# Aerial and Bathymetric Spatial Change Analysis of the West Bay Sediment Diversion Receiving Area, Louisiana for U.S. Army Engineer District, New Orleans (MVN) Report


by

John A. Barras[1], William C. Padgett[2],

and C. Brett Sanders[2]

[1] U.S. Army Engineering Research and Development Center, Environmental Lab; Baton Rouge, Louisiana

[2] U.S. Army Corps of Engineers, Mobile District, Operations Division, Spatial Data Branch; Mobile, Alabama

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# West Bay 1956 to 2009 Land Area Trends

## Introduction

The West Bay Sediment Diversion (MR-03) is a Coastal Wetlands Planning, Protection, and Restoration (CWPPRA) project that was constructed in 2003 to restore vegetated wetlands in the shallow open water environment of northern West Bay, roughly opposite Main Pass, on the west bank of the Mississippi River (MR03 Fact Sheet).

The purpose of this report is to provide recent land area measurements, acquired after project construction, and to provide a more detailed trend history of the West Bay project area from 1956 to 2009, a 53-year period.

## Methodology

Existing classified coastal land-water datasets developed for prior trend assessments were used as a data source for the MR-03 trend analyses (Barras et al., 2008; Barras, 2009). These datasets were developed using a standard land and water classification methodology used for prior coastal trend studies (Barras et al., 1994; Barras et al., 2003; Morton et al., 2005).

The coastal datasets were reviewed for possible mud flat and aquatic vegetation problems within the West Bay area. Five datasets required a more extensive mud flat and aquatic vegetation classification for West Bay to reduce short-term land area fluctuations (Table 1). The coastal Landsat classifications are based on a full Landsat TM 5 scene (image) land and water classification that provides the optimal land and water classification over the scene (Barras et al., 2003; Barras, 2006; Barras et al., 2008; Barras, 2009). Flats and aquatic vegetation are identified and classified when feasible, but problematic areas are sometimes present within a scene where mud flats and aquatic vegetation cannot be completely identified (Barras et al., 2003; Morton et al., 2005) . The Active Mississippi Delta, which includes West Bay, the Atchafalaya Delta, and the Wax Lake Delta, are typical of these problem areas. Landsat imagery review shows that these areas all contain broad shallow flats that may be exposed to varying degrees depending on water levels and winds. These flats are often colonized by ephemeral aquatic vegetation that varies depending on image acquisition time of year.

The fresh water environment in West Bay also supports extensive floating aquatic vegetation growth in the northern project area. Both the flats and aquatic vegetation can be misclassified as land unless a more detailed classification is used to identity these problem classes. Classified mud flats and aquatic vegetation are then typically identified as water during the final image classification and area quantification. The end result is a lowering of classified land area and a dampening of short-term land-area variability and a more reliable land area estimate within the West Bay project area than what would be provided using only the coastal land and water datasets.

Eight additional classified land and water datasets were added to fill out gaps in the data record using Landsat 5 Thematic Mapper (TM) satellite imagery provided by the U.S. Geological Survey (USGS) Center for Earth Resources Observation and Science (EROS). Mud flats and aquatics were identified for the West Bay project area and incorporated into the classified land and water data for these images. Landsat TM 5 imagery was used because the majority of the existing coastal land and water datasets are based on classified Landsat TM imagery. The Landsat data archive offers much greater temporal coverage from 1984 to 2009 than aerial photography, and the imagery is free. A 1965 photo-interpreted land and water interpretation was also added to provide an additional land area measurement between 1956 and 1978, the period of greatest land loss (Table 1; Barras et al., 2008). The spatial resolution of the 1965 classified photography was reduced to 25m x 25m to match the spatial resolution of the classified Landsat TM imagery.

Table 1: Classified land and water data summary

| Date | Julian | Data Type | Land (acres) | Water (acres) | Total (acres) | % Land | % Water | River Stage Pilot's Station[1] | River Stage Head of Pass[2] | Grand Isle Tide Gauge[3] | Data Source |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9/30/1952 | 1956.8 | habitat | 9312.5 | 2979.9 | 12292.4 | 75.8 | 24.2 | - | - | - | Barras and others (2008) |
| 1/17/1961 | 1965.0 | Tobin pan | 3989.8 | 8302.6 | 12292.4 | 32.5 | 67.5 | 1.58 | 1.13 | - | This study |
| 9/30/1974 | 1978.8 | habitat | 1223.2 | 11069.2 | 12292.4 | 10.0 | 90.0 | - | - | - | Barras and others (2008) modified[4] |
| 3/24/1980 | 1984.2 | TM | 828.1 | 11464.3 | 12292.4 | 6.7 | 93.3 | 3.1 | 1.85 | 1.86 | This study |
| 10/10/1981 | 1985.9 | TM | 760.2 | 11532.3 | 12292.4 | 6.2 | 93.8 | 3.45 | 1.96 | 1.62 | Barras and others (2008) |
| 12/3/1983 | 1987.9 | TM | 866.0 | 11426.5 | 12292.4 | 7.0 | 93.0 | 3.45 | 1.96 | 1.57 | Barras and others (2008) modified[4] |
| 10/25/1984 | 1988.8 | habitat | 1259.8 | 11032.6 | 12292.4 | 10.2 | 89.8 | - | - | - | Barras and others (2008) |
| 2/13/1987 | 1991.1 | TM | 1119.1 | 11173.3 | 12292.4 | 9.0 | 90.9 | 2.52 | 1.73 | 1.77 | Barras and others (2008) modified[4] |
| 5/6/1988 | 1992.4 | TM | 767.0 | 11525.5 | 12292.4 | 6.2 | 93.8 | 2.42 | 1.67 | 2.00 | This study |
| 3/6/1989 | 1993.2 | TM | 1149.3 | 11143.1 | 12292.4 | 9.4 | 90.6 | - | - | 1.69 | This study |
| 12/9/1991 | 1995.9 | TM | 1036.1 | 11256.3 | 12292.4 | 8.4 | 91.6 | - | - | 1.63 | This study |
| 2/16/1994 | 1998.1 | TM | 916.0 | 11376.4 | 12292.4 | 7.5 | 92.5 | 3.38 | 2.85 | 2.12 | Barras and others (2008) |
| 11/26/1995 | 1999.9 | TM | 1321.2 | 10971.2 | 12292.4 | 10.7 | 89.3 | 1.16 | 2.85 | 1.68 | Barras and others (2008) modified[4] |
| 10/6/1997 | 2001.8 | TM | 1519.1 | 10773.3 | 12292.4 | 12.4 | 87.6 | 2.11 | - | 1.89 | Barras and others (2008) modified[4] |
| 1/29/1998 | 2002.1 | TM | 1274.1 | 11018.3 | 12292.4 | 10.4 | 89.6 | 1.65 | - | 2.03 | Barras and others (2008) modified[4] |
| 10/14/2000 | 2004.9 | TM | 1473.4 | 10819.0 | 12292.4 | 12.0 | 88.0 | 1.67 | - | 1.90 | Barras and others (2008) |
| 9/15/2001 | 2005.8 | TM | 1022.9 | 11269.6 | 12292.4 | 8.3 | 91.7 | - | - | 2.28 | This study |
| 10/17/2001 | 2005.8 | TM | 1274.1 | 11018.3 | 12292.4 | 10.4 | 89.6 | - | - | 1.89 | Barras and others (2008) |
| 1/24/2003 | 2007.1 | TM | 1316.1 | 10976.3 | 12292.4 | 10.7 | 89.3 | 3.54 | - | 1.91 | Barras and others (2008) |
| 10/25/2004 | 2008.8 | TM | 1604.0 | 10688.4 | 12292.4 | 13.0 | 87.0 | 2.39 | - | 2.13 | Barras and others (2008) |
| 1/29/2005 | 2009.1 | TM | 1370.2 | 10922.2 | 12292.4 | 11.1 | 88.9 | 1.88 | - | 1.72 | This study |
| 6/6/2005 | 2009.4 | TM | 1463.5 | 10828.9 | 12292.4 | 11.9 | 88.1 | 4.6 | - | 2.23 | This study |

[1]USACE

[2]USACE Stage Data Mississippi River At Head Of Passes (LA) # 01545

[3]NOAA Grand Isle Tide Guage #8761724

[4]Dataset revised by adding adding a mud flat and aquatic vegetaion classification for West Bay.

## Discussion

The net land area change numbers are presented using the same time-periods used by Barras and others (2008) to compare and contrast coastal and area changes. Slight adjustments were made to time intervals to accommodate Landsat TM image acquisition dates for Landsat Worldwide Reference System, Path 21 and Rows 39-40 rather than the Path 22 and Rows 39-40 acquisition dates used in the 2008 study (Table 1).

Total net loss within the 12,292 acre project area between 1956 and 2009 was -7,849.0 acres, or 84.3% of the 1956 land area (figs. 1 and 2.) The greatest loss occurred between 1956 and 1965, when -5,322.7 acres, 57.2% of the project's 1956 land, was removed. The next greatest loss was an additional -2,766.7 acres, 29.7% of the project's initial land area, between 1965 and 1978. An additional -104.1 acres was lost between 1978 and 1991, accounting for 1.1 % of the 1956 project land area. The 1991 to 2001 period showed a slight land gain of 400 acres. The 2001 to 2009 period was basically flat, showing a slight loss of -45.7 acres from 2001 to 2004, followed by another slight land loss of -157.2 acres between 2004 and 2007, and a final slight land gain of 147.3 acres from 2007 to 2009.

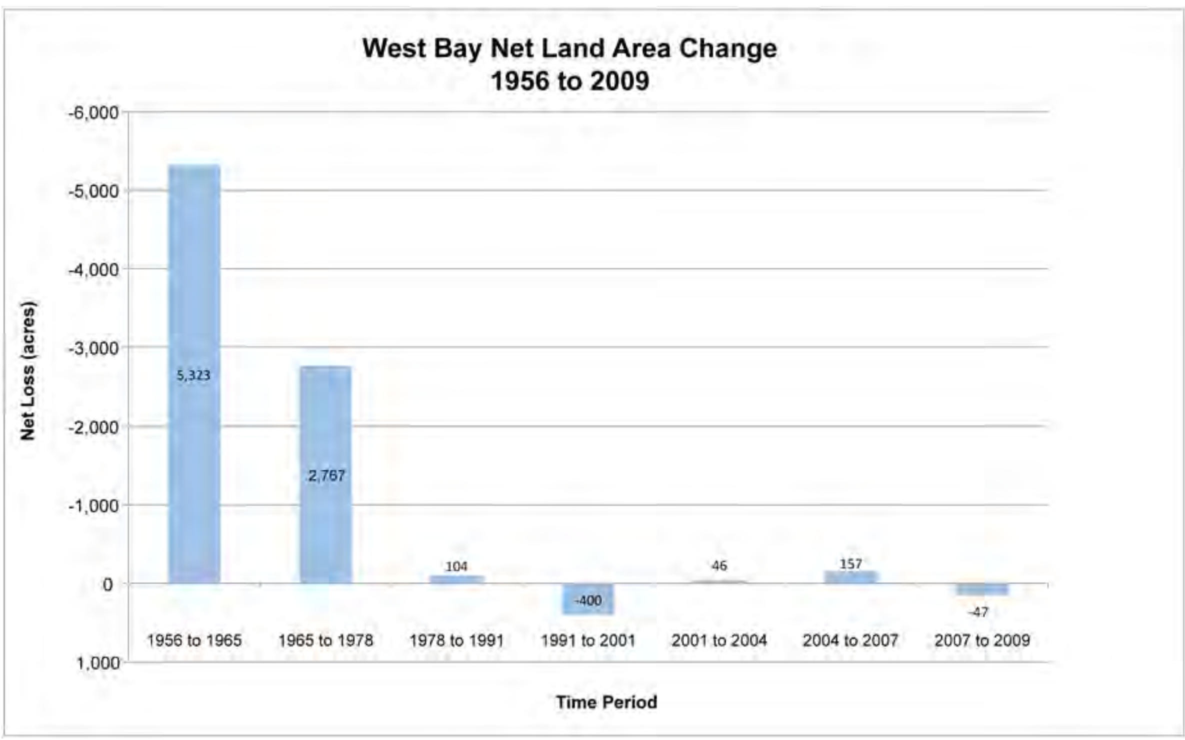


*Figure 1*: West Bay Net Land Area Change 1956 to 2009 (Produced by ERDC-EL, Baton Rouge)

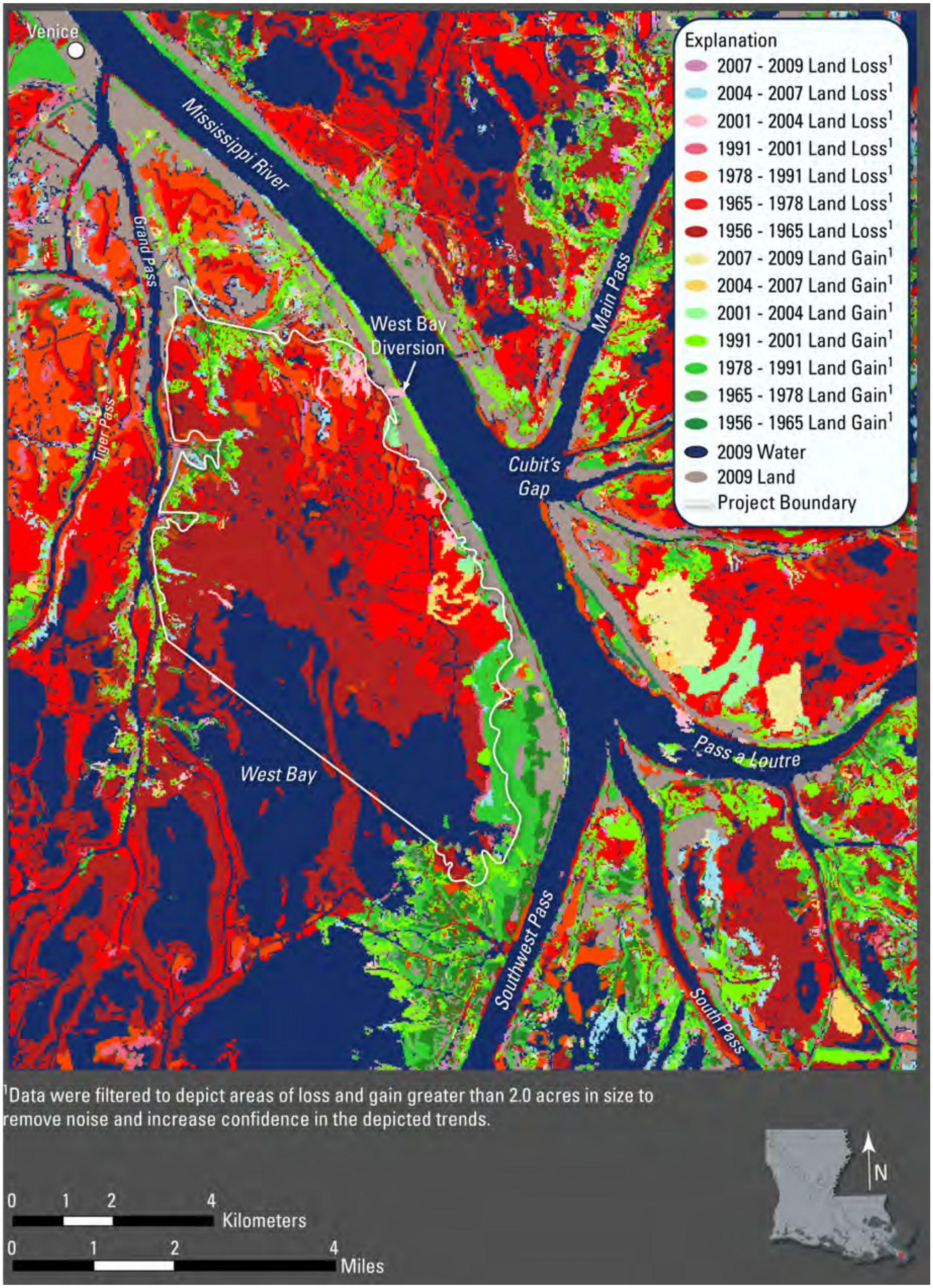


*Figure 2*: West Bay Trend Map 1956 to 2009 (Produced by ERDC-EL, Baton Rouge)

Hurricane Katrina (August 29, 2005) caused minimal loss within the project area, unlike the significant surge-induced losses observed east and northeast of South Pass (Barras 2006; Barras 2007; Figs. 3A, 3B, and 3C). The Landsat TM-derived land area measurements agree well with high-resolution aerial photography land area measurements produced for West Bay project monitoring by the USGS (Map ID: USGS-NWRC 2009-02-0378). The difference between the 2002 TM-derived land area estimate and the photography-based estimate is 164 acres; the difference between the 2008 measurements is 111.0 acres.

Plotting all of the data points over time provides a broader picture of land area trends and short-term variability caused by differing image environmental acquisition conditions (Figure 3). The majority of land loss within the project area occurred between 1956 and 1965, a period of eight years. Loss continued to an average low land area of 818 acres, with a standard deviation of ± 53.6 acres, between 1984 and 1987. Some small land gain occurred from 1987 to 2009. The average project land area after 2002 is 1,360.6 acres, with a standard deviation of ±185.4 acres. Most of the land gain, based on imagery review, is attributable to placement of dredge material in the southeastern project area, adjacent to the west bank of the Mississippi River, starting in the late 1980s. Some minimal land growth appears to have occurred in the northern and northwestern project area during this period. A simple linear regression-based land area change estimate provides a moderate correlation ($r^2 = 0.59$; $p = < 0.001$) of land growth with time of 23.8 ±4.6 acres/year from 1984 to 2009 while visually depicting short-term land area classification variability (Figure 4). A similar regression from 2004 to 2009 shows no relationship of land growth with time ($r^2 = 0.05$; $p = 0.545$). The only persistent land gain after 2004 outside of normal variation occurred in 2005 from placement of an approximate 140 acres of spoil material (based on Jan. 30, 2009 TM 5 imagery) within the central project area, adjacent to the west bank of the Mississippi River opposite Cubit's Gap. An estimated 45 acres of land gain (Oct. 15, 2004 TM 5 imagery) also formed immediately south of the West Bay cut (Figure 2).

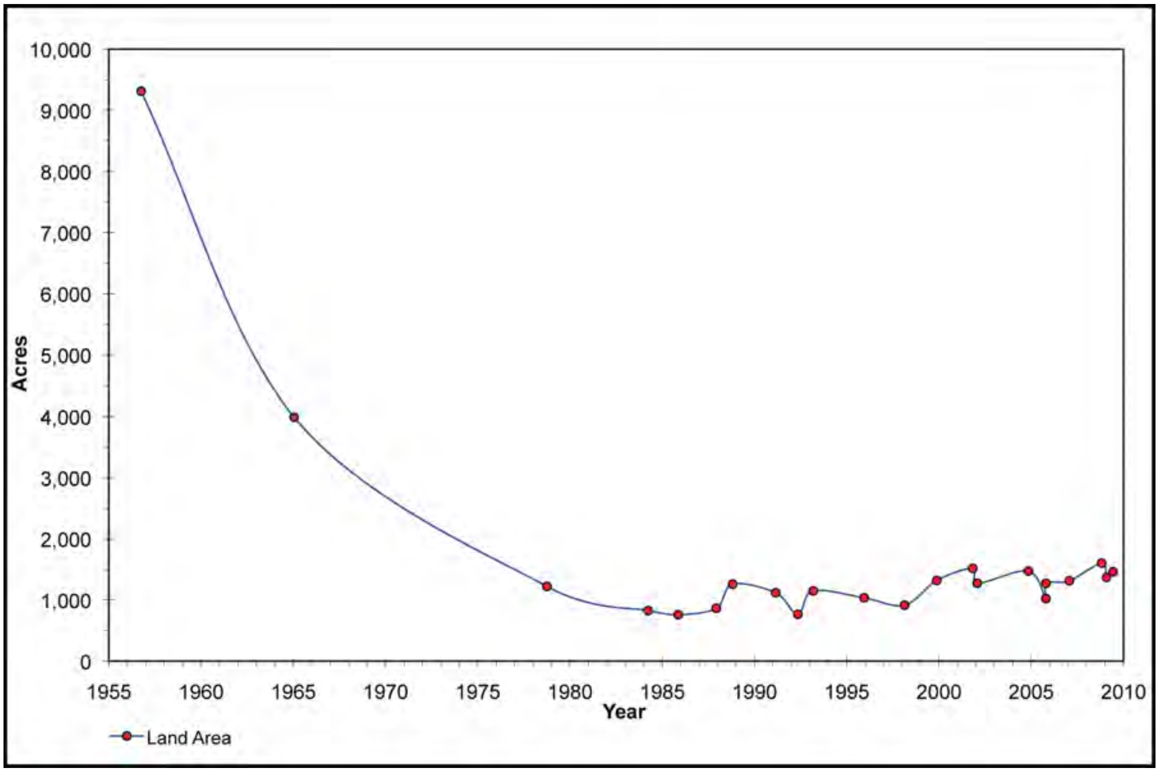


*Figure 3*: West Bay Land Area 1956 to 2009 (Produced by ERDC-EL, Baton Rouge)

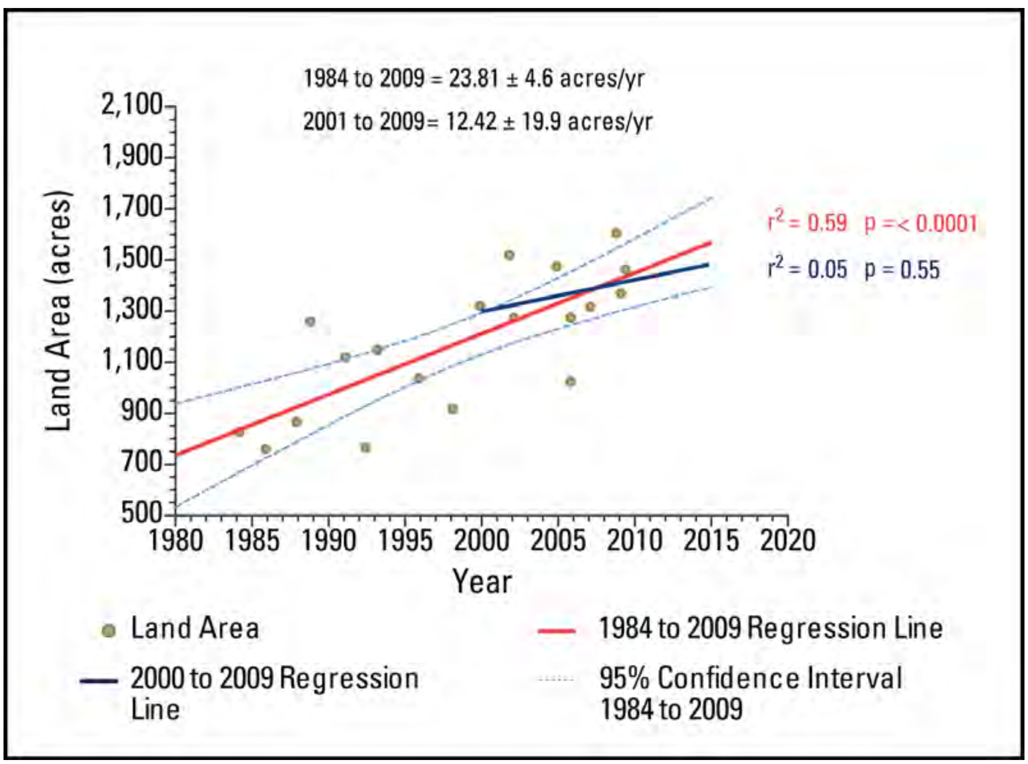


*Figure 4*: West Bay Land Area Trends 1984 to 2009 (Produced by ERDC-EL, Baton Rouge)

The lowest land area measurements with time, used in the 1984 to 2009 regression, are May 7, 1992, February 17, 1998, and September 16, 2005 (Figure 4, Table 1). The measurements are associated either with higher river stages and tidal levels or with an immediate post-2005 hurricane area estimate, coupled with a high tide level. Conversely, the highest land area estimates were obtained from the 1988 National Wetlands Inventory habitat data acquired on October 1, 1988, October 7, 2001, and October 26, 2008 (Figure 4, Table 1). The October 1, 1988, datapoint is a date placeholder for the 1988 National Wetlands Inventory Habitat dataset, based on aerial photography interpretation, that was acquired in the fall of 2008. The exact acquisition date for the 1988 photography used to photo-interpret the 1988 habitat data is unknown. The October 7, 2001, image was obtained at moderate water levels with some flat exposure but contained non-senesced aquatic vegetation that could not be completely identified (Table 1). The October 26, 2008, image was acquired under conditions similar to the image from October 7, 2001.

## Conclusions

### *1956 to 1978 Period*

The loss of 57.2 % of the West Bay project's land area between 1956 and 1965 indicates possible hurricane surge-induced loss from one of the larger storms that impacted the Louisiana Coast between 1956 and January 18, 1965. Likely candidates include Hurricane Audrey ( June 27, 1957), a Category Four storm that made landfall at Cameron, Louisiana; Hurricane Ethel (September 15, 1960), a Category One storm that weakened overnight from a Category Five storm just south of the Mississippi Delta; and Hurricane Hilda (October 3, 1964) a Category Two storm that made landfall at Marone Point, Louisiana. The surge impacts of Hurricane Katrina, Hurricane Rita (September 24, 2005), Hurricane Gustav (September 1, 2008), and Hurricane Ike (September 13, 2008) demonstrate that hurricanes can cause large scale land loss over short time periods (Barras, 2006; Barras 2007, Barras et al., 2008; Barras, 2009).

Older decadal or greater land loss updates lacked the temporal specificity to separate episodic land loss from other types of loss, particularly in areas undergoing rapid change such as the Mississippi Delta Plain (Barras et al., 1994; Barras et al., 2003; Britsch and Dunbar, 1993). Examination of 1956 and 1957 aerial photography of the marsh 5 km east of Ironton, Louisiana, by the primary author shows evidence of rapid land loss occurring within a year, likely related to Hurricane Audrey. Hurricane Rita's surge caused marsh shearing and pond expansion 11 km east-northeast of the Ironton location in 2005 (Barras 2007; Figures 11A and 11B). The area is located 84 km northeast of West Bay but is 60 km due east of West Bay. Hurricane Rita's landfall near Johnson's Bayou, Louisiana, was 31 km east of Hurricane Audrey's landfall at Cameron, Louisiana. Significant surge-removed marsh at the Ironton location may indicate that similar loss processes occurred at West Bay. Unfortunately, 1958 or 1961 aerial photography is needed to link observed loss to individual storms.

An additional 29.7% of the project's 1956 land area was lost between 1965 and 1978. West Bay was directly impacted by Hurricane Betsy (September 11, 1965, Category Four) and by Hurricane Camille (Aug. 17, 1965, Category Five). It is possible that some of the land loss incurred during this 13-year period is related to these storms, but the relationship cannot be verified without obtaining and interpreting event-bracketing aerial photography. The 1956 to 1978 period accounts for 7,205.3 acres or 90.1 % of the 7,996.3 acres of total land loss occurring within the project area between 1956 and 2009. The 1965 dataset eliminates consideration of either Hurricane Betsy or Hurricane Camille as the primary cause of land loss in the project area.

*1978 to 2009 Period*

The 1979 to 2008 period shows that project land area declined to an average of 818.1 ± 53.6 acres in the mid-1980s and then increased to an average of 1,360.6 ±185.4 acres after 2002, primarily because of placement of dredge material in the southeast project area. Average land gain was 23.8 ±4.6 acres/year from 1984 to 2009 (Figure 4). Land area measurements after 2001 showed no discernable linear gain trend with time. The most noticeable persistent area of land gain was from placement of an approximate 140 acres of spoil material (based on January 30, 2009, TM 5 imagery) within the central project area adjacent to the west bank of the Mississippi River opposite Cubit's Gap (Figure 5). An estimated 45 acres of land gain (October 15, 2004, TM 5 imagery) also formed immediately south of the West Bay cut.

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Barras, J. A., Bourgeois, P. E., & Handley, L. R. (1994). *Land loss in coastal Louisiana 1956-90: National Biological Survey*. National Wetlands Research Center Open-File Report 94-01, 4 p.

Barras, J., Beville, S., Britsch, D., Hartley, S., Hawes, S., Johnston, J., Kemp, P., Kinler, Q., Martucci, A., Port-House, J., Reed, D., Roy, K., Sapkota, S., & Suhayda, J. (2003). Historical and projected coastal Louisiana land changes 1978–2050. Appendix B of Louisiana Coastal Area (LCA), *Louisiana Ecosystem Restoration Study: U.S. Geological Survey Open-File Report 2003-334,* 39p. Available online at http://pubs.er.usgs.gov/usgspubs/ofr/ofr03334

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Morton, R., Bernier, J., Barras, J., & Fernia, N. (2005). *Rapid subsidence and historical wetland loss in the Mississippi Delta Plain, likely causes and future implications: U.S. Geological Survey Open-File Report 2005-1216,* 124 p. Available online at http://pubs.usgs.gov/of/2005/1216/

## West Bay Depth Analysis Process Report

### Introduction

This section explains the processes that were necessary to generate and subsequently analyze bathymetric data over time in a diversion project off of the Mississippi River delta in Southern Louisiana. Using a geospatial information system (GIS), data from three bathymetric surveys were utilized, generated, analyzed and plotted as part of a larger analysis of the effect a diversion has had on West Bay since its creation in 2003.

### Survey Comparison Scope

The Spatial Data Branch performed a bathymetric survey comparison of pre-construction and a pending new survey taken in FY09. The bathymetric survey comparison has been generated using a custom survey tool application to display the subaqueous land contours and profile. A third dataset was provided to use for analysis if a plausible spatial match existed.

### Survey Data Preparation

The 2003 and 2009 data are based on LIDAR surveys, and the 2009 survey transect lines are an exact overlay with the 2003 data except for the position of the beginning and end points. These data were in Excel format and were imported into ArcGIS using the eCoastal Tools designed for USACE for assessing different coastal land and sea conditions. 3-D point features were generated from source data files using the provided longitude and latitude for X and Y coordinates; the elevation values served as a text attribute and a Z coordinate.

Data from 2009 were provided in both 1999 and 2003 geoids. The original 2003 survey was based on the 1999 geoid, so in the interest of keeping the data consistent, the 1999 geoid data from the 2009 survey were used in this analysis. The 2003 geoid data were imported into the GIS; they represent the current geoid standard and are available for reference. It should be noted and taken into consideration in this study that the elevation difference in the area of interest for this project was -.53 feet between the geoid used in the most recent study and the current geospatial standard. The resulting point features were projected into NAD83 State Plane coordinate system, Louisiana South, FIPS zone 1702, with units of feet. This projection was used for all subsequent data. The elevation is based on the WGS84 ellipsoid for all datasets, and mean sea level is referenced by the elevation of 0. A single boundary polygon was created to encompass the extents of both surveys to create 3-D surfaces with exactly the same bounds for accurate comparison.

2006 data were captured by different means, but because the survey transect lines were close enough to the 2003 and 2009 survey transects to be spatially relevant in this study, they were utilized as well. There were many more collection points resulting in a very dense survey, so some extra steps need to occur to eliminate duplicate points and to import a much larger dataset than the other two surveys. These transect lines covered a dissimilar shape and significantly smaller area than the other datasets, so a different boundary polygon was created around the 2006 survey for comparison to the 2003 and 2009 surfaces.

Neither of these boundaries includes the diversion cut itself as there were no data supplied in the 2003 survey. The cut did not yet exist, and a disparate survey of the crevasse alone was provided in the 2009 data. A third boundary was generated around that dataset to provide a bathymetric representation in its current state and for volume calculation.

**Data Analysis/Map Production**

Using the eCoastal Tools, the survey point data from the various years were converted into surface raster elevation models for analysis. This format provides several display options for representing elevation on a map as well as performing 3-D analyses. Volume calculations, cross section profiles, depth difference, and cut/fill analyses were performed on the data, and several map products were produced.

Some anomalous data readings occurred when comparing the different surveys. One such anomaly exists along the north and west areas of the surveys. The depth analysis shows areas that are generally hourglass shaped with a large depth difference because of  inconsistent data between the surveys and the terrain.

## Map Products

*Survey Overviews (4)*

The survey overviews indicate the location and depth of original data transects.

- West Bay Crevasse 2009 Survey Overview (Figure 5)
- West Bay 2003 Survey Overview (Figure 6)
- West Bay 2006 Survey Overview (Figure 7)
- West Bay 2009 Survey Overview (Figure 8)

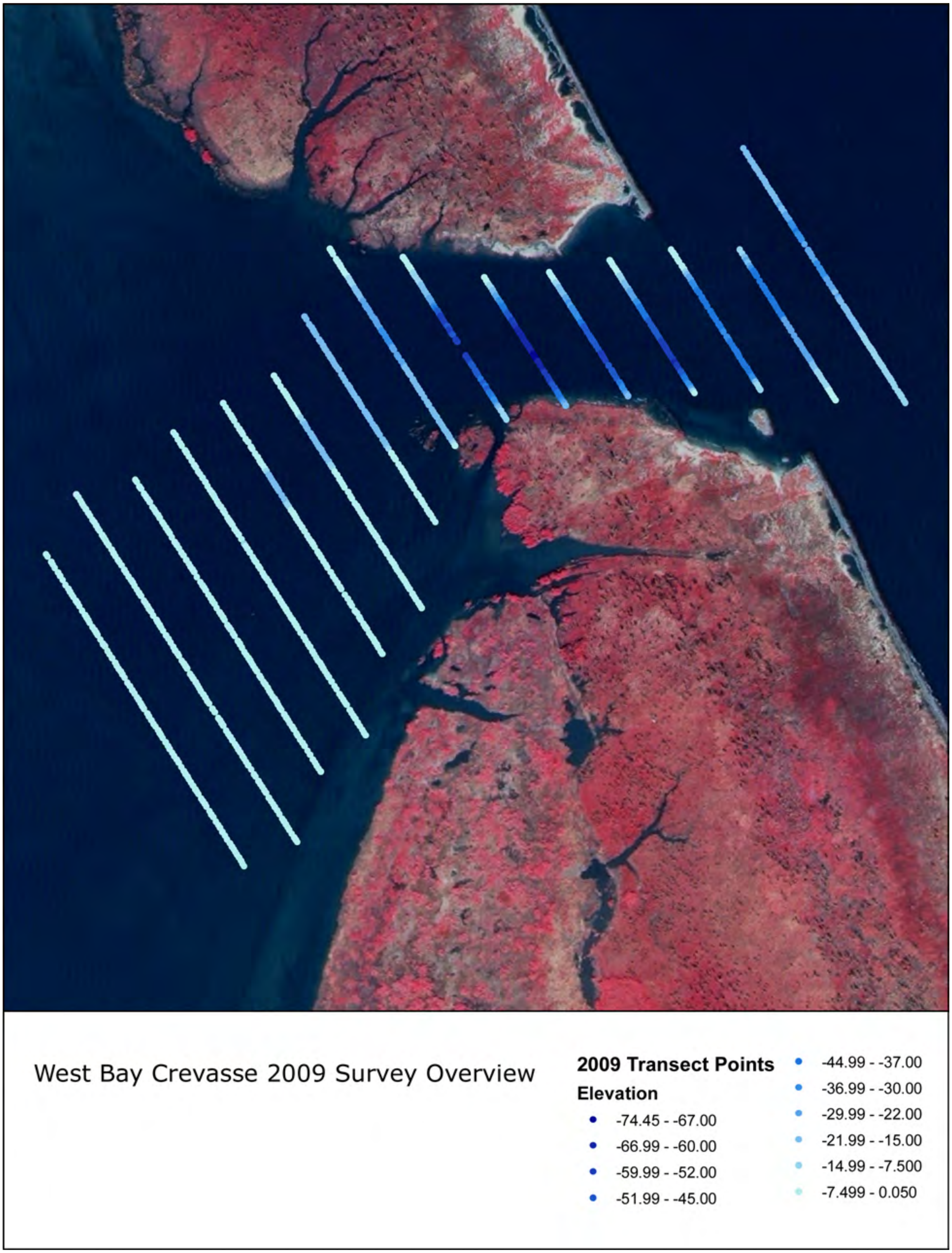


Figure 5: West Bay Crevasse 2009 Survey Overview (Produced by the Spatial Data Branch, Mobile District)

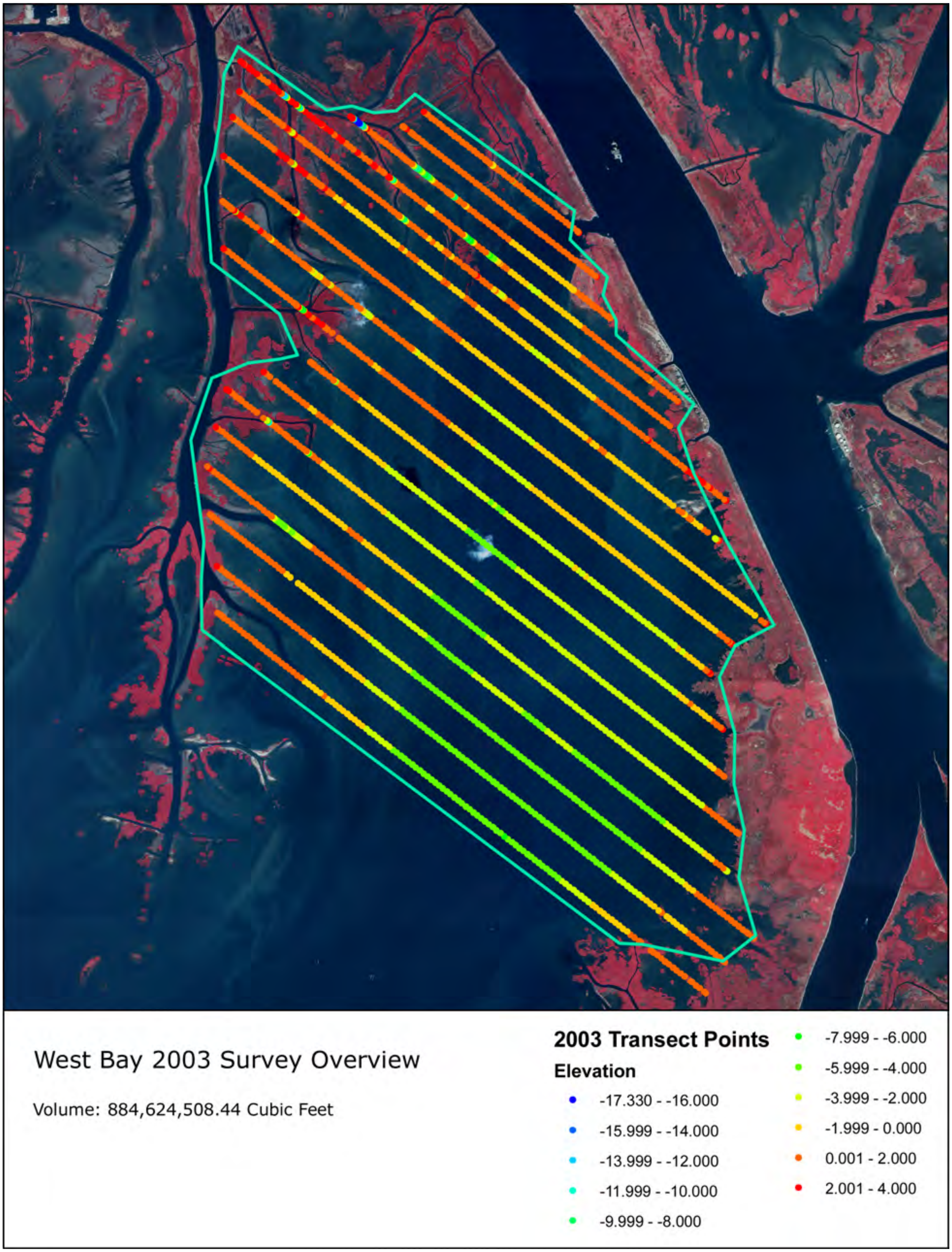


Figure 6: West Bay 2003 Survey Overview (Produced by the Spatial Data Branch, Mobile District)

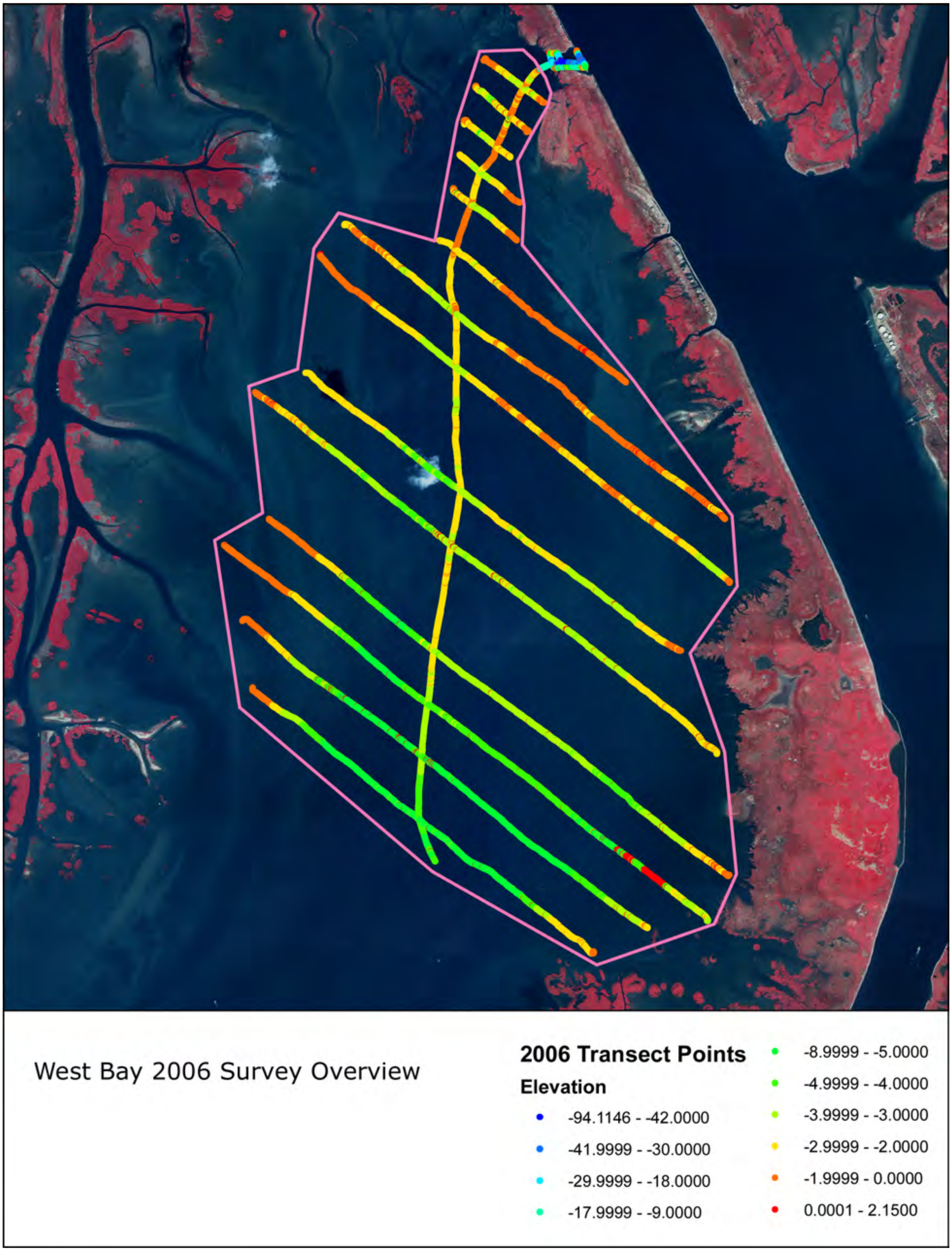


Figure 7: West Bay 2006 Survey Overview (Produced by the Spatial Data Branch, Mobile District)

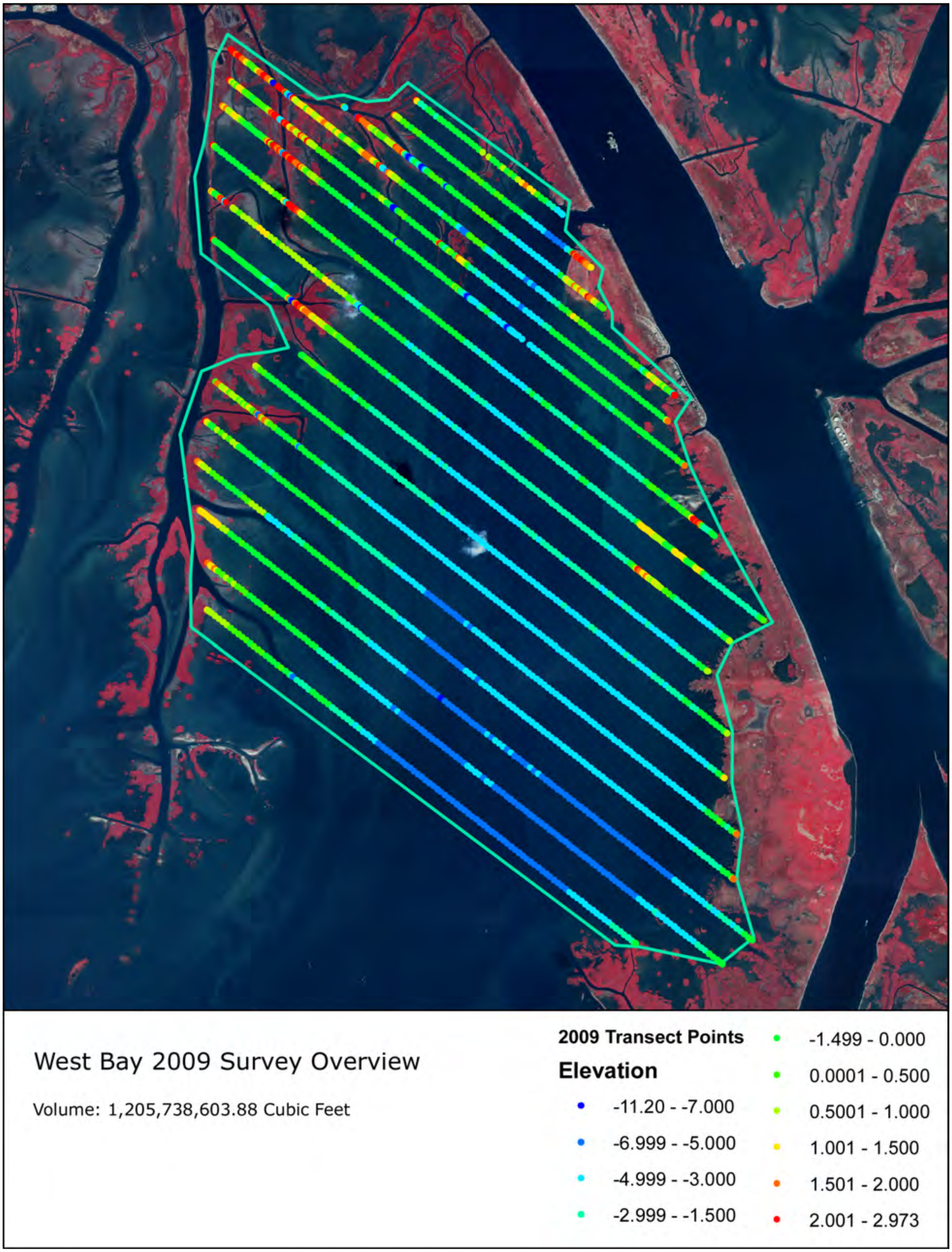


Figure 8: West Bay 2009 Survey Overview (Produced by the Spatial Data Branch, Mobile District)



Mobile District spatial data

*Depth Analysis*

The 3D bathymetric surfaces were compared to previous year surveys to generate a surface that represents the difference depths between the surveys. The eCoastal Tools created the difference surface and performed a detailed analysis. The following analysis results are displayed at the bottom of the map page: Recent and Base Surveys, Volume Units, Accretion, Erosion, Total, Maximum and Minimum Difference. Bathymetric contours were also generated and displayed on the Depth Difference maps to help further refine and visually clarify the color ramp legend on the printed maps.

- West Bay from 2003 to 2009 Depth Difference Analysis Results (Figure 9)
- West Bay from 2003 to 2006 Depth Difference Analysis Results (Figure 10)
- West Bay from 2006 to 2009 Depth Difference Analysis Results (Figure 11)

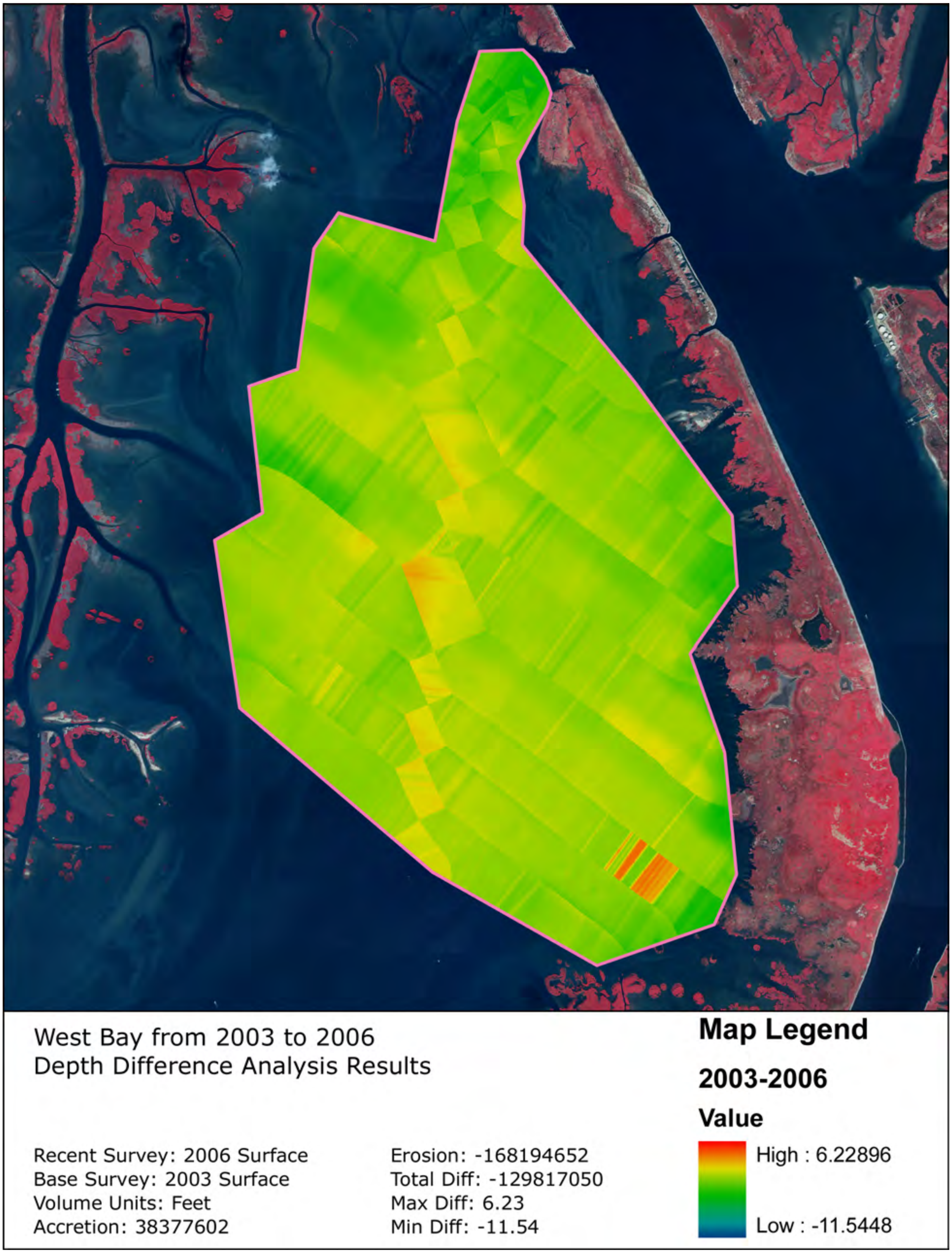


Figure 9: West Bay, 2003 to 2009 Depth Difference Analysis (Produced by the Spatial Data Branch, Mobile District)

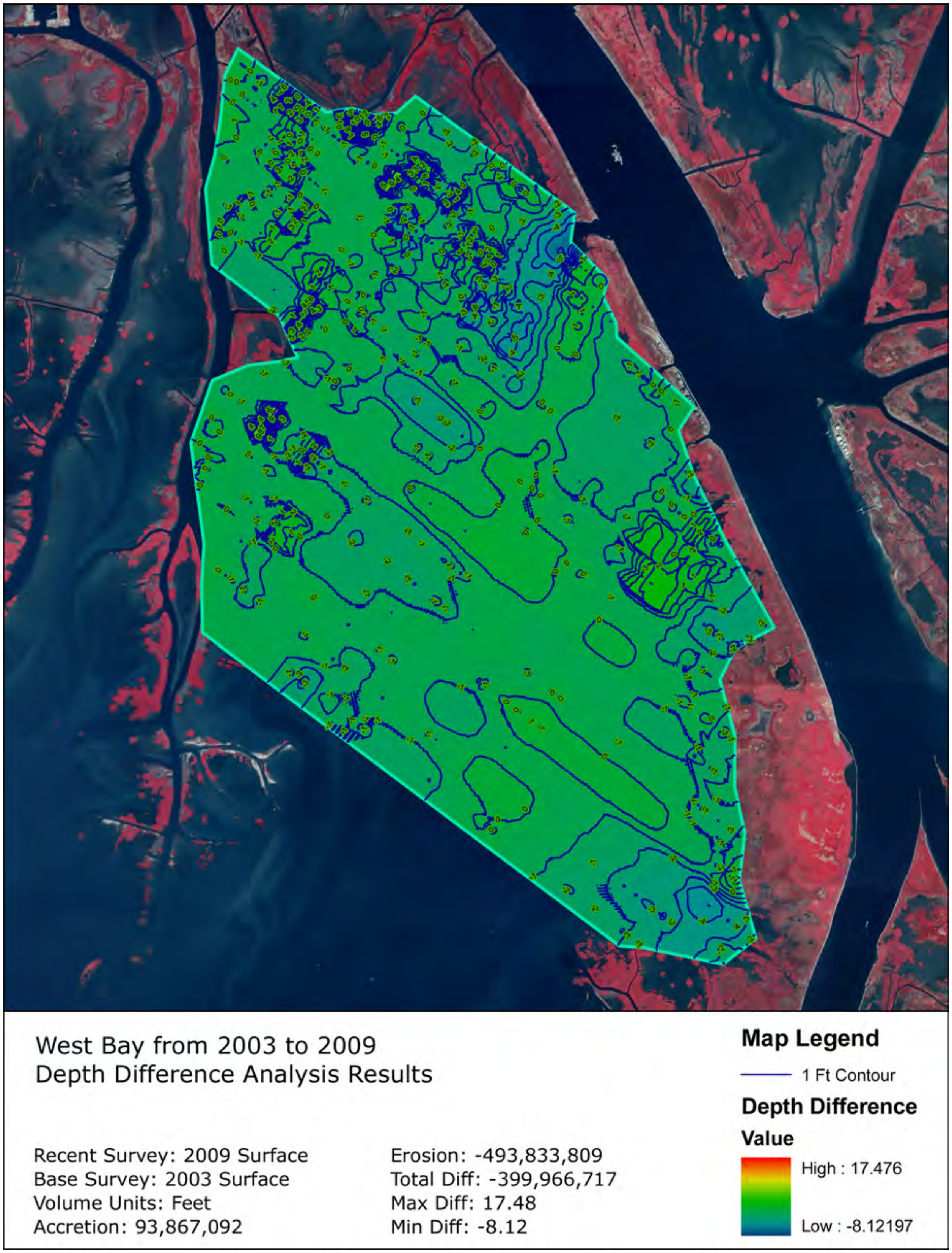


Figure 10: West Bay, 2003 to 2006 Depth Difference Analysis (Produced by the Spatial Data Branch, Mobile District)

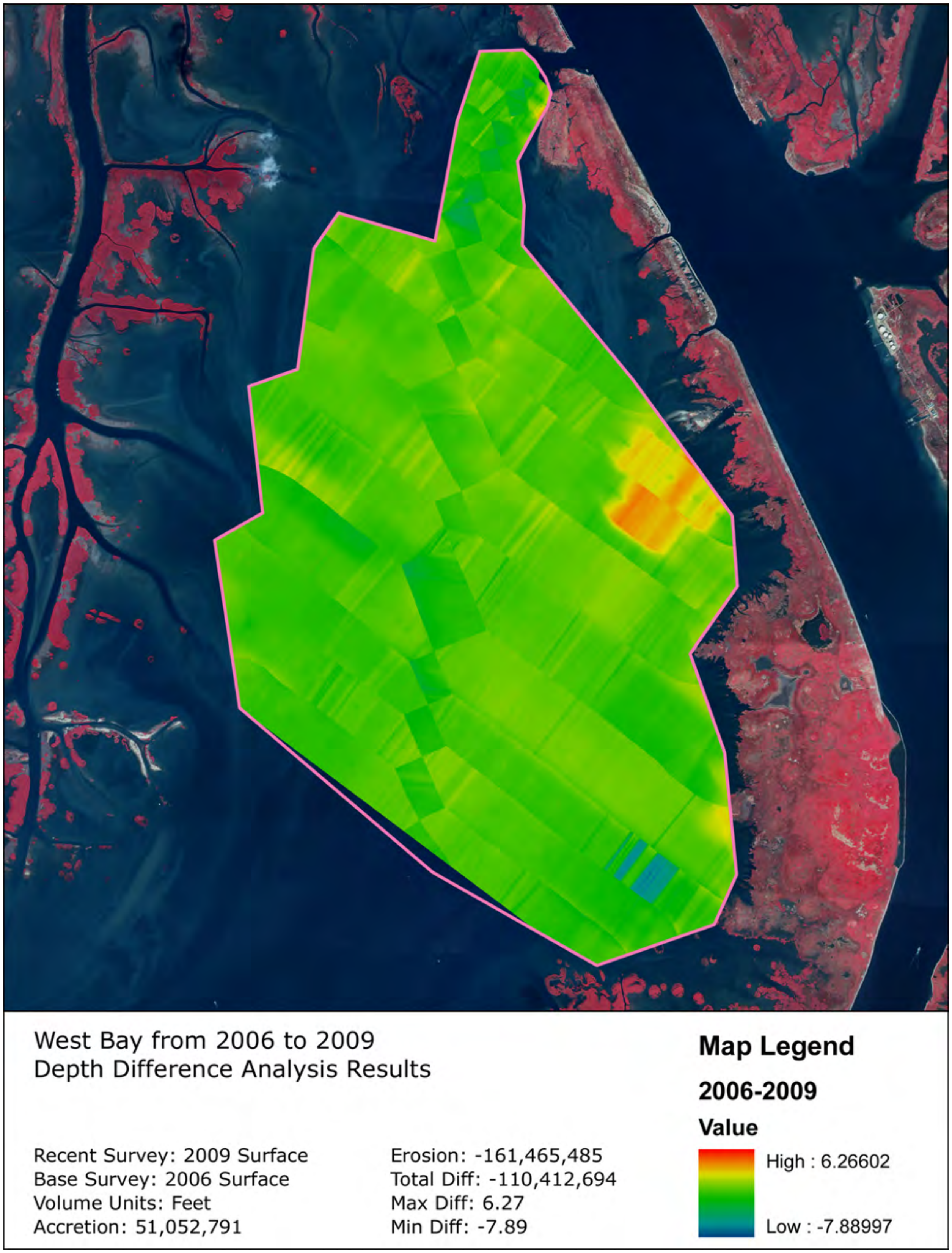


Figure 11: West Bay, 2006 to 2009 Depth Difference Analysis (Produced by the Spatial Data Branch, Mobile District)

A final map was generated, depicting only the crevasse with the 2009 survey 3-D surface. Only water volume was generated as there are no other surveys to perform a comparison. The map also shows the location of the original West Bay Survey Boundary provided as source material to indicate any depth changes to that area near to and as a result of the crevasse over time.

- West Bay Crevasse 2009 Survey Depth Analysis Results (Figure 12)

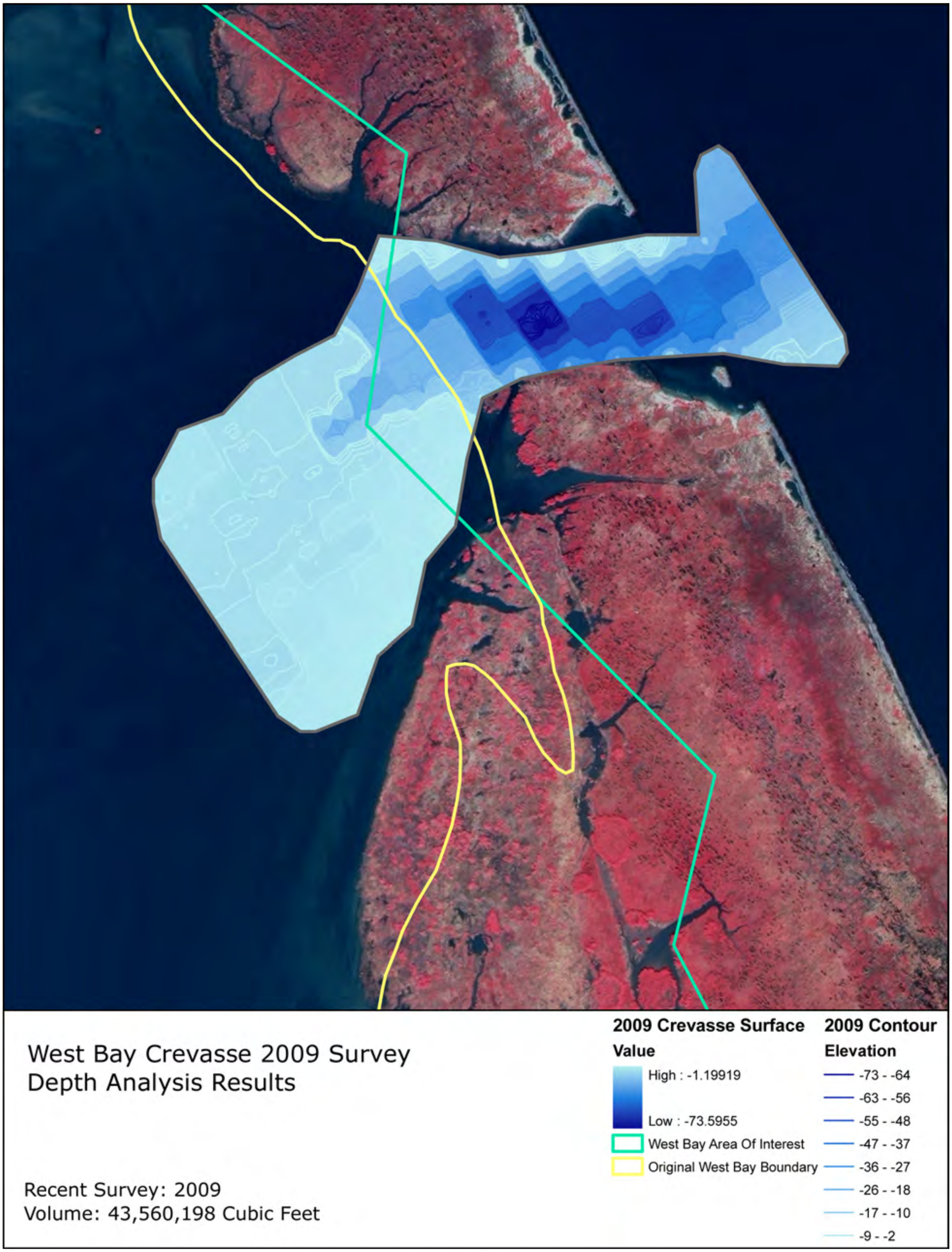

Figure 12: West Bay Crevasse 2009 Survey Depth Analysis (Produced by the Spatial Data Branch, Mobile District)

*Cut/Fill Analysis*

A cut/fill analysis was performed on the comparison of 2003 and 2009 surveys. This map shows the amount of material gained and lost. The following analysis results are displayed at the bottom of the map page: Recent and Base Surveys, Volume Units, Accretion, Erosion, Total, Maximum and Minimum Difference. Net Volume Gain and Loss are indicated by different colors.

- West Bay from 2003 to 2009 Cut/Fill Analysis Results (Figure 13)

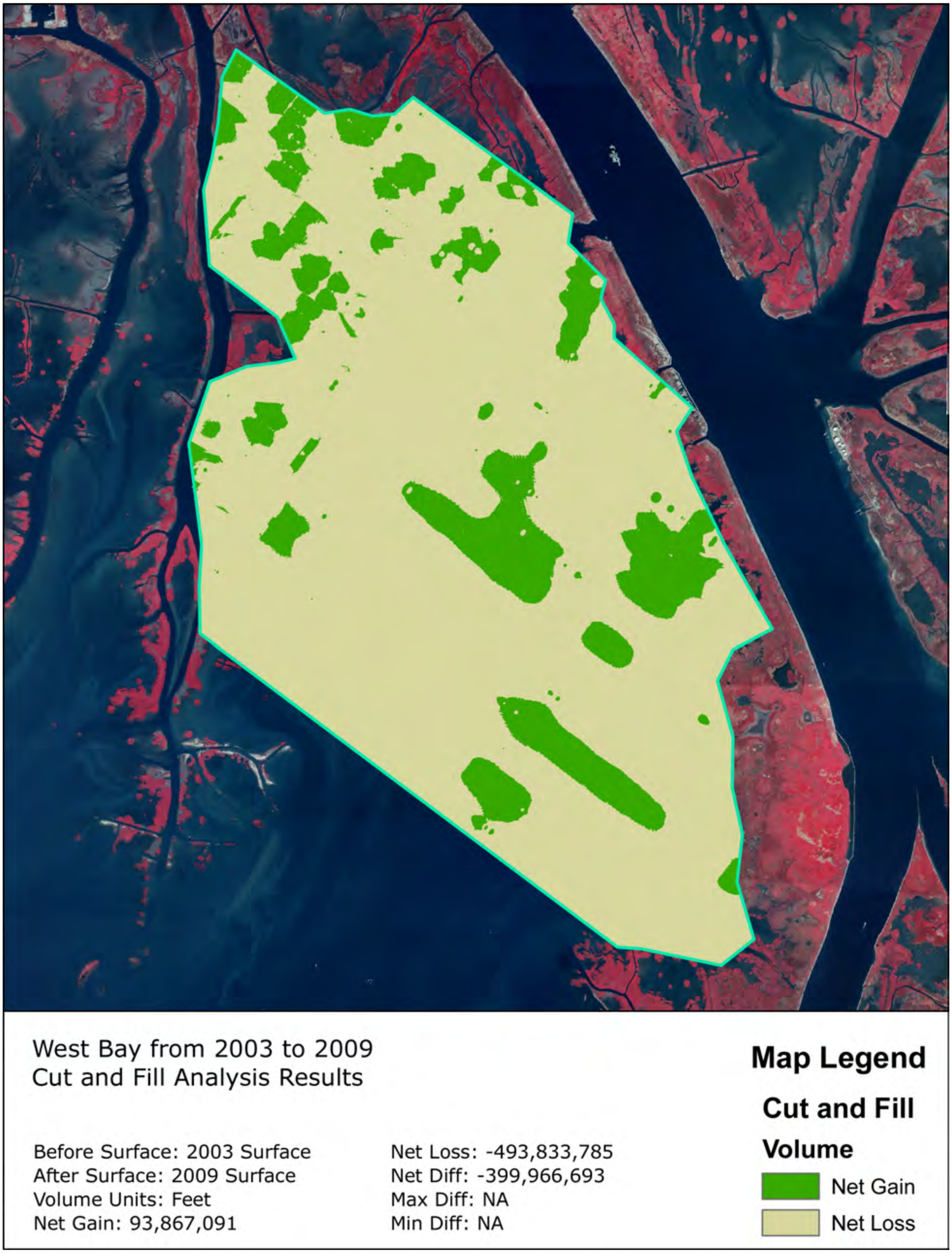


Figure 13: West Bay, 2003 to 2009 Cut/Fill Analysis Results (Produced by the Spatial Data Branch, Mobile District)

*Cross Section Profiles*

Seventeen cross section profiles were generated throughout the bay using the eCoastal Surface Profile Generator. These profiles are coincident with the 2003 and 2009 survey transects and represents all three elevation surfaces. In each of the profiles, line 1 represents the 2003 survey; line 2 represents the 2006 survey; and line 3 represents the 2009 survey. A map was generated (Figure 14) to indicate the location of the cut lines and lettered A-A to Q-Q in reference to the appropriate profile graph.

- West Bay from 2003, 2006 and 2009 Surveys Cross Section Profiles (Figures 15-31)

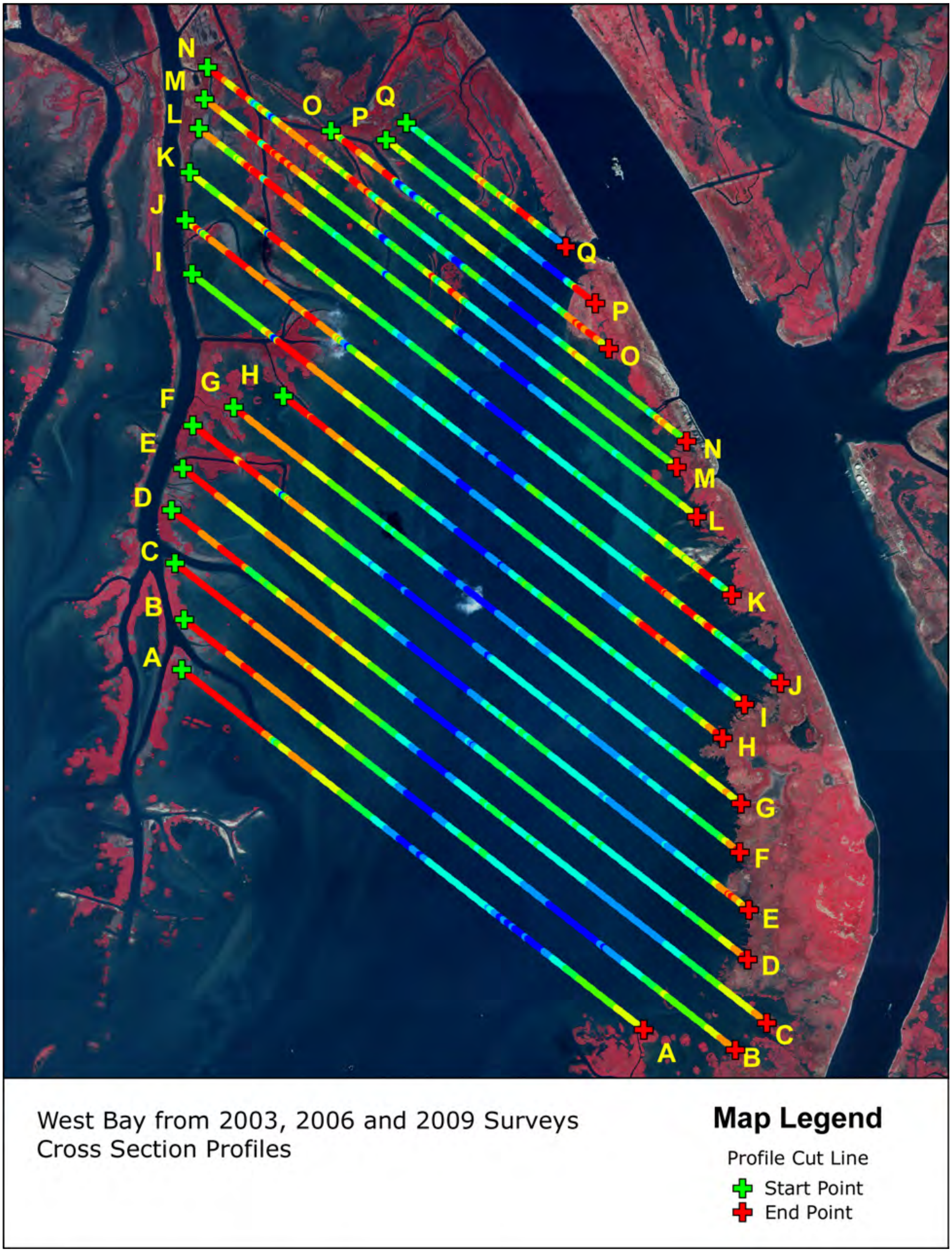


Figure 14: West Bay, Survey Cross Section Profile Map (Produced by the Spatial Data Branch, Mobile District)

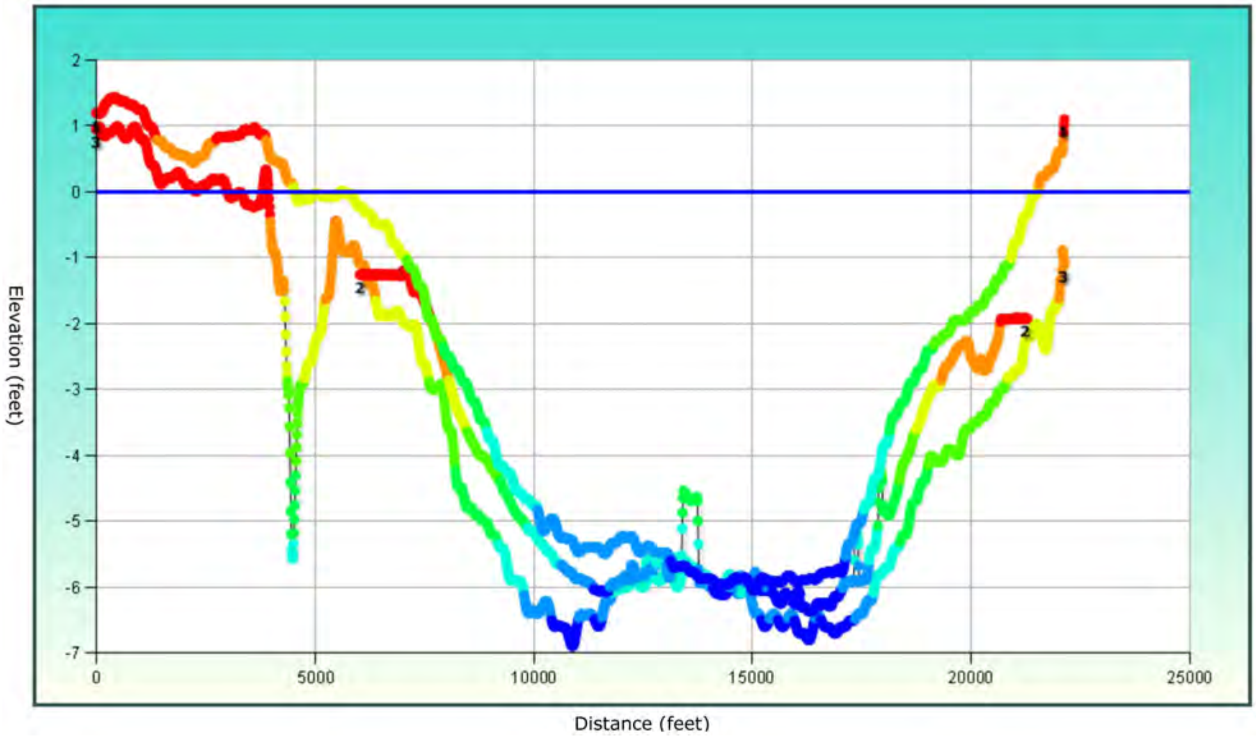


Figure 15: West Bay, Survey Cross Section Profile A-A (Produced by the Spatial Data Branch, Mobile District)

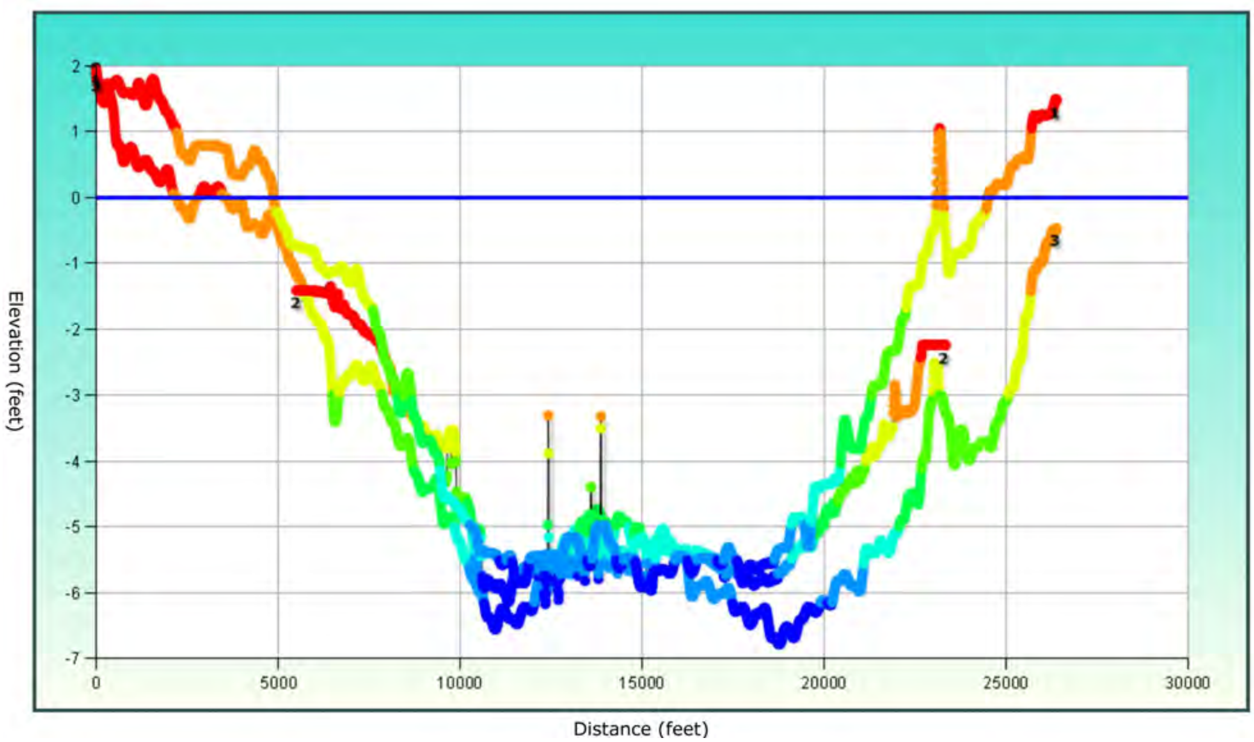


Figure 16: West Bay, Survey Cross Section Profile B-B (Produced by the Spatial Data Branch, Mobile District)

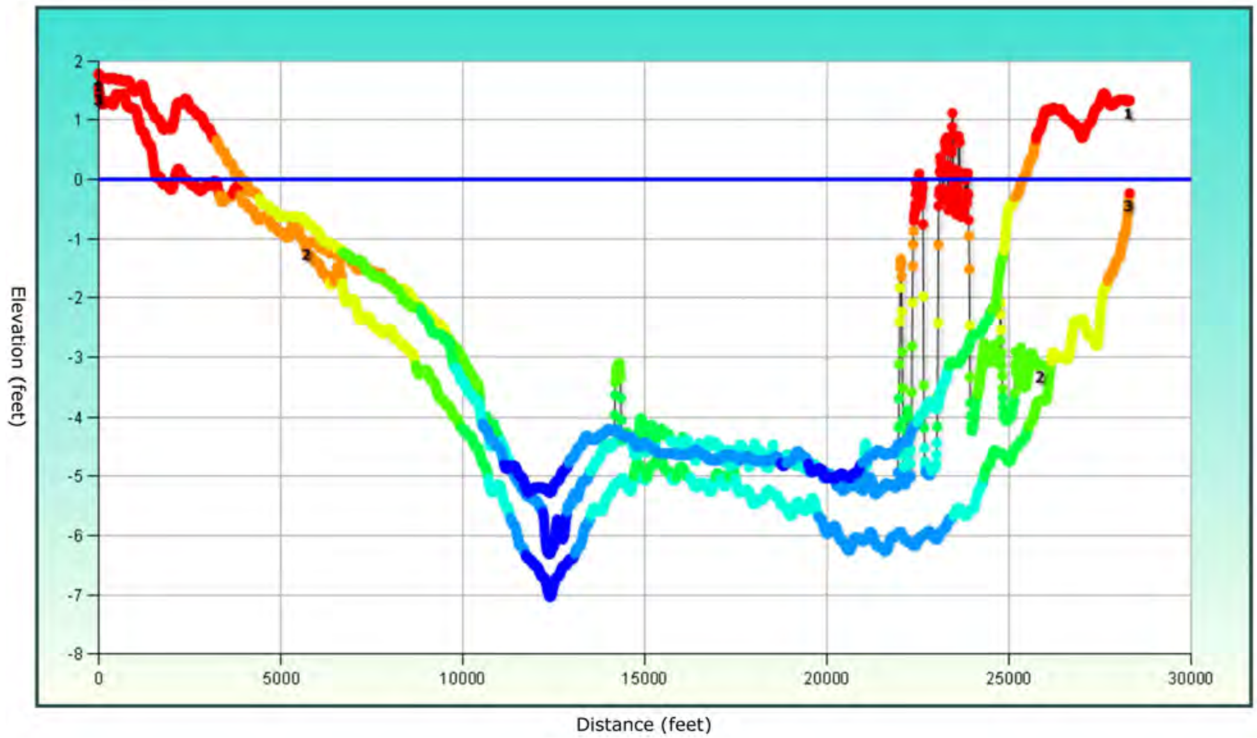


Figure 17: West Bay, Survey Cross Section Profile C-C (Produced by the Spatial Data Branch, Mobile District)

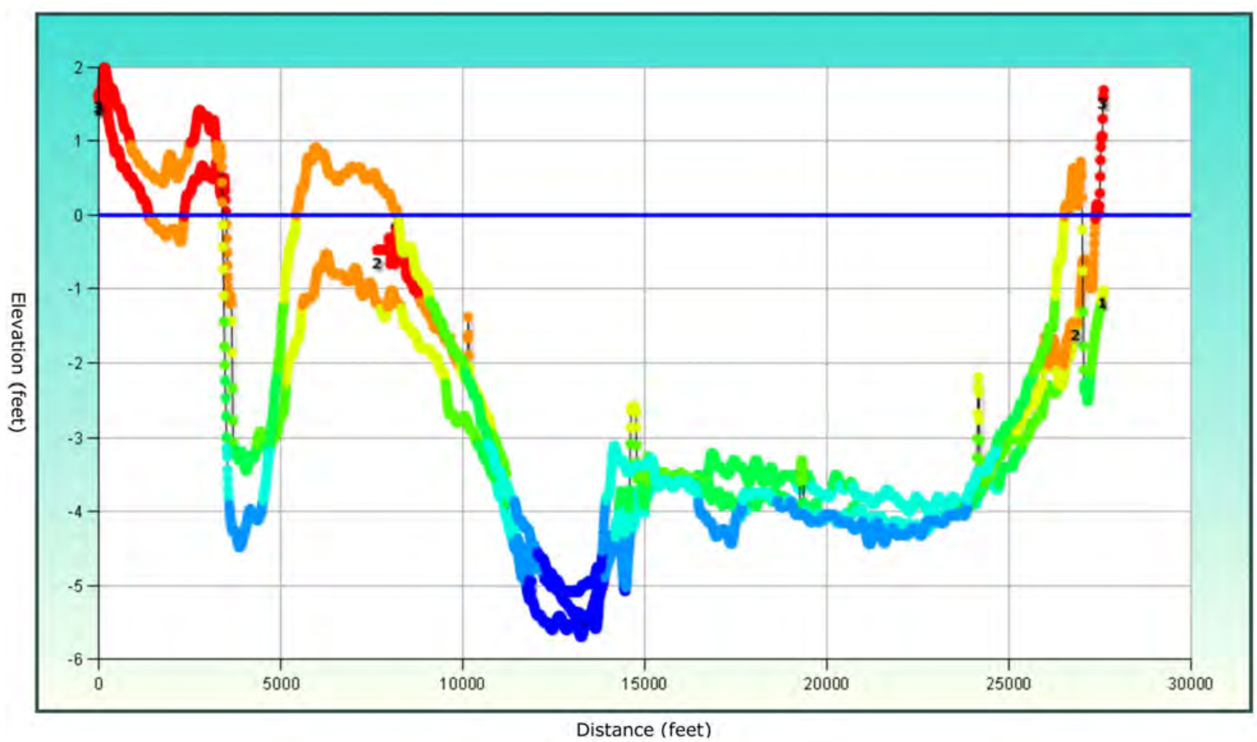


Figure 18: West Bay, Survey Cross Section Profile D-D (Produced by the Spatial Data Branch, Mobile District)

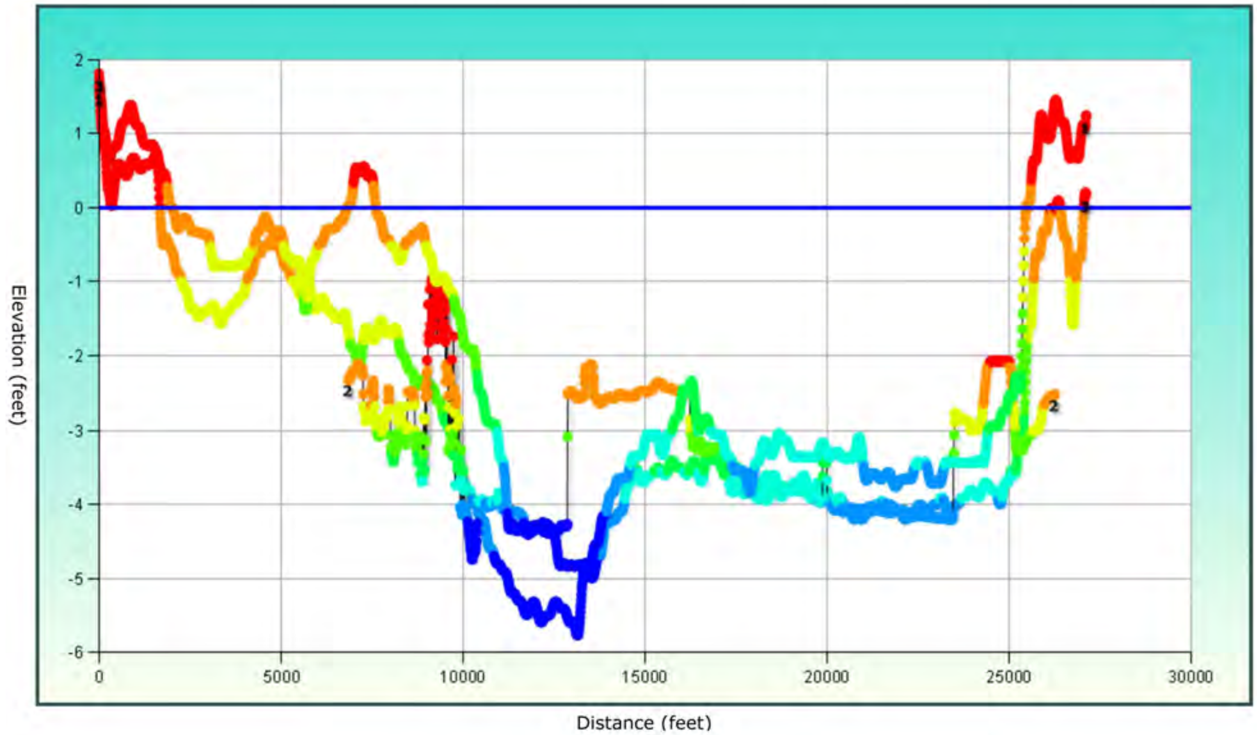


Figure 19: West Bay, Survey Cross Section Profile E-E (Produced by the Spatial Data Branch, Mobile District)

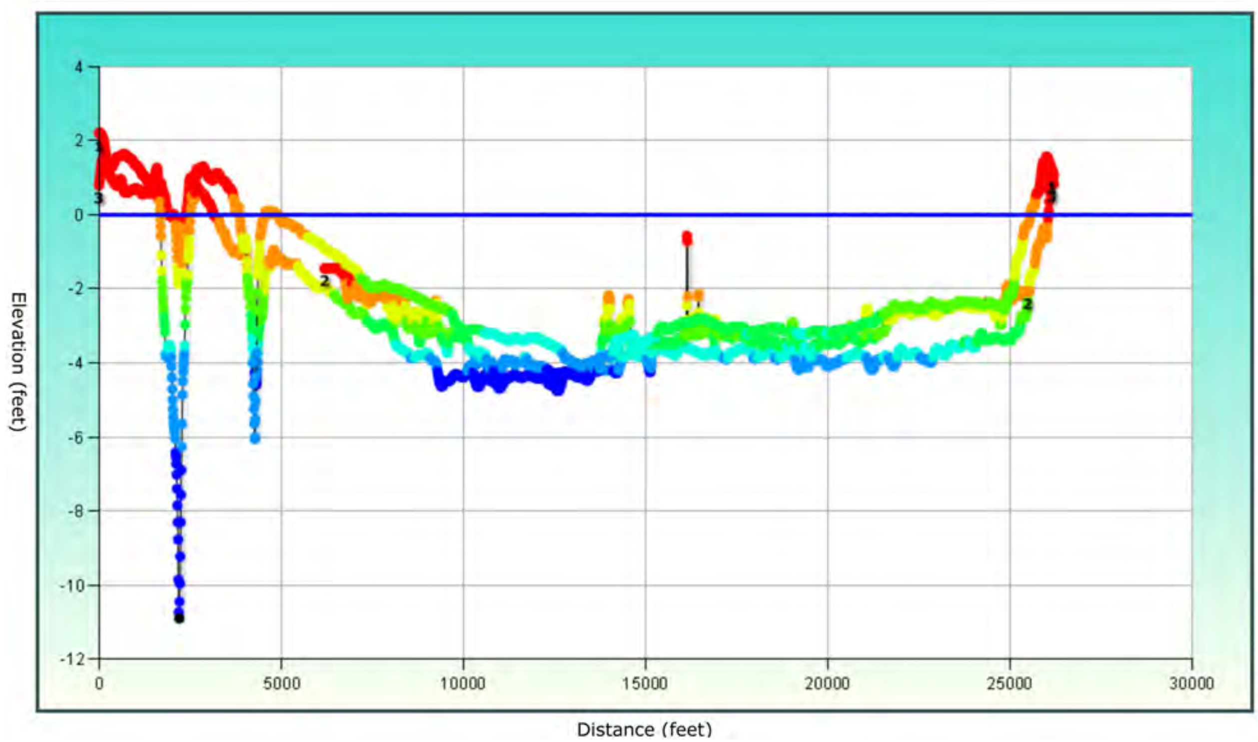


Figure 20: West Bay, Survey Cross Section Profile F-F (Produced by the Spatial Data Branch, Mobile District)

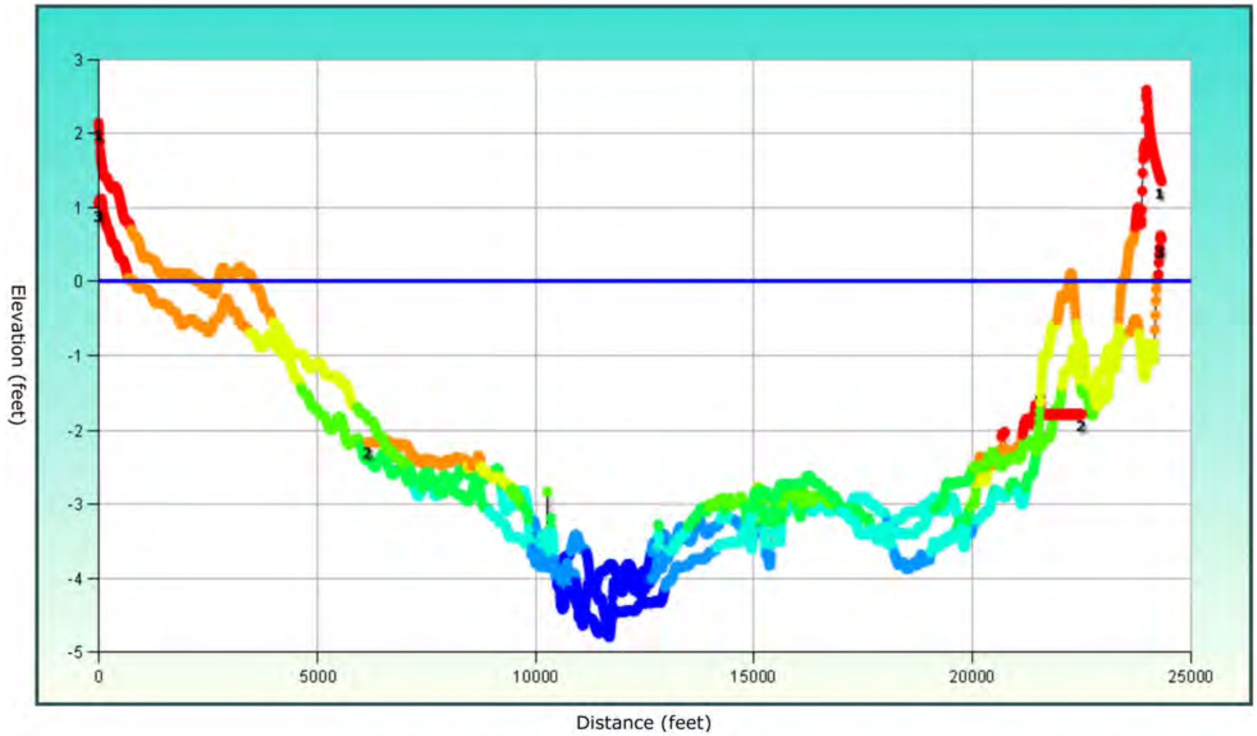


Figure 21: West Bay, Survey Cross Section Profile G-G (Produced by the Spatial Data Branch, Mobile District)

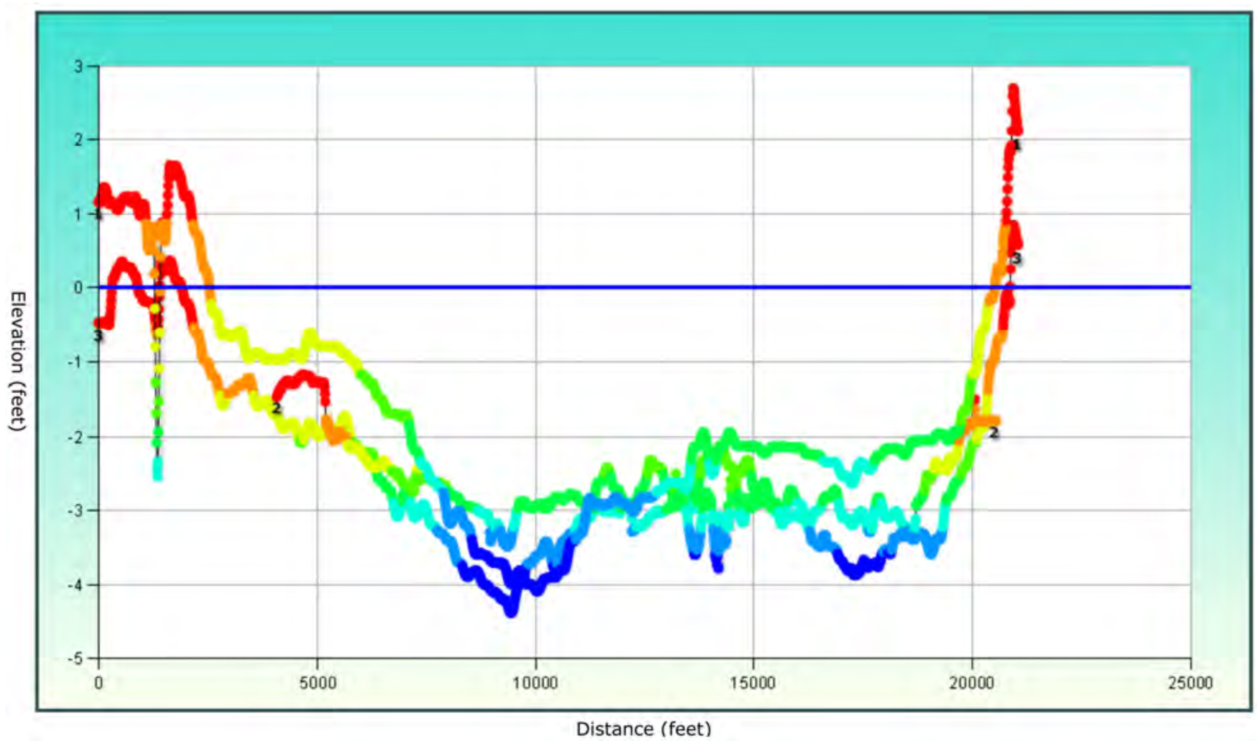


Figure 22: West Bay, Survey Cross Section Profile H-H (Produced by the Spatial Data Branch, Mobile District)

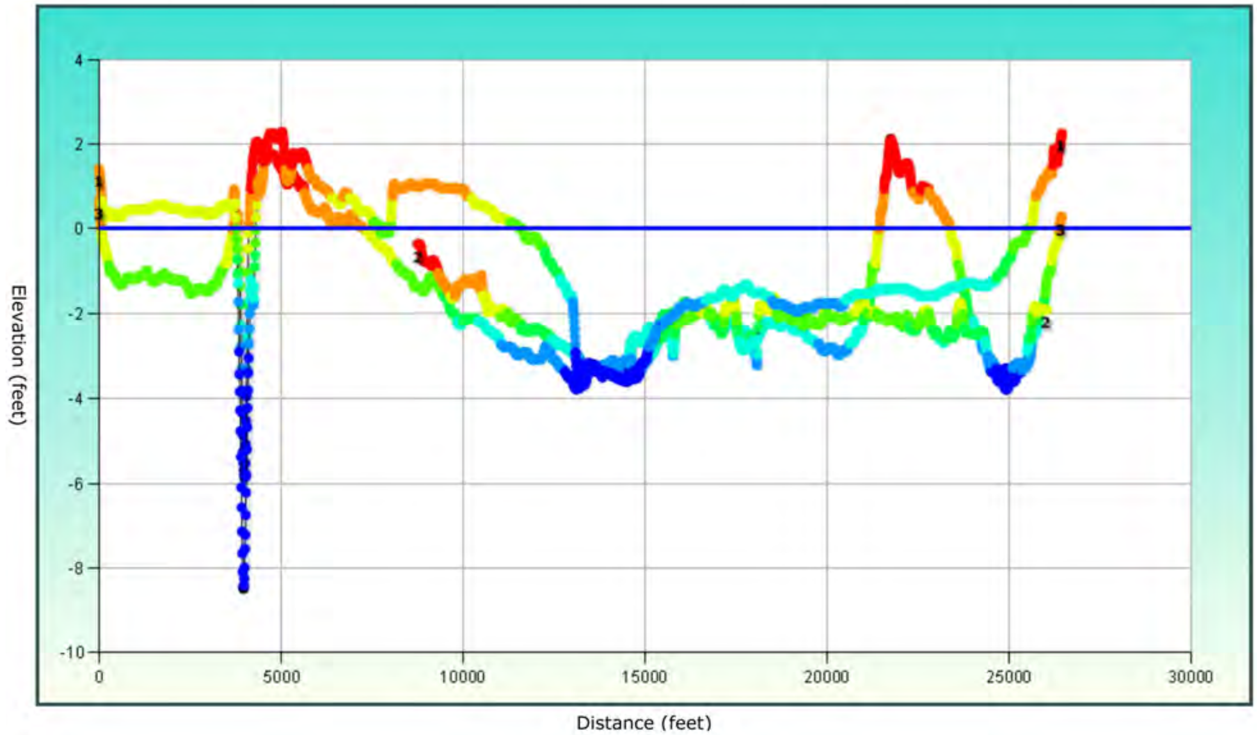


Figure 23: West Bay, Survey Cross Section Profile I-I (Produced by the Spatial Data Branch, Mobile District)

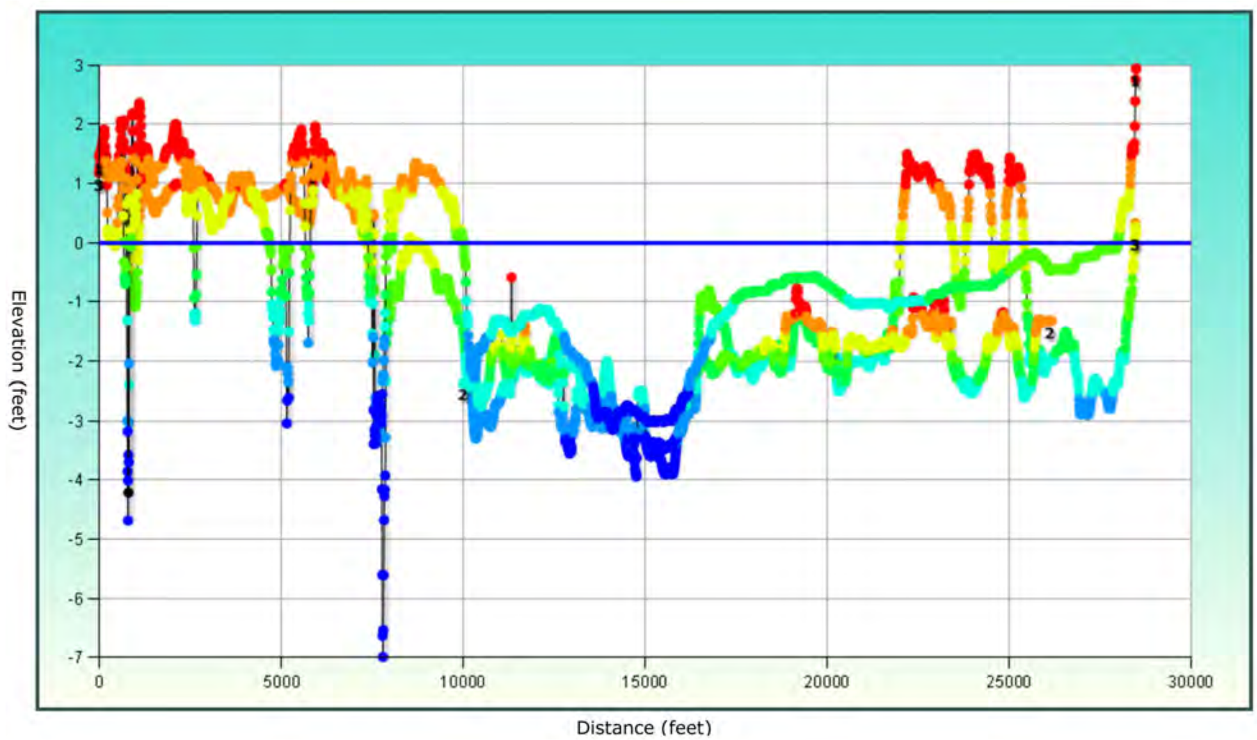


Figure 24: West Bay, Survey Cross Section Profile J-J (Produced by the Spatial Data Branch, Mobile District)

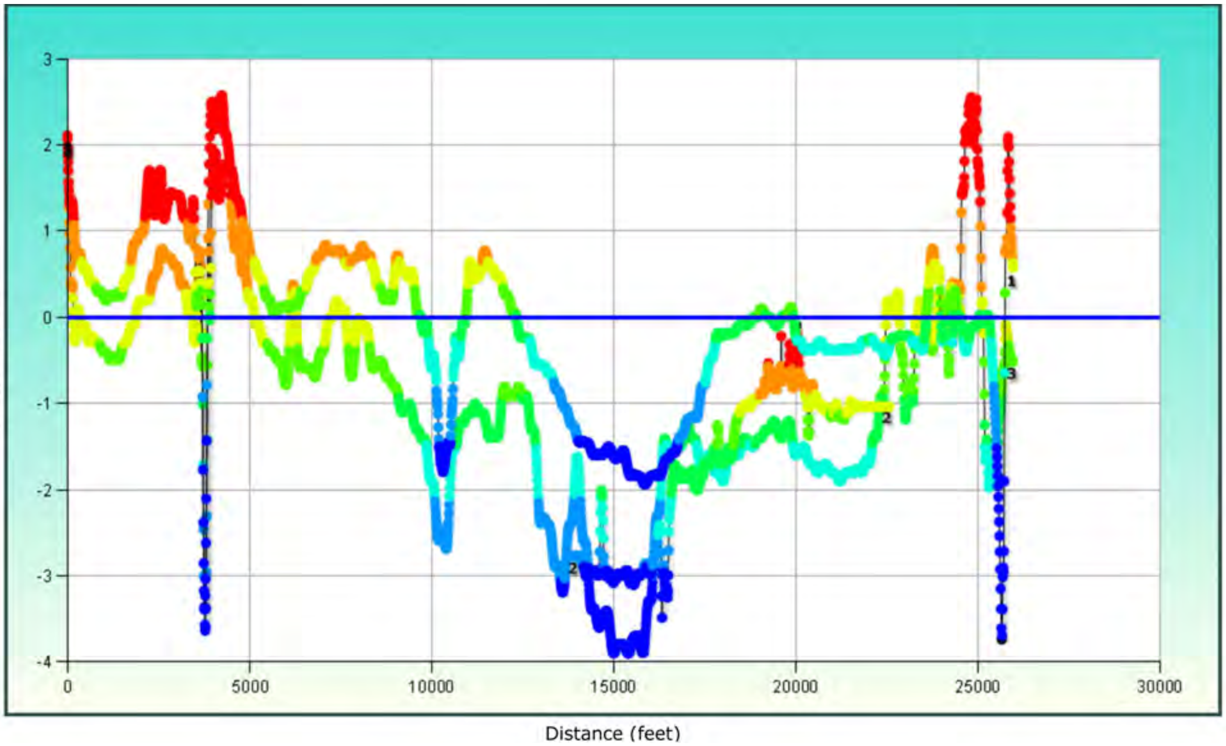


Figure 25: West Bay, Survey Cross Section Profile K-K (Produced by the Spatial Data Branch, Mobile District)

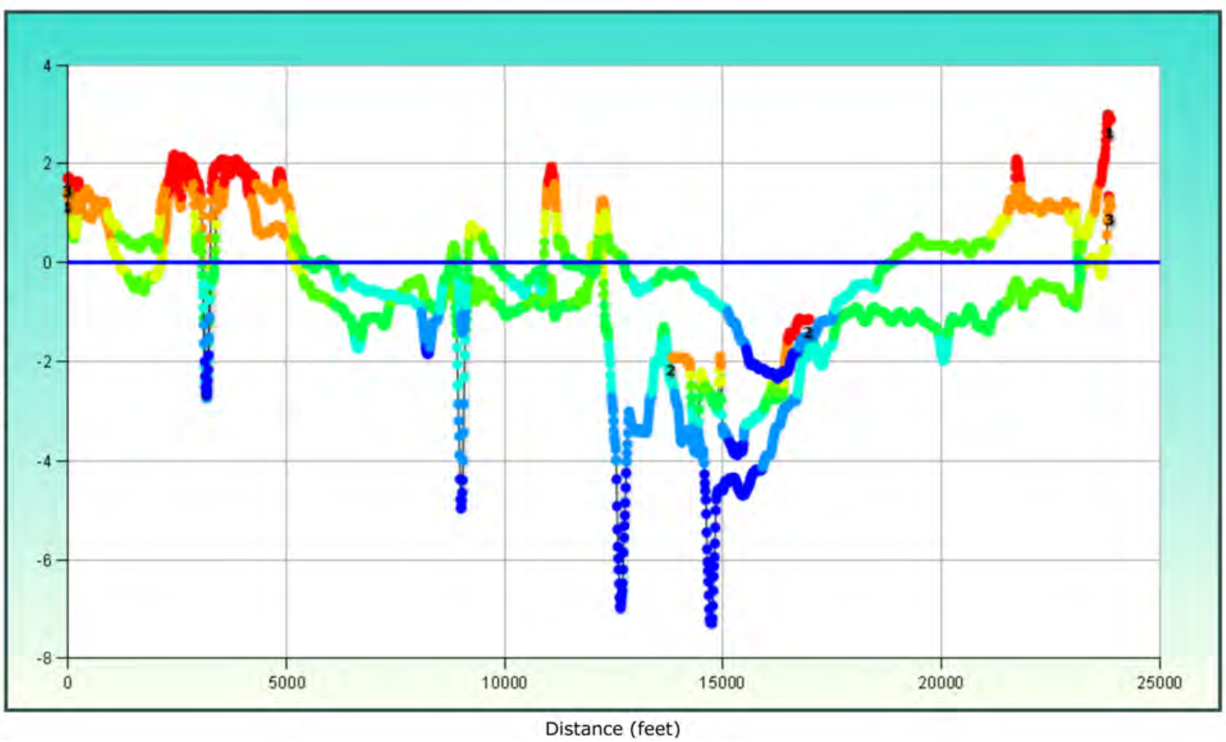


Figure 26: West Bay, Survey Cross Section Profile L-L (Produced by the Spatial Data Branch, Mobile District)

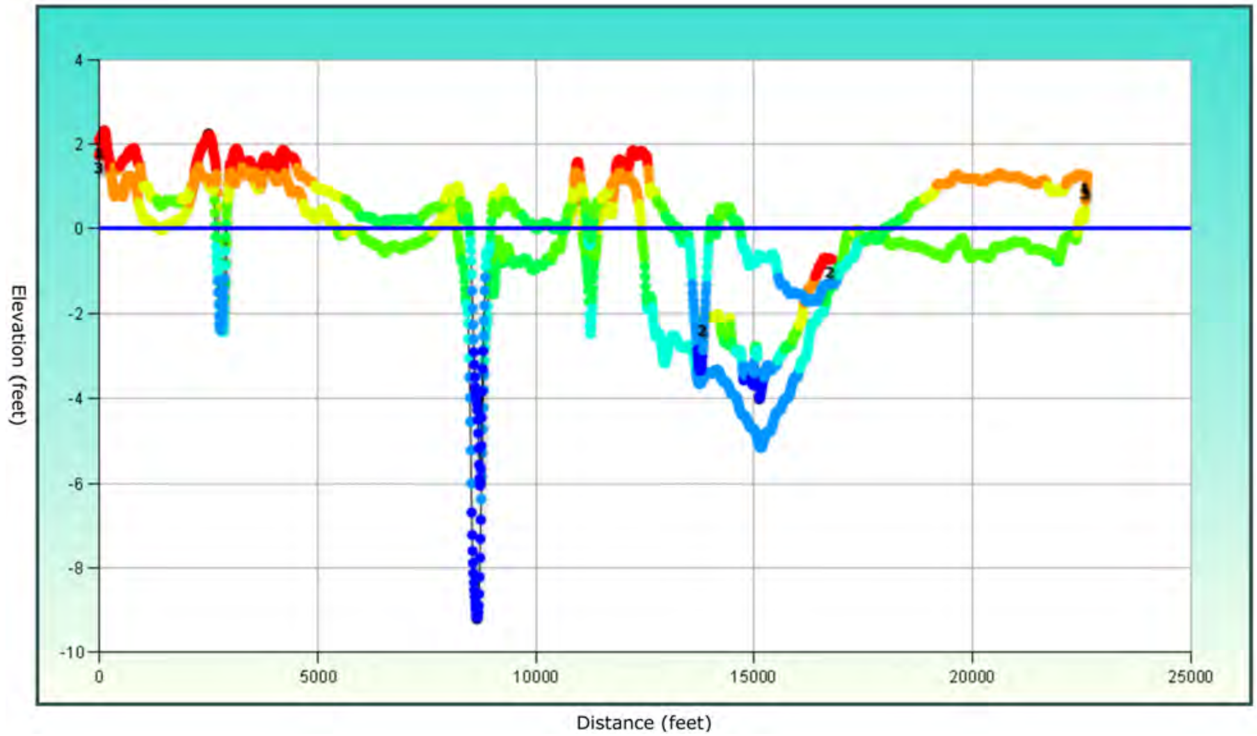


Figure 27: West Bay, Survey Cross Section Profile M-M (Produced by the Spatial Data Branch, Mobile District)

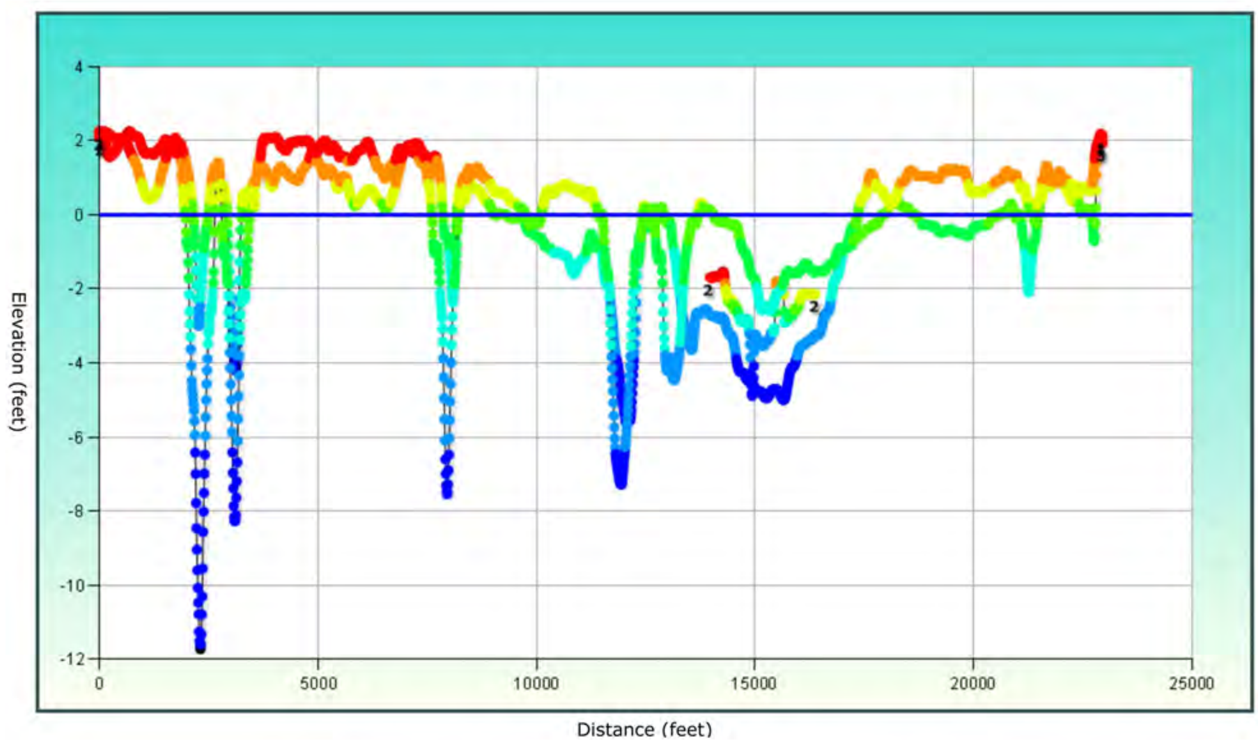


Figure 28: West Bay, Survey Cross Section Profile N-N (Produced by the Spatial Data Branch, Mobile District)

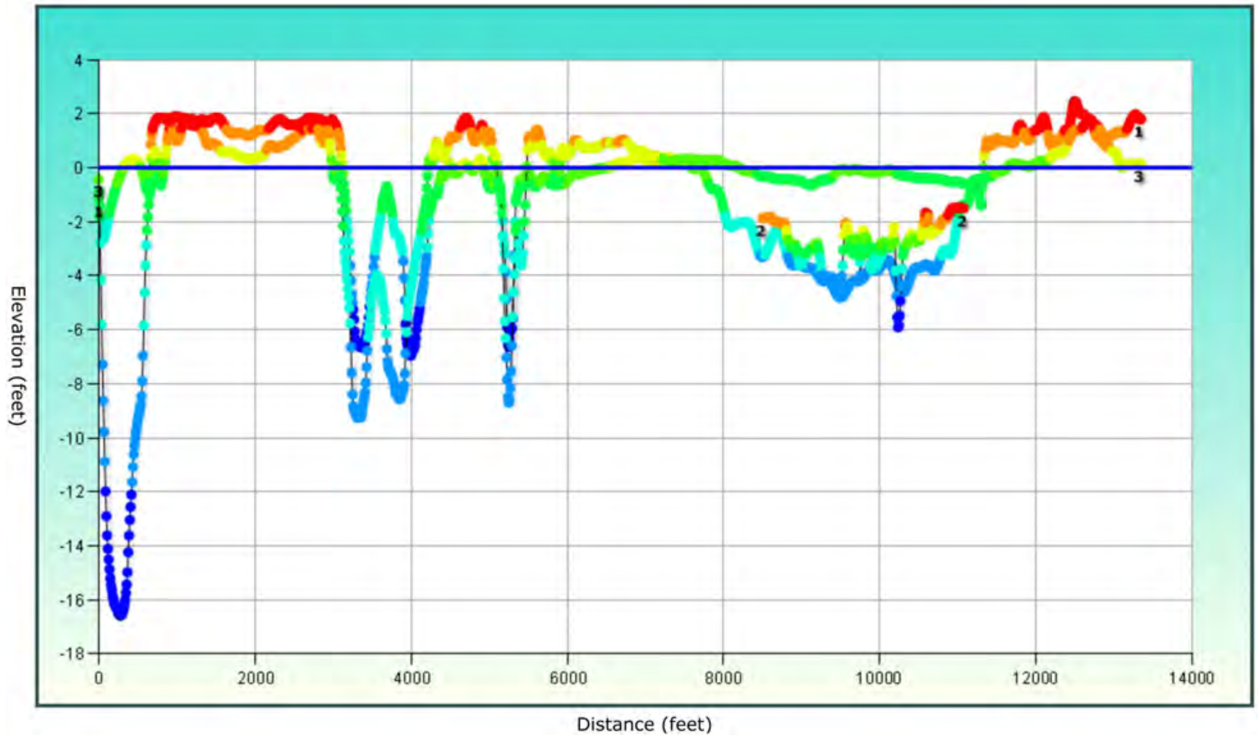


Figure 29: West Bay, Survey Cross Section Profile O-O (Produced by the Spatial Data Branch, Mobile District)

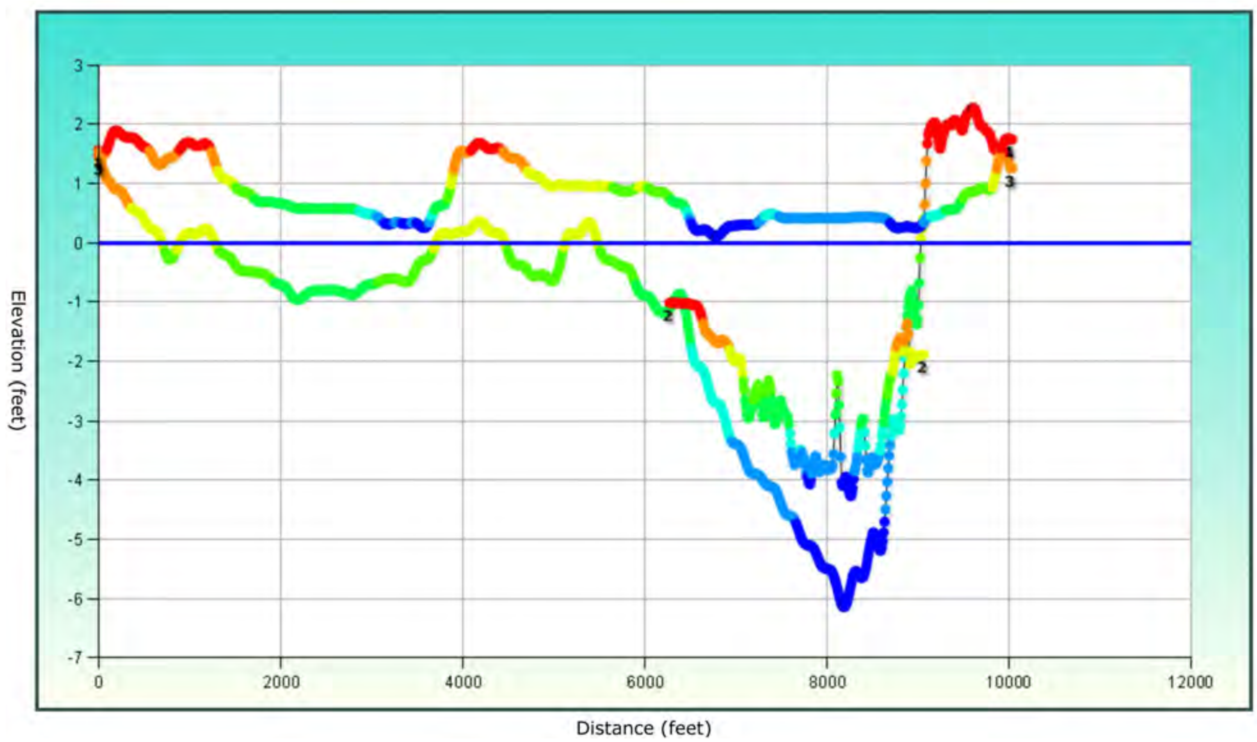


Figure 30: West Bay, Survey Cross Section Profile P-P (Produced by the Spatial Data Branch, Mobile District)


Figure 31: West Bay, Survey Cross Section Profile Q-Q (Produced by the Spatial Data Branch, Mobile District)

**Data Anomalies**

Some anomalous data readings were found when comparing the different surveys. Along the north and west areas of the surveys, the depth analysis shows areas that are generally hourglass shaped, indicating a large depth difference. These areas exist because of inconsistent data point locations between the different year surveys and the shape of the terrain. Some of these areas are valid depth changes across the natural channels. Some exist because of offset (non-coincident collection locations between surveys). Some exist because of missing data collection points across the channels. In the latter case, the survey surface would interpret the missing data as a flat area between the surrounding existing points (sometimes at or close to sea level). When compared with actual depth of these deeper channels, the profile will appear to display a depth change of many feet, when in reality the anomaly is a data issue. It should be noted that these data gap anomalies occurred only at channels.