Hydraulic Evaluation of the Two Culverts Feeding the Salt Marshes South of Salt Marsh Lane and North of Wings Neck Road Bourne, MA

April 16, 2021

Prepared for:
Town of Bourne Conservation Department
24 Perry Avenue
Buzzards Bay, MA 02532
Attn: Samuel Haines – Conservation Agent

Prepared by:
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April 16, 2021

Town of Bourne, MA
24 Perry Avenue
Buzzards Bay, MA 02532
Attn: Samuel Haines, Conservation Agent

RE: Hydraulic Evaluation of Culverts Feeding Salt Marshes South of Salt Marsh Lane and North of Wings Neck Road

Dear Mr. Haines:

BSC Group, Inc. (BSC) is pleased to submit this report on the Hydraulic Evaluation of the Culverts feeding the salt marshes south of Salt Marsh Lane and north of Wings Neck Road in Bourne, MA (the Sites). The purpose of this evaluation is to determine if the existing culverts under Salt Marsh Lane and Wings Neck Road are hindering tidal flushing of the two adjacent salt marshes. The attached report is broken into the following sections:

1. Intro: Purpose, Scope of Work, & Background
2. Site History
3. Water Levels & Water Chemistry
4. Modeling
5. Conclusions: Wings Neck Road & Salt Marsh Lane
6. Appendix A

If you have any questions or require additional information, please don't hesitate to contact our office at (508) 778 - 8919.

Sincerely,

BSC Group, Inc.

Matthew Creighton, PWS, MVP
Manager of Ecological Services – West Yarmouth
Sr. Associate/Coastal Scientist

David Crispin, PE, PLS, LSP
Sr. Associate

cc: Samuel Haines, 24 Perry Avenue, Buzzards Bay, MA 02532

Attachments: Hydraulic Evaluation of the Two Culverts Feeding the Salt Marshes South of Salt Marsh Lane and North of Wings Neck Road Bourne, MA

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1. Introduction: Purpose, Scope of Work, & Background

The two salt marshes located (1) south of Salt Marsh Lane and (2) north of Wings Neck Road in Bourne, MA have been reported to be experiencing decline in vegetative cover over time. This may or may not be due to tidal restrictions caused by culverts connecting the salt marshes to the adjacent embayment's. The two culverts in question are located underneath Salt Marsh Lane and Wings Neck Road. The purpose of this study is to determine if these culverts or fill from adjacent roads are hindering tidal flushing and/or effecting the water levels in the salt marshes.

An outline of the Scope of Work is presented below:

Task I: Initial Data Collection

- Topographic survey of both culverts (inverts) and the areas directly adjacent to culverts (channels, salt marshes, embayments) to obtain elevations relative to NAVD88.
- Deploy tide gauges (Onset HOBO Water Level Loggers) on the marsh and bay side of each culvert to monitor water levels through multiple tide cycles.
- Recover tide gauges, then process and analyze data to compare water levels in salt marshes compared to the adjacent embayments.

Task II: Continued Data Collection

- Using Lidar and available USGS topographic information, prepare 1-foot contour map of the marsh and immediately surrounding the upland. (Note: depending on tide levels at the time of lidar survey imagery, this may or may not include elevations below the high tide line).
- Research historic aerial photographs of the site or available GIS information to document changes in limits of the salt marsh.
- Research existing permits and/or licenses for the culverts and channels, if any (e.g. OOC's, Chapter 91, ACOE)
- Compile available record information on the marsh including available GIS information and available/relevant studies.

Task III: Hydraulic Modeling

- Obtain record tidal range information from NOAA.
- Calculate available storage of the marsh (volume of water) based on the lidar topography data (and estimated bathymetry below mean high water if lidar topography is not available below this level).
- Create and calibrate a hydraulic model spreadsheet to calculate the flows through the various control points (i.e. culverts or channels) using published tide levels and calculate resulting water levels on either side of the control point.
- Evaluate any increases in flow to the marshes and resulting highwater levels as a result of modifications to the culverts, creation of new channels; outlets or similar options.

Task IV: Final Report

- Create and submit a report to the Town of Bourne Natural Resources Department summarizing BSC's findings on whether the two culverts underneath Salt Marsh Lane and Wings Neck Road are hindering tidal flushing of the adjacent salt marshes.
- Suggestions for future work.
- Prepare for and attend one meeting with the Client to discuss the report.

The two areas of study are (1) the culvert underneath Salt Marsh Lane and (2) the culvert underneath Wings Neck Road and their adjacent salt marshes. Figures 1, 1A, and 1B below shows the locations of both salt marshes.

The Massachusetts Wetlands Protection Act 310 CMR 10.32 defines a Salt Marsh as…

> *" a coastal wetland that extends landward up to the highest high tide line" (elevation 2.0 for this site),"that is, the highest spring tide of the year, and is characterized by plants that are well adapted to or prefer living in, saline soils. Dominant plants within salt marshes typically include salt meadow cord grass (Spartina patens) and/or salt marsh cord grass (Spartina alterniflora), but may also include, without limitation, spike grass (Distichlis spicata), high-tide bush (Iva frutescens), black grass (Juncus gerardii), and common reed grass (Phragmites). A salt marsh may contain tidal creeks, ditches, and pools.*
>
> *Spring Tide means the tide of the greatest amplitude during the approximately 14-day tidal cycle. It occurs at or near the time when the gravitational forces of the sun and the moon are in phase (new and full moons)."*

Figure 1: Town of Bourne Parcel Map showing both study areas. The star in the upper left is the location of the culvert underneath Wings Neck Road with the salt marsh to the north of the star. The start in the center of the map is the location of the culvert beneath Salt Marsh lane with the salt marsh to the south east of the star. (Additional parcel maps and ownership information is presented in the appendix).

Figure 1A: Town of Bourne Parcel Map showing the Salt Marsh Lane Salt Marsh. The star is the location of the culvert underneath Salt Marsh Lane.

Figure 1B: Town of Bourne Parcel Map showing the Wings Neck Road Salt Marsh. The star is the location of the culvert underneath Wings Neck Road.

The culvert underneath Salt Marsh Lane is a precast concrete box. The dimensions of the culvert are 8' wide x 1.5' high x 25 feet long. Figures 2 through 4 below show the Salt Marsh Lane culvert and adjacent salt marsh.

Figure 2: View of the culvert underneath Salt Marsh Lane. Facing north towards the bay.

Figure 3: View from Salt Marsh Lane of the adjacent Salt Marsh. Facing south east.

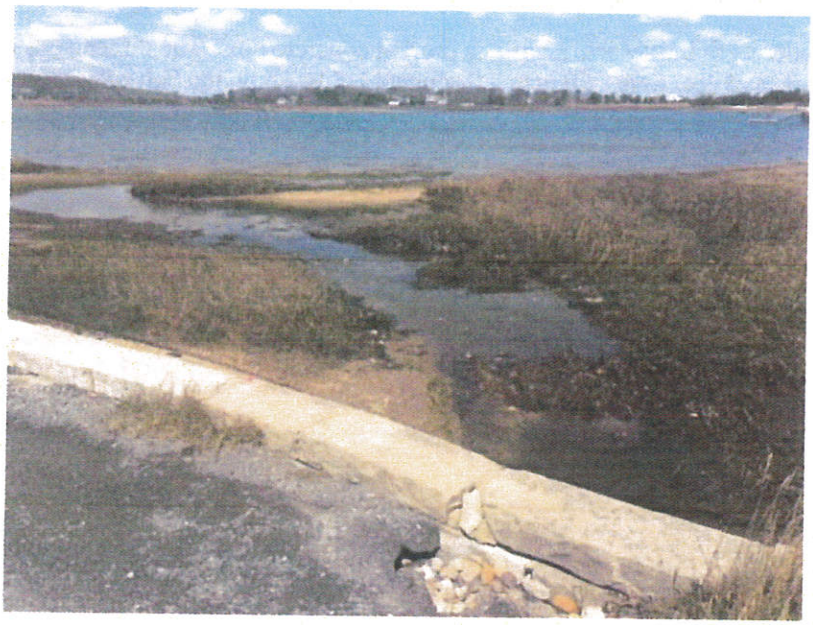

Figure 4: View from Salt Marsh Lane looking at the channel and embayment. Facing north west

The culvert underneath Wings Neck road contains two precast concrete boxes. The dimensions of each box are 4.5' wide x 3' high x 40' long? Figures 5 through 8 show the Wings Neck Road culvert and the adjacent salt marsh.

Figure 5: View of the culvert underneath Wings Neck Road. Facing north towards the marsh

Figure 6: View from Wings Neck Road of the adjacent Salt Marsh. Facing north.

Figure 7: View from Wings Neck Road looking at the channel and embayment. Facing north.

Both culverts appear in good condition based on observations only. Both salt marshes are dominated by native halophyte (salt tolerant) vegetation; primarily consisting of *Spartina alterniflora* and *Spartina patens*.

2. Site History

Human development has impacted almost the entire coastline if New England and these two salt marshes are no different. It had been brought to the attention of the Town of Bourne that the salt marsh south of Salt Marsh Lane used to have another open connection to Hen Cove. Apparently when Circuit Avenue was built, this connection was filled in and removed.

The purpose of this study was to determine if the existing culverts at Salt Marsh Lane and Wings Neck Road were hindering tidal flushing and/or affecting water levels within the adjacent salt marshes. If tidal flushing of the salt marsh south of Salt Marsh Lane has been restricted by the culvert, then one potential solution to the problem could be to re-open the old Hen Cove channel.

Regardless, the salt marsh south of Salt Marsh Lane still has two openings to the bay; (1) the culvert under Salt Marsh Lane and (2) a much larger opening to the south connecting from Barlow's Landing. The historical USGS maps BSC found of this area from 1935 and 1954 do not show a connection from Hen's Cove; see Figures 8 & 9 however, Figure #10 below from 1886 does appear to show a connection to Hen Cove.

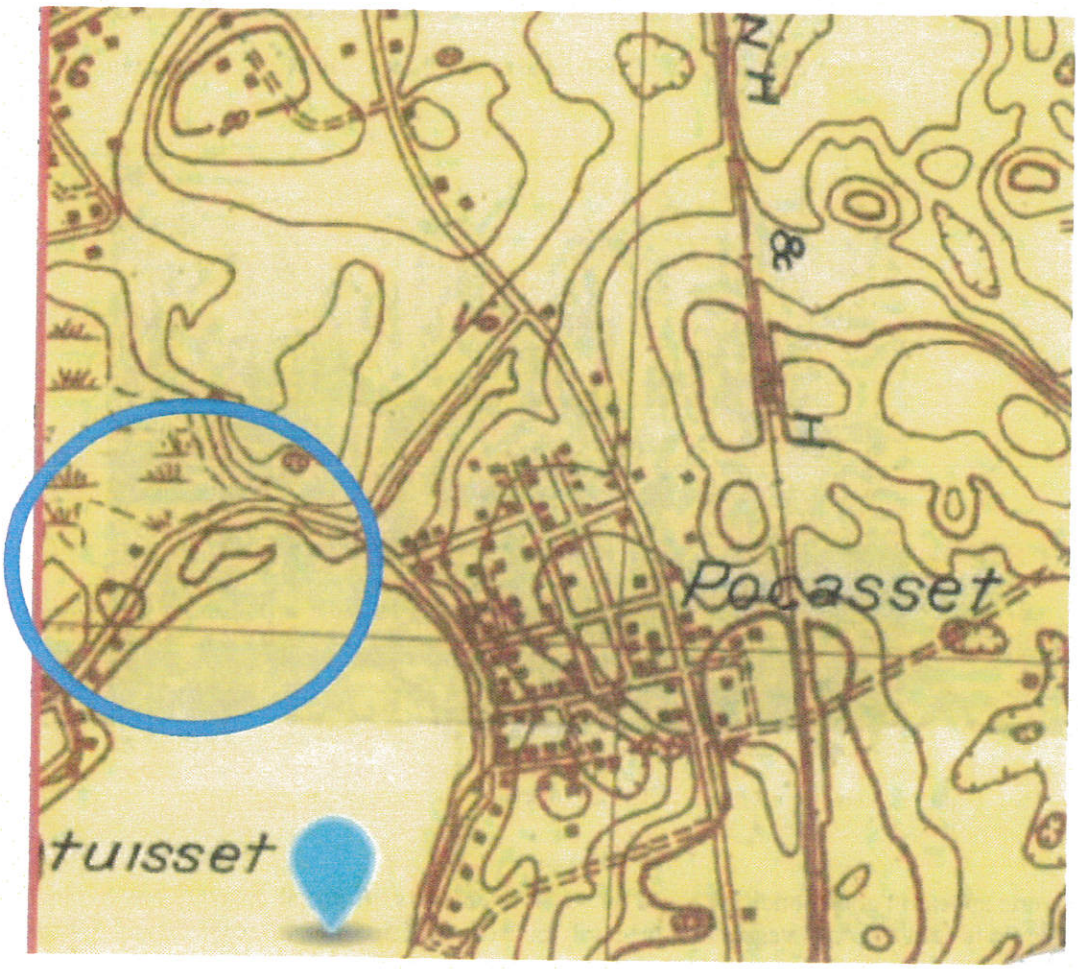

Figure 8: 1935 USGS map. Note no apparent connection to marsh west of Hen Cove.

Figure 9: 1953 USGS map. Note no apparent connection to marsh west of Hen Cove

It was also brought to the attention of the Town of Bourne that the salt marsh north of Wings Neck Road used to have another connection to the north with Buzzards Bay. If tidal flushing of the salt marsh north of Wings Neck Road has been restricted by the culvert under Wings Neck Road, then one potential solution to the problem could be to open up the channel to the north to Buzzards Bay. Historical USGS maps that BSC found of this area from 1886, 1915, and 1967 do not show this connection (Figures 10, 11, & 12). However, a USGS map from 1941 does show a connection to Buzzards Bay at the northern end of the salt marsh (Figure 13).

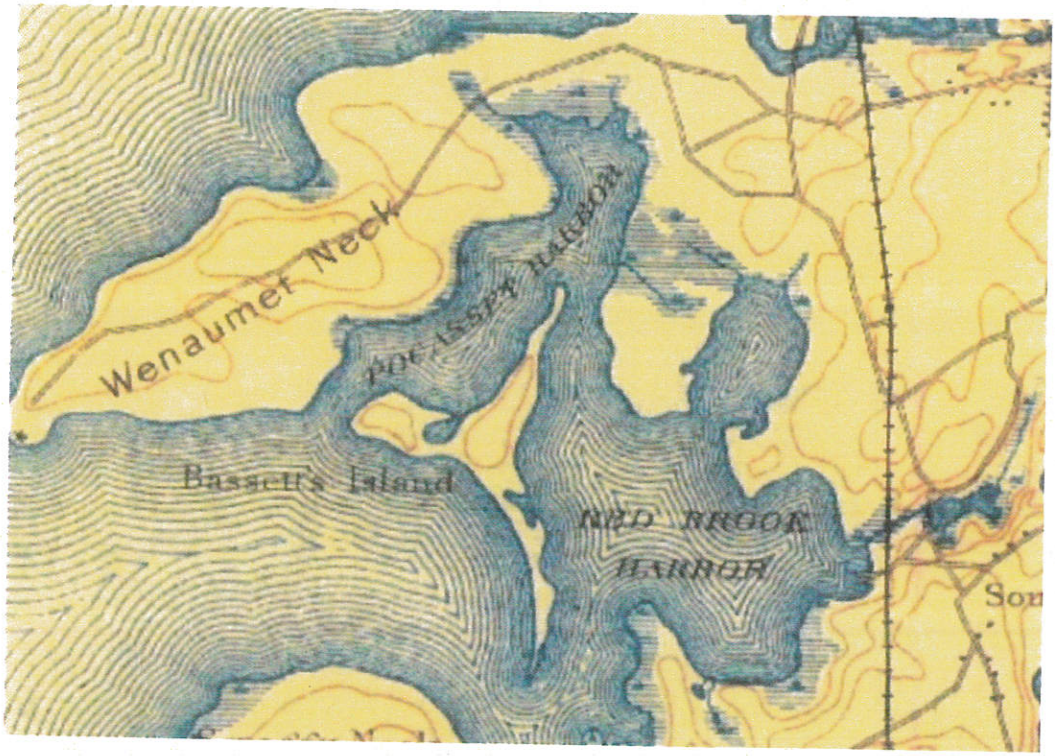

Figure 10: 1886 USGS map. Note Wings Neck Road marsh does not reach northern shoreline of Wenaumet Neck or connect to Buzzards Bay

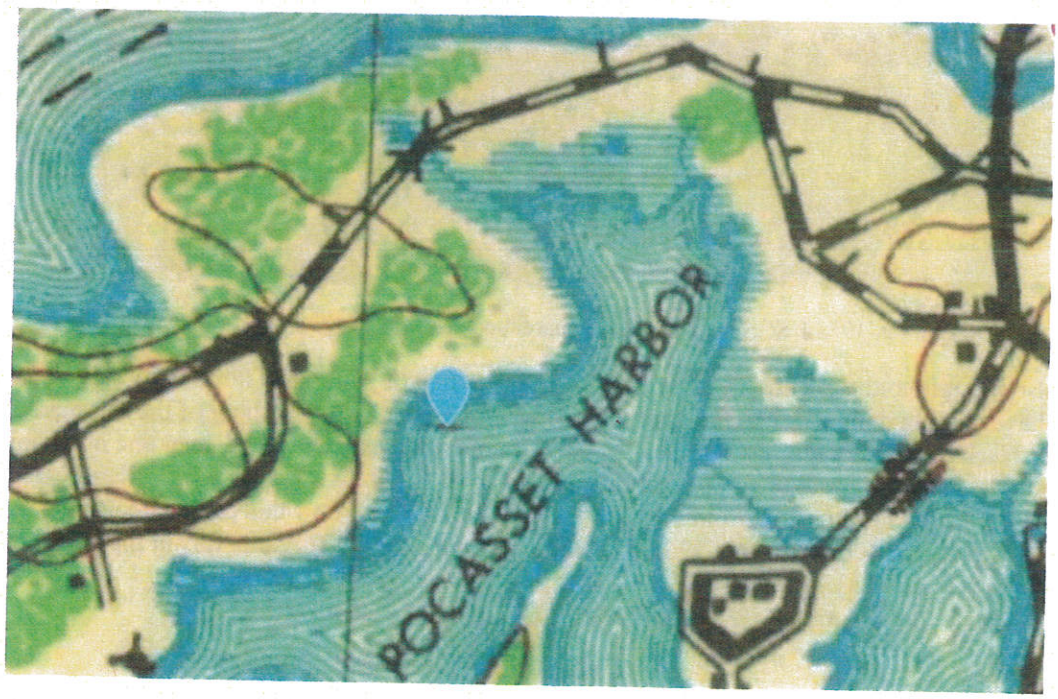

Figure 11: 1915 USGS map. Note Wings Neck Road marsh does not reach northern shoreline of Wenaumet Neck or connect to Buzzards Bay.

Figure 12: 1941 USGS map. Note Wings Neck Road marsh reaches northern shoreline of Wenaumet Neck and connects to Buzzards Bay.

Figure 13: 1967 USGS map. Note Wings Neck Road marsh does not reach northern shoreline of Wenaumet Neck or connects to Buzzards Bay.

This series of USGS maps showing Wings Neck Road from 1886, 1915, 1941, and 1967 indicate that the channel opening to the salt marsh north of Wings Neck Road was not a natural connection, but most likely a man-made channel. Currently this channel opening has been filled in and there is no tidal exchange or flushing between the Wings Neck salt marsh and the northern Channel to Buzzards Bay.

BSC's continued research into these Sites did not reveal the presence of any prior permits under the Mass General Law Wetland Protection Act, Chapter 91 Waterways, or other environmental permits. It is also important to note that both sites are located within the Natural Heritage Endangered Species Program mapped priority habitat for rare and endangered species. Therefore, if the results of this study suggest it may be beneficial to re-open either of the historic channels mentioned above, permits from MGL-WPA, Chapter 91, ACOE, and NHESP would be required.

3. Water Levels & Water Chemistry

In order to properly model the hydrodynamics of each Site, information on tidal range, and local elevations had to be collected. BSC researched the tide ranges at the site and based on the Buzzards Bay National Estuary Program; see Figure 14 below. The tide ranges for the area of study are summarized to range typically from -2.2' to +1.7' NAVD88 datum meaning the site experiences a typical normal tide range of 3.9 feet.

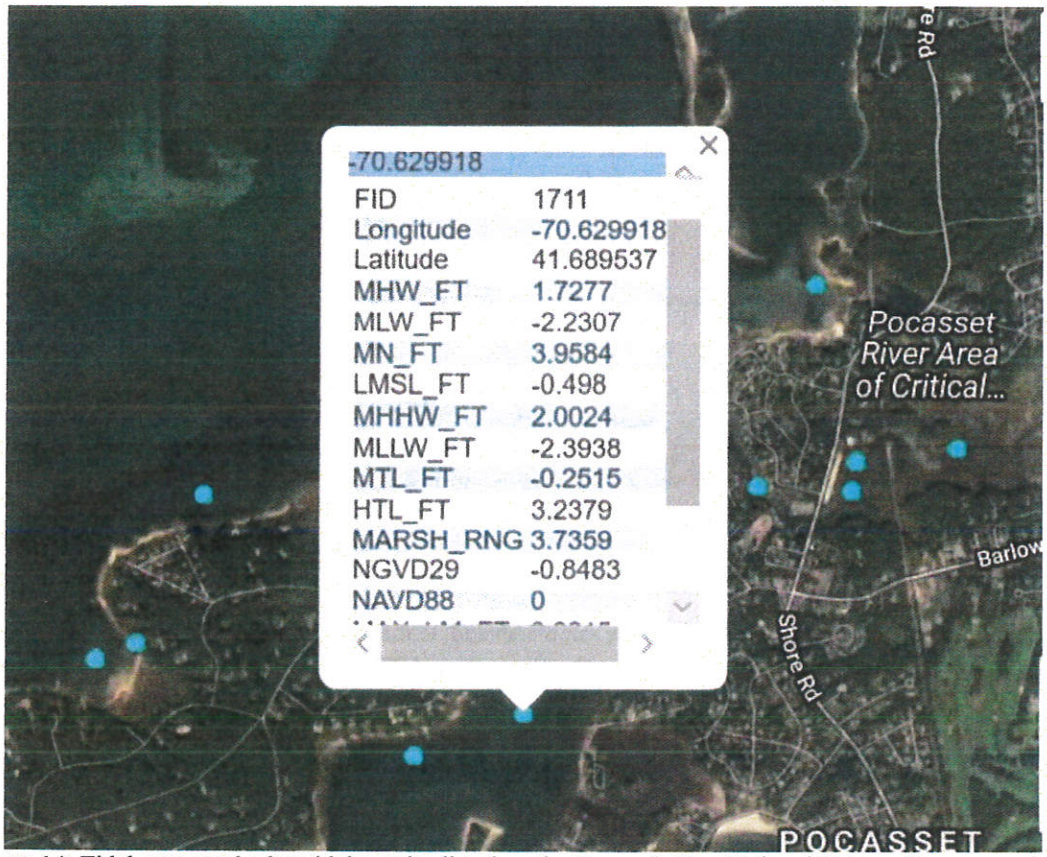

Figure 14: Tidal range and other tidal metrics listed on the Buzzards Bay National Estuary Program website (https://buzzardsbay.org/technical-data/tidal-datums-ma/interactive-tidal-datum-viewer/) for Pocasset Harbor.

Mean High High Water = 2.0
According to FEMA the still water surges for Bourne are as listed below:
10-year elevation 4.9
50-year elevation 7.5
100-year elevation 9.1
Roadway surface elevation at Wings Neck Road culvert 6.0
Roadway surface elevation at Salt Marsh Lane culvert 4.0

To supplement the tidal data obtained from Buzzards Bay NEP, BSC deployed tide gauges (Onset HOBO water level loggers) at both sites (Photos of instruments included in Appendix A). Tide gauges were deployed on the marsh side and on bay side of both culverts simultaneously to obtain a time series dataset

showing water levels in the marsh vs out in the bay. This data was used to determine if the culverts were causing significant tidal restriction or if there was a lag in the tides reaching the salt marshes. Figures 16 & 17 are plots showing water levels in the salt marsh vs water levels on the bay side of each culvert.

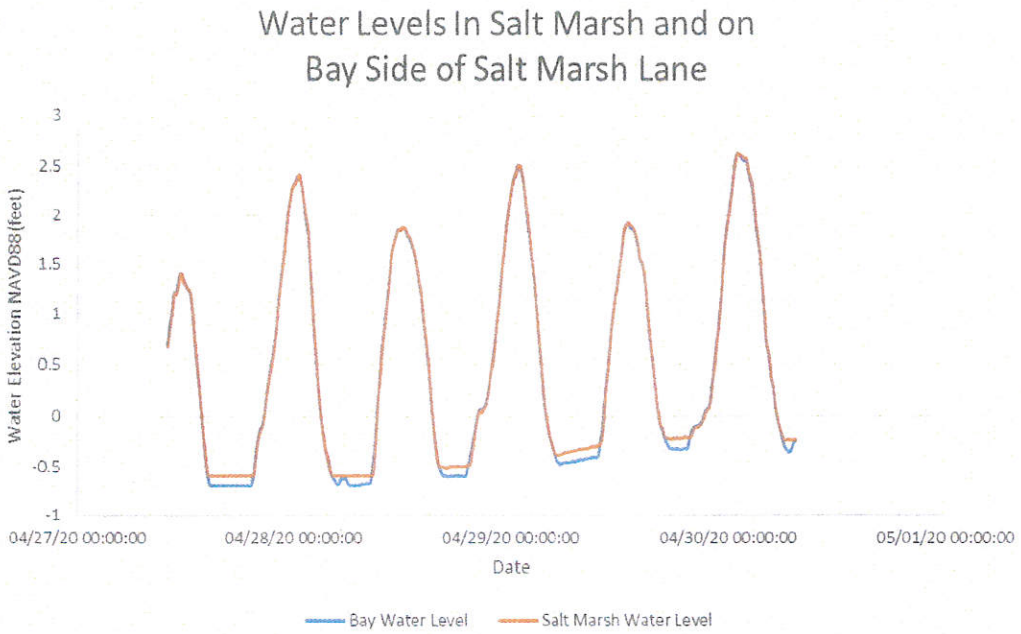

Figure 16: Plot showing water levels in the salt marsh and on the bay side of the culvert underneath Salt Marsh Lane. Data included in the plot is from 4/27/2020 through 4/30/2020.

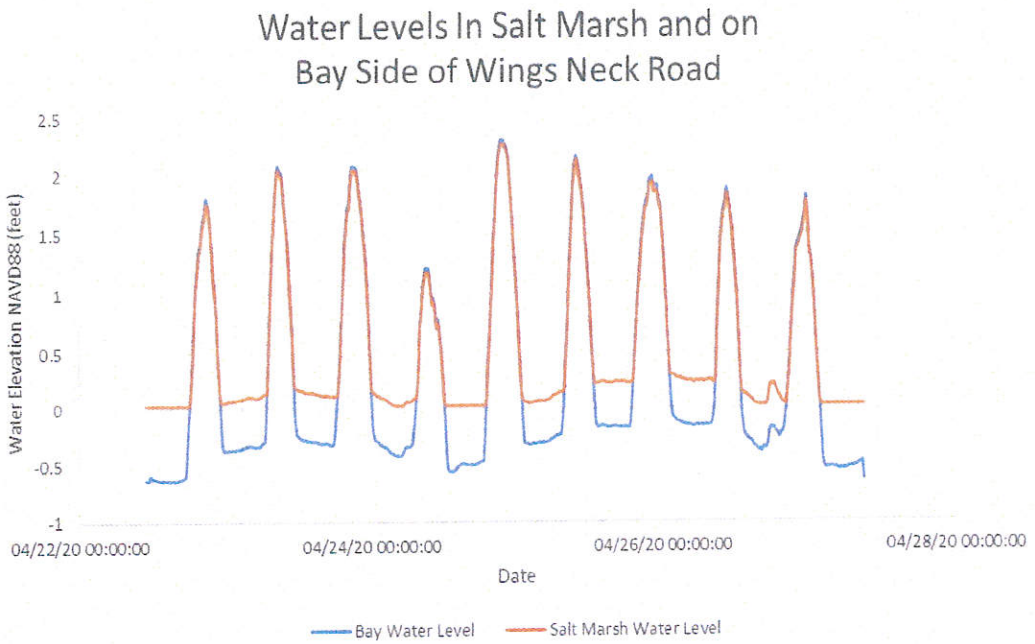

Figure 17: Plot showing water levels in the salt marsh and on the bay side of the culvert underneath Wings Neck Road. Data included in the plot is from 4/23/2020 through 4/27/2020.

The plots above shown in Figures 16 & 17 indicate that both salt marsh systems flood and drain with each tide. In both plots you can see that as the tide rises in the bay, the tide also rises in the salt marsh. The peak on each plot for the water levels in the salt marsh mirror the peaks for water levels on the bay side. There is no difference in the high tide peaks for the salt marsh south of Salt Marsh Lane. There is a minor difference in the high tide peaks (0.05') for the salt marsh North of Wings Neck Road. This is a very minor difference and can hardly be seen in Figure 17. If the culvert were significantly restricting tidal flow in and out of the Wings Neck marsh, then there would be a larger more visible difference in the high tide peaks in Figure 17.

BSC also collected topography data for each Site using USGS lidar and mapped with 6" contours to aid in the site analysis. The datum of the topography is NAVD88. Volumes were calculated within the tide range from -2 to +3. The marsh topography was supplemented with instrument field survey to generate 6-inch contours over the marshes and determine inverts and culvert dimensions. The grades in the marshes vary from -1 (drains empty of standing water at low tide) to elevation +3 above Mean High Water (Topographic plans of the marshes as generated by USGS LIDAR data are included in Appendix).

The volumes of water by elevation are presented in Tables 1 & 2 below (for the normal tide ranges).

Table 1. Summary of the total volume by stage in the salt marsh south of Salt Marsh Lane. The elevation of the marsh starts at 0 (not MLW @ -2.2) because the marsh fully drains with each outgoing tide; not accounting for groundwater discharge or residual flow that drains from the soils and root mass of the surrounding salt marsh vegetation.

Elevation	Area (sf)	Acres	Vol (cf)	Cumulative Vol (cf)
-2	10,000	0.23	-	-
-1.5	234,933	5.39	61,233	61,233
-1	308,865	7.09	135,949	197,182

-0.5	440,120	10.10	187,246	384,429
0	520,749	11.95	240,217	624,646
0.5	591,835	13.59	278,146	902,792
1	664,509	15.26	314,086	1,216,878
1.5	774,748	17.79	359,814	1,576,692
2	961,702	22.08	434,112	2,010,805
2.5	1,025,670	23.55	496,843	2,507,648
3	1,082,859	24.86	527,132	3,034,780

The table above documents from low tide (fully drained marsh) to MHW, the marsh gains and loses 2,507,000 CF (58+/0 acre feet) of ebb and flow each tide cycle. Over the course of an incoming or outgoing tide, the combined open bay side inlet flow and the culverted flow averages 110 CFS of flow. Peak inflow of 275 CFS occurs at mid tide. At this peak flow rate time, by rough estimate, the 8 x 1.5-foot culvert passes about 12 CFS, meaning that only about 3% of the flow (12/275) to the marsh comes in through the culvert and as such, the culvert is vastly less significant to the marsh flooding than that of flow from the open water body to the south. Due to the finding that the marsh is primarily inundated from the water body to the south (not through the culvert), the culvert is not worthy of further assessment. As long as the southern inlet remains open, the salt marsh will flood and drain with each tide. There is no need to open the historic channel to Hen Cove in order to help flush the salt marsh south of Salt Marsh Lane as it completely flushes at a low tide and does not show a restriction preventing/slowing flood.

Table 2. Summary of the total volume by stage in the salt marsh north of Wings Neck Road. The elevation of the marsh starts at 0 (not MLW @ -2.2) because the marsh fully drains with each outgoing tide; not accounting for groundwater discharge or residual flow that drains from the soils and root mass of the surrounding salt marsh vegetation.

Elevation	Area (sf)	Ave Area	Vol (cf)	Area (acres)	Cumulative Vol (cf)
0	0	0	0	0	0
0.5	92	46	23	0	23
1	1,326	709	354.5	0.02	378
1.5	9,568	5,447	2,723.5	0.13	3,101
2	106,971	58,269	29,134.75	1.34	32,236
2.5	183,668	145,319	72,659	3.34	104,896
3	298,590	241,129	120,564	5.54	225,460

From the information in Table 2 above, it can be reasoned that during a normal tidal cycle at the Wings Neck salt marsh with a high tide elevation of +1.7', the volume of water entering the marsh is about ½ acre foot. This means that on average ~24,000 CF of seawater flood the salt marsh with each tide. During a spring tide (flood elevation +3.2') the volume of water flooding the marsh is over 225,000 CF with each tide; this volume is just over 5 acre-feet

When studying salt marshes, it is important to consider sea level rise since salt marshes persist as intertidal ecosystems. NOAA has several long-term gauges with sea level trends data available to the public. According to the NOAA Tides and Current Sea Level Trend Data Mapper (https://tidesandcurrents.noaa.gov/sltrends/sltrends.html), sea level rise in the northeastern region of the US is on the order of 1 foot per 100 years.

It has also been documented in scientific literature that salt marshes naturally accumulate sediment over time. The rate of sediment accumulation varies site by site, but this natural occurrence can help salt

marshes keep up with sea level rise. The culverts will not increase in elevation or keep up with sea level rise. The two culverts at the two Sites are not currently restricting tidal flows, but once sea level rises to the top of the culverts, this could become an issue. Regardless, the current sea level during normal tides, does not exceed the elevations of the culverts at the Sites, so this is currently not a concern.

BSC also collected three water samples at each Site and were sent to a lab to be run for salinity and specific conductivity. At each Site, one water sample was collected on the bay side of the culvert, another sample was collected on the marsh side of the culvert, and a third sample was collected from the back of the marsh. Figure 18 shows the approximate sample locations at each Site, and Table 3 displays results from lab analysis.

Sample #	1	2	3	4	5	6
Site	Salt Marsh Lane	Salt Marsh Lane	Salt Marsh Lane	Wings Neck Road	Wings Neck Road	Wings Neck Road
Location	Back of Marsh	Marsh Side of Culvert	Bay Side of Culvert	Bay Side of Culvert	Marsh Side of Culvert	Back of Marsh
Salinity (ppt)	28	28	29	29	29	29
Specific Cond. (umhos/cm)	44,000	44,000	45,000	45,000	45,000	45,000

Table 3: Displays lab results for 6 water samples that were run for salinity and specific conductivity.

The information presented in Table 3 above shows that there is no difference between samples 3, 4, and 5 indicating that the salinity of the waters within the salt marsh north of Wings Neck Road and the salinity of the flood waters from the bay are identical. This further demonstrates that the culvert at Wings Neck Road is not restricting tidal flow to the marsh. There is a difference of 1 ppt between the water samples collected within the salt marsh south of Salt Marsh Lane and the salinity of the adjacent bay waters. This is a very minor difference, and a salinity of 28 ppt is still typical of what would be found in a healthy New England salt marsh. Therefore, this data also suggests that the culvert underneath Salt Marsh lane is not causing significant tidal restriction to the adjacent salt marsh.

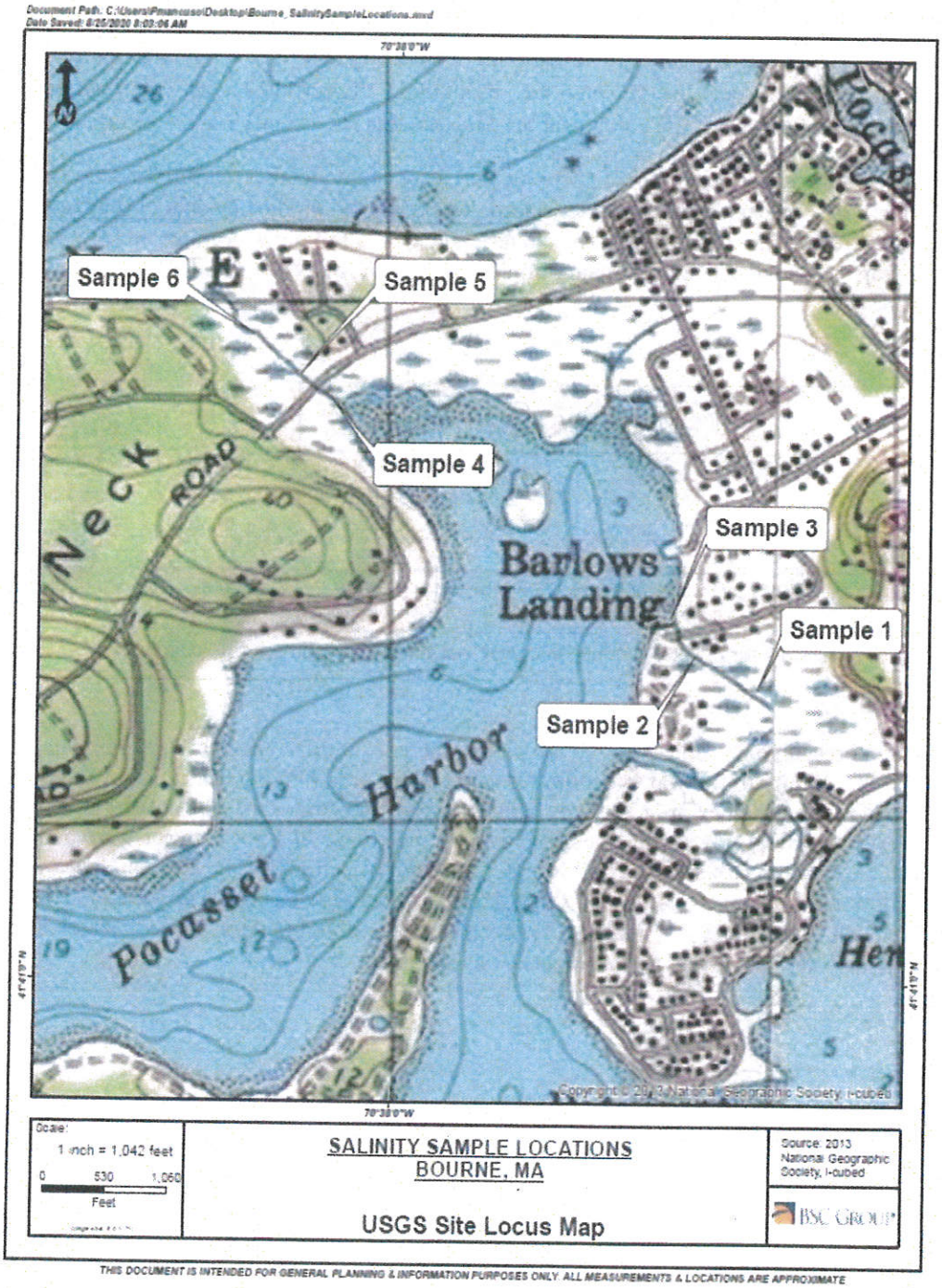

Figure 18: USGS Locus Map showing water sample collection locations. Samples 1, 2, and 3 were collected for the Salt Marsh Lane marsh and samples 3, 4, and 5 were collected for the Wings Neck Road marsh. Samples were collected on 7/23/2020

4. Modeling

BSC prepared a limited spreadsheet model based on the stage storage data of the marshes, the tidal range and Manning's equation for open channel flow.

It is presumed that Manning's Equation will accurately model the flow based on water surface flow calculated from the initial ocean side tide level and the water level in the marsh calculated by the initial marsh water level as effected by the change in volume (inflow/outflow) for each 15 minute interval.

Manning's Equation uses:

$$V = \frac{1}{n} R_h^{2/3} S_f^{1/2} \quad \leftrightarrow \quad Q = \frac{1}{n} A R_h^{2/3} S_f^{1/2}$$

- S is the slope of the water surface being used as the hydraulic gradient
- N is the Manning's roughness coefficient, presumed to be for smooth concrete = 0.013
- R is the hydraulic radius, (ft), wetted perimeter determined by the water level above the culvert invert and the width of the channel
- A is the flow area, (ft^2)
- V is the velocity, (ft/s)
- Q is the flow rate, (ft^3/s)

Once the existing conditions model was calibrated to approximate those observed with the data recorders, the culvert sizes were changed and the water levels were compared. This calibration was accomplished by varying N (friction) factors and Ke (culvert entrance) factors.

This analysis was concluded to be useful for the Wings Neck Road Culvert, but not the Marsh Lane culvert, because in this location the majority of the flow came from the south rather than through the culvert.

The models allowed for the calculation of peak velocities and flow rates, as well as the relative rise in water levels within the marsh if the size of the culvert was increased. For Wings Neck, even the of an additional second culvert of the same size would not measurably change the peak. The existing culvert does not significantly restrict flows into/out of the marsh as to result in water levels differing significantly from that of the bay side of the culvert.

5. Conclusions

Salt Marsh Lane Marsh

The Salt Marsh Lane salt marsh is not tidally restricted by the 8'x 1.5' culvert underneath Salt Marsh Lane. This marsh has two openings which tidal waters flow through: (1) the culvert underneath Salt Marsh Lane, and (2) the open inlet to the south. Based on the volume of water required to fill the marsh and the slow velocity of the flow in the culvert (less than 1 foot per second) Approximately 97% of flow into the marsh comes through the southern inlet; meaning only 3% of the flow comes in through the culvert. Water levels in the marsh and in the adjacent bay mirror each other as shown in Figures 16 & 17. There is no time lag between high tide in the bay and in the marsh. Salinity of bay waters (29 ppt) and marsh waters (28 ppt) are almost identical with a measured difference of 1 ppt. The salinity of both the bay and the salt marsh waters are within the typical salinity range found in healthy New England Salt Marshes. Historical mapping does show a hydraulic connection or old inlet between the marsh and Hen Cove. However, the installation of a new culvert would not improve or measurably change the ebb and flood from the marsh system due to the existing larger inlet to the south.

Wings Neck Road Marsh

The Wings Neck Road salt marsh is not significantly tidally restricted by the culvert underneath Wings Neck Road. The culvert is the only open hydrologic connection to the marsh. Based on the tide gauge data, the high tide in the marsh lags ~15 minutes behind the high tide in the adjacent bay. This minor lag time along with the fact that the marsh fully drains at low tide indicates the culvert is causing only a very minor tidal restriction. There was no difference in the salinity of the waters in the bay compared to the waters within the salt marsh; both 29 ppt. This adds to the case that the culvert is not currently "significantly" restricting tidal flow into the marsh. Based upon the modeling it was shown that increasing the culvert size would not measurably change the peak water level in the marsh. However, it should be considered when replacing the culvert to keep pace with sea level rise as this is the only current inlet/outlet for this marsh system. Historic mapping does show that a hydrologic connection did exist at one point to the north of the marsh. However, there is no current need to reopen that inlet, as the marsh already floods and drains effectively with each tide and future maintenance work to the culvert would allow for changes to keep pace with sea level rise.

Appendix A

This appendix contains additional maps, photos, and information related to the Hydraulic Evaluation of the Two Culverts Feeding the Salt Marshes South of Salt Marsh Lane and North of Wings Neck Road Bourne, MA

Assessors Maps, Parcel Maps, & Abutters Lists

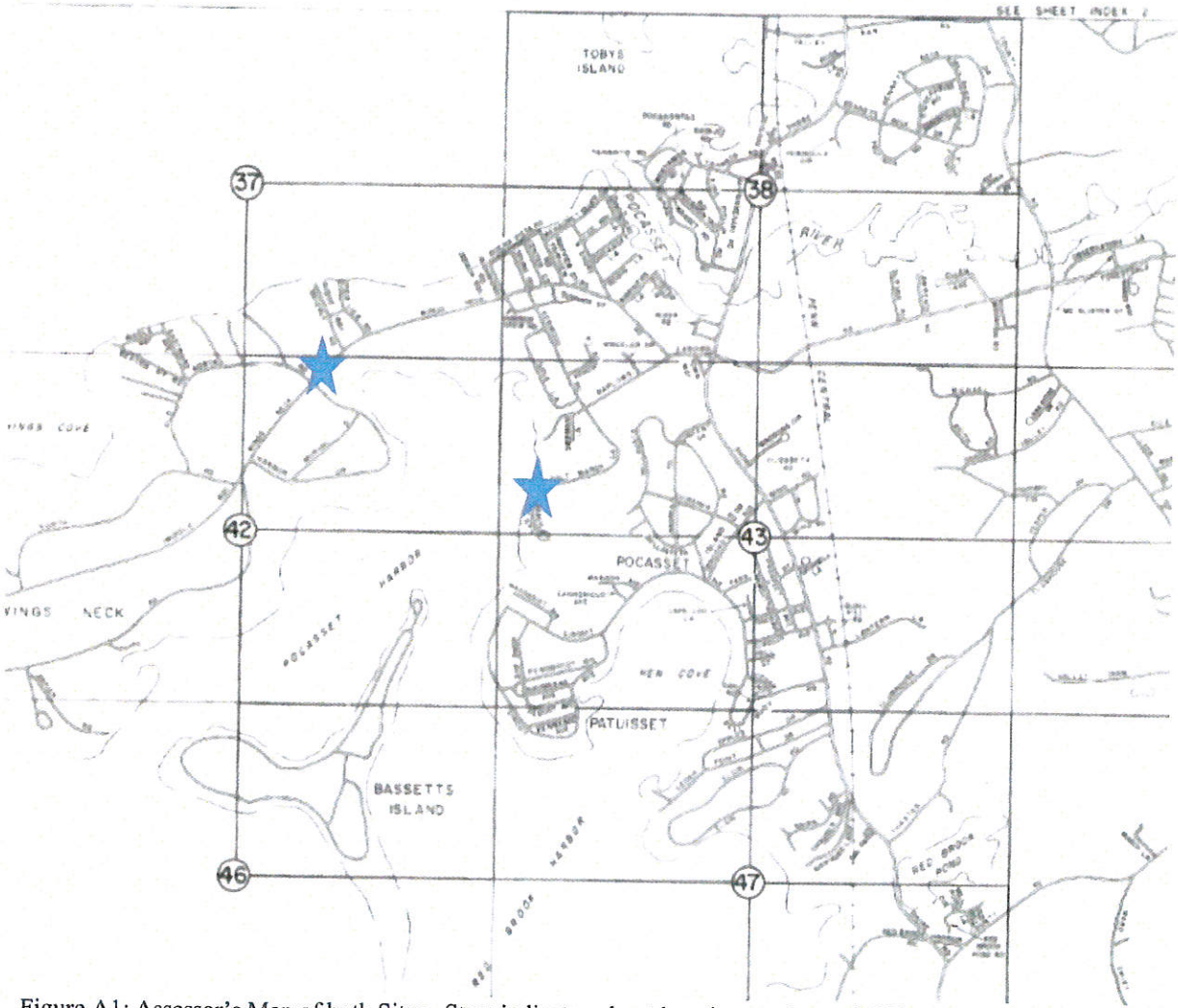

Figure A1: Assessor's Map of both Sites. Stars indicate culvert locations underneath Wings Neck Road (top left star) and Salt Marsh Lane (middle star).

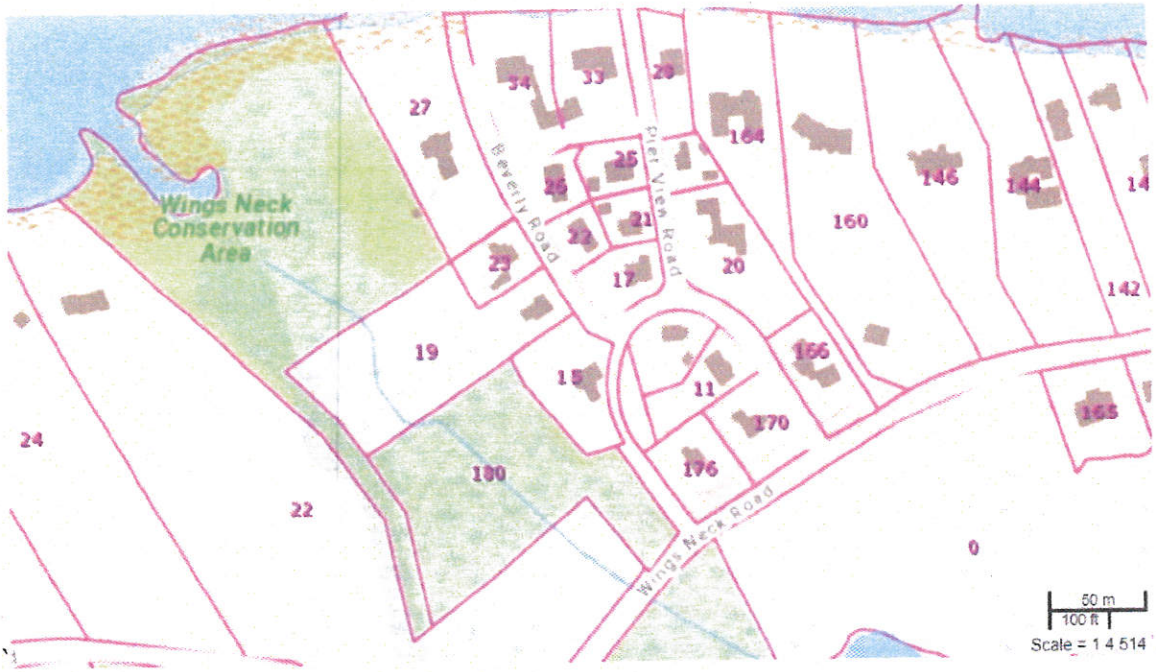

Figure A2: Parcel map showing the location of the Wings Neck Road salt marsh and abutting properties.

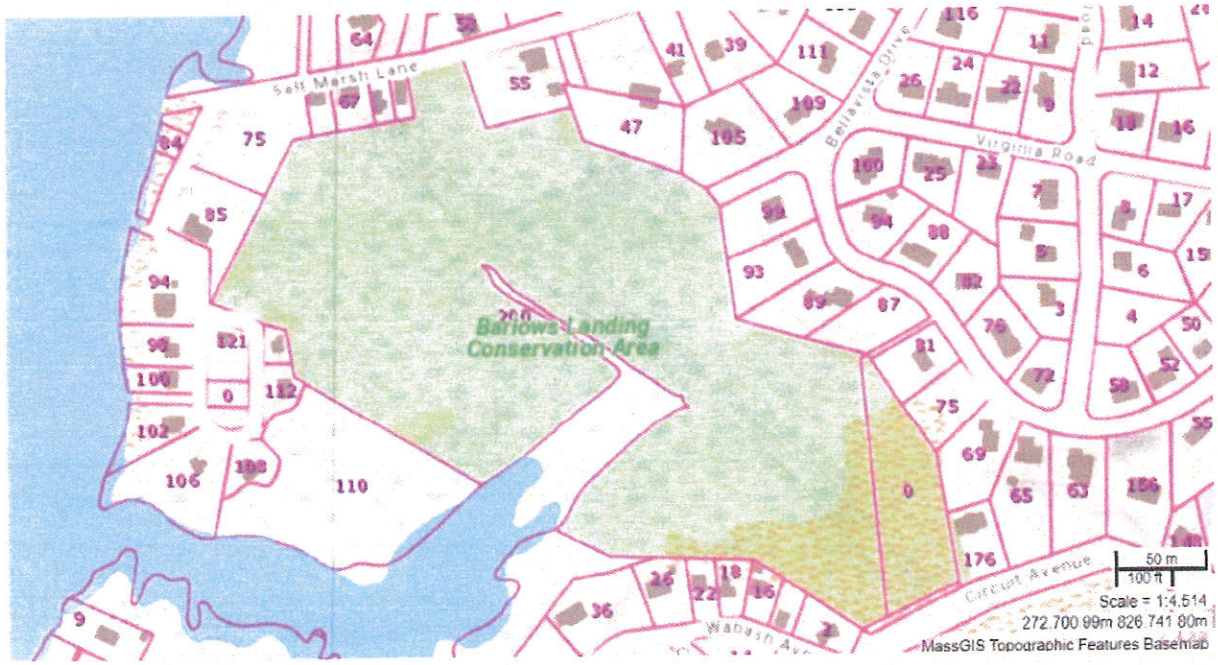

Figure A3: Parcel map showing the location of the Salt Marsh Lane salt marsh and abutting properties.

Figure A4: Assessor's Map showing the Wings Neck Road salt marsh and abutting properties.

According to the Bourne Assessors database, the owners of the Wings Neck Road Salt Marsh are:

map_par_id	owner1	own_city	own_state
37.4_004.00	HOGAN WILLIAM E ETUX	BOSTON	MA
37.4_005.00	WIJNTJES GEERT J	CHELSEA	MA
37.4_058.00	LOVELL LAVERNE A	DOVER	MA
42.0_095.00	WINCOVE HOMEOWNERS ASSOC INC	POCASSET	MA
37.0_024.01	TOWN OF BOURNE	BUZZARDS BAY	MA
37.4_019.00	GALBRAITH BETTY J	POCASSET	MA
37.4_002.01	CORLISS ROBERT H &	POCASSET	MA
42.0_020.00	UGOLYN VICTOR & DIANE M TRS OF	RIDGEFIELD	CT
37.4_010.00	SELBY KIMBERLY O TRS OF 15	WESTWOOD	MA
42.2_033.00	WEIDNER LINDA J TRUSTEE	POCASSET	MA
37.0_022.00	HOWLAND JAY TR OF	WESTWOOD	MA
37.4_014.00	BROWNE JAN M TR OF JAN M	POCASSET	MA
37.4_015.00	DONOVAN JOSEPH A &	WALPOLE	MA
42.2_001.00	TOWN OF BOURNE	BUZZARDS BAY	MA
37.4_020.00	NUGENT PAUL F	POCASSET	MA
37.4_003.00	SELBY KIMBERLY O TRS OF 15	WESTWOOD	MA
42.0_017.00	LOCKE JEFFREY A ETUX	WELLESLEY	MA
37.4_012.00	LANDSMAN HERBERT S ETUX	SUDBURY	MA
37.4_002.00	TOWN OF BOURNE	BUZZARDS BAY	MA
37.4_021.00	GALBRAITH BETTY J	POCASSET	MA
37.4_013.00	LYNCH PETER F JR & MARGUERITE	ATTLEBORO	MA
37.4_057.00	BEVERLY ASSOCIATES	POCASSET	MA
37.4_006.00	34 BEVERLY ROAD LLC	BOSTON	MA
37.4_008.00	OFRIA ROSS A & BARBARA A OFRIA	POCASSET	MA
37.4_017.00	HOLIAN SUSANNE F	POCASSET	MA
37.4_023.01	AL-AYOUB EVELYN	POCASSET	MA
37.4_011.00	SCAIFE BENJAMIN L	POCASSET	MA
42.0_019.00	BALLENTINE STEPHEN ET AL TR OF	CATAUMET	MA
37.4_016.00	COCCA THEODORE A &	WATERTOWN	MA
42.2_020.00	CRECCO REGINA A TR	PLYMOUTH	MA
42.0_022.00	HANNAH JAMESON H ETUX	POCASSET	MA
42.2_035.00	SLEPCHUK WALTER M &	POCASSET	MA
42.0_021.00	MCGOVERN KATE N & MICHAEL J TR	BOSTON	MA
42.0_020.01	FLECKER KATHERINE L &	NEW YORK	NY
37.4_007.00	DANIELS PAUL M ETUX	POCASSET	MA

Figure A5: Assessor's Map showing the Salt Marsh Lane salt marsh and abutting properties.

Figure A6: Assessor's Map showing the Salt Marsh Lane salt marsh and abutting properties.

According to the Bourne Assessors database, the owners of the Salt Marsh Lane Salt Marsh are:

map_par_id	owner1	own_city	own_state
43.3_020.00	MURRAY ROSEMARY E TR	POCASSET	MA
43.1_085.00	PARRY DOROTHY J TR	BERKLEY	MA
43.3_058.00	MCDERMOTT GREGORY F ETUX	NATICK	MA
43.1_088.00	SACHS STEVEN B	POCASSET	MA
43.3_018.00	TOWN OF BOURNE	BUZZARDS BAY	MA
43.3_002.00	LINDSEY CHARLES C &	HOLLISTON	MA
43.1_097.00	WILLIAMS H JAMES JR	HINGHAM	MA
43.3_008.00	LINDBERG LEOCARDIA	POCASSET	MA
43.3_014.00	ZAHLAWAY JOHN M	READING	MA
43.1_214.00	MAGOON DENNIS &	MARSHFIELD	MA
43.3_001.00	GOLAND JANE & SUSAN MARANDETT	POCASSET	MA
43.1_070.00	FURCINITI CHARLES A	POCASSET	MA
43.3_065.00	LAURENCE WILLIAM M &	NEEDHAM	MA
43.1_073.00	NISBET DAVID A &	BROOKLINE	MA
43.3_028.00	MCDONALD THOMAS C &	HANOVER	MA
43.3_264.00	WALKEY VIRGINIA M &THEODORE J	AIEA	HI
43.3_012.00	BRISTOW CHARLES E JR ETUX	POCASSET	MA
43.1_132.00	FLANAGAN JOANNE D &	GREENWICH	CT
43.3_016.00	WING RUSSELL S	POCASSET	MA
43.1_053.00	TOWN OF BOURNE	BUZZARDS BAY	MA
43.3_062.00	HUIZENGA CHARLES G & JUDITH N	WESTON	MA
43.1_223.00	JACOBS GRACE C	POCASSET	MA
43.1_158.00	CAMPOSANO JON &	POCASSET	MA
43.1_222.00	PERRY JOSEPHINE D TR OF	HUDSON	FL
43.3_050.00	POULOS VASILIOS TR VASILIOS	BOSTON	MA
43.3_052.00	PRINDLE BONNIE L TR	BELCHERTOWN	MA
43.1_231.00	MCGARR MARGARET TRUSTEE	POCASSET	MA
43.3_056.00	SHEPHERD JANE N	DEDHAM	MA
43.3_022.00	ANTHONY ROBERT J ETUX	POCASSET	MA
43.1_216.00	THOMPSON WILLIAM A & SUSAN TRS	POCASSET	MA
43.1_159.00	RAGO KENNETH A &	POCASSET	MA
43.3_009.00	GREELEY AUDREY L	FOXBORO	MA
43.1_079.00	BUTMAN ROBERT F & PEGGY W	POCASSET	MA
43.1_224.00	DIMLICH DAVID J	ARLINGTON	VA
43.1_074.00	FERRARA RAYMOND JR	POCASSET	MA
43.1_081.00	BRISTOW CHARLES E JR	POCASSET	MA
43.1_242.00	MCLEOD TRACEY &	BROOKLINE	MA
43.1_096.00	CULHANE BONNIE ETUX	LEXINGTON	MA
43.1_093.00	FLANAGAN JOANNE D &	GREENWICH	CT
43.3_026.00	MOTTLA PETER D &	WAYLAND	MA

43.1_067.00	GORDON MARILYN B	POCASSET	MA
43.1_092.00	WISE CLIFFORD R & ROBERT B MAC	POCASSET	MA
43.1_068.00	DUGRE MARC S ETUX	LONGMEADOW	MA
43.1_057.00	DALY ROBERT M ETUX	ASHLAND	MA
43.3_007.00	RICE MARION G & SCOTT G RICE &	FOXBORO	MA
43.1_076.00	BROWN ROBERT W &	BRIDGEWATER	MA
43.3_055.00	MCCLORY PATRICIA M	WOLLASTON	MA
43.3_010.00	HUSSEY DONALD B JR &	NORTH ATTLEBORO	MA
43.1_056.00	SALLEY IRVING C & CLAIRE A	POCASSET	MA
43.1_212.00	FREW-NEHMS MARGARET M TR	POCASSET	MA
43.1_083.00	BRISTOW CHARLES E JR	POCASSET	MA
43.3_266.00	WAGNER NORMAN T &	POCASSET	MA
43.1_094.00	MATOIAN MARK L ETUX	LINCOLN	RI
43.1_080.00	KRUEGER FRANK L JR	POCASSET	MA
43.1_221.00	GLYNN LAWRENCE R &	POCASSET	MA
43.1_210.00	CARON PATRICIA S &	POCASSET	MA
43.1_219.00	SHAUGHNESSY WALTER E	POCASSET	MA
43.1_161.00	ALLAIRE ROBERT F ETUX	WESTWOOD	MA
43.3_017.01	TOWN OF BOURNE	BUZZARDS BAY	MA
43.3_051.00	HANDY MARGARET B BRIAN S HANDY	POCASSET	MA
43.1_069.00	JOHNSON JOHN A &	POCASSET	MA
43.1_062.00	MANTHEI DONALD W	NEWTON	MA
43.1_061.00	HOWE ALICE S & FREDERICK H	POCASSET	MA
43.1_089.00	BUTMAN ROBERT F	POCASSET	MA
43.1_160.00	SULLIVAN CATHERINE T	POCASSET	MA
43.1_217.00	TARANTINO ANTHONY P	POCASSET	MA
43.3_025.00	FEDEROW WALTER &	NEEDHAM	MA
43.1_211.00	BARBER JOHN KEITH ETUX	NORTH ATTLEBOROUGH	MA
43.1_127.00	GALVANI NANCY M TR OF THE	BRIDGEWATER	MA
43.3_023.00	CHEN YIBIN A ETUX	NEEDHAM HEIGHTS	MA
43.1_064.00	MONROE PAUL &	POCASSET	MA
43.3_013.00	BULLARD BONNIE M &	E SANDWICH	MA
43.1_075.00	KRUEGER FRANK L JR	POCASSET	MA
43.1_086.00	PARRY DOROTHY J TR	BERKLEY	MA
43.3_054.00	LEMAN CAROL A	QUINCY	MA
43.1_215.00	BUCKLEY ROBERT W &	POCASSET	MA
43.3_265.00	TOWN OF BOURNE	BUZZARDS BAY	MA
43.3_057.00	COLETTA LAWRENCE A	NORWOOD	MA
43.3_033.00	LEDWELL ROBERT J & JAMES R	FALMOUTH	MA
43.1_063.00	ERKMAN BRETT ETUX	NEW YORK	NY
43.3_067.00	MCDONOUGH SUSAN HANDY	NOKESVILLE	VA

43.1_130.00	OLIVER KEVIN W TR	NORTH SWANZEY	NH
43.3_029.00	ARMS MARCY S ETUX	ASHLAND	MA
43.1_076.01	BROWN NANCY ETALS TR OF	BRIDGEWATER	MA
43.1_213.00	FREW JOSEPH G	POCASSET	MA
43.1_065.00	BYRNE MARIANNE C & BONNIE	POCASSET	MA
43.3_061.00	DEVELLIS BRIAN TR OF DAAS	BEDFORD	MA
43.1_077.00	MURPHY GERALDINE R	WALPOLE	MA
43.1_129.00	LONG SUSAN S TR	POCASSET	MA
43.3_027.00	STELMACH BERNARD C ETUX	FOXBORO	MA
43.1_066.00	SAWYER C THOMAS &	POCASSET	MA
43.1_078.00	CONSTANT STEPHEN ETUX	HADLEY	MA
43.1_230.00	ANTHONY ROBERT J ETUX	POCASSET	MA
43.3_064.00	SUSI ANTHONY A & PATRICIA A	MILTON	MA
43.1_218.00	WILDER CHRISTOPHER M	LONDON	
43.1_220.00	MURRAY JAMES W	POCASSET	MA
43.3_003.00	HUSSEY DONALD B JR &	NORTH ATTLEBORO	MA
43.1_072.00	MCNAMARA MARTIN J &	WETHERSFIELD	CT
43.1_091.00	WISE CLIFFORD R & ROBERT BRUCE	POCASSET	MA
43.3_069.00	HANDY ARTHUR M ET UX TRS	POCASSET	MA
43.3_060.00	SHEPHERD RICHARD J &	ABINGTON	MA
43.1_157.00	TARANTINO PAUL ETUX	MEDFORD	MA
43.1_128.00	WOOD THOMAS S &	POCASSET	MA
43.3_019.00	CUCCI NICHOLAS L &	ATLANTIS	FL
43.1_131.00	MCCARTY PHILIP & INGRID TRS OF	NATICK	MA
43.1_257.00	PREVETT RICHARD ETUX	POCASSET	MA
43.3_021.00	MCCANN J ROBERT &E JOAN MCCANN	POCASSET	MA
43.1_095.00	CERBO ANTHONY A TR OF	WALPOLE	MA
43.3_059.00	BENDER SANDRA M	POCASSET	MA
43.1_071.00	GOLDBERG LAWRENCE S & JANET	ASHLAND	MA
43.1_087.00	SHEEHAN FRANCIS H & JUSTINE T	POCASSET	MA

Aerial Imagery

Figure A7: Aerial imagery from Google Earth showing the Wings Neck Road salt marsh.

Figure A8: Zoomer in aerial imagery from Google Earth showing the Wings Neck Road salt marsh.

Figure A9: Aerial imagery from Google Earth showing both salt marshes near high tide (2010).

FEMA Flood Maps

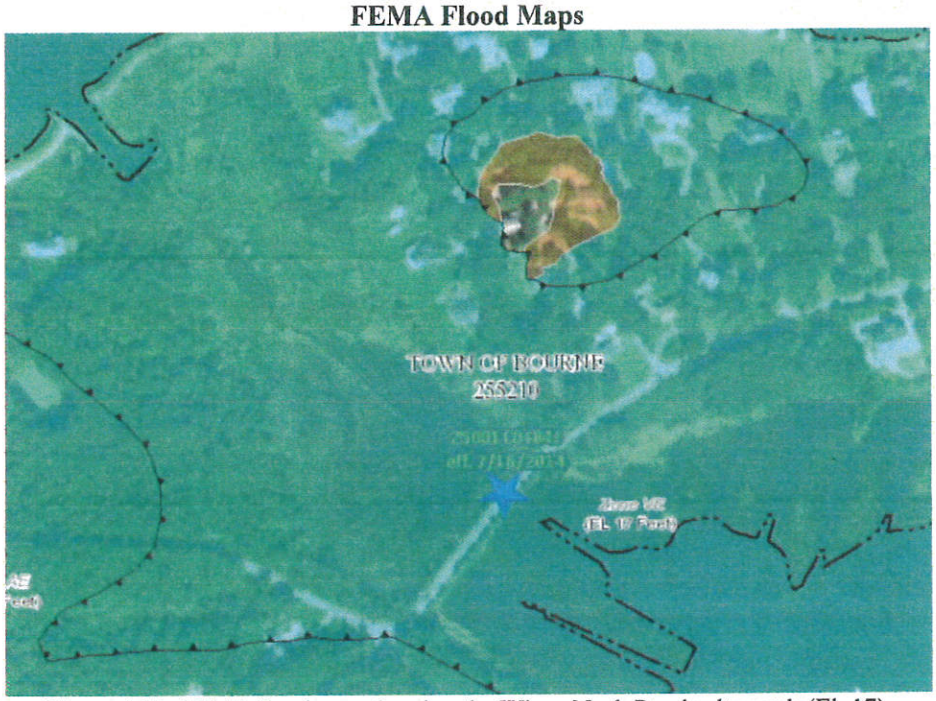

Figure A10: FEMA flood map showing the Wings Neck Road salt marsh (El. 17).

Figure A11: FEMA flood map showing the Salt Marsh Lane salt marsh (El. 16 & 17).

NHESP Priority Habitat Map

Figure A12: Natural Heritage and Endangered Species priority habitat map showing both Site locations.

Topography Maps

Figure A13: Topography map showing the Wings Neck Road salt marsh.

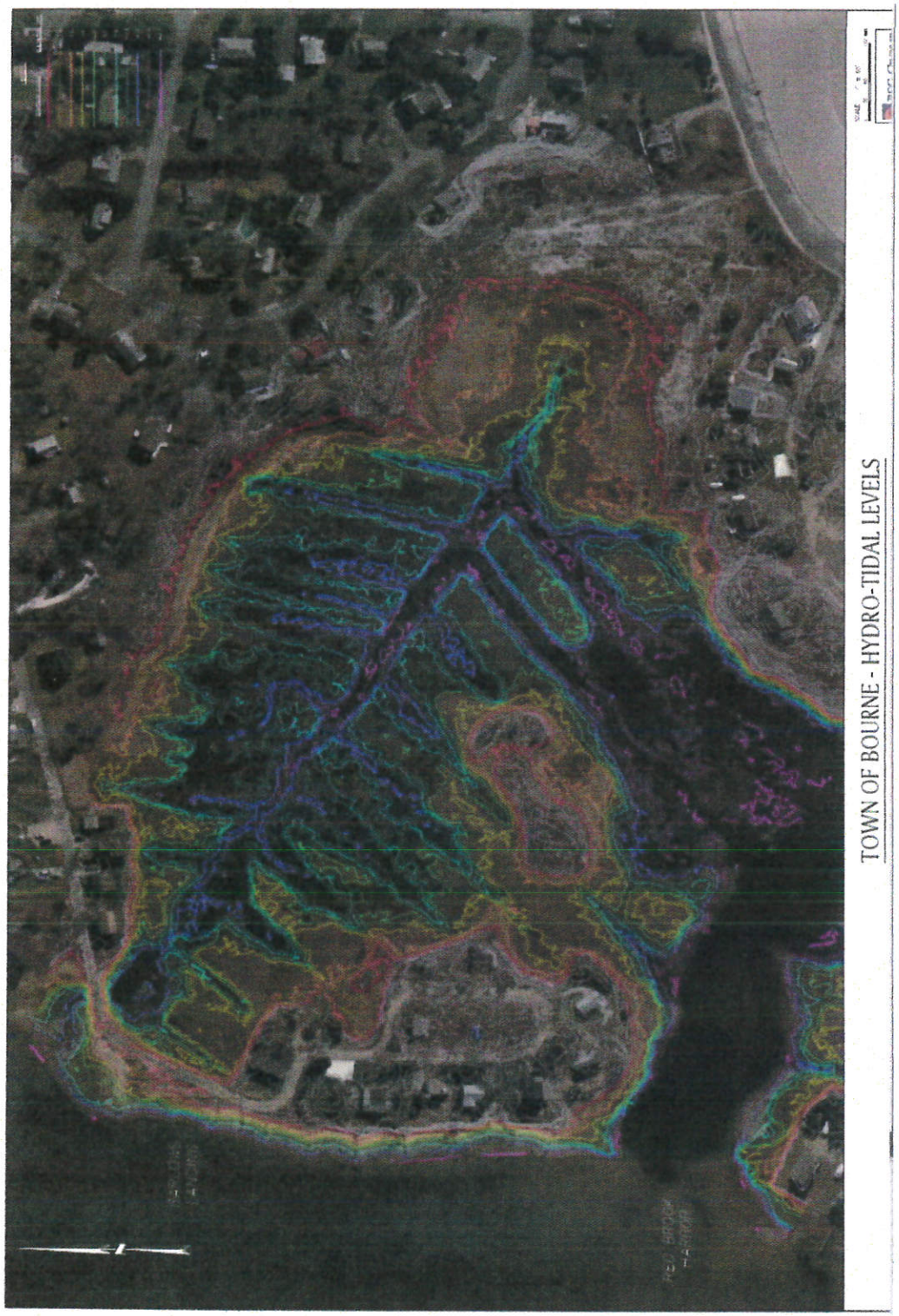

Figure A14: Topography map showing the Salt Marsh Lane salt marsh..

Onset HOBO Water Level Logger

Figure A15: Photo of one Onset HOBO Water Level Logger and the instrument housing; vented PVC housing, large stone anchor. HOBO logger inserts into PVC housing and fastens with zip ties.

Soil Conservation Service Map

Figure A16: Soil Conservation Service map (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm) of both Sites. Based on the Soil Conservation Service soil type mapping the marhes are classified as soil type 66A (Ipswich – Pawcatuck – Matunuck complex, 0 to 2 percent slopes, very frequently flooded) and 38A (Pipestone loamy coarse sand, 0 to 3 percent slopes).

It is important to consider local sea level rise and land subsidence when studying potentially tidally restricted salt marshes. The following pages contain relevant information on these topics.

Sea Level Rise

There are several long-term gauges with sea level trends data available to the public. According to the National Oceanic and Atmospheric Administration Tides and Current Sea Level Trend Data Mapper, linked below, sea level rise in the northeastern region of the US is on the order of 1 foot per 100 years. Based on the Boston Gauge, the tide levels have risen about 1 foot per 100 years. This is order of magntude rise has been confirmed by guages located on Nantucket (1.23 feet/100 years) and Woods Hole (0.96 feet / 100 year).

https://tidesandcurrents.noaa.gov/sltrends/sltrends.html

The map above illustrates relative sea level trends , with arrows representing the direction and magnitude of change. Click on an arrow to access additional information about that station.

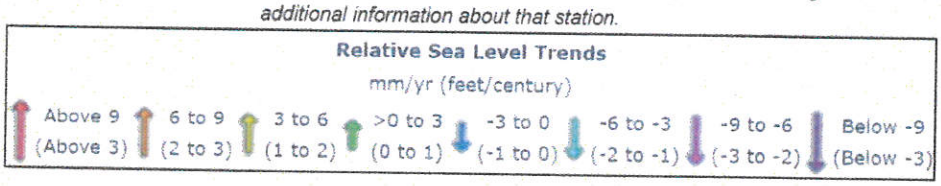

Figure A17: Map displaying local sea level rise trends along the northern Atlantic coast of the USA.

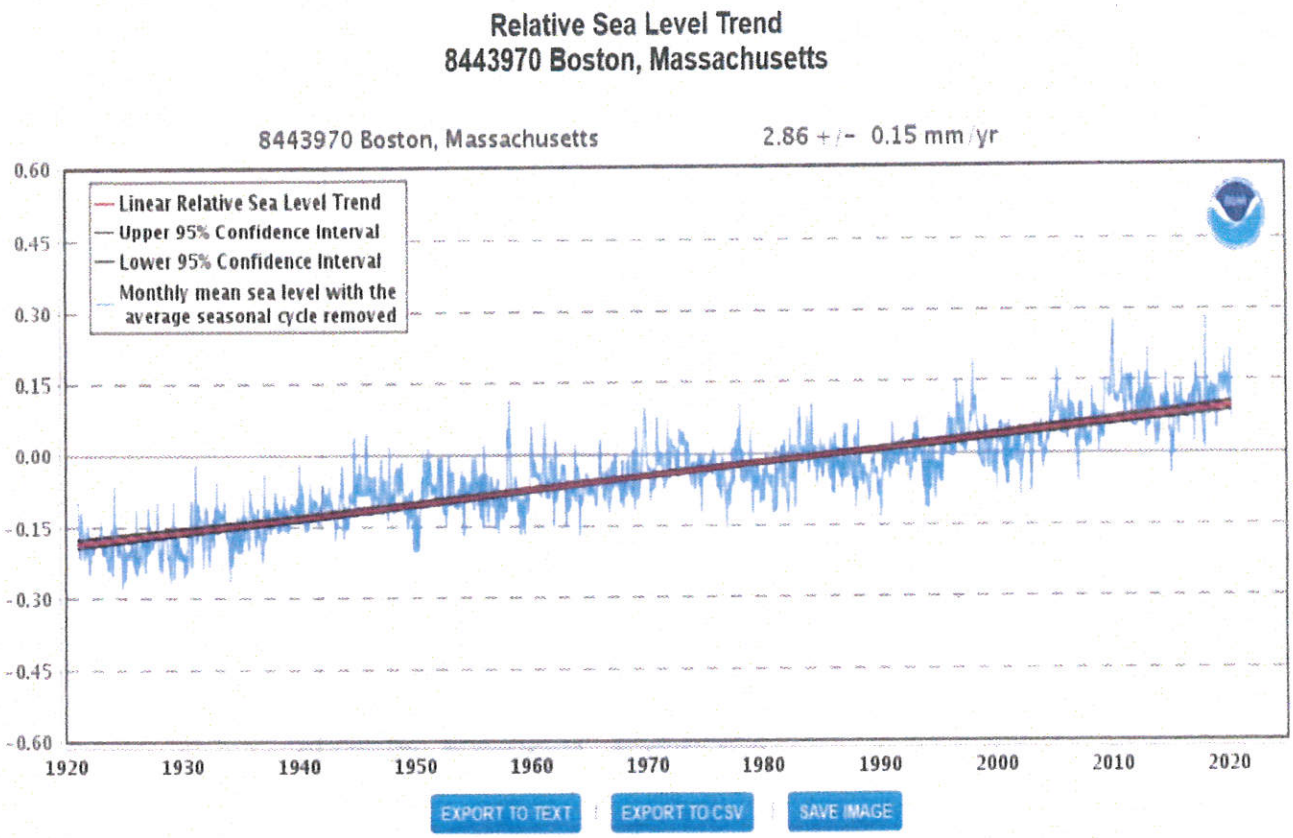

Figure A18: Plot displaying the relative sea level trend in Boston, MA.

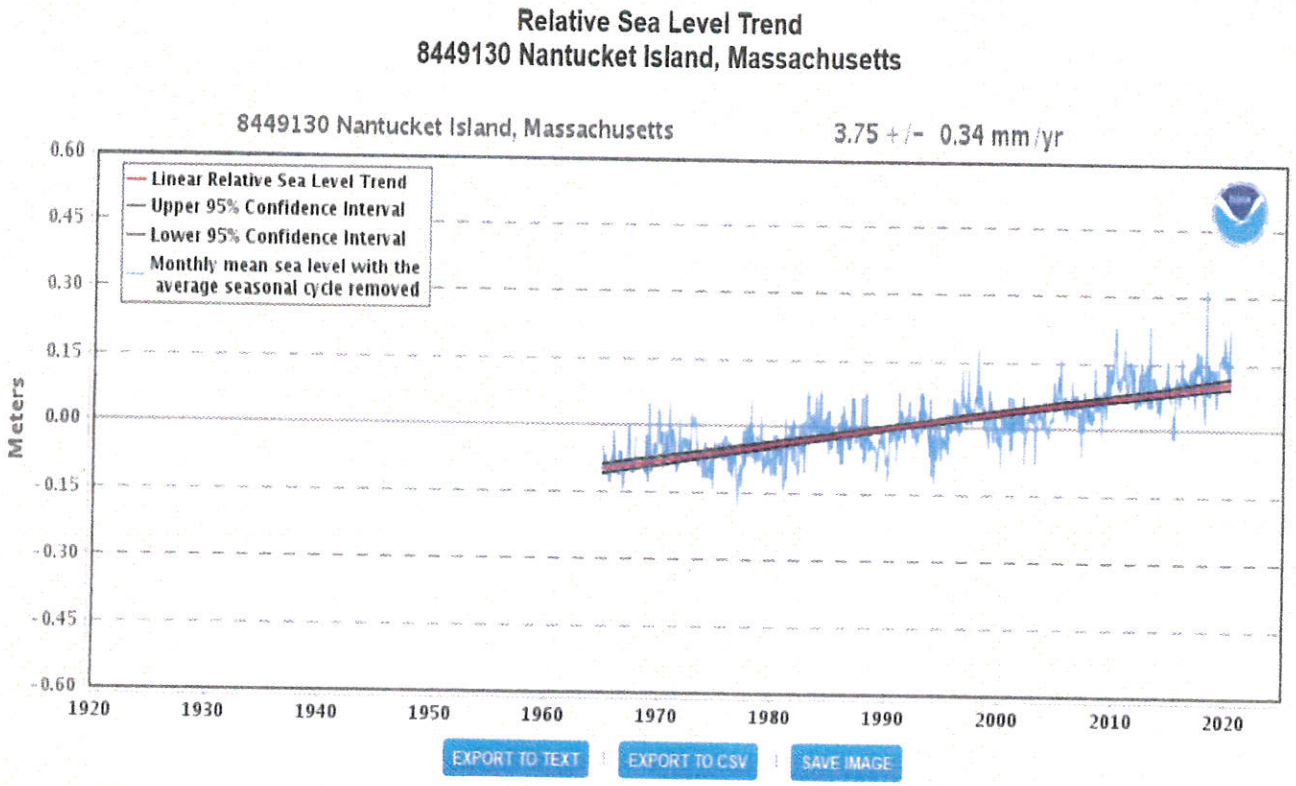

Figure A19: Plot displaying the relative sea level trend in Nantucket, MA.

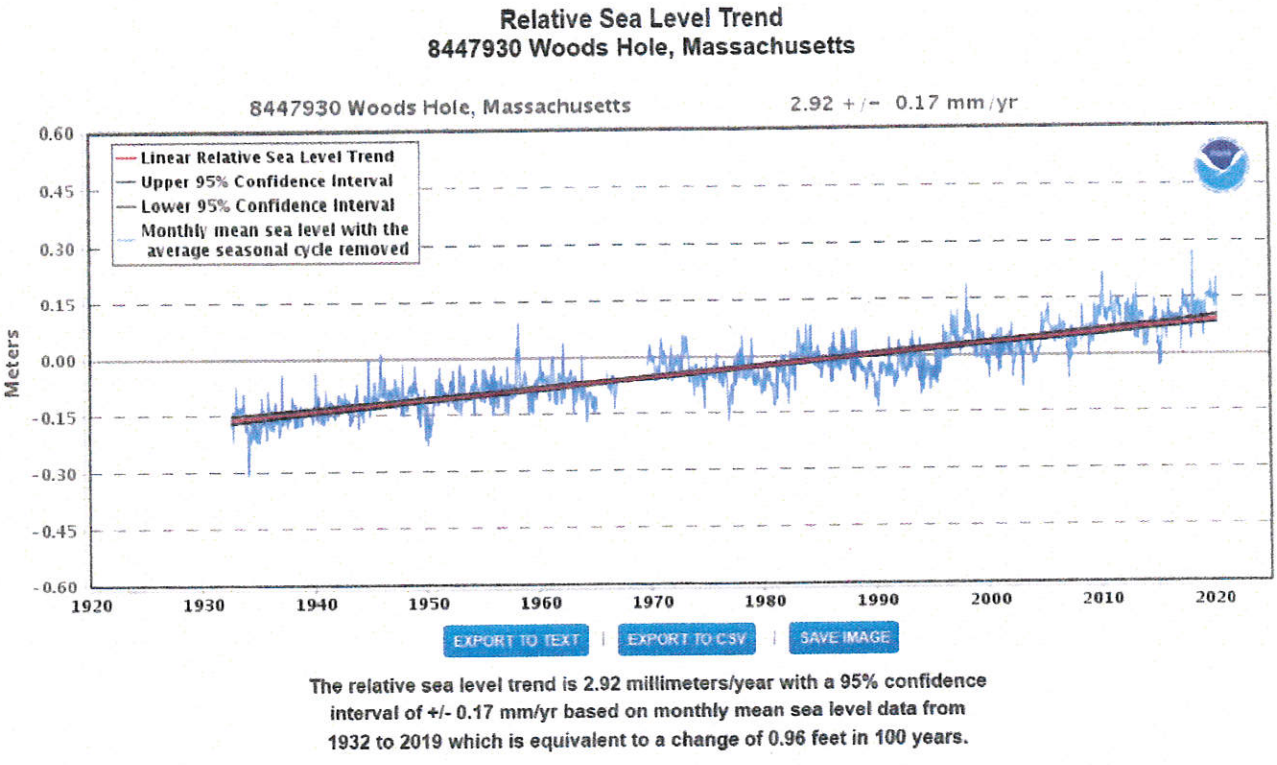

Figure A20: Plot displaying the relative sea level trend in Woods Hole, MA.

Land Subsidence

The figure below, taken from a research study titled "Subsidence along the Atlantic Coast of North America: Insights from GPS and late Holocene relative sea level data" by Karegar et al, published in Vol 43, Issue 7 of the American Geophsyical Unions' Geophysical Research Letters, indicates Cape Cod has a marginal continentiual deflection (settlement) of 1.5 mm/year or 0.5 feet per 100 years. The aformentioned study is linked below.

https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016GL068015.

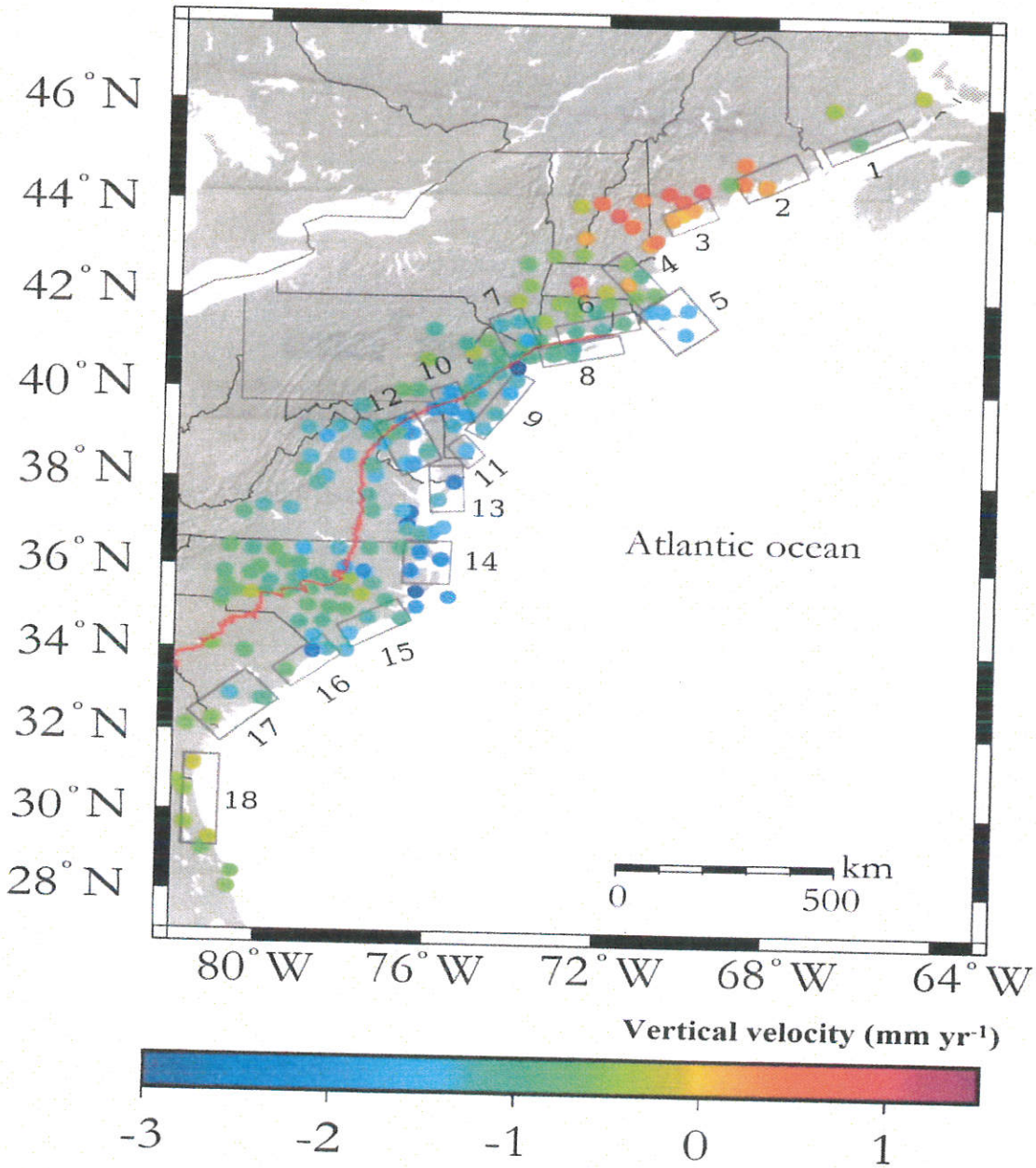

Figure A21: Map displaying vertical velocity of subsidence along the northern Atlantic coast of the USA.

Combined Effect of Sea Level Rise and Marginal Continental Deflection

Based on the above limited data and presuming the surface elevation and mass of the salt marsh is not increasing, one could project that the salt marsh is currently or will be impacted by rising water levels. The combined effect of sea level rise and downward Marginal Continental Deflection is projected to be about 1.5 feet / 100 years or 0.015'/year (1/16" / year). It is beyond the scope of this assessment as to how the marsh will adjust to or be impacted by these predicted conditions.

USACOE Stream Crossing Standards

The US Army Corps of Engineers regulations include guidance on new construction for stream crossings. It is expected that if the culverts are modified or new channels are opened/ reopened, they should be brought into conformance for this guidance.

Guidance on the USACOE can be found at the link below
https://www.mass.gov/files/documents/2018/08/23/Stream%20Crossings%20booklet%20Web.pdf

There are five items in the standards that may be applicable if the culverts were replaced:

1. TYPE OF CROSSING
   General: Spans (bridges, 3-sided box culverts, open bottom culverts or arches) are strongly preferred.

   Based on conceptual costs, precast box culverts with inverts set to below the existing stream floor are expected to be the most likely solution. The placement of the water line under or around the culverts may become an important factor in the design.

2. EMBEDMENT
   All culverts should be embedded (sunk into stream) a minimum of 2 feet, and round pipe culverts at least 25%.

   Imbedment of 2 feet should be attainable if culverts replacement. Existing culverts have sediment floor.

3. CROSSING SPAN:
   General: Spans channel width (a minimum of 1.2 times the bankfull width of the stream). Optimum: Spans the streambed and banks (at least 1.2 times bankfull width) with sufficient headroom to provide dry passage for wildlife.

Location	Existing channel width at culvert outlet	Existing channel width at culvert outlet	1.2 Times Average Stream Width	Existing culvert width	% of 1.2 back full width
Wing Neck Road	12' (bay side)	14' (marsh side)	15.6	9	60%
Salt Marsh Lane	NA- no specific channel	NA- no specific channel	NA	8	NA

4. OPENNESS

General: Openness ratio (cross-sectional area/crossing length) of at least 0.82 feet . The crossing should be wide and high relative to its length.

Location	Existing Culvert Width	Existing Culvert Height (soffit to earthen invert)	Square feet culvert opening (at high tide)	Existing channel area at high tide	Openness Ratio (at High tide)
Wing Neck Road	2 X 4.5 = 9.0 feet	3.0	27 sf	20 sf	1.35 (exceeds 0.82 standard)
Salt Marsh Lane	1 x 8 = 8	1.5	12 s.f	NA- no specific channel	NA- no specific channel

5. SUBSTRATE

Natural bottom substrate (soil type) should be used within the crossing and it should match the upstream and downstream substrates. The substrate and design should resist erosion during floods and maintain the bottom during normal flows.

The floor of the culverts should be sand and silt to match the existing channel floors.

6. WATER DEPTH AND VELOCITY

Water depths and velocities are comparable to those found in the natural channel at a variety of flows.

Location	Existing Channel Velocity at mid-tide (peak velocity)	Existing Culvert Velocity at mid-tide (peak velocity)	Comment
Wing Neck Road	0.5 ft/sec (9.7 cfs)	0.7 ft/sec (9.7cfs)	(similar velocities)
Salt Marsh Lane	Not applicable no defined channel at mid tide	2'ft/sec	Not applicable no defined channel at mid tide

Conclusion: The stream crossing standards may be applied if the culverts are replaced.