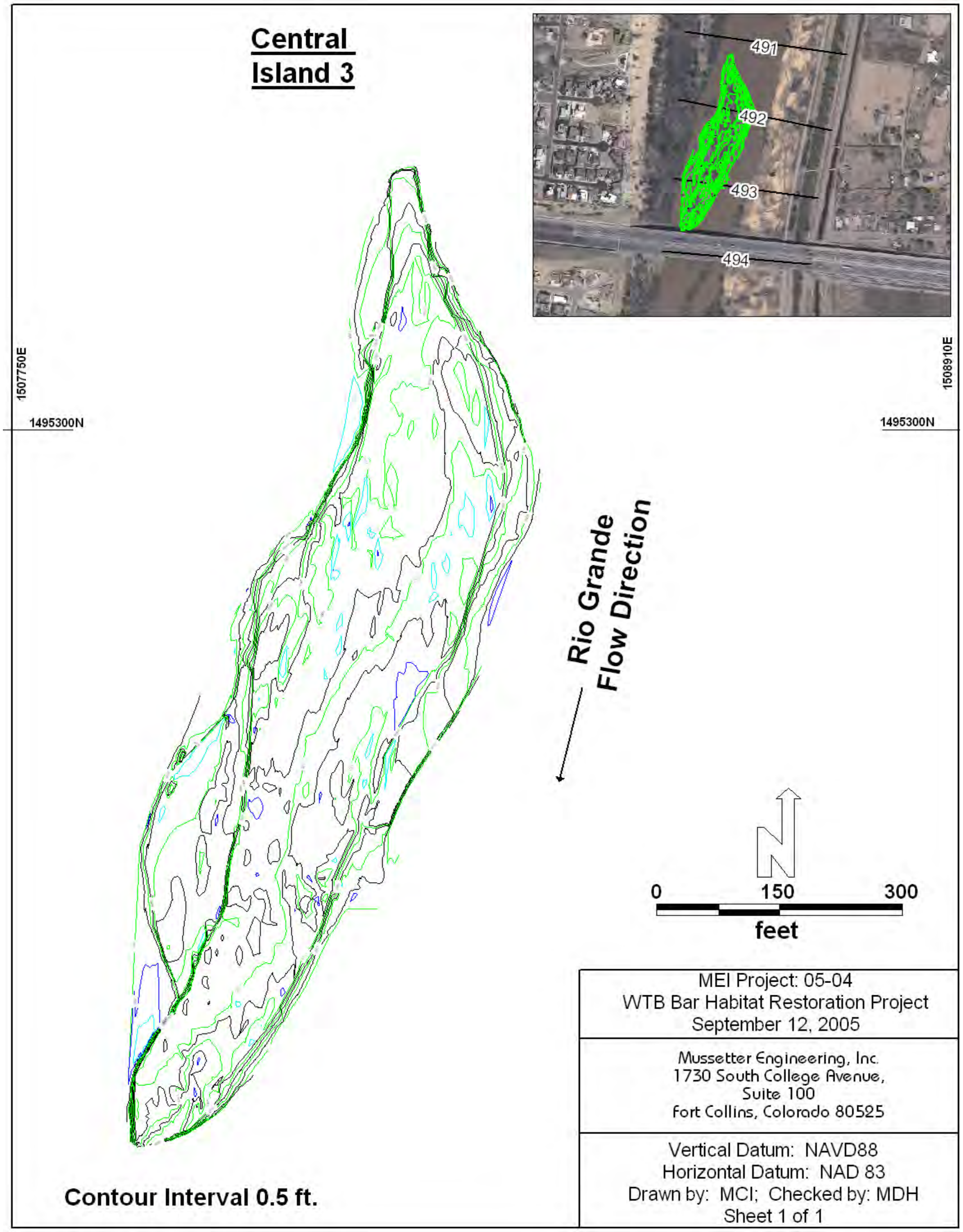

Central
Bar 2
Rio Grande
Flow Direction
500
501
502
503
504
1507930E
1509870E
1490300N
1490300N
0
200
400
feet
Contour Interval 0.5 ft.
MEI Project: 05-04
WTB Bar Habitat Restoration Project
September 12, 2005
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525
Vertical Datum: NAVD88
Horizontal Datum: NAD 83
Drawn by: MCI; Checked by: MDH
Sheet 1 of 1

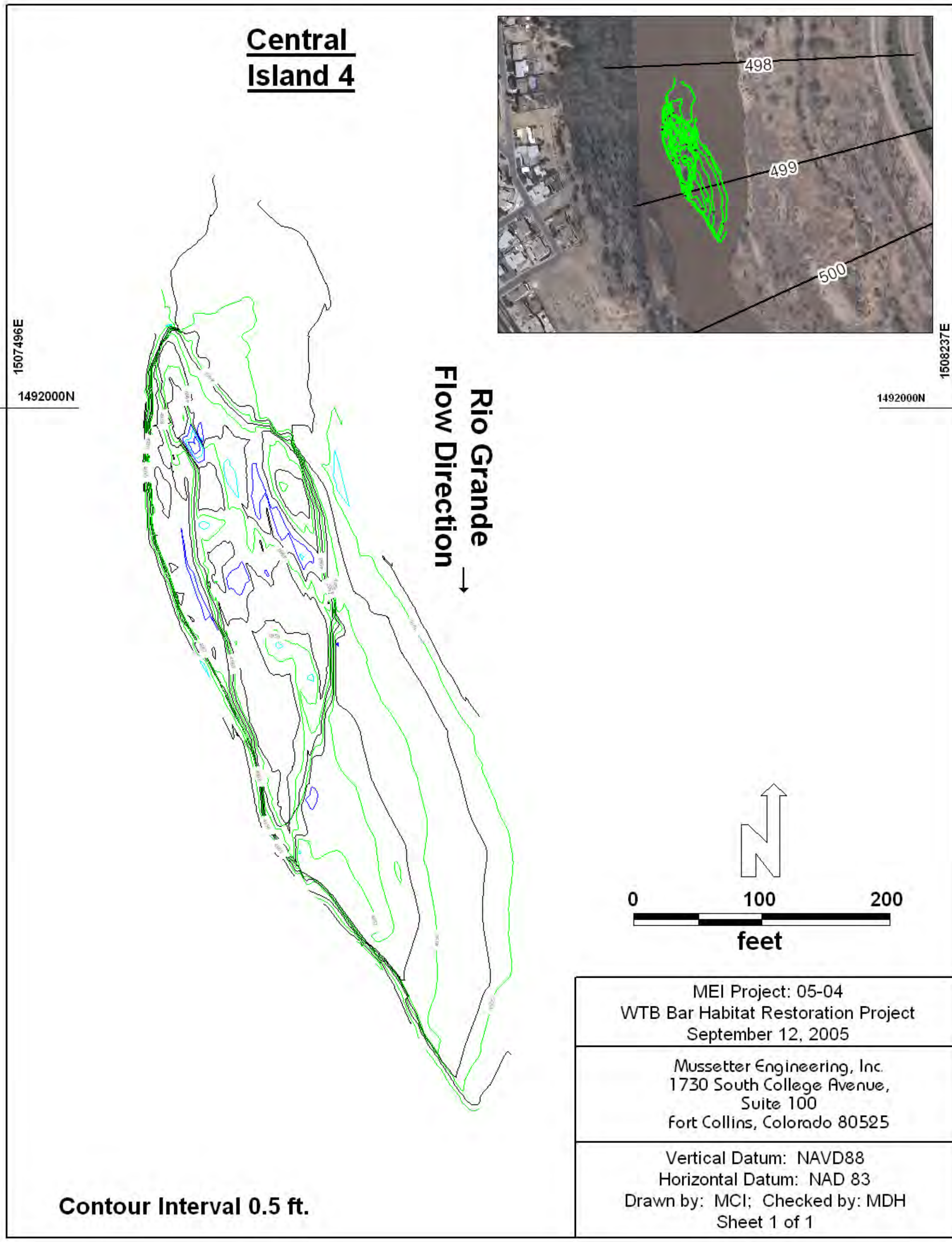


Central Bar 3
503
504
505
506
507
1509480E
1510630E
1489600N
1489600N
Rio Grande Flow Direction
0
200
400
feet
Contour Interval 0.5 ft.
MEI Project: 05-04
WTB Bar Habitat Restoration Project
September 12, 2005
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525
Vertical Datum: NAVD88
Horizontal Datum: NAD 83
Drawn by: MCI; Checked by: MDH
Sheet 1 of 1


Central Island 1
488
489
1508114E
1497200N
1508789E
1497200N
Rio Grande Flow Direction
0
100
200
feet
MEI Project: 05-04
WTB Bar Habitat Restoration Project
September 12, 2005
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525
Vertical Datum: NAVD88
Horizontal Datum: NAD 83
Drawn by: MCI; Checked by: MDH
Sheet 1 of 1
Contour Interval 0.5 ft.

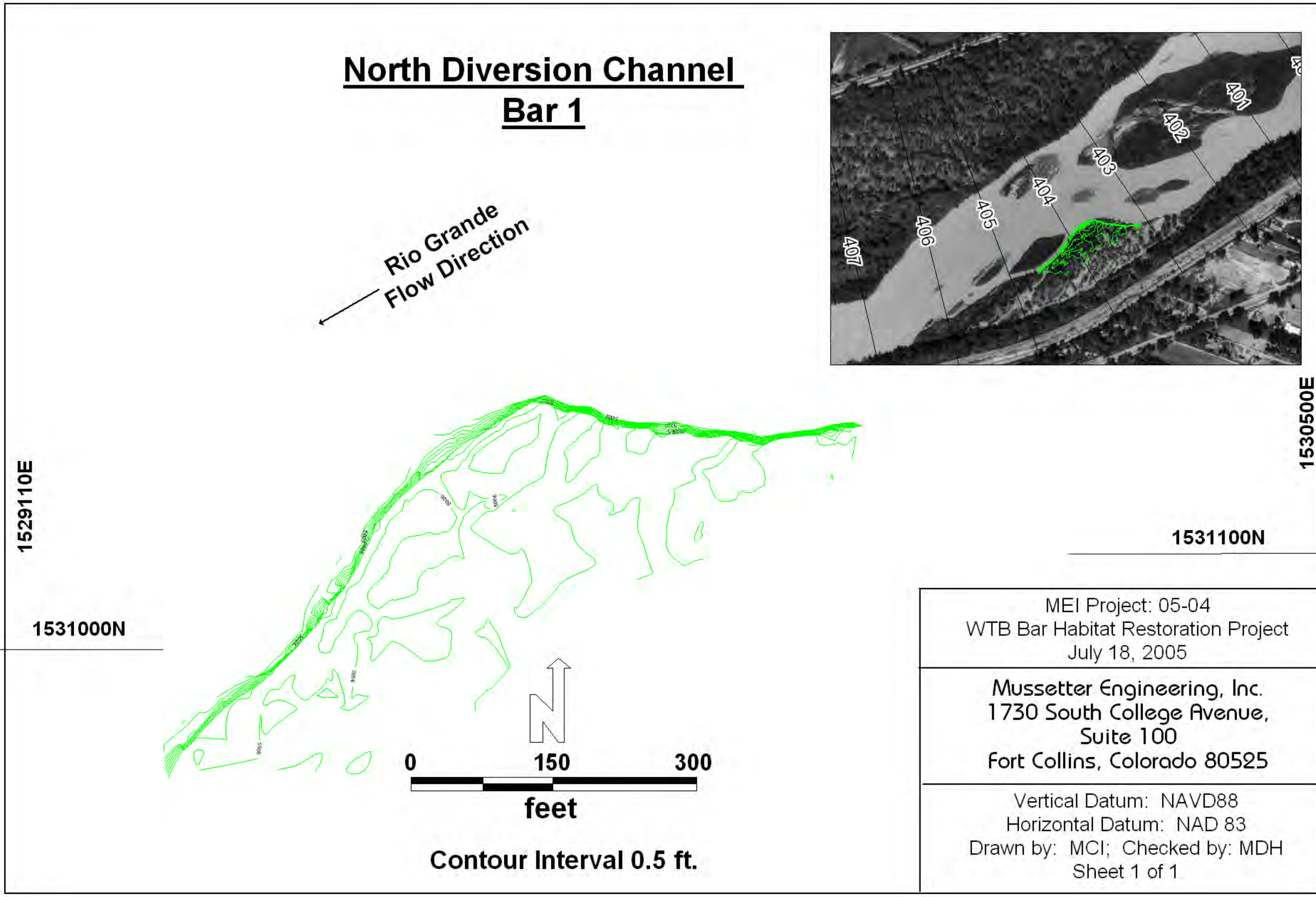

Central Island 2
488
489
490
491
1508220E
1509200E
1496500N
1496500N
Rio Grande
Flow Direction
0
150
300
feet
MEI Project: 05-04
WTB Bar Habitat Restoration Project
September 12, 2005
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525
Vertical Datum: NAVD88
Horizontal Datum: NAD 83
Drawn by: MCI; Checked by: MDH
Sheet 1 of 1
Contour Interval 0.5 ft.

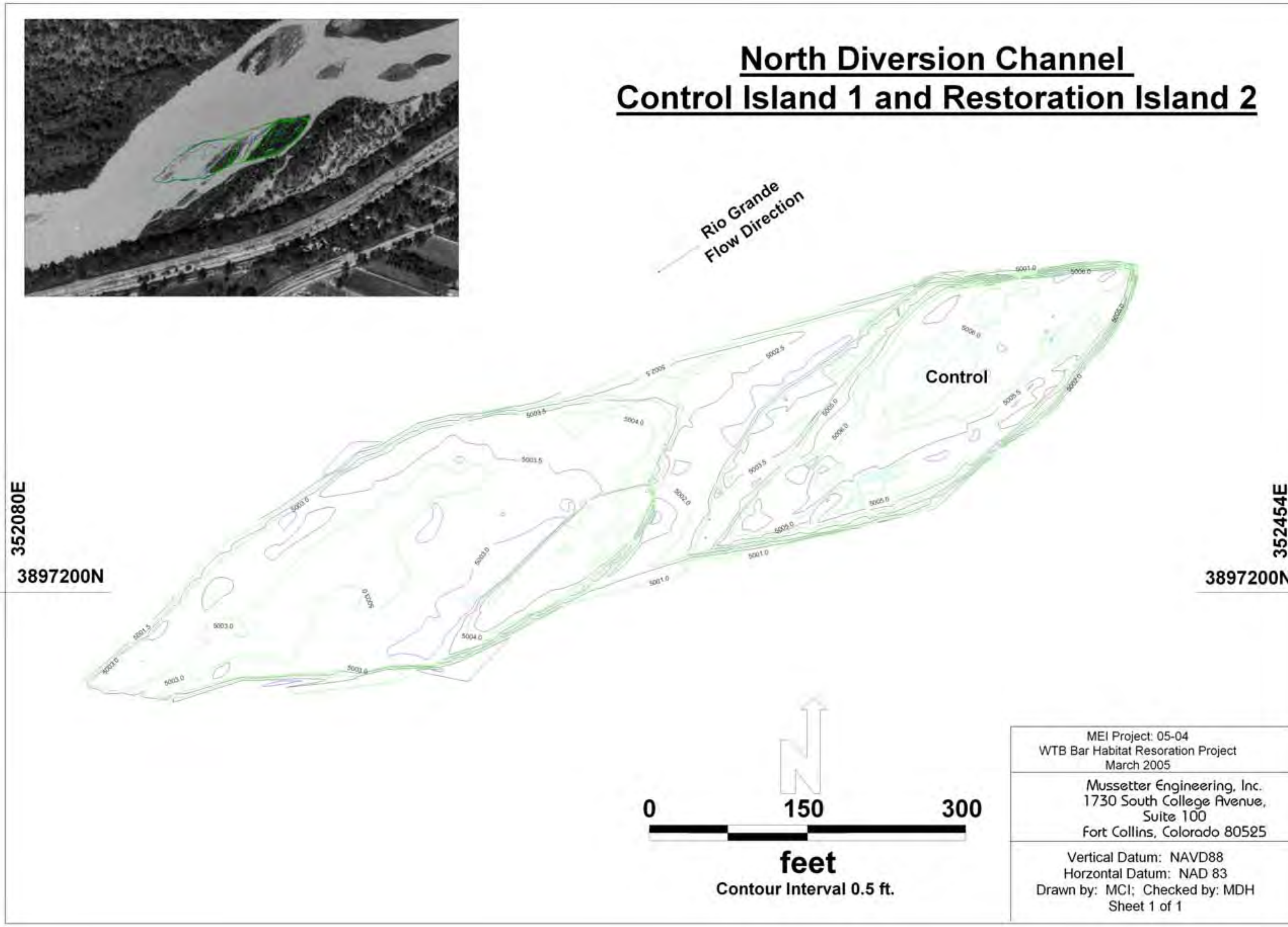

Central Island 3
491
492
493
494
1507750E
1508910E
1495300N
1495300N
Rio Grande Flow Direction
0
150
300
feet
MEI Project: 05-04
WTB Bar Habitat Restoration Project
September 12, 2005
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525
Vertical Datum: NAVD88
Horizontal Datum: NAD 83
Drawn by: MCI; Checked by: MDH
Sheet 1 of 1
Contour Interval 0.5 ft.

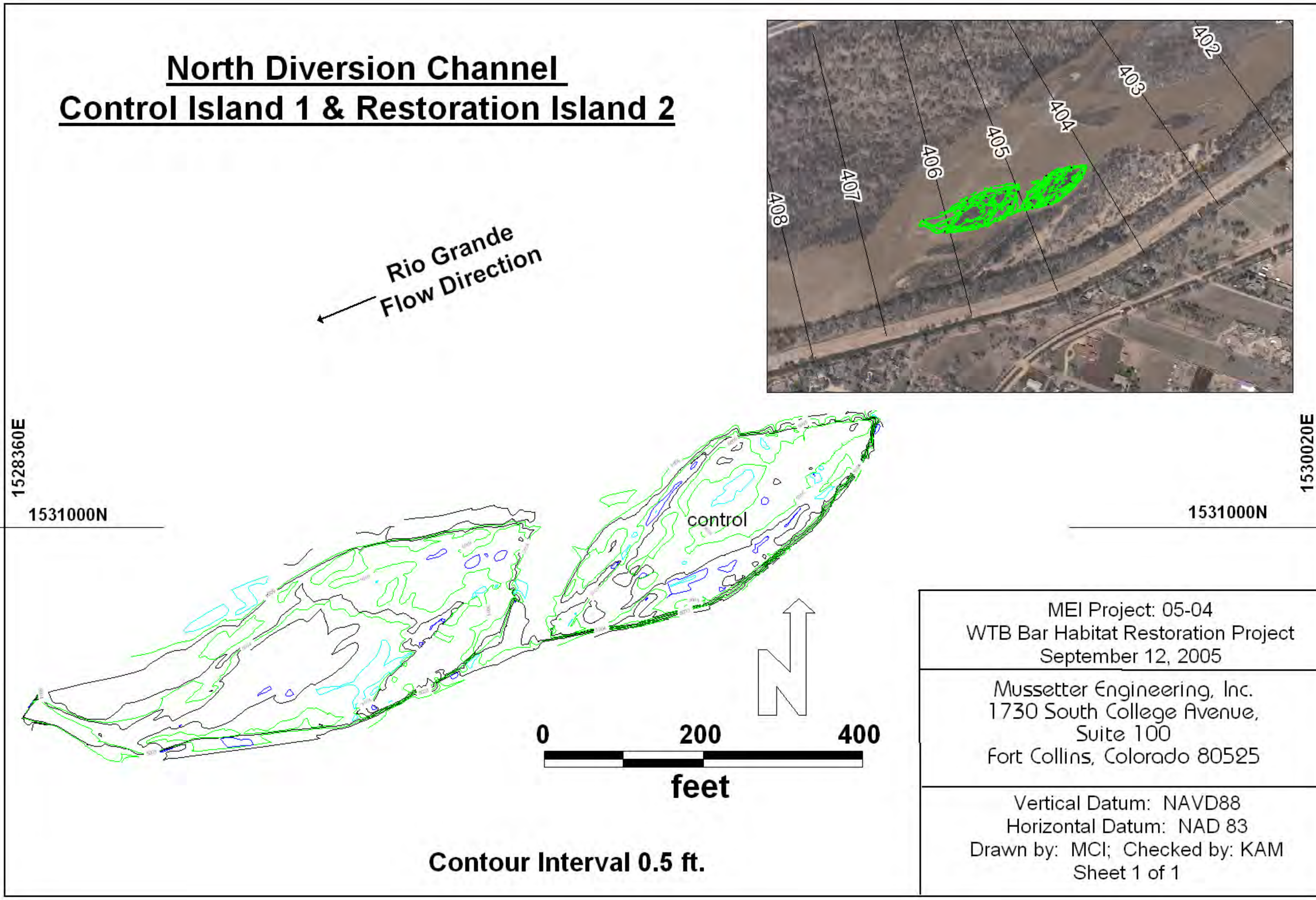

Central Island 4
498
499
500
1507496E
1508237E
1492000N
1492000N
Rio Grande Flow Direction
0
100
200
feet
MEI Project: 05-04
WTB Bar Habitat Restoration Project
September 12, 2005
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525
Vertical Datum: NAVD88
Horizontal Datum: NAD 83
Drawn by: MCI; Checked by: MDH
Sheet 1 of 1
Contour Interval 0.5 ft.

APPENDIX C

NORTH DIVERSION CHANNEL SUBREACH CONTOUR MAPS


North Diversion Channel
Bar 1
Rio Grande
Flow Direction
401
402
403
404
405
406
407
1529110E
1530500E
1531000N
1531100N
0
150
300
feet
Contour Interval 0.5 ft.
MEI Project: 05-04
WTB Bar Habitat Restoration Project
July 18, 2005
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525
Vertical Datum: NAVD88
Horizontal Datum: NAD 83
Drawn by: MCI; Checked by: MDH
Sheet 1 of 1


North Diversion Channel
Control Island 1 and Restoration Island 2
Rio Grande
Flow Direction
Control
352080E
3897200N
352454E
3897200N
0
150
300
feet
Contour Interval 0.5 ft.
MEI Project: 05-04
WTB Bar Habitat Resoration Project
March 2005
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525
Vertical Datum: NAVD88
Horzontal Datum: NAD 83
Drawn by: MCI; Checked by: MDH
Sheet 1 of 1


North Diversion Channel
Control Island 1 & Restoration Island 2
Rio Grande
Flow Direction
402
403
404
405
406
407
408
1528360E
1530020E
1531000N
1531000N
control
0
200
400
feet
N
Contour Interval 0.5 ft.
MEI Project: 05-04
WTB Bar Habitat Restoration Project
September 12, 2005
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525
Vertical Datum: NAVD88
Horizontal Datum: NAD 83
Drawn by: MCI; Checked by: KAM
Sheet 1 of 1

North Diversion Channel
Restoration Island 3

1524112E

1529600N

1524896E

1529600N

0 80 160

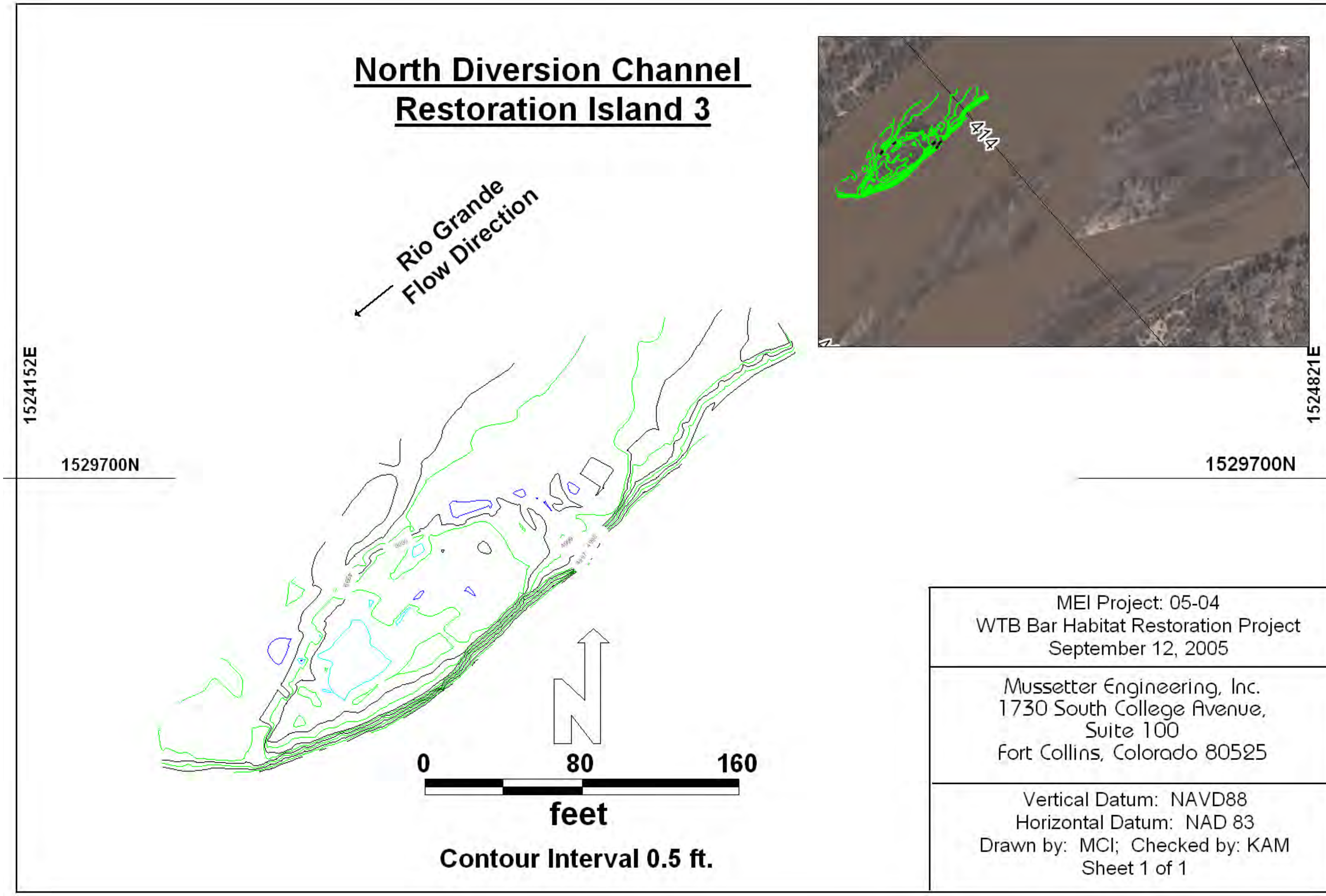
feet

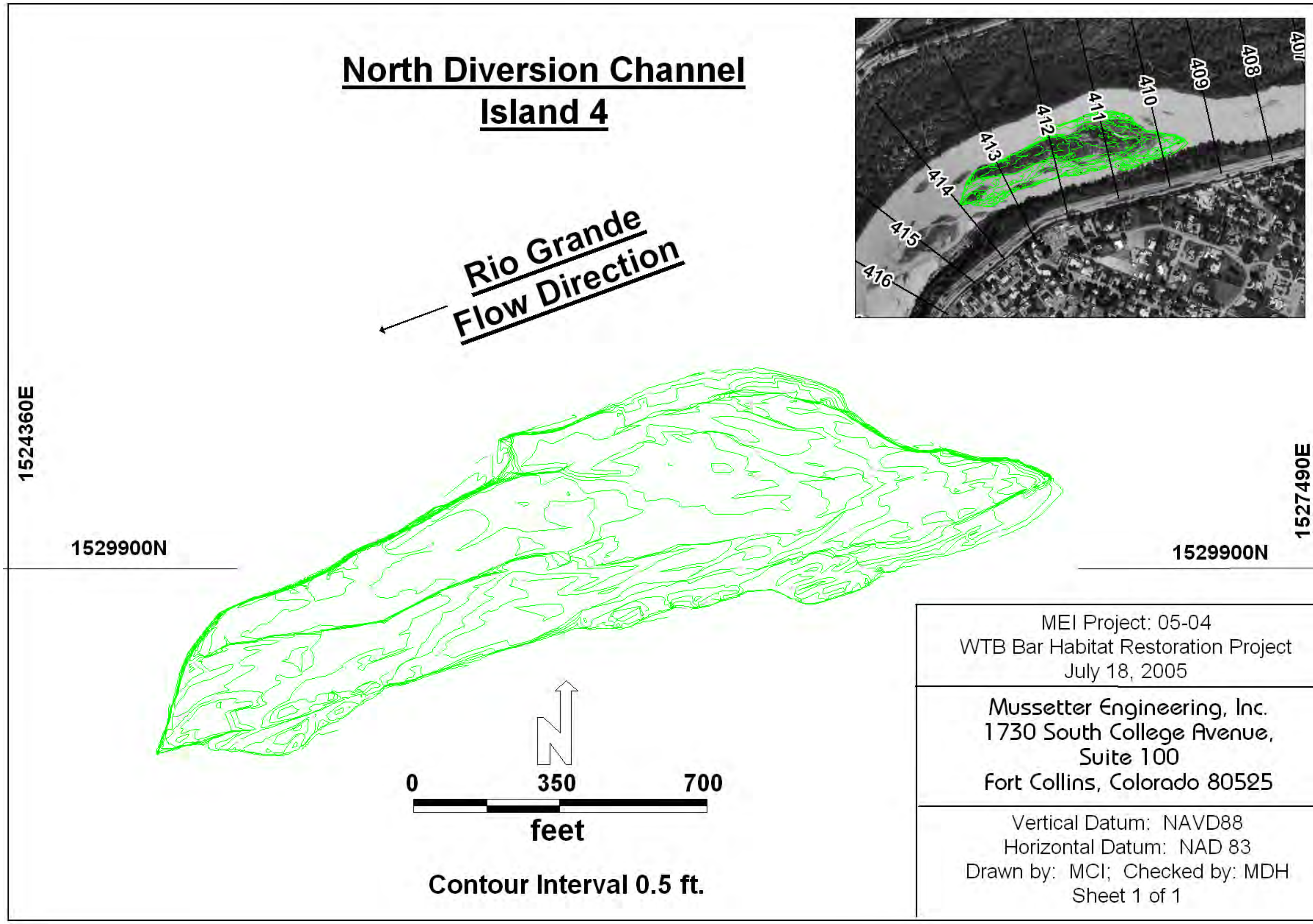
Contour Interval 0.5 ft.

MEI Project: 05-04
WTB Bar Habitat Resoration Project
March 2005

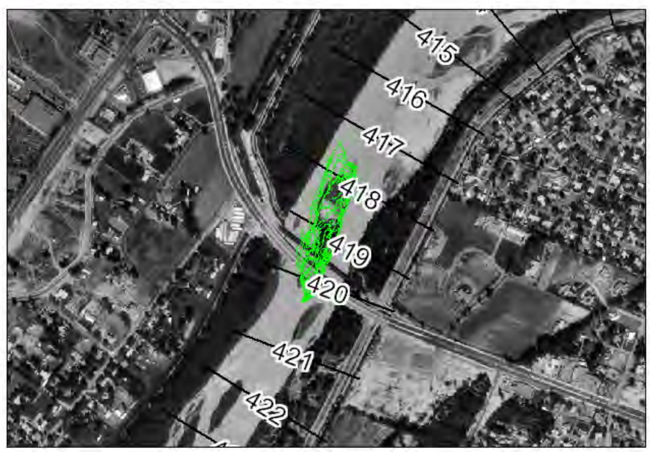
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525

Vertical Datum: NAVD88
Horizontal Datum: NAD 83
Drawn by: MCI; Checked by: MDH
Sheet 1 of 1


North Diversion Channel
Restoration Island 3
Rio Grande
Flow Direction
1524152E
1529700N
1524821E
1529700N
414
0
80
160
feet
Contour Interval 0.5 ft.
MEI Project: 05-04
WTB Bar Habitat Restoration Project
September 12, 2005
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525
Vertical Datum: NAVD88
Horizontal Datum: NAD 83
Drawn by: MCI; Checked by: KAM
Sheet 1 of 1


North Diversion Channel
Island 4
Rio Grande
Flow Direction
407
408
409
410
411
412
413
414
415
416
1524360E
1527490E
1529900N
1529900N
0
350
700
feet
Contour Interval 0.5 ft.
MEI Project: 05-04
WTB Bar Habitat Restoration Project
July 18, 2005
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525
Vertical Datum: NAVD88
Horizontal Datum: NAD 83
Drawn by: MCI; Checked by: MDH
Sheet 1 of 1

North Diversion Channel
Island 5



Contour Interval 0.5 ft.

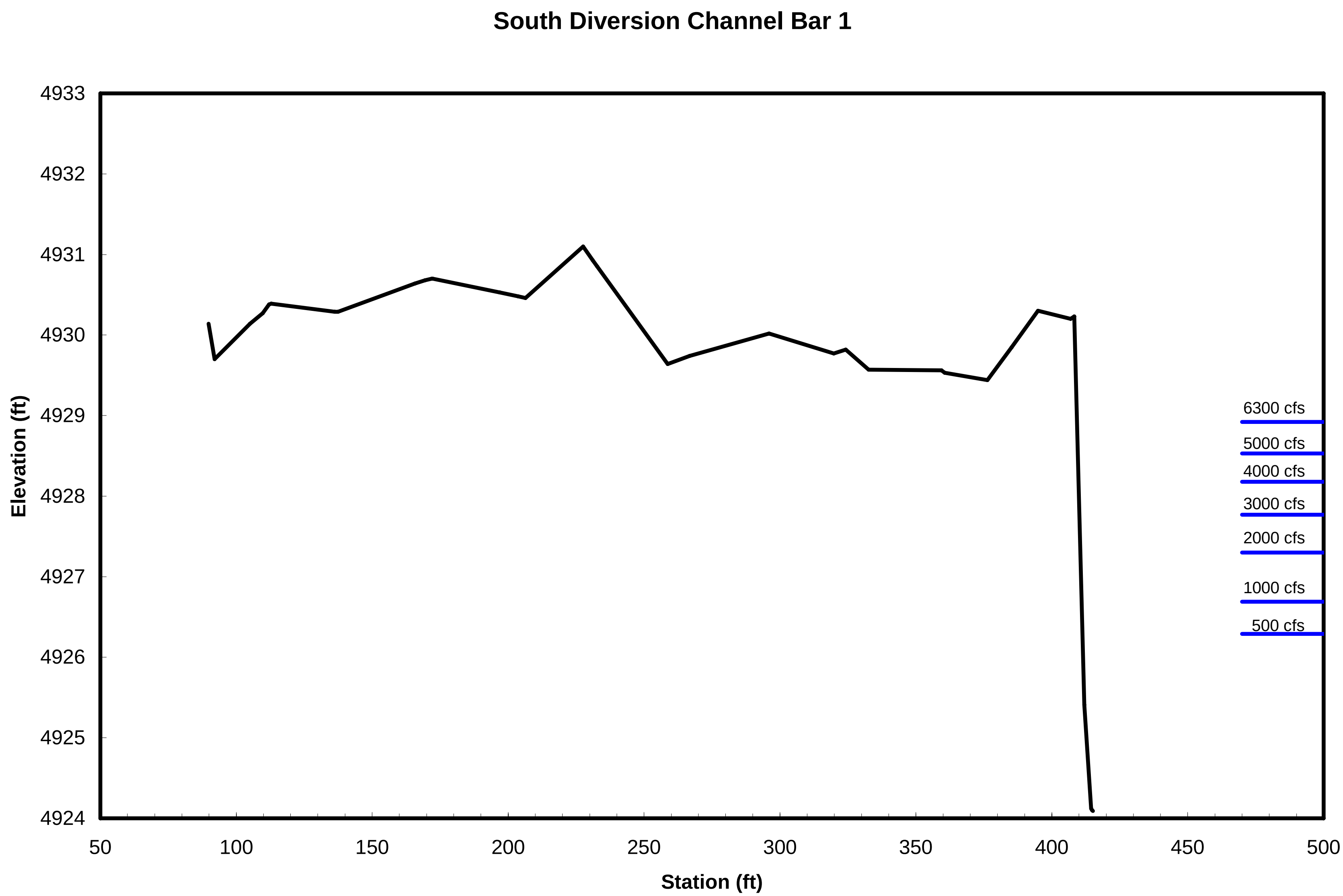
MEI Project: 05-04
WTB Bar Habitat Restoration Project
July 18, 2005

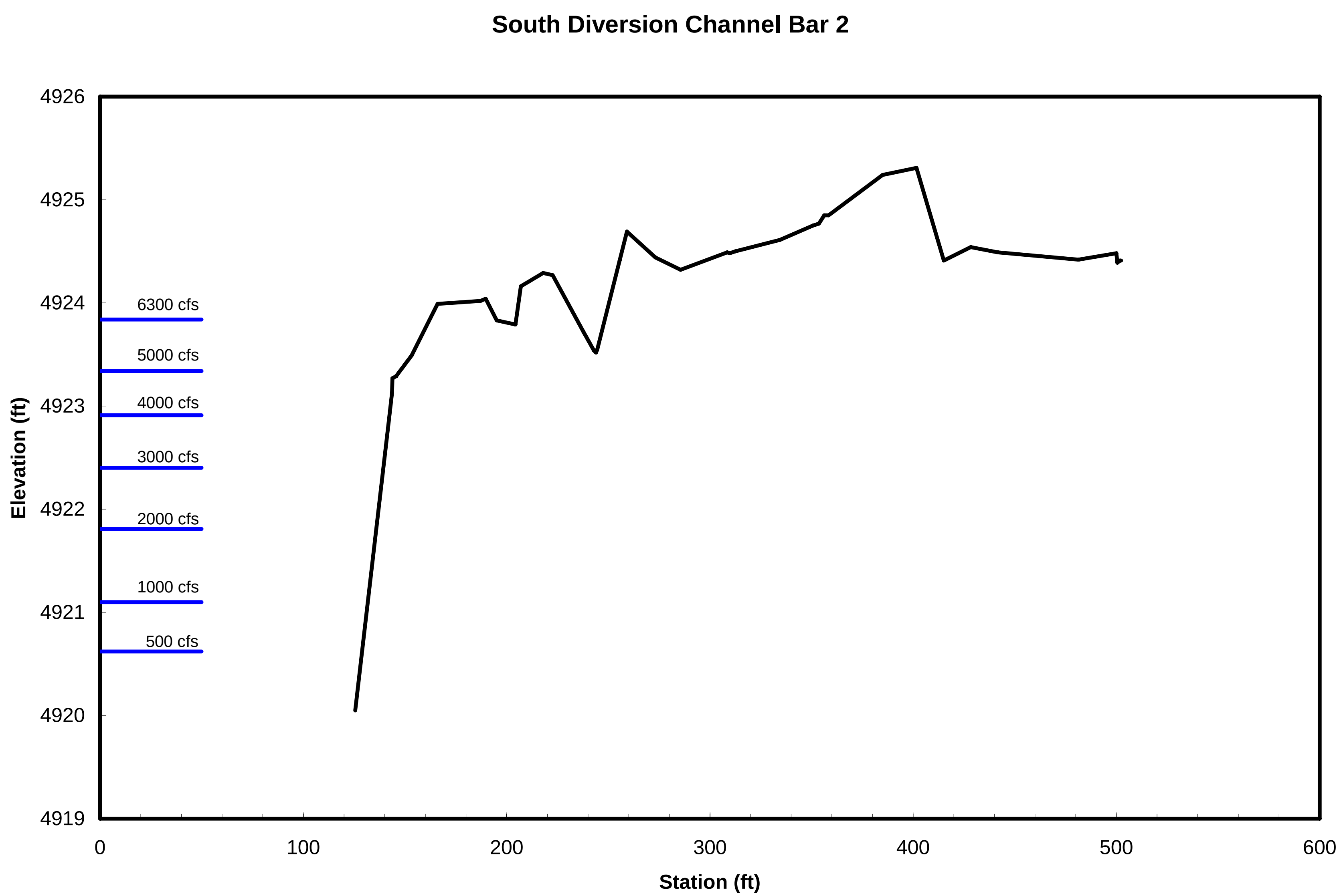
Mussetter Engineering, Inc.
1730 South College Avenue,
Suite 100
Fort Collins, Colorado 80525

Vertical Datum: NAVD88
Horizontal Datum: NAD 83
Drawn by: MCI; Checked by: MDH
Sheet 1 of 1

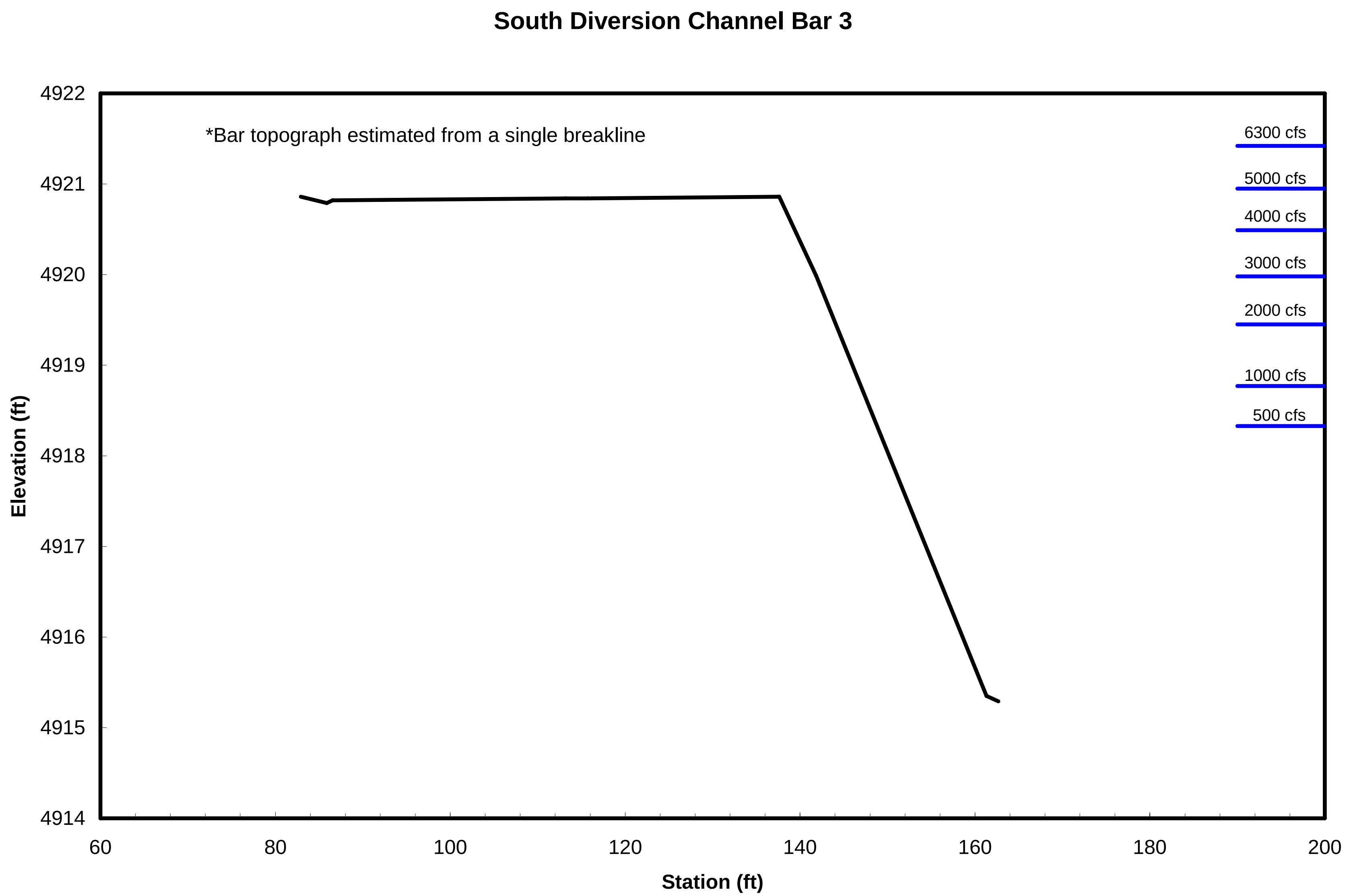
APPENDIX D

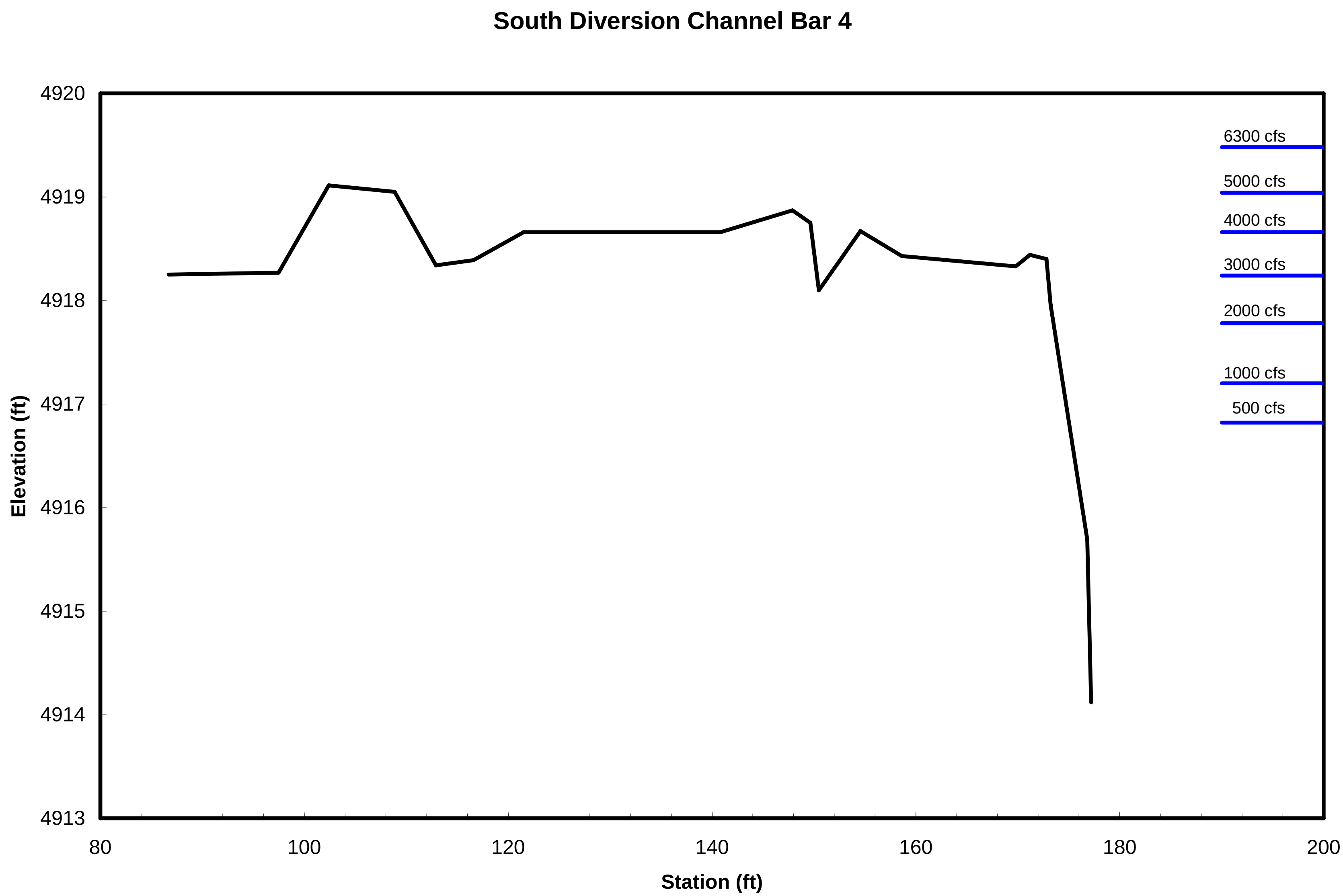
CROSS-SECTION PLOTS FOR BARS AND ISLANDS IN THE SOUTH DIVERSION CHANNEL, INTERSTATE-40/CENTRAL AVENUE, AND NORTH DIVERSION CHANNEL SUBREACHES

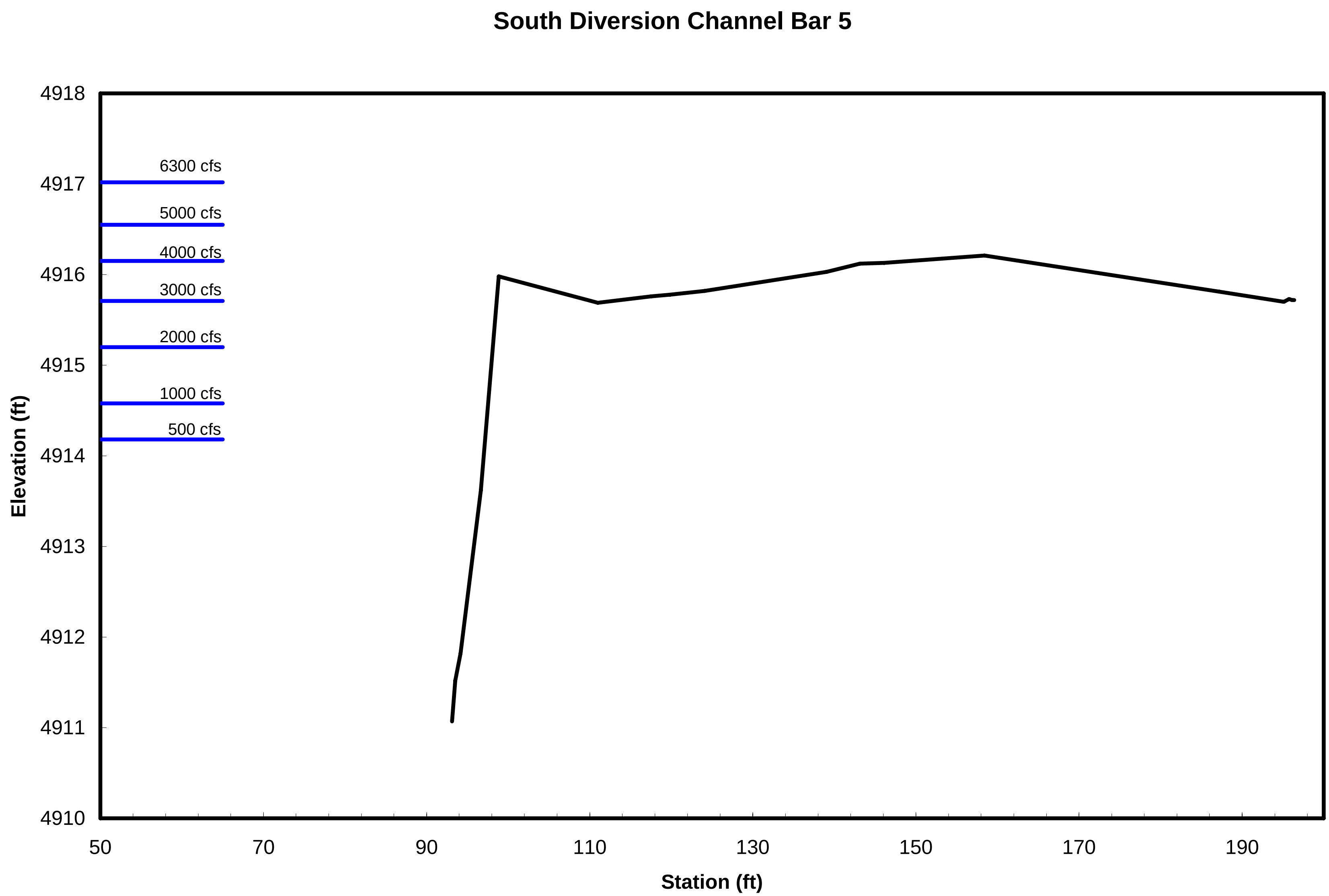

South Diversion Channel Bar 1
4933
4932
4931
4930
4929
4928
4927
4926
4925
4924
Elevation (ft)
50
100
150
200
250
300
350
400
450
500
Station (ft)
6300 cfs
5000 cfs
4000 cfs
3000 cfs
2000 cfs
1000 cfs
500 cfs

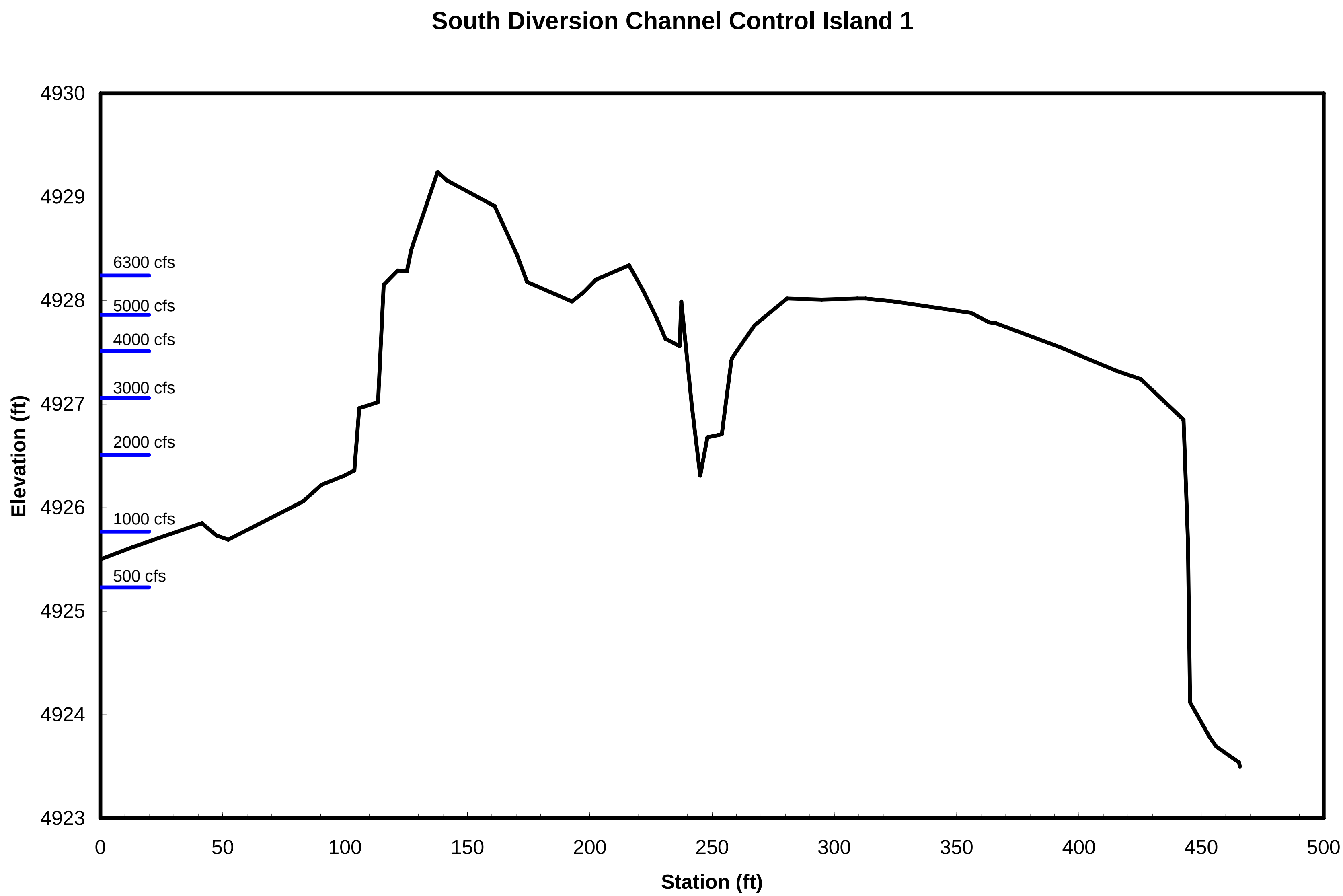


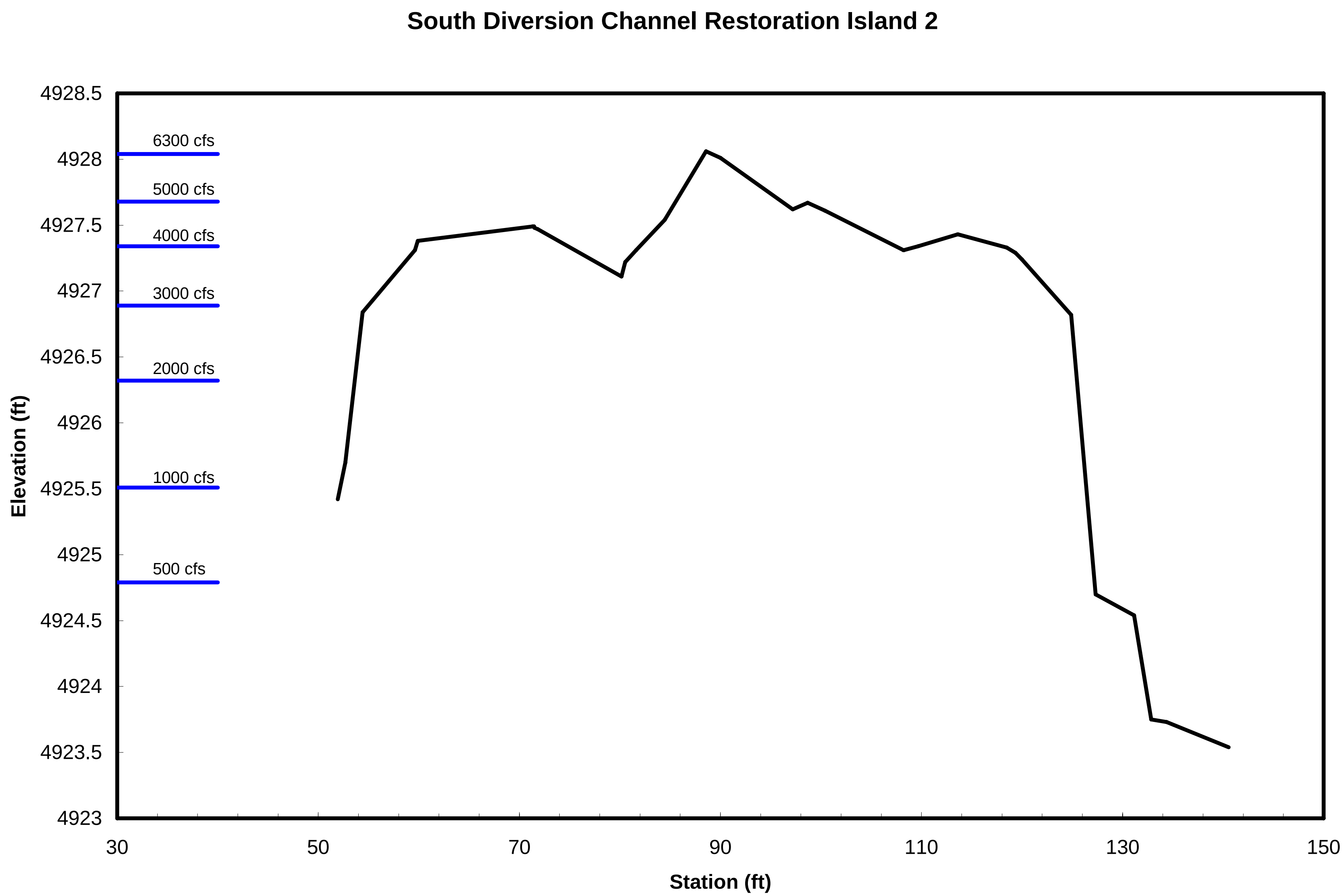
South Diversion Channel Bar 2
Elevation (ft)
Station (ft)
4926
4925
4924
4923
4922
4921
4920
4919
0
100
200
300
400
500
600
6300 cfs
5000 cfs
4000 cfs
3000 cfs
2000 cfs
1000 cfs
500 cfs


South Diversion Channel Bar 3
*Bar topograph estimated from a single breakline
6300 cfs
5000 cfs
4000 cfs
3000 cfs
2000 cfs
1000 cfs
500 cfs
Elevation (ft)
4922
4921
4920
4919
4918
4917
4916
4915
4914
60
80
100
120
140
160
180
200
Station (ft)

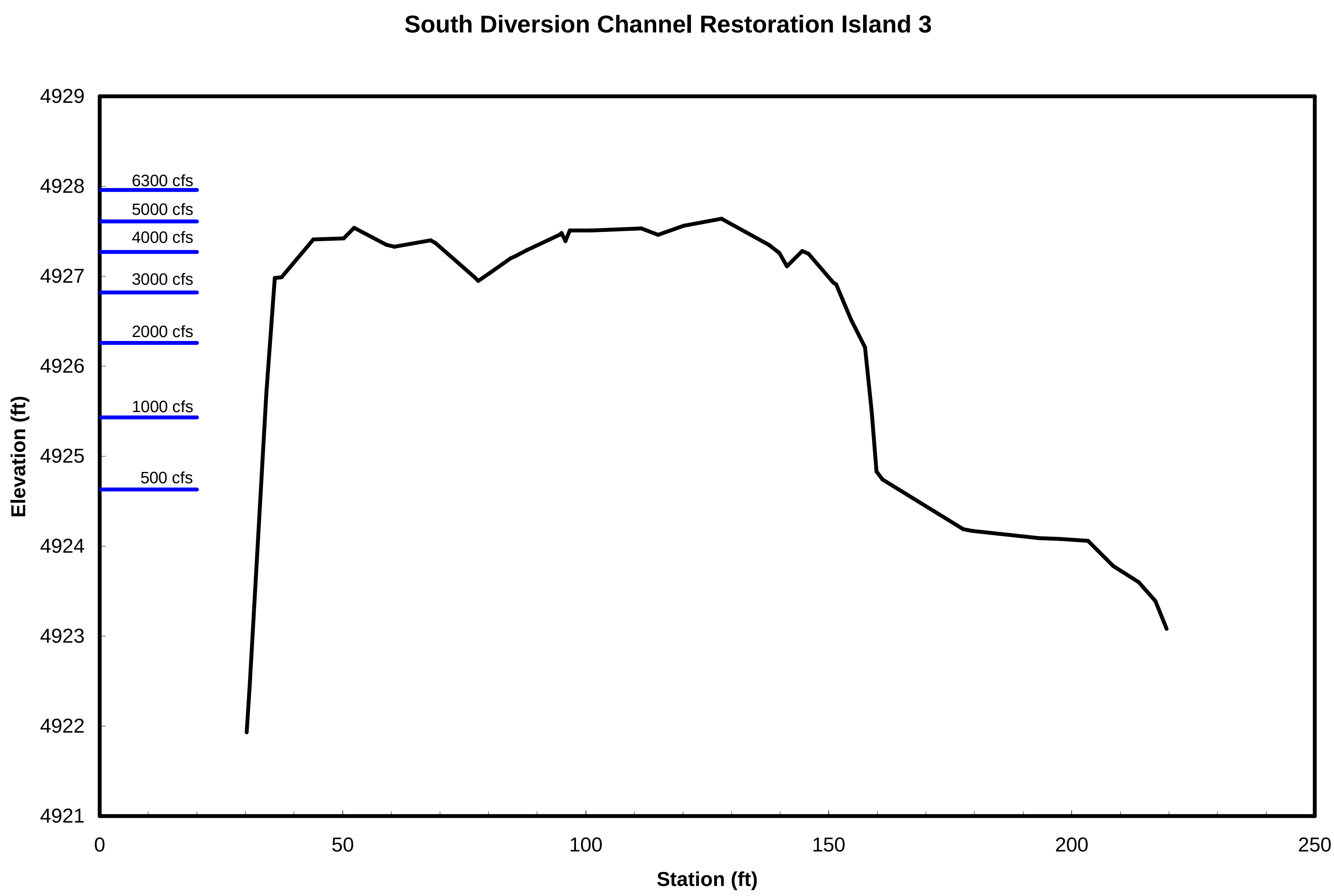

South Diversion Channel Bar 4
4920
4919
4918
4917
4916
4915
4914
4913
Elevation (ft)
80
100
120
140
160
180
200
Station (ft)
6300 cfs
5000 cfs
4000 cfs
3000 cfs
2000 cfs
1000 cfs
500 cfs


South Diversion Channel Bar 5
Elevation (ft)
Station (ft)
4918
4917
4916
4915
4914
4913
4912
4911
4910
50
70
90
110
130
150
170
190
6300 cfs
5000 cfs
4000 cfs
3000 cfs
2000 cfs
1000 cfs
500 cfs

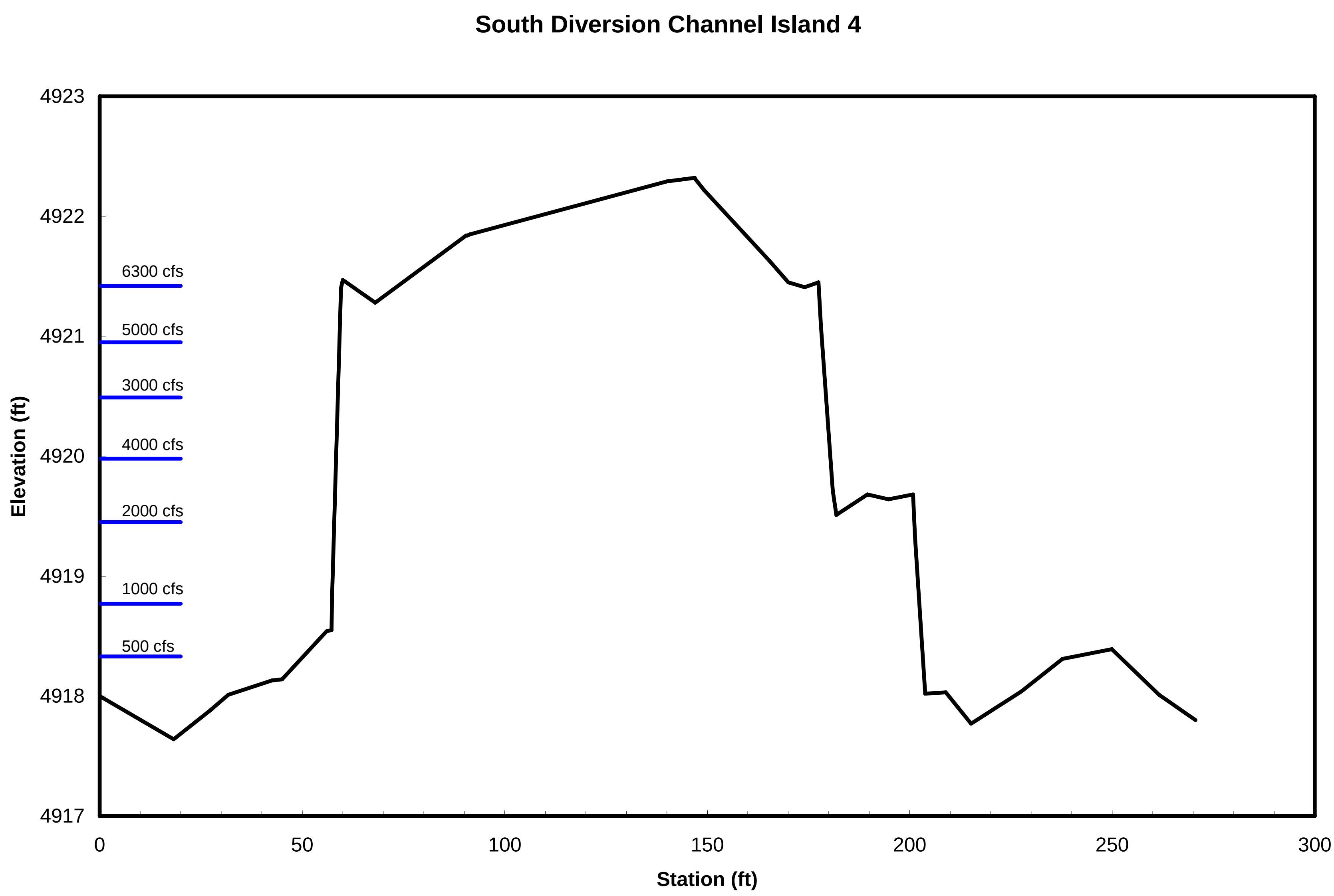

South Diversion Channel Control Island 1
Elevation (ft)
4930
4929
4928
4927
4926
4925
4924
4923
6300 cfs
5000 cfs
4000 cfs
3000 cfs
2000 cfs
1000 cfs
500 cfs
0
50
100
150
200
250
300
350
400
450
500
Station (ft)

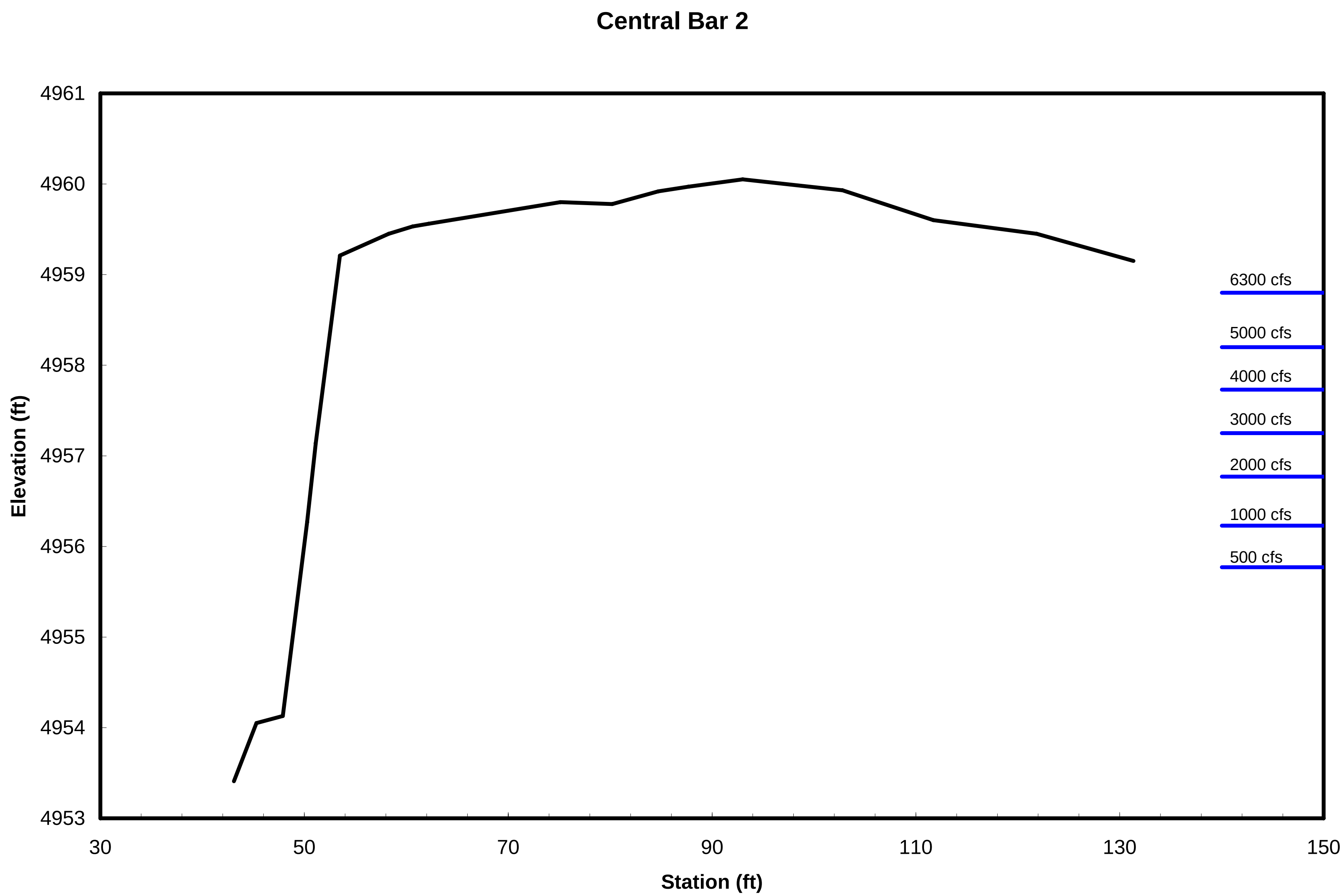


South Diversion Channel Restoration Island 2
Elevation (ft)
4928.5
4928
4927.5
4927
4926.5
4926
4925.5
4925
4924.5
4924
4923.5
4923
6300 cfs
5000 cfs
4000 cfs
3000 cfs
2000 cfs
1000 cfs
500 cfs
30
50
70
90
110
130
150
Station (ft)

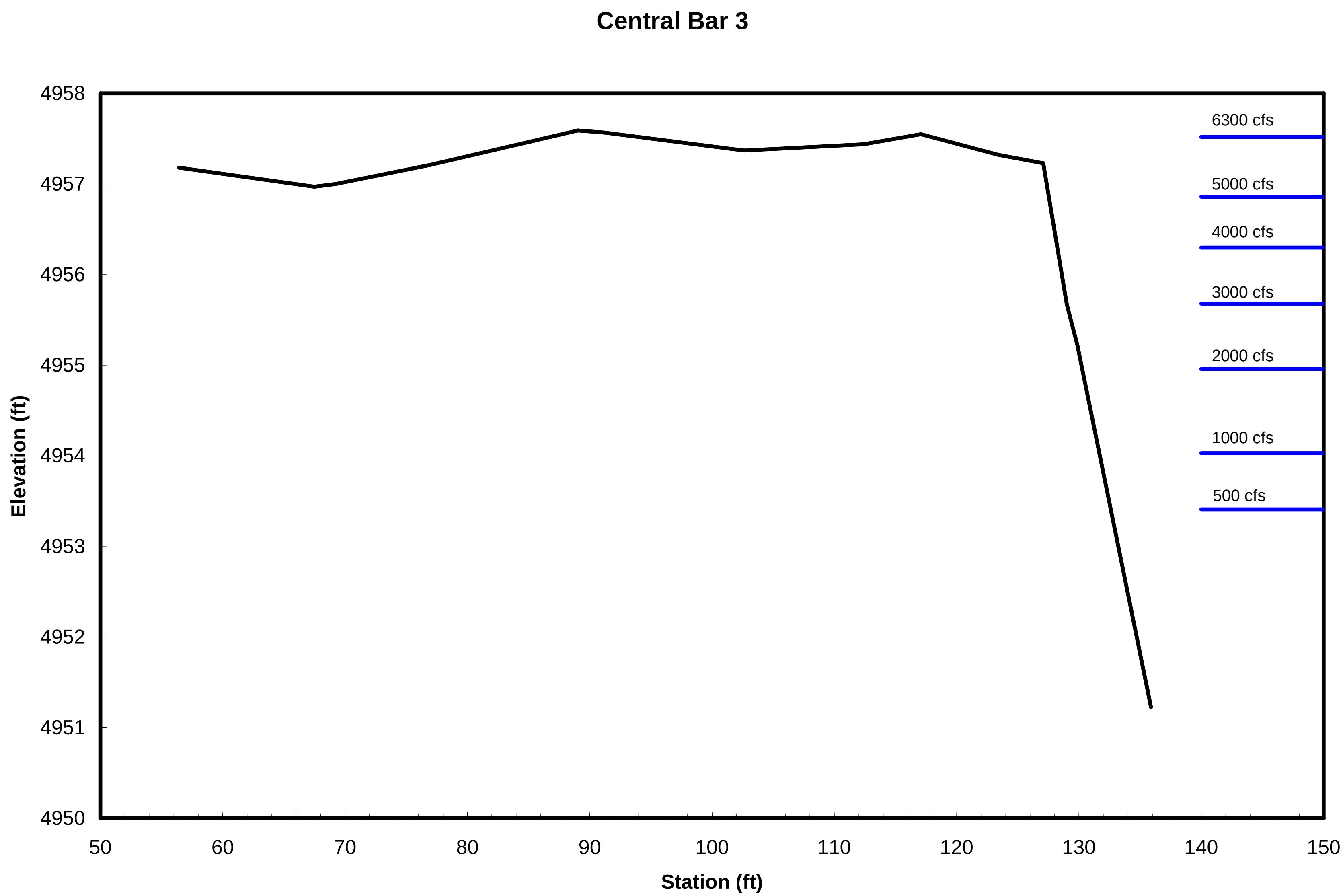


South Diversion Channel Restoration Island 3
4929
4928
4927
4926
4925
4924
4923
4922
4921
6300 cfs
5000 cfs
4000 cfs
3000 cfs
2000 cfs
1000 cfs
500 cfs
Elevation (ft)
0
50
100
150
200
250
Station (ft)

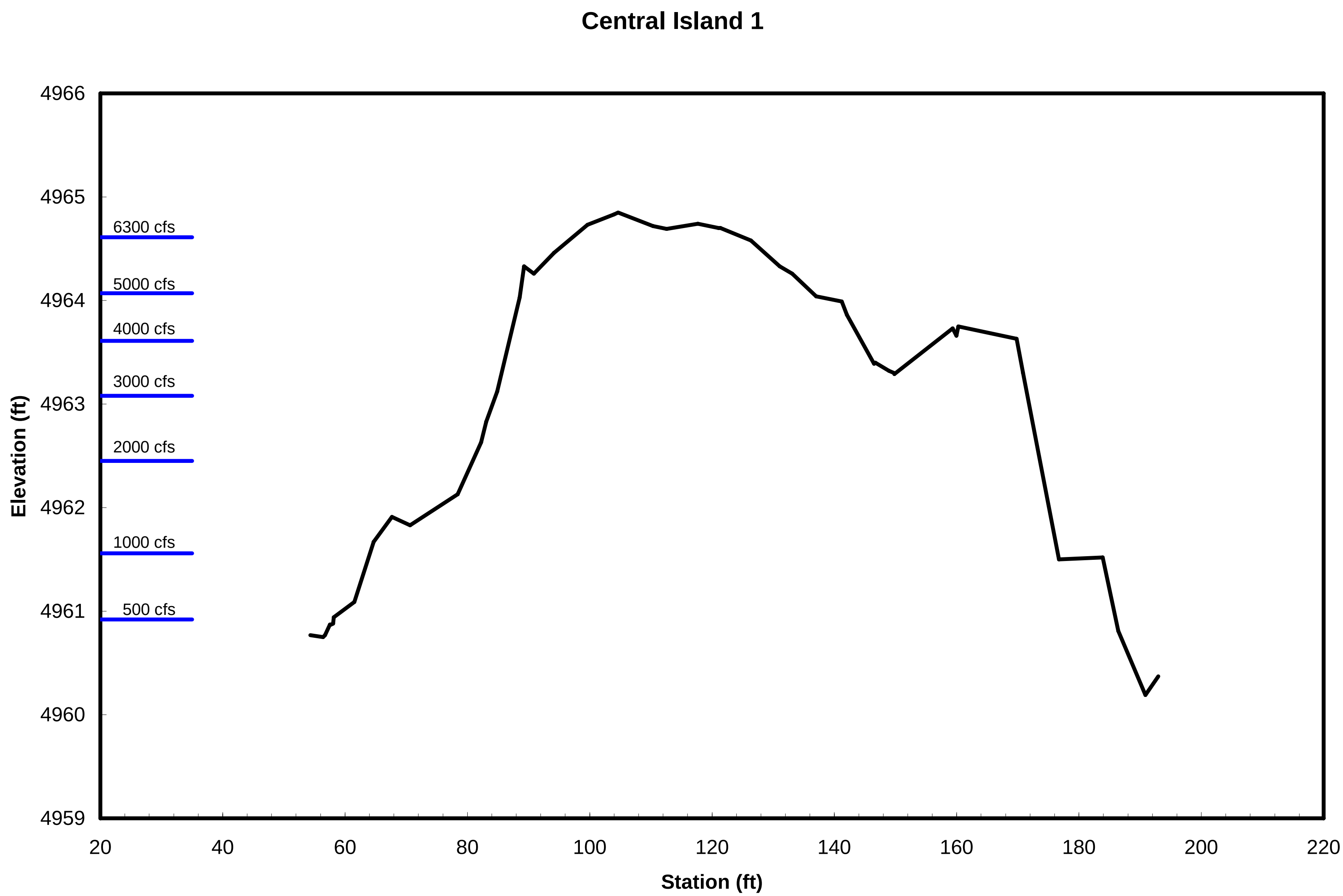

South Diversion Channel Island 4
Elevation (ft)
Station (ft)
4923
4922
4921
4920
4919
4918
4917
0
50
100
150
200
250
300
6300 cfs
5000 cfs
3000 cfs
4000 cfs
2000 cfs
1000 cfs
500 cfs

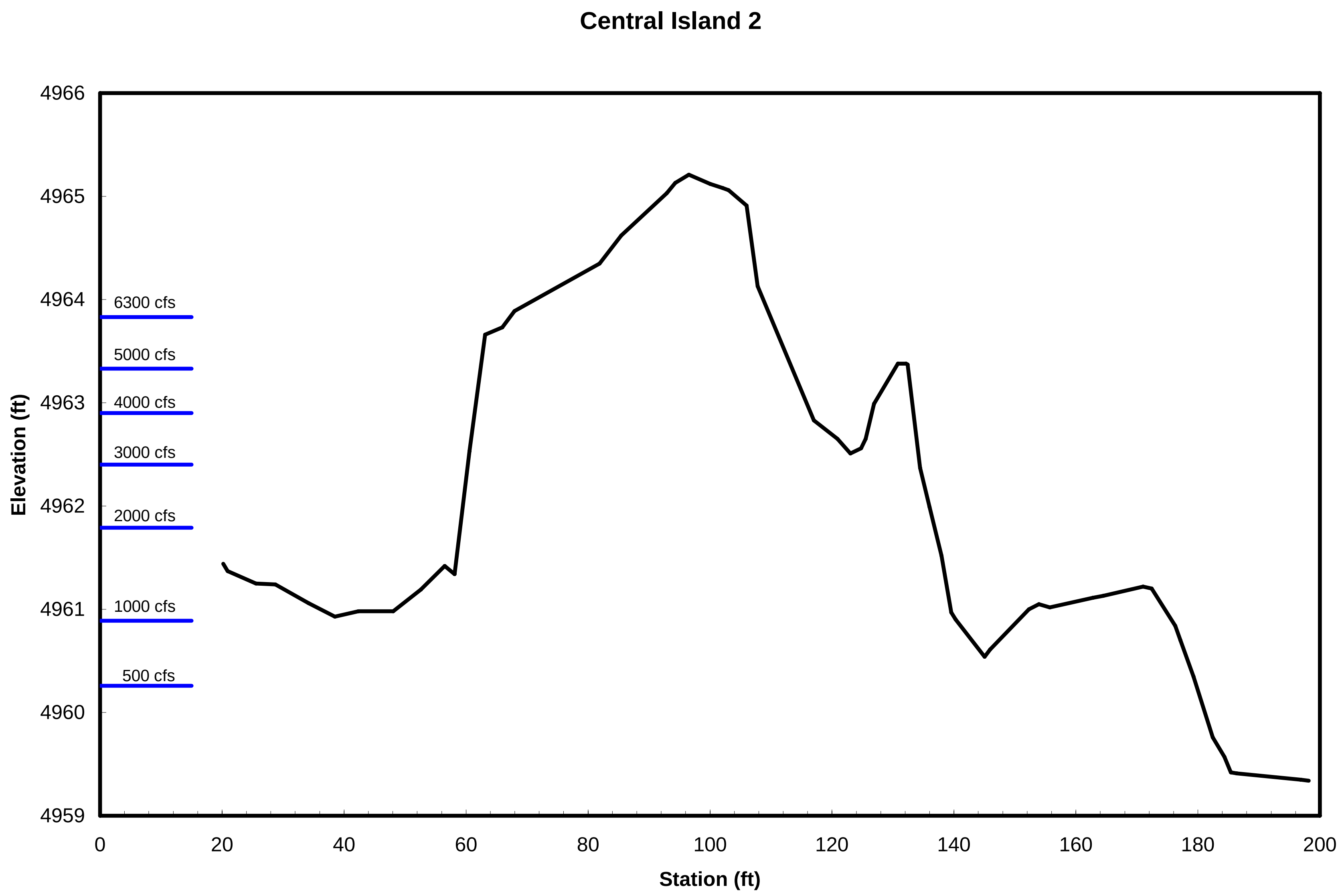


Central Bar 2
4961
4960
4959
4958
4957
4956
4955
4954
4953
Elevation (ft)
30
50
70
90
110
130
150
Station (ft)
6300 cfs
5000 cfs
4000 cfs
3000 cfs
2000 cfs
1000 cfs
500 cfs



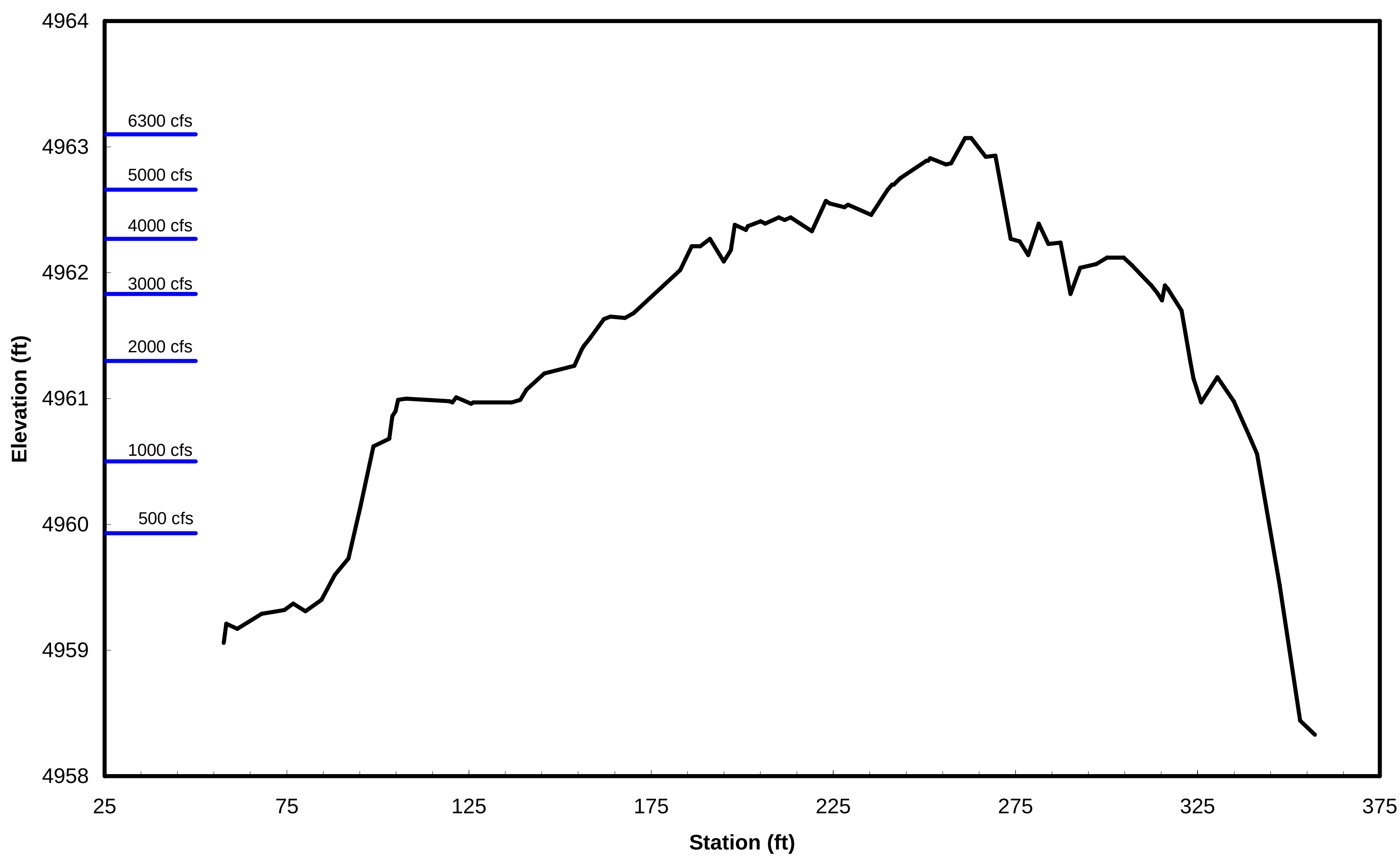
Central Bar 3
Elevation (ft)
Station (ft)
4958
4957
4956
4955
4954
4953
4952
4951
4950
50
60
70
80
90
100
110
120
130
140
150
6300 cfs
5000 cfs
4000 cfs
3000 cfs
2000 cfs
1000 cfs
500 cfs

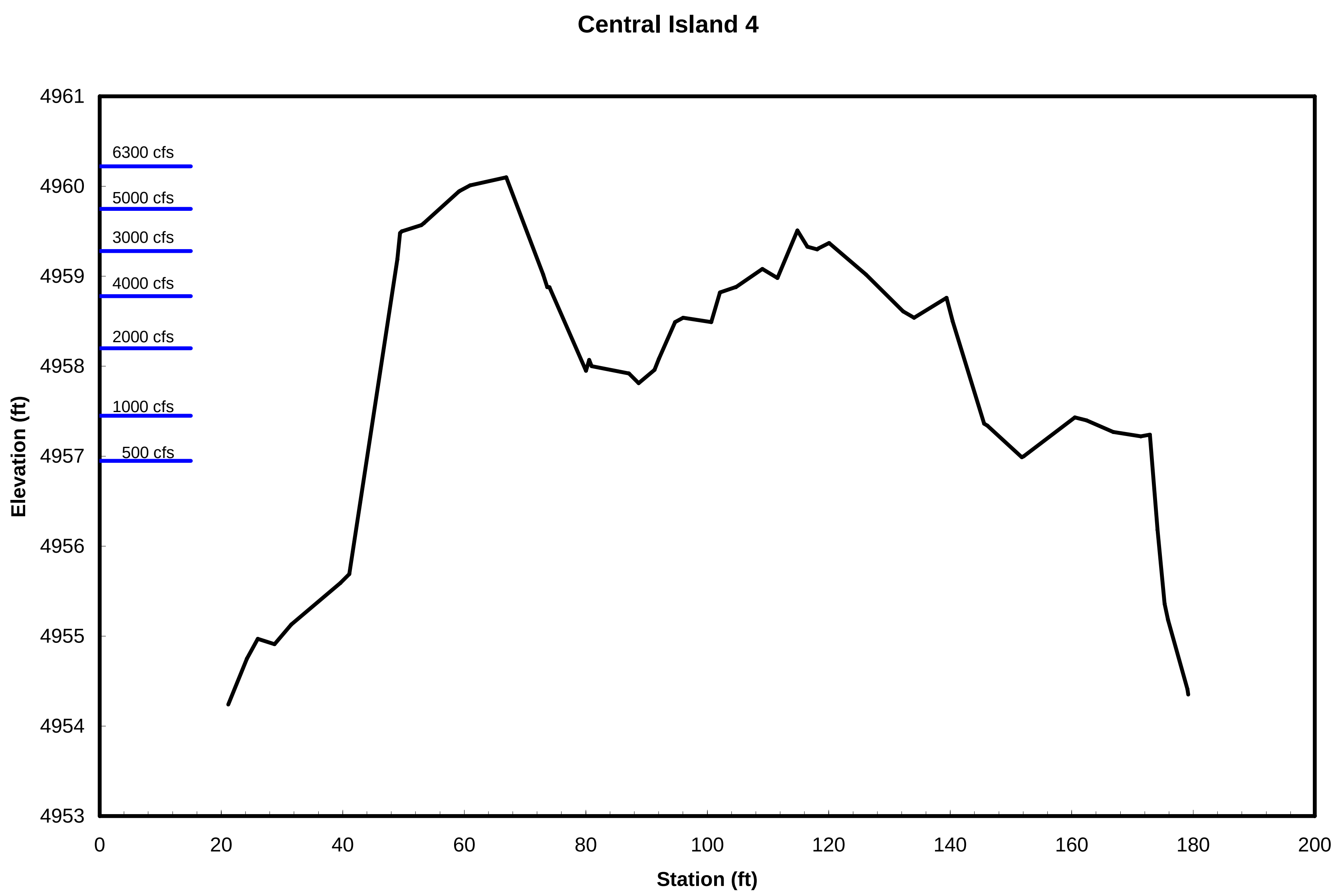

Central Island 1
Elevation (ft)
Station (ft)
4966
4965
4964
4963
4962
4961
4960
4959
20
40
60
80
100
120
140
160
180
200
220
6300 cfs
5000 cfs
4000 cfs
3000 cfs
2000 cfs
1000 cfs
500 cfs



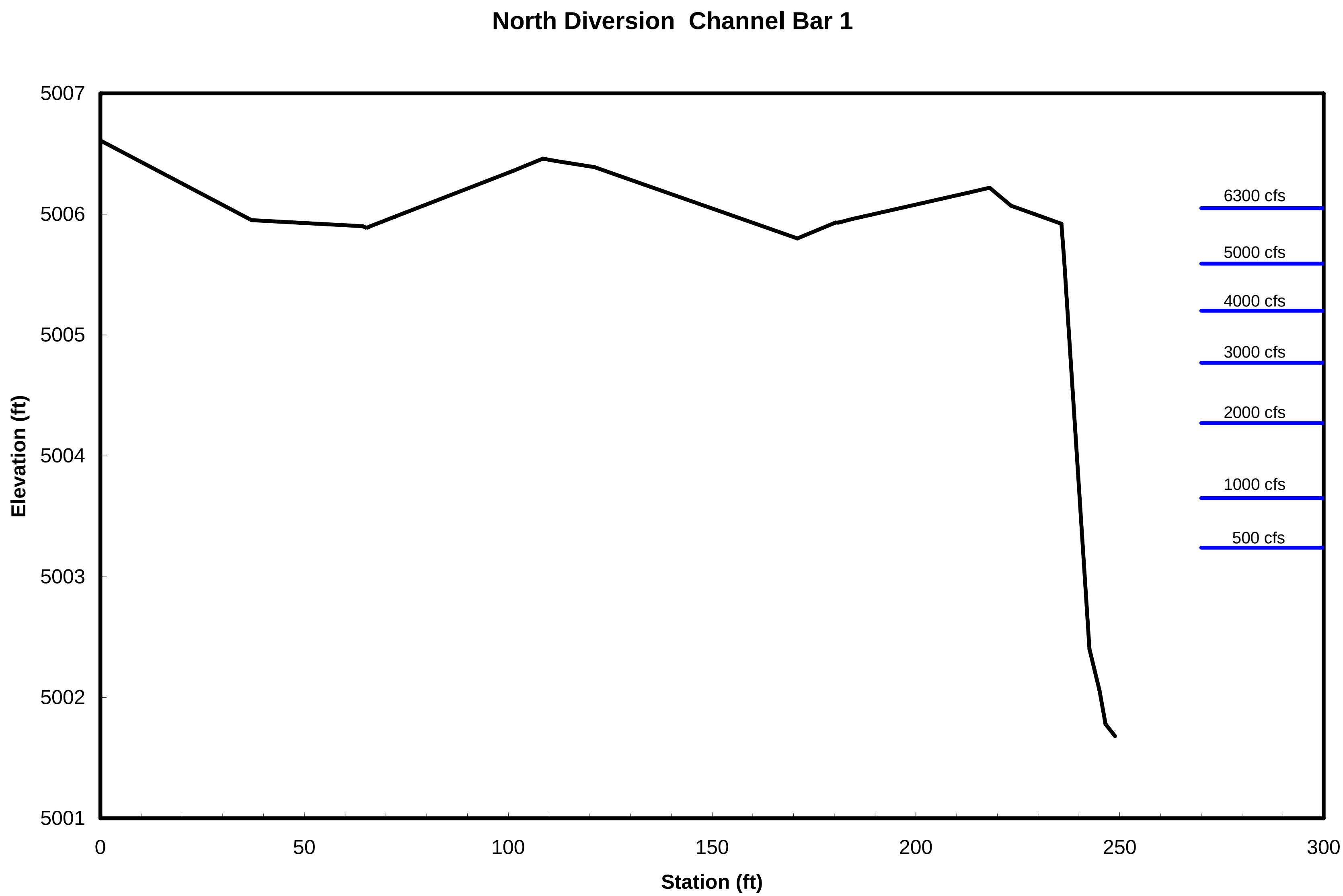
Central Island 2
Elevation (ft)
Station (ft)
4966
4965
4964
4963
4962
4961
4960
4959
0
20
40
60
80
100
120
140
160
180
200
6300 cfs
5000 cfs
4000 cfs
3000 cfs
2000 cfs
1000 cfs
500 cfs

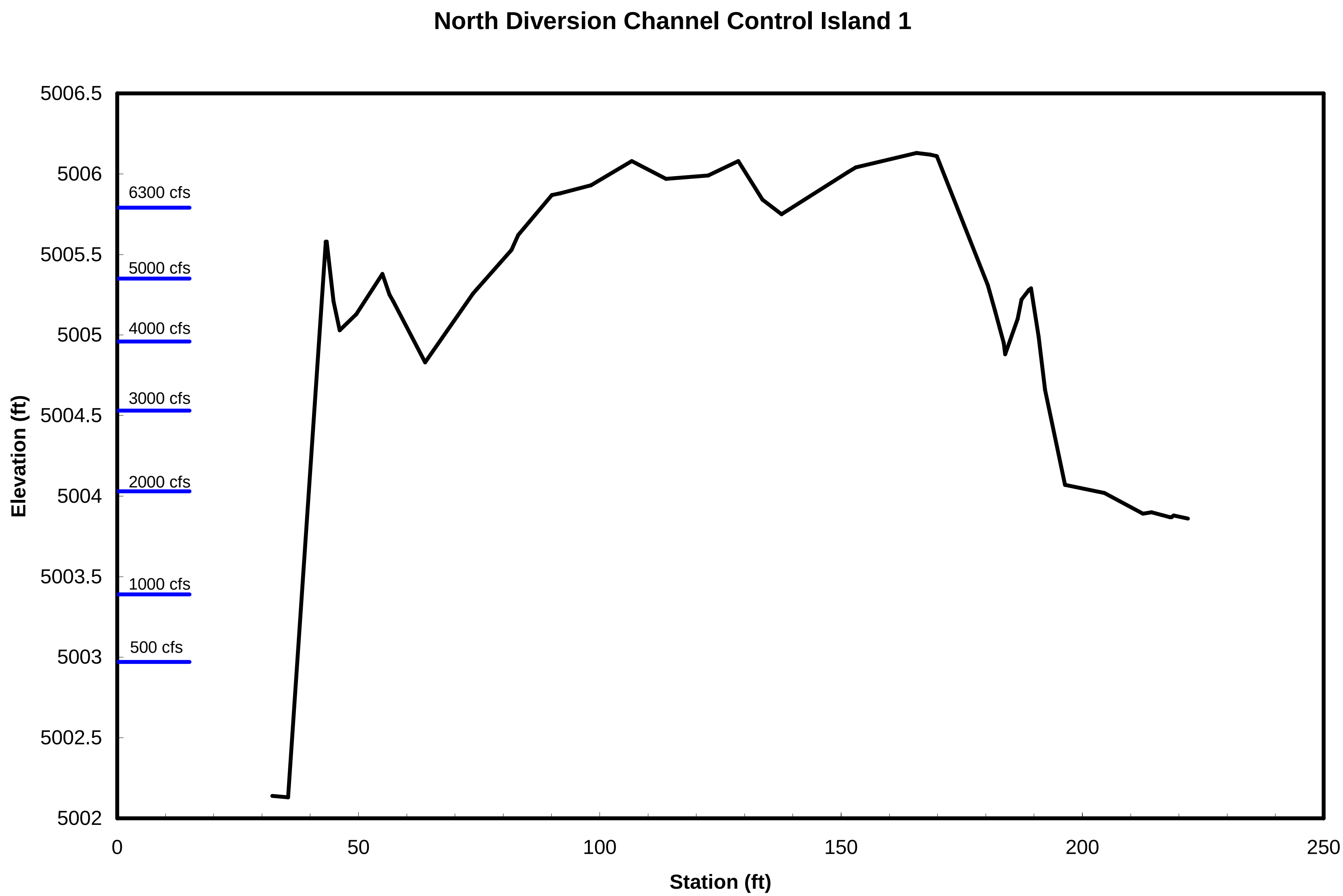
Central Island 3

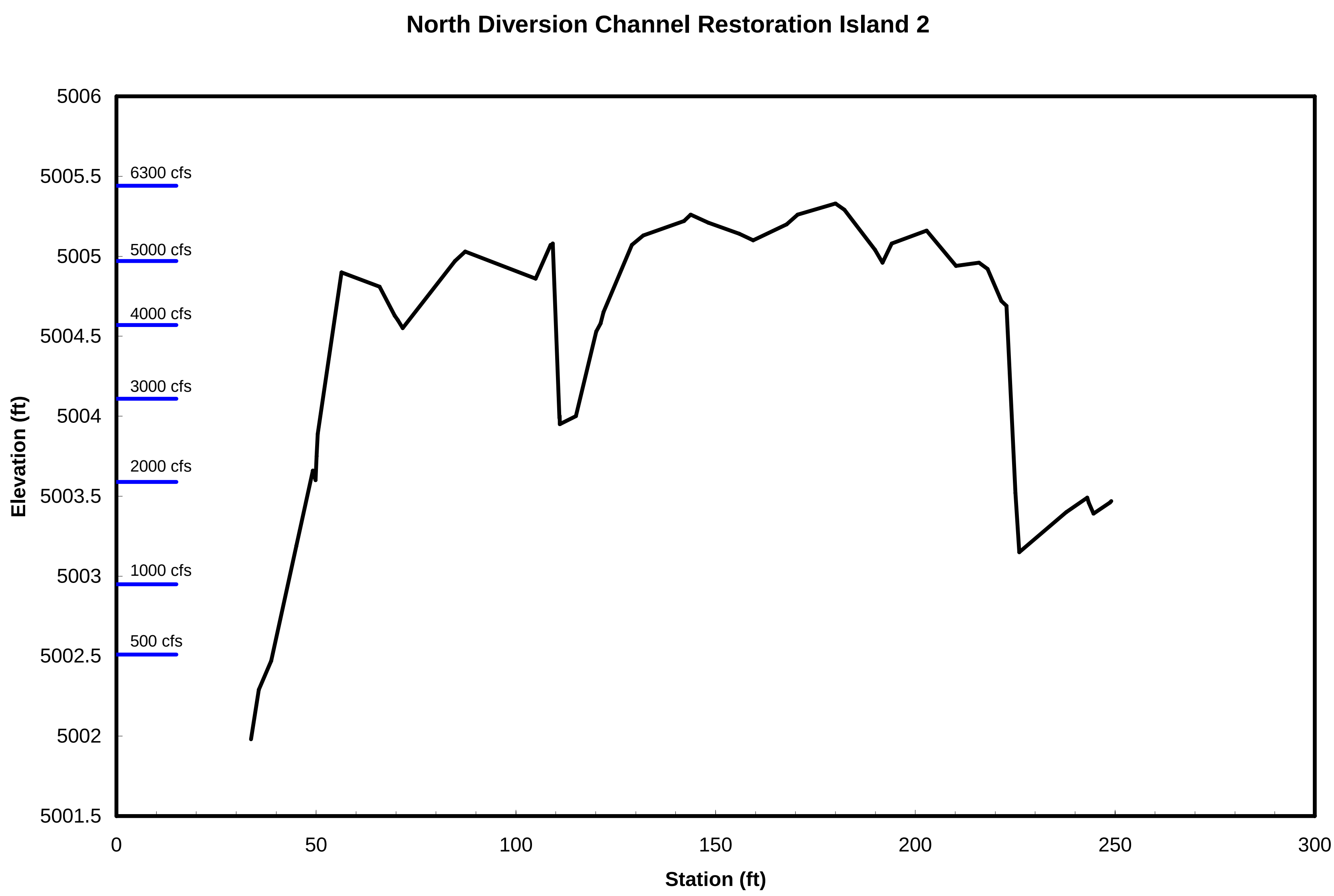


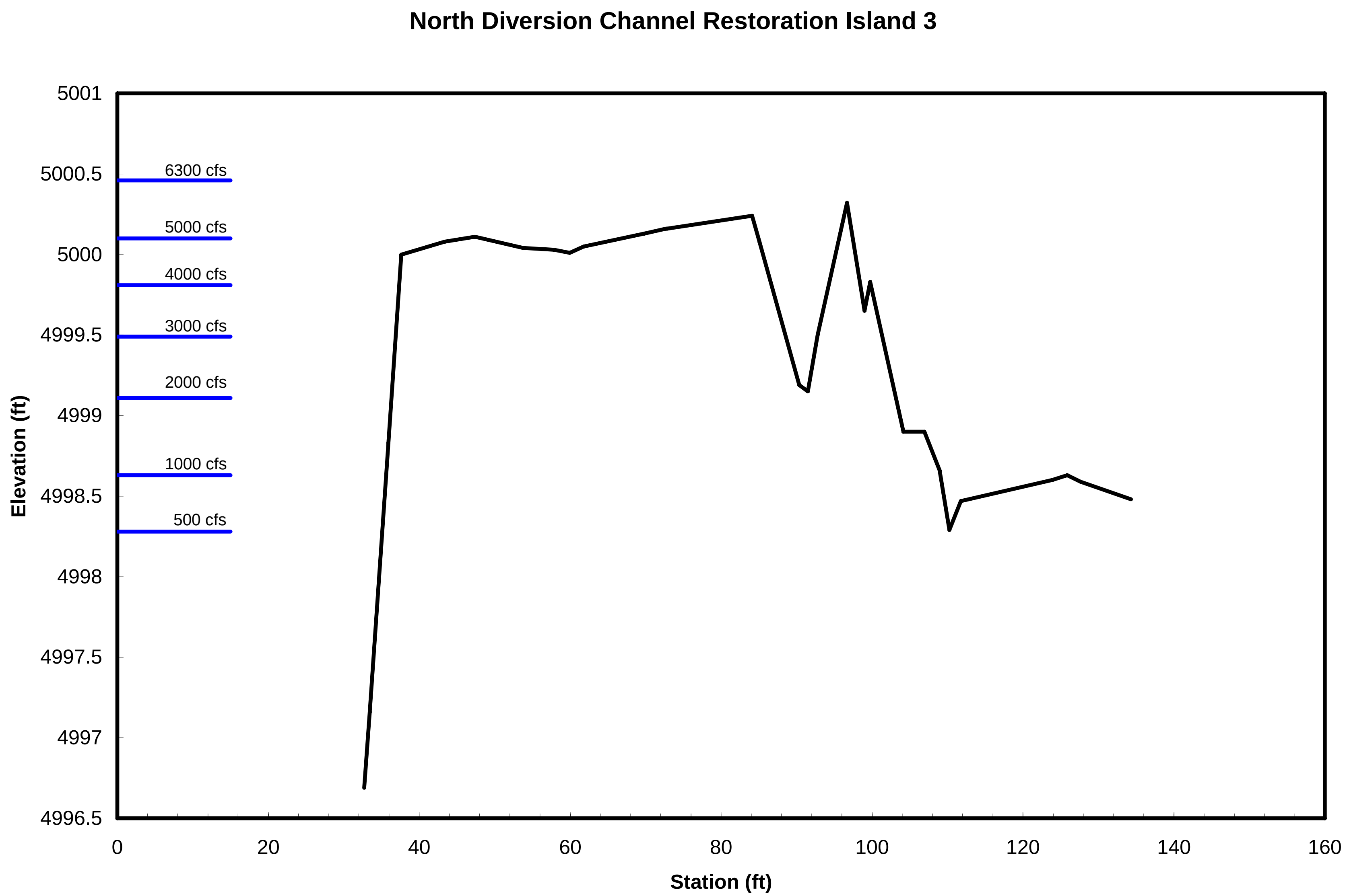


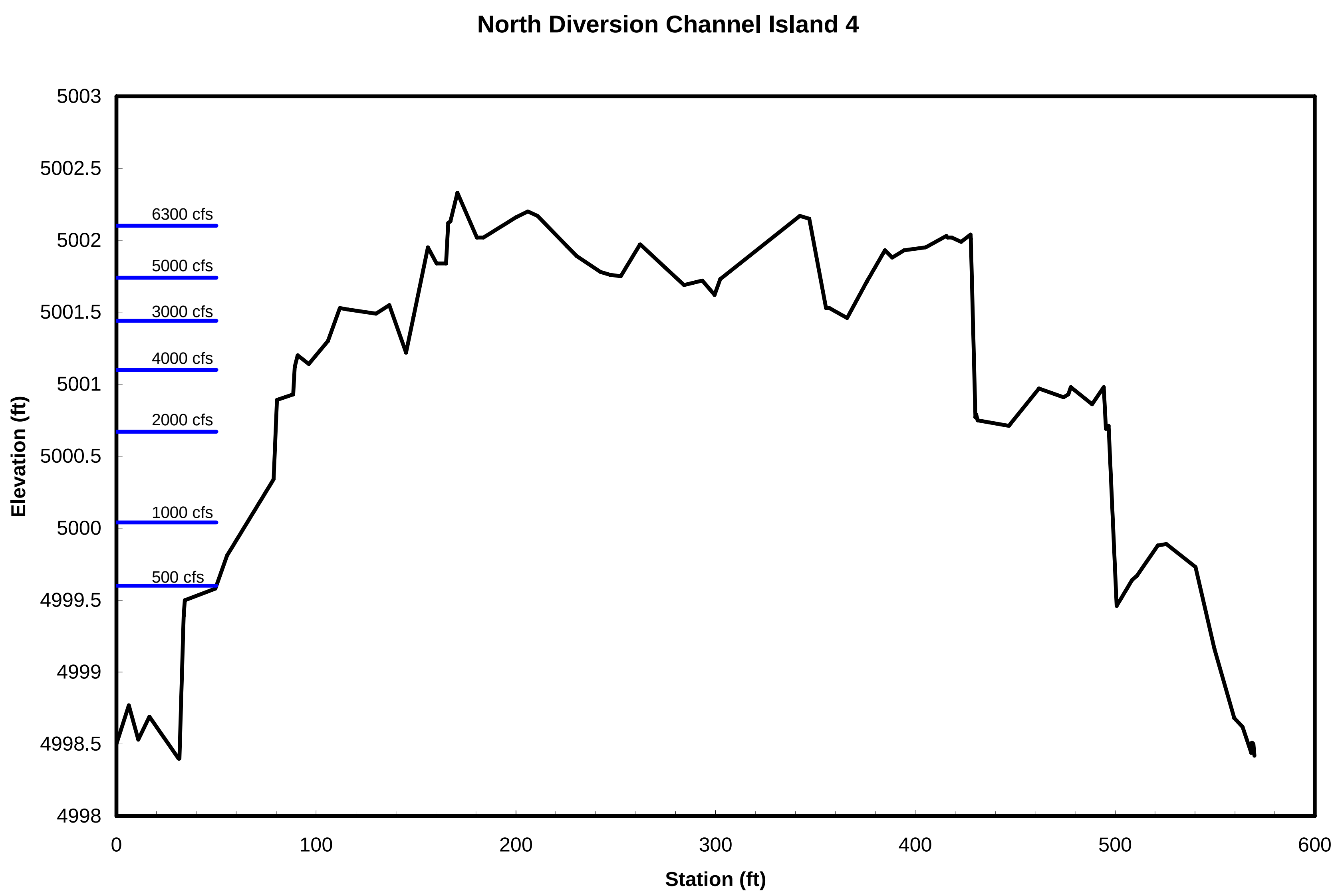
Central Island 4
Elevation (ft)
Station (ft)
6300 cfs
5000 cfs
3000 cfs
4000 cfs
2000 cfs
1000 cfs
500 cfs
4961
4960
4959
4958
4957
4956
4955
4954
4953
0
20
40
60
80
100
120
140
160
180
200


North Diversion Channel Bar 1
5007
5006
5005
5004
5003
5002
5001
Elevation (ft)
0
50
100
150
200
250
300
Station (ft)
6300 cfs
5000 cfs
4000 cfs
3000 cfs
2000 cfs
1000 cfs
500 cfs


North Diversion Channel Control Island 1
Elevation (ft)
Station (ft)
5006.5
5006
5005.5
5005
5004.5
5004
5003.5
5003
5002.5
5002
0
50
100
150
200
250
6300 cfs
5000 cfs
4000 cfs
3000 cfs
2000 cfs
1000 cfs
500 cfs


North Diversion Channel Restoration Island 2
Elevation (ft)
Station (ft)
5006
5005.5
5005
5004.5
5004
5003.5
5003
5002.5
5002
5001.5
0
50
100
150
200
250
300
6300 cfs
5000 cfs
4000 cfs
3000 cfs
2000 cfs
1000 cfs
500 cfs


North Diversion Channel Restoration Island 3
5001
5000.5
5000
4999.5
4999
4998.5
4998
4997.5
4997
4996.5
6300 cfs
5000 cfs
4000 cfs
3000 cfs
2000 cfs
1000 cfs
500 cfs
Elevation (ft)
0
20
40
60
80
100
120
140
160
Station (ft)


North Diversion Channel Island 4
5003
5002.5
5002
5001.5
5001
5000.5
5000
4999.5
4999
4998.5
4998
Elevation (ft)
6300 cfs
5000 cfs
3000 cfs
4000 cfs
2000 cfs
1000 cfs
500 cfs
0
100
200
300
400
500
600
Station (ft)

North Diversion Channel Island 5