Year 2 – 2017 Monitoring Report

Hamilton Wetland Restoration Project

Prepared for:

U.S. Army Corps of Engineers – San Francisco District

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Table of Contents

1 Introduction 1-1
1.1 Project Description 1-1
1.2 Monitoring Program 1-7
2 Water Levels 2-1
2.1 Methods 2-1
2.1.1 Tidal Water Levels 2-1
2.1.2 Seasonal Water Levels 2-5
2.2 Results 2-5
2.2.1 Tidal 2-14
2.2.2 Seasonal Wetlands 2-14
2.3 Discussion 2-15
3 Geomorphic Monitoring 3-1
3.1 Interior Marsh 3-1
3.1.1 Methods 3-1
3.1.2 Tidal Marsh Results 3-5
3.1.3 Detailed Survey Results (Sediment Elevation Table) 3-8
3.1.4 South Seasonal Pond Crest Survey Results 3-10
3.2 Outboard Marsh and Main Channel 3-10
3.2.1 Methods 3-10
3.2.2 Levee Breach and Outboard Channel Development Results 3-11
3.2.3 Fringing Marsh Scour Results 3-11
3.3 Planform 3-13
3.3.1 Methods 3-13
3.3.2 Aerials 3-13
3.4 Discussion 3-13
4 Vegetation 4-1
4.1 Mapping Methods 4-1
4.2 Results 4-2
4.2.1 Upland 4-3
4.2.2 Invasive Tidal Wetland Plants 4-3

4.2.3 North Seasonal Wetlands....4-3
4.2.4 Tidal Wetland....4-3
4.2.5 Species Diversity and Plant Community Structure....4-3
4.2.6 Comparison to Project Monitoring and Performance Criteria....4-7
4.3 Discussion....4-7
5 Fish Survey....5-1
5.1 Materials and Methods....5-1
5.1.1 Fish Sampling Methods....5-1
5.1.2 Site Conditions....5-1
5.2 Fish Sampling Results....5-5
5.2.1 Species Composition....5-5
5.2.2 Main Tidal Channel....5-5
5.2.3 Secondary and Tertiary Tidal Channels....5-6
5.3 Invertebrate Sampling....5-8
5.4 Discussion....5-9
6 Bird Surveys....6-1
6.1 Introduction....6-1
6.2 Methods....6-2
6.2.1 Timing of Hamilton Wetland Censuses....6-3
6.2.2 Absolute Counts....6-3
6.2.3 Species Richness....6-3
6.2.4 Densities....6-4
6.2.5 Diversity (Evenness)....6-4
6.3 Results....6-5
6.4 Discussion....6-9
7 Wind Speed and Direction....7-1
7.1 Methods....7-1
7.2 Results....7-1
7.3 Discussion....7-2
8 Photo Documentation....8-1
8.1 Methods....8-1

8.2 Results.. 8-1
8.2.1 Tidal Wetland 8-1
8.2.2 Seasonal Wetlands 8-2
8.2.3 Transitional/Upland 8-4
8.3 Discussion 8-4

List of Tables

Table 1-1. Monitoring Team Tasks 1-7
Table 2-1. Dates of Deployment 2-5
Table 3-1. Sediment Elevation Table 3-9
Table 4-1. Area of Habitats Mapped in 2017 4-2
Table 4-2. Plant Species Observed Spring 2017 4-4
Table 5-1. Predicted Tide Height During Sampling Periods 5-5
Table 5-2. Fish Species Present in the Project Site – 2017 5-5
Table 5-3. Fishes Captured in the Main, Secondary and Tertiary Channels 5-7
Table 5-4. Comparison between survey years 5-8
Table 6-1. Coverage of the study areas1 6-1
Table 6-2. The ten most abundant waterbird species1 6-5
Table 6-3. Summary statistics all seasons combined, 2014/15, 2015/16, and 2016/2017: sum, mean standard deviation and coefficient of variation for all observations. 6-6
Table 6-4. Summary statistics for the fall season, 2014 compared with fall season 2015 and 2016: sum, mean standard deviation and coefficient of variation. 6-7
Table 6-5. Summary statistics the winter season, 2014-2015 compared with winter season 2015-2016 and 2016-2017: sum, mean standard deviation and coefficient of variation. 6-7
Table 6-6. Summary statistics the spring season 2015 compared with spring season 2016 and 2017: sum, mean standard deviation and coefficient of variation. 6-8
Table 6-7. Species richness indices for the 2014-2015 compared to the 2015-2016 and 2016-2017 monitoring seasons. 6-9
Table 6-8. Species diversity indices for the 2014-2015 compared with the 2015-2016 and 2016-2017 monitoring seasons. 6-9

List of Figures

Figure 1-1. Vicinity Map 1-3
Figure 1-2. Base Map 1-5
Figure 2-1. Tidal Marsh Level Logger Locations 2-3
Figure 2-2. Seasonal Pond Level Logger Locations 2-7
Figure 2-3. Fall Tidal Water Levels Spring-Tide Cycle 2-9
Figure 2-4. Winter Tidal Water Levels Spring-Tide Cycle 2-10
Figure 2-5. Spring Tidal Water Levels Spring-Tide Cycle 2-11
Figure 2-6. Spring Tidal Water Levels 48 Hour Detail 2-12
Figure 2-7. North Seasonal Wetland Pond Water Levels 2-13

Figure 3-1. Survey Plan 3-3
Figure 4-1. Vegetation Map....... 4-5
Figure 5-1. Fish Sampling Locations 5-3
Figure 6-1. Annual pattern of abundance of waterbirds at Hamilton Wetlands, 2016-2017....... 6-10
Figure 7-1. Wind Roses for Sonoma Baylands and Novato Fire for 2016-2017, with site locations....... 7-3
Figure 7-2. Seasonal Wind Rose for 2016-2017 at Sonoma Baylands 7-4
Figure 7-3. Seasonal Wind Rose for 2016-2017 Novato Fire-Robinhood 7-5
Figure 8-1. Permanent Photo Documentation Station Locations....... 8-3

List of Appendices

Appendix A Tidal Hydrology Figures

Appendix B Interior Transect Elevation Data

Appendix C Aerial Photo Plates

Appendix D Avian

Appendix E Photo Documentation Plates

Abbreviations and Acronyms

A

Ac	acre(s)
ARA	Avocet Research Associates

B

BCDC	San Francisco Bay Conservation and Development Commission
BRAC	Defense Base Realignment and Closure Act of 1988

C

CIMIS	California Irrigation Management Information System
CIR	color infrared
Cal-IPC	California Invasive Plant Council

D

DMg	Margalef's Index
DMn	Menhinick's Index
D_{max}	The maximum value of the Equitability Index that is evenly distributed

E

ESA	Environmental Science Associates

F

ft	feet (foot)

G

(None)

H

ha	hectare
HWRP	The Hamilton Wetlands Restoration Project

I

in.	inch(es)

J

(none)

K

knots	nautical mile per hour

L

LiDAR	Light Detection and Ranging
LWCS	lower water control structure

M

MAMP	HWRP Monitoring and Adaptive Management Plan
mi	mile(s)
mm	millimeters
mph	miles per hour

N

NAVD88	North American Vertical Datum
NDVI	normalized difference vegetation index

NVHC1 Bureau of Land Management Station (Novato Fire-Robinhood)

O

O&M operations and maintenance

P

(none)

Q

(none)

R

RTK-GPS Real-Time Kinetic GPS

RWQCB Regional Water Quality Control Board

S

SCC California State Coastal Conservancy

SET Sediment Elevation Table

T

TAC Technical Advisory Committee

U

USACE United States Army Corps of Engineers

USFWS U.S. Fish and Wildlife Service

UWCS Upper Water Control Structure

V

(none)

W

(none)

X

(none)

Y

(none)

Z

(none)

(Note: This Year 2 monitoring report is an update of the Year 1 monitoring report prepared (ESA, 2017). Where appropriate, text or figures from the Year 1 monitoring report have been incorporated into this report.)

1 Introduction

1.1 Project Description

The Hamilton Wetlands Restoration Project (HWRP) is a 648 acre (ac) tidal marsh restoration Project in Marin County, California (Figure 1-1), constructed by the United States Army Corps of Engineers (USACE), San Francisco District, in partnership with the California State Coastal Conservancy (SCC). The goal of the HWRP is to create a diverse array of wetland and wildlife habitats that benefit a number of special-status and migratory species as well as other resident species.

The HWRP site was once part of an extensive tidal wetland system along the western margin of San Pablo Bay in Novato, California (Figure 1-1). Diked and drained for agriculture around the turn of the 20th century, the land was developed in the late 1920s into what would eventually become Hamilton Army Airfield, named for First Lieutenant Lloyd Andrews Hamilton, the first American pilot to fly with the Royal Flying Corps during World War I. The airfield remained in operation until 1974, and in 1988 began a closure process under the Defense Base Realignment and Closure Act of 1988 (BRAC). The base began its redevelopment and reuse starting in 1996 when part of the base was repurposed to mix residential and commercial use.

In 1998, the USACE, SCC, and San Francisco Bay Conservation and Development Commission (BCDC) teamed up to write a feasibility report of restoration alternatives for the airfield and runways. There were multiple studies over the course of many years led by a range of government departments and private consultants with funding from the Federal Government and the State of California. The land subsided considerably over its century of use, and the Project design took advantage of the availability of dredged materials from the Port of Oakland minus-50 feet (ft.) deepening Project as well as operations and maintenance (O&M) dredging, and other private dredging projects in order to raise the site closer to marshplain elevation before it was reconnected to tides. The HWRP site was breached on April 25, 2014, reconnecting tides to a mix of tidal and seasonal wetland, transitional ecotone, and upland habitats. The site is currently owned by the SCC.

The restored site is shown in Figure 1-2. The Bayfront levee was breached in one location to restore tidal inundation to the site, and graded lower to permit overtopping of the levee during high tides and to encourage reestablishment of marsh vegetation. A levee along the northern boundary of the site was constructed to provide flood protection to the adjoining Bel Marin Keys site. The large central portion of the site was dedicated as a full tidal wetland, while two separate seasonal wetland habitat areas were created using dredged materials in the northern and southern areas of the site. Seasonal wetlands form and function are highly sensitive to hydrology, salinity, and topography. Dredged material is unique in its composition and its use for seasonal wetlands creation is somewhat experimental. Two distinct design approaches were used for the two different seasonal wetlands complexes with an eye towards comparing and contrasting effectiveness: a managed system with water control structures to optimize function, and an unmanaged system open to tides. Wildlife Corridor along the western boundary of the site was developed as upland transitional habitat. Interior berms and breaches were designed to both dampen wind wave fetch across the site as well as to train channel development.

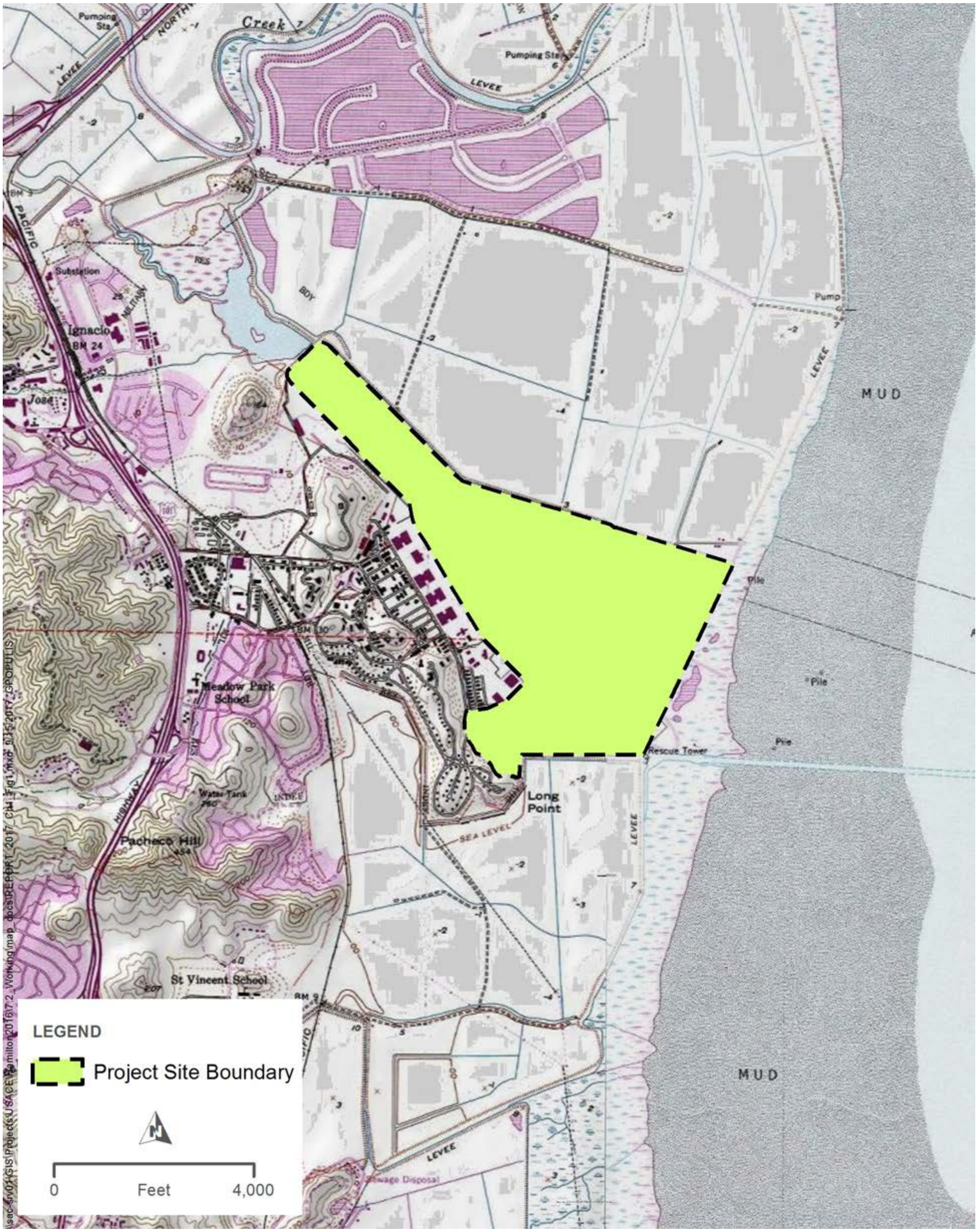

Figure 1-1. Vicinity Map

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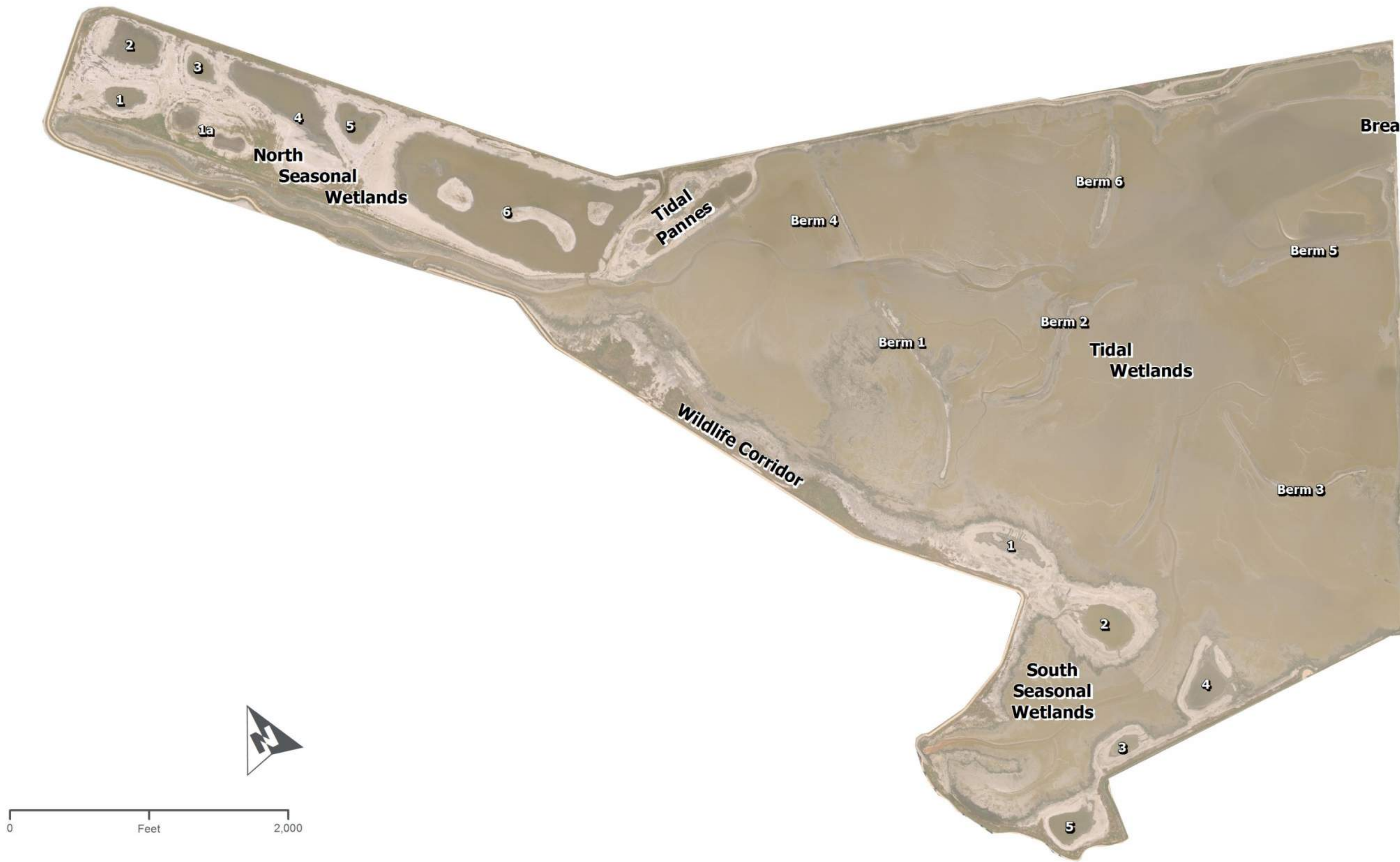

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Figure 1-2. Base Map

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1.2 Monitoring Program

The HWRP Monitoring & Adaptive Management Plan (MAMP) (ESA-PWA and BMP Ecosciences, 2013) outlines physical and ecological requirements to track the evolution of tidal wetlands, seasonal wetlands, and associated transitional and upland areas created through the placement and grading of dredged material. The monitoring plan set forth a program to meet the permit requirements set in consultation by the USACE with the U.S. Fish and Wildlife Service (USFWS), the BCDC and the Regional Water Quality Control Board (RWQCB). The Technical Advisory Committee (TAC) directly oversee the monitoring, management, and research activities.

The MAMP was based upon preconstruction site designs. The monitoring program was governed by the MAMP with supplementary input from the post-construction assessment. This monitoring report presents the 2017 (year 2) of post construction monitoring data and site development since Project completion. The report is cumulative, presenting the baseline 2015 (year 0), the year 1 data collected in 2015 and 2016, and the year 2 data collected in 2016 and 2017. The USACE and SCC are separately monitoring a variety of physical and biological parameters to provide information on the development of the Project. This monitoring report documents data collected on: tidal hydrology, water levels, geomorphology, vegetation establishment, and presence and abundance of bird and fish species in accordance with the approved monitoring plan for the Project. This monitoring report characterizes the rate and pattern of: tidal action and exchange, seasonal pond flooding and seepage, channel erosion, sediment deposition and consolidation, vegetation establishment, and assesses the value of habitat at the site. The monitoring task breakdown is listed in Table 1-1 including the consultant responsible for each main monitoring task.

Table 1-1. Monitoring Team Tasks

Parameter	Team Member
Water Levels	HDR
Sediment Geomorphology	HDR
Vegetation	HDR
Presence and Abundance of Bird Species	Avocet Research Associates
Fish Usage	ESA
Photo Documentation	HDR

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2 Water Levels

Water level data was collected in both the Tidal Marsh as well as the North Seasonal Wetlands. Tidal Marsh water levels were monitored to assess if the site was receiving the full range of tidal action. Seasonal Wetlands water levels were monitored in order to evaluate flooding duration and depth of the ponds as well as seepage rates of the ponds into the soils.

2.1 Methods

Submersible pressure transducers (level loggers) were deployed at each of the monitoring locations. One barometric pressure transducer was deployed onsite to account for atmospheric pressure changes. Onset U20 TI level loggers were deployed at the Railroad Bridge, Breach and Back Marsh locations and were placed inside 1.5-inch (in.) perforated schedule 80 PVC stilling wells in order to capture tidal water level fluctuations. Onset MX2001 Bluetooth level loggers were deployed in Pond 1, Pond 2 and Pond 6 and placed in (2) 1.5-in. perforated ABS stilling wells to account for water surface fluctuations in the North Seasonal Wetland area. Both variations of level loggers were programmed to record water level and temperature at 10-minute sample intervals. Downloading and maintenance was initially performed on a monthly basis and later performed in conjunction with geomorphic survey work. Utilizing RTK-GPS, water surface elevations were collected during each download and maintenance effort for quality control and to convert level logger depth measurements to ft NAVD88.

Area-specific methods for data collection are broken down separately below.

2.1.1 Tidal Water Levels

Submersible pressure transducers (level loggers) were deployed at three specific locations chosen in order to monitor tidal exchange across the site as it develops (Figure 2-1). Level loggers were deployed just inside the breach location to capture the water levels at the tidal entrance to the site and at the back of the site furthest from the breach in order to capture tidal response near the panhandle channel as well as monitor erosion of a sill located in the north of the site blocking the panhandle channel. The Petaluma River Railroad Bridge was the third deployment location to facilitate reference San Pablo Bay tidal water levels. Stilling wells at the Railroad Bridge and Breach locations were attached to a preexisting structure. Stilling wells at the Back Marsh location were attached to galvanized steel stands with broad bases inserted deep into the mud and held steadfast by 40 pound concrete anchors. A leash was attached to the anchor and fastened to the stand to aid in removal of the whole apparatus. All tidal level loggers were compensated with barometric pressure data from a barometric transducer installed on site at the breach location during the fall/winter and at the North Seasonal Wetland Pond 6 water control structure.

The tidal marsh pressure transducers were deployed for two-week intervals both in the fall/winter and the spring of 2014/2015 (year 0), 2015/2016 (year 1), and 2016/2017 (year 2) monitoring (Table 2-1). During the Year 1 fall deployment, the Petaluma River railroad bridge gauge was vandalized and all data was lost. During 2016/2017 (year 2) monitoring, two level loggers were deployed at each location as an added precaution against vandalism, malfunction and any other unforeseen circumstances. The 2015/2016 (year 1) gauge deployment location was moved to a different, more hidden bridge pier for spring deployment. During the 2016/2017 (year 2) deployment this more hidden 2015/2016 (year 1) deployment location could not be relocated. 2016/2017 (year 2) stilling wells were attached to southern facing piers at the base of the swivel bridge and the gauge was not tampered with during the fall and spring monitoring period. Breach and Back Marsh deployment locations utilized in 2014/2015 (year 0) and 2015/2016 (year 1) were reestablished at the same locations at the initiation of 2016/2017 (year 2) monitoring. The Back Marsh deployment location was reestablished further east and deeper in the low tide channel after early download efforts and subsequent data review indicated the loggers were out of the water.

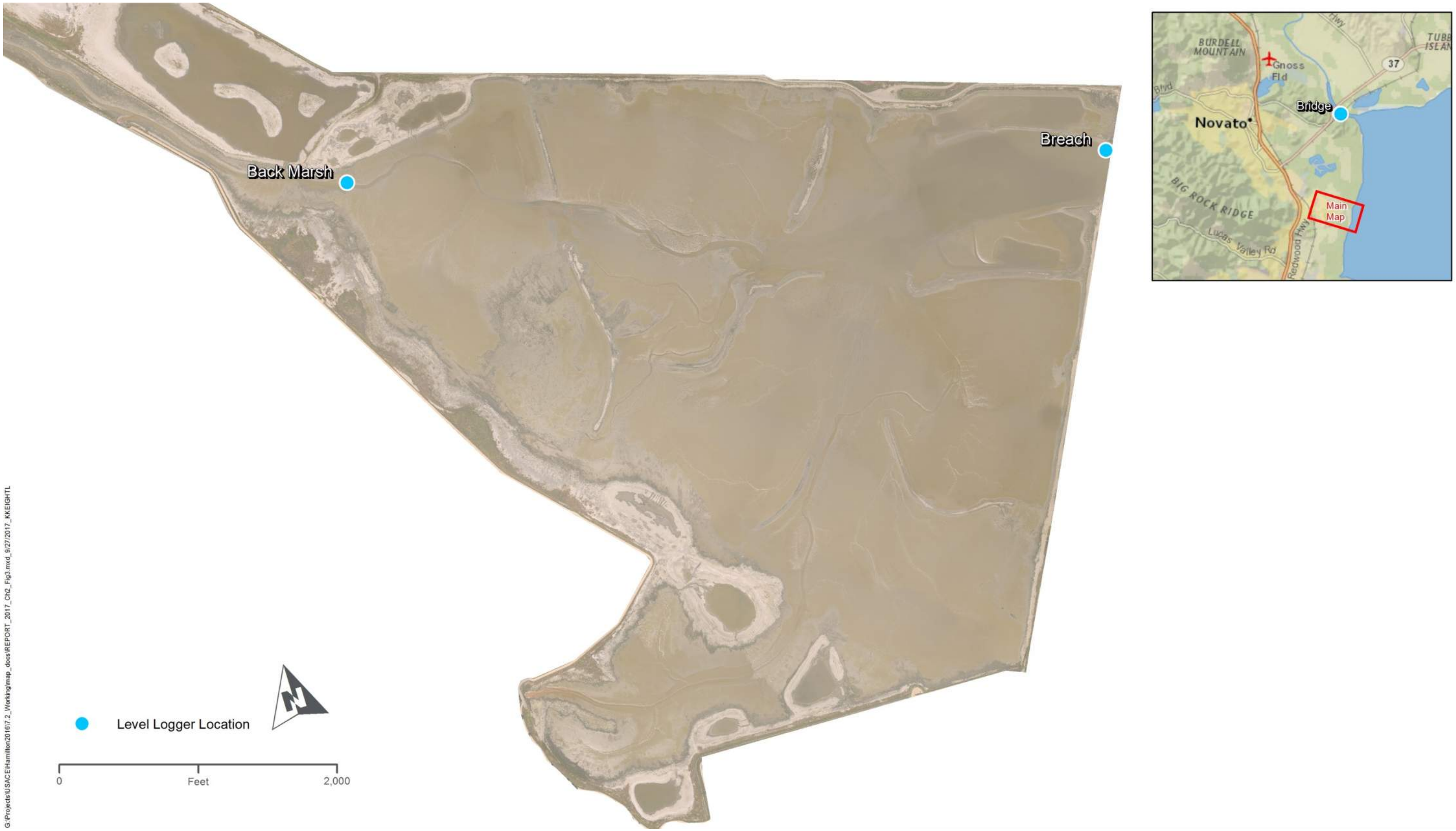

Figure 2-1. Tidal Marsh Level Logger Locations

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2.1.2 Seasonal Water Levels

Continuous water level monitoring at the North Seasonal Wetland in 2016/2017 (year 2) was completed in Pond 1, Pond 2 and Pond 6 (Figure 2-2). The level loggers recorded water surface elevation fluctuations in these three different ponds, which have variable tidal inundation frequency. For 2014/2015 (year 0) and 2015/2016 (year 1) monitoring, non-vented submersible pressure transducers were used. For 2016/2017 (year 2) monitoring, Bluetooth enabled level loggers were utilized with the intent to increase download efficiency and limit the impact extent on the pond mud surface from accessing each logger. The Bluetooth loggers are also non-vented but are self-compensating with a barometric sensor coupled to each logger apparatus and situated well above the water surface at the top of each stilling well. Two level loggers were deployed at each location as an added precaution against vandalism, malfunction and any other unforeseen circumstances. The level loggers in Ponds 1 and 2 were deployed in the deepest portion of the pond with the transducer head sitting just above the pond mud surface. Pond 1 and Pond 2 stilling wells were attached to pressure-treated wood frames anchored with concrete blocks to avoid penetrating the carefully constructed soil lenses and affecting infiltration rates. The gauge in Pond 6 was placed within a stilling well, which was fastened to the concrete headwall of the water control structure, at the deepest portion of the pond.

Table 2-1. Dates of Deployment

Tidal Wetland Level Loggers	Fall and Spring Deployment		
	Year 0	11/11/2014 - 11/27/2014	5/1/2015 - 5/15/2015
	Year 1	9/24/2015 - 10/8/2015	5/27/2016 - 6/12/2016
	Year 2	11/22/2016 -12/8/2016	5/17/2017 - 6/4/2017
		1/19/2017 - 2/10/2017	--
Seasonal Wetland Level Loggers	Continuous Deployment		
	Year 0	11/25/2014 - 6/17/2015	
	Year 1	8/1/2015 - 7/16/2016	
	Year 2	10/20/2016 - 7/27/2017	

2.2 Results

2016/2017 (year 2) water level monitoring results are presented in in Figures 2-3, 2-4, 2-5, 2-6 and 2-7. Water level data collected in year 0 and 1 are presented in Appendix B.

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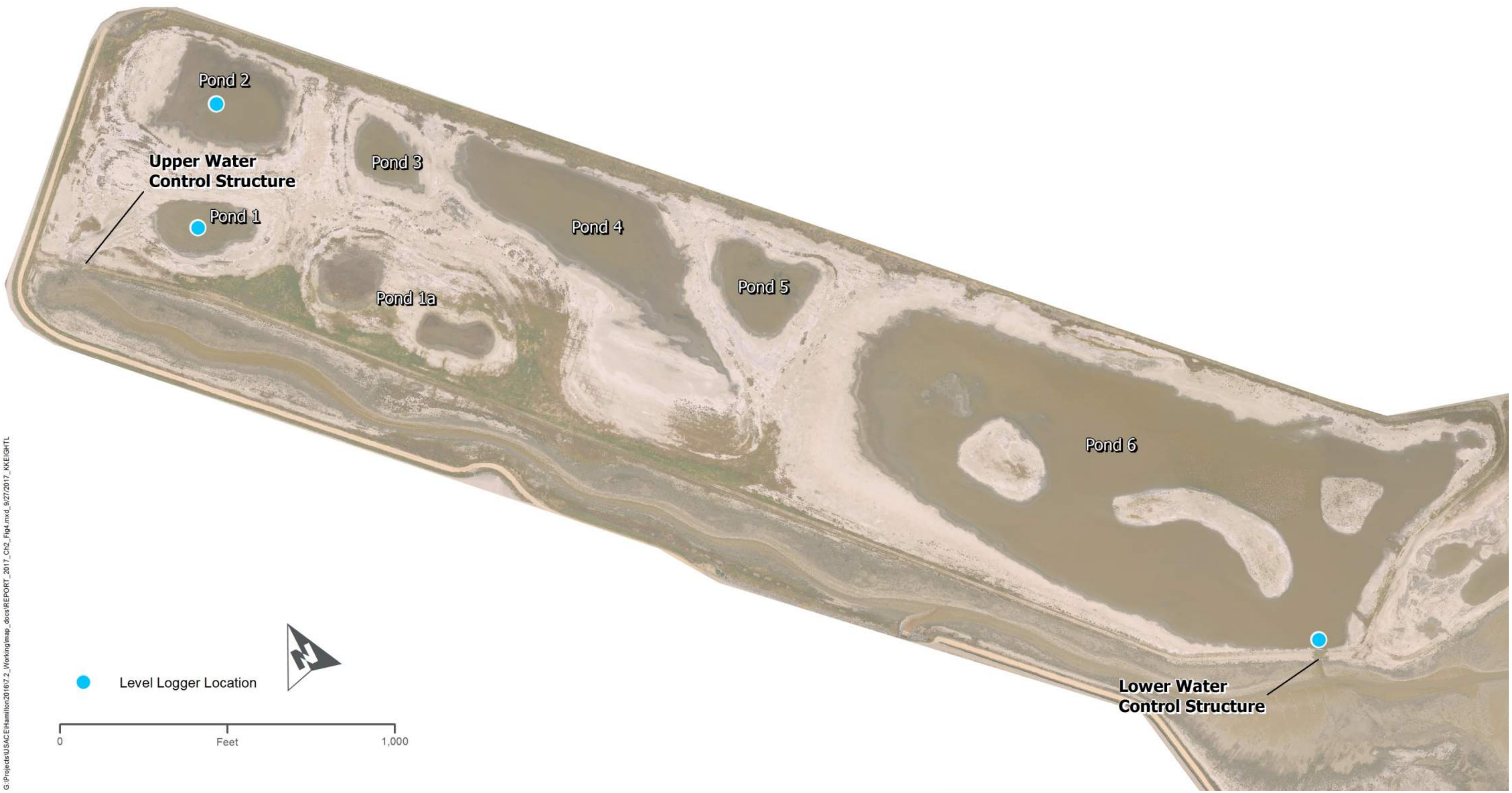

Figure 2-2. Seasonal Pond Level Logger Locations

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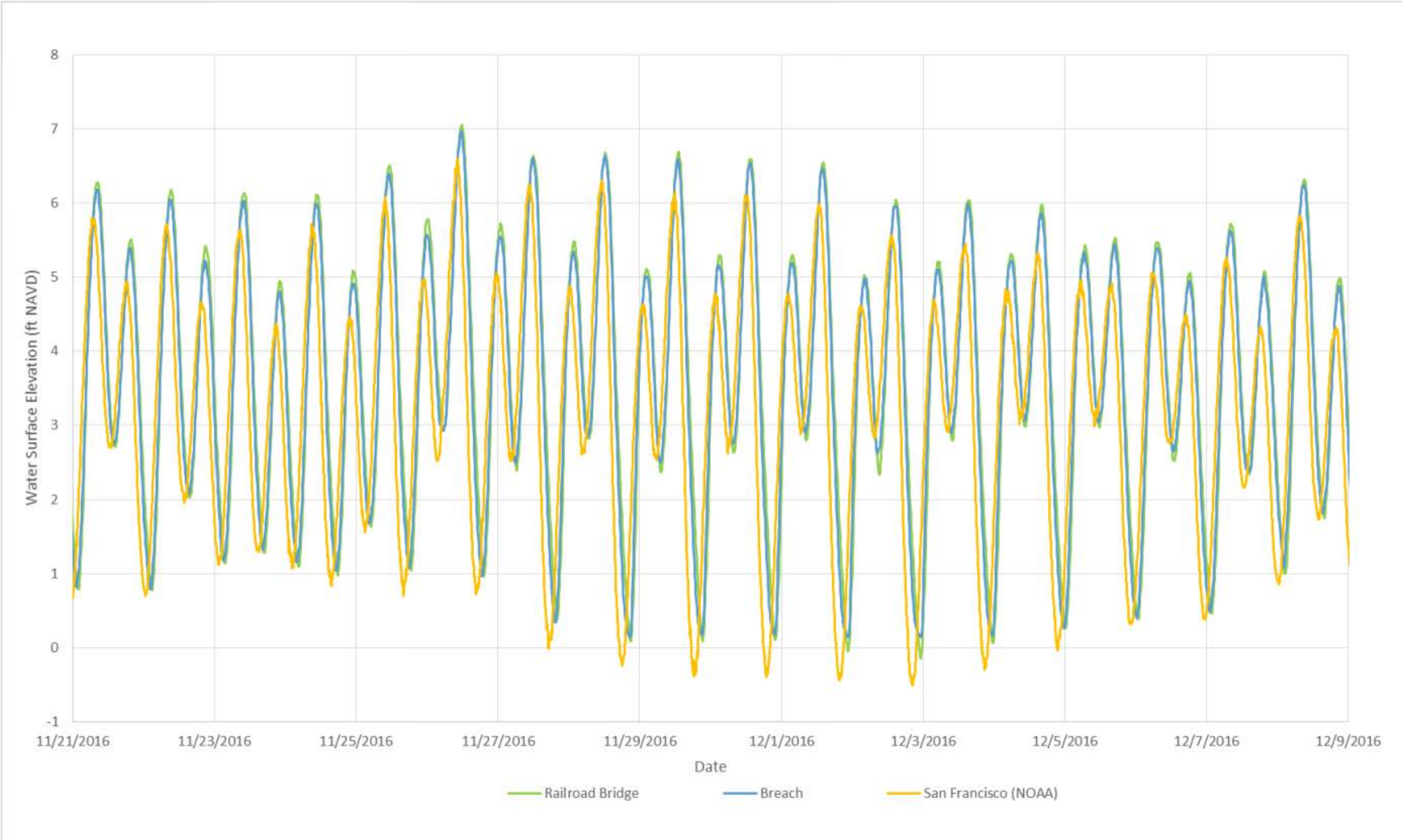

Figure 2-3. Fall Tidal Water Levels Spring-Tide Cycle

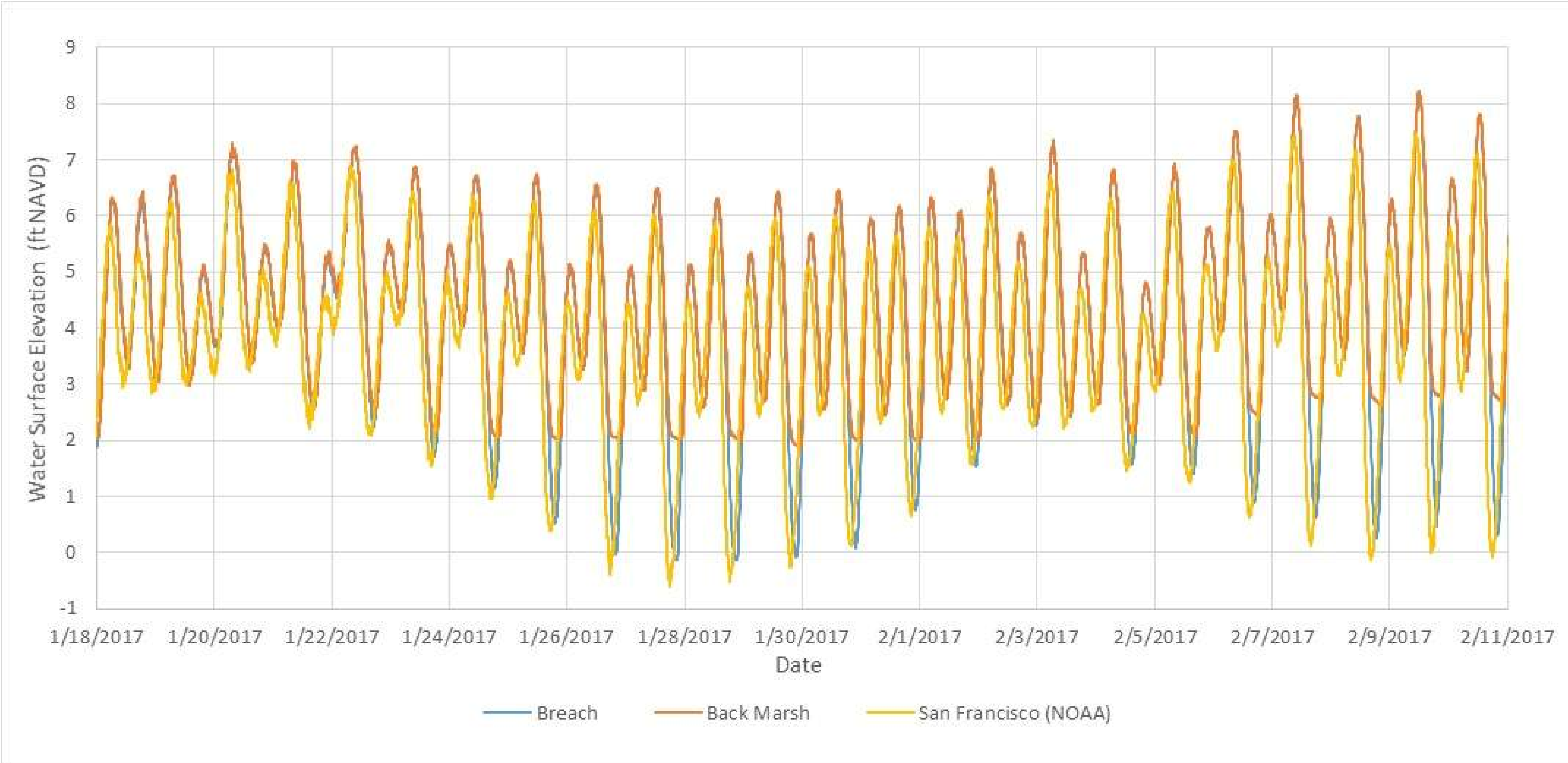

Figure 2-4. Winter Tidal Water Levels Spring-Tide Cycle

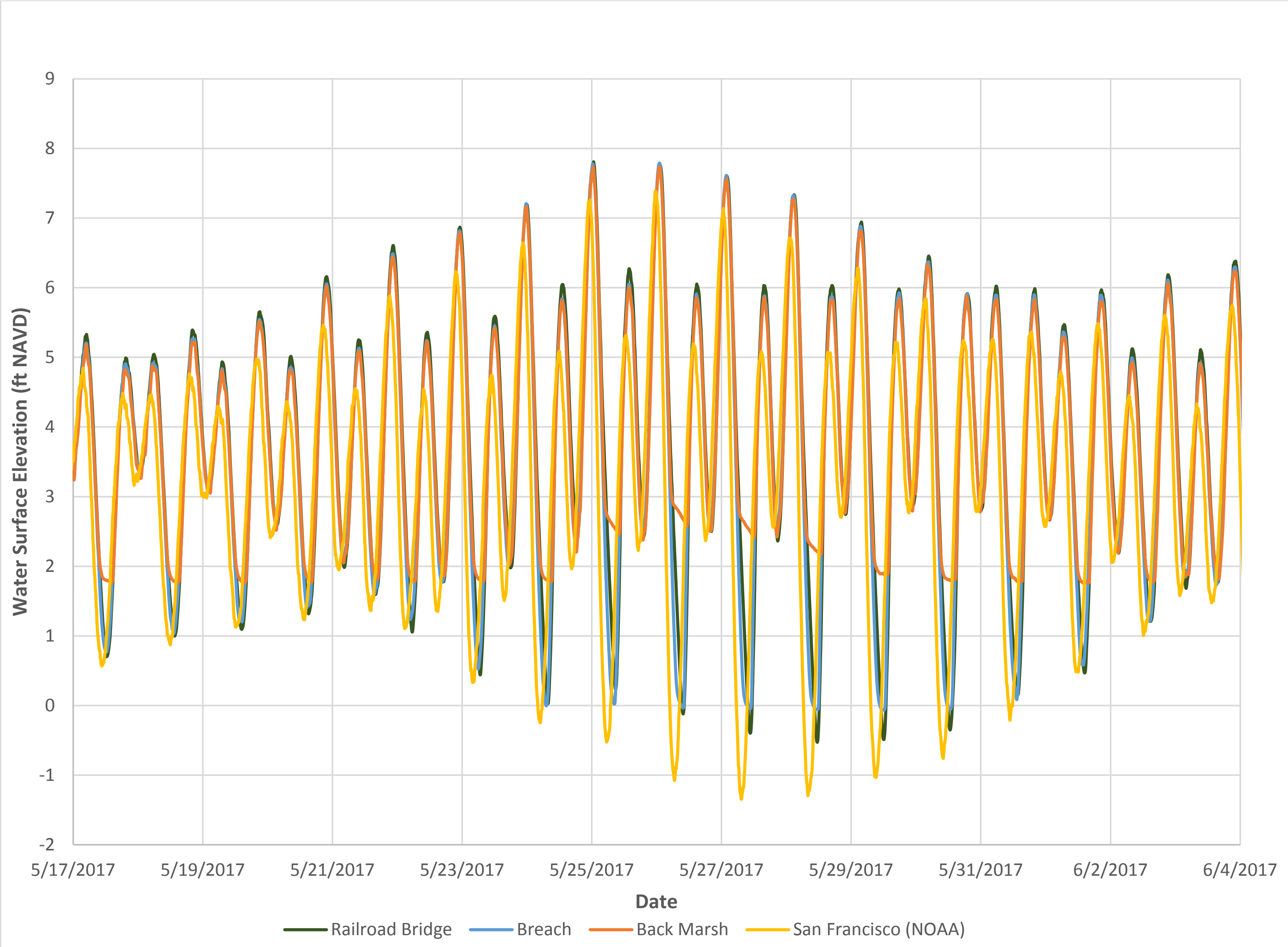

Figure 2-5. Spring Tidal Water Levels Spring-Tide Cycle

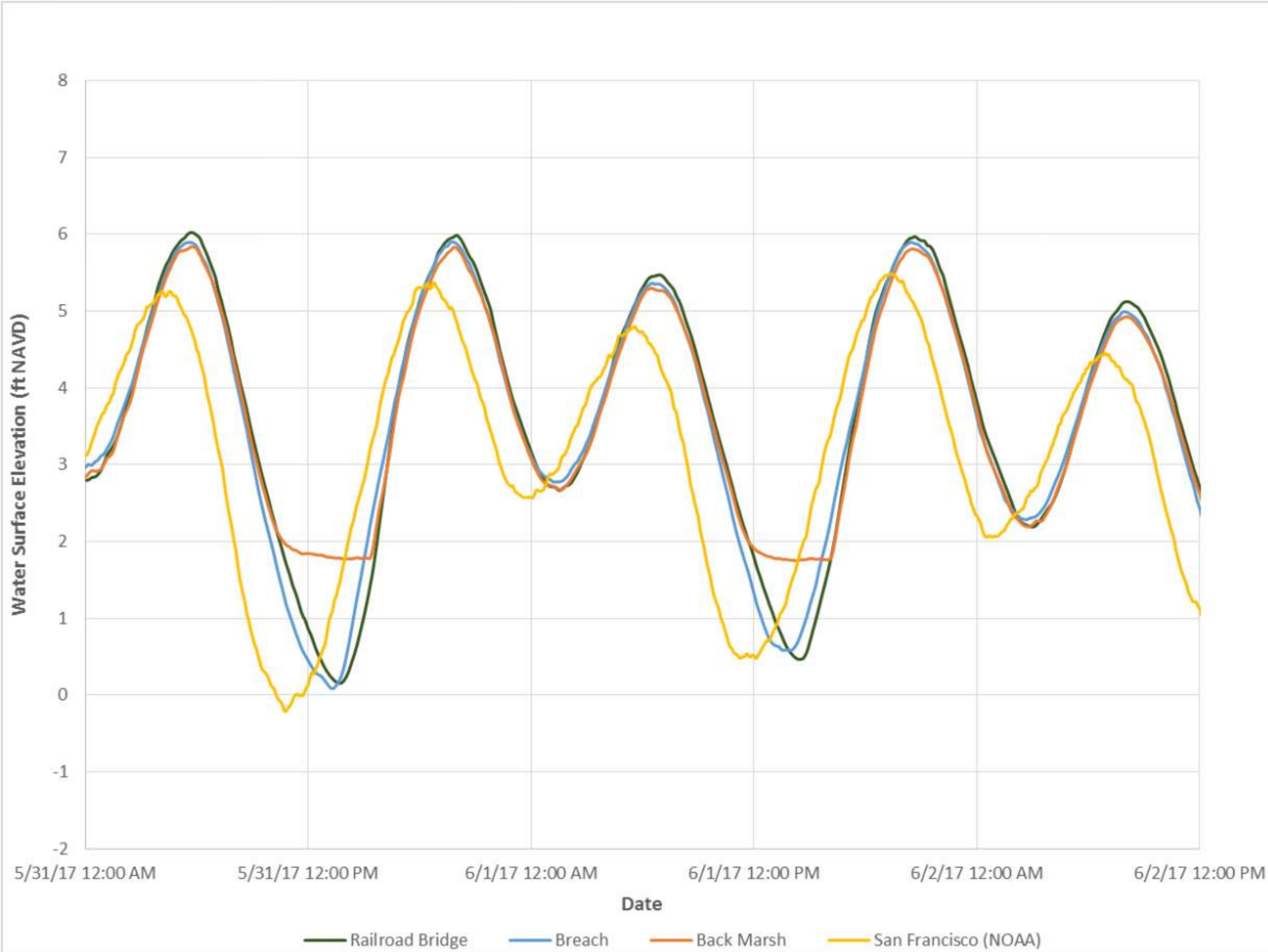

Figure 2-6. Spring Tidal Water Levels 48 Hour Detail

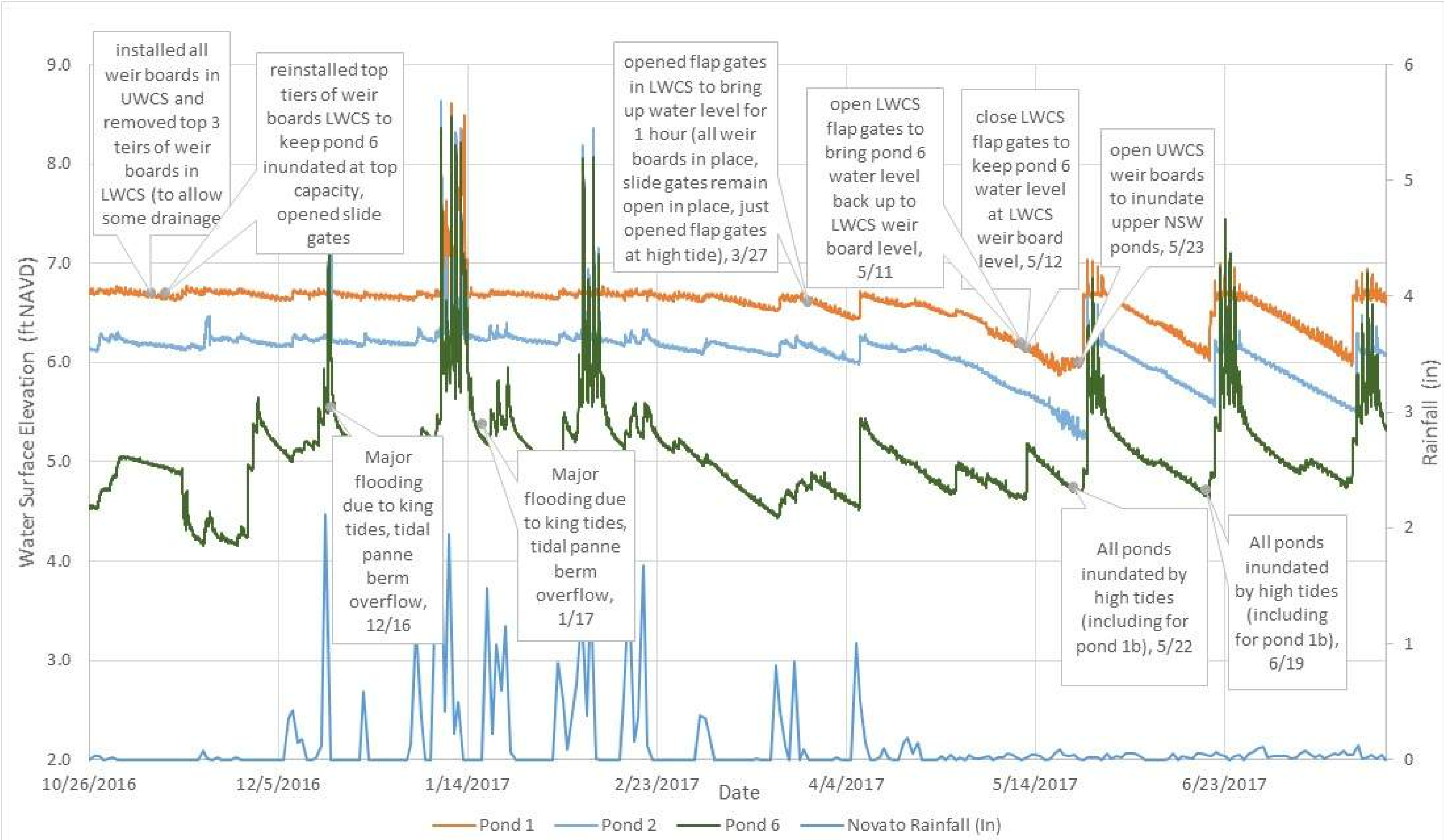

Figure 2-7. North Seasonal Wetland Pond Water Levels

2.2.1 Tidal

Tide signals recorded in the tidal marsh (Figures 2-3, 2-4, 2-5, 2-6 indicate that while flood tides are not limited, ebb tides remain limited both inside the breach as well as in the back marsh.

The breach monitoring logger was located just on the inboard side of the breach. Tide data collected at the breach during the fall and spring deployments indicated that lower low tides were slightly limited as compared to the Petaluma River railroad bridge (Figures 2-3, 2-4 and 2-5). The spring-tide lower lows during the 2016/2017 (year 2) monitoring period did not drop much below 0.0 ft NAVD in the fall/winter and spring. During these spring season lower lows, a detailed look at 48 hours of tide data collected at the breach implies that ebb-tide drainage remains limited by the outboard channel (Figure 2-6).

The Back Marsh level logger location is in a channel behind a sill in the far north-west end of the site at the downstream limit of the panhandle channel. The initial deployment location established in October of 2016 was determined to be too shallow for the logger deployment apparatus (not included in Figure 2-3) and the Back Marsh level loggers were redeployed in January of 2017 at an alternate location approximately 150 ft north east. The Breach level loggers were reinstalled at their original location for consistency (Figure 2-4). During 2016/2017 (year 2) fall/winter monitoring, the Back Marsh lower low tides were cut off at roughly 2.03 ft NAVD, which is similar to the cut off elevation observed during the 2015/2016 (year 1) spring monitoring, 2.08 ft NAVD. By the spring of 2017 during the year 2 monitoring schedule, and after a wet winter with more extreme tidal conditions, the Back Marsh location shows a trend of continued channel formation with sill subsidence by up to 0.38-ft and lower low tides cut off as low as 1.70 ft NAVD (Figures 2-5 and 2-6). Data from the Back Marsh loggers at their initial deployment location during the fall or 2016 is available for review but not detailed in this report.

2.2.2 Seasonal Wetlands

Water levels inside Ponds 1, 2 and 6 display very similar hydrologic trends to each other, with Pond 6 water levels showing some variation from Ponds 1, and 2. Pond 6 variation is a result of it being periodically subject to tidal inundation at lower tidal elevations than the other ponds and the operation of the lower water control structure (LWCS) (Figure 2-7). Ponds 1, 2, 3, 4 and 5 are primarily inundated via rainfall, during higher spring tides, or when the upper water control structure (UWCS) weir boards are removed. In Previous years, the water levels in these ponds are primarily reliant upon rainfall, evapotranspiration, and infiltration. During 2016/2017 (year 2) the water level variation in Pond 6 appears to have been strongly influenced by tidal inundation and over topping of the eastern crest of the pond, and secondarily influenced by operation of the LWCS. In combination with Pond 6, water surfaces in Ponds 1 and 2 were inundated during six different tidal cycles.

Daily rainfall totals from a California Irrigation Management Information System (CIMIS) station located in Black Point, Novato are shown along with the pond water levels in Figure 2-7. Direct correlation between local rainfall and pond water levels was apparent during the fall and winter months of the 2017 monitoring schedule. The majority of local rainfall for the year was concentrated between December 14, 2016 and February 22, 2017. The water surface elevations of Ponds 1, 2 and 6 reached peaks of approximately 7.5, 8.5, and 8.0 ft NAVD during three different high tide cycles. Water surface elevation increases influenced exclusively by rainfall events were observed numerous times through this same period, as well as in March and April, 2017. Ponds 1 and 2 are at different elevations, but both are relatively shallow (1 and 1.5 ft deep, respectively) and overtop with significant rainfall. Pond 6 is the deepest and lowest pond in the North Seasonal Wetland and receives excess rainfall-runoff from the five upgradient ponds. Pond 6 water levels are much more sensitive to rain events than Ponds 1 and 2 and display similar timing but variable magnitude of elevation change during rainfall events.

The rate of infiltration and evaporation for Ponds 1 and 2 remained nearly identical over the course of Year 2 monitoring, although Pond 2 sits almost exactly 1-ft lower than Pond 1. The upper weir boards, located at the far west end of the site, divide the North Seasonal Wetlands from the tidal channel on the southern side of the panhandle. On November 8, 2016, all weir boards at the UWCS were installed and remained in place until May 23, 2017.

Pond 6 drains more rapidly than Ponds 1 and 2. Water levels in Pond 6 were primarily influenced by tidal inundation and overtopping at the eastern crest of the pond and were secondarily maintained by the LWCS to maximize capacity. The LWCS was closed on November 11, 2016 and opened twice to bring water levels up: once for an hour on March 27, 2017, and again for a 24 hour period beginning May 11, 2017.

2.3 Discussion

Water level data collected during the second year of monitoring indicates some progress towards meeting design criteria. In the tidal marsh, flood tides were not limited at either the entrance to the site or the back of the site matching trends with the previous years. As in Year 0 and Year 1, Year 2 data indicates that ebb tide drainage at the entrance to the site may only be limited during extreme spring lows, but remains limited at the back of the site during most lower tides. As the interior tidal channel network continues to develop and deepen, ebb tide drainage throughout the site should continue to improve. The lower low tides are still limited at the breach and the control for channel through outboard mudflat, discussed in Section 3.2.2 appears to have stabilized just below 0.0 ft NAVD between 2015/2016 (year 1) and 2016/2017 (year 2) monitoring. Drainage at the Back Marsh location remains limited but continued cannel formation and improved tidal exchange is evident by the lower cutoff elevation observed during the spring of 2017.

Seasonal pond water level data for this third year of monitoring gives a good indication of pond elevation, watershed size, and seepage rates of Ponds 1, 2, and 6. What is primarily apparent by the data collected during the 2017 monitoring schedules is the regular inundation of all ponds during high tides in conjunction with rainfall events and storm surge. Additionally, the data continues to show the operational impact of the two water control structures, though limited during the 2017 monitoring schedule.

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3 Geomorphic Monitoring

Geomorphological change throughout the HWRP site was monitored according to the MAMP. This chapter presents results of the 2016/2017 (year 2) monitoring and is broken out into three different sections based on a combination of geomorphological units and methods: Interior Marsh, Outboard Marsh and Main Channel, and Planform.

3.1 Interior Marsh

The interior marsh was monitored in accordance with the MAMP and supplemented based on ESA's Post-Construction Assessment. Geomorphologic features were monitored with a mixture of topographic and bathymetric surveying along cross-sections that span representative areas of the tidal marsh (Figure 3-1). These surveys track the distribution of sediment across the site, the formation of tidal channels, and the effectiveness of specific design elements.

3.1.1 Methods

Eleven cross-sections were surveyed within the marsh and mudflat areas (Figure 3-1). PVC endpoints that were established in 2014/2015 (year 0) and 2015/2016 (year 1) were used again during the 2016/2017 (year 2) survey in order to line up cross-sections for accurate comparison. At locations where the endpoint was no longer occupied by a PVC marker, the endpoint horizontal coordinates were staked out using Real-Time Kinematic (RTK-GPS). Established cross-sections span all major levee/berm breaches (Cross-Sections BR1, BR2, 14, 25, 26, NS2 and SS1), the area between the north levee and Berm 6 (Cross- section 6), and across the mudflats between berms (Cross-Sections 27, 35, 37, 56, and NS1). Cross-section numbering is organized as a function of the two berms the cross-section spans between. For example, Cross-Section 26 runs north to south, spanning between berm 2 and berm 6 and Cross-Section 27 runs east to west, spanning between berm 2 and berm 7. Cross-Sections SS1, NS1, and NS2 do not run between numbered berms and are numbered as a function of their location. NS1 and NS2 are located at the entrance to the North Seasonal Wetland complex, and are located to monitor the entrance channel to the panhandle of the site. SS1 is similarly located at the entrance to the South Seasonal Wetland complex. All interior marsh surveys were completed utilizing RTK-GPS outfitted with 12 in. diameter mud boot for out of water topographic data collection, and RTK-GPS coupled to a single beam echosounder for bathymetric data collection. Topographic and bathymetric data collection was completed during the weeks of October 21, 2016 and November 18, 2016. Light Detection and Ranging (LiDAR) data used for validation was collected on May 3, 2017.

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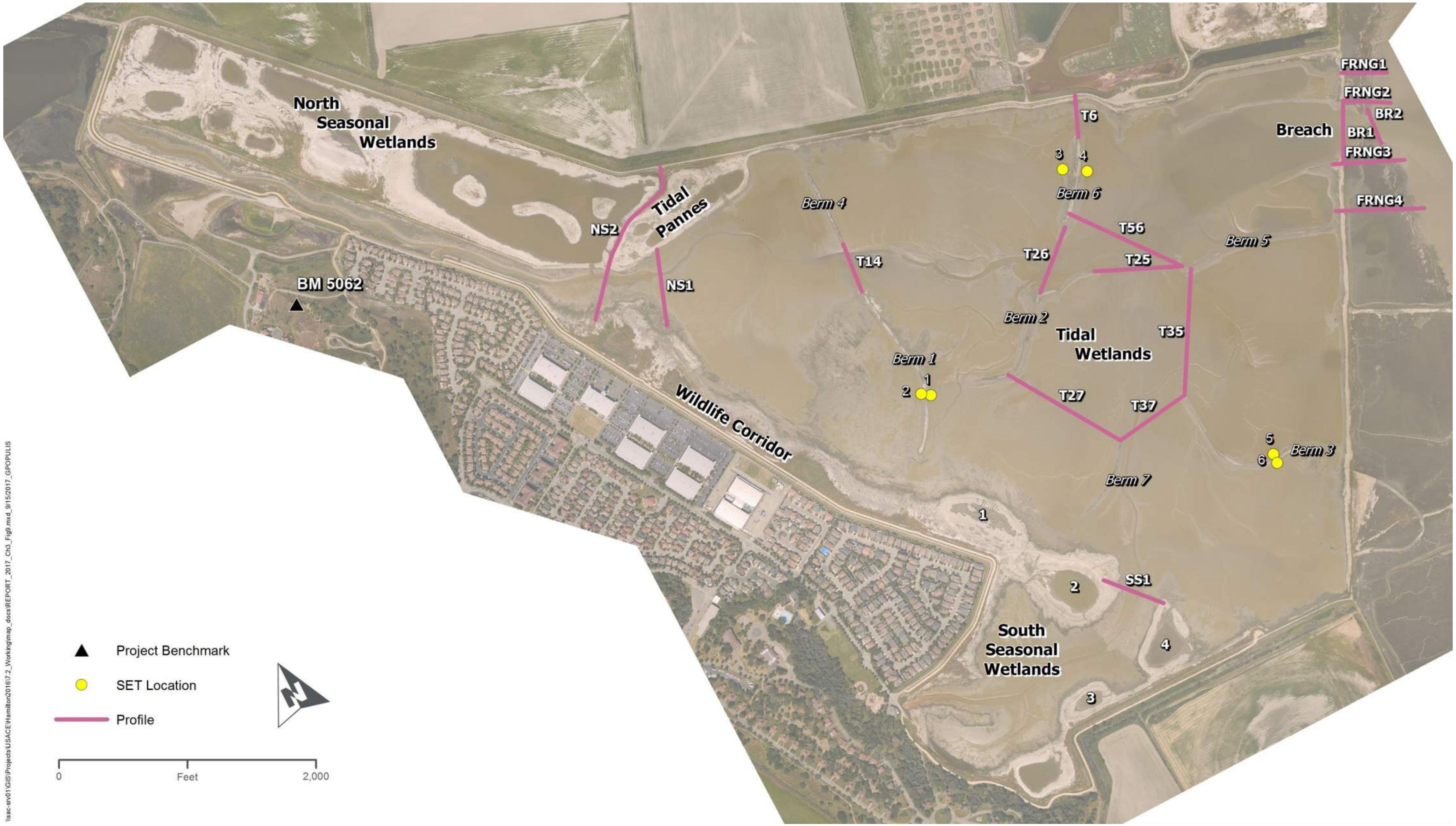

Figure 3-1. Survey Plan

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Detailed sediment elevation surveys were completed at the six Sediment Elevation Table (SET)-locations using RTK-GPS outfitted with a small mud boot to ensure consistency and at the very top surface of the mudflat. Four survey points were taken at each of the four SET arm positions and an average mudflat elevation was derived from each cluster of points. The plot corners were marked with PVC poles for future occupation efforts, and care was taken to avoid disturbing any sediment within the plot.

The crests of South Seasonal Ponds 1, 2, 3, and 4 were reviewed and compared to previous years to monitor potential subsidence and/or erosion. Subsidence at these locations was recorded during 2014/2015 (year 0) and 2015/2016 (year 1). Relative to the tidal regime, these locations are subject to a higher risk of erosion with relatively frequent inundation during spring high tides. The Pond 5 crest was not surveyed because its elevation is above normal spring tides and erosion has not been noted along the crest of Pond 5. This additional assessment was completed in 2016/2017 (year 2) utilizing airborne LiDAR data collected in tandem with aerial photography by reviewing elevations around each pond crest at the same horizontal locations measured with RTK-GPS in 2015/2016 (year 1). Several RTK-GPS points were recorded along the pond crests to validate LiDAR elevation results.

All surveys were completed in the horizontal coordinate system NAD83, State Plane Zone 3, US Survey Feet (Epoch 2010.00) and North American vertical datum (NAVD)88, Feet (Geoid 12a).

3.1.2 Tidal Marsh Results

Tidal marsh cross-section figures comparing 2016/2017 (year 2) results with 2014/2015 (year 0) and 2015/2016 (year 1) results are presented in Appendix B.

Cross-Section 56 (Figure B-1) runs between berms 5 and 6, and cuts across the two excavated interior areas that direct flow through breaches 25 and 26, just to the west of where they converge on their way out through the breach into San Pablo Bay. The two excavated areas distinctly visible in the 2014/2015 (year 0) profile were observed to have filled in after the 2015/2016 (year 1) survey with the channel near berm 6 (to the north) filled in by approximately 1.7 ft and the channel near berm 5 (to the south) filled in by approximately 2 ft. This aggradation trend appears to have continued between 2015/2016 (year 1) and the 2016/2017 (year 2) survey, specifically with the channel near berm six being barely discernable and further filling in between approximately 0.5-ft and 2.0 ft depending on the location across the transect. Aggradation in the channel near berm 5 appears to have stabilized to some extent with elevation increases ranging from near zero to approximately 1.0-foot and a discernable ebb-tide channel still located along the toe of berm 5. The ebb-tide channel has further filled in between 2015/2016 (year 1) and 2016/2017 (year 2) with the width at -1-ft NAVD reduced from approximately 100 ft to approximately 50 ft respectively and a maximum depth reduction of 0.5-ft to -1.9 NAVD. The non-excavated high point separating the two excavated areas in 2014/2015 (year 0) was less pronounced in 2015/2016 (year 1) and fully concealed after two years of aggradation, 2016/2017 (year 2).

These areas were over-excavated during construction to remove hard, non-erosive materials, and were expected to fill in with sediment entering from the bay and dredged materials being redistributed within the site. Over time, as the subsided area inboard of the outboard levee breach fills in with sediment, the wide over-excavated areas will allow the tidal channels to develop to equilibrium width and depths and to migrate in response to hydraulic forces.

The bed elevation of these excavated areas is relatively consistent with the bed elevation of the breaches they flow to, shown in Cross-Sections 25 (Figure B-2) and 26 (Figure B-3). Nearly 3 ft of sediment had accumulated along much of both cross-sections between the 2014/2015 (year 0) and 2015/2016 (year 1) surveys. The 2016/2017 (year 2) survey revealed up to another 1.0-ft and 1.5 ft of accumulated sediment at cross-sections 25 and 26 respectively, with some short sections along each cross-section showing near zero additional sedimentation. Ebb-tide drainage channels remain open at each section but have been reduced in width. The defined ebb-tide drainage channel width at Cross-Section 25 at -0.2-ft NAVD was reduced from 190 ft (year 1) to approximately 80 ft in 2016/2017 (year 2) and maximum depth was reduced by approximately 0.3-ft to -2.3 NAVD. The defined ebb-tide drainage channel width at Cross-Section 26 generally stayed the same with a minor increase of 10 ft from 90 ft in 2015/2016 (year 1) to 100 ft in 2016/2017 (year 2). Maximum depth at Cross-Section 26 reduced by 1.1 ft to roughly -1.7 ft NAVD in 2016/2017 (year 2).

Cross-Section 35 (Figure B-4) runs between berms 3 and 5 through the lowest mudflats at the site. The ebb-tide channels on both sides of the profile remained similar in size and shape between the 2014/2015 (year 0) and 2015/2016 (year 1) monitoring, but with the southern channel migrated 14 ft to the north in 2015/2016 (year 1). In 2016/2017 (year 2) the southern ebb-tide channel remained in the same location as in 2015/2016 (year 1) but decreased slightly in width and depth. The northern ebb-tide channel experienced some aggradation between 2015/2016 (year 1) and 2016/2017 (year 2) with a maximum depth reduction of 1.3 ft to approximately -0.3 NAVD.

The ebb-tide drainage channels forming along Cross-Sections 27 (Figure B-5) and 37 (Figure B-6) are located near the edges of the profile along the berms. Cross-Section 27 showed little channel development between 2014/2015 (year 0) and 2015/2016 (year 1) and had ebb-tide channels of 0.5-ft deep and 1.4 ft deep on its north and south sides, respectively. By 2016/2017 (year 2), the southern channel had widened slightly and decreased in depth to 1.0-ft. The northern channel in 2016/2017 (year 2) remains at a similar elevation to 2015/2016 (year 1).

The ebb-tide channel on the west side of Cross-Section 37 grew considerably between 2014/2015 (year 0) and 2015/2016 (year 1), deepening 0.5-ft and expanding by 20 ft in width. 2016/2017 (year 2) monitoring shows no obvious change in the western ebb-tide channel. The ebb-tide channel on the eastern side of Cross-Section 37 was not distinguishable in 2015/2016 (year 1), but in 2016/2017 (year 2), it appears to have maintained the general shape of that observed in the original 2014/2015 (year 0) monitoring, only with slightly higher elevations.

Cross-Section 14 (Figure B-7), situated across the excavation of breach 14 filled in with up to 2 ft of sediment between 2014/2015 (year 0) and 2015/2016 (year 1),with a defined ebb-tide channel approximately 230 ft wide at 0 ft NAVD at the toe of Berm 4. 2016/2017 (year 2) monitoring identifies and additional 2.5 ft to 1.0 ft of aggradation across most of the cross-section. Year 2 profile data near Berm 4 details an ebb-tide channel 250 ft wide at 1.5 NAVD.

Cross-Section 6 (Figure B-8) is located near the northeastern part of the project site and runs north to south from the northern levee to the top of Berm 6. 2016/2017 (year 2) monitoring details that the excavated channel at the toe of Berm 6 remains open with a similar profile to previous years. The ebb-tide channel however is narrower by approximately 20 ft. with the southern side seeing increased sediment deposition between year 1 and year 2.

The two cross-sections located near the entrance to the North Seasonal Wetland complex were established at the entrance to the excavated panhandle channel where tidal drainage could be limited. Cross-Section NS1 (Figure B-9) is located near the entrance to the channel to monitor the development of a drainage channel over time. As of the 2014/2015 (year 0) survey, a small channel 0.8-ft deep had begun to scour through the sill, and the 2015/2016 (year 1) survey documents, that channel had scoured to become 3.7 ft deep. The year 2 survey indicates additional scour within the channel and minor subsidence across much of the adjacent mudflat. The down cutting in this channel will significantly improve low- tide drainage in the panhandle channel.

Cross-Section NS2 (Figure B-10) is located in-line with the berm separating the North Seasonal Wetland complex from the tidal panne habitat. The berm itself was identified as an area of concern moving forward due to overtopping during storm conditions in December 2014 causing some erosion. Cross-Section NS2 extends across to the berm crest and panhandle channel to the opposite marsh plain. The low points along the berm where overtopping occurred can be clearly seen along the profile. 2015/2016 (year 1) monitoring showed no significant changes to the berm profile from the 2014/2015 (year 0) condition. 2016/2017 (year 2) RTK GPS surveys conducted in the Fall of 2016 detailed approximately 1.0 and 1.25 feet of erosion in the two channels now forming on the berm crest. Given the alignment along this transect was difficult to replicate, LiDAR data collected in May 2017 was reviewed utilizing the horizontal coordinates from 2015/2016 (year1). The 2017 LiDAR data validated elevations of the berm crest channels measured with RTK GPS. It should be noted that Pond 6 water surface elevations were affected by tidal over topping numerous times through the 2017 monitoring schedule and specifically between the RTK GPS survey of Cross-Section NS2 in the fall of 2016 and the collection of 2017 LiDAR data in May of 2016. The profile displayed in Figure B-10 includes RTK GPS bathymetric data for the ebb tide channel and LiDAR data along the berm crest and marsh plain on the southern end of the cross-section.

Overtopping at high tide was observed in the field twice during 2016/2017 (year 2) monitoring schedule; a slight overtopping was observed during field efforts on October 26th, and complete inundation of the North Seasonal Wetland was observed on January 11th during a field visit specifically to observe a king tide combined with storm surge. Additional over topping events that occurred during the 2016/2017 (year 2) monitoring schedule are detailed in Chapter 2. The thalweg of the channel along Cross-Section NS2 is on top of the historic runway that was not removed during construction. During the 2014/2015 (year 0) survey, the concrete runway was exposed. The 2015/2016 (year 1) surveys document limited sediment deposition on the runway surface. The 2016/2017 (year 2) survey documents an additional 0.7-ft of aggradation in the thalweg.

Cross-Section SS1 (Figure B-11) is located near the entrance to the South Seasonal Wetlands, spanning from the crest of Pond 2 to the crest of Pond 4. As of 2015/2016 (year 1) surveys, the channel was approximately 4 ft deep, its thalweg sitting at -0.13-ft NAVD. When compared to 2014/2015 (year 0) surveys the channel had aggraded roughly 0.5-ft. 2016/2017 (year 2) monitoring indicates additional aggradation or 1.5 ft and maximum depth at approximately 1.4 ft NAVD in elevation.

3.1.3 Detailed Survey Results (Sediment Elevation Table)

Detailed marsh plain survey results are presented in Table 3-1.

All SET locations have shown a sediment aggradation trend at the end of 2016/2017 (year 2) and are similar to the trends observed in 2015/2016 (year 1) with the exception of SET 3 and SET 6 which showed minor sediment loss in 2015/2016 (year 1). During 2016/2017 (year 2) monitoring, both SET 3 and SET 6 saw minor aggradation. SET 3 is located on the backside of Berm 6 and is separated from SET 4. SET 6 is located on the backside of Berm 3 and is separated from SET 5. SET 4 and 5 sit at the lowest SET elevations, and have seen the most sediment accumulation at the SET locations in 2015/2016 (year 1) and 2016/2017 (year 2). The reasons for this could be due to the SET locations closer to the breach receiving an increase in sediment due to their proximity to the breach and increased tidal action, and the lower elevations allow for additional sediment delivery due to increased period of tidal inundation.

Review of the SET changes between surveys identifies elevation losses at nearly all SETs at the time of the October survey, Jun 2016 – Oct 2016, and elevation gains at all SETs at the time of the February survey, Oct 2016 – Feb 2016. These observations point to there being an issue with the October survey and specifically at SET 3 and SET 4. It was found that monitoring methods used for the October survey were not consistent with previous year's surveys. The monitoring methods were adjusted for the remaining February, May and July surveys which show a trend similar to that observed during 2015/2016 (year 1) Monitoring with minor aggradation/degradation from survey to survey.

Table 3-1. Sediment Elevation Table

Position		Jun-16	Oct-16*	Elev. Change (Jun-16 - Oct-16)*	Feb-17	Elev. Change (Oct-16 - Feb-17)	May-17	Elev. Change (Feb-17 - May-17)	Jul-17	Elev. Change (May-17 - Jul-17)	Total Elevation Change
SET 1	Total	3.92	3.77	-0.15	4.03	0.26	3.89	-0.14	4.02	0.13	0.10
	1	3.93	3.85	-0.08	4.04	0.19	3.89	-0.15	4.04	0.16	0.11
	2	3.92	3.82	-0.10	4.02	0.20	3.88	-0.13	4.03	0.14	0.11
	3	3.87	3.60	-0.27	3.98	0.38	3.85	-0.13	3.97	0.12	0.10
	4	3.94	3.80	-0.14	4.08	0.28	3.92	-0.16	4.03	0.11	0.09
SET 2	Total	4.03	4.06	0.03	4.37	0.31	4.25	-0.12	4.40	0.15	0.37
	1	3.98	4.22	0.24	4.46	0.24	4.36	-0.10	4.49	0.14	0.51
	2	3.99	3.90	-0.09	4.22	0.32	4.14	-0.07	4.33	0.19	0.34
	3	4.03	3.87	-0.16	4.32	0.46	4.20	-0.12	4.30	0.10	0.27
	4	4.13	4.26	0.13	4.48	0.22	4.29	-0.18	4.45	0.16	0.32
SET 3	Total	3.21	2.98	-0.23	3.37	0.39	3.26	-0.11	3.28	0.02	0.07
	1	3.21	3.02	-0.19	3.39	0.38	3.31	-0.09	3.32	0.01	0.11
	2	3.18	2.97	-0.21	3.35	0.38	3.26	-0.09	3.27	0.00	0.09
	3	3.22	2.95	-0.27	3.37	0.42	3.22	-0.15	3.23	0.01	0.01
	4	3.22	2.96	-0.26	3.35	0.39	3.25	-0.10	3.30	0.05	0.08
SET 4	Total	1.99	1.75	-0.24	2.19	0.44	2.31	0.12	2.57	0.26	0.58
	1	2.00	1.77	-0.23	2.22	0.45	2.31	0.09	2.59	0.28	0.59
	2	1.95	1.72	-0.23	2.13	0.41	2.29	0.16	2.56	0.27	0.61
	3	1.95	1.74	-0.21	2.17	0.43	2.29	0.12	2.54	0.25	0.59
	4	2.05	1.78	-0.27	2.23	0.45	2.33	0.10	2.59	0.26	0.54
SET 5	Total	2.21	2.21	0.00	2.64	0.43	2.70	0.06	2.85	0.14	0.64
	1	2.27	2.25	-0.02	2.61	0.36	2.73	0.12	2.89	0.15	0.62
	2	2.19	2.15	-0.04	2.57	0.41	2.69	0.12	2.82	0.13	0.63
	3	2.17	2.15	-0.02	2.67	0.52	2.68	0.00	2.81	0.13	0.64
	4	2.22	2.28	0.06	2.71	0.43	2.72	0.01	2.88	0.16	0.66
SET 6	Total	3.69	3.53	-0.16	3.93	0.40	3.93	0.01	3.95	0.02	0.26
	1	3.66	3.56	-0.10	3.94	0.38	3.92	-0.02	3.93	0.01	0.27
	2	3.68	3.49	-0.20	3.96	0.47	3.94	-0.02	3.97	0.03	0.29
	3	3.68	3.52	-0.16	3.89	0.37	3.89	0.00	3.89	0.00	0.21
	4	3.73	3.54	-0.19	3.92	0.38	3.98	0.06	4.02	0.04	0.29

*Inconsistent survey methods as compared to the previous year's survey likely bias the measurements.

3.1.4 South Seasonal Pond Crest Survey Results

South seasonal pond crest survey results are presented in Appendix B, Figures B-12 through B-15. All four of the pond crests subsided from 2014/2015 (year 0) to 2015/2016 (year 1). Subsidence continued between 2015/2016 (year 1) and 2016/2017 (year 2) but generally to a lesser degree than that observed between 2014/2015 (year 0) and 2015/2016 (year 1). Some minor aggradation was observed in some sections along the crests of Pond 1, Pond 3 and Pond 4.

The majority of the Pond 1 crest is above the pond sill elevation, although areas on the northern part of the perimeter have seen channel erosion cutting the crest down past the pond base. In one area, there is up to a 0.76-ft difference in crest elevation from baseline surveys limiting the pond's water holding function as a result of dipping below post-construction pond base elevation (Figure B-12).

Pond 2 has six areas that dip below the pond sill elevation. 2016/2017 (year 2) monitoring details additional subsidence throughout the profile and the area near the end of the profile with the highest degradation observed in 2015/2016 (year 1) has further down cut to approximately 1.2 ft from the baseline condition and reached the pond base.

Pond 3 has the largest channel forming that has eroded the crest with approximately 1.62 ft of deepening since baseline monitoring and reached the pond base in 2015/2016 (year 1) (Figure B-14). 2016/2017 (year 2) monitoring details approximately half of the profile below the sill elevation and the scoured channel stabilizing at the pond base elevation with some additional but more minor erosion observable at or below the pond sill elevation.

Pond 4 in 2015/2016 (year 1) had the greatest amount of pond crest that is sitting beneath the design sill elevation and down-cutting 0.5-ft away from the pond base (Figure B-15). 2016/2017 (year 2) monitoring details that subsidence appears to have stabilized and shows some slight aggradation.

3.2 Outboard Marsh and Main Channel

3.2.1 Methods

Per the MAMP, a total of six cross-sections and a thalweg profile were established and surveyed in the outboard marsh and main channel. Two of those cross-sections are across the main breach, and four cross-sections are located along the fringing marsh on either side of the main breach. The main channel thalweg profile was surveyed utilizing RTK-GPS coupled to a single beam echosounder. The two breach cross-sections and four shore normal fringing marsh profiles were surveyed with RTK-GPS, and RTK-GPS in combination with single beam echosounder and validated with LiDAR data.

The thalweg profile data was collected in a tight parabolic formation perpendicular to tidal exchange and continuing out past the outboard pilot channel parallel and centered in the middle of the breach. Thalweg profile data was assimilated in ArcGIS and the lowest elevations across each perpendicular pass were identified. These lowest elevations were stationed onto a distance from the beginning of the thalweg profile consistent with previous year's surveys.

3.2.2 Levee Breach and Outboard Channel Development Results

The main channel thalweg profile is presented in Appendix B, Figure B-16. The profile starts at Cross-Section 26 and travels out through the breach and pilot channel. Additional aggradation has been observed from year to year from station zero to station 1900 ranging from up to approximately 2.0 ft to near zero ft respectively. The highest current velocities are found from rising and falling tides being funneled through the breach area. The profile shows the scour hole continuing to lengthen to the east of the breach towards the outboard pilot channel from 2015/2016 (year 1) to 2016/2017 (year 2). The design thalweg of the breach was -6.5 ft NAVD. The 2015/2016 (year 1) survey documented up to 3.2 ft of down cutting from design to approximately -9.7 ft and the 2016/2017 (year 2) survey data documents approximately an addition 1.0 feet to 2.5 ft of down cutting. The design thalweg for the pilot channel was -6.0 ft NAVD sloping up to -3 ft NAVD. Within the deeper portion of the pilot channel, up to 1 ft to 2.5 ft of down cutting been documented in 2015/2016 (year 1). 2016/2017 (year 2) down cutting was similar to 2016 with the pilot channel scouring and continuing to deepen to the east with highly variable topography and intermittent sections of aggradation before eventually reaching elevations similar to 2016 at the eastern end of the profile. Highly variable topography was observed from station 2900 to station 3580 and a subset profile detailing this variability on less extreme vertical to horizontal scale is provided inset on Figure B-16. The inset profile details elevation changes of up to approximately 1.5 ft across 10.0 ft horizontal which is still somewhat extreme but entirely possible given outboard marsh widening that occurred and the regularity and magnitude of hydrodynamic forces acting on the outboard channel bedform.

The two main breach cross-sections are presented in Appendix B. Cross-Section BR2 (Figure B-17) is located at the mouth of the site and documents evolution of the smaller pilot channel excavated through the outboard marsh into the mudflat. The design thalweg within the pilot channel was -6.0 ft NAVD. The 2014/2015 (year 0) cross section survey detailed a deeper thalweg at -9.3 ft NAVD and the 2015/2016 (year 1) survey detailed additional down cutting of 0.4 ft. Between 2015/2016 (year 1) and 2016/2017 (year 2), the channel down cut by another foot to -10.6 ft NAVD. The channel widening observed in 2015/2016 (year 1) has continued through to the 2016/2017 (year 2) monitoring survey. The width of the channel is approximately 195 ft.

Cross-Section BR1 (Figure B-18), on the other hand, is located at the outboard levee where the breach was excavated about 417 ft wide with a design thalweg of -6.5 ft NAVD. The width of the breach has not changed since 2014/2015 (year 0) and remains approximately 424.4 ft. The thalweg for BR2 was observed to have filled in by approximately 0.7 ft in between the 2014/2015 (year 0) and 2015/2016 (year 1) surveys. The 2016/2017 (year 2) survey documents some minor scouring from the 2014/2015 (year 0) condition and remains approximately at the design thalweg.

3.2.3 Fringing Marsh Scour Results

The four fringing marsh profiles are presented in Appendix B, (Figures B-19 through B-22). Fringe marsh profiles 1 and 2 are located north of the breach, and fringe marsh profiles 3 and 4 are located south of the breach. Each profile runs from the lowered levee out across the outboard marsh to the mudflat beyond and crosses a tidal channel that parallels the lowered outboard levee.

The fringe profiles showed little to no erosion between 2014/2015 (year 0)and 2015/2016 (year 1) monitoring schedules. By 2016/2017 (year 2), erosion was evident on the eastern edge of all fringes but most apparent on the eastern edge of Fringe 1, Fringe 2 and Fringe 3. 2017 LiDAR data was reviewed to validate these changes and is included in the figures for comparison. Furthermore, the LiDAR data was collected in May well after the RTK bathymetric survey and details additional changes to the eastern end of each fringe after wet winter in 2017 with more extreme tidal and wave action. 2016/2017 (year 2) LiDAR validates RTK bathymetry data for the eastern edge on Fringe 2, Fringe 3, and Fringe 4, and identifies additional erosion over the winter of 2017 on Fringe 1. Between 2015/2016 (year 1) and 2016/2017 (year 2), the eastern edge of Fringe 1 experienced up to 30 feet of erosion, Fringe 2 saw up to 19 ft of erosion, 22 ft of erosion was observed on Fringe 3, and nine feet of erosion was observed on Fringe 4. LiDAR data was not sorted to remove returns from vegetation which is viewable in the undulation and variation compared RTK GPS topography across the top of each fringe cross-section. During the LiDAR data collection, tidal water surfaces were at or just below 1.0 NAVD. The LiDAR data was especially valuable to validate the lower elevations on the eastern end of each profile as it was difficult to keep the bathymetric equipment on transect. These eastern lower elevations between 2015, 2016 and 2017 LiDAR data are all similar. The RTK bathymetric data is comparable on all fringe cross-sections but Fringe 2 where LiDAR elevations measured are near the tidal water surface elevation.

A slight deepening of the tidal channels was observed between 2014/2015 (year 0) and 2015/2016 (year 1). The channel along Fringe Profile 1 (Figure B-19) deepened by 0.4-ft to 3.4 ft NAVD, the channel along Fringe Profile 2 (Figure B-20) deepened by 0.1-ft to 1.2 ft NAVD, the channels along Fringe Profile 3 (Figure B-21) and Fringe Profile 4 (Figure B-22) deepened by 0.5 to 1.3 ft NAVD and 1.5 ft NAVD respectively. Between 2015/2016 (year 1) and 2016/2017 (year 2) monitoring aggradation of approximately 1.0-ft was observed within the channels along Fringe 3 and Fringe 4 to 2.26 ft and 2.42 feet NAVD respectively. The channels on the north side of the breach appear to have stabilized between 2015/2016 (year 1) and 2016/2017 (year 2) with slight aggradation of approximately 0.3-ft observed at Fringe 2 and 0.1-ft aggradation or erosion observed at Fringe 1 depending on the dataset, 2016/2017 (year 2) RTK GSP collected in the fall of 2016 or 2016/2017 (year 2) LiDAR collected in May of 2017.

Similar to the observations of the lost eastern endpoint on Fringe Profile 4 and the resulting offline profile alignment in 2015/2016 (year 1), all fringe profile eastern endpoints were lost prior to 2016/2017 (year 2) surveys. RTK GPS bathymetric survey data collection along the eastern end of each profile required additional field effort and data review and assimilation. Final topographic and bathymetric survey data at these locations used for comparison between years remained at or near the original alignment.

3.3 Planform

3.3.1 Methods

Towill, Inc. took a series of true color and infrared (RGB/IR) aerial photos (0.15-ft pixel resolution) of the Hamilton Wetlands Project site on May 3, 2017 for 2016/2017 (year 2) monitoring. Photos were taken at low tide in order to capture exposed mudflat, tidal channels, and emergent vegetation. The photos were taken at a tide height of -0.1-ft MLLW. 2014/2015 (year 0) and 2015/2016 (year 1) true color and color infrared aerial photos were taken by Air Flight Service Inc. at 0.5-ft pixel resolution on August 8, 2014 and October 1, 2015 respectively. 2014/2015 (year 0) photos were taken at a tide height of 1.1 ft MLLW and 2015/2016 (year 1) photos were taken at a tide height of 1.8 ft MLLW. The photos were ortho-rectified to NAD83, California State Plane Zone 3, ft. The photos were analyzed and comparisons were made between 2016/2017 (year 2), 2015/2016 (year 1), and 2014/2015 (year 0).

3.3.2 Aerials

Results of the 2016/2017 (year 2) aerial photos can be found in Appendix C. Figure C-1 shows a color photo of the project site and Figure C-2 shows a color infrared photo of the Project site. Figure C-3 and Figure C-4 show 2015/2016 (year 1) aerial photos and Figure C-5 and Figure C-6 show 2014/2015 (year 0) aerial photos.

The low tide level in the 2016/2017 (year 2) photos reveal aggradation and dendritic channel formation in the mudflat areas throughout the site. First and second-order channels continue to emerge across the mudflat expanses, and pre-existing channels are widening in some locations and narrowing in others.

Large amounts of sediment have accumulated throughout the site but most evidently within Nina's Pond between the North Seasonal Wetland Tidal Pannes and Berm 4; the settling basin just east of Berm 6; and the south eastern area of the site just north of Berm 5 and between Berm 5 and Berms 3. Nina's pond was approximately 6.0 to 8.0 ft deep at time of breach, and is now completely full of sediment with a defined ebb tide channel running through it. The settling basin has seen a similar amount of sedimentation expanding east from Berm 4. The south eastern area of the site has seen aggradation in multiple locations with both stable channels formed and evidence of early channel formation through these new higher elevation areas.

With the exception of Pond 5, which sits much higher than the others, the south seasonal ponds are not holding water as well as they were in 2014/2015 (year 0) though they do appear to be holding similar amounts in 2015/2016 (year 1) and 2016/2017 (year 2).

3.4 Discussion

Tidal marsh cross-section surveys conducted in 2016/2017 (year 2) continue to show a site in progress. Interior breaches between berms continue to aggrade and channels between berms remain open supporting tidal exchange across the site. First and second-order channels across the mudflats continue to develop and stabilize throughout the site with dendritic channels further developing within the interior, and breach channels taking shape between the berms toward equilibrium dimensions. Mudflat areas have expanded and new smaller channels have formed throughout much of the site. Mudflat expansion has reduced the tidal prism with additional filling of main tidal channel. Some cross-section profiles confirm that channels are filling in while other cross-sections are yet to see much aggradation.

A moderate amount of change in marsh plain elevation was observed during the SET survey effort. The highest elevation SET locations experienced minor elevation loss or aggradation while the lower elevation locations experienced varying amounts of aggradation. The mudflats at these locations are still very soft and SET installation is still not yet recommended due to the softness of the substrate.

Similar to 2015/2016 (year 1), the main channel through the outboard mudflat in 2016/2017 (year 2) continues to erode through the breach, but remains limiting to the lowest low tides within the site. This limitation does not appear to be negatively affecting the development of the site at this time.

Significant erosion was identified at all fringe cross-sections during 2016/2017 (year 2) monitoring. RTK bathymetric survey data assimilation in all years could contribute to some of the observed differences. The eastern fringe boundary running south to north is highly variable in some locations. Data assimilation and normalizing along a straight line between fringe cross-section end points could produce some of these differences if the survey data was collected slightly off transect. LiDAR data collected in year 2 details the exact topography between cross-section endpoints and is not normalized. Utilization of LiDAR data collected in future years and aerial/latitudinal comparison of the eastern fringe boundary to that measured in year 2 could provide more accurate picture of how this area is evolving. Two key areas of concern were identified in the post-construction assessment: the North Seasonal Wetland berm and the south seasonal pond crests. Initial post construction surveys suggested that the constructed elevation, compaction, and delayed vegetation establishment of these features may make them more susceptible to erosion than originally anticipated.

The North Seasonal Wetland berm was observed overtopping twice in the field and numerous time in the Pond 6 water surface elevation dataset. This area is expected to continue overtopping during the higher spring-cycle tides and during rainfall and storm surge events. 2016/2017 (year 2) surveys show some additional signs of scour and channel formation beyond what was observed in during 2014/2015 (year 0) and 2015/2016 (year 1) monitoring. Future monitoring surveys will document additional erosion that may occur along the berm and provide data to inform potential adaptive management with continued degradation.

The south seasonal pond crests have shown signs of degradation since construction. The crests of South Seasonal Pond 1 and South Seasonal Pond 3 show the most advanced erosion with areas dipping below the post-construction elevations providing almost complete drainage. In year 1, it appeared that the other south seasonal ponds may follow a similar trajectory although at a slower rate due to their higher initial elevations. As of the completion of 2016/2017 (year 2) monitoring, south seasonal pond crest erosion appears to have stabilized and aerial imagery in 2016/2017 (year 2), which was collected at a lower tide than in 2014/2015 (year 0) and 2015/2016 (year 1) supports that some water is retained at low tide. It is still recommended that the TAC evaluate potential remedial actions to reduce and/or reverse the erosion of these pond sills.

4 Vegetation

This chapter presents an assessment of marsh vegetation establishment at HWRP as of 2017 (Year 2) monitoring. In addition, invasive species detections and vegetation cover relative to both physical parameters and the project's biological success criteria are presented.

4.1 Mapping Methods

Marsh vegetation at HWRP was mapped in 2017 approximately 3 years after the wetlands was breached in April 2014, using imagery collected on May 3, 2017. Vegetation mapping was done using a combination of aerial imagery interpretation and field verification (i.e., ground-truthing). Plant species were mapped using manual aerial photo interpretation aided by ground-truthing. An analysis of color infrared (CIR) aerial imagery was used to map vegetation in ArcGIS 10.4.1 using aerial imagery interpretation supported by field verification and refinement.

For the 2017 mapping, the true color and color infrared photos taken by Towill, Inc. were utilized. The photography was timed near the beginning of the growing season to capture the current extent of tidal marsh vegetation cover in 2017.

Vegetation was mapped at HWRP using the following procedure:

1. Image analysis was performed on the CIR imagery using ArcGIS toolsets. The first step was to map surface water based on the normalized difference vegetation index (NDVI) which leverages the reflectance differential between red and infrared light and its interaction with liquid surface water. The imagery was then masked to hide both surface water and areas outside the Project boundary. The remaining areas were then analyzed visually to identify patterns of texture and color (spectra) to identify 3 groups of land cover corresponding to upland, salt march and bare soil (mud). NDVI threshold values were established to classify the three land cover classes and the imagery was then classified to categorical format for analysis and display.

2. CIR imagery is useful for mapping vegetation because the photosynthetic molecule chlorophyll reflects infrared wavelengths, creating a sharp visual signature. However, other photosynthetic organisms like cyanobacteria and algae also contain chlorophyll and can show similar signatures in CIR imagery. This was particularly true at HWRP where algae are common in large areas of exposed mudflat. Therefore, a field visit to HWRP was conducted on June 21, 2017 to refine the vegetation mapping and distinguish tidal vegetation from open mudflat in areas where the spectral signature was similar. An iPad with the aerial imagery and geospatial data collection capabilities (sub-meter accuracy) was used in the field to collect data in order to delineate habitat types. Printed maps were also used to take additional notes on plant species and locations. Areas where the delineation between open mudflat and tidal vegetation was not easily distinguishable using the CIR imagery were visited and mapped. Photos were also taken to document vegetation at the time of the survey.

3. Geospatial data collected in the field was then incorporated into the classified image within ArcMap and used to delineate the boundaries between difficult to distinguish land-cover types (mudflat, salt marsh and upland vegetation).

The following protocols were applied during vegetation mapping:

- Biotic habitats field estimated to have an absolute cover of vegetation greater than or equal to 5 percent were mapped as "vegetated"
- Vegetated habitats were classified as salt marsh with greater than 5 percent relative cover in the polygon. For example, a polygon with a mix of pickleweed (*Salicornia pacifica*), alkali heath (*Frankenia salina*), and cordgrass (*Spartina* spp.) were categorized as salt marsh
- Upland areas were mapped as "annual grassland" because the upland areas were dominated by non-native and invasive grasses and herbs
- Scientific nomenclature used in reporting and mapping followed Jepson eFlora (Jepson Flora Project 2016)
- Mapping results were summarized as the overall percent vegetated and the percent of vegetation in the north seasonal wetlands and tidal wetlands

4.2 Results

Vegetated habitats covered 23.9 percent of the Project site in 2017, with 3.6 percent of the site being annual grassland vegetation and 20.3 percent of the site being wetland vegetation dominated by pickleweed (*Salicornia pacifica*) (Table 4-1). Marsh vegetation at HWRP was dominated by low cover of pickleweed (122 ac). The site also supported a few plants and small patches of cordgrass (*Spartina* spp.) and alkali heath (*Frankenia salina*) at the upper elevation edges of the picklweed. Levee slopes and the wildlife corridor were dominated by a mix of upland non-native invasive grasses and herbs (22 ac). The lower elevation edges of upland vegetation are dominated by non-native and invasive brass buttons (*Cotula coronopifolia*) and Russian thistle (*Salsola soda*).

Table 4-1. Area of Habitats Mapped in 2017

Habitat Class	Area 2017 (ac)	Percent Cover of Project Area
Salt Marsh	122	**20.3%**
Upland – Annual grassland	**22**	**3.6%**

4.2.1 Upland

Above the high-tide line, annual grassland was extensively distributed along the wildlife corridor and along the side slopes of levees (Figure 4-1). Between stands of annual grassland on levee side slopes and the wildlife corridor, some native shrubs and grasses were present including coyote brush (*Baccharis piluaris*) and meadow barley (*Hordeum brachyantherum*). The upland areas were dominated by non-native invasive species, such as bur clover (*Medicago polymorpha*), black mustard (*Brassica nigra*), Italian rye grass (*Festuca perennis*), wild oat (*Avena* sp.), radish (*Raphanus sativus*), sweet clover (*Meliotus* sp.), Rabbitsfoot grass (*Polypogon monspeliensis*), fennel (*Foeniculum vulgare*), English plantain (*Plantago lanceolata*), yellow starthistle (*Centaurea solstitialis*), and rip-gut brome (*Bromus diandrus*). To see a full list of species commonly encountered during the vegetation survey, see Table 4-2.

4.2.2 Invasive Tidal Wetland Plants

A few small patches of cordgrass (*Spartina* spp.) are present in mudflat areas in the tidal marsh within the Project. Although the cordgrass appears to be the native California cordgrass (*Spartina foliosa*), hybrids exhibit variable morphology and are frequently difficult to distinguish from the native California cordgrass and non-native invasive smooth cordgrass (*S. alterniflora*).

4.2.3 North Seasonal Wetlands

In 2017, 31.3 percent of the north seasonal wetlands area was vegetated (Figure 4-1). The salt marsh accounted for 23.7 percent of the vegetation cover and annual grassland accounted for 7.6 percent of the vegetation cover in the seasonal wetland.

4.2.4 Tidal Wetland

In 2017, 22.1 percent of the tidal wetland area was vegetated (Figure 4-1). The salt marsh accounted for 19.4 percent of the vegetation cover and annual grassland accounted for 2.7 percent of the vegetation cover in the tidal wetland.

4.2.5 Species Diversity and Plant Community Structure

In 2017, plant species diversity on the marsh plain at HWRP was typical of early successional tidal salt marsh plant communities, dominated by a low number of species. Pickleweed dominated the marsh plain elevations and is tolerant of physiological stress caused by frequent inundation and high salinity. By contrast, diversity was higher along transition zones between the salt marsh and upland. In the high marsh, pickleweed was mixed with invasive brass button, and sometimes native species such as alkali heath, salt grass, fat hen, and dodder (*Cuscuta salina*). Within the transition zone some high marsh species co-occur with upland plants and invasive species were common. The transition zone was dominated by brass button, Russian thistle, Rabbitsfoot grass, and Italian ryegrass (*Festuca perennis*).

Table 4-2. Plant Species Observed Spring 2017

Common Name	Scientific Name	Native/Non-Native/Invasive
UPLAND*		
bur clover	*Medicago polymorpha*	**Invasive – Limited**
black mustard	*Brassica nigra*	**Invasive – Moderate**
Italian rye grass	*Festuca perennis*	**Invasive - Moderate**
meadow barley	*Hordeum brachyantherum*	**Native**
wild oat	*Avena sp.*	**Invasive – Moderate**
cultivated radish	*Raphanus sativus*	**Invasive – Limited**
ripgut brome	*Bromus diandrus*	**Invasive – Moderate**
vetch	*Vicia sp.*	**Non-native**
Italian thistle	*Carduus pycnocephalus*	**Invasive – Moderate**
alkali Russian thistle	*Salsola soda*	**Invasive – Moderate**
stinkwort	*Dittrichia graveolens*	**Invasive – Moderate**
coyote brush	*Baccharis pilularis*	**Native**
cut leaf geranium	*Geranium dissectum*	**Invasive – Limited**
sow thistle	*Sochus sp.*	**Non-native**
yellow starthistle	*Centaurea solstitialis*	**Invasive - High**
blue wildrye	*Elymus glaucus*	**Native**
Fennel	*Foeniculum vulgare*	**Invasive - High**
sweet clover	*Meliotus* sp.	**Invasive – Not Listed**
TRANSITION*		
brass button	*Cotula coronopifolia*	**Invasive – Limited**
Russian thistle	*Salsola soda*	**Invasive – Moderate**
Rabbitsfoot grass	*Polypogon monospeliensis*	**Invasive – Limited**
Italian ryegrass	*Festuca perennis*	**Invasive - Moderate**
sand spurrey	*Spergularia sp.*	**Native/Non-native**
prostrate knotweed	*Polygonum aviculare*	**Non-native**
Australian saltbush	*Atriplex semibaccata*	**Invasive – Moderate**
cut leaf plantain	*Plantago coronopus*	**Non-native**
ice plant	*Carpobrotus edulis*	**Invasive - High**
perennial	*Lepidium latifolium*	**Invasive – High**
HIGH MARSH*		
pickleweed	*Salicornia pacifica*	**Native**
alkali heath	*Frankenia salina*	**Native**
salt grass	*Distichlis spicata*	**Native**
Cordgrass	*Spartina spp.*	**Native/Non-native**
fat hen	***Atriplex triangularis***	**Non-native**

* Listed in order of most encounters to least encounters within each plant zone (approximate).

Figure 4-1. Vegetation Map

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4.2.6 Comparison to Project Monitoring and Performance Criteria

Mapping results were compared with the following biological performance criteria, which were established in the project's monitoring and adaptive management plan (ESA PWA and BMP Ecosciences 2013):

- **Monitoring for Phase I**: Phase I will monitor the extent of vegetation in the HWRP tidal wetlands, transitions, and upland until it is determined that the site has achieved 5 percent cover tidal marsh vegetation across the restoration site

- **Monitoring Phase II**: Phase II will begin once marsh vegetation has become established on 5 percent or more of the restoration site. At this time, vegetation transects will begin to be conducted to provide more detailed information. See the project's monitoring and adaptive management plan for more specifics (ESA PWA and BMP Ecosciences 2013)

- **Invasive Plant Monitoring**: Major infestations (more than 100 m2) will be immediately eradicated once detected. The USACE will completely control non-native cordgrass and perennial pepperweed (essentially 0% absolute cover) in the vegetated areas within the tidal and seasonal wetlands, the transition, and upland zones. Other non-natives identified by the AMWG should be maintained in the acceptable range of 0-5 percent absolute cover in these same areas over the 15-year monitoring period

In 2017, 20.3 percent of the HWRP Wetland tidal area had cover by salt marsh vegetation which was dominated by pickleweed (Figure 4-1), which exceeds the 5 percent threshold to begin Phase II monitoring.

4.3 Discussion

Successional patterns will be documented at the Project site through annual vegetation monitoring. Succession refers to shifts in species composition in plant communities over time. Succession in tidal salt marshes and seasonal wetlands may be the result of abiotic changes to factors such as elevation, inundation duration, and drainage (which affects species physical tolerance limits and relative competitive abilities). Temporal changes in biotic factors (e.g., propagule supply, herbivory) also play a role in succession.

Pickleweed is quite prevalent for the newly restored tidal salt marsh. The pickleweed dominant salt marsh has and will continue to spread throughout the mid and high marsh elevations in the tidal marsh. Cordgrass was found in a few small clumps throughout low marsh elevations at the site. Cordgrass is also expected to continue to spread throughout low marsh elevations within the tidal marsh. More cordgrass clumps will likely colonize throughout the site as well as expand from existing populations. Overtime, other tidal marsh plants are expected to colonize the site and plant diversity will increase within the tidal marsh.

The site contains a diversity of native and non-native plant species. Cover of non-native invasive plant species within the upland and transition habitats could, without proper management and control, take over as monocultures within the site. Many of these invasive species are currently being managed by the onsite field and nursery manager. It is recommended that all plant species that have potential to pose severe or substantial ecological impacts to the Project site should be managed to maintain or reduce populations of invasive plants to the extent feasible. Management of invasive species is necessary to encourage native plant establishment in the crucial first few years of vegetation establishment. Table 4-2 shows commonly encountered plant species found at HWRP in spring 2017.

Three of the most common transition zone plants within the Project site are brass button, yellow starthistle, and Russian thistle. Although brass button is considered invasive by the California Invasive Plant Council (Cal-IPC), they are considered to have minor ecological impacts and are common first colonizers at salt marsh restoration sites. Brass button is thought to not to pose a long-term threat to the project site and will likely become outcompeted within the tidal wetland by other vegetation over time. Yellow starthistle is rated as high by Cal-IPC and is considered to have severe ecological impacts on physical processes, plant and animal communities, and vegetation structure. Yellow starthistle is considered one of the most serious rangeland weeds in the state and is a major concern for long-term viability at the Project site in both the transition areas and seasonal wetland areas between pond edges and upland edge. Russian thistle is a major concern for long-term viability at the Project site in both the transition areas and seasonal wetland areas between the pond edges and upland edge. As long as invasive species continue to be managed and controlled, species diversity is expected to gradually increase.

Overall, there is a distinct vegetation change between upland and tidal wetland vegetation within HWRP. The percent coverage of salt marsh vegetation within HWRP has increased during the 2017 (year 2) sampling effort compared to 2015 and 2016 (years 0 and 1). Salt marsh vegetation, dominated by pickleweed has increased from 20.3 percent cover in 2017 compared to 5.6 percent cover in 2015 along the mid to high marsh section of HWRP. Compared to Years 0 and 1, pickleweed is quickly colonizing the high marsh, all while, decreasing the acreage of bare ground within HWRP.

Compared to Year 1 where six patches of cordgrass were mapped within HWRP, Year 2 had additional patches or cordgrass growth along the low marsh edge. New patches of cordgrass were not mapped during the vegetation survey because surveyors could not safely access low marsh habitat because of soft mud conditions.

Upland vegetation continues to become established with additional upland plants observed within the community. Additional invasive plant species, such as yellow star thistle were observed along the upland community in Year 2 compared to Years 0 and 1. Invasive species will need to be managed for upcoming years to control upland plant viability.

5 Fish Survey

This chapter presents the results of the annual fish monitoring, completed to document species richness, abundance, and distribution within the HWRP site. Documenting annual changes in the fish community throughout the course of the site's evolution over time serves as an important variable in evaluating the overall health of the site, and will help inform future restoration efforts in the region.

5.1 Materials and Methods

5.1.1 Fish Sampling Methods

Environmental Science Associates (ESA) conducted the third year of fish sampling throughout the HWRP site on April 27 and 28, 2017. The fish sampling methodology for 2017 (year 2) survey was consistent that of 2015 and 2016 (year 0 and year 1), in that it consisted of the same modes of sampling and reoccupied the same locations within the site. The timing of the survey was also relatively similar (i.e. late April to early May).

The habitat complexity within HWRP is such that, in order to comprehensively sample all available habitats, multiple sampling methods were utilized. A 40-ft. beach seine was used to sample the nearshore areas within the main and tertiary tidal channels. Since seining is a depth-limited method, an otter trawl was used to survey the in-channel habitat within the main, secondary and tertiary channels. The net head line dimensions of the otter trawl 12 ft. wide by 3 ft. high. Sampling locations are shown in Figure 5-1.

Over the course of the 2-day sampling event, 8 seine hauls and 4 otter trawls were conducted within the main tidal channel (Figure 5-1). Each trawl was towed for approximately 10 minutes beginning at the time the gear was fully deployed (on the bottom) at a speed of approximately 1-1.5 nautical miles per hour (knots).

The trawl was also deployed within both the secondary and tertiary channels, but because of access difficulties, the seine was deployed only in portions of the tertiary channel network and not at all in the secondary channels. Each trawl followed the same methodology as the main channel, with the tow lasting approximately 10 minutes at 1-1.5 knots. This effort was similar to past sampling years.

All fishes captured were identified to the species, measured (total length in millimeters [mm]), and returned to the channel in which they were caught. The sampling results represent a snapshot of the species abundance and distribution at a given point in time, as such they are not assumed to capture all species that may be present within the site.

5.1.2 Site Conditions

Fish sampling was conducted spring 2017 (April 27 and 28) and timed to coincide with tidal elevations appropriate for ensuring sufficient depth for both sampling and navigation. Tidal elevations for the sampling dates are reported in Table 5-1.

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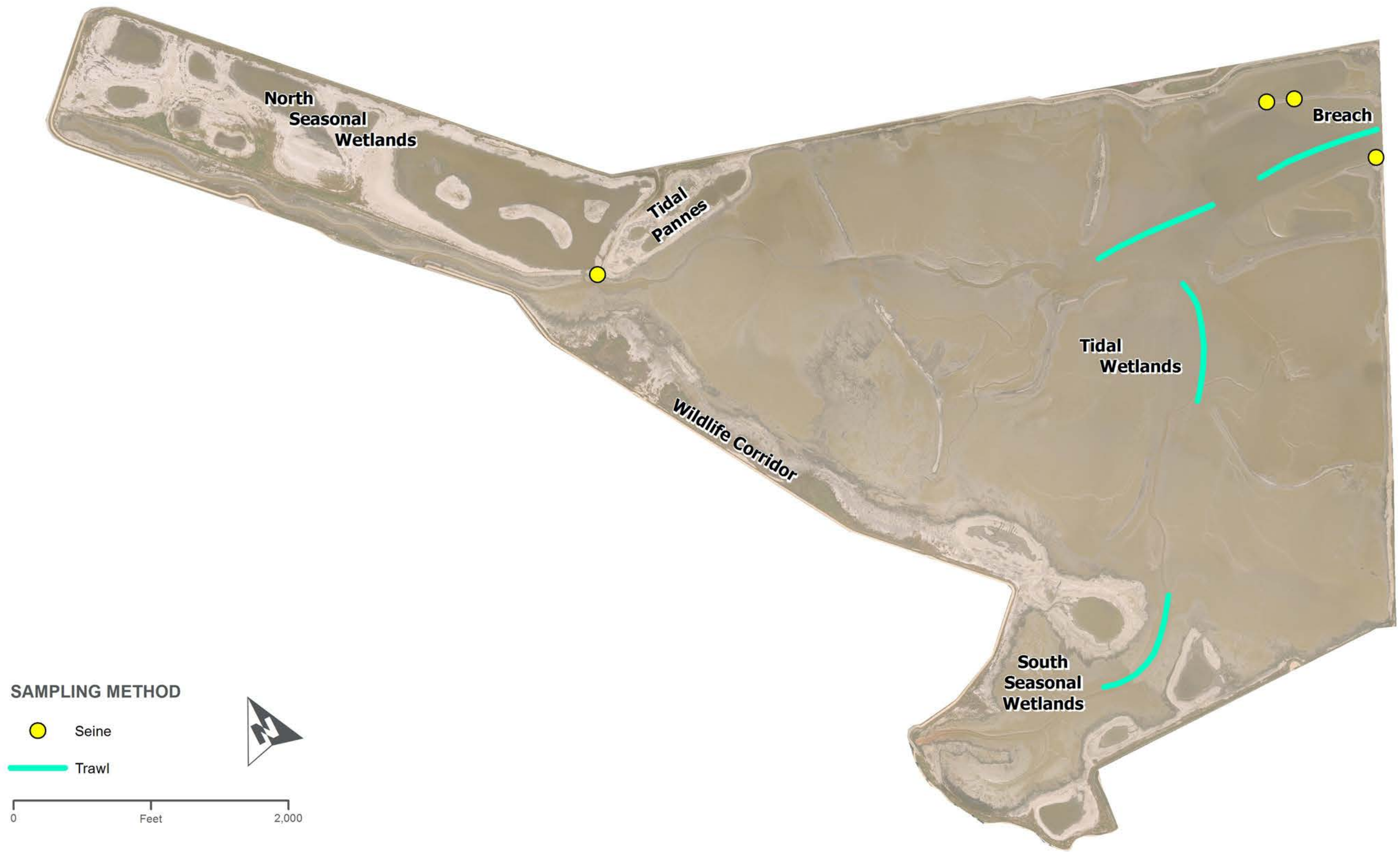

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Figure 5-1. Fish Sampling Locations

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Table 5-1. Predicted Tide Height During Sampling Periods

Date	Tide Height (ft MLLW) and Time (PT)
April 27, 2017	High Tide: 6.67 (01:44)
	Low Tide: -0.88 (08:51)
	High Tide: 5.40 (15:01)
	Low Tide: 1.30 (20:49)
April 28, 2017	High Tide: 6.75 (02:25)
	Low Tide: -1.05 (09:40)
	High Tide: 5.29 (15:59)
	Low Tide: 1.63 (21:38)
Petaluma River Entrance, San Pablo Bay California, Sta.ID 9415252	

5.2 Fish Sampling Results

5.2.1 Species Composition

This sampling effort resulted in the capture and identification of 1,841 individual fish representing 10 families and 12 species presented in Table 5-2.

Table 5-2. Fish Species Present in the Project Site – 2017

Common Name	Scientific Name	Scientific Family
	Native Species	
Northern anchovy	*Engraulis mordax*	Engraulidae
Pacific herring	*Clupea pallasii*	Clupeidae
Pacific staghorn sculpin	*Leptocottus armatus*	Cottidae
Three-spined stickleback	*Gasterosteus aculeatus*	Gasterosteidae
Topsmelt	*Atherinops affinis*	Atherinopsidae
California halibut	*Paralichthys californicus*	Paralichthyidae
Chinook salmon	*Oncorhynchus tshawytscha*	Salmonidae
	Non-Native Species	
Chameleon goby[1]	*Tridentiger trigonocephalus*	Gobiidae
Yellowfin goby	*Acanthogobius flavimanus*	Gobiidae
Rainwater killifish	*Lucania parva*	Fundulidae
Shokihaze goby	*Tridentiger barbatus*	Gobiidae
Striped bass	*Morone saxatilis*	Moronidae

5.2.2 Main Tidal Channel

Ten fish species were captured in the main channel during the survey, with the assemblage split between native and non-native species (6 native species, 4 non-native species) (Table 5-3). Juvenile yellowfin goby was the most abundant species captured in the main tidal channel, both nearshore and in-channel, comprising over 68 percent of the total catch. The benthic assemblage was dominated in number by three non-native goby species, the aforementioned yellowfin goby, shokihaze goby (10%), and chameleon goby (2%). The dominant native benthic species were Pacific staghorn sculpin (4%) and California halibut (3%). The native three-spine stickleback represented 3 percent of total catch. Only four pelagic species were recorded in the main tidal channel, the most common being juvenile northern anchovy (13%). The other three pelagic species were Chinook salmon (juvenile), striped bass, and topsmelt, for which only a single individual was recorded.

1 Chameleon goby and shimofuri goby are known to hybridize in the San Francisco Bay-Delta, it is unclear to what extent the chameleon gobies observed were of hybrid stock.

5.2.3 Secondary and Tertiary Tidal Channels

The secondary and tertiary channels showed similar species abundance patterns as observed in the main channel, albeit with slightly less diversity. Northern anchovy was by far the most abundant pelagic species observed (77% in secondary and 86% in tertiary channel). Only a small number (less than 1%) of other pelagic species including; topsmelt, striped bass, and Pacific herring were recorded. Yellowfin goby was once again the most abundant benthic species encountered (21% in secondary and 9% in tertiary channel). The native benthic species sculpin and flatfish were also observed and represented (less than 5% of catch). All species recorded in the secondary and tertiary channels were also present in the main channel, with the exception of Pacific herring and rainwater killifish (both representing less than 1% of catch).

Table 5-3. Fishes Captured in the Main, Secondary and Tertiary Channels

Species	Main Tidal Channel					Secondary Tidal Channels					Tertiary Tidal Channels			
	Count	**Total Length (mm)**				**Count**	**Total Length (mm)**				**Count**	**Total Length (mm)**		
		Mean	**Min**	**Max**			**Mean**	**Min**	**Max**			**Mean**	**Min**	**Max**
Seine														
Northern anchovy	**32**	30	28	30							**14**	30	30	30
Chameleon goby	**2**	61	56	65							**1**	60	60	60
California halibut	**1**	20	20	20										
Pacific staghorn sculpin	**30**	45	20	75							**11**	37	20	80
Rainwater killifish						**No Seine in Secondary Channels**					**3**	40	35	45
Three-spined stickleback	**30**	31	25	47							**4**	29	25	35
Topsmelt											**3**	125	105	140
Yellowfin goby	**346**	37	10	103							**27**	43	25	60
Pacific herring											**1**	160	160	160
Trawl														
Northern anchovy	**94**	30	30	30		**86**	30	30	30		**628**	31	30	40
Topsmelt	**1**	180	180	180										
California halibut	**28**	152	5	245							**1**	20	20	20
Chameleon goby	**21**	56	45	70										
Shokihaze goby	**65**	71	50	98										
Yellowfin goby	**321**	42	30	150		**23**	40	30	50		**38**	65	30	135
Pacific staghorn sculpin	**8**	50	20	75		**1**	25	25	25		**13**	26	20	35
Three-spined stickleback	**5**	38	30	48										
Chinook salmon	**1**	103	103	103										
Striped bass	**1**	160	160	160		1	314	314	314					

Table 5-4. Comparison between survey years

Species	Origin	2015	2016	2017
Marine				
Bat ray	Native	3	4	0
Bay pipefish	Native	3	1	0
Northern anchovy	Native	2,439	981	854
California halibut	Native	11	10	30
California tonguefish	Native	20	3	0
Diamond turbot	Native	1	7	0
Leopard shark	Native	12	0	0
Shiner surfperch	Native	4	1	0
Walleye surfperch	Native	1	0	0
Topsmelt	Native	142	290	4
Pacific herring	Native	0	2	1
Estuarine				
Chameleon goby	Non-Native	15	101	24
Pacific staghorn sculpin	Native	45	7	63
Prickly sculpin	Native	10	0	0
Rainwater killifish	Non-Native	1	3	3
Shimofuri goby	Non-Native	7	0	0
Shokihaze goby	Non-Native	119	22	65
Yellowfin goby	Non-Native	1	0	755
Longjaw mudsucker	Native	0	4	0
Anadromous				
American shad	Non-Native	6	0	0
Chinook salmon	Native	0	0	1
Striped bass	Non-Native	2	3	2
Freshwater (Brackish)				
Three-spined stickleback	Native	1	11	39
Species Origin (raw count and [species count])				
Native		2,692 [13]	1,321 [12]	992 [7]
Non-Native		151 [7]	129 [4]	849 [5]
Total		**2,843**	**1,450**	**1,841**

5.3 Invertebrate Sampling

No targeted invertebrate sampling was conducted as part of the survey effort, however, as with previous survey years, multiple species and age classes were observed throughout the site. Multiple shrimp species (*Crangon* spp.) and age classes were observed throughout the site; however larval individuals were extremely abundant within all of the tidal channels. The high abundance of larval shrimp is important for the rearing larval and juvenile fish, and suggests a large amount of production at lower trophic levels. The combination of consistently high numbers of juvenile shrimp and domination of the fish assemblage by juveniles suggest that HWRP is serving as an important rearing site for multiple species.

5.4 Discussion

Overall, the distribution and diversity fish species encountered during the 2017 (year 2) sampling effort showed a reduction in species diversity as seen from 2015 and 2016 (years 0 and 1). The number of species recorded decreased from 20 species in 2015, and 16 in 2016, to 12 during 2017 (year 2) as shown in Table 5-4 presented above. While there was a slight increase in the raw number of individual fish captured, this was primarily caused by the dramatic increase in abundance of juvenile yellowfin goby over previous years.

It is likely that the continued reduction in species diversity is a result of the significant drop in salinity from the preceding two survey years. During the 2015 and 2016 sampling events (years 0 and 1) salinities within the Project site fluctuated between 22 and 27 psu due to the respective critically dry and below normal water years; however, during the 2017 (year 2) sampling event (anticipated to be a wet water year) the salinity within the Project site was 8 psu. This dramatic shift in salinity is further reflected in the shift from marine fish dominated assemblage to one made up primarily of estuarine species (Table 5-4).

The relative abundance of pelagic species generally remained consistent with previous years, as northern anchovy were once again the most common fish encountered within the site. Topsmelt abundance did significantly reduce and is likely due to the drop in water salinity. Nonetheless, the benthic assemblage continued to be dominated by non-native goby species and showed a dramatic increase in the number of juvenile yellowfin goby.

Native species captured during the 2015 (year 0) and 2016 (year 1) surveys including bat ray, shiner surfperch, bay pipefish, California tonguefish and diamond turbot were not observed during the year 2 survey, and, the proportion of native to non-native species decreased from 88 percent to only 58 percent native from 2015 (year 0) to 2017 (year 2). However, one native fish species, Chinook salmon, recorded during the year 2 survey, was not encountered during the preceding 2 survey years.

Consistent with the preceding two survey years, the fish collected during this sampling event represent a diversity of trophic levels, life stages, and life history requirements. Larval and juvenile fish were primarily represented by northern anchovy and yellowfin goby. California halibut were also common within the nearshore habitats. Occupation of nearshore habitat along with usage of secondary and tertiary channels suggests that these species may be using the tidal marsh as rearing habitat.

Both seine and trawl were utilized throughout the site in order to comprehensively sample both nearshore and in-channel habitat, however, nearshore conditions made seining in secondary channels impossible. Trawling and seining captured both benthic and pelagic species, with northern anchovy and yellowfin goby being the dominant species encountered by each method. Unlike previous years when seine hauls produced significantly less biomass and showed less diversity than trawl, both sampling methods yielded similar levels of abundance and showed a similar composition of species (biomass remained lower). Additionally, there seemed to be a fairly even distribution of fish life-stage regardless of the method used, with large numbers juvenile fish captured by both methods. However, as with previous years, the largest fish sampled were captured by trawl. All species captured by seine were also captured by trawl, with the exception of Pacific herring and rainwater killifish.

Monitoring over the past three years has documented a diverse assemblage of species throughout the tidal wetland restoration site. While the number and abundance of individual species has fluctuated annually, utilization of all portions of the project site by multiple species and life stages has consistently been documented.

The trends established over the recent three years of monitoring are insightful and provide a relatively early look as to how the HWRP site is functioning for aquatic species. Continued monitoring over numerous different water years and through varying annual conditions will allow for an improved understanding of how the restoration site design will benefit fishes over time. The early results suggest that the site is meeting its intended goal by providing habitat to important native species.

6 Bird Surveys

6.1 Introduction

Following the reintroduction of tidal influence to the HWRP in fall of 2014, Avocet Research Associates (ARA) began monitoring avian use of the site. Censuses for this baseline monitoring effort were conducted over a one-year cycle from August 2014 through July 2015 (ESA and ARA 2016). This chapter presents the results of the 2017 (year 2) monitoring. The 2017 (year 2) survey was completed from August 2016 through July 2017 (Table 6-1).

Avian monitoring surveys were conducted:

- to document abundance and species compositions of waterbirds using the site;
- to quantify changes in abundance and habitat use among three assemblages of waterbirds over time; and,
- to provide population data against which future monitoring years might be compared and trends evaluated.

Table 6-1. Coverage of the study areas[1]

Date	Time	Sky	Beaufort	Tidal level
Fall				
14 Aug 2016	1015-1145	clear	1-2	1133 (4.4’) ↑
9 Sept 2016	0900-1050	clear	2-3	0755 (4.2’) ↓
10 Oct 2016	0845-1045	100% ovc	0	0924 (4.8’) ↑
24 Oct 2016	0730-0920	100% ovc	2-3	0935 (5.1’) ↑
Winter				
15 Nov 2016	0900-1030	100% ovc	0-2	1247 (7.3’) ↑
29 Nov 2016	0830-1000	clear	0-2	1212’ (6.4) ↑
16 Dec 2016	1015-1140	clear	4-5	1404 (6.9’) ↑
16 Jan 2017	1200-1330	10% 0vc	0-1	1525 (5.7’) ↑
15 Feb 2017	1330-1500	70% ovc	2	1554 (5.0’) ↑
21 Feb 2017	1330-1500	80% ovc	3	1617 (0.5) ↓
13 Mar 2017	1230-1400	20% ovc	0-1	1428 (5.7’) ↑
27 Mar 2017	1000-1130	10% ovc	1	1321 (5.8) ↑
Spring/Summer				
13 Apr 2017	1315-1445	75% ovc	2-4	1547 (4.7) ↑
28 Apr 2017	1330-1500	10% ovc	0-2	1601 (5.1’) ↑
25 May 2017	1130-1335	clear	5	1402 (5.0’) ↑
05 June 2017	0920-1100	clear	0-1	1129 (4.1’) ↑
03 July 2017	0915-1030	clear	1	1000 (3.9’) ↑
30 July 2017	1600-1745	clear	0-2	1945 (5.8’) ↑

1. dates, census times, sky conditions, Beaufort wind scale & direction, and tidal level (time of high tide at the Petaluma River mouth). Rising tide is indicated with an up arrow (↑), falling tide is indicated with a down arrow (↓).

6.2 Methods

Methods for conducting avian surveys were modeled after those used at Sonoma Baylands Wetland Restoration since 1996 as originally designed by the USACE and modified during the 15-year review of that project (ESA-PWA et al. 2014). Coverage was scheduled to correspond to the annual period of maximum use by waterbirds (mid-August through early-May) as well as the period of reduced use (mid-May through July). To capture avian use patterns, surveys were assigned to the following seasonal periods: fall (August through October); winter (November through March); and spring/summer (April through July). On each census effort, coverage was timed to capture the peak diurnal-use of the site by waterbirds as determined by the influences of weather, tides, and water levels. (It should be noted that during the migratory the periods of spring and fall, there is high temporal variation in bird occurrence, therefore peak-use may have been missed due to episodic avian use and intermittent coverage.)

The study site included the 455.6 ac (184 ha) of tidally influenced habitat below 6.5' North American Vertical Datum of 1988 (NAVD88) within HWRP as calculated by ESA Associates (D. Kunz, pers. comm.). Absolute counts of birds (Cranswick et al. 1997, Bibby et al. 2002, Gregory et al. 2004) were used to document species composition and abundance. The HWRP site was covered by two to four observers on each census, with more observers during periods of greater use (August 2016 - May 2017) and fewer during the summer months (June – July 2017) when fewer numbers of birds were present.

For the purposes of this study, the main focus of which is categorizing bird use and detecting changes over time, birds are grouped into three assemblages (or guilds) based primarily on taxonomic relationships, but also on similar foraging behaviors:

> "Waterfowl" includes true waterfowl (Anatidae: swans, geese and ducks) in addition to "waterfowl-like" species with similar foraging behaviors, i.e., pelicans and cormorants, loons and grebes, and American Coot.
>
> "Waders" includes most members of the order Charadriiformes ("shorebirds"), but excludes the Laridae (gulls, terns, and skimmers) and the Alcidae (auks, murres, and puffins). Ardeids (herons egrets, night-herons) are lumped with the waders because of similar foraging behaviors.
>
> "Other waterbirds" is a catch-all assemblage of species that are attracted to the wetlands including Larids (gulls and terns), raptors, Common Raven and Belted Kingfisher.

Taxonomic order of waterbird species follows the 57th Supplement to the American Ornithologists' Union Checklist of North American Birds (AOU 2016). A list of all species detected on the site to date is provided in taxonomic order in Appendix D.

<u>Semantic note</u>: These three groups collectively are termed "waterbirds," a category that encompasses all wetland-dependent species that were observed within the study site. "Waterbirds" is a more inclusive and broader term than "waterfowl," which is a subset of the "waterbird" community. With the exception of Common Raven and Belted Kingfisher, no other "landbirds" or passerines were counted or included in the community analysis.

Data gathered from 2017 (year 2) are summarized here to document species' compositions, densities, and patterns of use for comparison with the Baseline Year (ESA & ARA 2016) as well as with future results. Methods of analysis for each criterion of evaluation are given under each respective subsection: Densities; Species Richness; Species Diversity and Percent Composition.

During the 2016/17 avian monitoring season, 18 surveys were completed within HWRP—4 in the fall period, 8 in winter period, and 6 in spring/summer period. Over the same time period, the 228 ac (92 ha) Rush Creek Unit of the Petaluma Marsh Wildlife Area ("Rush Creek") was monitored using the same methodology used at HWRP. The results of the Rush Creek surveys are provided in Appendix D.

6.2.1 Timing of Hamilton Wetland Censuses

All censuses but two (9 September 2016 and 21 February 2017) were conducted on a rising tide when the tidal level was ≥ 3.0' on the adjacent San Pablo Bay shoreline, thus inundating nearby tidal flats, eliminating wader foraging habitat there while exposed tidal flats remained available within the study area. Extremely high tides (>5.5') were observed on 15 and 29 November 2016, 16 December 2016, 16 January 2017, and 13 March 2017.

6.2.2 Absolute Counts

On each field effort observers attempted to count every individual of every species present on the HWRP site during the census period (Cranswick et al. 1997). When exceptionally large, mixed species flocks were encountered, the observer estimated the flock-size and species-composition. This potential source of error was most often encountered in assemblages of small Calidrine sandpipers (Least Sandpipers, Western Sandpipers, and Dunlin), which tend to flock and forage in mixed species' flocks. When estimations of percentages of each species comprising a mixed flock were not possible, the observer lumped the birds into a single generic category ("Peep spp."). In data analysis, the percentages of identified species within this three-species ensemble were calculated and the number of lumped species were attributed to each species according to the observed percentages. The same attribution of unidentified individuals was used with the two species of Scaups (Lesser and Greater) and the two "large Grebe" species (Aechmophorus spp.) Two species of dowitcher (Limnodromus) occur in the San Francisco Bay area, but are difficult to separate in the field in most plumages, therefore for purposes of data analysis the dowitchers were lumped into "Dowitcher species."

Biodiversity values were calculated using a biodiversity calculator and the program Estimates.[1] [2]

6.2.3 Species Richness

Species richness (d) is a simple measure of biodiversity that is expressed by the number of species observed in the sample. Richness provides a value against which future census results can be compared. Two commonly used species richness indices attempt to compensate for sampling effects are Menhinick's Index, and Margalef's Index (Magurran 2004).

[1] http://viceroy.eeb.uconn.edu/EstimateS/EstimateSPages/EstimateS.php
[2] http://www.alyoung.com/labs/biodiversity_calculator.html

Menhinick's Index (D_{Mn}) where the number of species (S) is divided by the square root of the total number of individuals of all species (N) in the sample:

$$\frac{S}{\sqrt{N}}$$

Margalef's Index (D_{Mg}) where the number of species (minus 1) is divided by the natural logarithm of the total number of individuals of all species (N) in the sample:

$$\frac{(S-1)}{\ln N}$$

6.2.4 Densities

Densities of waterbird totals and individual guilds were calculated for each census based on the extent of intertidal habitat below 6.5' within HWRP [(455.6 ac (184 ha)]. Densities are provided in Appendix D.

6.2.5 Diversity (Evenness)

Three statistical methods were used to calculate evenness diversity: Simpson's, Shannon's, and Equitability indices.

Simpson's Index (D)

$$\frac{\sum_i n_i(n_i-1)}{N(N-1)}$$

where n_i = the number of individuals in the i-th species and N = the total number of individuals.

Equitability Index (E_D) is calculated by expressing Simpson's index as a proportion of the maximum value *D* could assume if individuals in the community were completely evenly distributed (D_{max}) which equals *S* (as in a case where there was one individual per species). Equitability takes a value between 0 and 1, with 1 being complete evenness.

$$-\frac{\sum_i\left(\frac{n_i}{N}\cdot\ln\left(\frac{n_i}{N}\right)\right)}{\ln N}$$

Shannon's diversity index —like Simpson's index—accounts for both abundance and evenness of the species present. The proportion of species relative to the total number of species (p_i) is calculated, and then multiplied by the natural logarithm of this proportion ($\ln p_i$). The resulting product is summed across species, and multiplied by -1:

$$-\sum_i \left(\frac{n_i}{N} \cdot \ln\left(\frac{n_i}{N}\right)\right)$$

Additional indices for all seasons combined and each individual season and are given in Appendix D. These various values provide comparisons with reference baselines and against which future results may be compared.

6.3 Results

The 2017 (year 2) monitoring effort represents observations of 144,652 individual waterbirds with an average of 8,036.2 waterbirds/census on 18 censuses conducted at HWRP. Summary statistics of the complete dataset and each season are given in Tables 2-7. Abundance values for each census and summary statistics for each census are provided in Appendix D. Results of Rush Creek monitoring are provided in Appendix D.

Rush Ranch

The Rush Ranch avian censuses documented 25 waterbird species occurring within the site during the 2016-2017 monitoring year. In comparison with HWRP, Rush Ranch showed different measures of abundance and diversity in 2017 (year 2). Rush Ranch is composed of seasonal wetland habitat compared to tidal marsh and seasonal wetland habitat at HWRP; hence, Rush Ranch attracted a higher percentage of waterfowl compared to waders as observed at HWRP. Winter numbers at Rush Ranch averaged 99 waterbirds per census, for an average density of 10.8 waterbirds per hectare.

Hamilton

The HWRP avian censuses documented 83 waterbird species occurring within the site during the 2014-2017 monitoring years. Composition of the waterbird community by foraging guild was similar to the baseline year. In 2017 (year 2), the community was dominated by waders, which accounted for 85 percent of all observations. Among the waders, three species of small calidrine sandpipers (Western Sandpiper, Least Sandpiper, Dunlin) were most abundant, comprising 78.9 percent of all waders and 64.1 percent of all waterbird observations. The waterfowl assemblage accounted for 17.5 percent of all waterbirds. Within the waterfowl guild (eliminating unidentified “duck species”), surface feeding “dabblers” represented 45.3 percent and diving ducks represented 54.7 percent of waterfowl. Among the waterfowl community, ten species comprised >90 percent of the waterfowl community (Table 6-2).

Table 6-2. The ten most abundant waterbird species[1]

Waterfowl	Total %	Fall %	Winter %	Spring %
Western Sandpiper	0.360	0.300	0.304	0.325
Dunlin	0.223	0.184	0.215	0.062
Least Sandpiper	0.162	0.136	0.147	0.041
American Avocet	0.096	0.149	0.062	0.064
Marbled Godwit	0.025	0.011	0.015	0.091
Waders				
Northern Pintail	0.028	0.066	0.012	0.000
Ruddy Duck	0.020	0.006	0.020	0.022

Green-winged Teal	0.014	0.000	0.012	0.024
Canvasback	0.032	0.000	0.038	0.007
Northern Shoveler	0.029	0.017	0.026	0.008

1. accounting for 85 percent of the waterbird community on an annual basis, ranked by percentage overall and by season.

Considering non-calidrine waders, the site supported substantial numbers of American Avocets. Avocets represented 52.6 percent of the non-calidrine waders with a peak of 1,643 counted on 11 November 2016. The peak number of all waterbirds was on 16 January 2017 with nearly 15,055 individuals estimated. Winter numbers averaged 12,743 waterbirds per census, for an average density of 69.2 waterbirds per hectare with a peak of 107.6 birds/ha.

Special status species

Several special status species were detected in the course of the 2017 (year 2) surveys.

- *Western Snowy Plover*: present except on two census on 22 September, 1 January 2017 with numbers ranging from 1-40. Census of Western Snowy Plover were not counted after 28 April 2017 because evidence of a nesting near Point 6 of the NSW (between the lower water control structure and N1N2 levee were observed). The Western Snowy Plover nesting site received several king-tides during spring 2017 with tides at or above 5.8', overtopping the water control structure and compromising the western snowy plover nesting site. The Western Snowy Plover nest site was observed inundated on 26 May 2017.

- *Bald Eagle*: One on 16 January 2017 and 15 February 2017.

- *Merlin*: individuals noted on one fall (22 September 2016) and two winter (14 November 2016, 15 February 2017) surveys.

- *Peregrine falcon*: Individuals present on 22 September 2016, 11 October 2016, 15 November 2016, 16 January 2017, 15 February 2017, 21 February 2017, 3 April 2017, and 3 July 2017.

Table 6-3. Summary statistics all seasons combined, 2014/15, 2015/16, and 2016/2017: sum, mean standard deviation and coefficient of variation for all observations.

Hamilton Wetlands	Sum	Mean	sd	cv
Observations 2014/15	174,326	10,895.4	10299.74	0.945
Observations 2015/16	160,867	8,468.3	6430.53	0.760
Observations 2016/17	144,652	8,036.22	7,158.80	0.891
Density (birds/ha) 2014/15	—	59.4	56.10	0.944
Density (birds/ha) 2015/16	—	46.0	35.0	0.760
Density (birds/ha) 2016/17	—	43.7	38.9	0.891
Species (richness) 2014/15	68.0	37.31	7.67	0.205
Species (richness) 2015/16	83.0	37.28	9.18	0.246
Species (richness) 2016/17	70.03	36.50	9.48	0.249
% Waterfowl 2014/15	14.2	22.23	18.04	0.811
% Waterfowl 2015/16	12.6	18.84	16.19	0.859

Table 6-3. (continued)

% Waterfowl 2016/17	16.1	21.40	14.61	0.683
% Waders 2014/15	85.1	73.66	22.34	0.303
% Waders 2015/16	87.9	78.62	18.10	0.230
% Waders 2016/17	81.3	75.46	15.61	0.207
% Other waterbirds 2014/15	0.7	4.01	7.08	1.764
% Other waterbirds 2015/16	0.7	2.39	3.59	1.502
% Other waterbirds 2016/17	2.1	6.54	17.13	2.618

Table 6-4. Summary statistics for the fall season, 2014 compared with fall season 2015 and 2016: sum, mean standard deviation and coefficient of variation.

Hamilton Wetlands	Sum	Mean	sd	cv
Observations 2014/15	121,535	17,362.14	9092.70	0.52
Observations 2015/16	75,560	12,760.00	6058.38	0.48
Observations 2016/17	101,944	12,743	7485.63	0.59
Density (birds/ha) 2014/15	—	94.7	49.41	0.52
Density (birds/ha) 2015/16	—	69.4	32.93	0.48
Density (birds/ha) 2016/17	—	69.3	40.7	0.59
Species (richness) 2014/15	59	42.6	3.64	0.09
Species (richness) 2015/16	65	43.5	2.43	0.06
Species (richness) 2016/17	70	43.4	4.31	0.10
% Waterfowl 2014/15	—	18.3	6.30	0.34
% Waterfowl 2015/16	—	18.0	11.1	0.62
% Waterfowl 2016/17	—	26.0	16.3	0.63
% Waders 2014/15	—	81.2	6.25	0.08
% Waders 2015/16	—	81.6	11.2	0.14
% Waders 2016/17	—	73.0	17.0	0.23
% Other waterbirds 2014/15	—	0.5	0.51	1.00
% Other waterbirds 2015/16	—	0.4	0.29	0.73
% Other waterbirds 2016/17	—	1.0	1.0	1.00

Table 6-5. Summary statistics the winter season, 2014-2015 compared with winter season 2015-2016 and 2016-2017: sum, mean standard deviation and coefficient of variation.

Hamilton Wetlands	Sum	Mean	sd	cv
Observations 2014/15	121,535	17,362.14	9092.70	0.52
Observations 2015/16	75,560	12,760.00	6058.38	0.48
Observations 2016/17	101,944	12,743	7485.63	0.59
Density (birds/ha) 2014/15	—	94.7	49.41	0.52
Density (birds/ha) 2015/16	—	69.4	32.93	0.48
Density (birds/ha) 2016/17	—	69.3	40.7	0.59
Species (richness) 2014/15	59	42.6	3.64	0.09

Table 6-5. (continued)

Hamilton Wetlands	Sum	Mean	sd	cv
Species (richness) 2015/16	65	43.5	2.43	0.06
Species (richness) 2016/17	70	43.4	4.31	0.10
% Waterfowl 2014/15	—	18.3	6.30	0.34
% Waterfowl 2015/16	—	18.0	11.1	0.62
% Waterfowl 2016/17	—	26.0	16.3	0.63
% Waders 2014/15	—	81.2	6.25	0.08
% Waders 2015/16	—	81.6	11.2	0.14
% Waders 2016/17	—	73.0	17.0	0.23
% Other waterbirds 2014/15	—	0.5	0.51	1.00
% Other waterbirds 2015/16	—	0.4	0.29	0.73
% Other waterbirds 2016/17	—	1.0	1.0	1.00

Table 6-6. Summary statistics the spring season 2015 compared with spring season 2016 and 2017: sum, mean standard deviation and coefficient of variation.

Hamilton Wetlands	Sum	Mean	sd	cv
Observations 2014/15	23,796	3966.00	7700.14	1.94
Observations 2015/16	33,762	4823.14	6961.92	1.44
Observations 2016/17	9,675	1,612.50	1,470.52	0.92
Density (birds/ha) 2014/15	—	25.0	41.87	1.94
Density (birds/ha) 2015/16	—	26.2	37.84	1.44
Density (birds/ha) 2016/17	—	8.7	7.99	0.91
Species (richness) 2014/15	57	31.67	8.07	0.26
Species (richness) 2015/16	61	33.70	9.45	0.28
Species (richness) 2016/17	52	25.83	6.97	0.27
% Waterfowl 2014/15	—	34.44	24.01	0.70
% Waterfowl 2015/16	—	18.94	22.64	1.19
% Waterfowl 2016/17	—	23.0	12.17	0.53
% Waders 2014/15	—	56.32	29.88	0.53
% Waders 2015/16	—	68.95	25.84	0.38
% Waders 2016/17	—	71.68	15.77	0.22
% Other waterbirds 2014/15	—	8.22	10.37	1.26
% Other waterbirds 2015/16	—	4.01	4.05	1.01
% Other waterbirds 2016/17	—	5.32	4.88	0.92

Table 6-7. Species richness indices for the 2014-2015 compared to the 2015-2016 and 2016-2017 monitoring seasons.

Season	Species Richness	Menhinick index (D_{Mn})	Margalef's Index (D_{Mg})
All seasons 2014/15	68	0.165	12.783
All seasons 2015/16	83	0.207	6.843
All seasons 2016/17	76	0.1998	6.312
Fall 2014	47	0.276	10.309
Fall 2015	57	0.276	5.632
Fall 2016	62	0.341	5.862
Winter 2014/15	59	0.172	11.407
Winter 2015/16	65	0.253	6.136
Winter 2016/17	70	0.2192	5.983
Spring/Summer 2015	57	0.363	12.79
Spring/Summer 2016	61	0.332	5.75
Spring/Summer 2017	52	0.5287	5.557

Table 6-8. Species diversity indices for the 2014-2015 compared with the 2015-2016 and 2016-2017 monitoring seasons.

Season	Species Richness	Menhinick index (D_{Mn})	Margalef's Index (D_{Mg})
All seasons 2014/15	68	0.165	12.783
All seasons 2015/16	83	0.207	6.843
All seasons 2016/17	76	0.1998	6.312
Fall 2014	47	0.276	10.309
Fall 2015	57	0.276	5.632
Fall 2016	62	0.341	5.862
Winter 2014/15	59	0.172	11.407
Winter 2015/16	65	0.253	6.136
Winter 2016/17	70	0.2192	5.983
Spring/Summer 2015	57	0.363	12.79
Spring/Summer 2016	61	0.332	5.75
Spring/Summer 2017	52	0.5287	5.557

6.4 Discussion

In comparison with Baseline Year results, measures of abundance and diversity in 2017 (year 2) show similarities (e.g. richness and community composition) and some decreases (e.g. annual densities). In general, avian populations show high interannual variation both locally and regionally. Therefore, comparison of only three years of data may be influenced by regional trends that are not site specific. There are several other factors that may influence the results of these surveys:

1. Coverage of the site was somewhat more thorough and frequent in 2015-16.

2. After several weeks of record rainfall during the winter months (February and March) the fields surrounding HWRP are flooded and attracting large numbers (1000s) of waterbirds, especially waders and dabbling ducks. These individuals were not counted

within the HWRP study area. Therefore, birds that would otherwise be using HWRP are dispersed over adjacent habitat, thus depressing the expected numbers of waterbirds in the HWRS.

3. Sears Point Restoration Project[3] opened up 1000 ac (~400 ha) of tidal marsh basin in October of 2015, creating similar habitat less than 10 miles NE of HWRP, perhaps attracting a proportion of the local waterbird community.

4. Worldwide, shorebird (wader) populations are in decline (Colwell 2010), including the calidrine sandpipers (Morrison et al. 2006, Fernández et al. 2010, Wood et al. 2011), the most abundant species assembledge at HWRP.

5. Several waterfowl are also in decline regionally, most notably Northern Pintail (Miller and Duncan 1999).

The phenology of waterbird occurrence at HWRP mirrored the expected regional pattern with peak numbers in early winter, a late winter decline and migratory peaks in September and April (Figure 6-1).

Species nesting within the site included Black-necked Stilt, American Avocet and Western Snowy Plover. California Ridgway's Rail and California Black Rail continued year-round occupancy of emergent tidal marsh habitat adjacent to HWRP.

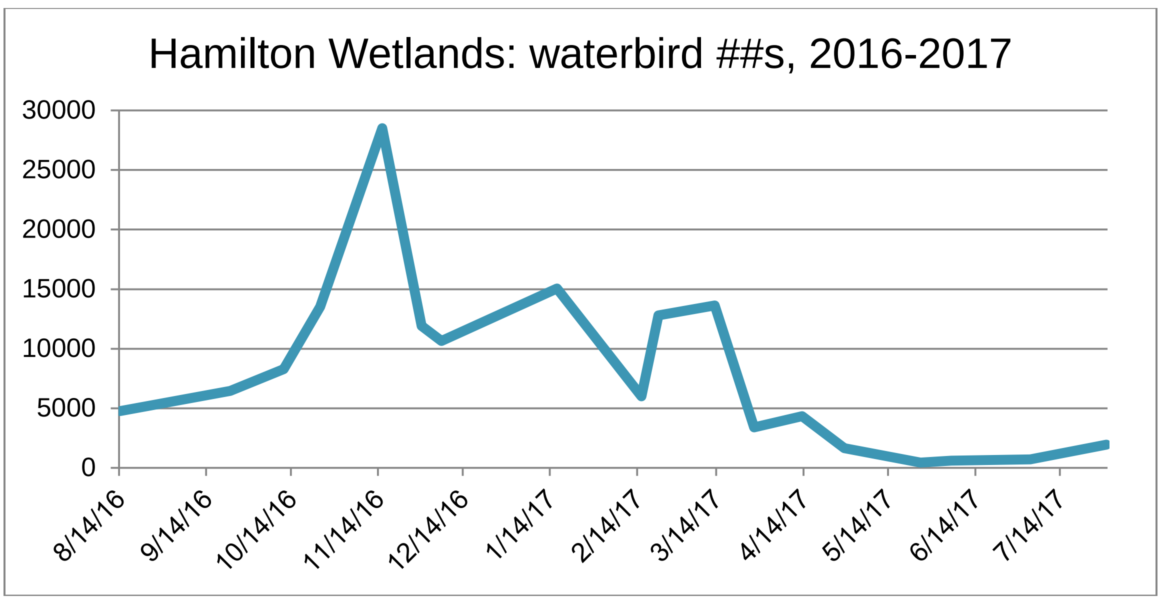

Figure 6-1. Annual pattern of abundance of waterbirds at Hamilton Wetlands, 2016-2017

[3] http://www.sfbayjv.org/project-sears-point-wetland-restoration-san-pablo-bay.php

7 Wind Speed and Direction

7.1 Methods

Wind data were collected from the Bureau of Land Management station NVHC1 (Novato Fire - Robinhood) and from the Environmental Protection Agency's AirNow station A1131 (Sonoma Baylands). The Sonoma Baylands station is located roughly 5 miles (mi) north of the HWRP, just east of highway 37 (Figure 7-1). Geographically, it is separated from the site by flat open fields and the Petaluma River's entrance into San Pablo Bay. Robinhood station is located roughly 4.5 mi northwest of the site within a region of low rolling hills ranging from 200-500 ft. The station itself is located at the top of one of the higher hills with an elevation of 482 ft. Both stations were chosen to be the most representative of the HWRP area due to their close proximity to the site, the quality of the dataset, and the lack of significant terrain influences relative to other weather stations in the area. The two stations used in last year's study, namely CIMIS sites 187 and 157, contained a significant amount of missing data after March of 2017 that ultimately deemed the sites inadequate for this year's study.

Wind data from both the Robinhood and Sonoma Baylands weather stations are provided as hourly average wind speed and direction. Measurements are taken with a standard anemometer located at a fixed elevation above the ground. The wind data were analyzed in Python to summarize the direction and speed statistics, which were then plotted onto wind roses. Each wind rose displays the distribution of the wind speed and direction for a given location in 5 mi per hour (mph) intervals. Data for each site were downloaded to cover the period from August 1, 2016 to July 1, 2017. Although the individual weather stations are located within 4.5 mi of each other, significant variability in the terrain exists between each site. This suggests that deviations in the wind regimes between each site may be due, in large part, to the differences in terrain.

The wind roses displayed in Figures 7-1 through 7-3 have been plotted in the standard Meteorological coordinate system, which plots the direction of wind origin in a clockwise fashion from due north. Each arm of the wind rose represents a directional range of 22.5 degrees and depicts the direction the wind is blowing from. A given arm describes both the frequency and the speed of the wind that is blowing from the direction of the arm over a defined time. The radial length of each arm corresponds to the percentage of time that the wind blows from that direction. The colors describe the percentage of time that the given wind speed occurred within a directional range.

7.2 Results

Winds summarized in this report are based on the entire data period (August 2016-July 2017) and by season. During this time period, wind observations at station Robinhood were predominantly from the west with the strongest winds generally coming in from the south and southwest. The Sonoma Baylands station also observed a predominately westerly flow; however, the winds contained more of a northerly component at this particular station (Figure 7-2).

A comparison between the two stations suggests winds at the Sonoma Baylands station are generally stronger than the Robinhood station (Figure 7-3). The strongest winds occurred primarily in the winter months for both locations, with the Robinhood station showing a strong tendency for the highest winds to come from the south. This station reported the strongest winds on January 8th, 2017 as a powerful storm moved in from the Pacific. Hourly averaged winds of 30 mph occurred throughout the day with a 60 mph wind gust reported during the late morning hours. This matches up well with the climatology in this region in which the strongest yearly winds are typically associated with winter storms.

Northeast of the Novato Fire-Robinhood station, at the Sonoma Baylands station, the prevailing wind direction is from the west or south throughout most of the year. Although the wind directions are similar between each station, winds speeds at the Sonoma Baylands station are often higher. This is likely due to a funneling effect caused by the local terrain as winds flow into the Petaluma River valley.

7.3 Discussion

Winds during the 2017 (year 2) Monitoring at the Hamilton wetlands site were likely strongest from a westerly direction. Given that the higher terrain surrounding both the Sonoma Baylands station and the monitoring site are similarly orientated, it is reasonable to expect the winds at the monitoring site might be slightly better represented by the Sonoma Baylands station. The lower wind speeds at the Robinhood station, however, tends to suggest the monitoring site may see slightly weaker winds relative to the Sonoma Baylands station. Both sites show strong evidence that winds ranging from 330°- 120° (i.e. northwest to the southeast) are rare. Comparing the 2017 (year 2) data to previous monitoring years at the Robinhood station was not possible due to the station’s limited dataset. Data from the Sonoma Baylands station, however, are available and show a similar wind profile to both 2015 (year 0) and 2016 (year 1) showing only a slightly lower frequency of easterly winds. This suggests the wind data from the 2017 (year 2) monitoring should be representative of the wind speed and direction for a given year.

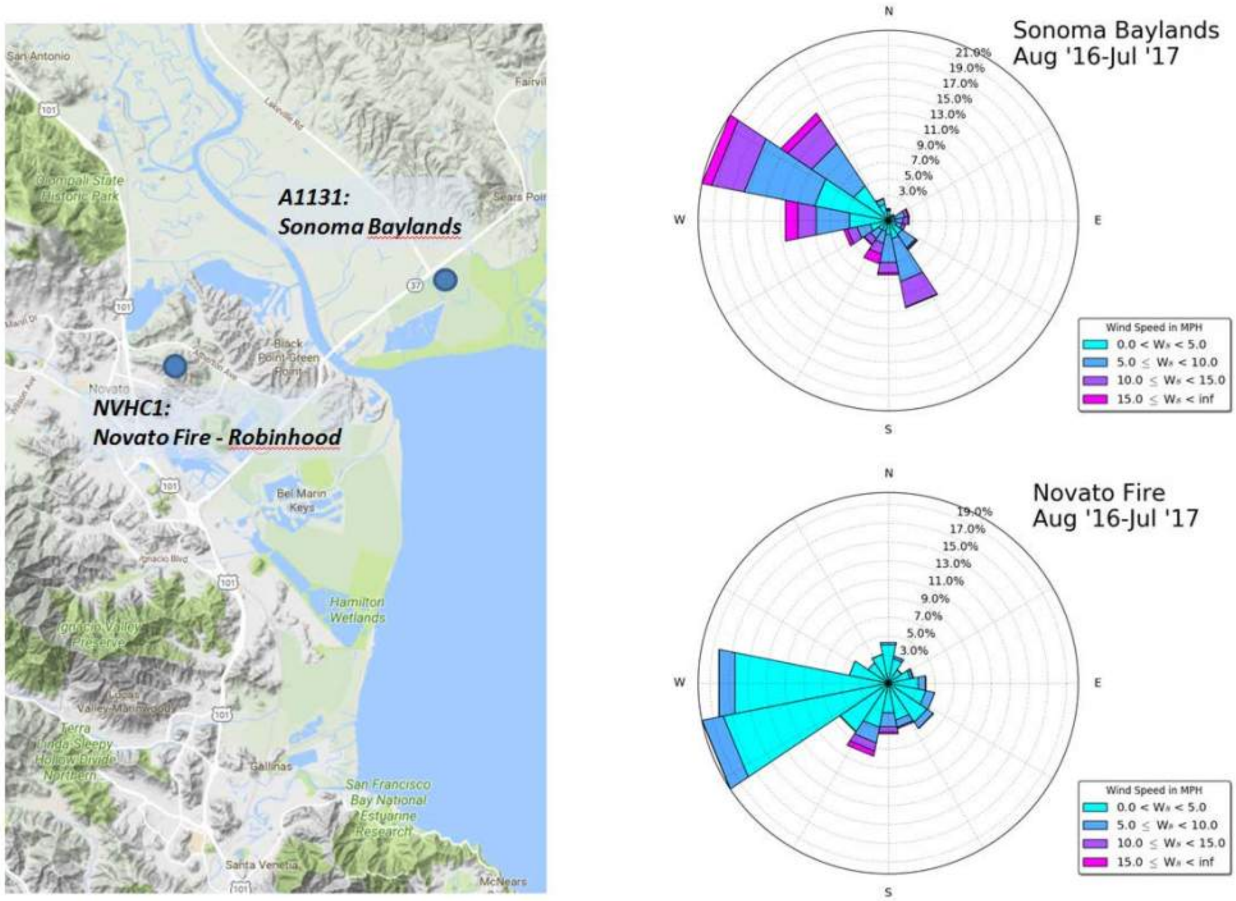

Figure 7-1. Wind Roses for Sonoma Baylands and Novato Fire for 2016-2017, with site locations

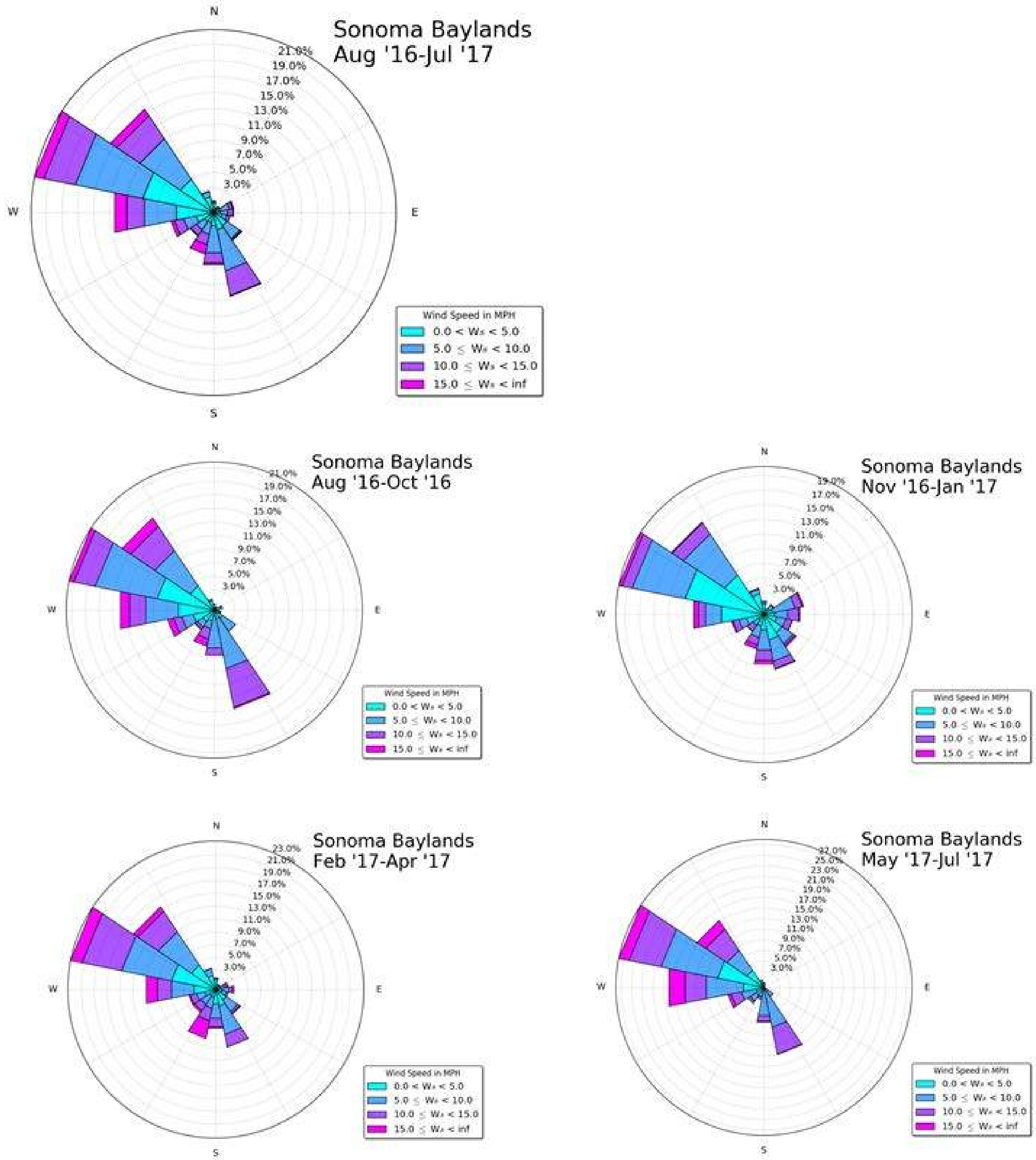

Figure 7-2. Seasonal Wind Rose for 2016-2017 at Sonoma Baylands

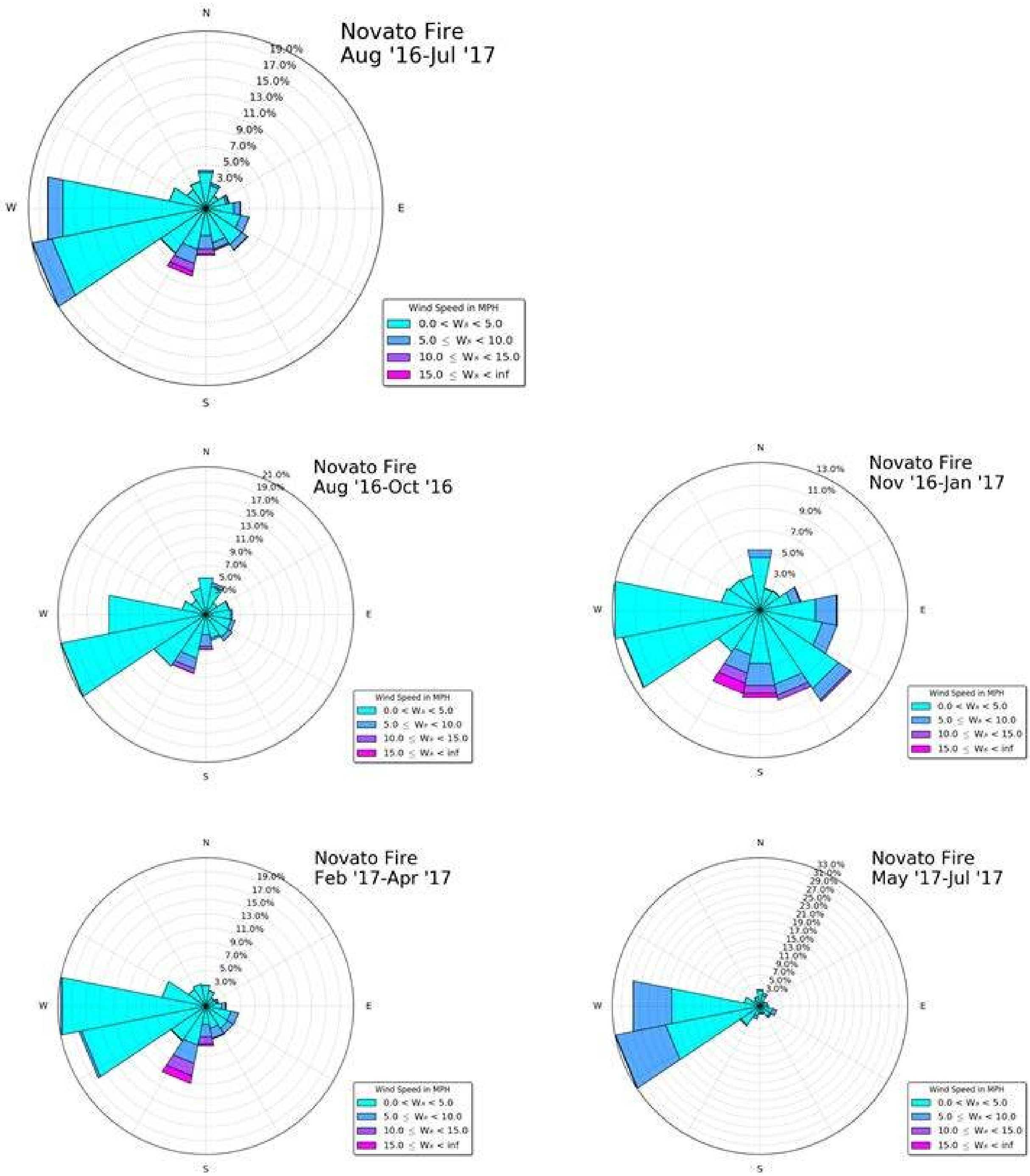

Figure 7-3. Seasonal Wind Rose for 2016-2017 Novato Fire-Robinhood

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8 Photo Documentation

8.1 Methods

Eighteen permanent photo-documentation stations (photo-points) were established during the baseline monitoring to document vegetation succession and the evolution of the channels (Figure 8-1). Eleven photo-points were established for tidal wetland documentation and seven photo-points were established to monitor seasonal wetlands. Photo point locations were chosen at semi-regular intervals around the site with an emphasis on critical areas of interest to document a wide variety of site characteristics. These photo points were reoccupied during the 2017 (year 2) monitoring. The photographic documentation techniques are based on the principals of re-photography, also known as repeat photography. This is a technique of landscape study where scenes are re-photographed at certain time intervals to determine the nature of long-term change. In addition to repeating the location of each photograph, a compass bearing of the direction of view was established at every station in order that repeat photos capture the same area.

8.2 Results

Photo documentation for 2017 (year 2) monitoring can be found in Appendix E.

8.2.1 Tidal Wetland

2017 (year 2) tidal wetland photo documentation plates are found in PBM 1 through PBM 10 (Appendix E). Photo benchmark locations are numbered starting at the north side of the breach and moving clockwise around the tidal wetland complex. Common pickleweed (*Salicornia virginica*) continues to establish itself along the interior berms and marsh edges as can be seen in nearly all the tidal wetland figures. The increased colonization in the short time between 2016 (year 1) and 2017 (year 2) monitoring is very promising at such early stages for the project site. Pickleweed colonization can be seen along the lowered outboard levee (PBMs 2, 3, and 4) and Berms 3 & 5 (PBMs 2 & 3). Pickleweed along the lowered outboard levee covers between 40-50 percent of the shoreline. In addition, clumps of cordgrass (*Spartina* sp.) are forming at approximately the 4.74 ft MLLW level of the marsh plain. Pickleweed is also colonizing along the bench and fill placement areas adjacent to the N-2 levee (PBMs 9 & 10). Pickleweed adjacent to N-2 levee covers 70-80 percent of the shoreline. Pickleweed is also established along the panhandle marsh plain (PBM 11 & 14) and on the marsh plain adjacent to the south seasonal wetlands (PBM 5, 14, & 16). Non-native vegetation has also established itself around the perimeter of the site, with Russian thistle (*Salsola tragus*), yellow-star thistle (*Centaurea solstitialis*), and wild fennel (*Foeniculum vulgare*) prevalent along with a number of various grasses.

Tide overtopping of the internal berms (Berms 3, 4, 5, and 6) can be seen in PBM 2, PBM 3, PBM 9 and PBM 10 suggesting regular tidal inundation of internal berms. Small channels are developed across the marsh plains which help drain the marsh edge.

8.2.2 Seasonal Wetlands

The North Seasonal Wetlands can be seen in PBM 11 through PBM 14. They consist of six seasonal ponds that receive water through rainfall in winter and spring.

There is a distinctive upland vegetative break consisting of annual grasses at the high water mark of Ponds 1, 2, 3, 4, and 5 (Appendix E), as well as along the tidal channel running parallel to the ponds (Appendix E). Pickleweed colonization with almost 90-100 percent vegetative cover can be seen along the margins of tidal channel. All of the North Seasonal Wetlands were dry during the survey, with salt crust and surface soil cracks present. Again, Russian thistle, yellow star thistle and wild fennel is prevalent along the upland portion of the channel and the N-2 levee, with very little native recruitment thus far.

The South Seasonal Wetlands can be seen in PBMs 15, 16, and 17 (Appendix E). Pickleweed is becoming established along the marsh plain between the ponds and the surrounding upland vegetation. Channel erosion through the sill of Pond 5 has reduced ponding in Ponds 1 and 2. The stormwater outfall channel at the outfall of the City of Novato's pump station can be seen in Appendix E.

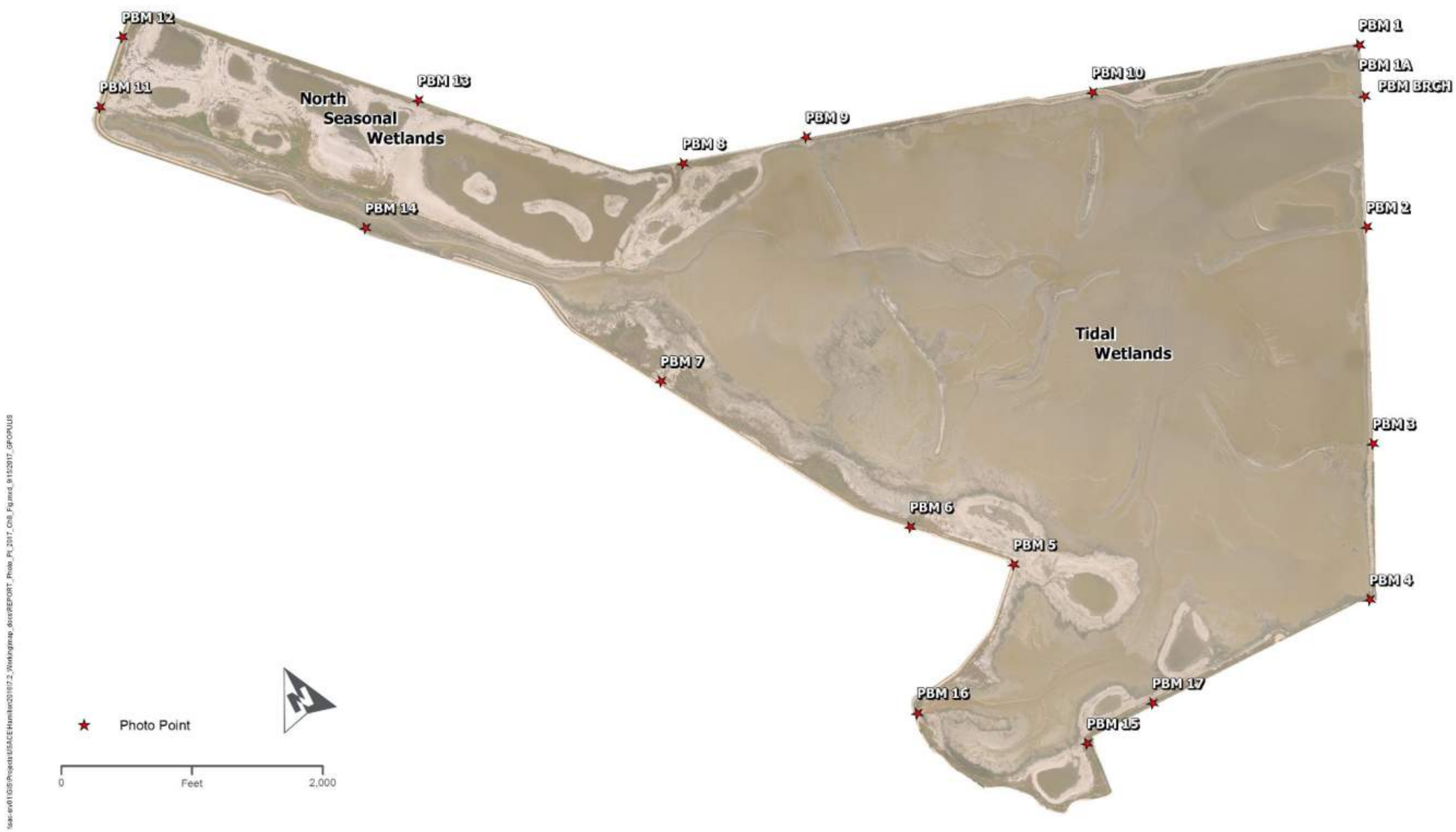

Figure 8-1. Permanent Photo Documentation Station Locations

8.2.3 Transitional/Upland

Photo-points PBM 6 and 7 are taken across the Wildlife Corridor, showing the upland habitat within the project site. The photos show that a high amount of vegetative cover is composed of mostly non-native grasses and herbs, including tumbleweed (*Salsola tragus*), brass button (*Cotula coronopifolia*), wild oat (*Avena fatua*), ripgut brome (*Bromus diandrus*), and burclover (*Medicago* sp.).

It is important to note that many plants colonizing the upland areas are mostly salt-tolerant transition plants. The presence of these plants may indicate unfavorable conditions for the native upland plants that were originally planned for this area.

8.3 Discussion

The photos presented in Appendix E provide a visual comparison between monitoring years in HWRP. Although the 2017 (year 2) photos were taken at a noticeably dryer time of the year in terms of precipitation (June in year 2 compared to November in year 1), it is still possible to see the changes that have occurred since the baseline year of monitoring. Vegetation presence are identifiable through the photos and vegetation succession and transition can be seen in almost all the photo-points. Although some of the salt-tolerant plants seen in the photos are non-native, native pickleweed (*Salicornia virginica*) and cordgrass (*Spartina* sp.) can be seen in numerous areas, particularly along the tidal wetlands and along the edge of the tidal channel. As discussed in Chapter 4, there was a dramatic increase in salt marsh vegetation coverage with HWRP from approximately 5 percent in 2016 (year 1) compared to approximately 22 percent in 2017 (year 2).

During 2017 (year 2), the most notable increase in salt marsh vegetation can be seen along PBM 1, PBM 4, PBM 9, and PBM 10. Changes in salt marsh vegetation coverage between years 1 and 2 within the HWRP can be observed in the year over year photo documentation. During year 2, new fleshy green leaves from pickleweed vegetation can be observed covering areas where bare dirt was observed in year 1. The most dramatic increases of new vegetation compared to bare dirt was observed along PBMs 9 and 10. At PBMs 9 and 10, salt marsh vegetation can be observed stretching from the upland edge to the edge of water, with minimal areas of bare dirt observed. Overall, there is less observable bare dirt within HWRP in year 2 compared to year 1.

Vegetation differences within the wildlife corridor area, PBMs 6 and 7, show more annual grasses and increased amounts of taller vegetation that could provide escape cover for many species birds and terrestrial animals. Upland vegetation can be seen covering the levees in PBM 4, PBM 6, PBM 9, PBM 10, PBM 11, PBM 12, PBM 13, PBM 15, and PBM 16. Much of the upland vegetation has 100 percent coverage of the levee, with many tall species observed in the photo. The photos within Appendix E do not focus on the upland vegetation, however, because of the angle of the photo, upland vegetation can be seen.

The upland area vegetation should be increase monitoring and control of upland areas to promote native plantings, as it is being noted that several invasive non-native species, categorized as “High”, “Moderate”, or “Limited” by the Cal-IPC are becoming established in the upland areas. Yellow star thistle is a categorized as a “High”, where this species can have a severe ecological impact on physical process, plant and animal communities, and vegetation structure. Yellow star thistle was observed along the tops of the levee banks.

Channel development and erosion are more time-sensitive processes and thus are difficult to see between the first monitoring years. During 2016 (year 1) photos were taken at about a 1.2 ft lower tide than in 2017 (year 2) and therefore, documentation of the channel development was not observed or photographed.

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Appendix A.

Tidal Hydrology Figures

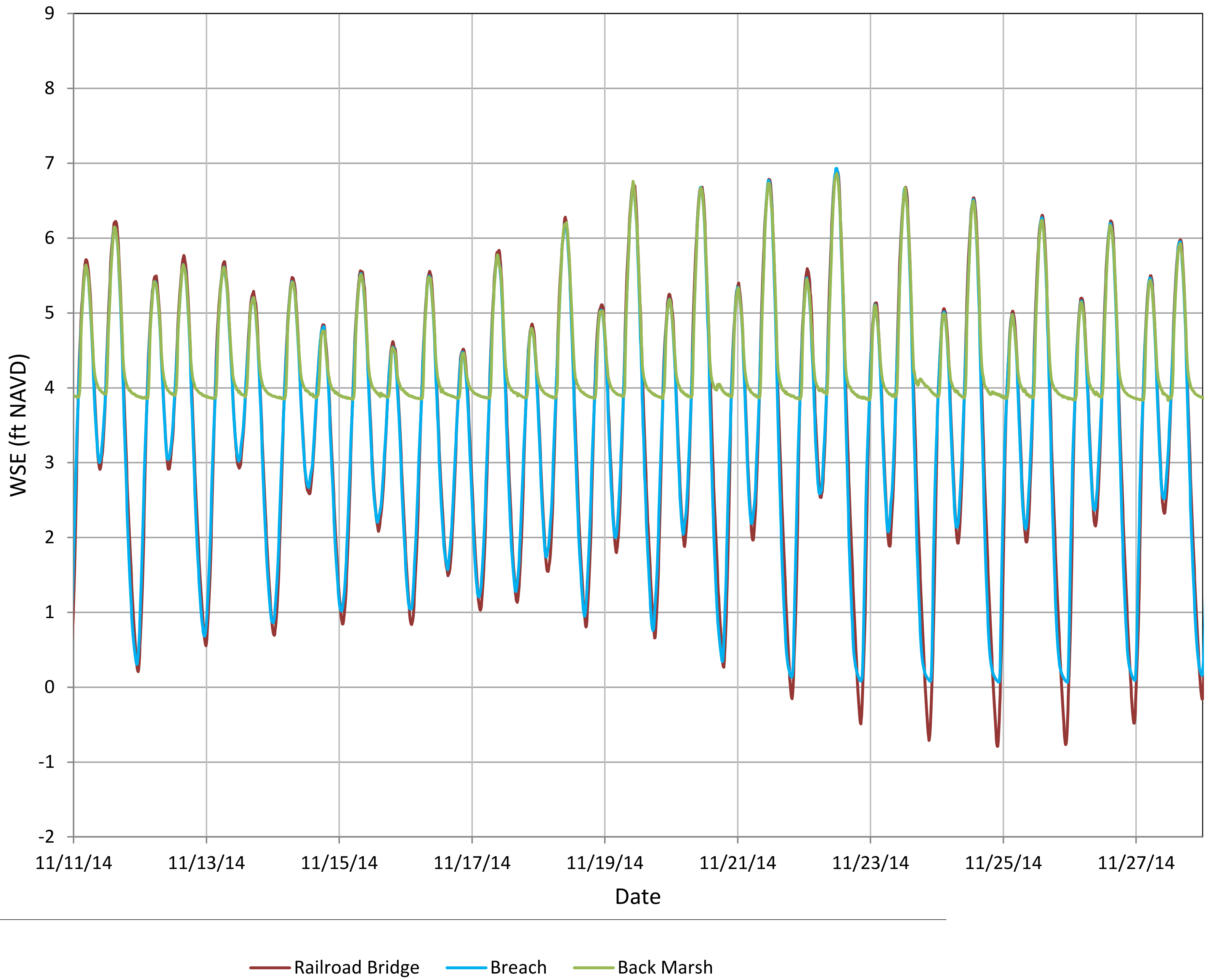
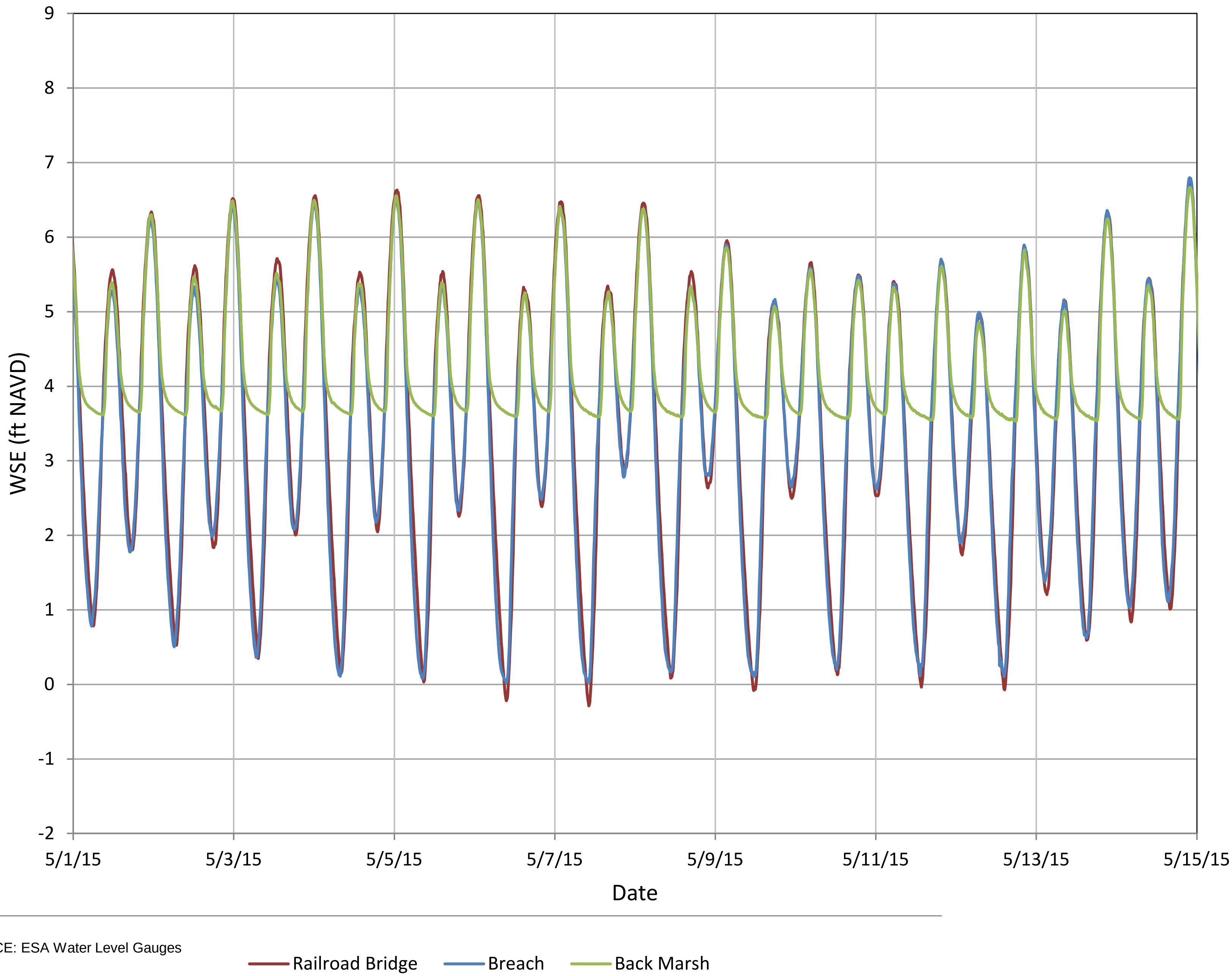


Figure A-1. Tidal Marsh Water Levels Winter 2014



SOURCE: ESA Water Level Gauges

Figure A-2. Tidal Marsh Water Levels Spring 2015

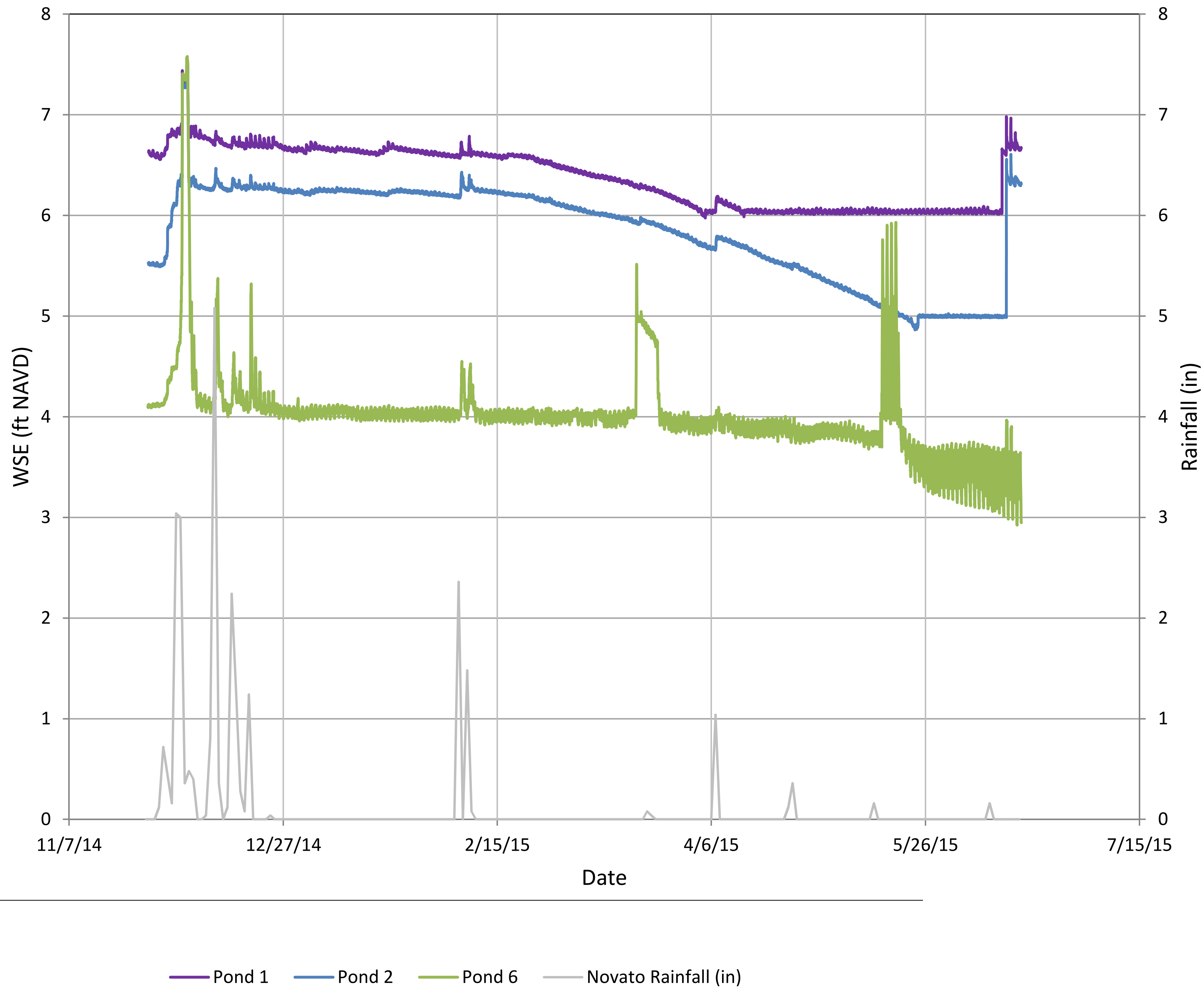


Figure A-3. North Seasonal Pond Water Levels 2014/2015

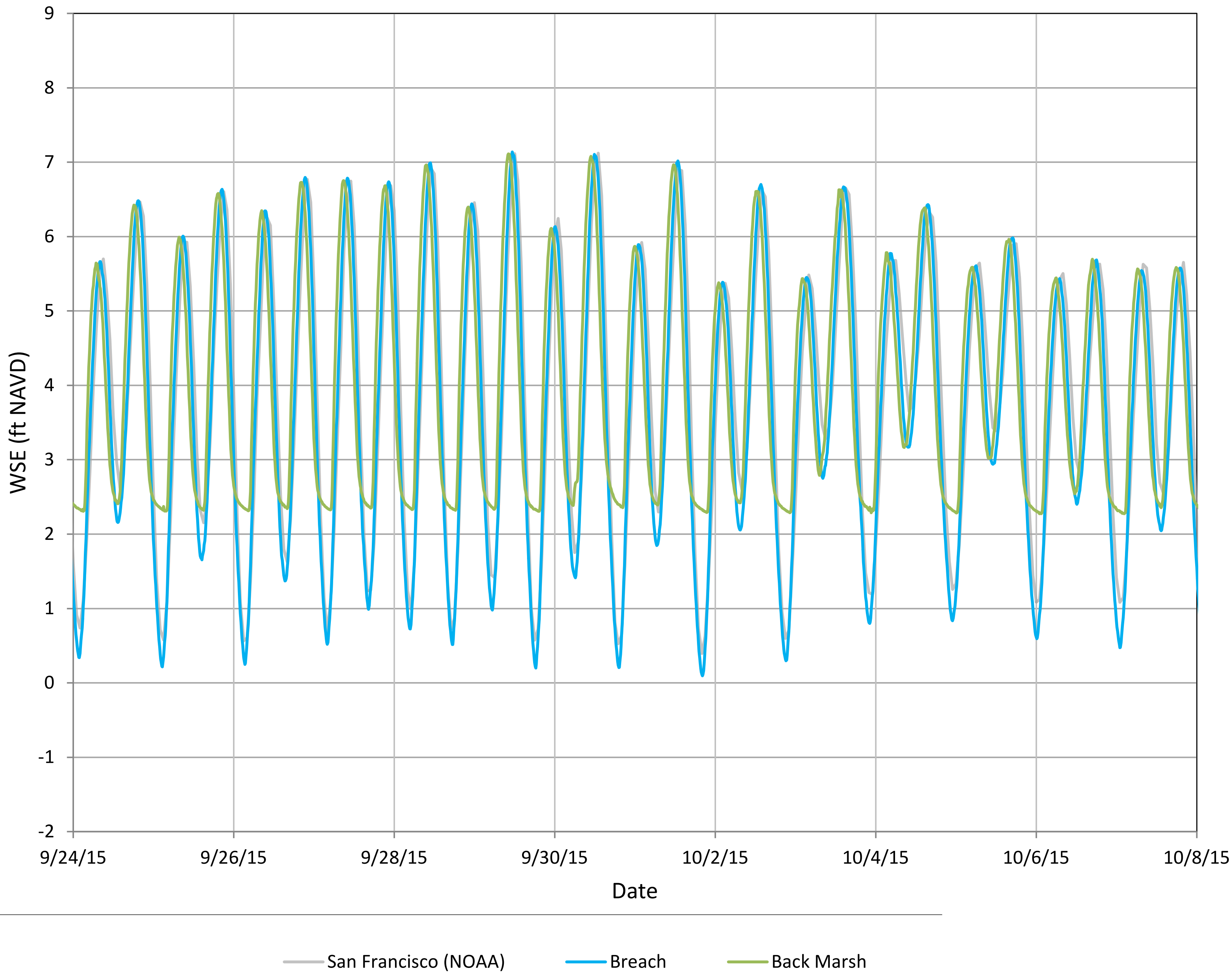


Figure A-4. Tidal Marsh Water Levels Fall 2015

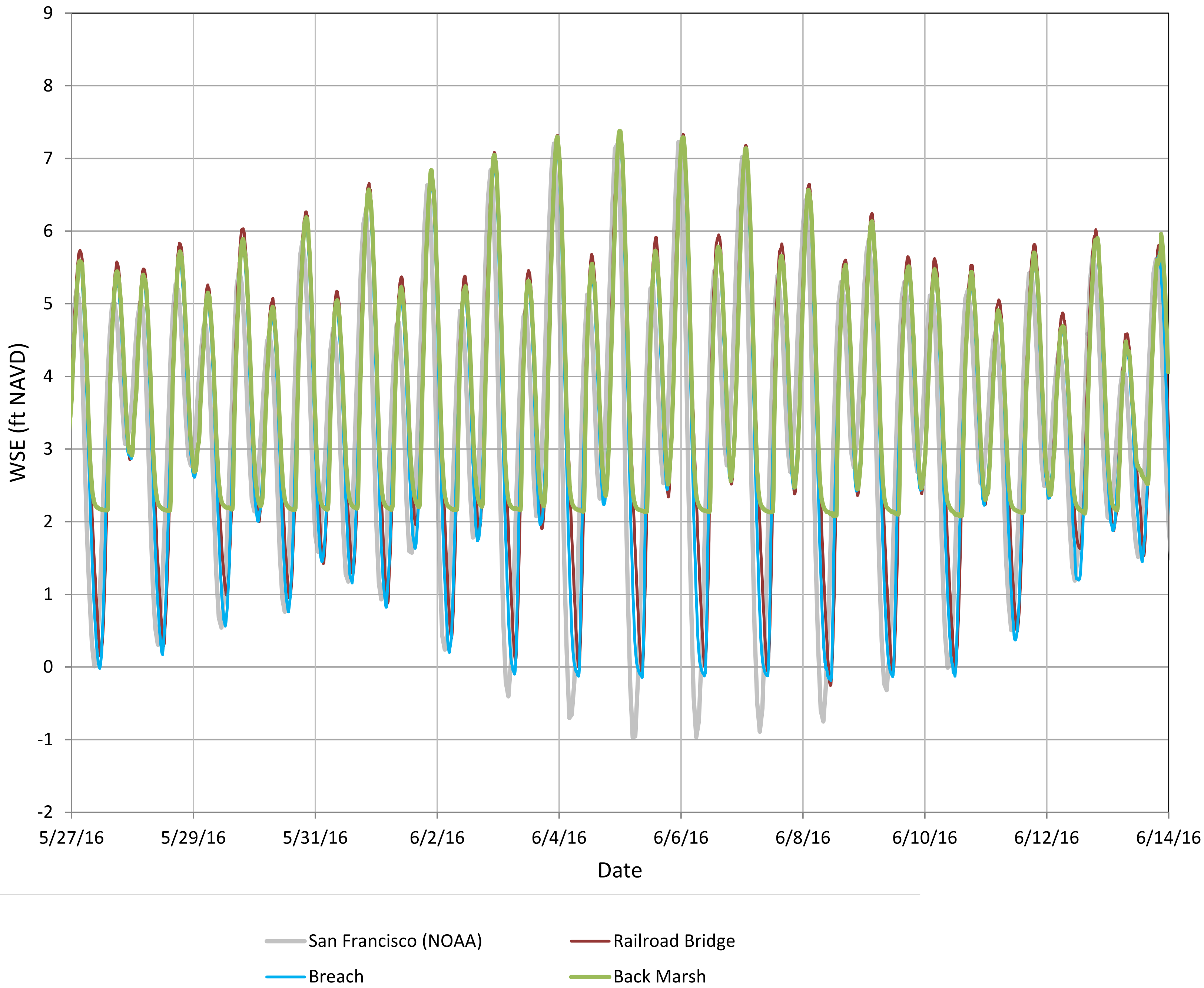


Figure A-5. Tidal Marsh Water Levels Spring 2016

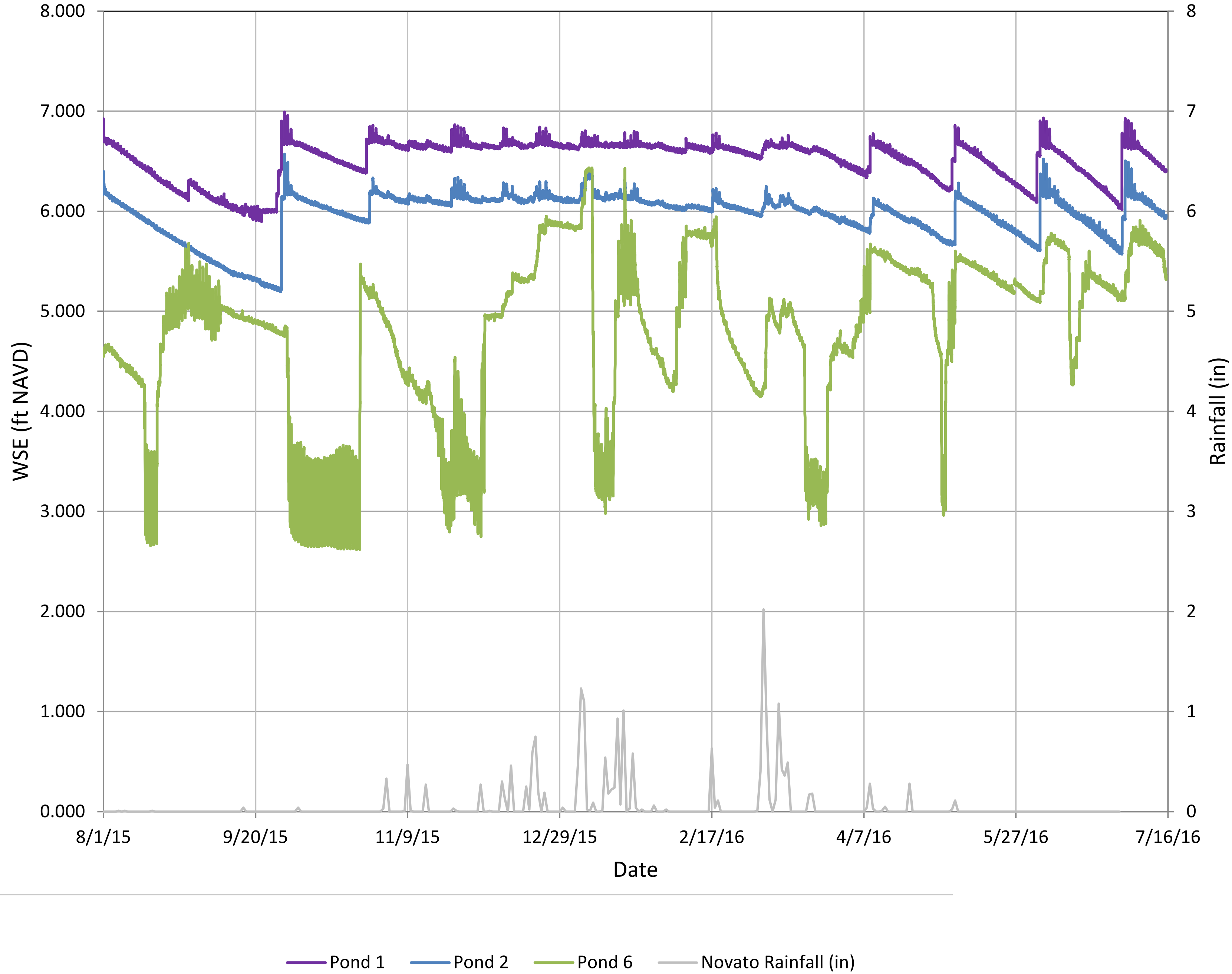


Figure A-6. North Seasonal Pond Water Levels 2015/2016

Appendix B.

Interior Transect Elevation Data

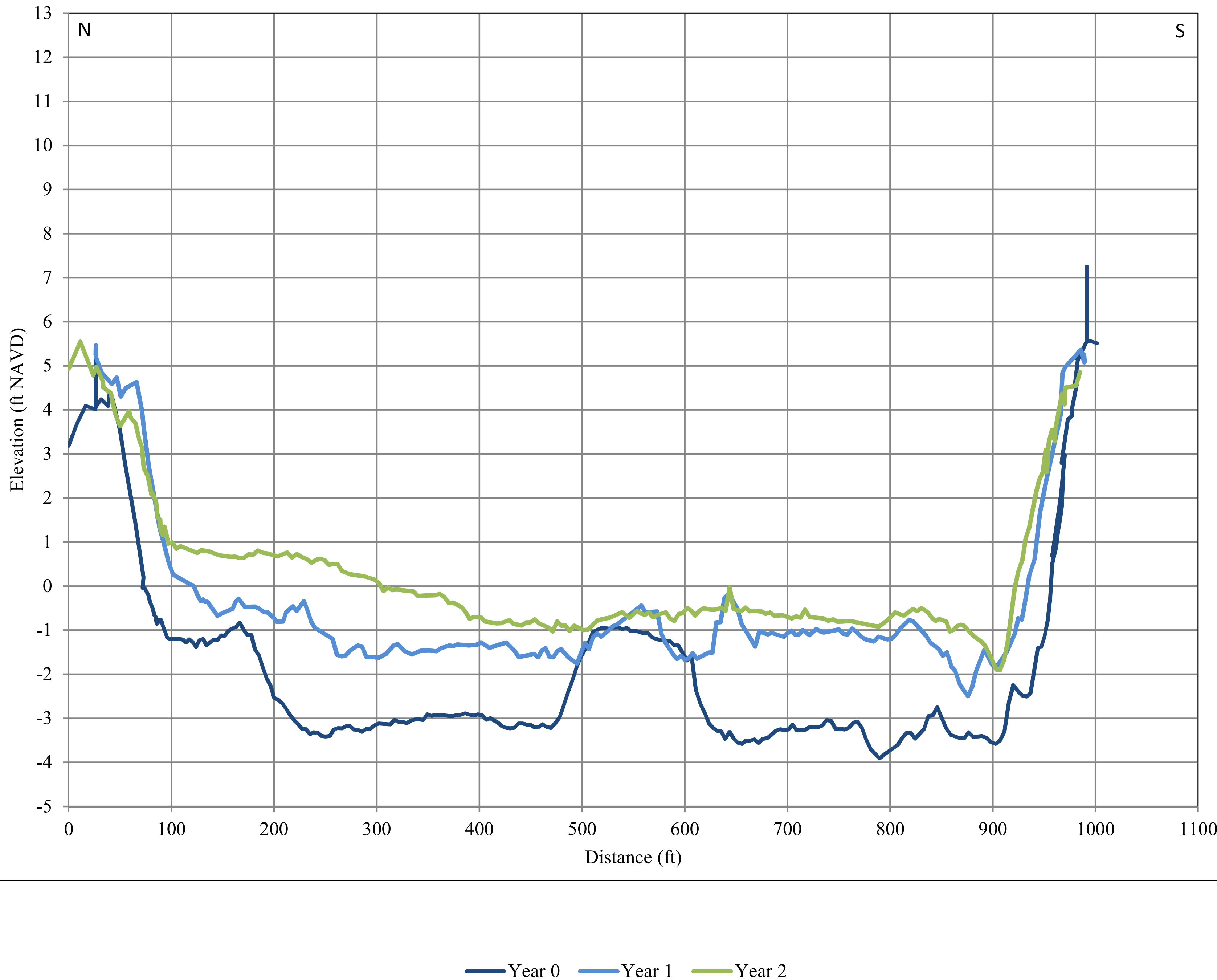


Figure B-1. Cross Section 56, North to South Interior Marsh

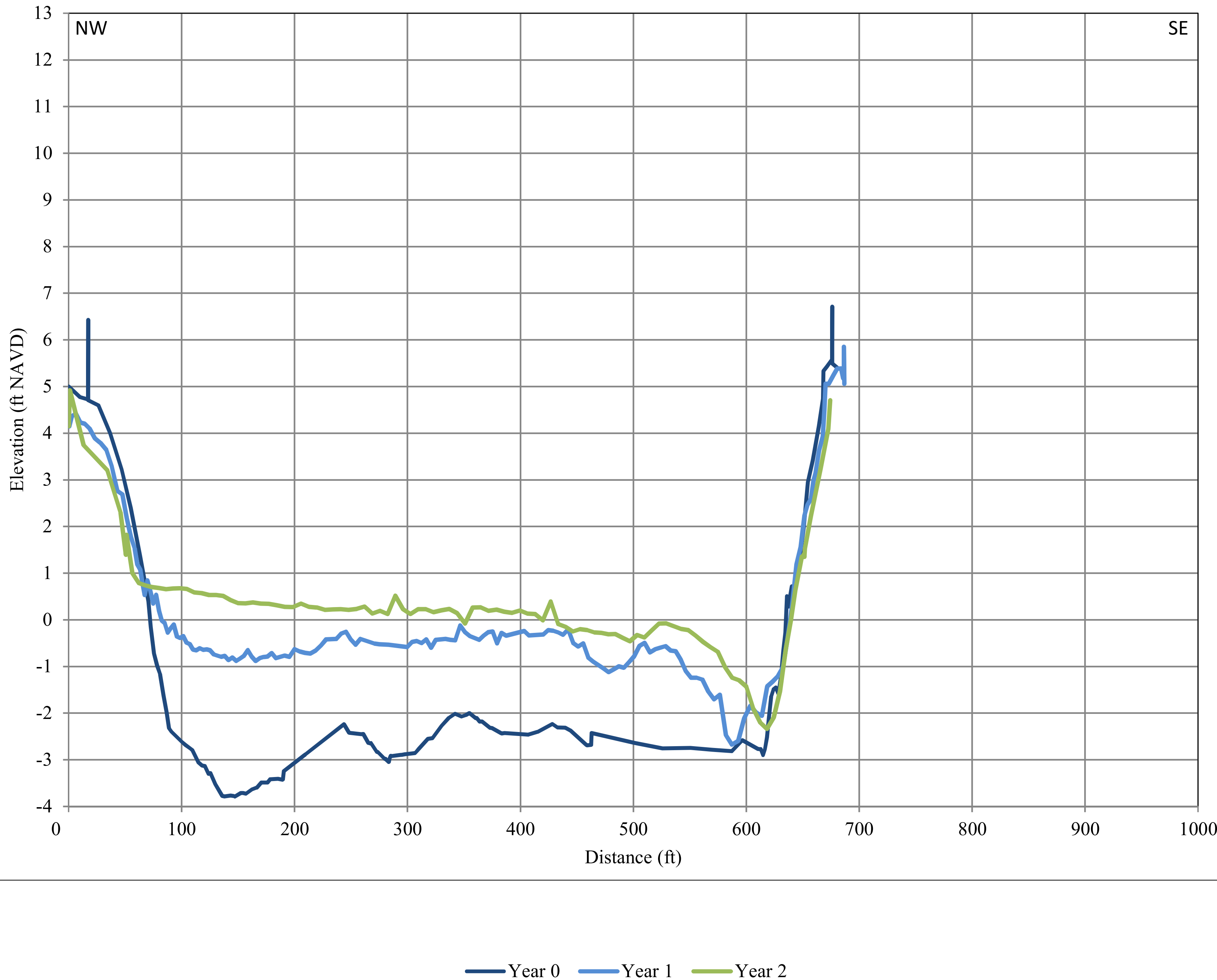


Figure B-2. Cross Section 25, Northwest to Southeast Interior Marsh

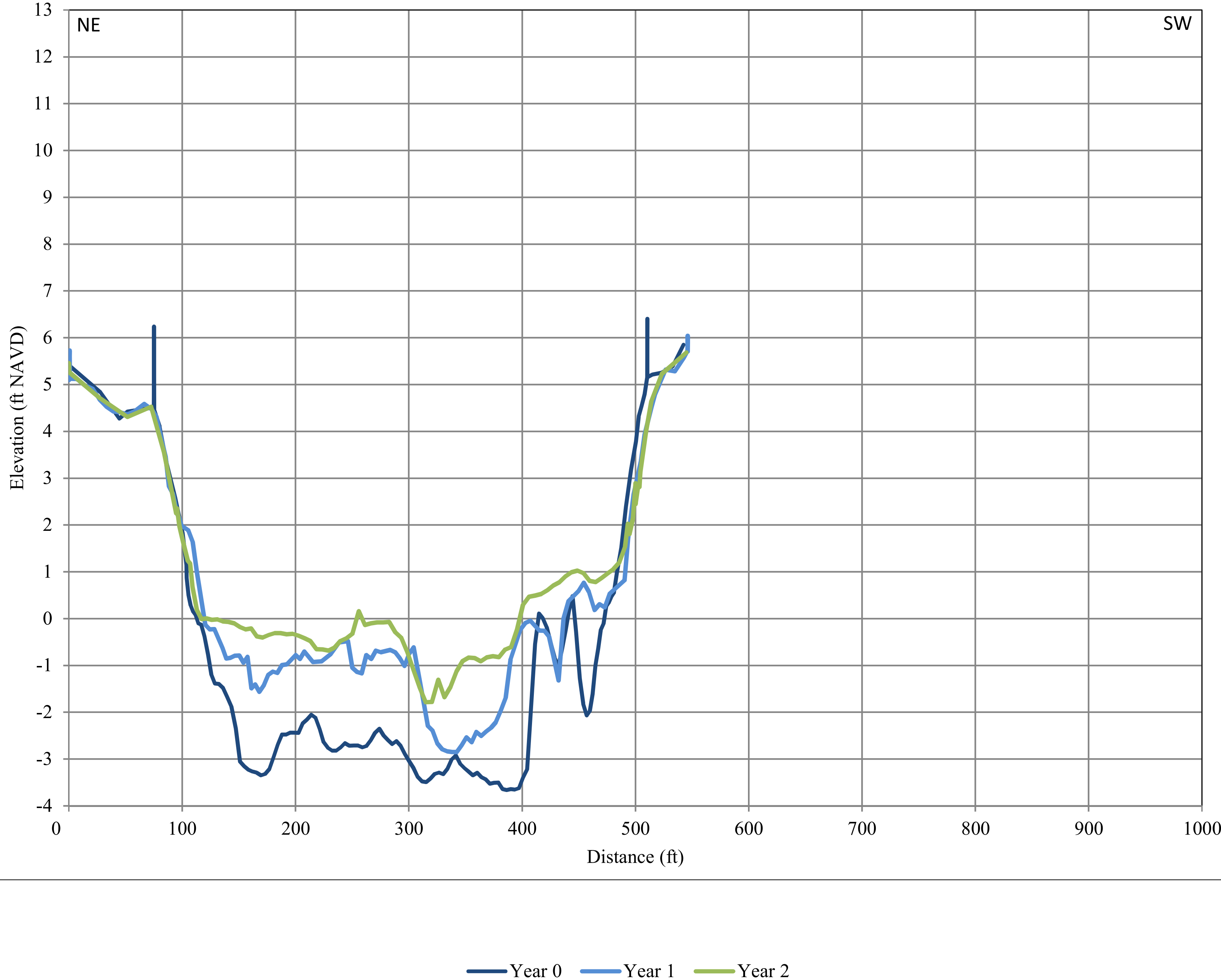


Figure B-3. Cross Section 26, Northeast to Southwest Interior Marsh

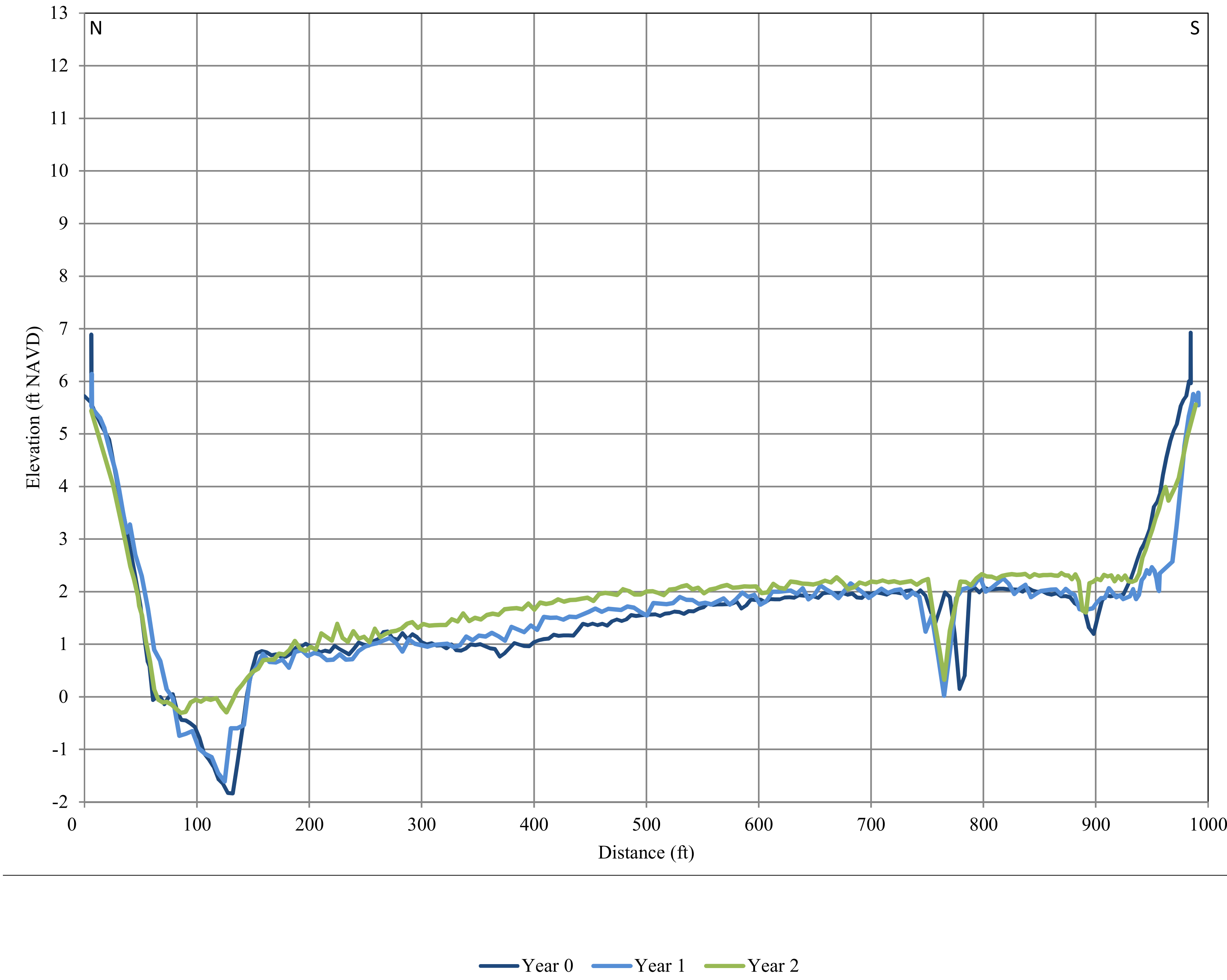


Figure B-4. Cross Section 35, North to South Interior Marsh

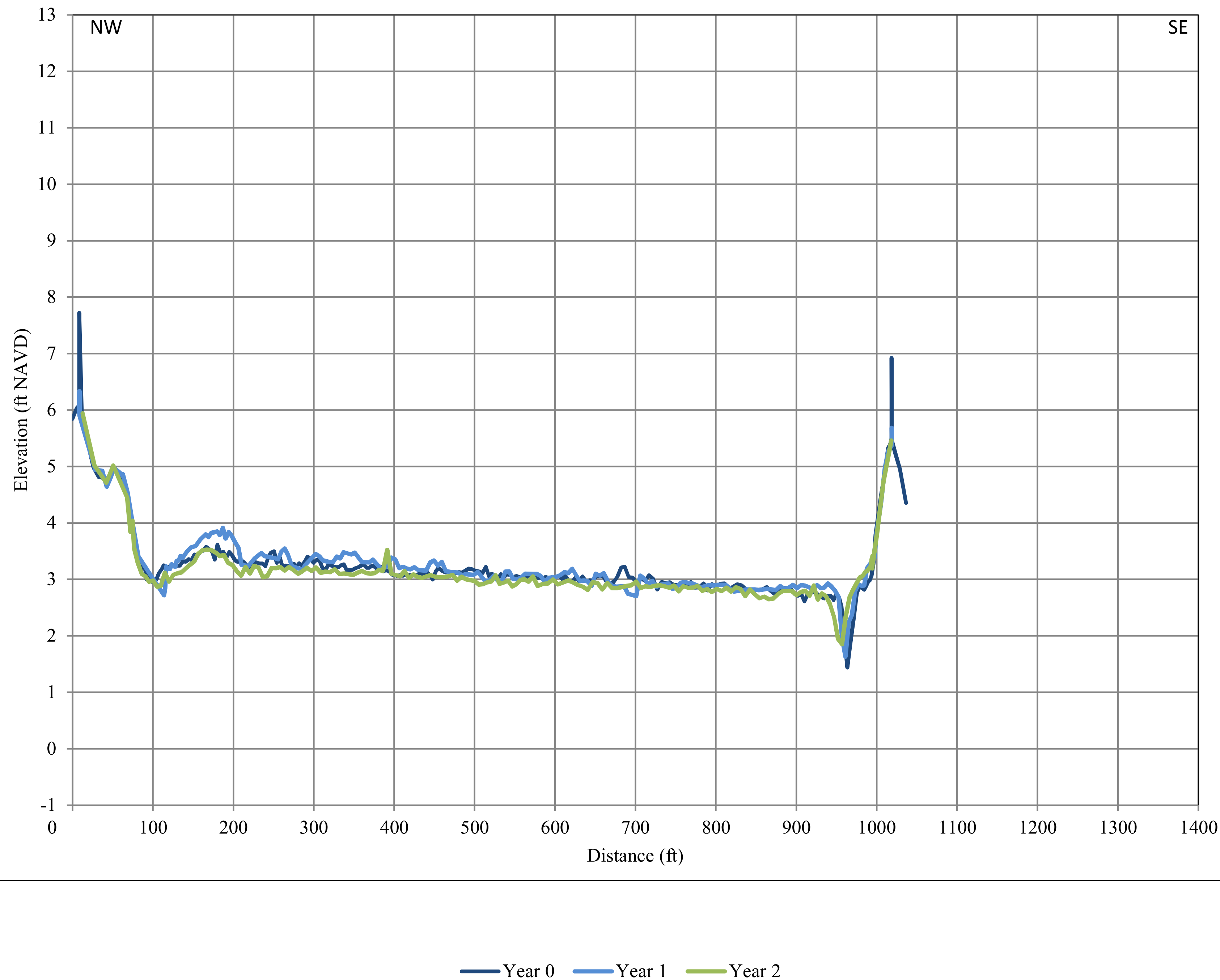


Figure B-5. Cross Section 27, Northwest to Southeast Interior Marsh

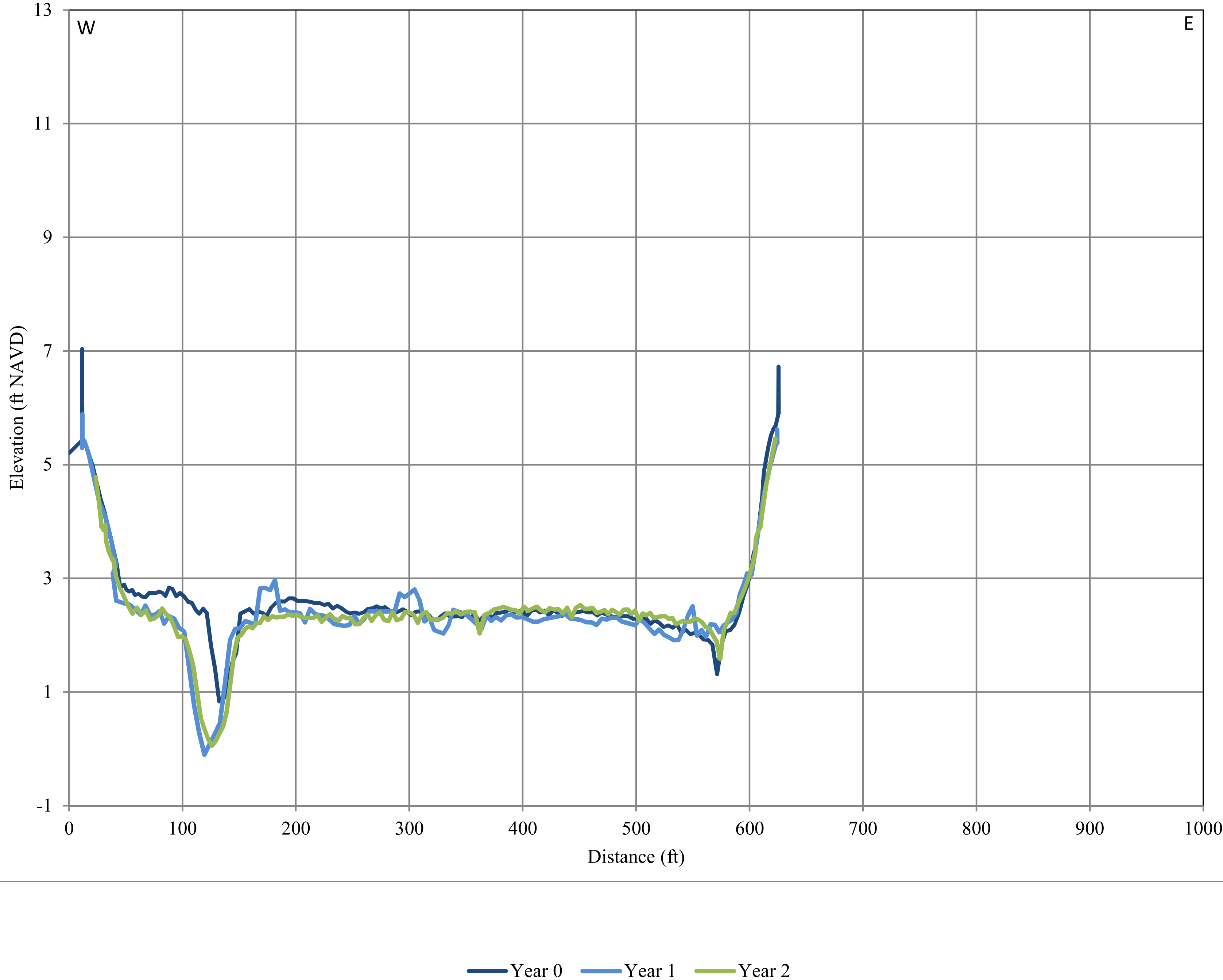


Figure B-6. Cross-Section 37, West to East Interior Marsh

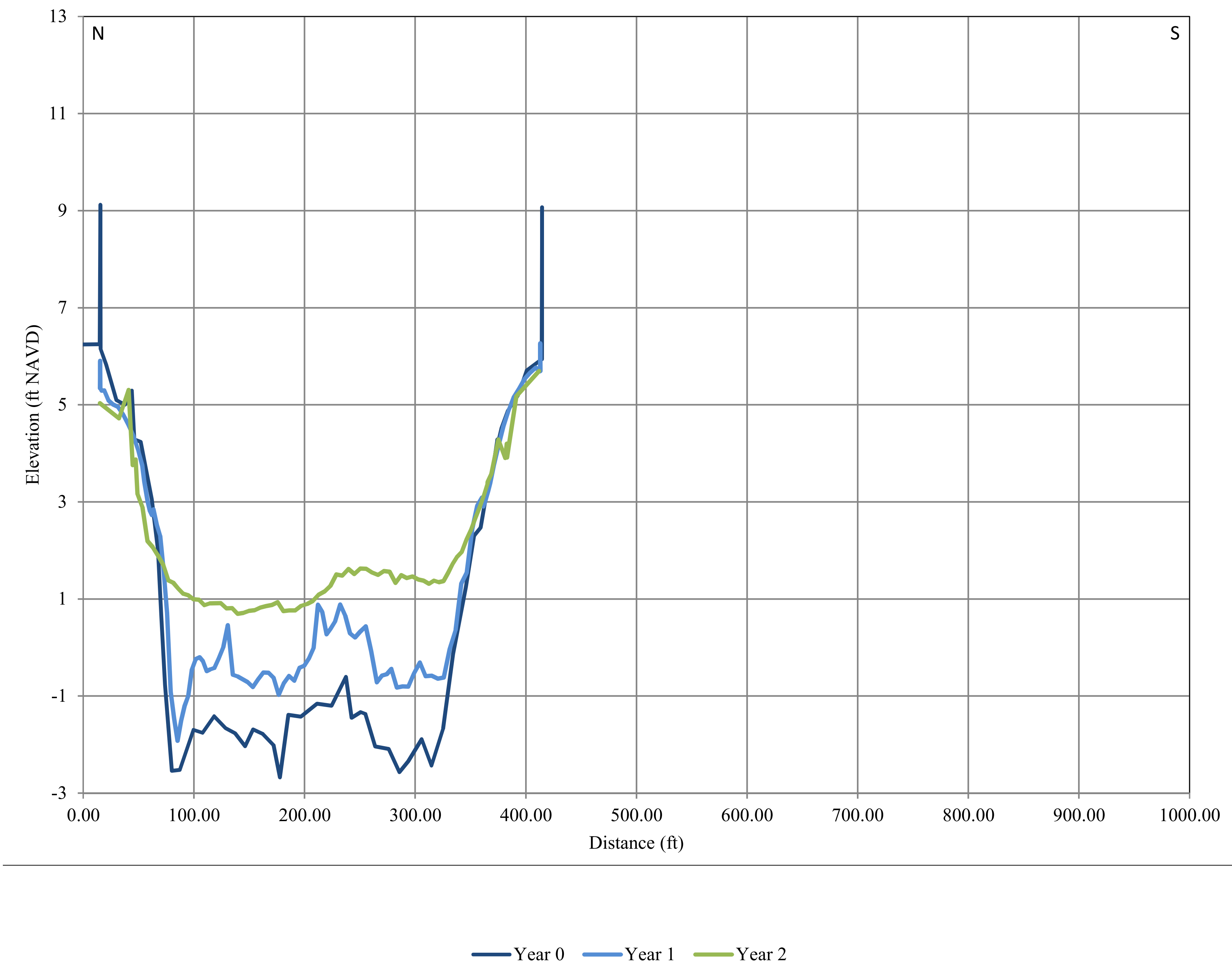


Figure B-7. Cross-Section 14, North to South Interior Marsh

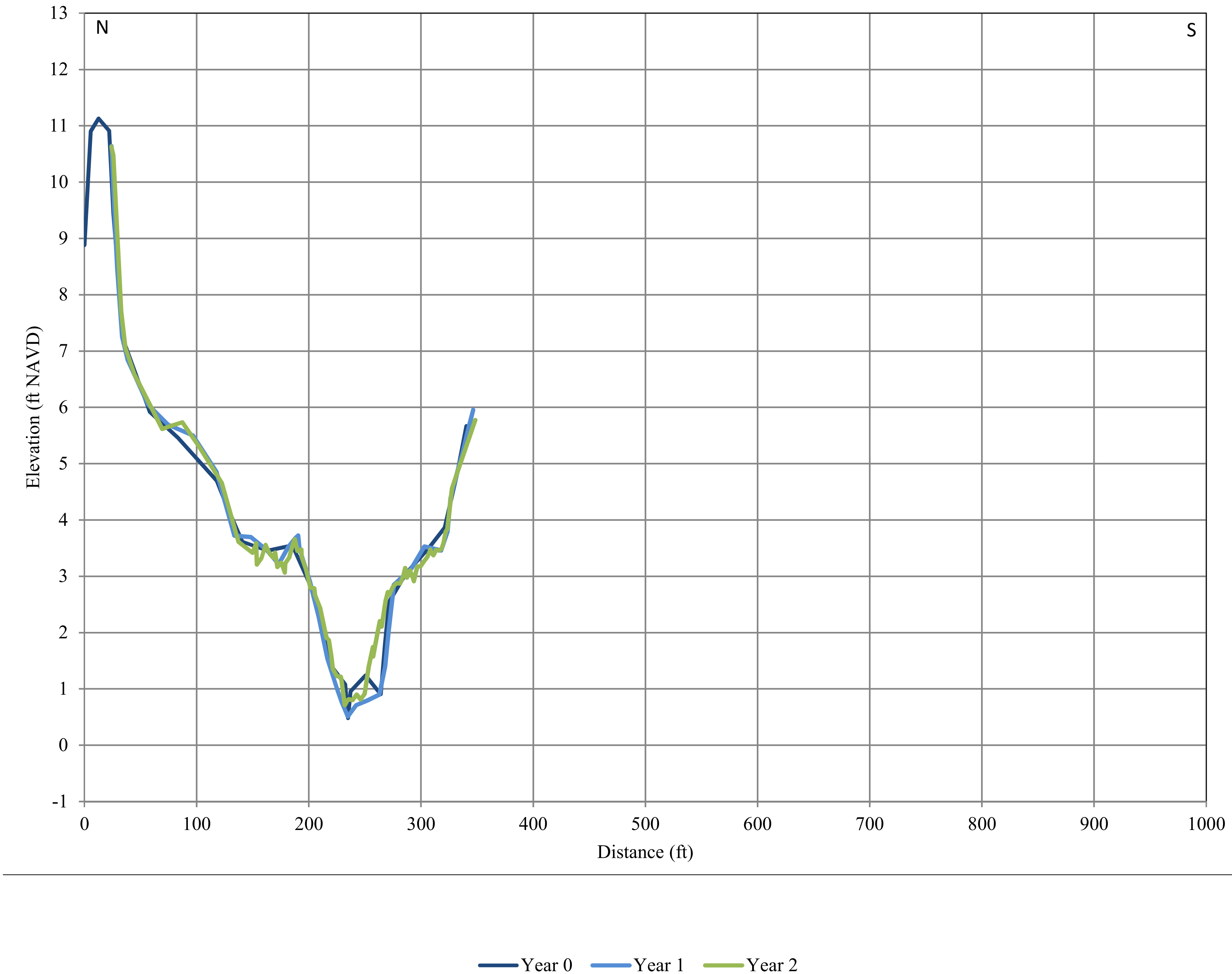


Figure B-8. Cross-Section 6, North to South Interior Marsh

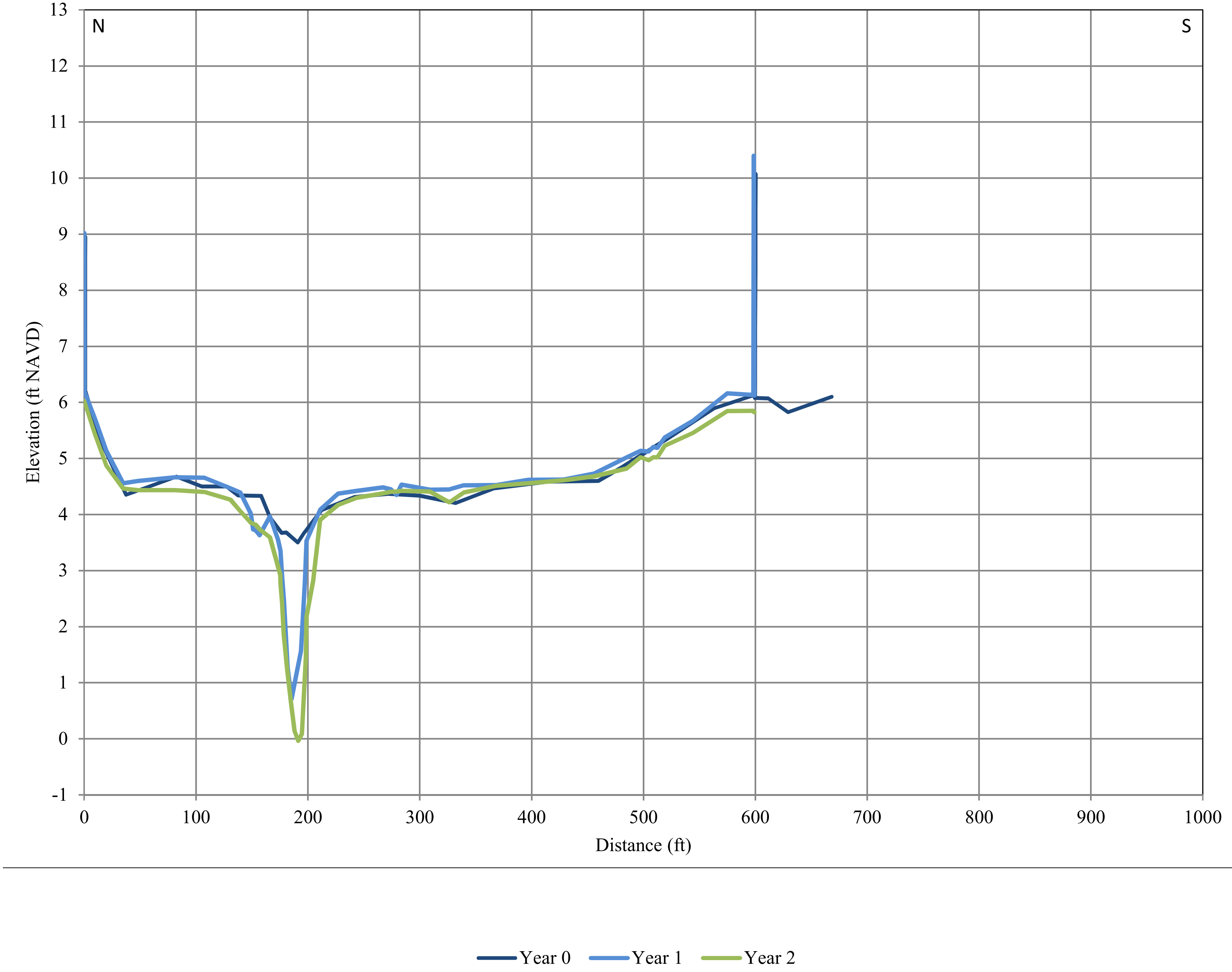


Figure B-9. Cross-Section NS1, North to South Interior Marsh

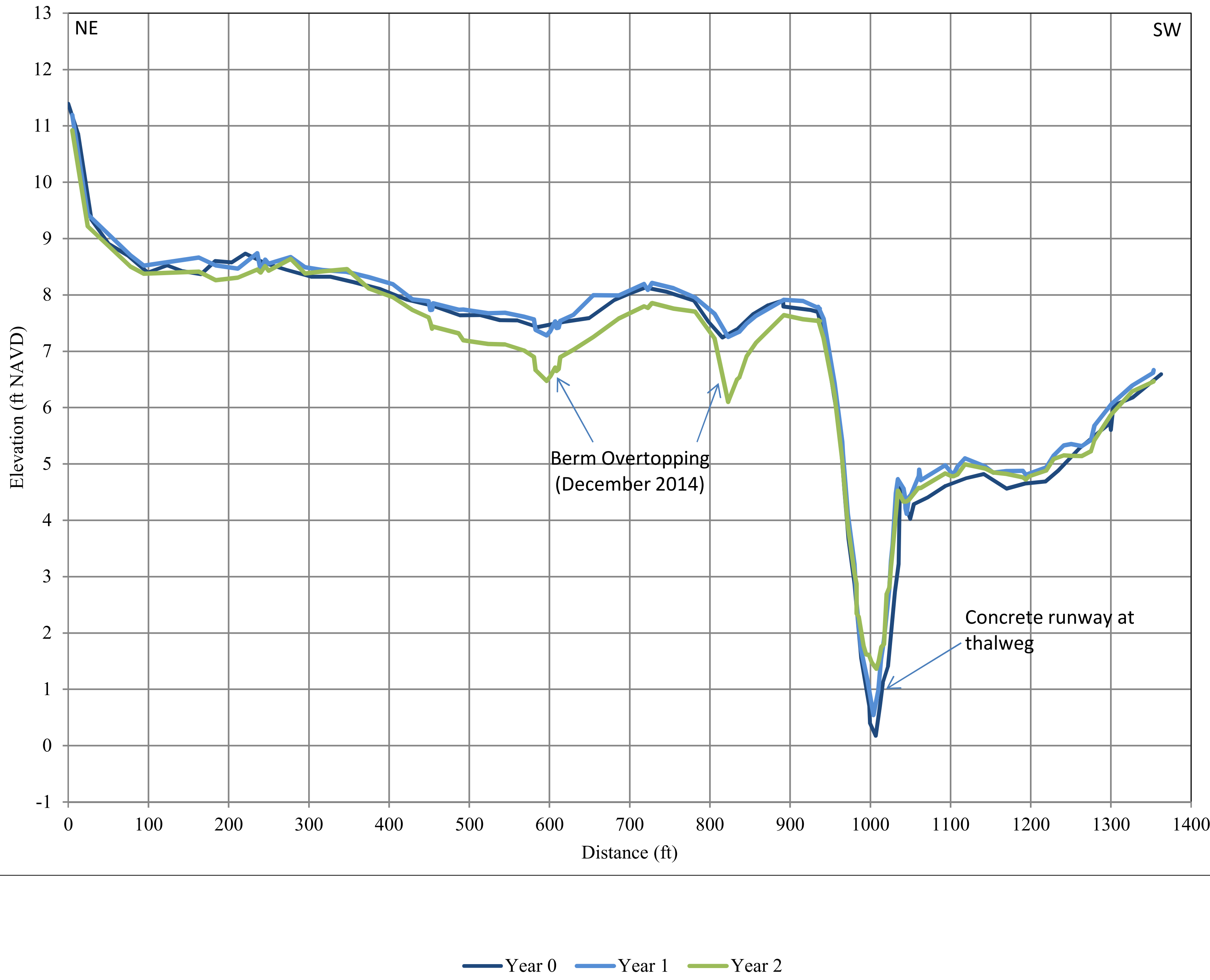


Figure B-10. Cross-Section NS2, Northeast to Southwest Interior Marsh

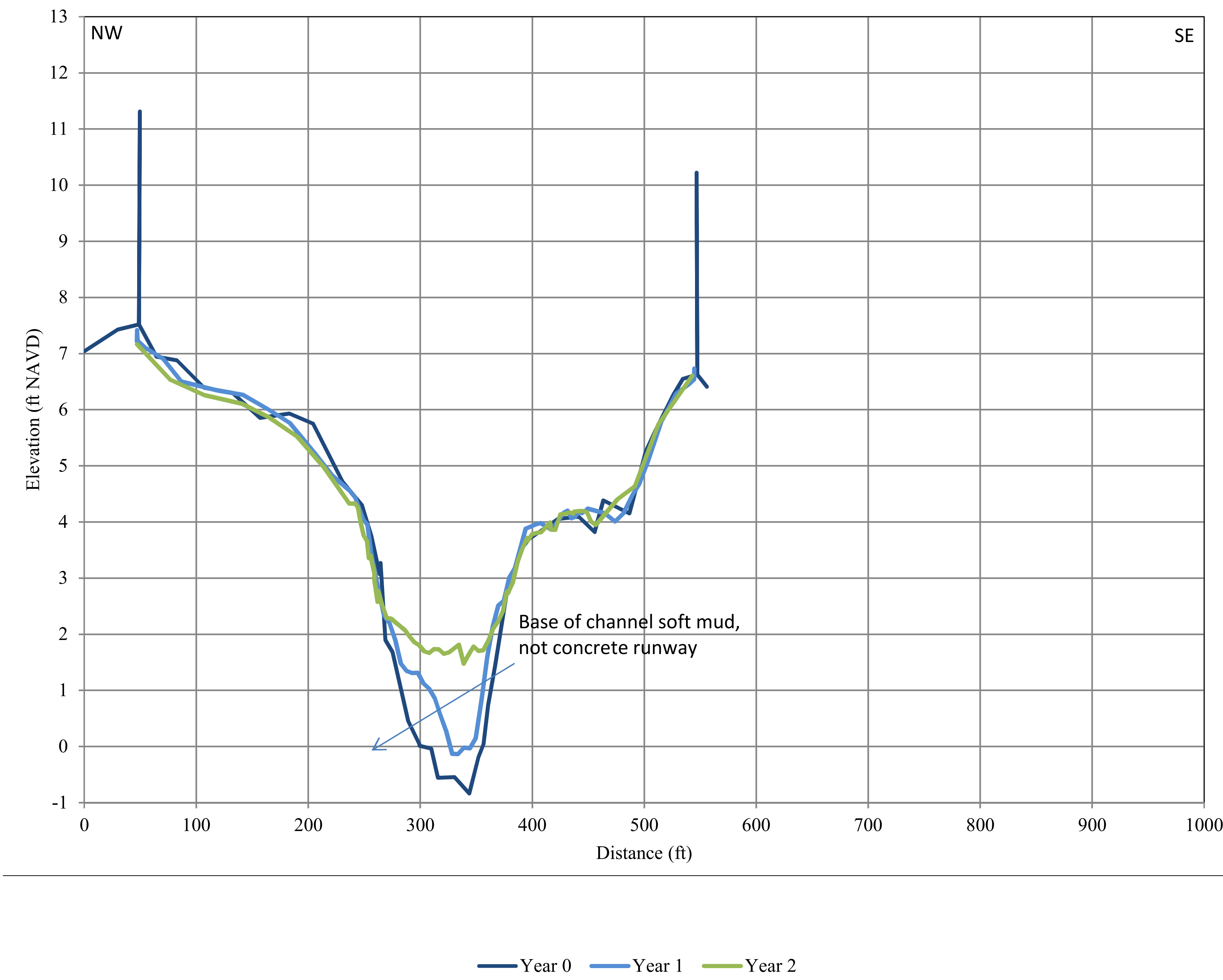


Figure B-11. Cross-Section SS1, Northwest to Southeast Interior Marsh

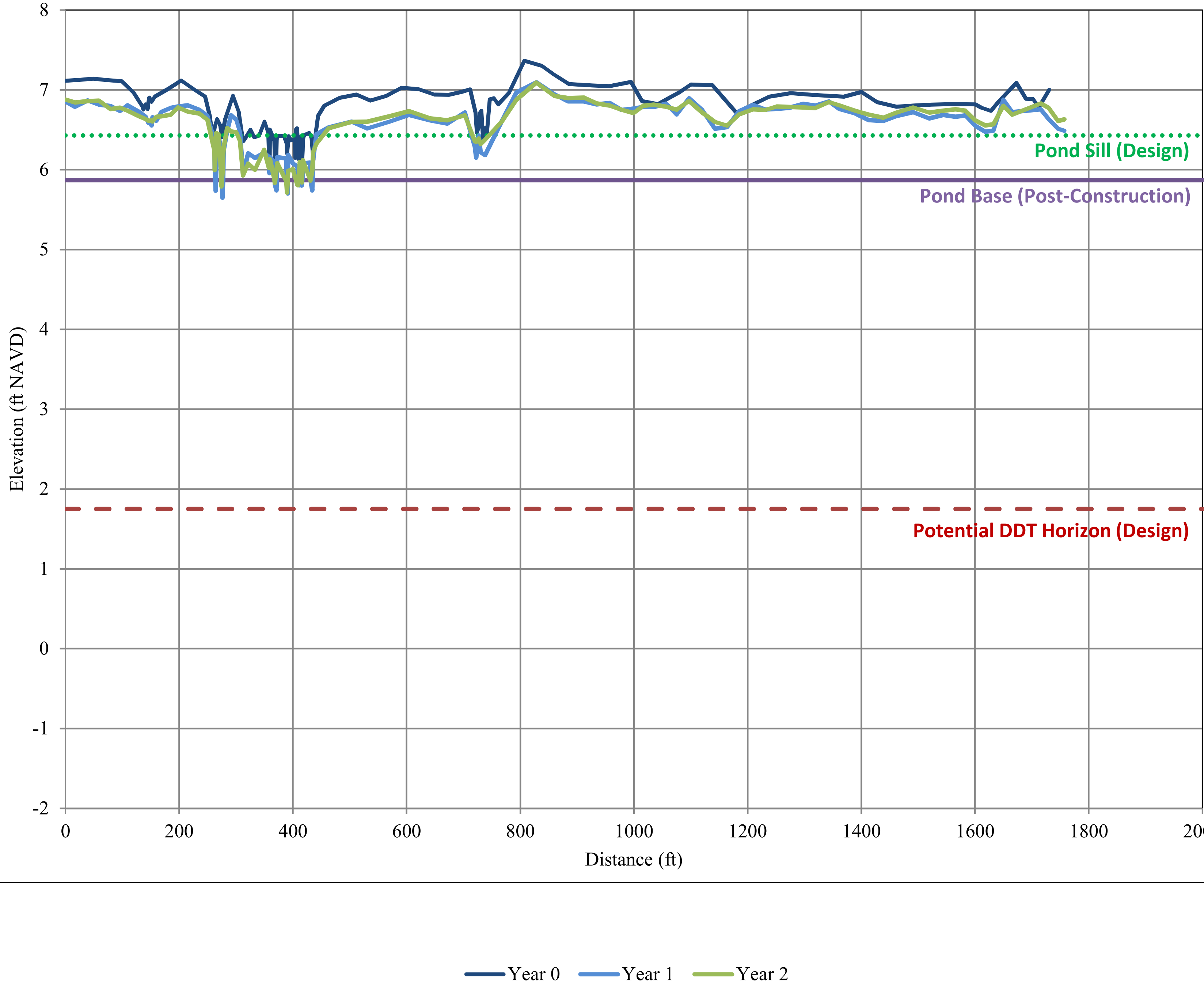


Figure B-12. South Seasonal Pond 1 Perimeter Crest Clockwise from Northwest corner

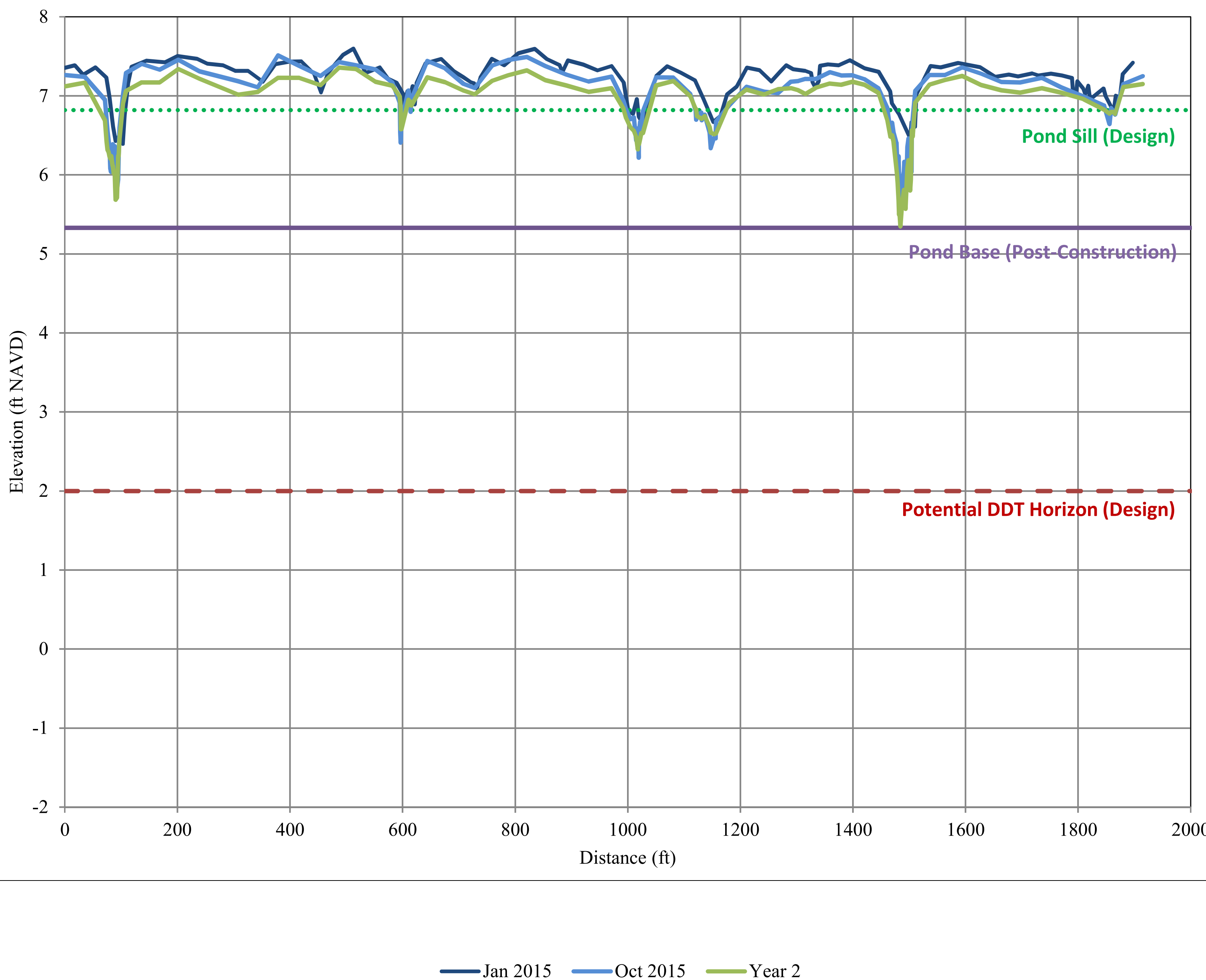


Figure B-13. South Seasonal Pond 2 Perimeter Crest Counter-Clockwise from Southwest corner

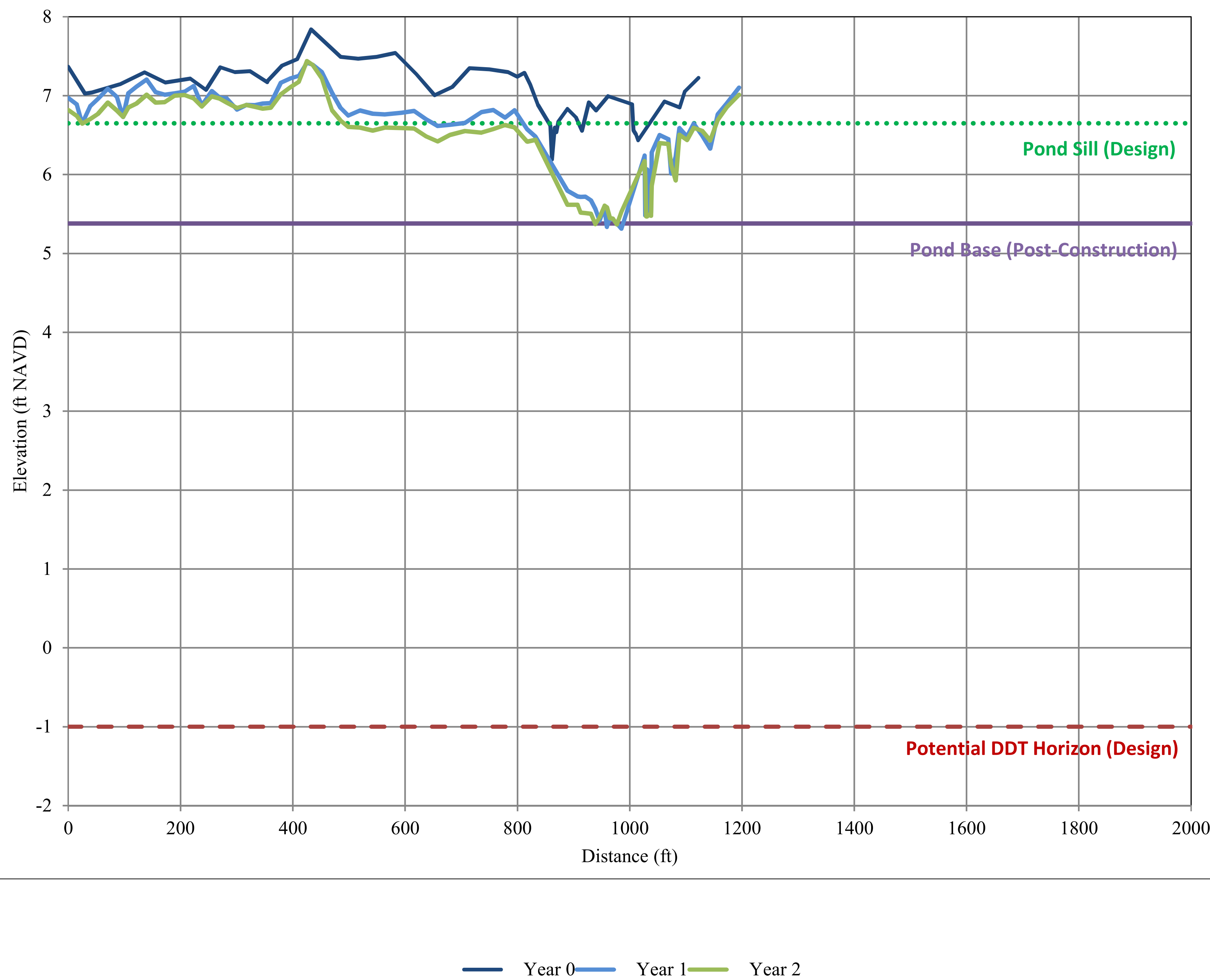


Figure B-14. South Seasonal Pond 3 Perimeter Crest Counter-Clockwise from Northeast corner

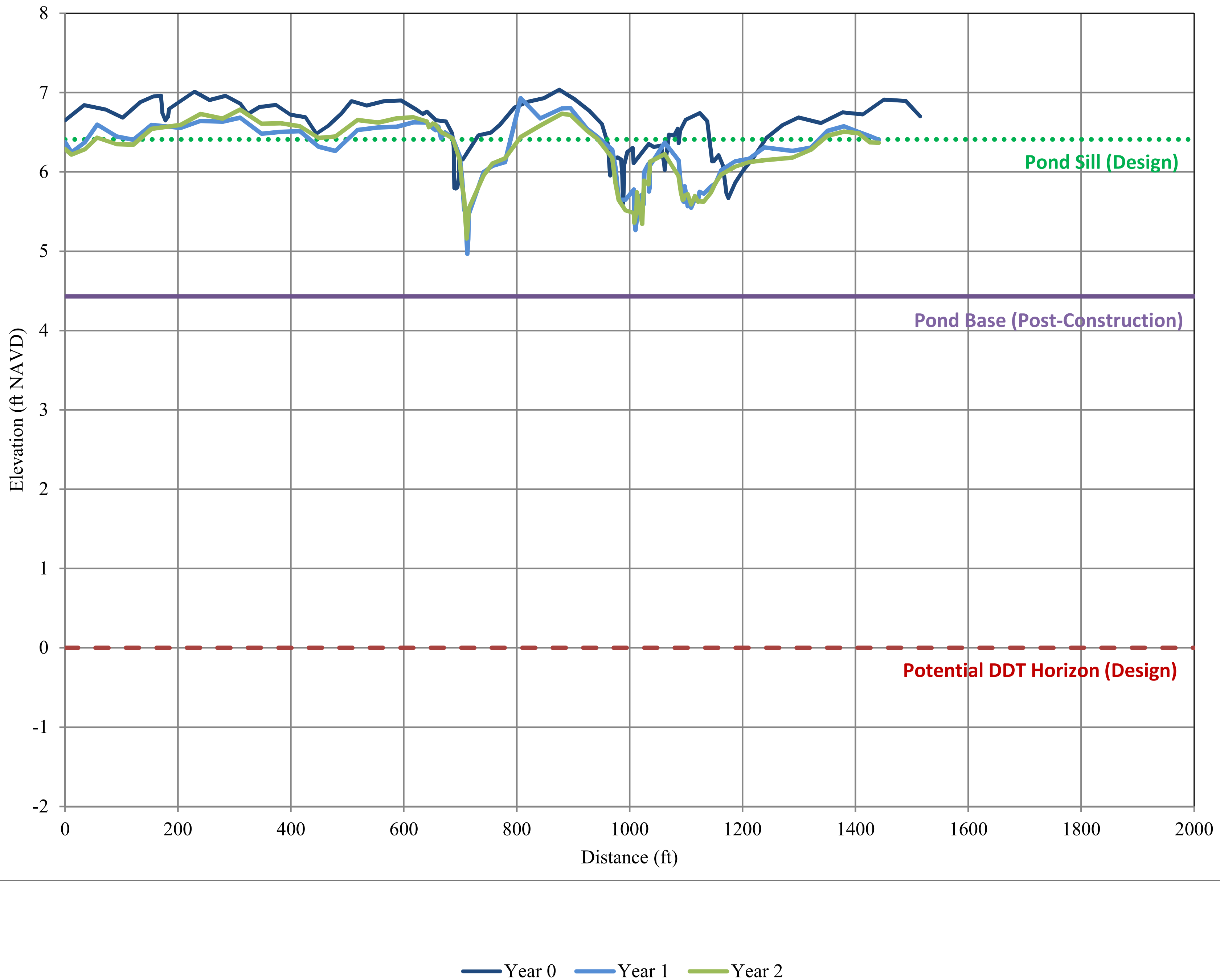


Figure B-15. South Seasonal Pond 4 Perimeter Crest Clockwise from Southwest corner

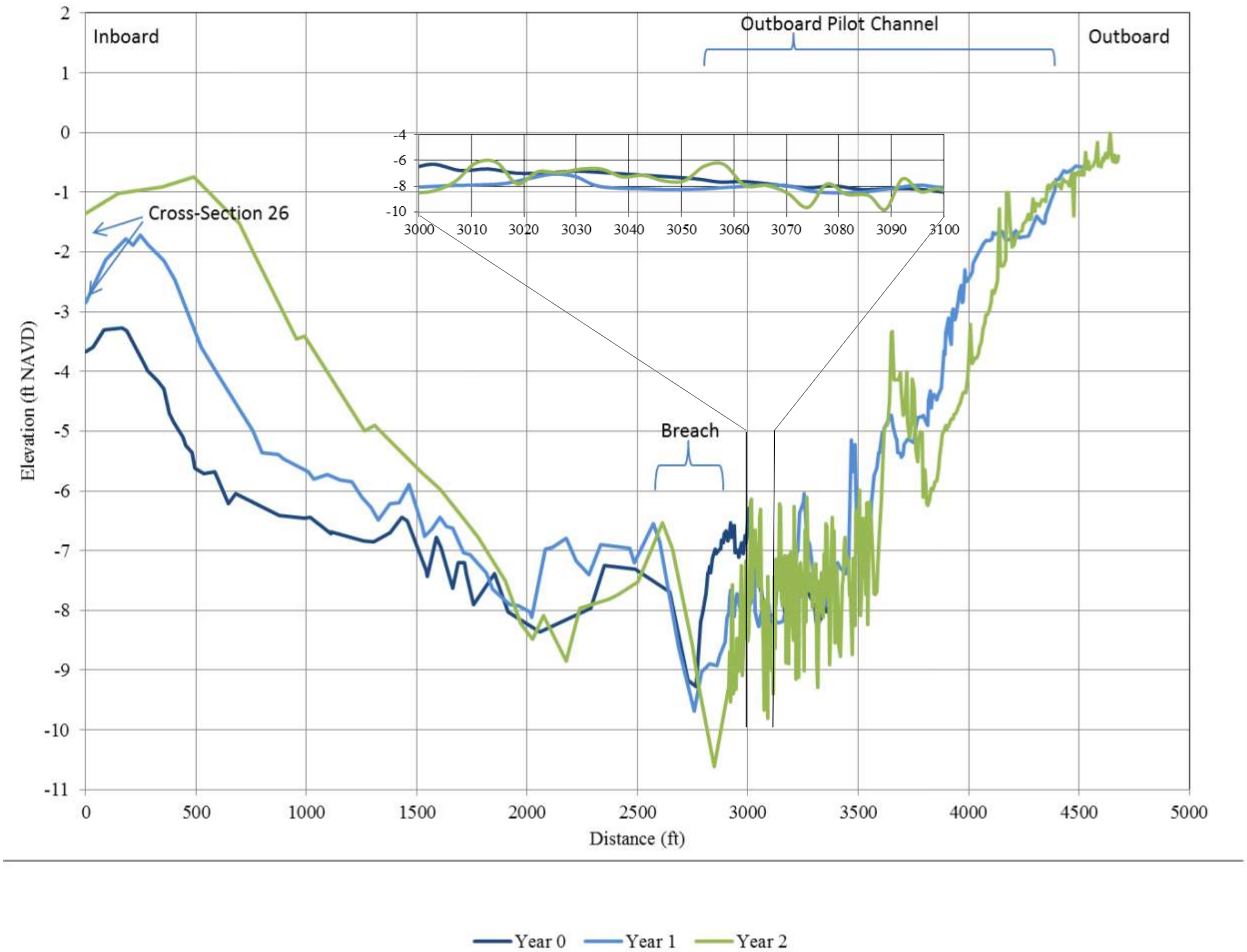


Figure B-16. Entrance Channel Thalweg Profile Inboard to Outboard

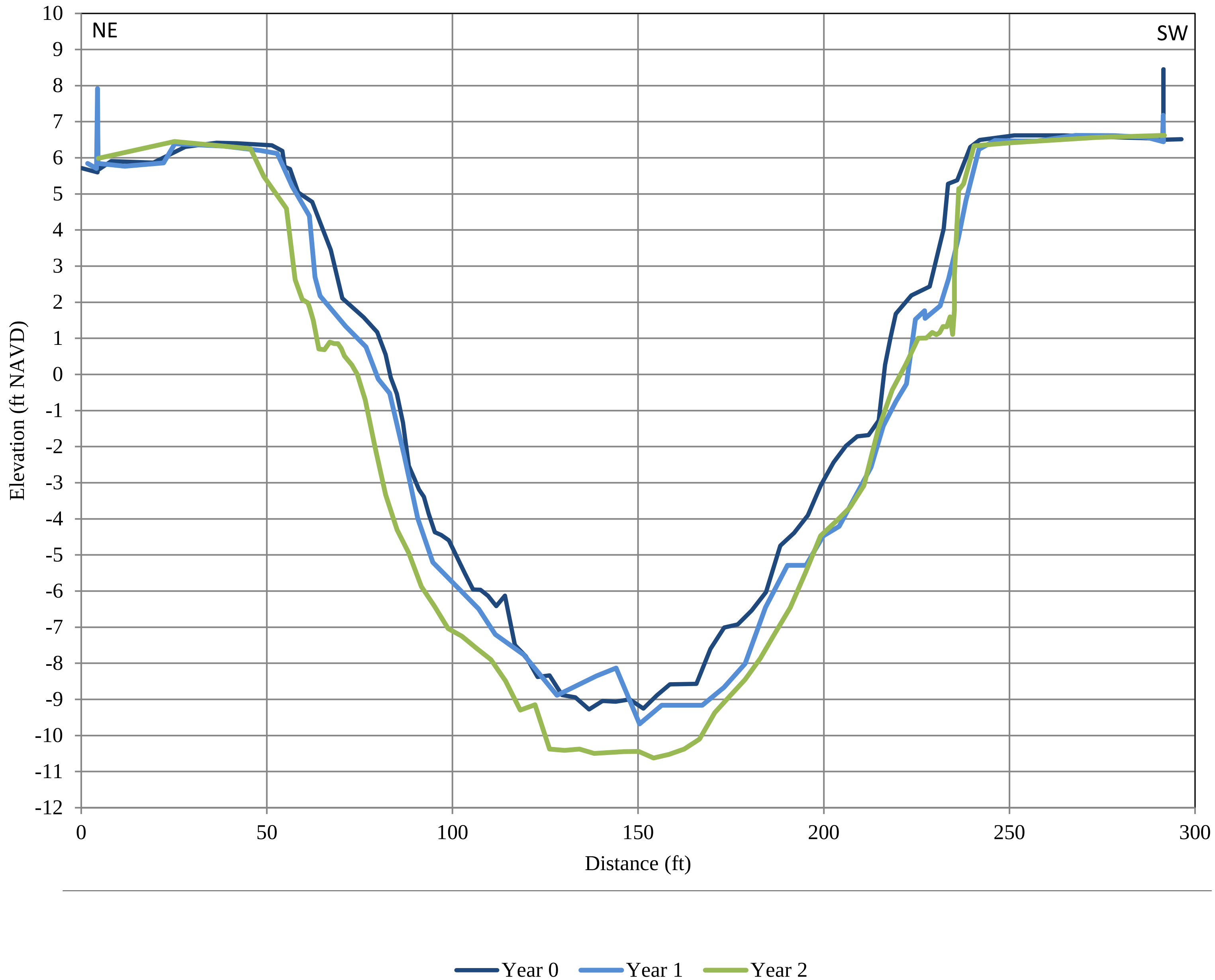


Figure B-17. Cross-Section BR2, Northeast to Southwest Outboard Marsh

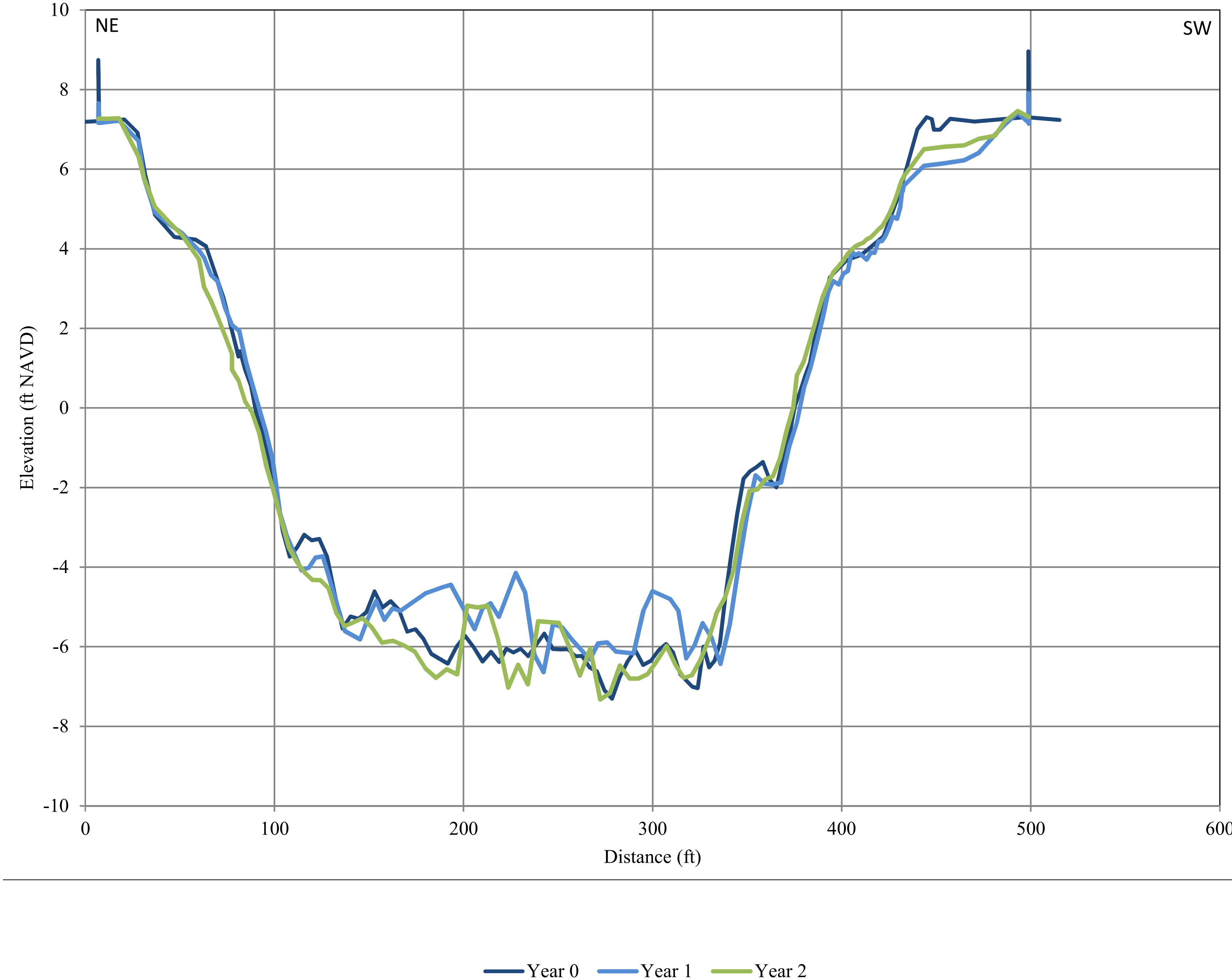


Figure B-18. Cross-Section BR1, Northeast to Southwest Outboard Marsh

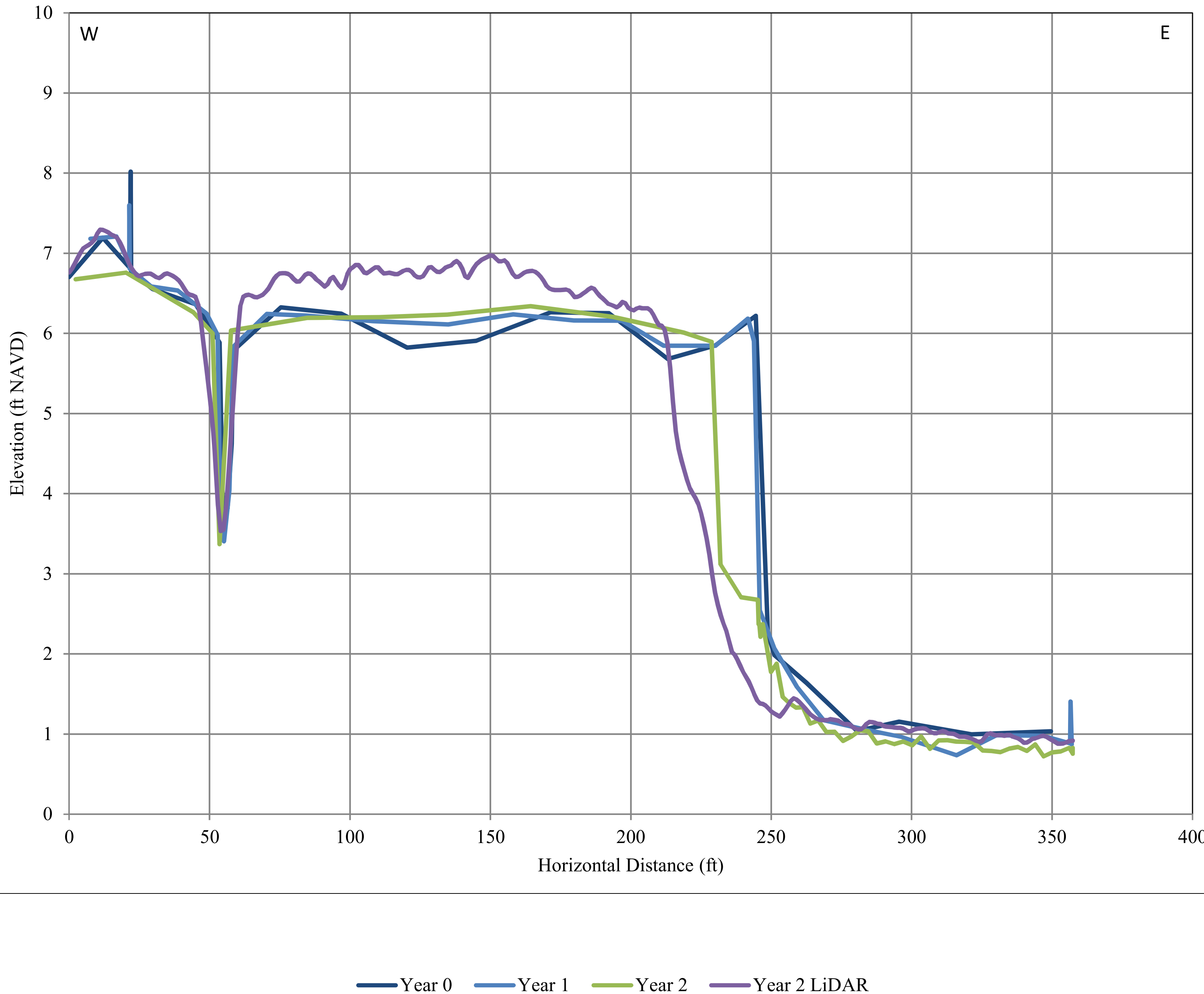


Figure B-19. Fringe Marsh Profile 1, West to East Fringing Marsh Scour

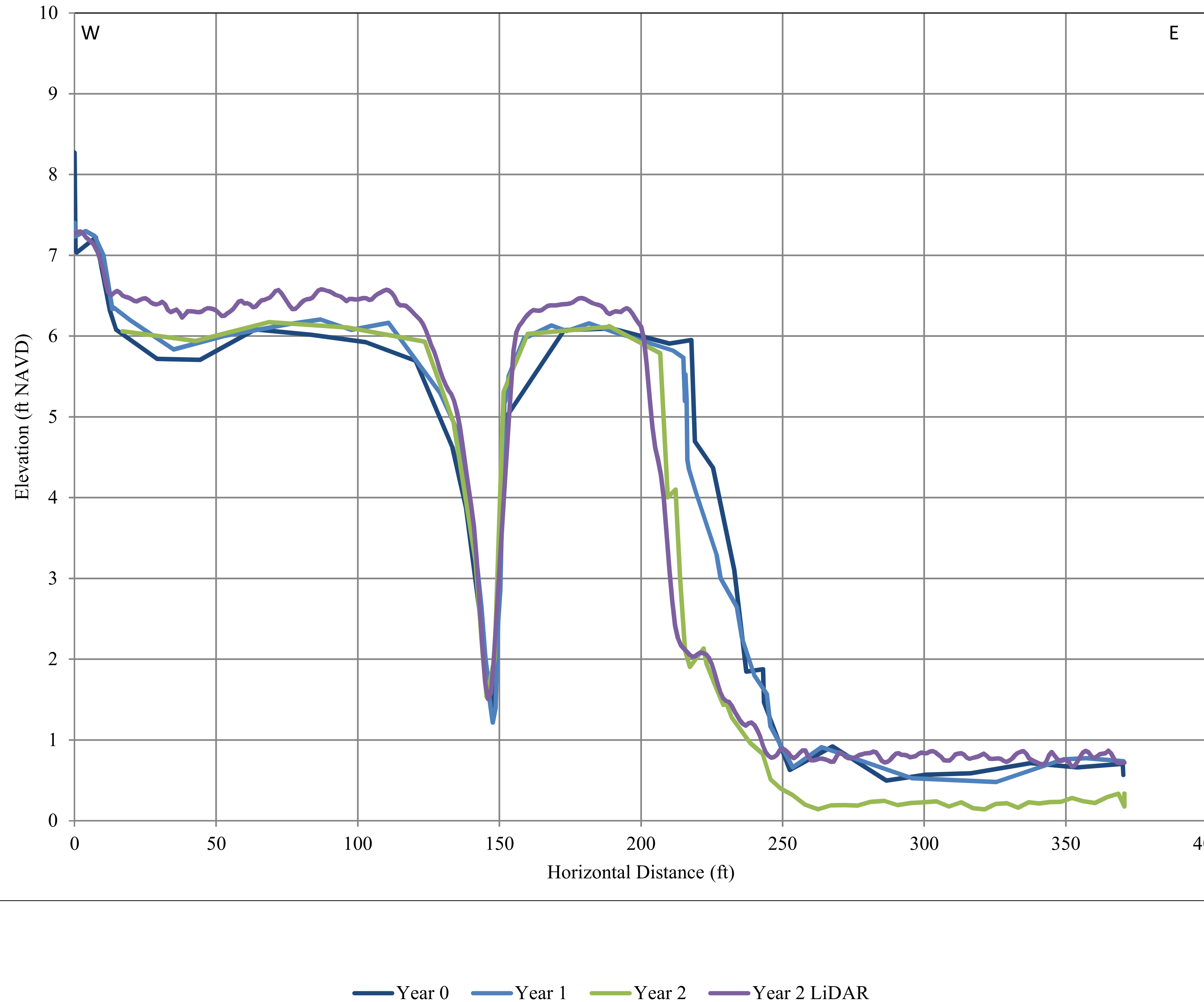


Figure B-20. Fringe Marsh Profile 2, West to East Fringing Marsh Scour

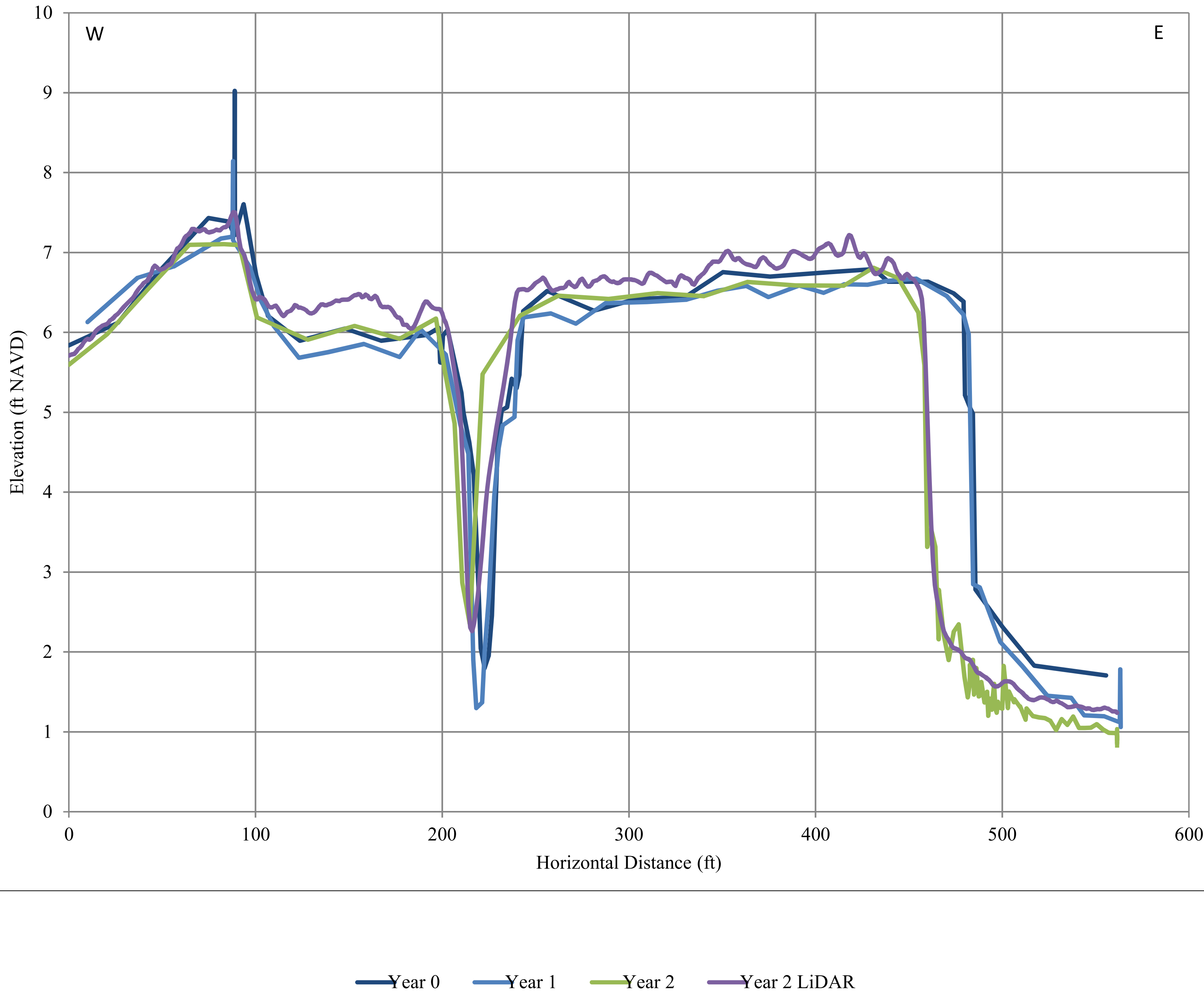


Figure B-21. Fringe Marsh Profile 3, West to East Fringing Marsh Scour

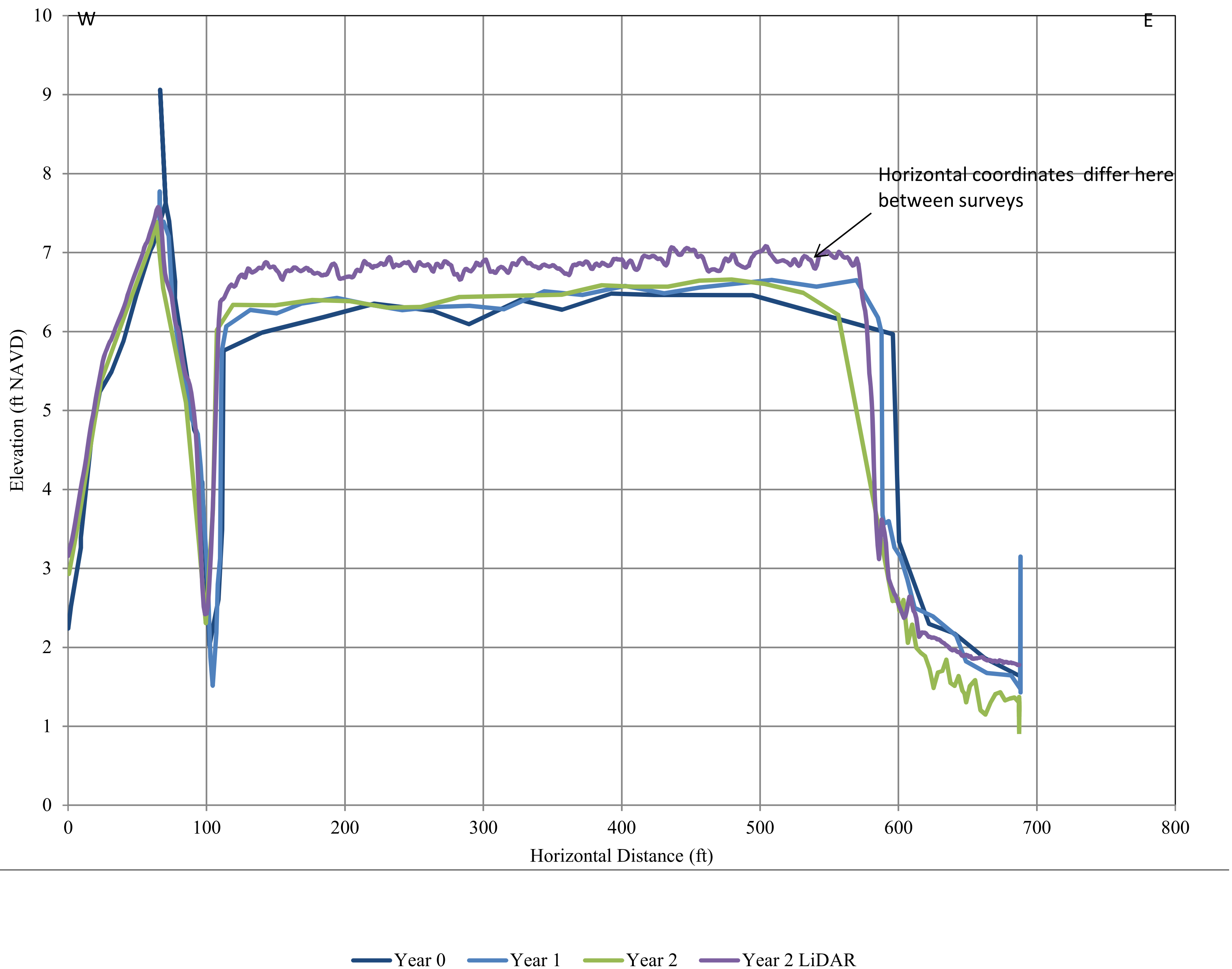


Figure B-22. Fringe Marsh Profile 4, West to East Fringing Marsh Scour

Appendix C.

Aerial Photo Plates

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Figure C-1. Project Site photo.

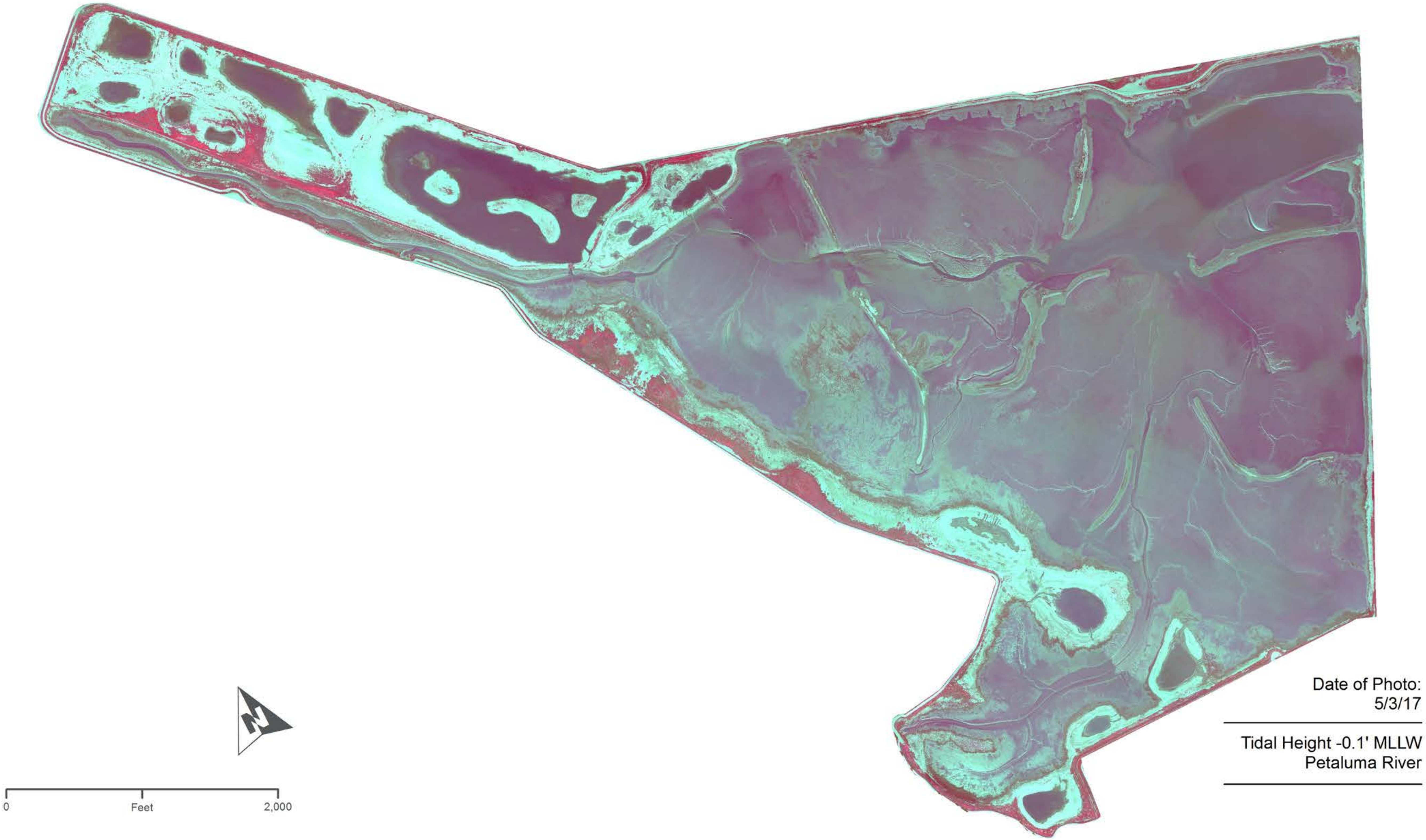

Figure C-2. Infrared photo of the Project site.

Figure C-3. Year 1 Aerial Photograph.

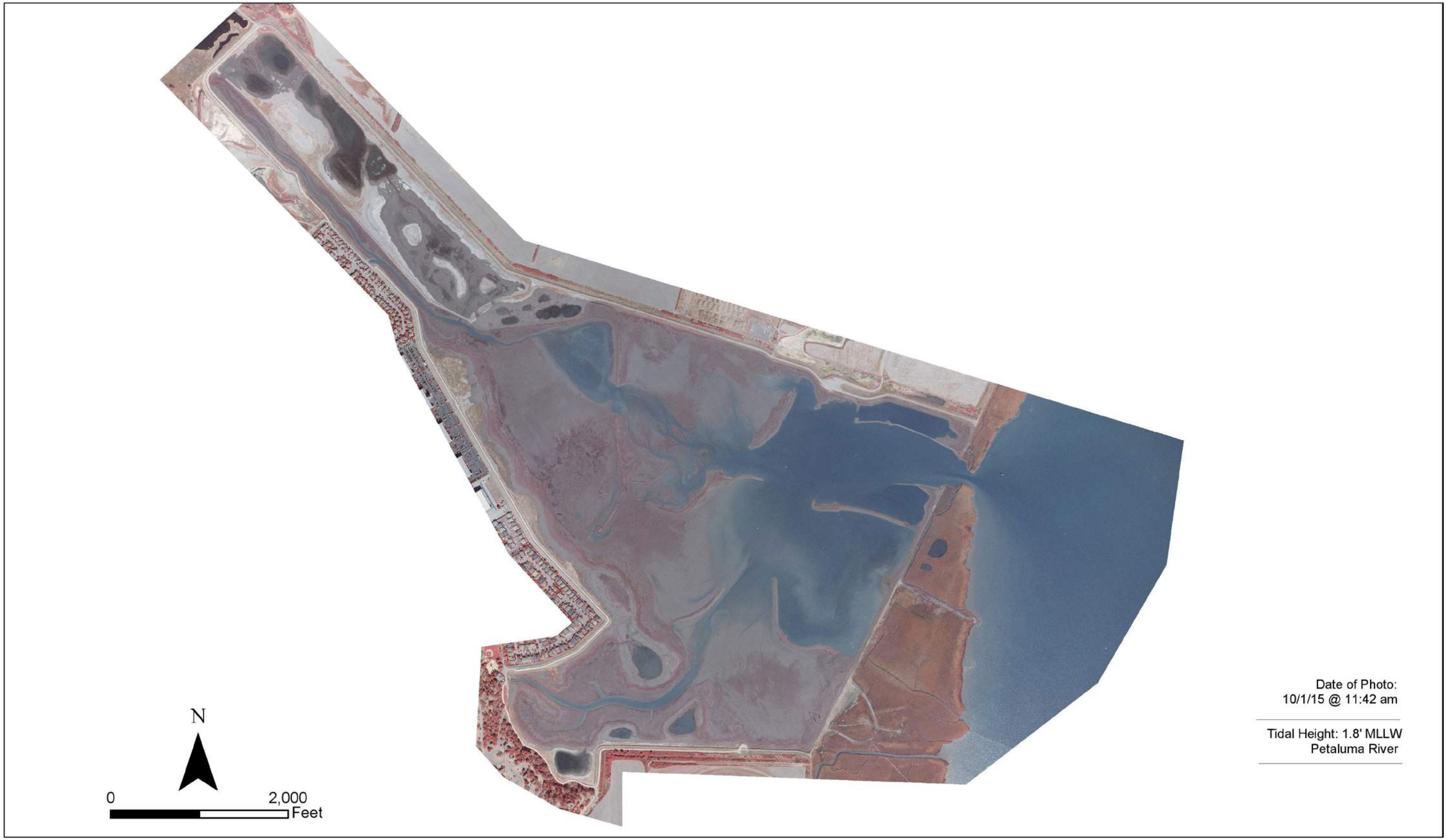

Figure C-4. Year 1 Aerial Photograph.

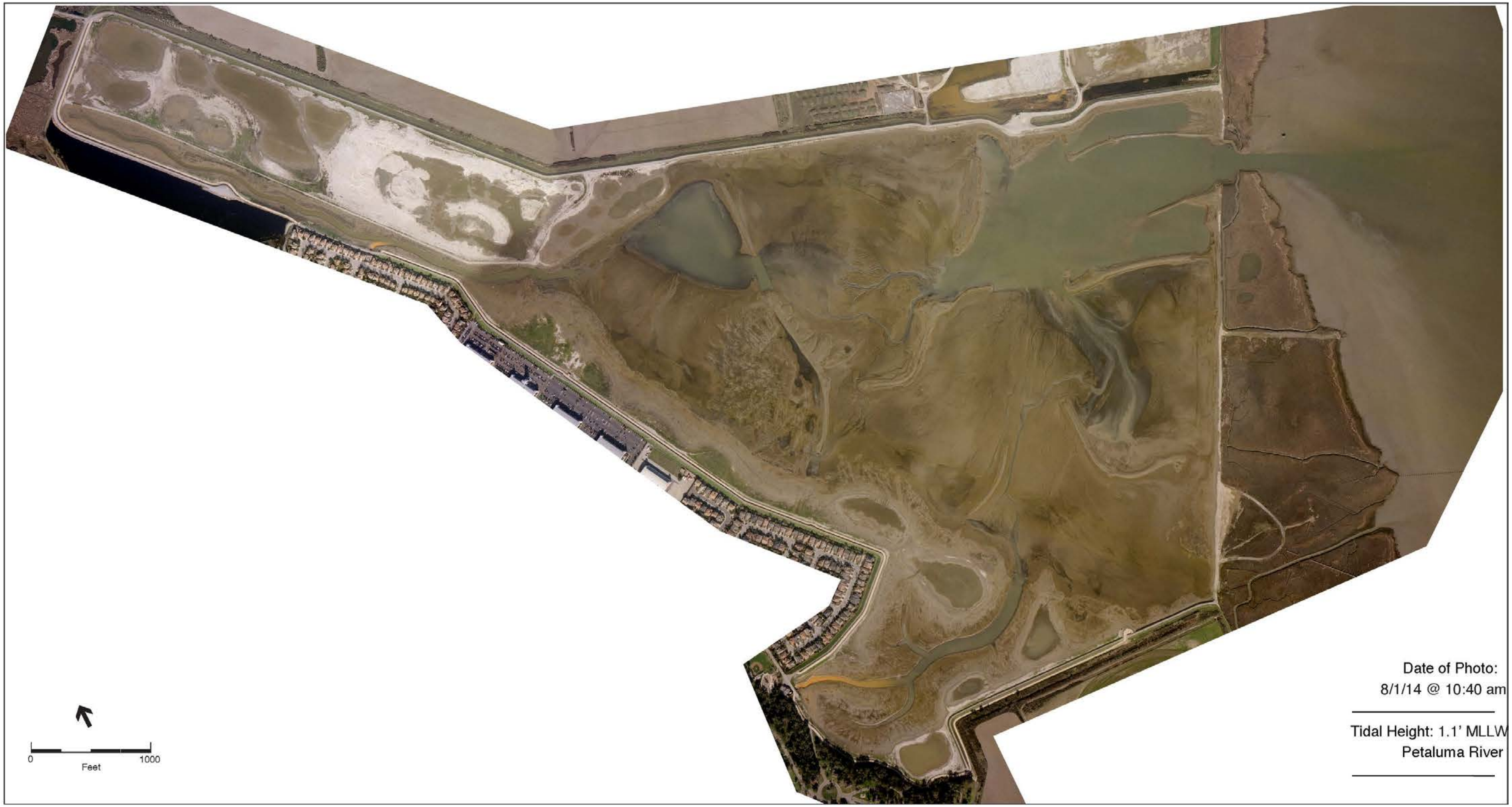

Figure C-5. Year 0 Aerial Photograph.

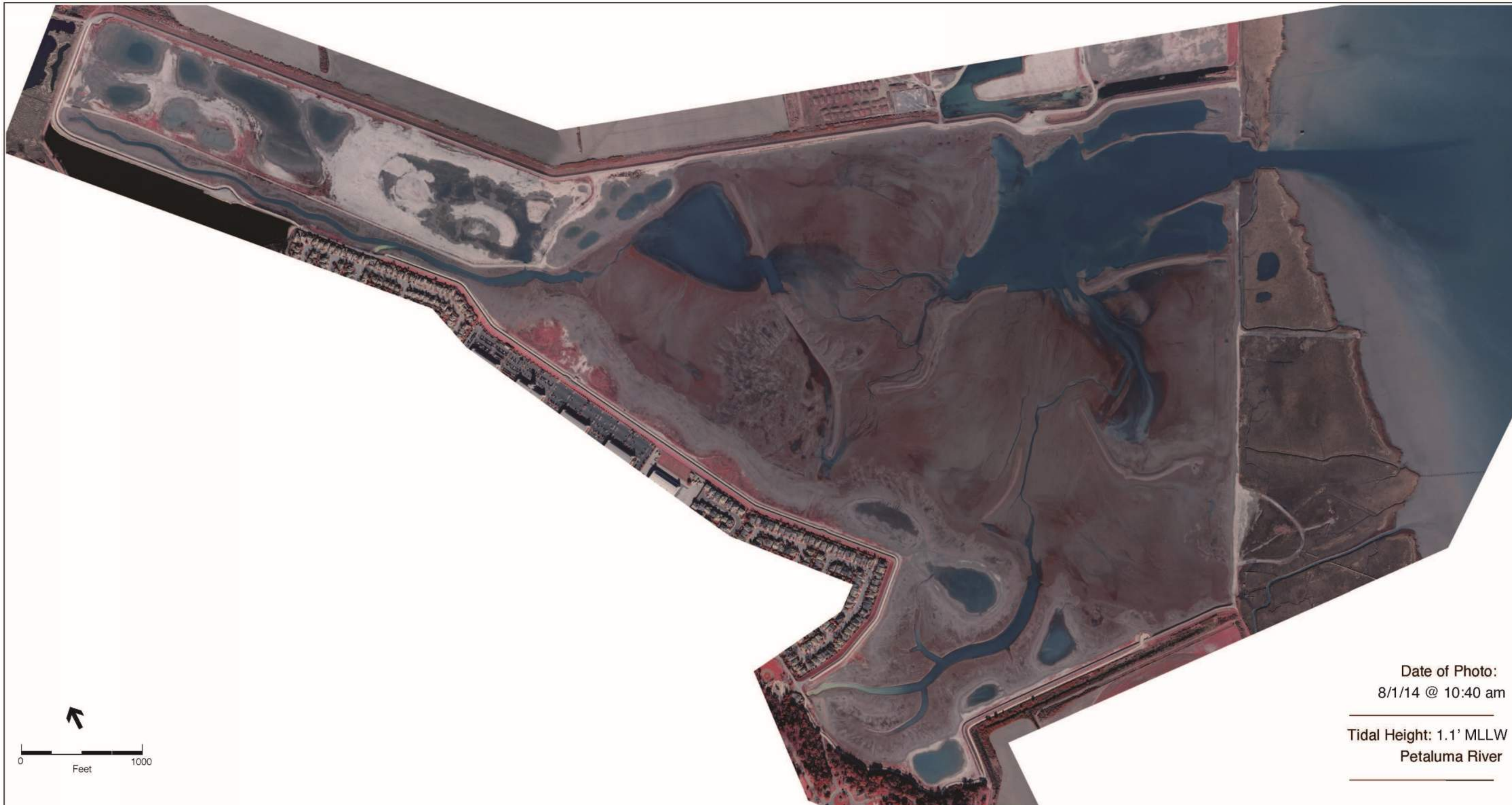

Figure C-6. Year 0 Aerial Photograph.

Appendix D.

Avian

	AVIAN SPECIES
CODES	**WATERFOWL (etcetra)**
CANG	Canada Goose *Branta canadensis*
MUSW	Mute Swan Cygnus olor
GADW	Gadwall *Anas strepera*
EUWI	Eurasian Wigeon *Anas penelope*
AMWI	American Wigeon *Anas americana*
MALL	Mallard *Anas platyrhynchos*
BWTE	Blue-winged Teal *Anas discors*
CITE	Cinnamon Teal *Anas cyanoptera*
NOSH	Northern Shoveler *Anas clypeata*
NOPI	Northern Pintail *Anas acuta*
GWTE	Green-winged Teal *Anas crecca*
CANV	Canvasback *Aythya valisineria*
GRSC	Greater Scaup *Aythya marila*
LESC	Lesser Scaup *Aythya affinis*
SUSC	Surf Scoter *Melanitta perspicillata*
BUFF	Bufflehead *Bucephala albeola*
COGO	Common Goldeneye *Bucephala clangula*
COME	Common Merganser *Mergus merganser*
RBME	Red-breasted Merganser *Mergus serrato* r
RUDU	Ruddy Duck *Oxyura jamaicensis*
PBGB	Pied-billed Grebe *Podilymbus podiceps*
HOGR	Horned Grebe *Podiceps auritus*
EAGR	Eared Grebe *Podiceps nigricollis*
WEGR	Western Grebe *Aechmophorus occidentalis*
CLGR	Clark's Grebe *Aechmophorus clarkii*
AMCO	American Coot *Fulica americana*
DCCO	Double-crested Cormorant *Phalacrocorax auritus*
WHPE	American White Pelican *Pelecanus erythrorhynchos*
	WADERS
GBHE	Great Blue Heron *Ardea herodias*
GREG	Great Egret *Ardea alba*
SNEG	Snowy Egret *Egretta thula*
GRHE	Green Heron *Butorides virescens*
BCNH	Black-crowned Night-Heron *Nycticorax nycticorax*
BNST	Black-necked Stilt *Himantopus mexicanus*
AMAV	American Avocet *Recurvirostra americana*
BBPL	Black-bellied Plover *Pluvialis squatarola*
PGPL	Pacific Golden-Plover *Pluvialis fulva*
SNPL	Snowy Plover *Charadrius nivosus*

	AVIAN SPECIES
CODES	**WATERFOWL (etcetra)**
SEPL	Semipalmated Plover *Charadrius semipalmatus*
KILL	Killdeer *Charadrius vociferus*
WHIM	Whimbrel *Numenius phaeopus*
LBCU	Long-billed Curlew *Numenius americanus*
MAGO	Marbled Godwit *Limosa fedoa*
SAND	Sanderling *Calidris alba*
DUNL	Dunlin *Calidris alpina*
BASA	Baird's Sandpiper *Calidris bairdii*
LESA	Least Sandpiper *Calidris minutilla*
PESA	Pectoral Sandpiper *Calidris melanotos*
SESA	Semipalmated Sandpiper *Calidris pusilla*
WESA	Western Sandpiper *Calidris mauri*
SBDO	Short-billed Dowitcher *Limnodromus griseus*
LBDO	Long-billed Dowitcher *Limnodromus scolopaceus*
SPSA	Spotted Sandpiper *Actitis macularius*
GRYE	Greater Yellowlegs *Tringa melanoleuca*
WILL	Willet *Tringa semipalmata*
LEYE	Lesser Yellowlegs *Tringa flavipes*
WIPH	Wilson's Phalarope *Phalaropus tricolor*
RNPH	Red-necked Phalarope *Phalaropus lobatus*
	OTHER SPECIES (Larids, raptors, etc.)
MEGU	Mew Gull *Larus canus*
RBGU	Ring-billed Gull *Larus delawarensis*
WEGU	Western Gull *Larus occidentalis*
CAGU	California Gull *Larus californicus*
HERG	Herring Gull *Larus argentatus*
GWGU	Glaucous-winged Gull *Larus glaucescens*
LETE	Least Tern *Sternula antillarum*
CATE	Caspian Tern *Hydroprogne caspia*
COTE	Common Tern *Sterna hirundo*
FOTE	Forster's Tern *Sterna forsteri*
TUVU	Turkey Vulture *Cathartes aura*
OSPR	Osprey *Pandion haliaetus*
WTKI	White-tailed Kite *Elanus leucurus*
BAEA	Bald Eagle *Haliaeetus leucocephalus*
NOHA	Northern Harrier *Circus cyaneus*
SSHA	Sharp-shinned Hawk *Accipiter striatus*
COHA	Cooper's Hawk *Accipiter cooperii*
RSHA	Red-shouldered Hawk *Buteo lineatus*

	AVIAN SPECIES
CODES	**WATERFOWL (etcetra)**
RTHA	Red-tailed Hawk *Buteo jamaicensis*
GOEA	Golden Eagle *Aquila chrysaetos*
BARO	Barn Owl *Tyto alba*
AMKE	American Kestrel *Falco sparverius*
MERL	Merlin *Falco columbarius*
PEFA	Peregrine Falcon *Falco peregrinus*
CORA	Common Raven *Corvus corax*
BEKI	Belted Kingfisher *Megaceryle alcyon*

Hamilton Wetland Restoration Site Avian Monitoring Data

HWRS, WATERFOWL, etc	8/14/2016	9/22/2017	10/11/2016	10/24/2016	Sum	Mean	p
CANG	0	0	0	2	2	0.50	0.000061
GADW	0	6	11	39	56	14.00	0.001695
EUWI	0	0	1	0	1	0.25	0.000030
AMWI	0	0	30	68	98	24.50	0.002967
MALL	6	2	20	33	61	15.25	0.001847
NOSH	0	104	218	252	574	143.50	0.017377
NOPI	0	1346	502	357	2205	551.25	0.066751
GWTE	0	40	147	114	301	75.25	0.009112
CANV	0	0	0	1	1	0.25	0.000030
GRSC	0	24	69	11	104	26.00	0.003148
LESC	0	0	0	1	1	0.25	0.000030
SCAUP sp	31	16	0	0	47	11.75	0.001423
SUSC	2	2	0	1	5	1.25	0.000151
RBME	1	0	1	1	3	0.75	0.000091
RUDU	0	6	72	135	213	53.25	0.006448
DUCK SP	6	0	0	1	7	1.75	0.000212
EAGR	0	0	0	2	2	0.50	0.000061
WEGR	0	1	2	1	4	1.00	0.000121
CLGR	0	1	0	0	1	0.25	0.000030
WHPE	8	11	15	14	48	12.00	0.001453
DCCO	4	5	23	33	65	16.25	0.001968
PECO	0	0	1	0	1	0.25	0.000030
WADERS							
GBHE	1	0	2	0	3	0.75	0.000091
GREG	11	2	3	3	19	4.75	0.000575
SNEG	10	9	6	0	25	6.25	0.000757
BCNH	0	15	0	0	15	3.75	0.000454
BNST*	6	17	32	26	81	20.25	0.002452
AMAV	618	1408	1643	1267	4936	1234.00	0.149426
BBPL	64	6	77	242	389	97.25	0.011776
SNPL	1	0	21	18	40	10.00	0.001211
SEPL	41	0	0	20	61	15.25	0.001847
KILL	27	29	4	3	63	15.75	0.001907
GRYE	38	33	21	29	121	30.25	0.003663
WILL	37	39	65	141	282	70.50	0.008537
LEYE	0	13	0	0	13	3.25	0.000394
WHIM	0	1	0	2	3	0.75	0.000091
LBCU	21	38	7	8	74	18.50	0.002240
MAGO	47	127	63	135	372	93.00	0.011261
LESA	644	1462	1600	793	4499	1124.75	0.136197
SESA	1	0	0	0	1	0.25	0.000030
WESA	2851	1408	2660	3010	9929	2482.25	0.300578
DUNL	0	0	2	6088	6090	1522.50	0.184361
BASA	1	0	0	0	1	0.25	0.000030

HWRS, WATERFOWL, etc	8/14/2016	9/22/2017	10/11/2016	10/24/2016	Sum	Mean	p
PEEPS	218	50	580	372	1220	305.00	0.036933
LBDO	0	0	2	19	21	5.25	0.000636
DOWS	0	1	61	0	62	15.50	0.001877
GULLS & TERNS							
RBGU	1	132	95	130	358	89.50	0.010838
WEGU	2	0	8	20	30	7.50	0.000908
CAGU	24	0	75	106	205	51.25	0.006206
GWGU	0	0	1	0	1	0.25	0.000030
GULL SPP.	5	81	110	0	196	49.00	0.005933
CATE	8	0	0	0	8	2.00	0.000242
FOTE	37	11	1	4	53	13.25	0.001604
RAPTORS							
TUVU	0	4	21	22	47	11.75	0.001423
OSPR	1	0	0	0	1	0.25	0.000030
WTKI	0	0	3	0	3	0.75	0.000091
NOHA	0	2	0	1	3	0.75	0.000091
AMKE	0	2	0	1	3	0.75	0.000091
MERL	0	1	0	0	1	0.25	0.000030
PEFA	0	1	1	0	2	0.50	0.000061
RTHA	0	0	0	1	1	0.25	0.000030
CORA	0	0	1	0	1	0.25	0.000030
TOTAL ##	4773	6456	8277	13527	33033	8258.25	1.000000
TOTAL SPP.	32	38	42	43	62	38.75	—
% waterfowl	0.012	0.242	0.134	0.079	0.115	0.117	0.12
%waders	0.972	0.722	0.827	0.900	0.857	0.855	0.86
%others	0.016	0.036	0.038	0.021	0.028	0.028	0.03

HWRS, WATERFOWL, etc	11/15/2016	11/29/2016	12/16/2016	1/16/2017	2/15/2017	2/21/2017	3/13/2017	3/27/2017	Sum	Mean	p
CANG	370	153	2	66	38	27	4	10	670	83.75	0.006572
MUTE SWAN	0	0	0	12	1	0	0	1	14	1.75	0.000137
GADW	151	137	59	213	155	80	36	99	930	116.25	0.009123
EUWI	0	5	3	0	2	2	0	0	12	1.50	0.000118
AMWI	519	597	2390	840	906	377	339	353	6321	790.13	0.062005
MALL	29	0	12	0	0	0	6	15	62	7.75	0.000608
BWTE	0	0	0	0	0	2	0	2	4	0.50	0.000039
CITE	0	0	0	0	0	0	0	1	1	0.13	0.000010
NOSH	225	103	173	230	235	204	1259	247	2676	334.50	0.026250
NOPI	123	72	877	124	28	12	3	5	1244	155.50	0.012203
GWTE	228	155	194	87	48	147	224	222	1305	163.13	0.012801
CANV	105	516	969	674	757	377	77	410	3885	485.63	0.038109
GRSC	43	7	0	8	1	0	0	4	63	7.88	0.000618
LESC	0	0	0	1	0	0	0	2	3	0.38	0.000029
SCAUP sp	32	0	0	0	0	0	0	0	32	4.00	0.000314
BUFF	6	2	33	16	12	13	28	29	139	17.38	0.001363
COGO	0	4	0	4	0	0	0	0	8	1.00	0.000078
RBME	0	0	0	1	0	0	0	0	1	0.13	0.000010
RUDU	294	497	154	344	164	227	156	251	2087	260.88	0.020472
DUCK SP	5	0	0	4	8	0	2	0	19	2.38	0.000186
PBGB	1	0	0	0	0	0	0	0	1	0.13	0.000010
EAGR	0	0	0	3	0	0	1	1	5	0.63	0.000049
WEGR	0	4	2	3	1	2	0	2	14	1.75	0.000137
CLGR	1	3	2	9	7	8	6	8	44	5.50	0.000432
WHPE (AWPE)	35	13	7	22	0	4	5	3	89	11.13	0.000873
DCCO	4	0	0	0	0	4	1	7	16	2.00	0.000157
AMCO	0	1	0	1	0	0	0	0	2	0.25	0.000020
WADERS											
GBHE	3	4	2	0	4	0	2	0	15	1.88	0.000147
GREG	7	5	1	1	1	1	4	0	20	2.50	0.000196
SNEG	3	0	0	2	2	5	3	2	17	2.13	0.000167
BCNH	7	0	0	0	0	0	0	0	7	0.88	0.000069
BNST*	45	35	41	69	66	38	0	5	299	37.38	0.002933
AMAV	1439	1024	1130	440	748	704	498	290	6273	784.13	0.061534
BBPL	431	183	135	289	256	134	257	70	1755	219.38	0.017215
SNPL	27	26	30	0	2	24	15	9	133	16.63	0.001305
SEPL	0	14	2	1	0	65	0	0	82	10.25	0.000804
KILL	66	68	36	23	9	3	5	1	211	26.38	0.002070
GRYE	27	18	2	0	17	4	7	2	77	9.63	0.000755
WILL	274	236	77	17	84	38	27	27	780	97.50	0.007651
LEYE	0	1	0	0	0	0	0	0	1	0.13	0.000010
WHIM	0	0	0	0	0	3	0	1	4	0.50	0.000039
LBCU	11	10	26	3	190	12	12	13	277	34.63	0.002717
MAGO	122	158	118	123	688	116	239	246	1810	226.25	0.017755
LESA	7740	1548	1408	2296	219	1423	218	151	15003	1875.38	0.147169
WESA	8487	2260	1220	5309	100	4282	8563	845	31066	3883.25	0.304736
DUNL	7259	3942	1355	3200	1000	4385	770	33	21944	2743.00	0.215255
PEEPS	0	10	3	440	0	0	838	1	1292	161.50	0.012674
LBDO	5	1	0	1	0	0	0	0	7	0.88	0.000069
DOWS	206	58	34	92	56	4	0	0	450	56.25	0.004414
WISN	1	1	1	0	0	0	0	0	3	0.38	0.000029
GULLS & TERNS											
MEGU	0	0	0	0	13	1	0	0	14	1.75	0.000137
RBGU	85	18	146	48	153	29	4	0	483	60.38	0.004738
WEGU	2	1	0	1	1	0	2	8	15	1.88	0.000147
CAGU	68	2	0	2	16	1	2	2	93	11.63	0.000912
HERG	0	2	0	0	0	0	0	1	3	0.38	0.000029
GWGU	0	0	0	1	0	1	0	1	3	0.38	0.000029
GULL SPP.	0	0	0	1	0	3	0	1	5	0.63	0.000049
CATE	0	0	0	1	0	0	1	7	9	1.13	0.000088
FOTE	5	2	2	5	0	10	0	1	25	3.13	0.000245
RAPTORS											
TUVU	8	1	5	20	5	4	11	14	68	8.50	0.000667
OSPR	1	0	0	0	0	1	0	0	2	0.25	0.000020
WTKI	3	0	0	3	2	0	0	1	9	1.13	0.000088
BAEA	0	0	0	1	1	0	0	0	2	0.25	0.000020

HWRS, WATERFOWL, etc	11/15/2016	11/29/2016	12/16/2016	1/16/2017	2/15/2017	2/21/2017	3/13/2017	3/27/2017	Sum	Mean	p
NOHA	2	2	2	1	2	4	2	3	18	2.25	0.000177
AMKE	0	0	1	0	1	0	0	0	2	0.25	0.000020
MERL	1	0	0	0	1	0	0	0	2	0.25	0.000020
PEFA	1	0	0	1	1	2	0	0	5	0.63	0.000049
RTHA	0	0	2	0	0	1	1	4	8	1.00	0.000078
RSHA	0	0	0	1	0	0	0	0	1	0.13	0.000010
CORA	0	0	0	1	0	3	0	0	4	0.50	0.000039
TOTAL ##	28507	11899	10656	15055	6001	12787	13628	3411	101944	12743.00	1.000000
TOTAL SPP.	46	44	38	50	42	44	37	46	70	43.38	—
% waterfowl	0.076	0.191	0.458	0.177	0.394	0.116	0.158	0.490	0.193	0.26	0.258
%waders	0.918	0.807	0.528	0.817	0.574	0.879	0.841	0.497	0.800	0.73	0.733
%others	0.006	0.002	0.015	0.006	0.033	0.005	0.002	0.013	0.008	0.01	0.010

HWRS, WATERFOWL, etc	4/3/2017	4/28/2017	5/25/2017	6/5/2017	7/3/2017	7/30/2017	Sum	Mean	p
CANG	4	1	14	0	0	7	26	4.33	0.002687
MUTE SWAN	1	0	0	0	0	0	1	0.17	0.000103
GADW	99	65	46	29	66	12	317	52.83	0.032765
AMWI	20	0	0	0	0	0	20	3.33	0.002067
MALL	25	19	79	83	107	19	332	55.33	0.034315
CITE	0	2	0	0	8	0	10	1.67	0.001034
NOSH	313	106	0	0	0	0	419	69.83	0.043307
GWTE	116	116	0	0	0	0	232	38.67	0.023979
CANV	81	5	0	0	0	0	86	14.33	0.008889
GRSC	0	0	16	0	7	0	23	3.83	0.002377
LESC	1	0	0	0	0	0	1	0.17	0.000103
SCAUP sp	4	0	0	0	18	0	22	3.67	0.002274
BUFF	25	21	0	0	0	0	46	7.67	0.004755
RUDU	186	26	0	0	0	0	212	35.33	0.021912
DUCK SP	0	0	0	2	0	12	14	2.33	0.001447
WEGR	0	2	1	1	0	0	4	0.67	0.000413
CLGR	5	1	0	0	0	0	6	1.00	0.000620
WHPE (AWPE)	0	0	1	0	53	23	77	12.83	0.007959
DCCO	0	2	0	0	0	2	4	0.67	0.000413
WADERS									
GBHE	1	3	0	3	2	0	9	1.50	0.000930
GREG	4	2	6	13	6	0	31	5.17	0.003204
SNEG	2	4	3	5	0	5	19	3.17	0.001964
BNST*	2	0	0	2	32	0	36	6.00	0.003721
AMAV	279	48	0	4	30	263	624	104.00	0.064496
BBPL	17	0	0	3	0	10	30	5.00	0.003101
(PGPL)	0	0	0	0	0	1	1	0.17	0.000103
SNPL	17	2	0	0	0	0	19	3.17	0.001964
SEPL	8	63	0	0	0	5	76	12.67	0.007855
KILL	1	0	0	4	2	0	7	1.17	0.000724
GRYE	0	0	0	0	5	18	23	3.83	0.002377
WILL	25	0	31	170	91	51	368	61.33	0.038036
LBCU	5	10	0	7	10	14	46	7.67	0.004755
MAGO	419	12	178	227	39	9	884	147.33	0.091370
LESA	0	165	0	0	0	229	394	65.67	0.040724
SESA	0	0	0	0	0	1	1	0.17	0.000103
WESA	1827	141	0	0	33	1148	3149	524.83	0.325478
DUNL	602	0	0	0	0	0	602	100.33	0.062222
PEEPS	207	760	0	0	168	102	1237	206.17	0.127855
DOWS	0	0	0	0	0	1	1	0.17	0.000103
GULLS & TERNS									
RBGU	0	4	10	7	6	0	27	4.50	0.002791
WEGU	1	9	0	5	0	0	15	2.50	0.001550
CAGU	0	0	1	3	4	0	8	1.33	0.000827
GULL SPP.	0	5	29	0	0	0	34	5.67	0.003514
CATE	13	31	13	12	13	8	90	15.00	0.009302
FOTE	28	9	1	0	3	0	41	6.83	0.004238
RAPTORS									
TUVU	3	2	6	14	3	8	36	6.00	0.003721
OSPR	1	0	1	1	0	0	3	0.50	0.000310
WTKI	1	1	0	1	1	0	4	0.67	0.000413
NOHA	1	1	0	0	0	1	3	0.50	0.000310
SSHA	0	0	0	1	0	0	1	0.17	0.000103
PEFA	1	0	0	0	1	0	2	0.33	0.000207
RTHA	0	1	0	0	1	0	2	0.33	0.000207
TOTAL ##	4345	1639	436	597	709	1949	9675	1612.50	1.000000
TOTAL SPP.	36	32	17	22	25	23	52	25.83	—
% waterfowl	0.203	0.223	0.360	0.193	0.365	0.038	0.191	23.033%	0.230
%waders	0.786	0.738	0.500	0.734	0.590	0.953	0.781	71.683%	0.717
%others	0.011	0.040	0.140	0.074	0.045	0.009	0.027	5.317%	0.053

HWRS, WATERFOWL, etc	FALL	Winter	Spring	Sum	Mean	p
CANG	2	670	26	**698**	**94.33**	0.00483
MUTE SWAN	0	14	1	**15**	**11.00**	0.00010
GADW	56	930	317	**1303**	**294.33**	0.00901
EUWI	1	12	0	**13**	**0.33**	0.00009
AMWI	98	6321	20	**6439**	**1029.00**	0.04451
MALL	61	62	332	**455**	**118.67**	0.00315
BWTE	0	4	0	**4**	**3.33**	0.00003
CITE	0	1	10	**11**	**5.33**	0.00008
NOSH	574	2676	419	**3669**	**583.00**	0.02536
NOPI	2205	1244	0	**3449**	**1451.00**	0.02384
GWTE	301	1305	232	**1838**	**430.67**	0.01271
CANV	1	3885	86	**3972**	**1022.00**	0.02746
GRSC	104	63	23	**190**	**114.33**	0.00131
LESC	1	3	1	**5**	**10.67**	0.00003
SCAUP sp	47	32	22	**101**	**22.67**	0.00070
SUSC	5	0	0	**5**	**0.33**	0.00003
BUFF	0	139	46	**185**	**59.67**	0.00128
COGO	0	8	0	**8**	**9.67**	0.00006
RBME	3	1	0	**4**	**0.67**	0.00003
RUDU	213	2087	212	**2512**	**1112.00**	0.01737
DUCK SP	7	19	14	**40**	**131.00**	0.00028
PBGB	0	1	0	**1**	**0.67**	0.00001
EAGR	2	5	0	**7**	**10.33**	0.00005
WEGR	4	14	4	**22**	**8.00**	0.00015
CLGR	1	44	6	**51**	**17.33**	0.00035
WHPE	48	89	77	**214**	**146.67**	2.81579
DCCO	65	16	4	**85**	**38.67**	0.00059
PECO	1	0	0	**1**	**38.67**	0.01316
AMCO	0	2	0	**2**	**3.33**	0.00001
WADERS						
GBHE	3	15	9	**27**	**8.33**	0.00019
GREG	19	20	31	**70**	**58.00**	0.00048
SNEG	25	17	19	**61**	**66.33**	0.00042
BCNH	15	7	0	**22**	**0.67**	0.00015
BNST	81	299	36	**416**	**112.00**	0.00288
AMAV	4936	6273	624	**11833**	**4134.33**	0.08180
BBPL	389	1755	30	**2174**	**468.33**	0.01503
PGPL	0	0	1	**1**	**468.33**	0.01316
SNPL	40	133	19	**192**	**119.00**	0.00133
SEPL	61	82	76	**219**	**150.67**	0.00151

HWRS, WATERFOWL, etc	FALL	Winter	Spring	Sum	Mean	p
KILL	63	211	7	**281**	**83.00**	0.00194
GRYE	121	77	23	**221**	**129.67**	0.00153
LEYE	13	1	0	**14**	**2.67**	0.00010
WHIM	3	4	0	**7**	**10.67**	0.00005
LBCU	74	277	46	**397**	**153.33**	0.00274
MAGO	372	1810	884	**3066**	**1003.00**	0.02120
LESA	4499	15003	394	**19896**	**9892.67**	0.13754
SESA	1	0	1	**2**	**0.33**	0.00001
WESA	9929	31066	3149	**44144**	**16167.67**	0.30517
DUNL	6090	21944	602	**28636**	**11942.67**	0.19796
BASA	1	0	0	**1**	**0.00**	0.00001
PEEPS	1220	1292	1237	**3749**	**1482.33**	0.02592
LBDO	21	7	0	**28**	**29.33**	0.00019
DOWS	62	450	1	**513**	**120.33**	0.00355
WILL	282	780	368	**1430**	**338.00**	0.00989
WISN	0	3	0	**3**	**7.33**	0.00002
GULLS & TERNS						
MEGU	0	14	0	**14**	**0.67**	0.00010
RBGU	358	483	27	**868**	**133.33**	0.00600
WEGU	30	15	15	**60**	**15.00**	0.00041
CAGU	205	93	8	**306**	**46.67**	0.00212
HERG	0	3	0	**3**	**1.00**	0.00002
GWGU	1	3	0	**4**	**3.00**	0.00003
GULL SPP.	196	5	34	**235**	**87.00**	0.00162
CATE	8	9	90	**107**	**31.00**	0.00074
FOTE	53	25	41	**119**	**18.33**	0.00082
RAPTORS						
TUVU	47	68	36	**151**	**20.00**	0.00104
OSPR	1	2	3	**6**	**2.67**	0.00004
BAEA	0	2	0	**2**	**0.33**	0.00001
WTKI	3	9	4	**16**	**3.33**	0.00011
NOHA	3	18	3	**24**	**7.67**	0.00017
SSHA	0	0	1	**1**	**0.33**	0.00001
AMKE	3	2	0	**5**	**1.00**	0.00003
MERL	1	2	0	**3**	**0.67**	0.00002
PEFA	2	5	2	**9**	**2.33**	0.00006
RTHA	1	8	2	**11**	**3.67**	0.00008
RSHA	0	1	0	**1**	**0.33**	0.00001
CORA	1	4	0	**5**	**1.67**	0.00003
TOTAL ##	**33033**	**101944**	**9675**	**144652**	**289304.00**	**3.841**
TOTAL SPP.	**62**	**70**	**52**	**76**	**61.3**	
% waterfowl	**0.012**	**0.193**	**0.191**	**0.175**	**0.13**	
%waders	**0.972**	**0.8**	**0.781**	**0.812**	**0.85**	
%others	**0.016**	**0.008**	**0.027**	**0.013**	**0.05**	

Rush Creek Avian Monitoring Data

Rush Creek WATERFOWL, etc	9/26/2016	10/12/2016	10/22/2016	Sum	Mean	sd	cv
CANG	44	50	47	141	47.000	3.000	0.064
GADW	0	0	8	8	2.667	4.619	1.732
MALL	0	14	0	14	4.667	8.083	1.732
NOSH	0	0	151	151	50.333	87.180	1.732
WHPE	0	25	23	48	16.000	13.892	0.868
WADERS							
GREG	3	3	2	8	2.667	0.577	0.217
SNEG	1	58	2	61	20.333	32.624	1.604
BNST	371	74	382	827	275.667	174.735	0.634
AMAV	280	0	184	464	154.667	142.286	0.920
KILL	0	6	1	7	2.333	3.215	1.378
GRYE	24	30	15	69	23.000	7.550	0.328
WESA	400	0	0	400	133.333	230.940	1.732
LESA	100	32	0	132	44.000	51.069	1.161
GULLS & TERNS							
RBGU	150	80	163	393	131.000	44.643	0.341
CAGU	20	0	6	26	8.667	10.263	1.184
GULL SPP.	0	5	0	5	1.667	2.887	1.732
RAPTORS							
TOTAL ##	**1393**	**377**	**984**	**2754**	**918**	**511.205**	**0.557**
TOTAL SPP.	**10**	**9**	**12**	**13**	**16**		
Waterfowl	**0.032**	**0.236**	**0.233**	**0.131**	**0.167**	**0.117**	**0.700**
Waders	**0.846**	**0.539**	**0.596**	**0.715**	**0.660**	**0.163**	**0.247**
Others	**0.122**	**0.225**	**0.172**	**0.154**	**0.173**	**0.052**	**0.298**

Rush Creek WATERFOWL, etc	11/29/2016	1/17/2017	1/23/2017	2/18/2017	2/28/2017	3/25/2017	Sum	Mean	sd	cv
CANG	52	9	41	55	21	51	229	38.167	18.936	0.496
CACG	0	0	0	0	0	1	1	0.167	0.408	2.449
MUTE SWAN	0	0	2	2	2	0	6	1.000	1.095	1.095
GADW	71	131	118	19	28	104	471	78.500	47.146	0.601
EUWI	0	0	0	1	0	0	1	0.167	0.408	2.449
AMWI	39	328	385	55	75	106	988	164.667	151.344	0.919
MALL	0	18	43	8	21	12	102	17.000	14.751	0.868
CITE	0	0	6	0	0	0	6	1.000	2.449	2.449
NOSH	183	274	79	21	48	380	985	164.167	141.596	0.863
NOPI	94	88	66	4	16	14	282	47.000	40.373	0.859
GWTE	44	0	39	3	8	29	123	20.500	19.233	0.938
CANV	0	0	396	0	0	0	396	66.000	161.666	2.449
SCAUP Sp.	0	0	2	0	0	0	2	0.333	0.816	2.449
BUFF	50	51	28	45	23	49	246	41.000	12.280	0.300
RUDU	33	274	44	105	235	128	819	136.500	98.936	0.725
WHPE	0	0	0	0	0	2	2	0.333	0.816	2.449
DCCO	2	0	0	0	1	3	6	1.000	1.265	1.265
AMCO	7	88	33	0	0	7	135	22.500	34.332	1.526
WADERS										
GBHE	0	0	0	o	1	0	1	0.167	0.447	2.683
GREG	2	2	2	3	5	3	17	2.833	1.169	0.413
SNEG	2	0	0	0	6	11	19	3.167	4.491	1.418
BNST	71	0	0	0	0	24	95	15.833	28.680	1.811
AMAV	231	0	0	0	0	459	690	115.000	192.194	1.671
KILL	4	0	0	0	2	0	6	1.000	1.673	1.673
GRYE	7	0	0	0	6	1	14	2.333	3.266	1.400
WESA	20	0	0	0	0	0	20	3.333	8.165	2.449
DUNL	220	0	0	0	0	0	220	36.667	89.815	2.449
DOWS	33	0	0	0	0	0	33	5.500	13.472	2.449
GULLS & TERNS										
RBGU	41	0	0	0	0	0	41	6.833	16.738	2.449
CAGU	19	0	0	0	0	0	19	3.167	7.757	2.449
CATE	1	0	0	0	0	0	1	0.167	0.408	2.449
RAPTORS										
TUVU	0	1	1	3	0	1	6	1.000	1.095	1.095
SSHA	0	0	0	0	0	1	1	0.167	0.408	2.449
AMKE	0	0	1	0	0	0	1	0.167	0.408	2.449
PEFA	1	0	0	0	0	0	1	0.167	0.408	2.449
RTHA	0	0	1	0	0	0	1	0.167	0.408	2.449
TOTAL ##	**1227**	**1264**	**1287**	**324**	**498**	**1386**	**5986**	**997.667**		
TOTAL SPP.	**23**	**10**	**18**	**13**	**16**	**20**	**36**			
Waterfowl	**0.469**	**0.998**	**0.996**	**0.981**	**0.960**	**0.639**				
Waders	**0.481**	**0.002**	**0.000**	**0.009**	**0.040**	**0.359**				
Others	**0.051**	**0.000**	**0.004**	**0.009**	**0.000**	**0.001**				

Rush Creek WATERFOWL, etc	5/2/2017	5/27/2017	6/7/2017	7/14/2017	Sum	Mean	sd	cv
CANG	25	39	27	26	117	29.250	6.551	0.224
GADW	29	19	33	0	81	20.250	14.728	0.727
AMWI	7	0	0	0	7	1.750	3.500	2.000
MALL	39	119	18	0	176	44.000	52.479	1.193
NOSH	48	3	0	0	51	12.750	23.543	1.846
NOPI	11	2	0	0	13	3.250	5.252	1.616
GRSC	4	0	0	0	4	1.000	2.000	2.000
RUDU	2	0	0	0	2	0.500	1.000	2.000
AWPE	1	0	0	0	1	0.250	0.500	2.000
WADERS								
GBHE	0	0	0	1	1	0.250	0.500	2.000
GREG	0	2	3	20	25	6.250	9.251	1.480
SNEG	0	0	2	17	19	4.750	8.221	1.731
BNST	23	80	52	0	155	38.750	34.769	0.897
AMAV	73	36	57	0	166	41.500	31.544	0.760
KILL	0	3	0	5	8	2.000	2.449	1.225
GRYE	0	0	0	42	42	10.500	21.000	2.000
MAGO	81	89	49	0	219	54.750	40.385	0.738
LESA	0	0	0	117	117	29.250	58.500	2.000
WESA	0	0	0	234	234	58.500	117.000	2.000
PEEPS	0	0	0	67	67	16.750	33.500	2.000
GULLS & TERNS								
BOGU	1	0	0	0	1	0.250	0.500	2.000
RBGU	0	0	0	1	1	0.250	0.500	2.000
GULL SPP.	5	0	0	0	5	1.250	2.500	2.000
CATE	1	0	0	0	1	0.250	0.500	2.000
RAPTORS								
TUVU	0	0	0	3	3	0.750	1.500	2.000
TOTAL ##	**350**	**392**	**241**	**533**	**1516**	**379.000**	**120.789**	**0.319**
TOTAL SPP.	**15**	**10**	**9**	**10**	**25**			
Waterfowl	**0.474**	**0.464**	**0.324**	**0.049**	**0.298**	**0.328**		
Waders	**0.506**	**0.536**	**0.676**	**0.942**	**0.695**	**0.665**		
Others	**0.020**	**0.000**	**0.000**	**0.008**	**0.007**	**0.007**		

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Appendix E.

Photo Documentation Plates

PBM 1, Looking South

06/22/2017 Tide = 4.74 ft MLLW

PBM 1, Looking West

06/22/2017 Tide = 4.74 ft MLLW

PBM Breach, Looking Southeast

06/22/2017 Tide = 4.74 ft MLLW

PBM 1, Looking South

10/19/2015 Tide = 2.9 ft MLLW

PBM 1, Looking West

10/19/2015 Tide = 2.9 ft MLLW

PBM Breach, Looking Southeast

10/19/2015 Tide = 2.9 ft MLLW

NOTE: Tide elevations refer to predicted tide elevations in mean lower low water (MLLW) at the Petaluma River Entrance (NOAA NOS Station 9415252).

PBM Breach, Looking West

06/22/2017 Tide = 4.74 ft MLLW

PBM 2, Looking Southwest

06/22/2017 Tide = 4.74 ft MLLW

PBM 2, Looking West

06/22/2017 Tide = 4.74 ft MLLW

PBM Breach, Looking West

10/19/2015 Tide = 2.9 ft MLLW

PBM 2, Looking Southwest

10/19/2015 Tide = 2.9 ft MLLW

PBM 2, Looking West

10/19/2015 Tide = 2.9 ft MLLW

NOTE: Tide elevations refer to predicted tide elevations in mean lower low water (MLLW) at the Petaluma River Entrance (NOAA NOS Station 9415252).

PBM 2, Looking North

06/22/2017 Tide = 4.74 ft MLLW

PBM 3, Looking North

06/22/2017 Tide = 4.74 ft MLLW

PBM 3, Looking Southwest

06/22/2017 Tide = 4.74 ft MLLW

PBM 2, Looking North

10/19/2015 Tide = 2.9 ft MLLW

PBM 3, Looking North

10/19/2015 Tide = 2.9 ft MLLW

PBM 3, Looking Southwest

10/19/2015 Tide = 2.9 ft MLLW

NOTE: Tide elevations refer to predicted tide elevations in mean lower low water (MLLW) at the Petaluma River Entrance (NOAA NOS Station 9415252).

PBM 3, Looking West

06/22/2017 Tide = 4.74 ft MLLW

PBM 4, Looking West

06/22/2017 Tide = 4.74 ft MLLW

PBM 4, Looking Northwest

06/22/2017 Tide = 4.74 ft MLLW

PBM 3, Looking West

10/19/2015 Tide = 2.9 ft MLLW

PBM 4, Looking West

10/19/2015 Tide = 2.9 ft MLLW

PBM 4, Looking Northwest

10/19/2015 Tide = 2.9 ft MLLW

NOTE: Tide elevations refer to predicted tide elevations in mean lower low water (MLLW) at the Petaluma River Entrance (NOAA NOS Station 9415252).

PBM 4, Looking North

06/22/2017 Tide = 4.74 ft MLLW

PBM 5, Looking Northeast

06/22/2017 Tide = 4.74 ft MLLW

PBM 5, Looking Southeast

06/22/2017 Tide = 4.74 ft MLLW

PBM 4, Looking North

10/19/2015 Tide = 2.9 ft MLLW

PBM 5, Looking Northeast

10/19/2015 Tide = 2.9 ft MLLW

PBM 5, Looking Southeast

10/19/2015 Tide = 2.9 ft MLLW

NOTE: Tide elevations refer to predicted tide elevations in mean lower low water (MLLW) at the Petaluma River Entrance (NOAA NOS Station 9415252).

PBM 5, Looking South

06/22/2017 Tide = 4.74 ft MLLW

PBM 6, Looking Northwest

06/22/2017 Tide = 4.74 ft MLLW

PBM 6, Looking Northeast

06/22/2017 Tide = 4.74 ft MLLW

PBM 5, Looking South

10/19/2015 Tide = 2.9 ft MLLW

PBM 6, Looking Northwest

10/19/2015 Tide = 2.9 ft MLLW

PBM 6, Looking Northeast

10/19/2015 Tide = 2.9 ft MLLW

NOTE: Tide elevations refer to predicted tide elevations in mean lower low water (MLLW) at the Petaluma River Entrance (NOAA NOS Station 9415252).

PBM 6, Looking Southeast

06/22/2017 Tide = 4.74 ft MLLW

PBM 7, Looking North

06/22/2017 Tide = 4.74 ft MLLW

PBM 7, Looking Northeast

06/22/2017 Tide = 4.74 ft MLLW

PBM 6, Looking Southeast

10/19/2015 Tide = 2.9 ft MLLW

PBM 7, Looking North

10/19/2015 Tide = 2.9 ft MLLW

PBM 7, Looking Northeast

10/19/2015 Tide = 2.9 ft MLLW

NOTE: Tide elevations refer to predicted tide elevations in mean lower low water (MLLW) at the Petaluma River Entrance (NOAA NOS Station 9415252).

PBM 7, Looking Southeast

06/22/2017 Tide = 4.74 ft MLLW

PBM 8, Looking Southeast

06/22/2017 Tide = 4.74 ft MLLW

PBM 8, Looking Southwest

06/22/2017 Tide = 4.74 ft MLLW

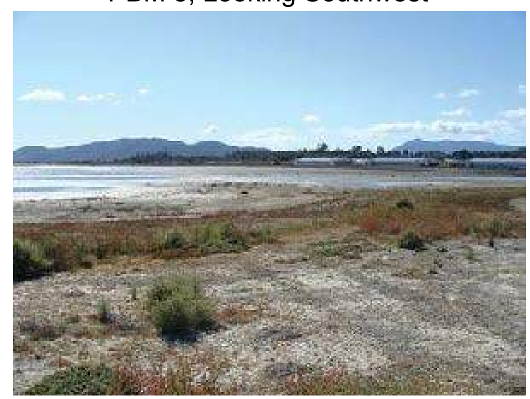
PBM 7, Looking Southeast

10/19/2015 Tide = 2.9 ft MLLW

PBM 8, Looking Southeast

10/19/2015 Tide = 2.9 ft MLLW

PBM 8, Looking Southwest



10/19/2015 Tide = 2.9 ft MLLW

NOTE: Tide elevations refer to predicted tide elevations in mean lower low water (MLLW) at the Petaluma River Entrance (NOAA NOS Station 9415252).

PBM 9, Looking Southeast

06/22/2017 Tide = 4.74 ft MLLW

PBM 9, Looking South

06/22/2017 Tide = 4.74 ft MLLW

PBM 9, Looking West

06/22/2017 Tide = 4.74 ft MLLW

PBM 9, Looking Southeast

10/19/2015 Tide = 2.9 ft MLLW

PBM 9, Looking South

10/19/2015 Tide = 2.9 ft MLLW

PBM 9, Looking West

10/19/2015 Tide = 2.9 ft MLLW

NOTE: Tide elevations refer to predicted tide elevations in mean lower low water (MLLW) at the Petaluma River Entrance (NOAA NOS Station 9415252).

PBM 10, Looking East

06/22/2017 Tide = 4.74 ft MLLW

PBM 10, Looking Southwest

06/22/2017 Tide = 4.74 ft MLLW

PBM 10, Looking Northwest

06/22/2017 Tide = 4.74 ft MLLW

PBM 10, Looking East

10/19/2015 Tide = 2.9 ft MLLW

PBM 10, Looking Southwest

10/19/2015 Tide = 2.9 ft MLLW

PBM 10, Looking Northwest

10/19/2015 Tide = 2.9 ft MLLW

NOTE: Tide elevations refer to predicted tide elevations in mean lower low water (MLLW) at the Petaluma River Entrance (NOAA NOS Station 9415252).

PBM 11, Looking Southwest

06/22/2017 Tide = 4.74 ft MLLW

PBM 11, Looking Southeast

06/22/2017 Tide = 4.74 ft MLLW

PBM 12, Looking Southeast

06/22/2017 Tide = 4.74 ft MLLW

PBM 11, Looking Southwest

10/19/2015 Tide = 2.9 ft MLLW

PBM 11, Looking Southeast

10/19/2015 Tide = 2.9 ft MLLW

PBM 12, Looking Southeast

10/19/2015 Tide = 2.9 ft MLLW

NOTE: Tide elevations refer to predicted tide elevations in mean lower low water (MLLW) at the Petaluma River Entrance (NOAA NOS Station 9415252).

PBM 12, Southwest

06/22/2017 Tide = 4.74 ft MLLW

PBM 13, Looking East

06/22/2017 Tide = 4.74 ft MLLW

PBM 13, Looking South

06/22/2017 Tide = 4.74 ft MLLW

PBM 12, Southwest

10/19/2015 Tide = 2.9 ft MLLW

PBM 13, Looking East

10/19/2015 Tide = 2.9 ft MLLW

PBM 13, Looking South

10/19/2015 Tide = 2.9 ft MLLW

NOTE: Tide elevations refer to predicted tide elevations in mean lower low water (MLLW) at the Petaluma River Entrance (NOAA NOS Station 9415252).

PBM 13, Looking West

06/22/2017 Tide = 4.74 ft MLLW

PBM 14, Looking Northwest

06/22/2017 Tide = 4.74 ft MLLW

PBM 14, Looking Northeast

06/22/2017 Tide = 4.74 ft MLLW

PBM 13, Looking West

10/19/2015 Tide = 2.9 ft MLLW

PBM 14, Looking Northwest

10/19/2015 Tide = 2.9 ft MLLW

PBM 14, Looking Northeast

10/19/2015 Tide = 2.9 ft MLLW

NOTE: Tide elevations refer to predicted tide elevations in mean lower low water (MLLW) at the Petaluma River Entrance (NOAA NOS Station 9415252).

PBM 14, Looking East

06/22/2017 Tide = 4.74 ft MLLW

PBM 15, Looking Southwest

06/22/2017 Tide = 4.74 ft MLLW

PBM 15, Looking West

06/22/2017 Tide = 4.74 ft MLLW

PBM 14, Looking East

10/19/2015 Tide = 2.9 ft MLLW

PBM 15, Looking Southwest

10/19/2015 Tide = 2.9 ft MLLW

PBM 15, Looking West

10/19/2015 Tide = 2.9 ft MLLW

NOTE: Tide elevations refer to predicted tide elevations in mean lower low water (MLLW) at the Petaluma River Entrance (NOAA NOS Station 9415252).

PBM 15, Looking Northeast

06/22/2017 Tide = 4.74 ft MLLW

PBM 16, Looking East

06/22/2017 Tide = 4.74 ft MLLW

PBM 16, Looking Southeast

06/22/2017 Tide = 4.74 ft MLLW

PBM 15, Looking Northeast

10/19/2015 Tide = 2.9 ft MLLW

PBM 16, Looking East

10/19/2015 Tide = 2.9 ft MLLW

PBM 16, Looking Southeast

10/19/2015 Tide = 2.9 ft MLLW

NOTE: Tide elevations refer to predicted tide elevations in mean lower low water (MLLW) at the Petaluma River Entrance (NOAA NOS Station 9415252).

PBM 17, Looking North

06/22/2017 Tide = 4.74 ft MLLW

PBM 17, Looking Northeast

06/22/2017 Tide = 4.74 ft MLLW

PBM 17, Looking Northwest

06/22/2017 Tide = 4.74 ft MLLW

PBM 17, Looking North

10/19/2015 Tide = 2.9 ft MLLW

PBM 17, Looking Northeast

10/19/2015 Tide = 2.9 ft MLLW

PBM 17, Looking Northwest

10/19/2015 Tide = 2.9 ft MLLW

NOTE: Tide elevations refer to predicted tide elevations in mean lower low water (MLLW) at the Petaluma River Entrance (NOAA NOS Station 9415252).