Task 2: Hydrologic Monitoring and Flushing Studies - Sawmill Brook Flood Mitigation and Restoration Project

TO: Mary Reilly, Manchester-by-the-Sea Grants Administrator

FROM: Gabrielle C. Belfit, CFM and David Azinheira, P.E., CFM

COPY: David A. Murphy, P.E.

DATE: Jun 18, 2018

1 Introduction

This memorandum describes the field methods, data collection, and hydrologic modeling completed under Task 2 "Hydrologic Monitoring and Flushing Studies for the Sawmill Brook Tide Gate Removal and Restoration Feasibility Study". The memo includes a discussion of the observed stream flow conditions over a five-month period, and hydrologic modeling to evaluate the consequences of the Central Street Bridge tide gate removal and limited stream restoration on flood levels of adjacent and upstream properties.

Georgeann Keer, Division of Ecological Restoration (DER) and Eric Hutchins, NOAA Restoration Center (NOAA) served as technical advisors for this project. The technical advisors reviewed the field methodology providing helpful suggestions to refine the approach, were onsite during the initial water level equipment deployment and stopped by the site to take photos during an extreme high tide event. The advisors also assisted with review of draft and final deliverables.

To provide a more accurate base plan for the hydrologic studies, an existing conditions survey was completed for the study area in November 2017 by Doucet Survey Inc., from just below Center Street to just above Norwood Avenues. The existing conditions plan included cross sections across Central Street Pond and along the stream channel from Central Street to Norwood Avenue to provide elevations for the hydraulic model (HEC-RAS). Steam water level monitoring locations including staff gages, culvert headwalls and pressure transducer reference points were established in the survey. All retaining walls along the stream banks, top of bank, sill elevations were picked up by the surveyor and noted on the plan. Wetland resource areas were located in the field by Tighe & Bond wetland staff using a Trimble hand held GPS and transposing the areas to the existing conditions plan. The existing conditions plans are provided in Appendix A.

2 Stream Monitoring

This task included a five-month period of water level monitoring covering a range of flow conditions (fall low stream flow, extreme high tides, winter storm surge and spring high stream flow). Existing stream flow conditions were observed for the lower reaches of Sawmill Brook, extending from below Norwood Avenue, through the School Street culvert, Central Pond and including Manchester Harbor. The data was used provide a basic understanding of the existing hydrologic conditions and refine the previously completed Sawmill Brook hydrologic model to evaluate flood potential on adjacent properties in the study area with modifications at Central Street.

Three methods were used to measure water level data. Pressure transducers collected continuous data, staff gages provided visual measurements, and depth to water from culvert

headwalls were provided as a back-up reference in case of any physical measurement equipment malfunction (which unfortunately did occur). Manual water level discharge measurements were also obtained to help validate the modeling. The methods are described in the next section. Figure 1 provides a graphic showing the monitoring locations.

2.1 Staff Gages

Non-recording vertical staff gages were installed at the upper and lower extent of the project area to supplement the pressure transducer readings and as a reference backup. The gages are 4-inch wide, fiberglass style A gage with a U.S. scale.

The gages were initially located just below Norwood Avenue and 100 feet above the Central Street Bridge. The gages were mounted on fence post well-hammered into the stream bed, placing the bottom of the gage on the stream bed bottom. The A reference point was marked at the top of the gage plate and tied into the level circuit in November 2017. Volunteers were trained on reading the gages[1] and observations are included in Appendix B surveyed to NAVD88 datum.

The Central Street staff gage was dislocated in January due to ice, and was reinstalled 2/28/18 directly onto the granite sidewall just above the bridge (Photo 1) and the bench mark elevation was resurveyed .

Photo 1: Central Street Bridge Surface Water Level Gage. Fiber glass gage is mounted on pressure treated lumber. Wall mount accomplished with lag bolts drilled into granite blocks.

2.2 Manual Stream Discharge Measurements

Manual discharge measurements of Sawmill Brook were obtained at the start and completion of the project for model calibration and flushing studies. The methodology used[2] is effective for wadable streams and culverts (Marsh-McBirney Flow-mate current meter with a wading rod to measure water depth). The measurements were made just south of Norwood Avenue and School Street, just north of Central Avenue, and at the north end of Central Pond (Photo

[1]Oklahoma Water Resource Board, Water Quality Program Division, "Standard Operating Procedure for the Installation of Nonrecording Gages and Measurement of State in Streams." October 2004
[2]Washington State Department of Ecology. "Standard Operating Procedure for Measuring Streamflow for Water Quality Studies, Version 3.0, March 2016.

2). The measurements were completed on an outgoing tide to capture base flow. The November and April discharge measurements are included in Appendix B.

Photo 2: Sawmill Brook Stream Discharge Measuring. Stream velocity in feet/second is measured at discrete intervals across the channel. Stream discharge in cubic feet per second is obtained by multiplying the area for each interval.

2.3 Salinity Measurements

Salinity profiles were obtained for two purposes: vertical profiling data to calculate the flushing time of Central Pond and salinity measurements at different points going upstream at high tide.

Vertical salinity profiles were completed for transects south of Central Street in Manchester Harbor and north of Central Street in Central Pond. The profiles were used to verify the flushing time in Central Pond. The methodology for vertical profiling followed the Washington State Department of Ecology "Standard Operating Procedure for Measuring Vertically Averaged Salinity in Brackish Waters[3], using a YSI 600XL salinity/conductivity probe with 20-foot cable. The transects were completed at high tide. At each transect, 5 vertical profiles were completed consisting of 5 or more measurements depending on the overall depth. The flushing time calculations require the use of discrete values, so for that purpose, the vertically averaged salinity were not used. For the determination of salinity to locate the freshwater/saltwater interface, the vertically averaged, area-weighed salinity was used. The profiles are provided in Appendix C.

[3] Washington State Department of Ecology. "Standard Operating Procedure for Measuring Vertically Averaged Salinity in Brackish Waters" November 2016

Salinity measurements were completed on April 18, 2018 just before and after the peak high tide event. Vertically averaged salinity just below Central Street Bridge in Manchester Harbor measured 17.61 parts per thousand(ppt), clearly reflecting the freshwater discharging from Central Pond. Vertically averaged salinity in Central Pond just above the Central Street Bridge was 1.68 ppt, indicating brackish conditions. (Note: salinity in the Gulf of Maine averages 30 ppt).

Two sets of measurements were taken 50 feet upstream (0.5 ppt just below the surface and 1.7 ppt just above the bottom) and 100 feet upstream from the Central Street Bridge (0.2 ppt just below the surface and 0.4 ppt just above the bottom), indicating high level of mixing as the stream discharge meets the tidal inflow. Measurements at School Street and Norwood Avenue measured 0.13 ppt both at high tide and low tide, indicating that brackish water was not present that far up Sawmill Brook. Up river salinity measurements are not indicative of tidal influence on flows. Backwatering conditions are anticipated up river of salinity limits.

2.4 Surface Water Level Pressure Transducers

Onset® HOBO® U20L Water Level Pressure Transducers were installed to monitor changing water levels in Sawmill Brook, including base flow, storm event drainage and tidal fluctuation over the five-month data collection period. The surface water level data was used to refine the Sawmill Brook model to more realistically represent observed hydraulic conditions, and improve predicted potential future conditions for events that did not occur during the study period (e.g., extreme precipitation events, storm surge, and changes to the Central Street Culvert).

Six HOBO pressure transducers units were deployed at locations along Sawmill Brook above and below the 3 culverts that are part of the project area (Figure 1)). One additional unit was installed above the highest expected water level to serve as a control for changing barometric pressure. The pressure transducers were calibrated prior to deployment using Onset® software and set up to record water levels at 6-minute intervals to match the Boston Harbor Tide gage observation frequencies.

The pressure transducers in Sawmill Brook were installed in 1-foot long, 2-inch diameter PVC pipe sections, that were drilled with holes and capped at both ends. The pipe sections were bolted onto rebar installed hammered in the stream bank. The transducers were suspended from a non-stretchable wire (Photo 3), inside the PVC, as referenced

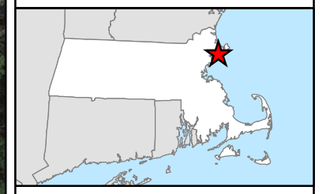
Photo 3: Method to deploy HOBO water level pressure transducers in stream bed below Norwood Ave. The PVC casing attached to fence post is shown to the left. The PVC was painted black to deter vandalism.

FIGURE 1:
Water Level Monitoring Stations

LEGEND

- Water Level Monitoring Station
- Stream Gage

LOCUS MAP



N
W E
S

0 50 100
Feet

1 inch equals 200 feet

NOTES

Sawmill Brook Area
Manchester By the Sea,
Massachusetts

February 2018

Tighe&Bond
Engineers | Environmental Specialists

G:\GIS\MA\Quincy\avproj\Ortho_SawmillBrook_11x17_stations.mxd Date Saved: 2/20/2018 User: JSM

in the U20L Operation Manual[4]. Reference points on top of the PVC cap were established by survey and tied into the circuit. The depth to water were recorded at the time of deployment and used to calibrate the unit. One transducer set to record barometric pressure was installed above highest water level and in a protected location north of Norwood Avenue. Pressure transducers were installed above and below Central Street, School Street and Norwood Avenue culverts.

The unit in Manchester Harbor was attach to a concrete cinderblock and secured to the Town Pier with steel cable (Photos 4).

Photo 4: Method to deploy HOBO water level pressure transducers in Manchester Harbor using granite block and steel cable.

A headwall reference point was established on either side of the culverts, surveyed, and tied into the circuit. The reference marks were used to establish water level elevation above the pressure transducers at the time of deployment. Elevations were reestablished at all locations before and after downloading data to compensate for any minor shifts in equipment position.

Data was downloaded at regular intervals, and calibrated to compensate for variations in barometric pressure, water density (fresh or salt) and adjusted to NAVD88. During January extremely cold conditions prevailed, with ice forming above several of the units. The unit at position C1, above Central Street was dislodged from ice flow movement when the gate was opened on January 11th. The unit at position B1 was also dislodged in January. Both units were eventually retrieved and data captured. In the interim, units were shifted in position

[4] Onset U20L Specifications, U20L Operation Manual, Barometric Compensation Assistant Users Guide.

to avoid losing data at the most important locations, just upstream of the Central Street bridge/tide gate, and upstream and downstream of the School Street culvert.

2.5 Tide Gate Operations

The tide gate at the Central Street Bridge was installed in the early 1900's to dam Sawmill Brook and create Central Pond just upstream. The gate is normally closed for most of the year, serving as a level control for the Pond. The top of the tide gate is at elevation 4.6 feet above MSL NAVD88, and regularly overtops during average to high tide events. When the gate is closed the hydrostatic pressure from impounded water leaks through the wingwalls adjacent to the bridge. Typically, the Town DPW only opens the gate to release flood waters if a large rain storm is predicted. The gate is also left open each year from March -May to provide an opportunity for fish passage.

For the purposes of this study the Town agreed to periodically leave the gate open, so that upstream water levels could be observed under a variety of storm and tide conditions. The Town opened the gate for increasing lengths of time on three occasions:

- One week in November-December (11/27/17- 12/7/17)
- Three weeks in January- February (1/11/18-2/6/18)
- Four months from March-June 2018

2.6 Data Collection

The hydrologic monitoring was conducted over a five-month period:

1. Manual stream discharge measurement at 3 locations were obtained in November and April to capture fall and spring base flow, and assist with model calibration.
2. Surface water level data collection extended from November – April, including the following:
    - Volunteers recorded staff gage stream elevations and culvert headwall depth to water at 6 locations on a weekly basis. Periodic observations were made to capture extreme events from rainfall, extreme lunar tides, or wind driven storm surge. (Staff gage elevations are provided in Appendix B).
    - Pressure transducer data was collected every 6-minues at 6 locations.
    - Tighe & Bond downloaded the logger data in January, February, and April.
3. Manual salinity profile measurement within Manchester Harbor and upstream of Central Street on April 18, 2018 to evaluate salinity mixing within Central Pond.
4. Records of daily precipitation from the Manchester-by-the-Sea Wastewater Treatment Facility were obtained to correlate with observed water levels. Precipitation values measured in inches are reported each day at 8AM for the preceding 24-hour period, and may not always correlate well with the more frequent measurements for surface water levels from the pressure transducers. Snowfall was not measured separately by the Treatment Plant operators, values reported for precipitation are assumed to include any melted snow captured by the rain gage. In several instances, data from the Beverly Airport was checked as a backup where there was poor correlation. Any deviations from the reported value are noted in figures summarizing the results. (Precipitation records for December through April are provided in Appendix B).
5. Notable conditions occurred over the five-month monitoring period.
    - On December 5th, January 7th, and February 5th astronomic high tides were observed. The January 7th high tide exceeded the 100-year high tide at the Boston Tide Gage (NOAA, Tides and Currents Station #8443970).

- Extreme cold conditions were experienced from the end of December thru mid-January where rapidly accumulating ice in Sawmill Brook and Manchester Harbor affected some staff gage readings and dislodged two of the pressure transducers. The remainder of January and February was seasonally cold with periodic rain and snow.
- The highest 24-hour rainfall of 1.98 inches was recorded on April 16th. The second highest 24-hour precipitation event was 1.91 inches recorded on March 2,2018 during Winter Storm Riley.
- Back to back Nor'easters occurred on March 2nd, 7th, and 17th with high wind, storm surge, rain and snow.

2.7 Observed Surface Water Trends

Water level data was downloaded from the pressure transducers on 1/23/2018, 2/28/18 and 5/4/18. The raw data was first calibrated to local barometric pressure, and then elevations for each unit were adjusted with the adjacent bench marks to create a normalized data set using NAVD88 datum. Graphs were prepared for each location and include the local precipitation data and tide gate position. All water elevation data reported is in feet NAVD88.

2.7.1 Manchester Harbor and Central Street Bridge- C1/C2

Data obtained from the pressure transducers above and below the Central Street Bridge were essential to evaluate the conditions at the Bridge under various hydrologic settings. The immediate goal was evaluating how high tide periods impacted upstream water levels and whether the tide gate provided upstream flood mitigation. The secondary goal was to provide the range of surface elevations for input into the hydraulic model and to evaluating flushing from Central Pond and sediment transport. Hydrologic conditions observed over the five-month monitoring period were sufficient to capture a wide range of conditions, including the record high tide set on January 4, 2018. Results at this location are provided in Figures 2 and 3 and summarized below.

Manchester Harbor (C2)

Water level data collected from 11/28/217- 5/04/2018) Station C2 in Manchester Harbor (Figure 2) depict the following local tidal conditions:

- The highest tide from the fall of 2017 was measured on 12/5/2017, a maximum tidal range of 13.3 feet was measured, with a maximum water level elevation of 7.2 feet recorded on 12/5/2017.
- Visual observations by the project team during the 12/4/2017 high tide indicated that the closed tide gate was not restricting water level fluctuation upstream of the gate.
- Over the five-month monitoring period, the maximum water level elevation recorded at Station C2 was 8.9 feet on 1/4/2018. This reading occurred during the January "Bomb-Cyclone", with record breaking[5] high tide and a reported 0.74 inches of precipitation.

[5] On 1/4/18 The Boston tide gage exceeded the previously recorded high-water level for approximately 20 minutes at 12:30 PM.

- Over the five-month monitoring period daily high tides exceeded the tide gate head wall elevation of 4.61 feet 203 out of the 313 recorded tides, or 64.86% of the monitoring period.

- Headwall measurements taken just outside the Seaside One building, seaward of the tide gate, fall within the range measured by the pressure transducer at site C2.

Photo 5: High Tide on December 3, 2017 the tide is well above the top of the tide gate

Central Street Bridge (C1)

Water level monitoring data from Sawmill Brook at Station C1 just above the Central Street Bridge (Figure 3) depicts the following conditions:

- The tide gate is regularly overtopped by high tide conditions. Over the five-month monitoring period there were 290 high tides recorded, and 194 were greater than the tide gate head wall crest elevation of 4.61 feet, (66.90%). Taking into account the tide gate position, when the tide gate was open 176 high tides were recorded, and 119 were greater than 4.61 or 67.91%. When the tide gate was closed, 114 high tides were observed and 75 were greater than 4.61 or 65.79%.

- During the reporting period, the maximum water level elevation recorded at Station C1 was 9.08 feet, at 12:48 on 1/4/2018. This reading occurred during a record breaking[6]

[6] On 1/4/18 the Boston tide gage (Station ID: 8443970) exceeded the previously recorded high-water level for approximately 20 minutes at 12:30 PM.

high tide and a recorded 0.74 inches of precipitation. Flooding was observed at several locations along Central Pond (Photo 6).

- The range of water level elevations at data logger C1 over five-months ranged from 0.45 feet to 9.09 feet. With the tide gate closed, the average elevation during high tide was 4.90 feet, and at low tide the average elevation was 4.25 feet. With the tide gate opened, the average elevation during high tide was 5.13 feet, and at low tide the average elevation was 1.03 feet.

Photo 6: Central Pond adjacent to the Manchester Fire Department shown on 1/4/2018. Rising water levels eventually overtopped the wall (elevation 5.4 ft. NAVD88) flooding the parking area and Fire Department basement and garage area.

2.7.2 School Street Culvert – B1/B2

Data obtained from the pressure transducers above and below the School Street Culvert were helpful to evaluate conditions under various hydrologic settings. The immediate goal was to evaluate how tidal conditions impacted water levels at School Street with the opening and closing of the tide gate. The secondary goal was to see if culvert restrictions were evident on the upstream side with a large rainfall event (Photo 7). Unfortunately, the first deployed upstream pressure transducer was dislodged during the January cold spell, and the response to the highest January rainfall event was not captured. As with the other sites, the information also provides the data to calibrate the hydrologic model. Hydrologic conditions observed over the five-month monitoring period were sufficient to capture a wide range of conditions. Results at this location are provided in Figures 4 and summarized below.

- The tidal response measured at Station B2 are evident when compared to Station C2 data (Figure 2). The surface water fluctuation here are due to increase pressure gradient from the high tide elevation, and are most notable on 12/2/2017 through 12/7/2017 (tide gate open), 1/1/2018 through 1/4/2018 (tide gate closed) and again from 1/28/2018-2/1/2018 (tide gate open). The tidal response was observed both during dry weather conditions and with precipitation event. Periods with ice accumulation are noted on the graph impacting manual surface water levels.

- Sudden water level increases are well correlated with precipitation events throughout the observation period, except for a 2/17/2018 rain event measuring 0.8 inches. This may have been a data entry error as it is hard to explain otherwise.

Photo 7: The upstream side of the School Street culvert is an example of the narrow, channelized character of Sawmill Brook. This location overtopped in the 2006 Mother's Day storm, causing extensive damage to adjacent properties. The gravel bottom and location just upstream from Central Pond provides a prime rainbow smelt spawning location.

2.7.3 Norwood Avenue Culvert – Stations A1 / A2

Data obtained from the pressure transducers above and below the Norwood Avenue Culvert, manual measurements at the Norwood Ave culvert headwall, and Staff Gage A were helpful to evaluate conditions under various hydrologic settings (Photo 8). The immediate goal was evaluating if culvert restrictions were evident on the upstream side with a large rainfall event. As with the other sites, the information also provides the data to calibrate the hydrologic model. Hydrologic conditions observed over the five-month monitoring period were sufficient to capture a wide range of conditions. Results at this location are provided in Figures 5 and summarized below.

- Water level monitoring data from the Norwood Avenue Culvert (Stations A1 / A2) does not indicate any tidal response as observed at Station B2 (Figure 4).

- A comparison of water elevations at Stations A1 and A2 suggests that the culvert was not a significant restriction to flow during the reporting period.

Figure 2: Station C2 - Manchester Harbor

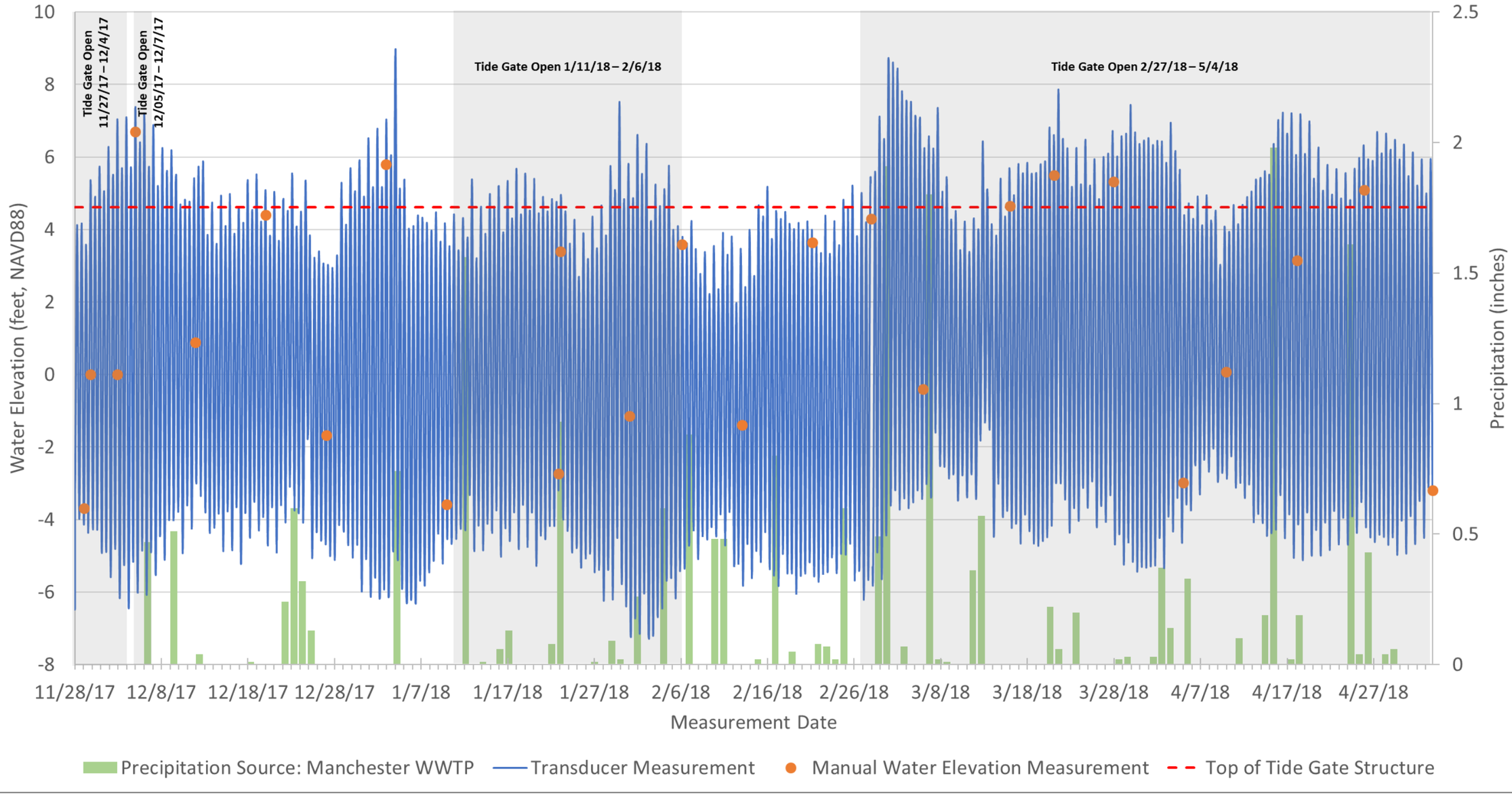


Figure 3: Station C1 - Central Street

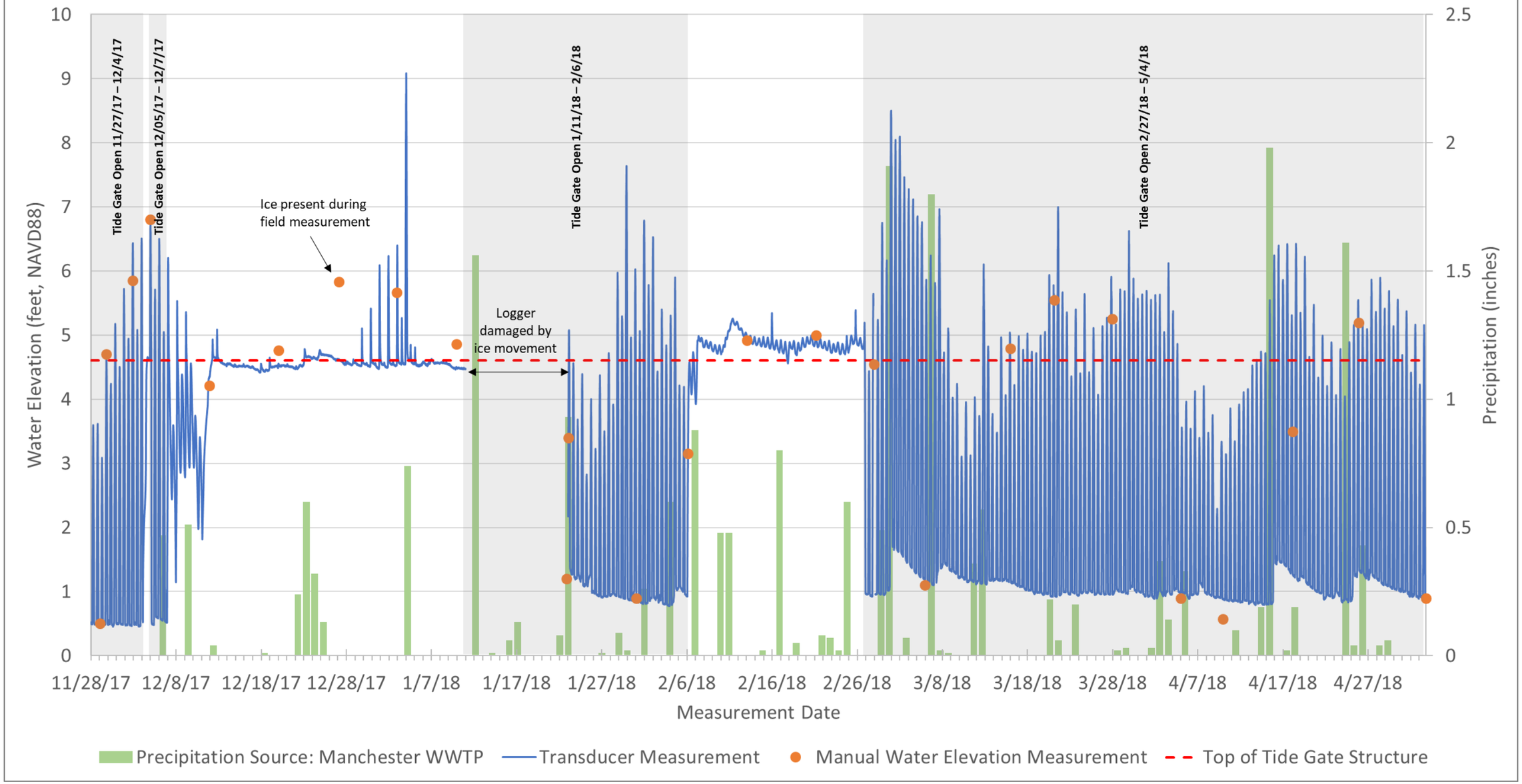


Figure 4: Station B2 - School Street

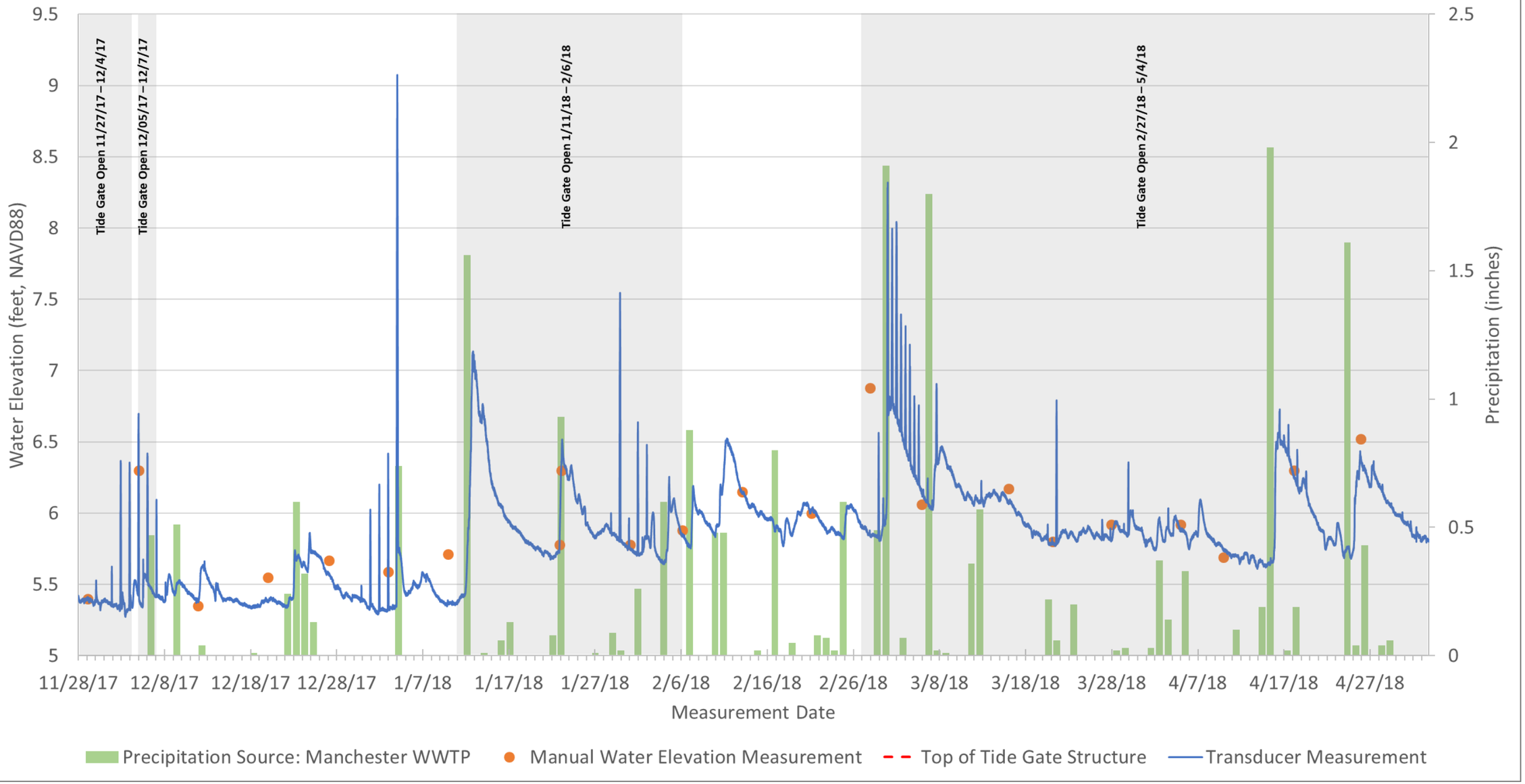
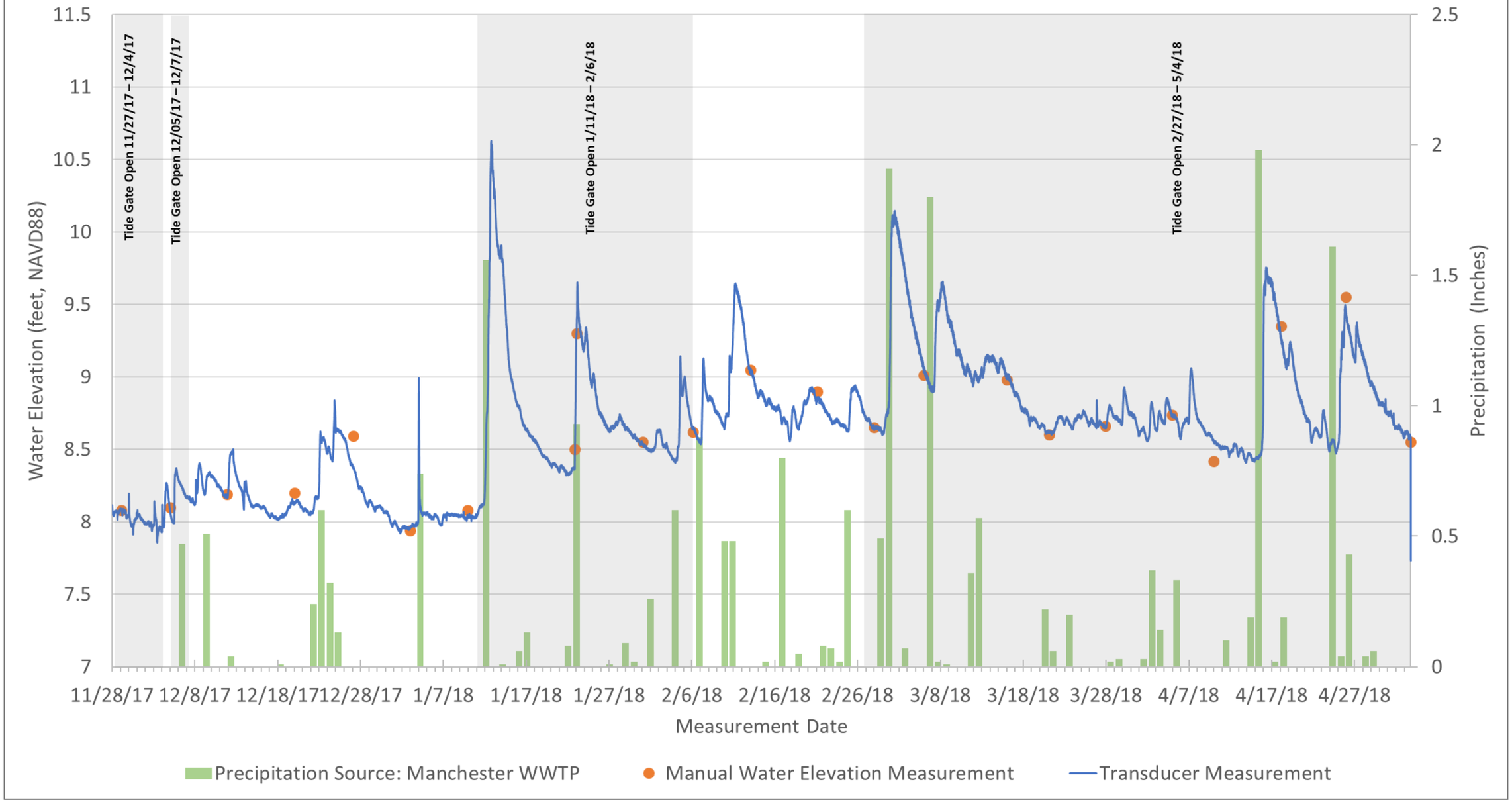


Figure 5: Station A2 - Norwood Avenue



- The majority of sudden water level increases are attributed to precipitation events. A few events don't follow this pattern and may be due to rapid snow melt, release of water due to the breaking of an identified upstream beaver dam (Photo 9).

Photo 8: The downstream side of the Norwood Avenue is shown here. Gage A is installed on a heavy-duty fence post, pounded deep into the stream bottom. Volunteers took weekly depth to water measurements at the headwall bench mark location, indicated by the orange mark at the edge of the pavement.

Photo 9 The upstream side of the Norwood Avenue is shown here. The pressure transducer is in the bottom right corner. Just upstream, evidence of recent beaver activity is still causing some backup, an ongoing issue at this location.

2.8 Baseflow Measurements

Data obtained from the manual flow measurements provide a reasonable range for anticipated baseflow as observed on November 28, 2017 (Fall), and April 18, 2018 (Spring). Table 1 summarizes the observed Fall and Spring flows. The Fall flows ranged from 1.3 to 2.3 cubic feet per second, while the Spring flows ranged from 15.1 to 26.7 cubic feet per second.

TABLE 1

Fall and Spring Baseflow Measruments[1]

Location	Fall Baseflow (ft^3/s)	Spring Baseflow (ft^3/s)	Average (ft^3/s)
Manchester Harbor (Downstream of Central Pond)	1.3	15.1	8.2
Upstream of Central Pond	1.5	26.7	14.1
School Street	2.3	26.7	14.5
Norwood Avenue	1.8	25.9	13.9

[1] The Fall measurements were taken on November 28, 2017, and the Spring measurements were taken on April 18, 2018.

3 Hydrologic Modeling

There are three components to the hydrologic modeling completed for this grant. First, the HEC-RAS model was updated to incorporate the topographic survey and surface water level monitoring, and second, a flushing analysis was completed to characterize the tidal hydrodynamics of Sawmill Brook. The end result of the modeling is to create a realistic representation of existing conditions at Sawmill Brook and to develop an understanding of the impacts of proposed improvements at Central Street. The developed HEC-RAS model will also be used as part of the sediment transport analysis as part of Task 3 “Characterization of Sediment and Sediment Transport” of this study.

The following sections provide the findings for each element.

3.1 Hydraulic Model

3.1.1 Model Geometry

A hydraulic analysis of Sawmill Brook was prepared using HEC-RAS, a hydraulic modeling program available from the U.S. Army Corps of Engineers. This model updates the previous planning level modeling performed as part of the “Sawmill Brook Culvert and Green Infrastructure Analysis Task 4 Final Report: Evaluation of Locations for Flood Mitigation” prepared by Tighe & Bond in February 2016, with updates based on the November 2017 survey by Doucet Survey Inc., and surface water level monitoring. The updated model includes Sawmill Brook from approximately 50 feet upstream of Norwood Avenue to approximately 100 feet downstream of Central Street.

To update the model, Tighe & Bond first created a Triangular Irregular Network (TIN) elevation surface using the 2017 survey and MassGIS LiDAR topographic data for overbank areas beyond the extent of the surveyed cross sections. A geometric representation of the channel, banks, and cross-sections was created using the HEC-GeoRAS tool to extract cross sections from the TIN. Sawmill Brook was modeled using 30 cross sections, culverts at Norwood Avenue, School Street, and Central Street, as well as the existing tide gate structure

immediately downstream of Central Street. The Manning's roughness coefficients were estimated to be 0.04 in the upstream area of the reach and 0.03 toward the downstream area based on the survey and orthographic imagery. The overbank area Manning's n varied from 0.035 (commercial/industrial land use) to 0.1 (forest cover). The overbank Manning's n varied horizontally along the cross sections and were calculated using the MassGIS 2015 land use dataset.

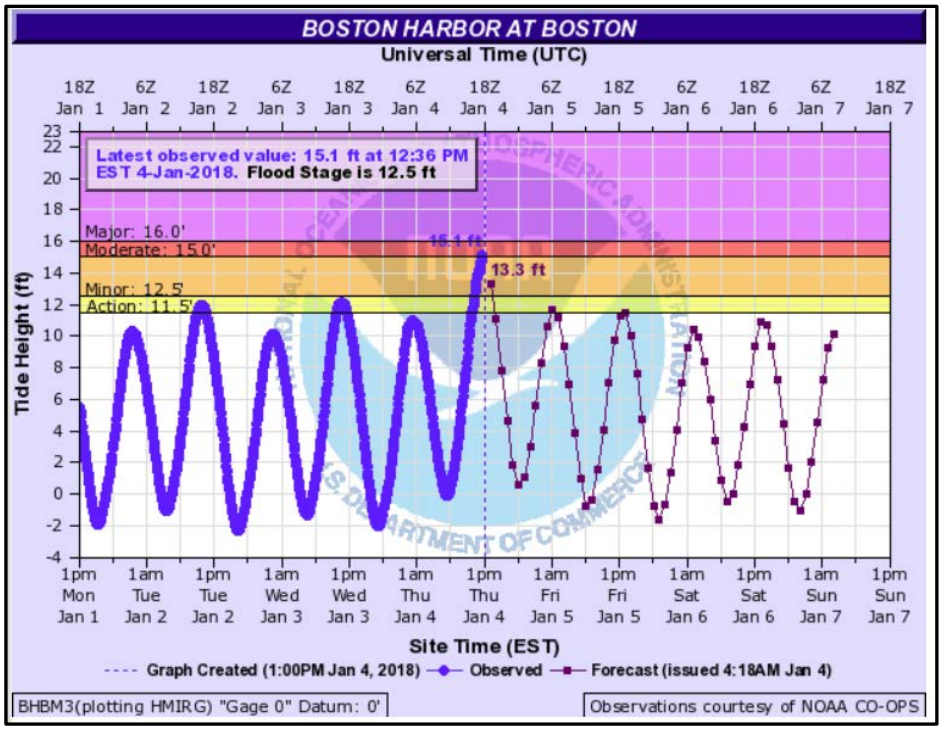
Model geometry scenarios were developed for:

1. Existing Conditions with the Tide Gate Closed
2. Existing Conditions with the Tide Gate Open
3. A Proposed Condition with the Tide Gate Removed and Larger Central Street Culvert

The proposed condition improvements include removing the tide gate and replacing the existing Central Street Culvert with an 18-foot wide Conspan arch culvert or equivalent opening. The proposed culvert would maintain the existing upstream and downstream invert elevations (-0.2 feet NAVD88, and -4 feet NAVD88, respectively), and provide a constant low chord elevation of 6 feet NAVD88. The Town is planning to replace the Central Street Bridge and the exact geometry of the proposed culvert may vary from the proposed model following a detailed underground utility survey and geotechnical investigation. The hydrology and hydrologic model will be adjusted to account for the exact dimensions once the final design is completed.

3.1.2 January 2018 Record High Tide Time-Varying Modeling

The January 2018 record high Tide was evaluated using the time-varying (also known as "unsteady") capabilities of HEC-RAS, utilizing the observed tide levels within Manchester Harbor as a downstream boundary condition when the tide gate was closed. The model time interval extended from January 1, 2018 to January 7, 2018, and included the record breaking high tide observed on January 4, 2018 (see inset below).



The Sawmill Brook baseflow upstream of Norwood Avenue and at the Central Pond was estimated based on the observed surface water level monitoring and stream discharge data. The Manning's roughness coefficient and seepage through the Central Street road bed were used as calibration parameters. Appendix C shows the observed and modeled water surface elevations within Sawmill Brook from January 1, 2018 to January 4, 2018.

Once the calibrated existing condition model was developed as observed with the tide gate closed, January 2018 record high tide conditions were used to run through a scenario with the tide gate open, and a scenario with the proposed improvements. It was determined that the maximum water surface elevation associated with the January 2018 record hightide would have been approximately the same whether the tide gate was open, or whether the proposed improvements had taken place. The similar peak water surface elevations can be attributed to the fact that the January 4, 2018 peak tide elevation was approximately 4 feet above the tide gate crest elevation. Figure 5 shows the HEC-RAS model cross sections and the inundation extent for the January 2018 record high tide.

3.1.3 Design Storm Steady-State Modeling

The 25-, 50-, and 100-year frequency design storm events were evaluated for existing conditions with the tide gate open, existing condition with the tide gate closed, and for proposed conditions. A detailed hydrologic analysis was performed using HEC-HMS as part of the February 2016 "Sawmill Brook Culvert and Green Infrastructure Analysis Task 4 Final Report: Evaluation of Locations for Flood Mitigation" prepared by Tighe & Bond. The 2016 study included 25-, 50-, and 100-year flow estimates for the present, 2025, 2050, and 2100 while incorporating multiple energy use climate change projections for rainfall, as well as sea level rise, and storm surge. The flows from the 2016 study were used for this 2018 model update, although the design storms were simplified into 9 scenarios as shown in Table 2.

TABLE 2

Design Storm Model Flow Rates from February 2016 study[1]

Model Scenario[1]	Downstream Boundary Condition[2]	Flow to Norwood Avenue (ft^3/s)	Flow to Central Pond (ft^3/s)
Present (2018) 25-Year	MHHW	1,228	1,363
Present (2018) 50-year	MHHW	1,565	1,772
Present (2018) 100-year	MHHW	2,000	2,267
Future (2100) 25-Year	MHHW + SLR	1,706	1,930
Future (2100) 50-Year	MHHW + SLR	1,717	1,946
Future (2100) 100-Year	MHHW + SLR	2,562	2,943
Present (2018) 25-Year with Storm Surge	Annual Storm Surge	1,228	1,363
Present (2018) 50-year with Storm Surge	Annual Storm Surge	1,565	1,772
Present (2018) 100-year with Storm Surge	Annual Storm Surge	2,000	2,267

[1] The proposed conditions involve removing the tide gate and providing an 18-foot wide Conspan arch culvert. The proposed culvert would maintain the existing upstream and downstream invert elevations and provide a constant low chord (underside of bridge) elevation of 6 feet NAVD88.

[2] MHHW = Mean Higher High Water, SLR = Sea Level Rise

The downstream boundary conditions for the design storm hydraulic modeling were the Mean Higher High Water (MHHW) and the annual storm surge elevation. The modeled MHHW elevation was 4.77 feet NAVD88 based on the NOAA Long Term Tide Water Level Monitoring Station ID: 8443970. The annual storm surge elevation was provided in the February 2016

Note:

1. The inundation area was calculated using an unsteady HEC-RAS model using boundary condition data from water level monitoring.
2. The inundation areas for the January 2018 King Tide was approximately the same for existing conditions with the tide gate closed, existing condition with the tide gate open, and for proposed conditions. A single inundation area is shown for clarity.
3. All elevations are in the North American Vertical Datum of 1988 (NAVD88).
4. Topographic and bathymetric data from modeling was from survey by Doucet Survey Inc. performed in December 2017 and from MassGIS LiDAR data.

Stanley Aven
Bell Court
Flatley Avenue
Filias Circle
Maple Avenue
Vine Street
Burnham Lane
Sumac Lane
2510 feet
2480 feet
2350 feet
2230 feet
Sawmill Brook
2070 feet
2550 feet
2600 feet
Friend Street
1360 feet
1870 feet
1730 feet
1090 feet
Putnam Court
Brook Street
1560 feet
1510 feet
Knight Circle
1220 feet
1020 feet
930 feet
830 feet
Desmond Avenue
710 feet
650 feet
Powder House Lane
School Street
310 feet
580 feet
500 feet
North Street
Elm Street
250 feet
200 feet
Morse Court
370 feet
Norwood Avenue
Smith Lane
90 feet
Washington Street
20 feet
Central Street
-30 feet
-40 feet
-70 feet
-100 feet
Peele House Square
Union Street
Church Street
Chapel Lane
Sea Street
127
Beach Street
Summer Street
Manchester Harbor
Tappan Street

Central Street Bridge (Existing tide gate located immediately downstream)

LEGEND

- Model Cross Section (label indicates feet upstream of Central Street)
- January 4, 2018 King Tide Model Inundation Area

1 in = 200 ft

0 100 200
Feet

N

Tighe&Bond
Engineers | Environmental Specialists

Based on MassGIS Color Orthophotography (2013).

FIGURE 5
JANUARY 4, 2018 KING TIDE MODEL INUNDATION AREA

Manchester-by-the-Sea
Sawmill Brook Feasibility Study

April 2018

V:\Projects\M\m1476\SawmillBrook_InundationFigures\SawmillBrook_MA_KingTideModelInundation.mxd

M-1476

study as approximately 8.2 feet NAVD88. The 2016 study estimated that the annual storm surge elevation in 2100 would overtop Central Street so future storm surge scenarios were not modeled.

The sea level rise increase in 2100 used for this study is 2 feet. This value falls within the 66% probability range provided in the Northeast Climate Science Center (NECSC) sea level rise projections for the Boston area for the two emissions scenarios evaluated[7]. The MHHW elevation accounting for sea level rise was therefore 6.77 feet NAVD88. The future (2100) flow estimates with Balanced Energy Use from the 2016 study were used for this study.

The geometry of the proposed culvert was selected so that it could pass the present (2018) and future (2100) 25- and 50-year frequency storm events. Table 3 summarizes the capacity of Central Street for existing (tide gate open and closed) and proposed conditions. Note that under existing conditions Central Street could not pass the present 25-year storm event during MHHW whether or not the tide gate is open. Figure 6 shows present 25-year frequency storm event during MHHW inundation area for existing (tide gate open and closed) and proposed conditions. The 25-year inundation area during MHHW is highest for existing conditions when the tide gate is closed, though it is similar to the inundation area if the tide gate were open. Note that the inundation areas are approximately the same upstream of School Street for existing (tide gate open or closed) and proposed conditions.

TABLE 3

Overtopping of Central Street for Existing and Proposed Conditions

Model Scenario[1]	Existing Conditions Tide Gate Open	Existing Conditions Tide Gate Closed	Proposed Conditions[2]
Present (2018) 25-Year	Overtops	Overtops	Capacity
Present (2018) 50-Year	Overtops	Overtops	Capacity
Present (2018) 100-Year	Overtops	Overtops	Overtops
Future (2100) 25-Year	Overtops	Overtops	Capacity
Future (2100) 50-Year	Overtops	Overtops	Capacity
Future (2100) 100-Year	Overtops	Overtops	Overtops
Present (2018) 25-Year with Storm Surge	Overtops	Overtops	Capacity
Present (2018) 50-Year with Storm Surge	Overtops	Overtops	Overtops
Present (2018) 100-Year with Storm Surge	Overtops	Overtops	Overtops

[1] "Sawmill Brook Culvert and Green Infrastructure Analysis Task 4 Final Report: Evaluation of Locations for Flood Mitigation" prepared by Tighe & Bond, February 2016.

[2] The proposed conditions involve removing the tide gate and providing an 18-foot wide Conspan arch culvert. The proposed culvert would maintain the existing upstream and downstream invert elevations and provide a constant low chord elevation of 6 feet NAVD88.

[7] Northeast Climate Science Center (NECSC) "Massachusetts Climate Change Projections - Statewide and for Major River Basins" for the Massachusetts Executive Office of Energy and Environmental Affairs, January 2018. Available from http://www. massclimatechange.org/.

Note:

1. The 25-year frequency storm event inundation areas were calculated using a steady-state HEC-RAS model with a Mean Higher High Water (MHHW) boundary condition and using flows calculated from the 2015 H&H study performed by Tighe & Bond.
2. All elevations are in the North American Vertical Datum of 1988 (NAVD88).
3. Topographic and bathymetric data from modeling was from survey by Doucet Survey Inc. performed in December 2017 and from MassGIS LiDAR data.

Stanley Avenue
Bell Court
Flatley Avenue
Filias Circle
Maple Avenue
Vine Street
Burnham Lane
Sumac Lane
Friend Street
Putnam Court
Brook Street
Knight Circle
Desmond Avenue
Powder House Lane
School Street
North Street
Elm Street
Morse Court
Norwood Avenue
Smith Lane
Washington Street
Sea Street
Central Street
Peele House Square
Church
Chapel Lane
Beach Street
Summer Street
127
Tappan Street
Manchester Harbor
Sawmill Brook

2510 feet
2480 feet
2350 feet
2230 feet
2600 feet
2550 feet
2070 feet
1870 feet
1730 feet
1360 feet
1090 feet
1510 feet
1560 feet
1220 feet
1020 feet
930 feet
830 feet
710 feet
650 feet
580 feet
500 feet
370 feet
310 feet
250 feet
200 feet
90 feet
20 feet
-30 feet
-40 feet
-70 feet
-100 feet

Central Street Bridge
(existing tide gate located immediately downstream)
Overtopping anticipated for existing conditions, but not for proposed improvements.

LEGEND

- Model Cross Section (label indicates feet upstream of Central Street)
- Proposed Conditions 25-year Storm Flow (Larger Culvert, and tidegate removed) Inundation Area
- Existing Conditions Tide Gate Open 25-year Storm Flow Inundation Area
- Existing Conditions Tide Gate Closed 25-year Storm Flow Inundation Area

1 in = 200 ft

0 100 200
Feet

N

Tighe&Bond
Engineers | Environmental Specialists

Based on MassGIS Color Orthophotography (2013).

FIGURE 6
25-YEAR FREQUENCY STORM EVENT INUNDATION AREA

Manchester-by-the-Sea
Sawmill Brook Feasibility Study

April 2018

V:\Projects\M\m1476\SawmillBrook_InundationFigures\SawmillBrook_MA_25Yr_StormEvent_Inundation.mxd

M-1476

3.2 Flushing Study

3.2.1 Tidal Prism

A flushing study of the immediate harbor and Central Pond was completed, based on tides and stream discharge. The tidal range, volume of water moving in and out of Central Pond through the stream channel and harbor, were estimated, and a tidal prism developed to calculate volumetric turnover.

The tidal range was determined by subtracting the volume of water stored in Sawmill Brook during the average low tide from the volume of water stored in Sawmill Brook during the average high tide. The average high tide observed during surface water monitoring in Manchester Harbor was approximately 4.7 feet NAVD88, and the average low tide was -4.9 feet NAVD88. The low tide elevations within Central Pond is limited by the tide gate elevation (4.6 feet NAVD88) when the tide gate is closed, and the Central Street culvert inlet (0.2 feet NAVD88) when the tide gate is open. The Central Street culvert inlet would also be the low-level control for proposed conditions (the proposed improvements would maintain the invert elevation).

The calibrated HEC-RAS hydraulic model was used model low tide and high tide conditions for existing conditions (tide gate open and closed) and proposed conditions. A baseflow of 14 cubic feet per second was provided based on the average Fall and Spring baseflow measurements shown in Table 1. Water surface elevation grids were exported from HEC-RAS for each model scenario and then imported into AutoCAD Civil3D as surfaces. The AutoCAD Civil3D surface volume tools were used to calculate the volumes during low and high tide for each scenario using the water surface elevation surfaces and the surveyed topographic surface provided by Survey Inc. from their November 2017 survey.

Table 4 shows the tidal volumes for existing conditions (tide gate open and closed) and proposed conditions. The tidal prism for existing conditions with the tide gate closed is relatively small (0.2 acre-feet) due the high tide only extends approximately 0.1 feet above the tide gate elevation, preventing the opportunity for tidal fluctuation. Low tide is lower than the bottom elevation of Central Pond, so the Central Street culvert inlet is the control for existing conditions with the tide gate open and for proposed conditions. The tidal prism for both these scenarios is controlled by tailwater backing up fresh water so the tidal prism is approximately the same for both (4.5 acre-feet and 4.4 acre-feet, respectively). The slight reduction in tidal prism is due to slightly lower high tide water levels in Central Pond if the tide gate were removed because the proposed hydraulic constriction (larger culvert with tide gate removed) would cause less of a backup than the existing constriction (smaller culvert with the tide gate). The tidal prism observed for conditions when the tide gate is open can be considered a reasonable approximation for anticipated proposed conditions.

TABLE 4

Central Pond and Sawmill Brook Tidal Range[1]

Model Scenario	Low Tide Volume (cubic yard)	High Tide Volume (cubic yard)	Tidal Prism (cubic yard)	Tidal Prism (acre-feet)
Existing Conditions (Tide Gate Closed)	7,430	7,700	270	0.2
Existing Conditions (Tide Gate Open)	510	7,700	7,190	4.5
Proposed Conditions[1]	510	7,670	7,160	4.4

[1] The proposed conditions involve removing the tide gate and providing an 18-foot wide Conspan arch culvert. The proposed culvert would maintain the existing upstream and downstream invert elevations and provide a constant low chord elevation of 6 feet NAVD88.

3.2.2 Salinity Profile and Flushing Time

Salinity profiles were developed along transects upstream and downstream of Central Street on April 18, 2018 during high tide while the tide gate was open. Figure 8 and Figure 9 show the salinity measured at varying depths along the transects upstream and downstream of Central Street, respectively. The salinity concentration upstream of Central Street was approximately 0.2 ppt within 2 feet of the water surface, and increased with the depth. The salinity concentrations downstream of Central Street increased from the water surface elevation to a depth of 2 feet, before stabilizing at approximately 26 ppt for all transects. The fresh and salt water do not appear to be well mixed, with fresh water generally observed at the surface, and salt water tending to settle toward the bottom of the water column. The salt concentrations observed upstream of Central Street can be considered highly stratified.

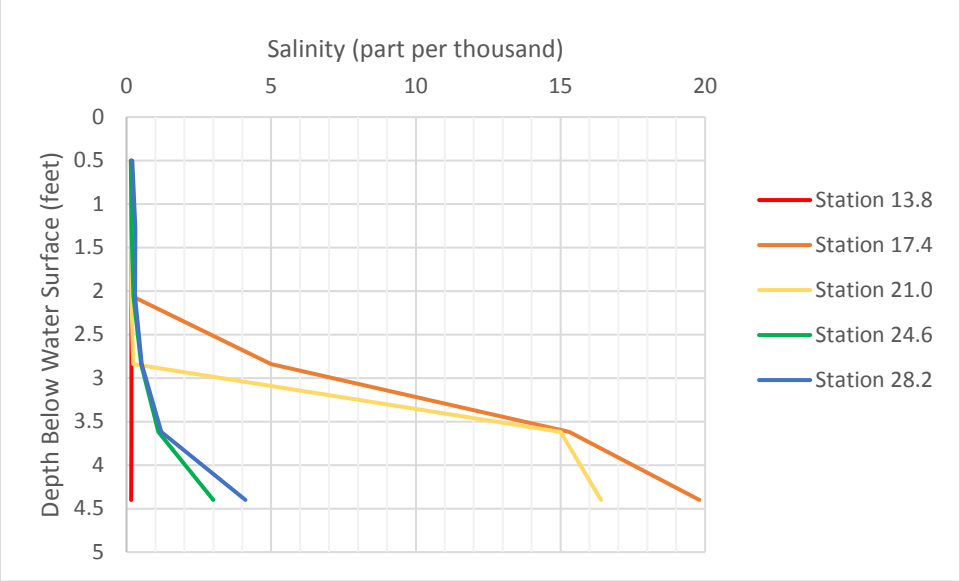


FIGURE 8
Salinity Profile Upstream of Central Street

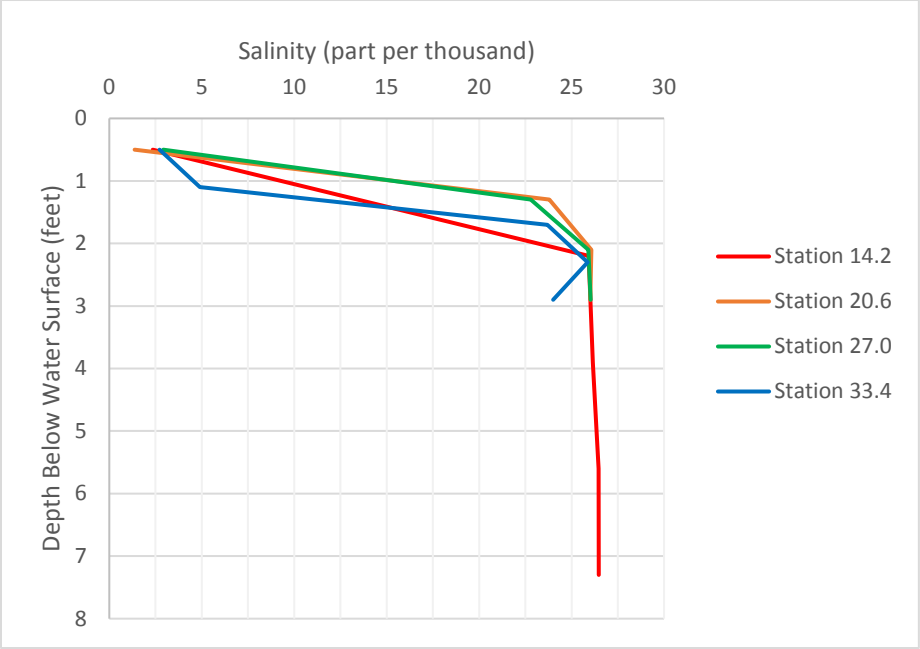


FIGURE 9
Salinity Profile Downstream of Central Street

The average salinity upstream of Central Street was calculated as approximately 1.7 part per thousand (ppt), whereas the average salinity downstream of Central Street was calculated as 19.8 ppt. The salinity decreases by an order of magnitude through Central Street, indicating that Central Pond is fresh water dominant. The tidal prism is therefore likely occurring primarily due to tailwater backing up fresh water from upstream and not flowing salt water. The salinity at School Street and Norwood Avenue was measured at 0.13 ppt, supporting this observation. The fraction of salt water from Manchester Harbor was estimated using the concentration dilution formula as shown in Appendix D. It is estimated that approximately 10-percent of the flow located upstream of Central Street is salt water from Manchester Harbor and the remaining 90-percent is fresh water from Sawmill Brook. It should be noted that salinity measurements were collected during the non-growing season for saltwater vegetation. It is possible that during the late spring and summer growing season that the fresh water stream influence could be less (particularly during periods of low baseflow), potentially resulting in higher salinities in Central Pond.

The flushing time was estimated using the Knudsen Formula[8], which is considered suitable for highly stratified estuaries as observed at Central Pond for the conditions observed during the high tide on April 18, 2018 while the tide gate was open. The inputs for the calculation include the tidal prism volume, the discharge leaving Central Pond, the salinity at the top of the water column, and the salinity at the bottom of the water column. The flushing time is estimated to be approximately 2 hours, as shown in Appendix D. Due to the similarity in the tidal prism between existing conditions with the tide gate open and proposed conditions, it is anticipated that the flushing time and salinity profile would be similar for proposed conditions as were observed while the tide gate was open.

[8] Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO) “Flushing Time”. https://www.mtoceanography.info/ShelfCoast/notes/chapter15.html.

4 Conclusions

4.1.1 Observed Response to Changing Hydrologic Conditions

Base flow was measured during low flow conditions in the fall and high spring flows. A gradual increase in water levels was observed over the five-month monitoring period, with accelerated rise from March- April due to above average precipitation.

Precipitation was measured at the Manchester Wastewater Treatment Plant, within a mile from Sawmill Brook. The winter(December-February) monthly precipitation totals were average, and spring (March-April) monthly precipitations totals were above average, with a maximum 24-hour precipitation of 1.98 inches recorded on April 16. This amount is equal to the regional 1-year 24-hour recurrence interval precipitation event[9]. This precipitation amount is common, and expected to occur every year. Sawmill Brook surface water elevation rapidly rose with almost every recorded precipitation event.

Backwater effects at School Street and Norwood Avenue due to culvert restrictions were not detected. The culverts are not currently sized to accommodate a 25-year 24-hour storm; however, they are likely designed to pass either the 2- or 10-year 24-hour storm events, so backwater impacts would not be expected with the size of precipitation events observed during the five-month monitoring period.

Tailwater conditions created by the fluctuating tide levels were observed in the hydrographs at upstream locations, including C-1, A1 and A2. Tidal prism results indicate that Central Pond is fresh water dominant. The tidal impacts observed on the hydrographs upstream are due to the rising water levels at the Central Street Bridge transferring pressure head upstream, and not actual saltwater inundation.

Tidal restrictions during high tide were not observed at the Central Street Bridge when the tide gate was closed. The tide gate crest elevation of 4.6 was set to provide drainage for high stream flows. Salt water flowed freely into the Pond over the tide gate once the Harbor elevations rose above elevation 4.6 feet NAVD88. The average high tide elevation of 4.7 is consistent with observed surface water elevation in Central Pond.

4.1.2 Modeling Results and Implications for Restoration

The modeling reinforced the observed similarity in high tide impacts to Central Pond whether tide gate is open or closed. For example, the modeled maximum water surface elevation calibrated for the January 2018 record high tide conditions were approximately the same whether the tide gate was open, or whether the proposed improvements had taken place. The 25-year inundation area during MHHW is highest for existing conditions when the tide gate is closed, though it is similar to the inundation area if the tide gate were open. The proposed Central Street Bridge improvements would be anticipated to reduce the 25-year inundation area due to increased hydraulic capacity through the Central Street Bridge. The inundation areas are approximately the same upstream of School Street for existing conditions (tide gate open or closed) and proposed conditions, in agreement with observed conditions in the field.

[9] https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=ma

Field sampling and modeling indicate that Central Pond is fresh water dominant. The flushing time is estimated to be approximately two hours, although the salinity was substantially lower upstream of Central Street than within Manchester Harbor. The tidal prism is therefore likely occurring primarily due to tailwater backing up fresh water from upstream and not flowing salt water. The low salinity measured at School Street and Norwood Avenue further support this observation. Due to the similarity in the tidal prism between existing conditions with the tide gate open and proposed conditions, it is anticipated that the flushing time and salinity profile would be similar for proposed conditions as were observed while the tide gate was open.

4.1.3 Long term gage and logger maintenance recommendations

The data collection completed during the winter/spring of 2017/2018 was sufficient to complete the feasibility assessment tasks. The next steps for Sawmill Brook restoration will be completing the design and permitting of the tide gate removal and Central Street Bridge repairs, and a restoration plan for Central Street Pond. Maintaining water level observations over the long term will provide the data to track any periodic or long-term changes to water levels during and after the restoration projects are completed.

A potential plan for long term monitoring would be to maintain Gages C1, C2 and A2 on a reduced schedule. Ongoing monitoring would support the restoration efforts planned for Central Pond and Central Street Bridge by tracking long-term changes in water level response. The reduced monitoring plan would include:

- Resetting the pressure transducer interval from 6 minutes to 30 minutes.
- Downloading the pressure transducer data quarterly. (September, December, March, June).
- Reducing the volunteer observations at the gages and headwalls from weekly to monthly.
- Removing any gathering debris from the gages and loggers quarterly or more often if needed.

APPENDIX A

TOWN OF MANCHESTER-BY-THE-SEA, MASSACHUSETTS

SAWMILL BROOK EXISTING CONDITIONS & TOPOGRAPHIC PLAN

CENTRAL STREET TO NORWOOD AVENUE

LIST OF DRAWINGS	
SHEET NO.	SHEET TITLE
1	COVER
2	NOTES
3	STA. 0+00 TO STA. 4+60
4	STA. 4+60 TO STA. 8+60
5	STA. 8+60 TO STA. 14+45
6	STA. 14+45 TO STA. 21+10
7	STA. 21+10 TO STA. 27+43
8	CROSS SECTION VIEWS OF SAWMILL BROOK PREPARED BY DOUCET SURVEY, INC., DECEMBER 2017 (SHEET 7 OF 8)
9	CROSS SECTION VIEWS OF SAWMILL BROOK PREPARED BY DOUCET SURVEY, INC., DECEMBER 2017 (SHEET 8 OF 8)

LOCATION MAP
SCALE: 1" = 2000'

PREPARED BY:
Tighe&Bond
www.tighebond.com

PROGRESS DRAFT
NOT FOR CONSTRUCTION

COMPLETE SET 9 SHEETS

Last Saved: 1/8/2018
Plotted: Jan 08, 2018 - 12:32pm By: CFY
Tighe & Bond: J:\MW\1476 Manchester MA Hydro Study\009_MET_Sawmill Feasibility\Drawings_Figures\AutoCAD\Sheet\COVER.dwg

NOTES:

1. REFERENCE: SAW MILL BROOK
   BRIDGE STREET TO NORWOOD AVE.
   MANCHESTER–BY–THE–SEA, MA
   D.S.I. PROJECT NO. 4536

2. FIELD SURVEY PERFORMED BY J.M.L. & J.C.M. DURING NOVEMBER 2017 USING A TRIMBLE S6 TOTAL STATION WITH A TRIMBLE TSC3 DATA COLLECTOR AND A. TRAVERSE ADJUSTMENT BASED ON LEAST SQUARE ANALYSIS.

3. HORIZONTAL DATUM BASED ON MASSACHUSETTS MAINLAND ZONE NAD83(2011) DERIVED FROM REDUNDANT GPS OBSERVATIONS UTILIZING THE KEYNET GPS VRS NETWORK.

4. VERTICAL DATUM IS BASED ON NAVD88 DERIVED FROM REDUNDANT GPS OBSERVATIONS UTILIZING THE KEYNET GPS VRS NETWORK AND CALIBRATED TO THREE MASSDOT GEODETIC CONTROL STATIONS.

5. PROPER FIELD PROCEDURES WERE FOLLOWED IN ORDER TO GENERATE CONTOURS AT 2' INTERVALS. ANY MODIFICATION OF THIS INTERVAL WILL DIMINISH THE INTEGRITY OF THE DATA, AND DOUCET SURVEY, INC. WILL NOT BE RESPONSIBLE FOR ANY SUCH ALTERATION PERFORMED BY THE USER.

6. THE ACCURACY OF MEASURED UTILITY INVERTS AND PIPE SIZES/TYPES IS SUBJECT TO NUMEROUS FIELD CONDITIONS, INCLUDING; THE ABILITY TO MAKE VISUAL OBSERVATIONS, DIRECT ACCESS TO THE VARIOUS ELEMENTS, MANHOLE CONFIGURATION, ETC.

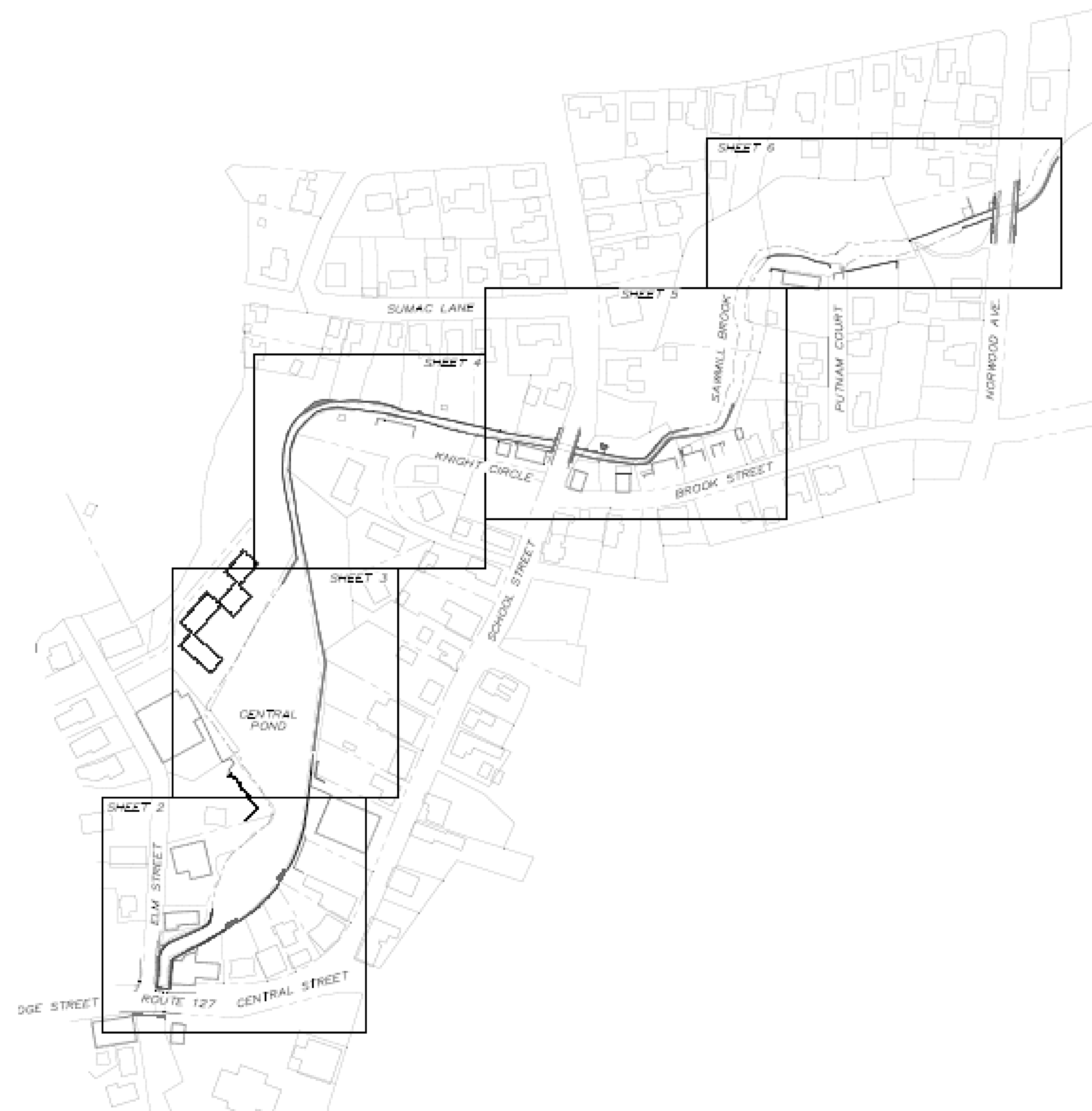
7. ALL ELECTRIC, GAS, TEL. WATER, SEWER AND DRAIN SERVICES ARE SHOWN IN SCHEMATIC FASHION, THEIR LOCATIONS ARE NOT PRECISE OR NECESSARILY ACCURATE. NO WORK WHATSOEVER SHALL BE UNDERTAKEN ON THIS SITE USING THIS PLAN TO LOCATE THE ABOVE SERVICES. CONSULT WITH THE PROPER AUTHORITIES CONCERNED WITH THE SUBJECT SERVICE LOCATIONS FOR INFORMATION REGARDING SUCH. CALL DIG–SAFE AT 1–888–DIG–SAFE.

8. WETLAND DELINEATION BY TIGHE & BOND, INC. WETLANDS TO THE NORTH–EAST OF NORWOOD AVENUE WERE DELINEATED ON JANUARY 23, 2017, AND FIELD LOCATED AS PART OF FIELD SURVEY BY CORNER POST LAND SURVEYING, INC., DATED MARCH 10, 2017. WETLANDS ALONG SAWMILL BROOK AND CENTRAL POND NORTH OF CENTRAL STREET AND SOUTH OF NORWOOD AVENUE WERE DELINEATED ON APRIL 18, 2018, AND FIELD LOCATED AS PART OF SURVEY BY DOUCET SURVEY, INC., DATED DECEMBER 2017.

9. FEMA FLOOD ZONES WITH REVISIONS ARE BASED ON FIRM PANELS FOR MANCHESTER–BY–THE–SEA, EFFECTIVE DATE JULY 16, 2014 AND APPROVED LETTER OF MAP REVISIONS FOR MANCHESTER BAY VIA MANCHESTER HARBOR AND BLACKS COVE, EFFECTIVE DATE JANUARY 2, 2017. SPECIAL FLOOD HAZARD AREAS (SFHA) INUNDATED BY 100–YEAR FLOOD SOURCES INCLUDES ZONES A, AE, AH, AO, V AND VE.

LEGEND

	GIS LOT LINE
SD	DRAIN LINE
10	MAJOR CONTOUR LINE
8	MINOR CONTOUR LINE
	CONCRETE
	RIP RAP
	WALL RUBBLE
	VARIABLE WIDTH RETAINING WALL
WV	WATER GATE VALVE
	CATCH BASIN
D	DRAIN MANHOLE
S	SEWER MANHOLE
▲	DATA COLLECTION LOCATION
	LEDGE OUTCROP
	DRAINAGE FLOW DIRECTION ARROW
TYP	TYPICAL
EP	EDGE OF PAVEMENT
VGC	VERTICAL GRANITE CURB
SBB	SLOPED BITUMINOUS BERM
BC	BITUMINOUS CURB
1D–4	BANK FLAG
1E–1	WETLANDS FLAG
	EDGE OF WETLANDS
	TOP OF BANK
	TOP OF BANK OBSERVED BY SURVEY



Tighe&Bond
www.tighebond.com

NOT FOR CONSTRUCTION

Sawmill Brook Existing Conditions & Topographic Plan

Central Street to Norwood Ave

Manchester -by-the-Sea, MA

VERIFY SCALE
BAR IS 1 INCH ON ORIGINAL DRAWING
0 ▬▬▬ 1 INCH
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY

May 2018

MARK	DATE	DESCRIPTION

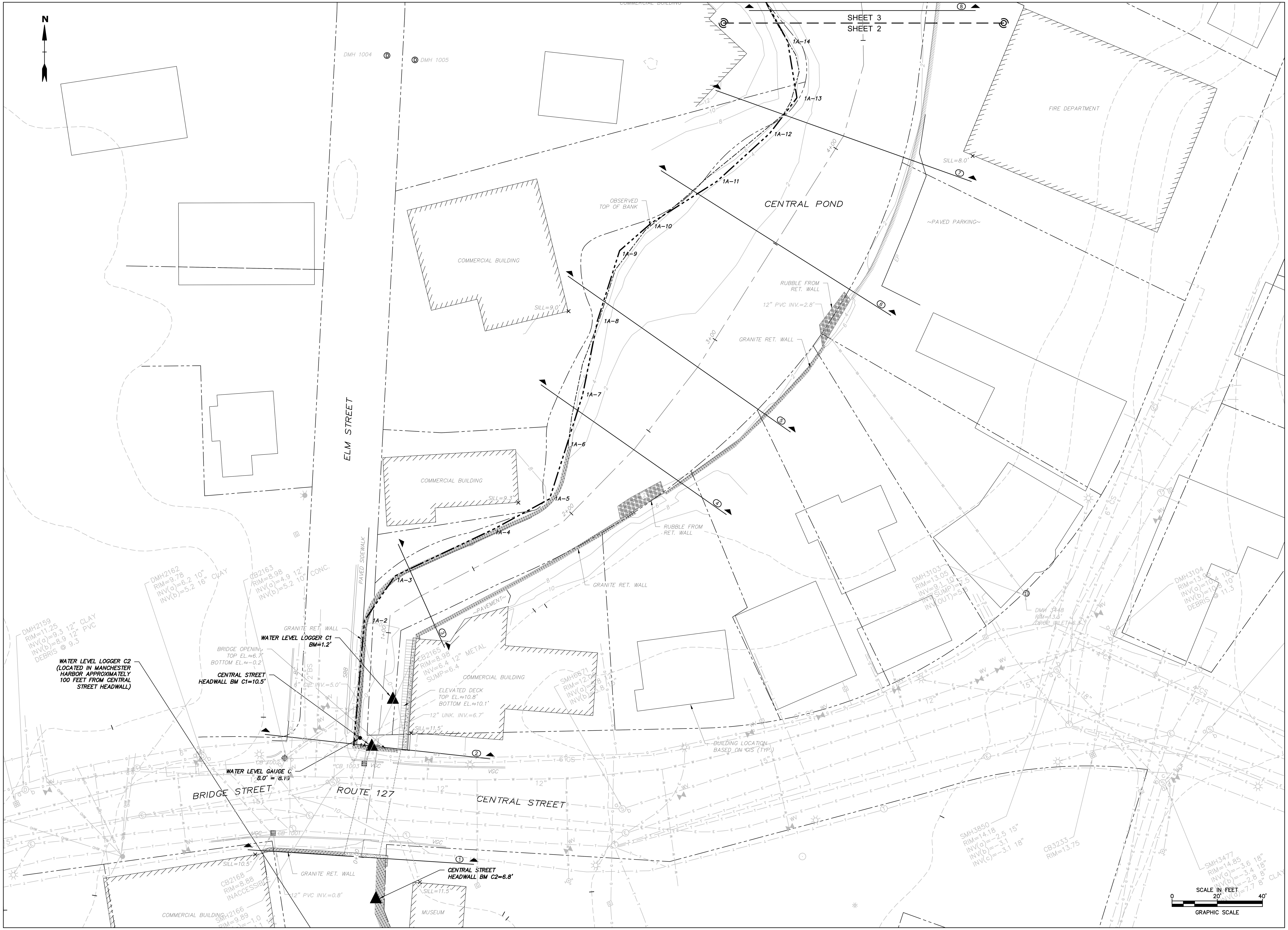
PROJECT NO:	22–1467
DATE:	2018/01
FILE: Site Plan.dwg	
DRAWN BY:	GSH
CHECKED:	XX
APPROVED:	GCB

NOTES

SCALE: 1" = 20'

G-01

Last Saved: 5/10/2018
Plotted On:May 10, 2018-2:44pm By: BJL
Tighe & Bond, Inc. \\tighebond.com\data\Data\Projects\M\M1476 Manchester MA Hydro Study\009_MET_Sawmill Feasibility\Drawings_Figures\AutoCAD\Sheet\Site Plan.dwg


N
SHEET 3
SHEET 2
DMH 1004
DMH 1005
FIRE DEPARTMENT
SILL=8.0'
1A-14
1A-13
1A-12
1A-11
1A-10
1A-9
1A-8
1A-7
1A-6
1A-5
1A-4
1A-3
1A-2
OBSERVED TOP OF BANK
CENTRAL POND
~PAVED PARKING~
COMMERCIAL BUILDING
SILL=9.0'
RUBBLE FROM RET. WALL
12" PVC INV.=2.8'
GRANITE RET. WALL
ELM STREET
COMMERCIAL BUILDING
SILL=9.3'
RUBBLE FROM RET. WALL
GRANITE RET. WALL
PAVED SIDEWALK
DMH2162 RIM=9.78 INV(a)=6.2 10" INV(b)=5.2 16" CLAY
CB2163 RIM=8.98 INV(a)=4.9 12" INV(b)=5.2 10" CONC.
DMH2159 RIM=11.25 INV(a)=9.3 12" CLAY INV(b)=8.9 12" PVC DEBRIS @ 9.3
GRANITE RET. WALL
WATER LEVEL LOGGER C1 BM=1.2'
BRIDGE OPENING TOP EL.≈6.7' BOTTOM EL.≈-0.2'
WATER LEVEL LOGGER C2 (LOCATED IN MANCHESTER HARBOR APPROXIMATELY 100 FEET FROM CENTRAL STREET HEADWALL)
CENTRAL STREET HEADWALL BM C1=10.5'
CB2165 RIM=8.98 INV=6.4 12" METAL SUMP=6.4
COMMERCIAL BUILDING
ELEVATED DECK TOP EL.≈10.8' BOTTOM EL.≈10.1'
12" UNK. INV.=6.7'
SILL=11.5'
DMH3103
DMH3104
BUILDING LOCATION BASED ON GIS (TYP)
WATER LEVEL GAUGE C 8.0' = 8.15
BRIDGE STREET
ROUTE 127
CENTRAL STREET
SILL=10.5'
CB2168 RIM=8.88 INACCESSIBLE
GRANITE RET. WALL
12" PVC INV.=0.8'
CENTRAL STREET HEADWALL BM C2=6.8'
SILL=11.5'
MUSEUM
COMMERCIAL BUILDING
SMH3850 RIM=14.18 INV(a)=-2.5 15" INV(b)=-3.1 INV(c)=-3.1 18"
CB3233 RIM=13.75
SMH3477 RIM=14.85
SCALE IN FEET
0
20'
40'
GRAPHIC SCALE

Tighe&Bond
www.tighebond.com

NOT FOR CONSTRUCTION

Sawmill Brook Existing Conditions & Topographic Plan

Central Street to Norwood Ave

Manchester -by-the-Sea, MA

VERIFY SCALE
BAR IS 1 INCH ON ORIGINAL DRAWING
0 — 1 INCH
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY

May 2018

MARK	DATE	DESCRIPTION

PROJECT NO:	22-1467
DATE:	2018/01
FILE:	Site Plan.dwg
DRAWN BY:	GSH
CHECKED:	XX
APPROVED:	GCB

EXISTING CONDITIONS STA. 0+00 TO STA. 4+60

SCALE: 1" = 20'

C-01

Last Saved: 5/10/2018
Plotted On:May 10, 2018-2:21pm By: BJL
Tighe & Bond, Inc. \\tighebond.com\data\Data\Projects\M\M1476 Manchester MA Hydro Study\009_MET_Sawmill Feasibility\Drawings_Figures\AutoCAD\Sheet\Site Plan.dwg

Tighe&Bond
www.tighebond.com

NOT FOR CONSTRUCTION

Sawmill Brook Existing Conditions & Topographic Plan

Central Street to Norwood Ave

Manchester -by-the-Sea, MA

VERIFY SCALE
BAR IS 1 INCH ON ORIGINAL DRAWING
0 1 INCH
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY

May 2018

MARK	DATE	DESCRIPTION

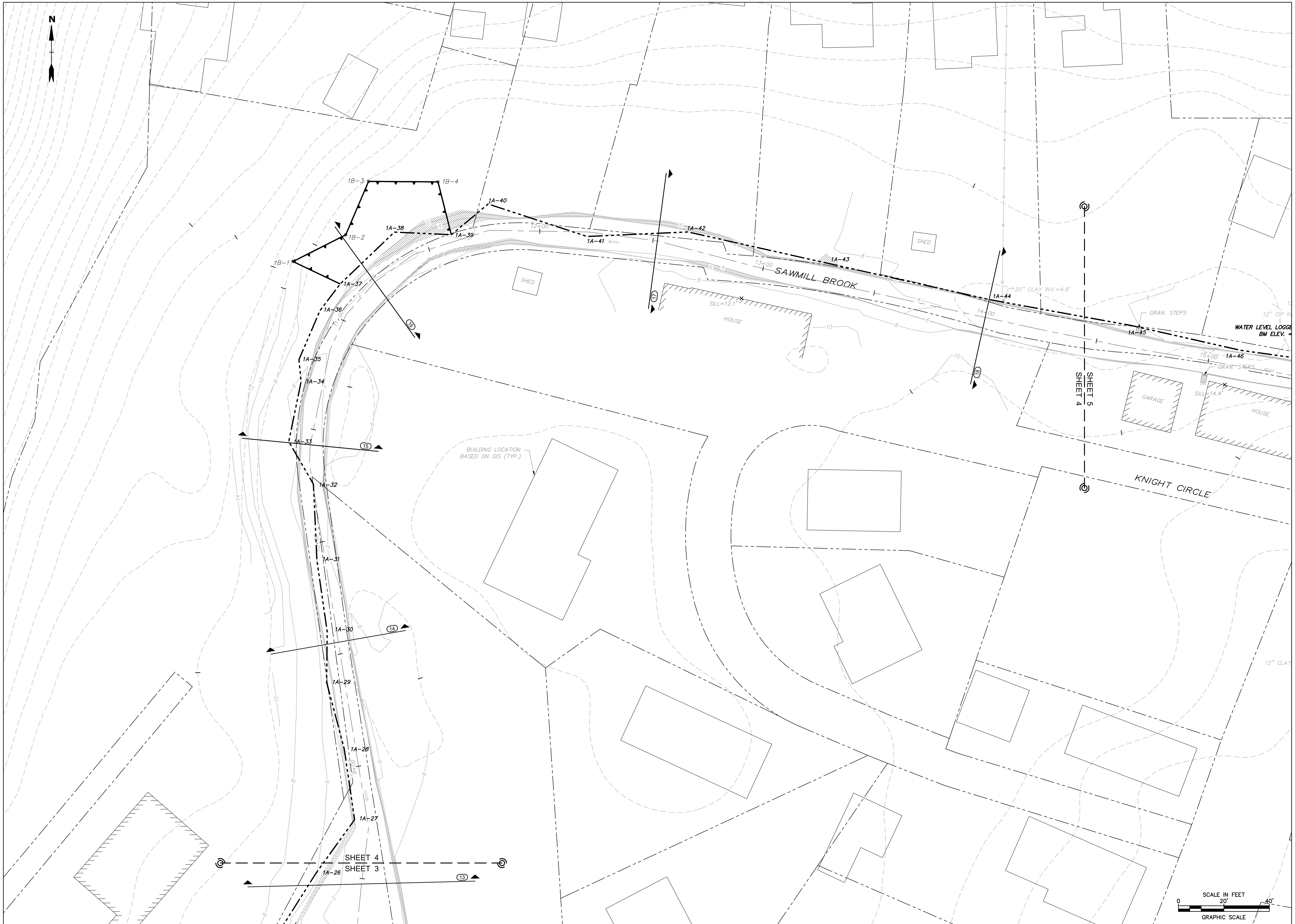
PROJECT NO:	22-1467
DATE:	2018/01
FILE: Site Plan.dwg	
DRAWN BY:	GSH
CHECKED:	XX
APPROVED:	GCB

EXISTING CONDITIONS STA. 4+60 TO STA. 8+60

SCALE: 1" = 20'

C-02

Last Saved: 5/10/2018
Plotted On:May 10, 2018-2:20pm By: BJL
Tighe & Bond, Inc. \\tighebond.com\data\Data\Projects\M\M1476 Manchester MA Hydro Study\009_MET_Sawmill Feasibility\Drawings_Figures\AutoCAD\Sheet\Site Plan.dwg



Tighe&Bond
www.tighebond.com

NOT FOR CONSTRUCTION

Sawmill Brook Existing Conditions & Topographic Plan

Central Street to Norwood Ave

Manchester -by-the-Sea, MA

VERIFY SCALE
BAR IS 1 INCH ON ORIGINAL DRAWING
0 — 1 INCH
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY

May 2018

MARK	DATE	DESCRIPTION

PROJECT NO:	22-1467
DATE:	2018/01
FILE:	Site Plan.dwg
DRAWN BY:	GSH
CHECKED:	XX
APPROVED:	GCB

EXISTING CONDITIONS STA. 8+60 TO STA. 14+45

SCALE: 1" = 20'

C-03

Last Saved: 5/10/2018
Plotted On:May 10, 2018-2:18pm By: BJL
Tighe & Bond, Inc. \\tighebond.com\data\Data\Projects\M\M1476 Manchester MA Hydro Study\009_MET_Sawmill Feasibility\Drawings_Figures\AutoCAD\Sheet\Site Plan.dwg

N

SHEET 6
SHEET 5

SHEET 5
SHEET 4

1A–58 1C–6 1C–4 1C–3 1C–2 1C–1 1A–57 1A–56 1A–55 1A–54 1A–53 1A–52 1A–51 1A–50 1A–49 1A–48 1A–47 1A–46 1A–45

1D–4 1D–5 1D–6 1D–7 1D–8

1E–1 1E–2 1E–3

21+00 20+00 19+00 18+00 17+00 16+00 15+00

SAWMILL BROOK

OBSERVED TOP OF BANK

DROP INLET W/GRAN. COVER
15" CLAY INV.=11.3'

CLAY INV.=4.8'

GRAN. STEPS

GRAN. BRIDGE ABUTMENT

12" CIP INV.=11.8'

12" CIP INV.=10.0'

WATER LEVEL LOGGER B2
BM ELEV. = 5.5'

WATER LEVEL LOGGER B1
BM ELEV. = 5.8'

PAVED SIDEWALK

VCC

CB 2511

15" CLAY INV.=6.7'

LEDGE OUTCROP

PAVED SWALE

CUT–OUT
UNK. INV.=9.5'

SSB

12" PVC INV.=7.8'

BUILDING LOCATION BASED ON GIS (TYP.)

SILL=14.1'

GARAGE

SILL=19.4'

HOUSE

DECK

SILL=17.9'

SILL=10.1'

SILL=16.0'

SILL=18.4'

SILL=18.6'

PORCH

CB 7000

CB 2619
RIM=14.3'
12" CLAY INV.=11.9'

KNIGHT CIRCLE

SCHOOL STREET

BROOK STREET

SCALE IN FEET
0 20' 40'
GRAPHIC SCALE

Last Saved: 5/10/2018
Plotted: 5/10/2018 2:15pm By: RJL
Tighe & Bond, Inc. \\tighebond.com\data\Data\Projects\M\M1476 Manchester MA Hydro Study\009_MET_Sawmill Feasibility\Drawings_Figures\AutoCAD\Sheet\Site Plan.dwg

Tighe&Bond
www.tighebond.com

NOT FOR CONSTRUCTION

Sawmill Brook Existing Conditions & Topographic Plan

Central Street to Norwood Ave

Manchester
-by-the-Sea, MA

VERIFY SCALE
BAR IS 1 INCH ON ORIGINAL DRAWING
0 1 INCH
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY

May 2018

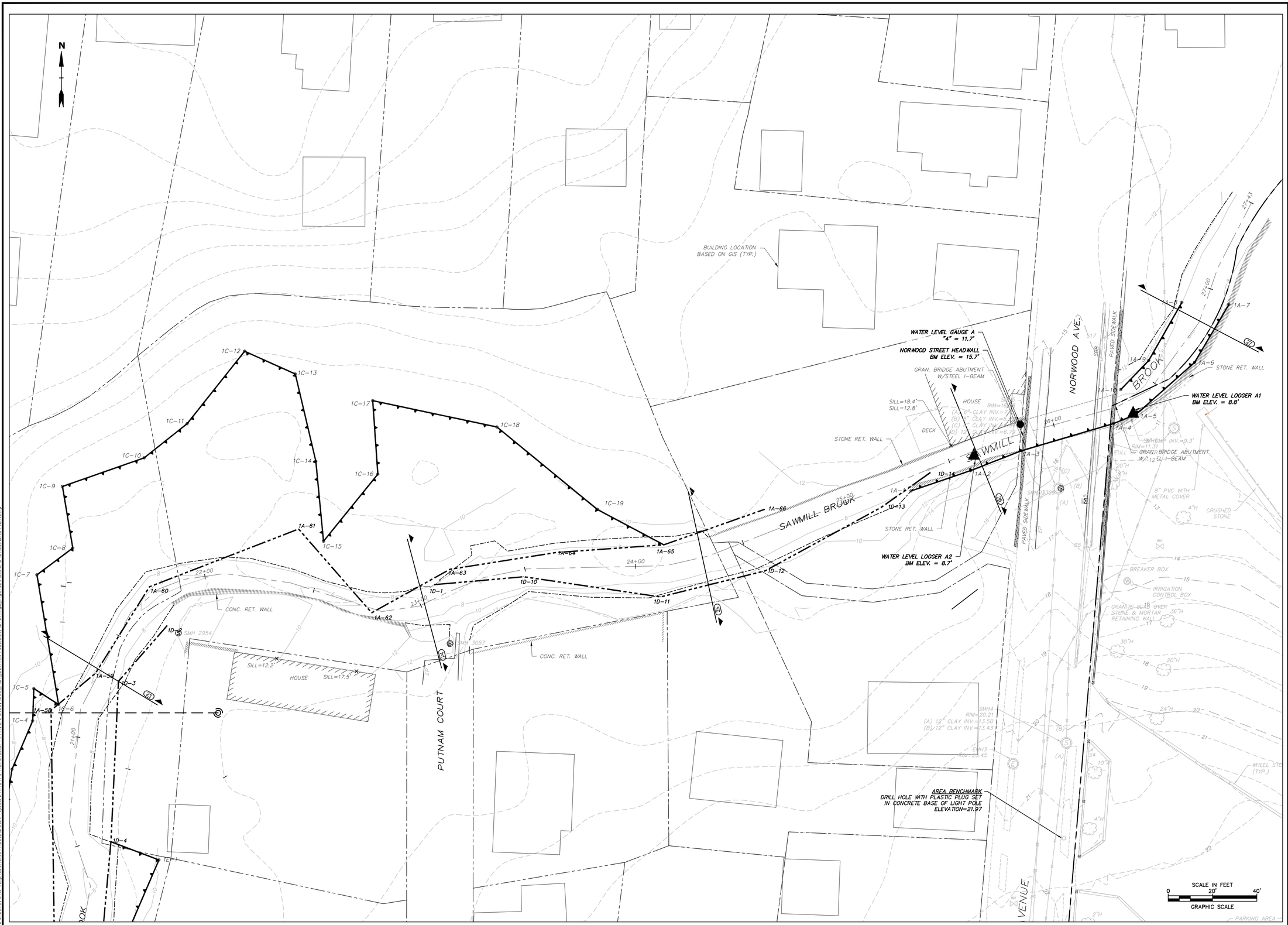
MARK	DATE	DESCRIPTION

PROJECT NO:	22–1467
DATE:	2018/01
FILE:	Site Plan.dwg
DRAWN BY:	GSH
CHECKED:	XX
APPROVED:	GCB

EXISTING CONDITIONS STA. 14+45 TO STA. 21+10

SCALE: 1" = 20'

C-04



Last Saved: 5/10/2018 By: BJL
Last Plotted: 10/5/2018 By: BJL
Tighe & Bond, Inc. \\tighebond.com\data\Data\Projects\M\M1476 Manchester MA Hydro Study\009_MET_Sawmill Feasibility\Drawings_Figures\AutoCAD\Sheet\Site Plan.dwg

Tighe&Bond
www.tighebond.com

NOT FOR CONSTRUCTION

Sawmill Brook Existing Conditions & Topographic Plan

Central Street to Norwood Ave

Manchester
-by-the-Sea, MA

VERIFY SCALE
BAR IS 1 INCH ON ORIGINAL DRAWING
0 — 1 INCH
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY

May 2018

MARK	DATE	DESCRIPTION

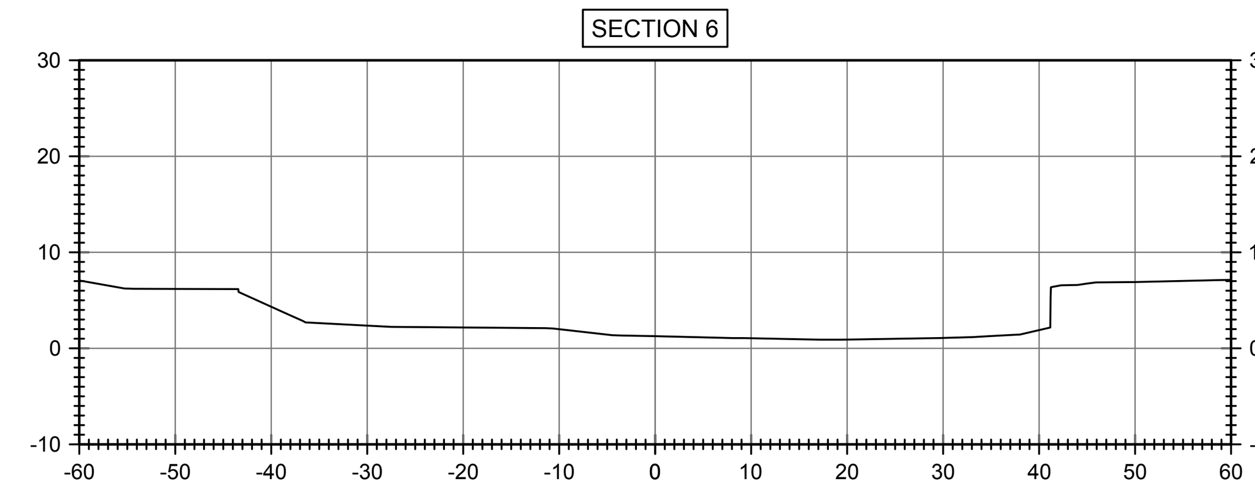
PROJECT NO:	22-1467
DATE:	2018/01
FILE:	Site Plan.dwg
DRAWN BY:	GSH
CHECKED:	XX
APPROVED:	GCB

EXISTING CONDITIONS STA. 21+10 TO STA. 27+43

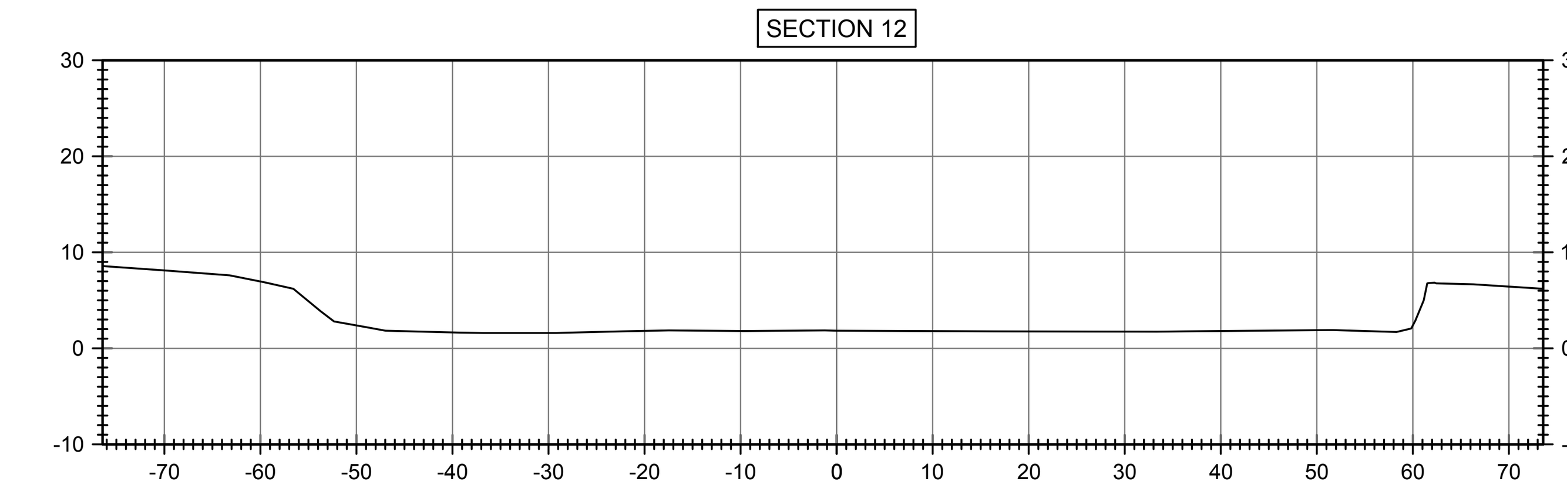
SCALE: 1" = 20'

C-05

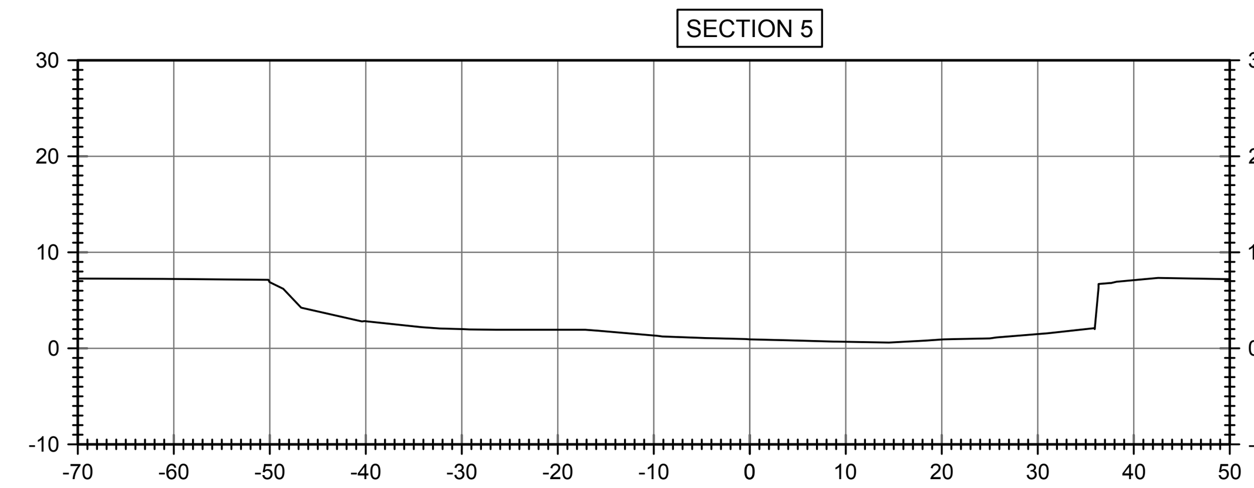
SECTION 6



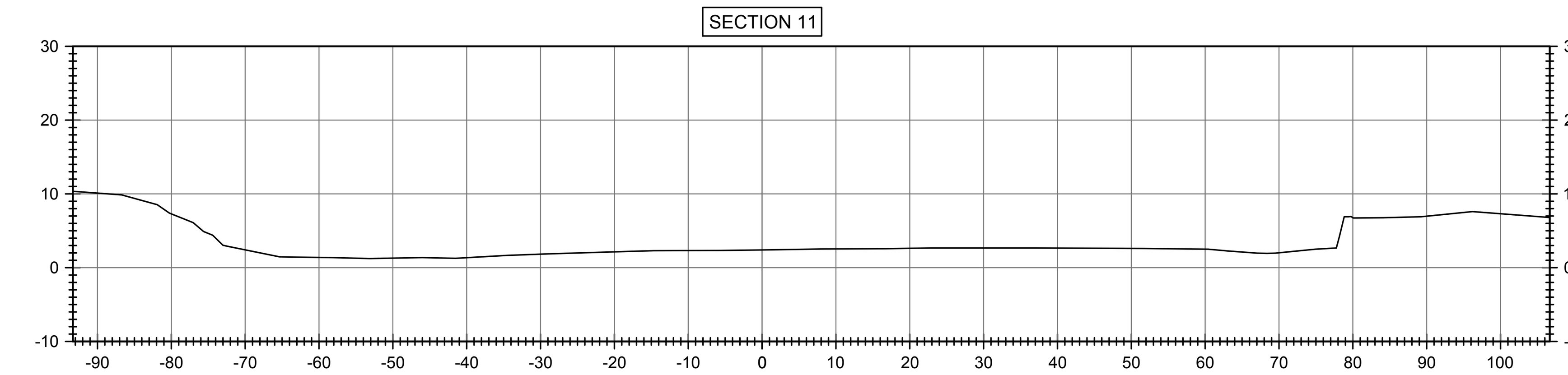
SECTION 12



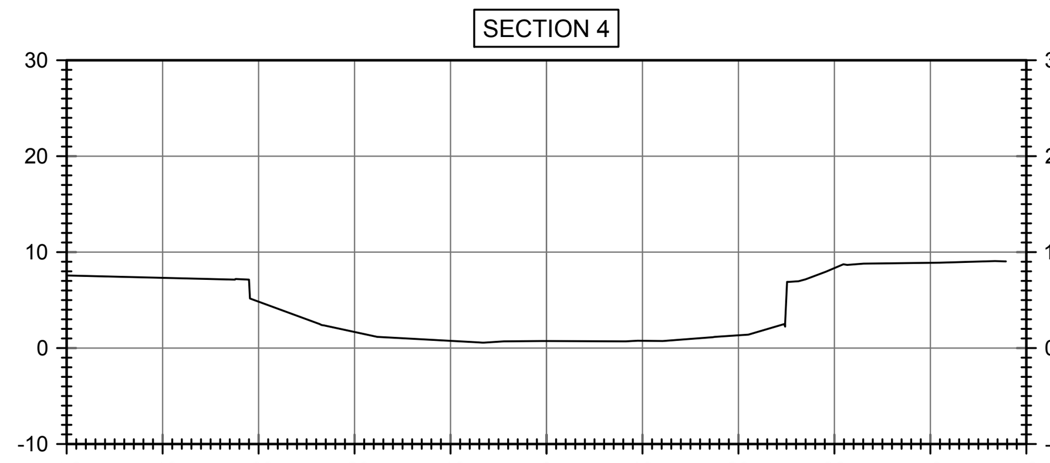
SECTION 5



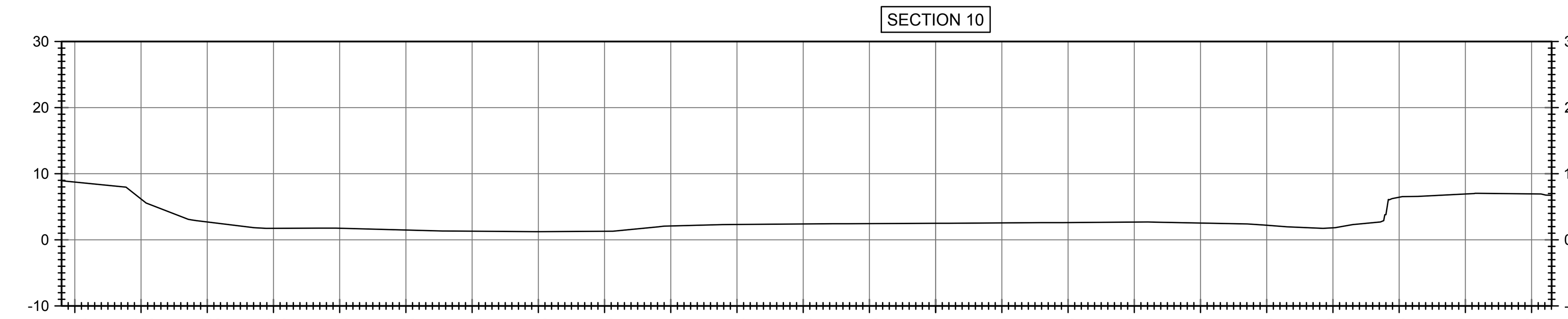
SECTION 11



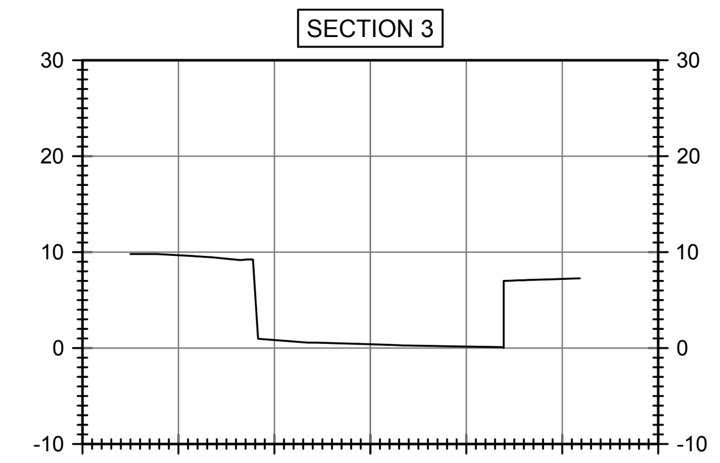
SECTION 4



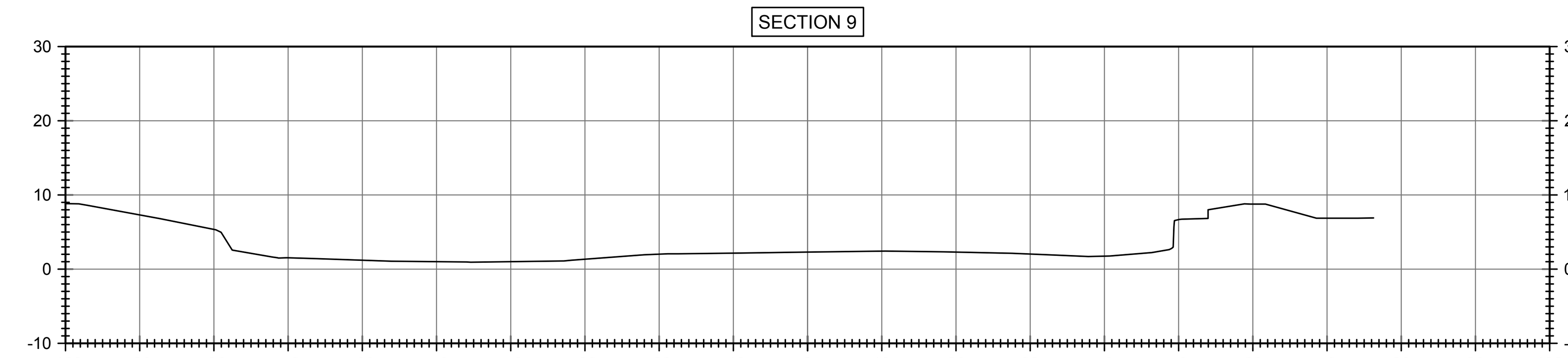
SECTION 10



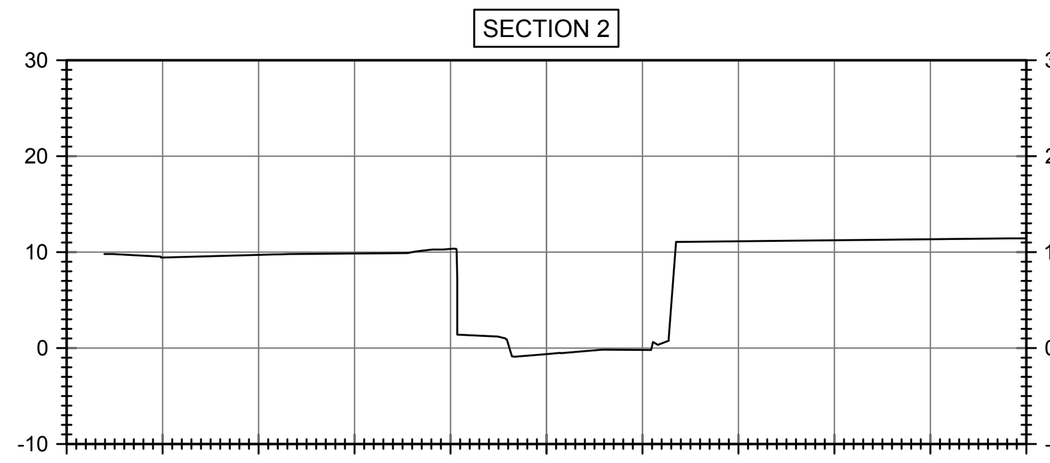
SECTION 3



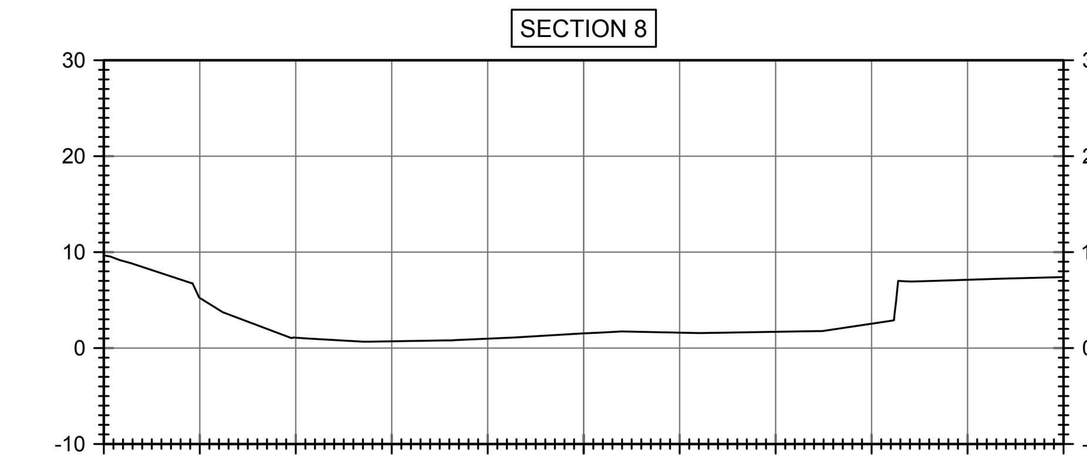
SECTION 9



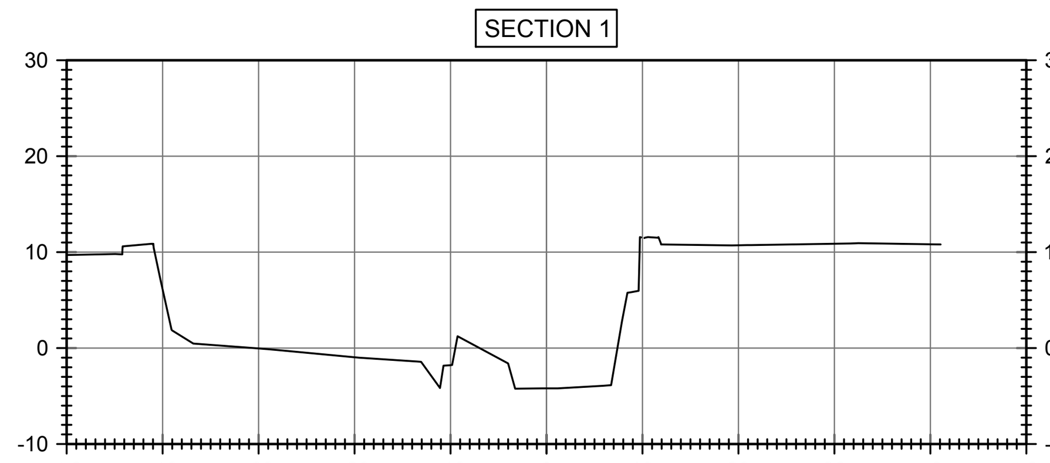
SECTION 2



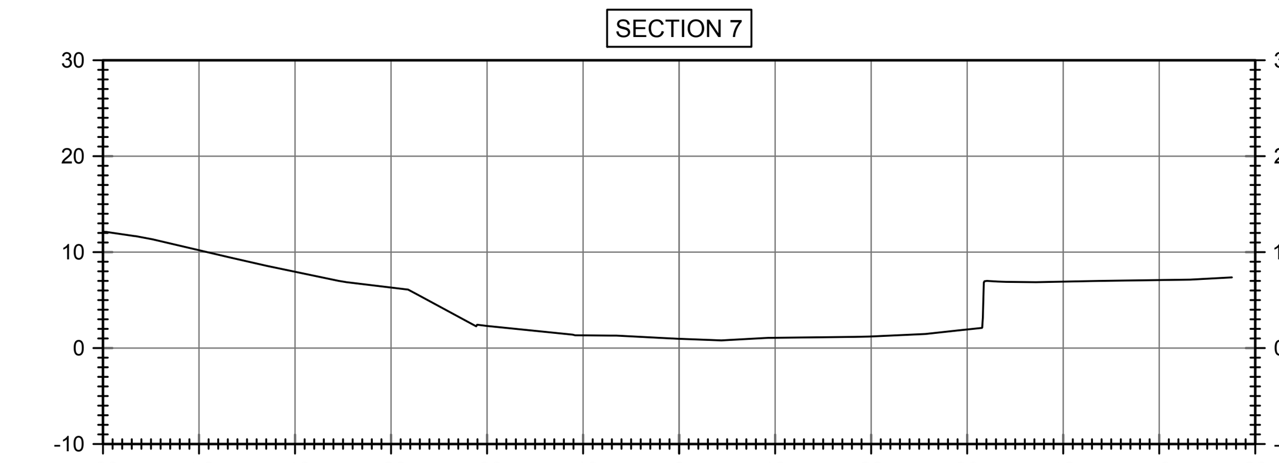
SECTION 8



SECTION 1



SECTION 7



20 0 20 40

SCALE: 1 INCH = 20 FT.

CROSS SECTION VIEWS

FOR

TIGHE & BOND

OF

SAW MILL BROOK

BRIDGE STREET TO NORWOOD AVE.

MANCHESTER-BY-THE-SEA, MASSACHUSETTS

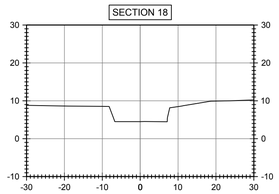
NO.	DATE	DESCRIPTION	BY

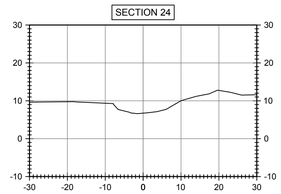
DRAWN BY: M.T.L.	DATE: DECEMBER 2017
CHECKED BY: J.A.G.	DRAWING NO.: 4536A
JOB NO.: 4536	SHEET 7 OF 8

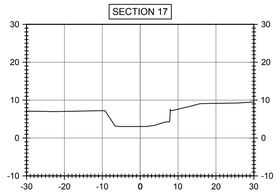
DOUCET SURVEY INC

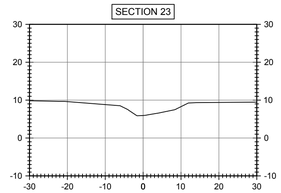
Serving Your Professional Surveying & Mapping Needs
102 Kent Place, Newmarket, NH 03857 (603) 659-6560
2 Commerce Drive (Suite 202) Bedford, NH 03110 (603) 614-4060
10 Storer Street (Riverview Suite) Kennebunk, ME (207) 502-7005
http://www.doucetsurvey.com

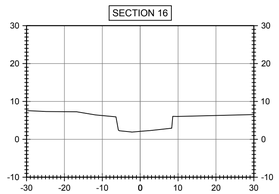
FILE NAME: C:\Users\Mike\appdata\local\temp\AcPublish_7624\4536A.dwg LAYOUT NAME: TOPO PLAN (7) PLOTTED: Tuesday, December 12, 2017 - 2:13pm

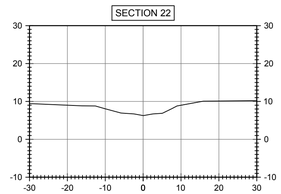


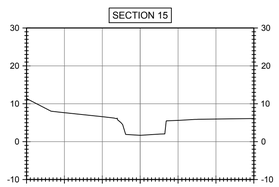


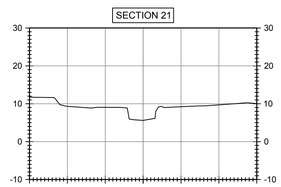


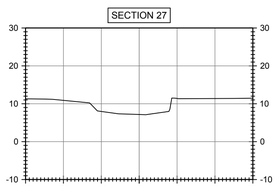


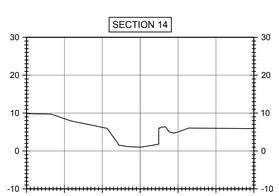


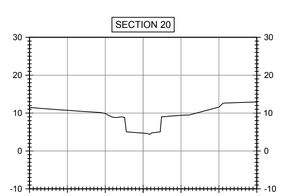


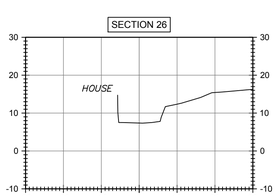


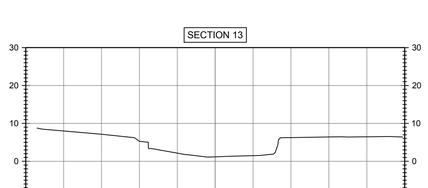


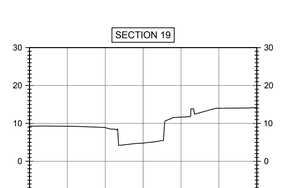


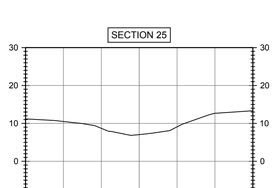












20 0 20 40

SCALE: 1 INCH = 20 FT.

CROSS SECTION VIEWS

FOR

TIGHE & BOND

OF

SAW MILL BROOK

BRIDGE STREET TO NORWOOD AVE.

MANCHESTER-BY-THE-SEA, MASSACHUSETTS

NO.	DATE	DESCRIPTION	BY

DRAWN BY:	M.T.L.	DATE:	DECEMBER 2017
CHECKED BY:	J.A.G.	DRAWING NO.:	4536A
JOB NO.:	4536	SHEET 8 OF	8

DOUCET SURVEY INC

Serving Your Professional Surveying & Mapping Needs
102 Kent Place, Newmarket, NH 03857 (603) 659-6560
2 Commerce Drive (Suite 202) Bedford, NH 03110 (603) 614-4060
10 Storer Street (Riverview Suite) Kennebunk, ME (207) 502-7005
http://www.doucetsurvey.com

APPENDIX B

Water Level Elevations Data adjusted to NAVD88:

Date:	Time	Norwood Avenue: A2 DTW:	Staff Gage:	School St B-2 DTW:	Central Street: C1 DTW:	Staff Gage:	C2 DTW:
11/27/2017	**Tide gate opened (8:00 AM)**						
11/29/2017	2:00	8.08	7.26	5.40	0.50	0.65	-3.68
11/30/2017	7:55				4.70	underwater	
12/3/2017	10:16				5.85		
12/4/2017	**Tide gate closed (3:00 PM)**						
12/5/2017	11:50	8.10	7.27	6.30	6.80	underwater	6.70
12/12/2017	9:35	8.19	7.18	5.35	4.21	4.49	0.88
12/20/2017	12:16	8.20	7.21	5.55	4.76	4.62	4.40
12/27/2017	1:55	8.59	6.96	5.67	5.83	4.75	-1.68
1/3/2018	10:40	7.94	7.36	5.59	5.67	5.68	5.80
1/10/2018	10:40	8.08	7.27	5.71	4.86	4.78	-3.59
1/11/2018	**Tide gate opened (12 noon)**						
1/23/2018	8:00	8.50	6.89	5.78	1.20	OUT	-2.73
1/23/2018	1:40	9.30	6.17	6.30	3.40	OUT	3.40
1/31/2018	1:55	8.55	6.82	5.78	0.90	OUT	-1.15
2/6/2018	3:02	8.62	6.81	5.88	3.15	OUT	3.59
2/6/2018	**Tide gate closed (2:00 PM)**						
2/13/2018	1:00	9.05	6.40	6.15	4.92	OUT	-1.40
2/21/2018	3:36	8.90	6.55	6.00	5.00	OUT	3.65
2/27/2018	**Tide gate opened (8:00AM)**						
2/28/2018	10:50	8.65	6.80	6.88	4.55	OUT	4.30
3/6/2018	10:50	9.01	6.36	6.06	1.10	1.10	-0.40
3/16/2018	12:05	8.98	6.45	6.17	4.79	MISSED	4.65
3/21/2018	2:50	8.60	6.82	5.80	5.55	5.50	5.50
3/28/2018	10:05	8.66	6.81	5.92	5.25	5.12	5.32
4/5/2018	11:34	8.74	6.70	5.92	0.90	0.94	-2.98
4/10/2018	10:45	8.42	6.80	5.69	0.57	0.88	0.08
4/18/2018	3:30	9.35	6.18	6.30	3.50	3.56	3.15
4/26/2018	9:48	9.55	5.95	6.52	5.19	5.20	5.10
5/4/2018	7:30	8.55	6.84	5.80	0.90	0.85	-3.20

Stream Discharge Measurements

	1					2					3					4				
	Date: 11/28/17 Time:7:30AM					Date: 11/28/17 Time:9:30AM					Date: 11/29/17 Time:2:00PM					Date: 11/29/17 Time:3:00PM				
	Location: **Norwood Ave**					Location: **School Street**					Location: **Above Central Pond**					Location: **Below Central Pond**				
Distance from Bank (ft)	Width of cell (ft)	Depth (ft)	Area (Sq Ft)	Velocity (ft/s)	Discharge (cfs)	Width of cell (ft)	Depth (ft)	Area (Sq Ft)	Velocity (ft/s)	Discharge (cfs)	Width of cell (ft)	Depth (ft)	Area (Sq Ft)	Velocity (ft/s)	Discharge (cfs)	Width of cell (ft)	Depth (ft)	Area (Sq Ft)	Velocity (ft/s)	Discharge (cfs)
0	0.5	0.4	0.2	0.37	0.074	0.5					0.5	1	0.5	0.14	0.07	0.5	0.4	0.2	0.44	0.088
0.5	0.5	0.3	0.15	0.39	0.0585	0.5	0.8	0.4	0.04	0.016	0.5	1	0.5	0.22	0.11	0.5	0.4	0.2	0.33	0.066
1	0.5	0.5	0.25	0.28	0.07	0.5	0.9	0.45	0.08	0.036	0.5	1.1	0.55	0.16	0.088	0.5	0.4	0.2	0.54	0.108
1.5	0.5	0.6	0.3	0.21	0.063	0.5	0.7	0.35	0.14	0.049	0.5	1	0.5	0.19	0.095	0.5	0.4	0.2	0.43	0.086
2	0.5	0.5	0.25	0.5	0.125	0.5	0.7	0.35	0.21	0.0735	0.5	1	0.5	0.22	0.11	0.5	0.4	0.2	0.53	0.106
2.5	0.5	0.6	0.3	0.13	0.039	0.5	0.7	0.35	0.14	0.049	0.5	0.7	0.35	0.09	0.0315	0.5	0.4	0.2	0.3	0.06
3	0.5	0.5	0.25	0.23	0.0575	0.5	0.7	0.35	0.37	0.1295	0.5	0.7	0.35	0.21	0.0735	0.5	0.4	0.2	0.35	0.07
3.5	0.5	0.5	0.25	0.3	0.075	0.5	0.7	0.35	0.52	0.182	0.5	0.7	0.35	0.25	0.0875	0.5	0.4	0.2	0.27	0.054
4	0.5	0.5	0.25	0.38	0.095	0.5	0.7	0.35	0.65	0.2275	0.5	1.1	0.55	0.05	0.0275	0.5	0.4	0.2	0.16	0.032
4.5	0.5	0.5	0.25	0.32	0.08	0.5	0.7	0.35	0.61	0.2135	0.5	0.9	0.45	0.17	0.0765	0.5	0.4	0.2	0.18	0.036
5	0.5	0.5	0.25	0.49	0.1225	0.5	0.8	0.4	0.61	0.244	0.5	1	0.5	0.15	0.075	0.5	0.3	0.15	0.08	0.012
5.5	0.5	0.4	0.2	0.34	0.068	0.5	0.8	0.4	0.62	0.248	0.5	1	0.5	0.34	0.17	0.5	0.2	0.1	0.01	0.001
6	0.5	0.2	0.1	0.37	0.037	0.5	0.8	0.4	0.73	0.292	0.5	1	0.5	0.33	0.165	0.5	0.4	0.2	0.15	0.03
6.5	0.5	0.3	0.15	0.48	0.072	0.5	0.7	0.35	0.63	0.2205	0.5	0.7	0.35	0.27	0.0945	0.5	0.4	0.2	0.11	0.022
7	0.5	0.5	0.25	0.36	0.09	0.5	0.7	0.35	0.62	0.217	0.5	0.7	0.35	0.26	0.091	0.5	0.4	0.2	0.16	0.032
7.5	0.5	0.5	0.25	0.27	0.0675	0.5	0.6	0.3	0.15	0.045	0.5	0.7	0.35	0.38	0.133	0.5	0.4	0.2	0.06	0.012
8	0.5	0.4	0.2	0.33	0.066	0.5	0.6	0.3	0.1	0.03	0.5	0.7	0.35	0.17	0.0595	0.5	0.3	0.15	0.1	0.015
8.5	0.5	0.2	0.1	0.17	0.017	0.5	0.3	0.15	0.04	0.006	0.5	0.7	0.35	0.1	0.035	0.5	0.4	0.2	0.14	0.028
9	0.5	0.4	0.2	0.37	0.074	0.5	0.3	0.15	0.16	0.024						0.5	0.4	0.2	0.22	0.044
9.5	0.5	0.4	0.2	0.4	0.08	0.5	0.3	0.15	0.27	0.0405						0.5	0.4	0.2	0.27	0.054
10	0.5	0.4	0.2	0.4	0.08											0.5	0.4	0.2	0.12	0.024
10.5	0.5	0.4	0.2	0.47	0.094											0.5	0.5	0.25	0.37	0.0925
11	0.5	0.4	0.2	0.45	0.09											0.5	0.4	0.2	0.45	0.09
11.5	0.5	0.4	0.2	0.47	0.094											0.5	0.4	0.2	0.49	0.098
12	0.5	0.3	0.15	0.38	0.057											0.5	0.4	0.2	0.41	0.082
12.5																0.5	0.4	0.2	0.39	0.078
Total Area			5.3					6.25					7.85					4.85		
Stream Flow (cfs)					1.772					2.343					1.5225					1.3325

	Date: 4/18/18 Time:10:30AM					Date: 4/18/18 Time:9:45AM					Date: 4/18/18 Time:9:00AM					Date: 4/18/18 Time:8:30AM				
	Location: **Norwood Ave**					Location: **School Street**					Location: **Above Central Pond**					Location: **Below Central Pond**				
Distance from Bank (ft)	Width of cell (ft)	Depth (ft)	Area (Sq Ft)	Velocity (ft/s)	Discharge (cfs)	Width of cell (ft)	Depth (ft)	Area (Sq Ft)	Velocity (ft/s)	Discharge (cfs)	Width of cell (ft)	Depth (ft)	Area (Sq Ft)	Velocity (ft/s)	Discharge (cfs)	Width of cell (ft)	Depth (ft)	Area (Sq Ft)	Velocity (ft/s)	Discharge (cfs)
0	0.5	1.4	0.7	1.1	0.77	0.5					0.5		0		0	0.5	0.6	0.3	0.95	0.285
0.5	0.5	1.4	0.7	1.56	1.092	0.5	1	0.5	1.02	0.51	0.5	0.9	0.45	0.53	0.2385	0.5	0.6	0.3	1.37	0.411
1	0.5	1.6	0.8	1.63	1.304	0.5	1.3	0.65	2.12	1.378	0.5	1	0.5	0.24	0.12	0.5	0.9	0.45	1.5	0.675
1.5	0.5	1.4	0.7	2.47	1.729	0.5	1.4	0.7	1.45	1.015	0.5	2	1	1.24	1.24	0.5	0.5	0.25	1.4	0.35
2	0.5	1.7	0.85	1.43	1.2155	0.5	1	0.5	2.2	1.1	0.5	2.2	1.1	1.39	1.529	0.5	0.9	0.45	1.5	0.675
2.5	0.5	1.7	0.85	1.58	1.343	0.5	1.6	0.8	1.85	1.48	0.5	2.2	1.1	1.81	1.991	0.5	0.6	0.3	1.81	0.543
3	0.5	1.7	0.85	1.4	1.19	0.5	1.5	0.75	1.88	1.41	0.5	2.2	1	2.43	2.43	0.5	0.6	0.3	0.98	0.294
3.5	0.5	1.6	0.8	1.11	0.888	0.5	1.6	0.8	2.03	1.624	0.5	2.2	1.1	2.45	2.695	0.5	0.6	0.3	2.52	0.756
4	0.5	1.7	0.85	2.25	1.9125	0.5	1.7	0.85	2.31	1.9635	0.5	3.2	1.1	2.41	2.651	0.5	0.6	0.3	1.83	0.549
4.5	0.5	1.8	0.9	1.41	1.269	0.5	1.7	0.85	2.71	2.3035	0.5	2	1.1	1.24	1.364	0.5	0.8	0.4	2.06	0.824
5	0.5	1.8	0.9	2.03	1.827	0.5	1.9	0.95	1.54	1.463	0.5	2.2	1.1	1.42	1.562	0.5	0.5	0.25	0.75	0.1875
5.5	0.5	1.8	0.9	1.4	1.26	0.5	1.7	0.85	1.57	1.3345	0.5	2.2	1.6	1.28	2.048	0.5	0.7	0.35	2.5	0.875
6	0.5	1.8	0.9	1.98	1.782	0.5	1.7	0.85	1.88	1.598	0.5	1.6	1	0.71	0.71	0.5	0.9	0.45	2.72	1.224
6.5	0.5	1.8	0.9	1.54	1.386	0.5	1.7	0.85	1.28	1.088	0.5	1.6	1.1	2.42	2.662	0.5	0.5	0.25	2.03	0.5075
7	0.5	1.9	0.95	1.62	1.539	0.5	1.7	0.85	2.81	2.3885	0.5	1.9	1.1	2.11	2.321	0.5	0.9	0.45	2.87	1.2915
7.5	0.5	1.9	0.95	1.45	1.3775	0.5	1.8	0.9	2.43	2.187	0.5	1.7	0.8	1.31	1.048	0.5	0.9	0.45	2.2	0.99
8	0.5	1.8	0.9	1.36	1.224	0.5	1.7	0.85	1.81	1.5385	0.5	1.6	0.8	1.4	1.12	0.5	0.9	0.45	2.37	1.0665
8.5	0.5	1.6	0.8	1.37	1.096	0.5	1.5	0.75	1.55	1.1625	0.5	1.6	0.95	1.03	0.9785	0.5	0.8	0.4	2.05	0.82
9	0.5	1.9	0.95	1.41	1.3395	0.5	1	0.5	2.41	1.205						0.5	0.8	0.4	2.56	1.024
9.5	0.5	1.7	0.85	1.34	1.139											0.5	0.8	0.4	1.53	0.612
10																0.5	0.6	0.3	1.6	0.48
10.5																0.5	0.5	0.25	1.14	0.285
11																0.5	0.4	0.2	1.63	0.326
11.5																0.5	0.2	0.1	2.04	0.204
12																0.5	0.2	0.1	1.4	0.14
12.5																				
Total Area			17					13.75					16.9					8.15		
Stream Flow (cfs)					25.913					26.749					26.708					15.11

gage A 1.6 ft Headwall B2 depth to w 6.8 ft Gage C 1.3? ft

Sawmill Brook, Massachusetts - Water Level Recording Sheet

OBSERVER NAME:	TIDE:	WEATHER:
Mary Reilly DATE: 12/5/17	☑ In ☐ Out ☐ Slack	☐ Sunny ☐ Pt Cloudy ☑ Cloudy ☐ Light Rain ☐ Rain ☐ Snow/Sleet ☑ Windy ☐ Extreme Conditions (describe): King tide at approx. 11:59 am

C-Central Street				B-School Street		A-Norwood Ave.		
TIME	Downstream: tape measure BM to water (#C-2)	Upstream: tape measure BM to water (#C-1)	Water Level at ruler (Gage C)	TIME	Downstream: tape measure BM to water (#B-2)	TIME	Downstream: tape measure BM to water (#A-2)	Water Level at ruler (Gage A)
11:50 am	1 “	3.7 ‘	Not visible	12:17 pm	7.1 ‘	12:23 pm	7.6’	.43 ‘

OBSERVER NAME:	TIDE:	WEATHER:
Jessica Lamothe and Mary Reilly DATE: 12/12/17	☐ In ☑ Out ☐ Slack	☐ Sunny ☐ Pt Cloudy ☑ Cloudy ☐ Light Rain ☐ Rain ☐ Snow/Sleet ☑ Windy ☐ Extreme Conditions (describe):

C-Central Street				B-School Street		A-Norwood Ave.		
TIME	Downstream: tape measure BM to water (#C-2)	Upstream: tape measure BM to water (#C-1)	Water Level at ruler (Gage C)	TIME	Downstream: tape measure BM to water (#B-2)	TIME	Downstream: tape measure BM to water (#A-2)	Water Level at ruler (Gage A)
9:35 am	5.92 ‘	6.29 ‘	4.29 ‘	9:46 am	8.05 ‘	9:53 am	7.51 ‘	.52 ‘

BM- Bench mark at culvert headwall

Sawmill Brook, Massachusetts - Water Level Recording Sheet

OBSERVER NAME: Reily, Atkinson, Cardill

DATE: 12/20/17

TIDE: ☑ In ☐ Out ☐ Slack

WEATHER: ☑ Sunny ☐ Pt Cloudy ☐ Cloudy ☐ Light Rain ☐ Rain ☐ Snow/Sleet ☑ Windy ☐ Extreme Conditions (describe):

C-Central Street				B-School Street		A-Norwood Ave.		
TIME	Downstream: tape measure BM to water (#C-2)	Upstream: tape measure BM to water (#C-1)	Water Level at ruler (Gage C)	TIME	Downstream: tape measure BM to water (#B-2)	TIME	Downstream: tape measure BM to water (#A-2)	Water Level at ruler (Gage A)
12:16 p.m.	2.4'	5.74'	4.42'	12:30pm	7.85'	12:38pm	7.5'	0.49

OBSERVER NAME: Jessica Lamothe

DATE: 12/27/17

TIDE: ☐ In ☑ Out ☐ Slack

WEATHER: ☑ Sunny ☐ Pt Cloudy ☐ Cloudy ☐ Light Rain ☐ Rain ☐ Snow/Sleet ☐ Windy ☑ Extreme Conditions (describe): COLD 21° some snow on ground

C-Central Street				B-School Street		A-Norwood Ave.		
TIME	Downstream: tape measure BM to water (#C-2)	Upstream: tape measure BM to water (#C-1) ice *	Water Level at ruler (Gage C)	TIME	Downstream: tape measure BM to water (#B-2) flowing	TIME	Downstream: tape measure BM to water (#A-2) free flowing	Water Level at ruler (Gage A)
1:55p	8.48'	4.67	4.55'	2:07p	7.73'	2:12p	7.11'	.74'

BM- Bench mark at culvert headwall

stood in front of stake (couldn't see "DSL" tabs - Couldn't see BM?)

* frozen solid upstream

Sawmill Brook, Massachusetts - Water Level Recording Sheet

OBSERVER NAME: Francie C., Carolyn K
DATE: 1/3/18

TIDE: 11:44 high
☑ In
☐ Out
☐ Slack

WEATHER:
☑ Sunny ☐ Pt Cloudy ☐ Cloudy
☐ Light Rain ☐ Rain
☐ Snow/Sleet ☐ Windy
☐ Extreme Conditions (describe):

C-Central Street				B-School Street		A-Norwood Ave.		
TIME	Downstream: tape measure BM to water (#C-2)	Upstream: tape measure BM to water (#C-1)	Water Level at ruler (Gage C)	TIME	Downstream: tape measure BM to water (#B-2)	TIME	Downstream: tape measure BM to water (#A-2)	Water Level at ruler (Gage A)
10:40	1.00'	4.83'	5.48	10:51	7.81'	11:00	7.76'	.34'

hard to see staining on ruler

OBSERVER NAME: Carolyn K
DATE: 1/10/18

TIDE: 12:09 low PM
☐ In
☑ Out
☐ Slack

WEATHER:
☑ Sunny ☐ Pt Cloudy ☐ Cloudy
☐ Light Rain ☐ Rain
☐ Snow/Sleet ☐ Windy
☐ Extreme Conditions (describe):

C-Central Street				B-School Street		A-Norwood Ave.		
TIME	Downstream: tape measure BM to water (#C-2)	Upstream: tape measure BM to water (#C-1) ice	Water Level at ruler (Gage C) ice	TIME	Downstream: tape measure BM to water (#B-2) ice	TIME	Downstream: tape measure BM to water (#A-2)	Water Level at ruler (Gage A)
10:40	10.39'	5.64' (frozen)	4.58' (frozen)	11:10	7.69' (frozen)	11:00	7.62'	.43'

BM- Bench mark at culvert headwall NO flow

DPW snow removal at sidewalk D:O next visit first

Sawmill Brook, Massachusetts - Water Level Recording Sheet

OBSERVER NAME: Francie Caudill

DATE: 1/31/18

TIDE: ☐ In ☑ Out ☐ Slack — High tide was at 10:36 A.M.

WEATHER: ☑ Sunny + cold ☐ Pt Cloudy ☐ Cloudy ☐ Light Rain ☐ Rain ☐ Snow/Sleet ☑ Windy - somewhat ☐ Extreme Conditions (describe):

C-Central Street				B-School Street		A-Norwood Ave.		
TIME	Downstream: tape measure BM to water (#C-2)	Upstream: tape measure BM to water (#C-1)	Water Level at ruler (Gage C)	TIME	Downstream: tape measure BM to water (#B-2)	TIME	Downstream: tape measure BM to water (#A-2)	Water Level at ruler (Gage A)
1:55 p.m.	7.95'	9.60'	ruler missing	2:10 p.m.	7.62'	2:15 p.m.	7.15'	0.88'

OBSERVER NAME: Jessica Lenothe

DATE: 2/6/18

TIDE: ☐ In ☐ Out ☐ Slack

WEATHER: ☐ Sunny ☐ Pt Cloudy ☒ Cloudy ☐ Light Rain ☐ Rain ☐ Snow/Sleet ☒ Windy - somewhat ☐ Extreme Conditions (describe):

C-Central Street				B-School Street		A-Norwood Ave.		
TIME	Downstream: tape measure BM to water (#C-2)	Upstream: tape measure BM to water (#C-1)	Water Level at ruler (Gage C)	TIME	Downstream: tape measure BM to water (#B-2)	TIME	Downstream: tape measure BM to water (#A-2)	Water Level at ruler (Gage A)
3:02p	3.21'	7.35'	ruler missing	3:11p	7.52'	3:15p	7.08'	.89'

BM- Bench mark at culvert headwall

Sawmill Brook, Massachusetts - Water Level Recording Sheet

OBSERVER NAME: Cardyn Kelly

DATE: 2/13/18

TIDE:
- ☐ In
- ☑ Out
- ☐ Slack

High 9:36am

WEATHER:
- ☑ Sunny
- ☐ Pt Cloudy
- ☐ Cloudy
- ☐ Light Rain
- ☐ Rain
- ☐ Snow/Sleet
- ☐ Windy
- ☐ Extreme Conditions (describe):

C-Central Street				B-School Street		A-Norwood Ave.		
TIME	Downstream: tape measure BM to water (#C-2)	Upstream: tape measure BM to water (#C-1)	Water Level at ruler (Gage C)	TIME	Downstream: tape measure BM to water (#B-2)	TIME	Downstream: tape measure BM to water (#A-2)	Water Level at ruler (Gage A)
1:00 PM	8.21'	5.58'	—	11:10pm	7.25'	1:15pm	6.65'	1.3'

OBSERVER NAME: Lynn Atkinson

DATE: 2/21/18

TIDE:
- ☐ In
- ☐ Out
- ☐ Slack

WEATHER:
- ☑ Sunny
- ☐ Pt Cloudy
- ☐ Cloudy
- ☐ Light Rain
- ☐ Rain
- ☐ Snow/Sleet
- ☐ Windy
- ☐ Extreme Conditions (describe):

C-Central Street				B-School Street		A-Norwood Ave.		
TIME	Downstream: tape measure BM to water (#C-2)	Upstream: tape measure BM to water (#C-1)	Water Level at ruler (Gage C)	TIME	Downstream: tape measure BM to water (#B-2)	TIME	Downstream: tape measure BM to water (#A-2)	Water Level at ruler (Gage A)
3:36 pm	3.15'	5.5'	—	3:43 pm	7.4'	3:51 pm	6.8'	1.15'

BM- Bench mark at culvert headwall

Sawmill Brook, Massachusetts - Water Level Recording Sheet

OBSERVER NAME: Francie Caudill

DATE: 2/28/18

TIDE: ☐ In ☑ Out ☐ Slack (Low Tide @ 9:28)

WEATHER: ☑ Sunny ☐ Pt Cloudy ☐ Cloudy ☐ Light Rain ☐ Rain ☐ Snow/Sleet ☑ Windy ☐ Extreme Conditions (describe):

C-Central Street				B-School Street		A-Norwood Ave.		
TIME	Downstream: tape measure BM to water (#C-2)	Upstream: tape measure BM to water (#C-1)	Water Level at ruler (Gage C)	TIME	Downstream: tape measure BM to water (#B-2)	TIME	Downstream: tape measure BM to water (#A-2)	Water Level at ruler (Gage A)
10:50 a.m.	2.50'	5.95'	no ruler	11:02	6.52'	11:07	7.05'	0.90'

OBSERVER NAME: Carolyn Kelly

DATE: 3/6/18

TIDE: ☐ In ☑ Out ☐ Slack low 8:11am

WEATHER: ☐ Sunny ☐ Pt Cloudy ☑ Cloudy ☐ Light Rain ☐ Rain ☐ Snow/Sleet ☐ Windy ☐ Extreme Conditions (describe):

C-Central Street				B-School Street		A-Norwood Ave.		
TIME	Downstream: tape measure BM to water (#C-2)	Upstream: tape measure BM to water (#C-1)	Water Level at ruler (Gage C)	TIME	Downstream: tape measure BM to water (#B-2)	TIME	Downstream: tape measure BM to water (#A-2)	Water Level at ruler (Gage A)
10:50 am	7.26'	9.40'	0.9'	11:00	7.34'	11:03	6.69'	1.34

BM- Bench mark at culvert headwall

Sawmill Brook, Massachusetts - Water Level Recording Sheet

OBSERVER NAME: Jessica

DATE: 3/16

TIDE: ☐ In ☒ Out ☐ Slack

WEATHER: ☐ Sunny ☒ Pt Cloudy ☐ Cloudy 37°
☐ Light Rain ☐ Rain
☐ Snow/Sleet ☒ Windy
☐ Extreme Conditions (describe): Was snowstorm Tues/Weds - why I'm measuring late this week!

C-Central Street				B-School Street		A-Norwood Ave.		
TIME	Downstream: tape measure BM to water (#C-2)	Upstream: tape measure BM to water (#C-1)	Water Level at ruler (Gage C)	TIME	Downstream: tape measure BM to water (#B-2)	TIME	Downstream: tape measure BM to water (#A-2)	Water Level at ruler (Gage A)
12:05p	2.15'	5.71'	no ruler	12:12p	7.23'	12:16p	6.72'	1.25'

OBSERVER NAME: Lynn

DATE: 3/21

TIDE: ☒ In ☐ Out ☐ Slack

WEATHER: ☐ Sunny ☐ Pt Cloudy ☒ Cloudy
☐ Light Rain ☐ Rain
☐ Snow/Sleet ☐ Windy
☐ Extreme Conditions (describe):

C-Central Street				B-School Street		A-Norwood Ave.		
TIME	Downstream: tape measure BM to water (#C-2)	Upstream: tape measure BM to water (#C-1)	Water Level at ruler (Gage C)	TIME	Downstream: tape measure BM to water (#B-2)	TIME	Downstream: tape measure BM to water (#A-2)	Water Level at ruler (Gage A)
2:50 pm	1.31'	4.95'	5.3'	3:00	7.6'	3:04 pm	7.1'	0.88'

BM- Bench mark at culvert headwall

Sawmill Brook, Massachusetts - Water Level Recording Sheet

OBSERVER NAME: Francie Caudill

DATE: 3/28/18

TIDE:
- ☐ In
- ☑ Out but barely
- ☐ Slack

High tide was at 9:16 a.m.

WEATHER:
- ☐ Sunny
- ☑ Pt Cloudy
- ☑ Cloudy
- ☐ Light Rain
- ☐ Rain
- ☐ Snow/Sleet
- ☐ Windy
- ☐ Extreme Conditions (describe):

C-Central Street				B-School Street		A-Norwood Ave.		
TIME	Downstream: tape measure BM to water (#C-2)	Upstream: tape measure BM to water (#C-1)	Water Level at ruler (Gage C)	TIME	Downstream: tape measure BM to water (#B-2)	TIME	Downstream: tape measure BM to water (#A-2)	Water Level at ruler (Gage A)
10:05 a.m.	1.48'	5.25'	4.92'	10:16 a.m.	7.48'	10:23	7.04'	0.89'

OBSERVER NAME: Jessica Hamathe

DATE: 4/5/18

TIDE:
- ☒ In
- ☐ Out
- ☐ Slack

low was at 9:29 am

WEATHER:
- ☒ Sunny
- ☐ Pt Cloudy
- ☐ Cloudy
- ☐ Light Rain
- ☐ Rain
- ☐ Snow/Sleet
- ☒ Windy
- ☐ Extreme Conditions (describe):

cold!! 35°

C-Central Street				B-School Street		A-Norwood Ave.		
TIME	Downstream: tape measure BM to water (#C-2)	Upstream: tape measure BM to water (#C-1)	Water Level at ruler (Gage C)	TIME	Downstream: tape measure BM to water (#B-2)	TIME	Downstream: tape measure BM to water (#A-2)	Water Level at ruler (Gage A)
11:34a	9.78'	9.6'	.74'	11:41a	7.48'	11:45a	6.96'	1.0'

BM- Bench mark at culvert headwall

Sawmill Brook, Massachusetts - Water Level Recording Sheet

OBSERVER NAME: Carolyn Kelly

DATE: 4/10/18

TIDE:
- ☐ In
- ☒ Out
- ☐ Slack

High 7:37am

WEATHER:
- ☐ Sunny
- ☐ Pt Cloudy
- ☑ Cloudy
- ☐ Light Rain
- ☐ Rain
- ☐ Snow/Sleet
- ☐ Windy
- ☐ Extreme Conditions (describe):

C-Central Street				B-School Street		A-Norwood Ave.		
TIME	Downstream: tape measure BM to water (#C-2)	Upstream: tape measure BM to water (#C-1)	Water Level at ruler (Gage C)	TIME	Downstream: tape measure BM to water (#B-2)	TIME	Downstream: tape measure BM to water (#A-2)	Water Level at ruler (Gage A)
10:45	6.72'	9.93'	.68	10:53	7.71'	11:01	7.28'	.90

OBSERVER NAME:

DATE:

TIDE:
- ☐ In
- ☐ Out
- ☐ Slack

WEATHER:
- ☐ Sunny
- ☐ Pt Cloudy
- ☐ Cloudy
- ☐ Light Rain
- ☐ Rain
- ☐ Snow/Sleet
- ☐ Windy
- ☐ Extreme Conditions (describe):

C-Central Street				B-School Street		A-Norwood Ave.		
TIME	Downstream: tape measure BM to water (#C-2)	Upstream: tape measure BM to water (#C-1)	Water Level at ruler (Gage C)	TIME	Downstream: tape measure BM to water (#B-2)	TIME	Downstream: tape measure BM to water (#A-2)	Water Level at ruler (Gage A)

BM- Bench mark at culvert headwall

Sawmill Brook, Massachusetts - Water Level Recording Sheet

OBSERVER NAME: Lynn Atkinson

DATE: 4/18/18

TIDE: ☐ In ☐ Out ☐ Slack

WEATHER: ☒ Sunny ☐ Pt Cloudy ☐ Cloudy ☐ Light Rain ☐ Rain ☐ Snow/Sleet ☐ Windy ☐ Extreme Conditions (describe): heavy rain 2 days before

C-Central Street				B-School Street		A-Norwood Ave.		
TIME	Downstream: tape measure BM to water (#C-2)	Upstream: tape measure BM to water (#C-1)	Water Level at ruler (Gage C)	TIME	Downstream: tape measure BM to water (#B-2)	TIME	Downstream: tape measure BM to water (#A-2)	Water Level at ruler (Gage A)
3:30 pm	3.65'	7'	3.36'	3:39	7.1'	3:42	6.35'	1.52'

OBSERVER NAME: Francie Caudill

DATE: 4/26/18

TIDE: ☐ In ☑ Out ☐ Slack High Tide was at 9:03 A.M.

WEATHER: ☐ Sunny ☑ Light Rain ☐ Snow/Sleet ☐ Extreme Conditions (describe): ☐ Pt Cloudy ☐ Rain ☐ Windy ☑ Cloudy just stopping rain after 24 hrs. of rain!

C-Central Street				B-School Street		A-Norwood Ave.		
TIME	Downstream: tape measure BM to water (#C-2)	Upstream: tape measure BM to water (#C-1)	Water Level at ruler (Gage C)	TIME	Downstream: tape measure BM to water (#B-2)	TIME	Downstream: tape measure BM to water (#A-2)	Water Level at ruler (Gage A)
9:48	1.70'	5.31'	5.00'	10:03	6.88'	10:07	6.15'	1.75'

BM- Bench mark at culvert headwall

Receiving Stream: Manchester Harbor
Plant: Manchester WWTP
Town or City: Manchester by the Sea
Month: December Year: 2017
Chief Operator: John S. Sibbalds
Assistant Chief Operator: Robert J Willwerth

Department of Environmental Quality Engineering
Division of Water Pollution Control

Monthly Operation and Maintenance Report

Region: Northeast
County: Essex
If Contract Operation Company: _____

Permit Number Sate: M18 Federal MA0100871
Plant Design Flow 0.67 mgd.
Monthly Average Flow .358 mgd.
Monthly Average Flow Last Year .527 mgd.

Chief Operator Certification of Report: _____ Date: _____

	Weather			Sewage Flows (mgd)				Grit & Scr	Disinfection				Settleable Solids				pH			
								Cubic	Gallons/	Cl2 Residual				Primary	Sec.		Influent		Disinfection	
Date	Rain	Temp	Influent Temp	Max	Min	Total	Bypass	Feet	24 hrs.	1	2	3	Raw	Effluent	Effluent	Final	High	Low	High	Low
12/1/2017		7	15	0.85	0.10	0.247		0.0	6.0	0.5	0.5	0.4					7.9		7.3	
12/2/2017		-1	14	0.95	0.10	0.274		0.0	4.0	0.9	0.6	0.8					7.9		7.2	
12/3/2017		-2	14	1.20	0.20	0.288		0.0	6.0	0.8	0.6	0.5					7.9		7.2	
12/4/2017		-1	15	1.00	0.20	0.321		0.5	7.0	0.5	0.7	0.5					7.9		7.1	
12/5/2017	0.47	3	15	0.95	0.15	0.303		1.5	7.0	0.4	0.5	0.4					7.9		7.1	
12/6/2017		10	15	0.90	0.15	0.305		2.5	7.0	0.4	0.9	0.5					7.9		7.1	
12/7/2017		-1	15	1.10	0.15	0.330		0.5	7.0	0.4	0.6	0.7					7.8		7.1	
12/8/2017		-1	14	0.80	0.15	0.269		0.5	4.0	0.7	0.9	0.5					7.9		7.0	
12/9/2017	0.51	1	14	0.95	0.20	0.316		0.5	4.0	0.9	0.5	0.6					7.8		7.2	
2/10/201		-2	13	1.00	0.20	0.340		0.5	4.0	0.4	0.7	0.6					7.8		7.2	
2/11/201		-1	15	0.90	0.15	0.305		3.0	4.0	0.6	0.4	0.4					7.8		7.2	
2/12/201	0.04	1	15	1.10	0.25	0.365		1.5	7.0	0.2	0.7	0.6					7.7		7.2	
2/13/201		-6	13	1.25	0.20	0.393		1.5	7.0	0.3	0.6	0.5					7.6		7.1	
2/14/201		-7	13	1.10	0.20	0.393		2.0	7.0	0.5	0.5	0.5					7.7		7.1	
2/15/201		-11	13	1.05	0.15	0.327		0.5	6.0	0.5	0.3	0.4					7.8		7.0	
2/16/201		-8	12	1.00	0.20	0.346		0.0	7.0	0.5	0.8	0.3					7.6		7.0	
2/17/201		-10	13	1.25	0.20	0.361		0.0	6.0	0.7	0.3	0.2					7.5		7.1	
2/18/201	0.01	-6	13	0.90	0.15	0.321		0.0	6.0	0.4	0.5	0.3					7.8		7.0	
2/19/201		1	14	1.00	0.15	0.303		1.5	7.0	0.5	0.6	0.6					7.8		7.1	
2/20/201		2	14	1.15	0.10	0.299		4.0	6.0	0.5	0.6	0.5					7.8		7.1	
2/21/201		-4	13	1.15	0.20	0.344		0.5	6.0	0.5	0.5	0.5					7.6		7.1	
2/22/201	0.24	-7	13	0.95	0.15	0.318		0.5	4.0	0.1	0.6	0.7					7.8		7.1	
2/23/201	0.60	-4	12	1.10	0.25	0.437		0.0	6.0	0.6	0.7	0.3					7.6		7.1	
2/24/201	0.32	-1	12	1.10	0.20	0.440		0.0	8.0	0.4	0.9	0.5					7.4		7.0	
2/25/201	0.13	1	12	1.20	0.25	0.511		2.0	7.0	0.5	0.5	0.6					7.4		7.0	
2/26/201		-8	11	1.10	0.20	0.483		3.0	6.0	0.5	0.6	0.5					7.3		7.0	
2/27/201		-13	11	1.05	0.05	0.423		5.0	6.0	0.5	0.3	0.5					7.5		7.1	
2/28/201		-18	11	1.40	0.20	0.492		0.5	6.0	0.4	0.6	0.6					7.4		7.2	
2/29/201		-20	10	1.05	0.10	0.403		0.0	6.0	0.6	0.6	0.6					7.4		6.9	
2/30/201		-19	10	1.10	0.20	0.416		2.0	4.0	0.5	0.5	0.7					7.5		7.0	
2/31/201		-17	10	1.10	0.20	0.413		1.0	6.0	0.5	0.5	0.7					7.5		6.8	
Total	2.32	-142	404	32.70	5.35	11.086		35.0	184.0	15.7	18.1	16.0					238.2		219.7	
Average	0.29	-5	13	1.05	0.17	0.358		1.1	5.9	0.5	0.6	0.5					7.7		7.1	

Receiving Stream: Manchester Harbor
Plant: Manchester WWTP
Town or City: Manchester by the Sea
Month: January Year: 2018
Chief Operator: John S. Sibbalds
Assistant Chief Operator: Robert J Willwerth

Department of Environmental Quality Engineering
Division of Water Pollution Control

Monthly Operation and Maintenance Report

Region: Northeast
County: Essex
If Contract Operation Company:

Permit Number Sate: M18 Federal MA0100871
Plant Design Flow 0.67 mgd.
Monthly Average Flow .514 mgd.
Monthly Average Flow Last Year .797 mgd.
Chief Operator Certification of Report: Date:

	Weather			Sewage Flows (mgd)				Grit & Scr	Disinfection				Settleable Solids				pH			
								Cubic	Gallons/	Cl2 Residual				Primary	Sec.		Influent		Disinfection	
Date	Rain	Temp	Influent Temp	Max	Min	Total	Bypass	Feet	24 hrs.	1	2	3	Raw	Effluent	Effluent	Final	High	Low	High	Low
1/1/2018		-22	10	1.20	0.15	0.435		1.0	6.0	0.5	0.5	0.5					7.4		7.0	
1/2/2018		-20	11	1.05	0.15	0.408		1.5	6.0	0.2	0.6	0.5					7.6		7.1	
1/3/2018	0.74	-12	10	1.00	0.05	0.342		2.0	4.0	0.4	0.6	0.5					7.8		7.0	
1/4/2018		-4	10	2.30	0.10	0.528		5.0	4.0	0.3	0.4	0.6					7.5		7.1	
1/5/2018		-9	10	1.00	0.05	0.299		0.5	4.0	0.5	0.6	0.5					7.7		7.0	
1/6/2018		-18	9	0.90	0.10	0.313		0.5	4.0	0.5	0.6	0.6					7.6		7.0	
1/7/2018		-22	9	1.15	0.15	0.340		0.0	6.0	0.4	0.8	0.7					7.7		7.1	
1/8/2018		-8	11	0.95	0.05	0.308		1.5	4.0	0.8	0.5	0.3					7.7		7.0	
1/9/2018		-3	11	0.90	0.15	0.310		1.5	4.0	0.4	0.5	0.5					7.8		7.2	
1/10/2018		-8	11	0.80	0.05	0.315		1.5	4.0	0.5	0.6	0.6					5.1		7.1	
1/11/2018		1	12	1.05	0.10	0.359		1.0	6.0	0.4	0.7	0.5					7.6		7.1	
1/12/2018	1.56	3	12	2.35	0.05	0.776		4.5	8.0	0.5	0.8	0.7					7.6		7.0	
1/13/2018		9	8	2.40	0.55	1.171		7.0	11.0	0.5	0.6	0.6					6.8		6.8	
1/14/2018	0.01	-12	8	1.75	0.40	0.790		3.5	8.0	0.5	0.5	0.6					7.1		6.8	
1/15/2018		-12	9	1.40	0.30	0.690		2.0	7.0	0.6	0.6	0.4					7.2		7.4	
1/16/2018	0.06	-9	9	1.50	0.25	0.585		1.5	7.0	0.5	0.3	0.6					7.4		7.0	
1/17/2018	0.13	0	10	1.30	0.10	0.516		2.5	6.0	0.6	0.5	0.6					7.4		7.1	
1/18/2018		-7	11	1.30	0.20	0.544		2.0	7.0	0.5	0.6	0.6					7.5		7.2	
1/19/2018		-7	10	1.05	0.20	0.470		1.0	6.0	0.6	0.6	0.6					7.4		7.0	
1/20/2018		0	10	1.15	0.10	0.440		1.0	6.0	0.4	0.6	0.5					7.3		7.0	
1/21/2018		0	10	1.05	0.20	0.441		0.5	7.0	0.5	0.3	0.6					7.2		7.0	
1/22/2018	0.08	2	11	0.95	0.10	0.420		0.5	6.0	0.6	0.6	0.5					7.4		6.9	
1/23/2018	0.93	-1	11	1.65	0.35	0.829		3.0	10.0	0.5	0.6	0.6					7.4		7.0	
1/24/2018		2	10	1.35	0.10	0.690		1.5	7.0	0.6	0.5	0.6					7.2		6.8	
1/25/2018		-9	10	1.20	0.30	0.611		2.0	7.0	0.5	0.5	0.5					7.3		6.9	
1/26/2018		-11	9	1.20	0.15	0.540		1.0	6.0	0.4	0.3	0.5					7.2		6.9	
1/27/2018	0.01	-1	9	1.10	0.15	0.490		1.0	7.0	0.4	0.4	0.6					7.2		7.1	
1/28/2018		7	10	1.00	0.25	0.493		1.0	6.0	0.5	0.5	0.4					7.1		6.9	
1/29/2018	0.09	1	11	1.40	0.20	0.516		2.0	6.0	0.5	0.6	0.5					7.3		6.9	
1/30/2018	0.02	-8	11	1.25	0.20	0.512		1.5	7.0	0.6	0.6	0.5					7.3		6.9	
1/31/2018		-11	10	1.05	0.10	0.465		1.0	6.0	0.4	0.6	0.5					7.4		6.8	
Total	3.63	-189	313	39.70	5.35	15.946		56.0	193.0	15.1	17.0	16.8					227.2		217.1	
Average	0.36	-6	10	1.28	0.17	0.514		1.8	6.2	0.5	0.5	0.5					7.3		7.0	

Receiving Stream: Manchester Harbor
Plant: Manchester WWTP
Town or City: Manchester by the Sea
Month: February Year: 2018
Chief Operator: John S. Sibbalds
Assistant Chief Operator: Robert J Willwerth

Department of Environmental Quality Engineering
Division of Water Pollution Control

Monthly Operation and Maintenance Report

Region: Northeast
County: Essex
If Contract Operation Company: _____

Permit Number Sate: M18 Federal MA0100871
Plant Design Flow 0.67 mgd.
Monthly Average Flow .627 mgd.
Monthly Average Flow Last Year .664 mgd.

Chief Operator Certification of Report: _____ Date: _____

	Weather			Sewage Flows (mgd)				Grit & Scr	Disinfection				Settleable Solids				pH			
								Cubic	Gallons/	Cl2 Residual				Primary	Sec.		Influent		Disinfection	
Date	Rain	Temp	Influent Temp	Max	Min	Total	Bypass	Feet	24 hrs.	1	2	3	Raw	Effluent	Effluent	Final	High	Low	High	Low
2/1/2018	0.26	-1	11	1.10	0.20	0.475		1.0	6.0	0.4	0.4	0.4					7.5		6.9	
2/2/2018		-1	10	1.10	0.20	0.492		1.0	6.0	0.4	0.2	0.7					7.4		7.0	
2/3/2018		-14	9	1.20	0.20	0.492		1.0	4.0	0.5	0.4	0.5					7.4		7.0	
2/4/2018	0.60	-2	9	1.15	0.30	0.571		2.0	6.0	0.5	0.3	0.7					7.3		7.0	
2/5/2018		3	10	1.35	0.05	0.582		3.0	7.0	0.5	0.3	0.4					7.2		6.9	
2/6/2018		-6	10	1.20	0.20	0.536		2.5	7.0	0.3	0.5	0.5					7.3		6.9	
2/7/2018	0.88	-7	10	1.40	0.05	0.684		3.0	8.0	0.6	0.7	0.6					7.4		6.9	
2/8/2018		-8	9	1.55	0.35	0.704		2.0	7.0	0.5	0.6	0.5					7.2		6.8	
2/9/2018		-9	9	1.60	0.10	0.559		1.0	6.0	0.2	0.4	0.5					7.3		6.7	
2/10/2018	0.48	1	9	1.15	0.20	0.662		2.0	6.0	0.6	0.6	0.5					7.2		6.9	
2/11/2018	0.48	3	8	1.75	0.50	1.050		2.5	13.0	0.6	0.7	0.4					7.0		6.8	
2/12/2018		4	9	1.75	0.35	0.820		2.0	10.0	0.6	0.5	0.6					7.0		6.8	
2/13/2018		-7	9	1.40	0.40	0.738		2.5	8.0	0.5	0.4	0.5					7.2		6.7	
2/14/2018		-2	10	1.80	0.20	0.659		1.5	7.0	0.5	0.5	0.7					7.1		6.8	
2/15/2018	0.02	-1	10	1.45	0.30	0.655		1.0	7.0	0.5	0.6	0.5					7.1		6.9	
2/16/2018		4	10	1.30	0.10	0.546		1.0	7.0	0.5	0.7	0.6					7.2		6.7	
2/17/2018	0.80	-5	8	1.10	0.25	0.556		1.0	7.0	0.6	0.6	0.7					7.1		6.9	
2/18/2018		-1	9	1.15	0.30	0.566		1.5	7.0	0.5	0.6	0.6					7.0		6.9	
2/19/2018	0.05	-4	9	1.15	0.30	0.610		1.5	8.0	0.5	0.6	0.7					7.2		6.9	
2/20/2018		8	10	1.30	0.30	0.675		1.5	8.0	0.5	0.5	0.5					7.1		6.9	
2/21/2018		4	9	1.30	0.15	0.596		1.5	8.0	0.6	0.5	0.6					7.0		6.8	
2/22/2018	0.08	4	10	1.30	0.25	0.624		2.5	8.0	0.5	0.3	0.7					7.0		6.8	
2/23/2018	0.07	-3	9	1.55	0.05	0.576		1.0	8.0	0.7	0.6	0.6					7.1		6.8	
2/24/2018	0.02	-2	10	1.10	0.30	0.546		1.5	8.0	0.5	0.5	0.5					7.1		7.1	
2/25/2018	0.60	2	9	1.40	0.40	0.724		2.0	11.0	0.5	0.7	0.8					7.0		6.8	
2/26/2018		1	10	1.35	0.15	0.684		2.0	10.0	0.5	0.5	0.7					7.1		6.8	
2/27/2018		-2	10	1.30	0.35	0.618		1.5	8.0	0.5	0.5	0.8					7.1		6.8	
2/28/2018		4	10	1.25	0.15	0.567		1.5	8.0	0.6	0.6	0.7					7.2		6.8	
Total	4.34	-37	265	37.50	6.65	17.567		48.0	214.0	14.2	14.3	16.5					200.8		192.0	
Average	0.36	-1	9	1.34	0.24	0.627		1.7	7.6	0.5	0.5	0.6					7.2		6.9	

Receiving Water Name: MANCHESTER HARBOR

DEPARTMENT OF ENVIRONMENTAL QUALITY ENGINEERING
DIVISION OF WATER POLLUTION CONTROL
MONTHLY OPERATION AND MAINTENANCE REPORT

Permit # State M18 Fed. MA0100871

Plant: MANCHESTER WWTP
Town or City: MANCHESTER BY THE SEA
Month: MARCH 2018
Chief Operator: ROBERT J. WILLWERTH
Assistant Chief Operator: THOMAS J. PARISI
Region: NORTHEAST
County: ESSEX
If Contract Operation, Company: _____

Plant Design Flow 0.67 mgd
Monthly Average Flow 0.341 mgd.
Monthly Average Flow Last Year 0.546 mgd.

Chief Operator, Certification of Report: Robert J. Willwerth Date: APRIL 3 2018

COMPLETE STAFFING PLAN MUST BE SUBMITTED IN JUNE AND JANUARY OF EACH YEAR, OR WHEN ANY PERSONNEL CHANGES OCCUR.

This Plant was in Complete Permit Compliance this Month. (YES) NO

	Weather			Sewage Flows (mgd)				grit & scr.	Disinfection		Settleable Solids				pH influent		pH effluent	
date	rain 1	temp 2	inf temp 3	max 3	min 4	total 6	bypass 7	8	GAL 24 hrs 9	Cl_2 resid 10	raw 11	pri eff 12	sec eff 13	final 14	hi 15	low 16	hi 17	low 18
1	0.49	3	11	1.25	0.30	0.563		2.5	10	0.6 0.8 0.5					7.2		6.8	
2	1.91	2	10	2.70	0.30	1.749		5.0	20	0.6 0.6 0.7					7.2		6.9	
3		2	9	2.35	0.80	1.353		1.5	14	0.5 0.7 0.6					6.9		6.7	
4	0.07	2	9	1.80	0.65	1.064		2.0	10	0.5 0.5 0.7					6.8		6.7	
5		-1	11	1.70	0.40	0.935		1.5	9	0.3 0.4 0.5					7.0		6.8	
6		0	10	1.60	0.30	0.792		1.5	7	0.4 0.5 0.5					7.1		6.8	
7	1.80	0	10	1.70	0.20	0.932		2.0	11	0.5 0.4 0.6					7.1		7.0	
8	0.02	-2	9	1.85	0.80	1.193		2.5	13	0.4 0.6 0.5					6.9		6.9	
9	0.01	-3	10	1.90	0.50	1.037		1.0	11	0.4 0.5 0.4					7.0		6.8	
10		-1	9	1.60	0.55	0.912		1.0	11	0.5 0.6 0.5					6.9		6.8	
11		-2	9	1.50	0.40	0.896		1.5	11	0.4 0.5 0.4					7.0		7.2	
12	0.36	-3	9	1.70	0.55	0.900		0.5	8	0.4 0.6 0.6					7.0		6.8	
13	0.57	-1	9	1.55	0.50	0.938		1.0	13	0.6 0.5 0.6					6.9		6.8	
14		-4	9	1.50	0.25	0.905		2.5	10	0.6 0.6 0.6					7.0		6.8	
15		-1	10	1.55	0.50	0.913		3.0	11	0.4 0.5 0.5					7.0		6.9	
16		-2	9	1.55	0.25	0.835		2.0	8	0.4 0.5 0.5					7.0		6.9	
17		-5	9	1.45	0.50	0.802		1.5	10	0.5 0.6 0.5					6.8		6.5	
18		-12	9	1.75	0.40	0.774		1.5	8	0.4 0.5 0.5					6.8		6.7	
19		-9	10	1.50	0.40	0.737		1.0	7	0.4 0.7 0.6					7.0		6.8	
20		-7	9	1.25	0.40	0.657		0	8	0.7 0.6 0.6					7.1		6.8	
21	0.22	0	10	1.30	0.30	0.643		1.5	7	0.6 0.5 0.6					7.2		6.9	
22	0.06	-2	10	1.55	0.35	0.660		3.0	7	0.5 0.6 0.6					7.2		6.9	
23		-2	10	1.30	0.20	0.614		1.5	7	0.5 0.7 0.6					7.2		6.9	
24	0.20	0	9	1.30	0.40	0.638		1.0	7	0.5 0.4 0.6					7.0		6.9	
25		-1	9	1.30	0.40	0.704		1.5	7	0.5 0.5 0.7					7.0		6.9	
26		-1	10	1.60	0.20	0.687		1.5	7	0.3 0.4 0.5					7.1		6.9	
27		-4	10	1.30	0.35	0.665		1.5	7	0.5 0.4 0.4					7.2		7.1	
28		1	10	1.35	0.20	0.637		1.5	7	0.5 0.5 0.3					7.1		6.9	
29	0.02	1	10	1.30	0.05	0.647		2.5	11	0.5 0.5 0.5					7.2		6.9	
30	0.03	7	11	1.55	0.15	0.644		1.0	7	0.8 0.6 0.4					7.2		6.9	
31		2	10	1.25	0.40	0.651		1.0	7	0.5 0.3 0.6					6.9		6.8	
TOTAL	5.76					26.677		52.5	290									
AVE		-1	10	1.60	0.40	0.841		1.5	9	0.5					7.0		6.9	

Receiving Stream: Manchester Harbor
Plant: Manchester WWTP
Town or City: Manchester by the Sea
Month: April Year: 2018
Chief Operator: John S. Sibbalds
Assistant Chief Operator: Robert J Willwerth

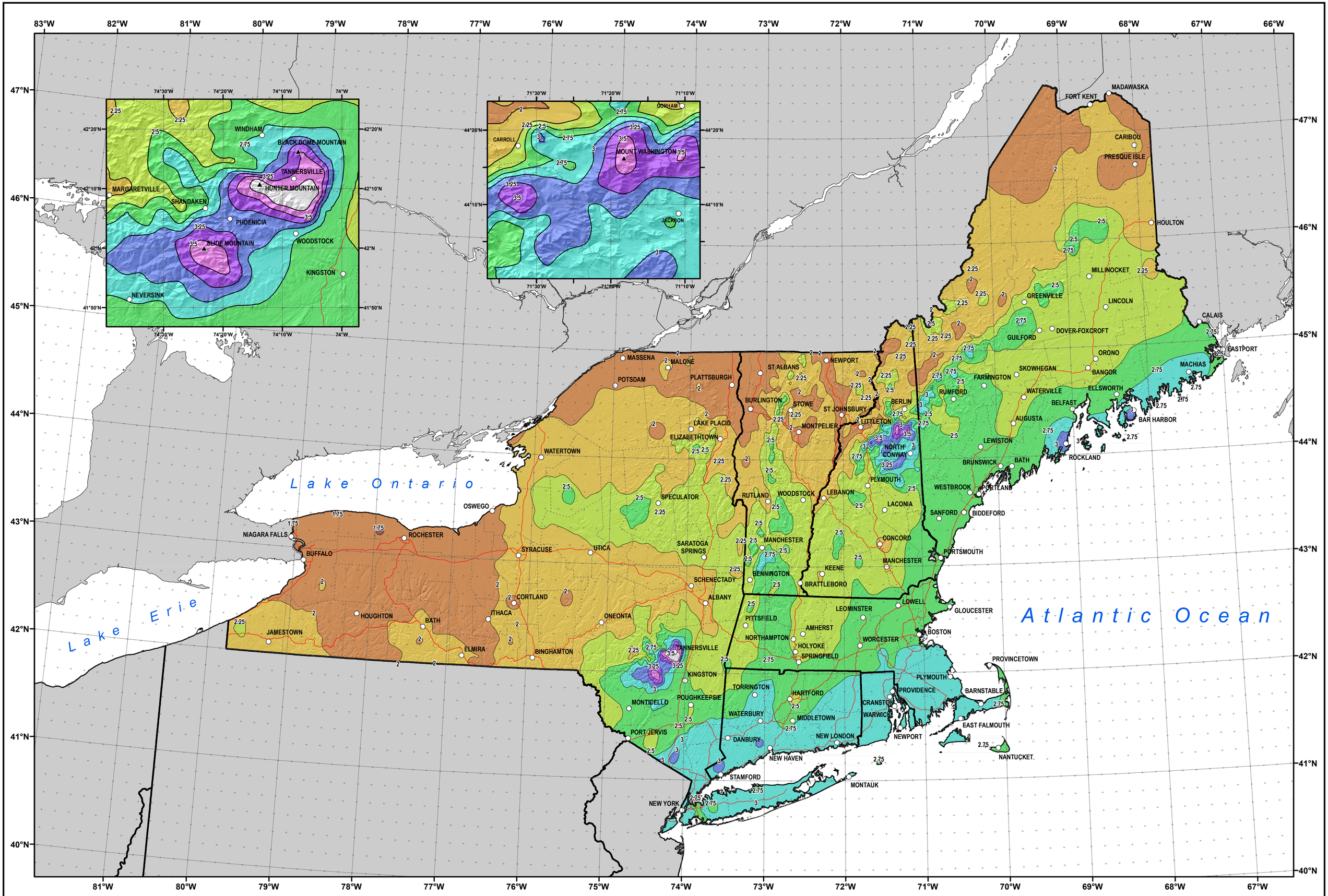
Department of Environmental Quality Engineering
Division of Water Pollution Control

Monthly Operation and Maintenance Report

Region: Northeast
County: Essex
If Contract Operation Company:

Permit Number Federal Sate: M
mgd.
mgd. Mor
Monthly Average Flow Last Year mgd.
Chief Operator Certification of Report:

	Weather			Sewage Flows (mgd)				Grit & Scr	Disinfection				Settleable Solids				pH			
								Cubic	Gallons/	Cl2 Residual				Primary	Sec.		Influent		Disinfection	
Date	Rain	Temp	Influent Temp	Max	Min	Total	Bypass	Feet	24 hrs.	1	2	3	Raw	Effluent	Effluent	Final	High	Low	High	Low
4/1/2018		6	10	1.40	0.25	0.608		2.0	7.0	0.5	0.4	0.5					7.1		6.9	
4/2/2018	0.03	1	11	1.30	0.15	0.606		1.0	7.0	0.4	0.5	0.5					7.2		6.9	
4/3/2018	0.37	1	11	1.25	0.05	0.585		1.5	6.0	0.5	0.5	0.5					7.2		6.9	
4/4/2018	0.14	4	11	1.25	0.10	0.600		2.0	6.0	0.4	0.4	0.6					7.1		6.9	
4/5/2018		-3	10	1.25	0.30	0.580		3.0	7.0	0.4	0.5	0.5					7.2		6.9	
4/6/2018	0.33	-4	10	1.25	0.10	0.568		1.5	7.0	0.5	0.4	0.5					7.2		7.1	
4/7/2018		1	10	1.20	0.30	0.577		1.5	6.0	0.5	0.5	0.4					7.1		7.0	
4/8/2018		-1	10	1.35	0.30	0.580		1.5	7.0	0.6	0.5	0.5					7.1		6.8	
4/9/2018		-4	10	1.30	0.15	0.547		2.0	4.0	0.3	0.2	0.6					7.2		7.0	
4/10/2018		1	11	1.10	0.20	0.493		2.0	7.0	0.4	0.4	0.4					7.3		6.9	
4/11/2018		-3	11	1.05	0.05	0.445		1.5	6.0	0.4	0.6	0.3					7.3		6.9	
4/12/2018	0.10	2	12	1.20	0.20	0.478		2.0	6.0	0.5	0.5	0.3					7.3		7.0	
4/13/2018		10	11	0.90	0.10	0.381		1.0	6.0	0.6	0.4	0.5					7.4		7.0	
4/14/2018		7	10	0.90	0.20	0.394		1.0	6.0	0.4	0.7	0.5					7.3		6.8	
4/15/2018	0.19	1	10	1.00	0.20	0.426		1.5	8.0	0.5	0.4	0.7					7.2		6.9	
4/16/2018	1.98	1	10	1.80	0.35	1.055		4.5	11.0	0.7	0.6	0.8					7.2		6.9	
4/17/2018		6	10	1.65	0.45	0.908		0.5	8.0	0.4	0.5	0.4					7.4		7.0	
4/18/2018	0.02	1	10	1.50	0.20	0.740		1.5	8.0	0.4	0.5	0.5					7.0		6.9	
4/19/2018	0.19	5	10	1.65	0.35	0.770		3.0	8.0	0.2	0.6	0.4					7.2		7.0	
4/20/2018		2	10	1.25	0.35	0.615		1.0	7.0	0.3	0.5	0.6					7.0		6.9	
4/21/2018		3	10	1.10	0.30	0.566		1.0	7.0	0.4	0.6	0.4					7.1		6.9	
4/22/2018		4	10	1.20	0.25	0.543		1.5	8.0	0.4	0.4	0.7					7.0		7.1	
4/23/2018		0	12	1.05	0.15	0.478		1.0	7.0	0.5	0.5	0.6					7.1		6.9	
4/24/2018		6	11	1.05	0.20	0.447		1.0	7.0	0.4	0.5	0.4					7.2		6.9	
4/25/2018	1.61	9	11	1.25	0.10	0.654		1.0	7.0	0.4	0.4	0.4					7.3		6.9	
4/26/2018	0.04	8	12	1.55	0.50	0.834		2.0	7.0	0.3	0.3	0.4					7.0		6.9	
4/27/2018	0.43	7	11	1.50	0.20	0.801		1.0	10.0	0.5	0.2	0.3					7.1		7.1	
4/28/2018		8	10	1.30	0.40	0.750		1.5	8.0	0.2	0.6	0.5					6.8		6.8	
4/29/2018	0.04	8	11	1.30	0.35	0.704		1.5	8.0	0.3	0.5	0.5					6.9		6.7	
4/30/2018	0.06	4	12	1.45	0.20	0.649		2.0	7.0	0.3	0.4	0.5					7.1		6.8	
Total	5.53	91	318	38.30	7.00	18.382		49.0	214.0	12.6	14.0	14.7					214.6		207.6	
Average	0.40	3	11	1.28	0.23	0.613		1.6	7.1	0.4	0.5	0.5					7.2		6.9	



CONNECTICUT, MAINE, MASSACHUSETTS, NEW HAMPSHIRE, NEW YORK, RHODE ISLAND, VERMONT

NOAA Atlas 14, Volume 10, Version 2
Northeastern States

Isopluvials of 1-year 24-hour precipitation in inches

SCALE 1:2,500,000

1.73 - 1.75 | 2.01 - 2.25 | 2.51 - 2.75 | 3.01 - 3.25 | 3.51 - 3.75
1.76 - 2.00 | 2.26 - 2.50 | 2.76 - 3.00 | 3.26 - 3.50 | 3.76 - 4.00

0 5 10 20 30 40 50 Miles

0 10 20 40 60 80 100 Kilometers

Projection: Lambert Conformal Conic; Datum NAD83; Standard Parallels: 43˚N and 45˚N; Central Meridian 72.5˚W.

Prepared by U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
NATIONAL WATER CENTER
HYDROMETEOROLOGICAL DESIGN STUDIES CENTER
September 2015

APPENDIX C

Sawmill Brook Flood Mitigation and Restoration Feasibility

Field Data Sheet- Salinity Profiles

Manchester Harbor- Below Central Bridge

TRANSECT #	**Date:** 4.18.18	**Observers:**
Highest High Water-HHW	1:51	**GCB and DBV**
Start Time	1:30	
Stop Time	2:00	
Transect Width (ft)	32 (43-11)	
EW (ft)	6.4	

EW=Equal Width Interval, LEW/REW- Left or Right Side of Transect, VMI= Vertical Measurement Interval

TABLE TO CALCULATE OBSERVATION POINTS

	LEW	1	2	3	4	5	REW
Tape from LEW (ft) =	0	14.2	20.6	27	33.4	39.8	43
Depth (ft) =	0	9.5	5	5	4	3.5	3.5
VMI (ft) =	n/a	1.7	0.8	0.8	0.8	n/a	n/a
Measurements at: (distance from water surface)		0.5	0.5	0.5	0.5		
		2.2	1.3	1.3	1.1		
		3.9	2.1	2.1	1.7		
		5.6	2.9	2.9	2.3		
		7.3	3.7	3.7	2.9		
		9	4.5	4.5	3.5		

TABLE TO ENTER SALINITY READINGS

	LEW	1	2	3	4	5	REW
Tape from LEW (ft) =	0	14.2	20.6	27	33.4	39.8	43
Depth (ft) =	0	9.5	5	5	4	3.5	3.5
VMI (ft) =	n/a	1.7	0.8	0.8	0.8	0.8	n/a
Salintiy (ppt)		2.35	1.37	2.92	2.72	3.32	2.95
		25.93	23.8	22.8	4.9	4.86	5.8
		26.15	26.07	25.9	23.7	26.7	
		26.46	26.01	26.03	25.87		
		26.47			24		
Vertical Average Salinity =		21.472	19.3125	19.4125	16.238	11.626667	n/a

V

NOTES:
include description of tidal activity during the measurement includign direction, velocity, and peak level

Section number	Tape from LEW (ft)	Width of Increment (ft)	Depth of Vertical (ft)	Area of Section (sq ft)	Vertical Average Salinity (ppt)	Product of area and vertical salinity
LEW	0	n/a	n/a	n/a	n/a	n/a
1	14.2	1.7	9.5	16.15	21.47	346.8
2	20.6	0.8	5	4	19.31	77.3
3	27	0.8	5	4	19.41	77.7
4	33.4	0.8	4	3.2	16.24	52.0
5	39.8	0.8	3.5	2.8	11.63	32.6
REW	43	n/a	n/a	n/a	n/a	n/a
			Sum=	30.15	Sum=	586.2
			Area-weighted Salinity=			19.4

Sawmill Brook Flood Mitigation and Restoration Feasibility

Field Data Sheet- Salinity Profiles

Above Central Bridge

TRANSECT #	**Date:** 4.18.18	**Observers:**
Highest High Water-HHW	1:51	**GCB and DBV**
Start Time	2:15	
Stop Time	2:30	
Transect Width (ft)	18	
EW (ft)	3.6	

EW=Equal Width Interval, LEW/REW- Left or Right Side of Transect, VMI= Vertical Measurement Int

TABLE TO CALCULATE OBSERVATION POINTS

	LEW	1	2	3	4	5	REW
Tape from LEW (ft) =	0	13.8	17.4	21	24.6	28.2	
Depth (ft) =	0	4.9	4.9	4.9	4.9	4.9	
VMI (ft) =	n/a	0.78	0.78	0.78	0.78	0.78	
Measurements at: (distance from water surface)		0.5	0.5	0.5	0.5	0.5	
		1.28	1.28	1.28	1.28	1.28	
		2.06	2.06	2.06	2.06	2.06	
		2.84	2.84	2.84	2.84	2.84	
		3.62	3.62	3.62	3.62	3.62	
		4.4	4.4	4.4	4.4	4.4	

TABLE TO ENTER SALINITY READINGS

	LEW	1	2	3	4	5	REW
Tape from LEW (ft) =	0	13.8	17.4	21	24.6	28.2	
Depth (ft) =	0	4.9	4.9	4.9	4.9	4.9	
VMI (ft) =	n/a	0.78	0.78	0.78	0.78	0.78	
Salintiy (ppt)		0.17	0.16	0.15	0.15	0.2	
		0.17	0.17	0.16	0.17	0.31	
		0.17	0.19	0.17	0.24	0.3	
		0.17	5	0.23	0.5	0.53	
		0.17	15.3	15	1.1	1.2	
		0.16	19.8	16.4	3	4.11	
Vertical Average Salinity =		0.17	4.164	3.142	0.432	0.508	

NOTES: include description of tidal activity during the measurement includign direction, velocity, and peak level	Gage C 4.9 tide hight

Section number	Tape from LEW (ft)	Width of Increment (ft)	Depth of Vertical (ft)	Area of Section (sq ft)	Vertical Average Salinity (ppt)	Product of area and vertical salinity
LEW	0	n/a	n/a	n/a	n/a	n/a
1	13.8	0.78	4.9	3.822	0.17	0.6
2	17.4	0.78	4.9	3.822	4.16	15.9
3	21	0.78	4.9	3.822	3.14	12.0
4	24.6	0.78	4.9	3.822	0.43	1.7
5	28.2	0.78	4.9	3.822	0.51	1.9
REW		n/a	n/a	n/a	n/a	n/a
			Sum=	19.11	Sum=	32.2
			Area-weighted Salinity=			1.7

Figure D-1: Station C2 - Manchester Harbor (Boundary Condition)

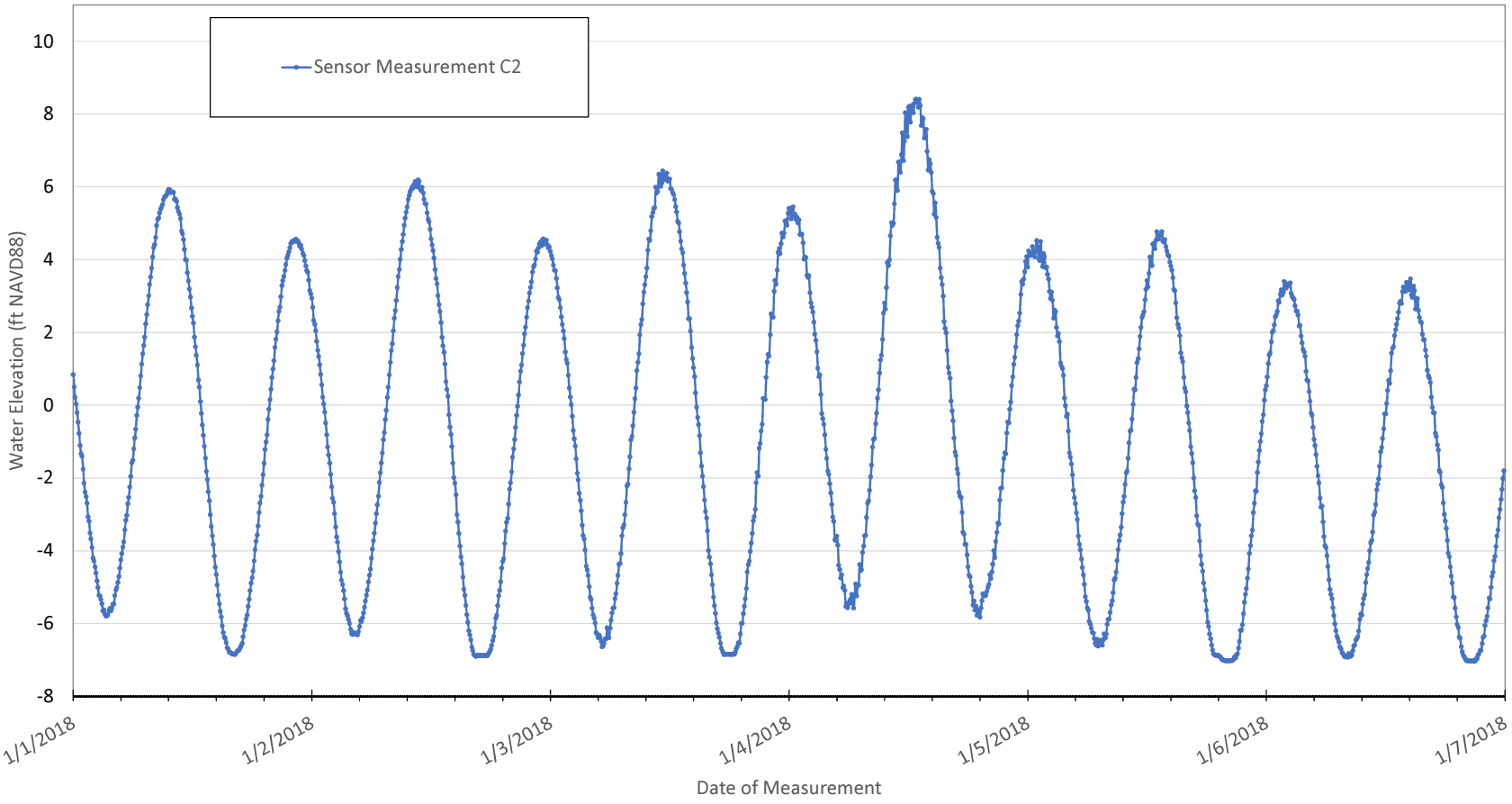


Figure D-2: Station C1 (model vs. measured)

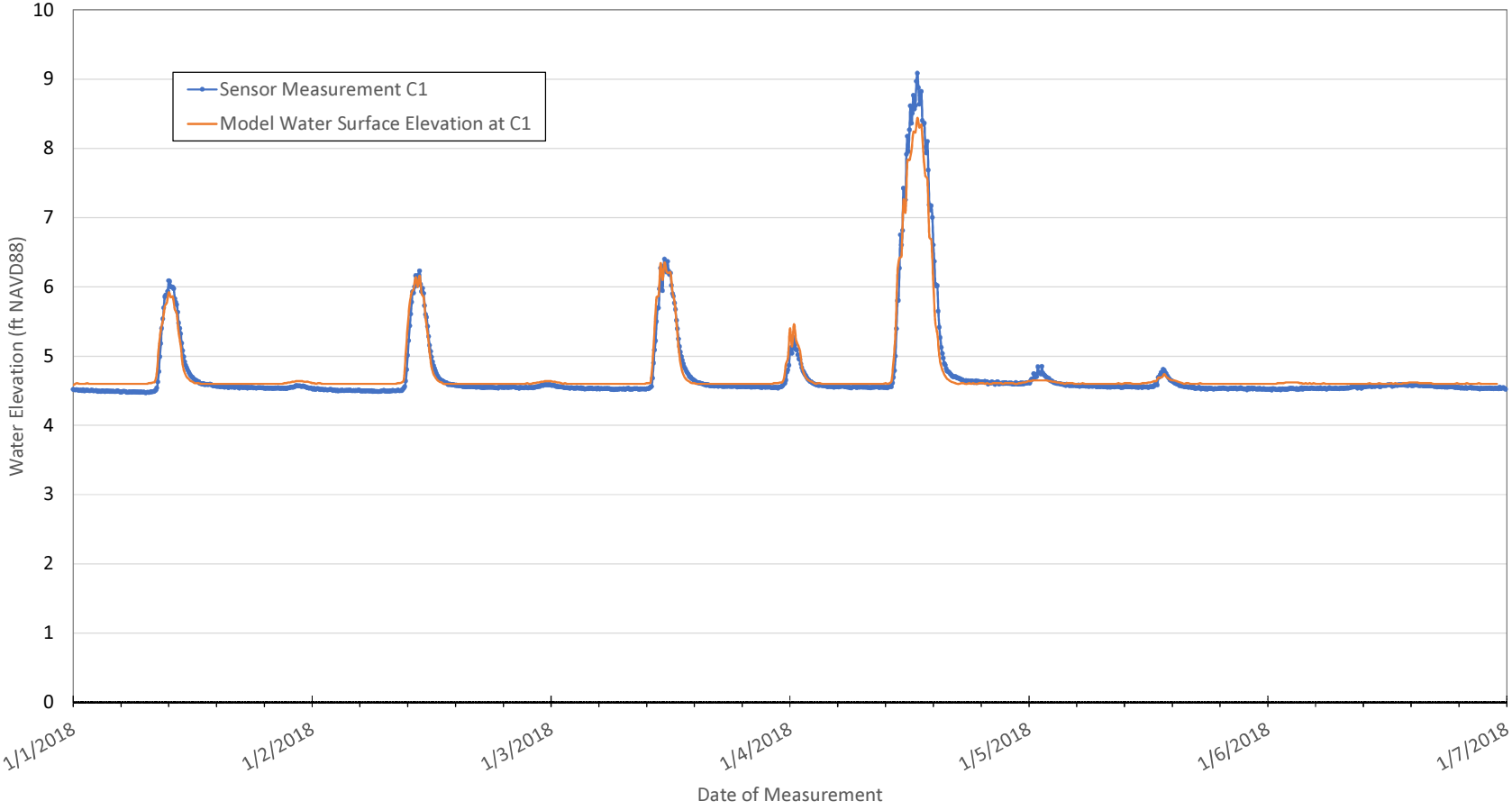


Figure D-3: Station B2 (model vs. measured)

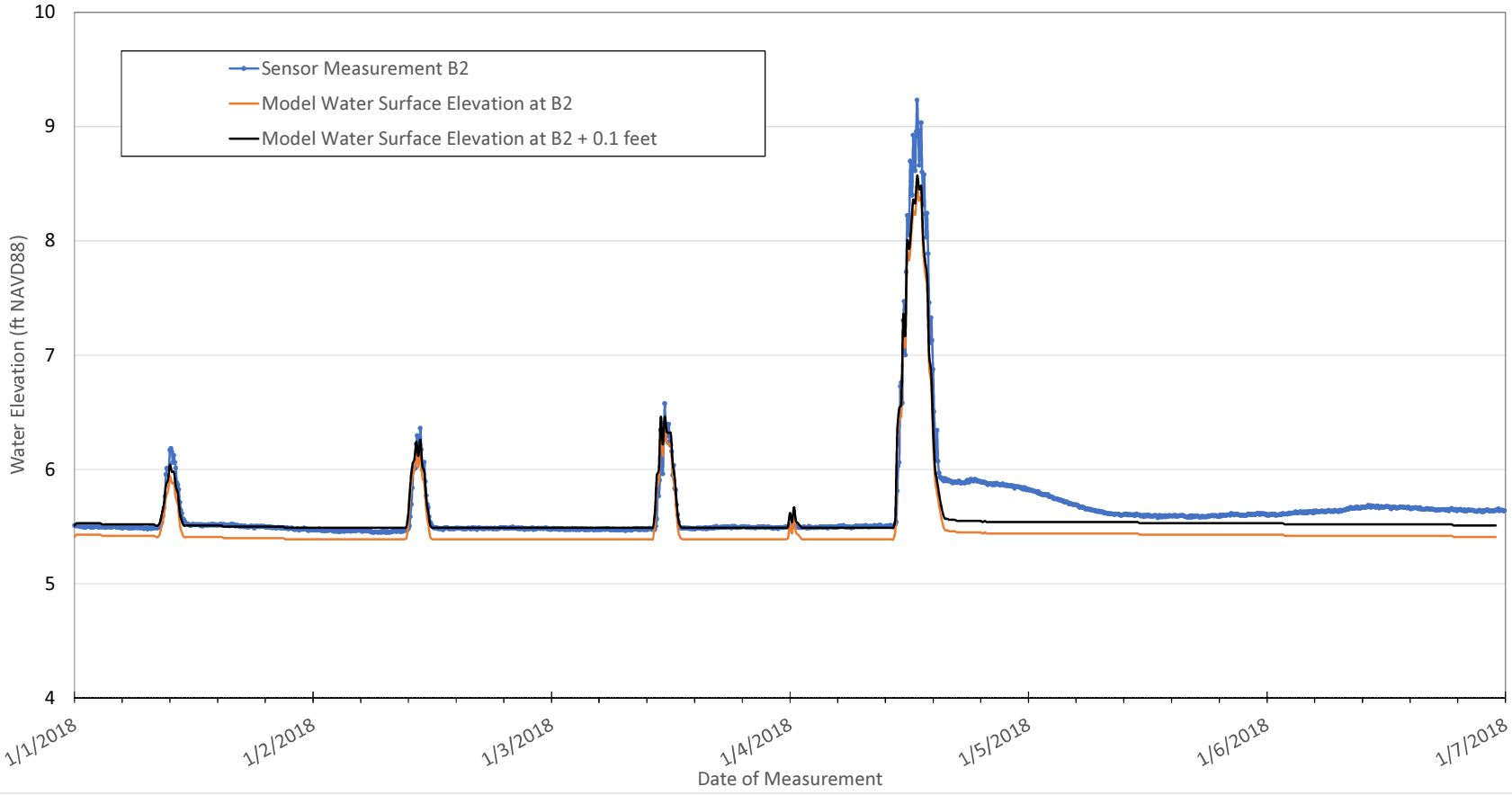


Figure D-4: Station A2 (model vs. measured)

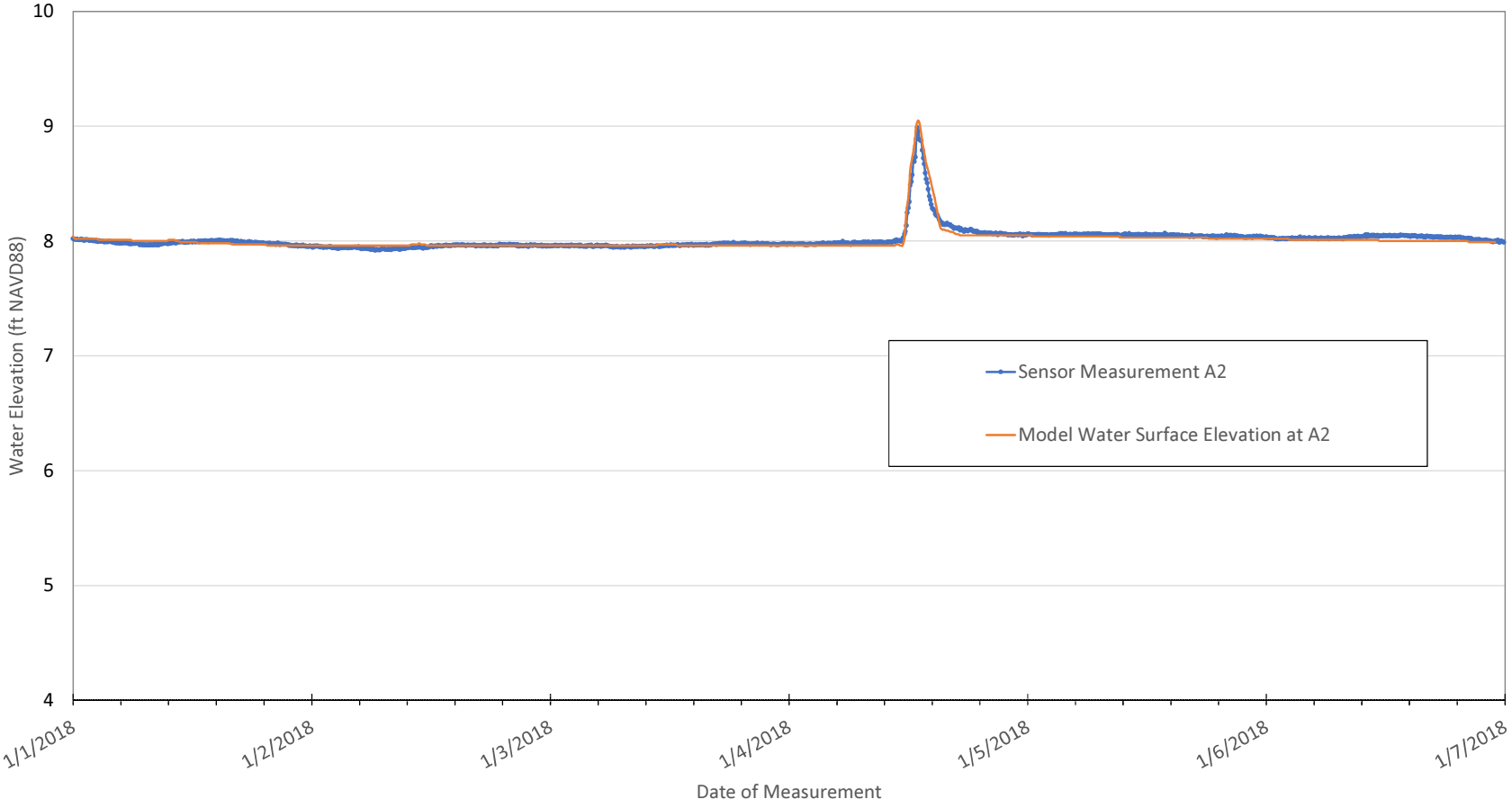
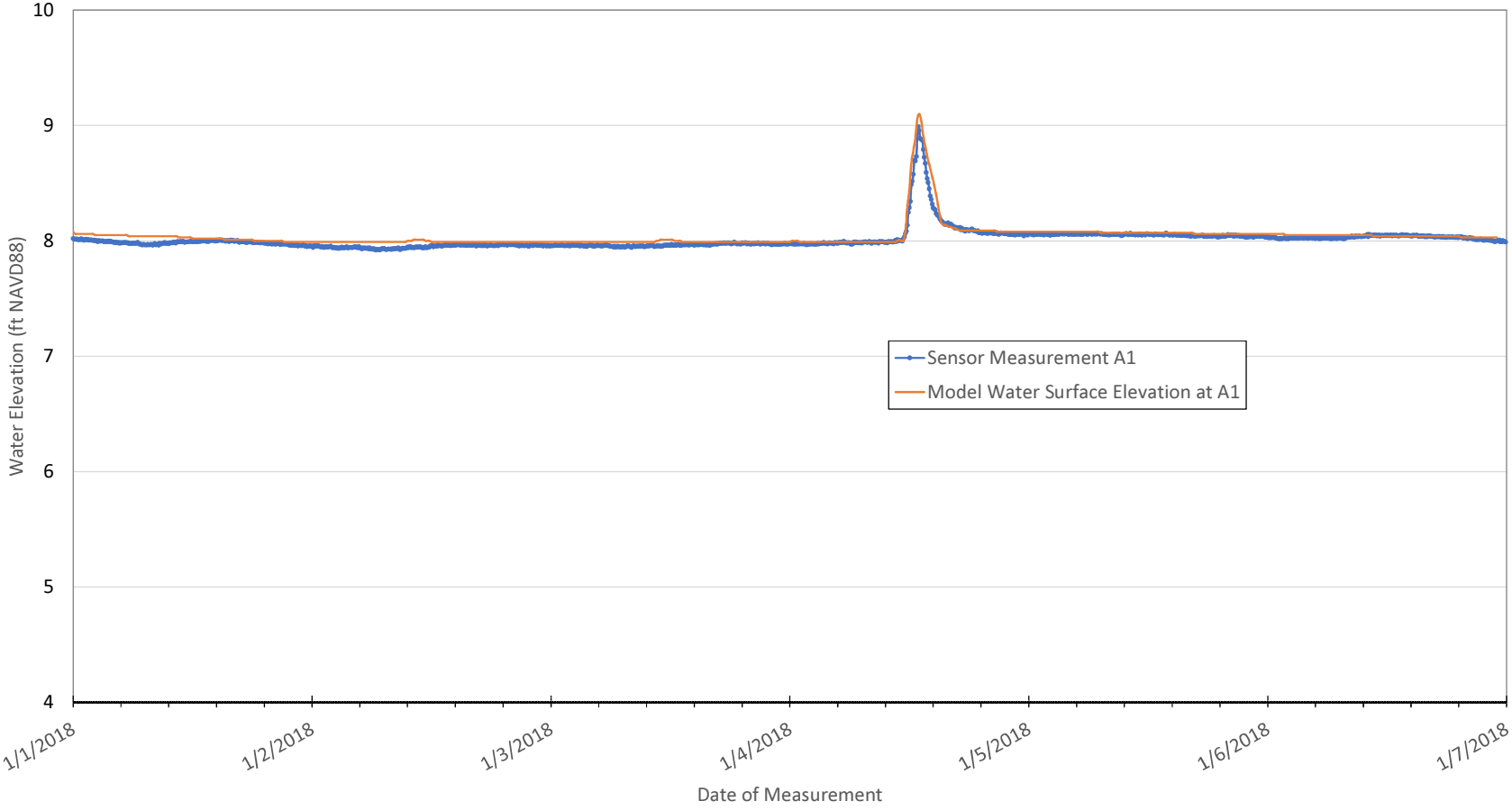


Figure D-5: Station A1 (Upstream Cross Section)



APPENDIX D

Appendix E

Salinity and Flushing Time Calculations

1. Fraction of Salt Water from Manchester Harbor Upstream of Central Street Calculations

Salinity measurements were taken upstream and downstream of Central Street on April 18, 2018, as described in the Task 2 memo. Based on field measurements the inflow from upstream of Sawmill Brook can be considered "freshwater" so the salinity upstream of Central Street can be used as an indicator for the fraction of water from Manchester Harbor. The concentration dilution formula is therefore used to calculate the ratio of inflow from Manchester Harbor to the total pond inflow. The concentration dilution formula as related to the site can be described as:

$$S_{US} = \frac{S_{FW}Q_{FW} + S_{DS}Q_{DS}}{Q_{FW} + Q_{DS}}$$

Where,

S_{US} = Salinity upstream of Central Street (downstream of Central Pond) (ppt)
S_{FW} = Salinity of freshwater Sawmill Brook flow from upstream of Central Pond (ppt)
Q_{FW} = Sawmill Brook freshwater flow from upstream of Central Pond (ft^3/s)
S_{DS} = Salinity of flow from downstream of Central Pond (Manchester Harbor)(ppt)
Q_{DS} = Flow from downstream of Central Pond (Manchester Harbor) (ft^3/s)

$$note, \quad S_{FW} = 0$$

$$therefore, \quad S_{FW}Q_{FW} = 0$$

$$therefore, \quad S_{US}(Q_{FW} + Q_{DS}) = S_{DS}Q_{DS}$$

$$rearranged, \quad \frac{S_{US}}{S_{DS}} = \frac{Q_{DS}}{(Q_{FW} + Q_{DS})}$$

$$Adding\ measured\ concentrations, \quad \frac{Q_{DS}}{(Q_{FW} + Q_{DS})} = \frac{1.7\ ppt}{19.8\ ppt} = 0.09 \approx 10\%$$

Approximately 10-percent of the water column upstream of Central Street appears to be from Manchester Harbor, with the other 90-percent from Sawmill Brook (freshwater).

2. Flushing Time Calculation

The flushing time was estimated using the Knudsen Formula[1], because it is considered a suitable method for highly stratified estuaries as observed at Central Pond. The Knudsen Formula as related to Central Pond is:

$$T_F = \frac{V}{R}\left(1 - \frac{S_{TOP}}{S_{BOTTOM}}\right)$$

Where,

T_F = Flushing Time (seconds)
V = Tidal Prism Volume of Central Pond (ft^3)
R = Flow of Water Leaving Central Pond (ft^3/s)
S_{TOP} = Salinity toward the top of the water column (defined as top 2.1 feet) (ppt)
S_{BOTTOM} = Salinity toward the bottom of the water column (defined as deep than 2.1 feet) (ppt)

Measured and computed parameters (as described in the Task 2 Memo) can be used to estimate the flushing time. The flow and salinity profiles measured upstream of Central Street on April 18, 2018 were used for the calculations, as well as the computed tidal prism when the tide gate is open. By adding the measured and computed parameters to the Knudsen Formula the equation becomes:

$$T_F = \frac{194{,}130\ ft^3/s}{26.7\ ft^3}\left(1 - \frac{0.18\ ppt}{4.19\ ppt}\right)$$

$$Therefore, \qquad T_F = 6{,}960\ seconds$$

$$With\ Unit\ Conversion\ to\ hours, \qquad T_F = 1.9\ hours$$

[1] Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO) "Flushing Time". https://www.mtoceanography.info/ShelfCoast/notes/chapter15.html.