STUDY ON EEL POND IMPROVEMENTS

June 2005
Revised January 2006

Prepared for:
Town of Mattapoisett
Board of Selectmen

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TABLE OF CONTENTS:

LIST OF FIGURES & TABLES.......................................................................................................................... ii
LIST OF EXHIBITS:........................................................................................................................................ iii
LIST OF APPENDICES...................................................................................................................................... vii
Executive Summary:....................................................................................................................................... 1
Introduction..................................................................................................................................................... 3
    Engineer/Firm Assigned .............................................................................................................................. 3
    Reference Documents ............................................................................................................................... 3
Site Description............................................................................................................................................. 3
Description of Field Work ............................................................................................................................. 5
Hydrologic Studies.......................................................................................................................................... 9
    Model Configuration:............................................................................................................................... 9
    Model Results:......................................................................................................................................... 10
    Eel Pond Flushing:.................................................................................................................................. 10
Calculations for Sizing Railroad Culvert:.................................................................................................... 19
    Simulated Storm Surge Model Methodology:.......................................................................................... 20
Cost Estimates.................................................................................................................................................. 25
Identification of Permits Required.................................................................................................................. 26
LIST OF FIGURES & TABLES

Figure 1: Eel Pond ..................................................................................................4
Figure 2: Pipe Alignment & West Channel .............................................................6
Figure 3: Sewer Pipe Profile – West Channel .........................................................7
Figure 4: Summary of Percentage of Original Volume ............................................11
Figure 5: Summary of Percentage of Increase ................................................……11
Figure 6: Railroad culvert, East Channel ...............................................................13
Figure 7: East Channel Entrance, 2.5’ above mean low water – restricting half of
tide cycle.............................................................................................................13
Figure 8: Approximate route of profiles ..............................................................14
Figure 9: Profiles of Eel Pond, and East & West Channels .................................15
Figure 10: East Channel ......................................................................................16
Figure 11: Typical precast culvert section ® Oldcastle Precast ...............................17
Figure 12: Profile of closing the West Channel .....................................................18
Figure 13: Estimated Storm Surge curve, and adjusted model curve ....................20
Figure 14: Summary of flow velocity conditions for several culvert sizes ..........22
Figure 15: Water elevation difference Eel Pond to Pond 1 & Pond 1 to Pond 2,
           based on 26’ culvert, 100 year rain event and storm surge .....................23
Figure 16: Model simulated storm surge condition .............................................24

Table 1: Model Configuration ............................................................................9
Table 2: Mean Tide Range Analysis ................................................................10
Table 3: Summary of Eel Pond Mean Tide Hydrologic Conditions ....................10
Table 4: Rainfall runoff into Eel Pond .................................................................19
Table 5: New Culvert flow calculation summary ..............................................21
LIST OF EXHIBITS:

- Exhibit 1: Elevation Graph of Existing Conditions for Mattapoisett Harbor and Eel Pond during Mean Tide, Dry Event
- Exhibit 2: Hydrograph of Existing Conditions for Eel Pond and East/West Channels during Mean Tide, Dry Event
- Exhibit 3: Elevation Graph of Existing Conditions for Mattapoisett Harbor and Eel Pond during Mean Tide, 2-Year Storm Event
- Exhibit 4: Hydrograph Existing Conditions for Flow in from Upland Sources and Eel Pond during Mean Tide, 2-Year Storm Event
- Exhibit 5: Hydrograph of Existing Conditions for Eel Pond and East/West Channels during Mean Tide, 2-Year Storm Event
- Exhibit 6: Elevation Graph of Existing Conditions for Mattapoisett Harbor and Eel Pond during Mean Tide, 10-Year Storm Event
- Exhibit 7: Hydrograph of Existing Conditions for Flow in from Upland Sources and Eel Pond during Mean Tide, 10-Year Storm Event
- Exhibit 8: Hydrograph of Existing Conditions for Eel Pond and East/West Channels during Mean Tide, 10-Year Storm Event
- Exhibit 9: Elevation Graph of Existing Conditions for Mattapoisett Harbor and Eel Pond during Mean Tide, 100-Year Storm Event
- Exhibit 10: Hydrograph of Existing Conditions for Flow In from Upland Sources and Eel Pond during Mean Tide, 100-Year Storm Event
- Exhibit 11: Hydrograph of Existing Conditions for Eel Pond and East/West Channels during Mean Tide, 100-Year Storm Event
- Exhibit 12: Elevation Graph of Existing Conditions for Mattapoisett Harbor and Eel Pond during Mean Tide, Spring Event
- Exhibit 13: Hydrograph of Existing Conditions for Eel Pond and East/West Channels during Mean Tide, Spring Event
- Exhibit 14: Elevation Graph of Existing Conditions for Mattapoisett Harbor and Eel Pond during Mean Tide, 2-Year Storm Event
- Exhibit 15: Hydrograph of Existing Conditions for Eel Pond and East/West Channels during Mean Tide, 2-Year Storm Event
- Exhibit 16: Elevation Graph of Existing Conditions for Mattapoisett Harbor and Eel Pond during Mean Tide, 10-Year Storm Event
- Exhibit 17: Hydrograph of Existing Conditions for Eel Pond and East/West Channels during Mean Tide, 10-Year Storm Event
- Exhibit 18: Elevation Graph of Dredging Only with West Channel Open for Mattapoisett Harbor and Eel Pond during Mean Tide, Dry Event
- Exhibit 19: Hydrograph of Dredging Only with West Channel Open for Eel Pond and East/West Channels during Mean Tide, Dry Event
- Exhibit 20: Elevation Graph of Dredging Only with West Channel Closed for Mattapoisett Harbor and Eel Pond during Mean Tide, Dry Event
LIST OF EXHIBITS (continued):

- Exhibit 21: Hydrograph of Dredging Only with West Channel Closed for Eel Pond during Mean Tide, Dry Event
- Exhibit 22: Elevation Graph of Dredging Only with West Channel Open for Mattapoisett Harbor and Eel Pond during Mean Tide, 2-Year Storm Event
- Exhibit 23: Hydrograph of Dredging Only with West Channel Open for Eel Pond and East/West Channels during Mean Tide, 2-Year Storm Event
- Exhibit 24: Elevation Graph of Dredging Only with West Channel Closed for Mattapoisett Harbor and Eel Pond during Mean Tide, 2-Year Storm Event
- Exhibit 25: Hydrograph of Dredging Only with West Channel Closed for Eel Pond during Mean Tide, 2-Year Storm Event
- Exhibit 26: Elevation Graph of Dredging Only with West Channel Open for Mattapoisett Harbor and Eel Pond during Mean Tide, 10-Year Storm Event
- Exhibit 27: Hydrograph of Dredging Only with West Channel Open for Eel Pond and East/West Channels during Mean Tide, 10-Year Storm Event
- Exhibit 28: Elevation Graph of Dredging Only with West Channel Open for Mattapoisett Harbor and Eel Pond during Mean Tide, 100-Year Storm Event
- Exhibit 29: Hydrograph of Dredging Only with West Channel Open for Eel Pond and East/West Channels during Mean Tide, 100-Year Storm Event
- Exhibit 30: Elevation Graph of Dredging and 22-foot Wide Culvert with West Channel Closed for Mattapoisett Harbor and Eel Pond during Mean Tide, Dry Event
- Exhibit 31: Hydrograph of Dredging and 22-foot Wide Culvert with West Channel Closed for Eel Pond during Mean Tide, Dry Event
- Exhibit 32: Elevation Graph of Dredging and 22-foot Wide Culvert with West Channel Closed for Mattapoisett Harbor and Eel Pond during Mean Tide, 2-Year Storm Event
- Exhibit 33: Hydrograph of Dredging and 22-foot Wide Culvert with West Channel Closed for Eel Pond during Mean Tide, 2-Year Storm Event
- Exhibit 34: Elevation Graph of Dredging and 10-foot Wide Culvert with West Channel Closed for Mattapoisett Harbor and Eel Pond during Spring Tide, Dry Event
- Exhibit 35: Hydrograph of Dredging and 10-foot Wide Culvert with West Channel Closed for Eel Pond during Spring Tide, Dry Event
- Exhibit 36: Elevation Graph of Dredging and 16-foot Wide Culvert with West Channel Closed for Mattapoisett Harbor and Eel Pond during Spring Tide, Dry Event
LIST OF EXHIBITS (continued):

- Exhibit 37: Hydrograph of Dredging and 16-foot Wide Culvert with West Channel Closed for Eel Pond during Spring Tide, Dry Event
- Exhibit 38: Elevation Graph of Dredging and 22-foot Wide Culvert with West Channel Closed for Mattapoisett Harbor and Eel Pond during Spring Tide, Dry Event
- Exhibit 39: Hydrograph of Dredging and 22-foot Wide Culvert with West Channel Closed for Eel Pond during Spring Tide, Dry Event
- Exhibit 40: Elevation Graph of Dredging and 26-foot Wide Culvert with West Channel Closed for Mattapoisett Harbor and Eel Pond during Spring Tide, Dry Event
- Exhibit 41: Hydrograph of Dredging and 26-foot Wide Culvert with West Channel Closed for Eel Pond during Spring Tide, Dry Event
- Exhibit 42: Elevation Graph of Dredging and 10-foot Wide Culvert with West Channel Closed for Mattapoisett Harbor and Eel Pond during Spring Tide, 10-Year Storm Event
- Exhibit 43: Hydrograph of Dredging and 10-foot Wide Culvert with West Channel Closed for Eel Pond during Spring Tide, 10-Year Storm Event
- Exhibit 44: Elevation Graph of Dredging and 16-foot Wide Culvert with West Channel Closed for Mattapoisett Harbor and Eel Pond during Spring Tide, 10-Year Storm Event
- Exhibit 45: Hydrograph of Dredging and 16-foot Wide Culvert with West Channel Closed for Eel Pond during Spring Tide, 10-Year Storm Event
- Exhibit 46: Elevation Graph of Dredging and 22-foot Wide Culvert with West Channel Closed for Mattapoisett Harbor and Eel Pond during Spring Tide, 10-Year Storm Event
- Exhibit 47: Hydrograph of Dredging and 22-foot Wide Culvert with West Channel Closed for Eel Pond during Spring Tide, 10-Year Storm Event
- Exhibit 48: Elevation Graph of Dredging and 26-foot Wide Culvert with West Channel Closed for Mattapoisett Harbor and Eel Pond during Spring Tide, 10-Year Storm Event
- Exhibit 49: Hydrograph of Dredging and 26-foot Wide Culvert with West Channel Closed for Eel Pond during Spring Tide, 10-Year Storm Event
- Exhibit 50: Elevation Graph of Dredging and 10-foot Wide Culvert with West Channel Closed for Mattapoisett Harbor and Eel Pond during Spring Tide, 100-Year Storm Event
- Exhibit 51: Hydrograph of Dredging and 10-foot Wide Culvert with West Channel Closed for Eel Pond during Spring Tide, 100-Year Storm Event
- Exhibit 52: Elevation Graph of Dredging and 16-foot Wide Culvert with West Channel Closed for Mattapoisett Harbor and Eel Pond during Spring Tide, 100-Year Storm Event
LIST OF EXHIBITS (continued):

- Exhibit 53: Hydrograph of Dredging and 16-foot Wide Culvert with West Channel Closed for Eel Pond during Spring Tide, 100-Year Storm Event
- Exhibit 54: Elevation Graph of Dredging and 22-foot Wide Culvert with West Channel Closed for Mattapoisett Harbor and Eel Pond during Spring Tide, 100-Year Storm Event
- Exhibit 55: Hydrograph of Dredging and 22-foot Wide Culvert with West Channel Closed for Eel Pond during Spring Tide, 100-Year Storm Event
- Exhibit 56: Elevation Graph of Dredging and 26-foot Wide Culvert with West Channel Closed for Mattapoisett Harbor and Eel Pond during Spring Tide, 100-Year Storm Event
- Exhibit 57: Hydrograph of Dredging and 26-foot Wide Culvert with West Channel Closed for Eel Pond during Spring Tide, 100-Year Storm Event
- Exhibit 58: Elevation Graph of Dredging Culvert Size Summary with West Channel Closed for Eel Pond during Spring Tide, Dry Event
- Exhibit 59: Elevation Graph of Dredging Culvert Size Summary with West Channel Closed for Eel Pond during Spring Tide, 10-Year Storm Event
- Exhibit 60: Elevation Graph of Dredging Culvert Size Summary with West Channel Closed for Eel Pond during Spring Tide, 100-Year Storm Event
- Exhibit 61: Hydrograph of Dredging Culvert Size Summary with West Channel Closed for Eel Pond during Spring Tide, Dry Event
- Exhibit 62: Hydrograph of Dredging Culvert Size Summary with West Channel Closed for Eel Pond during Spring Tide, 10-Year Storm Event
- Exhibit 63: Hydrograph of Dredging Culvert Size Summary with West Channel Closed for Eel Pond during Spring Tide, 100-Year Storm Event
- Exhibit 64: Eel Pond Condition Summary
LIST OF APPENDICES

- Letter dated June 16, 2005 from Russ Kempton, New England Geophysical to Mr. Nicholson, Town of Mattapoisett, RE: GPR Location Survey of Forced Main from STA 17+90 to STA 24+00

- GeoTechnical Test Report for Eel Pond Project East Channel, by GeoTesting Express, dated June 10, 2005 & September 27, 2005

- Plans Titled: “Eel Pond, Mattapoisett Harbor” by CLE Engineering, Inc., dated: 06-07-05, Revised 12-07-05, 5-sheets
EXECUTIVE SUMMARY:

Following several studies from 1992 to 2001, there has been increasing concern over the condition of Eel Pond, which at least one report concluded was among the most eutrophic embayments within the Buzzards Bay Monitoring Program. As a follow on to these studies, CLE was provided a contract for engineering services by The Town of Mattapoisett to perform a study that was intended to find ways to increase salt-water flow and improve the water quality within Eel Pond. Most of the prior reports cited the general lack of sufficient exchange with the adjacent tidal waters of Mattapoisett Harbor, which became one of the focuses of this study. In addition, tasks were included to provide detailed topographic mapping of the pond and adjacent areas, and investigation of the existing 12” sewage force main that crosses both the railroad embankment and the Western channel. These studies have been completed by CLE and are presented in this report and summarized in the following paragraphs.

Mapping and Sewer Line: Topographic mapping of Eel Pond and its adjacent environment, including resource areas, shellfish, water bodies, beaches, entrance channels and the existing sewer line route has been completed and is attached to this report. The Town of Mattapoisett located the sewer pipeline using Ground Penetrating Radar (see attached report). The identified sewer line locations were then surveyed by CLE and included in the attached map. In general, the sewer line was buried approximately five feet below existing grade; however, the portion of the pipe that crosses the West channel was found to have only 18” of cover at the deepest point of the channel. This is a matter of serious concern, as a major storm event (such as a hurricane) could uncover and possibly rupture the pipe. Such an event would be catastrophic in that it would cause several million gallons of raw sewage to be discharged into the Harbor before it could be repaired. CLE has recommended that plans be made to close the West Channel by filling and restoring the original beach grades to an elevation of +6.5 MLW (+5.5 NGVD). However, in order to perform this closure, plans must be made to enlarge the East Channel and increase the size of the railroad culvert.

Improving the Flushing of Eel Pond: CLE created a computer model of the Eel Pond watershed and connecting channels. A number of programs were then run simulating the existing conditions as well as various potential improvements, along with the tidal effects and rainstorms ranging from minor to extremely severe. The average daily exchange within Eel Pond (without rainfall) is presently 65%. If the East Channel is dredged as outlined herein, the exchange will improve to 84%, which is an increase of 30%. If the East channel is dredged, and the West channel closed, the exchange drops to 40%, or a reduction of 39%, thus CLE cannot recommend closing the West channel until railroad culvert improvements are completed. However, if the East Channel is dredged, the West channel closed and it is combined with enlarging the railroad culvert, the flows improve to 120% of the original volume, or an improvement of 86%.

Enlarging the Railroad Culvert: CLE investigated several methodologies, and performed a number of calculations with respect to the optimal method and size of a new culvert.
under the railroad embankment. It was determined that a 24’ x 8’ culvert would provide
the most optimal flow, while providing adequate scour protection during most storm
conditions. In addition, when considering a hurricane storm surge event, the 24’ culvert
was also found to be the minimum advisable culvert that would provide adequate storm
surge flowage. The size of the culvert was found to be critical toward reducing the
damage to the barrier beach from storm surge overtopping.

Phased Approach & Conclusions: Based on the results of this study, it is reasonable to
conclude that the water quality of Eel Pond can be improved, and the existing sewer line
protected by taking a phased approach.

- CLE recommends a Phase 1 program that would require dredging the Eastern
  channel to Eel Pond. This would involve dredging approximately 6,100 cubic
  yards from the channel and removing the restriction at its mouth. Dredging would
  improve the flushing and water quality by increasing the tidal flows to Eel Pond
  by 30%. In addition, the flowage through the West Channel would be reduced by
  approximately 40%, thereby reducing the short term erosion risks to the sewer
  pipeline.

- CLE recommends a Phase 2 program that would involve installing a new 24’ x 8’
  culvert adjacent to the existing culvert, using the open-cut method and
  temporarily bypassing the existing utilities. Opening of the new culvert could be
  followed by a closure of the Western Channel, and filling in the contours of the
  adjacent barrier beach with approximately 7,000 cubic yards of material. This
  would improve the tidal exchange in Eel Pond by almost double the present rate,
  and provide far better protection for the existing sewer force pipeline.

- At some point in the above process, CLE recommends replacing the portions of
  the asbestos cement pipeline in the railroad embankment and barrier beach with a
  more durable material such as HDPE.

When completed, this program would greatly improve the tidal exchange of Eel Pond, as
well as better protect the harbor from an unfortunate environmental accident by way of an
untimely sewer pipeline break.
INTRODUCTION

Engineer/Firm Assigned

Pursuant to a proposal dated April 15, 2005, the Town of Mattapoisett contracted CLE Engineering, Inc. (CLE) to perform surveying and engineering services. The scope of services included developing existing conditions site plans, engineering design and evaluations, hydrographical modeling, construction cost estimates, analysis of impacts from proposed activities and the preparation of permit applications and supporting documents for the improvements to the Eel Pond drainage system. CLE performed the services referenced in this report. Questions regarding this report, its scope and/or content should be addressed to John DeRugeri, P.E. or Susan Nilson, P.E. at (508) 748-0937.

This report has been prepared for the Town of Mattapoisett with the intent that it will be utilized for assessing the existing conditions of Eel Pond and proposed improvements. Any other use, publication or the like of any data contained herein, by other parties without express consent of CLE Engineering is prohibited.

Reference Documents

The following is a list of the references that were used for this project.

- “Nitrogen Management Options for Eel Pond, Mattapoisett” by Nick Nicholson, Mattapoisett Water Department, January 30, 1999
- Letter dated September 18, 2001 from Applied Coastal Research and Engineering, Inc. to Rebecca Haney, CZM Coastal Geologist, RE: Eel Pond, Mattapoisett
- Letter dated May 23, 1005 from Gregory Sawyer, Marine Biologist, Division of Marine Fisheries to Michael Botelho, Town Administrator, Town of Mattapoisett, RE: May 10, 2005 Shellfish Survey of Eel Pond

SITE DESCRIPTION

Eel Pond is a small coastal salt pond containing approximately 30 acres, and is located within the Northwest shoreline of Mattapoisett Harbor. It is directly west of Mattapoisett Village, and is surrounded by developed land on the East, salt marsh on the North and West, a Golf Course on the Northwest and a coastal barrier beach on the South. The
main source of fresh water (other than run-off from adjacent land) is Tub Mill Brook, which enters from the North. The main connection to salt water (Mattapoisett Harbor) is through two channels, one located at the extreme East end, and one located at the extreme West end of the pond (Figure 1). The East channel is believed to be the original connection, and it includes two smaller salt ponds along its route that are approximately two acres each. The East Channel has two restrictions, one being a box culvert, which is situated within a former railroad embankment. The embankment forms somewhat of a barrier separating Eel Pond from the Harbor over approximately one third of its length. The remaining two-thirds of the former railroad alignment was destroyed by hurricanes and, with little exception is no longer evident. The second obstruction in the East Channel is two-fold, consisting of the shallow braided connecting channel and a rocky shoal at its entrance. The high point of the channel, at the shoal is presently +2.5 feet above mean low water (MLW), (or +1.2 NVGD). The West Channel cuts through a salt marsh, then the barrier beach, and with the exception of a shoal at its entrance, it is relatively unimpeded; as such it presently carries most of the salt-water ebb and flow of the tides.

Eel Pond has filled in with upland sediment over the years and its bottom elevation is now approximately +1.3 to +2.3 MLW, (or 0.0 to +1.0 NGVD as shown on the attachments). High water stages (exclusive of storm water effects) lag behind the Harbor by an hour or more, and reach +3.8 to +4.8 (MLW) depending on the Harbor’s tidal range for the particular day. Low water ranges from +2.2 to +2.4 (MLW), again depending on the tidal range of the Harbor. This puts net water depths in the pond from 0.0 to 2.4 feet, with the higher tidal elevations generally lagging the Harbor high tides by one to two hours. Because of its low rate of tidal exchange, and the inflow of upland fresh water, Eel Pond has been rated among the most eutrophic embayments within the Baywatchers Monitoring Program (1992-1998) performed by the Coalition for Buzzards Bay.
A twelve inch (12”) diameter sewage force (pressure) main traverses the barrier beach from the railroad embankment to where it crosses the West Channel, then is routed toward Fairhaven via an upland service road. The pipe material is asbestos cement, and it is generally unprotected except by earth cover; however, the portion of the pipe that crosses the West Channel is said to be encased in approximately six inches of concrete. Based on the Ground Penetrating Radar survey conducted by The Town of Mattapoisett, the cover over the pipe is approximately five to six feet over most of its alignment; however, at the point where it crosses the West Channel its soil cover is quite thin (approximately 18” of cover at the deepest point of the channel). The alignment of the West Channel has migrated further to the west since the pipe was first installed, and presently the center of the channel is believed to have migrated to the extreme west end of the concrete encasement. The age of the pipe, the lack of cover and migration of the West Channel all represent serious concerns with respect to the environmental safety of Mattapoisett Harbor and Buzzards Bay.

DESCRIPTION OF FIELD WORK

As part of its task order for the subject project, CLE performed detailed topographic and hydrographic surveys of Eel Pond and the surrounding areas including portions of the barrier beach, the East and West channels, and the nearby wetlands. Water depths were also obtained for the East and West channels as well as their connections to Mattapoisett Harbor. The Horizontal Datum used was NAD 83, and Vertical Datum utilized was NGVD, which is approximately 1.3 feet above local mean low water (MLW). Land portions of the surveys were performed using Real Time Kinematic (RTK) GPS survey systems, using a survey grid appropriate to the topography. RTK GPS has a moving or “On the Fly” (OTF) accuracy of one to two centimeters, and the system stores the survey points in a data collector.

In Eel Pond and the channels, where water depths were 12” or greater hydrographic surveys were performed using automated GPS/ electronic sounder survey systems. Water elevation levels were logged during the surveys from tide staffs, and the final hydrographic data was converted to project datum. Where water depths were too shallow for operation of the survey boat, additional RTK-GPS shots were taken to fill in the transitional zones. All of the above survey data was reduced and converted to a topographic map of the study area using AutoCAD Version 2000, computer aided drafting software. The maps were then used to prepare the hydrological studies that are also part of this report.

In addition to topographic surveys, CLE worked with the Town of Mattapoisett Water and Sewer Department to locate the existing Asbestos Cement Force Main that connects the sewer system of the Town of Mattapoisett to the Fairhaven Treatment Plant. This is a 12” pressure pipe that was installed in the late 1970s across the railroad embankment, then the barrier beach that fronts Eel Pond. Figure 2 below shows the approximate area of the pipe alignment that was surveyed using Ground Penetrating Radar (GPR).
During the month of June 2005, the Town of Mattapoisett and New England Geophysical performed Ground Penetrating Radar (GPR) investigations of the pipe alignment shown in Figure 2. In conjunction with that investigation CLE provided survey services to locate the GPR soundings using RTK GPS, and referencing the location and elevation to NAD 83 and NGVD vertical datum. Using the information provided by New England Geophysical a plan and profile of the pipeline was mapped and added to the topographic plan prepared by CLE. In addition a profile of the pipeline was prepared and is included in Figure 3.
The surveyed profile of the pipeline was overlaid on the topographic data obtained by CLE, as it is shown above. It clearly shows that at the point where the pipe crosses the channel, the deepest part of the West Channel is only 1.5 feet above the top of the pipe barrel, and therefore only 12 inches away from the top of the concrete encasement. This is a source of significant concern over two issues:

(1) The West Channel is known to be migrating to the West. If the channel continues its present migration where the pipe burial is much shallower, it may begin to expose the pipe. Further, while the exact location of the concrete encasement is not known, it is estimated that the present location of the West Channel is very near to the end of that encasement. Thus any further migration to the West could potentially expose bare unprotected pipe.

(2) It is known that the flows out the Western Channel have increased as the Eastern Channel literally continues to choke itself off due to the structural restrictions. This means that the Eastern channel will be come less viable with respect to its ability to carry storm flows, such as the hurricane overtopping. This would, in-turn route more water toward the Western Channel, and in the event of a severe storm surge, overtopping flows could gouge the existing Western Channel even wider and deeper. Exposure of the pipe under such severe flows could cause it to rupture and begin spilling most of the untreated sewage into the Harbor.

The Mattapoisett lift station cycles approximately every 20 minutes (thus there is little reserve storage), and a total of approximately 210,000 gallons of raw sewage is pumped through this pipeline every day to the Fairhaven treatment plant. Any failure of this sewer line would be catastrophic, as it would cause 210,000 gallons of raw sewage to be discharged into Mattapoisett Harbor and Buzzards Bay every day until the line could be repaired. During the aftermath of a severe hurricane, this could amount to several days.
One of the present contingency plans to avert this catastrophe would be to truck the sewage to Fairhaven using tankers, this would require at least 4 to 6 five thousand (5,000) gallon tank trucks running around the clock, and even at this rate trucking (considering potential hurricane related road closures and power failures) may not be able to keep up with peak flows. CLE therefore recommends that serious consideration be given to improving the East Channel to a condition where it can contain known storm flows, and closing the West Channel. Further, CLE recommends the portion of the sewer line that lies within the potential “wash-out” zone of the West Channel, be replaced with more suitable material for submarine crossings.
HYDROLOGIC STUDIES

As part of its task order to study the flow issues of both tidal exchange (flushing), and storm water flows, CLE preformed a watershed flow analysis of Eel Pond and its surroundings. This included preparing a computer model of the Eel Pond watershed and its connections to Mattapoisett Harbor.

Model Configuration:
To fulfill the modeling task of this study, CLE utilized the Haestad Methods “Pond Pack” software, which utilizes baseline programs such as TR-20 and TR-55 to model flows of watersheds. The Model area was mapped from USGS charts and aerial photographs, followed up by field investigations of critical drainage culverts and junctions. The details of the various watersheds, catchments and routes are available upon request (Hydrologic printout) for the various conditions, however a generalized map is included in Table 1 below:

![Diagram of Eel Pond watershed]

Input to models included “No Rain”, 2 year (3” rainfall), 10 year (4.5” rainfall) and 100 year (7.1” rainfall) storms. In addition smaller, more common storms, such as 1 and 2 inch rainfalls were checked to assess their relevant significance. Tidal conditions from Mattapoisett Harbor were added to the outfalls of the two channels, which included a typical mean tide of a 3.9 foot range, as well as a typical spring tide of 5.74 foot range. Also as a verification of adequacy of the railroad culvert, one storm surge tide that
approximated a +11.0 NGVD surge was run with the 100 year storm condition to check flow velocity and scouring potential.

Model Results:

Eel Pond Flushing:

Several model conditions were run to compute the various conditions that Eel Pond is subjected to during mean and spring tides, as well as various rain events. As part of the study the following Mean Tidal Range hydrographs were run as shown in Table 2¹:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Tide Range (ft. NGVD)</th>
<th>Rainfall (Storm)</th>
<th>Eel Pond Flush (% of Orig Volume)</th>
<th>East Channel (% of Total)</th>
<th>West Channel (% of Total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>Mean Dry</td>
<td>64.84%</td>
<td>14.69%</td>
<td>85.31%</td>
<td></td>
</tr>
<tr>
<td>Dredge Only</td>
<td>Mean Dry</td>
<td>83.94%</td>
<td>40.69%</td>
<td>59.31%</td>
<td></td>
</tr>
<tr>
<td>Dredge Only Close West Chan</td>
<td>Mean Dry</td>
<td>39.79%</td>
<td>39.79%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td>Dredge &amp; 24’ Culv- Close West Chan</td>
<td>Mean Dry</td>
<td>120.51%</td>
<td>59.62%</td>
<td>4.14%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Condition</th>
<th>Tide Range (ft. NGVD)</th>
<th>Rainfall (Storm)</th>
<th>Eel Pond Flush (% of Orig Volume)</th>
<th>East Channel (% Increase)</th>
<th>West Channel (% Decrease)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>Mean Dry</td>
<td>0.00%</td>
<td>100.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Dredge Only</td>
<td>Mean Dry</td>
<td>29.46%</td>
<td>277.06%</td>
<td>30.48%</td>
<td></td>
</tr>
<tr>
<td>Dredge Only Close West Chan</td>
<td>Mean Dry</td>
<td>-38.64%</td>
<td>270.90%</td>
<td>100.00%</td>
<td></td>
</tr>
<tr>
<td>Dredge &amp; 24’ Culv- Close West Chan</td>
<td>Mean Dry</td>
<td>85.86%</td>
<td>820.54%</td>
<td>100.00%</td>
<td></td>
</tr>
</tbody>
</table>

¹ The model used a 26-foot size culvert to account for the proposed 24-foot culvert in addition to the cross-sectional area of the existing area.
Figure 4: Summary of Percentage of Original

Condition

- 0.00%
- 20.00%
- 40.00%
- 60.00%
- 80.00%
- 100.00%
- 120.00%
- 140.00%

Exchange of Original Volume (%)

- Existing
- Dredge Only
- Dredge Only & Close West Channel
- Dredge & 24' Culvert & Close West Channel

Figure 5: Summary of Percentage

Condition

- 0.00%
- 20.00%
- 40.00%
- 60.00%
- 80.00%
- 100.00%
- 120.00%
- 140.00%

Percent Increase (%)

- Existing
- Dredge Only
- Dredge Only & Close West Channel
- Dredge & 24' Culvert & Close West Channel
There are a number of important analyses that can be drawn from this summary chart; they are as follows:

1. With each daily tide there is a minor tide then a major tide. The minor tide is usually approximately 75% of the height of the major tide (see typical tidal curves used in this study – Exhibits 1 & 12 (Mean & Spring Dry Existing). All tides run in cycles, with each cycle having a maximum (spring) and minimum (neap) elevation difference between high and low; the “Mean Tide” represents a mathematical average of the high and low cycles over a given period or “epoch”. Because the “Mean Tide” is the functional average condition, this will be the focus of the tidal flushing analysis, since it is known that while there will be higher and lower cycles, they should mathematically all average out to the mean condition. The high tidal volume of Eel Pond is approximately 820,000 cubic feet on the lower of the two daily tides, and approximately 1,600,000 cubic feet at the higher of the mean cycle. The daily total is approximately 2,420,000 cubic feet. In its present condition during a mean tide Eel Pond exchanges about 65% of its volume twice a day, leaving approximately 35% of the original volume. Between each tide the residual water mixes with the new incoming water for a period of tide. Typically, the water in the region most distant from the salt-water outlets mixes less than the region closer to the outlet(s). This leaves a condition of variable salinity from one part of the pond to the other that has shown itself in the variety of wetland grasses that are found around the perimeter.

2. It can also be noted that at the present time approximately 85% of the present tidal flow occurs through the West Channel, with the remainder of 15% flowing through the East Channel. This imbalance occurs for a number of reasons; however, two conditions are the primary cause: one is a restriction caused by the Rail Road Culvert, which measures only 5.0 feet wide by 5.5 high, with an invert elevation of +1.3 MLW (0.0 NGVD) (See Figure 6). The second restriction occurs all along the East Channel before it empties into Mattapoisett Harbor. The restriction is caused by the shallow, almost braided condition of the east channel (in general), which culminates near the harbor jetties where an area of large gravel that runs the width of the channel that is at approximately elevation +2.5 MLW (+1.2 NGVD), (See Figure 7).
Figure 6: Railroad culvert, East Channel

Figure 7: East Channel Entrance, 2.5’ above mean low water – restricting half of tide cycle
3. An example of the typical tidal restriction is shown in Exhibit 1, which represents the comparison of a Mean tidal curve for Mattapoisett Harbor versus that of the same tidal cycle in Eel Pond. Note that because the high tide in Eel Pond lags the harbor by over an hour, the high tide in Eel Pond is approximately 0.4 feet lower, because the flow restrictions do not allow the volume of water needed to fill Eel Pond to pass through the channels. Additionally note that the low tide in Eel Pond is about +2.3 MLW (+1.0 NGVD). This is because the restrictions at the entrance to the harbor act as a dam, and will not let all of the water out. As a result of this long-term restriction, Eel Pond has acted as a detention pond, and essentially trapped much of any silt-laden run-off from upland sources. Eventually the pond filled with mud to the approximate level of the tidal restrictions. Figure 9, shows the present profile of Eel Pond, and the East and West channels, Figure 8 shows the route used to take the profiles.

Figure 8: Approximate route of profiles
4. Another part of the study tasked to CLE was to determine what could be done to improve the water flow in and out of Eel Pond (flushing). Three methods of improving flow to and from Eel Pond were investigated; the first was to improve the East Channel by dredging. A number of channel sizes and widths were analyzed, the most effective channel was determined to be one approximately 30 feet wide at the base, with a depth of –2.7 MLW (–4.0 NGVD), the channel would have 3:1 sideslopes to meet the existing grade lines. Cross sections of the proposed channel are included in the Appendix section. Generally speaking the proposed channel fits within the “top of bank” lines that bound the existing channel; however, there are two places where the channel is narrow, and it is bounded by salt marsh on one or both sides. These locations occur adjacent to the existing jetty (See Figure 7) and between the small ponds designated as 1 & 2 in this report (See Figure 10).
5. In addition to dredging, CLE investigated increasing the size of the culvert under the railroad embankment. It is envisioned that the most viable way to increase the size of the culvert would be to select a location approximately 50 feet Northeast of the existing culvert and construct an open cut, sheeted excavation large enough to allow “open cut” installation of precast culverts. This would also require the temporary bypassing of existing utilities, the most difficult of which would be the bypassing of the existing asbestos cement sewage force main. The temporary sewer bypass could be accomplished by installing a HDPE bypass pipe around the excavation while the construction is taking place. Typically such tie-ins require two to three hours, and are performed late at night when sewer flows are low. In addition, the temporary access would need to be provided for the one homeowner that resides on Goodspeed Island. It is expected that the entire road closure would last about two weeks. A typical precast culvert (manufactured in Rehoboth, MA) is shown in Figure 11, spans of up to 30 feet are available.
6. Based on the preliminary dredging and culvert designs discussed above CLE did an analysis using on the following scenarios:

a. Dredging only to a depth of –2.7 MLW by a 30 foot base width, and no change to the West Channel or Railroad culvert.

b. Dredging only to a depth of –2.7 MLW by a 30 foot base width, closing the West Channel and no change to the Railroad culvert.

c. Dredging only to a depth of –2.7 MLW by a 30 foot base width, closing the West Channel, and enlarging the railroad culvert to 20’.

Based on a no-rainfall condition (matching the baseline condition of mean tide range, no rain & existing conditions), the following comparison can be drawn from Tables 2 & 3.

a. If dredging only is performed, and the West channel is left open, the flows in Eel Pond increase from 65% to 84%, or an increase in flow volume of about 30%.

b. If dredging only is performed, and the West channel is closed the flows in Eel Pond are reduced to 40%, or a reduction by about 60%.

c. If dredging is performed, and a 24’ culvert is installed, and the West channel is closed the flows in Eel Pond increase from 64% to 120%, or an increase of 186%.

In addition to the above, an analysis was performed of the flow velocities that would occur in the new channel under both mean and spring tidal conditions, and how flow velocity would be affected by the closure of the west channel.
Hydrographs show that under a “dredging only” condition, that is dredging, without enlarging the culvert or closing the West Channel, the flow velocities under most conditions are quite low (well under 1.0 foot per second). This condition will make the channel prone to shoaling from fine-grained materials (silt). However, when the Culvert is enlarged, and the West channel is closed the new flow velocities range from 1.1 to 2.0 feet per second. This is enough velocity to keep the channel somewhat free of silt, however will allow the deposition of sand and gravel. As such the new channel area has a potential to become viable shellfish habitat.

This means that a phased program could be employed to accomplish long and short-term needs of Eel Pond as well as the sewer issue. If a Phase 1 program were put in place to dredge the East Channel, the flows in Eel Pond would be increased by 30%, and the flows in the West channel would be reduced by about 30%. However, Dredging only would not allow the West Channel to be closed, as this would reduce the Eel Pond flows to about 60% of the present levels, as well as present a serious storm surge issue.

A Phase 2 program could also be instituted when funding becomes available to install a new culvert under the railroad embankment. The flow calculations that were used to size the culvert indicate that the culvert should be about 24 feet wide by 8 feet high, with an invert depth of –1.7 feet MLW (-3.0 NGVD). It should be noted that while smaller culverts would function well in most rainfall storm events, a 24 foot culvert would allow for a reasonably secure closure of the West channel, and would give reasonable assurance that erosion would be contained and the West channel would remain closed in the event of a barrier beach overtopping by storm surge.

![Figure 12: Profile of closing the West Channel](image-url)
7. It should be noted that most of the discussion above is based on tidal fluctuations only; none of the data thus far has included the effects of rain. CLE also performed calculations for various storm events ranging from 1” to 7.1” (100 year). The purpose of the rainfall analysis was two-fold, (1) to calculate the estimated volume of rainfall (fresh water) that enters Eel Pond during a classic storm event. In addition, while some of the larger storm events are by definition, rare, they are useful in determining cumulative rainfall from numerous, shorter duration storms that are far more common in New England. Table 4 shows the volumes of fresh water generated by the various classic storm events:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Tide Range (ft. NGVD)</th>
<th>Rainfall (Storm)</th>
<th>Eel Pond Fresh W (cf)</th>
<th>Eel Pond Vol % Fresh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>N/A</td>
<td>Dry</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>Existing</td>
<td>N/A</td>
<td>1”</td>
<td>7,200</td>
<td>0.44%</td>
</tr>
<tr>
<td>Existing</td>
<td>N/A</td>
<td>2”</td>
<td>281,000</td>
<td>17.35%</td>
</tr>
<tr>
<td>Existing</td>
<td>N/A</td>
<td>3”</td>
<td>832,380</td>
<td>49.46%</td>
</tr>
<tr>
<td>Existing</td>
<td>N/A</td>
<td>4.5”</td>
<td>2,477,177</td>
<td>147.20%</td>
</tr>
</tbody>
</table>

Rainfall events shown in this report are as follows: 1 & 2 inch are 1 year or more frequent storms, 3” is a 2 year storm (typically used for storm drain design), and 4.5” is a 10 year storm event, which could also emulate the effects of a series of smaller storms spaced over several days. It can be seen from the table above, that a 1 inch storm by itself does not represent a significant issue, as most of the rainfall is absorbed by the environment before it reaches Eel Pond. However, larger storms, (which could also be 1” storms) could produce more significant flows if the ground is already saturated from prior storms. The baseline condition of Tub Mill Brook was also measured during a relatively dry period and was found to be 2.5 cfs, which while small, was factored into the freshwater intrusion volumes. It can be ascertained from these analyses that prolonged periods of sustained rainfall will produce significant volumes of fresh water intrusion into Eel Pond, which in turn dilutes the salinity of the pond, and takes a considerable time to flush out under the present conditions.

**CALCULATIONS FOR SIZING RAILROAD CULVERT:**

After much study of the existing culvert, the historic nature of the stone bridge and the surroundings, it was determined that the most cost effective methodology for increasing the size of the existing railroad culvert was to build an additional culvert elsewhere in the present embankment. Because any culvert is subjected to both normal and extreme conditions, its design must be planned around both; as such CLE performed a number of hydrograph studies for various sized culverts that took into account both routine and extreme events. Consideration was given to several rainfall storm events, and applied to
culvert sizes ranging from 10’ wide x 8’ high to 24’ wide x 8’ high. Culvert widths were calculated in 4 to 6-foot size increments. Storm events considered were 4.5” (10 year), 7.1” (100 year), and 100-year rainfall combined with storm surge over topping.

**Simulated Storm Surge Model Methodology:**

Unfortunately, storm surge overtopping is almost impossible to model with present day commercially available software. As such, calculations for such a condition were based on an approximation of the conditions that occurred during Hurricane Bob, wherein the storm surge reached an approximate elevation of +12.3 MLW (+11.0 NGVD). Typical storm surges in Buzzards Bay, while severe – last only a short time, normally an hour or less (see Figure 13 below). However, for purposes of modeling, once tidal inundation were to exceed the height of the barrier beach, the model’s routing conditions would change dramatically, and that flow would occur freely in and out of Eel Pond over the beach crest. To simulate the beach overtopping the West Channel “dam” was widened and held at elevation 5.5 so that an approximation of the time and flow velocity could be attained. Compensation also needed to be given for the condition of a +12.3 MLW surge and the consequential inundation of a considerable amount of land. This is because once the surge begins to recede; it would take additional time for the inundation to flow back to the bay. To allow for this factor, the model’s period of inundation was extended by one hour. Once the surge again fell to an elevation below the beach crest (assuming erosion has not been too severe) routing would return to the original modeled condition, and the program would then resume giving viable results.

Figure 13: Estimated Storm Surge curve, and adjusted model curve
Table 5, below shows the storm conditions considered in the culvert design, and the flow conditions that occur under each condition. The factor considered most important was the flow velocity through the culvert, as excessive velocity would cause scouring of the headwalls, leading to possible breach of the railroad embankment. Failure of the railroad embankment could in turn rupture the embedded sewer line, and could again create a condition not unlike a break of the sewer line at the Western Channel. The design criteria for the culvert was based on maintaining the present day flow velocities for all rainfall events, and containing the extreme condition of a storm surge overtopping to a culvert velocity of between 5 and 7.5 feet per second for the shortest a time as possible.2

<table>
<thead>
<tr>
<th>Size New Culvert for Closing West Channel</th>
<th>Harbor Max Tide El. NGVD</th>
<th>Eel Pond Max Tide El. NGVD</th>
<th>Eel Pond Max Flow (Peak cfs)</th>
<th>RR Culv Max Flow (Peak cfs)</th>
<th>RR Culv Flow Area (s. ft.)</th>
<th>RR Culv Flow Vel (fps)</th>
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<tr>
<td><strong>Spring Tide</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Existing</td>
<td>No Rain</td>
<td>4.00</td>
<td>3.51</td>
<td>220.00</td>
<td>50.00</td>
<td>17.55</td>
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<td></td>
<td>2 yr Storm</td>
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<td>3.61</td>
<td>244.00</td>
<td>57.00</td>
<td>18.05</td>
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<td></td>
<td>10 yr Storm</td>
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<td>3.91</td>
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<td>61.00</td>
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<td></td>
<td>100 yr Storm</td>
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<td>4.40</td>
<td>420.00</td>
<td>90.00</td>
<td>22.00</td>
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</tr>
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<td>Dredge - Add 10' x 8' Culvert (inv. -3.0 NGVD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>No Rain</td>
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<td>3.53</td>
<td>300.00</td>
<td>300.00</td>
<td>65.30</td>
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<tr>
<td></td>
<td>10 yr Storm</td>
<td>4.00</td>
<td>3.94</td>
<td>354.00</td>
<td>354.00</td>
<td>69.40</td>
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<tr>
<td></td>
<td>100 yr Storm</td>
<td>4.00</td>
<td>4.43</td>
<td>428.00</td>
<td>428.00</td>
<td>74.30</td>
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</tr>
<tr>
<td>Dredge - Add 16' x 8' Culvert (inv. -3.0 NGVD)</td>
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<tr>
<td></td>
<td>No Rain</td>
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<td>3.67</td>
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<td>4.01</td>
<td>461.00</td>
<td>461.00</td>
<td>112.16</td>
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<td>100 yr Storm</td>
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<td>4.43</td>
<td>560.00</td>
<td>560.00</td>
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</tr>
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<td>Dredge - Add 22' x 8' Culvert (inv. -3.0 NGVD)</td>
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<tr>
<td></td>
<td>No Rain</td>
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<td>3.72</td>
<td>453.00</td>
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<td>176.00</td>
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<td></td>
<td>Storm Surge Out</td>
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<td>5.00</td>
<td>1300.00</td>
<td>1300.00</td>
<td>176.00</td>
</tr>
<tr>
<td><strong>Spring Tide</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dredge - Add 26' x 8' Culvert (inv. -3.0 NGVD)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>No Rain</td>
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<td>175.50</td>
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<td>4.03</td>
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<td>208.00</td>
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<td></td>
<td>Storm Surge Out</td>
<td>7.00</td>
<td>5.00</td>
<td>1450.00</td>
<td>1450.00</td>
<td>208.00</td>
</tr>
</tbody>
</table>

Table 5: New Culvert flow calculation summary

2 The model used a 26-foot size culvert to account for the proposed 24-foot culvert in addition to the cross-sectional area of the existing culvert.
Table 5 is summarized in Figure 14, which provides an overview of the flow velocity conditions that would occur through a new culvert for a number of storm events with the West Channel blocked. The existing conditions are also provided for comparison.

![Figure 14: Summary of flow velocity conditions for several culvert sizes](image)

Normal peak flow velocities through the existing railroad culvert with the West Channel open, range from between 2.8 and 3.2 feet per second, occasionally the flow could exceed 4.0 feet per second. This seems to have been a stable condition at the existing culvert for many years. Even so there is still evidence of scour at the openings, which leads one to the opinion that it is not prudent to change the culvert condition to exceed these flow values. It can be noted from the chart and the preceding analysis that dredging and closing the West Channel would require the enlargement of the existing railroad culvert. A number of hydrographs were computed using culverts that ranged in size from 10’(W) by 8’ (H), to 26’ (W) by 8’ (H); each culvert was also checked for performance during a classic 10 and 100-year storm rainfall event. The tidal elevation and hydrograph charts are included as Exhibits 30 to 57. It can be ascertained by viewing these charts that a 10’ x 8’ culvert is too small for most rainfall storm events, as flow velocities and durations would increase considerably, also a 16’ x 8’ culvert shows only a slight increase. Under all rainfall “only” conditions the 20’ x 8’ and the 24’ x 8’ culverts showed reduced flow velocities, and considerably improved flushing of Eel Pond.
The deciding and most unpredictable condition of storm surge however rules out the 20’ x 8’ culvert, as flow velocities during a storm surge event could exceed 8 feet per second. To further demonstrate the severity of high flow velocities Figure 15 shows the water elevation difference from one side of a 26 foot culvert to the other, as well as the water level difference from the first small pond to the second. (The model used a 26-foot size culvert to account for the proposed 24-foot culvert in addition to the cross-sectional area of the existing culvert).

![Figure 15: Water elevation difference Eel Pond to Pond 1 & Pond 1 to Pond 2, based on 26’ culvert, 100 year rain event and storm surge](image)

During the peak incoming surge the water elevation from one side of the culvert to the other will exceed one foot for a short time (this is not considered serious), however during the outflow of the storm surge the flows would reach such velocity that the water elevation from one side of the culvert to the other would exceed one foot for over 2 hours, and would exceed 18” for about 30 minutes. This is sufficient time for serious erosion to occur, thus it clearly indicates that the wing walls and invert of the culvert would need to be heavily armored. The lower line on the chart also shows considerable elevation difference between Pond 1 and Pond 2, indicating considerable flow velocities occurring in the channel between the two water bodies. This clearly indicates that the size of the planned dredged channel of 30’ base width and –2.7 MLW (–4.0 NGVD), is also a minimal channel design, since a smaller channel would only cause more flow restriction during a storm surge event, and thus more potential for erosion damage.
Also of concern is the erosion that would take place at the barrier beach and blocked West Channel as the overtopping occurred. Figure 16, which shows the water elevations in Eel Pond versus the Harbor elevations as the storm surge approaches. Note that at the point of overtopping, the water level in Eel Pond is about 2.5 feet lower than the Harbor. This condition while it will start as a trickle, will quickly increase in size, volume and velocity until the water level in Eel Pond matches that of the storm surge elevation. This will cause a condition that will quickly cause erosion to the West Channel plug and the beach crest, how much erosion takes place will depend on the amount of time that the water levels remain different between Eel Pond and the surge elevation. Historically, however the more severe erosion takes place as the surge recedes, as the erosion from the incoming surge usually creates gullies that become focus point of residual outflows. Again, the severity of erosion is proportional to the time that the water elevations remain different. A larger railroad culvert will reduce the time required for both transitions to take place, and thus will reduce the severity of the erosion.

The conclusion of the culvert design study is that the minimum culvert size to be considered would be a 24’ x 8’ culvert, and that the culvert wings and inverts should be protected from scour. The rational for a conservative design is substantiated by the need to protect the sewer main that is buried within the embankment during a storm surge event.
COST ESTIMATES

CLE prepared the following preliminary cost estimate for the culvert replacement, dredging of the East Channel and closure of the West Channel. This estimate is preliminary and subject to change as the final design is completed. No allowances have been made for alternate disposal sites for the dredge material as it is assumed that it will be used in the closure of the West Channel.

Town of Mattapoisett
Eel Pond – Improvements Preliminary Cost Estimate

Culvert Work
Mobilization/Demobilization $15,000
Temporary shoring $40,000
Excavation $25,000
Fill $25,000
Utility supports $50,000
Precast Structure $50,000
Placement $30,000
Subtotal: $235,000
OH/profit $47,000
Subtotal: $282,000

Dredging of East Channel
Mobilization/Demobilization $75,000
Dredging (9,700 cy @ $12/cy) $116,400
Beach nourishment/grading $50,000
Backhoe work $15,000
Subtotal: $256,400

Closure of West Channel
Placement and grading: $10,000
Subtotal: $10,000

Estimated Total Project Cost: $548,400
IDENTIFICATION OF PERMITS REQUIRED

CLE has identified the following required permit applications for the proposed project based on the following project components:

- East Channel Dredging = approximately 9,700 cy
- Beach Nourishment = 132,025 sf
- Fill in West Channel & Beach Nourishment = approximately 9,700 cy
- New Culvert

Due to the uniqueness of this site and restoration benefits of the proposed project, the application and supporting documentation would describe the project as a proactive restoration project. The permits identified below are based on the agencies’ review of the project as such a project.

**Local:**

- Notice of Intent filing to the Mattapoisett Conservation Commission and Department of Environmental Protection Southeast Regional Office

**State:**

- Environmental Notification Form to the Massachusetts Executive Office of Environmental Affairs
- Water Quality Certificate Application for Major Project Certification BRP WW 08 based on a dredge volume greater than 5,000 cy
- Division of Waterways Chapter 91 Permit BRP WW 01 application
- Division of Waterways Chapter 91 License BRP WW 01 application for licensing any proposed new structures located below mean high water (new culvert).
- Consistency Statement submitted to the Massachusetts Office of Coastal Zone Management

**Federal:**

- U.S. Army Corps of Engineers Programmatic General Permit Category II. Application includes submittal to the Massachusetts Historical Commission, the Narragansett Tribal Historic Preservation Officer and the Wampanoag Tribal Historic Preservation Officer
Eel Pond
Mean Tide, Dry Event, Existing Conditions

Min. Elev. Harbor = -1.05 ft @ 11.0 hrs

Max. Elev. Harbor = 2.85 ft @ 16.50 hrs

Max. Elev. Pond = 2.47 ft @ 17.9 hrs

Min. Elev. Pond = 0.96 ft @ 14.14 hrs
Eel Pond
Mean Tide, Dry Event, Existing Conditions

Eel Pond Max. Flow In: 171.66 cfs @ 16.35 hrs
Eel Pond Max. Flow Out: 95.03 cfs @ 19.90 hrs
West Channel Max. Flow In: 136.85 cfs @ 16.35 hrs
West Channel Max. Flow Out: 80.64 cfs @ 18.75 hrs
East Channel Max. Flow Out: 18.63 cfs @ 19.80 hrs
East Channel Max. Flow In: 37.75 cfs @ 15.75 hrs

Time (24 hour period)

Exhibit 2
Eel Pond
Mean Tide, 2-Year Storm Event, Existing Conditions

Max. Elev. Pond = 2.63 ft @ 17.85 hrs
Max. Elev. Harbor = 2.85 ft @ 16.5 hrs
Min. Elev. Pond = 1.04 ft @ 11.8 hrs
Min. Elev. Harbor = -1.05 ft @ 11.0 hrs
Eel Pond
Mean Tide, 2-Year Storm Event, Existing Conditions

Eel Pond Max. Flow In: 128.48 cfs @ 16.55 hrs
Max. Flow In from Upland Sources: 87.16 cfs @ 12.55 hrs
Eel Pond Max. Flow Out: 110.63 cfs @ 18.80 hrs
Eel Pond
Mean Tide, 2-Year Storm Event, Existing Conditions

Eel Pond Max. Flow Out: 110.63 cfs @ 18.80 hours

West Channel Max. Flow Out: 96.33 cfs @ 18.75 hours

East Channel Max. Flow Out: 19.24 cfs @ 19.80 hours

East Channel Max. Flow In: 26.76 cfs @ 16.15 hours

West Channel Max. Flow In: 104.86 cfs @ 16.55 hours

Eel Pond Max. Flow In: 128.48 cfs @ 16.55

Time (24 hour period)
Eel Pond
Mean Tide, 10-Year Storm Event, Existing Conditions

Max. Elev. Harbor = 2.85 ft @ 16.5 hrs
Max. Elev. Pond = 2.78 ft @ 17.75 hrs
Min. Elev. Harbor = -1.05 ft @ 11.0 hrs
Min. Elev. Pond = 1.08 ft @ 2.0 hrs
Eel Pond
Mean Tide, 10-Year Storm Event, Existing Conditions

Max. Flow In from Upland Sources: 332.10 cfs @ 12.35

Eel Pond Max. Flow Out: 127.41 cfs @ 18.85 hrs

Eel Pond Max. Flow In: 96.67 cfs @ 16.35 hrs

Exhibit 7
Eel Pond
Mean Tide, 10-Year Storm Event, Existing Conditions

- Eel Pond Max. Flow Out: 127.41 cfs @ 18.85 hrs
- West Channel Max. Flow Out: 107.75 cfs @ 18.75 hrs
- East Channel Max. Flow Out: 23.03 cfs @ 19.75 hrs
- East Channel Max. Flow In: 34.06 cfs @ 12.55 hrs
- West Channel Max. Flow In: 79.90 cfs @ 16.35 hrs
- Eel Pond Max. Flow In: 96.67 cfs @ 16.35 hrs

Exhibit 8
Eel Pond
Mean Tide, 100-Year Storm Event, Existing Conditions

Max. Elev. Pond = 3.18 ft @ 13.25 hrs
Min. Elev. Pond = 1.08 ft @ 2.0 hrs
Min. Elev. Harbor = -1.05 ft @ 11.0 hrs
Max. Elev. Harbor = 2.85 ft @ 16.5 hrs
Eel Pond
Mean Tide, 100-Year Storm Event, Existing Conditions

Max. Flow In from Upland Sources: 800.98 cfs @ 12.35 hrs

Eel Pond Max. Flow Out: 241.83 cfs @ 13.45 hrs

Eel Pond Max. Flow In: 50.09 cfs @ 4.15 hrs

Exhibit 10
Eel Pond
Mean Tide, 100-Year Storm Event, Existing Conditions

Eel Pond Max. Flow Out: 241.83 cfs @ 13.45 hrs

West Channel Max. Flow Out: 196.65 cfs @ 13.25 hrs

East Channel Max. Flow Out: 48.89 cfs @ 13.85 hrs

West Channel Max. Flow In: 43.82 cfs @ 4.05 hrs

Eel Pond Max. Flow In: 50.09 cfs @ 4.15 hrs

East Channel Max. Flow In: 68.08 cfs @ 12.40 hrs

Exhibit 11
Eel Pond
Spring Tide, Dry Event, Existing Conditions

Max. Elev. Harbor = 4.0 ft @ 12.0 hrs
Max. Elev. Pond = 3.51 ft @ 12.75 hrs
Min. Elev. Pond = 0.88 ft @ 8.75 hrs
Min. Elev. Harbor = -1.74 ft @ 4.5 hrs

Time (24 hour period)
## Eel Pond
**Spring Tide, Dry Event, Existing Conditions**

<table>
<thead>
<tr>
<th>Time (24 hour period)</th>
<th>Flow (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Channel Max. Flow In: 260.73 @ 11.60 hrs</td>
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<tr>
<td>East Channel Max. Flow In: 76.38 @ 11.25 hrs</td>
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<td>Eel Pond Max. Flow In: 332.24 @ 11.60 hrs</td>
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<tr>
<td>West Channel Max. Flow Out: 179.23 @ 14.05 hrs</td>
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<td>East Channel Max. Flow Out: 51.44 @ 14.40 hrs</td>
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<tr>
<td>Eel Pond Max. Flow Out: 220.88 @ 14.45 hrs</td>
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</tbody>
</table>

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![Graph showing flow changes over time for Eel Pond, East Channel, and West Channel.](image-url)
Eel Pond
Spring Tide, 2-Year Storm Event, Existing Conditions

Max. Elev. Harbor = 4.0 ft @ 12.0 hrs
Max. Elev. Pond = 3.62 ft @ 12.85 hrs
Min. Elev. Harbor = -1.74 ft @ 4.5 hrs
Min. Elev. Pond = 0.88 ft @ 8.75 hrs

Exhibit 14
Eel Pond
Spring Tide, 2-Year Storm Event, Existing Conditions

Eel Pond Max. Flow Out: 244.66 cfs @ 14.55 hrs
West Channel Max. Flow Out: 204.01 cfs @ 14.05 hrs
East Channel Max. Flow Out: 57.22 cfs @ 14.55 hrs
East Channel Max. Flow In: 76.37 cfs @ 11.25 hrs
West Channel Max. Flow In: 260.68 cfs @ 11.60 hrs
Eel Pond Max. Flow In: 332.17 cfs @ 11.60 hrs

Exhibit 15
Eel Pond
Spring Tide, 10-Year Storm Event, Existing Conditions

Max. Elev. Harbor = 4.0 ft @ 12.0 hrs
Max. Elev. Pond = 3.92 ft @ 12.90 hrs
Min. Elev. Pond = 0.88 ft @ 8.75 hrs
Min. Elev. Harbor = -1.74 ft @ 4.5 hrs

Exhibit 16
Eel Pond
Spring Tide, 10-Year Storm Event, Existing Conditions

Eel Pond Max. Flow Out: 306.64 cfs @ 14.15 hrs
West Channel Max. Flow Out: 251.03 cfs @ 14.45 hrs
East Channel Max. Flow Out: 60.99 cfs @ 14.80 hrs
West Channel Max. Flow In: 258.68 cfs @ 11.60 hrs
East Channel Max. Flow In: 75.93 cfs @ 11.20 hrs
Eel Pond Max. Flow In: 329.36 cfs @ 11.60 hrs

Time (24 hour period)
Flow (cfs)
Eel Pond
Mean Tide, Dry Event, Dredging Only with West Channel Open

Max Elev. Harbor = 2.85 ft @ 16.5hrs
Max. Elev. Pond = 2.52 ft @ 17.85 hrs
Min. Elev. Pond = 0.60 ft @ 13.90 hrs
Min. Elev. Harbor = -1.05 ft @ 11.0 hrs

Elev. (ft) - NGVD Datum

Time (24 hour period)

Exhibit 18
Eel Pond

Mean Tide, Dry Event, Dredging Only with West Channel Open

<table>
<thead>
<tr>
<th>Time (24 hour period)</th>
<th>Flow (cfs)</th>
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<td>West Channel Max. Flow In: 136.93 cfs @ 16.35 hrs</td>
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<td>East Channel Max. Flow In: 54.27 cfs @ 16.40 hrs</td>
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<td>Eel Pond Max. Flow Out: 113.11 cfs @ 18.90 hrs</td>
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<td>West Channel Max. Flow Out: 82.46 cfs @ 18.75 hrs</td>
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<tr>
<td>East Channel Max. Flow Out: 40.52 cfs @ 19.55 hrs</td>
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</tbody>
</table>
Eel Pond Mean Tide, Dry Event, Dredging Only with West Channel Closed

Max. Elev. Harbor = 2.85 ft @ 16.5 hrs

Max. Elev. Pond = 1.75 ft @ 19.10 hrs

Min. Elev. Harbor = -1.05 ft @ 11.0 hrs

Min. Elev. Pond = 0.70 ft @ 14.05 hrs
Eel Pond
Mean Tide, Dry Event, Dredging Only with West Channel Closed

Eel Pond Max. Flow Out: 31.52 cfs @ 20.05 hrs

Eel Pond Max. Flow In: 57.33 cfs @ 16.65 hrs

Time (24 hour period)
Eel Pond
Mean Tide, 2-Year Storm Event, Dredging Only with West Channel Open

Max. Elev. Pond = 2.65 ft @ 17.80 hrs
Max. Elev. Harbor = 2.85 ft @ 16.50 hrs
Min. Elev. Pond = 0.72 ft @ 11.80 hrs
Min. Elev. Harbor = -1.05 ft @ 11.0 hrs
Eel Pond
Mean Tide, 2-Year Storm Event, Dredging Only with West Channel Open

Exhibit 23
Eel Pond
Mean Tide, 2-Year Storm Event, Dredging Only with West Channel Closed

Min. Elev. Harbor = -1.05 ft @ 11.0 hrs

Max. Elev. Harbor = 2.85 ft @ 16.5 hrs

Max. Elev. Pond = 2.21 ft @ 18.65 hrs

Min. Elev. Pond = 0.88 ft @ 11.85 hrs

Elev. (ft) - NGVD Datum

Time (24 hour event)

Exhibit 24
Eel Pond
Mean Tide, 2-Year Storm Event, Dredging Only with West Channel Closed

Eel Pond Max. Flow In: 55.86 cfs @ 16.65 hrs

Eel Pond Max. Flow Out: 44.34 cfs @ 20.10 hrs
Eel Pond
MeanTide, 10-Year Storm Event, Dredging Only with West Channel Open

Min. Elev. Harbor = -1.05 ft @ 11.0 hrs
Min. Elev. Pond = 0.80 ft @ 11.30 hrs
Max. Elev. Harbor = 2.85 ft @ 16.5 hrs
Max. Elev. Pond = 2.77 ft @ 17.65 hrs

Elev. (ft) - NGVD Datum

Time (24 hour period)

Exhibit 26
Eel Pond
Mean Tide, 10-Year Storm Event, Dredging Only with West Channel Open

Eel Pond Max. Flow Out: 148.60 cfs @ 18.95 hrs
West Channel Max. Flow Out: 102.95 cfs @ 18.75 hrs
East Channel Max. Flow Out: 49.42 cfs @ 18.95 hrs

East Channel Max. Flow In: 35.69 cfs @ 16.45 hrs
West Channel Max. Flow In: 86.51 cfs @ 16.45 hrs
Eel Pond Max. Flow In: 122.20 cfs @ 16.45 hrs

Exhibit 27
Eel Pond
Mean Tide, 100-Year Storm Event, Dredging Only with West Channel Open

Max. Elev. Pond = 2.90 ft @ 17.3 hrs
Max. Elev. Harbor = 2.85 ft @ 16.5 hrs
Min. Elev. Pond = 0.93 ft @ 10.55 hrs
Min. Elev. Harbor = -1.05 ft @ 11.0 hrs

Exhibit 28
Eel Pond
Mean Tide, 100-Year Storm Event, Dredging Only with West Channel Open

- West Channel Max. Flow In: 43.47 cfs @ 4.05 hrs
- West Channel Max. Flow Out: 170.90 cfs @ 13.20 hrs
- East Channel Max. Flow Out: 71.89 cfs @ 13.20 hrs
- East Channel Max. Flow In: 27.26 cfs @ 4.15 hrs
- Eel Pond Max. Flow Out: 242.79 cfs @ 13.20 hrs
- Eel Pond Max. Flow In: 70.55 cfs @ 4.15 hrs

Time (24 hour period)
Eel Pond
Mean Tide, Dry Event, Dredging with West Channel Closed & 22 ft. Wide Culvert

Max. Elev. Harbor = 2.85 ft @ 16.5 hrs
Max. Elev. Pond = 2.72 ft @ 17.45 hrs
Min. Elev. Harbor = -1.05 ft @ 11.0 hrs
Min. Elev. Pond = -1.05 ft @ 11.15 hrs

Elev. (ft) - NGVD Datum
Time (24 hour period)

Exhibit 30
Eel Pond
Mean Tide, Dry Event, Dredging with West Channel Closed & 22 ft. Wide Culvert

Eel Pond Max. Flow Out: 192.95 cfs @ 19.40 hrs

Eel Pond Max. Flow In: 247.49 cfs @ 15.25 hrs

Exhibit 31
Eel Pond
Mean Tide, 2-Year Storm Event, Dredging with West Channel Closed & 22 ft. Wide Culvert

Min. Elev. Harbor = -1.05 ft @ 11.0 hrs
Max. Elev. Harbor = 2.85 ft @ 16.5 hrs
Max. Elev. Pond = 2.75 ft @ 17.6 hrs
Min. Elev. Pond = -1.05 ft @ 11.15 hrs
Eel Pond
Mean Tide, 2-Year Storm Event, Dredging with West Channel Closed & 22 ft. Wide Culvert

Eel Pond Max. Flow Out: 206.75 cfs @ 19.45 hrs

Eel Pond Max. Flow In: 220.78 cfs @ 15.25 hrs
Eel Pond
Spring Tide, Dry Event, Dredging with West Channel Closed & 10 ft. Wide Culvert

Min. Elev. Harbor = -1.74 ft @ 4.5 hrs
Min. Elev. Pond = -1.72 ft @ 5.45 hrs
Max. Elev. Harbor = 4.0 ft @ 12.0 hrs
Max. Elev. Pond = 3.53 ft @ 12.95 hrs
Eel Pond

Spring Tide, Dry Event, Dredging with West Channel Closed & 10 ft. Wide Culvert

Eel Pond Max. Flow In: 304.53 cfs @ 11.40 hrs

Eel Pond Max. Flow Out: 300.67 cfs @ 14.60 hrs

Exhibit 35
Eel Pond
Spring Tide, Dry Event, Dredging with West Channel Closed & 16 ft. Wide Culvert

Max. Elev. Harbor = 4.0 ft @ 12.0 hrs
Max. Elev. Pond = 3.67 ft @ 12.75 hrs
Min. Elev. Harbor = -1.74 ft @ 4.5 hrs
Min. Elev. Pond = -1.72 ft @ 5.40 hrs

Elev. (ft) - NGVD Datum

Time (24 hour period)

Exhibit 36
Eel Pond
Spring Tide, Dry Event, Dredging with West Channel Closed & 16 ft. Wide Culvert

Eel Pond Max. Flow In: 364.54 cfs @ 10.70 hrs
Eel Pond Max. Flow Out: 377.37 cfs @ 15.05 hrs

Exhibit 37
Eel Pond
Spring Tide, Dry Event, Dredging with West Channel Closed & 22 ft. Wide Culvert

Min. Elev. Harbor = -1.74 ft @ 4.5 hrs
Min. Elev. Pond = -1.73 ft @ 5.65 hrs
Max. Elev. Harbor = 4.0 ft @ 12.0 hrs
Max. Elev. Pond = 3.72 ft @ 12.65 hrs

Exhibit 38
Eel Pond
Spring Tide, Dry Event, Dredging with West Channel Closed & 22 ft. Wide Culvert

Eel Pond Max. Flow Out: 453.39 cfs @ 14.60 hrs
Eel Pond Max. Flow In: 392.66 cfs @ 10.55 hrs
Eel Pond
Spring Tide, Dry Event, Dredging with West Channel Closed & 26 ft. Wide Culvert

Max. Elev. Harbor = 4.0 ft @ 12.0 hrs
Max. Elev. Pond = 3.74 ft @ 12.60 hrs
Min. Elev. Pond = -1.72 ft @ 5.40 hrs
Min. Elev. Harbor = -1.74 ft @ 4.50 hrs

Elev. (ft) - NGVD Datum

Time (24 hour period)

Exhibit 40
Eel Pond
Spring Tide, Dry Event, Dredging with West Channel Closed & 26 ft. Wide Culvert

Eel Pond Max. Flow In: 494.92 cfs @ 10.60 hrs
Eel Pond Max. Flow Out: 427.37 cfs @ 14.65 hrs

Exhibit 41
Eel Pond
Spring Tide, 10-Year Storm Event, Dredging with West Channel Closed & 10 ft. Wide Culvert

Max. Elev. Harbor = 4.0 ft @ 12.0 hrs
Max. Elev. Pond = 3.94 ft @ 13.0 hrs
Min. Elev. Pond = -1.72 ft @ 5.45 hrs
Min. Elev. Harbor = -1.74 ft @ 4.50 hrs

Exhibit 42
Eel Pond
Spring Tide, 10-Year Storm Event, Dredging with West Channel Closed & 10 ft. Wide Culvert

Eel Pond Max. Flow In: 302.85 cfs @ 11.40 hrs

Eel Pond Max. Flow Out: 354.69 cfs @ 14.65 hrs
Eel Pond
Spring Tide, 10-Year Storm Event, Dredging with West Channel Closed & 16 ft. Wide Culvert

Max. Elev. Harbor = 4.0 ft @ 12.0 hrs
Max. Elev. Pond = 4.02 ft @ 12.85 hrs
Min. Elev. Pond = -1.72 ft @ 5.40 hrs
Min. Elev. Harbor = -1.74 ft @ 4.5 hrs

Exhibit 44
Town of Mattapoisett
CLE #04054.100

Eel Pond
Spring Tide, 10-Year Storm Event, Dredging with West Channel Closed & 16 ft.Wide Culvert

Eel Pond Max. Flow In: 363.67 cfs @ 10.70 hrs
Eel Pond Max. Flow Out: 460.90 cfs @ 14.70 hrs

Exhibit 45
Eel Pond
Spring Tide, 10-Year Storm Event, Dredging with West Channel Closed & 22 ft. Wide Culvert

Max. Elev. Harbor = 4.0 ft @ 12.0 hrs
Max. Elev. Pond = 4.03 ft @ 12.75 hrs
Min. Elev. Harbor = -1.74 ft @ 4.50 hrs
Min. Elev. Pond = -1.73 ft @ 5.65 hrs

Exhibit 46
Eel Pond
Spring Tide, 10-Year Storm Event, Dredging with West Channel Closed & 22 ft. Wide Culvert

Eel Pond Max. Flow In: 423.96 cfs @ 10.60 hrs
Eel Pond Max. Flow Out: 561.17 cfs @ 14.75 hrs
Eel Pond
Spring Tide, 10-Year Storm Event, Dredging with West Channel Closed & 26 ft. Wide Culvert

Max. Elev. Harbor = 4.0 ft @ 12.0 hrs
Min. Elev. Harbor = -1.74 ft @ 4.5 hrs
Max. Elev. Pond = 4.04 ft @ 12.75 hrs
Min. Elev. Pond = -1.72 ft @ 5.4 hrs

Elev. (ft) - NGVD Datum

Time (24 hour period)

Exhibit 48
Eel Pond
Spring Tide, 10-Year Storm Event, Dredging with West Channel Closed & 26 ft. Wide Culvert

Eel Pond Max. Flow In: 432.13 cfs @ 10.60 hrs

Eel Pond Max. Flow Out: 531.11 cfs @ 14.70 hrs
Eel Pond
Spring Tide, 100-Year Storm Event, Dredging with West Channel Closed & 10 ft. Wide Culvert

Max. Elev. Harbor = 4.0 ft @ 12.0 hrs
Max. Elev. Pond = 4.44 ft @ 13.0 hrs
Min. Elev. Harbor = -1.74 ft @ 4.5 hrs
Min. Elev. Pond = -1.72 ft @ 5.45 hrs

Exhibit 50
Eel Pond
Spring Tide, 100-Year Storm Event, Dredging with West Channel Closed & 10 ft. Wide Culvert

Eel Pond Max. Flow In: 298.38 cfs @ 11.35

Eel Pond Max. Flow Out: 428.83 cfs @ 13.95
Eel Pond
Spring Tide, 100-Year Storm Event, Dredging with West Channel Closed & 16 ft. Wide Culvert

Exhibit 52
Eel Pond
Spring Tide, 100-Year Storm Event, Dredging with West Channel Closed & 16ft. Wide Culvert

Eel Pond Max. Flow In: 338.92 cfs @ 11.15 hrs

Eel Pond Max. Flow Out: 559.68 cfs @ 14.8 hrs
Eel Pond
Spring Tide, 100-Year Storm Event, Dredging with West Channel Closed & 22 ft. Wide Culvert

Max. Elev. Harbor = 4.0 ft @ 12.0 hrs
Max. Elev. Pond = 4.42 ft @ 12.80 hrs
Min. Elev. Pond = -1.73 ft @ 5.65 hrs
Min. Elev. Harbor = -1.74 ft @ 4.5 hrs

Exhibit 54
Eel Pond
Spring Tide, 100-Year Storm Event, Dredging with West Channel Closed & 22 ft. Wide Culvert

Eel Pond Max. Flow In: 419.878 cfs @ 10.60 hrs
Eel Pond Max. Flow Out: 635.72 cfs @ 14.10 hrs
Eel Pond

Spring Tide, 100-Year Storm Event, Dredging with West Channel Closed & 26 ft. Wide Culvert

Max. Elev. Harbor = 4.0 ft @ 12.0 hrs
Max. Elev. Pond = 4.41 ft @ 12.75 hrs

Min. Elev. Harbor = -1.74 ft @ 4.5 hrs
Min. Elev. Pond = -1.72 ft @ 5.4 hrs

Exhibit 56
Eel Pond
Spring Tide, 100-Year Storm Event, Dredging with West Channel Closed & 26 ft. Wide Culvert

Eel Pond Max. Flow Out: 688.35 cfs @ 14.10 hrs

Exhibit 57
Eel Pond
Culvert Size Summary of Spring Tide, Dry Event

Exhibit 58
Eel Pond
Culvert Size Summary of Spring Tide, 10-Year Storm Event

<table>
<thead>
<tr>
<th>Time (24 hour period)</th>
<th>Elev. (ft) - NGVD Datum</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Existing Conditions</td>
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<tr>
<td></td>
<td>Dredging w/ 10' Wide Culvert</td>
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<td>Dredging w/ 16' Wide Culvert</td>
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<td>Dredging w/ 22' Wide Culvert</td>
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<td></td>
<td>Dredging w/ 26' Wide Culvert</td>
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</table>

Exhibit 59
Eel Pond
Culvert Size Summary of Spring Tide, 100-Year Storm Event

![Graph showing time (24 hour period) vs. elevation (ft) - NGVD Datum for different culvert sizes.]

Legend:
- Existing Conditions
- Dredging w/ 10' Wide Culvert
- Dredging w/ 16' Wide Culvert
- Dredging w/ 22' Wide Culvert
- Dredging w/ 26' Wide Culvert

Exhibit 60
Eel Pond
Culvert Size Summary of Spring Tide, Dry Event

Flow (cfs) vs. Time (24 hour period)

- Dredging w/ 10' Wide Culvert
- Dredging w/ 16' Wide Culvert
- Dredging w/ 22' Wide Culvert
- Dredging w/ 26' Wide Culvert

Exhibit 61
Eel Pond
Culvert Size Summary of Spring Tide, 10-Year Storm Event

- Dredging w/ 10’ Wide Culvert
- Dredging w/ 16’ Wide Culvert
- Dredging w/ 22’ Wide Culvert
- Dredging w/ 26’ Wide Culvert

Exhibit 62
Eel Pond
Culvert Size Summary of Spring Tide, 100-Year Storm Event

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<thead>
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<th>Flow (cfs)</th>
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Legend:
- Dredging w/ 10' Wide Culvert
- Dredging w/ 16' Wide Culvert
- Dredging w/ 22' Wide Culvert
- Dredging w/ 26' Wide Culvert

Exhibit 63
Eel Pond
Condition Summary

Max Flow Vel (fps)

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Exhibit 64
June 16, 2005

Mr. Bill Nicholson
Water Department
Town of Mattapoisett
Mattapoisett, MA 02739

Re: GPR Location Survey of Forced Main from STA 17+90 to STA 24+00

Mr. Nicholson:

On May 23, 2005 we began a ground penetrating radar study of the immediate area on both sides of the Eel Pond channel. The purpose of this study was to determine the channel crossing location and depth of an existing 12” AC forced sewer main.

The GPR data was collected using a 400Mhz antenna that seemed to offer the best resolution for sand-based soils. Upon review of the data it was determined that the pipe location could be imaged along the abandoned railroad bed (West side of channel) but a lower frequency antenna would be needed to penetrate the salinity of the sand and sediment based soils in the immediate area of the channel.

A second attempt to locate the line was conducted on Tuesday, May 31, 2005 using a 200Mhz GPR system. The pipe and subsurface trench was located and staked.

Pipe station location and the measured depth:

| STA 17+90  | 5' 4" | STA 21+30  | 3' 10" |
| STA 19+20  | 5' 6" | STA 21+80  | 4' 8"  |
| STA 19+00  | 5' 1" | STA 22+20  | 4' 9"  |
| STA 20+60  | 4' 11"| STA 22+80  | 5' 1"  |

The measured pipe depth from STA 22+80 to the shutoff valve located in the (YMCA) road was consistent at 5’ 1" to 5’ 2”.

Attached are several GPR and site images for your files.

Please contact me if you have any question on this information.

Thank you.

Russ Kempton
New England Geophysical

P.O. Box 440
Mendon MA 01756
Pipe adjacent to peat deposit
Westerly side of channel
PIPE LOCATION AT ARROW
NOTE:
A temporary construction easement extends 13 feet on each side of the permanent easement shown.

FORCE MAIN
STA. 12+00 TO STA. 24+00

WATER POLLUTION CONTROL PROGRAM
BOARD OF SELECTMEN
TOWN OF MATTAPoissett, MASS.

TIGHE & BOND, CONSULTING ENGINEERS
HOLYOKE, MASS.

SCALE: HORIZ. 1"=40' VERT. 1"=4'
DATE: APRIL 1977
Geotechnical Test Report

Eel Pond Project
East Channel

Prepared for:

CLE Engineering, Inc.
Particle Size Analysis - ASTM D 422

<table>
<thead>
<tr>
<th>Sieve Name</th>
<th>Sieve Size, mm</th>
<th>Percent Finer</th>
<th>Spec. Percent</th>
<th>Complies</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 inch</td>
<td>50.80</td>
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<td>100</td>
<td></td>
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<tr>
<td>1.5 inch</td>
<td>38.10</td>
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<td>25.30</td>
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</tr>
<tr>
<td>3/4 inch</td>
<td>19.00</td>
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<td>3/8 inch</td>
<td>12.70</td>
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</tr>
<tr>
<td>#4</td>
<td>9.51</td>
<td>51</td>
<td></td>
<td></td>
</tr>
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<td></td>
</tr>
<tr>
<td>#60</td>
<td>0.25</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#100</td>
<td>0.15</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#200</td>
<td>0.074</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Coefficients**
- $D_{95}=29.7132$ mm
- $D_{90}=2.2155$ mm
- $D_{60}=14.1587$ mm
- $D_{50}=9.0765$ mm
- $D_{10}=0.6383$ mm
- $C_{u}=22.182$
- $C_{c}=0.543$

**Classification**
- ASTM: Poorly graded gravel with sand (GP)
- AASHTO: Stone Fragments, Gravel and Sand (A-1-a (O))

**Sample/Test Description**
- Sand/Gravel Particle Shape: ROUNDED
- Sand/Gravel Hardness: HARD
Particle Size Analysis - ASTM D 422

<table>
<thead>
<tr>
<th>Sieve Name</th>
<th>Sieve Size, mm</th>
<th>Percent Finer</th>
<th>Spec. Percent</th>
<th>Complies</th>
</tr>
</thead>
<tbody>
<tr>
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<td>50.80</td>
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<td></td>
</tr>
<tr>
<td>1.5 inch</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>3/4 inch</td>
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<td>69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/2 inch</td>
<td>12.70</td>
<td>62</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/8 inch</td>
<td>9.51</td>
<td>55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#4</td>
<td>4.75</td>
<td>49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#10</td>
<td>2.00</td>
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</tr>
<tr>
<td>#20</td>
<td>0.84</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#40</td>
<td>0.42</td>
<td>23</td>
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<td></td>
</tr>
<tr>
<td>#60</td>
<td>0.25</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#100</td>
<td>0.12</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#200</td>
<td>0.074</td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

% Cobble = 0%  
% Gravel = 51.0%  
% Sand = 43.9%  
% Silt & Clay Size = 5.1%

Coefficients:
\[ D_{S5} = 38.4535 \text{ mm} \]
\[ D_{S0} = 11.7857 \text{ mm} \]
\[ D_{S0} = 5.2517 \text{ mm} \]
\[ C_u = 75.841 \]
\[ C_c = 0.222 \]

Classification:
ASTM: N/A
AASHTO: Stone Fragments, Gravel and Sand (A-1-a (0))

Sample/Test Description:
Sand/Gravel Particle Shape: ROUNDED
Sand/Gravel Hardness: HARD
Particle Size Analysis - ASTM D 422

<table>
<thead>
<tr>
<th>Sieve Name</th>
<th>Sieve Size, mm</th>
<th>Percent Finer</th>
<th>Spec. Percent</th>
<th>Compiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 inch</td>
<td>50.80</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1 inch</td>
<td>25.70</td>
<td>77</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/4 inch</td>
<td>19.00</td>
<td>69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/2 inch</td>
<td>12.70</td>
<td>54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/8 inch</td>
<td>9.51</td>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#4</td>
<td>4.75</td>
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<td></td>
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<td>#40</td>
<td>0.42</td>
<td>7</td>
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<td></td>
</tr>
<tr>
<td>#60</td>
<td>0.25</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#100</td>
<td>0.15</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#200</td>
<td>0.074</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

% Cobble      | 71.0
% Gravel      | 26.9
% Sand        | 2.1

Coefficients
- $D_{50} = 31.5349$ mm
- $D_{15} = 14.9312$ mm
- $D_{10} = 11.1114$ mm
- $C_u = 25.770$
- $C_c = 2.828$

Classification
- Well-graded gravel with sand (GW)
- Stone Fragments, Gravel and Sand (A-1-a (0))

Sample/Test Description
- Sand/Gravel Particle Shape: ROUNDED
- Sand/Gravel Hardness: HARD
**GeoTesting express**

1145 Massachusetts Avenue
Boxborough, MA 01719
978 635 0424 Tel
978 635 0266 Fax

---

**Transmittal**

**TO:**
Ms. Susan Nilson
CLE Engineering
15 Creek Road
Marion, MA 02738

**DATE:** 9/27/2005  **GTX NO:** 5949
**RE:** Eel Pond Project

<table>
<thead>
<tr>
<th>COPIES</th>
<th>DATE</th>
<th>DESCRIPTION</th>
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<tbody>
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<td>1</td>
<td>9/27/2005</td>
<td><strong>June 2005 Laboratory Test Reports</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 Grain Size Analyses (ASTM D 422) – sieve portion only</td>
</tr>
</tbody>
</table>

**REMARKS:**


---

**CC:**

**SIGNED:**
Joe Tomei – Laboratory Manager

**APPROVED BY:**
Gary Torosian – Director of Testing Services
GeoTesting
express

1145 Massachusetts Avenue
Boxborough, MA 01719
978 635 0424 Tel
978 635 0266 Fax

Geotechnical Test Report

September 27, 2005

Eel Pond Project

East Channel

Prepared for: CLE Engineering, Inc.
Particle Size Analysis - ASTM D 422

<table>
<thead>
<tr>
<th>Sieve Name</th>
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<th>Spec. Percent</th>
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<tbody>
<tr>
<td>1 inch</td>
<td>25.70</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>19.00</td>
<td>96</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/2 inch</td>
<td>12.70</td>
<td>88</td>
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<tr>
<td>3/8 inch</td>
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<td>90</td>
<td></td>
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<tr>
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<td></td>
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<tr>
<td>#100</td>
<td>0.15</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#200</td>
<td>0.074</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

% Cobble: 36.5 % Gravel: 63.2 % Sand: 0.3

**Coefficients**
- \( D_{85} = 11.4614 \text{ mm} \)
- \( D_{10} = 1.2884 \text{ mm} \)
- \( D_{50} = 4.1278 \text{ mm} \)
- \( D_{20} = 2.7406 \text{ mm} \)
- \( C_u = 8.469 \)
- \( C_c = 0.825 \)

**Classification**
- ASTM: Poorly graded sand with gravel (SP)
- AASHTO: Stone Fragments, Gravel and Sand (A-1-a (0))

**Sample/Test Description**
- Sand/Gravel Particle Shape: ---
- Sand/Gravel Hardness: ---
Particle Size Analysis - ASTM D 422

<table>
<thead>
<tr>
<th>Sieve Name</th>
<th>Sieve Size, mm</th>
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<th>Spec. Percent</th>
<th>Complies</th>
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</tr>
<tr>
<td>1/2 inch</td>
<td>12.70</td>
<td>84</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/8 inch</td>
<td>9.51</td>
<td>79</td>
<td></td>
<td></td>
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<tr>
<td>#4</td>
<td>4.75</td>
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</tr>
<tr>
<td>#200</td>
<td>0.074</td>
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</table>

<table>
<thead>
<tr>
<th>%Cobble</th>
<th>%Gravel</th>
<th>%Sand</th>
<th>%Silt &amp; Clay Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>—</td>
<td>30.5</td>
<td>69.4</td>
<td>0.1</td>
</tr>
</tbody>
</table>

**Coefficients**

- $D_{85} = 12.9878$ mm
- $D_{10} = 0.5710$ mm
- $D_{60} = 2.1523$ mm
- $D_{50} = 1.2075$ mm
- $D_{10} = 0.2637$ mm
- $C_u = 8.162$
- $C_c = 0.574$

**Classification**

- ASTM: Poorly graded sand with gravel (SP)
- AASHTO: Stone Fragments, Gravel and Sand (A-1-b (0))

**Sample/Test Description**

- Sand/Gravel Particle Shape: ---
- Sand/Gravel Hardness: ---
**Particle Size Analysis - ASTM D 422**

<table>
<thead>
<tr>
<th>Percent Finer (mm)</th>
<th>Percent Finer</th>
<th>Spec. Percent</th>
<th>Complies</th>
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</thead>
<tbody>
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<td>25.70</td>
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</tr>
<tr>
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<td></td>
</tr>
<tr>
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<td>12.76</td>
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<tr>
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<td>0.004</td>
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- **%Cobble**: —
- **%Gravel**: 47.1
- **%Sand**: 52.0
- **%Silt & Clay Size**: 0.9

<table>
<thead>
<tr>
<th>Coefficients</th>
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<tbody>
<tr>
<td>D_{85} = 14.5844 mm</td>
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<tr>
<td>D_{90} = 0.6424 mm</td>
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<tr>
<td>D_{50} = 6.6010 mm</td>
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<td>D_{15} = 0.2385 mm</td>
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<tr>
<td>D_{50} = 4.0162 mm</td>
</tr>
<tr>
<td>C_u = 33.508</td>
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<tr>
<td>C_c = 0.317</td>
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</table>

**Classification**

- ASTM: Poorly graded sand with gravel (SP)
- AASHTO: Stone Fragments, Gravel and Sand (A-1-a (0))

**Sample/Test Description**

- Sand/Gravel Particle Shape: —
- Sand/Gravel Hardness: —
WARRANTY and LIABILITY

GeoTesting Express (GTX) warrants that all tests it performs are run in general accordance with the specified test procedures and accepted industry practice. GTX will correct or repeat any test that does not comply with this warranty. GTX has no specific knowledge as to conditioning, origin, sampling procedure or intended use of the material.

GTX may report engineering parameters that require us to interpret the test data. Such parameters are determined using accepted engineering procedures. However, GTX does not warrant that these parameters accurately reflect the true engineering properties of the in-situ material. Responsibility for interpretation and use of the test data and these parameters for engineering and/or construction purposes rests solely with the user and not with GTX or any of its employees.

GTX’s liability will be limited to correcting or repeating a test which fails our warranty. GTX’s liability for damages to the Purchaser of testing services for any cause whatsoever shall be limited to the amount GTX received for the testing services. GTX will not be liable for any damages, or for any lost benefits or other consequential damages resulting from the use of these test results, even if GTX has been advised of the possibility of such damages. GTX will not be responsible for any liability of the Purchaser to any third party.

Commonly Used Symbols

A  pore pressure parameter for $\Delta \sigma_3 - \Delta \sigma_1$
B  pore pressure parameter for $\Delta \sigma_3$
CIU  isotropically consolidated undrained triaxial shear test
CR  compression ratio for one dimensional consolidation
C  coefficient of curvature, $(D_{30})^2 / (D_{10} \times D_{60})$
C  coefficient of uniformity, $D_{60} / D_{10}$
C  compression index for one dimensional consolidation
C  coefficient of secondary compression
C  coefficient of consolidation
c  cohesion intercept for total stresses
c  cohesion intercept for effective stresses
D  diameter of specimen
D  diameter at which 10% of soil is finer
D  diameter at which 15% of soil is finer
D  diameter at which 30% of soil is finer
D  diameter at which 50% of soil is finer
D  diameter at which 60% of soil is finer
D  diameter at which 85% of soil is finer
d  displacement for 50% consolidation
d  displacement for 90% consolidation
d  displacement for 100% consolidation
E  Young’s modulus
e  void ratio
e  void ratio after consolidation
e  initial void ratio
G  shear modulus
G  specific gravity of soil particles
H  height of specimen
P  plasticity index
i  gradient
K  lateral stress ratio for one dimensional strain
k  permeability
LI  Liquidity Index
m  coefficient of volume change
n  porosity
P  plasticity index
Pc  preconsolidation pressure
P  $(\sigma_1 + \sigma_3) / 2, (\sigma_1 + \sigma_3) / 2$
Pc  $p' = (\sigma_1 + \sigma_3) / 2, (\sigma_1 + \sigma_3) / 2$
Pc  $p' = (\sigma_1 + \sigma_3) / 2, (\sigma_1 + \sigma_3) / 2$
Q  quantity of flow
q  $(\sigma_1 + \sigma_3) / 2$
q  q at failure
q  initial q
q  q at consolidation
S  degree of saturation
SL  shrinkage limit
Su  undrained shear strength
T  time factor for consolidation
T  temperature
t  time
U, UC  unconfined compression test
UU, Q  unconsolidated undrained triaxial test
u  pore gas pressure
u  excess pore water pressure
u  pore water pressure
V  total volume
V  volume of gas
V  volume of solids
V  volume of voids
V  volume of water
V  initial volume
v  velocity
W  total weight
W  weight of solids
W  weight of water
w  water content
w  water content at consolidation
w  final water content
w  liquid limit
w  natural water content
w  plastic limit
w  shrinkage limit
w  liquid limit
w  initial water content
a  slope of $q_t$ versus $p_t$
a  slope of $q_t$ versus $p_t$
Y  total unit weight
Y  dry unit weight
Y  unit weight of solids
Y  unit weight of water
E  strain
Es  void strain
Es  horizontal strain, vertical strain
\mu  Poisson’s ratio, also viscosity
\sigma  normal stress
\sigma  effective normal stress
\sigma  consolidation stress in isotropic stress system
\sigma  horizontal normal stress
\sigma  vertical normal stress
\sigma  major principal stress
\sigma  intermediate principal stress
\sigma  minor principal stress
\tau  shear stress
\phi  friction angle based on total stresses
\phi  friction angle based on effective stresses
\phi  residual friction angle
psi  \phi for ultimate strength
WEST CHANNEL PROFILES

PROPOSED PROFILE

EXISTING PROFILE

5+00

5+07

5+11

5+13

5+15

5+20

5+25

5+00

6+00

6+15

6+20

6+25

6+30

6+40

6+50

7+00

7+07

7+11

7+13

7+15

7+20

7+25

7+30

7+35

7+40

7+45

7+50

NOTE:

All notes are on sheet 1.

WEST CHANNEL SECTIONS

SCALE: 1"=80' H, 1"=6' V

PROJECT:

POND

MATTAPOOSE HARBOR, MA

CITY:

TOWN OF MATTAPOOSE
P.O. BOX 435
MATTAPOOSE, MA 02739

CLE ENGINEERING, INC.
15 Creek Road, Norton, MA 02766 (508) 746-0527

WEST CHANNEL PROFILE

SHEET 5 OF 5

WEST CHANNEL SECTION

SHEET NUMBER

SHEET SIZE

DATE

DRAWN BY

CHECKED BY

REVISED BY

FCW

6/14/14

6/16/14

6/22/14