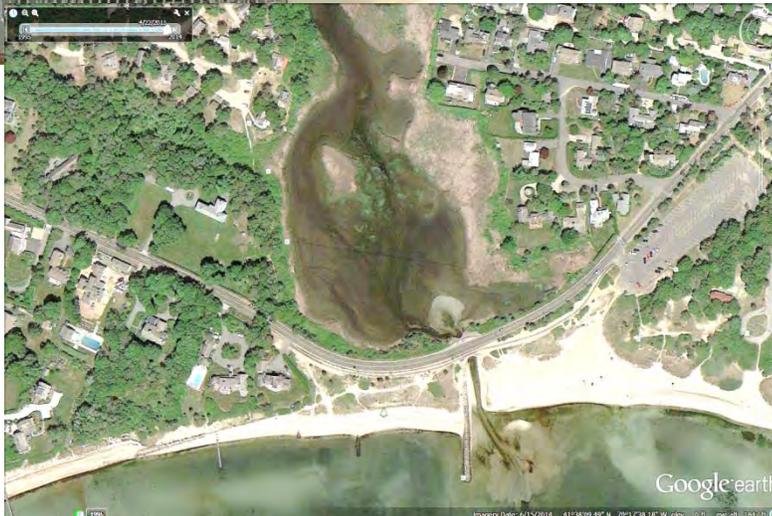


Final Report

Stewart's Creek Phase II Technical Memorandum Summary



Prepared For:
Town of Barnstable
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SUMMARY

The Phase II investigation is focused on evaluating the performance of the Stewarts Creek project, and determining:

- What have been the effects of the project?
- What additional estuary response may occur?
- Has the project performed as expected?
- What complementary actions should be taken to enhance project performance?

In addressing these questions, new data were collected also advancing monitoring protocols in the operations and maintenance (O&M) plan. These data include tide and salinity measurements, vegetation surveys, sediment sampling and testing, benthic invertebrate sampling and sorting, and elevation surveys within the marsh system. The work was completed in cooperation with the Town of Barnstable Public Works Department including Survey Teams, as well as the Cape Cod Conservation District.

Tides and Salinity

Tide and salinity measurements were collected at one (1) location outside of and three (3) locations within Stewarts Creek. 100% data return was achieved, and the data provide direct insight into how the tide makes its way from Nantucket Sound/Lewis Bay through the new Stewarts Creek culvert under Ocean Avenue, and within the Stewarts Creek system. Results show tidal action has been restored to the Creek. In the main embayment upstream from the culvert, the water level fluctuates between 1 and 1.5 ft every tide cycle. Farther up within the system (e.g., north of “The Cove” near Stetson Street), water level fluctuates between 0.5 and 1 ft on a regular basis. Salinity in Stewarts Creek fluctuates between nearly salty ocean water to nearly fresh water on most tides.

These tide and salinity characteristics reflect those of an estuarine system; thus, one of the purposes of the project has been advanced. Historically (~1880), Stewarts Creek was an estuarine system, but since Ocean Avenue became a closed causeway, Stewarts Creek had very limited tidal action and has mostly been a freshwater impoundment.

The full tide range from the Sound has not been restored, nor was it expected. Tides in Lewis Bay typically fluctuate between 2 and 3 ft, with higher tides typically 0.5 ft higher and lower tides typically 1 ft lower than Stewarts Creek, respectively. The USACE pre-project analysis anticipated the new culvert would restore tidal action to Stewarts Creek. Their pre-project analysis predicted high tide elevations within Stewarts Creek to within 0.2 ft of the post-project measurements presented herein. Low tide elevations were anticipated to be approximately 0.7 ft lower. Thus, the actual tide levels measured within Stewarts Creek are fluctuating less than expected, but mostly at low tides (i.e., the pre-project USACE predictions suggested the tide level would fall lower at low tide). The difference may be due to uncertainty in the analysis, and also may be affected by accumulation of vegetation on the debris racks observed to limit drainage of water from the system at low tides.

If the system did drain lower at low tides, then additional mudflat area would be exposed. One recommendation is to repeat the tide measurements as part of a future annual monitoring effort (required by the O&M Plan), and to plan a couple of debris rack clearings during the measurement period to quantify the effects of accumulated debris on tides in Stewarts Creek.

Vegetation

The type of density of vegetation was measured along transect lines. Similar transects were also measured pre-project, and focused on areas of dense *Phragmites*. One of the project purposes is to introduce tides and salt water with potential to limit advance of invasive *Phragmites* and reduce its areal coverage so more desirable salt marsh vegetation can establish. The vegetation surveys showed no meaningful reduction in *Phragmites* and initial recruitment of other desirable salt marsh vegetation on the mud flats. Soil pore water testing also showed the water in the soils where the *Phragmites* grows remains relatively fresh. Comparison of the tide measurements with the elevation of the land where the *Phragmites* is growing also shows that the high tide levels do not inundate the *Phragmites*. Thus, the project objective for *Phragmites* retreat has not yet been achieved, nor is it expected to occur given prevailing conditions. Additional actions, such as physical removal and/or herbicide application would be required. Lowering of the marsh plain elevation to a level regularly inundated by tides along with installation of ditches to convey salt water flow could be effective as well. This type of wetland modification or marsh plain skimming has been practiced on the east coast, but is not common in this region and can be costly.

Data also showed there are areas of intertidal mudflat now exposed as a result of introducing tides to the system. Whereas the previously impounded system largely inundated these mudflats, the newly introduced low tides expose these areas. Although the survey data to date are inconclusive, qualitative observations suggest Stewarts Creek may be accumulating sediment on a flood tidal shoal, with potential to further increase the exposed intertidal areas at low tide. These intertidal areas may provide suitable habitat for colonization of salt marsh vegetation such as *Spartina* species. Colonization of these areas may happen naturally over the next 5 to 10 years, and there were initial signs of salt marsh vegetation on the intertidal flats in summer 2016. There may be a need to supplement the natural seed source in the system (which is dominated presently by *Phragmites*) or introduce new vegetation in certain areas; salt marsh seed set on the mud flats may also be inhibited by a combination of high ebb velocities across the relatively unstable soils on the flats. Establishing salt marsh vegetation on the shoals, if desired by the community, may require proactive seeding/plugging and perhaps use of fiber rolls or berms to restrict high velocity sheet flow over the intertidal areas.

Marsh Elevations/Sediment Management

As mentioned above, marsh plain elevation data were collected (by Town Survey Teams). These data were collected to corroborate and compare elevation data with other data sources (e.g., LiDAR and pre-project USACE measurements), and provide more insight on the system. A key finding is the marsh elevation where the *Phragmites* grows is above the high tide level; thus, inhibiting the ability of the system to naturally control *Phragmites*. The new data also were compared to pre-project data to determine if there was evidence of sediment accumulation or erosion from within Stewarts Creek. Qualitative observations suggest a flood shoal is forming

within the main embayment upstream from the culvert. The elevation measurements are so far inconclusive, so a recommendation moving forward is to continue to survey these areas on an annual basis. Meanwhile, a recommendation is to consider regular removal of sediment from the upstream sediment catch basin (part of the USACE design), and to consider removing sand from the approach channel to the culvert on the Sound side and placing the clean sand on adjacent downdrift beaches.

Another aspect of sediment management is related to establishment of channels and flushing of sediment from within the system. In Phase I, public stakeholders communicated an interest and expectation for the restored tidal flow to establish channels within the system, and to possibly transport sediments out of Stewarts Creek. Although not conclusive, no evidence was uncovered that reflects this type of change is occurring naturally, nor is it expected given prevailing conditions. Conversely, again although the data are not conclusive, qualitative observations suggest the system may be impounded sediment on the flood shoal. Personal communication with USACE indicated the potential for establishing flow patterns and channels through a variety of measures. Ideas exchanged include a combination of fiber rolls to channelize flow, community-scale sediment modifications (e.g., teams with shovels in certain areas where channels are desired), and possibly utilization of the tide gate to impound water at a high tide and release the water at a lower tide to create a sediment flushing condition. Such measures should be considered experimental, and would require close cooperation with regulatory officials. Dredging, of course, also could be implemented to directly remove sediment from the system and establish open water.

How/whether sediment is managed will depend upon community decisions for the project as related to establishing salt marsh wetland areas and maintaining areas of open water. For instance, more sediment may be desirable in the system on the flood shoal if the goal is to colonize salt marsh vegetation. If the goal is alternatively to dredge and maintain open water, then more proactive measures should be taken to restrict transport of sediments into the system from the adjacent beaches and through the culvert.

Benthic Invertebrates

Samples of the sediment were collected and sorted for presence and type of benthic invertebrates living in the sediments. Pre-project sampling and testing revealed nearly no benthic life within Stewarts Creek, whereas certain species were detected pre-project in a nearby control area (Halls Creek). New samples collected for this Phase II work indicated benthic invertebrates are starting to colonize Stewarts Creek with the new tidal flow restored. As might be expected, only opportunistic (stress tolerant) species have colonized so far due to the large fluctuations in salinity throughout the daily tidal cycle. The benthic community is expected to improve with regard to abundance and diversity over the next 3-years. The benthic sampling and testing work should proceed annually targeting summer months and with care to repeat the locations and analysis from the pre-project testing.

Dredging Technology Review

In Phase I, there remained clear community stakeholder interest in pursuing the dredging aspect of the project that was eliminated from the USACE project for budgetary reasons. There are

challenges associated with dredging in Stewarts Creek related to access, soil types, operating in shallow water, relatively small dredging quantities, and limited areas available for sediment dewatering. Challenges with disposal include large proportion of fine sediment, which precludes use for adjacent beach nourishment and introduces need for dewatering and offsite disposal, or non-traditional beneficial reuse within the marsh system (e.g., berm or marsh island creation). In Phase II, a review of dredging technologies was conducted, including: long reach excavator from land or barge; drag line (from land or barge); small hydraulic dredge; belt filter press; and centrifuge dewatering. A preliminary consideration of cost also was pursued. Depending upon the dredging and disposal methods, primary cost elements potentially include: equipment mobilization; dredging/removal; onsite re-handling/grading; onsite dewatering; loading/trucking offsite; disposal/tipping fees; and site restoration/mitigation. For planning purposes, assuming a rough quantity of 3,000 cubic yards, mobilization would be on the order of \$150,000, dredging would be around \$45/cubic yard, and offsite disposal including dewatering, trucking, and disposal fees would be approximately \$85/cubic yard. A total rough estimate for planning purposes for dredging and offsite removal of 3,000 cubic yards would thus be approximately \$550,000 plus engineering, permitting, and site restoration/mitigation as required.

Path Forward

Next steps for this project will be refined after the public workshop. For discussion purposes, however, there are three categories of potential actions:

- Monitoring and data collection in summer/early fall
 - H₂S monitoring for a future summer event, likely to span a warm period with an afternoon low tide
 - Continue annual vegetation sampling including marsh pore water testing as required to correlate possible causalities if and when vegetation changes occur (e.g., dieback of *Phragmites* or advancement of *Spartina*)
 - Continue annual benthic sampling as required to gauge the colonization of species including abundance and diversity, which is expected to improve over the next 3-5 years
 - Repeat tide and salinity measurements for at least three (3) locations (one inside and one outside Stewarts Creek, plus at least one at an upstream location possibly in the Cove area), including planned debris rack clearings to quantify the influence of debris on tide fluctuations, particularly at low tide
 - Incorporate topographic/bathymetric transect surveys into the annual plan to determine if sediment is accumulating or eroding in certain areas such as the flood shoal
 - Share data with USACE and discuss implications and possibilities for support

- Short-term actions to enhance the project are identified below. As not all of these measures should be implemented immediately, the first step will be for the working group or committee recommended below to decide immediate next steps. Some activities may require supplemental design and permitting, whereas other measures may be readily implemented within current protocols.

- Establish a working group or committee to improve overall communication, and to actively participate in the planning and decision process with Town staff, USACE, and outside consultants as/if required. The suggestion is for at least three (3) residents representing different areas and perspectives, and perhaps a fourth (4th) person representing properties that might be flooded if any alternatives considered pose this risk.
- Regular removal of sediment from the sedimentation basin; consider expanding the basin within reasonable reach of available equipment; consider also removing sand from the jettied approach channel and placing sand on the adjacent downdrift beach
- Eradicate *Phragmites* through physical removal, cutting, burning, and/or herbicide application; general guidelines on effective herbicide application include:
 - Remove dead canes by mowing, hand removal or burning to allow for more efficient herbicide application to live plants
 - Utilize a glyphosate-based photosynthesis blocking product, such as Rodeo, which has been approved for aquatic use
 - Application is most effective in the fall prior to first frost, when the plant begins to senesce and sugars are being translocated from leaves to roots and rhizomes; early spring before desirable species start to grow is a secondary option, but will likely only kill the top of the plant
 - Application may be done locally by dripping, spraying, or wiping
 - Multiple years of seasonal applications may be required
 - Herbicide contacting the mud has been shown to bind to fine sediments and remain bound to the sediments
- Communicate with the fire department for advice and planning if burning *Phragmites* is included in the path forward.
- Utilize the flow control structure to help eradicate *Phragmites*, help manage sediment load, and create conditions suitable for salt marsh growth. Examples may include:
 - Close tide gate at low tide to create low water condition (target a lower low tide) for freshwater to drain from the *Phragmites* marsh plains for a period to be determined depending upon weather and other considerations
 - Subsequently open the tide gate allowing salt water to flow in until high tide (a higher high tide), and then close the tide gate again to capture the salt water for a time period to be determined depending upon weather and other conditions, and allow it to enter the pore water in the *Phragmites* marsh plain
 - Consider draining the impounded area by opening the tide gate as the tide in the Sound ebbs toward low water, thereby allowing for possible export of sediment from the Creek system due to higher velocity flows
- Limit fertilizer use adjacent to the waterway, particularly the dense *Phragmites* stands
- Consider using stop logs to pond water at a certain elevation so the mud flats are less exposed, at least during summer periods when most residents are present. The purpose of this would be visual to preserve open water for residents who

prefer this aesthetic. It should be recognized, however, that this management practice would not promote salt marsh colonization, nor would it help reduce *Phragmites*. Tidal flats that wet and dry are more conducive to *Spartina alterniflora* growth, and measurements show that the water at low tide has freshwater characteristics that allow for *Phragmites* growth. The spring and summer also are the most active growing seasons for salt marsh.

- Community-scale sediment management/channel formation. This may include small-scale disturbances to the existing tidal creeks and flats in an effort to encourage flow to certain areas and potentially help export sediment on ebbing tides.
 - Coordinate closely with USACE on implementing short-term actions
 - Proceed with next steps as required to plan, design, and permit (if needed) supplemental activities.
 - Identify a grant opportunity to provide supplemental funding for the ongoing monitoring efforts. There are unique experiences in Stewarts Creek that can have wider utility for similar estuary restoration projects.
- Mid- to long-term actions to enhance the project
 - Ditching to drain ponded freshwater from high marsh plains and convey saltwater into the dense *Phragmites* areas; consider **perimeter ditches** to capture freshwater from the upland before it drains to the marsh plain; ditches may also be used to connect between the primary marsh channels and perimeter ditches to further enhance drainage, and also create separate *Phragmites* patches for purposes of selective treatment/eradication (e.g., to test relative effectiveness of herbicides on an isolated stand of *Phragmites*, for instance)
 - Marsh plain skimming to eradicate *Phragmites* by reducing the elevation to a level that will be inundated by salt water during high tides
 - Planting *Spartina alterniflora* on the mudflats and other key areas, perhaps with fiber rolls or equivalent protection to reduce flow velocities and allow plants to take hold; consider also supplemental seeding
 - Consider establishing a woody shrub buffer (~25 ft) adjacent to the marsh
 - Install fiber rolls in strategic locations to channelize flow and encourage channel formation
 - Dredge a channel and/or open water embayment with offsite disposal, or beneficial reuse onsite for marsh island or berm creation
 - Consider pumping salt water onto the *Phragmites* marsh plains if other measures are not proven effective

1.0 INTRODUCTION/PURPOSE

This technical memorandum summarizes the work completed by Woods Hole Group for Phase II of the Stewart's Creek Independent Assessment. A stepwise approach was recommended and approved by the Town of Barnstable for Stewart's Creek in an effort to answer the key questions that need to be addressed:

- Did the USACE project perform according to plan or is it performing as expected? What have been the effects of USACE project, and what additional estuary response should be expected and on what timeframe?
- Are there complementary actions that can be taken to enhance the USACE project performance?
- Did the project provide the estuary responses the community expected, and is it feasible for the USACE project to address community desires/expectations?

Phase I was completed previously, and included the following two (2) tasks:

- Task 1. Obtain and review information – Including reports and data from the Town, USACE, independent sources, and similar project(s)
- Task 2. Meeting and documentation – Including correspondence with Town staff, USACE personnel, and a stakeholder meeting/workshop inviting members of the public to understand expectations, observations, and concerns.

The product of Phase I was a technical memorandum, outlining key findings and recommendations for Phase II. A primary objective also for Phase II is to determine whether the expected outcomes from the USACE project are consistent with community expectations. For instance, tidal flow has been enhanced, sedimentation patterns have changed, and certain areas may be more conducive to colonization of salt marsh grasses as compared to pre-project conditions. An area of particular interest is the establishment salt marsh on the intertidal mudflats (previously submerged), and on new areas of sedimentation. Expansion of salt marsh to these areas would be considered successful from the perspective of estuary habitat restoration, but it also may reduce the visible area of open water. There also are community desires well upstream in the system likely outside of the salt water influence from the USACE project, which would require other future projects to achieve. Understanding and managing these expectations is a subject of the Phase II work. Based on discussions with the Town and other stakeholders, the following task scope of work was agreed upon for Phase II:

- 1) Conduct post-construction monitoring and data collection including:
 - a. Air quality (H₂S) measurements - pending
 - b. Updated vegetation and benthic sampling to compare with pre-project data to determine whether the marsh grasses and benthic biological communities are evolving in response to the new culvert
 - c. Tide and salinity measurements to determine if the salt water tidal regime has been restored as predicted for the project

- d. Land and seafloor elevation surveys and sediment samples (with basic grain size, organic content, and density testing) to help determine areas expected for salt marsh establishment and to compare with pre-project data to help gauge sediment characteristics and sedimentation since the new culvert was installed
- 2) Updated review of available dredging technologies suitable for the Stewart's Creek
- 3) Host a public workshop
- 4) Develop a report to address key questions and next steps, clarify restoration goals and success criteria, and refine the project operations and maintenance (O&M) plan.

A Draft Report was issued to document the data collected and preliminary findings in advance of a public workshop held on July 27, 2016 where the data were presented and discussed. This Final Report reflects the July 27 discussions, and includes detailed meeting notes in Section 4. Copies of the public notice and attendance sheets are included in Attachment A, along with written comments received before and after the meeting.

2.0 POST-CONSTRUCTION FIELD DATA AND ANALYSIS

A post-construction monitoring survey was conducted to provide data for comparison against the February 2013 pre-construction monitoring report and the USACE design.

2.1 TIDE AND SALINITY MONITORING

The water surface elevation (tide), salinity, and temperature were measured at four (4) locations within the Stewart's Creek system as shown in Figure 1 using In-Situ AquaTROLL 200s instruments. The AquaTROLL 200 incorporates pressure, conductivity, and temperature sensors to accurately calculate water depth, salinity, and temperature. The instruments were synchronized with a universal clock and programmed to autonomously record a time-stamped data point every 6 minutes during the deployment period. The elevation of each instrument was surveyed by the Town of Barnstable Surveyors to reference the water level records to a common vertical datum (NAVD 88). The instruments were deployed from September 15 through October 31, 2015 for a period of 46 days, which captured at least one (1) full lunar tide cycle. Gauge 1 was deployed, with permission, off a piling at the Hyannis Port Yacht Club to capture the exterior forcing tides for Stewart's Creek from within Lewis Bay. Gauge 2 was deployed in Stewart's Creek in the tidal creek upstream of the flood tidal pool to capture the tide signal that immediately enters the Stewart's Creek system. Gauge 3 was deployed upstream of the tide gate between the main basin and Cove area to capture the tide as it propagates from the main basin and enters the creek portion of Stewart's Creek. Gauge 4 was deployed upstream of the Cove as far north as the condition of the marsh would allow (where the water depth was sufficiently deep to deploy the equipment at low tide) to evaluate the tides reaching the upper portion of the creek.



Figure 1. Tide, salinity, and temperature monitoring locations.

Upon recovery of the instruments, the data were downloaded, checked for accuracy, and processed. The pressure data recorded by the AquaTROLLs was corrected for atmospheric pressure changes using a meteorological data record for the time period from the Barnstable Municipal Airport. A summary of the tidal datums for each gauge are found in Table 1 including mean lower low water (MLLW), mean low water (MLW), mean tide level (MTL), mean high water (MHW), mean higher high water (MHHW), and the mean tide range (MR). The mean high tide level is attenuated from 1.6 ft in Lewis Bay to 1.1 ft in the Stewart’s Creek basin, and

then stays relatively consistent up to and beyond the Cove. The low tide level increases with distance upstream in Stewart’s Creek. The mean range (average difference between high tide and low tide) decreases from over 3 ft in Lewis Bay to 1.3 ft upstream of the culvert in Stewart’s Creek, and then decreases to around three-quarters of one foot upstream of the Cove. The restored tidal prism within Stewart’s Creek (the wetted area between MLW and MHW) is approximately 429,000 ft³. Overall, tidal activity has been restored to Stewart’s Creek, but is attenuated compared to the open Nantucket Sound/Lewis Bay tides.

Figure 2 illustrates the time series of water surface elevation (top), salinity (2nd panel), and temperature (3rd panel) recorded at Stewart’s Creek along with rainfall (bottom) recorded at the Barnstable Municipal Airport. Rainfall values taken from the meteorological data record for Barnstable Municipal Airport were added to identify large rainfall events that could influence the creek. The top panel of Figure 2 shows the modulated neap and spring tidal cycle over the course of the month+ measurement period as the phase of the moon evolves. The plot also illustrates there is attenuation of the tide between Lewis Bay (black line) and Stewart’s Creek (blue, red and green lines), but once the tide enters the system there is little dampening of the high tide between Gauges 2, 3, and 4. The plot also demonstrates the alternating higher high and lower high tides that occur each day (known as the *diurnal inequality*). In addition, the salinity data shows salinity within Stewart’s oscillates from salt water (32 ppt around high tides) to nearly fresh water (0 ppt around low tides) on every tidal cycle. This indicates that tides are being restored to the pond, but there is still significant freshwater input that drains from the system.

Table 1. Tide datums based on observed water levels at Stewart’s Creek.

Tidal Datum	Gauge 1	Gauge 2	Gauge 3	Gauge 4
ft NAVD88	Harbor	lower	middle	upper
MHW	1.66	1.12	1.24	1.09
MLW	-1.42	-0.18	0.40	0.34
MTL	0.12	0.47	0.82	0.71
MHHW	1.86	1.25	1.37	1.21
MLLW	-1.59	-0.24	0.38	0.33
MR	3.09	1.30	0.84	0.75

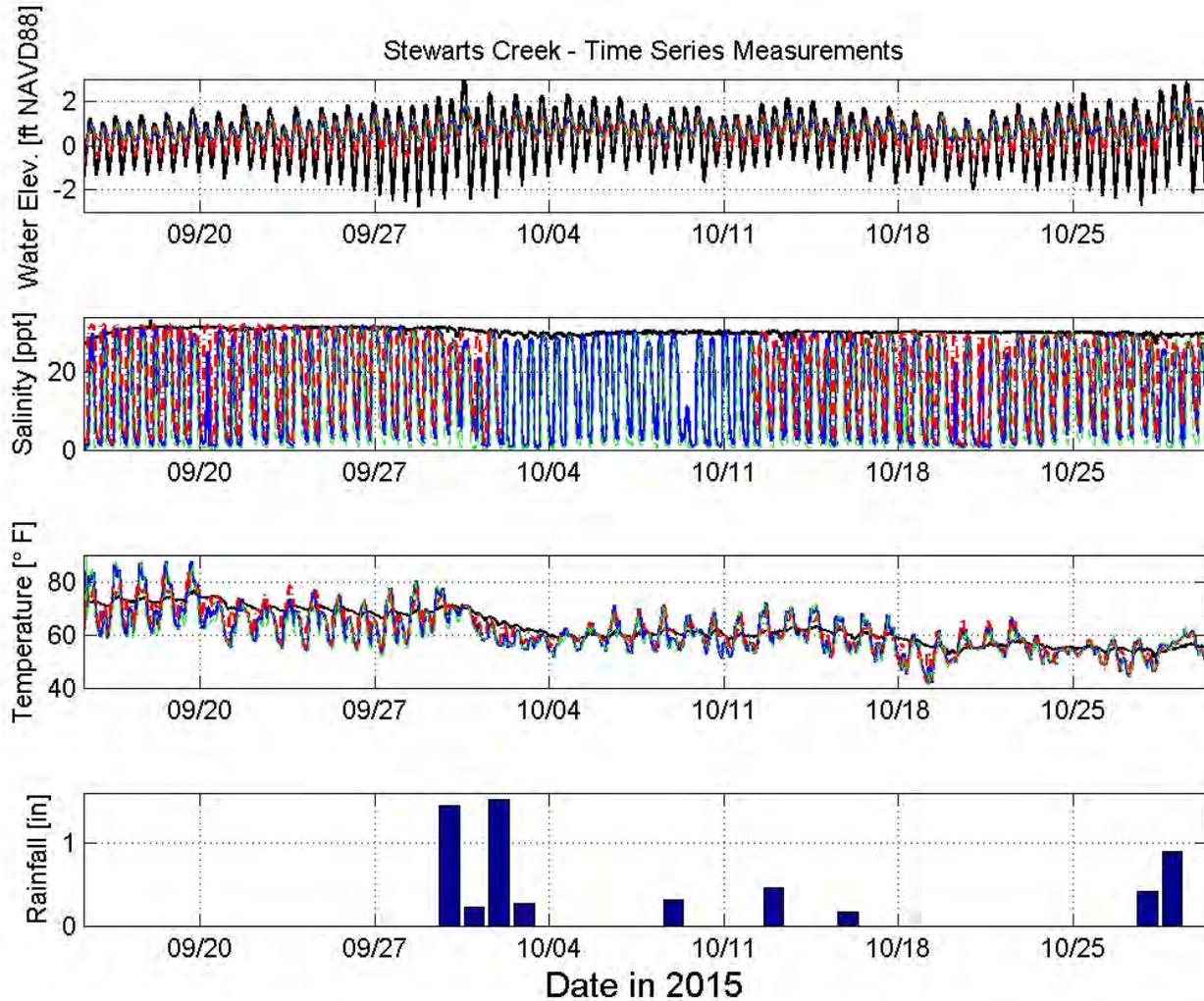


Figure 2. Times series measurements showing water surface elevation (top), salinity (second), temperature (third), and rainfall (bottom) at the four monitoring locations at Stewart's Creek including Lewis Bay (black), lower basin of Stewart's Creek (red), mid-creek (blue), and upper creek (green).

Greater insight into the tidal dynamics within the Stewart's Creek system is revealed through examination of the measured time series data over a shorter period of time. Figures 3 and 4 illustrate a 2-day sample zoom view of the water surface elevation and salinity time series data during a representative spring and neap tide, respectively. Figures 3 and 4 show that during both spring and neap tides there is significant attenuation of the high tide from Lewis Bay (black line) to Stewart's Creek (blue, red and green lines). There is a reduction of peak water surface elevation at high tides and a delay in the time high tide occurs (phase lag) within the system. Although the elevation of high tide matches well at the three locations within Stewart's Creek, the elevation of low tide increases within the system. Salinity oscillates from nearly salt to nearly fresh water with each change of the tide, typical of an estuary system.

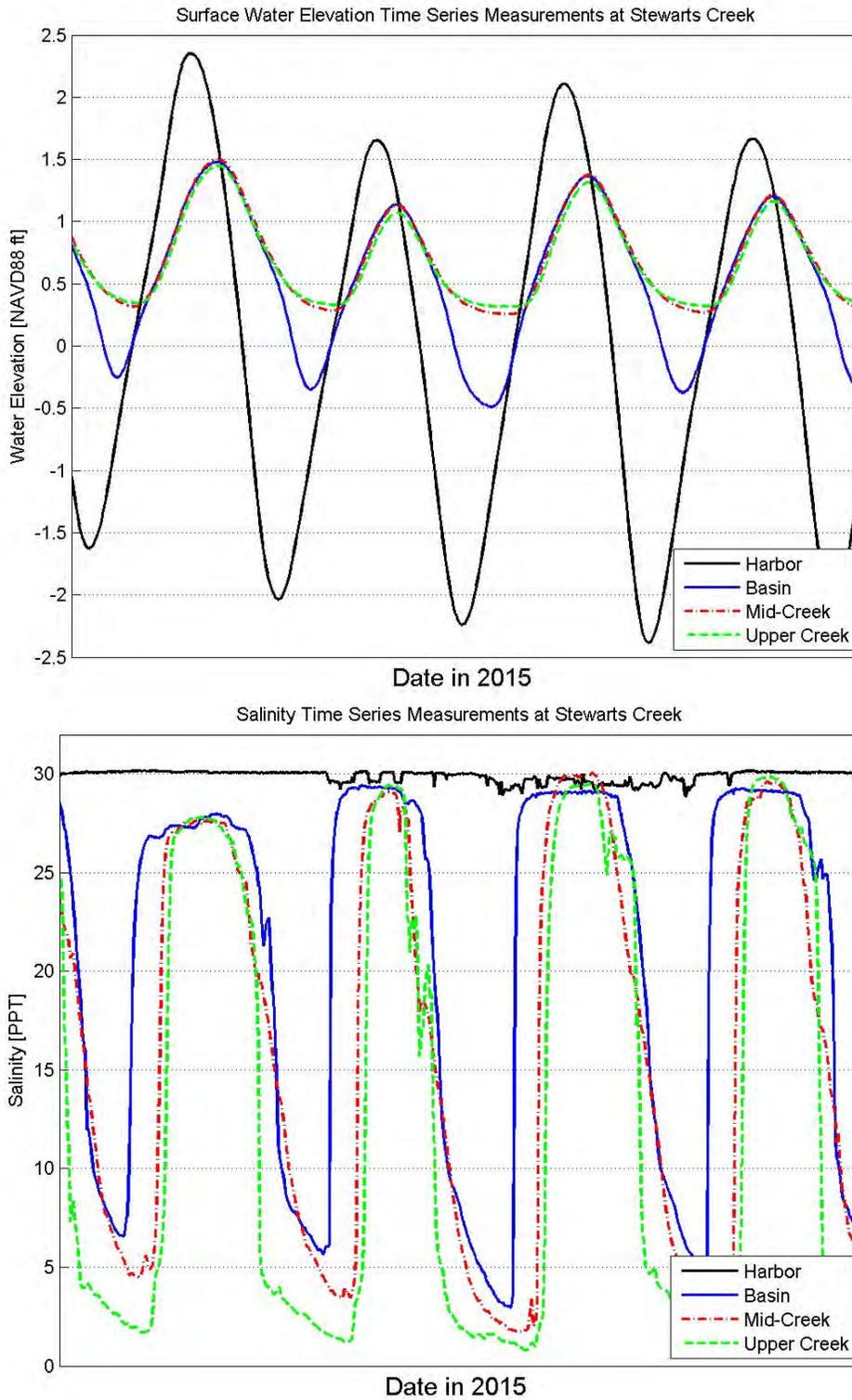


Figure 3. Example of spring tide conditions for water surface elevation (top) and salinity (bottom) at Stewart's Creek.

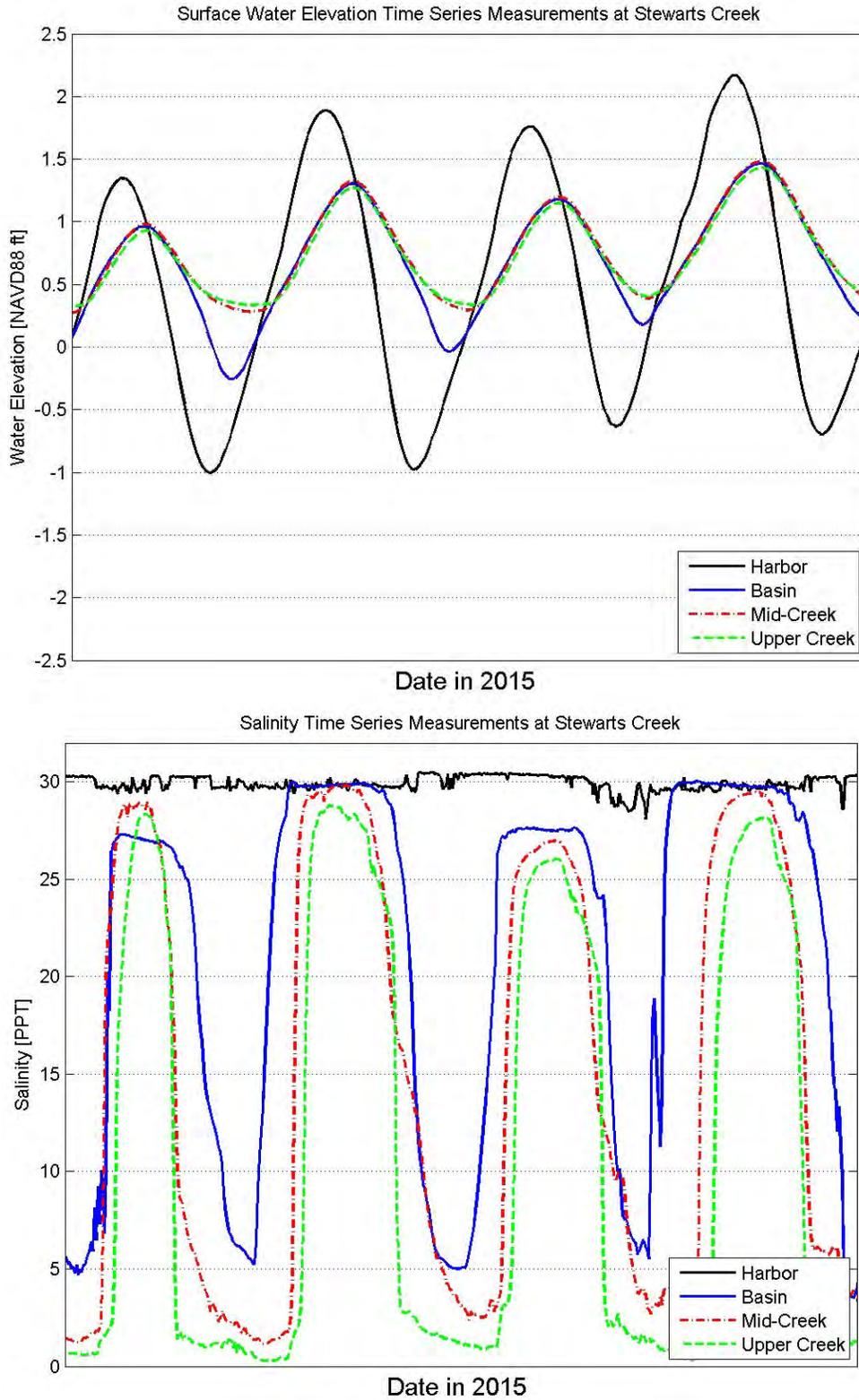


Figure 4. Example of neap tide conditions for water surface elevation (top) and salinity (bottom) at Stewart's Creek.

Results from the post-construction tidal survey were compared to the pre-construction hydrodynamic modeling results and predictions by the USACE. The USACE results were performed using the older NGVD29 (ft) datum, and results were converted to the modern NAVD88 (ft) datum using VDATUM. USACE predicted tidal restoration within the system after the culvert was installed. The new post-construction field measurement indicated the actual measured MHW is slightly greater than the modeled results (within ~0.2 ft), but MLW is almost 0.5 ft greater than the pre-construction model predictions. Consequently, the mean tidal range is ~0.8 ft less than pre-construction model simulations. In summary, the culvert is allowing the designed MHW to enter through the culvert, but there is a lag in draining through the culvert on the ebb tide.

Table 2. Comparison of the measured tidal datums by WHG at Gauge 2 to the pre-construction modeled tidal datums by the USACE.

Tidal Datum (ft NAVD88)	WHG Gauge 2 (ft NAVD88)	USACE (ft NAVD88)	Difference (ft)
MHW	1.12	0.90	0.23
MLW	-0.18	-0.87	0.70
MTL	0.47	0.01	0.46
MR	0.94	1.77	0.83

2.2 ELEVATION SURVEYS

Elevation data for Stewart’s Creek were updated using survey data collected by the Town of Barnstable department of Surveying, along with the latest available LIDAR data (2011). The Survey Department used a Trimble R10 RTK GPS to occupy similar cross-section locations as surveyed by USACE during the pre-construction monitoring as shown in Figure 5.

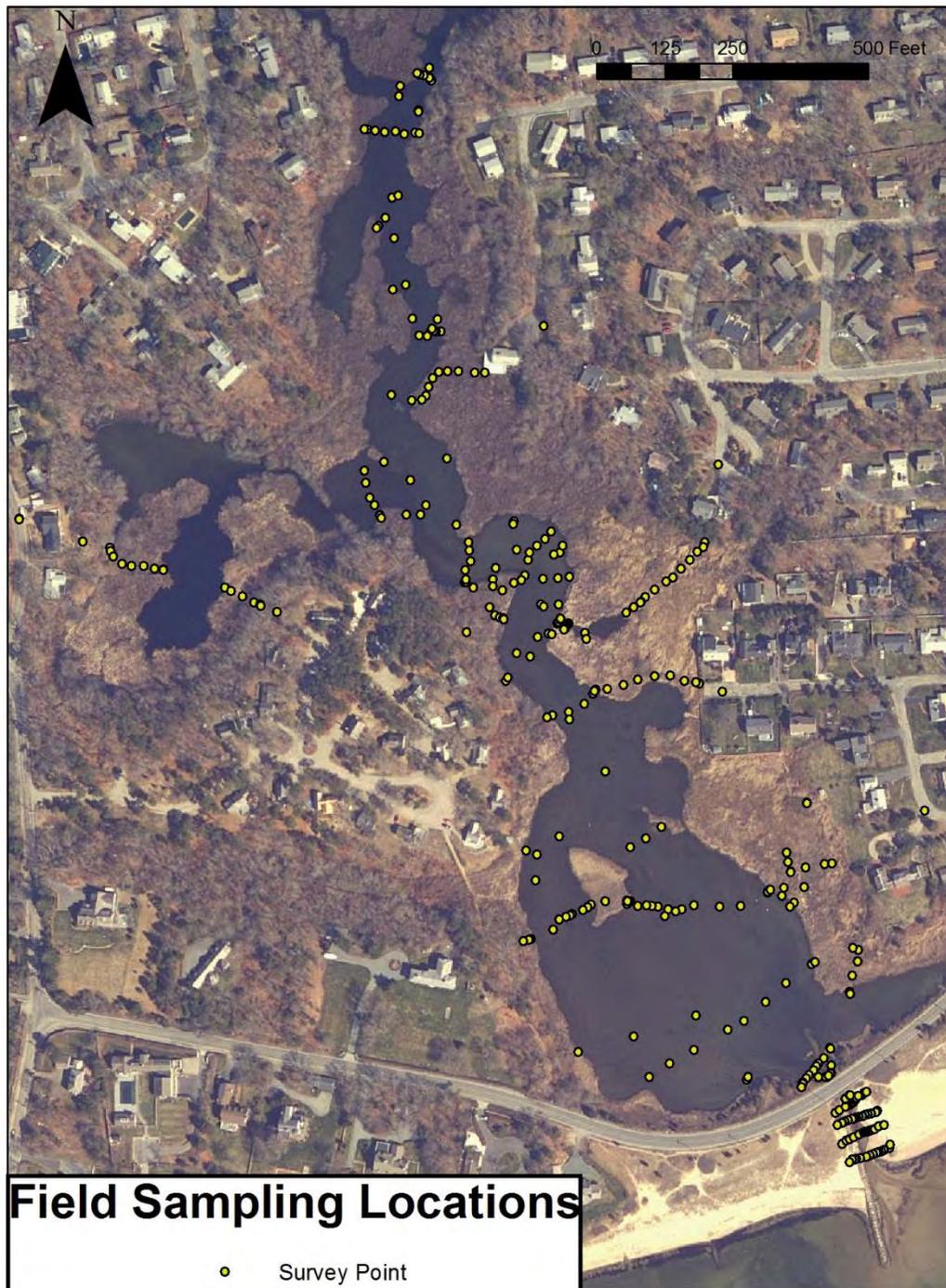


Figure 5. Survey data points collected by the Town of Barnstable department of surveying.

Light Detection and Ranging (LIDAR) is a remote sensing method employed from a plane that uses light pulses (lasers) to measure ranges, which are converted to elevation data sets. The most recent LIDAR data set collected by U.S. Geological Survey (USGS) was used to supplement the survey data collected by the Town. In addition, the LIDAR data was ground-truthed and

adjusted, where necessary, using the survey data collected by the town. A combined survey and LIDAR elevation data referenced to NAVD88 (feet) is shown in Figure 6.

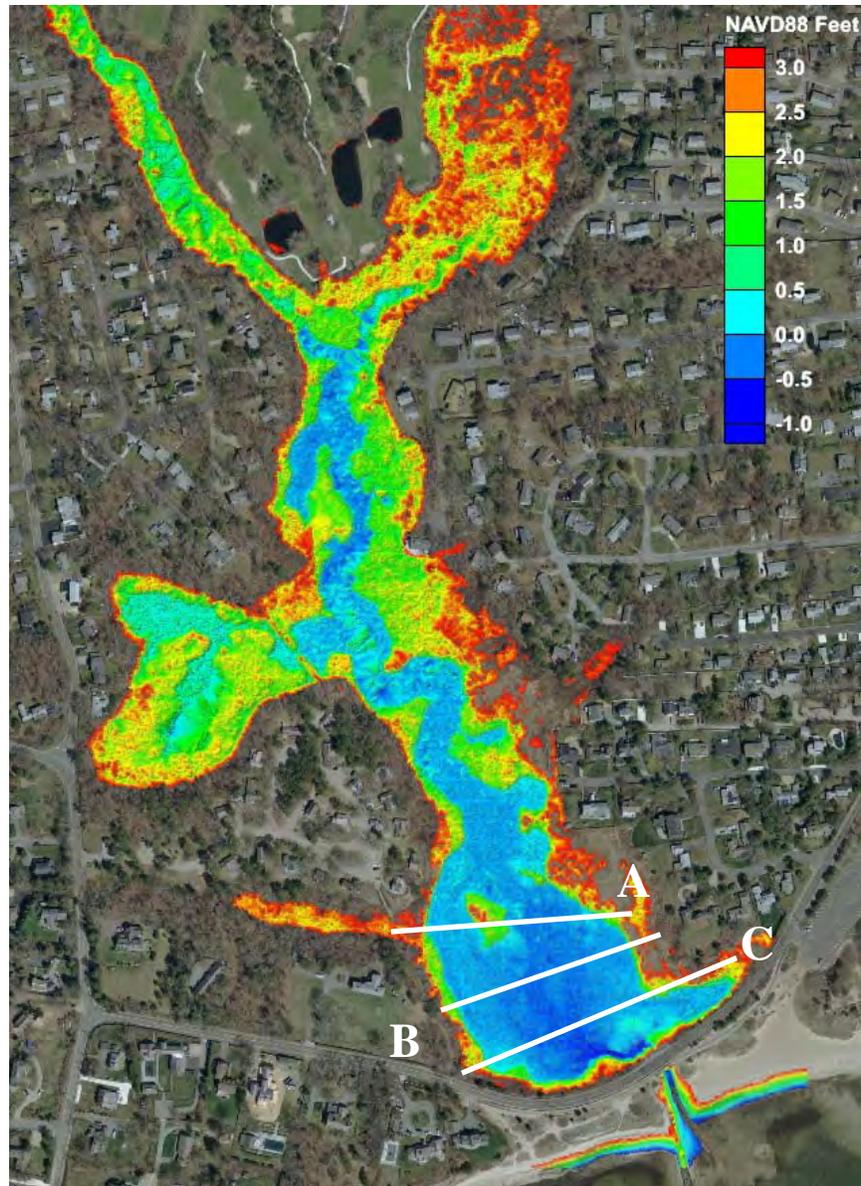


Figure 6. Composite map of LIDAR data adjusted using Town Survey Data.

From this data, three (3) cross sections were extracted based upon the original USACE survey cross-section locations as indicated by the white lines in Figure 6 for Cross sections A (upper basin), B (middle basin), and C (lower basin). A depiction of the USACE pre-construction cross sections versus the post-construction cross sections are shown in Figure 7 below. The figure indicates that about a 0.5 – 1 ft layer of sediment has eroded away in the middle (B) and lower portion (C) of the basin. The upper basin, Transect C, has been relatively stable although the two creek channels on either side of the island appear to have scoured by up to a foot. While these

results would seem to indicate that the ~1ft top layer has scoured in the Stewart's Creek basin, the sediment cores appear to indicate that this layer is still present. It is quite possible that some of this fine top layer was removed though just not completely.

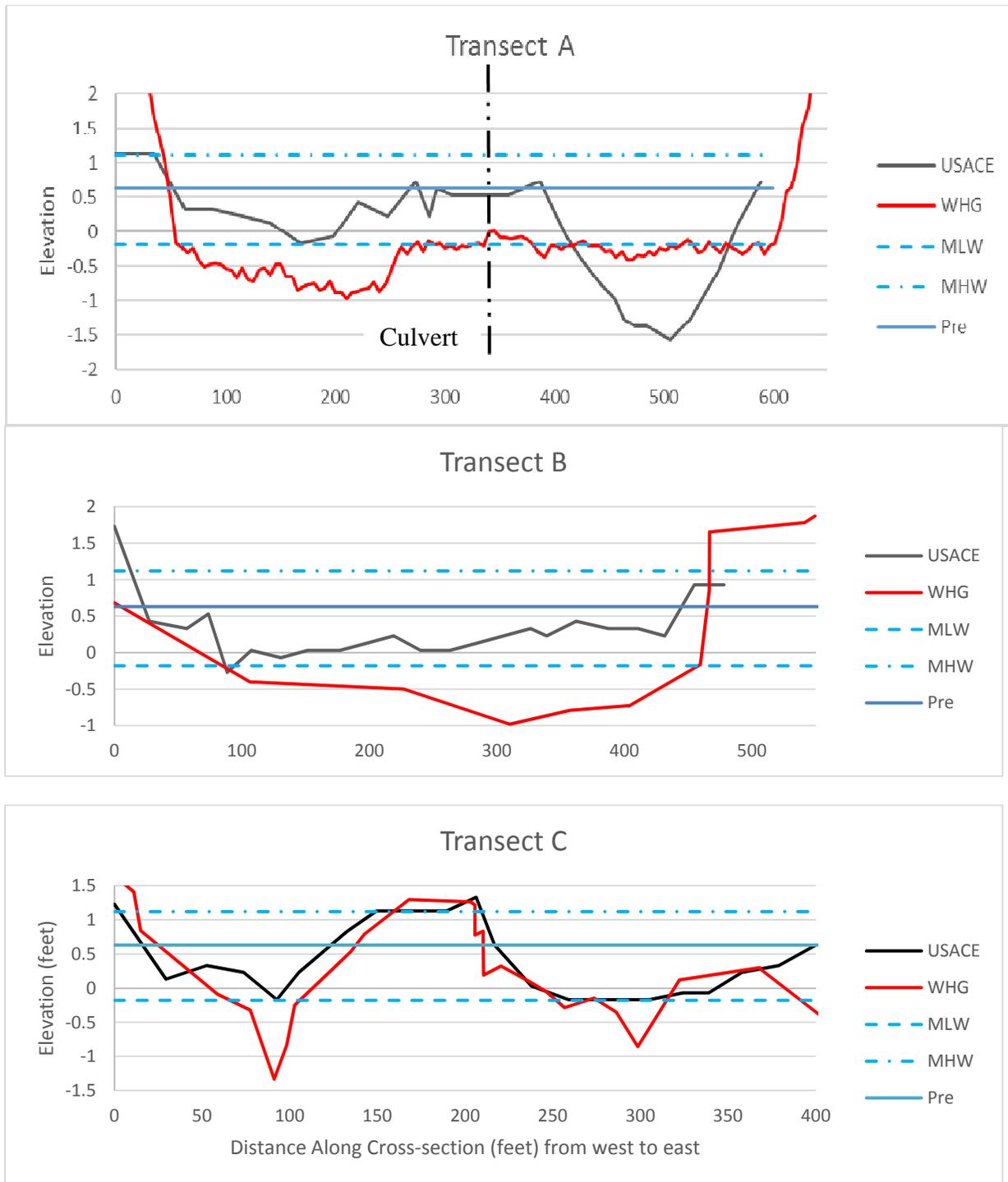


Figure 7. Cross section from lower (top), middle (middle), and upper (bottom) basin of Stewart's Creek.

2.3 HYDRODYNAMIC ASSESSMENT

From the combined bathymetric and LIDAR data, a hypsometric curve was generated for Stewart’s Creek. The hypsometric curve provides information to estimate the area of the basin inundated for a given water surface elevation or tidal stage. For instance, Figure 8 shows the estimated wetted area at MHW is ~20 acres, whereas the area inundated at MLW is ~12 acres. The intertidal area, then, is around ~8 acres. Figure 8 also shows if the MHHW level in Lewis Bay was somehow introduced to Stewart’s Creek (e.g., no tidal restriction at all), the estimated wetted area could increase to 25.8 acres.

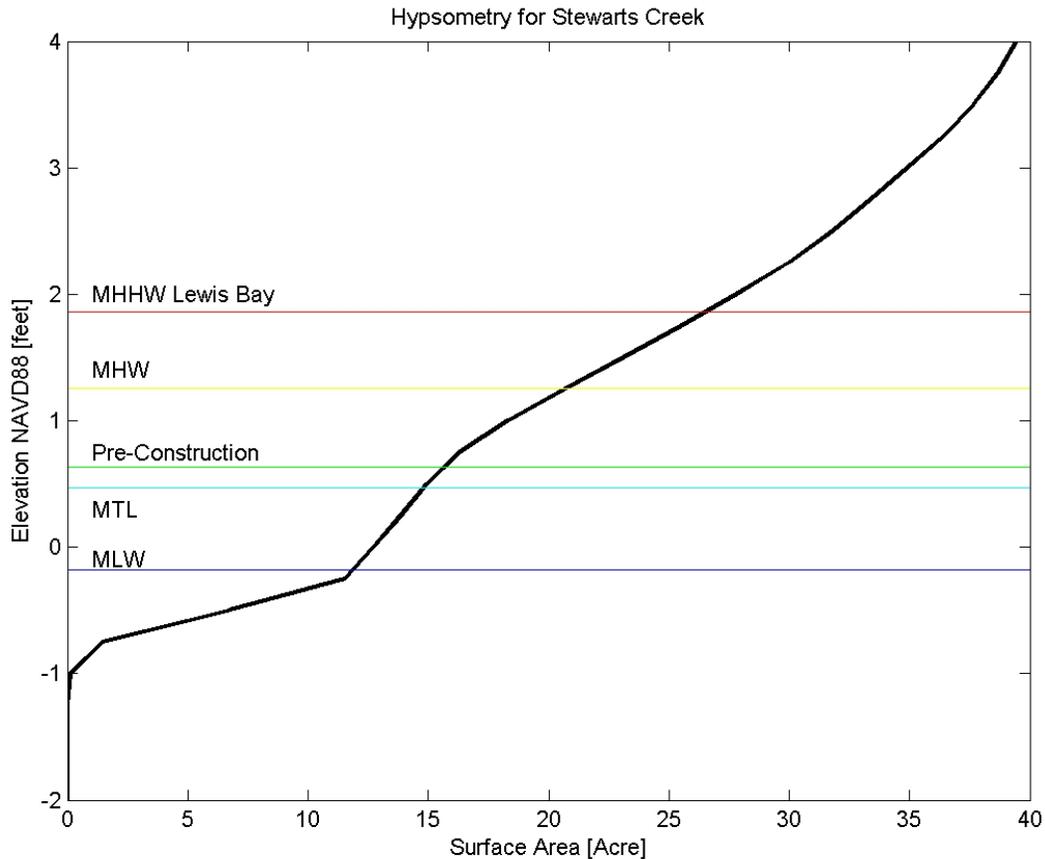


Figure 8. Hypsometric Curve showing the area of inundation for Stewart’s Creek at various tidal stages.

Figure 9 below indicates areas of inundation (flooding) during various phases of the tidal cycle including inundation at: MLW (dark blue); MTL (light blue); MHW (orange); and if the MHHW in Lewis Bay (red) somehow entered the system. This figure reveals several interesting trends at Stewart’s Creek. The first is that a typical MHW reaches far up Stewart’s Creek past the fork at the Golf Course, which means tidal flow has been restored up a significant portion of the creek. At low tide (MLW), the main stem of the creek and basin are still flooded, but the eastern cove has gone dry, a trend that has also been noted by the residents living there. Significant dampening of the tidal signal from Lewis Bay into Stewart’s Creek was noted previously, and the potential for further tidal restoration into Stewart’s Creek from Lewis Bay

was evaluated. The figure shows that even if the full high tide from Lewis Bay at MHHW entered Stewart's Creek that there would not be a significant gain in the inundated area as the red and orange areas are blended together.

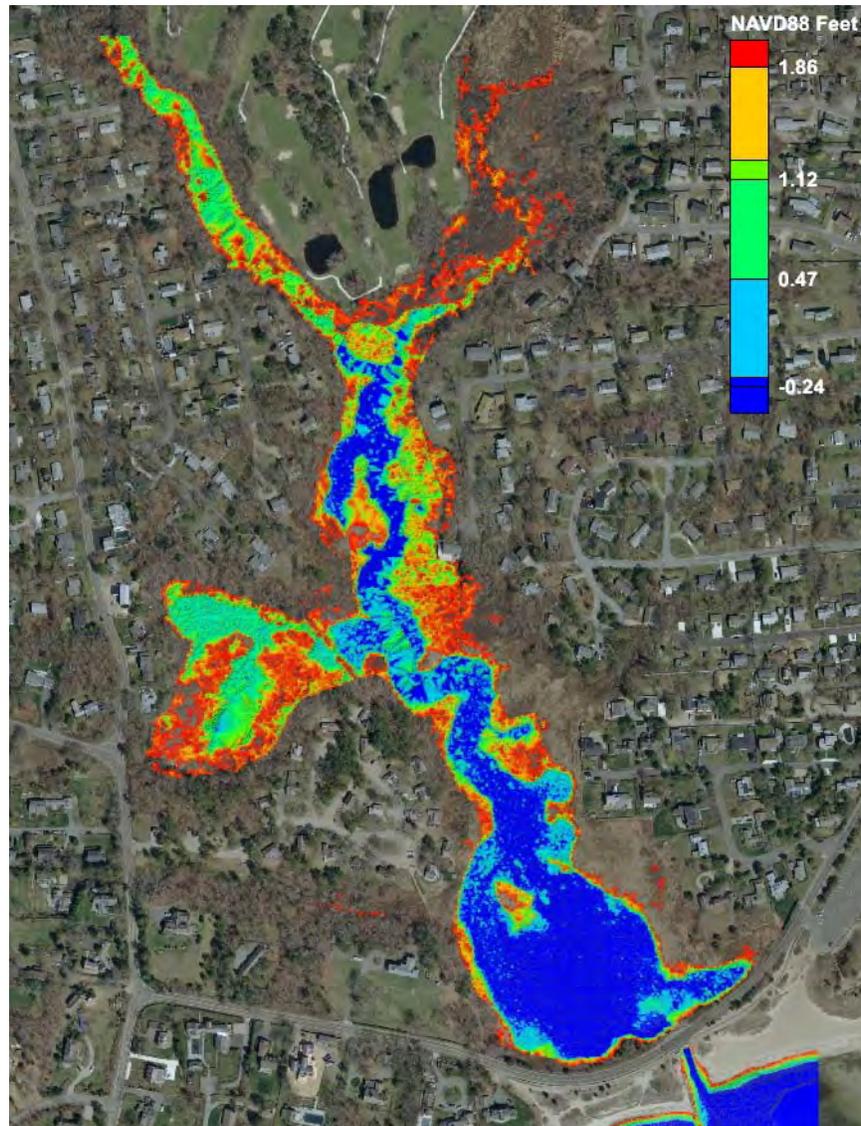


Figure 9. Areas of inundation at MLW (blue), MTL (light blue), MHW (orange), and MHHW in Lewis Bay (Red).

2.4 VEGETATION SAMPLING

Figure 10 shows a map of the vegetation transects surveyed post-construction by our project partners, the Cape Cod Conservation District (CCCD). Prior to the restoration, this series of sampling stations were established in both Stewarts Creek and Halls Creek to establish a baseline of existing conditions. The initial vegetation sampling in Stewarts Creek showed no desirable marsh plain vegetation at any of the sampling stations.

The results of the year-2 monitoring showed there has been little change in vegetation at these locations. During the year-2 monitoring 15 stations (red dots on Figure 10) were sampled in the Stewarts Creek system. At each station the percent cover of each species was noted and the stem density was recorded. Only one station recorded an increase in *Spartina alterniflora* (low marsh species) and *Spartina patens* (high marsh species). This station was located closest to the culvert. All of the other 14 sampling stations were dominated by *Phragmites* and other non-desirable fresh water species. None of these 14 stations had any desirable marsh species.

One of the objectives of the restoration was to improve marsh habitat by reducing the aerial coverage of *Phragmites*, and increasing the coverage of desirable marsh species such as *Spartina alterniflora*, *Spartina patens*, *Distichlis spicata*, etc. This was to be accomplished by increasing the tide range and salinity within the Stewarts Creek system. Increasing the tide range would allow the marsh plain to be covered on a regular basis with saline tidal waters; thus, covering the marsh plain with salt water. The introduction of salt water on the marsh plain would stress and/or kill the *Phragmites*.

There are two potential reasons the *Phragmites* is not dying back and allowing for possible recolonization by desirable marsh species. First, the high tide level has not increased to the level where the tide is covering the *Phragmites* marsh plain on a regular basis. Therefore, a primary mechanism for killing invasive *Phragmites* (saltwater inundation of the higher marsh plains) has not been realized.

Second, the pore water salinity within the system has not increased in porewater where *Phragmites* was sampled. Porewater samples were collected at each of the vegetation sampling locations and analyzed by refractometer in the field and using a YSI multiparameter sonde at Woods Hole Group headquarters to evaluate whether salinity has infiltrated into the marsh plain. Although the tide and salinity measurements within the open water indicate a fluctuating saline and fresh water regime, the pore water of the marsh plain sediments remains fresh. This is reported to occur because the ground water table is close to the surface within the marsh plain, which is at an elevation above the high tide benchmarks recorded by the tide gauges. As a result, the *Phragmites* continues to thrive in the predominately fresh water environment soils and are not being inundated with saltwater during high tide.

Another key concern is time. Although some vegetative response can be expected, it can take 5-10 years for vegetation response to occur in restored systems. Additional factors included a limited natural seed source within Stewart's Creek for desirable vegetation. Tidal currents may also preclude establishment of marsh vegetation in certain areas, such as the newly exposed mudflats, in the central portion of the system upstream from the culvert. Future reduction of the *Phragmites* is unlikely without further intervention within the Stewarts Creek system, such as *Phragmites* eradication (e.g., cutting and herbicide application), salt marsh grass

planting/plugging, and perhaps redirection of tidal currents with fiber rolls or other measure. Reduction of the well-established *Phragmites* also is hampered where the marsh plain has built (by way of sedimentation and accumulated detritus) above the high tide elevation (even above the Lewis Bay high tide elevation in certain *Phragmites* stands within Stewart's Creek).



Figure 10. Benthic and vegetation post-construction monitoring locations.

Figure 11 illustrates initial emergence of *Spartina alterniflora* on the mudflats exposed as a result of the expanded tidal range introduced to Stewarts Creek by the new culvert system. This was a new observation between the Draft and Final Reports. These areas can potentially expand with appropriate tide, velocity, and salinity conditions, as well as seed source. Figure 12 shows an area of vegetation die-back, believed to be previously freshwater species that now are exposed to salt water. The evolution of these areas is a key component of the project to ensure salt marsh species are established instead of invasive species, such as *Phragmites*. These areas should be closely monitored, perhaps with supplemental support from an outside grant agency. There are unique characteristics of Stewarts Creek and its response to the new culvert that have potential wider utility for planning other similar future projects.



Figure 11. Emergent salt marsh vegetation observed in Stewarts Creek (July 2016)



Figure 12. Area of vegetation change with previous freshwater species dying back.

2.4.1 Background on Phragmites and Herbicides

Given the importance of *Phragmites* control to this project, it is important to understand more about the plant. *Phragmites* is a clonal plant that can grow from a single plant and rhizome source. The plant seeds are not very viable and the plant most often spreads by a section of plant breaking off and moving through the estuary looking for a place to grow. Most commonly, the rhizomes become water born through erosion of the channel bank and are carried through a system to a potential new area to establish. Since this type of erosion often occurs during a storm and high water it is well-suited for transporting the rhizome up into an area above the normal high salinity line (MHHW). Ideal places for the rhizome to land are fresh water break out locations and higher plains where salt water does not regularly flood. These can be natural ground water, septic or other sources of fresh water the mother plant can access.

The plant can survive high salinity water during this migration processes as long as it lands in an area where there is freshwater (or low salinity). Once in-place, the plant sends a root down that develops a rhizome at its terminus. Once the rhizome is established it will send out more roots and continue to generate more rhizomes. These additional rhizomes will do two things. First, some of the rhizomes will quickly establish new growth and send up shoots generating more plants. Second, as the plant matures over the years, additional rhizomes will develop that can

remain dormant. These dormant rhizomes can remain below ground for decades. However, if the mother plant is injured or dies, the dormant rhizomes can become active and send up new shoots. There have been experiments where old rhizomes have been excavated from 8+ feet below grade and taken to the lab, where the seemingly dead rhizomes start to grow through an unknown trigger that the mother plant is dead or injured. The other way the plant spreads (can be quite quickly) is when the green stems fall over. Once the stem falls over it shoots across the ground because it can concentrate its energy in growing along the ground and does not need to consume energy thickening the stem to stand up. When on the ground, the stem will send roots down and start new plants generating more roots and rhizomes. These new plants are still connected to the mother plant, which is important because this allows the plant to spread up to 30 ft in any direction in a year. The record horizontal spreading we have measured is 60 ft by one stem in one year. This stem put down a root every 2-3 feet.

With a plant that can spread in a 30+ ft diameter in one year, the plant can reach into areas where there is salt. This is a region where if it was a single plant or rhizome landed; the *Phragmites* would be stressed and most likely would not grow. However, since the plant is still connected to the mother plant in the upland or in an area where there is a freshwater source, the mother plant can send fresh water to all the clones allowing them to grow in a saltier area. Once established, the plants grow and start to terra form. They raise the elevation by producing a large number of rhizomes and through the prolific leaf and stem litter deposited on the marsh plain. This increases the marsh plain elevation, and if located in a marginal region, can elevate the marsh plain from a salty to a brackish elevation allowing for more stability and *Phragmites* expansion.

With this understanding, controlling *Phragmites* essentially introduces a need to kill the rhizomes. Killing, damaging, or destroying the above ground plant will not kill the rhizomes and the plant will return. Herbicides can effectively control *Phragmites* when the herbicide accesses the rhizomes. This is best done in the fall when the plant begins to senesce. When a plant senesces, it is translocating sugars from the leaves to the root and rhizomes to store energy for over-wintering. The following is a potentially successful sequence of events:

- If this is a mature stand of *Phragmites* it is best to first remove the dead canes. This can be done in the late fall or early spring after *Spartina* and other species have senesced and/or before they start to grow in the spring. The dead canes can be mowed mechanically, cut by hand, or burned. Removing the dead canes allows more efficient herbicide application to the plant.
- In the fall after the plant begins to senesce the herbicide is applied by dripping, spraying, or wiping. The most common herbicide to use is a glyphosate-based herbicide. Rodeo is currently registered and approved for aquatic use. Glyphosate is a photosynthesis blocker and prevents the plant from generating amino acids through photosynthesis. When applied over mud, over spray binds almost instantly to the fine grained sediments and remains bound.
- A mature stand of *Phragmites* can take several applications to eradicate the plant (especially considering dormant rhizomes mentioned above). The best application method is to spray the plant in year one, allow growth in year two, remove the dead standing at the end of year two, and then re-spray in year or season three. It may take

longer to fully eradicate the plants, and takes a long-term commitment with monitoring and adaptive management.

2.5 BENTHIC SAMPLING

Prior to the restoration, benthic sampling was conducted in both Stewarts Creek and Halls Creek to establish a baseline for the existing benthic communities. Post-construction benthic sampling was conducted at both Stewarts Creek and the reference site Halls Creek to evaluate whether the benthic communities have changed since the construction of the culvert at Stewarts Creek. Benthic sampling was conducted at five (5) locations within each marsh system during a spring tide low. Benthic sampling was conducted both within the intertidal and subtidal zones as shown in Figure 10; only four (4) of the five (5) sampling locations within Stewart's Creek are shown in Figure 10 due to a GPS malfunction on the fifth location. Samples were placed on ice for transport to the laboratory, where they were sieved through a 0.5-mm mesh size. All sieved organisms were counted and identified to the lowest practical classification.

Pre-construction samples within Stewart's Creek revealed nearly zero benthic life within Stewart's Creek sediments. The updated benthic sampling showed limited increased abundance and diversity. Fifteen to 19 species (depending on date collected) were collected in Halls Creek versus 10-15 species in Stewarts Creek (Table 3). Opportunistic stage 1 species, such as *capitella capitata* (annelida or ringed worms), have colonized Stewart's Creek, which is expected given the stressed condition (e.g., high range of salinity and sediment characteristics with high root/detritus content); however, these were also the most common species at Halls Creek. In comparing composition between the two marsh systems, based on relative densities, the intertidal benthic infauna is not remarkably different, especially if the stress-tolerant species are compared. That is, Stewarts Creek is within the variation exhibited by the two sample dates for Halls Creek. This is in sharp contrast to the infauna composition before the culvert was replaced, in that prior to replacement, there were only four species and 15 individuals at four stations in Stewarts Creek. Thus, it appears that with the introduction of higher quality salt water from Lewis Bay on rising tides that the intertidal infauna of Stewarts Creek is recovering, although the composition still is not equivalent to that of Hall's Cove. However, Halls Creek is more a broad embayment than a tidal creek, so one might not expect its composition to be completely similar even after complete recovery to the best attainable condition. More time (3-5 years is typical) and suitable sediment substrate will be required to establish more diversity including higher level predator polychaetes (annelida), for instance.

Table 3. Composition of benthic infauna data from Halls Creek (reference site) and Stewarts Creek.

Sample Date	HALLS CREEK				STEWARTS CREEK			
	09/29/15		10/10/15		09/29/15		01/20/16	01/01/00
Benthic location	Subtidal	Intertidal	Subtidal	Intertidal	Subtidal	Intertidal	Subtidal	COE
Percent Composition by Phylum								
PLATYHELMINTHES (flat worms)	0	0	17.5	12.5	0	0	1.2	0
ANNELIDA (ringed worms)	91.2	83.1	65.0	77.9	95.0	97.0	95.1	53.3
MOLLUSCA (Mollusks)	4.4	2.0	15.0	4.2	3.6	1.5	0	0
CRUSTACEA (crustaceans)	4.4	14.9	2.5	5.4	1.4	1.5	2.5	0
INSECTA (insects)	0	0	0	0	0	0	1.2	46.7
Total No. of Species	17	17	15	19	15	10	11	4
Total No. of Individuals	155	99	80	159	221	66	81	15

2.6 SEDIMENT SAMPLING

Sediment grab sampling was conducted at the benthic and vegetation sampling locations and coring was conducted at the pre-construction benthic sampling locations as shown in Figure 10 and summarized in Table 4. The grab samples collected from both the benthic samples and vegetation sampling stations and sent for grain size analysis to Geoplan, Inc. Both the vegetation and benthic stations yielded similar results with the median grain size (D₅₀) approximately 0.4 mm in either case, which is indicative a medium grain sand. At the vegetation sampling stations, there was significant *Phragmites* root matter present in the samples that needed to be removed prior to analysis.

Table 4. Sediment grab sampling locations.

Sample ID	D50 (mm)	Std. Dev (mm)
BENTHIC SAMPLING LOCATIONS		
Grab H-1	0.66	0.43
Grab H-2	0.58	0.42
Grab S-1	0.60	0.43
Grab S-2	0.41	0.47
VEGETATION SAMPLING LOCATIONS		
T1P1-0	0.66	0.37
T1P1-12	0.49	0.52
T1P2-0	0.52	0.37
T1P2-8	0.44	0.50
T1P3-0	0.57	0.44
T1P3-9	0.48	0.54
T1P4-0	0.50	0.45
T1P4-10	0.49	0.54
T1P4-13	0.32	0.49
T1P5-0	0.28	0.53
T1P5-15	0.60	0.45
T3P4-0	0.19	0.59
T3P4-11	0.61	0.41

Figure 13 shows a comparison of a typical pre-construction core log (left) collected by the USACE versus a typical post-construction core taken by Woods Hole Group (right). The pre-construction coring results indicated there was a 0.5 – 1 ft layer of fine, silty sediment overlying a sandy layer with some cores showing a peat layer underneath as well. The post-construction coring results indicate that a similar layering composition is still present.

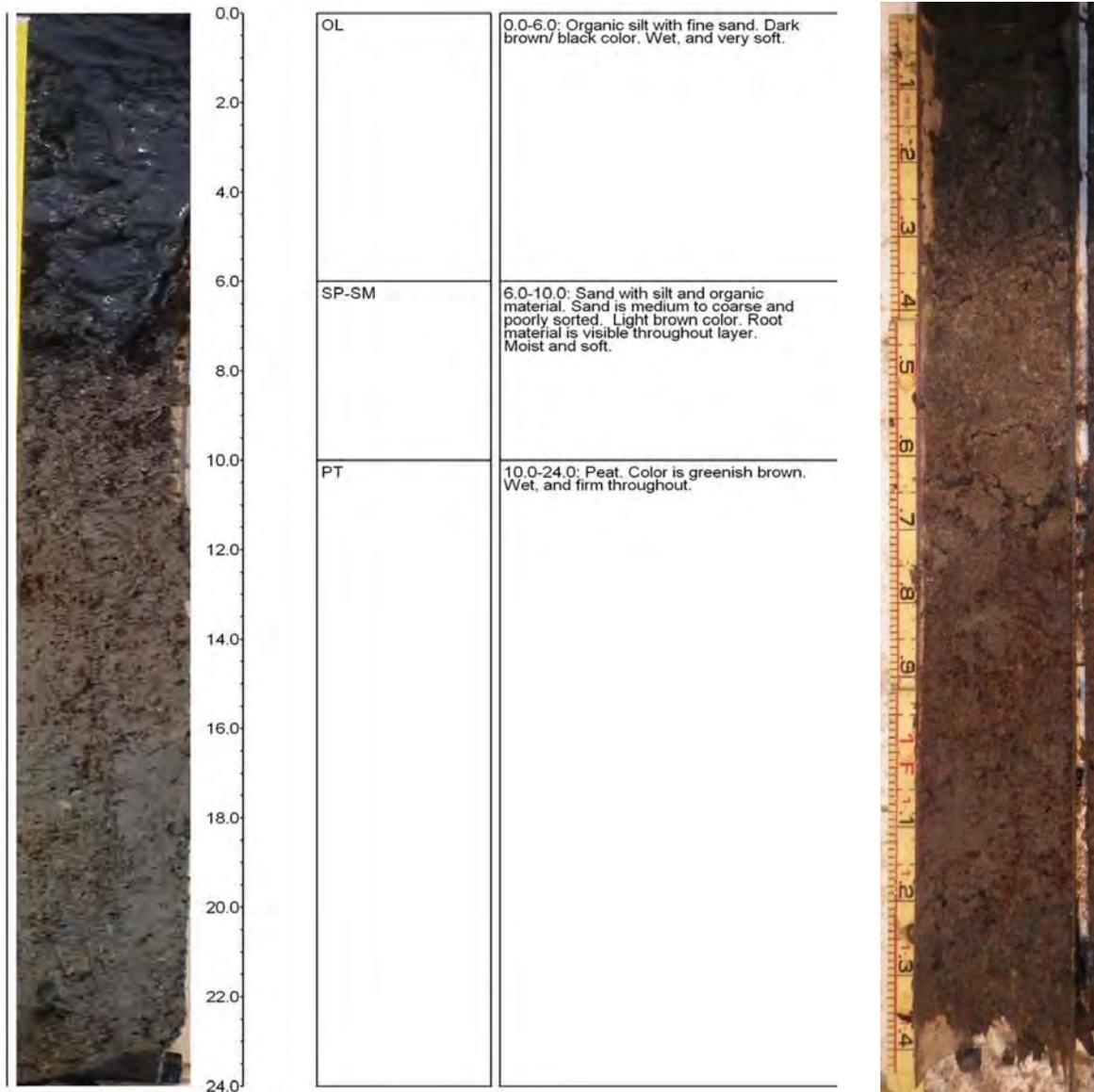


Figure 13. Comparison of a pre-construction sediment core collected by the USACE (left) to the post-construction sediment core collected by the Woods Hole Group, Inc. (right). Composition is very similar between pre- and post-construction cores.

3.0 REVIEW OF DREDGING TECHNOLOGIES

There is interest in dredging Stewarts Creek for the purpose of maintaining open water and channels for circulation. Dredging also was contemplated as part of the USACE alternatives analysis, but was not implemented due to financial constraints. Dredging the Stewarts Creek wetland system presents the following challenges:

- Limited access to the system
- Relatively shallow water depths within the system
- Relatively small dewatering area(s)
- Sediment size; fine sediments limit disposal opportunities
- Level of investment required

In Phase I of this project, the community indicated interest in understanding more about available dredging technologies. In spite of the challenges, dredging technologies do exist that will allow for sediment to be removed from Stewarts Creek and disposed offsite or beneficially reused onsite. Choosing the appropriate technology will depend on the composition of the sediments. Some of the technologies are most effective with fine grain sediment and are less efficient in dredging sediments with a high sand content. Others are just the opposite and are most efficient when dredging sediments with high sand content, and lose efficiency as the percent of fine grained sediments increases. The technologies discussed below can operate in shallow water and within an area with limited access such as Stewarts Creek.

Another consideration will be the disposal location for the dredged sediments. The sediments with a high sand content potentially could be re-used within the Town and therefore would be the least costly to dispose. Dredged sediments with a high percentage of fine grained material will most likely have to be disposed of at a municipal landfill either at Bourne or off Cape, or reused onsite. Fine sediments are not considered beach-compatible; therefore, unlikely useful for beneficial reuse on adjacent beaches. The cost of disposal will depend on the sediment characteristics and the needs of the landfill at the time of disposal. The sediment characteristics will depend on the location of the dredging, which in turn depends on the goals and objectives of the dredging project. The following paragraphs describe some of the dredging technologies considered for this project if a dredging component is incorporated.

These limitations present a challenge when evaluating possible equipment that might be used to dredge either the channel or the flood shoal located upstream of the culvert. The following technologies have been identified that may be applicable dredge the system.

Long-Reach Excavator – From Land

A long reach excavator is simply a conventional excavator that has a long arm that allows the operator to reach out 45-50 feet from the base of the machine. This allows the machine to be positioned on the bank and reach out into the system to remove sediment. This option would be most applicable to dredging the shoal located upstream of the culvert. The dredged material could be directly offloaded onto a dump truck positioned on the road.

Long-Reach Excavator – From Barge

A long reach excavator could be located on a barge and moved through the system. The dredged material would be placed in a small barge and offloaded by an excavator positioned on the road near the culvert. However, offloading would require coordination with the tide as the loaded barge would require a larger draft when loaded.

Dragline – From Land

A long dragline is a crane with a bucket attached that looks like a large scoop. The crane can cast the bucket 45-50 feet from the base of the machine. This allows the machine to be positioned on the bank and reach out into the system to remove sediment. This option would be most applicable to dredging the shoal located upstream of the culvert. The dredged material could be directly offloaded onto a dump truck positioned on the road.

Dragline – From Barge

A dragline could be located on a barge and moved through the system. The dredged material would be placed in a small barge and offloaded by an excavator positioned on the road near the culvert. However, offloading would require coordination with the tide as the loaded barge would require a larger draft when loaded.

Small Hydraulic Dredge

A small truck mounted hydraulic dredge could be launched into the system from the culvert area. The dredge could excavate the shoal and the channel. The channel could be deepened and widened. The dredged material could be pumped into a dewatering area located in the parking lot across the street from the culvert. Once dewatered the material could be placed into dump trucks and disposed of. The area that can be dredged will be dependent on the sediment and the length of the disposal line. Typically, the total length on a small dredge will be on the order of 1,000 to 1,500 ft for sand. This would cover most of the lower estuary.

Belt Filter Press

A belt filter press is a truck mounted series of units that treats the slurry of fine grained sediment generated by hydraulic dredge with flocculants and changes the solids within the slurry into a consolidated cake. The filter cake can be trucked offsite and disposed of. The effluent from the processing can be disposed of directly back into the estuary. The belt filter press is most efficient for fine grained sediments. Its efficiency drops dramatically as the percent of sand in the dredged slurry increases. The truck mounted units could be set up in the parking lot near the culvert.

Centrifuge Dewatering

The centrifuge dewatering unit use centrifugal pump technology mounted in a truck based unit. The system is designed to remove fine grained material from dredge slurry produced by a hydraulic dredge using a centrifugal pump system. The dredged slurry is treated with a flocculent (as with the belt filter press) and then the pump system removes the flocculated solids

passing the water without solids back into the estuary. The cake is then trucked offsite. The centrifuge dewatering unit is most efficient for fine grained sediments. Its efficiency drops dramatically as the percent of sand in the dredged slurry increases. The truck mounted units could be set up in the parking lot near the culvert.

A preliminary consideration of cost also was pursued. Depending upon the dredging and disposal methods, primary cost elements potentially include: equipment mobilization; dredging/removal; onsite re-handling/grading; onsite dewatering; loading/trucking offsite; disposal/tipping fees; and site restoration/mitigation. For planning purposes, assuming a rough quantity of 3,000 cubic yards, mobilization would be on the order of \$150,000, dredging would be around \$45/cubic yard, and offsite disposal including dewatering, trucking, and disposal fees would be approximately \$85/cubic yard. A total rough estimate for planning purposes for dredging and offsite removal of 3,000 cubic yards would thus be approximately \$550,000 plus engineering, permitting, and site restoration/mitigation as required.

4.0 PUBLIC OUTREACH

A public meeting was held on July 27, 2016 at the Steamship Authority offices to present the Draft Report, and to gain public input on the process. Woods Hole Group (Bob Hamilton, President and Coastal Engineer, and Mitch Buck, P.E. and Coastal Engineer) provided an overview presentation as the basis for discussions. Several members of the Town staff attended (Dan Santos, Public Works Director; Roger Parsons, Town Engineer; and Dale Saad, Sr. Project Manager), along with Council Members Jennifer Callum and Paul Hebert. Attachment A provides a copy of the public notice for the meeting, along with copies of attendance sheets for those members of the public who signed-in, and copies of written comments received before and after the meeting. Larry Oliver, Chief of the Evaluation Branch of the US Army Corps of Engineers New England District also attended and spoke at the meeting.

Notes recorded by Woods Hole Group at the meeting are copied below with brief responses [in brackets] or references to sections of report that address the matter. Comments and questions are quoted or paraphrased to the best of the ability. Comments represent the opinions of the public as communicated during the workshop.

Meeting notes:

- Why does there appear to be more visible low tide algae on the bottom growing on the Sound side than in the Stewarts Creek? [No resolution to this question was intended to be addressed as part of this project scope of work. Other testing by the Town may help resolve/identify.]
- Point of emphasis to the community is the odor, which has not been improved. [Noted, H₂S measurements pending to test against health standards, and while tidal wetlands will always have an odor, there is an expectation that the odor will reduce over time as the sediments are oxygenated. Measurements are recommended at low tide during hot weather; a protocol and schedule must be established.]
- Point of emphasis; a community objective was to have open water, and there is not. [Noted, and a major source of discussion and future decision-making with regard to

project expectations, use of tide gate control structure features, dredging, salt marsh expansion, etc.]

- Point of emphasis to the community is dredging – why was this not done, how much would it cost, who made the decision not to do it? [This was a joint decision between the Town and the USACE. Prior cost estimates were made by USACE. Independent cost ranges are provided in Section 3 of the Phase II report.]
- How is it that the project performance is so far off from the projections? [High tides are within 0.2 ft, low tides are perched a bit higher than expected. Salinity has been restored, and wildlife is responding. *Phragmites* has not been reduced substantially, and there is less open water than the public expected. Whether the performance matches projections is partly related to the science and time required for the system to respond, and partly related to public communications and managing expectations particularly since the dredging component was not included in the project, which directly affects visible open water.]
- One resident reported that Sandwich won a suit against USACE for a project that did not meet expectations; is this an opportunity for Barnstable? [This was not addressed directly. If this is related to the Section 111 Project in Sandwich, there is a different set of circumstances related to erosion of a downdrift beach as related to federal navigation of the Cape Cod Canal.]
- A resident reported that in the past there was the ability to take a small boat up and down stream within Stewarts Creek. This is no longer possible. Is there expected to be a waterway in the future for this type of activity, or will be a true marsh? [As implemented, the project was not designed to support or promote navigation.]
- A point of emphasis to the community was to knock back the *Phragmites*. This does not appear to be happening, and is believed to be a failure. Is more saline water needed? One resident suggested if this means opening the inlet more at the expense of flooding low-lying properties, than that may be “too bad.” [The team acknowledges the need for supplemental measures to control the *Phragmites*, and options will be outlined in the *Final Report*. The relative priorities of wetland restoration and upland flooding are not within the scope of this project. The Town could not, however, advance a project that flooded property or represent any kind of “taking.”]
- Why were tides not measured in the cove area? [Measurements were taken in the primary marsh creek outside the cove area in an attempt to represent the overall system dynamics. A recommendation, and supported by Town staff, has been made as part of future monitoring to collect tide and salinity measurements specifically in the cove.]
- Members of the community feel they were told by Conservation Commission there would be open water at all tides. There is not. [Noted.]
- Larry Oliver from USACE addressed some questions. His input is being incorporated into the final Phase II report.
 - The project was originally designed to eradicate *Phragmites* in the lower creek and preserve a pond.
 - The dredging was eliminated because of the substantially increased cost after the geotechnical work showed the bearing strengths of the soils weren't sufficient.

- A decision was made together with the Town to move forward with the project components that would be completed within the fixed budget.
- He believed absent the dredging there was a chance that the surficial black “mayonnaise” type sediment could be flushed from the system. Based on GoogleEarth images, he believes this may be happening slowly at least in certain areas where channels seem to be forming.
- There is other evidence of change as we’ve discussed this evening related to tides, salinity, wildlife habitat, vegetation starting to respond, reported wildlife use.
- If change is not what was expected or desired, then move to an adaptive management approach, which would require clear expectations, decision points, schedule, and alternatives. Adaptive management is fundamentally a process to improve a project incrementally by refining future actions based on observed performance of prior/ongoing actions.
- The structure provides tremendous flexibility.
- Consider cutting, burning, removing, and applying herbicides to the *Phragmites*. If there is substantial root/bio mass causing the soil elevations in the dense *Phragmites* stands above the high tide level, consider a novel approach whereby burning may potentially burn the roots too and cause a lowering of the soil elevation? Coring would be needed to understand the biomass thickness, depth, etc. [Subsequent conversations with Woods Hole Group staff with experience suggested burning will not likely breakdown the biomass or damage roots and rhizomes.]
- A perimeter ditch to intercept freshwater from the upland also can be considered, along with ditching within the *Phragmites* stands.
- Can utilize the tide gate system to trap salt water at high tides to inundate higher areas of *Phragmites* for longer periods of time with salt water. Could even allow freshwater to accumulate for a bit to raise the overall level, while still preserving a relatively high salt content.
- Could also use stop logs to pond some water at low tides to preserve open water visual, but understand this would come at expense of new salt marsh grasses colonizing mud flats. Resident raised possibility of doing this only in the season when most residents are around. Point made that this also is the most active salt marsh growing season, though, so salt marsh restoration would be stunted. [Note, discouraging drainage of water from the system at low tide (which has been shown to be the measurements at low tide to be largely freshwater), will neither advance salt marsh colonization, nor *Phragmites* reduction.]
- Town staff (Roger Parsons) inquired how much focus was on the upper parts of the system and the cove area during the early project planning stages. Generally seemed these were not areas of focus then, but are now, which is part of the challenge.

- A resident raised the question about whether salt water could be pumped up on the *Phragmites*. [Noted need for exposing the *Phragmites* areas to more salt water, which can be accomplished in different ways. This is addressed directly in Section 5 of the Final Phase II report.]
- Overall point of emphasis on the need for better communication. Request for a citizens “committee” of sorts with at least 3 representatives from different areas/perspectives. Requested an “active” role in the planning and decision process; not just to be informed. [Noted, and incorporated as a recommendation in Section 5 of the Final Phase II report.]
- Resident suggested a next step would be for a conceptual plan for designing and permitting a *Phragmites* removal project. [Noted, and incorporated as a recommendation in Section 5 of the Final Phase II report.]
- There was strong voiced opposition to use of herbicides. [Noted. Section 5 of the Final Phase II provides more information about herbicides as a possible measure to help control the *Phragmites*. It is important to understand the application is targeted and not widespread. Whether this is appealing to the Town and public remains to be determined.]
- Concern for the cove area was voiced as there is a feeling that it used to be wet most of the time, but now is mostly dry and looks like “black mayonnaise.” Vegetation also is dying. A couple of photos were provided showing a different landscape between June 2012 and July 2016. [Noted, and the team agrees that more information is needed in this area since there are indications of tidal fluctuations and salinity (hence, the observed vegetation change), but residents are not observing the high tide inundation. More information is included in the Section 5 recommendations of the Final Phase II report to address this matter directly.]? Two residents offered their points of contact for follow-up.
- Dale Saad suggested consulting with the fire department about opinion on burn potential, and obtaining information on root depth and composition. [Noted, and included in Section 5 recommendations.]

5.0 POTENTIAL PROJECT ENHANCEMENTS AND RECOMMENDATIONS

Next steps are detailed in the upfront Summary section of this report, and include:

- Continued monitoring in summer/early fall 2016 to satisfy project O&M objectives and provide supplemental information to address some remaining uncertainty.
- Short-term actions to engage residents in the decision process, select actions to pursue in the short-term, decide and select those measures that can be implemented within existing protocols, and initiate a process for these actions requiring additional planning, design, and/or regulatory approval.
- Mid- to long-term actions for subsequent consideration.

There are certain short-term steps, such as continued monitoring, forming the advisory committee, removing sediment from the capture basin, utilizing the features of the flow control structure, eradicating *Phragmites* by way of cutting and strategic herbicide application, planting/plugging *Spartina*, controlling fertilizer use, pursuing a grant, and perhaps ditching that can potentially proceed in relatively short order. More details are provided in the Summary. A specific prioritization and plan of action will be decided by the Town in cooperation with interested parties. The actual plan of action will depend upon priorities, necessity for supplemental engineering/permitting, USACE participation, and availability of resources.

ATTACHMENT A. MEETING NOTES



Town of Barnstable
Department of Public Works
382 Falmouth Road, Hyannis MA 02601
<http://www.town.barnstable.ma.us>

Daniel W. Santos, P.E.
Director

Office: 508-790-6400
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FOR IMMEDIATE RELEASE

July 13, 2016

CONTACT: Roger D. Parsons, P.E.
Town Engineer
Telephone: 508-790-6302

Stewarts Creek Waterway Project

A meeting is to be held July 27, 2016 at 6:30 PM in the Steamship Authority Conference Room located at 142 School Street Hyannis, MA 02601. The items to be discussed include an overview of recent scientific studies and a presentation of visual charts and graphs showing the project effectiveness. Public comments will be recorded and questions answered.

Stewarts Creek Waterway Project

July 27, 2016

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Stewarts Creek Waterway Project
July 27, 2016

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Stewarts Creek Waterway Project
 July 27, 2016

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Richard Berigault	Tivoli, NY	"	" " "

Stewarts Creek Waterway Project
July 27, 2016

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STEWART'S CREEK PHASE II MEMORANDUM SUMMARY

Woods Hole Group, Inc. for
Town of Barnstable

Public Hearing: Wednesday, July 27, 2016

Questions and Comments from:

Laurence (Larry) P. Morin
Resident of Town of Barnstable and
Member of Town of Barnstable Conservation Commission

Page 1 – Summary paragraph:

- ** what is meant by “new data”?
- ** “advancing monitoring protocols”?
- ** what and where were “elevation surveys within the marsh system”? Situated?

Tides and Salinity

- ** regarding “tidal action restored TO the Creek”, have those been platted or positioned?
- ** same regarding “water level” fluctuations?

Second paragraph, third line... the word “because”, should this be “became”?

Third paragraph: regarding:

“... full tidal range from the Sound...” wise to agree that it was neither restored or expected, however, for the vast amount of property owners who live up stream, this is what they either expected or desired, so what can be done, even if incrementally, to move in that direction?

Also, changes to vegetation in the marsh have been a long-recognized objective to reduce and then hopefully eradicate the phragmites, so what can be done to move this along, especially up stream?

Page 2. continuation of Tides and Salinity

- ** what is meant by the phrase “... plan a couple [should be another word?] debris rack clearings”?
- ** at first glance, this seems like an easy and affordable action to take, at issue though is: what will it accomplish towards the overall goal?

Page 2.

Vegetation

- ** acknowledged that at least one of “focus” was on “areas of dense Phragmites”, and that
- ** surveys reveal/confirm no meaningful reduction of phragmites or advancement of salt marsh vegetation, SO,
- ** what can be done to change this course, even if gradual?
- ** list of suggested “Additional actions” deserves establishing priorities and time table for doing so.
- ** to do so, what can be done to:
 - ** establish, identify and implement Target zones/areas, cost criteria and priorities?
- ** second paragraph starts off with: “Data also showed there are **AREAS** (emphasis added), but
 - **no clear identification as to where they are, sizes, impacts of change, etc?

Marsh Elevations/Sediment Management

- ** again, back to “marsh plain elevation data”, has this been documented and marked on the plans and area, and what affirmative, optimistic, and aggressive plan can and will be proposed to deal with this?
- ** at the last sentence at the bottom of page 3, begins:
 - “Meanwhile.... consider regular removal of sediment from the UPSTREAM catch basin...”
- ** this is probably the focal point and basis of concern from the abutters because most of them own property “upstream”

Page 3 – continuation of Marsh Elevations/Sediment Management

- ** at best, it comes across as “*suggestions*” that you might:
 - consider removing sand from the approach channel (at the culvert?)
 - establish channels and flushing
 - identify changes that occur naturally versus those that must be “managed” and “created”
 - what is contemplated by “a variety of measures”? That WILL be pursued?
 - What can be done to increase the flow pressure through the culvert to get the water changes “upstream”?, and finally

WHAT and WHO makes up the “Community Decisions”? Does that relate to the abutters? Town officials only? Or is it environmental?

Page 3 --- Bethnic Invertebrates

at this time, and without diminishing the significance of this aspect of the project, I do not have any questions or comments to propose.

Dredging Technology Review – continues over onto Page 4

From the outset, this project offered optimistic, perhaps grandiose proposals, for concentrated, extensive and deep dredging objectives. Yet, for reasons that have never been publicly disclosed, those “promises”, especially what was included in the initial proposals and perhaps in the Order Of Conditions, as well, somehow evaporated (no pun intended) or just disappeared. Unless and until some credible and honest explanations are provided, perhaps the public will remain justified in feeling that they have been misled. Yet, to move on at this time, the following questions deserve both answers and forthcoming actions:

1. regarding the “... clear **community stakeholder interest**”, who makes up the “community”, who and what are the “stakeholders”, and are their interests clearly identified, and if so, are they conflicting?
2. further, the very first sentence of this portion admits that the dredging aspect was eliminated from the USACE [U. S. Army Corps of Engineers] project for budgetary reasons.
3. whether or not either the USACE or Town of Barnstable will be forthcoming enough to ever provide credible explanations of these “eliminations”, the continuing absence of them can do nothing to encourage “community” – ie. The public --- from gaining confidence and/or trust moving forward.

It is suggested, therefore, that under this Phase II, including any revisions thereto based on public comment, that an intensified DREDGING plan be proposed, discussed candidly, including costs, probabilities, etc. be set forth front and center.

Page 4 – Path Forward

based on the foregoing comments, it seems that this portion of the Report will and should be the focal points of the following:

1. the public meeting dialog
2. the specific content of the report that comes from that meeting
3. and specific responses as to what WILL be included in a Revised Phase II, and
4. then the future Phase III or any other publicly disclosed plans or revisions thereto.

Pages 5 and 6

It does not appear necessary at this point to propose responses or questions to the sections labeled Introduction/Purpose as well as Post-Construction Field Data and Analysis. The proof of these sections will be measured by: (a) the responses to the public's concerns at and after the meeting, and (b) the quality and frequency of reports and disclosures following this and any future public meeting.

Comments received from Steve and Angela Richards on July 28, 2016

Hi Jen and Bob,

First of all, thank you for all of your work on the Stewart Creek Project. It is never easy to please everyone, especially when it involves individual preferences and ultimately, what we all perceive as impact on our monetary investments.

Based on our perspective and observations of last night's meeting at the Steamship Authority, we would like the following recommendations to be noted:

- **Return the Stewarts Creek to a saltwater estuary as soon as possible.** This was the point of the project in the first place, which includes tidal flow and flushing. Before we move on to another project, let's make sure the goals of the intended project have been met.
 - In areas where fresh water vegetation has died due to salt water intrusion, implement plans to return the habitat to that of a thriving saltwater marsh with appropriate vegetation (spartina seed, plugs, etc).
 - Invasive vegetation would be denied a foothold in areas where the fresh water vegetation has died.
 - Reduce/remove Phragmites.
 - Physical removal, saltwater ditches, burning, herbicide
 - Perhaps we could learn from other communities, in similar situations, what method works best?
 - No dredging
 - Dredging will help appearances at low tide, it does nothing to support returning the marsh to a true estuary. This should be taken on as a separate project, once the objectives of the intended project have been met.
 - No boarding of the culvert
 - Boarding does nothing to support returning the marsh to a true estuary. It will ultimately slow the process, as flushing may be reduced.
- **Communication must be improved**
 - Based upon the limited communication pertaining to this estuary, expectations have run rampant with several stakeholders developing their own understanding of this project. This leads to gross misunderstandings and frustrations.
 - We like the idea of having representatives appointed from each area of the marsh to ensure all involved parties are represented and there is communication to those parties.
 - In addition to having 3 representatives based on geographic location, we also think it is important to have 1 representative of the property owners who would be at considerable flood risk if decisions are made to open the flood gates so to speak. It was

very troubling to hear the comments from some meeting participants who are clearly insensitive to this concern and have their own personal gain objectives in mind.

Time is truly of the essence. As was stated last evening, we can't afford to wait... the transition of the estuary from fresh water to a salt water marsh must be completed as soon as possible or we run the risk of further Phragmites infestation.

Thank you for allowing us to be a part of the stakeholder feedback. We look forward to hearing how we can expeditiously proceed from this point.

Regards,

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