UPPER NEWPORT BAY ECOSYSTEM RESTORATION PROJECT
POST-RESTORATION MONITORING PROGRAM

ANNUAL REPORT
YEAR 1 – 2011

UPPER NEWPORT BAY ECOLOGICAL RESERVE
ORANGE COUNTY, CALIFORNIA

August 2012
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UPPER NEWPORT BAY ECOSYSTEM RESTORATION PROJECT POST-RESTORATION MONITORING PROGRAM

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1.0 INTRODUCTION

Newport Bay is located on the southern California coast, approximately 40 miles south of Los Angeles (Figure 1). From the harbor entrance at the rocky headland at Corona del Mar, Newport Bay extends about 3.5 miles north northeastward. Newport Bay is a combination of two distinct units, termed "Lower Bay" and "Upper Newport Bay" (UNB), divided by the narrows at Pacific Coast Highway (PCH) Bridge (Figure 1). The 752-acre Lower Bay, where the majority of commerce and recreational boating exists, is heavily developed (predominantly as residential properties) and is a deep basin coastal lagoon. The 1,000-acre UNB is a drowned river valley, geologically much older than the Lower Bay, and is largely undeveloped. This portion of the bay is more formally considered to be an estuary. Much of UNB is included in the Upper Newport Bay Ecological Reserve, managed by the California Department of Fish and Game (CDFG).

Upper Newport Bay is one of the largest coastal wetlands remaining in southern California. Natural habitats within UNB include open marine waters, intertidal mudflats, cordgrass-dominated low salt marsh, pickleweed-dominated mid salt marsh, high salt marsh, salt panne, riparian, freshwater marsh and upland. Because of its diversity of habitats and its location on the Pacific Flyway, UNB supports an impressive number and diversity of birds, particularly during fall and winter when shorebirds and waterfowl arrive from their northern breeding grounds. Upper Newport Bay also supports several endangered bird species and an endangered plant. The subtidal and intertidal waters of UNB provide important habitat for marine and estuarine fishes.

1.1. Restoration Need and Design

By the end of the 20th century, the ecological diversity and functionality of UNB was increasingly threatened by sedimentation from the surrounding urbanized watershed. The primary source of freshwater and sediment loads to UNB is San Diego Creek, which drains approximately 85 percent of the 98,500-acre San Diego Creek watershed. Sediment from the San Diego Creek watershed had increasingly filled open water areas within UNB. This sedimentation decreased the extent of tidal inundation, diminished water quality, degraded habitat for endangered species, migratory water birds, and marine and estuarine fishes. It also resulted in navigation problems in UNB marinas and navigation channels. If sediment deposition within UNB had been allowed to continue, the remaining open water areas would have eventually evolved into mudflats, and later, marsh or upland habitat, resulting in a loss of ecological diversity.

Site Locator and Vicinity Map

Upper Newport Bay Ecosystem Restoration Project
Post-restoration Monitoring Program

Figure 1

It became clear that a program was needed to develop a long-term management plan to control sediment deposition in UNB and to preserve the health of its habitats. Through a partnership among the U.S. Army Corps of Engineers (ACOE), the County of Orange, CDFG, and the California Coastal Conservancy, the UNB Ecosystem Restoration Project was developed.

The restoration project was designed to allow for the effective management of sediments deposited into the bay, reduce the frequency of maintenance dredging, improve or restore estuarine habitats, sustain a mix of open water, mudflat, and marsh habitat, increase tidal circulation for water quality, reduce predator access to sensitive habitats, improve public use and recreational access, and improve educational opportunities. Sediment will continue to be deposited into UNB to varying degrees depending on what control measures are implemented in the watershed. Therefore, one of the most important components of the project was to develop a plan to control sediments by designing two in-bay basins into which the bulk of the sediment would be captured and from which effective maintenance dredging removals could be undertaken.

1.2. UNB Ecosystem Restoration Project Implementation

After an extensive process of planning and environmental review, the restoration project was initiated in 2006. The first phase was conducted from April 2006 to July 2009. The second phase was conducted November 2009 to October 2010. The total cost of restoration was approximately $37.4 million. Key project features included expansion and deepening of two sediment control basins (Basin I/III and Basin II), deepening of channels around five restoration islands, creation of three large mudflats, relocation of a least tern nesting island, installation of maintenance access at the two nesting islands, and installation of interpretive signs and buoys. Approximately 2.35 million cubic yards of sediment was dredged as part of the project. A detailed project summary and map labeled with key restoration features is provided in Appendix A.

1.3. Post-restoration Monitoring

In order to detect and document the long-term development processes following the restoration, the ACOE prepared the Post-restoration Monitoring Program for the Upper Newport Bay Ecosystem Restoration Project (ACOE 2010). The program outlines ten years of biological and physical monitoring, as detailed in the following sections. The schedule for the various monitoring events is provided in Table 1.

The ACOE has contracted with Merkel & Associates, Inc. (M&A) to implement the first three years of the Post-Restoration Monitoring Program, after which time the ACOE commitment to post-restoration reporting will be completed and the County of Orange will assume responsibility for the monitoring and reporting in Years 4 through 10.

Table 1. Post-restoration monitoring program schedule.

TASK	Post-Restoration Annual Cycle												Post-Restoration Program					
	J	F	M	A	M	J	J	A	S	O	N	D	Year 1 2011	Year 2 2012	Year 3 2013	Year 5 2015	Year 8 2018	Year 10 2020
Physical Monitoring Program																		
Bathymetric Mapping						▬							X-ACOE Jan	X-ACOE Jan	X-ACOE Jan	X	X	
Tidal Monitoring	▬			▬			▬			▬			X	X		X		X
Water Quality	▬			▬			▬			▬			X	X		X		X
Least Tern Island Elevations	▬	▬	▬										X	X	X	X	X	X
Biological Monitoring Program																		
General Avian Surveys	▬			▬			▬			▬				X		X		X
Species of Special Concern				▬	▬	▬	▬	▬	▬					X-CDFG				
Fisheries	▬			▬			▬			▬				X		X		X
Epibenthic	▬			▬			▬			▬				X		X		X
Benthic Infauna	▬						▬							X		X		X
Vegetation																		
Aerial Photogrammetry and Georeferencing						▬							X-ACOE Jan	X-JUNE	X-JUNE	X	X	
Vegetation Mapping and Groundtruthing								▬					X-Aug	X-Aug	X-Aug	X	X	
Veg Transects								▬						X		X	X	
Cordgrass Monitoring					▬	▬	▬							X		X	X	
CRAM Survey					▬	▬	▬							X				
Data Management and Analysis																		
Quality Assurance Program	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	X	X	X	X	X	X
Reporting Program																		
Quarterly Summary Reports		✦			✦			✦			✦			X		X		X
Annual and Final Reports												✦	X	X	X	X	X	X

RESTORATION CONSTRUCTION COMPLETED OCTOBER 2010

▬ Data Collection ✦ Project Milestone / Report Deliverable

The goals and questions to be assessed by the program, as excerpted from the Monitoring Program document, include:

1. Are the sediment basins performing according to the design goals?
    a. Do the basins have enough capacity such that maintenance dredging will not be required for 20+ years (given the rate of sediment accumulation within the basins)?
    b. Are the basins trapping the majority of the sediment that enters the upper bay, and thus minimizing sediment accumulation in the tidal channels and the lower portions of the bay?

2. Has the restoration project reduced turbidity in the bay (by trapping incoming sediment deep in the basins)?

3. Are the deepened basins receiving adequate dissolved oxygen? There are concerns about increased density stratification and reduced oxygen supply to the deepest layers.

4. Has the project resulted in increased eelgrass survival in the upper bay?

5. Has the project resulted in increased (water) volume within the bay such that the water residence time in the bay is significantly increased [sic]?

6. Has the project resulted in improved diversity and abundance of benthic infauna and epifauna?

7. Has the project resulted in a significant increase in the number of targeted birds using UNB? Targeted species include listed species.

8. Has the project led to significant increases in fisheries habitat? Tracking habitat utilization and relative abundance across multiple species.

9. Has the project resulted in the gain or loss of any habitat type greater then 10%?

The restoration project was completed in October 2010. The first monitoring year extended from January to December 2011. This document serves as the annual report for 2011.

1.4. Horizontal and Vertical Reference Data

Measurement units of numerical data from the monitoring program are presented as a combination of metric and English Standard System units in this report. Typically, collected scientific data would be reported using metric units such as hectares and meters. However, UNB has a long regulatory, engineering, and biological monitoring history that has made use of a blend of metric and English units. As a result, presentation of data has sought to continue using the units of measure that are most applicable to the various monitoring elements. Additionally, for some parameters such as tidal elevation and habitat area measurements, metric unit presentations are less familiar to most readers than English units. Therefore, where an area measurement has been made through GIS-based mapping efforts, the results are presented in hectares, with conversions to

acres provided due to the greater ease with which many readers can envision areas in this unit of measurement. Tidal data are presented in feet, rather than meters, due to the greater familiarity of most readers with tidal ranges in feet and the historic usage of English units for this element of the project. Additionally, discussion of sediment accumulation and dredging volumes will be in cubic yards due to the prevalence of this unit in the commercial dredging field. All other data, primarily biological measurements taken in the field, are reported in metric units.

The vertical datum used throughout this document is Mean Lower Low Water (83-01 epoch). Horizontally geo-referenced data are on the California State Plane Zone 6, North American Datum of 1983 (NAD 83).

2.0 PHYSICAL MONITORING

During the first year post-restoration, physical monitoring was limited to collection of baseline data on bathymetry and tidal conditions, documenting water quality, and checking the elevation of the new least tern island (Table 1). Monitoring stations were established using direction provided in the Post-Construction Monitoring Program for the Upper Newport Bay Ecosystem Restoration Project (Monitoring Program), as well as observations made in the field at the time of station determination (Figure 2). Appendix B provides geographic coordinates for the sampling locations.

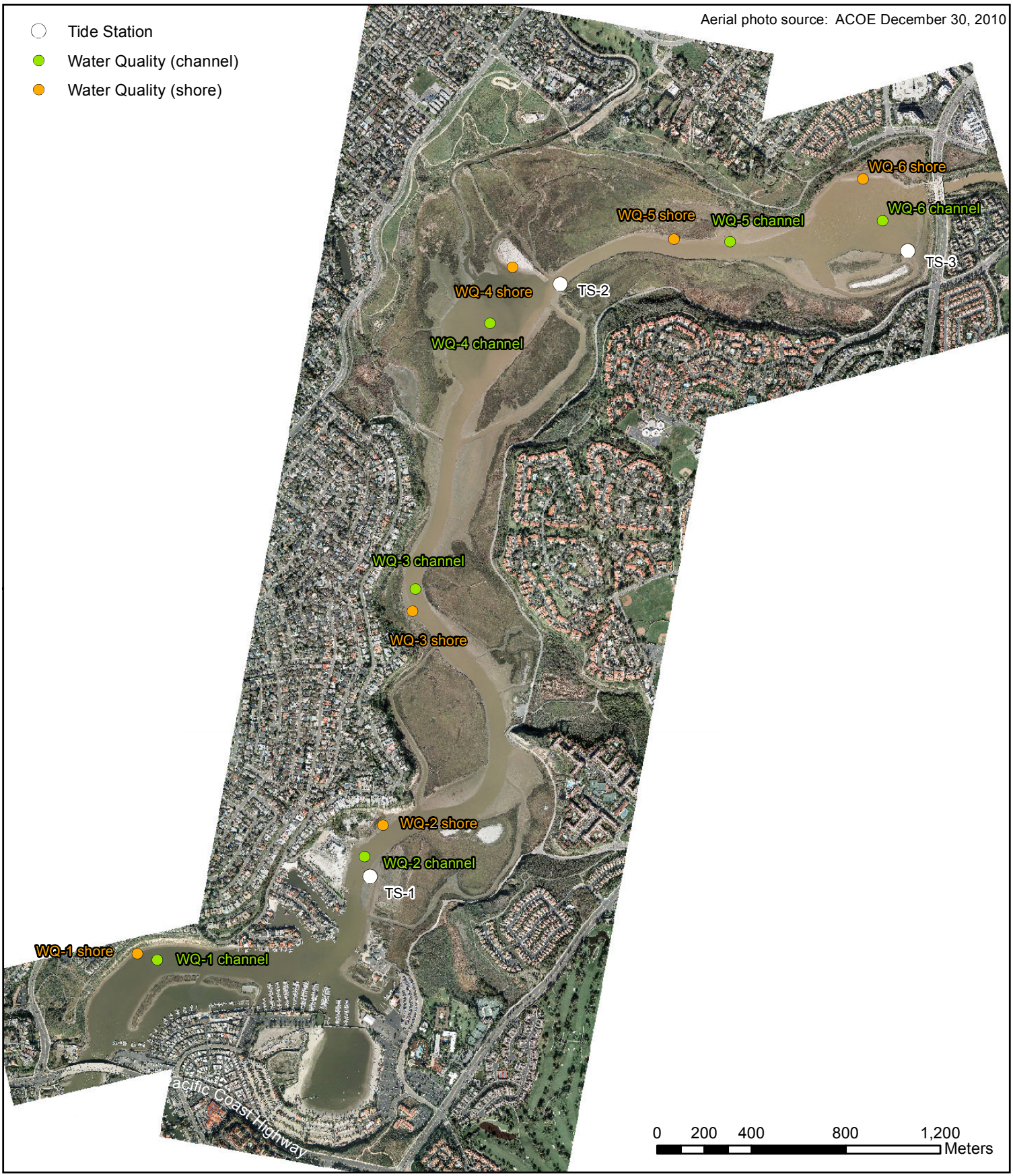
2.1. Bathymetric Monitoring

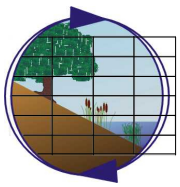
The ACOE completed the annual bathymetric surveys of the restoration project area and provided the collected data to M&A for analysis. ACOE Los Angeles District survey personnel collected bathymetric data in 2011 on January 3-6, February 7, and March 10, 15, & 17. The information collected was a merged dataset from single beam and multi-beam sonar on a 3-foot grid. The vertical datum was feet MLLW and the horizontal datum was State Plane, Zone 6, NAD 83, feet. This dataset served as the post-restoration baseline bathymetric condition.

The bathymetric data were provided to M&A as point data. The point data were imported into the GIS software ESRI ArcView and converted to a grid with no interpolation. These data are presented in Figure 3. The maximum recorded depth was –22.3 feet MLLW.

Regions within the study area that were not captured by the bathymetric survey have been left blank, including the Newport Dunes basin, the area around the Newport Dunes launch ramp, two fingers of bay across from the launch ramp on the west shore of UNB, and portions of the mail channel just north of Pacific Coast Highway.

This dataset will be compared to subsequent annual datasets to identify the location and volume of sediment accretion and erosion, and to evaluate Question 1 posed in Section 1.3 above (Are the sediment basins performing according to the design goals?).

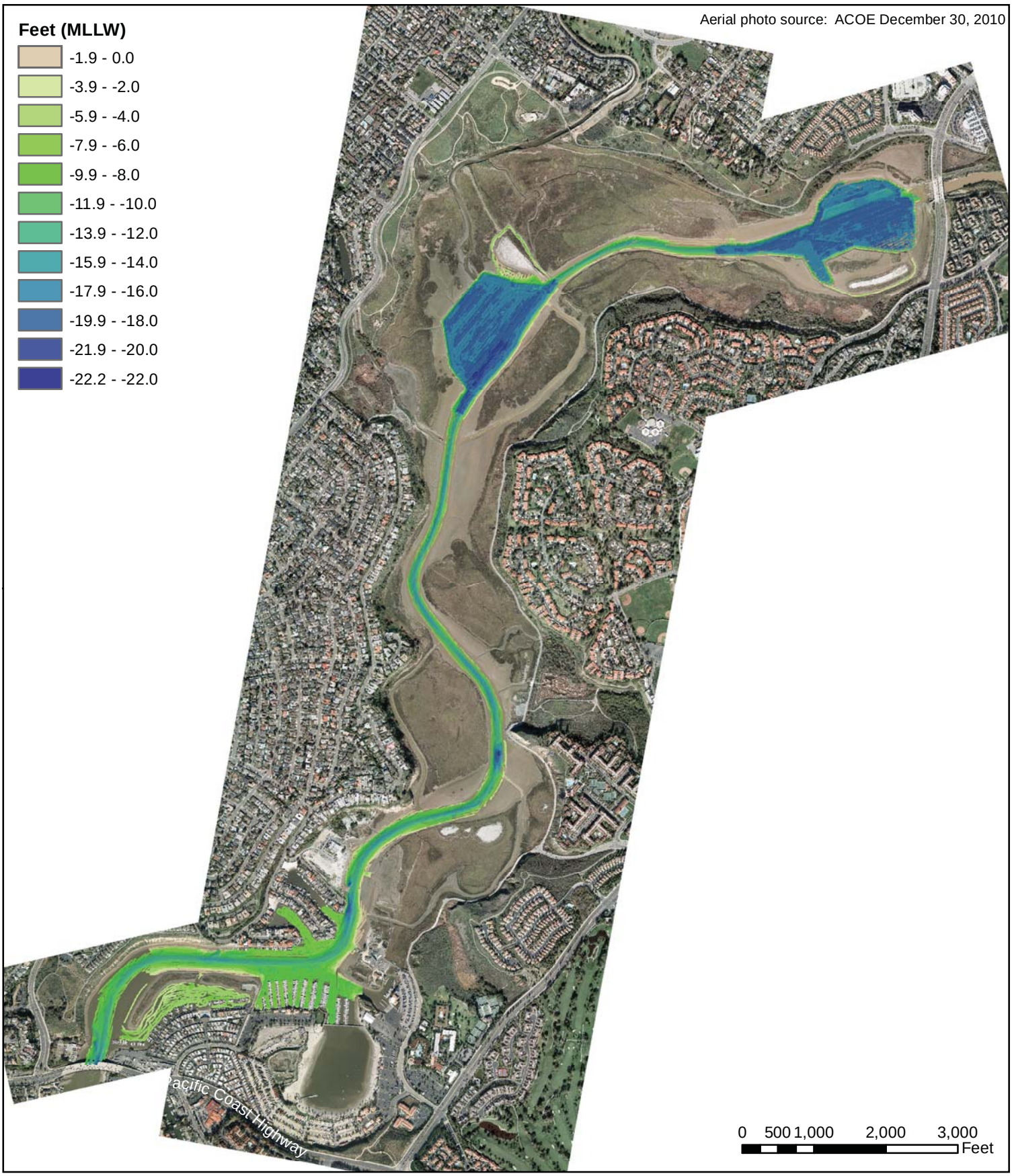


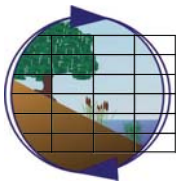


Tide and Water Quality Monitoring Stations

Upper Newport Bay Ecosystem Restoration Project
Post-restoration Monitoring Program

Figure 2





2011 Bathymetry
Collected Jan/Feb/Mar 2011 by ACOE
Upper Newport Bay Ecosystem Restoration Project
Post-restoration Monitoring Program

Figure 3

2.2. Tidal Monitoring

The tidal monitoring element was designed to evaluate the degree of post-restoration tidal lag and muting in UNB, in comparison to the ocean tides. The Year 1 condition will be compared to available pre-restoration data and data collected in upcoming Monitoring Years 2, 5, and 10.

Methods

Logging pressure gauges (loggers) were deployed at three locations in UNB on January 25, 2011 (Figure 2). Two of the stations were locations similar to those used in a 1992 tide study conducted by Coastal Frontiers, Inc. and referenced in the Upper Newport Bay Feasibility Study Final Report Engineering Appendix (ACOE 2000). These were located at the Back Bay Science Center dock and on the pile located off of New Least Tern Island (referred to as the main dike in prior years). A third station was established to the northeast in Basin I/III.

The tidal data were initially collected with Solinst Levelogger Gold 3001 logging pressure gauges. However, after several instrument failures, alternative loggers with nearly identical specifications were deployed in October 2011: RBR Instruments TGR2050 pressure gauges. The TGR2050 has a depth accuracy of ± 0.2 inches and a resolution of ± 0.004 inches. A fourth TGR2050 pressure gauge was deployed on shore at the Back Bay Science Center and used to correct the submerged pressure gauge for atmospheric pressure. Tidal sampling occurred every six minutes coincident with monitoring intervals used by NOAA for regional tidal monitoring stations.

The elevation data collected and reported in this study are subject to ±0.016 ft of error associated with the tide loggers and ±0.0018° associated with distance of the local benchmarks from the measured tide station. Given the benchmark distances to the tide stations and instrument error, there is a measurement error of ±0.047, ±0.038, and ±0.041 ft for the elevations reported at Stations 1, 2, and 3, respectively.

Tidal monitoring was continuous from January 25 through December 31, 2011 with the following exceptions. Station 1 was dismantled on February 14, 2011 by construction work at the Back Bay Science Center boat dock. Station 1 was moved to a new location on March 25, where it is anticipated to remain for all future monitoring. At Station 3, both the primary and the backup loggers failed between July 8 and October 24, 2011.

The water level loggers were downloaded quarterly, concurrent with other monitoring activities. The pressure data obtained from the submerged and atmospheric pressure gauges were used to calculate water depth at the sensor with the following formula:

$$\text{Depth} = (P_w - P_{atm}) / (\lambda * 0.980665);$$

where depth is the water depth in meters at the pressure gauge, P_w is the pressure in deciBars read at the in-water pressure gauge, P_{atm} is the local atmospheric pressure in deciBars, λ is the density of seawater at the site (1.027 g/cm^3), and 0.980665 is a gravitational constant (UNESCO 1983).

For analyses of tidal lag and tidal muting, the Los Angeles Outer Harbor (LAOH) (NOAA Station 9410660) historic data collected by NOAA were corrected to estimate conditions at the Newport Bay entrance channel. The NOAA gauge is located immediately adjacent to the open ocean, and the recorded tides represent the ocean tidal conditions. The data were obtained from the NOAA Tides and Currents website (http://tidesandcurrents.noaa.gov). NOAA no longer collects tide data at the Newport Bay entrance channel. However, for predictive purposes, NOAA uses temporal and elevation corrections to determine the timing and elevation of high and low tidal events at the Newport Bay entrance channel. Those temporal corrections consist of a deduction of 3 minutes at high tides and 4 minutes at low tides. The elevation correction is LAOH*0.98 to determine the Newport Bay entrance channel elevation throughout the tide range.

Tidal ranges were determined for all three UNB monitoring stations and the Newport Bay entrance channel. The tidal ranges were determined for the UNB monitoring stations by inspecting the data for the highest and lowest tidal events. The differences between the highest and lowest events at each of the three UNB monitoring stations were used to determine the tidal range over the period inspected. The range for the entrance channel was corrected by inspecting the LAOH tide data and then multiplying the highest and lowest observed values by 0.98.

An analysis of tidal lag and muting was performed by determining the timing and elevation of the higher high, lower high (referred to below as simply high), higher low (referred to below as simply low) and lower low tides for all three UNB monitoring stations. For comparison, the timing and elevation of the LAOH tides were determined from the NOAA data. The LAOH data were then corrected to the Newport Bay entrance channel using the corrections noted above. The time of tidal events at the Newport Bay entrance channel was subtracted from the UNB monitoring stations to determine the extent of tidal muting. The elevation of tidal events at the UNB monitoring stations was subtracted from the Newport Bay entrance channel values to determine the extent of muting at the monitoring stations.

Results

All three tide monitoring stations recorded a full tide range in 2011, with no dampening of the upper or lower end of the typical oceanic range. At Station 1, tides ranged from -2.1 to +7.1 feet MLLW, at Station 2 from -2.3 to +7.1 feet MLLW, and at Station 3 from -2.0 to +7.2 feet MLLW. The highest tides were recorded on October 27 and November 24, 2011. The lowest tides were recorded on December 23 and 24, 2011. The oceanic range at the Newport Bay entrance channel was -2.0 to +7.0 feet MLLW.

Table 2 presents the findings of the tidal lag and muting analysis. In the table, positive tidal lag values represent observations where UNB stations were lagging relative to the entrance channel. Negative tidal lag values represent observations where the UNB tidal events occurred first (opposite of expectation assuming lag occurs) relative to the entrance channel. In the table, positive tidal muting values represent observations where the UNB stations were lower than the entrance channel at high tides. For example, at low tide negative muting values represent observations that UNB did not drain to the same elevation as the entrance channel. The mean values represent the averages of all tidal events (maximum or minimum) within each combination of the tide and monitoring station factors for all valid data obtained during 2011.

Table 2. Results of tidal lag and muting analyses performed to compare the Upper Newport Bay tidal monitoring stations to the Newport Bay entrance channel (January 25 to December 31, 2011).

Higher High Water

Monitoring Station	Tidal Lag (minutes)				Tidal Muting (feet)			
	Mean	SD	Maximum	Minimum	Mean	SD	Maximum	Minimum
Station 1	12.6	17.8	70.0	-44.0	0.05	0.06	0.22	-0.12
Station 2	18.9	21.6	64.0	-56.0	0.05	0.09	0.29	-0.96
Station 3	18.4	22.8	64.0	-44.0	0.13	0.13	0.41	-0.76

Lower High Water

	Tidal Lag (minutes)				Tidal Muting (feet)			
	Mean	SD	Maximum	Minimum	Mean	SD	Maximum	Minimum
Station 1	6.3	22.4	82.0	-80.0	0.02	0.05	0.14	-0.16
Station 2	8.9	25.8	70.0	-86.0	0.01	0.08	0.22	-0.33
Station 3	9.2	26.5	76.0	-92.0	0.08	0.11	0.33	-0.34

Higher Low Water

	Tidal Lag (minutes)				Tidal Muting (feet)			
	Mean	SD	Maximum	Minimum	Mean	SD	Maximum	Minimum
Station 1	5.3	21.9	63.0	-111.0	0.02	0.05	0.18	-0.13
Station 2	8.4	27.5	93.0	-93.0	-0.09	0.07	0.13	-0.28
Station 3	8.8	26.3	93.0	-75.0	-0.05	0.09	0.21	-0.36

Lower Low Water

	Tidal Lag (minutes)				Tidal Muting (feet)			
	Mean	SD	Maximum	Minimum	Mean	SD	Maximum	Minimum
Station 1	8.4	16.5	69.0	-51.0	0.04	0.09	0.33	-0.14
Station 2	10.9	22.3	87.0	-87.0	-0.10	0.11	0.75	-0.39
Station 3	12.5	23.1	87.0	-81.0	-0.05	0.12	0.79	-0.37

Statistics represent the difference across all logged high and low tide events from January 25, 2011 through December 31, 2011. Tidal lag equals Station minus Entrance and muting equals Entrance minus Station.

Tidal lag was variable across the three monitoring stations relative to the entrance channel. The shortest average lag was 5.3 minutes during low tides at Station 1. The greatest average lag was 18.9 minutes at Station 2 during higher high tides. Overall, tidal lag was generally shortest at Station 1, intermediate at Station 2, and greatest at Station 3. The one exception to this was a slightly higher average lag at Station 2 relative to Station 3 (18.9 versus 18.4 minutes) during higher high tides. Across tidal events, the shortest lag occurred during high tides, followed by low tides, lower low tides, with the longest lag at higher high tides.

Tidal muting was minimal for all UNB monitoring stations. The greatest average muting was 0.13 ft at Station 3 during higher high tides. The maximum observed muting at higher high tides was 0.29 ft. During lower low tides, the lowest muting of –0.10 ft was observed at Station 2. This means that, on average, Station 2 experienced slightly higher elevations than the entrance channel during

low tides. In general during high and higher high tides, average muting ranged from 0.01 to 0.13 ft across all monitoring stations. During these tides the muting was greatest at Station 3. During low and lower low tides, muting ranged from -0.10 to 0.04 ft. On average, Station 1 was lower than the entrance channel during low and lower low tides. Station 2 and Station 3 both experienced higher water levels relative to the entrance channel during low and lower low tides.

Discussion

Overall, tidal lag and muting were minor relative to the entrance channel. The values observed indicate that tidal movements through Lower Newport Bay and UNB are relatively unrestricted. The lack of significant tidal muting means that the upper bay flora and fauna are subjected to tidal patterns similar to those found closer to the open coast. Thus, the zonation of flora and fauna in the back bay should be similar to that observed at other coastal salt marsh habitats with unimpeded connections to the ocean.

The lag and muting values found within the 2011 monitoring are similar to observations within UNB prior to the restoration project. The Upper Newport Bay Feasibility Study (2000) referenced tidal lag and muting values resulting from a tide and current data collection program performed in 1992. The 1992 study utilized the entrance channel NOAA tide monitoring station (no longer functioning) and loggers placed at Dover Shores and the main dike (at the present day New Least Tern Island). The Dover Shores and main dike monitoring stations were positioned similarly to Station 1 and Station 2 of this study, respectively. The 1992 tide study was summarized in the Feasibility Study as having found a temporal lag from the entrance channel of 12 and 25 minutes during high tides at Dover Shores and the main dike, respectively. It is not clear from this statement whether all high tides (higher high and lower high) were grouped or whether the values represent lag during higher high water only. However, the values reported are similar to the 5.3 minutes and 18.9 minutes of lag observed at the corresponding stations in this study. It is difficult to fully glean the benefits of the 1992 study given that it was performed for only one month and the specific month, which is critical to any comparison, was not referenced in the Feasibility Study and the original tide study report was not available for review. The slightly lower values observed in the present monitoring could be due either to improved flow resulting from the restoration project or due to differences associated with the time of year the data were collected in the 1992 study, or even the selection of specific high tides presented in the 1992 study.

The 1992 tidal study (ACOE 2000) found that at higher high tides, the main dike station was 0.1 foot higher than the entrance channel for the one-month period. This is close to the finding of 0.05 foot lower than the entrance channel value observed as the average for 2011. No significant value can be ascribed to the small difference between the two studies given the unknown timing of the 1992 study and the unreported level of error surrounding the elevation measurements.

The plots of tide data for Stations 1, 2, and 3 and LAOH are provided for each month in 2011 as Appendix C. In the charts, the LAOH data are not corrected to the Newport Bay entrance channel. This is because the corrections applied in the lag and muting analyses only apply to the high and low water events. Given the small amount of observed lag and muting, any such corrections would be imperceptible in the data plots. The plots support the lag and muting analysis; the UNB monitoring stations closely follow the NOAA measured tides at LAOH.

2.3. Water Quality Monitoring

The Monitoring Plan calls for collection of quarterly spot water quality data in monitoring years 1, 2, 5, and 10. During Years 2, 5, and 10 the monitoring will be conducted concurrently with fisheries sampling. Since there was no fisheries work in Year 1, the water quality monitoring was performed concurrently with the servicing of the tide loggers.

Methods

Spot readings were taken at each of six fisheries monitoring station (Figure 2) with a Hydrolab Quanta® multi-probe, calibrated in accordance with manufacturer specifications. At each station, readings were taken near the shoreline where the shore-based fish sampling will be done and also in the channel where the boat-based fish sampling will be done. Parameters recorded were temperature, dissolved oxygen (DO), pH, salinity, and turbidity. Data were collected from the bottom to the surface to create a vertical profile of the water column. Water quality monitoring was performed on January 25, March 25, July 8, and October 24, 2011. The monitoring scheduled for April was performed a week early (March 25) to coincide with the scheduled tide logger servicing.

Results

On January 25, 2011, data were collected between 1200 to 1500 hours, capturing an incoming tidal condition when the tide was rising from 2.9 feet MLLW to a high of 3.2 feet MLLW, then falling down to 3.0 feet MLLW by the time monitoring was complete. The sampling date fell on the quarter moon, neap tide series.

Table 3 presents the January water quality data. Dissolved oxygen was high at all stations and depths, ranging from 6.1 to 10.7 mg/L. As expected, salinity decreased from south to north, with bottom waters maintaining salinities around 31 ppt and surface waters measuring as low as 17 ppt at Station 6, the furthest north. There had not been precipitation regionally since January 3; therefore, the extent of freshwater influence was limited. Temperature, pH, and turbidity all fell within anticipated ranges, given the season, past weather conditions, and tide stage. Temperature was generally higher at the shallow shoreline portion of each station.

Data collected on March 25, 2011 are presented in Table 4. Sampling was performed between 1200 to 1428 hours, capturing an incoming tidal condition when the tide was rising from about 1.5 feet MLLW to a high of 2.8 feet MLLW. The sampling date fell on the quarter moon, neap tide series.

The March sampling was completed on a day preceded by multiple days of heavy rain events, and there had been some rainfall several hours prior to the sampling. There was heavy flow from San Diego Creek into the basin at Station 6 (see photo 1 in Appendix D). The flow appeared to have eroded the unarmored south bank of the creek where it spills into Upper Newport Bay (see photo 2).

The freshwater input from the recent rains was evident at all stations, with reduced salinity at the surface for approximately the top two meters at each station. Dissolved oxygen was within normal ranges at all stations and depths, ranging from 4.1 to 10.4 mg/L, and was highest at the surface and decreased with depth. The widest range of DO was recorded at Station 6 near the San Diego Creek

Table 3. Water quality data collected January 25, 2011 at Upper Newport Bay.

1/25/2011 Station 1	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.0	15.3	7.6	8.1	30.4	4.0
	0.5	15.0	7.6	8.1	30.8	4.4
15:10	1.0	14.7	7.8	8.1	31.3	3.5
	1.7	14.6	7.8	8.1	31.7	2.2
	2.3	14.5	7.7	8.1	32.1	2.2
	3.1	14.5	7.7	8.1	32.2	3.4
	4.0	14.5	7.8	8.1	32.2	4.0
Shore	0.1	15.5	7.6	8.1	30.5	4.0
15:15	0.3	15.4	7.6	8.1	31.7	4.1
	0.5	15.4	7.7	8.1	31.9	4.0

1/25/2011 Station 2	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0	15.4	8.0	8.1	30.7	1.7
	0.7	15.4	7.9	8.1	30.9	1.4
14:55	1.5	14.9	7.6	8.1	31.0	1.4
	2.4	14.4	7.6	8.1	31.7	1.5
	3.5	14.4	7.9	8.1	31.9	1.5
Shore	0.1	15.6	7.6	8.1	30.6	1.2
15:00	0.3	15.5	7.6	8.1	30.7	1.3
	0.5	14.9	7.8	8.1	31.7	1.1

1/25/2011 Station 3	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.0	15.8	8.4	8.2	29.4	2.1
	0.7	15.8	8.2	8.2	29.3	2.4
14:40	1.3	15.1	7.7	8.1	29.8	2.5
	2.1	14.6	7.7	8.1	30.6	2.6
	2.8	14.5	7.7	8.1	30.7	2.4
	3.5	14.5	7.7	8.1	30.9	2.6
	4.5	14.4	8.1	8.1	31.1	1.9
Shore	0.1	15.9	8.0	8.1	29.3	2.1
14:45	0.3	15.8	7.8	8.1	29.2	3.2
	0.5	15.4	7.8	8.1	30.4	3.5

Table 3 (cont'd). Water quality data collected January 25, 2011 at Upper Newport Bay.

1/25/2011 Station 4	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.0	15.4	8.6	8.2	26.3	3.2
	0.6	15.0	8.4	8.2	29.6	3.2
14:30	1.2	15.0	8.4	8.2	30.1	3.7
	1.9	14.4	8.2	8.1	30.5	4.4
	2.6	14.8	7.9	8.1	30.7	4.9
	3.2	14.7	7.6	8.1	30.7	5.0
	4.0	14.6	7.5	8.1	30.9	5.0
	4.7	14.6	7.4	8.1	31.1	5.2
	5.5	14.5	7.2	8.1	31	5.9
	6.2	14.5	7.0	8.0	31.5	6.0
Shore	0.1	14.4	8.2	8.1	23.3	3.8
	0.5	14.5	8.2	8.1	28.3	3.9
12:00	0.8	14.3	8.5	8.1	28.4	4.8
	1.1	15.0	8.5	8.1	29.8	5.6
	1.5	15.0	8.3	8.1	29.9	7.3
	1.8	14.9	8.4	8.1	30.3	10.0

1/25/2011 Station 5	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.1	15.9	8.9	8.2	23.6	2.9
	0.7	14.9	8.6	8.1	29.2	3.5
14:20	1.5	15.1	8.9	8.2	30.1	5.3
	2.0	14.9	8.5	8.1	30.4	6.4
	2.5	14.9	7.7	8.1	30.5	7.0
	3.0	14.8	7.6	8.1	30.5	6.3
	3.7	14.8	7.5	7.9	30.8	8.4
	4.5	14.6	7.5	7.8	31.1	5.0
Shore	0.1	17.2	10.2	8.3	22.7	4.0
	0.3	16.4	10.2	8.3	26.3	4.0
14:10	0.5	15.8	10.7	8.2	29.4	7.2

1/25/2011 Station 6	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.1	16.2	9.8	8.2	17.2	7.1
	0.9	15.9	10.4	8.2	29.2	5.7
14:00	1.6	15.2	9.6	8.2	30.3	6.9
	2.3	15.1	9.0	8.1	30.5	6.7
	3.1	15.0	8.0	8.1	30.5	6.9
	3.8	14.9	7.4	8.1	30.6	7.1
	4.5	14.9	6.8	8.0	30.7	6.5
	5.3	14.9	6.1	8.0	30.8	8.1
Shore	0.1	16.0	10.1	8.2	17.5	6.4
	0.3	15.6	9.6	8.1	26.3	5.0
13:30	0.7	15.8	9.8	8.2	29.3	4.7
	1.0	15.6	10.0	8.2	30.1	5.2
	1.3	15.6	10.1	8.2	30.1	5.2
	1.7	15.4	9.9	8.2	30.4	7.2
	2.1	15.2	9.3	8.1	30.4	6.1

Table 4. Water quality data collected March 25, 2011 at Upper Newport Bay.

3/25/2011 Station 1	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.1	17.2	9.2	8.0	10.5	13.4
	0.7	17.0	7.4	8.0	12.6	10.6
14:20	1.4	15.6	7.0	8.1	23.1	7.3
	2.1	14.8	6.7	8.2	30.3	11.1
	2.8	14.7	6.5	8.2	31.8	10.0
	3.5	14.7	6.7	8.2	32.0	32.6
	4.2	14.7	6.6	8.2	32.0	25.1
Shore	0.1	16.6	8.2	8.1	9.8	7.6
	0.2	15.8	7.8	8.1	10.8	5.2
14:28	0.3	16	7.6	8.1	10.7	4.8
	0.4	15.6	4.5	8.1	11	6.0

3/25/2011 Station 2	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.1	15.4	8.2	7.9	4.6	20.0
	0.7	14.9	7.3	7.9	7.6	17.0
13:55	1.4	14.8	6.1	8.0	24.4	8.4
	2.1	14.7	5.9	8.0	28.3	5.7
	2.8	14.7	6.0	8.1	29.9	7.9
Shore	0.1	15.5	8.0	7.9	5.3	21.0
14:10	0.4	15.3	7.9	7.9	9.1	21.0
	0.7	15.4	7.9	7.9	8.3	21.0

3/25/2011 Station 3	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.1	17.6	8.4	8.1	3.0	30.9
	0.7	15.8	8.2	8.0	5.3	30.0
13:30	1.4	14.8	6.8	7.8	23.6	9.6
	2.1	14.8	6.1	8.0	27.4	6.1
	2.8	14.8	5.9	8.0	28.9	5.1
	3.5	14.7	5.9	8.0	28.9	3.9
	4.2	14.7	5.8	8.0	29.0	4.7
Shore	0.1	17.7	8.5	8.1	4.2	27.8
13:40	0.2	17.7	8.5	8.1	4.2	28.1
	0.3	17.7	8.3	8.1	4.3	28.0
	0.4	16.4	8.3	8.1	4.6	33.6

Table 4 (cont'd). Water quality data collected March 25, 2011 at Upper Newport Bay.

3/25/2011 Station 4	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.1	16.3	8.8	8.0	3.2	39.1
	0.7	16.2	8.4	8.0	3.2	39.1
13:05	1.4	14.7	7.3	7.9	13.9	22.3
	2.1	14.9	6.0	8.0	26.7	10.1
	2.8	14.8	5.8	8.0	27.8	8.7
	3.5	14.7	5.8	8.0	28.2	7.3
	4.2	14.7	8.9	8.1	29.1	6.8
	4.9	14.7	6.0	8.1	29.7	6.5
	5.6	14.7	6.0	8.1	30.7	17.0
Shore	0.1	16.4	8.6	8.1	4.0	38.1
13:15	0.2	16.4	8.4	8.1	4.0	38.3
	0.3	16.1	8.3	8.0	4.0	39.7
	0.4	16.1	8.2	8.0	4.1	38.6
	0.5	15.9	8.2	8.0	4.1	40.4
	0.6	15.9	8.1	8.0	4.5	39.2
	0.7	15.7	8.1	8.0	4.5	42.2
	0.8	15.6	8	8	4.7	58

3/25/2011 Station 5	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.1	16.3	9.0	8.1	3.0	52.8
	0.7	16.1	8.6	8.1	3.5	53.2
12:35	1.4	15.5	8.3	8.1	5.0	52.4
	2.1	14.9	6.1	7.9	23.4	17.4
	2.8	14.9	5.4	7.9	27.0	11.6
	3.5	14.9	5.3	7.9	27.2	11.4
	4.2	15.0	5.1	7.9	27.8	10.4
	4.9	15.0	4.9	7.9	28.2	9.2
	5.6	14.9	4.9	7.9	29.0	12.0
Shore	0.1	18.1	9.8	8.4	2.7	83.0
12:43	0.2	18.7	10.0	8.5	2.7	107.0
	0.3	18.7	10.1	8.5	2.7	112.0

3/25/2011 Station 6	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.1	15.5	10.4	7.8	2.6	69.0
	0.7	15.7	8.8	7.9	3.1	61.1
12:10	1.4	15.3	8.8	8.0	3.7	74.9
	2.1	14.9	6.5	7.9	23.6	10.0
	2.8	14.9	6.0	7.9	27.1	8.6
	3.5	15.0	5.5	7.9	27.5	7.0
	4.2	15.0	5.2	7.9	28.1	7.0
	4.9	15.2	4.1	7.8	29.1	10.0
Shore	0.1	16.1	8.8	8.1	3.2	53.0
	0.4	16.1	9.0	8.1	3.2	50.0
12:00	0.2	16.1	8.7	8.1	3.2	50.4
	0.3	16.1	8.6	8.1	3.2	49.4

inflow point. The input of sediment from the bank erosion described above and from upstream sources was evident in the highly turbid surface waters of all stations. Temperatures decreased along a vertical gradient coincident with the salinity gradient. Overall the data reflected stratified conditions with cooler, less turbid marine waters on the bottom, and a thick, warm, and turbid freshwater lens at the surface.

The July 8, 2011 sampling was conducted from 0754 to 0948 hours, capturing a moderate slack low tide, at approximately 1.5 feet MLLW. The sampling date fell on the quarter moon, neap tide series. Table 5 presents the collected water quality data, measured as the tide reached a moderate low and began to come back in. Temperatures generally increased from south to north and from the bottom to surface. Dissolved oxygen was within the expected range at most stations and depths, generally ranging from 4.0 to 9.1 mg/L, except near the bottom of the channel stations at Stations 5 and 6, where DO was as low at 1.5 mg/L. As expected, salinity decreased from south to north, with the surface waters at Stations 5 and 6 reflecting freshwater input from San Diego Creek. The lowest salinity (18.9 ppt) was at the surface of Station 6. Turbidity and pH all fell within the ranges anticipated.

Table 6 presents the water quality data collected on October 24, 2011 between 0953 and 1325 hours, capturing a tide falling from a 6.0 feet MLLW high tide. The sampling date fell near the new moon, spring tide series. Dissolved oxygen was lower than that recorded in prior quarters and ranged from 2.6 to 6.3 mg/L across all stations. The largest variation between surface and bottom DO was recorded at the two northernmost stations 5 and 6. Salinity was lowest at the surface and increased with depth. Temperatures generally increased from south to north and from the bottom to surface. Turbidity and pH all fell within the ranges anticipated.

Discussion

These data do not document the full range of water quality conditions present within the UNB restoration area as data were collected at four discrete points in time, rather than continuously. There are many factors that will considerably affect the conditions at a given sampling time including tidal condition (whether oceanic water is coming in with the tide or whether creek-influenced water is flowing out with the tide), recent precipitation, recent wind conditions, and time of day. Primary production and thus dissolved oxygen levels would be expected to be lower early in the morning than later in the day after photosynthetic processes had been underway for a longer period of time. Additionally, the July and October water quality was assessed at a falling or low tide, and therefore do not reflect the incoming tidal waters later in the day. However, the collected data do provide some indication of water quality during the specific tidal, time, and weather conditions noted above. Overall they reflect a well-flushed system consistent with the findings of the tide monitoring work.

Dissolved oxygen is a parameter of particular interest in relation to the restoration project. There were some concerns raised during the development of the restoration plans that there would be increased density stratification and reduced oxygen levels (hypoxia) in the deepest basins and channels. Hypoxic conditions can develop as a result of several contributory factors. After an algal bloom or influx of organic debris, the resulting accumulation of organic material and the

Table 5. Water quality data collected July 8, 2011 at Upper Newport Bay.

7/8/2011 Station 1	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.1	23.3	5.8	8.4	33.0	1.7
	0.7	23.3	5.8	8.4	33.0	2.6
7:54	1.4	23.3	5.9	8.4	33.0	2.8
	2.1	23.3	5.9	8.4	33.1	3.4
	2.8	22.9	6.1	8.4	33.2	4.5
	3.5	22.6	6.2	8.4	33.1	4.7
Shore	0.1	23.2	6.1	8.4	33.1	1.4
8:00	0.3	23.2	6.1	8.4	33.0	1.7
	0.6	23.3	5.8	8.4	33.0	0.7

7/8/2011 Station 2	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.1	24.8	6.1	8.4	31.9	2.8
	0.7	24.7	6.0	8.4	32.1	2.4
8:14	1.4	24.4	5.8	8.4	32.3	2.7
	2.1	24.1	5.4	8.4	32.6	2.2
	2.8	23.9	5.5	8.4	32.7	2.4
	3.5	23.9	5.5	8.4	32.7	2.7
Shore	0.1	24.6	6.1	8.4	32.7	1.9
8:20	0.3	24.5	6.0	8.4	32.1	1.8
	0.6	24.5	6.1	8.4	32.2	1.5

7/8/2011 Station 3	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.1	25.5	6.7	8.5	30.8	3.1
	0.7	25.6	6.9	8.5	31.1	3.8
8:33	1.4	25.3	6.4	8.4	31.9	4.4
	2.1	25.0	6.1	8.4	31.1	3.5
	2.8	24.5	5.8	8.3	32.6	3.4
	3.4	24.4	5.5	8.3	32.6	9.9
Shore	0.1	24.8	6.0	8.5	30.3	2.9
8:40	0.3	24.8	6.1	8.5	30.6	2.9

Table 5 (cont'd). Water quality data collected July 8, 2011 at Upper Newport Bay.

7/8/2011 Station 4	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.1	25.5	7.1	8.7	27.9	1.4
	0.7	25.8	7.0	8.6	31.0	2.0
8:57	1.4	25.6	6.7	8.5	32.0	2.0
	2.1	24.8	5.9	8.4	32.5	1.9
	2.8	24.4	5.5	8.3	32.7	2.4
	3.5	24.3	5.5	8.3	32.7	2.5
	4.2	24.2	5.5	8.3	32.7	3.2
	4.9	24.0	5.6	8.3	32.9	2.2
	5.4	23.6	5.8	8.3	33.0	7.4
Shore	0.1	26.0	7.6	8.7	27.8	2.4
	0.3	25.9	7.6	8.6	28.9	2.1
9:08	0.6	25.9	7.1	8.6	29.2	2.4
	0.9	25.6	6.9	8.5	31.1	3.2
	1.2	25.3	6.1	8.4	31.9	3.2

7/8/2011 Station 5	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.1	25.6	7.2	8.8	24.8	1.7
	0.7	27.5	8.1	8.7	29.6	2.4
9:22	1.4	25.7	7.3	8.4	32.0	3.2
	2.1	24.9	6.4	8.4	32.3	2.0
	2.8	24.5	5.8	8.3	32.3	1.9
	3.5	24.2	5.1	8.2	32.5	2.2
	4.2	23.7	4.2	8.1	32.6	4.2
	4.9	23.5	3.5	8.0	32.6	6.5
Shore	0.1	25.5	7.0	8.8	24.6	1.2
9:30	0.3	25.8	9.1	8.9	25.5	NC

NC- Not collected due to fouling by filamentous algae

7/8/2011 Station 6	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.1	26.0	6.8	8.7	18.9	2.0
	0.7	27.8	8.0	8.7	29.1	1.9
9:40	1.4	25.5	7.5	8.5	32.0	1.9
	2.1	24.7	6.4	8.3	32.3	1.6
	2.8	24.1	5.6	8.2	32.4	0.9
	3.5	23.9	4.3	8.2	32.4	1.1
	4.2	23.5	4.0	8.1	32.5	1.3
	4.9	23.1	2.6	7.9	32.6	2.0
	5.6	22.3	1.5	7.8	32.6	2.8
Shore	0.1	25.5	6.5	8.7	19.7	4.5
9:48	0.3	27.7	6.8	8.7	27.8	7.2
	0.3	27.7	6.8	8.7	27.8	7.2

consumption of DO due to respiration and decomposition can result in the formation of hypoxic bottom waters and an interruption of the exchange of oxygen between surface and bottom waters, due to stratification or windless conditions.

The EPA and Regional Water Quality Control Board have prepared a Basin Plan for the watershed and UNB with a water quality objective that DO shall not be depressed to levels that adversely affect beneficial uses. Although no numerical criterion exist, concentrations above 5 mg/L typically are considered adequate to support biological organisms. The conventionally accepted DO threshold at which lethal and sublethal impacts occur is 2 mg/L, although new research has found the number to be highly variable among benthic organisms, with higher thresholds for many sensitive fish and invertebrates (Vaquer-Sunyer and Duarte 2008). Kamer and Stein (2003) considered values below 3 mg/L as hypoxic following a literature review of criteria developed for other embayments. Other factors influencing the lethality of hypoxia include the duration of the condition and the thickness of the hypoxic layer. Many species are well adapted to survive brief periods of extremely low or even no DO by either physiologic or behavioral responses. If necessary, motile organisms can move to other areas, while some sessile invertebrates are able to stretch from their burrows or extend body parts up into better oxygenated waters, increase water flow over respiration organs, or even shut down most metabolic functions until conditions improve.

Figures 3 and 4 summarize the salinity (density) and DO data as depth profiles, by station and sampling interval. Recognizing that these data represent only four points in time over any entire year, stratification appears limited at Stations 1, 2, and 3 (the southernmost stations) except after storm events such as that documented in March 2011. Stations 4, 5, and 6 at the northern reach of UNB were stratified during all four sampling events, with a lens of fresher water evident in the top one to two meters. A review of the January and March DO depth profiles (Figure 4) reveals no negative relationship between stratification and DO, with DO well within a normal range at all stations and depths.

Incidences of low DO appeared later in the year in July and October, at the depths of Stations 4, 5, and 6. Only at Station 6 (Basin I/III) did daytime DO fall below 2 mg/L (in July). There are likely heavy accumulations of detritus on the bottom of Stations 4, 5, and 6, which likely consume the available oxygen as a part of the decomposition process. In conjunction with the warmer summer and fall water temperatures, which reduces the ability of water to hold DO in solution, an anoxic or hypoxic bottom layer likely forms in some portions of the UNB basins (Stations 4 and 6) and upper channel (Station 5). When viewing the results in the context of the Basin Plan objective and a goal of achieving DO above 5 mg/L, lower values were often seen at the deeper parts of Stations 5 and 6, and at nearly all stations and depths in October 2011. Whether this had an adverse affect on biological resources is not known. The results of upcoming monitoring of benthic communities using an otter trawl may provide additional information as to the suitability of the benthic conditions for marine life.

Continual water quality monitoring performed with deployed instruments over a six-month period in 2005 found hypoxic events to be most closely tied to increased freshwater discharge, low solar radiation, and reduced bottom water circulation during neap tide series (Nezlin et al. 2006). Without similar monitoring during the current program, it is not possible to determine for how long and over what area hypoxic conditions continue to occur post-restoration, however the dredging

Table 6. Water quality data collected October 24, 2011 at Upper Newport Bay.

10/24/2011 Station 1	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.1	18.5	5.2	8.6	32.5	3.9
	0.7	18.5	4.9	8.6	32.5	2.9
Time: 13:17	1.4	18.4	5.0	8.6	32.7	3.6
	2.1	18.3	4.9	8.6	32.7	4.3
	2.8	18.3	4.9	8.6	32.8	4.8
	3.5	18.3	4.9	8.6	32.8	4.8
Shore	0.4	18.6	4.9	8.6	32.5	0.9
Time: 13:25	0.1	18.7	4.7	8.6	32.4	3.2

10/24/2011 Station 2	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.1	18.9	4.4	8.6	31.8	2.3
	0.7	18.9	4.3	8.6	31.9	1.8
	1.4	18.8	4.3	8.6	32.0	2.4
	2.1	18.8	4.3	8.6	32.0	2.5
Time:13:08	2.8	18.8	4.2	8.6	32.0	2.5
	3.5	18.8	4.2	8.6	32.0	3.7
Shore	0.1	18.9	5.2	8.7	32.3	4.4
	0.3	18.7	5.2	8.7	32.5	4.4
Time: 13:02	0.6	18.7	5.2	8.7	32.4	5.4
	0.9	18.5	5.3	8.7	33.0	8.3

10/24/2011 Station 3	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.1	18.9	4.7	8.6	32.6	3.7
	0.7	18.5	4.6	8.6	32.7	6.7
Time: 09:53	1.4	18.5	4.8	8.6	33.0	5.2
	2.1	18.3	4.7	8.6	33.2	5.5
	2.8	18.1	5.0	8.6	33.4	6.4
	3.5	17.9	5.3	8.6	33.5	7.1
	4.2	17.9	5.3	8.6	33.5	7.3
	4.9	17.8	5.4	8.7	33.6	8.2
	5.5	17.9	5.3	8.7	33.6	7.5
Shore	0.1	17.6	4.6	8.5	33.6	1.5
Time:10:09	0.3	17.6	4.8	8.5	33.7	2.0
	0.6	17.8	5.3	8.5	33.6	3.2

Table 6 (cont'd). Water quality data collected October 24, 2011 at Upper Newport Bay.

10/24/2011 Station 4	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.1	18.8	4.3	8.6	30.0	1.8
	0.7	18.8	4.3	8.6	30.0	1.4
Time:10:41	1.4	18.8	4.2	8.6	32.0	2.5
	2.1	18.6	4.3	8.6	32.8	3.7
	2.8	18.5	4.4	8.6	32.9	4.1
	3.5	18.4	4.4	8.6	33.0	4.1
	4.2	18.3	4.5	8.6	33.2	3.3
	4.9	18.1	4.7	8.6	33.4	3.4
	5.6	17.9	4.8	8.7	33.5	4.3
Shore	0.1	18.9	4.0	8.6	29.4	2.5
Time: 10:35	0.3	19.0	3.7	8.5	31.4	2.4
	0.6	18.9	4.9	8.6	32.3	6.4

10/24/2011 Station 5	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.1	19.1	6.3	8.7	23.1	1.8
	0.7	19.8	4.8	8.6	28.6	3.4
Time: 11:02	1.4	19.7	4.1	8.5	32.3	1.1
	2.1	19.6	3.5	8.5	32.7	2.7
	2.8	19.4	3.5	8.5	32.7	2.7
	3.5	18.8	3.7	8.6	32.7	4.9
	4.2	18.6	4.0	8.6	32.8	6.5
Shore	0.1	18.6	5.1	8.7	22.3	2.5
Time: 11:15	0.4	18.8	5.0	8.6	25.3	9.2

10/24/2011 Station 6	Depth (m)	Temp (°C)	Dissolved Oxygen (mg/L)	pH	Salinity (ppt)	Turbidity (NTU)
Channel	0.1	20.0	5.2	8.6	27.4	3.7
	0.7	19.9	4.3	8.6	28.9	3.4
Time: 11.40	1.4	19.7	3.9	8.5	32.1	2.2
	2.1	19.5	3.8	8.5	32.2	1.4
	2.8	19.3	3.7	8.5	32.4	1.8
	3.5	19.2	3.7	8.6	32.5	1.8
	4.2	19.2	3.6	8.6	32.6	2.4
	4.9	19.6	3.0	8.5	32.8	3.0
	5.6	19.8	2.6	8.4	32.9	5.0
Shore	0.1	20.0	4.3	8.5	28.1	6.0
Time: 11:38	0.3	20.0	4.4	8.5	29.2	5.3
	0.6	20.0	4.8	8.5	29.7	4.8

Figure 4. Depth Profile of Salinity (ppt) by Station at Upper Newport Bay (2011).

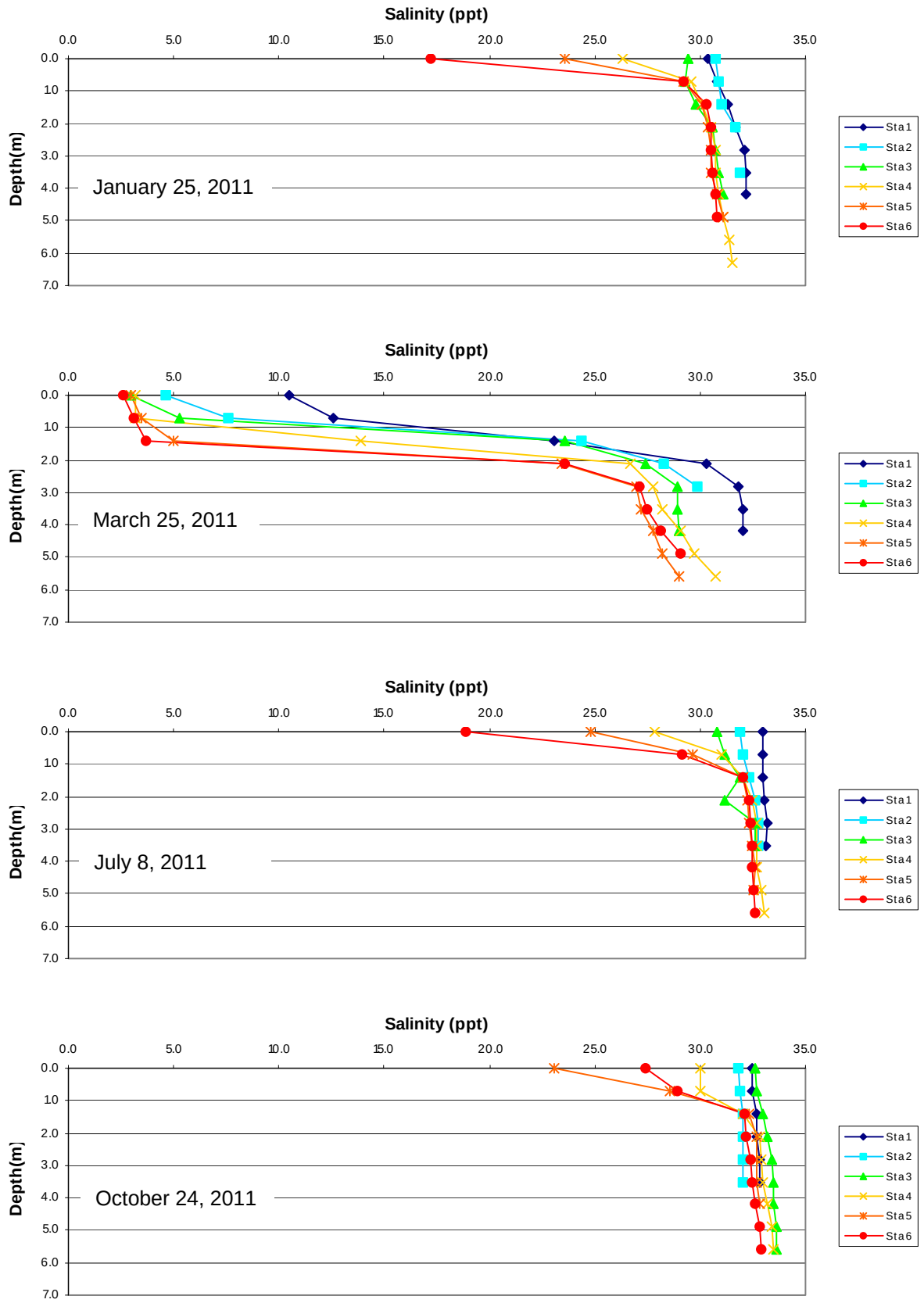
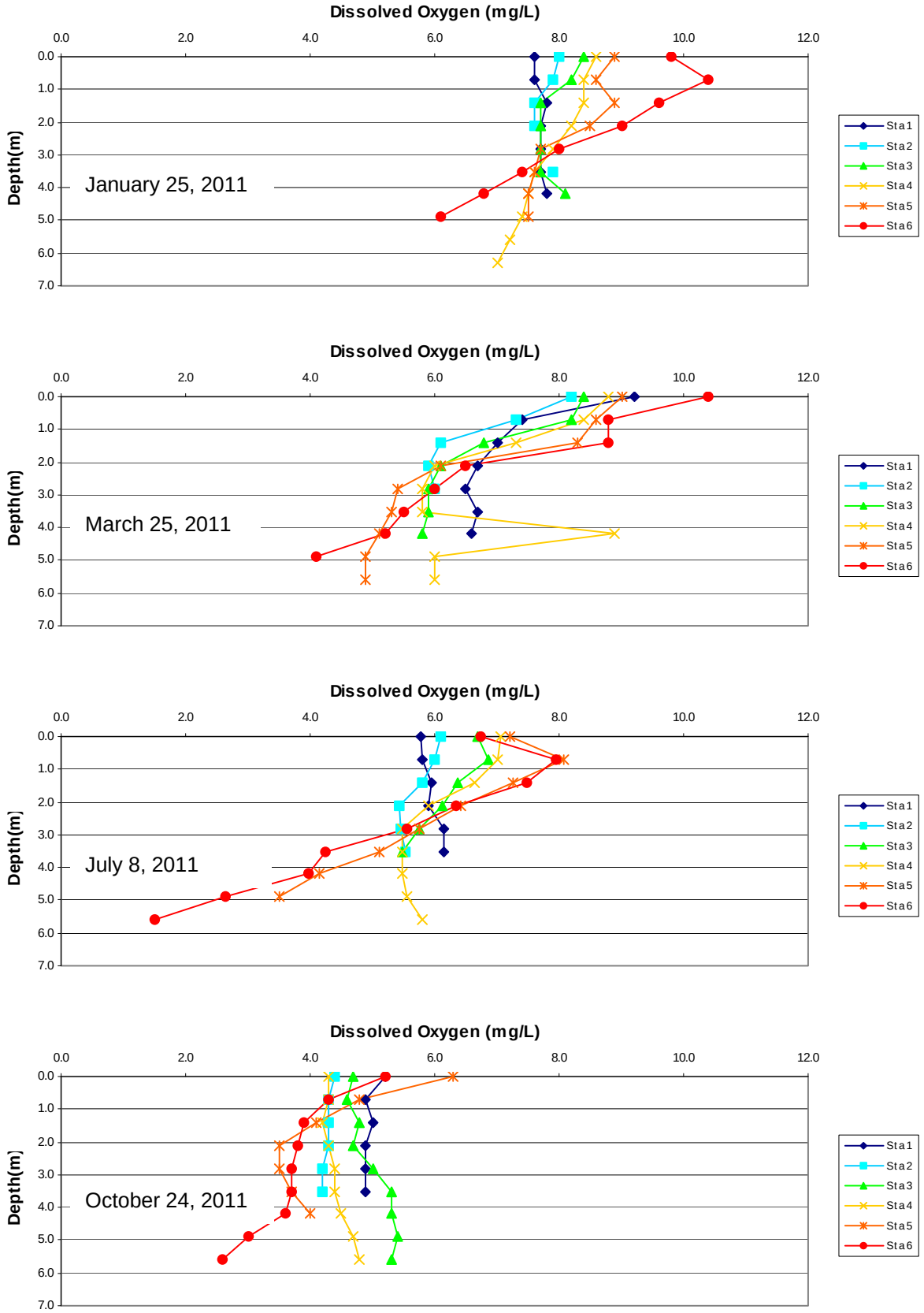


Figure 5. Depth Profile of Dissolved Oxygen (mg/L) by Station at Upper Newport Bay (2011).



project should have resulted in improved water circulation and reduced residence time in the upper portions of UNB. Deployment of such instrumentation in the basins of UNB would be difficult however, due to the depth and the intensive maintenance that would be needed to keep the DO probe functioning properly at the basin bottom. The Nezlin et al. study required intensive quality control procedures and replacement of missing data as a result of biofouling, instrument failure, and vandalism. While a robust dataset resulted from the effort, the intensity is outside the scope of the current biological monitoring program and comparisons of the 2005 findings to the current data are not appropriate.

A second question asked by the Monitoring Program was "Has the restoration project reduced turbidity in the bay by trapping incoming sediment deep in the basins?". Turbidity was elevated during the March 2011 sampling that followed several rain events, with a high of 74.9 NTU at the channel stations and as high as 112.0 NTU at the shore stations. During the other three quarters turbidity was low at all stations, with a maximum of 10.0 NTU. The degree to which the basins have trapped sediment will be determined by the bathymetric monitoring in Years 2, 3, 5, and 8.

2.4. Least Tern Island Elevations

Prior to nesting season, a general assessment of the two least tern nesting sites was made on January 25, 2011. Per CDFG nomenclature, these islands will be referred to as follows: the nesting site present prior to the restoration, in the uppermost reach of the bay near Jamboree Rd., is named Tern Island, and the newly created nesting site near the old salt dike is named New Least Tern Island (Figure 1). At each tern island notes were taken on the condition of the surface, photos were collected, and spot elevation data were collected with a rod and total station using known benchmarks.

Tern Island was well prepared for nesting season, with the white sand cap intact and weeds mostly limited to the edges of the site. The elevation of the nesting area ranged from roughly +9.4 feet (+2.9 meters) to +9.8 feet (+3.0 meters) MLLW. This is consistent with the design elevation of +3.0 $\pm$ 0.2 meters. An existing control point on the colony was measured at +10.2 feet (+3.1 meters) MLLW. Minor erosion was evident on the south edge of the island (see photos 3-8 in Appendix D). No evidence of land bridges to the main marsh or trespassing was detected.

New Least Tern Island was less prepared for nesting due to the extensive areas of weeds (see photos 9-12 in Appendix D). Despite several attempts by CDFG at treatment with herbicides, repeated rain events resulted in considerable spread of weed cover that was not easily controlled prior to nesting season. Although there were some native plants present, the majority were invasive non-natives. Hottentot fig (*Carpobrotus edulis*) was becoming established, but was limited enough in size and distribution that a targeted removal effort after the spring nesting season is highly recommended. It was estimated that approximately one third of the island was free enough of weeds to effectively attract nesting least terns. The created island appeared to be in good condition, with limited erosion and a generally flat surface. Similar to the other island, the elevation of the nesting area ranged from roughly +9.4 feet (+2.9 meters) to +9.8 feet (+3.0 meters) MLLW. This is consistent with the design elevation of +3.0 $\pm$ 0.2 meters. An existing elevated control point on the colony (NLTI 2) was measured at +10.38 feet (+3.16 meters) MLLW. This point was installed and measured by ACOE in May 2009, roughly one year after the island was completed

in March 2008, and was recorded at +10.77 feet (3.28 meters). This suggests the ground near the control point may have settled in the eight months between measurements by approximately 0.4 feet (+0.1 meter). No evidence of land bridges to the main marsh or trespassing was detected. The south-facing (windward) shoreline was heavily lined with plastic trash and plant debris that is continually pushed up against the island scarp by the wind and tides (see photo 10 in Appendix D).

An assessment was also made of the cordgrass that was previously transplanted in November 2009 on the seaward shore of New Least Tern Island. The cordgrass was persisting in a 1 to 2-meter wide band at approximately +3-feet MLLW elevation along the lower edge of the nest site slope. Although the plants were all small and most of the plant material had senesced, each had new green shoots emerging (see photos 13-14). It is anticipated that it will take several years for the cordgrass to become established and expand. The cordgrass was planted into sandy substrate that is considerably different from the mud substrate supporting the extensive cordgrass stands throughout the rest of UNB. It is unlikely that cordgrass will ever expand to a form dense stands around the island; more likely, it will persist or spread to particular areas along the island shoreline where substrate and wave exposure are most opportune.

3.0 BIOLOGICAL MONITORING

3.1. Vegetation Monitoring

The distribution, composition, and evolution of vegetation communities and unvegetated habitats are being monitored through the use of aerial photography and quantitative transect methods. The Monitoring Plan calls for collection of aerial photographs in Years 1, 2, 3, 5, and 8 and surveys of transects in Years 2, 5, and 8. Therefore Year 1 monitoring was limited to aerial image collection and habitat mapping.

Methods

To map vegetated and non-vegetated habitats during Year 1 (2011), the UNB study area was contract flown by the ACOE on December 30, 2010 to photograph the site from true vertical position on full-color film. The orthophotos were taken between 1100 and 1300 at roughly a 0 foot MLLW tidal elevation. This allowed photography of as much exposed intertidal habitat as possible while lighting and weather conditions were suitable for the photography. Collection of aerial imagery in subsequent years will be conducted at the same tidal elevation.

The collected imagery was provided to M&A by ACOE as a single orthophoto of UNB in June 2011. To establish a consistent study area, a boundary was established at the extreme high water line, which is 7.8 feet (2.4 meters) MLLW for UNB, and corresponds to the upper boundary of salt marsh habitat. The topographic data used to delineate this boundary were obtained through photogrammetric interpretation of aerial photographs collected by ACOE contractor Johnson-Frank & Associates, Inc. on December 30, 2010. All areas extending from that outer boundary toward the channel are included, including raised areas above 7.8 feet (2.4 meters), such as the least tern islands.

Heads-up digitization of vegetation boundaries visible in the imagery was performed using ArcGIS 10, generally following the Holland (1986) and Oberbauer (2008) classification system where appropriate, with other habitat types assigned as needed. Because it is not feasible to distinguish between low, middle, and high salt marsh vegetation using the available true color aerial imagery, and no transect monitoring was conducted during the Year 1 monitoring to assist in such a distinction, all zones of coastal salt marsh were mapped as a single habitat.

The only habitat that was not mapped strictly from the aerial was intertidal mudflat. During the project planning process, the existing acreage of mudflat was calculated in 2004 based on bathymetry and aerial photos. To capture comparable mudflat expanses during the present mapping effort, the lower edge of the 2010 mudflat was extended from the 0 MLLW line (visible in the aerial image) down to the -1.54 feet (-0.47 meter) MLLW contour, based on the bathymetric and topographic data provided by the ACOE. There were four locations where bathymetric data were not available to make a delineation. These were the Newport Dunes basin, the area around the Newport Dunes launch ramp, and two fingers of bay across from the launch ramp on the west shore of UNB. In these four areas, the lower edge of the mudflat was delineated from the aerial

image, which showed the mudflat at a 0 foot MLLW tidal elevation. The upper edge of the mudflat was determined based on inspection of the aerial image, where the mudflat met the salt marsh. Additionally, the extent of eelgrass (*Zostera marina*) present during a September 28, 2010 post-construction survey conducted following completion of the second phase of construction was added to the habitat map (M&A 2010). It was added as a layer over open water and therefore did not displace open water acreage in distribution calculations.

The draft digitized habitat maps were printed and taken into the field for ground-truthing from various vantage points along the shoreline and from the water. No survey work was done in the marsh itself, though dominant species visible from the shoreline were noted. Vegetation transects will be surveyed in Year 2 of this monitoring program, at which time the characteristic species in each habitats will be identified and reported. Following field efforts, the habitat maps were updated and map products and summary statistics of habitat acreage and distribution were generated. Attempts were made to compare the Year 1 data to existing pre-restoration datasets.

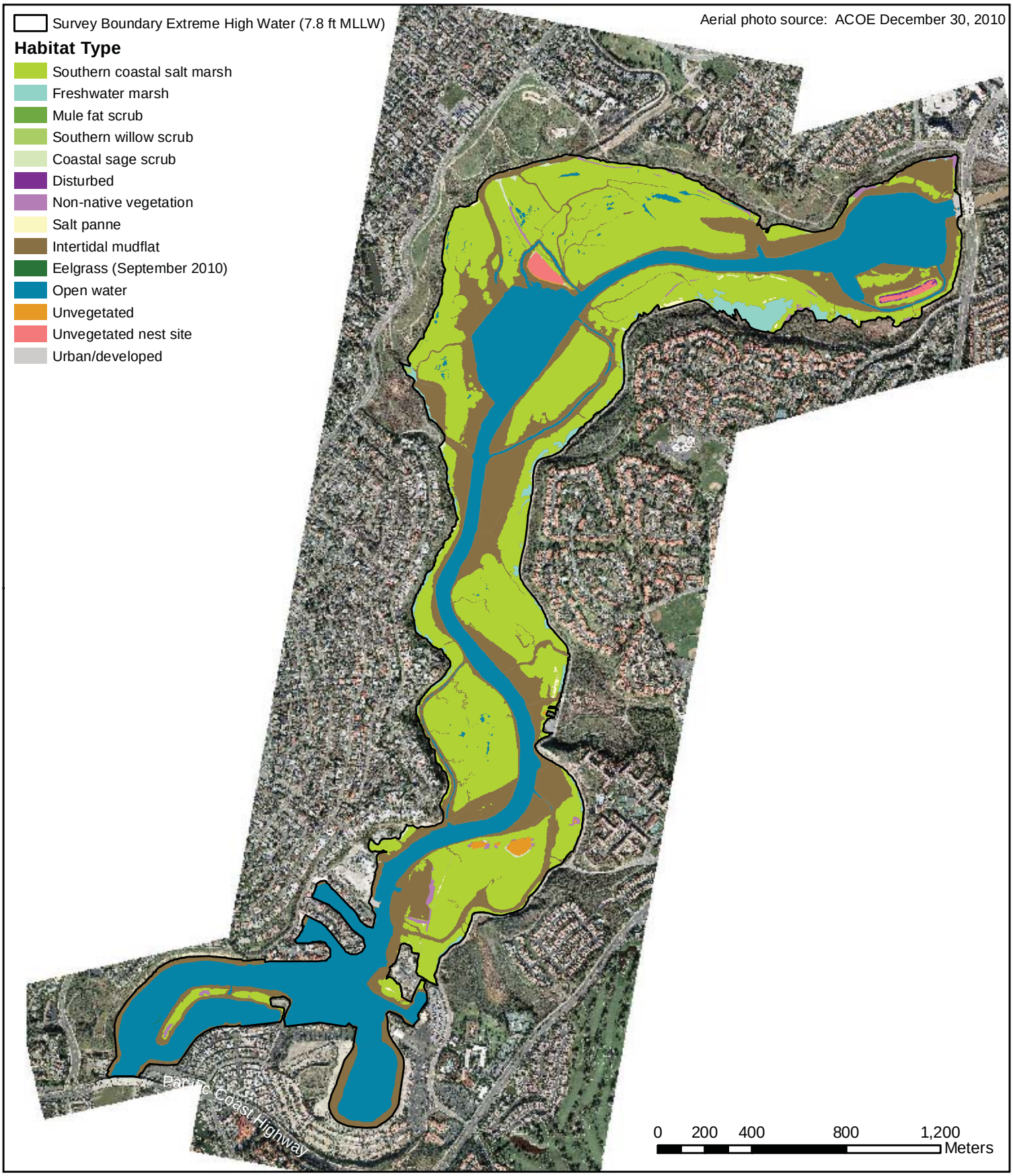
Results

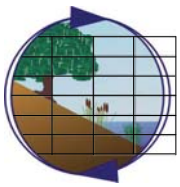
Based on the December 2010 imagery, seven vegetated and six non-vegetated habitats were mapped within the study area. Vegetated habitats included southern coastal salt marsh, freshwater marsh, mule fat scrub, southern willow scrub, coastal sage scrub, disturbed, and non-native vegetation. Non-vegetated habitats included salt panne, intertidal mudflat, open water, unvegetated, unvegetated nest site, and urban/developed. The September 2010 eelgrass is included as well. Figure 6 presents the habitats mapped on-site, and Table 7 summarizes the extent of each.

Table 7. Area of habitats within the UNB study area (December 2010).

Habitat	Hectares	Acres
Southern coastal salt marsh	141.6	349.9
Freshwater marsh	5.8	14.2
Mule fat scrub	0.0	0.1
Southern willow scrub	0.5	1.3
Coastal sage scrub	1.4	3.5
Disturbed	0.2	0.6
Non-native vegetation	2.0	5.0
Salt panne	0.7	1.7
Intertidal mudflat	74.3	183.6
Eelgrass (overlapping open water)	0.02*	0.04*
Open water	99.2	245.1
Unvegetated	1.1	2.6
Unvegetated nest site	1.6	3.8
Urban/developed	0.5	1.2

* Data retrieved from September 2010 survey report (M&A 2010).





Habitat Map - December 2010

Upper Newport Bay Ecosystem Restoration Project
Post-restoration Monitoring Program

Figure 6

Merkel & Associates, Inc.

The habitats of primary interest in relation to the effect of the restoration work are salt marsh, mudflat, and open water.

As it was prior to the restoration project, southern coastal salt marsh continues to be the dominant habitat occurring in UNB post-restoration, covering 141.6 hectares (349.9 acres). As mentioned above, without infrared photography it was not possible to distinguish from the imagery the delineations between low, middle, and high marsh. However, observations made of these various zones during the groundtruthing effort allowed for a general characterization of each area. The low marsh was dominated by cordgrass (*Spartina foliosa*), which extended down onto the mudflat to an approximate low elevation of +2.2 feet (0.7 meters) MLLW, though in some areas the lower edge was higher based on the morphology of the shoreline, such as a scarp eroded by the main channel. Pacific pickleweed (*Sarcocornia pacifica*) also occurred mixed in the cordgrass in many low marsh areas. Pickleweed was the dominant flora in the middle marsh, with saltwort (*Batis maritima*), jaumea (*Jaumea carnosa*), salt grass (*Distichlis spicata*), alkali heath (*Frankenia salina*), western marsh-rosemary (*Limonium californicum*), estuary seablite (*Suaeda esteroa*), and cordgrass common components as well. The high marsh was primarily salt grass, shore grass (*Monanthochloe littoralis*), and some Parish's pickleweed (*Anthrocnemum subterminale*).

The 74.3 hectares (183.6 acres) mapped as mudflat reflect the amount of mudflat that occurs between the salt marsh edge and open water, which was set at -1.54 feet (-0.47 meter) MLLW for this project by prior habitat mapping efforts. Therefore, the 99.2 hectares (245.1 acres) mapped as open water covers all waters below -1.54 feet (-0.47 meter) MLLW, including the main channel, inundated side channels, and the dendritic network of smaller channels flooded at that tide level. Pools of ponded water fed by these channels on the salt marsh plain were also mapped as open water.

Areas identified in the field as brackish marsh and coastal and valley freshwater marsh were grouped together as freshwater marsh, and tended to be dominated by cattails (*Typha latifolia, T. domingensis,* and *T. angustifolia*) and bulrush (*Bolboschoenus robustus* and *Bolboschoenus maritimus*). Other emergent wetland habitats occurring between the salt marsh and the upper edge of the survey boundary included southern willow scrub and mule fat scrub. These generally constituted small groupings of arroyo willow (*Salix lasiolepis*) and mule fat (*Baccharis salicifolia*) growing along Back Bay Drive at the upper edge of the marsh, and in the northwestern corner of the bay.

Small areas of coastal sage scrub dominated by goldenbush (*Isocoma menziesii*) occurred on elevated areas in the salt marsh and at the upper edge of the marsh. Other species within this habitat included California sagebrush (*Artemisia californica*), California buckwheat (*Eriogonum fasciculatum*), coyote brush (*Baccharis pilularis*), bladder pod (*Isomeris arborea*), and four-wing saltbush (*Atriplex canescens*). The steep slopes on either side of UNB, which support extensive expanses of coastal sage scrub, were outside of the survey area for this monitoring program.

Habitats mapped as non-native vegetation were well-established stands of exotic species including castorbean (*Ricinus communis*), tree tobacco (*Nicotiana glauca*), hottentot fig, white sweetclover (*Melilotus albus*), large Brazilian peppertrees (*Schinus terebinthifolius*), pampas grass (*Cortaderia selloana*), giant reed (*Arundo donax*), and Canary Island date palms (*Phoenix canariensis*). Only a

small portion of the non-native vegetation on the margins of UNB fell within the survey boundary (extreme high tide line: +7.8 feet MLLW), with additional ornamental exotic species occurring higher in the adjacent upland between the marsh and Back Bay Drive or northern trail system.

Disturbed habitat was mapped in areas that had a growth of opportunistic weedy species as a result of human action, primarily on the least tern island in the northeastern corner of UNB. The dominant vegetation was telegraph weed (*Heterotheca grandiflora*), with some wild radish (*Raphanus sativus*) (see photo 4 in Appendix D).

Areas mapped as urban/developed had been constructed upon or otherwise physically altered to an extent that native vegetation was no longer supported. Within the survey area at UNB this included riprap and concrete, particularly where San Diego Creek enters the Unit I/III basin (see photo 1 in Appendix D) and on the south shore of the Newport Aquatic Center across from Shellmaker Island.

Several other habitats devoid of vegetation were distinguished due to the variable origins of their unvegetated condition. The bare sand portions of the created tern islands were called out as "unvegetated nest site" in order to track the extent of habitat available for nesting over time. This excluded the portions of the tern islands that were vegetated to a degree that nesting by tern species or plovers would be unlikely. Areas mapped as salt panne collect seawater at higher tides and remain ponded as the tide falls due to the microtopography of the area. Evaporation of the ponded seawater leads to hypersaline conditions and depressed oxidation-reduction potential that are inhospitable to most vascular plants. The expansion of pickleweed into salt panne areas is variable year to year; therefore, variations in the extent of salt panne present each year is anticipated. Finally, areas with no vegetation, but apparently unaltered by human action, were mapped as simply "unvegetated". These were generally raised areas on Shellmaker Island made up of unstabilized sands that may preclude the establishment of most plant species. These raised areas were generally ringed by hottentot fig and goldenbush. Once established these species can expand into shifting sands and some reduction in the extent of unvegetated habitat may occur in future years.

A small bed of eelgrass was detected during the September 2010 survey in the southernmost region of UNB. Approximately 160 square meters (0.04 acre) of eelgrass grew on the western shoreline of the DeAnza Peninsula, the arm of land that parallels the main channel just north of Pacific Coast Highway (Figure 6). The extent of this eelgrass bed varies annually, and improvements in water clarity envisioned by the restoration project were projected to improve the vigor and extent of this bed.

Discussion

Because this is the first monitoring year, analysis of the key habitats (salt marsh, mudflat, and open water) is focused on comparisons to pre-restoration conditions. Question 9 posed in Section 1.3 above asks if the restoration project has resulted in a 10 percent gain or loss of any habitat. The distribution of habitats present prior to the 2006 start of construction was not documented, making such an evaluation difficult. There were earlier assessments of habitats made that provide some insight into conditions in the years during which restoration was being planned. For example, in 1997 a vegetation survey was performed by MEC Analytical Systems (MEC) using a combination of

transect investigations and inspections of infrared images from April 1997. The report of the survey included a map of the habitats present, but did not include acreages (MEC 1997). Neither a hard copy, nor the digitized GIS file, of the 1997 MEC habitat map is available for comparison to current conditions.

The project EIS/EIR (Chambers 2000) presented a table of habitat acreages referred to as the existing vegetation and non-vegetated habitats within the study area based on 1997 surveys, mapping, and correlation with project contours. The source of these acreage data is unknown, given that the 1997 MEC vegetation report did not provide habitat acreages. The boundary of the areas reported in the table is unknown, making close comparisons of those acreages to the current conditions difficult. The table indicates the presence of 71.8 acres of urban/developed land, in contrast to the 1.2 acres mapped in the present study, suggesting a dramatically different survey boundary, perhaps even crossing Back Bay Drive. Gross comparisons could be made, but the source of gains or losses in the 10 percent range could not be clearly attributed to the project work.

Table 8 presents a summary of habitat data available from various sources since 1997.

Table 8. Summary of habitat acreages reported at Upper Newport Bay since 1997 (acres).

Habitat Type	MEC 1997[1]	UNBERP EIR/EIS Table 3.4-1 (data source unknown)[2]	UNBERP EIR/EIS Table 3.4-6 Sediment Model [3]	ACOE Mudflat Re-evaluation 2004[4]	Tetra Tech TMDL Veg Monitoring 2001[5]	WRA TMDL Veg Monitoring 2004[6]	M&A Year 1 Monitoring 2010[7]
Salt marsh (low/mid/hi)	270.0	309.3	333.6				349.9
Low salt marsh					99.4	165	
Middle salt marsh					93	157	
Freshwater marsh		17.6					14.2
Mule fat scrub							0.1
Southern willow scrub							1.3
Coastal sage scrub							3.5
Disturbed							0.6
Non-native vegetation							5.0
Salt panne		7					1.7
Intertidal mudflat		274.5	217.2	232.8	347.4		183.6
Open water		175	216.4				245.1
Unvegetated							2.6
Unvegetated nest site							3.8
Urban/developed		71.8					1.2
"Uplands"		57.6					

1 MEC. 1997. Biological Resources of Upper Newport Bay, California, Final Report. No habitat acreages calculated, except text reference to 270 acres of salt marsh. Survey boundary unknown. No hard copy or GIS data available for habitat map referred to in report.
2 Chambers Group Inc. 2000. UNBERP EIR/EIS. Includes an existing habitat acreage table (3.4.1) and map cited as from MEC 1997 report, but is believed to be from a different source, becasuse MEC made no acreage calculations and EIR/EIS habitat map is labeled *Source: County of Orange* . Boundary of acreages in table unknown.
3 Chambers Group Inc. 2000. UNBERP EIR/EIS. Predicted habitat acreages inYear 0 of Sediment Model, reflecting 1998/1999 Unit I/III dredging.
4 Unpublished 2004 ACOE adjustment to mudflat calculation using 2001 photo, 2002 bathy data, and 2002 LIDAR, reflects 1998/1999 Unit I/III
5 Tetra Tech, Inc. 2001. TMDL monitoring performed for the County of Orange. Survey boundaries unknown.
6 Wetlands Research Associates, Inc. 2004. TMDL monitoring performed for the County of Orange. Survey boundaries unknown.
7 Merkel & Associates, Inc. Present document. Habitat acreage based on December 2010 aerial and groundtruthing.

Mudflat

Following the 1997 MEC study, but prior to the start of the restoration project in 2005, the Unit I/III basin was dredged in late 1998 and early 1999 by the County of Orange, converting a large expanse of what had been captured in the above reports as mudflat, to open water. The 2000 EIR/EIS did not reflect this large habitat shift. Efforts were made by the ACOE in 2004 to account for this shift, through a re-evaluation of the extent of mudflat present based on a review of a 2001 aerial photograph provided by the City of Newport, bathymetric survey data from May 2002, and LIDAR data from March 2002. Mudflat was designated between -1.54 feet (-0.47 meter) MLLW and +4.3 feet (+1.3 meters), with "modification based upon aerial photos". Because salt marsh vegetation generally extends down well below +4.3 feet MLLW, it is assumed that the modification involved pulling down the upper edge of the mudflat based on salt marsh visible in the aerial image. This resulted in an adjusted pre-restoration mudflat acreage of 94.2 hectares (232.8 acres), down from the 274.5 acres reported in the EIR/EIS (L. Smith, pers. comm.).

Based on construction drawings, the restoration project was anticipated to result in the loss of approximately 11 percent of the mudflat present at the start of restoration. This loss was considered acceptable by state and federal resource agencies and was directly attributable to project elements that converted mudflat to open water primarily in the two sediment basins. Comparing the 2004 ACOE pre-restoration estimate of 94.2 hectares (232.8 acres) of mudflat to the 74.3 hectares (183.6 acres) of mudflat present in Year 1 (December 2010) results in a 21 percent loss of mudflat. Although the GIS files used by the ACOE to calculate the 2004 value are no longer available, an examination of printouts of the 2004 mudflat maps allows some qualitative comparison to the 2010 mudflat distribution. It appears that a large portion of the reduction in mudflat is due to the restoration dredging and basin expansion, as anticipated. It is also evident that there was considerable expansion of the salt marsh onto mudflat between 2004 and 2010 throughout Upper Newport Bay, which also resulted in a loss of mudflat. For example, reviewing aerial images of Skimmer Island, a now removed nesting island north of the existing least tern island, it is evident that between 2004 and the end of construction there was considerable expansion of salt marsh onto mudflat (See Appendix A feature map for location of Skimmer Island).

In many areas the marsh expanded down to lower elevations. The reason for this downward expansion is unknown. It is possible that the dredging reduced ponding and prolonged inundation periods associated with storm events, allowing salt marsh to expand, however examination of aerial photos available from the website Google Earth in the years prior to the restoration show the salt marsh expansion was under way well before construction started in 2006. The final loss of mudflat evident from the 2004 printouts relates to subtle differences in bathymetry in the many back channels. Because the break between mudflat and open water was determined by the -1.54 feet (-0.47 meter) MLLW boundary, small shifts in the mapped depths of these channels resulted in shifts in the mapped habitat.

Given these various sources of mudflat loss between 2004 and 2010, it is reasonable to conclude that the anticipated removal of approximately 11 percent of mudflat was achieved and that the other processes and mapping error discussed above could account for the additional reduction. Removal of mudflat was a major goal of the restoration project, to improve water circulation and expand the capacity of the upper bay to capture incoming sediment. Question 9 posed in Section 1.3 above, *Has the project resulted in the gain or loss of any habitat type greater then 10 percent?,*

therefore does not apply meaningfully to mudflat habitat, given the pre-assumed project related removal of 11 percent of the existing mudflat, other than to confirm that there indeed was a loss of more than 10 percent of the mudflat. Annual monitoring in Years 2, 3, 5 and 8 can examine whether there are such gains or losses over time post-restoration.

Salt Marsh

While a relatively accurate pre-restoration value for mudflat is available, values for salt marsh are not. The 2007 MEC report mentions in the text that 270 acres of salt marsh were present in 2007, though the survey boundary is unknown. The 2000 EIR/EIS reports that in 1997 there were 309.3 acres of salt marsh present. The source of this calculation and the boundary included are unknown. As mentioned above, examination of aerial images between 1995 and the completion of construction using Google Earth shows considerable year to year variation in the extent of salt marsh present. In general the marsh appears to be expanding during this time period, suggesting that neither the 2007 values in MEC nor the EIR/EIS reflect the pre-construction extent of salt marsh when construction began in 2006.

A report entitled *Baseline Vegetation Monitoring, 2001* was prepared by Tetra Tech, Inc in 2001 to document vegetation acreages in support of efforts by the County of Orange to be compliant with the Total Maximum Daily Load (TMDL) established for Newport Bay. This study used transect investigations and habitat delineation on infrared imagery to determine the acreage of three habitats: intertidal mudflat, low marsh, and middle marsh. The boundary of the area surveyed is not presented in the report and the GIS files are not available for review. The acreages of the other habitats on site, including high marsh, were not presented, preventing comparisons with the current conditions. The methodology used in the present Monitoring Program does not allow for distinction between low, middle, and high marsh, as that determination must be made through use of infrared imagery and field investigations along monitoring transects. Therefore this Year 1 report provides a single acreage for salt marsh, preventing comparisons to the 2001 Tetra Tech report, which excluded high marsh from its calculations. Of note is the reporting in this study that there were 347.4 acres of mudflat present in 2001 (Tetra Tech, Inc 2001), considerably more than was calculated in the ACOE 2004 revised estimate discussed above.

A report entitled *Vegetation Monitoring, 2004* was prepared by Wetlands Research Associates, Inc (WRA) to continue the TMDL monitoring. It generally followed the same methodology as the 2001 study, but did not have the benefit of infrared imagery to accurately distinguish between the low and middle marsh, relying instead on the 2001 data to determine the breakpoint between the two (WRA 2004). They were also unable to calculate the acreage of mudflat due to a lack of bathymetric data. The report therefore presented the acreages of low and middle marsh only, totaling 322 acres. The discussion of the WRA report noted the wide disparity in historic estimations of salt marsh in Upper Newport Bay, citing a 1989 CDFG estimate of 351 acres of salt marsh, a 1998 reference to 277 acres of salt marsh in the TMDL, the 2001 Tetra Tech finding of 192 acres of low and mid salt marsh, and the 2004 WRA report found 322 acres of low and mid salt marsh.

The present Year 1 monitoring found 141.6 hectares (349.9 acres) of salt marsh within the study area, which is greater than all prior estimates except the 1989 CDFG number, which is essentially the same. It is apparent that there were some salt marsh losses that resulted from the project.

One such loss was related to the removal of Skimmer Island as mentioned above. Prior to its removal in 2010, the island was heavily vegetated by several acres of salt marsh on its fringe and surface. Another loss of salt marsh occurred with the removal of marsh to create a channel around the new least tern island. Without a pre-construction habitat map it is not possible to quantify these project-related losses of salt marsh, nor is it possible to determine if there was more than a 10 percent loss of these habitats. However, based on visual estimates from available aerial images, and a rough assumption that there may have been around 300 acres of salt marsh present pre-restoration, it appears that no more than 10 percent (30 acres) of salt marsh were excavated by the project. Loss of cordgrass-dominated salt marsh around the new least tern island were offset to some extent through the transplant of cordgrass on the shorelines of the island and natural expansion of cordgrass elsewhere during and following construction.

Open Water

An accurate pre-restoration value for the extent of open water habitat is also not available. The 2004 adjustment of the pre-restoration mudflat acreage by the ACOE accounted for the 1998/1999 dredging of the Unit I/III basin, by removing dredged areas from the mudflat count. It is not known if the extra 16.9 hectares (41.7 acres) created by that adjustment was then attributed to open water, however it seems a relatively safe assumption that dredged mudflat would be converted to open water. Therefore, considering the 1997 MEC open water estimate was 71 hectares (175 acres), adding the 16.9 hectares (41.7 acres) would result in 87.9 hectares (216.7 acres) estimated in 2004. This value matches a Year 0 no project estimate of open water extent predicted in the EIR/EIS.

Comparing this pre-restoration estimate of 87.9 hectares (216.7 acres) of open water to the 99.2 hectares (245.1 acres) of open water present in Year 1 (December 2010) results in a 13 percent gain of open water post-restoration. These gains were the result of conversions of mudflat and marsh to open water. This gain is a reasonable outcome for a project whose goal was to increase the capacity of the system to capture incoming sediment through the excavation of open water basins. Conversion of marsh and mudflat around the new least tern island to open water was essential to removing any land bridges to the island, for the protection of nesting birds.

Peripheral Habitats

The task of determining if the restoration project has resulted in the gain or loss of any of the other habitats by more than 10 percent is also complicated. It was assumed that because the restoration work was water-based and limited primarily to excavation of sediment accumulated at intertidal elevations, shifts in habitat associated with that work would be primarily limited to open water, mudflat, salt panne, and salt marsh habitat, with fringing habitats such as freshwater emergent wetlands and coastal sage scrub largely unchanged by the restoration. It is possible that the improvements in tidal flushing could have brought greater saltwater influence into fringing habitats that were previously under freshwater influence. The 1997 table of acreages presented in the EIR/EIS references 7.1 hectares (17.6 acres) of freshwater marsh. The present 2010 survey mapped 5.7 hectares (14.2 acres). Although this represents a 19 percent reduction in freshwater marsh, it is not possible to know if this reduction is due to varying survey boundaries, differences that occurred between 1997 and the start of construction in 2006, natural fluctuations in marsh distribution, or tidal effects of the restoration.

The 1997 EIR/EIS table reports 2.8 hectares (7.0 acres) of salt panne. The present survey mapped 0.7 hectares (1.7 acres), representing a 75 percent reduction in salt panne. A fair portion of that is likely a true reduction related to construction, resulting from the excavation of salt panne, upland, and salt marsh in the Bullnose Wetland Restoration Area to create intertidal mudflat. The remaining change is likely due to the natural fluctuations in salt panne that occur in a salt marsh environment, with variable colonization and retreat of salt marsh into salt panne based on rainfall and ponding history.

Other peripheral habitats mapped in 2010 including mule fat scrub, southern willow scrub, coastal sage scrub, and non-native vegetation were not quantified in previous reports and are therefore not discussed further.

Overall, the above analysis highlights the difficulty in quantifying changes in acreage year to year without stringent standards for methodology and without baseline pre-restoration data collected immediately prior to the start of construction. Additionally, the origin of the question of whether a 10 percent change in habitat distribution has occurred is unknown. However, based on the results of the first year of monitoring, the restored system appears to be functioning well. UNB is fully tidal, has a greatly improved capacity to capture incoming sediment, and provides good water quality with some, but limited, hypoxia at depth in the basins. The salt marsh appears healthy and supports numerous migratory and sensitive bird species and the two least tern nesting islands are better protected from mammalian predators through the creation of channels around them. More extensive biological monitoring to be conducted in Year 2, including bird, fish, and invertebrate investigations, will further reveal the condition of UNB post-restoration.

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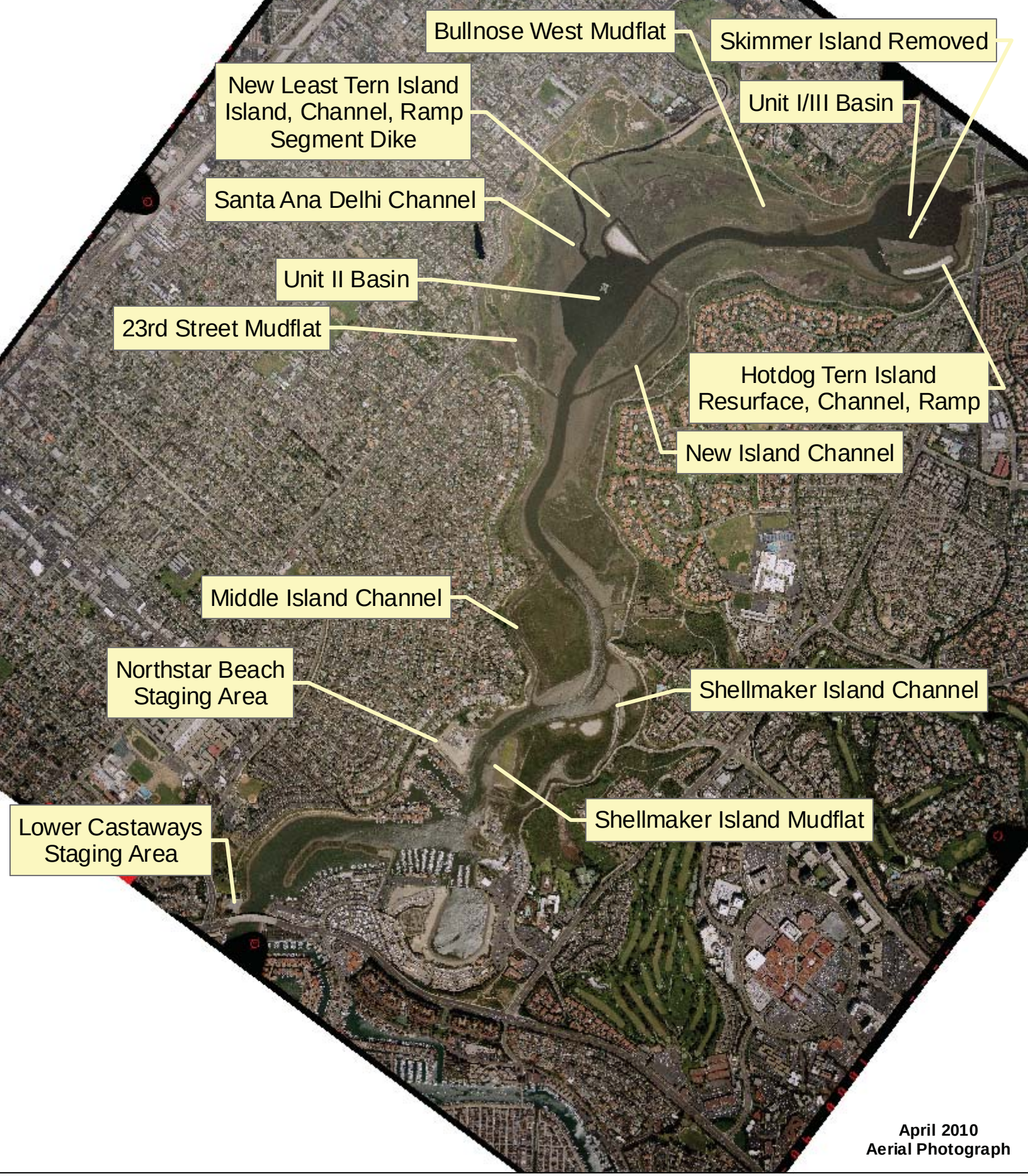
Appendix A

Upper Newport Bay Ecosystem Restoration Project Features and Summary

Retrieved from http://www.newportbeachca.gov/index.aspx?page=115

Document entitled Project Completion Summary Report 11/2010



Upper Newport Bay Ecosystem Restoration
Project Features

Upper Newport Bay Ecosystem Restoration

14 October 2010 Project Summary

- Period of Contractual Construction: November 2005 to October 2010
- Period of Dredging Construction: April 2006 to September 2010
- 2.35 million cubic yards (mcy) dredged, 2.2 mcy removed from the bay and 0.15 placed in-bay
- Constructed the following:
    - Widened and deepened 2 Sediment Control Basins (Unit II and Unit I/III)
    - Deepened 5 shallow island restoration channels (Shellmaker Island, Middle Island, New Island, Hotdog Tern Island, and New Least Tern Island)
    - Created 3 mudflats (Shellmaker, 23rd Street, Bullnose West)
    - Relocated 1 tern nesting island
    - Provided maintenance access to 2 nesting islands (New Least Tern and Hotdog)
    - Provided interpretive signs and buoys
- Phase 1 Contractor was DD-M Crane and Rigging dredged 1.737 mcy from April 2006 to July 2009
- Phase 2 Contractor was RDA, Contracting Inc. dredged 613 kcy from January 2010 to September 2010
- 1.05 mcy removed from Unit II Basin (DD-M Phase 1 removed 865 kcy; RDA Phase 2 removed 186 kcy)
- 905 kcy removed from Unit I/III Basin (DD-M Phase 1 removed 494 kcy; RDA Phase 2 removed 411 kcy)
- 92% disposed offshore at LA3 and 1% nearshore at Newport Beach
- 7% disposed in-bay for construction of nesting islands
- Approximately 5,000 tug and scow trips passed underneath PCH without incident (from 1,685 DD-M tug and scow trips to LA3, 680 RDA tug and scow trips to LA3 and numerous tug and scow maneuvers)
- 2 to 4 scows were in use at any one time for construction, 7 different scows ranging from 1000 cy capacity to 3000 cy capacity
- 2 tugs
- Staging areas were Lower Castaways and Northstar Beach
- 1,558,000 cy were disposed at LA3 under Phase 1, 565 days of actual dredging for an average production of 2,750 cy per dredge day, over a period of 1,183 days. Primary dredge was a 5 cy clamshell bucket mounted on the CB-3 Crane Barge, with some of the dredging performed by 10-inch hydraulic dredge “Pelican”.
- 613,000 cy were disposed at LA3 under Phase 2, 175 days of actual dredging for an average production of 3,500 cy per dredge day, over a period of 240 days. Primary dredge was a Cat 385 excavator mounted on the CB-3 Crane Barge, with a minor amount of dredging performed by 10-inch hydraulic dredge “Pelican”.
- An amphibious excavator was used to: complete the shallow dredging at Middle Island and Shellmaker Island Restoration Channels; construct the maintenance access ramps at New Least Tern Island and Hotdog Tern Island; and excavate the Skimmer Island to mudflat elevation. In December 2009 there was an incident where the excavator, while being parked on the mudflat for the day, turned over into the bay. No injuries and no environmental damage occurred. It took a few days to bring the excavator upright.

UPPER NEWPORT BAY ECOSYSTEM RESTORATION PROJECT
April 2006 to September 2010
TOTAL

FEATURE	START	FINISH	Volume Removed CM	Placed LA-3 CM	Placed Nearshore CM	Placed NLTI/Pit CM	Hotdog Tern Island	Scow Volume CM	e-trac report
Access Channel Between PCH and Unit II Basin	Apr-06	Sep-10	5,800	5,800				15,467	
Northstar Beach Wetland Restoration	Feature not built per County request		na						
Shellmaker Island Wetland Restoration	Feb-07	May-08	39,400	0		33,700	5,700		
Shellmaker Island Restoration Channel	May-06	Jun-06	9,700	9,700				8,318	
Middle Island Restoration Channel	May-06	May-06	9,600	9,600				11,148	
Access Channel to 23rd Street Wetland Restoration	Apr-07	Apr-07	4,600	4,600				4,752	
23rd Street Wetland Restoration	Aug-07	Mar-08	98,200	20,000		62,200		38,305	
Rev A Nearshore	Mar-08	Apr-08			15,000			20,479	
Rev B Nearshore	May-08	May-08			1,000			1,270	
New Island Restoration Channel	Jun-06	Jul-06	16,800	16,800				9,230	
Unit II Basin	Jun-06	Sep-10	803,860	803,860				796,778	
Access Channel to New Least Tern Island Pit	Jun-06	Jun-06	3,000	3,000					
New Least Tern Island Pit	Jun-06	Feb-07	74,600	74,600				69,113	
New Least Tern Island	Feb-07	Mar-08	na						
Segment Main Dike	Jun-07	Oct-07	900			900			
Cordgrass Transplant	Nov-09	Nov-09	na						
New Least Tern Island Channel	Jan-10	Jan-10	11,000	11,000					
New Least Tern Island Ramp	Jan-10	Jan-10	na						
Access Channel Between Unit II and Unit I/III	Feb-07	Apr-07	1,060	1,060				part of Unit I/III S	
Bullnose Access	Apr-07	Apr-07	1,800	1,800				2,485	
Bullnose West Wetland Restoration	Feb-07	Nov-07	18,100			18,100			
Hotdog Tern Island Restoration Channel	Feb-07	Apr-07	6,400	6,400				7,552	
Hotdog Tern Island Sand/Shell Layer	Mar-07	Apr-07	na						
Hotdog Tern Island Maintenance Access Ramp	Mar-10	Mar-10	na						
Unit I/III Basin	Feb-07	Sep-10	691,680	691,680				661,698	
Cubic Meters			1,796,500	1,659,900	16,000	120,600	<-------	1,624,846	1,946,239
		check	1,796,500					1,632,098	
Cubic Yards	0.764555		2,349,733	2,171,067	20,927	157,739		2,125,218	2,545,584
			Volume Removed	LA-3	Nearshore	In-Bay		Scow	e-Trac
Cubic Yards, Rounded			2,349,700	2,171,100	20,900	157,700		2,125,200	2,545,600
Disposal Percentage of Total Removed				92%	1%	7%			8%

Note: September 2000 Feasibility Study estimated the total volume of material to be dredged from the Upper Bay would be approximately 2.1 million cubic yards, and initial construction would take 2 years. The project was dredged in two phases, taking close to five years, and 2.35 million cubic yards were dredged and placed at LA3, Nearshore and In-Bay.
2,190,000 cubic yards were removed from the bay
158,000 cubic yards were placed in the bay

UPPER NEWPORT BAY ECOSYSTEM RESTORATION PROJECT
April 2006 to July 2009
PHASE 1

FEATURE	START	FINISH	Bid Volume CM	Volume Removed CM	Placed LA-3 CM	Placed Nearshore CM	Placed NLTI/Pit CM	Hotdog Tern Island	Scow Volume CM	e-Trac START	e-Trac FINISH	e-Trac Approx. Volume
Access Channel Between PCH and Unit II Basin	Apr-06	May-06	Lump Sum	5,800	5,800				15,467	Apr-06	Jul-06	89,720
Northstar Beach Wetland Restoration	Feature not built per County request		NA	NA	NA					Sep-06	Jun-07	515,050
Shellmaker Island Wetland Restoration	Feb-07	May-08	Lump Sum	39,400	0		33,700	5,700		Jun-07	Apr-08	500,400
Shellmaker Island Restoration Channel	May-06	Jun-06	Lump Sum	9,700	9,700				8,318	May-08	Aug-08	127,000
Middle Island Restoration Channel	May-06	May-06	Lump Sum	9,600	9,600				11,148	Mar-09	Jul-09	149,850
Access Channel to 23rd Street Wetland Restoration	Apr-07	Apr-07	Lump Sum	4,600	4,600				4,752			
23rd Street Wetland Restoration	Aug-07	Mar-08	124,906	98,200	20,000		62,200		38,305			
Rev A Nearshore	Mar-08	Apr-08				15,000			20,479			
Rev B Nearshore	May-08	May-08				1,000			1,270			
New Island Restoration Channel	Jun-06	Jul-06	Lump Sum	16,800	16,800				9,230			
Unit II Basin Base + Option + Santa Ana Delhi Channel	Jun-06	Jan-08	678,811	661,800	661,800				656,832			
Base			144,543	114,500					122,587			
Option 1			172,299	181,800					534,245			
Option 2			361,969	363,900								
Santa Ana Delhi Channel			part of Options	1,600								
Access Channel to New Least Tern Island Pit	Jun-06	Jun-06	Lump Sum	3,000	3,000							
New Least Tern Island Pit	Jun-06	Feb-07	74,626	74,600	74,600				69,113			
New Least Tern Island	Feb-07	Mar-08	NA	NA								
Segment Main Dike	Jun-07	Oct-07	part of Bullnose	900			900					
Access Channel Between Unit II and Unit I/III	Feb-07	Apr-07	Lump Sum	0	0							
Bullnose Access	Apr-07	Apr-07	part of Bullnose	1,800	1,800				2,485			
Bullnose West Wetland Restoration	Feb-07	Nov-07	19,994	18,100			18,100					
Hotdog Tern Island Restoration Channel	Feb-07	Apr-07	Lump Sum	6,400	6,400				7,552			
Hotdog Tern Island Sand/Shell Layer	Mar-07	Apr-07	part of Bullnose		0		NA					
Unit I/III Basin + Modifications	Feb-07	Jul-09	379,149	377,300	377,300				354,438			
Base			111,149	140,500								
Mod Phase 1			150,000	153,600								
Mod Phase 2			40,000	40,000								
Mod CLIN 42 & 43			78,000	43,200								
Cubic Meters			1,277,486	1,328,000	1,191,400	16,000	120,600	<-------	1,177,640			1,382,020
		check		1,328,000					1,177,639			
Cubic Yards	0.764555		1,670,888	1,736,958	1,558,292	20,927	157,739		1,540,295			1,807,614
			Bid Volume	Volume Removed	LA-3	Nearshore	In-Bay		Scow			e-Trac
Cubic Yards, Rounded			1,670,900	1,737,000	1,558,300	20,900	157,700		1,540,300			1,807,600
Disposal Percentage of Total Removed				100%	90%	1%	9%					4%

UPPER NEWPORT BAY ECOSYSTEM RESTORATION PROJECT 10/13/2010
September 2009 thru September 2010
PHASE 2

FEATURE	START	FINISH	Bid Volume CM	Approximate Volume Removed CM	Placed LA-3 CM	Scow Volume		
Access Channel Between PCH and Unit II Basin	na	na	na	na	na	na		
Cordgrass Transplant	Nov-10	Nov-10	na	na	na	na		
New Least Tern Island Channel	Jan-10	Jan-10	Lump Sum	11,000	11,000	7,252		
New Least Tern Island Ramp	Jan-10	Jan-10	na	na	na	na		
Top of Skimmer Island	Dec-10	Mar-10	10,600	10,600	10,600	part of Unit I/III S		
Southern Unit I/III Basin	Jan-10	Jun-10	225,000	235,836	235,836	256,788		
Additional Southern Unit I/III Basin, Closeout Phase 1	Jan-10	Feb-10	Phase 1	17,944	17,944	part of Unit I/III S		
Northern Unit I/III Basin	Jun-10	Jul-10	50,000	50,000	50,000	50,472		
Access Channel Between Unit II and Unit I/III	Mar-10	Mar-10	Lump Sum	1,060	1,060	part of Unit I/III S		
Unit II Basin	Jul-10	Aug-10	140,000	142,060	142,060	139,946		
Hotdog Tern Island Ramp	Mar-10	Mar-10	na	na	na	na		
Cubic Meters			425,600	468,500	468,500	454,458	564,219	
		check		468,500				
Cubic Yards	0.764555		556,664	612,775	612,775	594,409	737,970	
			Bid Volume	Volume Removed	LA-3	Scow	e-Trac	
Cubic Yards, Rounded				613,000	613,000	594,000	738,000	
Disposal Percentage of Total Removed					100%		20%	higher than actual

* Volume included in Phase 1

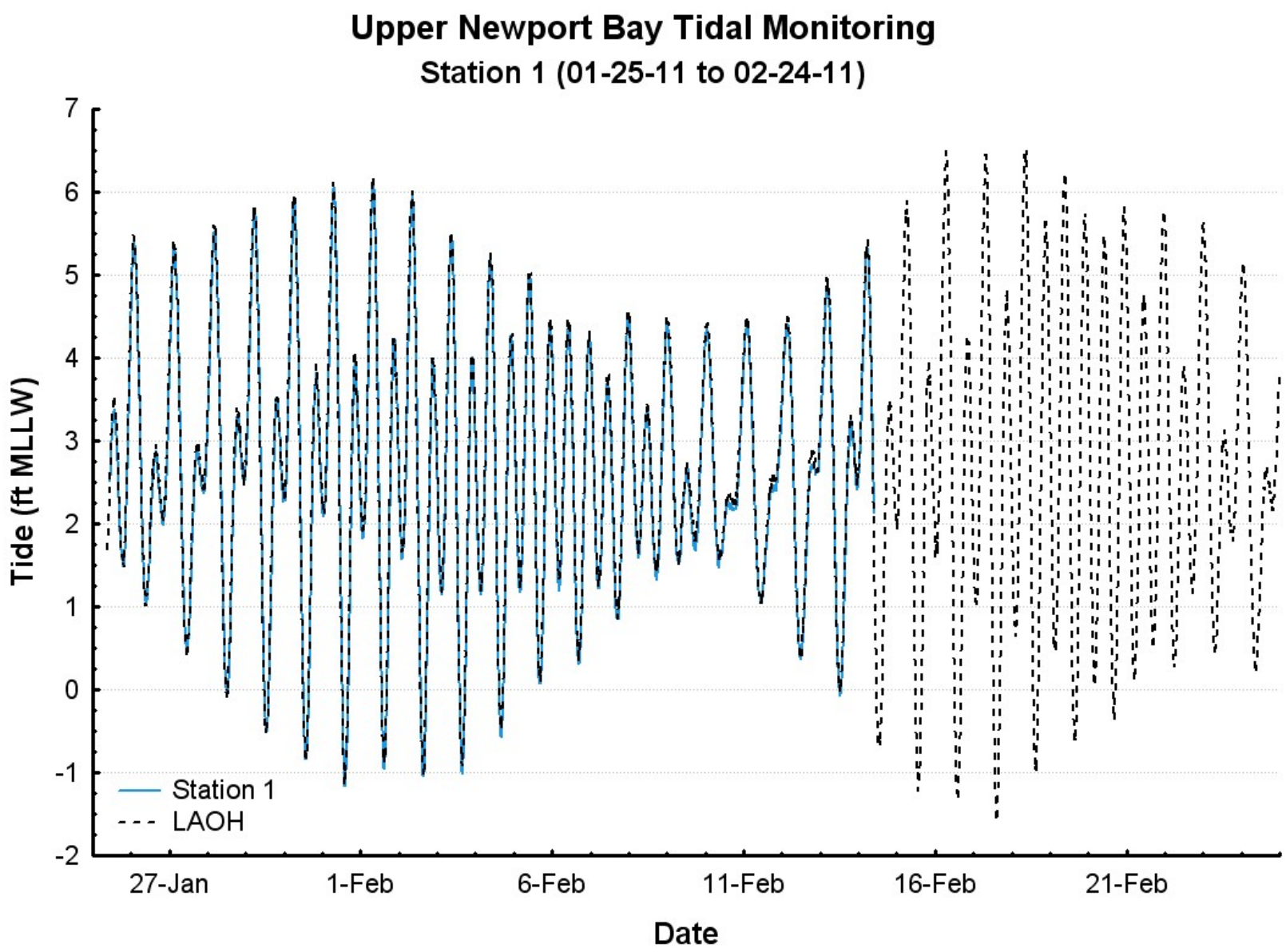
Appendix B
Sample Station Coordinates

Sampling Station Coordinates

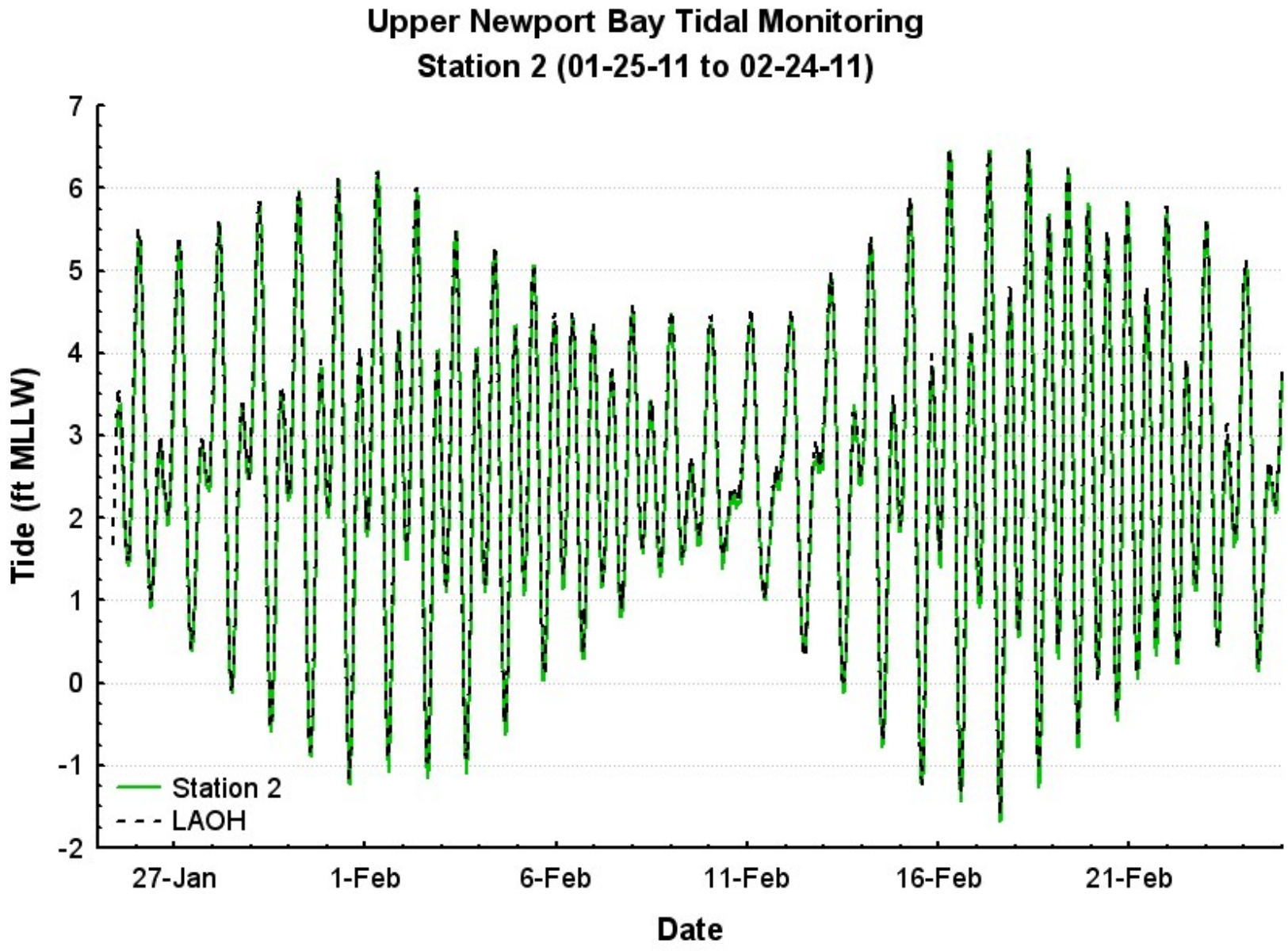
California State Plane, Zone 6, NAD 83, Feet

EQUIPMENT	STATION ID	X	Y
Water Quality	Station 1 - shore	6,068,633.74	2,184,404.65
	Station 2 - shore	6,066,003.56	2,183,564.40
	Station 3 - shore	6,063,755.12	2,183,173.36
	Station 4 - shore	6,062,363.22	2,178,385.52
	Station 5 - shore	6,061,953.56	2,175,408.53
	Station 6 - shore	6,058,536.67	2,173,623.28
	Station 1 - channel	6,058,814.25	2,173,534.64
	Station 2 - channel	6,061,698.02	2,174,974.30
	Station 3 - channel	6,062,404.14	2,178,694.97
	Station 4 - channel	6,063,445.73	2,182,393.05
	Station 5 - channel	6,066,781.15	2,183,531.33
	Station 6 - channel	6,068,905.90	2,183,821.86
Tides	Station 1	6,061,777.61	2,174,690.76
	Station 2	6,064,424.12	2,182,934.58
	Station 3	6,069,256.39	2,183,397.90

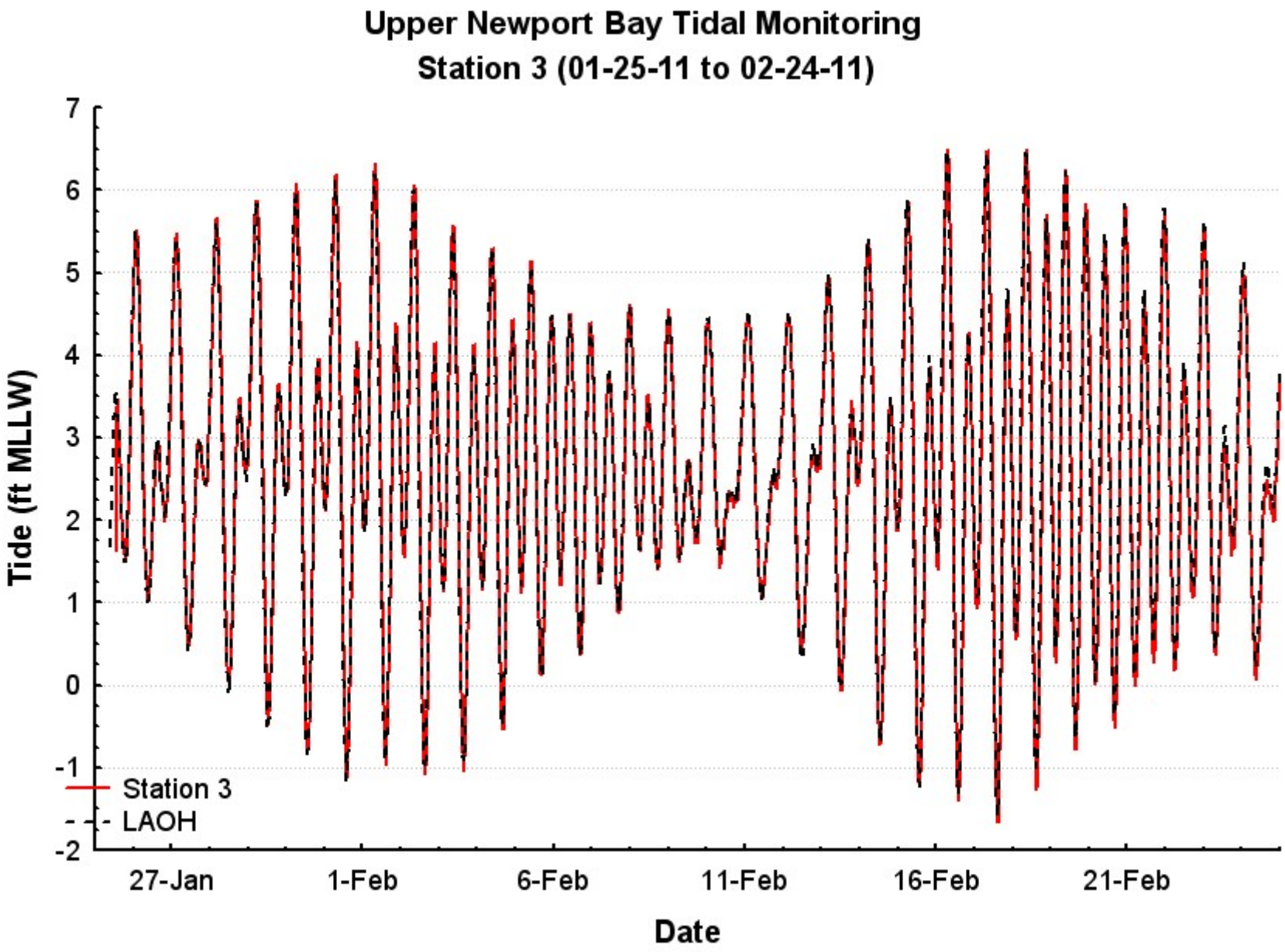
Appendix C
Monthly Plots of Tidal Data



Tide data at UNB Station 1 and Los Angeles Outer Harbor, January and February 2011 (feet, MLLW).

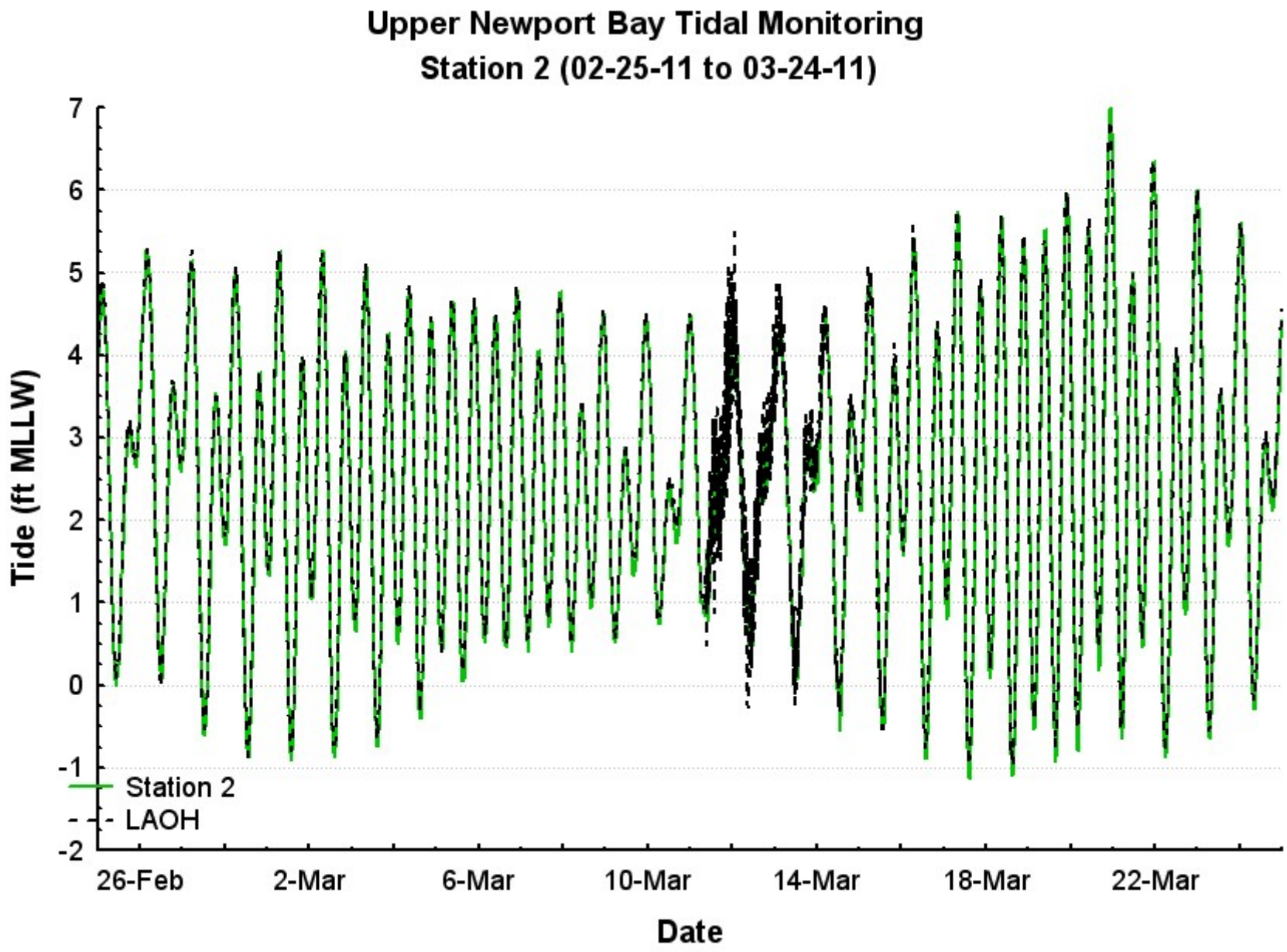


Tide data at UNB Station 2 and Los Angeles Outer Harbor, January and February 2011 (feet, MLLW).

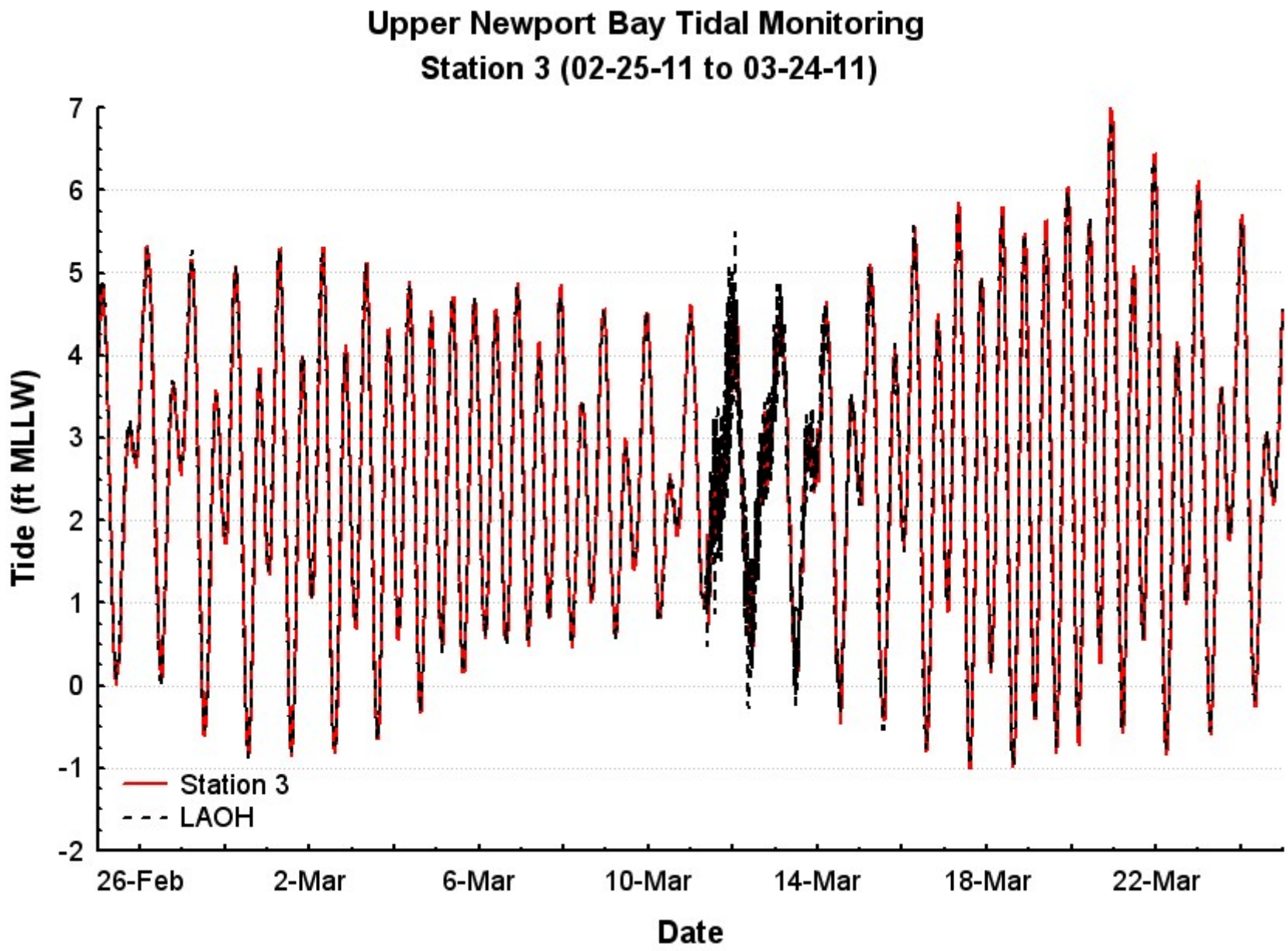


Tide data at UNB Station 3 and Los Angeles Outer Harbor, January and February 2011 (feet, MLLW).

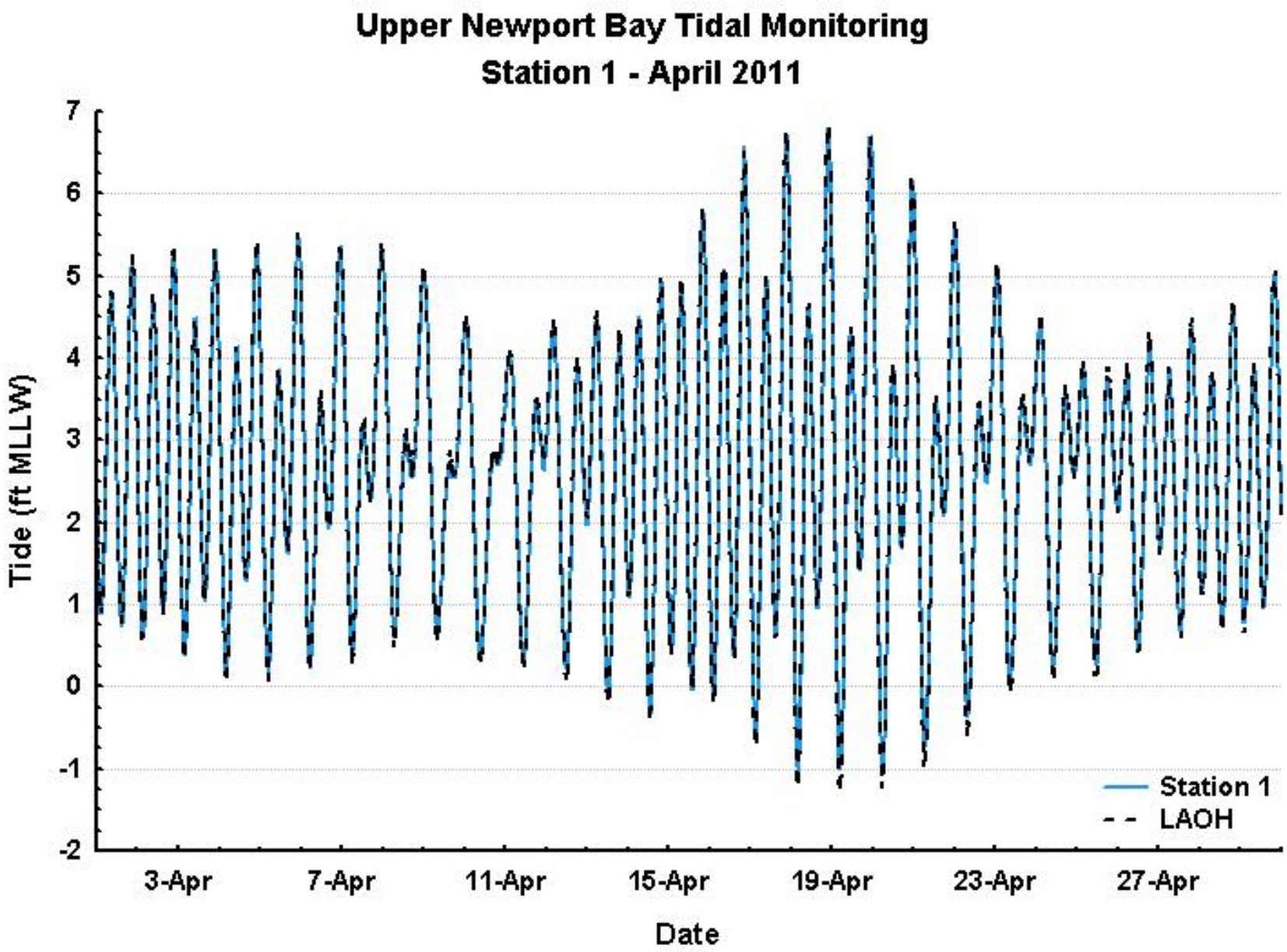
March 2011 tide data at UNB Station 1 lost due to destruction of the station as part of adjacent construction.



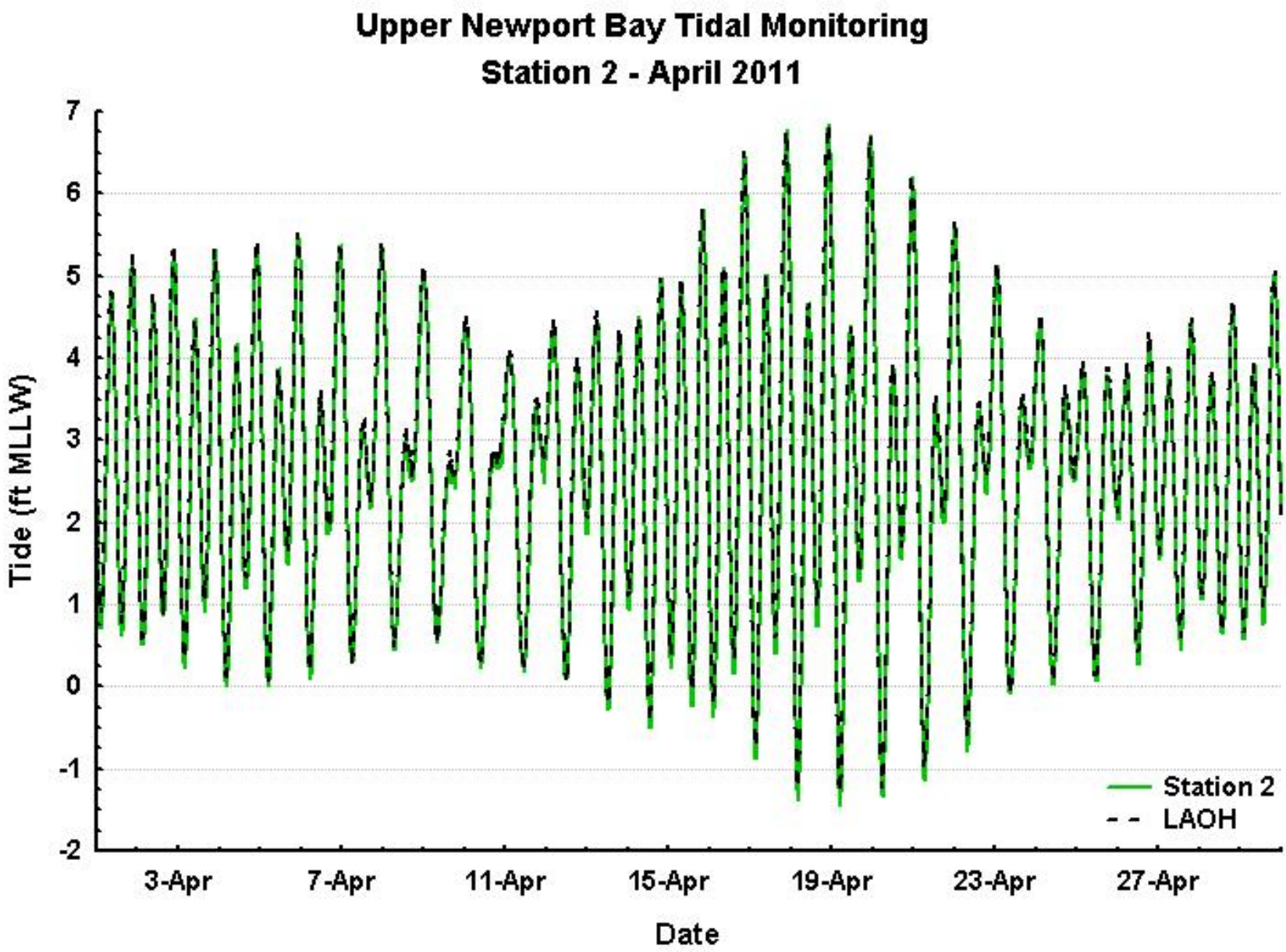
Tide data at UNB Station 2 and Los Angeles Outer Harbor, March 2011 (feet, MLLW).



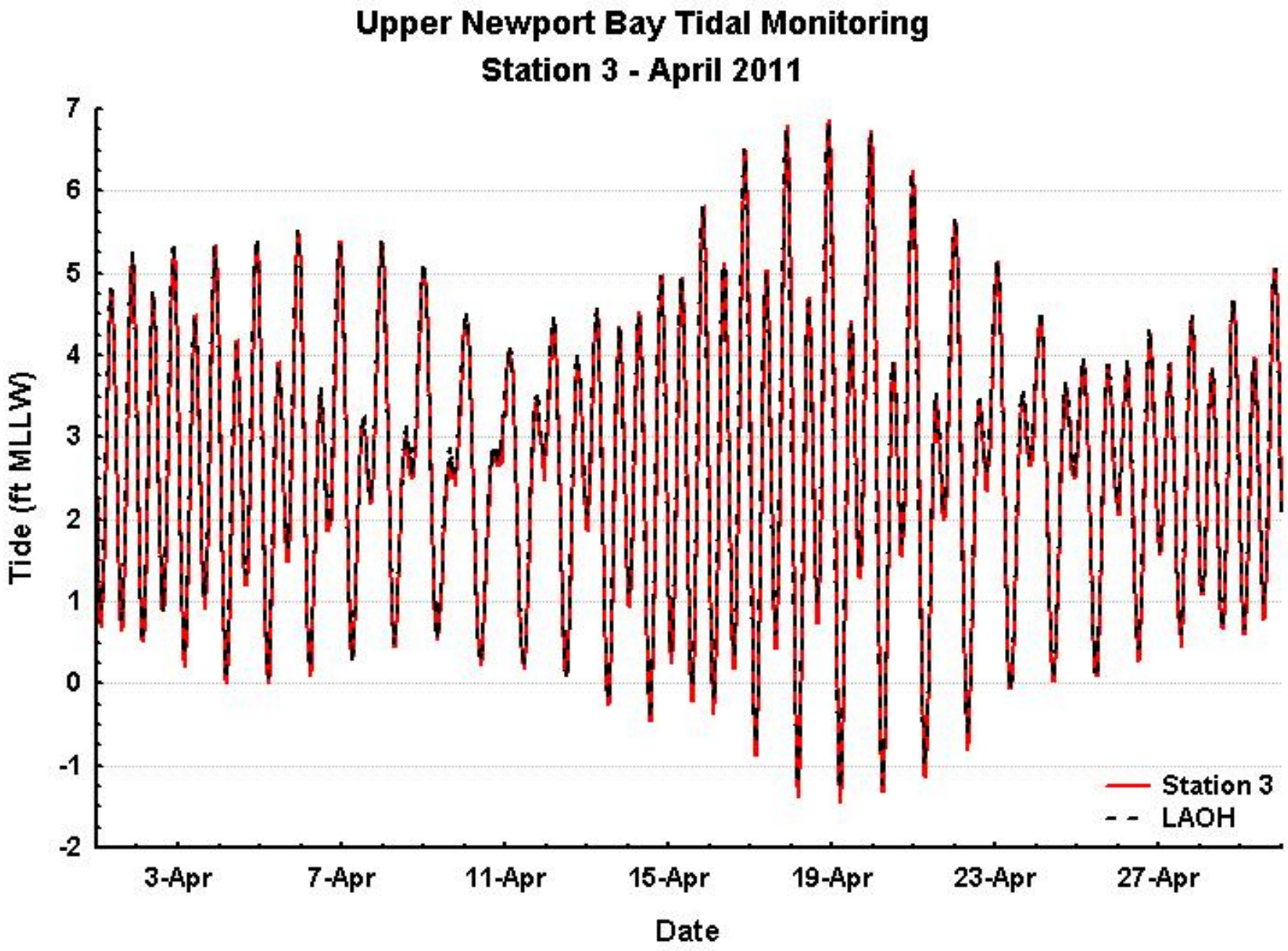
Tide data at UNB Station 3 and Los Angeles Outer Harbor, March 2011 (feet, MLLW).



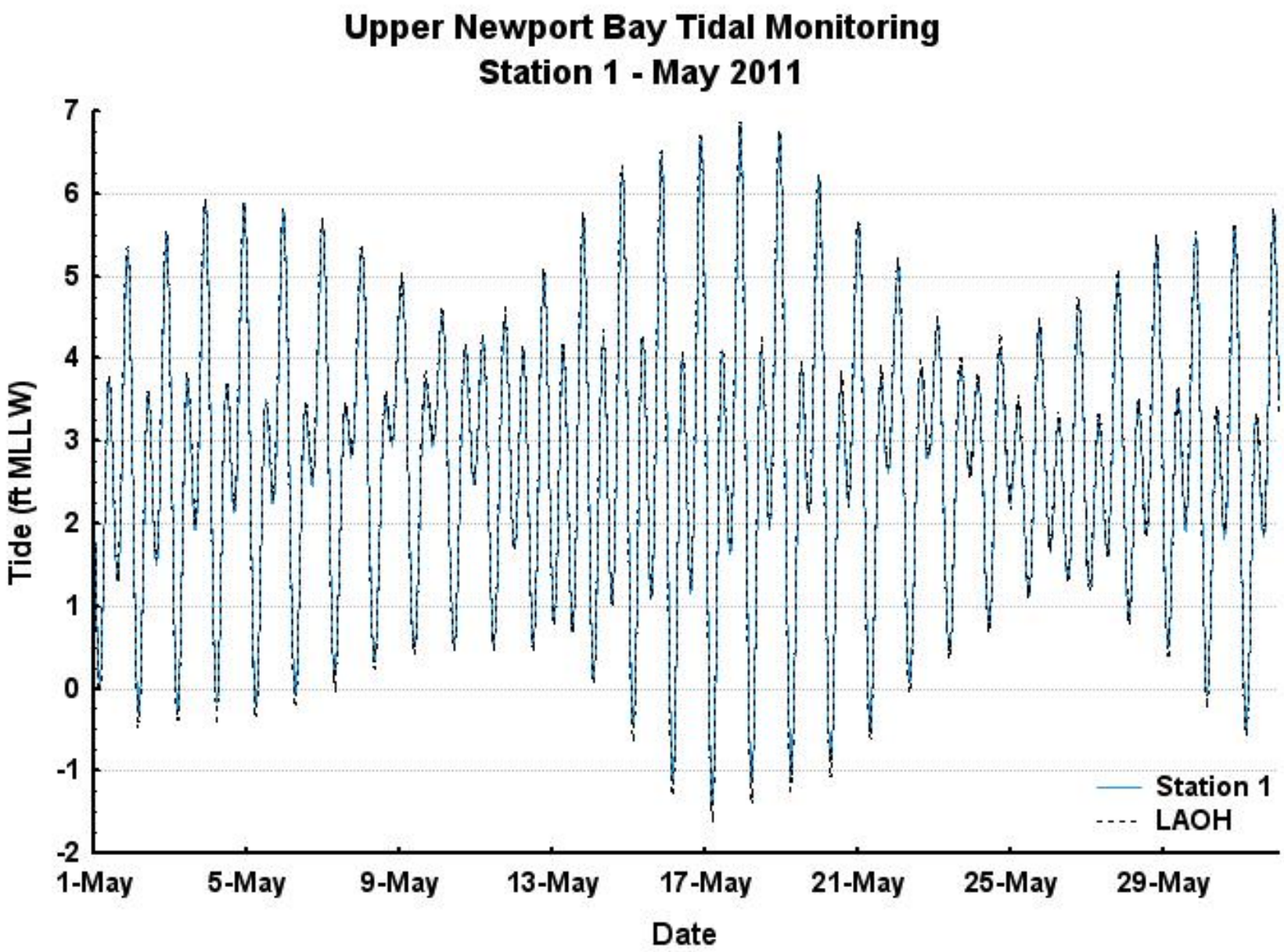
Tide data at UNB Station 1 and Los Angeles Outer Harbor, April 2011 (feet, MLLW).



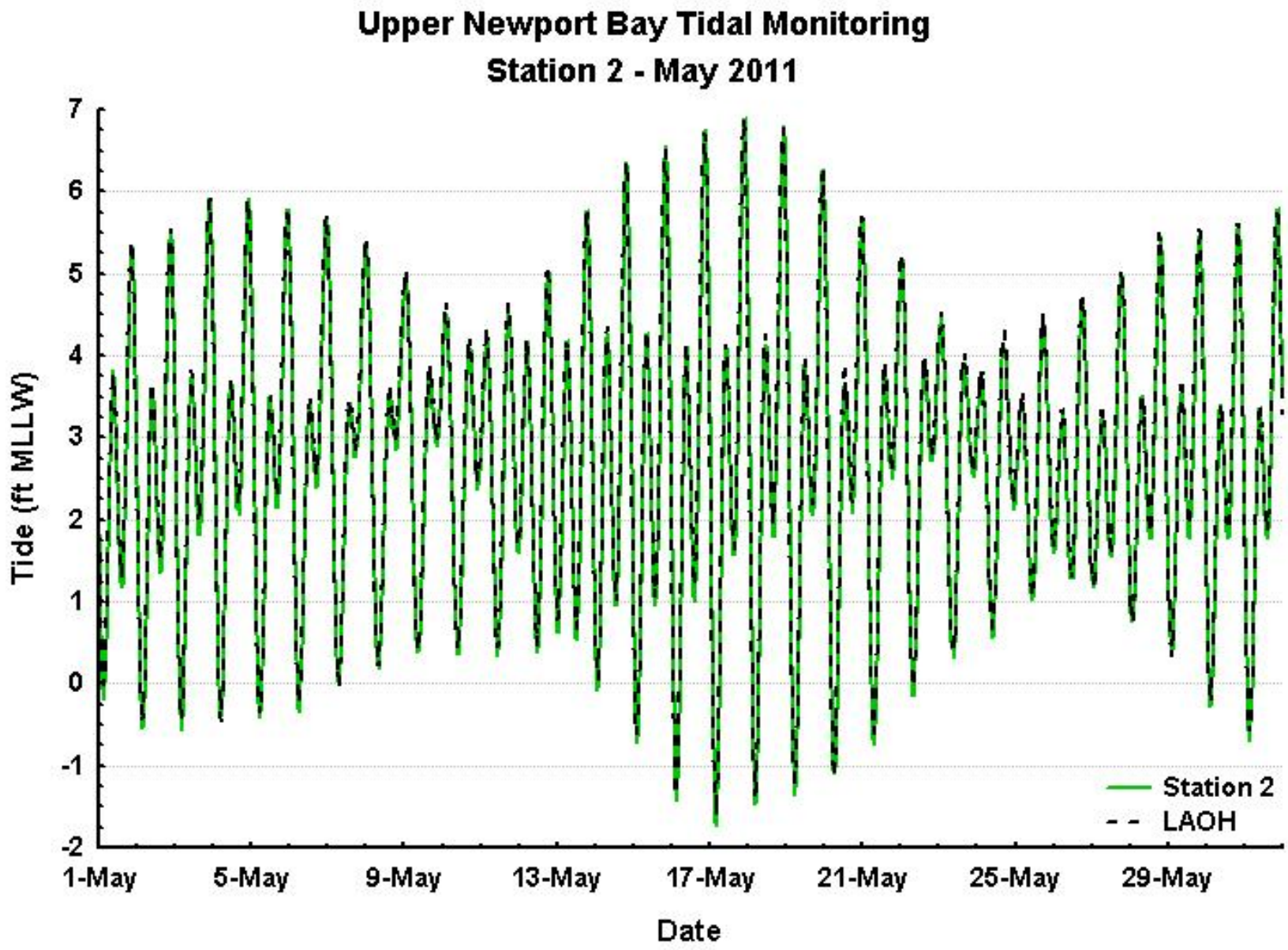
Tide data at UNB Station 2 and Los Angeles Outer Harbor, April 2011 (feet, MLLW).



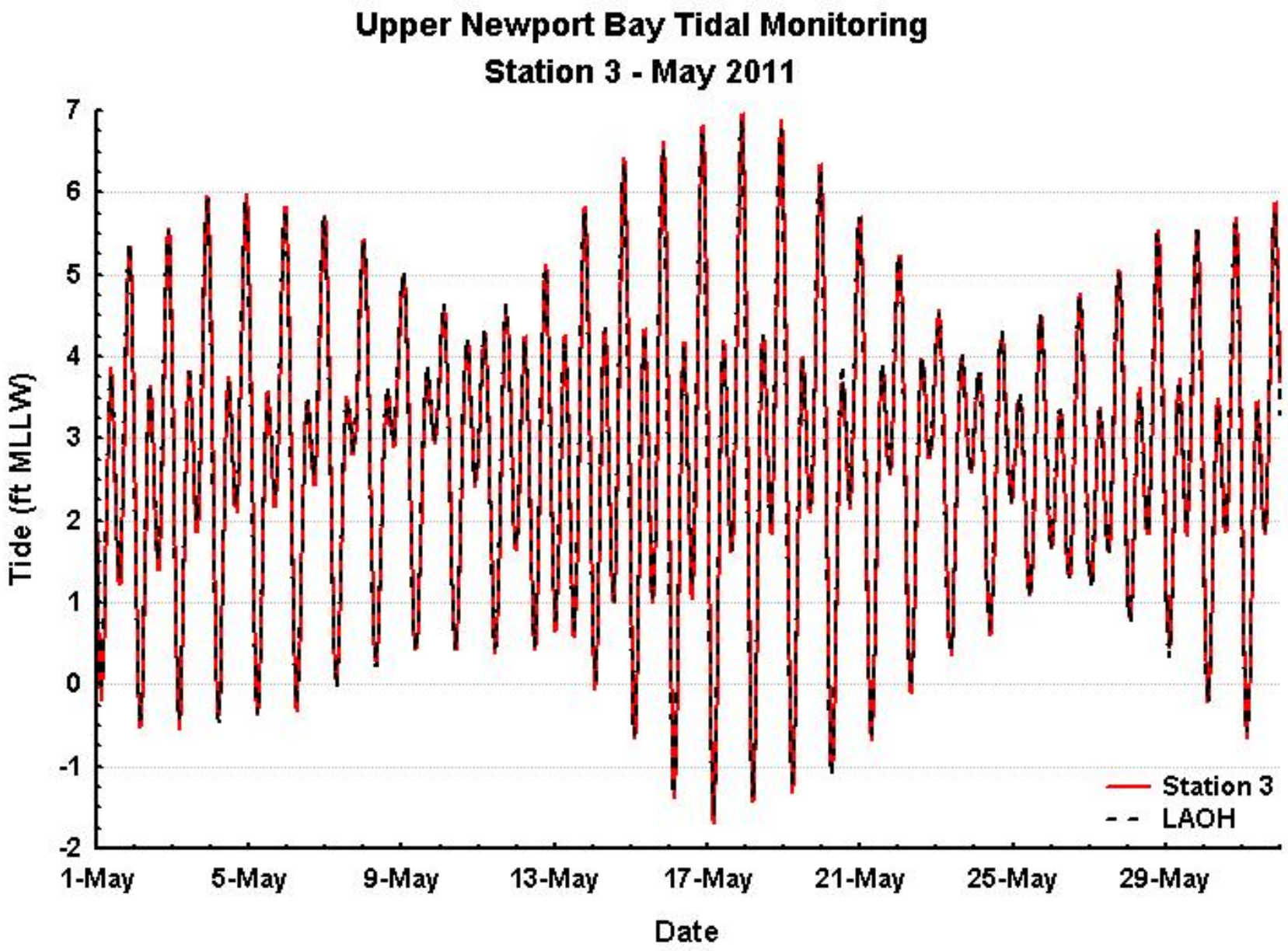
Tide data at UNB Station 3 and Los Angeles Outer Harbor, April 2011 (feet, MLLW).



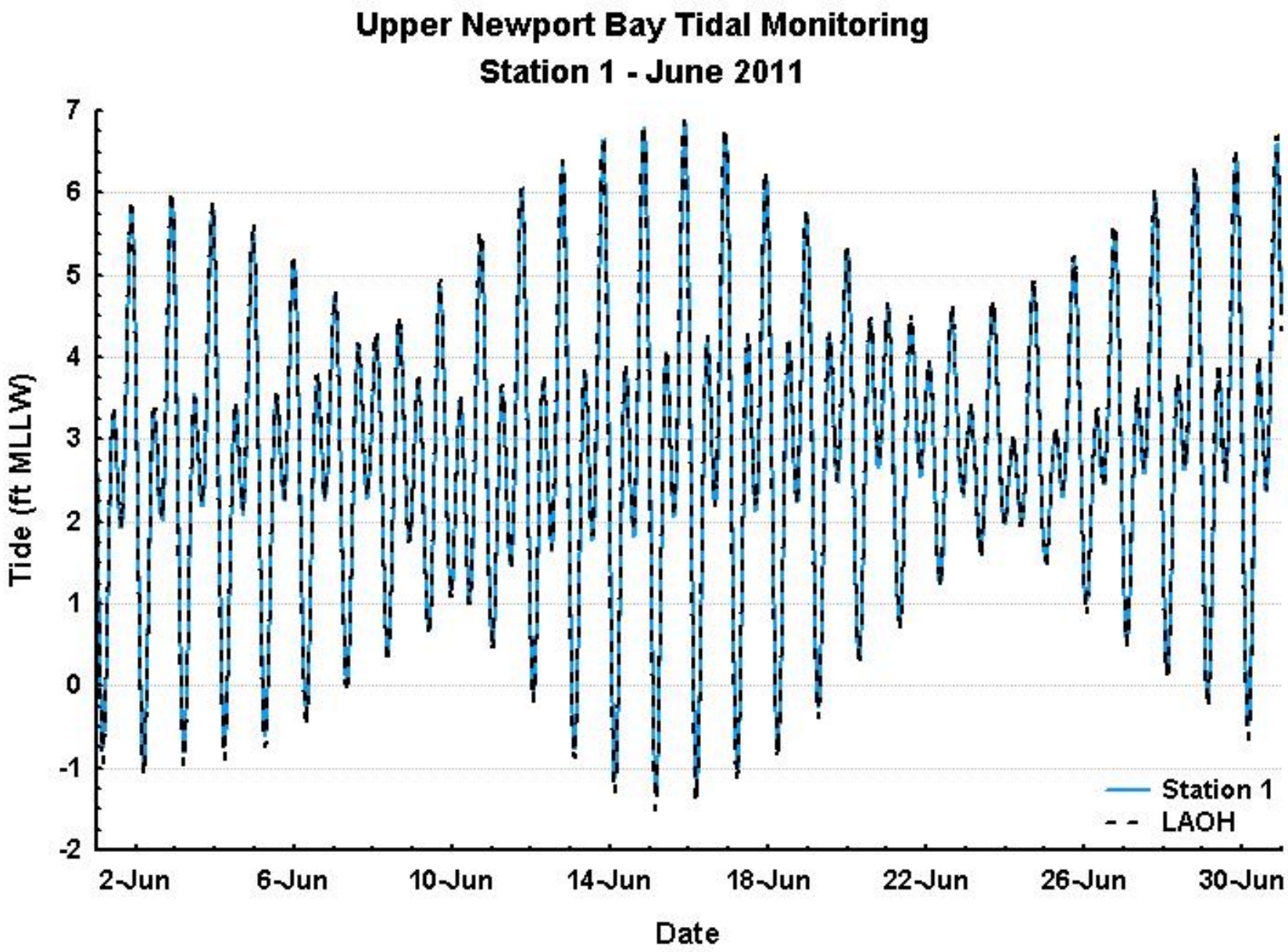
Tide data at UNB Station 1 and Los Angeles Outer Harbor, May 2011 (feet, MLLW).



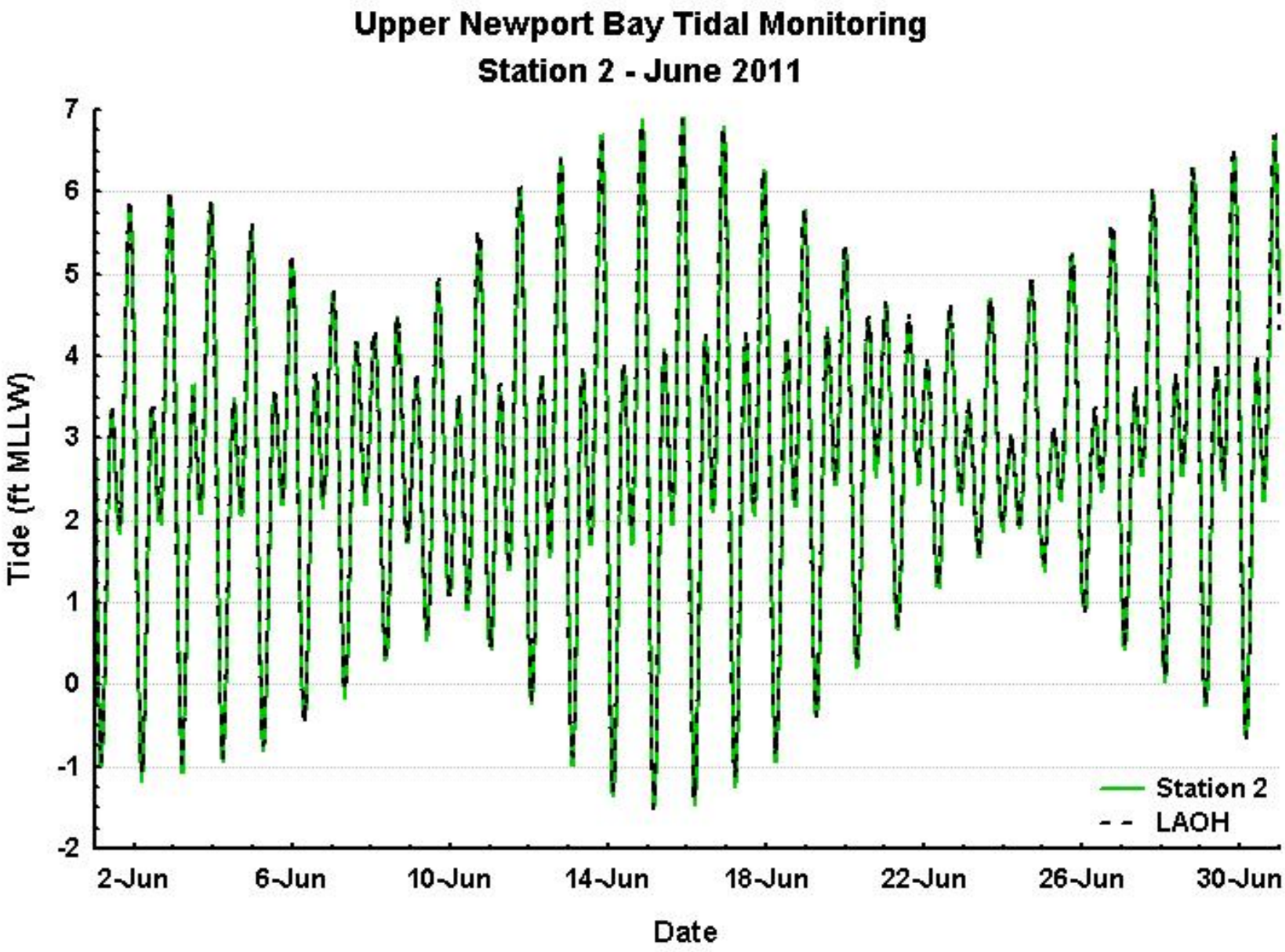
Tide data at UNB Station 2 and Los Angeles Outer Harbor, May 2011 (feet, MLLW).



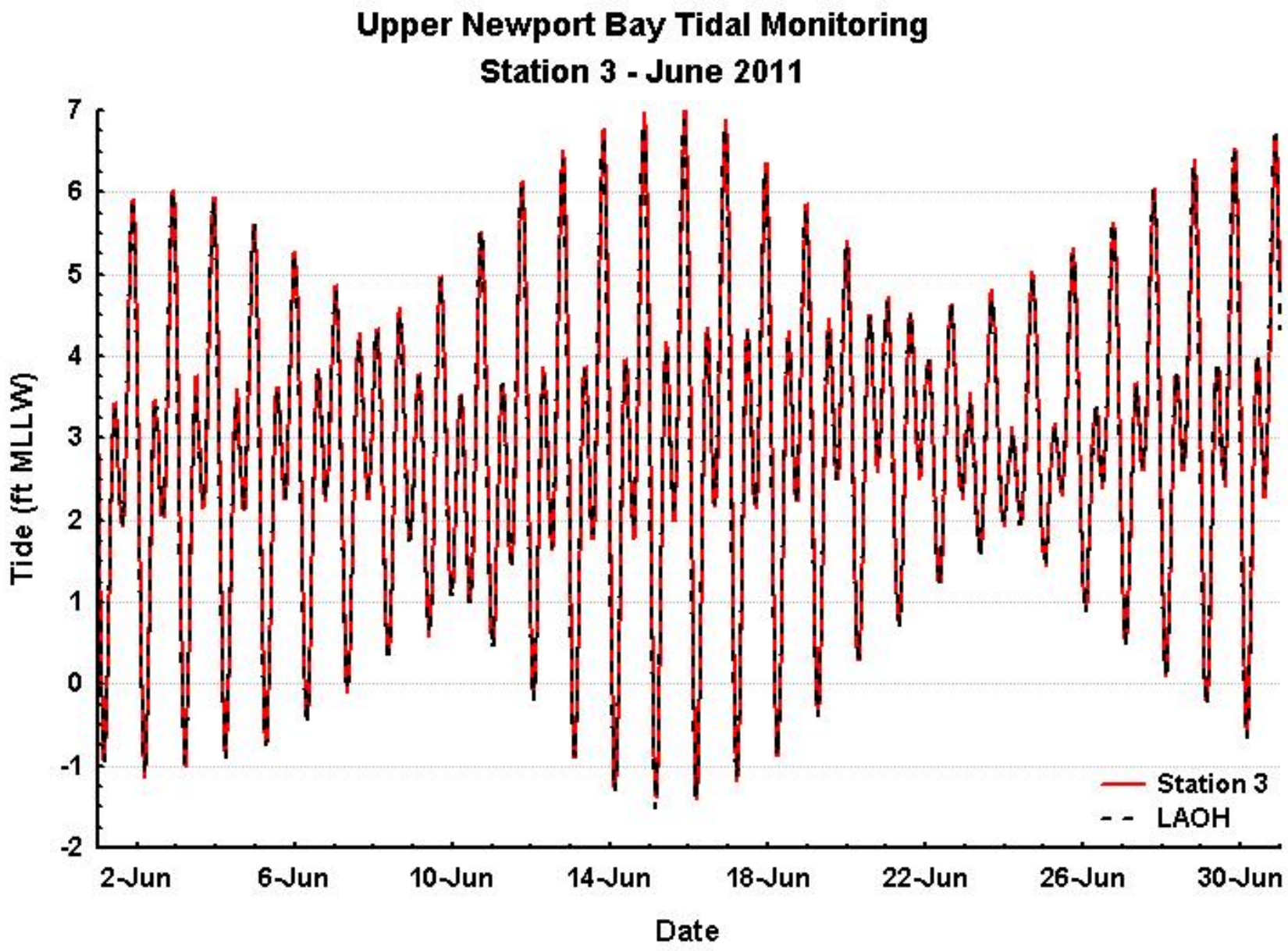
Tide data at UNB Station 3 and Los Angeles Outer Harbor, May 2011 (feet, MLLW).



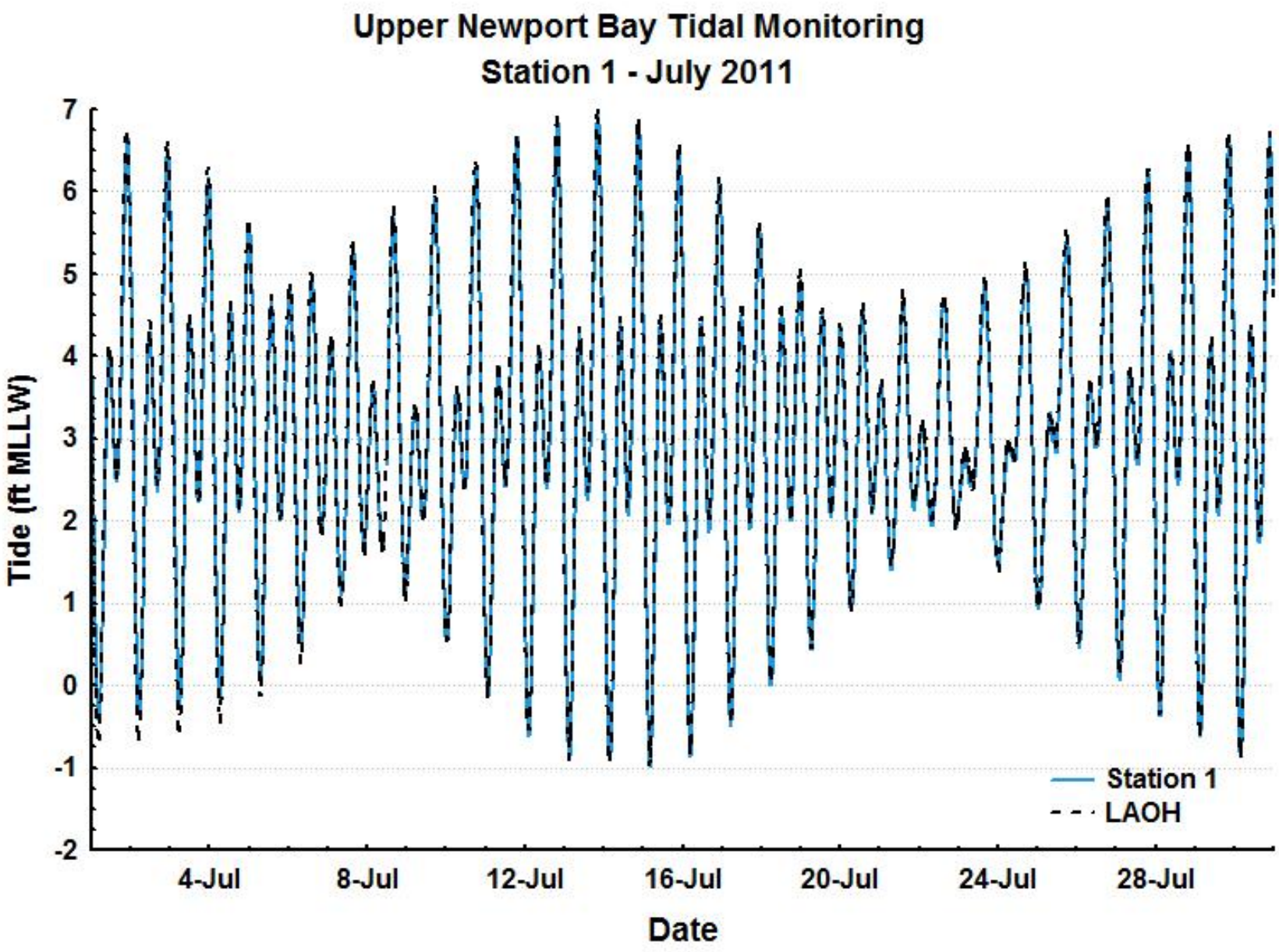
Tide data at UNB Station 1 and Los Angeles Outer Harbor, June 2011 (feet, MLLW).



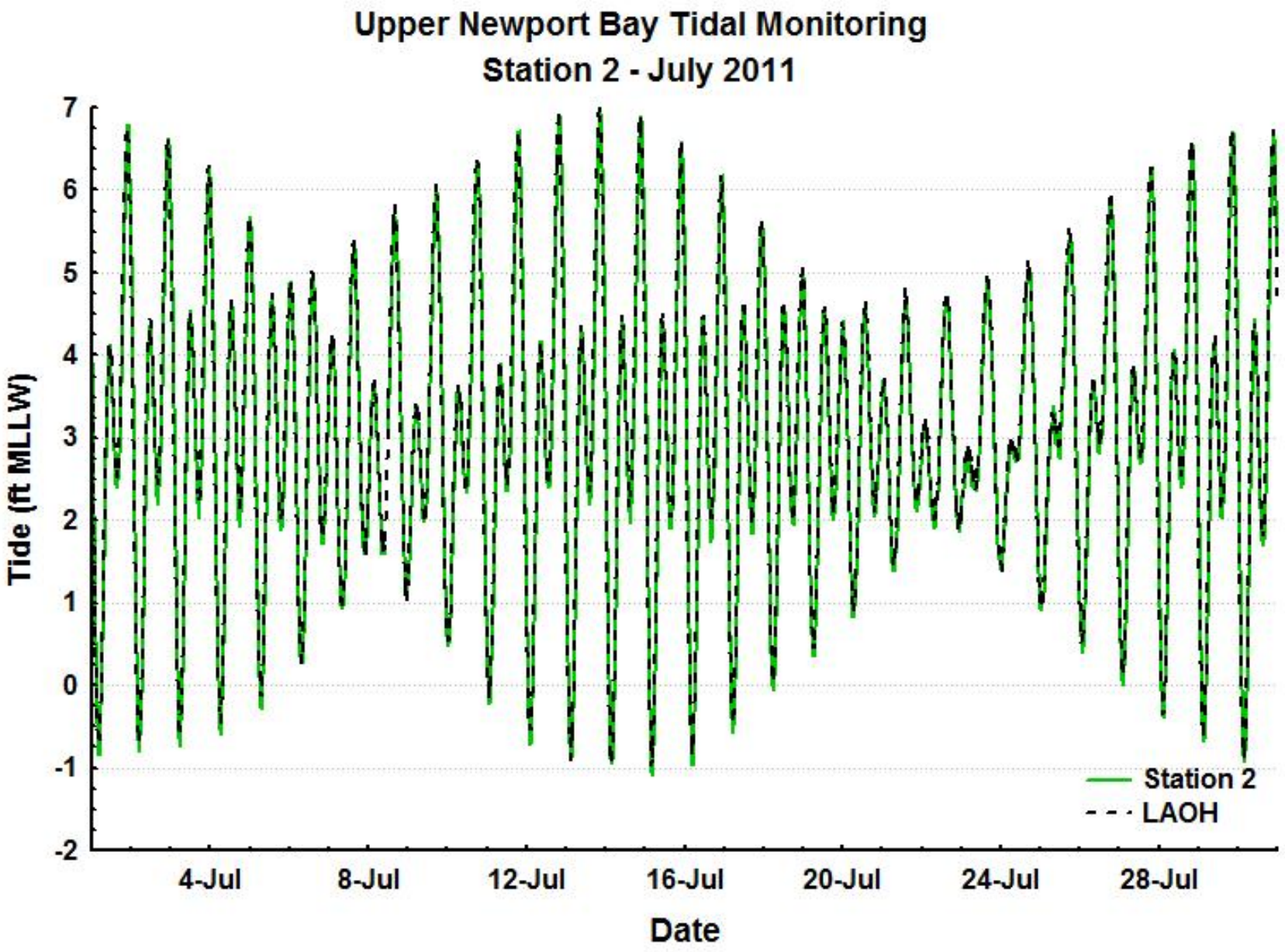
Tide data at UNB Station 2 and Los Angeles Outer Harbor, June 2011 (feet, MLLW).



Tide data at UNB Station 3 and Los Angeles Outer Harbor, June 2011 (feet, MLLW).

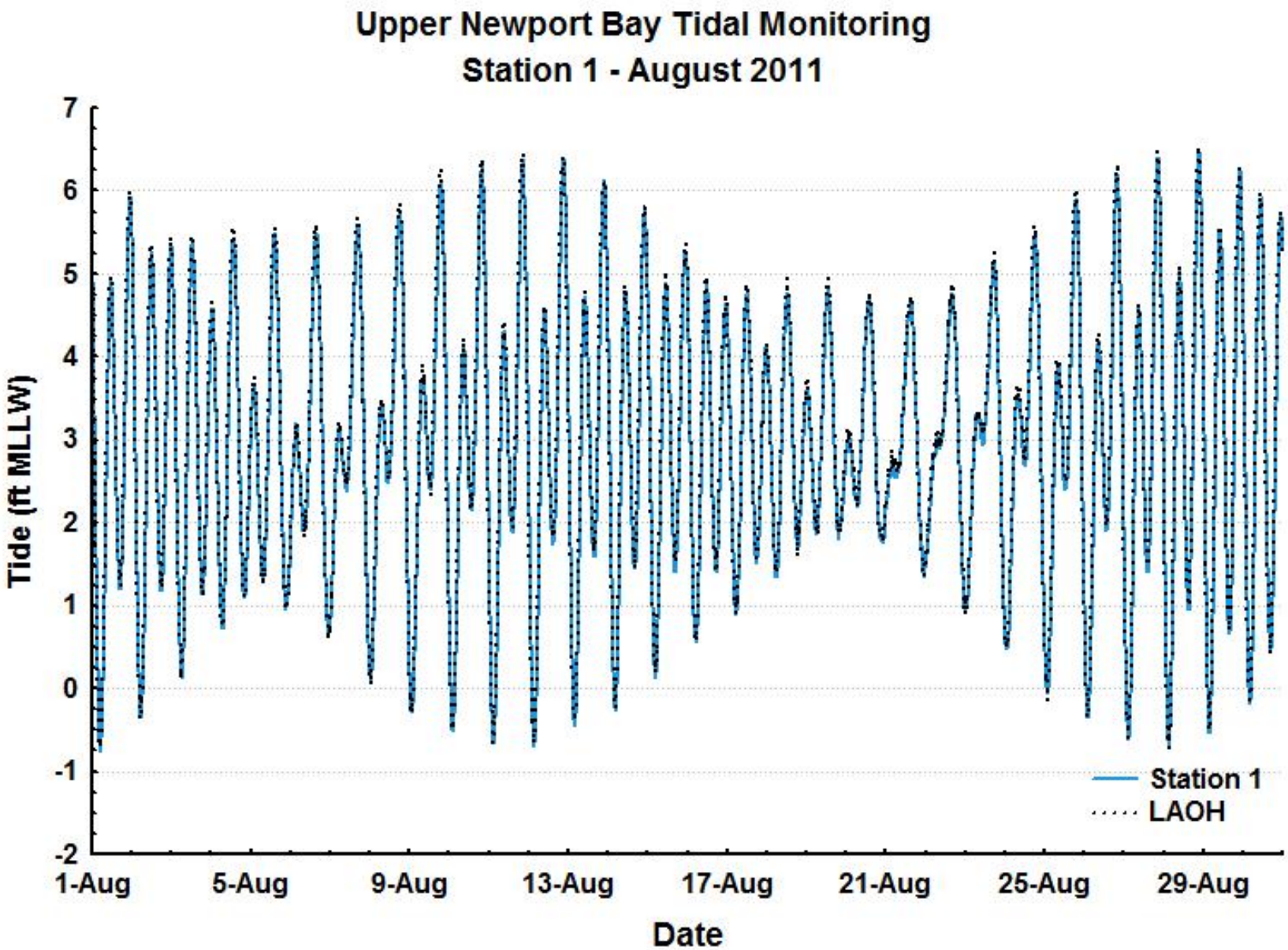


Tide data at UNB Station 1 and Los Angeles Outer Harbor, July 2011 (feet, MLLW).

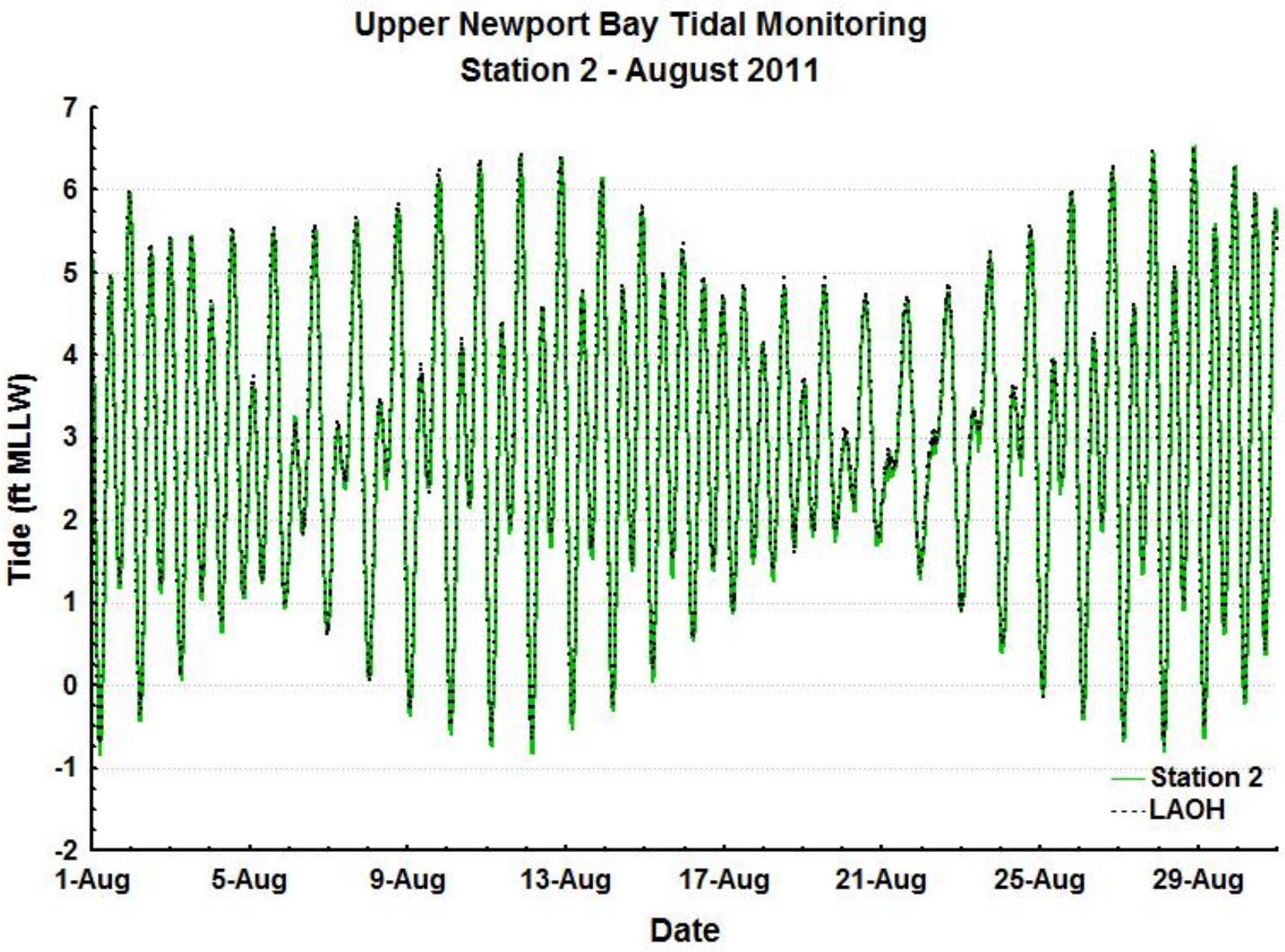


Tide data at UNB Station 2 and Los Angeles Outer Harbor, July 2011 (feet, MLLW).

July 2011 tide data at UNB Station 3 lost due to equipment failure.

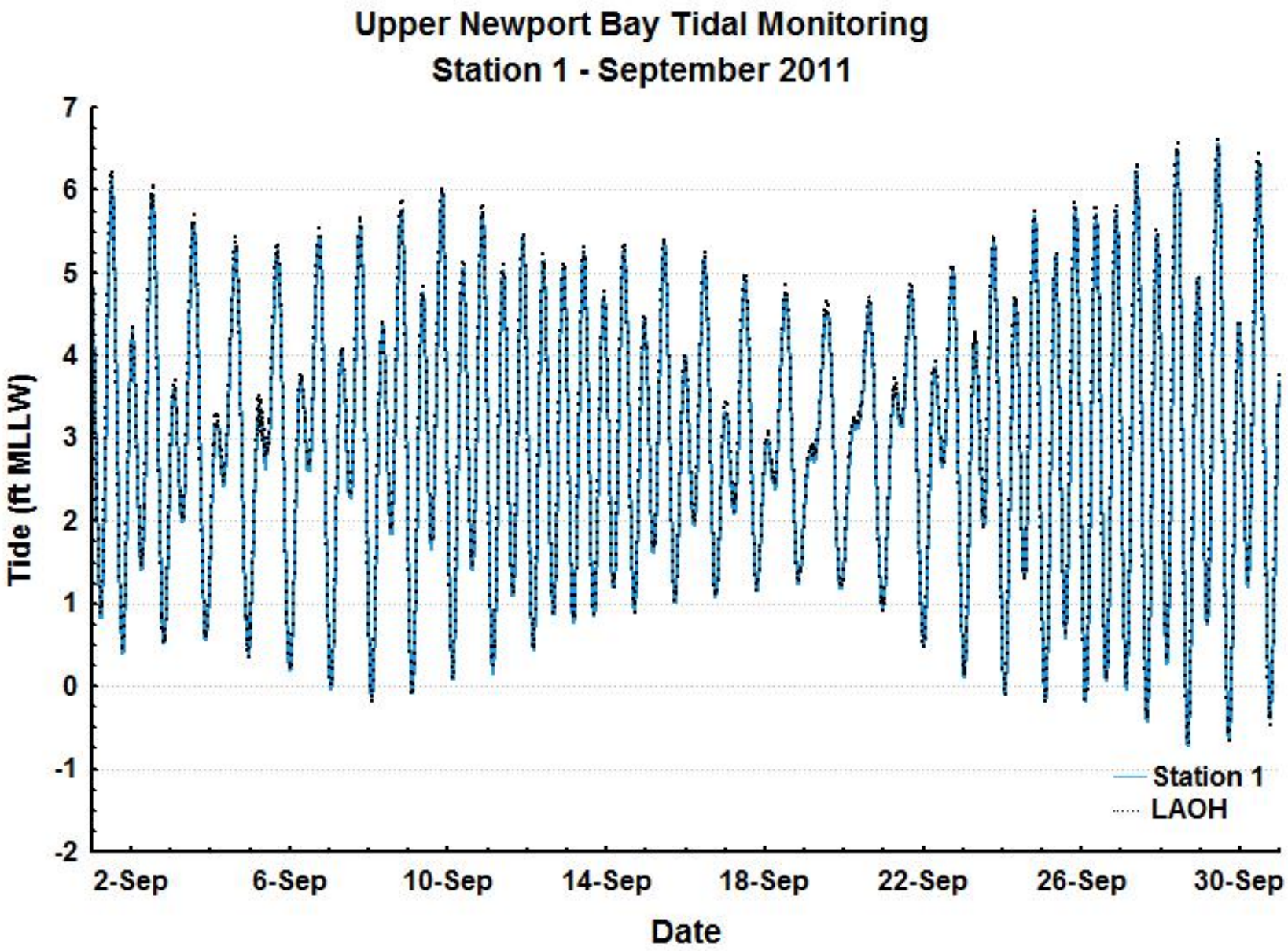


Tide data at UNB Station 1 and Los Angeles Outer Harbor, August 2011 (feet, MLLW).

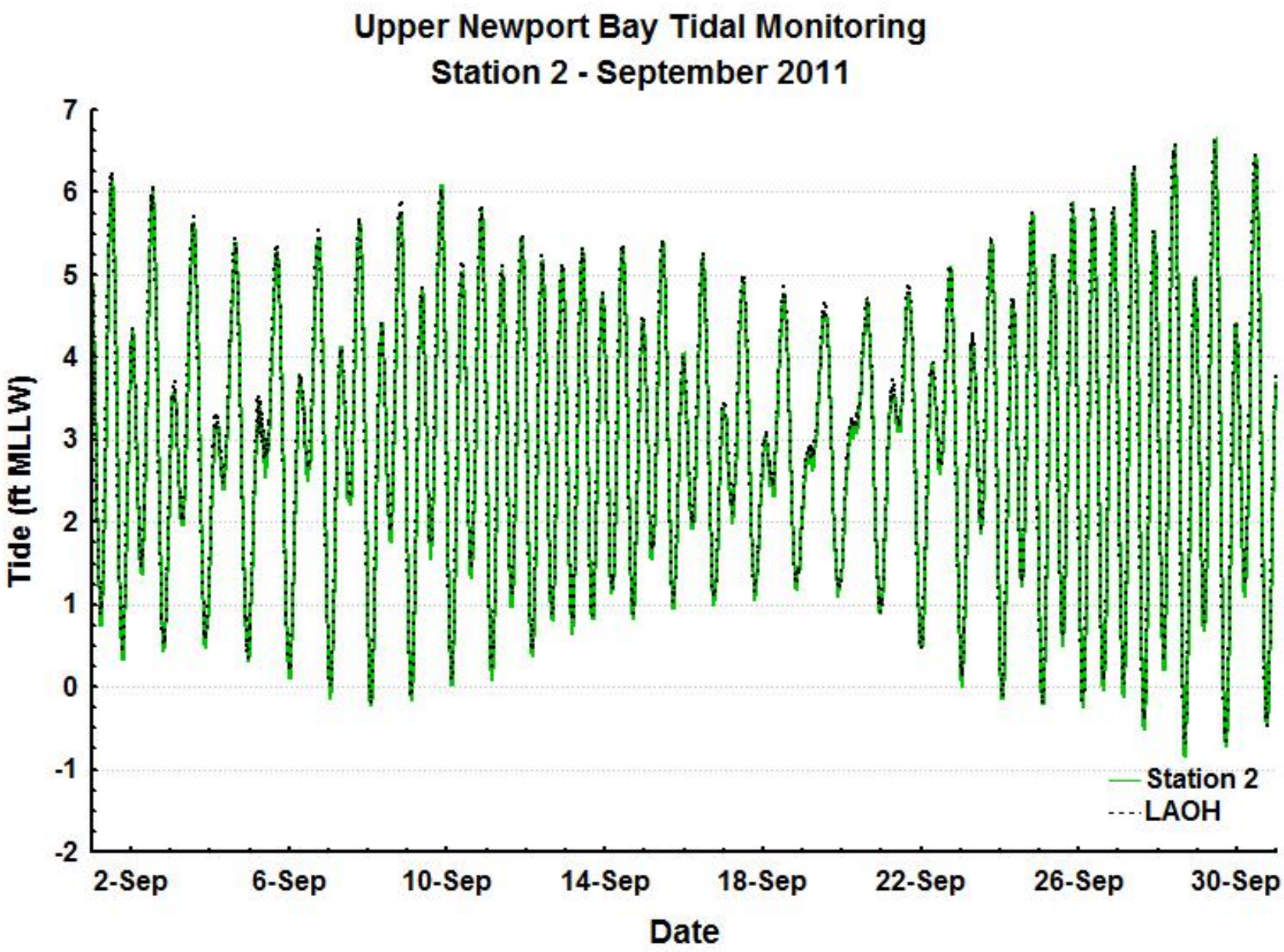


Tide data at UNB Station 2 and Los Angeles Outer Harbor, August 2011 (feet, MLLW).

August 2011 tide data at UNB Station 3 lost due to equipment failure.

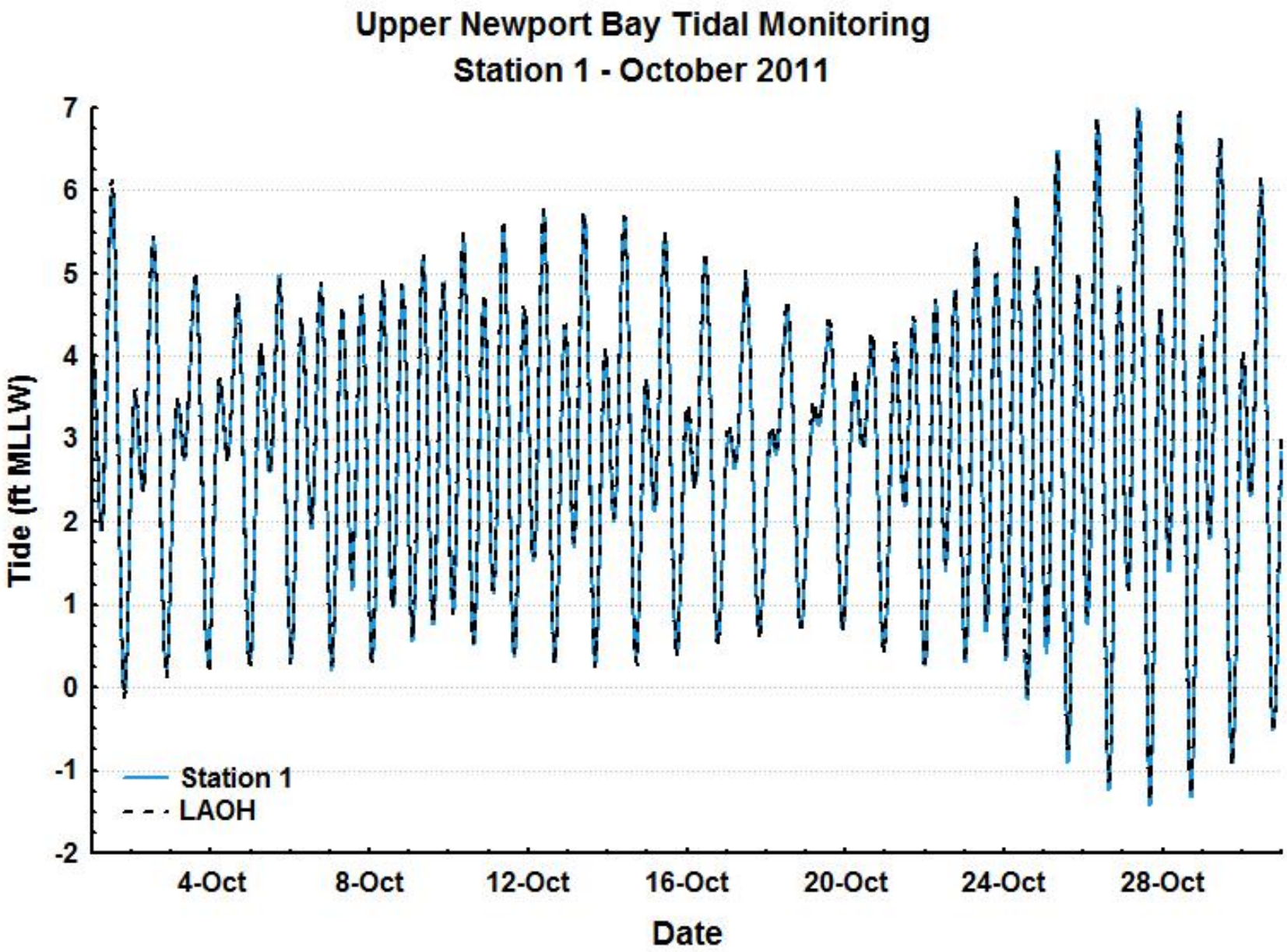


Tide data at UNB Station 1 and Los Angeles Outer Harbor, September 2011 (feet, MLLW).

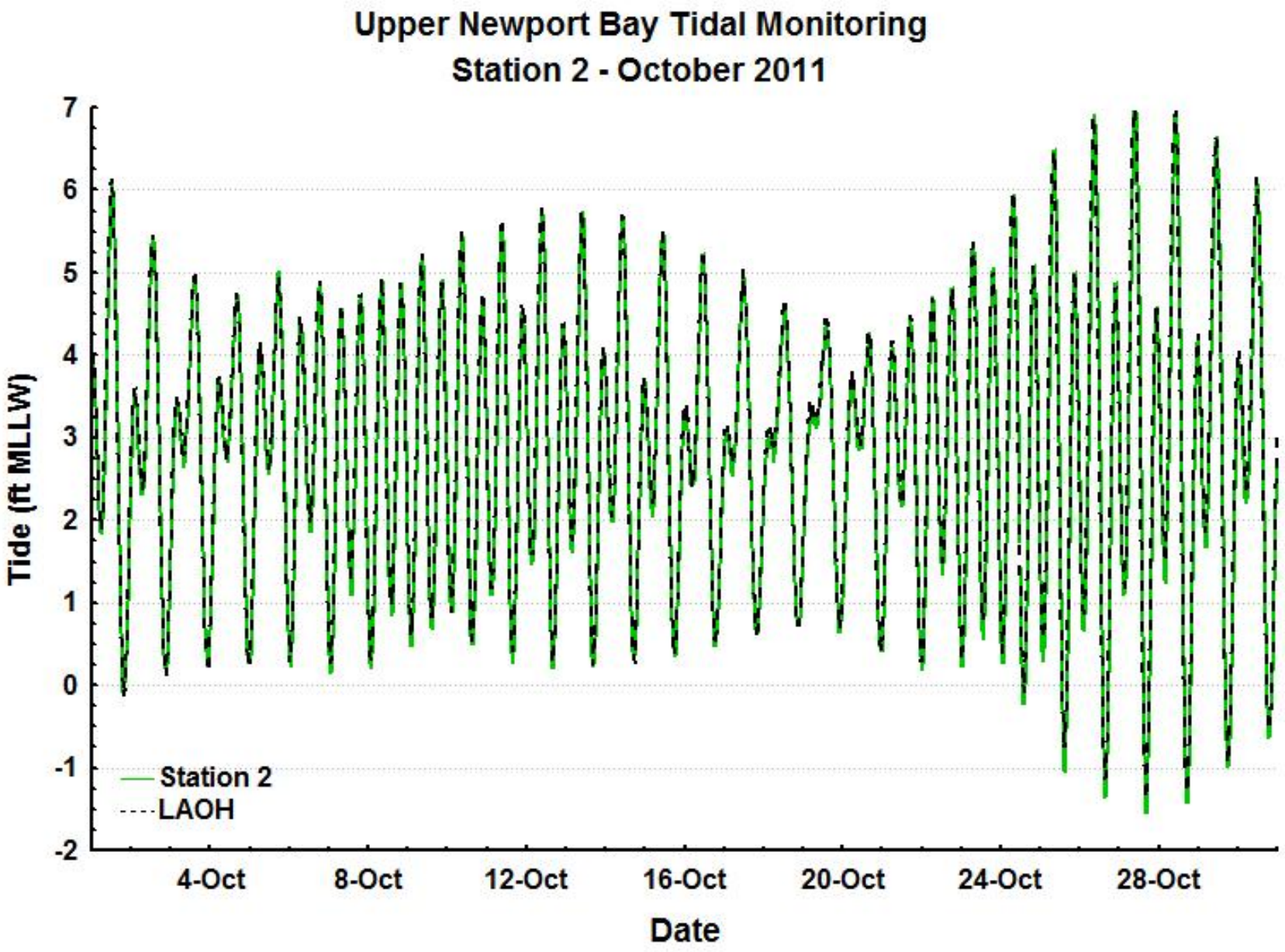


Tide data at UNB Station 2 and Los Angeles Outer Harbor, September 2011 (feet, MLLW).

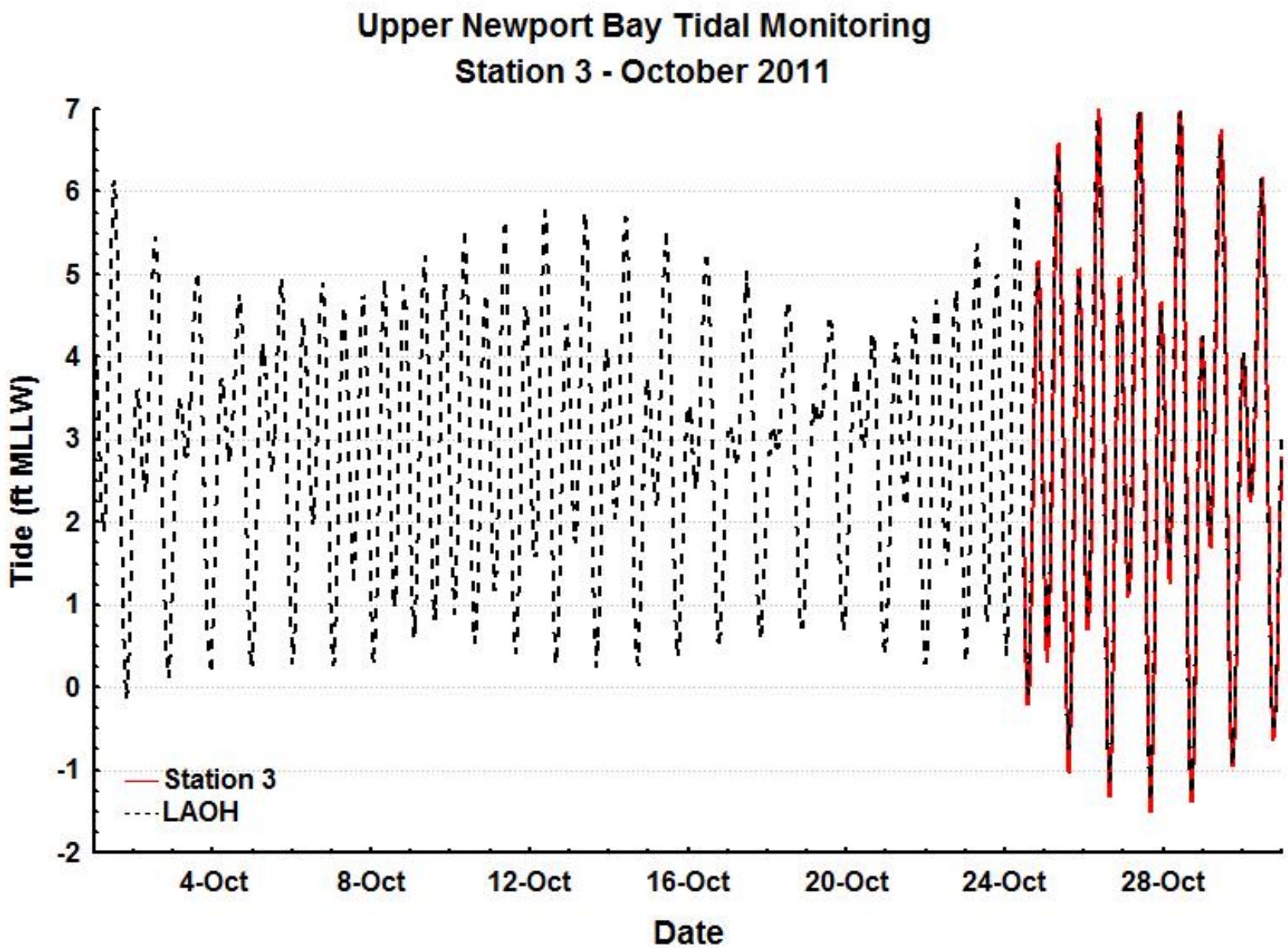
September 2011 tide data at UNB Station 3 lost due to equipment failure.



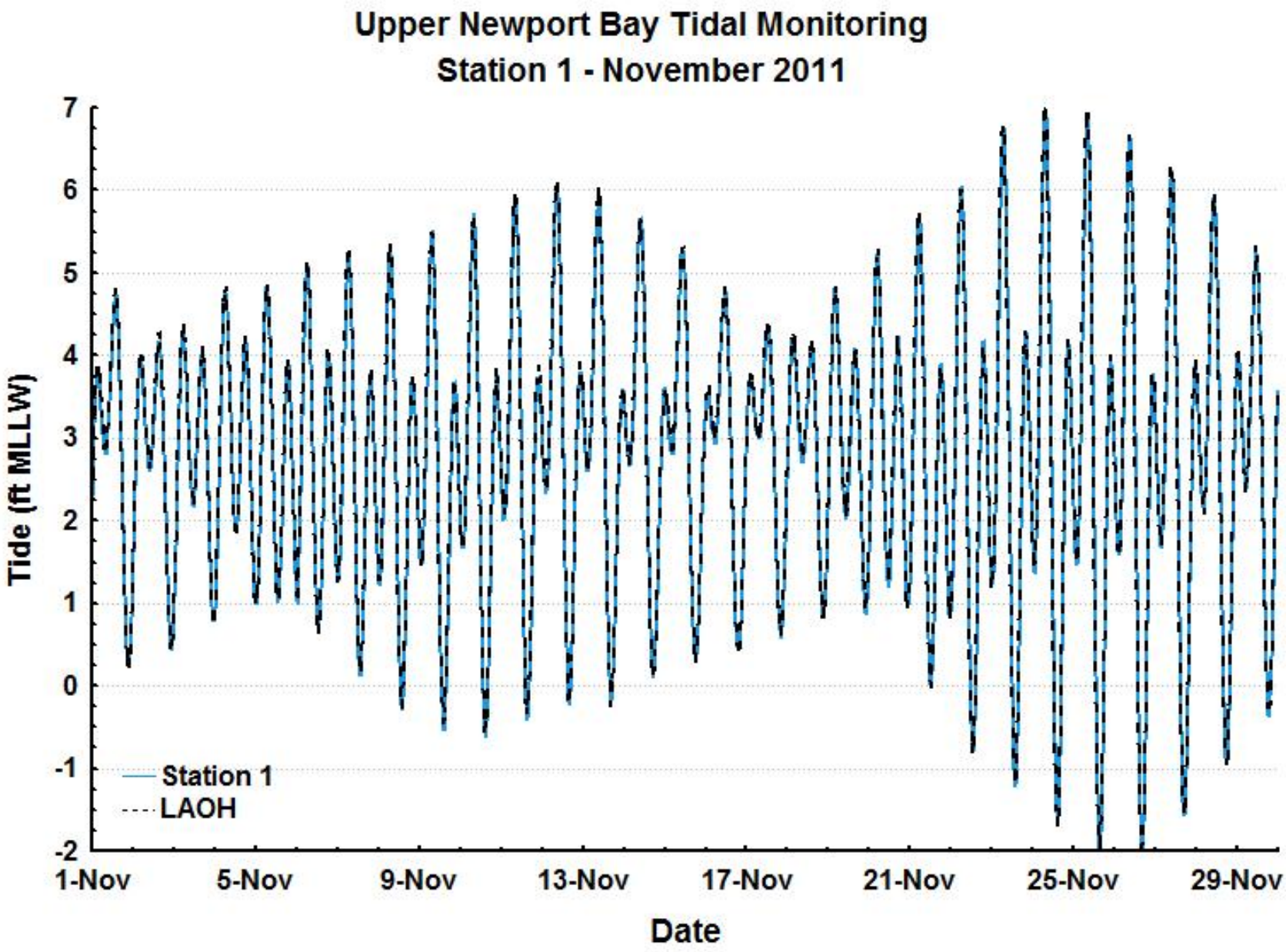
Tide data at UNB Station 1 and Los Angeles Outer Harbor, October 2011 (feet, MLLW).



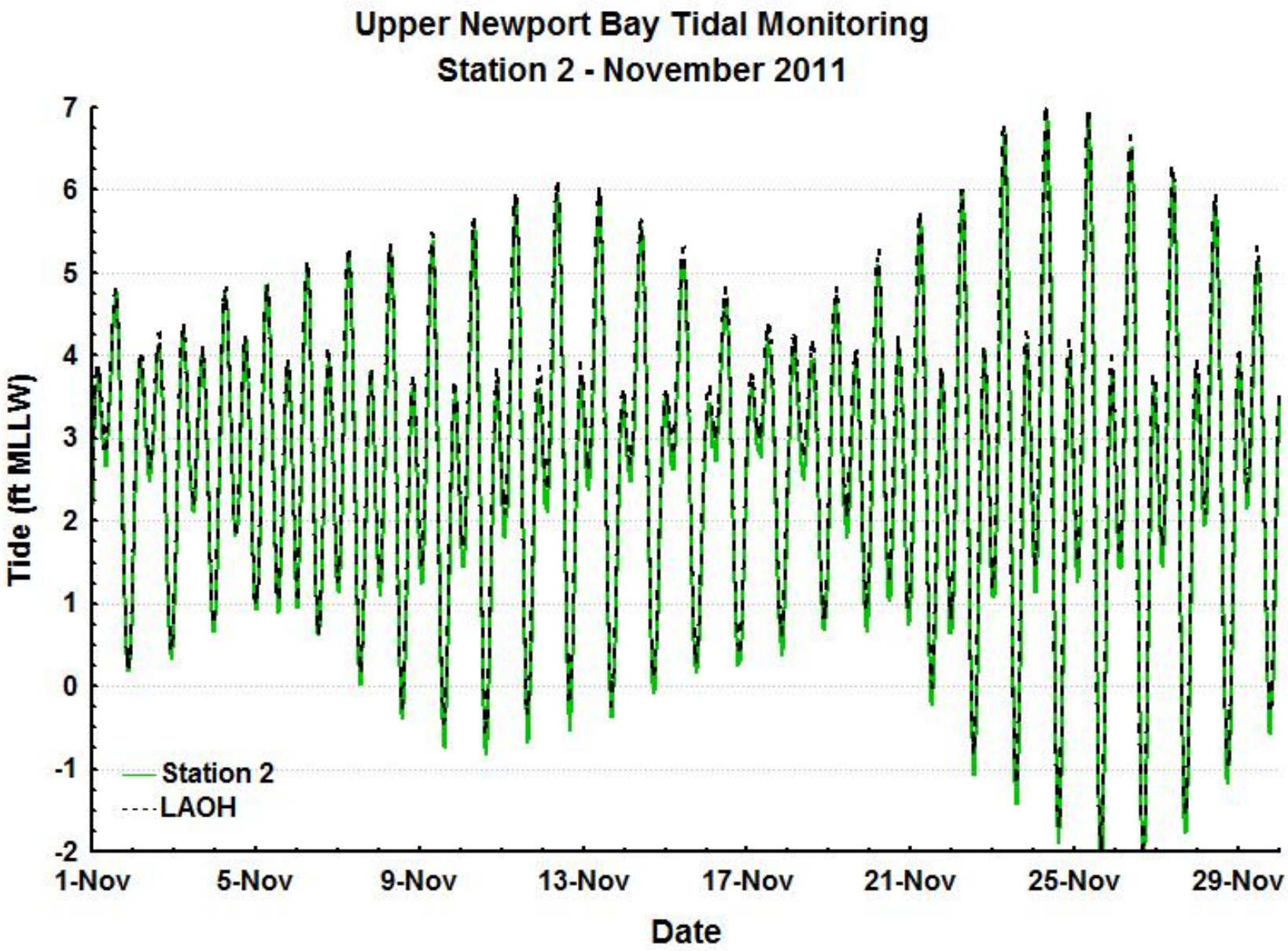
Tide data at UNB Station 2 and Los Angeles Outer Harbor, October 2011 (feet, MLLW).



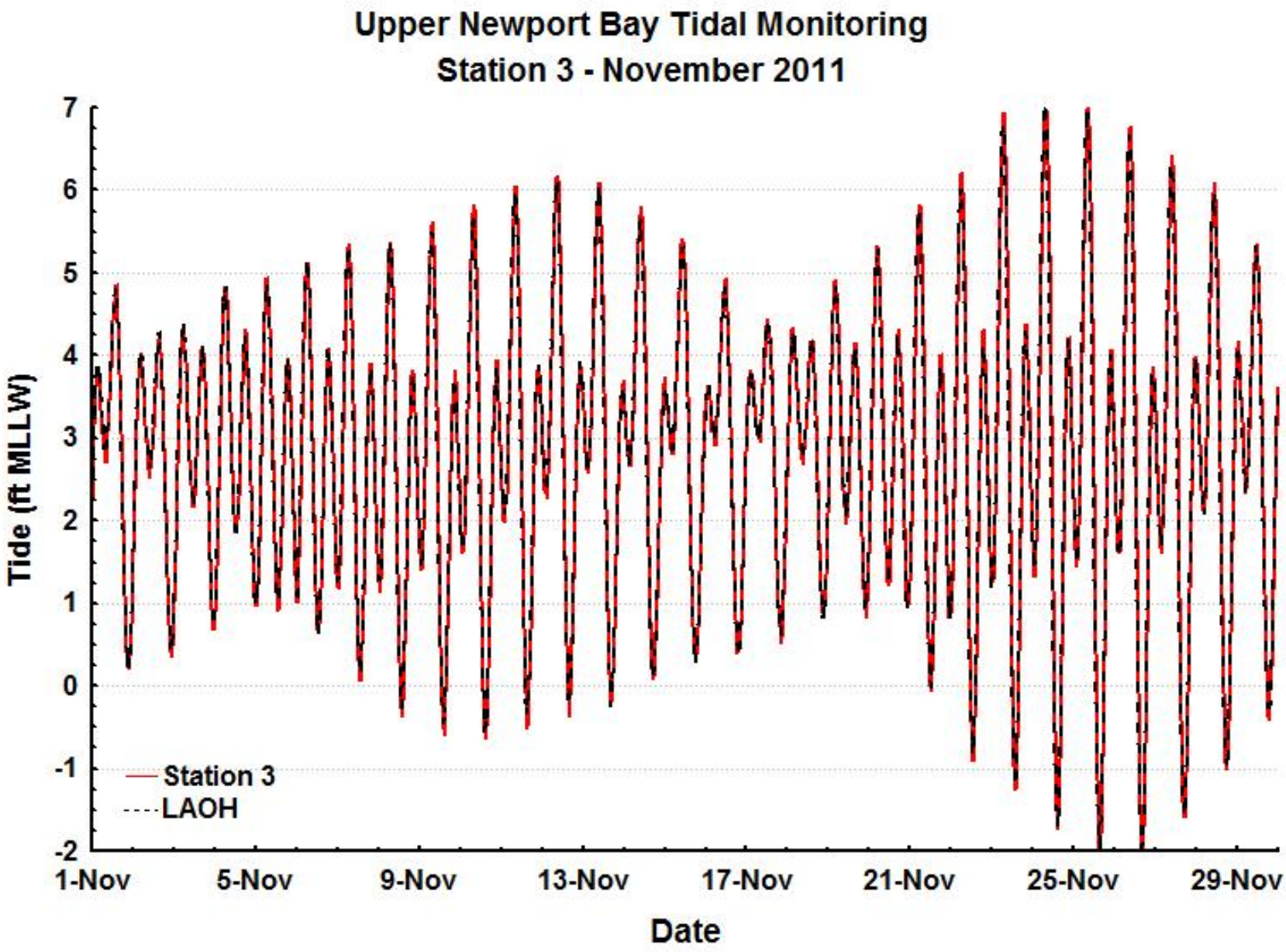
Tide data at UNB Station 3 and Los Angeles Outer Harbor, October 2011 (feet, MLLW), partial data loss at Station 3.



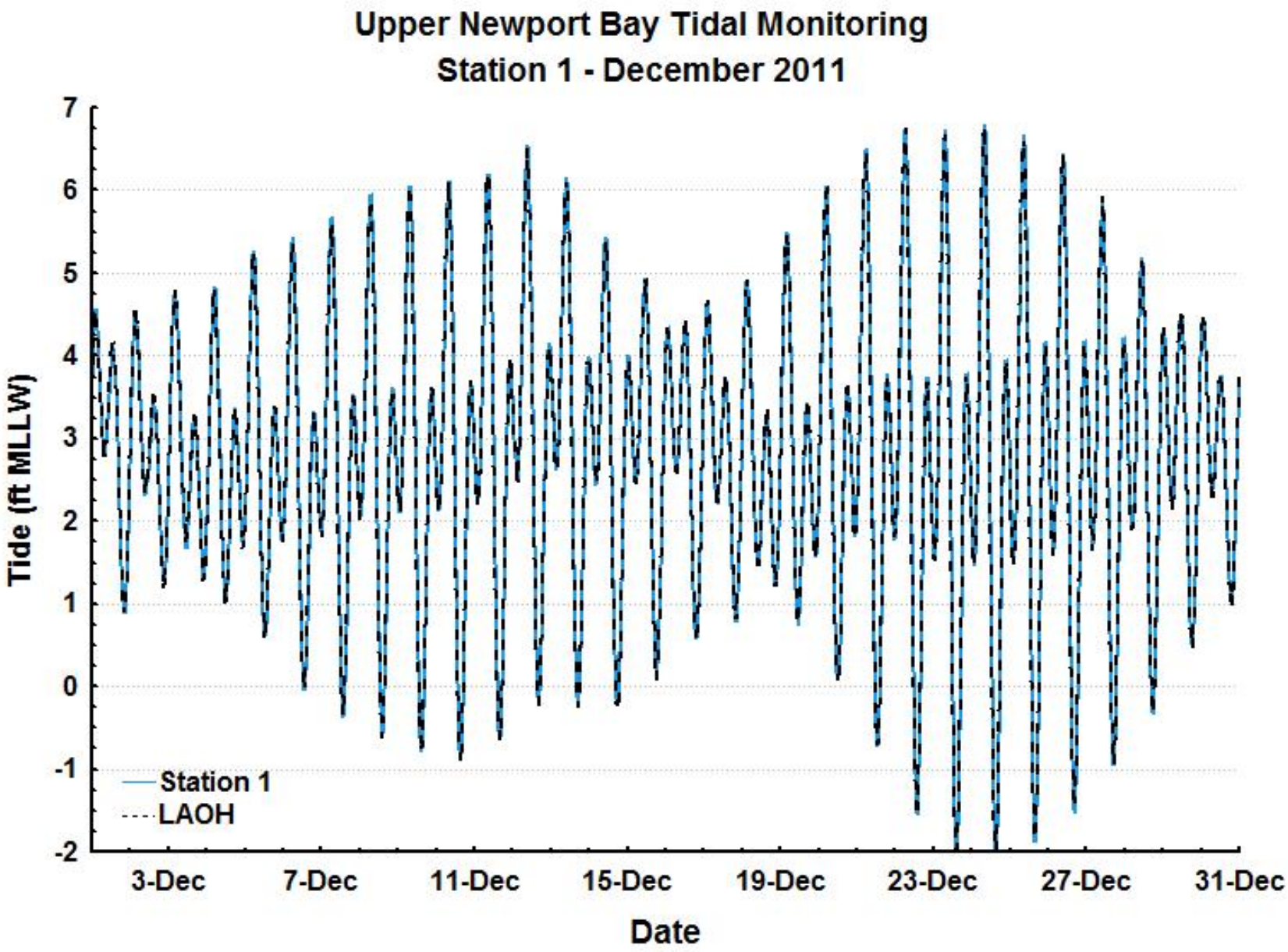
Tide data at UNB Station 1 and Los Angeles Outer Harbor, November 2011 (feet, MLLW).



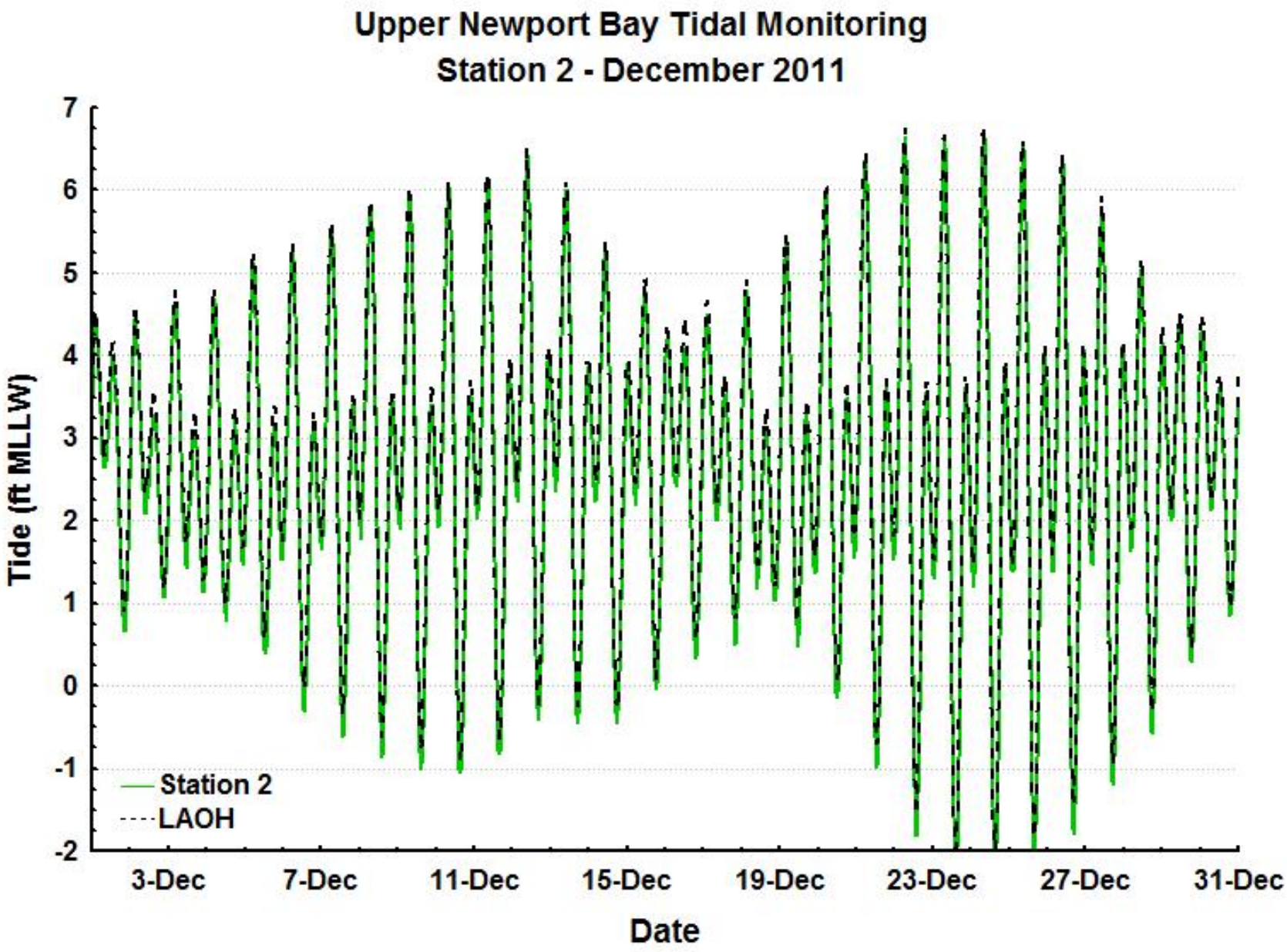
Tide data at UNB Station 2 and Los Angeles Outer Harbor, November 2011 (feet, MLLW).



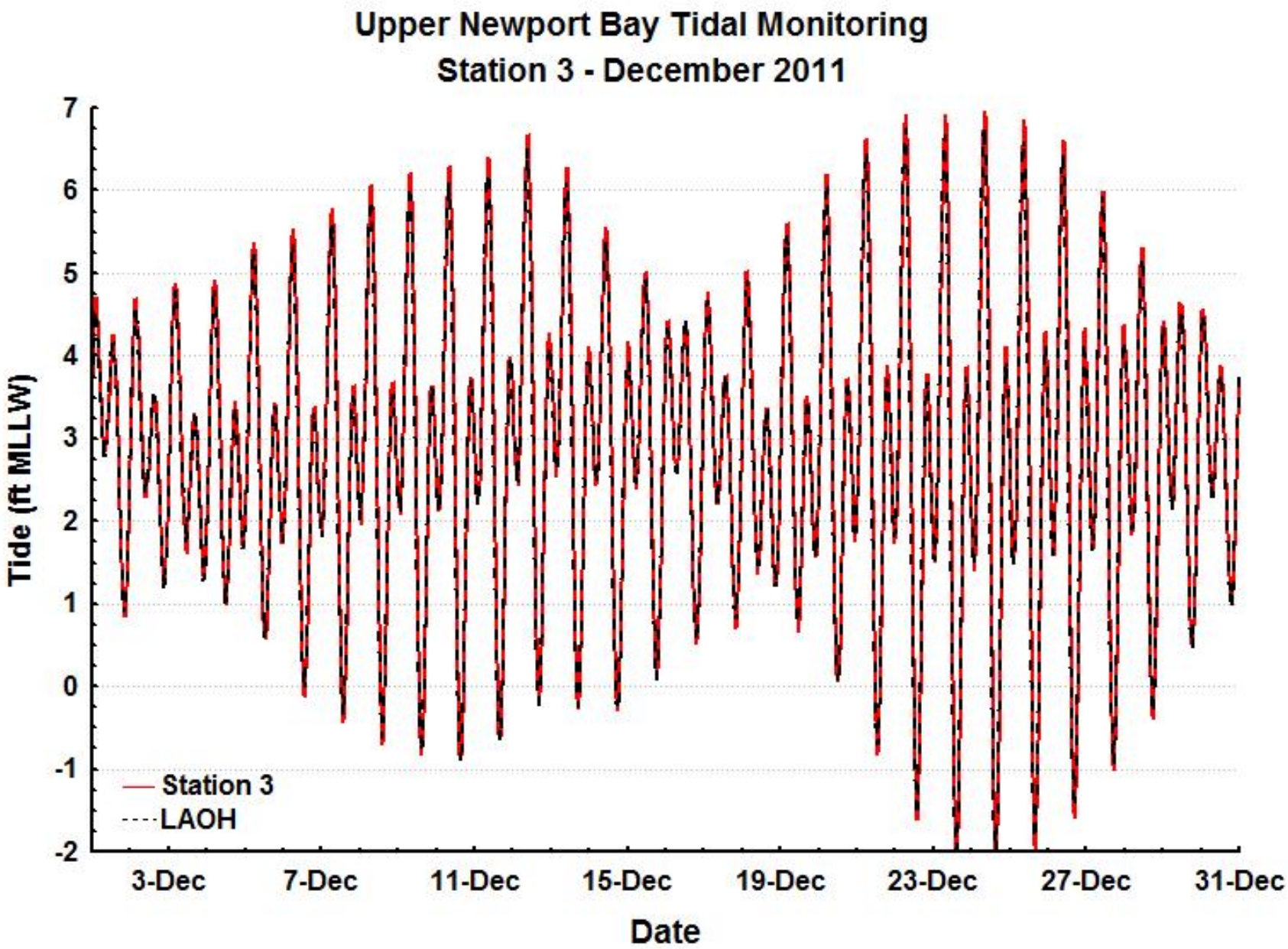
Tide data at UNB Station 3 and Los Angeles Outer Harbor, November 2011 (feet, MLLW).



Tide data at UNB Station 1 and Los Angeles Outer Harbor, December 2011 (feet, MLLW).



Tide data at UNB Station 2 and Los Angeles Outer Harbor, December 2011 (feet, MLLW).



Tide data at UNB Station 3 and Los Angeles Outer Harbor, December 2011 (feet, MLLW).

Appendix D
Photos

Photo 1. Looking east from Station 6 at the San Diego Creek weir under Jamboree Road (3/25/11).

Photo 2. Looking east at south end of Jamboree Road bridge and weir (3/25/11).

Photo 3. Tern Island nesting area (1/25/11).

Photo 4. Tern Island weeds on north shoreline slope (1/25/11).

Photo 5. Tern Island controlled weeds on south shoreline slope (1/25/11).

Photo 6. Tern Island nesting area (1/25/11).

Photo 7. Tern Island gravel ramp placed for maintenance access by California Department of Fish and Game.

Photo 8. Tern Island erosion on south shore (1/25/11).

Photo 9. New Least Tern Island – suitable nesting area (1/25/11).

Photo 10. New Least Tern Island weeds (1/25/11).

Photo 11. New Least Tern Island (1/25/11).

Photo 12. New Least Tern Island (1/25/11).

Photo 13. New Least Tern Island (September 21, 2011).

Photo 14. New Least Tern Island cordgrass planting area with small plants visible (1/25/11).

Photo 15. Cordgrass plant with new green shoots (1/25/11).