

June 2011

Damde Meadows Tidal Assessment Post-Construction Hingham, Massachusetts



Geosyntec
consultants
engineers | scientists | innovators



Prepared by:

Geosyntec Consultants
289 Great Road, Suite 105
Acton, MA 01720

Prepared for:

MA Dept. of Fish & Game
Division of Ecological Restoration
251 Causeway Street, Suite 400
Boston, MA 02114

Project Background

Damde Meadows (Site) is located at The Trustees of Reservations World's End property in Hingham and originally was a 14-acre salt marsh that extended east-west from Hingham Harbor to the Weir River (HRTC, 2007). In the 1600s, two dikes and associated tide gates were constructed, one near the harbor's cove and another near Weir River, and used to improve forage conditions for livestock. In the 1880s, a second dike was constructed near the harbor end to improve access to the World's End Reservation (National Estuaries Restoration Inventory, 2006). These dikes, and associated tide control structures restricted tidal influence and eventually failed, completely impounding the upstream marsh. This converted the once salt marsh into a stagnant, backwater area with only freshwater species. To restore tidal flow to the marsh, both culverts were replaced in 2003 with four foot by eight foot concrete box culverts (HRTC, 2007). Although high tides reached further upgradient, the upstream marsh remained impounded and did not drain adequately at low tide, preventing the reestablishment of salt marsh vegetation (HRTC, 2007).

In 2006, Louis Berger Group was hired by the Massachusetts Wetland Restoration Program to assess post-construction tidal conditions.

In 2009, the outer causeway and box culvert were removed to reduce flow velocities and improve public safety. Phase two, initiated in April, 2010, is the removal of the inner causeway and culvert to create an open channel to convey flows from Damde Meadows to Martin's Cove. The removal and grading occurred in April and May of 2011 (prior to installation of the transducers). Construction of a walking bridge over the expanse was being constructed in June of 2011, when the transducers were removed. According to the New York State Salt Marsh Restoration and Monitoring Guidelines, the most basic means of restoring salt marshes is reintroduction of tidal regime (Niedowski, 2000). To assess the post-construction restoration, a tidal assessment was conducted and used for comparison to the pre-construction (box culvert scenario) tidal assessment data, collected in 2006.

Tidal Survey

To assess the post-construction restoration at the Site, three tide-gauges were installed on May 11, 2011. Tide-gauges consisted of Onset® HOBO U20 Water Level Data Loggers that have operational range from 0 to 30 feet with ± 0.02 ft accuracy. One tide-gauge was installed in the Damde Meadows marsh (Damde Meadows) (D3), one in the channel between the two causeways / dikes (Mid Marsh) (D2) (Photo 1), and one downstream in Martin's Cove (D1) (locations are shown in Attachment A). The tide-gauges were deployed to collect continuous water level data at 6-minute intervals for 28 days,



Photo 1. Mid marsh tide-gauge location.

spanning the monthly spring tide. The tide-gauges were assigned elevations using a known benchmark at the Site, which is referred to as BM-3 on the as-built drawings and described as top of stone bound (elevation 8.54 feet NGVD 29), found near the inner causeway and culvert.

Pre-construction data at Damde Meadows was collected by UMASS SMAST for 13-days from April 28 to May 10 of 2006, at 10-minute intervals (data was provided by Massachusetts Division of Ecological Restoration). Figure 1 is a plot of the 13-days of pre-construction data for the Site, which includes the spring tide for the Damde Meadows system.

Geosyntec Consultants, Inc. (Geosyntec) collected post-construction restoration data at the Site for 30-days from May 11 to June 10 of 2011. Figure 2 is a plot of water elevation data over the complete tidal assessment period, Figure 3 is a plot of 7-days of water elevation data from May 14 to May 21 of 2011 and Figure 4 is a single day hydrograph on May 17 of 2011. To determine the differences between pre-construction and post-construction and evaluate restoration, tidal metrics were evaluated on the tidal assessment data sets. The tidal metrics include:

- Mean Higher-High Water – the average of the higher-high water height of each tidal days within the survey period;
- Mean High Water – the average of all observed high water levels;
- Mean Tide Level – mean of high water and low water levels;
- Mean Low Water – average of all observed low water levels;
- Mean Lower-Low Water – average of the lower-low water height of each tidal day within the survey period;
- Tidal Maximum – highest tide during the survey period;
- Tidal Minimum – lowest tide during the survey period;
- Mean Tide Range – difference in height between Mean High Water and Mean Low Water;
- Tidal Range Ratio – ratio of upstream (restricted) mean tide range over downstream mean tide range; and
- Maximal Tidal Dampening and Associated Phase Delay – largest disparity between up and downstream gauges and associated time delay between peak water elevations.

Tidal Assessment

Prior to deployment of the post-construction tide-gauges at the Site, the gauge calibration, completed by the manufacturer, were verified by Geosyntec to ensure that the loggers were accurately recording water depth. The tide-gauges were verified by resting the gauges in a bucket of fresh water for approximately 15-minutes and recording water level during this time. All gauges appeared to be accurately recording water level. At the end of the deployment period, the depth of water was measured prior to removing the gauges and used as verification that the gauges were accurately recording water depth during the deployment period. Since the gauges appeared to be accurately recording water level, no correction factors needed to be applied to the data.

On-site elevation surveys of the tide-gauges were conducted by Geosyntec on May 11 of 2011. Each of the tide gauges were assigned an elevation using the existing Site benchmark (top of stone bound

at El. = 8.54 ft NGVD 29). The elevations were converted in NAVD 88 using the Massachusetts Highway Survey Manual (Mass Highway, 1996), using the following datum relation conversion for the City of Quincy:

$$\text{NGVD29 Datum (-1.774 meters)} - \text{NAVD 88 Datum (-2.02 meters)} = 0.246 \text{ meters (0.807 feet)}$$

$$\text{NAVD 88 Benchmark El. (ft)} = \text{NGVD29 Benchmark El. (ft)} - 0.807 \text{ ft}$$

$$\text{NAVD 88 Benchmark El. (ft)} = 8.54 \text{ ft} - 0.807 \text{ ft} = 7.73 \text{ feet}$$

Based on the benchmark elevation of 7.73 feet (NAVD 88) it was determined that the Damde Meadow tide-gauge was installed at an elevation of -2.06 ft NAVD 88, Mid Marsh tide-gauge was installed at an elevation of -4.12 ft NAVD 88 and the Martin's Cove tide-gauge was installed at an elevation of -5.11 ft NAVD 88.

Table 1. Damde Meadows Tidal Metrics

Tidal Metrics	Damde Meadows Condition		Mid Marsh Condition		Martin's Cove Condition ³	
	Pre-Construction ¹ Water Elevation (ft)	Post-Construction ² Water Elevation (ft)	Pre-Construction ₁ Water Elevation (ft)	Post-Construction ₂ Water Elevation (ft)	Pre-Construction ₁ Water Elevation (ft)	Post-Construction ₂ Water Elevation (ft)
Mean Higher-High Water	3.53	5.15	4.15	5.17	4.70	5.24
Mean High Water	3.52	4.58	3.84	4.60	4.60	4.66
Mean Tide Level	2.71	1.75	2.83	1.10	0.04	0.04
Mean Low Water	1.90	-1.08	1.81	-2.39	-4.52	-4.58
Mean Lower-Low Water	1.90	-1.12	1.82	-2.44	-4.94	-4.80
Tidal Maximum	4.52	6.97	4.80	6.99	5.74	7.04
Tidal Minimum	1.83	-1.20	1.79	-2.47	-6.97	-5.14
Mean Tide Range	1.63	5.66	2.03	6.99	9.12	9.24

Notes:

1. Analysis based on 13 days of pre-construction data that occurred during the spring tide, at 10-minute collection interval
2. Analysis based on 30 days of post-construction data, at 6-minute collection interval
3. Pre-construction data based off Boston Harbor, approximately 7 miles northeast of the Site

Table 2. Damde Meadows Pre-Construction and Post-Construction Tidal Metrics

Tidal Metrics ¹	Mid Marsh		Damde Meadows	
	Pre-Construction	Post-Construction	Pre-Construction	Post-Construction
Tidal Range Ratio	22%	76%	18%	61%
Maximal Tidal Dampening (feet)	0.94	0.13	1.26	0.14
Phase Delay (minutes)	20	0	83	6

Notes:

1. Analysis based on 13 days of pre-construction data that occurred during the spring tide, at 15-minute collection interval and 30-days of post-construction data at 6-minute intervals

Hydrographs collected in 2006 and published reports illustrate that restoration objectives were not fully achieved with the installation of box culverts in 2003. Damde Meadows remained impounded and the tidal hydrology restricted.

To compare tidal hydrology changes at Damde Meadows for pre-construction (box culverts present) to post-construction (open-channel) which includes the removal of the box culverts in 2009 and 2011, tide metrics were calculated and are presented in Table 1. Table 2 presents the tidal metrics to assess the overall pre-construction and post-construction restriction severity. The tidal metrics presented in Table 2 were assessed between Martin's Cove and the referenced tide-gauge.

The Tidal Metrics indicate the following tidal assessment results:

- Post construction tidal hydrographs illustrate the complete restoration of tidal flow to the Damde Meadows salt marsh as evidenced by the synchrony among hydrographs for the three study areas. The divergence of the falling limbs in the hydrographs for Damde Meadows and Mid Marsh from that of Martin's Cove is the result of the drop in elevation between Damde Meadows, Mid Marsh and Martin's Cove;
- The Mean Higher-High Water increased by 1.6 feet for Damde Meadows and 1 foot for the Mid Marsh system when compared to the pre-construction condition, indicating that the removal of the box culverts has allowed more salt water into the marsh;
- Upstream Mean Tide Range increased by more than 4 feet in Damde Meadows and 5 feet in the Mid Marsh from pre- to post-construction, showing a definite change in the tidal regime in the marsh due to removal of the culverts and impoundments;
- Mean Low Water and Mean Lower-Low Water elevations in Damde Meadows and Mid Marsh decreased during low tide events between pre and post-construction suggesting that the marsh drains more completely post-construction;
- Maximal Tidal Dampening decreased by 86% from 0.94 feet pre-construction to 0.13 feet post-construction in the Mid Marsh and decreased by 89% from 1.26 feet pre-construction to 0.14 feet post-construction; and
- The Phase Delay for Damde Meadows pre-construction was estimated to be 83 minutes. The Phase Delay for the post-construction is less than 6 minutes, showing a great improvement in timing of the peaks between Martin's Cove and Damde Meadows.

One indicator of the severity of a tidal restriction is the Tidal Range Ratio, which represents the ratio of the upstream and downstream tidal range (Carlisle, et. al., 2002). While several factors can influence the Tidal Range Ratio (e.g. differences in channel elevations and logger location, as well as physical hydrologic restrictions), comparison of pre and post-restoration Tidal Range Ratios offers another useful means to assess the achievement of tidal restoration goals.

Under the pre-construction condition the Tidal Range Ratio was 22% for Mid Marsh and 18% for Damde Meadows, indicating that the upstream side received only 22% and 18% of the tidal range, respectively. Under the post-construction, the Tidal Range Ratio increased to 76% for Mid Marsh and 61% for Damde Meadows. Viewed together with the tidal hydrograph (figure 3) it is clear that the tidal restoration objectives have been achieved, and that the differences in channel elevation account for post-restoration Tidal Range Ratios that are less than 100%.

References

Carlisle, B.K., A.M. Donovan, A.L. Hicks, V.S. Kooken, J.P. Smith, and A.R. Wilbur. 2002. *A Volunteer's Handbook for Monitoring New England Salt Marshes*. Massachusetts Office of Coastal Zone Management, Boston, MA.

Herring River Technical Committee (HRTC). October 2007. *Herring River Restoration Project Conceptual Restoration Plan*.

Hingham Journal. March 2011. *Restoration project at World's End begins*. (<http://www.wickedlocal.com/hingham/news/x1306272539/Restoration-project-at-World-s-End-begins#ixzz1QQ1Pl4aR>)

Massachusetts Highway Department, 1996. *The Commonwealth of Massachusetts Survey Manual*.

Niedowski, N.L. 2000 *New York State Salt Marsh Restoration and Monitoring Guidelines*. New York State Department of State Division of Coastal Resources and Department of Environmental Conservation, Albany, NY.

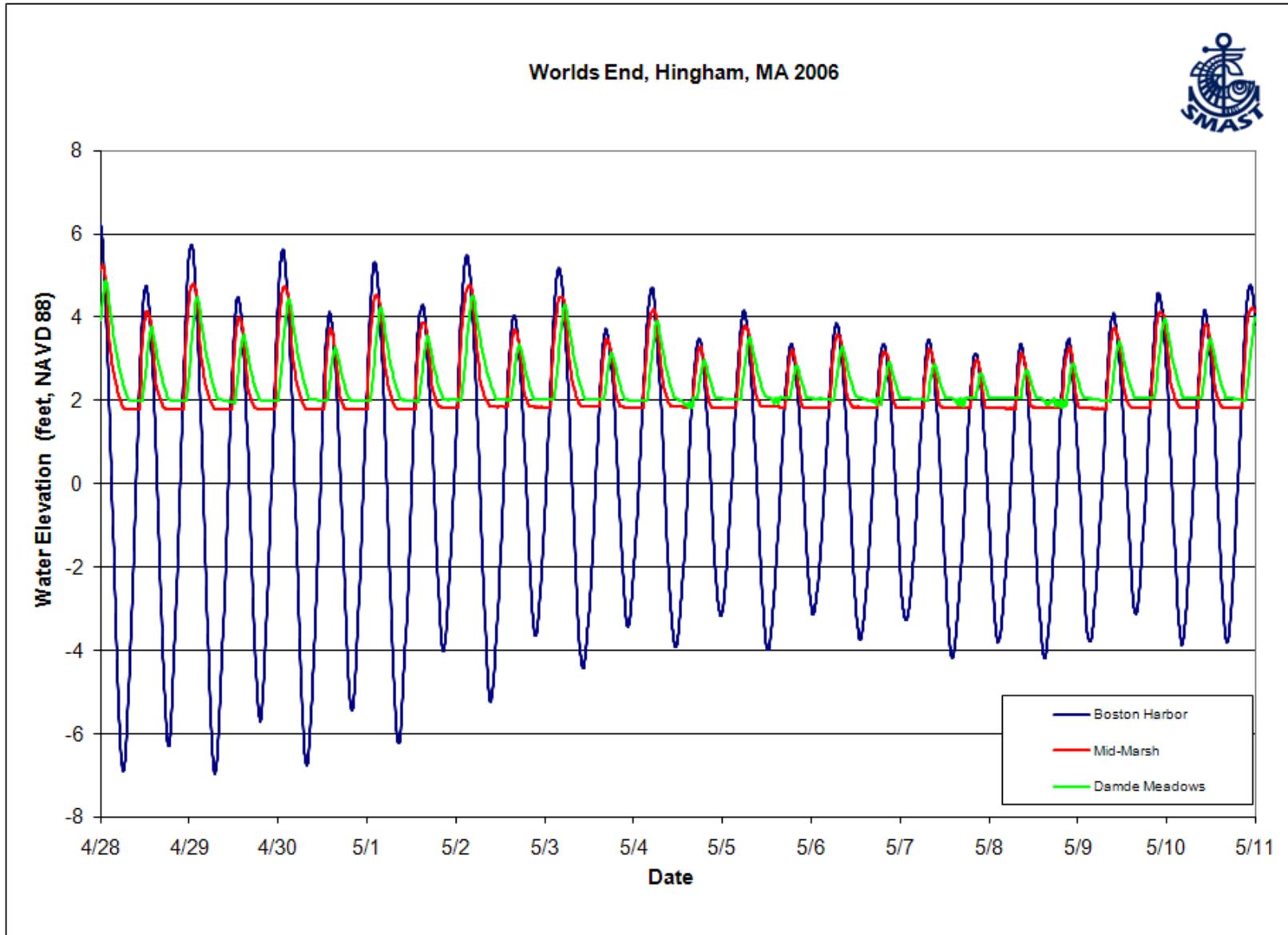


Figure 1. Damde Meadows Pre-construction data from April 28 to May 11 of 2006.

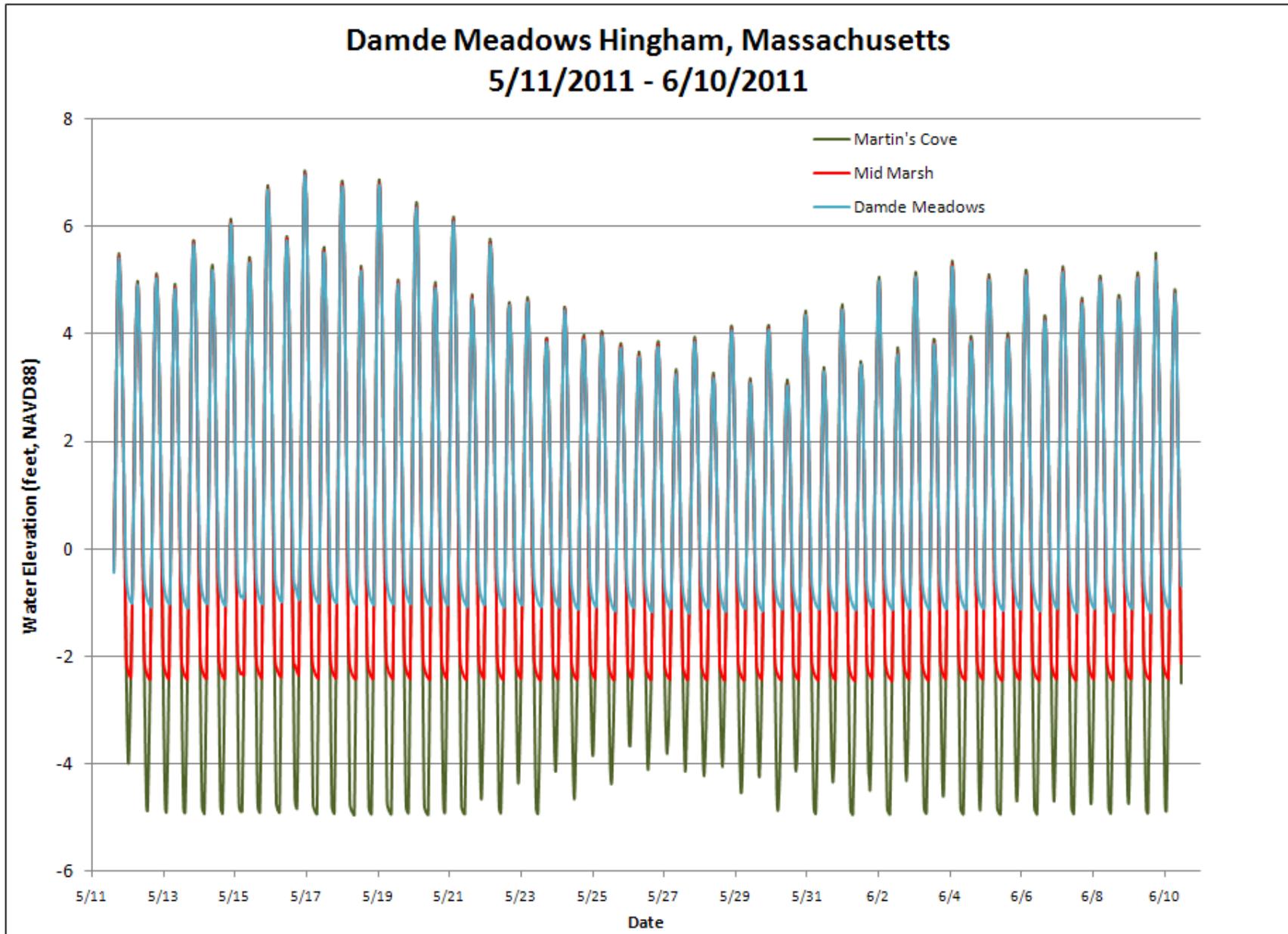


Figure 2. Damde Meadows Post-construction data.

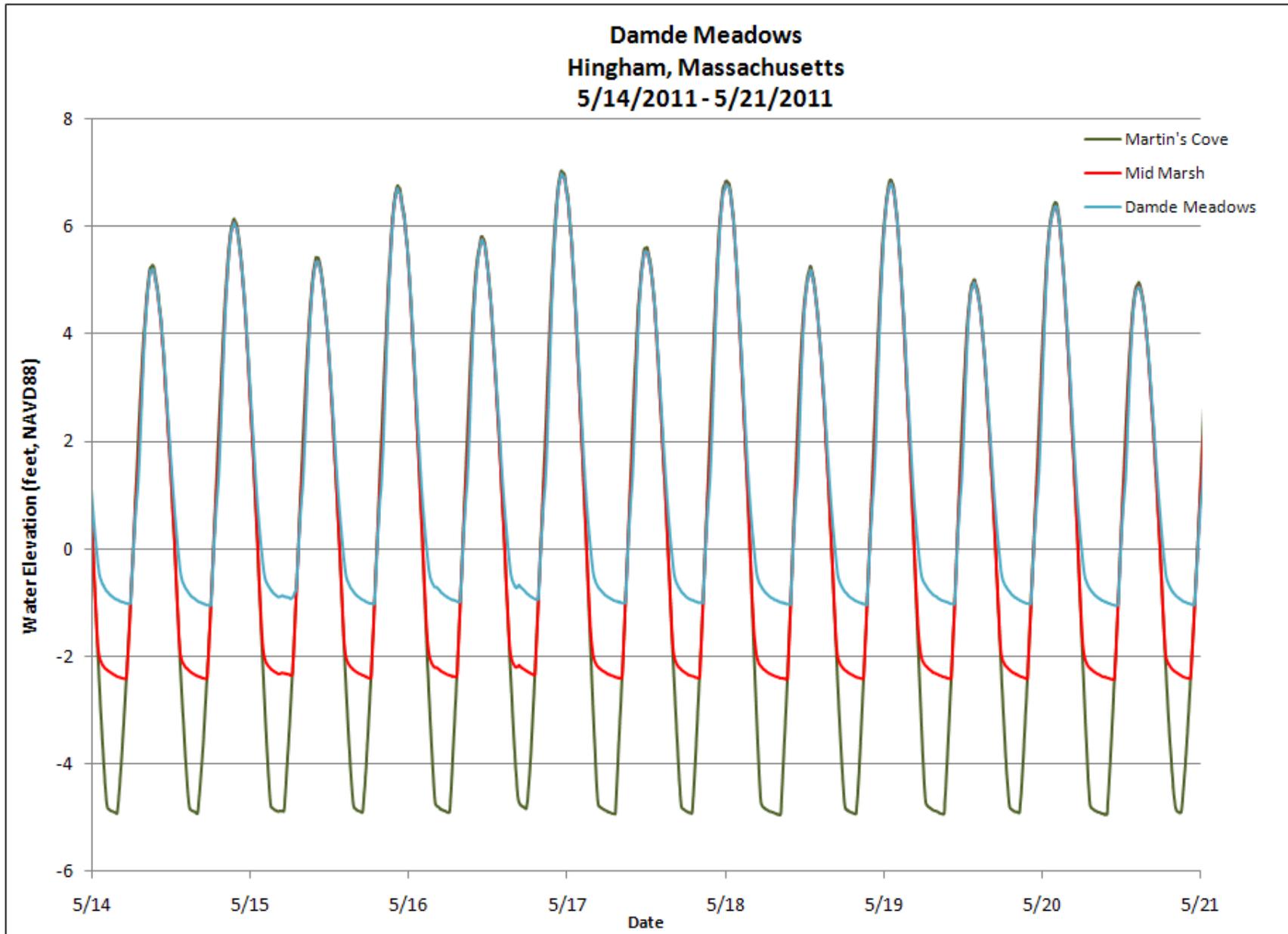


Figure 3. Damde Meadows Post-construction data from May 14 to May 21 of 2011.

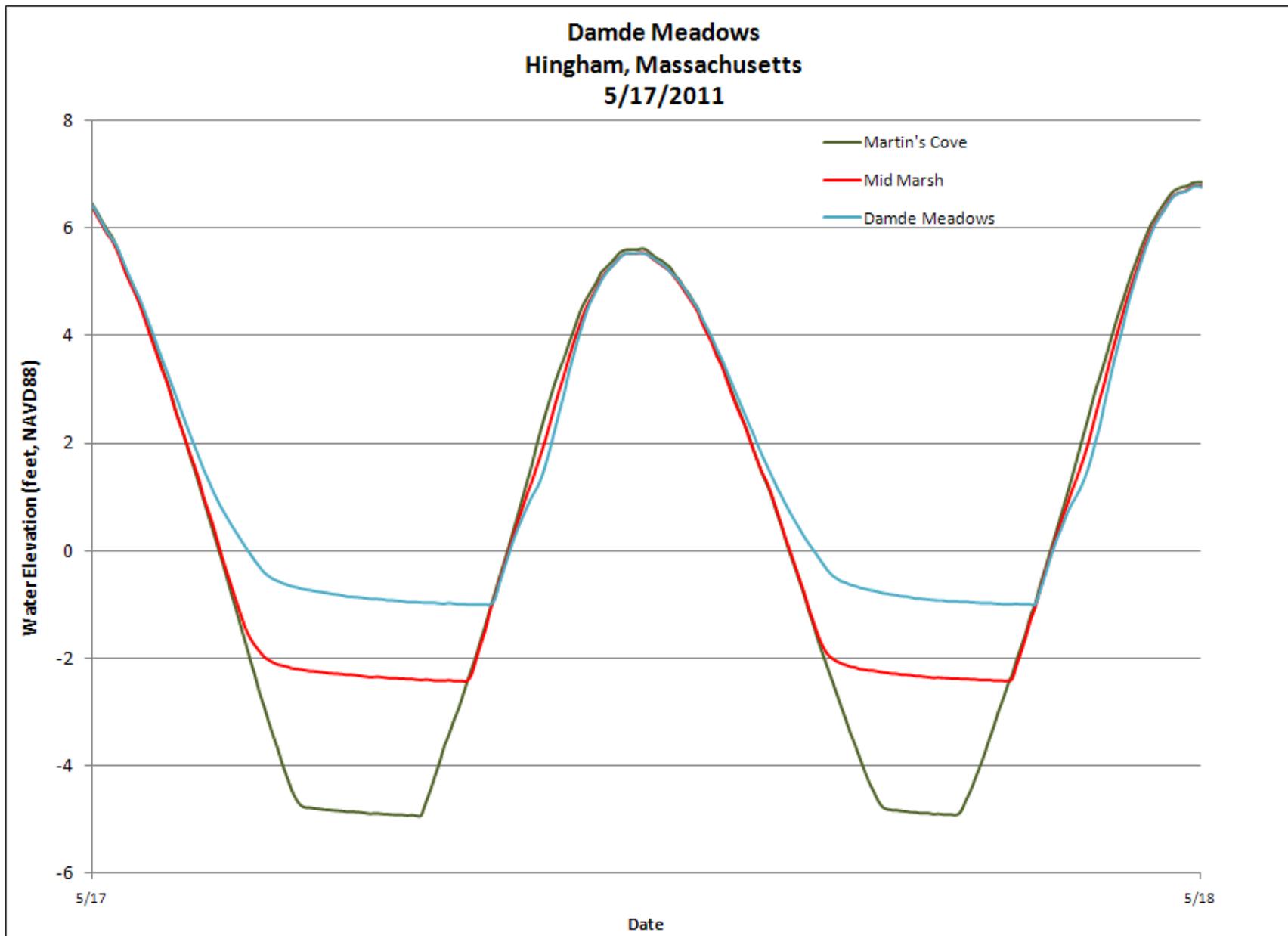


Figure 4. Damde Meadows Post-Construction data on May 17 of 2011.

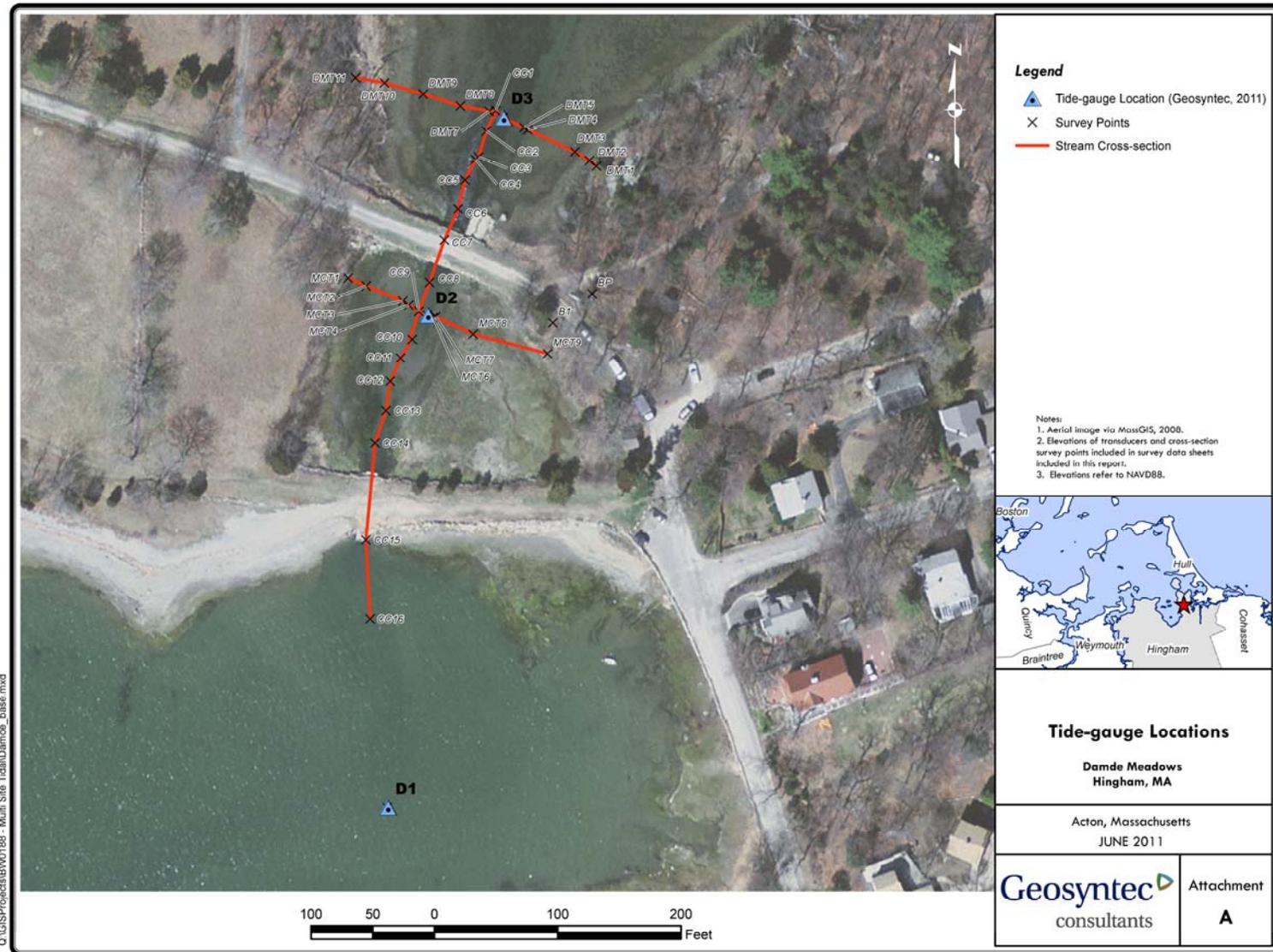


Figure 5. Tide gauge locations