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Fort McHenry Wetlands Restoration Project

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U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Center for Operational Oceanographic Products and Services

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National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

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INTRODUCTION

In 1982, the man-made Fort (Ft.) McHenry wetland was created by the Maryland Department of Transportation to offset environmental impacts from the development of the Ft. McHenry tunnel (USACE 1987). The 10-acre wetland is located at the southern extent of the Ft. McHenry National Monument and Historic Shrine. The National Park Service (NPS) received grant funding in 1997 to remove debris aggregation, as well as restore and research the wetland (Sullivan 2013). The wetlands were reconstructed in early 2004 from mitigation credits for filling in a nearby port slip that allowed more shipping containers to be offloaded. Figure 1 is an aerial photograph of Ft. McHenry wetlands and the vicinity showing where the wetlands are relative to the Fort, and Figure 2 is a photo overlook view of the wetland before restoration.

When constructed in 1982, this wetland had 3 small culverts through the riprap that encircled the site, allowing tidal exchange with adjacent harbor waters. These culverts eventually silted in, largely cutting off tidal exchange and degrading wetland function at the site. The purpose of the modifications described in this report was to promote regular, natural tidal flooding to the site, control debris accumulation, and enhance the site's habitat value to plant and animal species.

The restriction of tidal flow had resulted in several deleterious effects that could be reversed if normal tidal exchange was restored. Primary among these was an invasion by the common wetland reed *Phragmites australis*. *Phragmites* tend to invade and successfully colonize salt wetlands that lose their source of tidal exchange (Chambers et al. 2012). This process can be exacerbated by the presence of freshwater runoff at the site, which was present in the wetlands at Fort McHenry (Chambers et al. 2012). The new modifications described in this report resulted in the physical removal of several existing *Phragmites* stands, which were, depending on the exact location, either replaced with planted native vegetation (e.g., smooth cordgrass [*Spartina alterniflora*]; salt meadow cordgrass [*Spartina patens*]) or converted to intertidal creek habitat. The return of tidal saltwater exchange to the site via the new inlets and network of created creeks potentially benefited the entire site by minimizing its susceptibility to continued *Phragmites* expansion (Morris et.al. 2002)

The system which had been in place prior to NOAA's restoration consisted mostly of silted-in culverts, which prevented the juveniles of migratory fish species (e.g., striped bass [*Morone saxatilis*], spot [*Leiostomus xanthurus*], and river herrings [*Alosa* spp.]) from utilizing the site as nursery habitat. The restoration plan produced 2 inlets to the harbor allowing fish access to the constructed creek network in the wetland. Tidal creeks are well known to be a high-quality foraging habitat for the juveniles of many fish species and many juvenile fish use the flooded wetland surface as foraging habitat during higher high tides (spring tides) (Desmond et al. 2000). As the plan was to return tidal flooding to the entire wetland surface during spring tides, it also had the potential to confer benefits to fish that would extend across the entire wetland. Other resident wetland fauna, including small fish and benthic invertebrates as well as birds and other larger animals that prey on these species, would also benefit from the return of natural tidal flooding to the constructed creeks and the wetland surface (Perry et al. 2001).

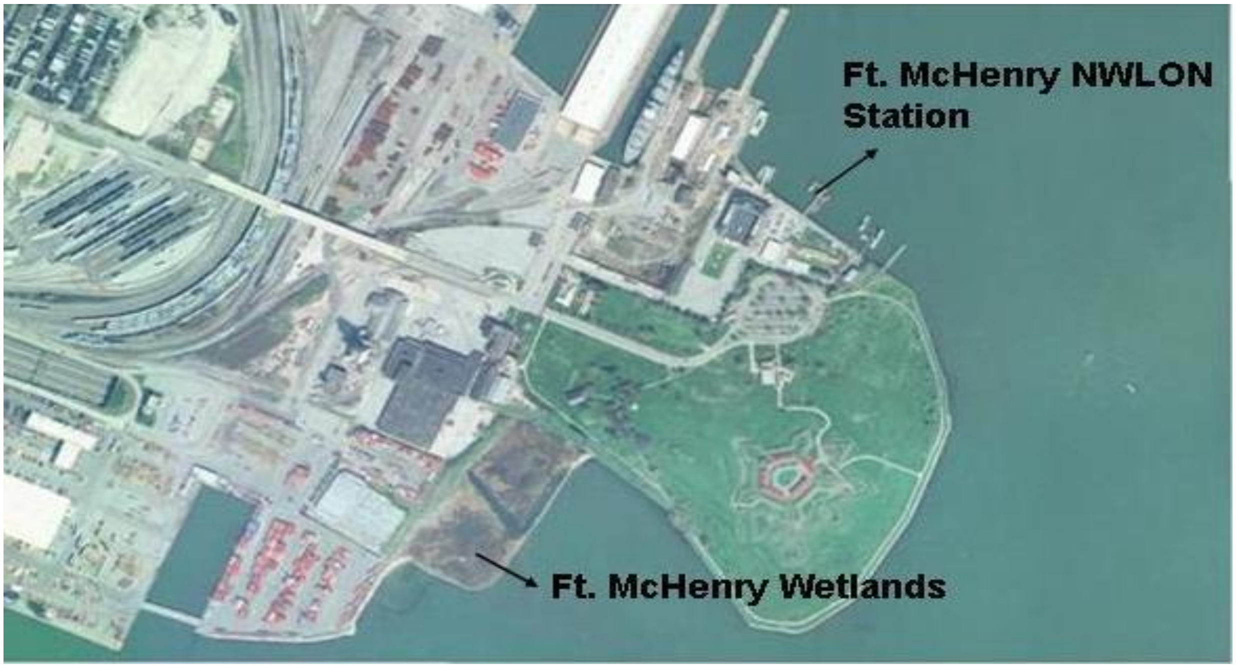

Figure 1. Location of Fort McHenry Wetlands Restoration Project with National Water Level Observation Network (NWLON) station at Patapsco River, Ft. McHenry, Baltimore, MD.

Figure 2. Photograph showing the extent of *Phragmites australis* across the Ft. McHenry wetland prior to 2002 restoration efforts.

The National Ocean Service (NOS) worked in partnership with the National Aquarium in Baltimore (NAIB) on these efforts to ensure the restoration of the Ft. McHenry wetland was completed. The NOS Center for Operational Oceanographic Products and Services (CO-OPS) and the NOS National Geodetic Survey (NGS) performed the tide and geodetic work described in this case study. A formal Memorandum of Agreement (MOA) had been established between NOS and the Maryland Port Authority (MPA) to transfer funds to cover costs for the installation of a new tide station, Ft. McHenry Marsh, MD (8574683).

METHODS

Perry et al. (2001) provide a discussion of the requirements for successful wetland restoration and the creation of salt wetlands within the Chesapeake Bay. Accurate tidal datums and an appropriate elevation gradient of the substrate are among the top considerations for the design and construction for wetland restoration. Information on the time-varying nature of inundation and drying is also required. The physiographic range of the associated vegetation is generally related to the elevation of mean high water (MHW) and mean higher high water (MHHW) for use in guidance of where to plant different species of wetland vegetation (McKee and Patrick 1988). Other considerations include how often wetland surfaces are irregularly flooded due to storm tides and maximum astronomical tides. The long-term viability of functioning wetlands is dependent upon proper accretion rates and sediment accumulation in response to local sea level rise.

Executing the construction plan entailed breaching the existing riprap at 3 locations to allow tidewater to enter the site unobstructed, and excavating a network of creek channels that tied into the existing creeks at several locations. The constructed creek network included primary creeks that communicated directly with the harbor via the inlets and smaller, second-order creeks branching off the primary creeks. After the site matures, third-order and smaller creeks formed as natural erosion forces shaped the site. The desired outcome was a fully-functioning wetland, characterized by a complex, dendritic channel network.

The technical approach for this project included the following:

- transfer tide and geodetic datums to the site from the nearby existing Baltimore (8574680) control tide station rather than establishing new control;
- conduct a topographic survey of the wetlands surface using Real-Time Kinematic Global Positioning System (RTK GPS) and develop a Digital Elevation Model (DEM) surface;
- provide the DEM and the tidal datum relationships to the wetlands design engineers; and
- design and construct the new wetlands using the reference information, establish a tide station on-site after construction for monitoring purposes, and conduct a new post-construction DEM.

PRE-CONSTRUCTION DATA ANALYSIS

Tide and Geodetic Datums

The Ft. McHenry wetlands are in very close proximity to the long-term NOAA National Water Level Observation Network (NWLON) station at Baltimore (located on a U.S. Army Corps of Engineers pier just north of the fort and the wetland; see Figure 1). Given this proximity, the tidal characteristics, tidal analyses, and tidal datums were transferred directly to the wetlands from the observations at this long-term station. Tidal datums for the project were computed for the location using standard methodologies (CO-OPS 2003). The 2004 restoration project used the accepted tidal datums and published bench mark sheet computed over the superseded 19-year National Tidal Datum Epoch (NTDE) of 1960-78 (CO-OPS 1988). The currently accepted tidal datums and resulting bench mark sheet were not formally accepted until after the 83-01 NTDE was completed (CO-OPS 2001). Since the wetland site was based on the current 83-01 NTDE, but the project began when the 60-78 NTDE datum was the official datum, a comparison of both datums is presented. Figure 3 displays two stick diagrams showing the elevation relationships of the tidal datums to NAVD 88 for both 60-78 and 83-01 NTDE (CO-OPS 2011). A comparison of these datums showed that while the relationships between the tidal datums remained consistent, the difference between NAVD88 and local mean sea level (LMSL) decreased due to local sea level rise. Elevations of the tidal datums were referenced to geodetic datums using leveling and Global Positioning System (GPS) surveys from the tidal bench marks to the National Spatial Reference System. The North American Vertical Datum of 1988 (NAVD 88) was the official orthometric vertical reference datum for the wetlands restoration project. After computing the tidal datums for the Ft. McHenry wetland location, the geodetic elevations from the Ft. McHenry NWLON were transferred to the wetland location via RTK GPS. Knowing tidal and geodetic relationships at both locations was fundamental to the project design.

Digital Elevation Model

NOS/NGS conducted RTK GPS surveys of the site to obtain existing wetlands surface elevations prior to restoration. The RTK GPS survey was conducted by establishing a base station over one of the existing bench marks with a known precise geodetic datum elevation, transferring the elevations to the wetland using a rover pole-mounted RTK GPS antenna and walking across the wetland along predetermined transect routes. Topographic elevations in the existing sloughs (underwater) were made using a small boat and inserting the RTK rover pole into the bottom substrate. Figure 4 is a diagram showing the RTK GPS measurement paths. The elevations, referenced to NAVD 88, were then used to develop the DEM (Figure 5)

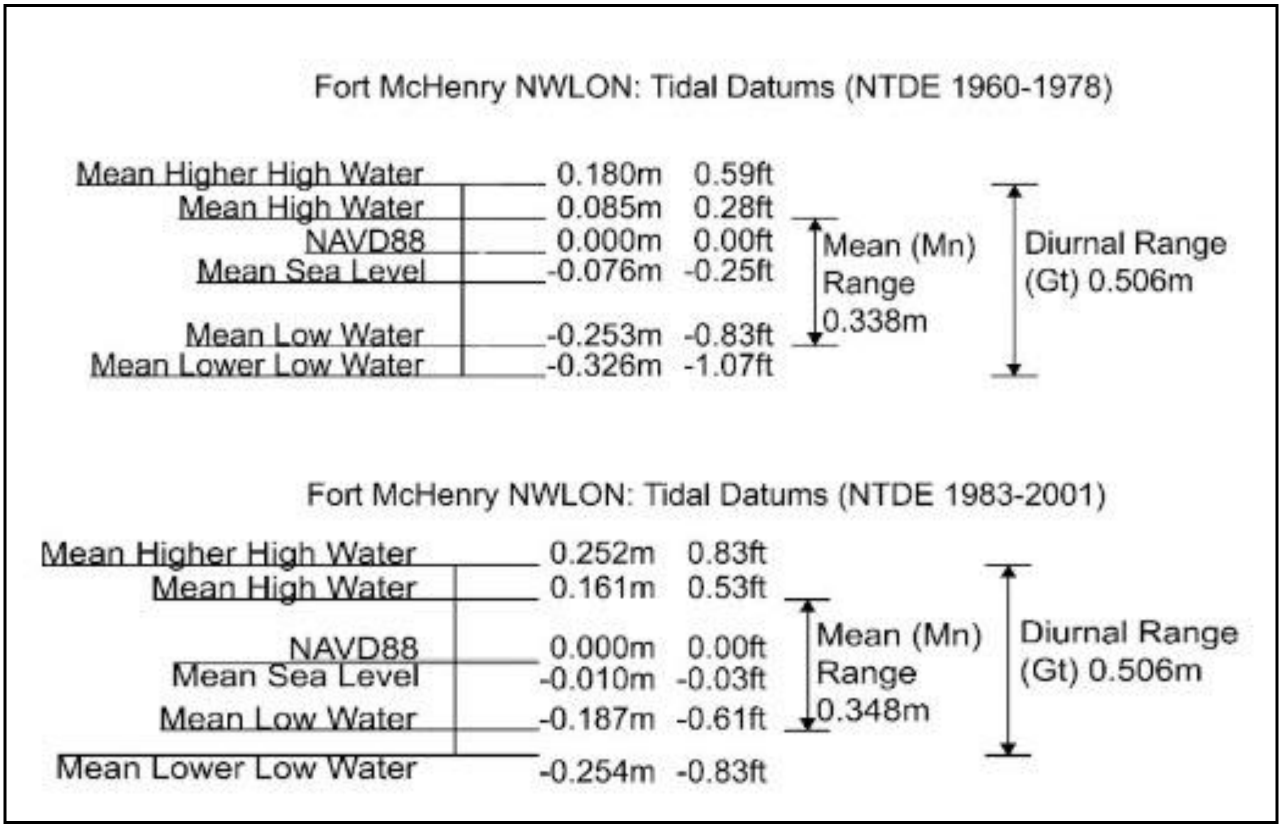

Figure 3. Datum Relationships at the Ft. McHenry National Water Level Observation Network (NWLON) station based on observations over the 1960-78 National Tidal Datum Epoch (NTDE; left) and the 1983-01 NTDE (right), referenced to North American Vertical Datum (NAVD 88).

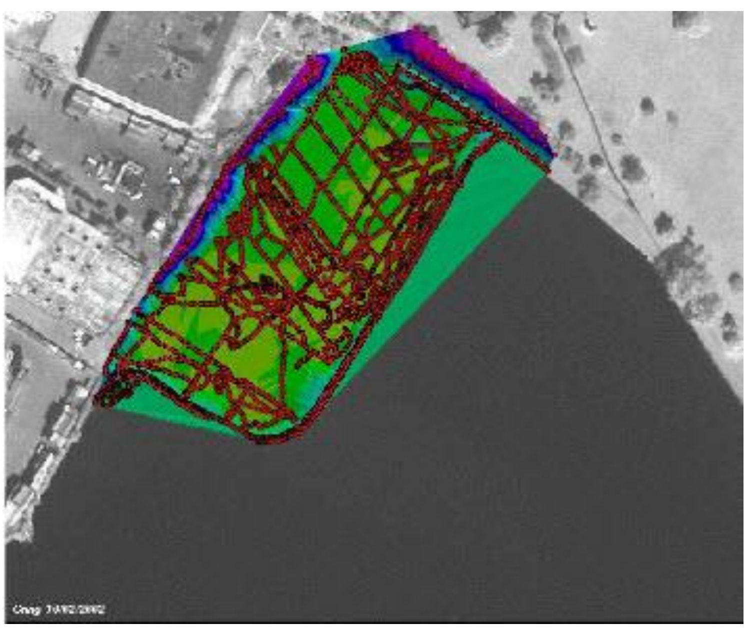

Figure 4. The Ft. McHenry Real Time Kinematic GPS (RTK GPS) Survey.

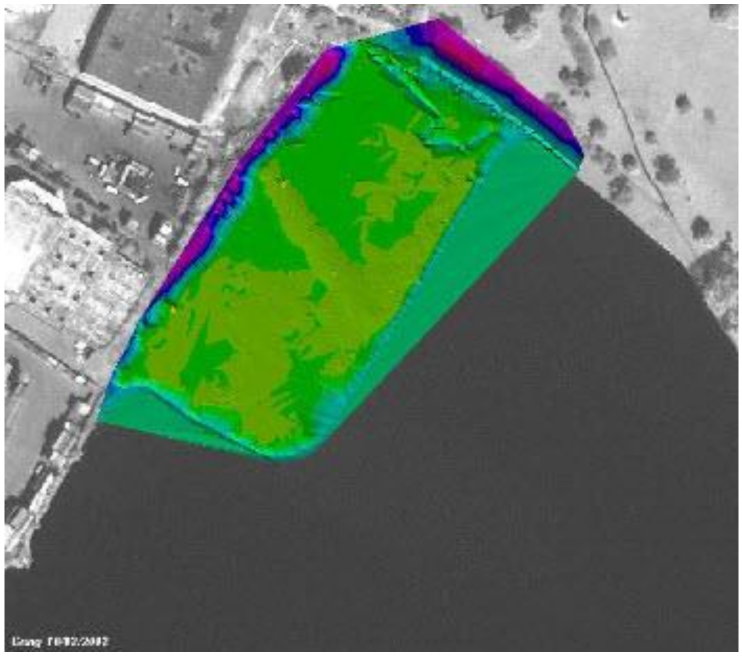

Figure 5. The Ft. McHenry pre-construction Digital Elevation Model (DEM).

Wetlands Engineering Design

The DEM in Figure 5 was used by the Maryland Port Administration's (MPA) engineering consultants, Moffatt & Nichol, to develop a construction elevation drawing of the new wetland (Figure 6). Figure 7 shows the newly designed wetlands topography relative to NAVD 88. The ability to overlay various elevation surfaces in this manner was critical to the final design elevations.

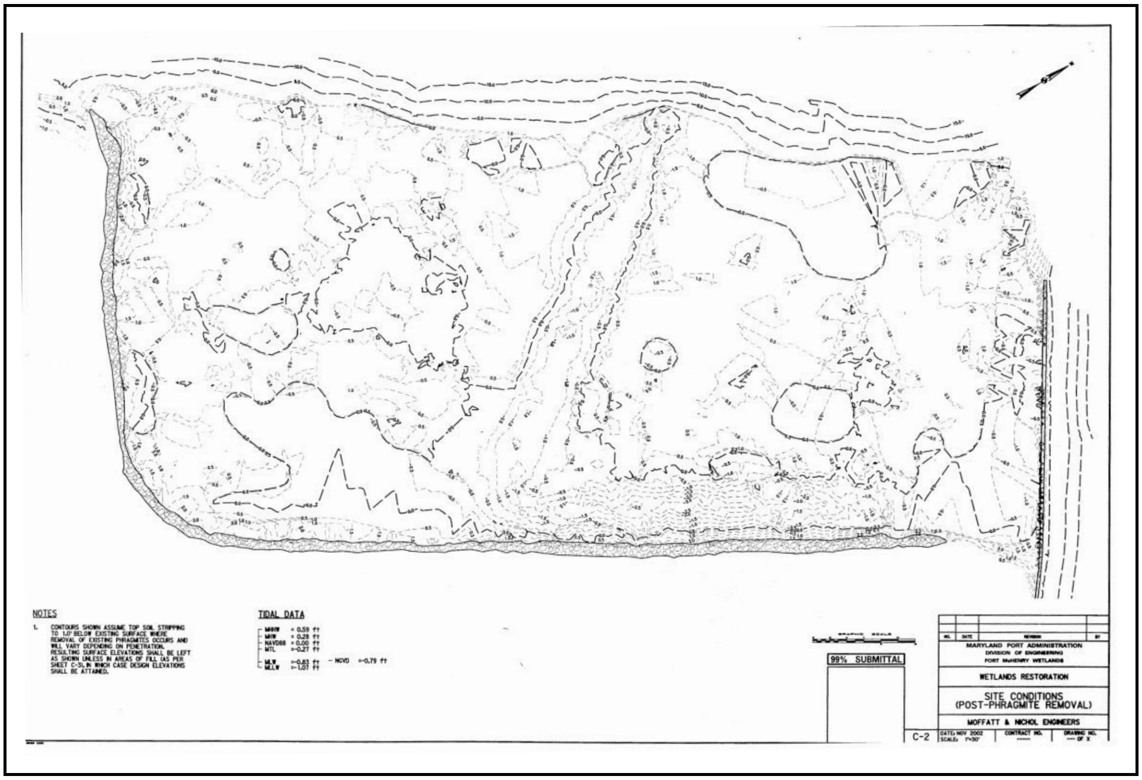

Figure 6. Pre-construction engineering drawing from November 2002 (Ref Datum: NAVD 88).

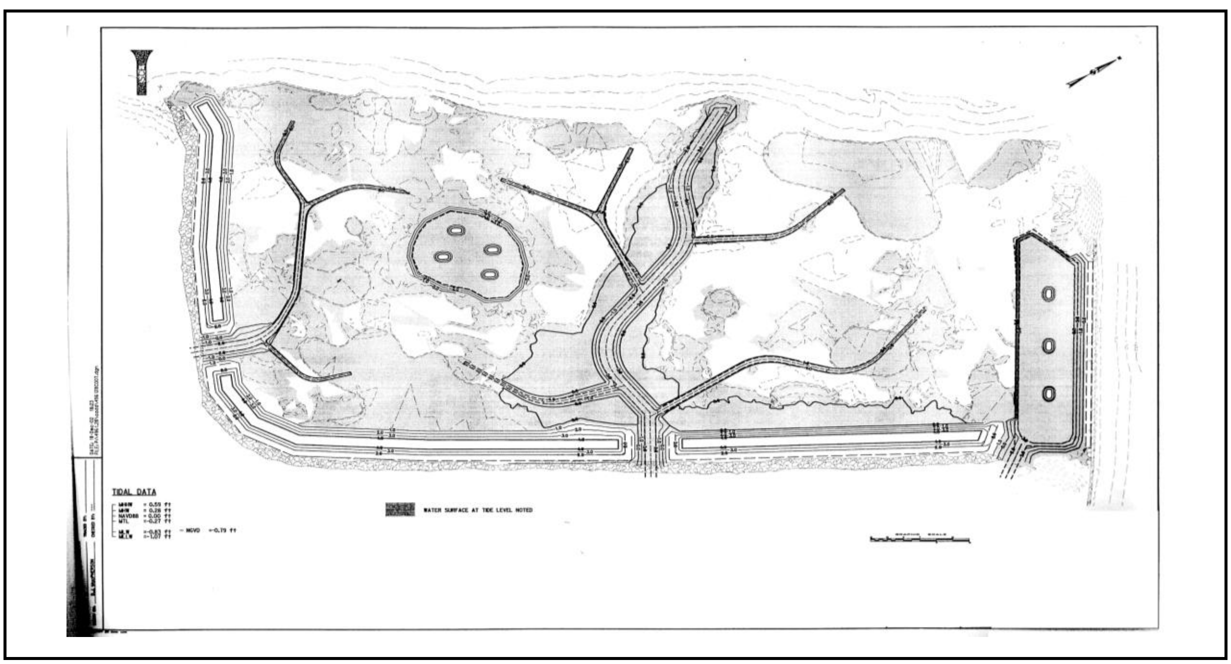

Figure 7. Newly designed wetlands engineering drawing from December 2002 (Ref Datum: NAVD 88).

Pre-Construction Frequency and Duration of Inundation Analyses

The frequency and duration of inundation analyses of the high waters for the site were obtained by analyzing the data from the long-term NWLON station at Baltimore (CO-OPS 2022). NAIB biologists used this information to determine where and when to plant different species of wetland vegetation for a successful restoration. Figure 8 shows the frequency analysis using observed times and heights of the high and low waters from 1980 through 2002. The frequency histogram is a count of high waters contained in various elevation bins relative to NAVD 88. The histogram also shows the associated cumulative percentage curve that is used to estimate inundation probabilities for given elevations. The majority of high waters are centered around the NAVD 88 datum with the highest frequency at 0.2 feet above NAVD 88.

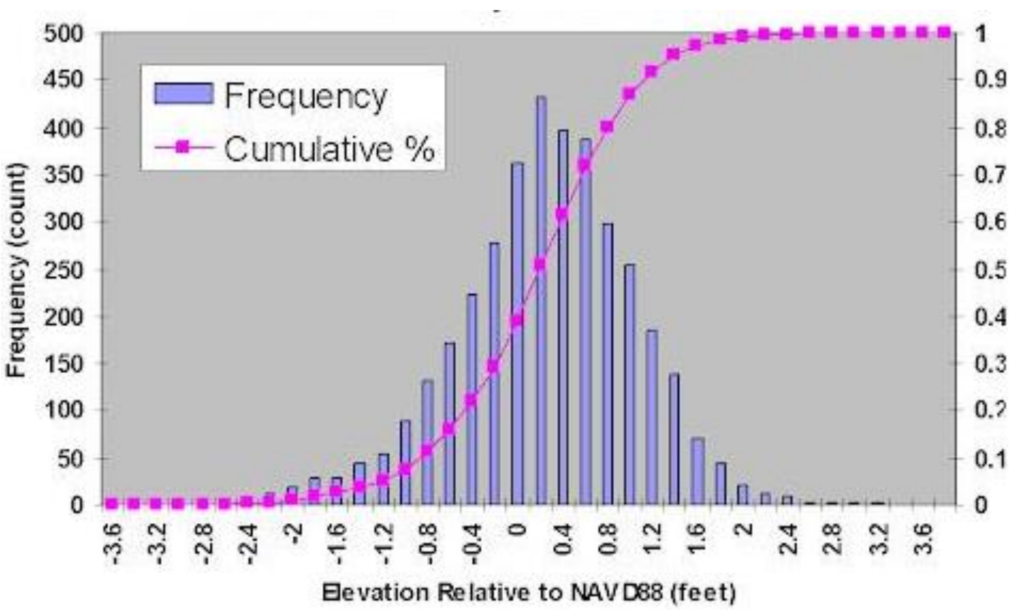

Figure 8. Frequency and cumulative percent of highwaters at Baltimore for January, February, and March from 1980 to 2002. Cumulative elevations are relative to NAVD 88.

Figure 9 is a Seasonal comparison of high water elevation frequencies relative to NAVD88 from 1980 to 2002. During the cooler winter months from October through March the count of high water elevations above NAVD88 are less frequent but span a slightly larger range of elevations than do those during the April through September months. This increased frequency and slightly smaller range of elevations during the Spring through Fall time period is most likely a result of intense rapidly moving rain events, some of which may be tropical in origin, that can dramatically impact water levels in the Chesapeake Bay estuary.

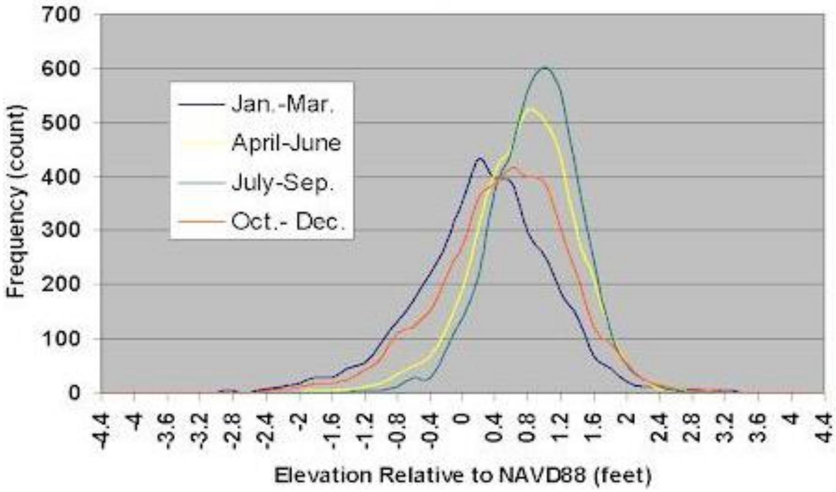

Figure 9. Seasonal comparison of high water elevation frequencies from 1980 to 2002.

A nearly 10-year plot of the duration of inundation for the years 1994-2003 is shown in Figure 10. The duration of inundation uses the 6-minute data before and after the time of each observed high water. This duration is the elapsed time that the high water elevation was observed at or above the specified datum of NAVD 88 (1.505m). The tiered distribution seen in the figure reveals the dependence of the duration of inundation on the elevation of the high waters. A distinct tiering from the elevation of NAVD 88 at time intervals of 12 hours is readily apparent. Less defined tiers are found above 60 hours. There were several extremely long durations of greater than 90 hours. The data point observed to the far right on the plot is from Hurricane Isabel at around 45 hours. Although extremely high in elevation, the duration of inundation was not considered extreme due to the fast-moving nature of the storm. This tiered distribution is attributed to the effects of weather on elevated water levels of the upper Chesapeake Bay for durations of longer than one day (e.g. multiple tidal cycles) (North et al. 2004; Kent 2015).

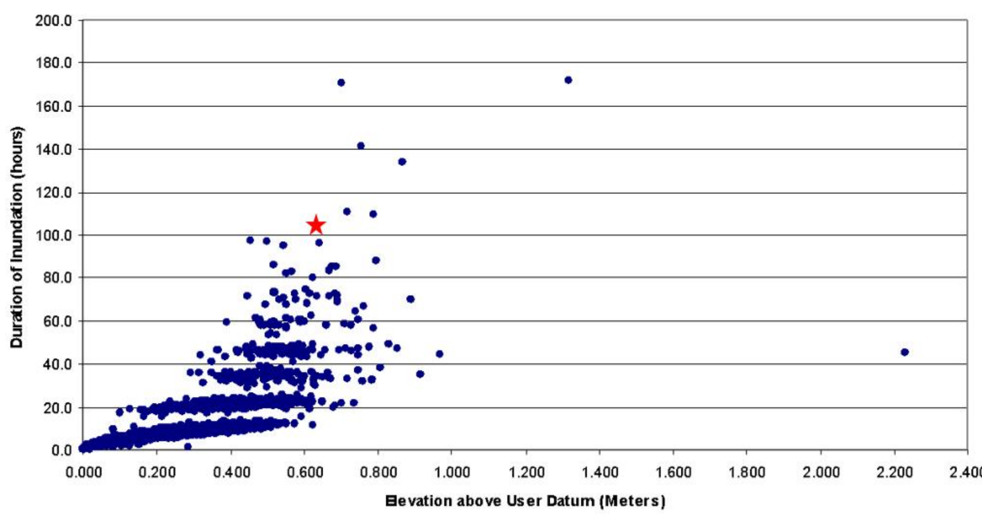

Figure 10. Duration of inundation for Baltimore, Ft. McHenry National Water Level Observation Network (NWLON) relative to NAVD 88 (1.505 m) from January 1994 to December 2003. The red star and above indicate where durations are over 100 hours during extreme water events. Hurricane Isabel is identified by the farthest right point.

This information, along with the frequency statistics in Figures 8 and 9, is used to determine at what elevations and durations of inundation certain plant species can survive. The engineering of the wetlands surface, the depths of the sloughs, and the elevation of the berms must also account for these statistics.

WETLAND RECONSTRUCTION

The wetlands construction phase began in February 2004. Figure 11(a) shows the leveling transit used to bring the desired wetland elevations into the project based on the engineering drawings and tide and geodetic datum relationships. Figure 11(b) shows the extent of some of the surface grading using heavy machinery. Figure 11(c) shows the use of a leveling rod to estimate the depth to which the ponds and sloughs were to be sculpted by heavy machinery.

Figure 11. (a). The use of the leveling transit to control the wetland surface. (b). The grading of the surface of the wetlands. (c). The use of leveling rods to determine the depth of one of the ponds being sculpted by the heavy machinery.

Post-Construction Activities

NOS installed a tide gauge that operated for approximately 1 year at the wetland site in March 2004 and connected it to the existing Ft. McHenry station bench mark network. Simultaneous comparisons between the long-term station and the short-term station were made to compute tidal datum elevations at the wetlands site. The resulting tidal datum was then compared to the nearby long-term tide station. Frequency and duration of inundation analyses were performed with data from the short-term (1-year) station, as well. NAIB used this station as part of the public relations and education aspects of the restoration effort.

This tide station was a “bubbler” pressure sensor located several yards offshore (to the right of the picture in Figure 12) in which the water level pressure was digitized from an air-vented pressure transducer inside the instrument shelter. The nitrogen bubbler tubing was buried under the beach and securely connected to the bottom of the offshore orifice. The equipment was installed on a raised platform designed to be higher than the expected highest tides.

Figure 12. The 1-year tide station at Ft. McHenry Marsh with the equipment shelter and Geostationary Operational Environmental Satellites (GOES) antenna and solar panel towers.

Figure 13 shows some of the surface features of the newly constructed wetland. The photographs were taken during an extreme low water stand. The photos feature some of the design work displayed in the engineering diagrams **(**see Figures 6 and 7). Tidal slough entrances were protected by inflatable barriers so debris could not choke the entrances. Debris nevertheless remained a problem during extreme high water events.

NOS performed a post-construction RTK GPS survey of the wetland surface to update the DEM (see Figure 14). The performance of the newly-planted wetland grass and the hydraulic performance and stability of the tidal sloughs and ponds were closely monitored for several years**.** The effectiveness of the wetland design was also evaluated over several years. NAIB conducted precise photo time-lapse monitoring and installed several deep rod Surface Elevation Table (SET) monuments on the wetland to measure wetland accretion and subsidence.

Figure 13 (a-d). Post-construction wetlands surface before planting.

Figure 14. Post-construction Real-Time Kinematic (RTK) GPS survey at Ft. McHenry Wetland.

FUTURE SEA LEVEL CONSIDERATIONS

The long-term sea level trend observed at the nearby NOAA Ft. McHenry NWLON station was used to estimate the relative sea level trend at the restoration site. At the time of estimation, the published sea level trend was 3.12 +/- 0.08 mm/yr based on data from 1854-1999 (Zervas 2001). Figure 15 shows the 2022 relative sea level trend at Ft. McHenry to be 3.24 millimeters/year with a 95% confidence interval of +/- 0.12 mm/yr based on monthly mean sea level data from 1902 to 2021, which is equivalent to a change of 1.06 feet in 100 years (CO-OPS 2013). Due to the proximity (< 0.5 km) of the temporary station to the Ft. McHenry NWLON station, it is a reasonable assumption that the sea level trend at the wetland location would be similar. This information provides a better understanding of how sea level rise could impact the wetland post-construction.

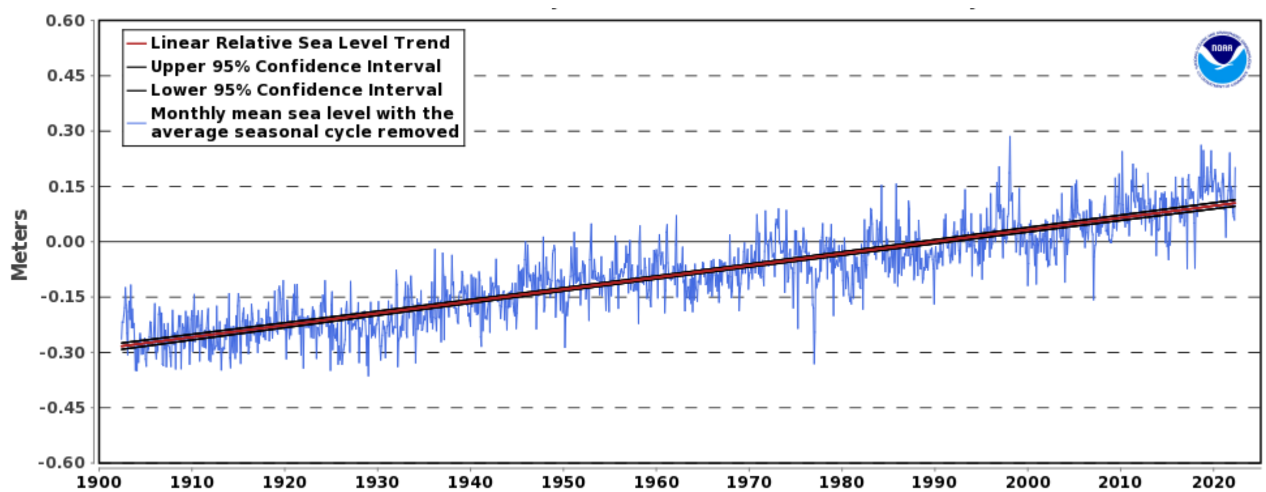

Figure 15. Current (2022) computed relative sea level trends for Baltimore, Ft. McHenry (8574680) National Water Level Observation Network (NWLON) Station (3.24 mm/yr +/- 0.12 mm/yr).

POST-CONSTRUCTION DATA ANALYSIS

After tidal flushing was reestablished within the newly designed wetland, volunteer efforts were also ramped up in 2004. According to a case study shared by Cooperative Conservation America, volunteers removed debris totaling 10,405 pieces (Cooperative Conservation America 2005). Between April 19 and April 22, 2004, volunteers also planted 55,000 units of cordgrass. A total of 344 volunteers helped make the restoration effort a success.

Comparison Of Tidal and Geodetic Datums and Monthly Means

Tidal datums computed from the water levels observed at the wetland between March 2004 and February 2005 were compared to the corresponding observations at the nearby NWLON. NAVD 88 was transferred directly to the wetland location through Mean Tidal Level (MTL) and not surprisingly, the resulting relationship between Mean Sea Level (MSL) and NAVD 88 at both locations was -0.010 m (Figure 16). Other tidal characteristics and tidal and geodetic datums from the wetland were then compared to those of the existing NWLON station at Ft. McHenry. Figure 18 shows that the Mean Range (MN) and Diurnal Range (GT) were both similar, within 0.001 m. The relationship between Mean Low Water (MLW) and NAVD 88 was -0.187 and -0.186 for the NWLON and the wetland, respectively. A similar comparison between MHW and NAVD88 showed the relationships were identical at 0.161 m. The comparison of tidal and geodetic relationships between the 2 locations indicated very little difference between the NWLON station and the temporary wetland water level gauge location and suggested that any additional water level analyses conducted for wetland restoration could rely on data from the Ft. McHenry NWLON station.

In addition to a comparison of tidal datums, a comparison of monthly means was also completed. In Figure 17, a comparison of the MHW monthly means for the stations at Ft. McHenry NWLON (red diamonds) and Ft. McHenry wetland (dark blue circles) is presented. The plot suggests that over the period from May 1st, 2004, to April 1st, 2005, the seasonal and annual variations appear to be well- correlated, demonstrating a similar regional response to seasonal weather patterns.

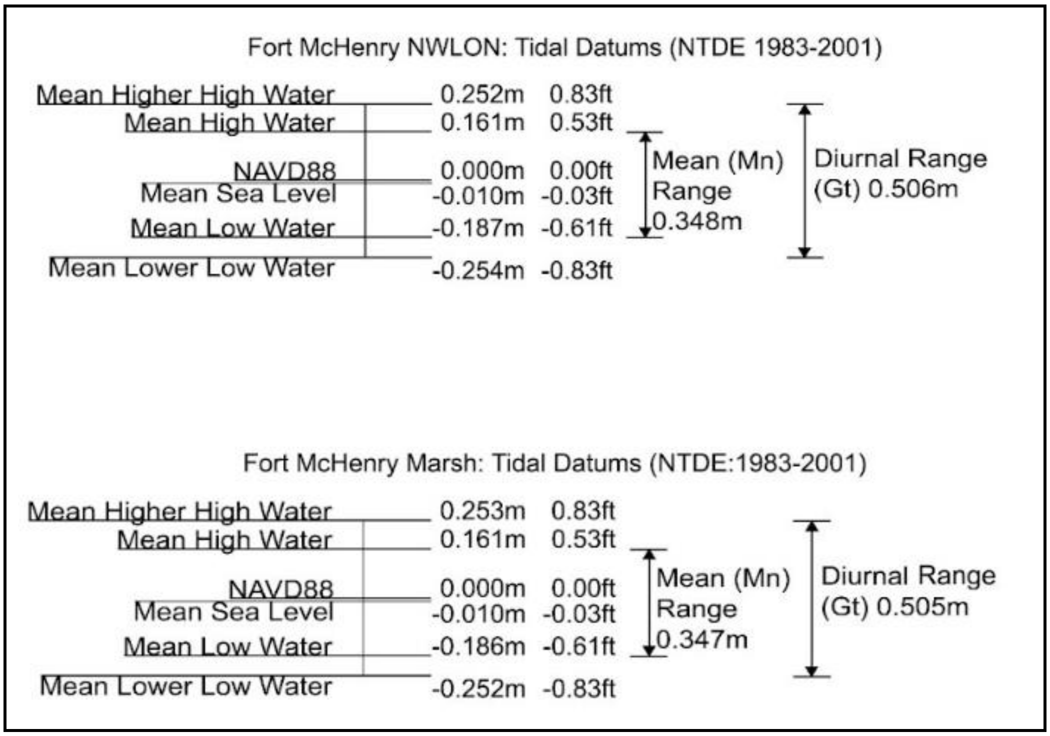

Figure 16. Datums comparison of the Ft. McHenry National Water Level Observation Network (NWLON) gauge and Ft. McHenry Marsh gauge.

Figure 17. Comparison of monthly means for 2004-2005 for Baltimore, Ft. McHenry National Water Level Observation Network (NWLON; red-diamond) and Baltimore, Ft. McHenry Marsh (black circle) water level stations.

POST-CONSTRUCTION INUNDATION DURATION FREQUENCY ANALYSIS

Information about the frequency and duration of water inundation is critical to the health and responsiveness of a naturally-functioning wetland (Kent, 2015). An inundation analysis was conducted that provided frequency and duration of inundation statistics above a MHW threshold elevation. Six-minute data from April 16, 2004-January 28, 2005, at the NWLON and wetland gauge locations were analyzed relative to MHW to obtain the frequency of elevations, frequency of durations, and duration vs. elevation plots. Tidal analyses were critical because it has been shown that the number of tides per day and the equality of the 2 daily high tides set limits to which specific wetland plants can thrive and grow (Gleason and Zeiman 1981). Additionally, MHW typically delineates the boundary between *Spartina patens* and *Spartina alterniflora*, with *S. patens* inhabiting higher, less flooded areas lying above the MHW line and *S. alterniflora* tolerating more inundated conditions below MHW (Gleason and Zieman 1981). The frequency of elevations plot shows that approximately 80% of high water elevations fall below 0.298 meters MHW (Figures 18 and 19). The highest elevation was approximately 0.698 meters (far right) above MHW. These data suggest that conditions at the wetland are favorable to support *S. patens*. Further, the similarities between the wetland gauge location and the NWLON gauge location suggest that any future restoration activities can rely on the inundation statistics from the Ft. McHenry NWLON gauge location.

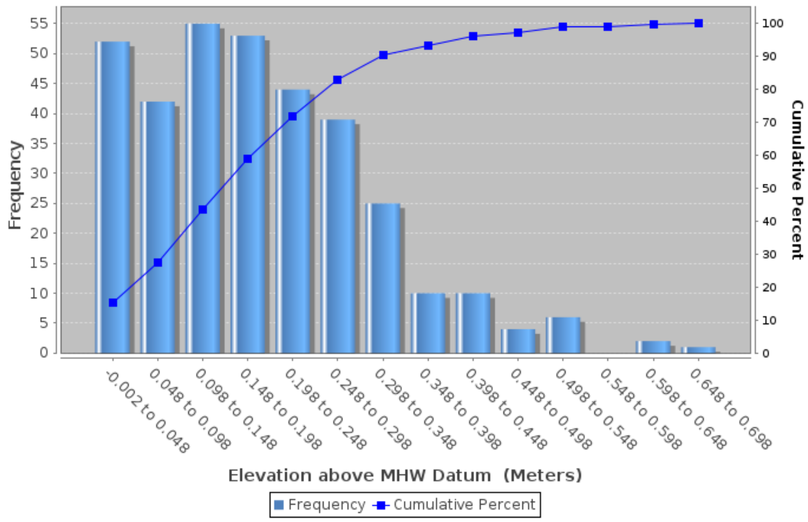

Figure 18. Frequency of high water elevation for Baltimore, Ft. McHenry National Water Level Observation Network (NWLON) gauge relative to Mean High Water (MHW) datum from April 2004 to January 2005.

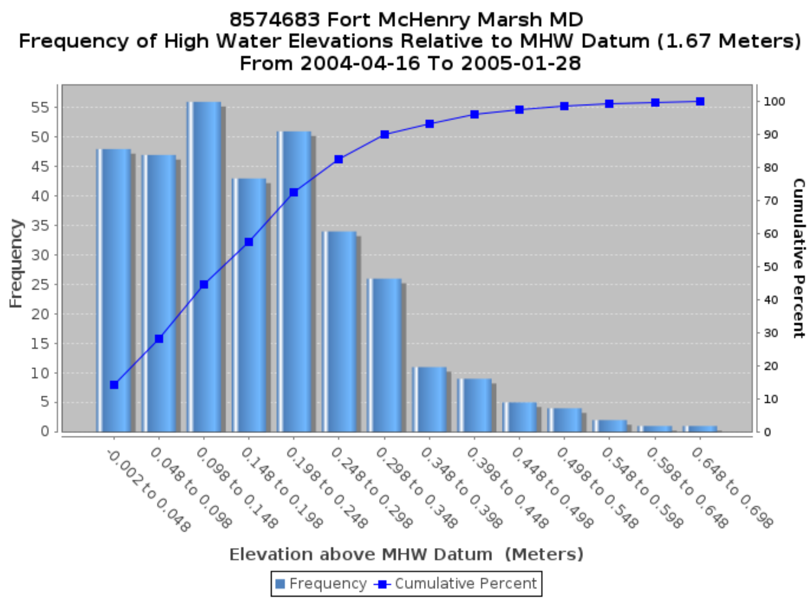

Figure 19. Frequency of high water elevation for Baltimore, Ft. McHenry Marsh gauge relative to Mean High Water (MHW) datum from April 2004 to January 2005.

An examination of the duration of inundation versus elevation plots provides the ability to model and extrapolate the inundation statistics. In general, the higher the elevation of the tide above a threshold value, the longer the duration of inundation for that tide. Figures 20 and 21 show the majority of inundations were below 12 hours and fell below 0.37 meters above MHW. The relationship is not linear but a complex multi-tiered relationship. As an example, at both locations for elevations above 0.25 meters above MHW, a second tier of inundation is centered around 20 hours. This suggests that during wind-driven events, the inundation above MHW lasts for successive high tides. Figures 22 and 23 show an extreme event occurring around October 24-October 26, 2005, where the period of inundation lasted for approximately 70 hours. Wind events driving multi-day high water inundation events were observed periodically near the restoration site. Comparing data from the 2 locations, these anomalous events were captured at both the Ft. McHenry location and the Marsh location.

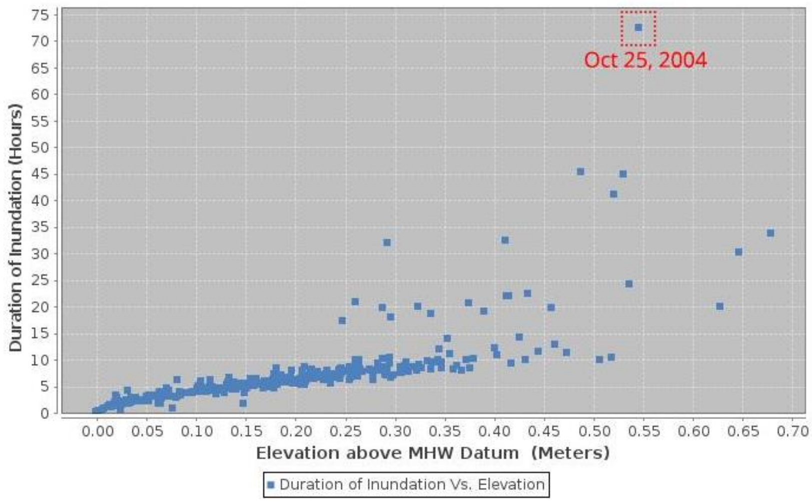

Figure 20. Duration of inundation versus elevation for Baltimore, Ft. McHenry National Water Level Observation Network (NWLON) gauge relative to Mean High Water (MHW) datum from April 2004 to January 2005.

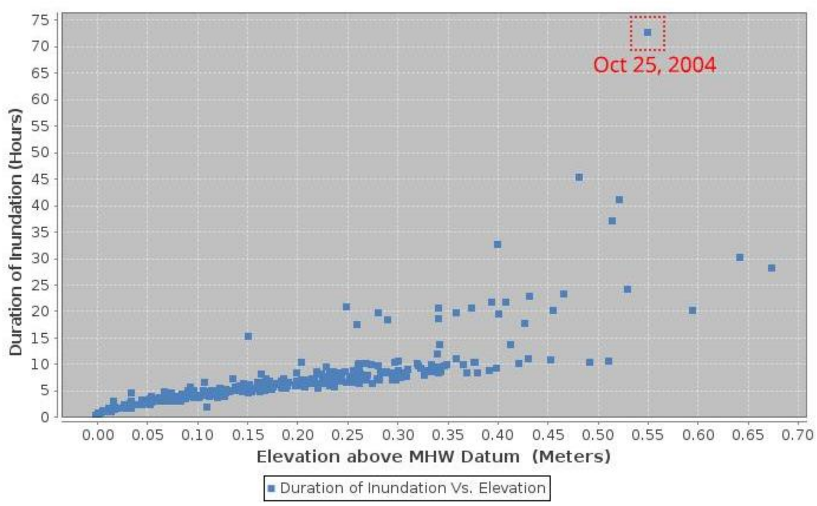

Figure 21. Duration of inundation versus elevation for Baltimore, Ft. McHenry Marsh gauge to Mean High Water (MHW) datum from April 2004 to January 2005.

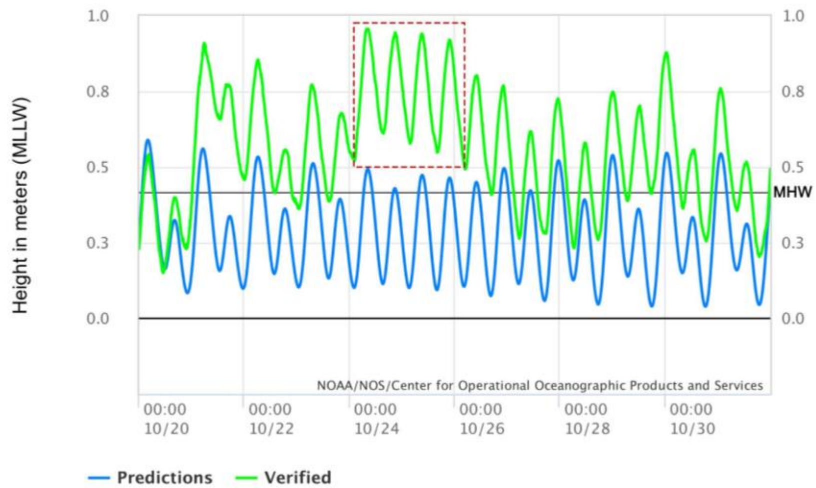

Figure 22. Baltimore, Ft. McHenry National Water Level Observation Network (NWLON) station time series from the end of October 2004 relative to Mean Lower Low Water (MLLW) with the Mean High Water (MHW) line identified Note the 70-hour inundation event boxed with a dashed line.

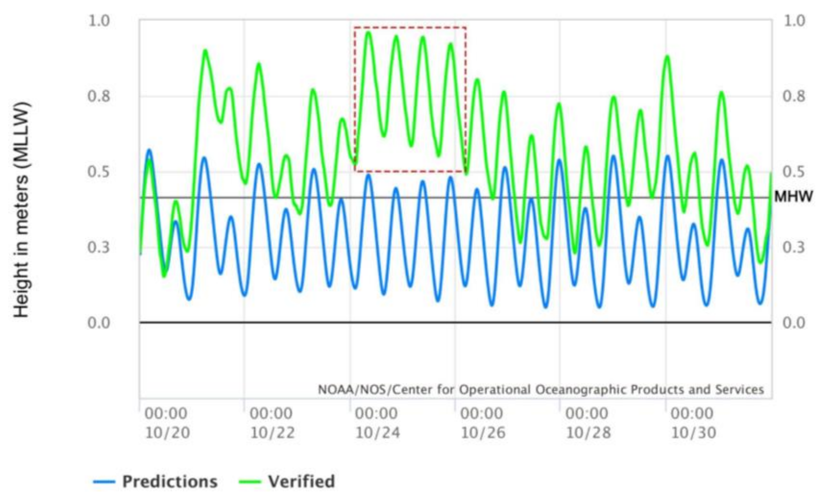

Figure 23. Baltimore**,** Ft. McHenry Marsh station time series from the end of October 2004 relative to Mean Lower Low Water (MLLW) with the Mean High Water (MHW) line identified Note the 70-hour inundation event boxed with a dashed line.

ADDITIONAL EXTREME WATER EVENTS

The 70-hour inundation event was not the only extreme event observed at the wetland. An extreme 100-year storm event was recorded at the marsh gauge during the passage of Hurricane Isabel in September of 2003 (Zervas, 2013). The debris line left by the hurricane was several feet above the wetland surface and caused some erosion to the high berm located upland of the wetlands. The effects of an extreme high water event followed by an extreme low water event were also captured on March 20 and 22, 2004 following the passage of a strong front that blew water first up into the Bay and then out the following day. Figure 24 shows the contrast from photographs taken from the same vantage point each day. Figure 25 shows how high and low the extremes were relative to predicted tides, and Figure 10 shows the event in the context of the duration of inundations over the longer time period, indicated by the red star.

Figure 24. The Ft. McHenry Wetlands during an extreme high water event (a,c,e) followed by an extreme low water event (b,d,f).

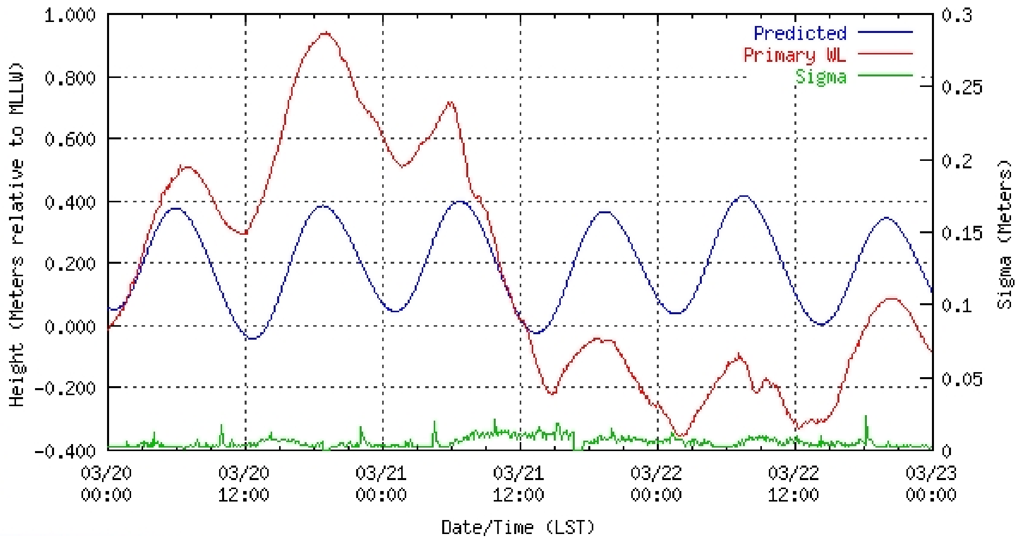

Figure 25. Baltimore, Ft. McHenry National Water Level Observation Network (NWLON) station time series showing extreme high water/low water events on March 20 and 22, 2004, relative to Mean Lower Low Water (MLLW).

CONCLUSIONS

The wetlands adjacent to the Ft. McHenry National Monument and Historic Shrine had been degraded by the removal of regular tidal flushing to the site and the accumulation of anthropogenic debris from tidal waters. The wetland restoration project described in this report provided direct benefits to the site through the construction of new aquatic habitat and the restoration of native wetlands vegetation. Benefits continued to accrue throughout the entire site as the natural tidal flooding regime and hydroperiod were restored.

The Ft. McHenry Wetlands Restoration Project serves as an example of how water level analysis can be used to plan and implement coastal restoration. Water level inundation analyses and tidal and geodetic datum information provided a baseline for the project and were applied during the initial phase of planning. These data were reflected in the engineering drawings and later updated during wetland reconstruction to inform the strategy for planting the new wetland vegetation.

Once construction was completed, vegetation was placed at specific locations based on elevations relative to tidal datums. These elevations were determined by the tidal and geodetic relationships transferred from the local NWLON station to the marsh location. After a temporary water level gauge was installed, new water levels were established at the marsh location. Water level data were further analyzed at the 2 gauge locations to compare the monthly means and inundation analysis. Calculated monthly means showed a reasonable correlation for the 1-year time series. Water levels captured above the MHW line were also consistent in terms of frequency, duration, and elevation. Also, the analysis indicated that extreme water level events similarly occurred at both stations.

The continued success of the wetlands restoration will only be known with time; however, the application of the tide and geodetic information has made the planning and construction phases more effective[1]. The full suite of capabilities in tide and water level analyses, RTK GPS surveys,

[1] Since the time of the second restoration in 2004, it was seen that the techniques employed resulted in a much longer-lived success than the first restoration. Lessons learned from the first restoration positively impacted the site and methods

Digital Elevation Modeling, and Light Detection and Ranging (LIDAR) has been used in support of this effort (Figure 26), and their application to programs other than traditional hydrographic and shoreline mapping has been successfully illustrated through this project.

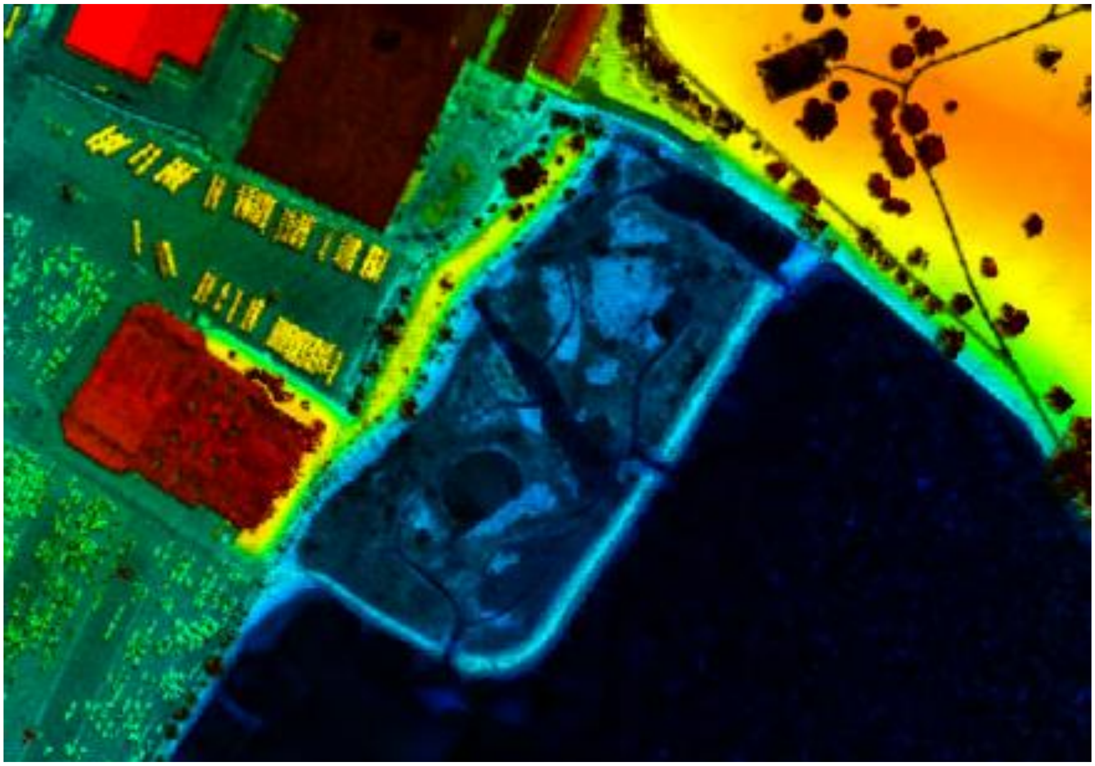

Figure 26. Light Detection and Ranging (LIDAR) imagery of the wetlands taken after completion of construction.

used for future efforts. Though the marsh has since returned to phragmites, the efforts employed during the second restoration resulted in a longer time of healthy wetland activity.

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ACRONYMS

CO-OPS	Center for Operational Oceanographic Products and Services
DEM	Digital Elevation Model
GT	Diurnal Range
GIS	Geographic Information System
GOES	Geostationary Operational Environmental Satellites
GPS	Global Positioning System
LMSL	Local Mean Sea Level
LIDAR	Light Detection and Ranging
MPA	Maryland Port Authority
MHHW	Mean Higher High Water
MHW	Mean High Water
MLLW	Mean Lower Low Water
MLW	Mean Low Water
MN	Mean Range
MOA	Memorandum of Agreement
MSL	Mean Sea Level
MTL	Mean Tidal Level
NAVD 88	North American Vertical Datum of 1988
NAIB	National Aquarium in Baltimore
NPS	National Park Service
NGS	National Geodetic Survey
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NTDE	National Tidal Datum Epoch
NWLON	National Water Level Observation Network
PORTS	Physical Oceanographic Real-Time System

RTK GPS	Real Time Kinematic Global Positioning System
SET	Surface Elevation Table
USACE	United States Army Corps of Engineers