Appendix A: Climate Ready Boston Implementation Timeline

Climate Ready Boston Project Timeline

Project	Neighborhood	Start year	Near term (by 2030)	Midterm (by 2050)	Long term (by 2070)	End year
Main Street Elevation	Charlestown	2017	X			2025
Schrafft's Center Waterfront	Charlestown	2017	X			2030
Ryan Playground (Part 1)	Charlestown	2017	X			2025
Ryan Playground (Part 2)	Charlestown	2040			X	2050
Moakley to Bayside Berm	Dorchester	2022	X			2028
Harbor Point Harborwalk	Dorchester	2024	X			2013
Morrissey Boulevard North	Dorchester					2030
Building Level Adaptation (McConnell Park)	Dorchester	~2024	X			2030
Morrissey Boulevard	Dorchester	2036			X	2050
Morrissey Boulevard South (Berms)	Dorchester	Account for in 2020, revisit in 2028			X	2034
Tenean Beach (Deployable)	Dorchester	2020				2024
Tenean Beach (Low berm, raising street)	Dorchester	2022				2030
Tenean Beach (Adapted berm, wetlands enhancements, boardwalk to Victory)	Dorchester	2038		X		2050
Floodwall along MBTA rail	Dorchester	2034			X	2040
Building Level Adaptation (Port Norfolk)	Dorchester	2024	X			*ongoing, expanding*
Port Norfolk (living shoreline, perimeter harborwalk, raising roads)	Dorchester	2022	X			2030
Neponset Circle	Dorchester	2022				2030
Davenport Creek Tide Gate	Dorchester	2022	X			2026
Pope John Paul II Park Geotech Study	Dorchester	2022	X			2030
Neponset Trail Raising	Dorchester	2040			X	2046
Building Level Adaptation (along the Neponset River)	Dorchester	2024	X			ongoing, expanding
Neponset Wetlands Monitoring program	Dorchester	2024	X			2030
Greenway Deployable	East Boston	2017	X			2020
Greenway Entrance	East Boston	2017	X			2025
Clippership-Hodge berm	East Boston	2017	X			2025
Piers Park II	East Boston	2017	X			2025
Border Street Priority	East Boston	2017	X			2025
Shore Plaza	East Boston	2025			X	2030
Mario Umana School Waterfront Elevation	East Boston	2025			X	2030
Clippership Wharf Deployable Flood Walls	East Boston	2030			X	2040
Porzio Park/MPA Harborwalk Park	East Boston	2030			X	2040
Lewis Street Mitigation	East Boston	2040			X	2050

Project	Neighborhood	Start year	Near term (by 2030)	Midterm (by 2050)	Long term (by 2070)	End year
Langone Park	North End/Downtown	2019	X			2021
Puopolo Playground	North End/Downtown	2019	X			2021
Long wharf	North End/Downtown	2020				2025
Central wharf	North End/Downtown	2020	X			2030
Harbor towers	North End/Downtown	2020	X			2030
Commercial wharf	North End/Downtown	2020		X		2030
Lewis Wharf	North End/Downtown	2020		X		2030
Sargent’s Wharf	North End/Downtown	2020		X		2030
Union Wharf	North End/Downtown	2020		X		2030
Lovejoy Waterfront	North End/Downtown	2030		X		2040
Waterfront from NW Bridge to Langone/Puopolo	North End/Downtown	2040		X		2050
Rowes Wharf - Northern Avenue Bridge	North End/Downtown	2050			X	2070
Burroughs Wharf	North End/Downtown	2050			X	2070
Battery Wharf	North End/Downtown	2050			X	2070
Christopher Columbus Park	North End/Downtown	2020	X			2030
100 Acre Master Plan Harborwalk	South Boston	2018	X			2025
GE Building	South Boston		X			
Building/Arcade (as seawall)	South Boston		X			
Seaport Boulevard (part 1)	South Boston	2018	X			
Between Bridges	South Boston	2020				2030
Children's Museum	South Boston	2020	X			2030
Martin's Park	South Boston	2018		X		2019
Gillette Manufacturing Facility Waterfront	South Boston	2020	X			2030
Seaport Boulevard (part 2)	South Boston	2020		X		2030
Reserved Channel	South Boston	2020		X		2040
South End of Fort Point Channel	South Boston	2030		X		2040
Additional Enhancements to Fort Point Channel	South Boston	2020		X		2050
Pleasure Bay	South Boston	2020		X		2050
Day Boulevard	South Boston	2020		X		2050
South Boston Waterfront	South Boston	2030		X		2050
West Side of Fort Point Channel	South Boston	2050			X	2070
Raymond L. Flynn Marine park	South Boston	2020			X	2070

Appendix B: Vieux & Associates Hyetograph Analysis

Technical Memorandum

From: Vieux & Associates, Inc., 301 David L. Boren Blvd. Suite 3050, Norman, Oklahoma 73074

To: Boston Water and Sewer Commission

Date: December 21, 2020

Subject: Hyetograph Analysis

Introduction

The Boston Water and Sewer Commission (BWSC) and Hazen and Sawyer required a review of hydrometeorological input as part of their coastal stormwater discharge project to support the analysis of proposed outfalls and siting of consolidated discharge facilities. Vieux & Associates Inc. completed this hydrometeorological review and updated the 10-year, 24-hour Type III synthetic design storm for the greater Boston area. This hyetograph update followed USDA Natural Resources Conservation Service (NRCS) methodology using NOAA Atlas 14 data to ensure that its shape and depth are representative of current and future design storms. Wet weather scenarios, based upon those already developed by the BWSC, were applied to the updated rainfall distribution to provide an estimate of precipitation depth and intensity for future storms in the greater Boston area, up until the year 2070. Comparisons between the currently used BWSC design storm, the updated NOAA Atlas 14-based design storm, and future projected design storms are made to identify any key changes in hydrometeorological patterns over time.

Hyetograph Development

The current 10-year, 24-hour design storm conditions that BWSC applies to facility planning and sewer design were reviewed (Figure 1) and recalculated to reflect updated recommendations for design storm development. One motivating reason for this hyetograph update is that studies of the Type III or other legacy rainfall distributions (e.g., SCS method) have concluded that their use be discontinued in areas covered by the NOAA Atlas 14 data. Furthermore, these studies have reported that the usage of the Type III or other legacy rainfall distributions in conjunction with the NOAA Atlas 14 data (e.g., utilizing the Type III rainfall distribution with the NOAA Atlas 14 rainfall depth) could introduce errors by application of inaccurate rainfall intensities during a storm event. The updated NRCS hyetograph for the 10-year, 24-hour design storm was completed following current guidance (USDA NRCS National Engineering Handbook).

The TP-40 depth-duration-frequency data was compiled by the U.S. Weather Bureau to generate a series of rainfall distributions applicable across the United States based upon rainfall-frequency data from the U.S. Weather Bureau in 1961 and the National Weather Service in 1977. The legacy SCS method was developed in 1979 by the NRCS (formerly Soil Conservation Service or SCS) using the 25-yr storm generalized to represent three areas identified as Type I, II, And III. The USDA NRCS method, which is based on NOAA Atlas 14 data and was last updated in 2019, provided an update to the legacy TP-40 method through the inclusion of the most recent 30 years of precipitation data, which inherently reflects any hydrometeorological changes to storm depth, duration, and frequency that have occurred since 1961 and 1977. Furthermore, by utilizing precipitation data local to the region of interest, the USDA NRCS method enables the generation of a rainfall distribution based upon localized rainfall characteristics, providing increased accuracy compared to those distributions generated by rainfall depths from TP-40.

The USDA NRCS method for the development of a temporal distribution of rainfall is based on the concept of nested depths and durations, which determines the shape of the hyetograph. Using this relationship between intensity and duration, incremental intensity is computed by the ratio of the difference in precipitation to the difference in duration. The NRCS hyetograph assumes that the rainfall depths for all durations correspond to a single return period within one 24-hour period and, thus, includes the maximum rainfall of any duration less than 24 hours within the rainfall distribution. Compared to the legacy SCS method, the updated NRCS hyetograph is more representative for a given location and more accurately reflects the rainfall depth vs. duration hyetograph shape. BWSC currently uses the SCS hyetograph 10-year 24-hour as seen in Figure 1, compiled for a depth of 5.15 inches.

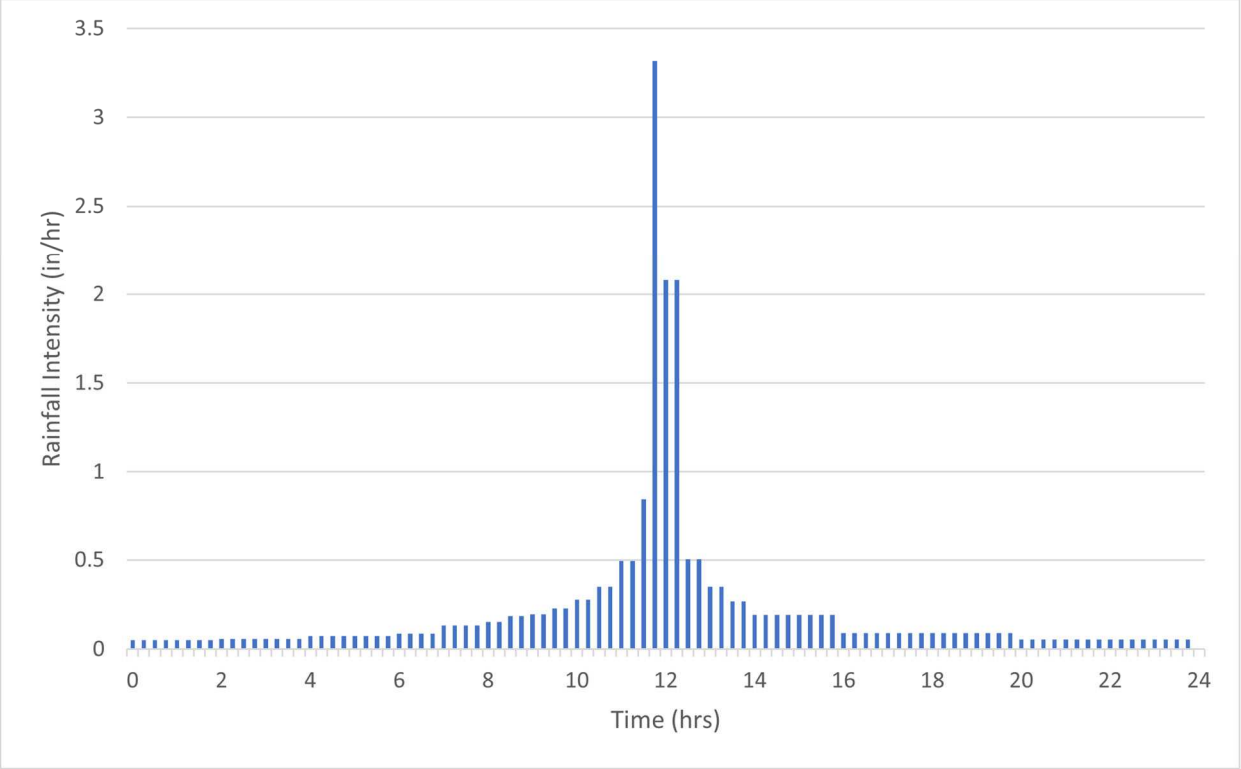


Figure 1: The 10-year, 24-hour design storm, with a total precipitation depth of 5.15 inches, currently used by BWSC.

We followed the USDA NRCS method to compute the cumulative rainfall ratios, encompassing a 24-hour period with a temporal interval of 15 minutes, using rainfall depths from NOAA Atlas 14 at the Boston Logan International Airport (19-0770) location. The rainfall depths for the 10-year return period and design storm durations ranging from 5 minutes to 24 hours are presented in Table 1. From these cumulative rainfall ratios, the dimensionless cumulative rainfall distribution for the Boston Logan Airport location was calculated and plotted in Figure 2. See the Appendix Table A-1 for dimensionless cumulative and incremental hyetographs. The maximum rainfall of any design storm duration less than 24 hours was included in the development of the rainfall distribution and constructed so that each smaller duration event was centrally nested within a longer duration event according to the NRCS method. The NOAA Atlas 14 rainfall depths presented in Table 1 are used to calculate both the rainfall depth and intensity for the 10-year, 24-hour design storm as shown in Figures 2 and 3 (see Table A-2).

Table 1. Rainfall depths for the 10-year return period and design storm durations ranging from 5 minutes to 24 hours from NOAA Atlas 14 at the Boston Logan International Airport (19-0770).

	5-MIN	10-MIN	15-MIN	30-MIN	60-MIN	2-HR	3-HR	6-HR	12-HR	24-HR
RAINFALL DEPTH (IN)	0.567	0.803	0.945	1.26	1.58	2.11	2.48	3.2	4.01	4.91

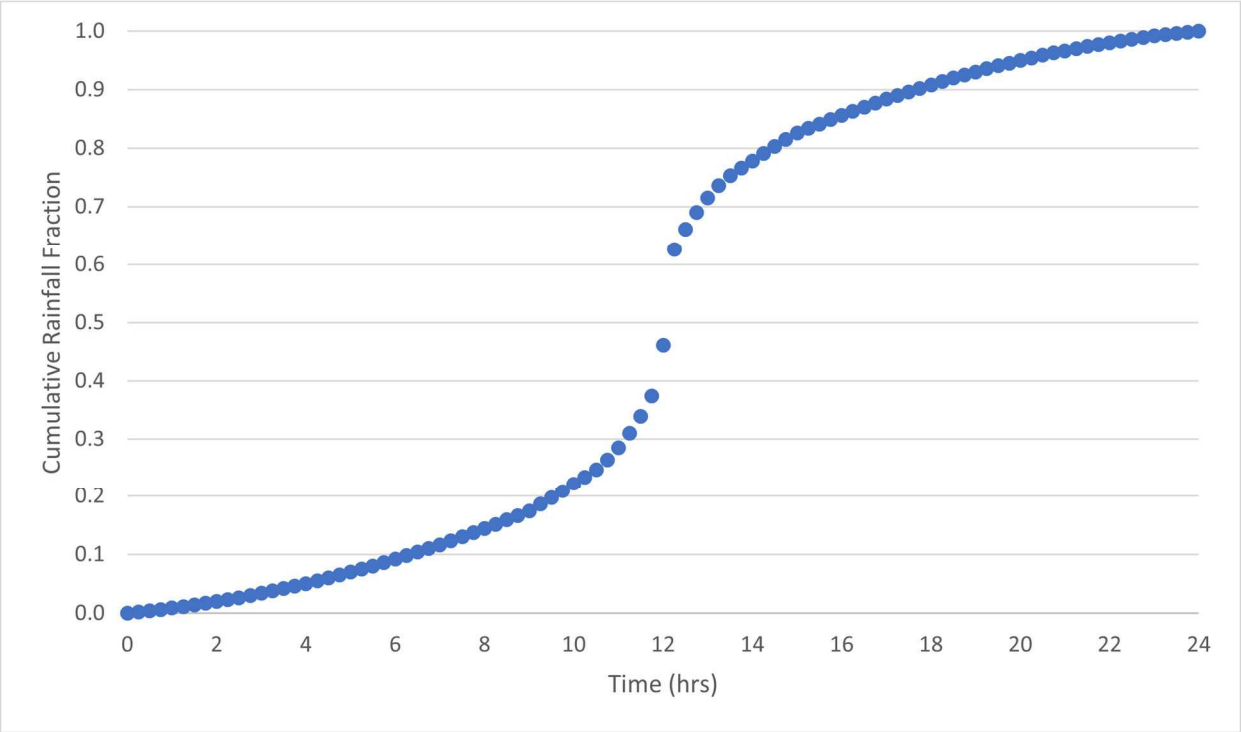


Figure 2: Cumulative dimensionless rainfall depth for 24 hours according to the NRCS hyetograph shape.

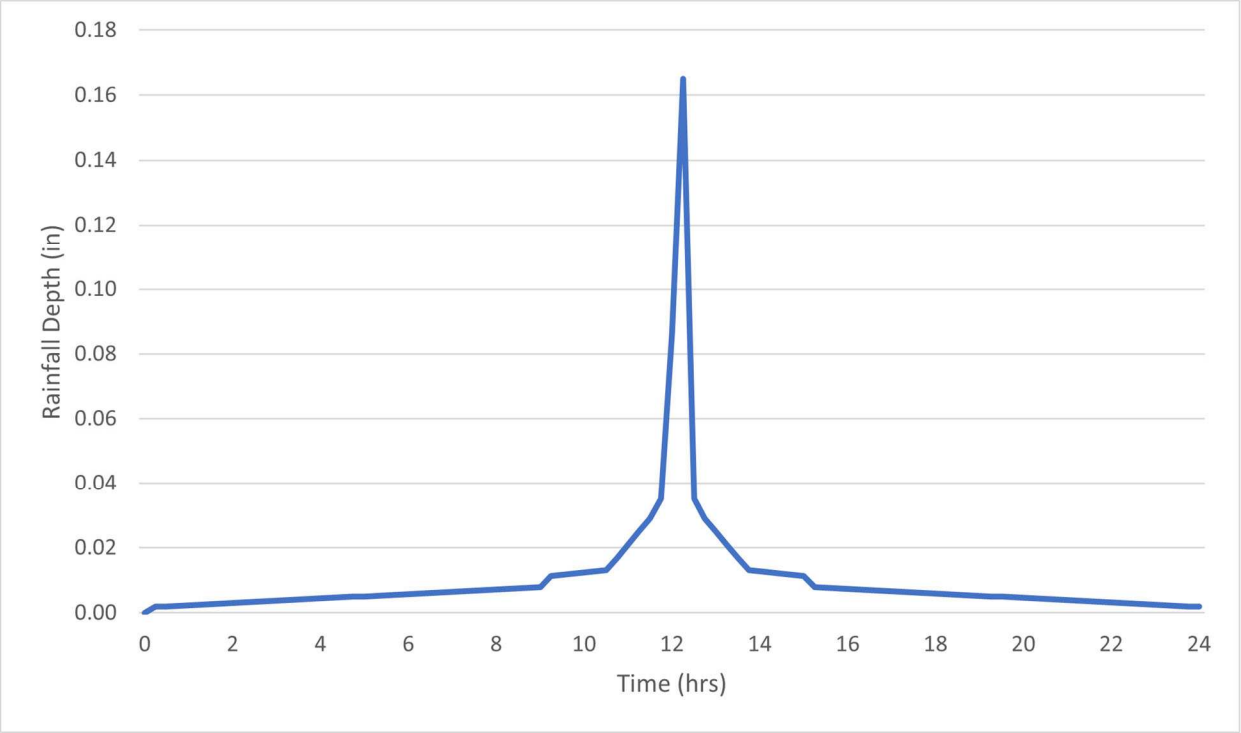


Figure 3: Incremental dimensionless rainfall depth for 24 hours according to the NRCS hyetograph shape

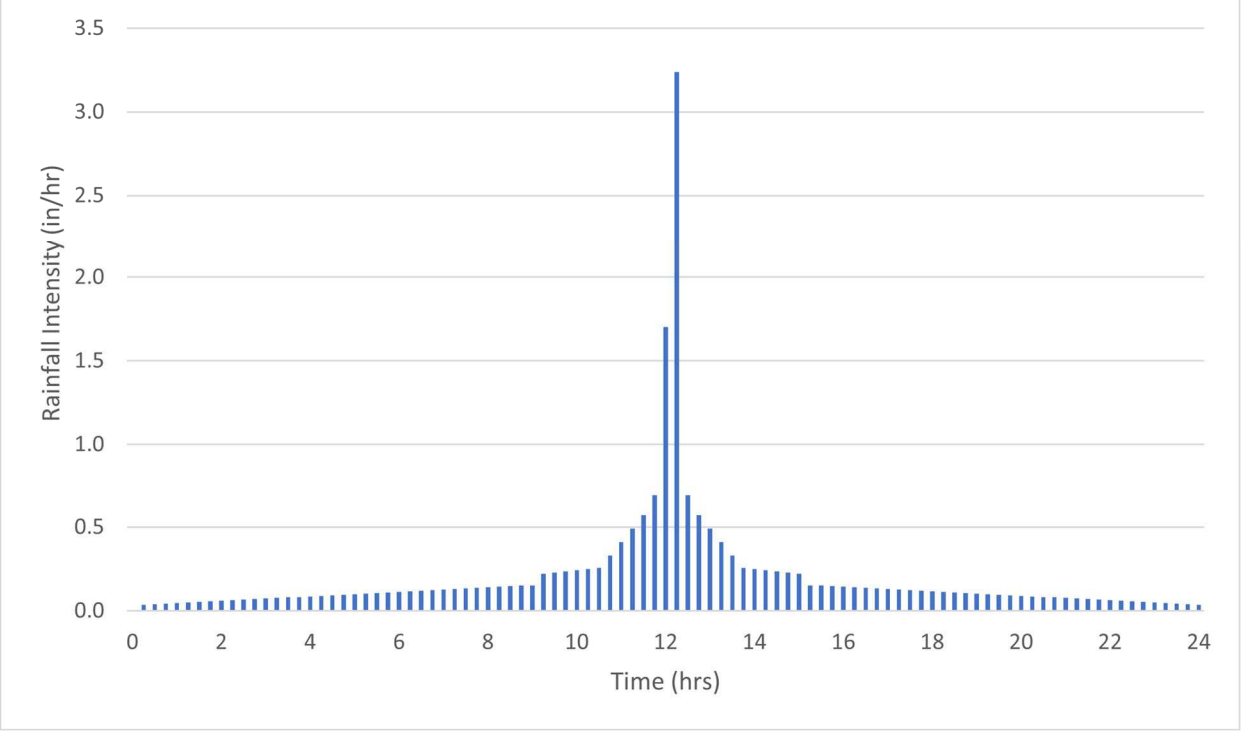


Figure 4: NRCS rainfall hyetograph at Boston Logan International Airport for the 10-year, 24-hour storm event

Future Climate Projections

The Boston Research Advisory Group (BRAG) wrote a report entitled "Climate Change and Sea Level Rise Projections for Boston" as part of the Climate Ready Boston project in 2016. The objective of this 2016 BRAG report was to outline potential climate change-driven alterations to weather and storm patterns in the greater Boston area, including changes to typical precipitation patterns.

One of the main findings of the BRAG report was that future short-term extreme precipitation would increase in the greater Boston area. In support of this finding, the BRAG report summarized estimates of future precipitation from independent reports by the BWSC and the Cambridge Climate Change Vulnerability Assessment (C-CCVA). To provide future precipitation estimates, BWSC utilized SimCLIM software with emissions scenarios from the Special Report on Emission Scenarios, or SRES, to represent plausible future conditions. The SRES scenarios are comparable to the Representative Concentration Pathway, or RCP, emissions scenarios and have been previously used by the Intergovernmental Panel on Climate Change (IPCC) for its third and fourth assessments. The two SRES scenarios used by BWSC, B2 and A1Fi, represent possible future emissions levels, with B2 representing moderate cuts in greenhouse gases (comparable to RCP 6) and A1Fi representing large increases in greenhouse gases or the "business as usual" scenario (comparable to RCP 8.5). In contrast to BWSC, C-CCVA statistically downscaled CMIP3 and CMIP5 output using the Asynchronous Regional Regression Model to provide estimates of future precipitation in the greater Boston area.

The future precipitation estimates by BWSC and C-CCVA are compared in Table 2, with the biggest difference between the two demonstrated in the baseline precipitation value. This difference is possibly due to the difference in record length analyzed by BWSC (i.e., 1948-2012) and C-CCVA (i.e., 1971-2000). However, the remainder of the years are similar between the two datasets, with the 2030s value equivalent between BWSC (A1Fi) and C-CCVA and the 2070s estimate by C-CCVA in line with the 2060 and 2100 estimates by BWSC.

Table 2. Precipitation depths (in) of the 10-year, 24-hour design storms. Note that the BWSC and C-CCVA precipitation estimates were obtained from the 2016 BRAG report.

<table>
<tr><th rowspan="2">CURRENT BWSC</th><th rowspan="2">UPDATED NOAA ATLAS 14</th><th colspan="5">BWSC</th></tr>
<tr><th></th><th>BASELINE (1948-2012)</th><th>2035</th><th>2060</th><th>2100</th></tr>
<tr><td rowspan="6">5.15</td><td rowspan="6">4.91</td><td>B2</td><td rowspan="2">5.24</td><td>5.55</td><td>5.76</td><td>6.08</td></tr>
<tr><td>A1Fi</td><td>5.60</td><td>6.03</td><td>6.65</td></tr>
<tr><td colspan="5">C-CCVA</td></tr>
<tr><td></td><td>BASELINE (1971-2000)</td><td>2030s</td><td colspan="2">2070</td></tr>
<tr><td>Average Values</td><td>4.9</td><td>5.60</td><td colspan="2">6.4</td></tr>
</table>

Due to the substantial uncertainty associated with projections of future precipitation generated by global climate models (GCMs) in the SRES, CMIP3, and CMIP5 experiments, particularly at sub-daily temporal scales, it is not recommended to develop individual rainfall distributions for the 2035, 2060, and 2070 precipitation projections. Thus, in order to generate individual hydrographs and hyetographs for the 2035,

2060, and 2070 design storms, we applied the future precipitation estimates generated by BWSC from the 2016 BRAG report for the SRES B2 and A1Fi scenarios to the 10-year, 24-hour rainfall distribution, generated previously (Figure 2). We estimated a precipitation depth of 5.83" and 6.18" using linear regression for the 2070 B2 and A1Fi scenarios, respectively, since BWSC did not provide a precipitation estimate for 2070. Analysis of the hydrographs reveals that the main difference between the 2035, 2060, and 2070 B2 and A1Fi design storms can be found in the peak rainfall depth shown in Figure 5. Precipitation intensity is highest under the A1Fi scenario in 2070 (Figure 6), which is as expected due to the higher levels of greenhouse gas emissions in the later years of the A1Fi scenario.

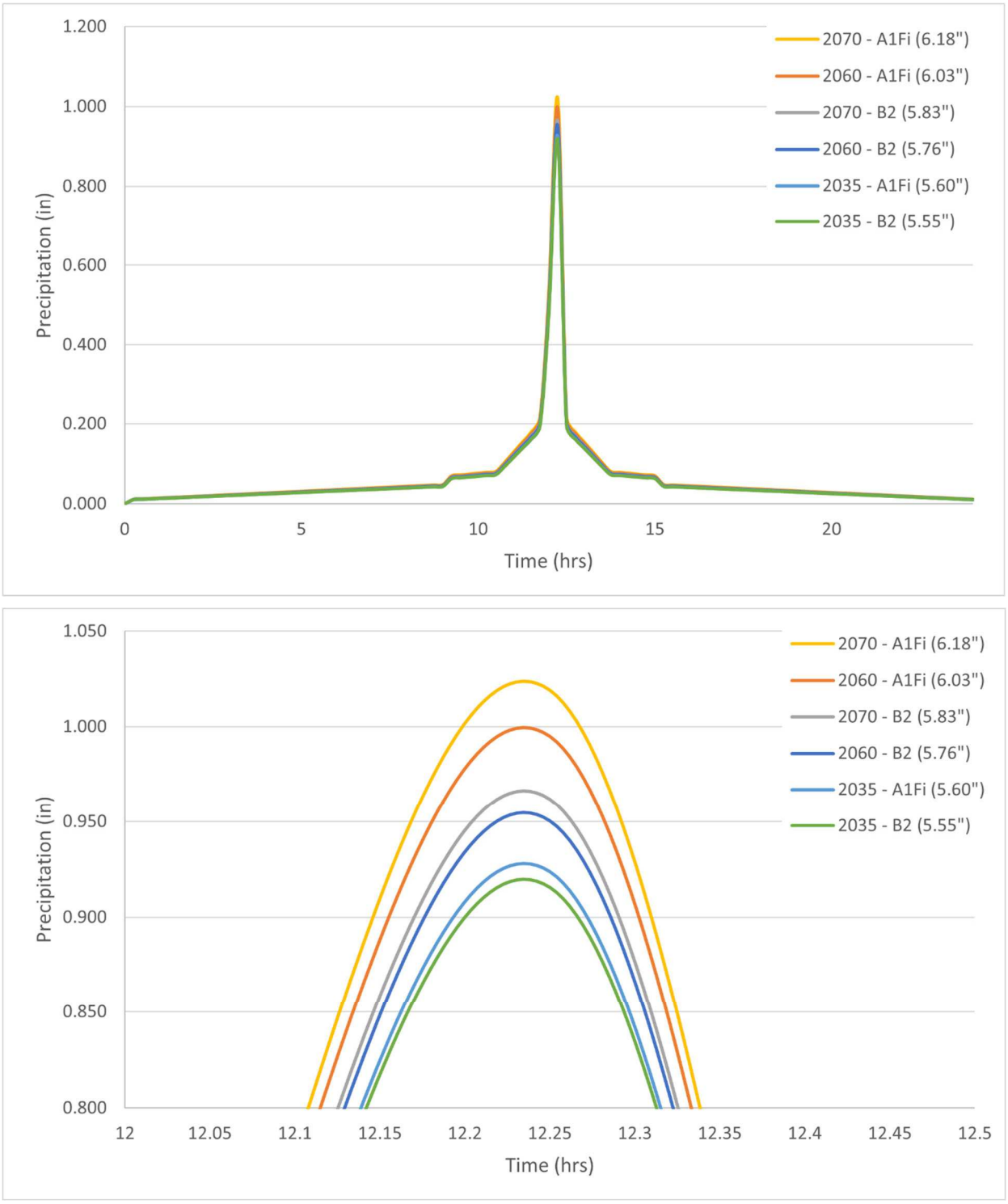


Figure 5. Projected future precipitation for the 10-year, 24-hour design storm under the SRES B2 and A1Fi scenarios for 2035, 2060, and 2070, using precipitation depths predicted by BWSC and a rainfall distribution generated by the USDA NRCS method. The image on the top shows the full design storm hydrograph, while the image on the bottom reveals a zoomed-in snapshot of the peak.

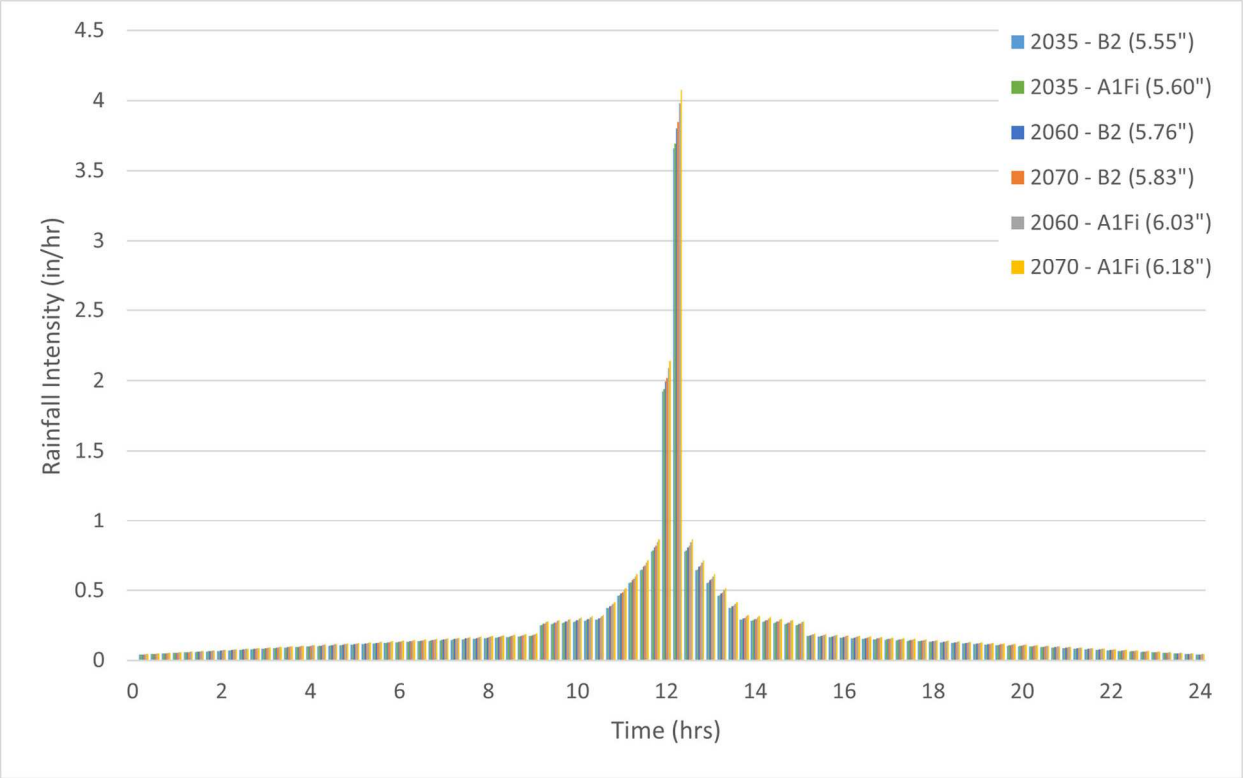


Figure 6. Design storm hyetograph for the projected future 10-year, 24-hour precipitation event under the SRES B2 and Al1Fi scenarios for 2035, 2060, and 2070, using precipitation depths predicted by BWSC and a rainfall distribution generated from the USDA NRCS method. The precipitation intensity is highest under the 2070 A1Fi scenario, followed by 2060 A1Fi, 2070 B2, 2060 B2, 2035 A1Fi, and 2035 B2.

Comparison of Past, Current, & Future Hyetographs

To better understand key changes in hydrometeorological patterns for the greater Boston area over time, we compared the 10-year, 24-hour design storm currently used by BWSC to the updated NOAA Atlas 14 10-year, 24-hour design storm and the future 10-year, 24-hour design storms developed using the BWSC projections from the 2016 BRAG report. For simplicity, we refer to the currently used BWSC 10-year, 24-hour design storm as "BWSC existing", the updated NOAA Atlas 14-based storm as "NOAA existing", and the future projected storms, which are based upon BWSC projections in the 2016 BRAG report, as "2035", "2060", and "2070", respectively.

We compared the updated rainfall distribution, which was generated following the USDA NRCS methodology and using NOAA Atlas 14 data, to the rainfall distribution for the design storm currently used by BWSC (Figure 7). Note that this updated rainfall distribution was used to generate hyetographs for NOAA Existing and for 2035, 2060, and 2070, as described previously. The rainfall distribution for the BWSC existing design storm was developed following the legacy TP-40 method for a Type III rainfall distribution and exhibits a pattern of rainfall that is characteristically more intense towards the middle of the storm and less intense at the beginning and the end. Because the same NRCS hyetograph shape is used, the precipitation depths for 2035, 2060, and 2070 follow a similar precipitation pattern, although with somewhat less intense rainfall than the BWSC existing design storm near the middle of the storm event.

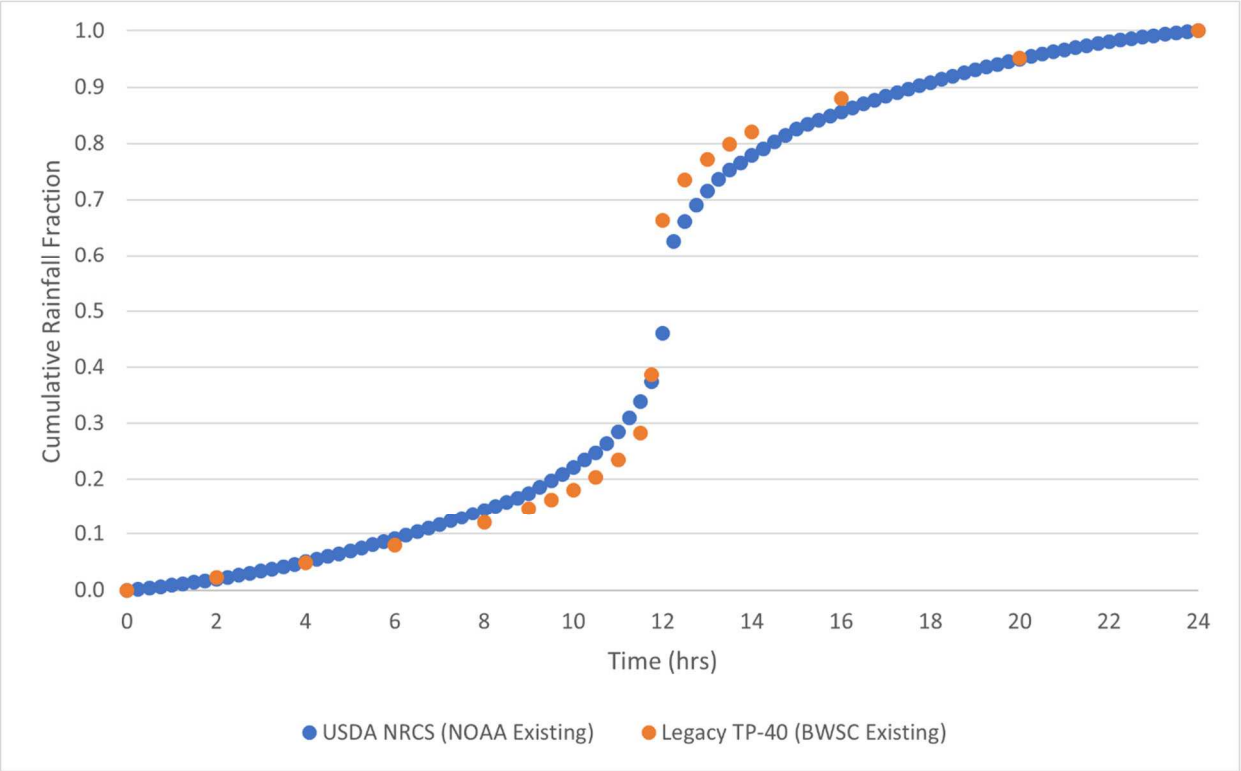


Figure 7. Comparison of the rainfall distribution generated from the legacy TP-40 method, which is used by the BWSC existing 10-year, 24-hour design storm and the USDA NRCS method, which is used by the NOAA existing and future (2035, 2060, 2070) 10-year, 24-hour design storms.

The precipitation depth for the 10-year, 24-hour design storm was highest under the 2070 A1Fi scenario (Table 3), which follows current knowledge of climate change-driven precipitation patterns and predict precipitation will increase towards the end of the 21st century, particularly under higher emissions scenarios such as A1Fi. However, even under the more "moderate" emission scenario of B2, precipitation depths for the 10-year, 24-hour design storm are still expected to increase when compared to the current and updated rainfall depths. Interestingly, the 10-year, 24-hour design storm rainfall depth of 4.91" from NOAA Atlas 14 is less than that of the 10-year, 24-hour design storm currently used by BWSC, which is due to differences, described in the following paragraph, between the legacy TP-40 and USDA NRCS methods used to estimate the storm recurrence and depth.

Table 3. Precipitation depths (in) for BWSC existing, NOAA existing, and future (2035, 2060, 2070) 10-year, 24-hour design storms. The future 2035, 2060, and 2070 design storms are also differentiated by the SRES B2 and A1Fi scenarios.

	BWSC EXISTING	NOAA EXISTING	2035	2060	2070
B2	5.150	4.91	5.55	5.76	5.830
A1Fi	5.150	4.91	5.6	6.03	6.177

Precipitation intensity for the 10-year, 24-hour storm events follows a similar pattern to precipitation depth, with the 2070 A1Fi scenario exhibiting the highest peak precipitation intensity (Table 4). This result also follows current knowledge of climate change-driven precipitation patterns which predict that precipitation will intensify towards the end of the 21st century, particularly under the higher emissions scenarios. However, as with precipitation depth, the intensity is also projected to increase even under the more "moderate" emissions scenarios, such as B2.

Interestingly, the peak rainfall intensity for the 10-year, 24-hour NOAA existing design storm is less than the BWSC existing design storm, which is likely due to methodological differences in the computation of the rainfall distribution between the USDA NRCS method and the legacy TP-40 method as described previously. This difference is highlighted in the pattern of intensity between the BWSC existing and NOAA existing 10-year, 24-hour design storms (Figure 8). The intensity of the BWSC existing 10-year, 24-hour design storm is higher in the rising limb of the hyetograph while the intensity of the NOAA existing 10-year, 24-hour design storm is higher in the falling limb and towards the beginning and end of the storm event.

Table 4. Peak precipitation intensity (in/hr) for BWSC existing, NOAA existing, and future (2035, 2060, 2070) 10-year, 24-hour design storms. The future 2035, 2060, and 2070 design storms are also differentiated by the SRES B2 and A1Fi scenarios.

	BWSC EXISTING	NOAA EXISTING	2035	2060	2070
B2	3.317	3.240	3.66	3.801	3.847
A1Fi	3.317	3.240	3.69	3.979	4.076

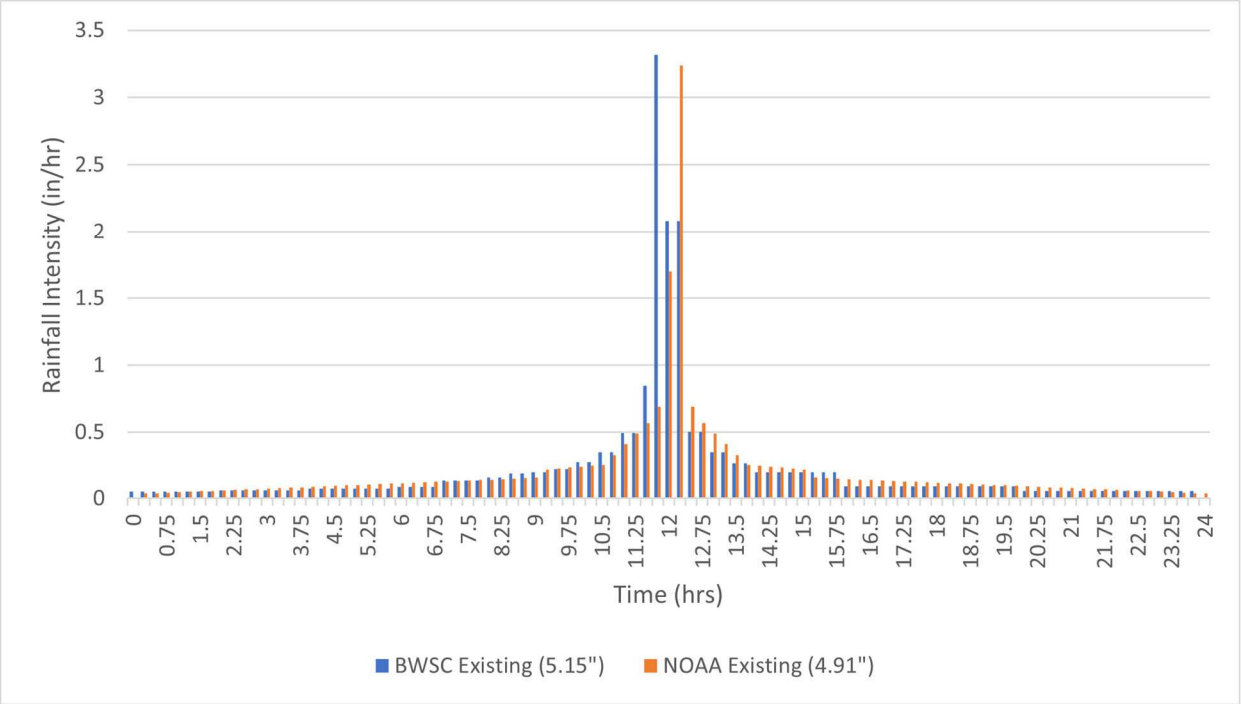


Figure 8. Hyetograph comparison between the BWSC existing 10-year, 24-hour design storm, which was generated using the legacy TP-40 method, and the NOAA existing 10-year, 24-hour design storm, which was developed following the USDA NRCS method and using NOAA Atlas 14 data.

Summary

The 10-year, 24-hour design storm currently used by BWSC was updated following USDA NRCS guidance used data from NOAA Atlas 14. The updated rainfall distribution was applied to future projected precipitation depths, which were previously generated by BWSC and published in the 2016 BRAG report, to provide the design storm hyetograph for a potential 10-year, 24-hour rainfall event in the years 2035, 2060, and 2070. Comparisons were made between the 10-year, 24-hour design storm currently used by BWSC, the updated 10-year, 24-hour design storm from NOAA Atlas 14, and the projected 2035, 2060, and 2070 10-year, 24-hour design storms. As expected, these comparisons revealed that precipitation depth and intensity would increase for the 10-year, 24-hour design storm towards the end of the 21st century. The updated rainfall distribution demonstrated a higher rainfall intensity during the latter half of a rainfall event, which is a change from the BWSC existing hyetograph, demonstrating higher intensity in the rising limb of a design storm.

The projected precipitation estimates previously generated by BWSC and published in the 2016 BRAG report are reliable estimates of future precipitation. Although future projections of precipitation and temperature are generally estimated using GCMs and RCP emissions scenarios, BWSC used comparable methods (SimClim) and emissions scenarios (SRES) which yielded comparable results to similar analysis done by C-CCVA with GCMs/RCP emissions scenarios (Table 2). However, as new technology and knowledge surrounding prediction of future climate becomes available, particularly now that CMIP has entered its sixth phase (CMIP6), we encourage BWSC to revisit and reassess their estimates of future precipitation. The release of new information with CMIP6 may result in regional changes to future rainfall depth and intensity that should be considered.

Appendix

Table A-1. The dimensionless cumulative and incremental hyetographs generated following USDA NRCS guidance and using NOAA Atlas 14 data from the Boston Logan Airport location.

Time (%)	Cumulative Depth (%)	Incremental Depth (%)
0.00	0.0000	0.0000
0.01	0.0019	0.0019
0.02	0.0039	0.0020
0.03	0.0061	0.0022
0.04	0.0085	0.0024
0.05	0.0110	0.0025
0.06	0.0137	0.0027
0.07	0.0166	0.0029
0.08	0.0197	0.0031
0.09	0.0229	0.0032
0.10	0.0263	0.0034
0.11	0.0299	0.0036
0.13	0.0336	0.0037
0.14	0.0375	0.0039
0.15	0.0416	0.0041
0.16	0.0458	0.0042
0.17	0.0502	0.0044
0.18	0.0548	0.0046
0.19	0.0596	0.0048
0.20	0.0645	0.0049
0.21	0.0696	0.0051
0.22	0.0748	0.0053
0.23	0.0803	0.0054
0.24	0.0859	0.0056
0.25	0.0916	0.0058
0.26	0.0976	0.0059
0.27	0.1037	0.0061
0.28	0.1100	0.0063
0.29	0.1164	0.0064
0.30	0.1230	0.0066
0.31	0.1298	0.0068
0.32	0.1368	0.0070
0.33	0.1439	0.0071
0.34	0.1512	0.0073
0.35	0.1587	0.0075
0.36	0.1663	0.0076

Time (%)	Cumulative Depth (%)	Incremental Depth (%)
0.38	0.1741	0.0078
0.39	0.1855	0.0113
0.40	0.1972	0.0117
0.41	0.2092	0.0120
0.42	0.2216	0.0124
0.43	0.2344	0.0127
0.44	0.2475	0.0131
0.45	0.2643	0.0168
0.46	0.2851	0.0209
0.47	0.3101	0.0249
0.48	0.3391	0.0290
0.49	0.3742	0.0351
0.50	0.4608	0.0866
0.51	0.6258	0.1650
0.52	0.6609	0.0351
0.53	0.6899	0.0290
0.54	0.7149	0.0249
0.55	0.7357	0.0209
0.56	0.7525	0.0168
0.57	0.7656	0.0131
0.58	0.7784	0.0127
0.59	0.7908	0.0124
0.60	0.8028	0.0120
0.61	0.8145	0.0117
0.63	0.8259	0.0113
0.64	0.8337	0.0078
0.65	0.8413	0.0076
0.66	0.8488	0.0075
0.67	0.8561	0.0073
0.68	0.8632	0.0071
0.69	0.8702	0.0070
0.70	0.8770	0.0068
0.71	0.8836	0.0066
0.72	0.8900	0.0064
0.73	0.8963	0.0063
0.74	0.9024	0.0061
0.75	0.9084	0.0059
0.76	0.9141	0.0058
0.77	0.9197	0.0056
0.78	0.9252	0.0054

Time (%)	Cumulative Depth (%)	Incremental Depth (%)
0.79	0.9304	0.0053
0.80	0.9355	0.0051
0.81	0.9404	0.0049
0.82	0.9452	0.0048
0.83	0.9498	0.0046
0.84	0.9542	0.0044
0.85	0.9584	0.0042
0.86	0.9625	0.0041
0.88	0.9664	0.0039
0.89	0.9701	0.0037
0.90	0.9737	0.0036
0.91	0.9771	0.0034
0.92	0.9803	0.0032
0.93	0.9834	0.0031
0.94	0.9863	0.0029
0.95	0.9890	0.0027
0.96	0.9915	0.0025
0.97	0.9939	0.0024
0.98	0.9961	0.0022
0.99	0.9981	0.0020
1.00	1.0000	0.0019

Table A-2. Rainfall depth and intensity for the 10-year, 24-hour design storm generated following USDA NRCS guidance and using NOAA Atlas 14 data from the Boston Logan Airport location.

Time (hr)	Rainfall Depth (in)	Rainfall Intensity (in/hr)
0.00	0.0000	0.0000
0.25	0.0092	0.0367
0.50	0.0100	0.0400
0.75	0.0108	0.0433
1.00	0.0117	0.0467
1.25	0.0125	0.0500
1.50	0.0133	0.0533
1.75	0.0142	0.0567
2.00	0.0150	0.0600
2.25	0.0158	0.0633
2.50	0.0167	0.0667
2.75	0.0175	0.0700
3.00	0.0183	0.0733
3.25	0.0192	0.0767
3.50	0.0200	0.0800
3.75	0.0208	0.0833
4.00	0.0217	0.0867
4.25	0.0225	0.0900
4.50	0.0233	0.0933
4.75	0.0242	0.0967
5.00	0.0250	0.1000
5.25	0.0258	0.1033
5.50	0.0267	0.1067
5.75	0.0275	0.1100
6.00	0.0283	0.1133
6.25	0.0292	0.1167
6.50	0.0300	0.1200
6.75	0.0308	0.1233
7.00	0.0317	0.1267
7.25	0.0325	0.1300
7.50	0.0333	0.1333
7.75	0.0342	0.1367
8.00	0.0350	0.1400
8.25	0.0358	0.1433
8.50	0.0367	0.1467
8.75	0.0375	0.1500
9.00	0.0383	0.1533
9.25	0.0557	0.2227

Time (hr)	Rainfall Depth (in)	Rainfall Intensity (in/hr)
9.50	0.0574	0.2296
9.75	0.0591	0.2365
10.00	0.0609	0.2435
10.25	0.0626	0.2504
10.50	0.0643	0.2573
10.75	0.0825	0.3300
11.00	0.1025	0.4100
11.25	0.1225	0.4900
11.50	0.1425	0.5700
11.75	0.1724	0.6896
12.00	0.4252	1.7008
12.25	0.8100	3.2401
12.50	0.1724	0.6896
12.75	0.1425	0.5700
13.00	0.1225	0.4900
13.25	0.1025	0.4100
13.50	0.0825	0.3300
13.75	0.0643	0.2573
14.00	0.0626	0.2504
14.25	0.0609	0.2435
14.50	0.0591	0.2365
14.75	0.0574	0.2296
15.00	0.0557	0.2227
15.25	0.0383	0.1533
15.50	0.0375	0.1500
15.75	0.0367	0.1467
16.00	0.0358	0.1433
16.25	0.0350	0.1400
16.50	0.0342	0.1367
16.75	0.0333	0.1333
17.00	0.0325	0.1300
17.25	0.0317	0.1267
17.50	0.0308	0.1233
17.75	0.0300	0.1200
18.00	0.0292	0.1167
18.25	0.0283	0.1133
18.50	0.0275	0.1100
18.75	0.0267	0.1067
19.00	0.0258	0.1033
19.25	0.0250	0.1000

Time (hr)	Rainfall Depth (in)	Rainfall Intensity (in/hr)
19.50	0.0242	0.0967
19.75	0.0233	0.0933
20.00	0.0225	0.0900
20.25	0.0217	0.0867
20.50	0.0208	0.0833
20.75	0.0200	0.0800
21.00	0.0192	0.0767
21.25	0.0183	0.0733
21.50	0.0175	0.0700
21.75	0.0167	0.0667
22.00	0.0158	0.0633
22.25	0.0150	0.0600
22.50	0.0142	0.0567
22.75	0.0133	0.0533
23.00	0.0125	0.0500
23.25	0.0117	0.0467
23.50	0.0108	0.0433
23.75	0.0100	0.0400
24.00	0.0092	0.0367

Appendix C: risQ Social Impact Scoring



Hazen-risQ Internal Update

Last Updated: 2021-08-13

‘Health Obstacle’ score -- Higher scores are seen where populations have higher rates of underlying health conditions/risks and more often lack health insurance. An example use case with this score is an investor looking to put money in places that need more & better funded hospital services.

'Housing Unaffordability' score -- Higher scores are seen in areas with populations that on average spend a higher percentage of income on housing. An example use case with this score is an investor is looking to put money in places that need more housing / affordable housing to be built for middle and lower income populations.

'Poverty Concentration' score -- Higher scores are seen in areas with populations with higher rates of poverty and the extent of that poverty. An example use case with this score is an investor is looking to put money in places that are broadly underserved in terms of well-paying jobs, affordable housing, and public services in general.

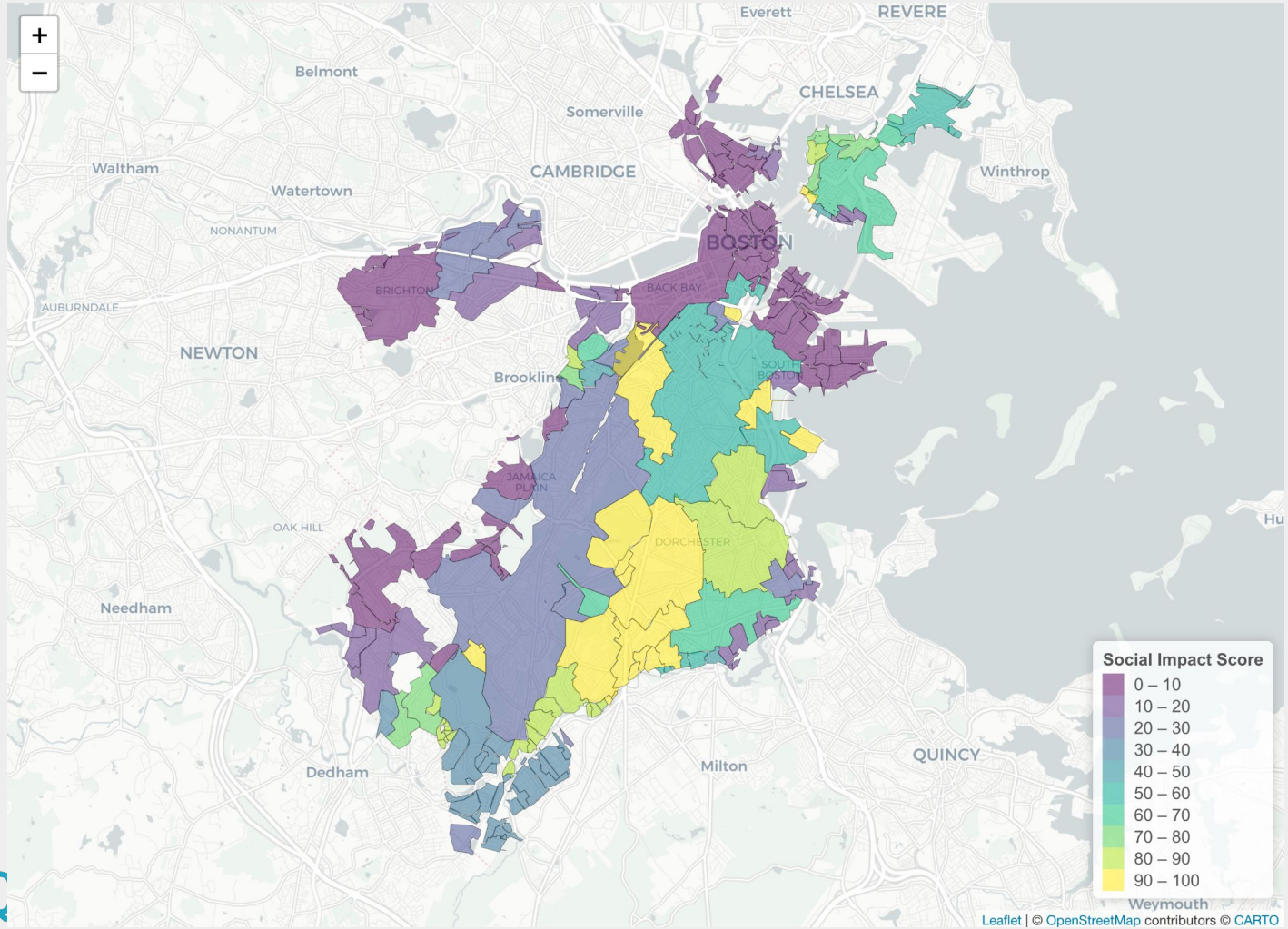
'Low Affluence' score -- Higher scores are seen in areas with populations with lower household incomes, per capita incomes, and higher income inequality. An example use case with this score is an investor is looking to put money in places that are broadly underserved in terms of well-paying jobs, affordable housing, and public services in general.

‘Low Educational Attainment’ scores -- Higher scores are seen in areas with populations with higher rates of lower educational attainment. An example use case with this score is when an investor is looking to put money in places / education bonds that are broadly underserved in terms of public school district funding, charter school funding, and/or university funding.

‘At-Risk Employment Sector’ scores -- Higher scores are seen in areas with populations with higher rates of employment in sectors that are generally lower paying, often at more risk to automation, often come with health risks, and may be more exposed to carbon transition risk. An example use case with this score is when an investor is looking to put money in bonds that will for example serve more jobs, green jobs, and educational funding.

‘Minority’ scores -- Higher scores indicate higher percentages of non-White population. This score can be used by investors looking to invest in racial equity broadly speaking.

‘Social Impact’ scores -- This score combines all of the other 7 scores. Locations with the highest scores represent racial minority populations that have been marginalized and face multiple structural socioeconomic obstacles in terms of health, jobs, income, and housing. Investors can use this score to identify bonds that could broadly serve communities that need more resources.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SOUTH BOSTON
JAMAICA PLAIN
OAK HILL
DORCHESTER
Needham
QUINCY
Dedham
Milton
Weymouth
Social Impact Score
0 – 10
10 – 20
20 – 30
30 – 40
40 – 50
50 – 60
60 – 70
70 – 80
80 – 90
90 – 100
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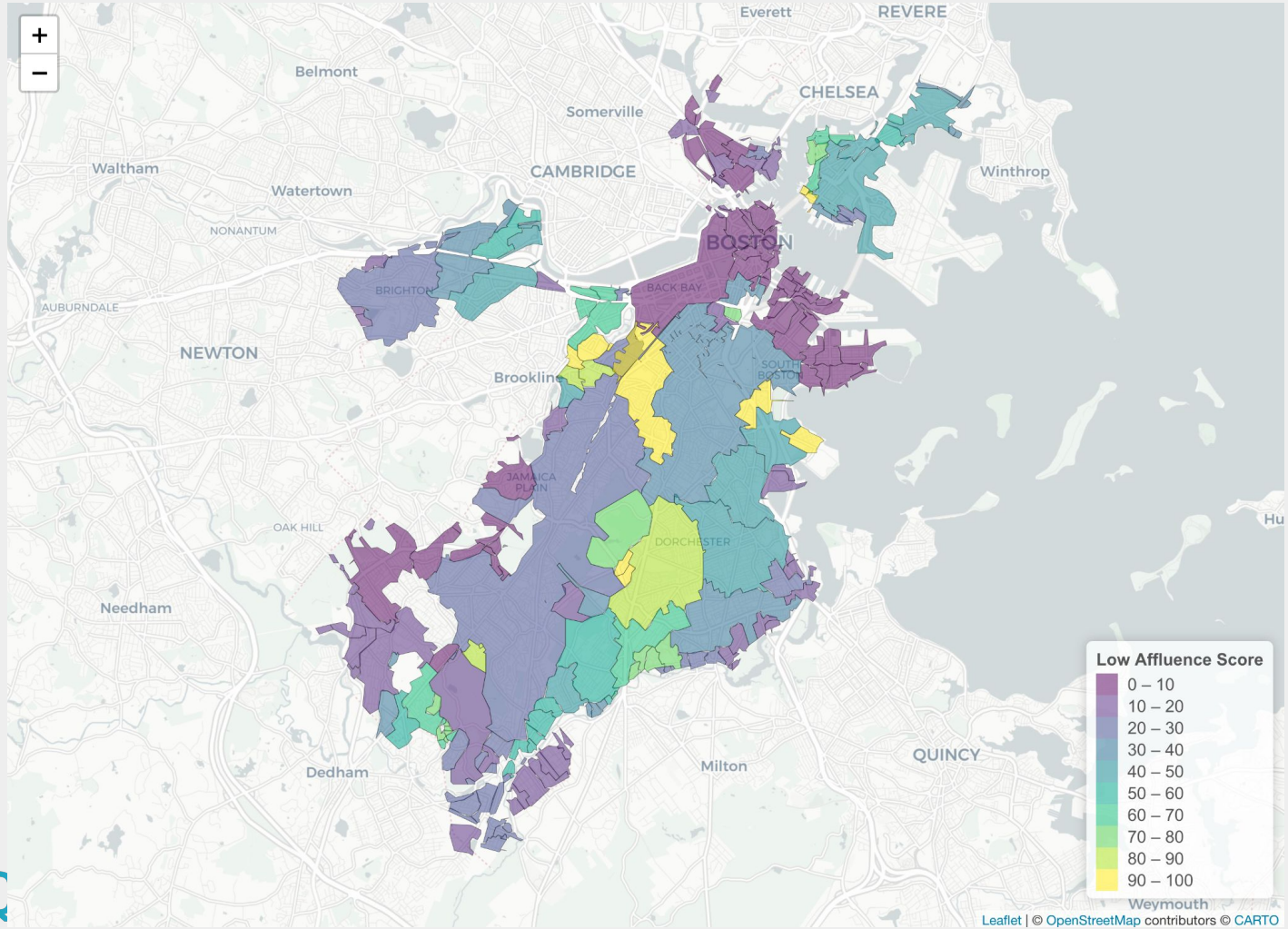
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Low Affluence Score
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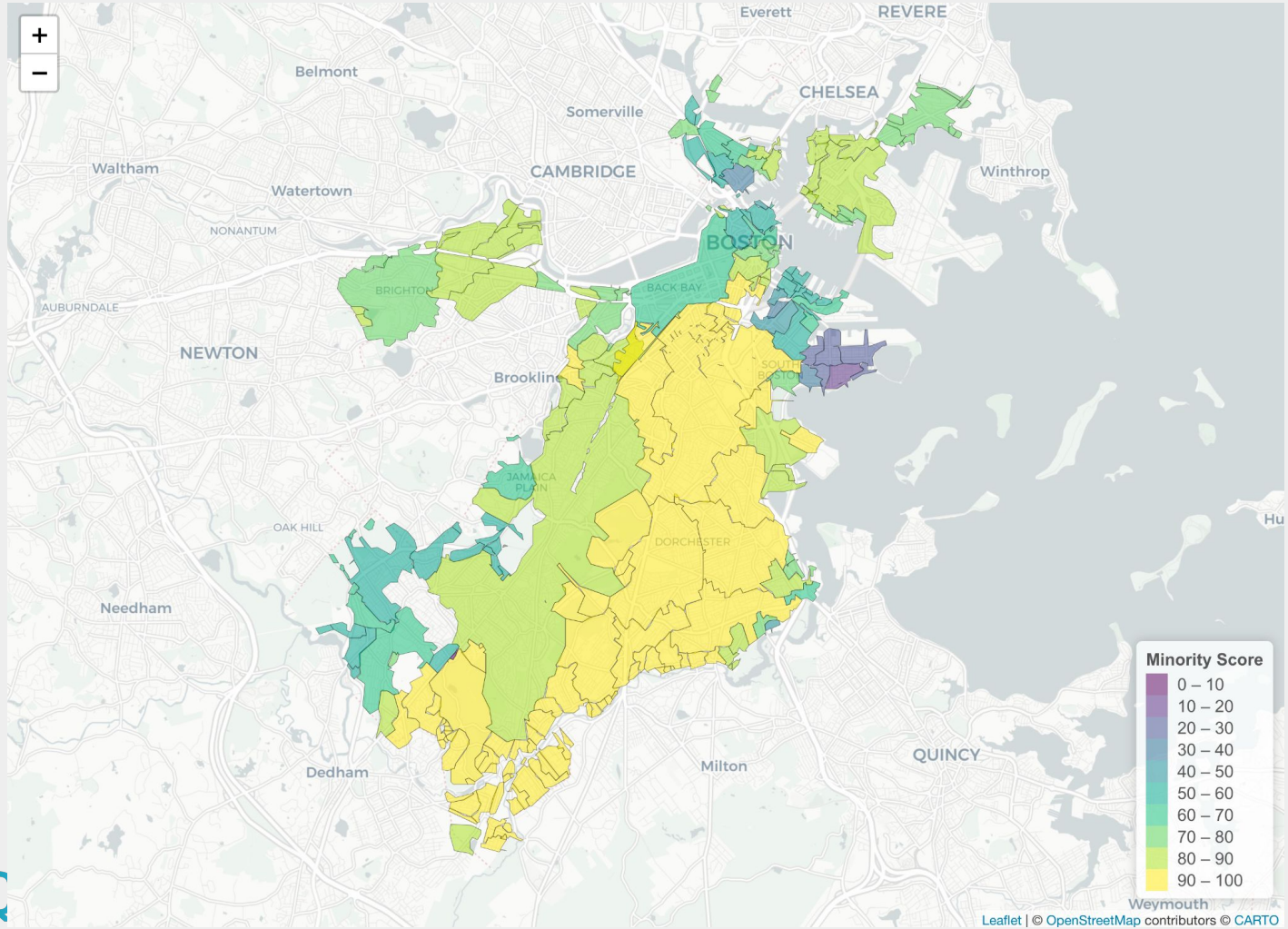
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Minority Score
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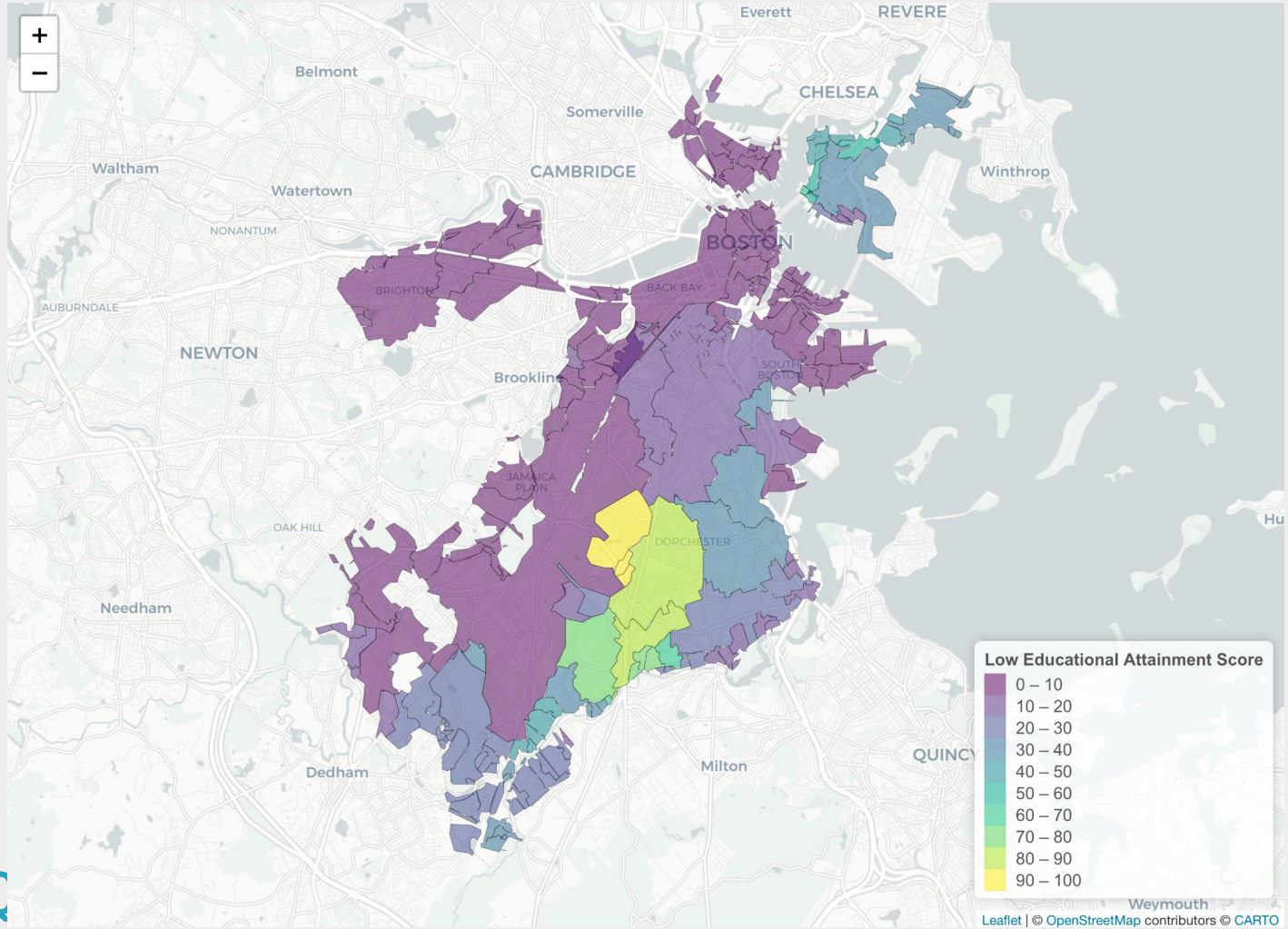
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Low Educational Attainment Score
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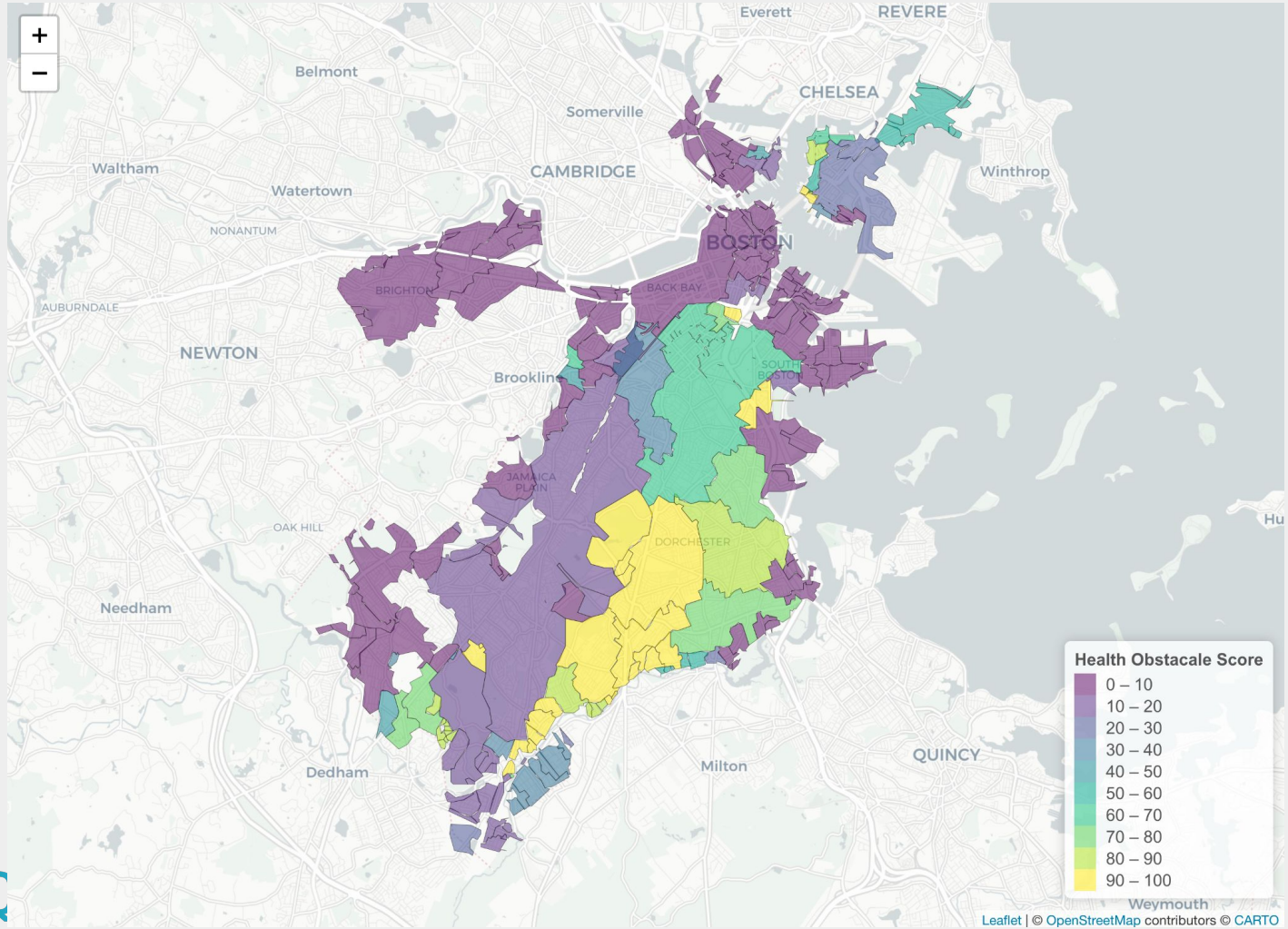
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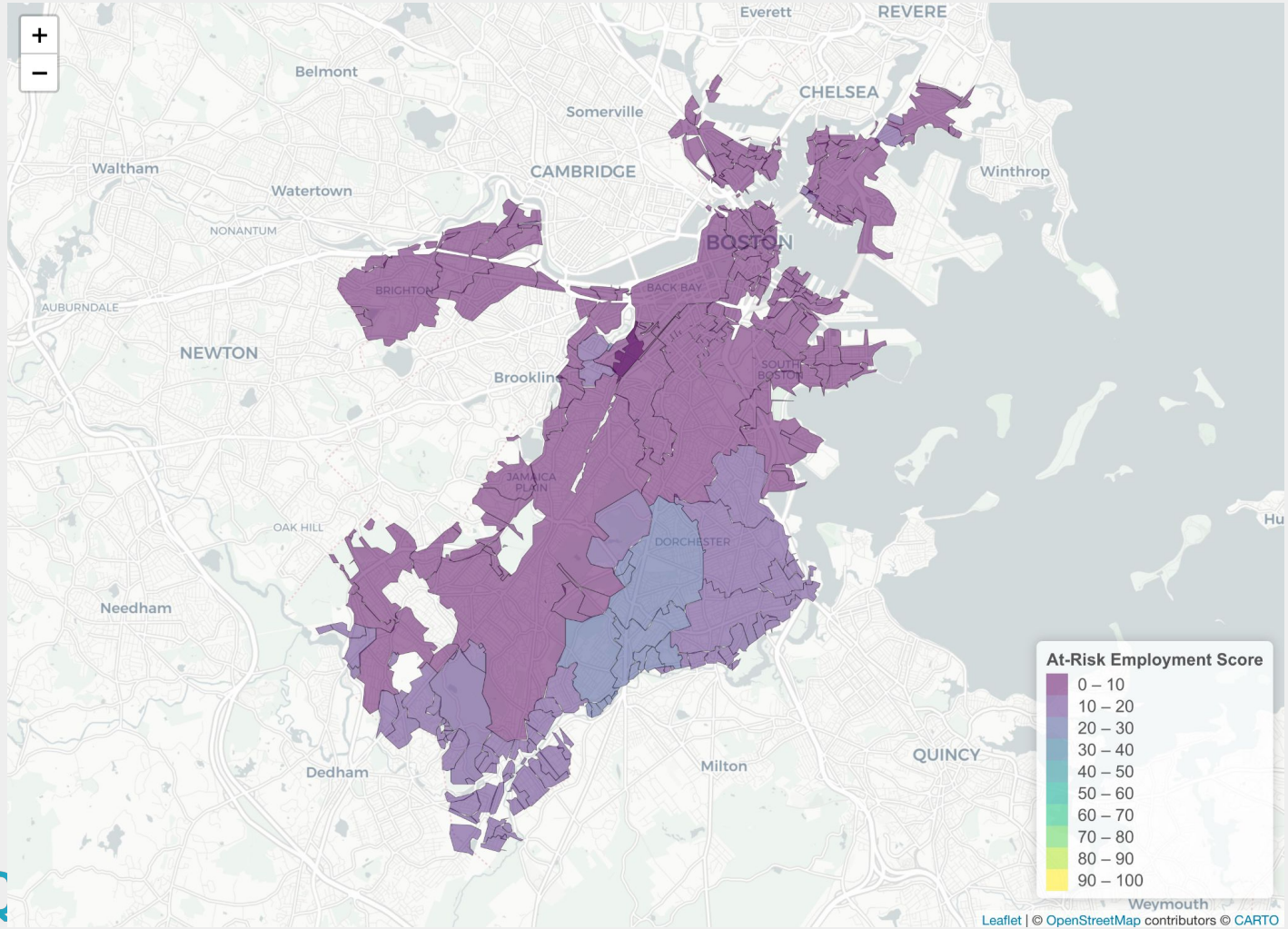
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Weymouth
At-Risk Employment Score
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70 – 80
80 – 90
90 – 100
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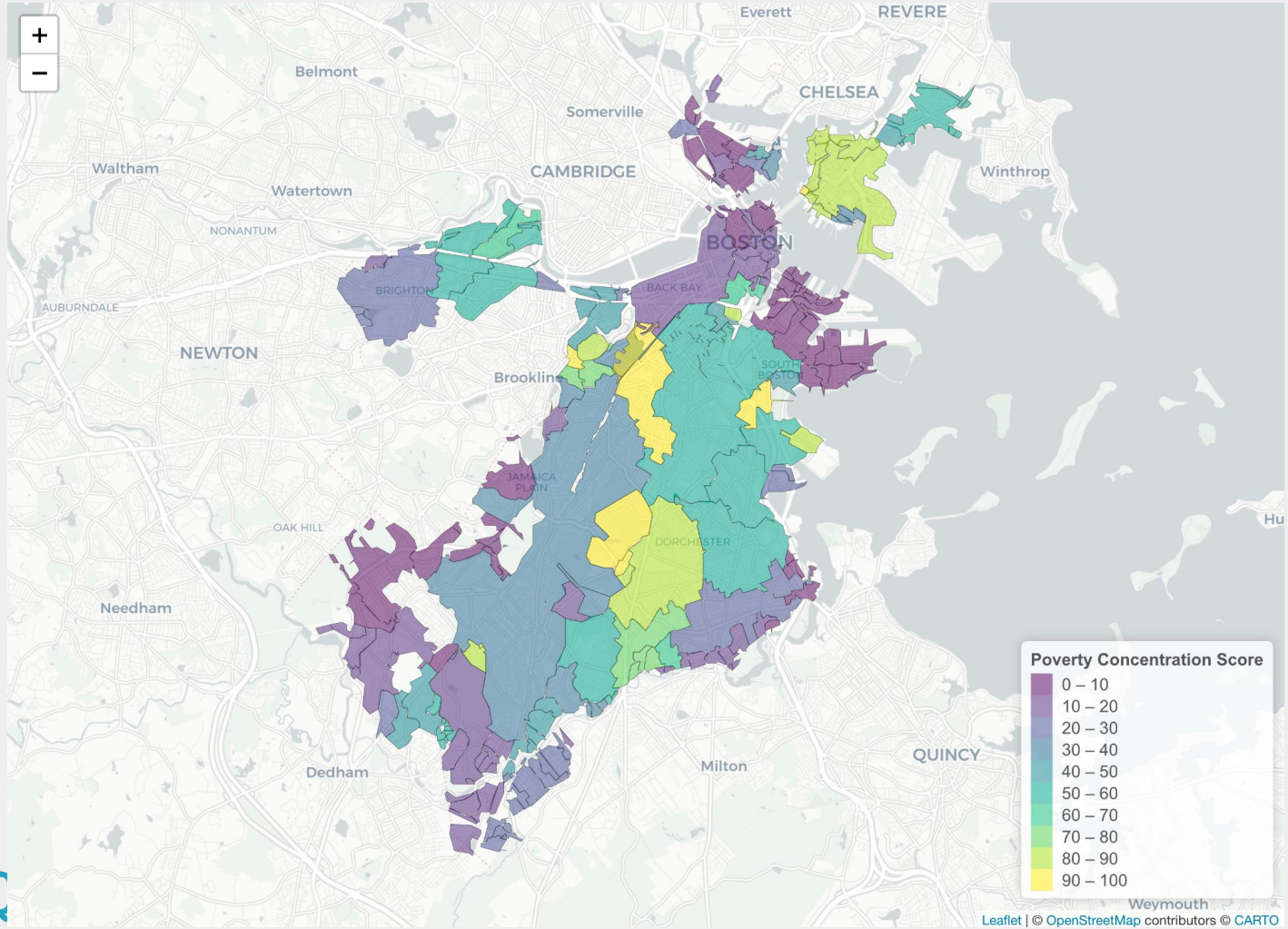
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Poverty Concentration Score
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80 – 90
90 – 100
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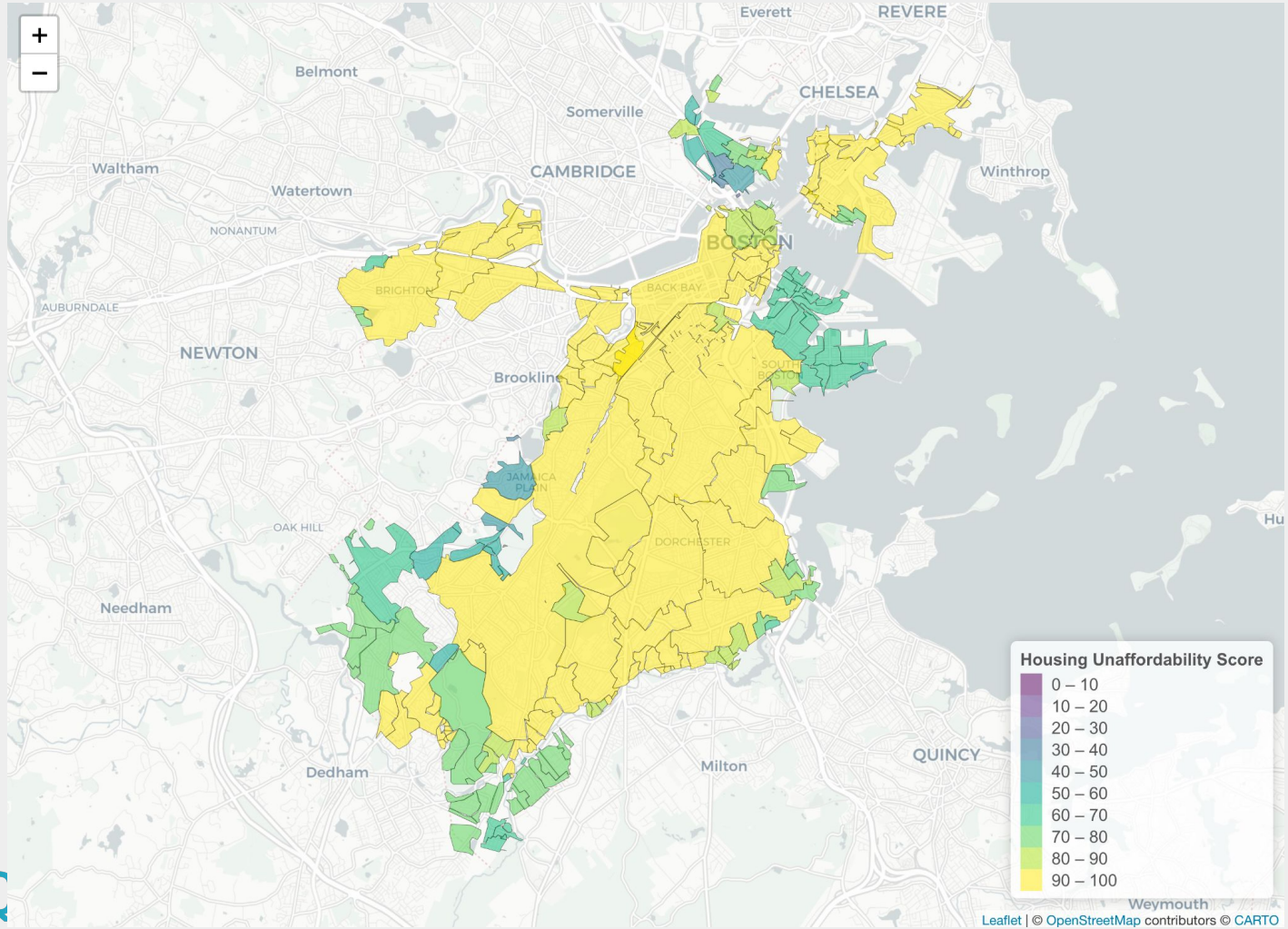
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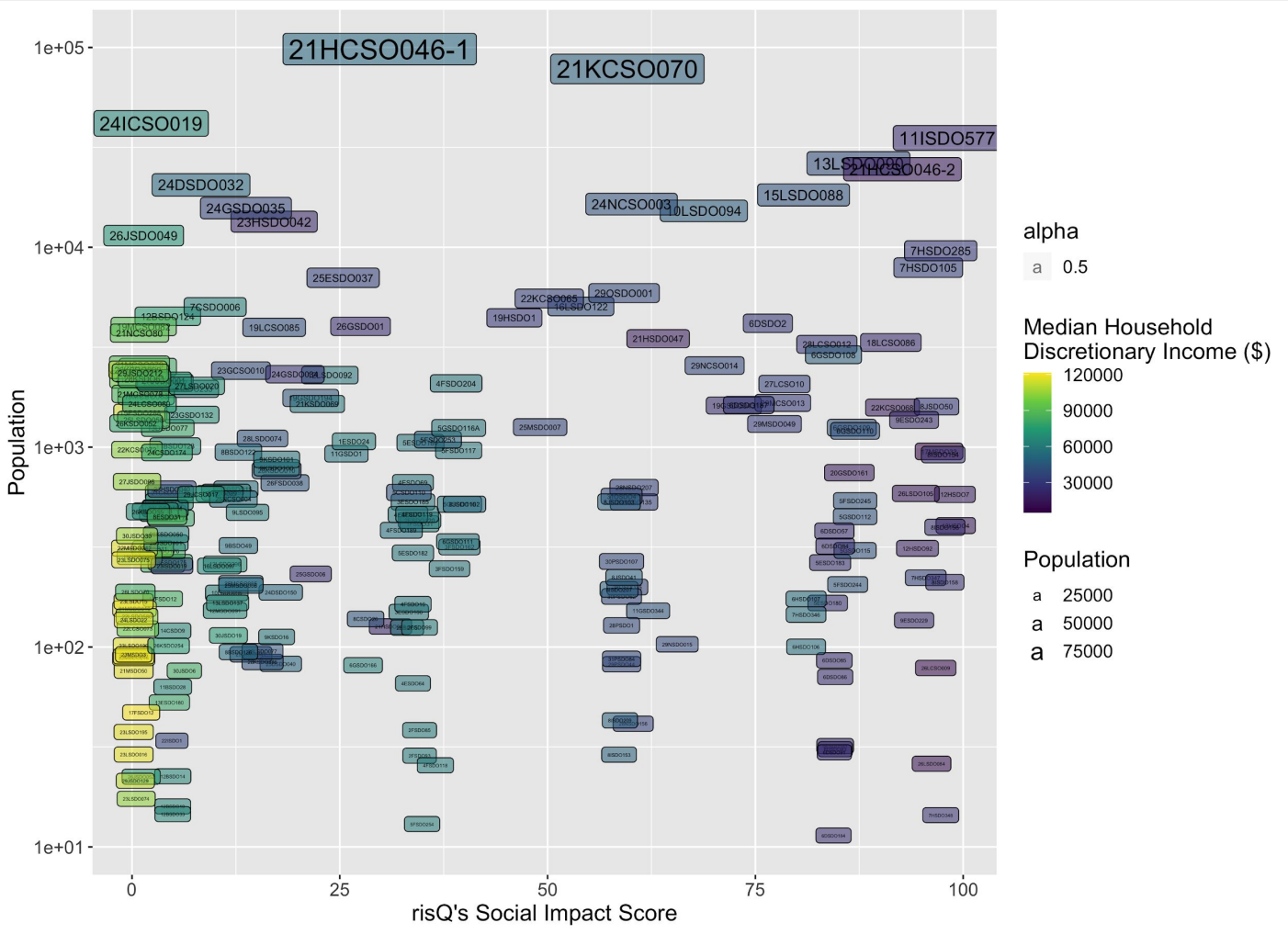
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21HCSO046-2
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7HSDO105
25ESDO037
7CSDO006
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26LSDO105
12HSDO7
1e+05
1e+04
1e+03
1e+02
1e+01
Population
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25
50
75
100
risQ's Social Impact Score
alpha
a 0.5
Median Household Discretionary Income ($)
120000
90000
60000
30000
Population
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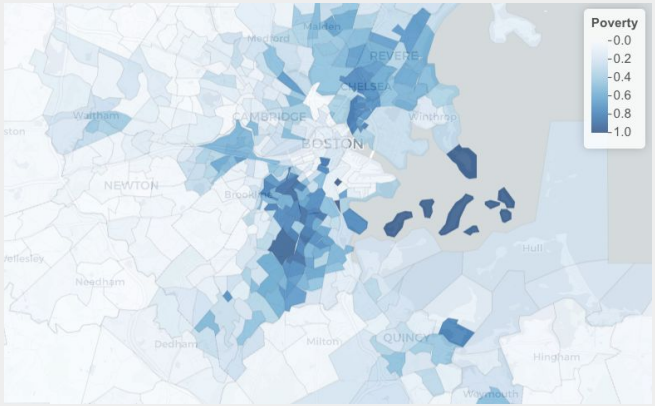
a 50000
a 75000

Social Impact Score

risQ

Poverty



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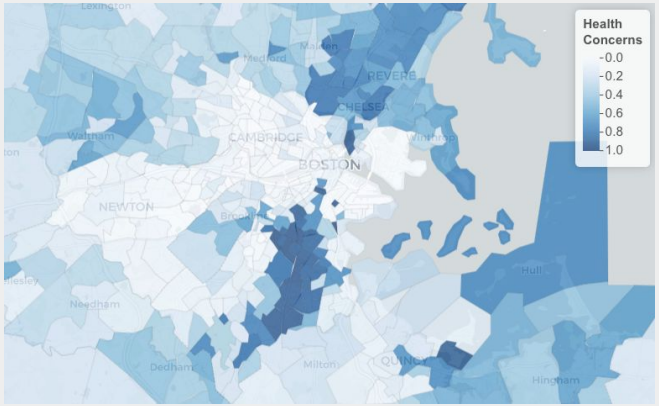
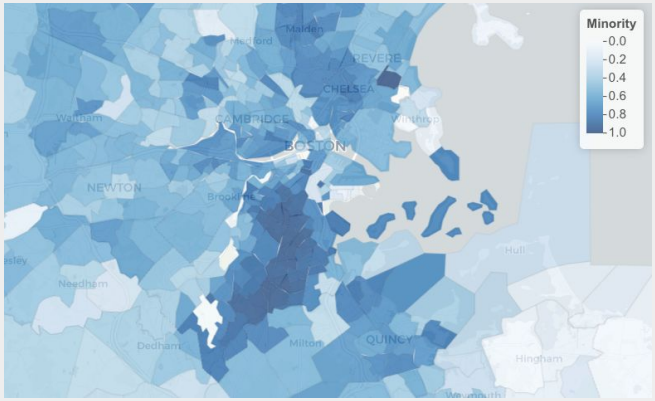
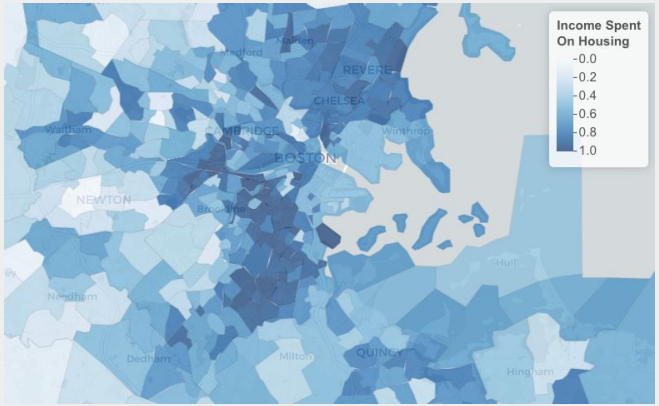


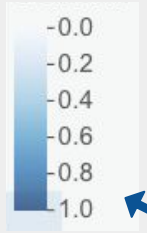
Minority Residents



Income Spent on Housing



investment in these are areas are **less likely** to have a positive social impact

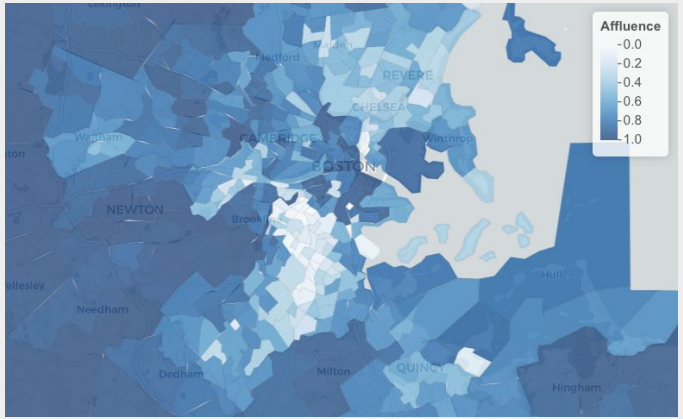


more likely an investment will have a **positive social impact**

risQ

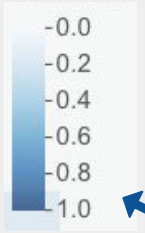
Percent Rank of Each Individual Metric: 1 = high poverty/minority groups/housing costs

Affluence



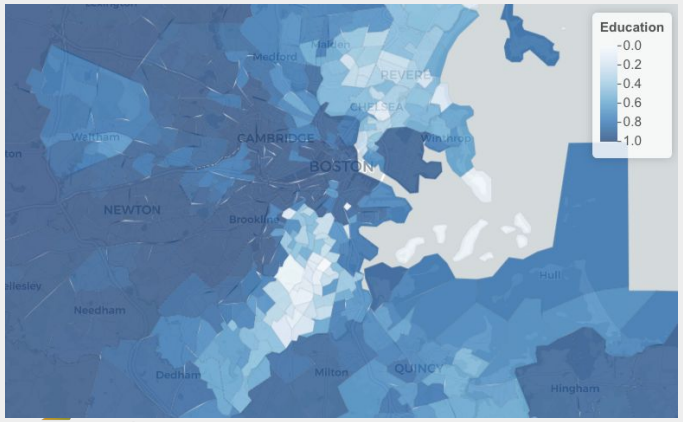


investment in these are areas are **more likely** to have a **positive social impact**

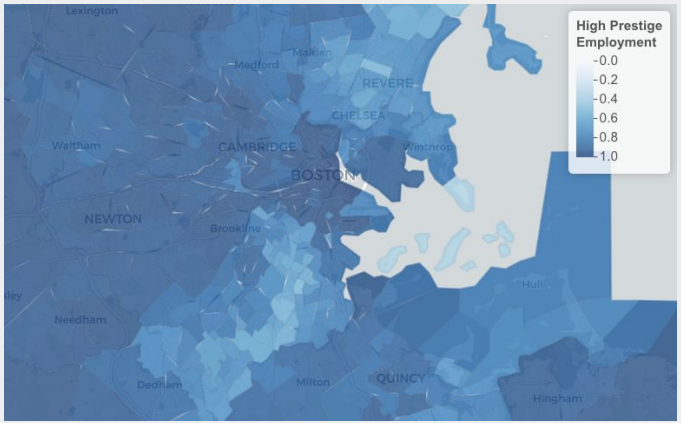


less likely an investment will have a social impact

Education



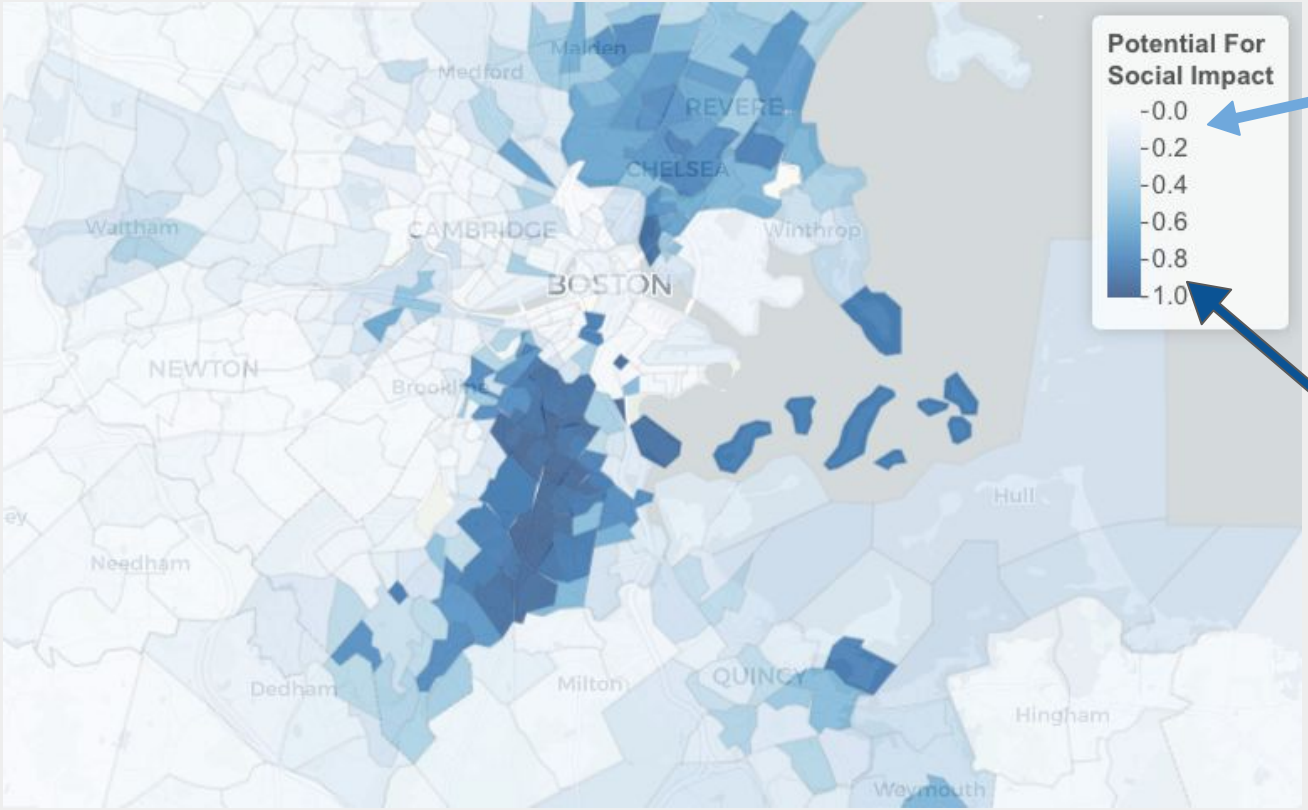
High Paying Employment



risQ

Percent Rank of Each Individual Metric: 1 = high affluence/health/education/employment

Boston Area Total "Social Impact Score"



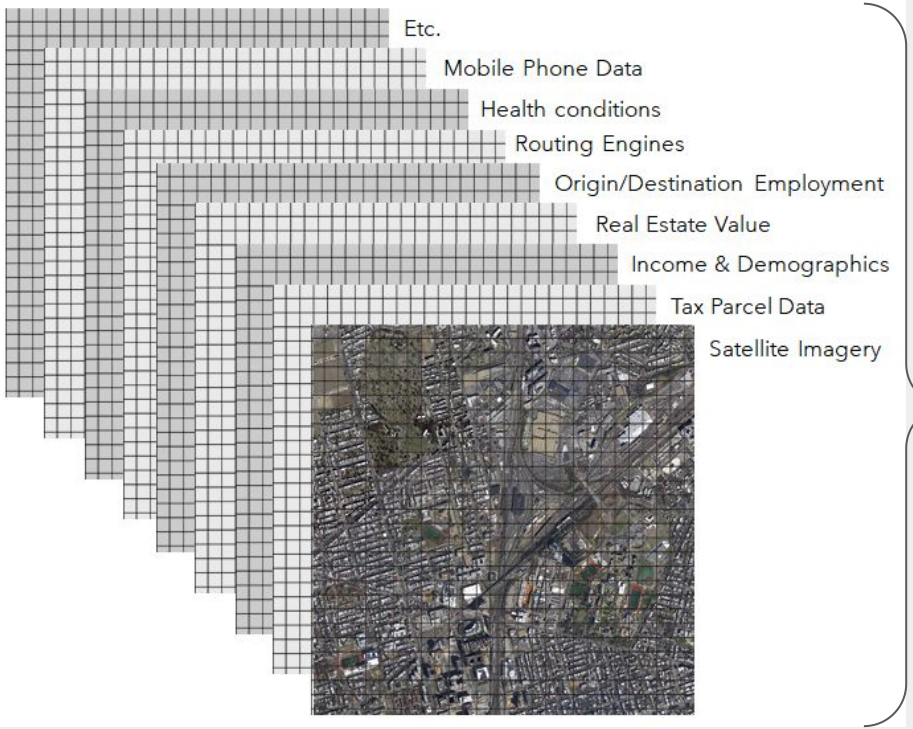
investment in these are areas are **less likely** to have a positive social impact

more likely an investment will have a **positive social impact**

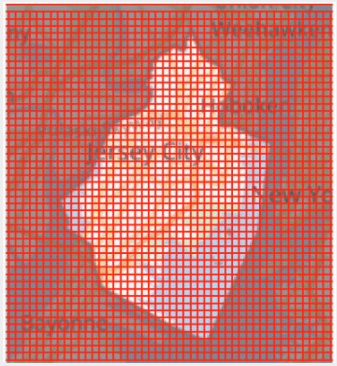
risQ

Dasymetric Modeling

Agile Geospatial Economic Architecture

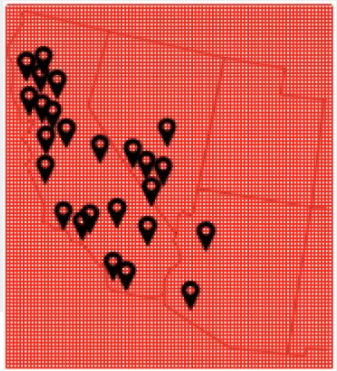


- Broad range of *economic* inputs, combined through dasymetric modeling and folded into a U.S. wide 100m grid
- Combination of public & proprietary data and models



Municipal Finance

- Comprehensive library of shapefiles and facility locations corresponding to issuers and obligors
- Layering onto the 100m Economic grid enables a full characterization of the municipal bond universe



Real Estate

- Best-in-class geospatial characterization of mortgage-backed security (MBS) pools
- Layering onto the 100m grid enables a full characterization of the MBS universe e.g. prepay and credit risk

risQ Social Impact Score Documentation

Last Edited: 05-17-2021

Social Impact Score

The **risQ Social Impact Score** is 0-100 score that quantifies the potential social impact of a financial investment in a community. The score is a combination of 7 individual metrics (each with a score of their own), that quantify the demographics and financial resources of the residents residing within a community. The underlying metrics capture the education level, type of employment, race, health challenges, affluence levels, poverty levels, and the percentage of income that a household spends on housing.

risQ also provides the tail metrics for each social score. The tail metrics quantify what percentage of the residents have local (census tract) social scores that fall within tails of the national distribution of census tract social scores. The tail metrics provide the user with a method of assessing whether the entire community needs resources, does not need resources, or if there is segregation within the community. A segregated community would suggest that some portions of the community are in need of resources while others are not. A quick reference guide to the various combinations of social scores and tail metrics is provided below.

<table>
<tr><th colspan="2">Interpreting Aggregate Social Scores</th><th>Large Proportion of Population in Lower Quartile</th><th>Large Proportion of Population in Upper Quartile</th></tr>
<tr><td rowspan="3">Social Score</td><td>high</td><td></td><td>Needs Resources</td></tr>
<tr><td>middle</td><td colspan="2">Some communities may need resources, could indicate high level of segregation</td></tr>
<tr><td>low</td><td>Does Not Need Resources</td><td></td></tr>
</table>

Social Impact Score Data and Methods

Data Preparation

risQ's social scores make use of two publicly available datasets: the American Community Survey (ACS)[1] data and the Longitudinal Employer-Household Dynamics (LEHD) Origin-Destination Employment Statistics (LODES)[2]. These datasets provide information on the demographics (including household income, socio-economic status, and employment information) of the residents within each census tract.

Following the approaches adopted by Chakraborty et al. (2020)[3] and Davies et al. (2019)[4], risQ defines 7 different categories: employment, education, affluence, poverty, health & wellness, race, and housing costs. Metrics are created for the first five categories by extracting the first principal components of several principal component analyses (PCA). The input variables to the PCAs, which come from the ACS and LODES datasets, are listed in the Appendix. The directions of correlations between the individual variables and the corresponding first principal components are also listed. The names of the resulting metrics are based on the underlying variables that are most strongly correlated with the first principal components. For example, the High Educational Attainment metric gets its name because the first principal component from the PCA on the education variables is strongly correlated with the number of residents who have bachelors, masters, professional, or doctorate degrees (see Appendix, Table 1).

The two remaining metrics, race and housing costs, are computed in the following manner:

$$\%\ \text{minority residents} = 1 - \%\ \text{white residents}$$

$$\%\ \text{income spent on housing} = 12 \times \text{median monthly housing costs} / \text{median household income}$$

Census Tract Level Individual Metric and Social Impact Scores

With the individual metrics defined, the next step is to compute scores for each metric as well as define an overall total social impact score. To ensure consistent interpretation of what a "high score" means for each individual metric/score, the affluence, education, and high prestige

[1] https://www.census.gov/programs-surveys/acs
[2] https://lehd.ces.census.gov/
[3] Chakraborty et al. (2020). A place-based socioeconomic status index: Measuring social vulnerability to flood hazards in the context of environmental justice. *International Journal of Disaster Risk Reduction*, **43**, 101394. https://doi.org/10.1016/j.ijdrr.2019.101394
[4] Davies et al. (2018). The unequal vulnerability of communities of color to wildfire. *PLoS One*, **13**(11): e0205825. 10.1371/journal.pone.0205825

employment metrics are first multiplied by a factor of -1. This produces three new, but related, metrics: low affluence, low education level, and less prestigious employment. To standardize the 7 metrics varying scales and ranges, each metric is normalized to produce tract level z-scores. We then sum each tract's seven z-scores to create a total social impact z-score.

The final scores for each of the underlying metrics as well as for the total social impact score are computed by percent ranking the z-scores. In the examples presented here, the ranking is done across all tracts within the country, including Puerto Rico, Hawaii, and Alaska. Each score falls in the range 0-100. A high score value indicates a high level of that metric relative to all other tracts in the country (e.g., a health challenge score of 80 means that only 20% of the tracts in the country have residents with more health challenges than the tract in question). For the total social impact score, a census tract with a high social score indicates that a financial investment in that community has a larger potential to have a social impact than an investment in a community with a low social score.

Aggregated Social Scores and Tail Metrics

Since investments do not happen at the tract level, it is necessary to aggregate the tract level score to a larger geographic boundary. To aggregate the scores, we compute the population weighted average of the tract scores within the boundary (e.g., a county). One disadvantage of this approach is that averaging across large geographic areas will smooth over the spatial differences in the tract scores, particularly areas that contain both high and low social scores. As an example, a city with high levels of segregation will contain clusters of tracts with low social scores and clusters of tracts with high social scores. Averaging across these different tracts will result in a mid-range aggregated social score (~40-60).

In order to characterize this spread in the underlying tract level scores within the larger aggregated region, we compute the percentage of the population with social scores that fall into the upper and lower tails of the national distribution of tract level social scores. This allows one to interpret the spread in social scores within a region and assess whether or not individual communities within the larger boundary are in need of resources.

Social Impact Scores and Outcomes

The individual metric scores are presented below for Boston, MA and the surrounding communities. For reference, a map of the Boston area is shown in the top right frame of Fig. 1. In each of these figures, dark blue regions represent tracts that rank high in the individual metrics on a national scale. Many of the scores have similar spatial distributions: tracts with highly educated residents often have prestigious employment, high affluence, lower poverty, and fewer health challenges. For the Boston, MA area, the income spent on housing and the minority residents scores show less distinct spatial patterns.



Figure 1. Low Affluence, Less Educated, and Less Prestigious Scores for census tracts in the Boston, MA area. A map of the Boston, MA area is also shown for reference. A high score indicates that the population residing in that census tract ranks high in that specific metric compared to all other census tracts in the country.

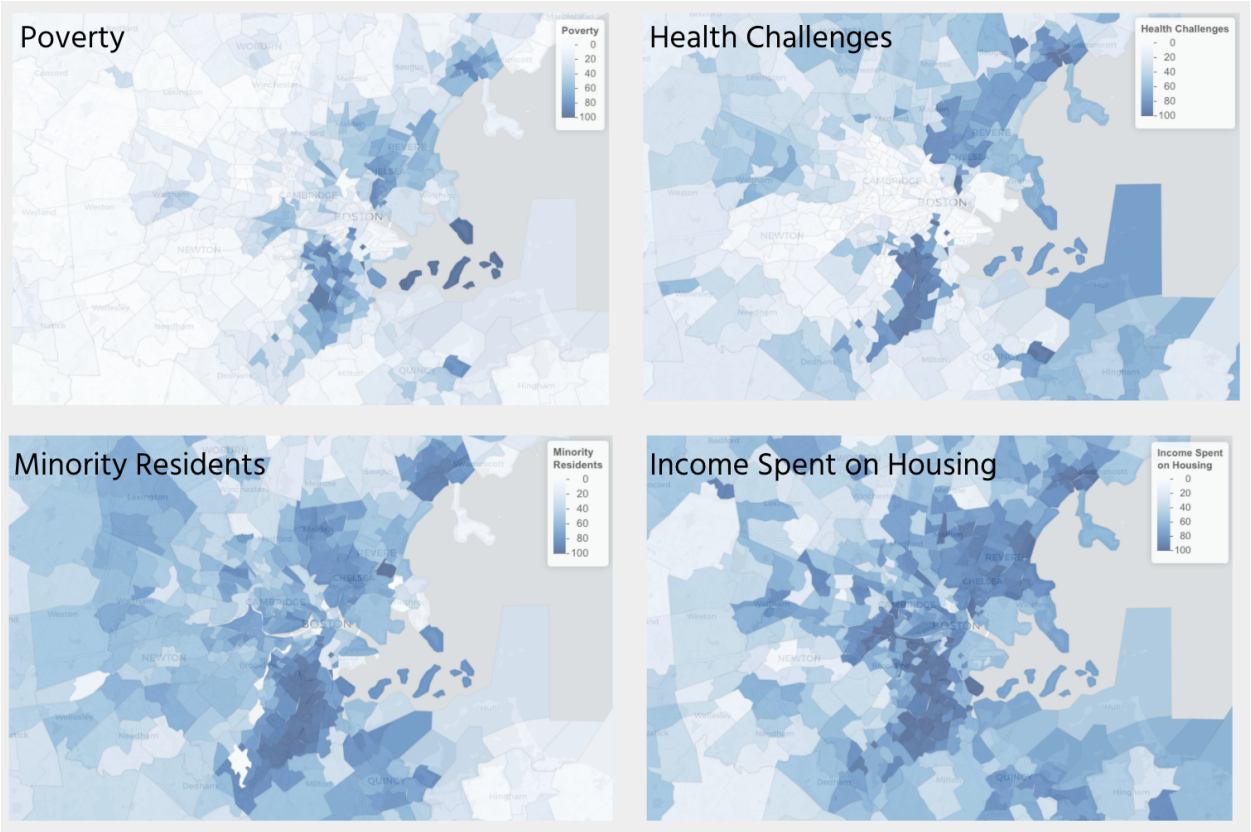


Figure 2. Poverty, Health Challenges, Minority Residents, and Income Spent on Housing Scores for census tracts in the Boston, MA area. A high score indicates that the population residing in that census tract ranks high in that specific metric compared to all other census tracts in the country.

The final social impact score for the Boston Area reveals similar spatial patterns as the individual metric scores. Since the total social impact is the sum of the individual metrics, the differences between high and low scoring regions is magnified and becomes more distinct.

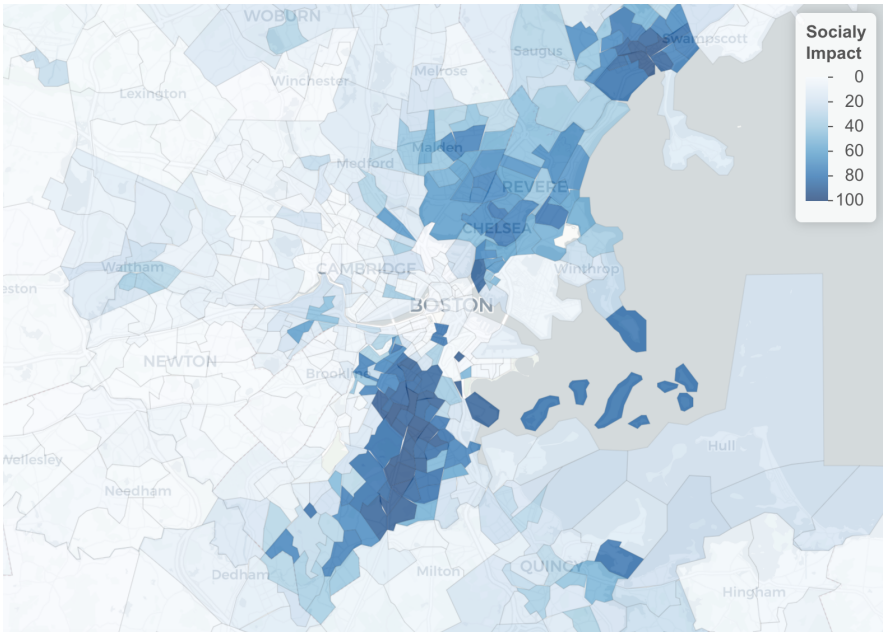


Figure 3. Total Social Impact Score for census tracts in the Boston, MA area. A high score indicates that a community is in need of resources and that an investment in that community will likely have a positive social impact. The ranking of census tracts is across all tracts in the country.

To understand how the aggregate social scores and tail metrics behave, we look at LA County in California (Fig. 3). Distinct clusters of high and low social impact scores are visible around Los Angeles, suggesting large amounts of segregation in the city. When we aggregate the social scores to the county level, we obtain a county social score of 44. In terms of the tail metrics, 25% of the residents within LA County fall into the lower tails of the national distribution of tract level social scores and 40% fall into the upper tail. With such a large percentage of the population spread between the tails, it becomes clear that although the total social score lies “somewhere in the middle”, there are many communities in the county that are still in need of resources.

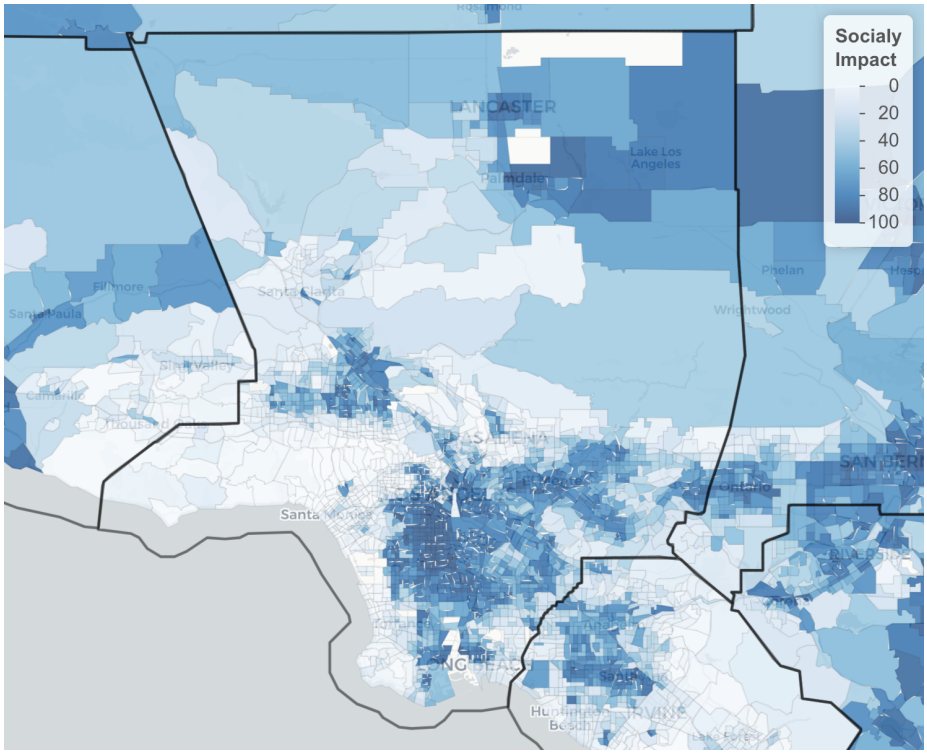


Figure 4. Total Social Impact Score for census tracts around Los Angeles, CA. The black lines show the bounding region of LA County.

Comparing the social scores and tail metrics for all counties within the U.S. provides additional insight into how to interpret the aggregated results (Fig. 5). As the percentage of residents that fall within the lower quartile increases, the social score falls to zero. These counties have very few communities in need of resources (e.g., Fairfax County, VA). At the other end of the spectrum are counties with very large percentages of residents with social scores in the upper quartile of the national distribution. These are counties where most, if not all, communities are in need of resources. As an example, Holmes County, MS has a social score of 100 and all of its residents have social scores in the upper tails of the national distribution.

The spread in the percentage of residents in the tails becomes more relevant for mid-range social scores (~40-60). LA County, as discussed above, is very segregated, with a large divide between communities in need of resources and those not in need. This is very different from a county like Wheeler County, TX. Although Wheeler County's total social score is similar to LA County's, none of the residents fall in either the upper or lower tails of the national distribution. This suggests minimal segregation relative to other counties and fewer communities in need.

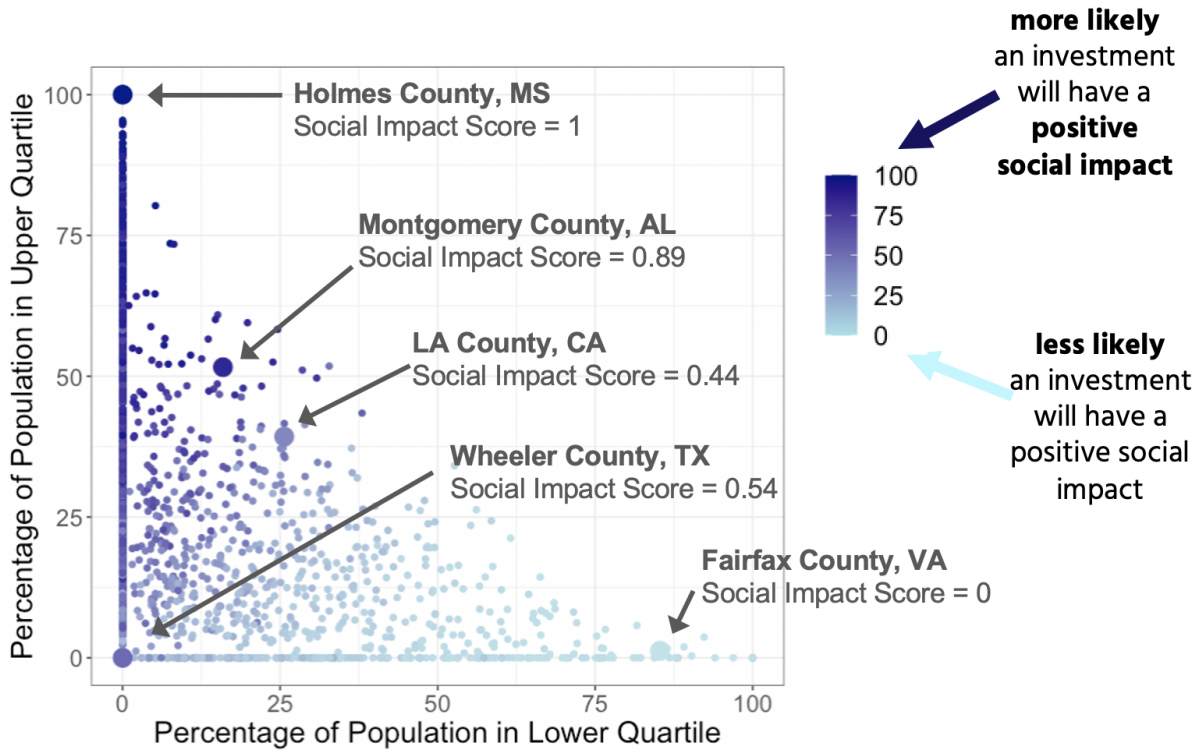


Figure 5. Poverty, Health Challenges, Minority Residents, and Income Spent on Housing Scores for census tracts in the Boston, MA area. A high score indicates that the population residing in that census tract rank high in that specific metric compared to all census tracts in the country.

Social Impact Score Municipal Bond Investor Use Cases

'Health Challenges' score -- Higher scores are seen where populations have higher rates of underlying health conditions/risks and more often lack health insurance. An example use case with this score is an investor looking to put money in places that need more & better funded hospital services.

'Income Spent on Housing' score -- Higher scores are seen in areas with populations that on average spend a higher percentage of income on housing. An example use case with this score is an investor is looking to put money in places that need more housing / affordable housing to be built for middle and lower income populations.

'Poverty' score -- Higher scores are seen in areas with populations with higher rates of poverty and the extent of that poverty. An example use case with this score is an investor is looking to put money in places that are broadly underserved in terms of well-paying jobs, affordable housing, and public services in general.

'Affluence' score -- Higher scores are seen in areas with populations with lower household incomes, per capita incomes, and higher income inequality. An example use case with this score is an investor is looking to put money in places that are broadly underserved in terms of well-paying jobs, affordable housing, and public services in general.

‘Low Educational Attainment’ scores -- Higher scores are seen in areas with populations with higher rates of lower educational attainment. An example use case with this score is when an investor is looking to put money in places / education bonds that are broadly underserved in terms of public school district funding, charter school funding, and/or university funding.

‘Less Prestigious Employment’ scores -- Higher scores are seen in areas with populations with higher rates of employment in sectors that are generally lower paying, often at more risk to automation, often come with health risks, and may be more exposed to carbon transition risk. An example use case with this score is when an investor is looking to put money in bonds that will for example serve more jobs, green jobs, and educational funding.

‘Minority’ scores -- Higher scores indicate higher percentages of non-White population. This score can be used by investors looking to invest in racial equity broadly speaking.

‘Social Impact’ scores -- This score combines all of the other 7 scores. Locations with the highest scores represent racial minority populations that have been marginalized and face multiple structural socioeconomic obstacles in terms of health, jobs, income, and housing. Investors can use this score to identify bonds that could broadly serve communities that need more resources.

Appendix

Table 1. List of variables used in the PCA to develop the education, high prestige employment, affluence, poverty, and health challenges metrics. The direction of correlation (either positive or negative) between each variable and its corresponding first principal component is also listed.

Metric	Variables	Correlation with PC1
High Prestige Employment	Information services	+
	financial services	+
	real estate	+
	wholesale trade	+
	professional science and technology services	+
	management services	+
	administrative support services	+
	education	+
	arts & entertainment	+
	other services	+
	agriculture	-
	utilities	-
	construction	-
	manufacturing	-
	retail	-
	transportation & warehouse	-
	mining, oil & gas	-
	healthcare	-
	hotel & food services	-
	public administration	-

High Educational Attainment	bachelor degree	+
	masters degree	+
	professional degree	+
	doctorate	+
	less than high school degree	-
	high school GED or equivalent	-
	some college education	-
	associate degree	-
Affluence	median household income	+
	per capita income	+
	household income quintiles 1-4: upper limit	+
	household income 5th quintile: 95th percent limit	+
	avg household income quintiles 1-5	+
	average household income 5th quintile: top 5	+
	Gini index	-
Poverty	under the poverty threshold	+
	1-1.37 times the poverty threshold	+
	1.38-1.99 times the poverty threshold	+
	2-3.99 times the poverty threshold	+
	above 4 times the poverty threshold	-
Health Challenges	blood pressure medication	+
	mental health issues	+
	asthma	+

	congenital heart defects	+
	chronic obstructive pulmonary disease	+
	high blood pressure	+
	diabetes	+
	high cholesterol	+
	kidney disease	+
	arthritis	+
	obesity	+
	stroke	+
	lack of access to insurance	+
	check-up in the last year	+
	mammograms	+
	cholesterol screening	-
	colon screening	-
	core prevention for men 65+	-
	core prevention for women 65+	-
	dental access	-
	binge drinking	-
	cancer	-

Appendix D: GIS Data Assumptions

All GIS data is based on information provided to Hazen and Sawyer by the Commission on 12/21/2020.

Table D-1: Outfalls with BWSC Owned Upstream Pipes

Outfall Facility ID	Outfall Owner
10BSDO45	Private
10BSDO56	Private
10BSDO58	Private
10BSDO62	Private
10BSDO64	Private
11GSDO1	Private
12FSDO001	Private
12FSDO003	Private
12FSDO004	Private
12HSDO1	Private
12HSDO10	Private
12HSDO7	Private
12HSDO95	Private
13DSDO150	DCR
13FSDO10	Private
13FSDO8	Private
22ISDO1	Private
22KSDO307	Private
22KSDO318	Private
22MSDO216	MPA
23ISDO3	DCR
23LSDO016	Private
23LSDO211	Private
24LSDO233	DOT
24LSDO244	Private
25NSDO15	MPA
26KSDO250	Private
26KSDO253	Private
27JSDO001	DOT
28KSDO1	Private
28KSDO2	Private
28LSDO011	Private
29JCSO108	MWRA
2FSDO98	Private
3FSDO159	DCR
3FSDO161	Private
4ESDO70	Private
4ESDO71	Private
4ESDO72	Private

Outfall Facility ID	Outfall Owner
4ESDO73	Private
4ESDO74	Private
4FSDO201	Private
4FSDO202	Private
5FSDO1	Private
5FSDO264	Private
5FSDO266	Private
5GSDO170	Private
5GSDO171	Private
6HSDO41	Private
6HSDO42	Private
6HSDO43	Private
7CSDO5	Private
7HSDO349	Private
7HSDO350	Private
7HSDO351	Private
8DSDO112	Private
8DSDO120	Private
8ISDO210	Private
8ISDO211	MBTA
8ISDO212	Private
9BSDO60	Private
9BSDO62	Private
9BSDO64	Private
9GSDO188	Private

Table D-2: Modeled Outfalls Matched with BWSC Shapefile Outfalls

Modeled Outfall ID	BWSC Outfall ID	BWSC Facility ID
4	NONE	NONE
1000311	2916640008	29PSDO005
1001045	NONE	NONE
1006831	NONE	NONE
1007139	NONE	NONE
1007449	2307640006	23GCSO010
1007701	2611640016	26KCSO203-2
1008431	NONE	NONE
1008587	2309640001	23ICSO018
1008595	2409640001	24ICSO019
1008603	2410640002	24JCSO219
1008807	NONE	NONE
810640001	810640001	8JSDO102
811640001	811640001	8KSDO49
911640001	911640001	9KSDO100
911640002	911640002	9KSDO101
911640003	911640003	9KSDO16
912640001	912640001	9LSDO095
1012640001	1012640001	10LSDO094
1012640002	1012640002	10LSDO096
1112520043	NONE	NONE
1113640001	1113640001	11MSDO093
1212460001	1212460001	12LSDO092
1212640001	1212640001	12LSDO296
1213640001	1213640001	12MSDO091
1312640001	1312640012	13LSDO090
1512640001	1512640011	15LSDO089
1512640002	1512640010	15LSDO088
1612640001	1612640001	16LSDO097
1612640002	1612640002	16LSDO122
1613640001	1613640001	16MSDO22
1713640001	1713640001	17MSDO33
1812640004	NONE	NONE
1812640006	1812640006	18LCSO086
1912640001	1912640001	19LCSO084
1912640002	1912640002	19LCSO085
1913640001	1913640001	19MCSO082
1913640002	1913640002	19MCSO083
1914640001	1914640001	19NCSO081
2011390011	NONE	NONE

Modeled Outfall ID	BWSC Outfall ID	BWSC Facility ID
2012640001	NONE	NONE
2012640002	NONE	NONE
2111640005	2111640004	21KCSO070
2112640001	2112640001	21LCSO076
2113640001	2113640001	21MSDO005
2113640004	2113640004	21MCSO078
2113640006	2113640006	21MSDO008
2113640009	2113640009	21MSDO15
2113880001	2113640003	21MCSO079
2114660005	2114640002	21NCSO80
2211640001	2211640001	22KCSO065
2211640003	2211640003	22KSDO285
2211640006	2211640006	22KSDO1
2211640007	2211640007	22KCSO068
2211660369	2211640008	22KCSO072
2212640001	2212640004	22LCSO073
2213640005	2213640005	22MSDO215
2213640010	2213640009	22MSDO224
2213640013	NONE	NONE
2213640018	2213640018	22MSDO38
2213640019	2213640023	22MSDO244
2213640020	2213640020	22MSDO241
2213640021	2213640021	22MSDO242
2214640002	2214640002	22NSDO18
2214640004	2214640004	22NSDO29
2312640001	2312640001	23LCSO062
2312640005	2312640005	23LCSO064
2312640009	2312640009	23LSDO016
2312640011	2312640011	23LSDO23
2312640013	2312640013	23LSDO164
2312640014	2312640014	23LSDO203
2313640001	2313640001	23MSDO3
2412640001	2412640001	24LSDO244
2412640002	2412640002	24LCSO060
2412640004	2412640004	24LSDO233
2412640005	2412640005	24LSDO22
2414640001	2414640001	24NCSO003
2512640001	2512640001	25LSDO144
2512640003	2512640003	25LSDO058
2512640004	2512640004	25LCSO057
2513640001	2513640001	25MCSO005

Modeled Outfall ID	BWSC Outfall ID	BWSC Facility ID
2513640002	2513640002	25MSDO006
2513640003	2513640004	25MSDO1
2514640001	2514640001	25NCSO004
2610640001	2610640008	26JSDO049
2611640005	2611640005	26KSDO254
2611640009	2611640024	26KSDO052
2611640019	2611640019	26KSDO35
2611880001	2611640003	26KSDO099
2612640004	2612640009	26LSDO106
2612640006	2612640006	26LSDO084
2612640007	2612640007	26LSDO70
2712640001	NONE	NONE
2712640002	2712640002	27LSDO022
2712640003	2712640003	27LSDO020
2811640001	2811640001	28KSDO61
2811640002	2811640002	28KSDO010
2811640003	2811640003	28KSDO386
2812640001	2812640001	28LSDO073
2812640003	2812640003	28LSDO075
2814640001	2814640001	28NSDO156
2814640002	2814640003	28NSDO207
2815640001	2815640001	28OSDO25
2816640001	2816640001	28PSDO1
2910640002	2910640002	29JSDO129
2910640003	2910640003	29JSDO029
2910640004	2910640004	29JCSO017
2910640005	2910640005	29JSDO212
2913640004	2913640004	29MSDO049
2914640001	2914640001	29NSDO015
2914640002	2914640002	29NCSO014
2914640003	2914640003	29NSDO135
2915640001	2915640001	29OSDO001
2916640001	2916640001	29PSDO15
2916640002	2916640002	29PSDO44
3010640001	3010640001	30JSDO6
3010640002	3010640002	30JSDO19
3010640003	3010640003	30JSDO30
3016640001	3016640001	30PSDO107
3016640002	3016640002	30PSDO62
3115640001	3115640001	31OSDO4
3116640001	3116640001	31PSDO84

Modeled Outfall ID	BWSC Outfall ID	BWSC Facility ID
2111640001_DC	2111640007	21KSDO069
2111640001_SC	2111640007	21KSDO069
2113640007_DC	2113640007	21MSDO010
2113640007_SC	2113640007	21MSDO010
2113640008_DC	2113640008	21MSDO50
2113640008_SC	2113640008	21MSDO50
2212640002_DC	2212640002	22LSDO580
2212640002_SC	2212640002	22LSDO580
2312640002_DC	2312640002	23LSDO196
2312640002_SC	2312640002	23LSDO196
2312640004_DC	2312640004	23LSDO075
2312640004_SC	2312640004	23LSDO075
2312640006_DC	2312640006	23LSDO074
2312640006_SC	2312640006	23LSDO074
2312640007_DC	2312640007	23LSDO195
2312640007_SC	2312640007	23LSDO195
2312640008_DC	2312640008	23LSDO202
2312640008_SC	2312640008	23LSDO202
2312640010_DC	2312640010	23LSDO15
2312640010_SC	2312640010	23LSDO15
2612640001_DC	2612640001	26LCSO009
2612640001_SC	2612640001	26LCSO009
2812660067_DC	2812660067	28LCSO012
2812660067_SC	2812660067	28LCSO012
2913640001_DC	2913640001	29MCSO013
2913640001_SC	2913640001	29MCSO013
bos_010_outfall	2712640004	27LCSO10
CH8249	NONE	NONE
Charles000000	NONE	NONE
CT10733	2812640008	28LCSO019
DummyTide	NONE	NONE
Neponset000000	NONE	NONE
1008409	NONE	NONE
1010447	NONE	NONE
106520002	206640004	2FSDO99
1507390037	NONE	NONE
1507660329	NONE	NONE
1708660088	NONE	NONE
1808390019	NONE	NONE
1808390031	NONE	NONE
1808580002_1	NONE	NONE

Modeled Outfall ID	BWSC Outfall ID	BWSC Facility ID
WROX_0578-outfall	NONE	NONE

Table D-3: Matching Tributary Areas with Outfalls

Tributary Area Discharge Location	BWSC Outfall Facility ID
08CSDO025/026	08CSDO025
08JSDO036/041	08JSDO041
08JSDO050/049	08JSDO050
Neponset	11GSDO1
12HSDO085	12HSDO4
12HSDO087	12HSDO7
13DSDO077/078	13DSDO077
14EMH036	13ESDO180
18LCSO086DR	18LCSO086
19HMH219	19HSDO1
19LCSO084DR	19LCSO084
19LCSO085DR	19LCSO085
19MCSO082DR	19MCSO082
19MCSO083DR	19MCSO083
19NCSO081DR	19NCSO081
15GMH469SB	21HCSO046-1
15FMH333	
Fallon	
Healy	
RBWalworth	
Greenwood	
Cleary	
Philbrick	
Barron	
Clarendon	
Calvary	
15GMH065SB	
14GMH130SB	
15GMH231SB	
15GMH208SB	
14GMH209SB	
17HMH086SB	
16HMH132SB	
15GMH298SB	

Tributary Area Discharge Location	BWSC Outfall Facility ID
15GMH399SB	
16HMH458SB	
16GMH214SB	
16HMH026SB	
17HMH523SB	
17HMH124SB	
18HMH226SB	
18HMH200SB	
17HMH087SB	
19HMH253SB	
19HMH254	
19HMH336	
19HMH237	
20HMH216	
21IMH757	
21IMH529	
19HMH311	
21IMH165	
18HMH255	
17HMH106SB	
16HMH476SB	
16HMH333SB	
15GMH264SB	
17HMH139SB	
21JMH075	
18HMH271SB	
State_Hospital	
20IMH579	21HCSO046-2
21IMH186	
21IMH189	
21IMH539	
21IMH667	
21HCSO046	
21HCSO046	
21JMH075	21KCSO070
21JMH183	
21KCSO070DR	
21JMH011	
21JMH371	
21JMH232	

Tributary Area Discharge Location	BWSC Outfall Facility ID
21MCSO078DR	21MCSO078
21NCSO080DR	21NCSO080
23HSDO001	22ISDO1
22KCSO065DR	22KCSO065
22KCSO068DR	22KCSO068
22KCSO072DR	22KCSO072
23GMH030	23GCSO010
23LCSO062DR	23LCSO062
23LCSO064DR	23LCSO064
22LCSO073	23LSDO203
BackBay	24ICSO19
24NCSO003DR	24NCSO003
25MCSO005DR	25MCSO005
27JMH055	27JSDO096
27LSDO020/022	27LSDO020
28LSDO074/076	28LSDO074
29NCSO014DR	29NCSO014
SBReservation	4ESDO77
Mount_Hill	8FSDO1
West_Roxbury	Open Drain
21EMH064	
21EMH086	
21DMH319	
20DMH055	
20DMH019	
23BMH089	
24CSDO039	
28IMH015	
20DMH062	
23GMH007	

Appendix E: Implementation Timeline

The primary focus of the Coastal Stormwater Discharge Analysis project was to identify the Commission's most critical and vulnerable outfalls and develop conceptual adaptation solutions at a subset of these outfalls. However, it is important to recognize that the Commission's stormwater system depends on the functionality of several hundred outfalls that are located throughout the City. To address the less critical - but still vulnerable - outfalls that were not advanced to the conceptual design phase of this project, an Implementation Timeline/Plan was developed that can be used as a "roadmap" to adapt these remaining outfalls. The Implementation Timeline groups outfall adaptation solutions into three time periods, based on the implementation time period chosen by Climate Ready Boston (as of December 2022) for the section of shoreline that the outfalls are along. The three time periods are: near term, defined as by 2030, mid term, defined as between 2030 and 2050, and long term, defined as between 2050 and 2070. As Climate Ready Boston continues to update and refine their plans for coastal flood protection, the timeline for adaptation of Commission outfalls will also need to be updated; Climate Ready Boston's presently completed and planned solutions for coastal flood protection are integral parts of all solutions designed for the outfalls in the Implementation Timeline. Insofar as it is feasible, the ideal method of advancing the Implementation Timeline solutions, enumerated herein, is one that co-ordinates most with the design of CRB's planned coastal flood mitigation projects.

The Implementation Timeline only includes outfalls which are owned by the Commission (based on GIS data provided by the Commission in 2020). Outfalls were further screened based on coastal flood vulnerability. Outfalls with inverts above 13.8 ft NAVD88 (the approximate projected 100-year storm surge elevation in 2070) were considered not coastal flood vulnerable, and therefore were excluded from the Implementation Timeline.

A second tier of screening was applied by analyzing the approximate drainage areas served by outfalls classified as coastal flood vulnerable and segregating them from outfalls that are not vulnerable. Outfalls which serve higher elevation drainage areas (above 13.8 ft, NAVD88) may be influenced by higher sea levels (at their downstream end), but still function as intended and discharge by gravity without additional modifications required (since they are not vulnerable to the coastal flood conditions evaluated during this project). Thus, these outfalls which serve areas with low coastal flood vulnerability were not included in the Implementation Timeline.

By following this two-tier screening process, a total of 66 outfalls were identified for inclusion in the Implementation Timeline.

A key objective when identifying a potential solution for each of the Implementation Timeline outfalls was replication of the design concepts developed (as shown in Section 5 of the accompanying report, and summarized in **Table 1**, below.)

Table 1 - Concept Solutions Overview

Concept Name	Neighborhood	Solution Type	Report Section
Airport	East Boston	Storage and Pumping	5.4
Constitution Beach	East Boston	Conveyance and Pumping	5.5
Waterfront	East Boston	Conveyance and Pumping	5.6
Greenway	East Boston	Conveyance	5.7
Schrafft Center	Charlestown	Storage and Pumping	5.8
Columbus Park	Downtown Boston	Storage and Pumping	5.9
Fort Point Channel	Downtown Boston	Storm Surge Barrier and Pumping	5.1
Davenport Creek	Dorchester	Storage and Pumping	5.11
Dorchester Bay Basin	Dorchester	Conveyance and Storage	5.12
Finnegan Park	Dorchester	Storage and Pumping	5.13
Old Harbor Park	Dorchester	Storage and Pumping	5.14

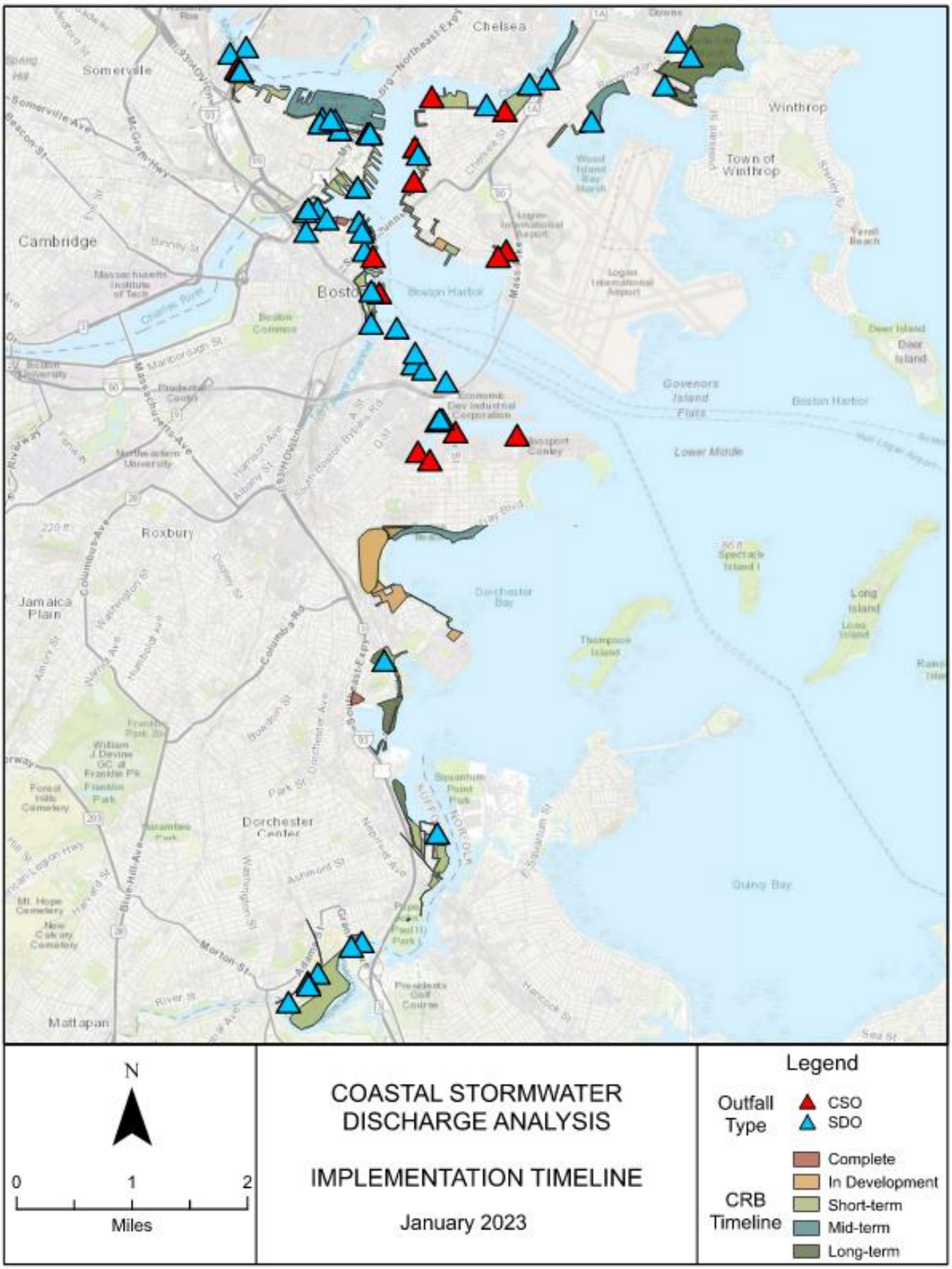
The solutions identified in the Implementation Timeline can be classified into the following categories:

- **Pump Station:** electric submersible units installed within wet wells or subsurface storage tanks to discharge stormwater against high tides.
- **Storage:** solutions that utilize natural features or constructed tanks and wetlands to manage flow from outfalls.
- **Storm Surge Barrier:** a structure that blocks higher tide levels and storm surge conditions from entering a protected area to maintain low tailwater elevations. Solutions utilizing a storm surge barrier typically "protect" multiple coastal flood vulnerable outfalls.
- **Conveyance:** modifications to existing pipe networks (or construction of new piping) to facilitate gravity drainage.
- **Consolidation and Pump Station:** new pipelines to intercept flow from multiple outfalls for conveyance to a single pump station.
- **Local Stormwater Management:** solutions that temporarily manage excess stormwater "on site" during high tide conditions.
- **Tide Gate:** devices/structures that prevent backflow of water through outfalls. Other improvements may be required to eliminate residual flooding in the future. Tide gates are a potential solution at all outfalls which do not currently have them installed.

The remainder of this document summarizes recommended solutions at each Commission owned coastal flood vulnerable outfall. Outfalls are grouped by neighborhood, and categorized as described previously according to the currently stated CRB timeline for implementation. Most outfalls are included in "single outfall concepts" (solutions that only address a single outfall), although some solutions have the potential to adapt multiple outfalls with a single project. The concepts included herein are intended only to provide a starting point for adaptation of outfalls; further analyses to determine feasibility, effectiveness, and cost-effectiveness should be conducted before advancing each concept.

Notes:

- All elevations in this document use the NAVD88 datum, unless otherwise noted (BCB = NAVD88 + 6.46').
- Outfalls that are currently intercepted by the South Boston CSO Storage Tunnel are not included in the Implementation Timeline.
- The Implementation Timeline only includes outfalls owned by the Commission. Coastal flood vulnerable outfalls owned by other entities are not included.
- Refer to the full *Coastal Stormwater Discharge Analysis* project report (Hazen, 2023) for additional information regarding coastal flood vulnerability, conceptual solutions, and other elements of the project.
- Tide gates could be installed on all coastal flood vulnerable outfalls (those identified in the full project report and this document) that do not already have them. It is important to note that although tide gates are effective at preventing backflow through vulnerable outfalls, they do not facilitate stormwater discharge. As such, installation of tide gates alone may not be sufficient to prevent significant flooding at many locations, especially in low-lying and large drainage areas. In some locations where a small amount of temporary flooding due to stormwater may be acceptable (or where the feasibility of constructing a solution for stormwater discharge is limited), tide gates may be the only solution appropriate for outfall adaptation.


Chelsea
Somerville
Winthrop
Town of Winthrop
Cambridge
Boston
Roxbury
Jamaica Plain
Dorchester Center
Mattapan
Governors Island Flats
Lower Middle
Long Island
Thompson Island
Squantum Point Park
Quincy Bay
N
0
1
2
Miles
COASTAL STORMWATER DISCHARGE ANALYSIS
IMPLEMENTATION TIMELINE
January 2023
Legend
Outfall Type
CSO
SDO
CRB Timeline
Complete
In Development
Short-term
Mid-term
Long-term

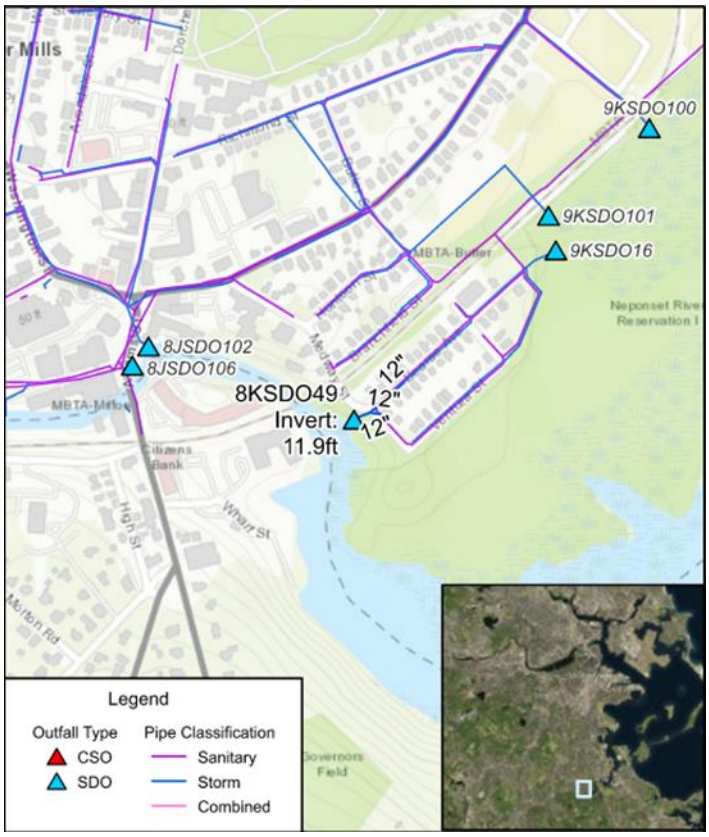
Dorchester Single Outfall Concepts



Outfall 8KSDO49
Mattapan Trolley and Butler Station, Dorchester
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

- CRB project type: Elevated roadways
- 12-inch outfall serves a 2.4-acre tributary area
- Opportunity for storage in nearby reservation
- Permitting challenges due to nearby wetland
- Tide gate to prevent backflow during high tide conditions
- Further study recommended because the high tributary area elevation suggests limited benefit from further adaptation



Outfall 12MSDO091
Port Norfolk, Dorchester
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

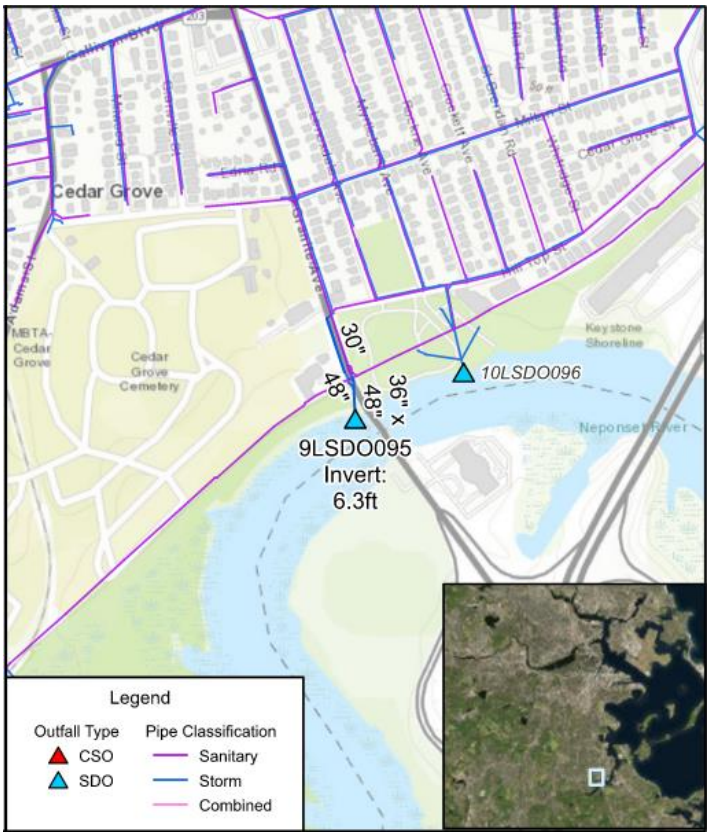
- CRB project type: Perimeter protection including berms and floodwalls
- 36-inch outfall serves a 5.5-acre tributary area
- Lack of open space limits the feasibility of construction at this location
- Localized stormwater management or tide gate



Outfall 9LSDO095
Neponset River Reservation, Dorchester
CRB Implementation Date: 2070

Existing Conditions and Recommendations:

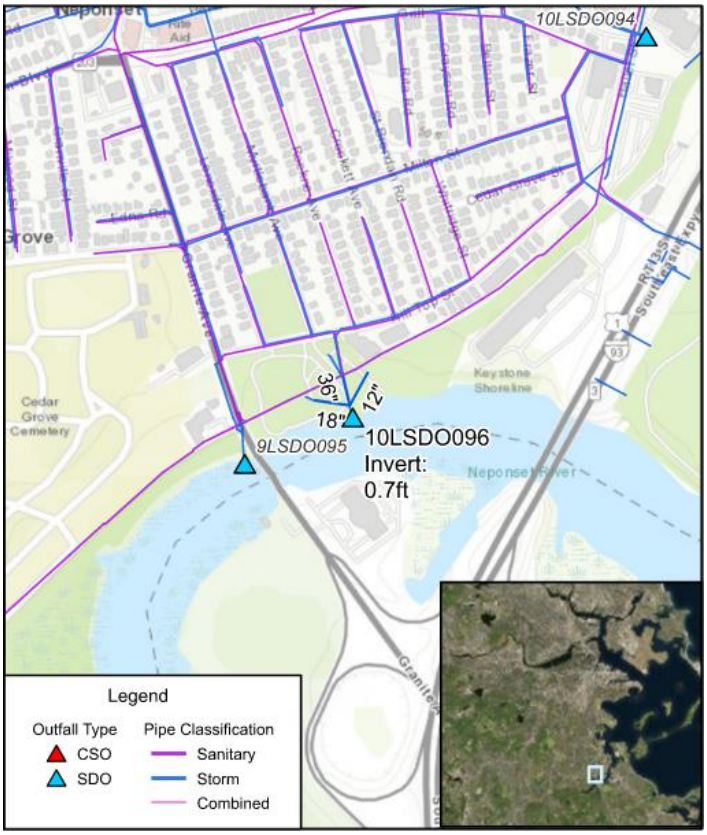
- CRB project type: Nature based solutions
- 36 by 48-inch outfall serves a 37.2-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Further study recommended because the high tributary area elevation suggests limited benefit from further adaptation



Outfall 10LSDO096
Neponset River Reservation, Dorchester
CRB Implementation Date: 2070

Existing Conditions and Recommendations:

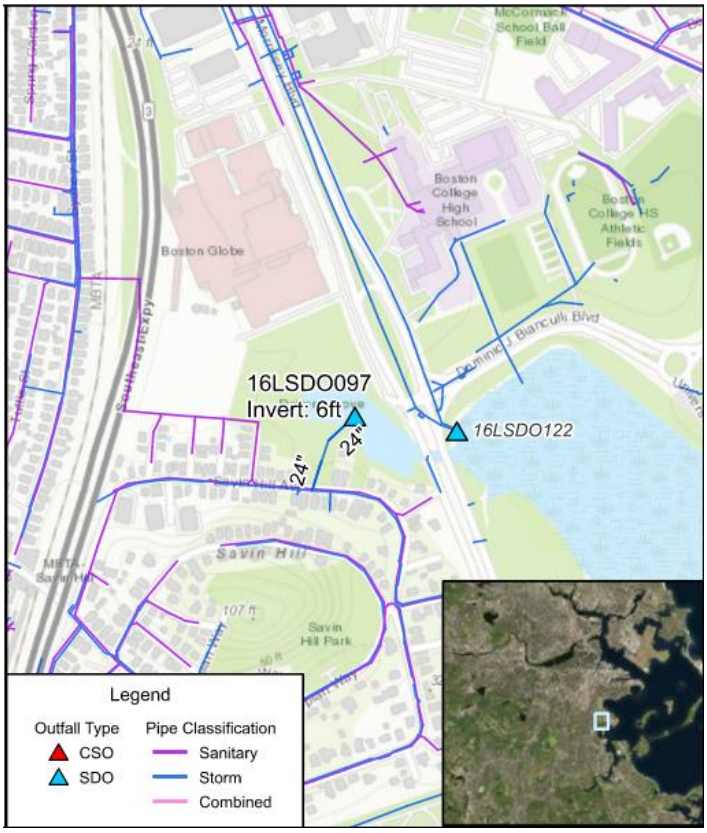
- CRB project type: Elevated waterfront parks and berms
- 36-inch outfall serves a 14.7-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Further study recommended because the high tributary area elevation suggests limited benefit from further adaptation



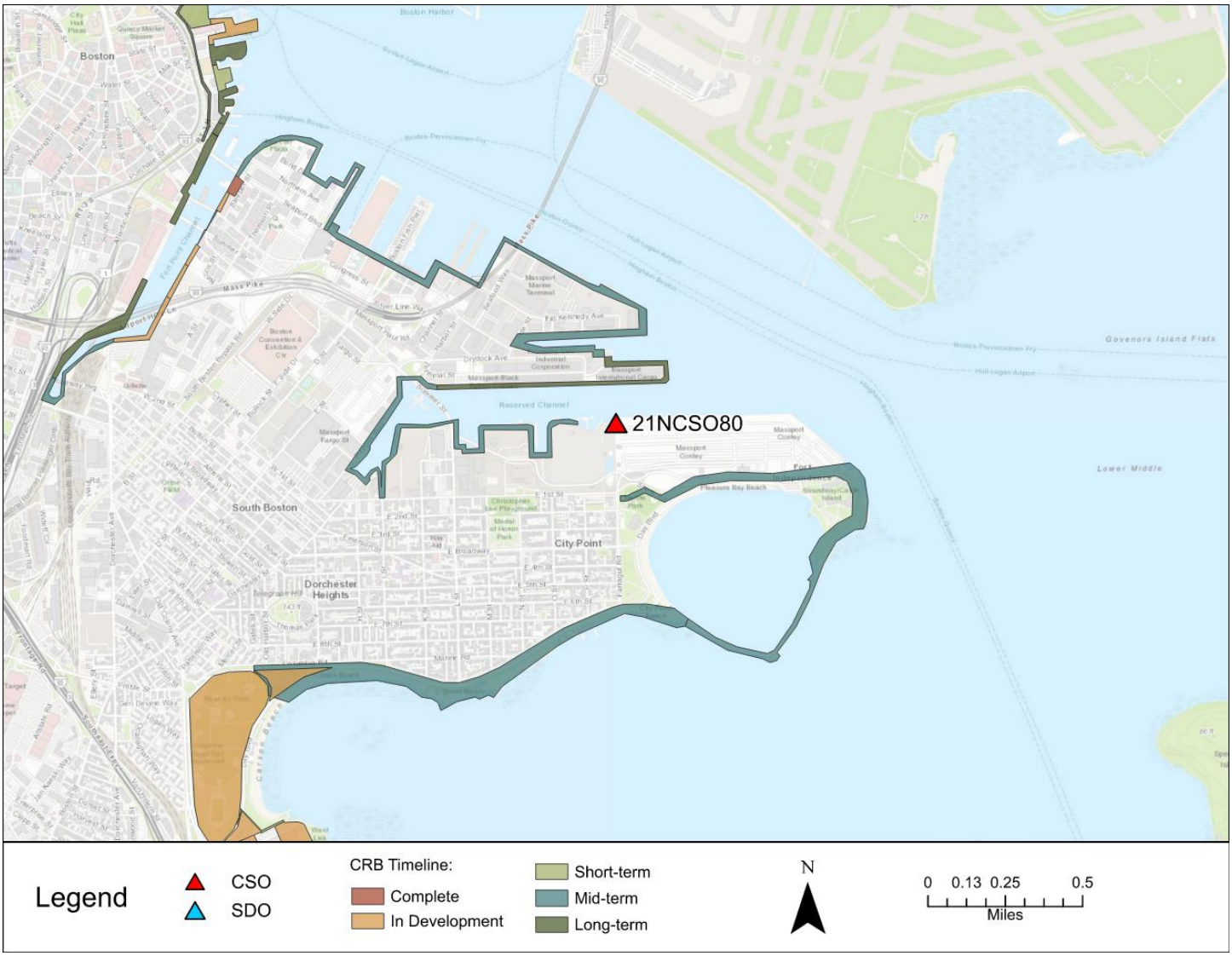
Outfall 16LSDO097
Pattens Cove, Dorchester
CRB Implementation Date: 2070

Existing Conditions and Recommendations:

- CRB project type: Nature based solution
- 24-inch outfall serves a 21.9-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Flow could be diverted to the DBB concept included in the complete Coastal Stormwater Discharge Analysis project report



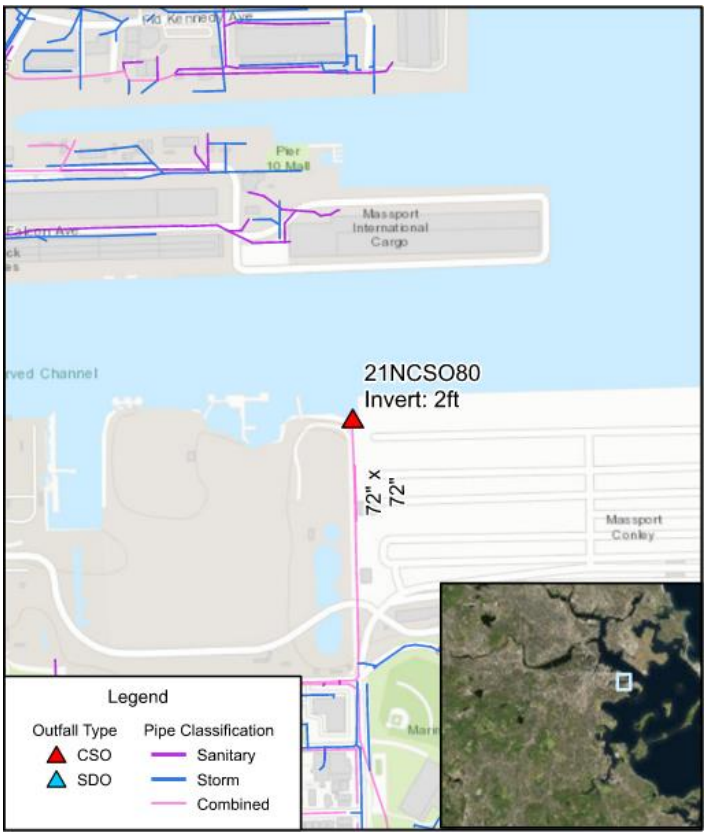
South Boston Single Outfall Concepts



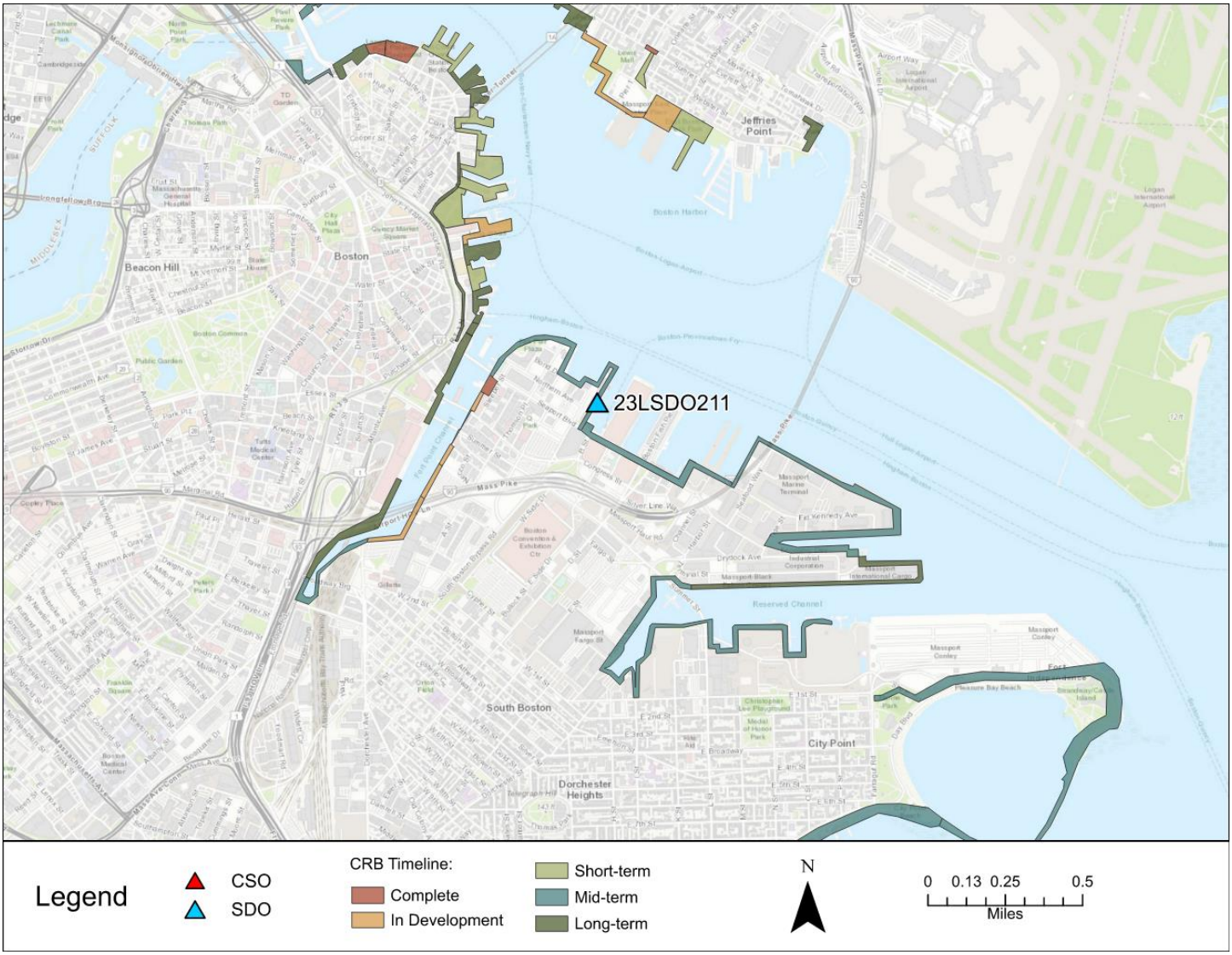
Outfall 21NCSO80
Pleasure Bay, South Boston
CRB Implementation Date: 2050

Existing Conditions and Recommendations:

- CRB project type: Elevated waterfront parks and berms.
- 72-inch outfall serves a 99.1-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Subsurface storage facility and pump station could be considered in the future



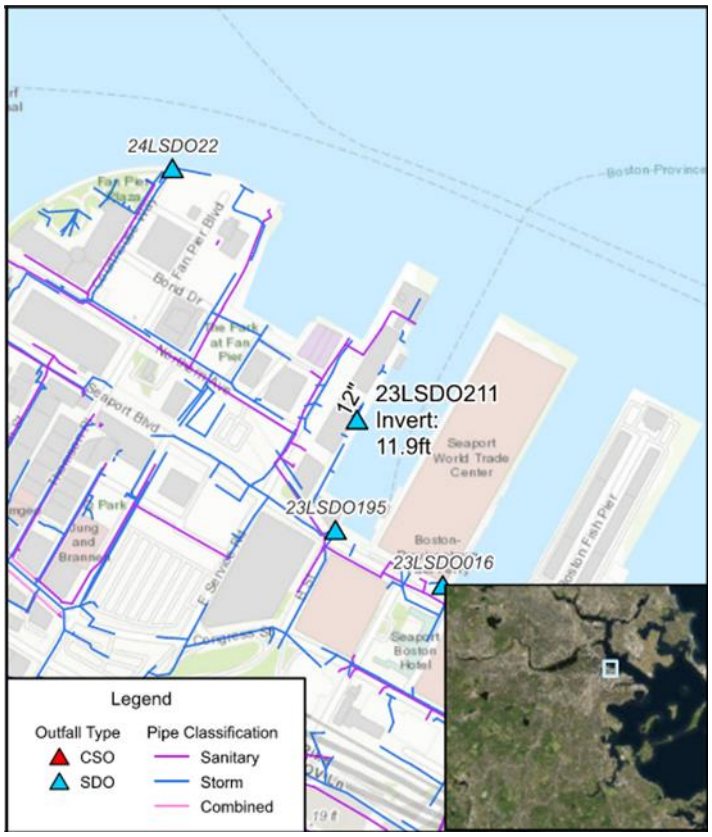
South Boston Waterfront Single Outfall Concepts



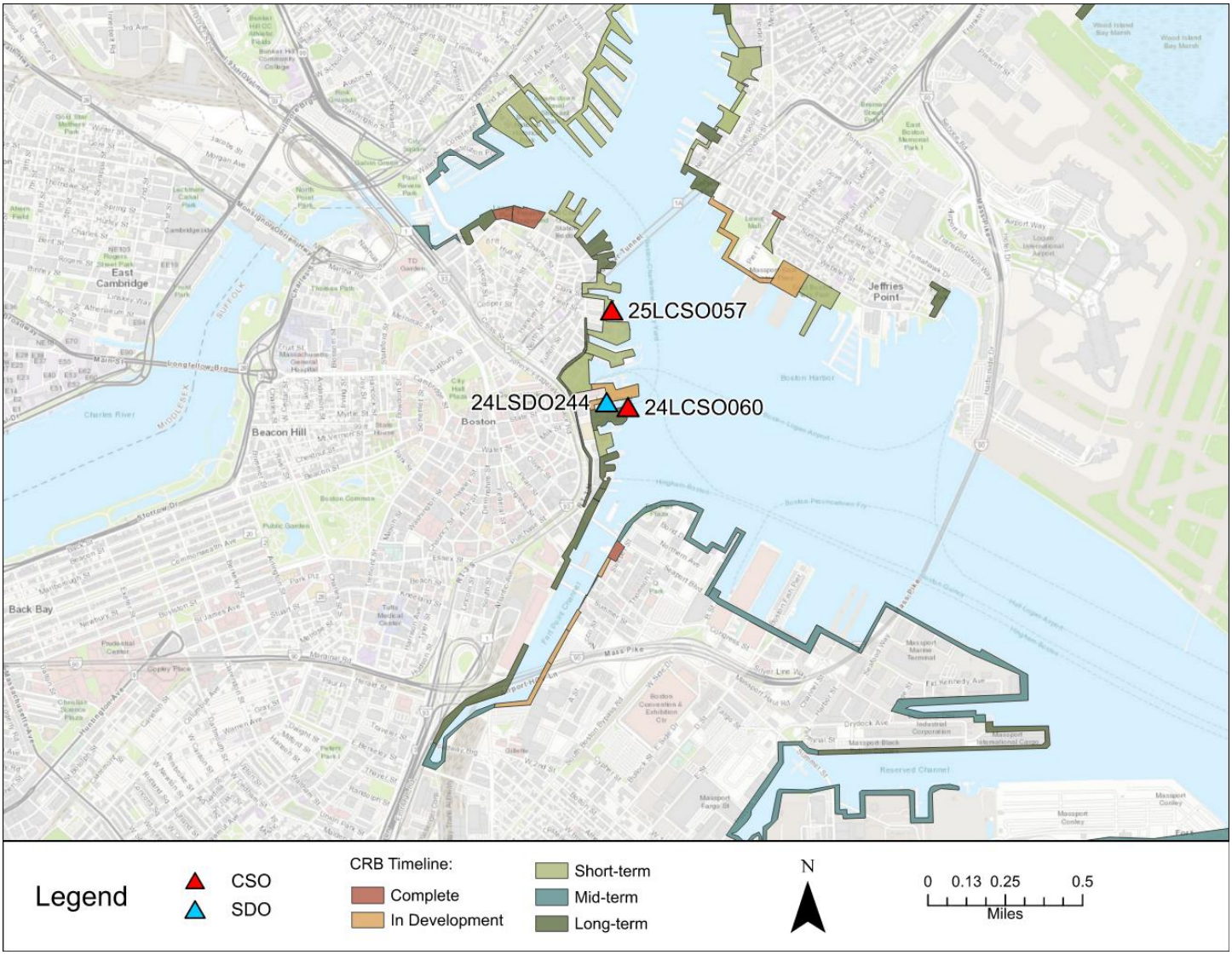
Outfall 23LSDO211
South Boston Waterfront
CRB Implementation Date: 2050

Existing Conditions and Recommendations:

- CRB project type: Elevated Harborwalk
- 12-inch outfall serves a small (localized) tributary area
- Lack of open space limits the feasibility of construction at this location
- Tide gate to prevent backflow during high tide conditions



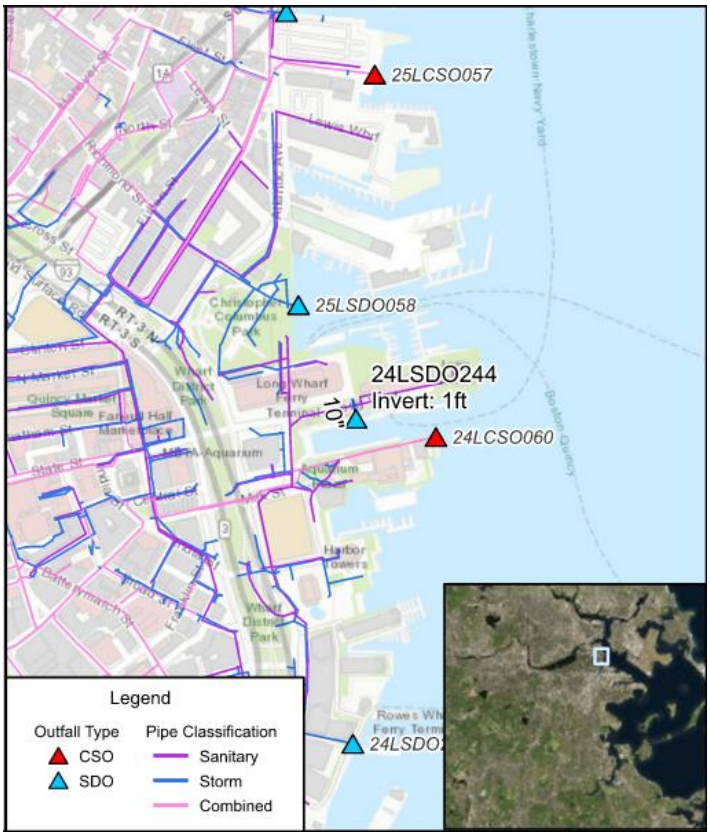
Downtown Single Outfall Concepts



Outfall 24LSDO244
Long Wharf, Downtown
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

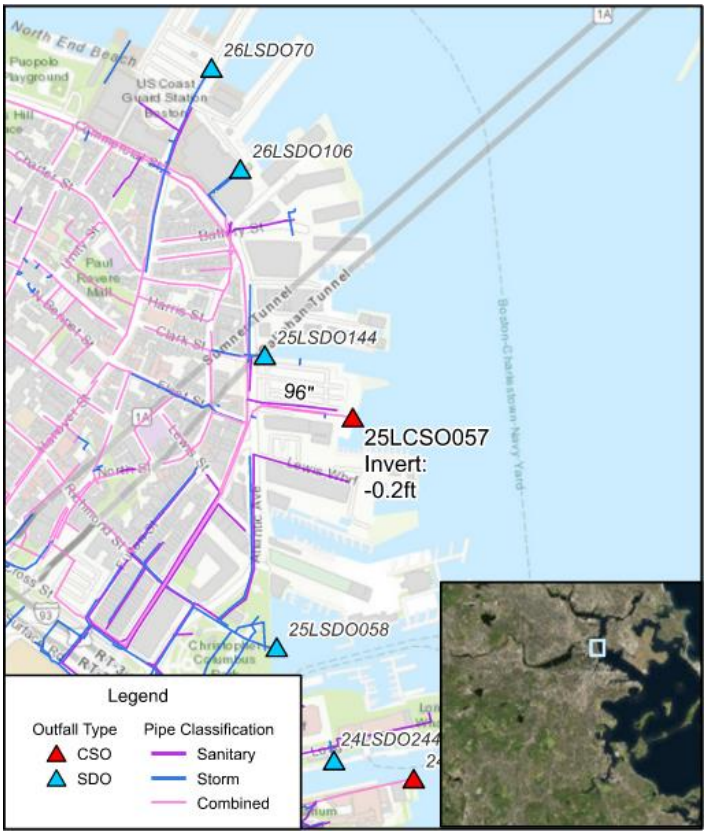
- CRB project type: Raised Harborwalk
- 10-inch outfall serves a small tributary area
- Tide gate to prevent backflow during high tide conditions
- Small, subsurface pump station could be installed to provide enhanced drainage for Long Wharf area, if flooding is found to occur during wet weather in the future (after shoreline protection is implemented)
- Flow could possibly be diverted to the nearby Columbus Park concept solution



Outfall 25LCSO057
Sargent's Wharf, Downtown
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

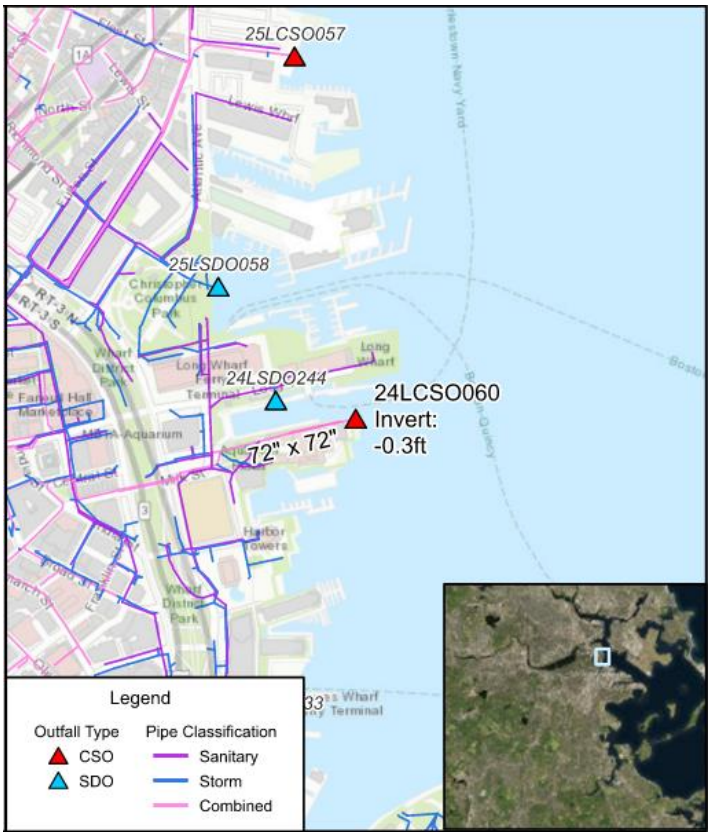
- CRB project type: Raised Harborwalk
- 96-inch outfall serves a 175.5-acre tributary area
- Lack of open space and sensitivity to visual impacts limit the feasibility of construction at this location
- Tide gate to prevent backflow during high tide conditions
- Subsurface pump station could be installed to facilitate discharge during high sea levels
- Flow could possibly be diverted to the nearby Columbus Park concept solution



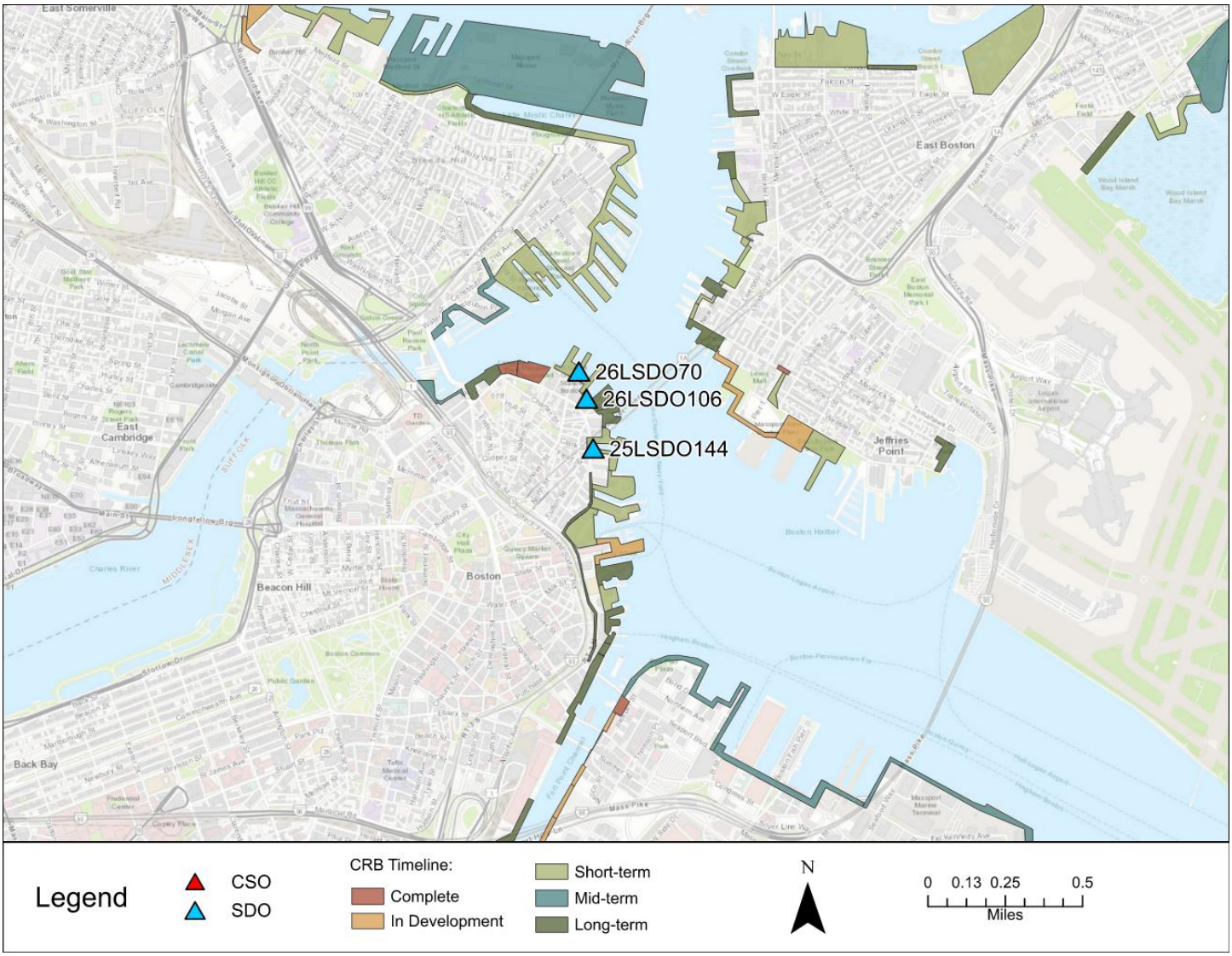
Outfall 24LCSO060
Central Warf and NEAQ, Downtown
CRB Implementation Date: 2070

Existing Conditions and Recommendations:

- CRB project type: Raised Harborwalk
- 72-inch outfall serves a 14.5-acre tributary area
- Lack of open space limits the feasibility of construction at this location
- Tide gate to prevent backflow during high tide conditions
- Subsurface pump station in Rowes Wharf Plaza could be considered



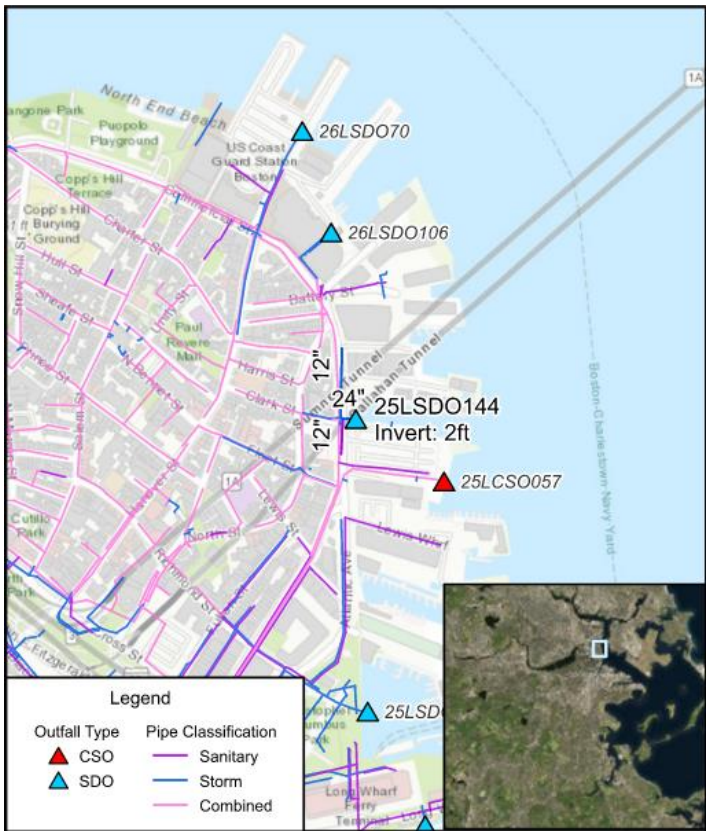
North End Single Outfall Concepts



Outfall 25LSDO144
Union Wharf, North End
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

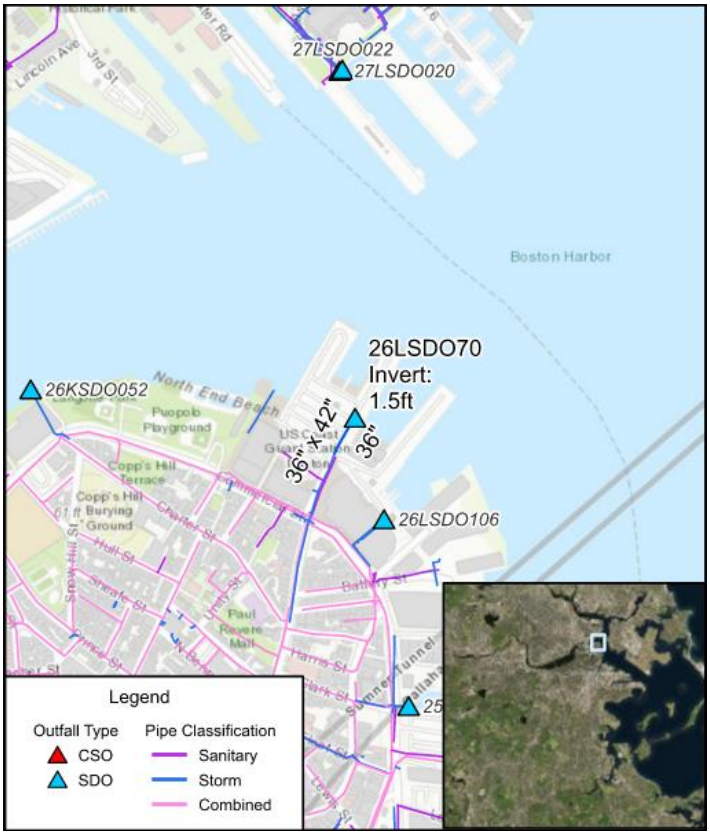
- CRB project type: Raised Harborwalk
- 24-inch outfall serves a 1.1-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Subsurface storage facility and small pump station could be installed in the adjacent parking lot



Outfall 26LSDO70
Commercial St at US Coast Guard, North End
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

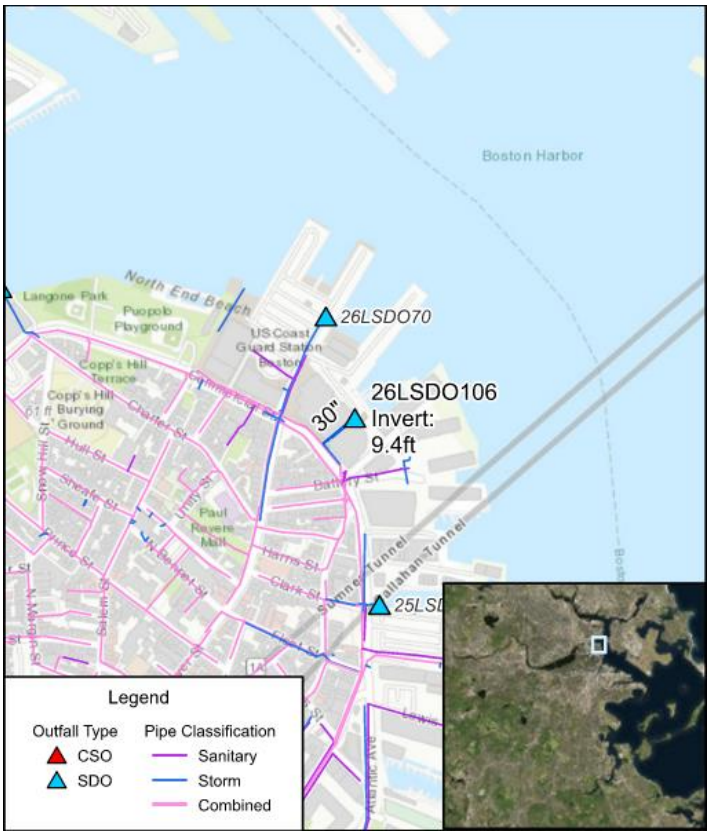
- CRB project type: Raised Harborwalk
- 36-inch outfall serves a 2.3-acre tributary area
- Publicly owned opened space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Subsurface storage facility and pump station could be installed in the Coast Guard parking lot to facilitate discharge during high sea levels



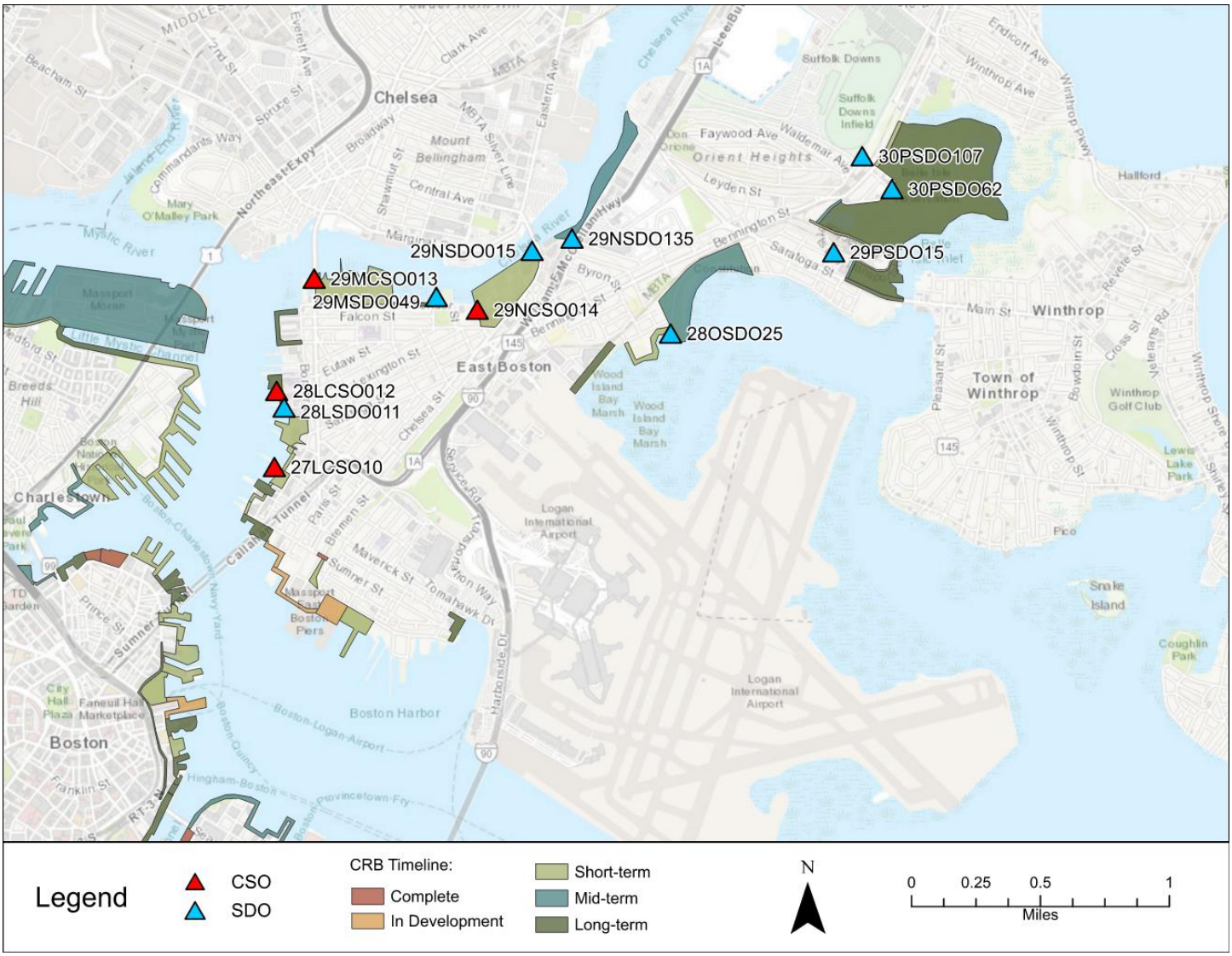
Outfall 26LSDO106
Battery Wharf, North End
CRB Implementation Date: 2070

Existing Conditions and Recommendations:

- CRB project type: Raised Harborwalk
- 30-inch outfall serves a 1.1-acre tributary area
- Proximity to the ocean and lack of public open space limit the feasibility of construction at this location
- Tide gate to prevent backflow during high tide conditions
- Subsurface storage facility and pump station could be installed in the Harborwalk Plaza to facilitate discharge during high sea levels



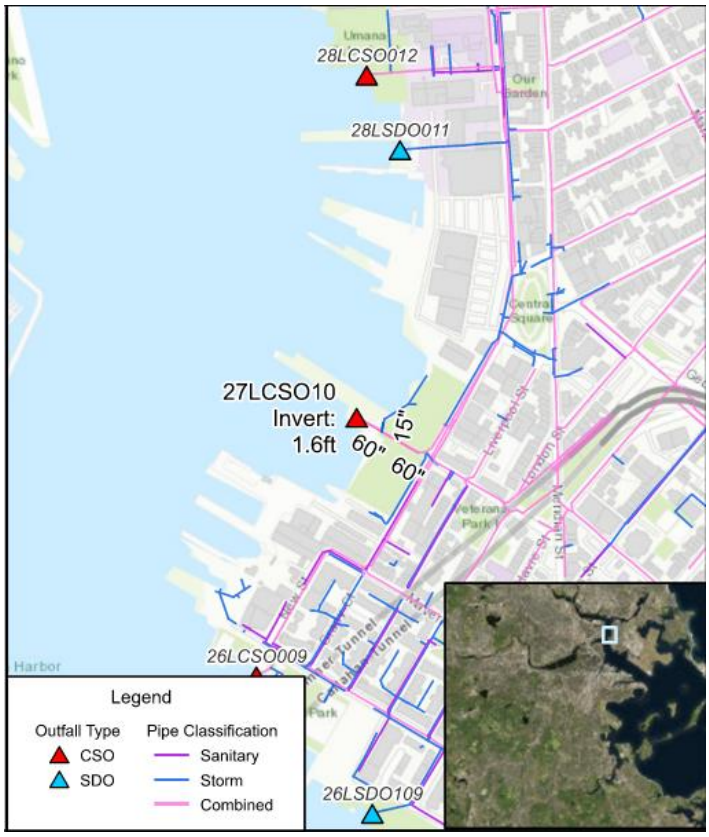
East Boston Single Outfall Concepts



Outfall 27LCSO10
Border Street, East Boston
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

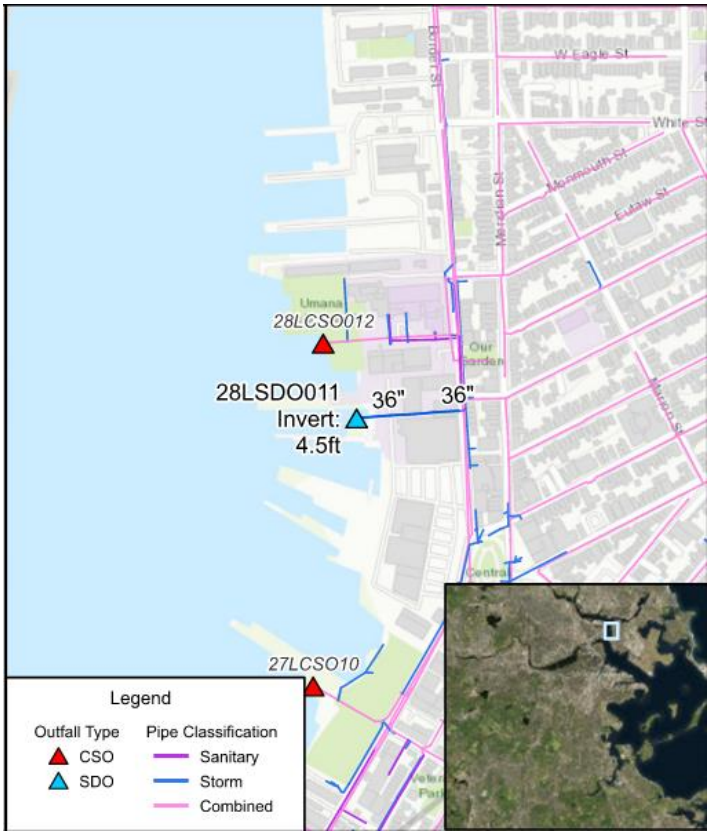
- CRB project type: Raised harborwalk and nature based solutions
- 60-inch outfall serves a 37.0-acre tributary area
- space (reduce inflow to this outfall, if it is converted to a SDO in the future)
- Tide gate to prevent backflow during high tide conditions
- Subsurface storage facility and pump station could be installed in the adjacent grassed area to facilitate discharge during high sea levels



Outfall 28LSDO011
Border St, East Boston
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

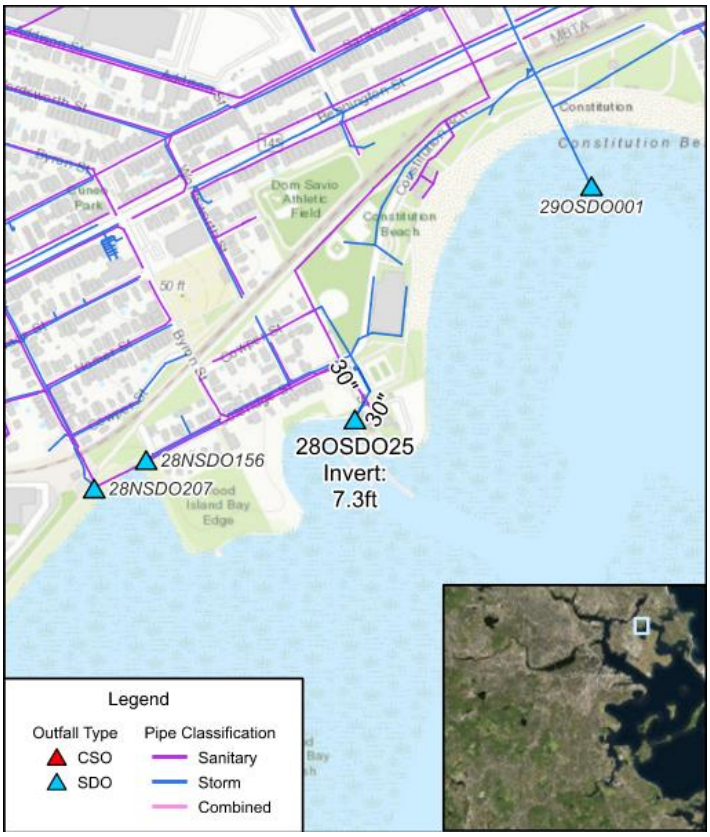
- CRB project type: Raised harborwalk and nature based solutions
- 36-inch outfall serves a 26.4-acre tributary area
- Lack of open space limits the feasibility of construction at this location
- Tide gate to prevent backflow during high tide conditions
- Outfall
- could be consolidated with adjacent (future) storm drain outfalls and pump station for discharge



Outfall 28OSDO25
Constitution Beach, East Boston
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

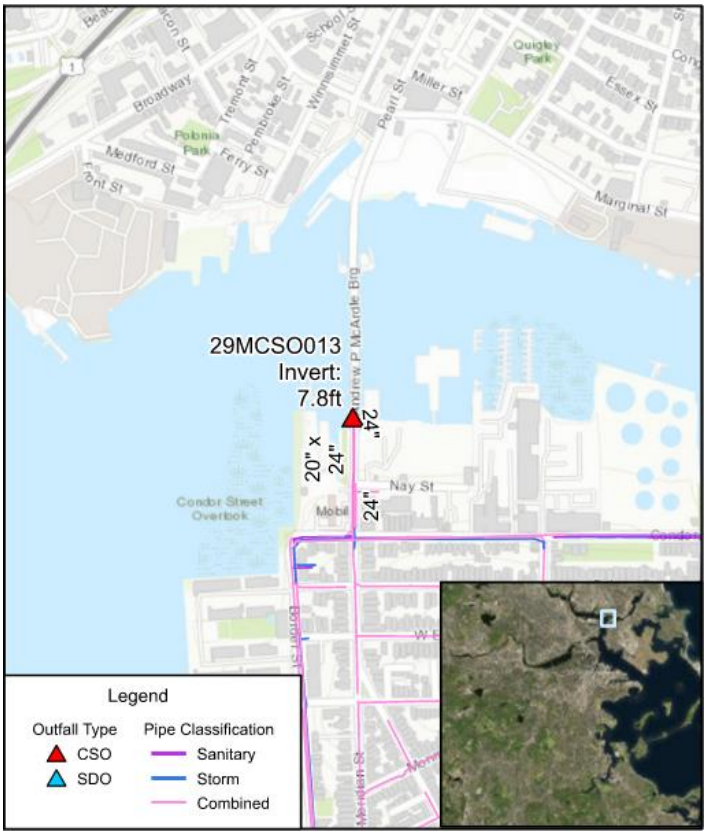
- CRB project type: Elevated waterfront parks and berms
- 30-inch outfall serves a 11.1-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Opportunity for storage at nearby Constitution Beach athletic fields
- Diversion of flow to potential future pump station at Outfall 29OSDO001
- Tide gate to prevent backflow during high tide conditions



Outfall 29MCSO013
Condor St Waterfront Properties, East Boston
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

- CRB project type: Building/site-scale adaptations.
- 24-inch outfall serves a 17.9-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Pump station could be installed in Chelsea Creek Marine field to facilitate discharge during high sea levels



Outfall 29NCSO014
Chelsea Creek Oil Terminal, East Boston
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

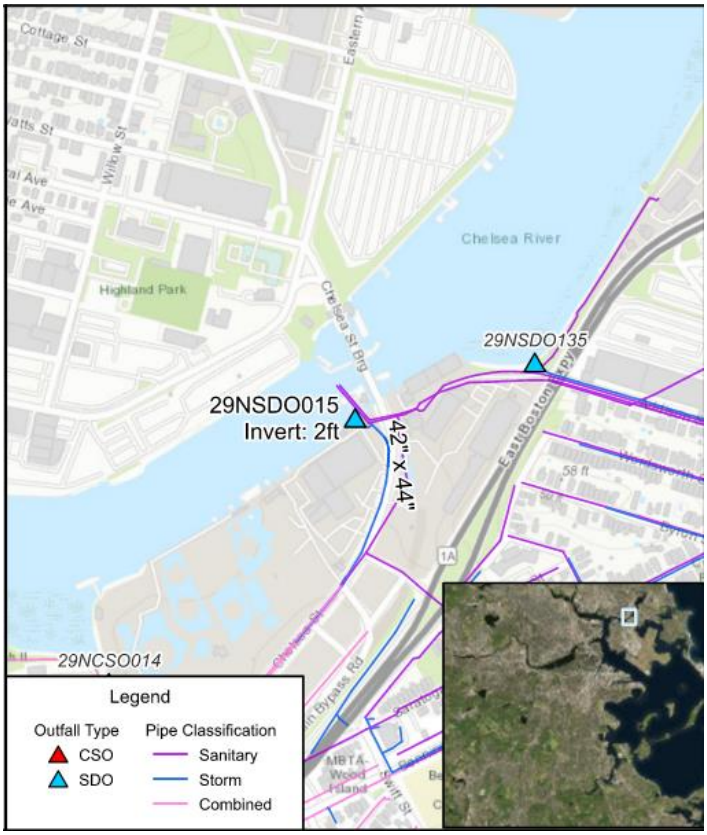
- CRB project type: Building/site-scale adaptations
- 48 by 60-inch outfall serves a 4.9-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Pump station could be installed in adjacent City-owned lot to facilitate discharge during high sea levels



Outfall 29NSDO015
Chelsea Creek Oil Terminal, East Boston
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

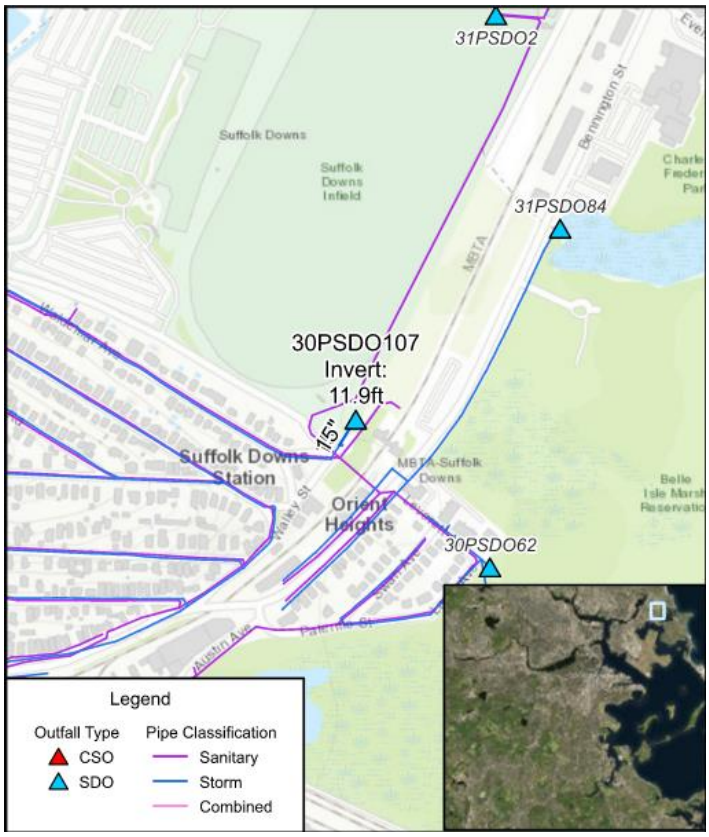
- CRB project type: Building/site-scale adaptations
- 42 by 44-inch outfall serves a 3.0-acre tributary area
- Lack of open space limits the feasibility of construction at this location
- Tide gate to prevent backflow during high tide conditions



Outfall 30PSDO107
East Boston
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

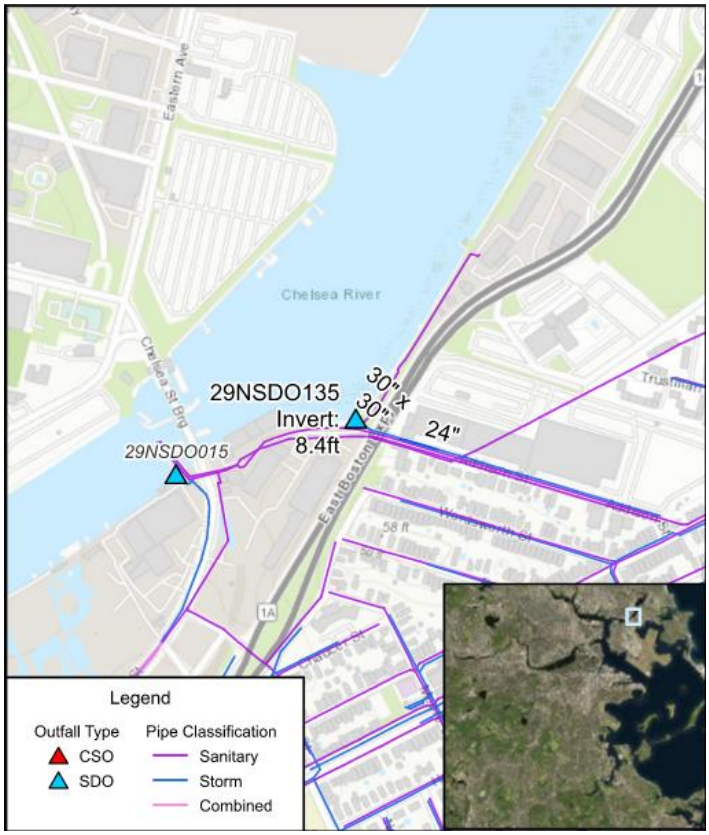
- CRB project type: TBD
- 15-inch outfall serves a 10.0-acre tributary area
- Potential o
- pportunity for storage in nearby privately owned track
- Tide gate to prevent backflow during high tide conditions
- Further study recommended because the high tributary area elevation suggests limited benefit to further adaptation



Outfall 29NSDO135
Chelsea Creek Berm, East Boston
CRB Implementation Date: 2050

Existing Conditions and Recommendations:

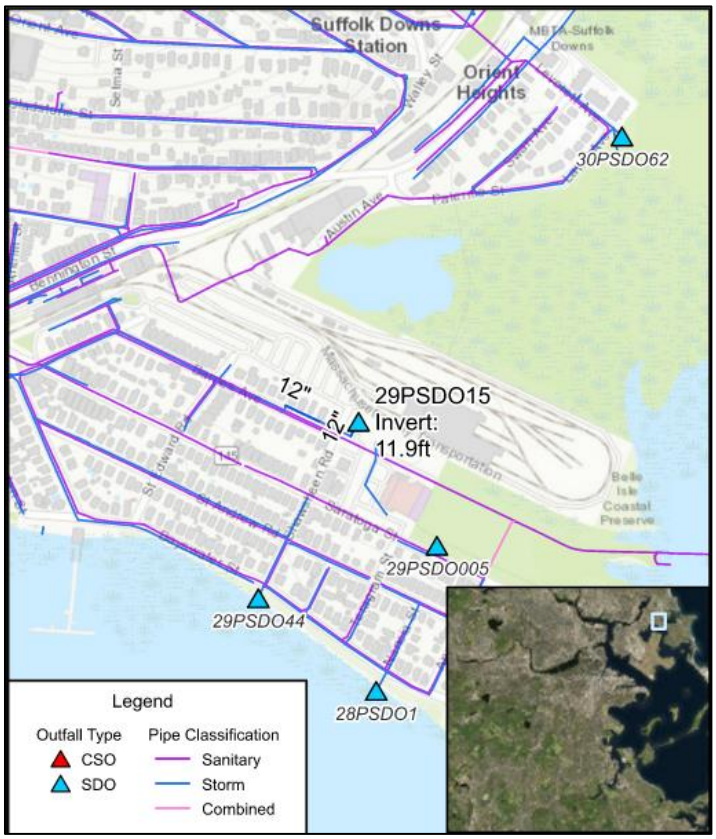
- CRB project type: Elevated waterfront parks and berms
- 30-inch outfall serves a 16.2-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Subsurface storage and pump station could be installed to facilitate discharge during high sea levels



Outfall 29PSDO15
Berm at Teragram and Saratoga St, East Boston
CRB Implementation Date: 2050

Existing Conditions and Recommendations:

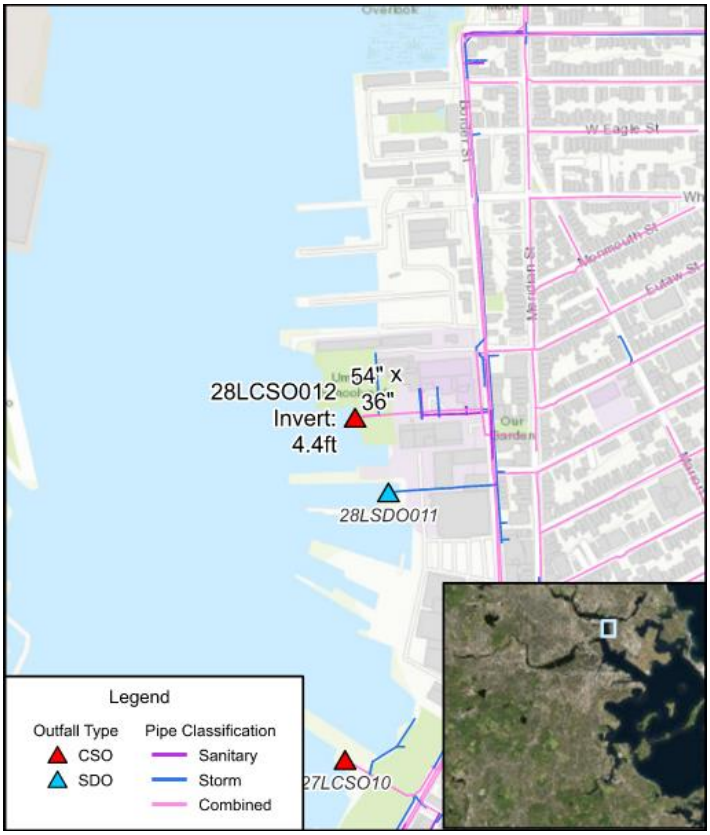
- CRB project type: Elevated waterfront parks and berms
- 12-inch outfall serves a small tributary area
- Possible stormwater management opportunity on adjacent MBTA parking lot
- Tide gate to prevent backflow during high tide conditions



Outfall 28LCSO012
Mario Umana School, East Boston
CRB Implementation Date: 2070

Existing Conditions and Recommendations:

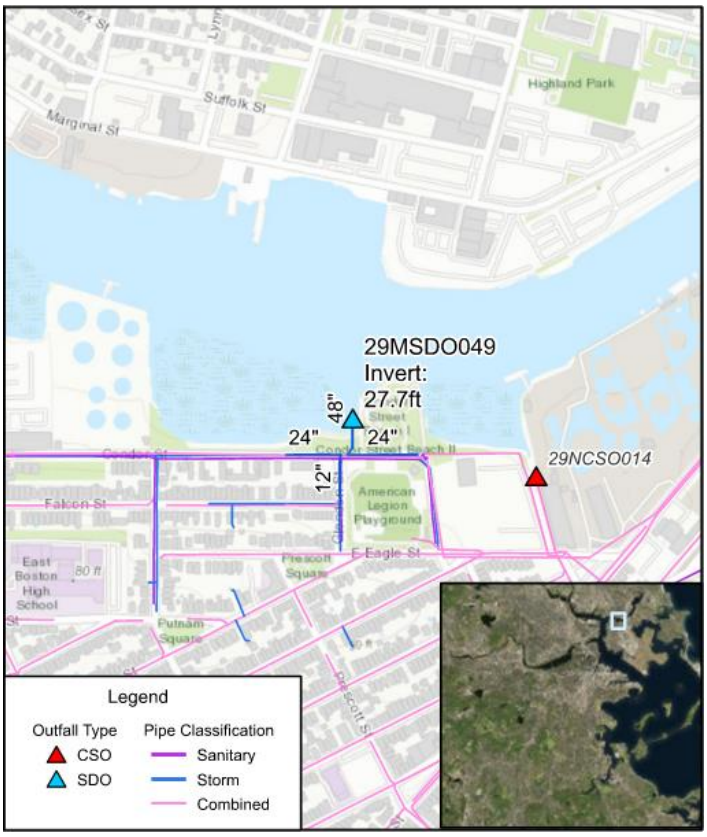
- CRB project type: Raised harborwalk and nature based solutions
- 54 by 36-inch outfall serves a 26.4-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Subsurface storage and pump station could be installed to facilitate discharge during high sea levels



Outfall 29MSDO049
Condor St Raised Harborwalk, East Boston
CRB Implementation Date: 2070

Existing Conditions and Recommendations:

- CRB project type: Raised harborwalk
- 48-inch outfall serves a 24.8-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Subsurface storage and pump station could be installed to facilitate discharge during high sea levels



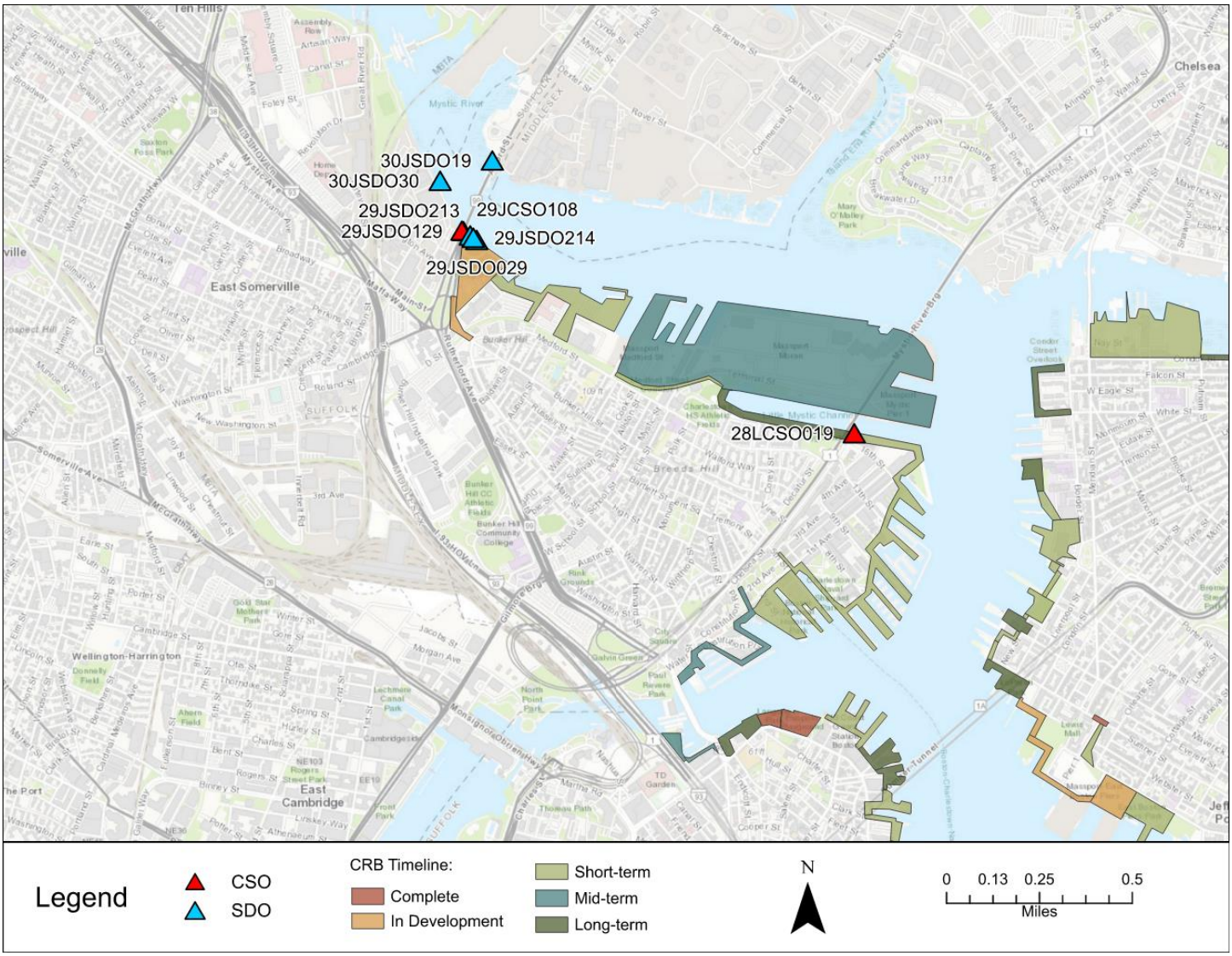
Outfall 30PSDO62
Belle Isle Marsh Restoration, East Boston
CRB Implementation Date: 2070

Existing Conditions and Recommendations:

- CRB project type: Nature based solutions
- 12-inch outfall serves a 6.4-acre tributary area
- Tide gate to prevent backflow during high tide conditions
- Possible opportunity for storage in coordination with CRB nature based solution



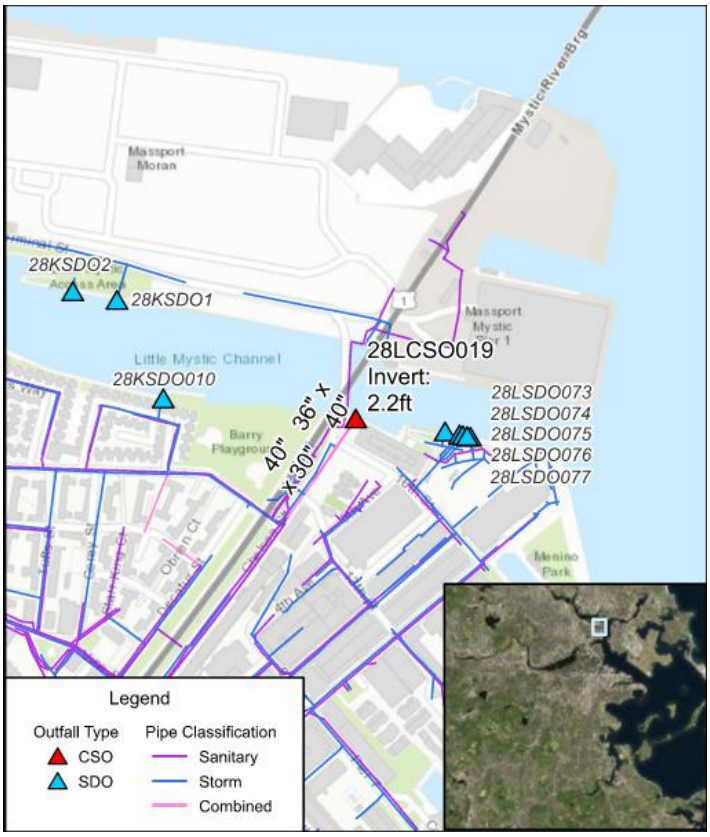
Charlestown Single Outfall Concepts



Outfall 28LCSO019
Raised Harborwalk to Chelsea St Bridge, Charlestown
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

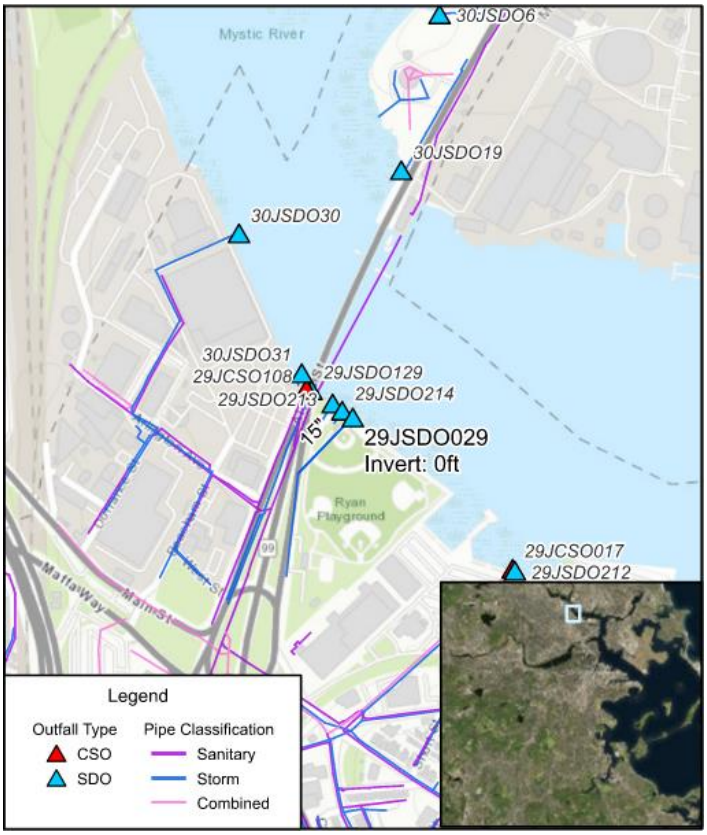
- CRB project type: Raised harborwalk
- 36 by 40-inch outfall serves a 5.5-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Storage basin could be installed in adjacent land owned by Boston Redevelopment Authority



Outfall 29JSDO029
Ryan Playground, Charlestown
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

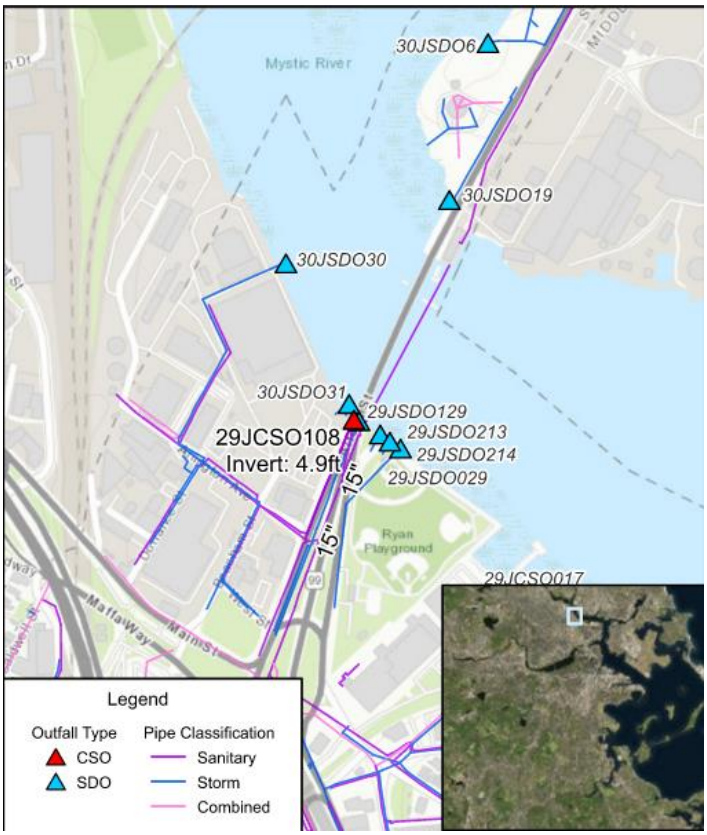
- CRB project type: Elevated waterfront parks and berms
- 15-inch outfall serves a 2.5-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Consolidation with adjacent outfalls for discharge at pump station



Outfall 29JCSO108
Ryan Playground, Charlestown
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

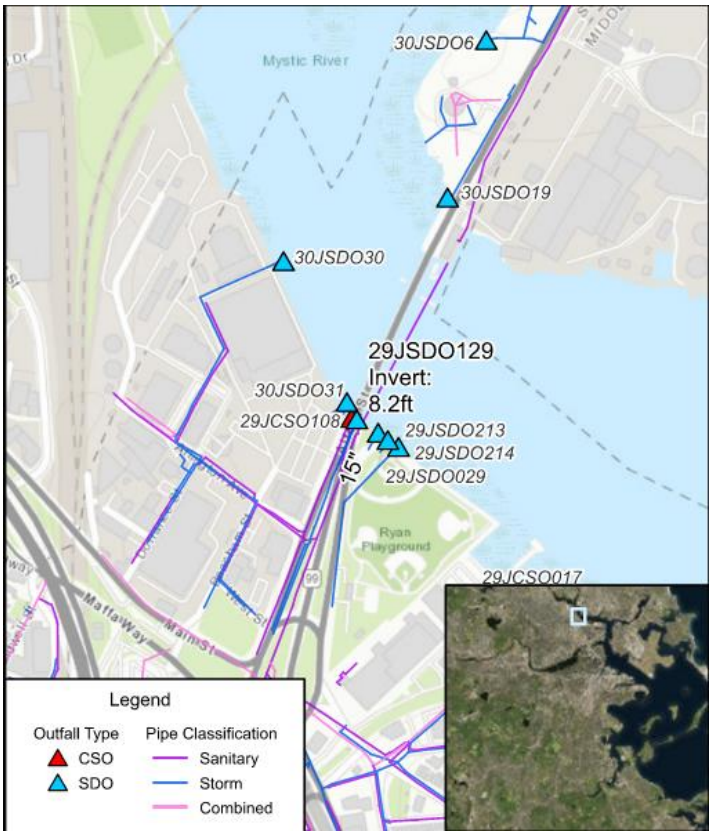
- CRB project type: Elevated waterfront parks and berms
- 15-inch outfall serves a 39.1-acre tributary area (shared with other outfalls)
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Consolidation with adjacent outfalls for discharge at pump station



Outfall 29JSDO129
Ryan Playground, Charlestown
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

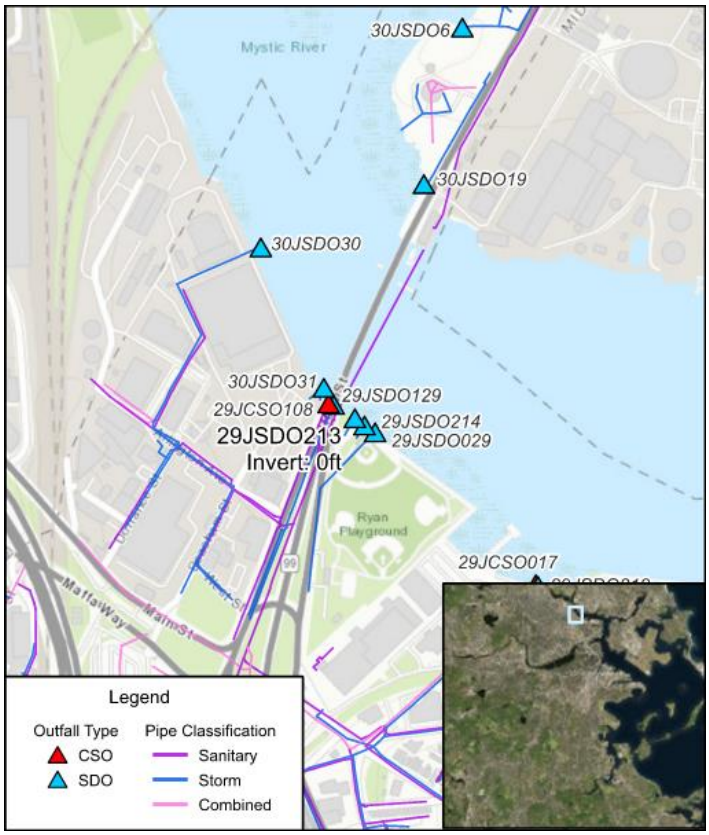
- CRB project type: Elevated waterfront parks and berms
- 15-inch outfall serves a 6.8-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Consolidation with adjacent outfalls for discharge at pump station



Outfall 29JSDO213
Ryan Playground, Charlestown
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

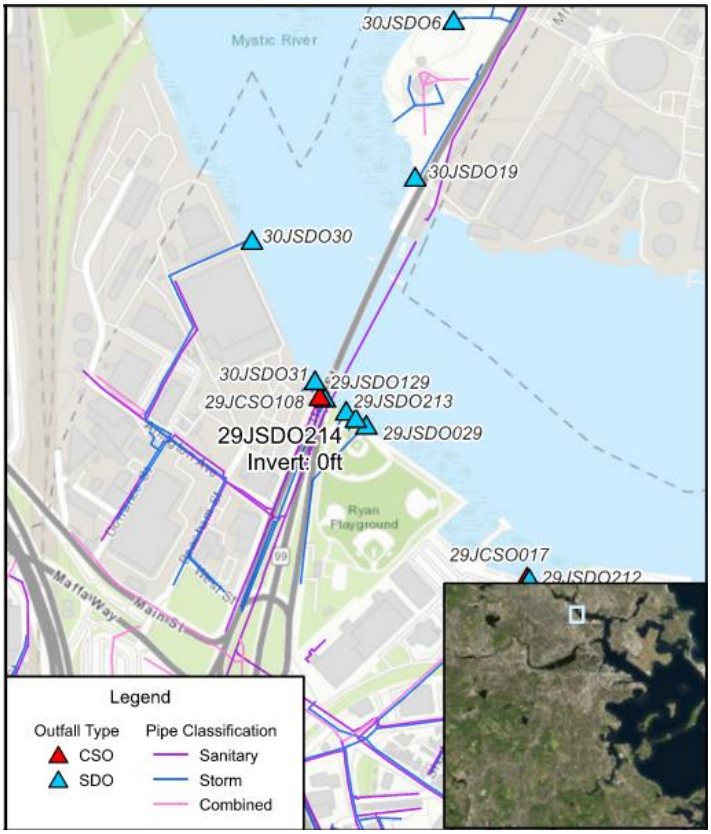
- CRB project type: Elevated waterfront parks and berms
- Outfall serves a small tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Consolidation with adjacent outfalls for discharge at pump station



Outfall 29JSDO214
Ryan Playground, Charlestown
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

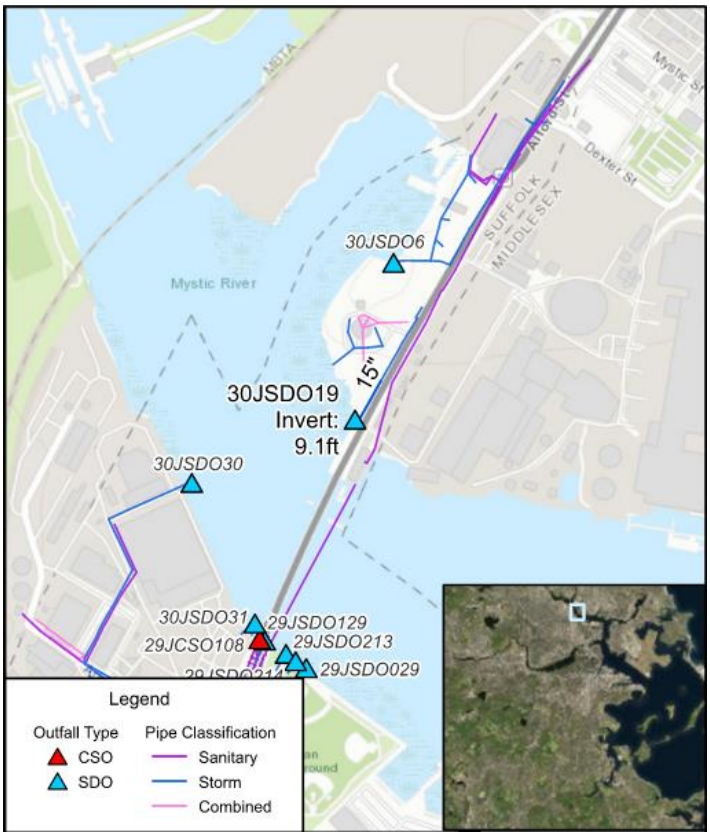
- CRB project type: Elevated waterfront parks and berms
- Outfall serves a small tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Consolidation with adjacent outfalls for discharge at pump station



Outfall 30JSDO19
No CRB Project Identified, Charlestown
CRB Implementation Date: N/A

Existing Conditions and Recommendations:

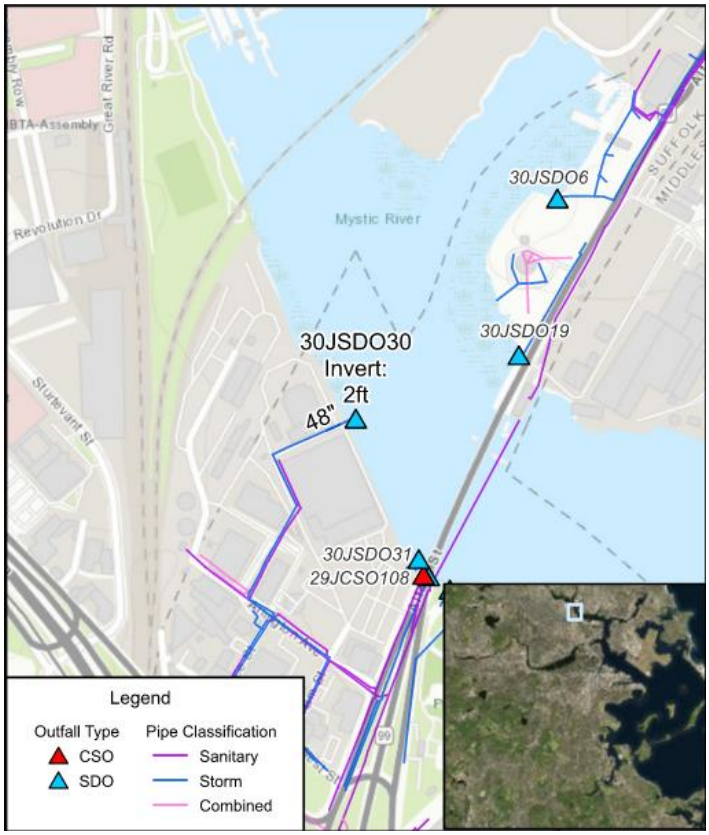
- CRB project type: N/A
- 15-inch outfall serves a 15.5-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Small, subsurface pump station could be considered for stormwater discharge



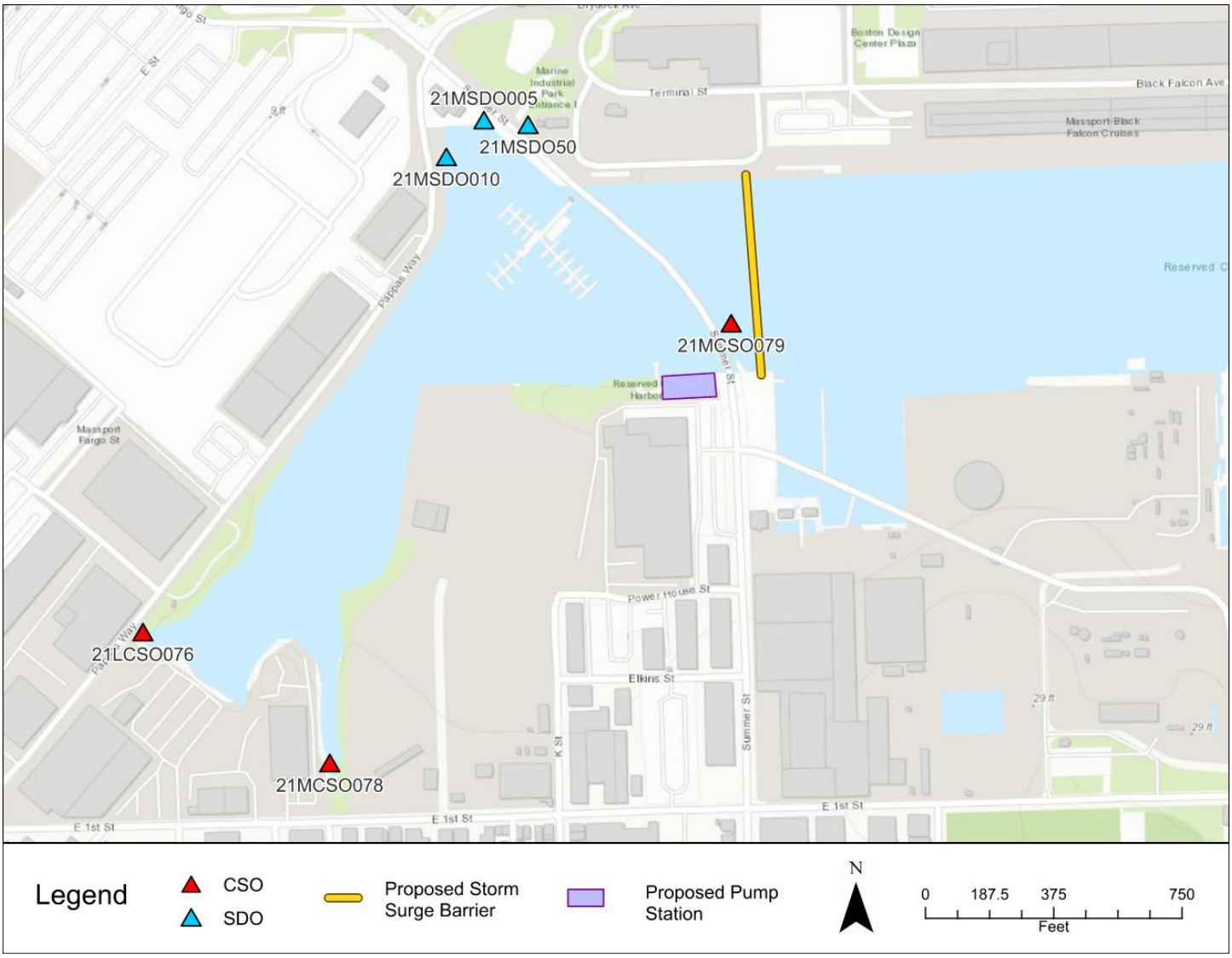
Outfall 30JSDO30
No CRB Project Identified, Charlestown
CRB Implementation Date: N/A

Existing Conditions and Recommendations:

- CRB project type: N/A
- 48-inch outfall serves a 32.3-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Shoreline elevation and a pump station may be required to prevent flooding and facilitate stormwater discharge in the future



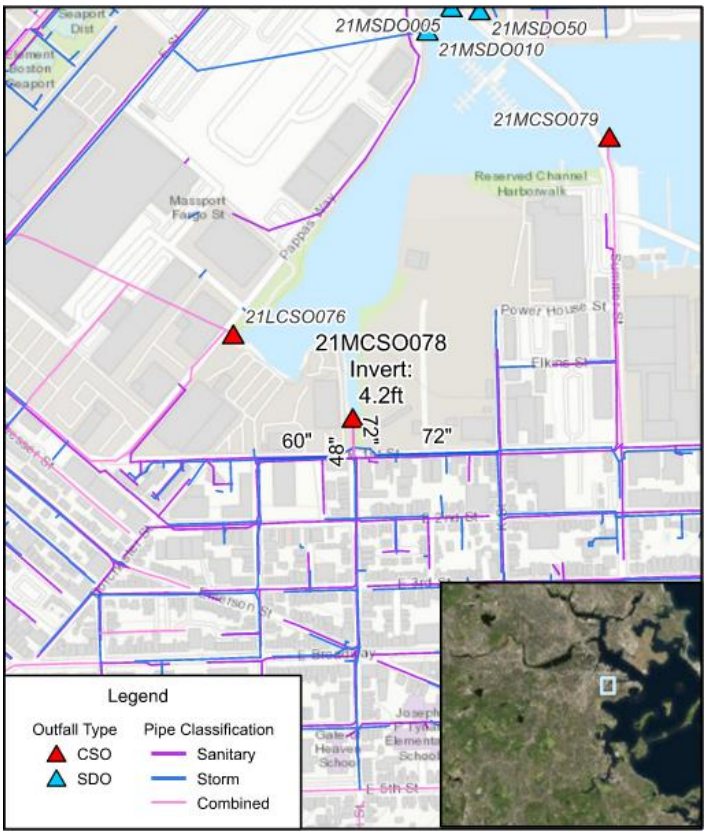
Summer Street Storm Surge Barrier and Pump Station



Outfall 21MCSO078
Reserved Channel, South Boston Waterfront
CRB Implementation Date: 2050

Existing Conditions and Recommendations:

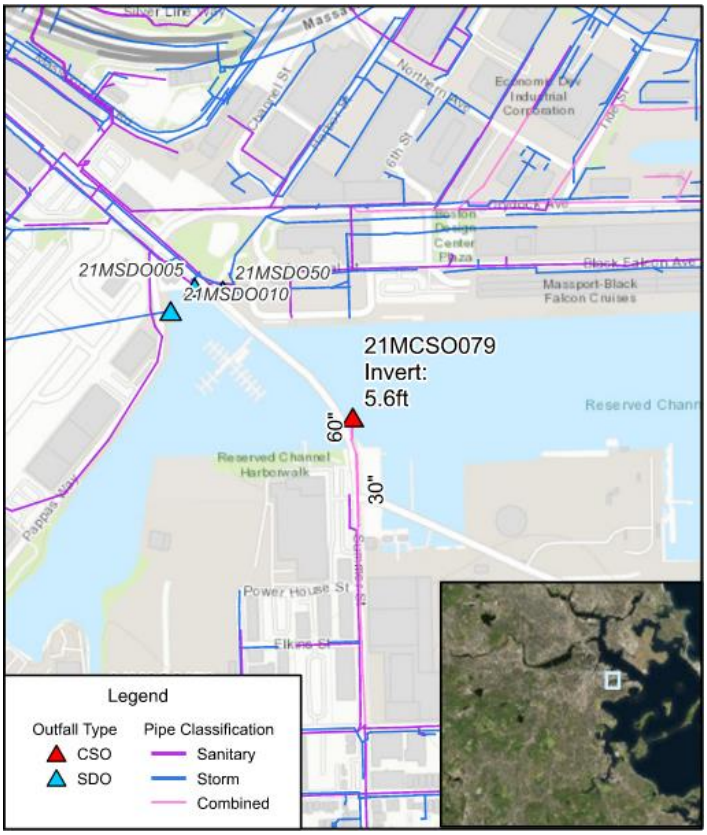
- CRB project type: Elevated waterfront parks and berms
- 72-inch outfall serves a 45.1-acre tributary area
- Possible stormwater management opportunity on adjacent, privately owned open space
- Tide gate to prevent backflow during high tide conditions
- Storm surge barrier and pump station near Summer Street could be considered to protect multiple outfalls



Outfall 21MCSO079
Reserved Channel, South Boston Waterfront
CRB Implementation Date: 2050

Existing Conditions and Recommendations:

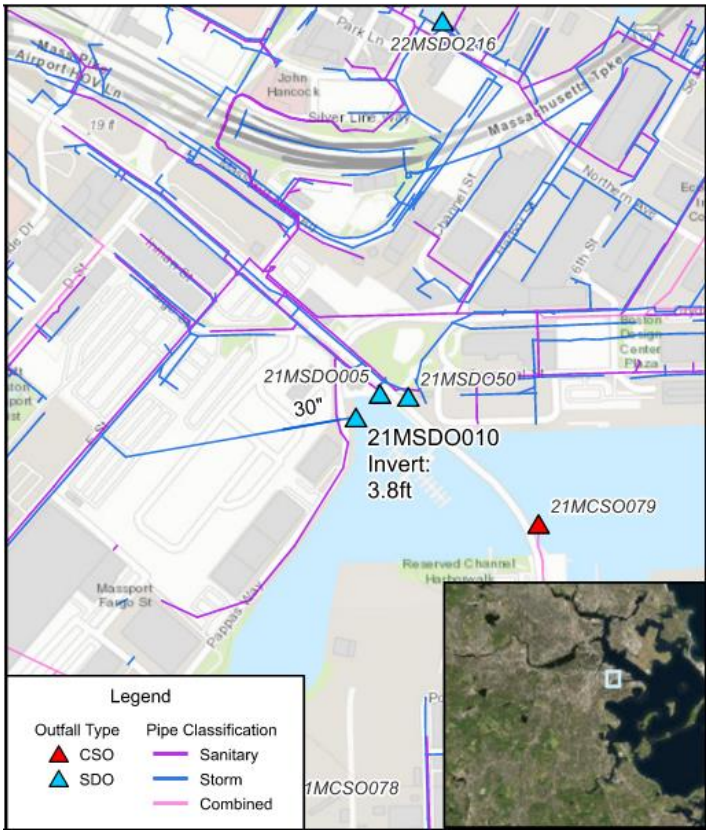
- CRB project type: Elevated waterfront parks and berms.
- 72-inch outfall serves a 35.7-acre tributary area
- Possible stormwater management opportunity on adjacent, privately owned open space
- Tide gate to prevent backflow during high tide conditions
- Storm surge barrier and pump station near Summer Street could be considered to protect multiple outfalls



Outfall 21MSDO010
Reserved Channel, South Boston Waterfront
CRB Implementation Date: 2050

Existing Conditions and Recommendations:

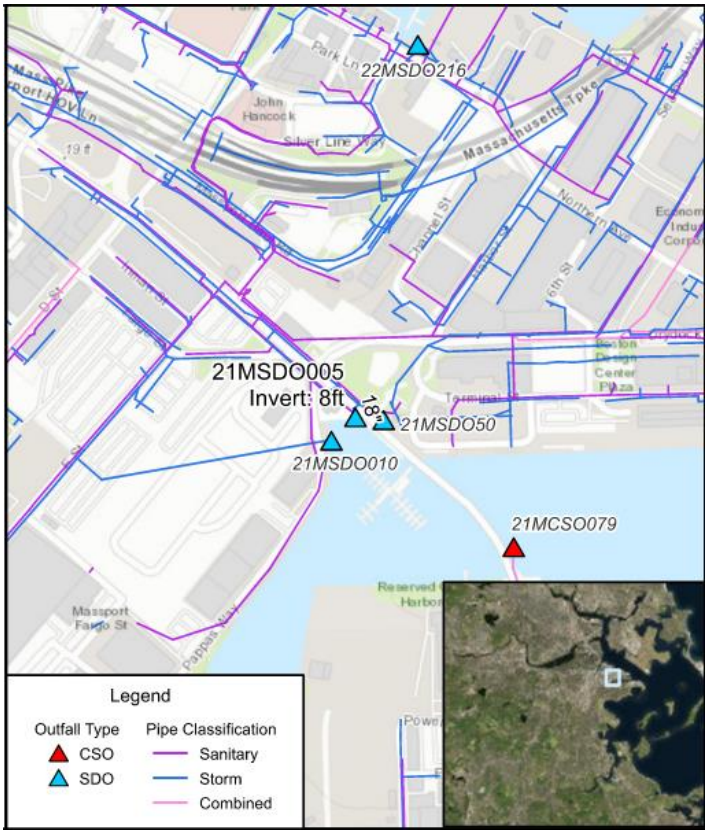
- CRB project type: Elevated waterfront parks and berms.
- 30-inch outfall serves a 29.1-acre tributary area
- Possible stormwater management opportunity on adjacent Mass Port owned land
- Tide gate to prevent backflow during high tide conditions
- Storm surge barrier and pump station near Summer Street could be considered to protect multiple outfalls



Outfall 21MSDO005
Reserved Channel, South Boston Waterfront
CRB Implementation Date: 2050

Existing Conditions and Recommendations:

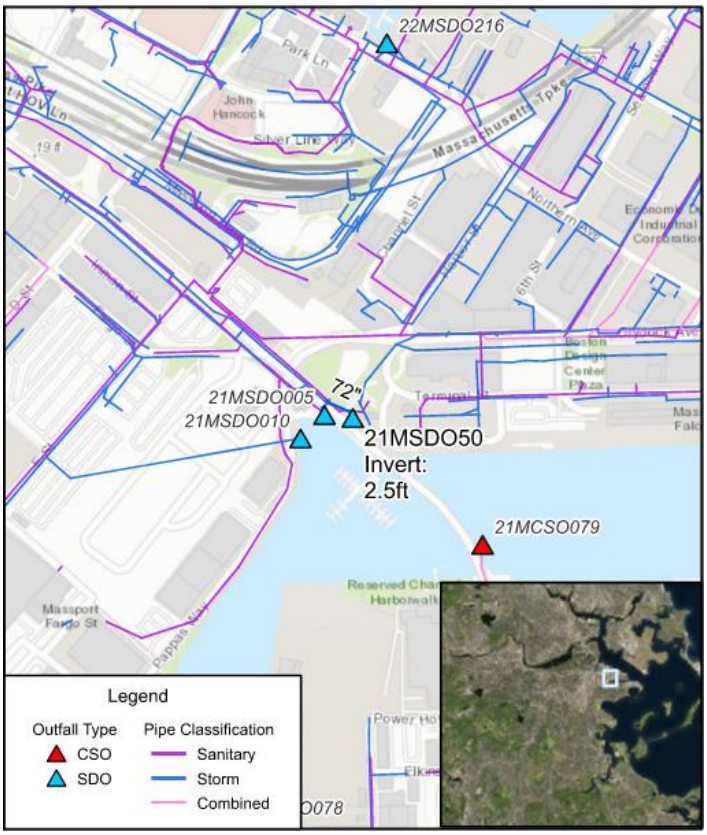
- CRB project type: Elevated waterfront parks and berms.
- 18-inch outfall serves a 9.2-acre tributary area (shared with Outfall 21MSDO50)
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Storm surge barrier and pump station near Summer Street could be considered to protect multiple outfalls



Outfall 21MSDO50
Reserved Channel, South Boston Waterfront
CRB Implementation Date: 2050

Existing Conditions and Recommendations:

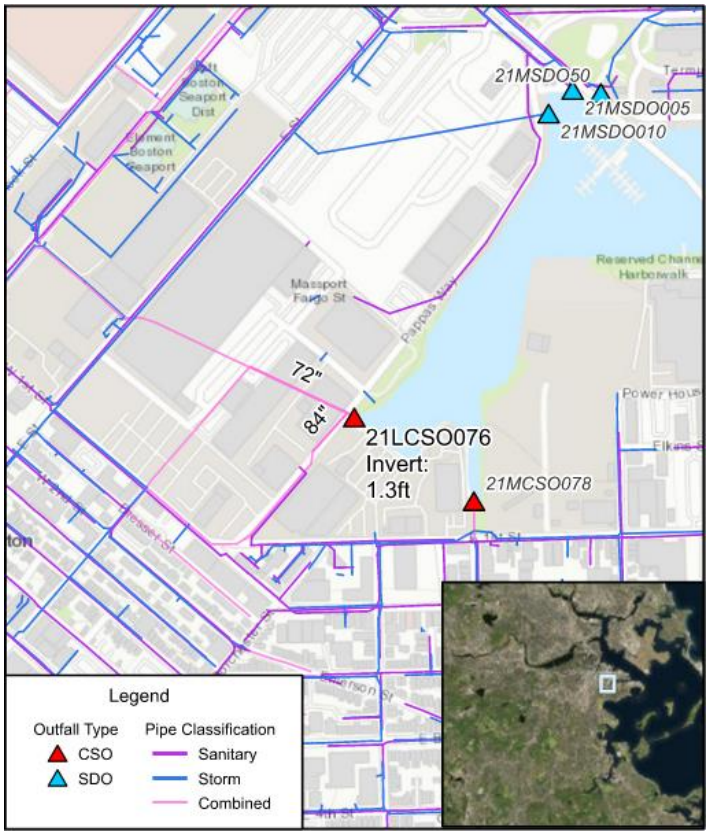
- CRB project type: Elevated waterfront parks and berms.
- 72-inch outfall serves a 9.2-acre tributary area (shared with Outfall 21MSDO005)
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Storm surge barrier and pump station near Summer Street could be considered to protect multiple outfalls



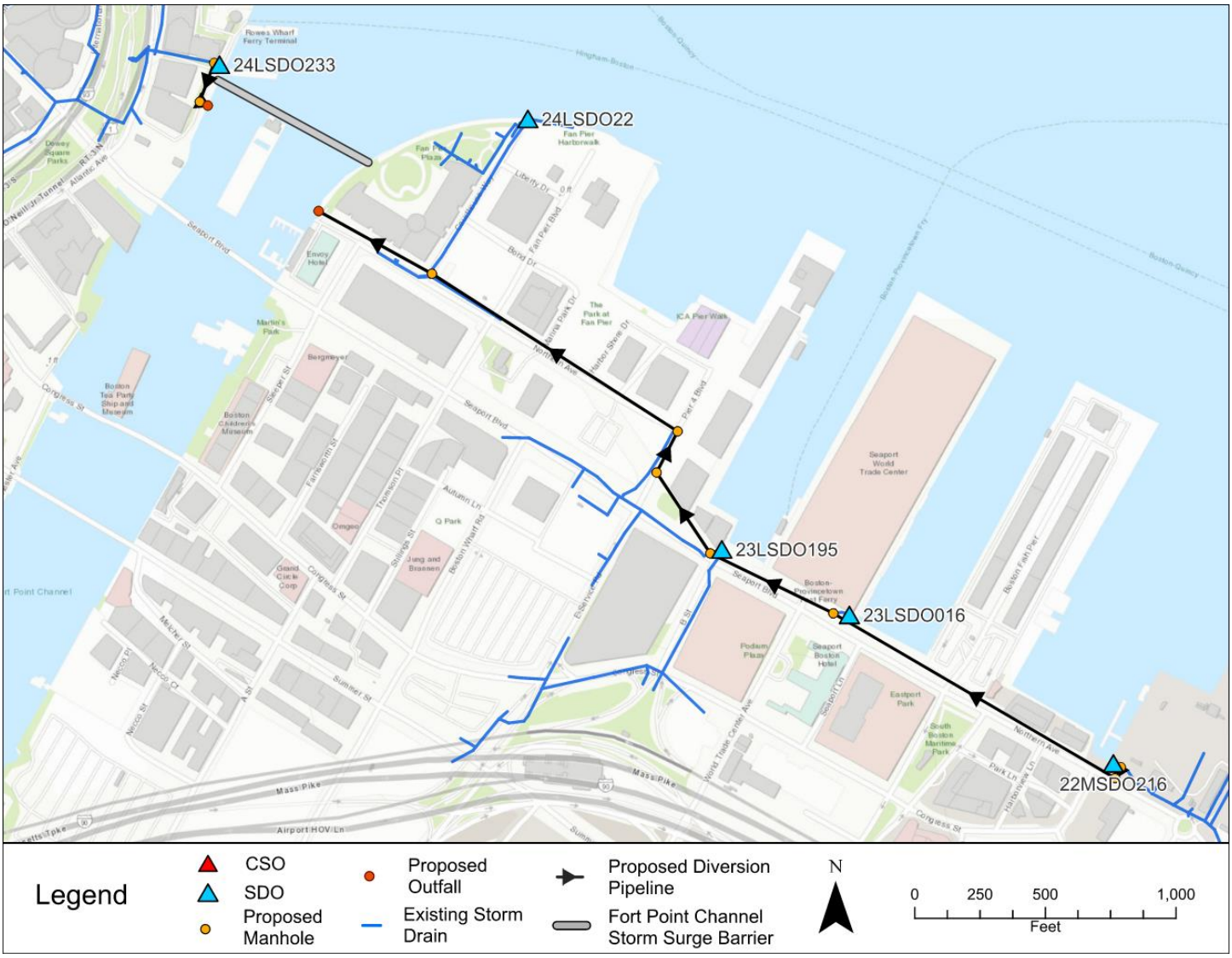
Outfall 21LCSO076
Reserved Channel, South Boston Waterfront
CRB Implementation Date: 2050

Existing Conditions and Recommendations:

- CRB project type: Elevated waterfront parks and berms
- 72-inch outfall serves a 43.2-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Storm surge barrier and pump station near Summer Street could be considered to protect multiple outfalls



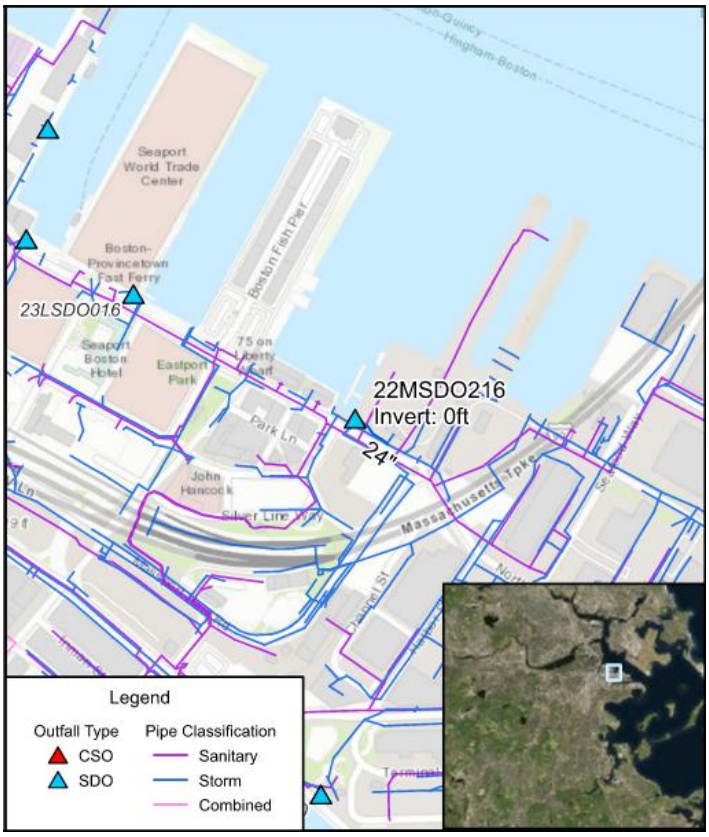
Fort Point Channel SSB Outfall Diversion



Outfall 22MSDO216
Seaport Boulevard, South Boston Waterfront
CRB Implementation Date: 2050

Existing Conditions and Recommendations:

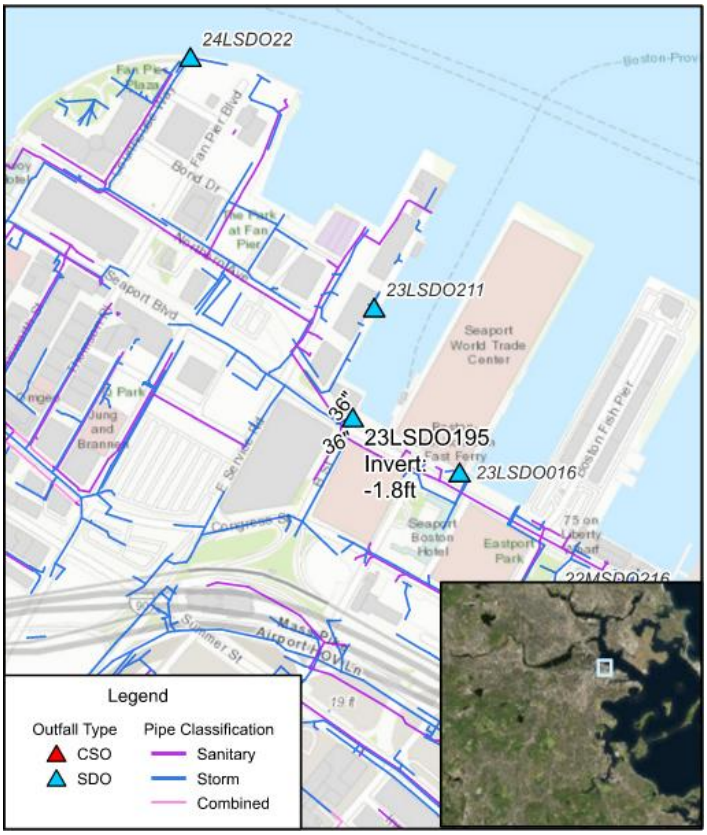
- CRB project type: Elevated roadways and floodwalls
- 24-inch outfall serves a 14.5-acre tributary area
- Lack of open space limits the feasibility of construction at this location
- Tide gate to prevent backflow during high tide conditions
- Consolidation with adjacent outfalls using a new conduit to redirect flow to a new outfall located behind potential future Fort Point Channel storm surge barrier



Outfall 23LSDO195
Seaport Boulevard, South Boston Waterfront
CRB Implementation Date: 2050

Existing Conditions and Recommendations:

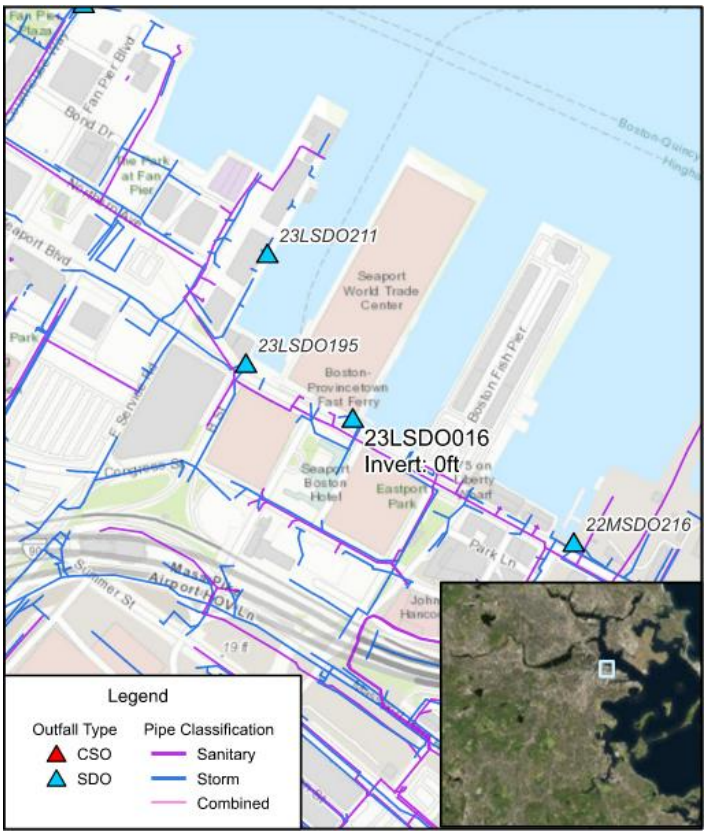
- CRB project type: Elevated roadways and floodwalls
- 36-inch outfall serves a 7.8-acre tributary area
- Lack of open space limits the feasibility of construction at this location
- Tide gate to prevent backflow during high tide conditions
- Consolidation with adjacent outfalls using a new conduit to redirect flow to a new outfall located behind potential future Fort Point Channel storm surge barrier



Outfall 23LSDO016
Seaport Boulevard, South Boston Waterfront
CRB Implementation Date: 2050

Existing Conditions and Recommendations:

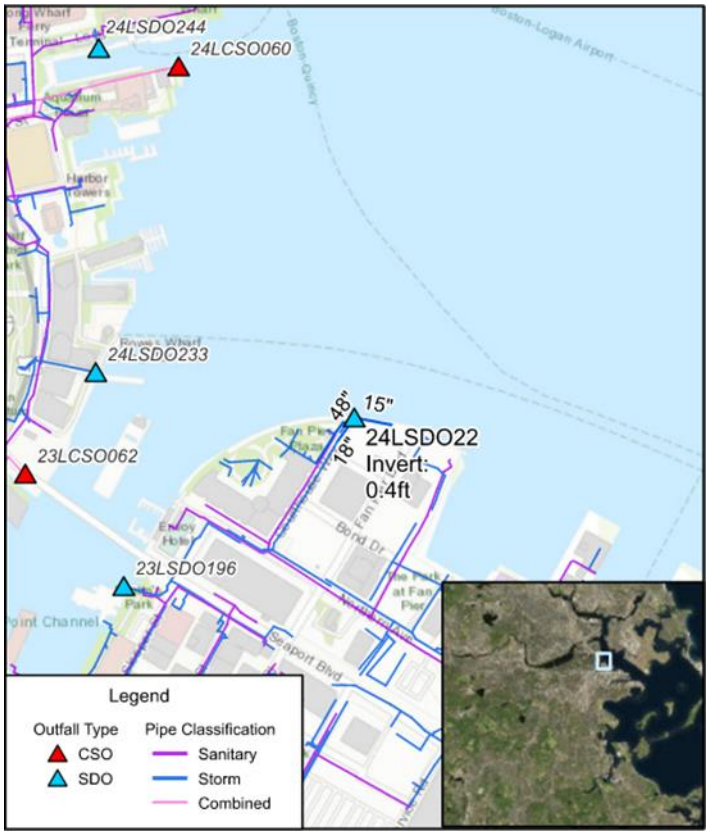
- CRB project type: Elevated roadways and floodwalls
- Outfall serves a 3.3-acre tributary area
- Lack of open space limits the feasibility of construction at this location
- Tide gate to prevent backflow during high tide conditions
- Consolidation with adjacent outfalls using a new conduit to redirect flow to a new outfall located behind potential Fort Point Channel storm surge barrier



Outfall 24LSDO22
South Boston Waterfront
CRB Implementation Date: 2050

Existing Conditions and Recommendations:

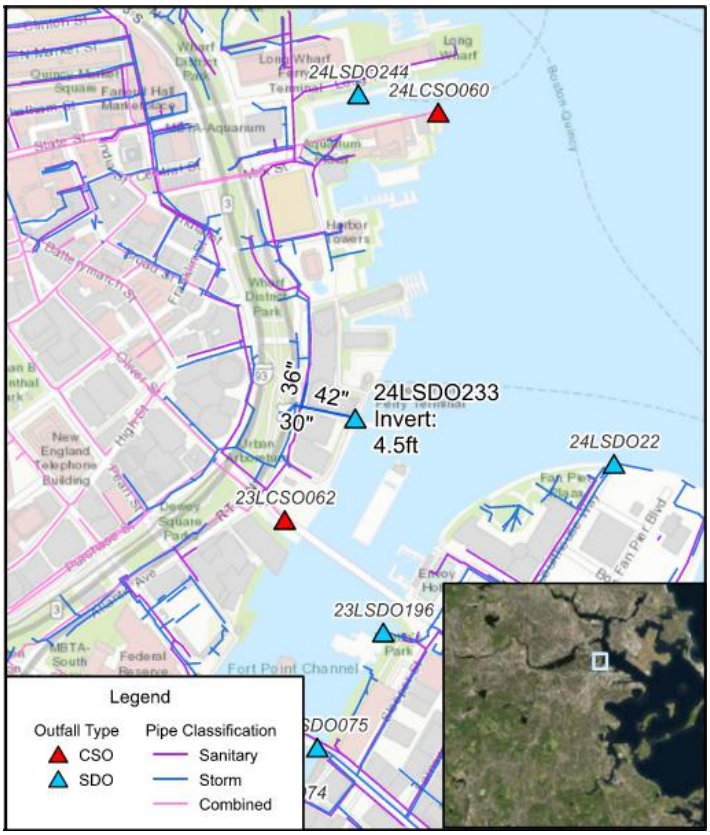
- CRB project type: Raised harborwalk
- 48-inch outfall serves an 8.0-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Consolidation with adjacent outfalls using a new conduit to redirect flow to a new outfall located behind potential Fort Point Channel storm surge barrier



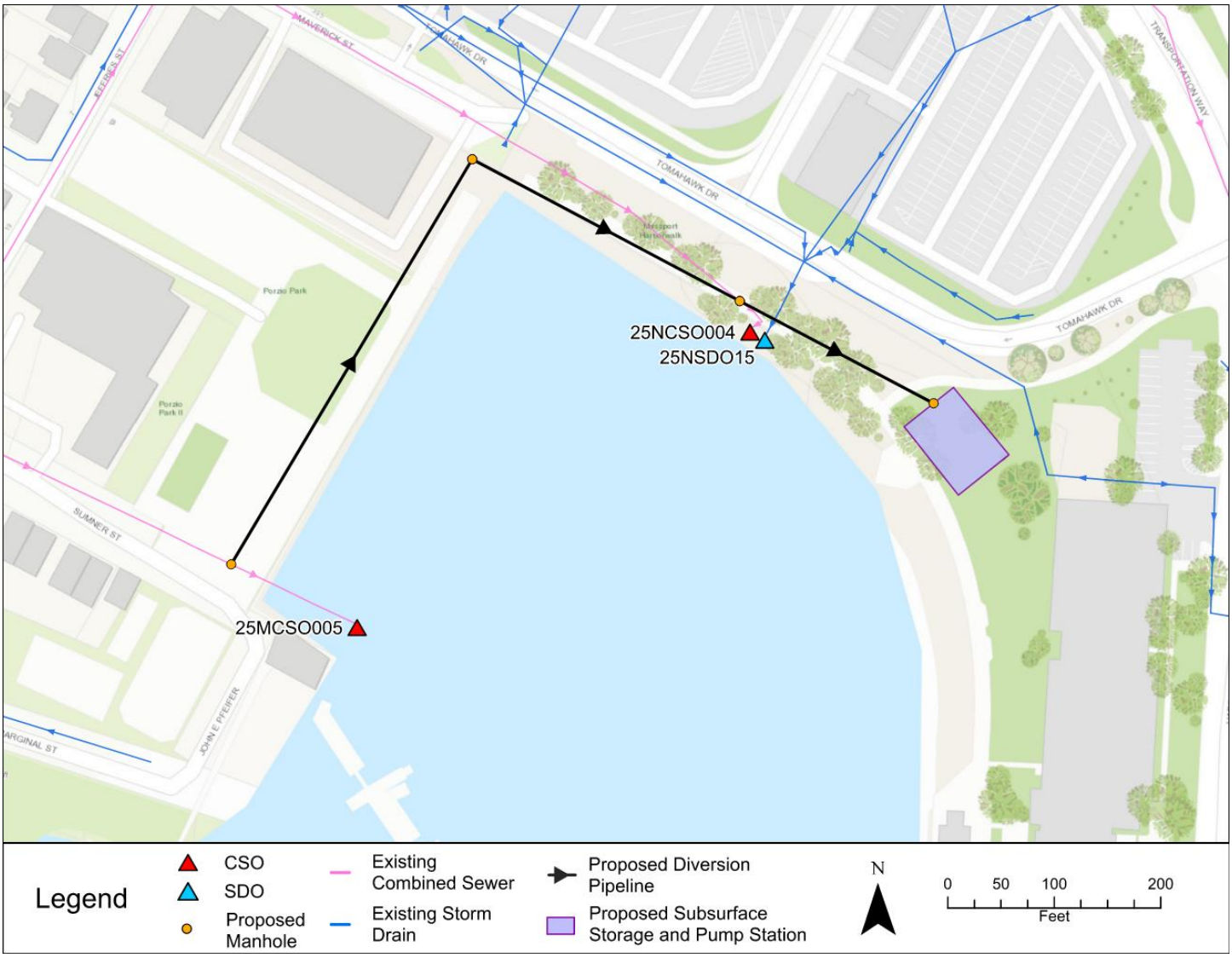
Outfall 24LSDO233
Rowes Wharf, Downtown
CRB Implementation Date: 2070

Existing Conditions and Recommendations:

- CRB project type: Raised harborwalk
- 42-inch outfall serves a 19.7-acre tributary area
- Lack of open space limits the feasibility of construction at this location
- Tide gate to prevent backflow during high tide conditions
- Redirect flow to new outfall located behind potential Fort Point Channel storm surge barrier



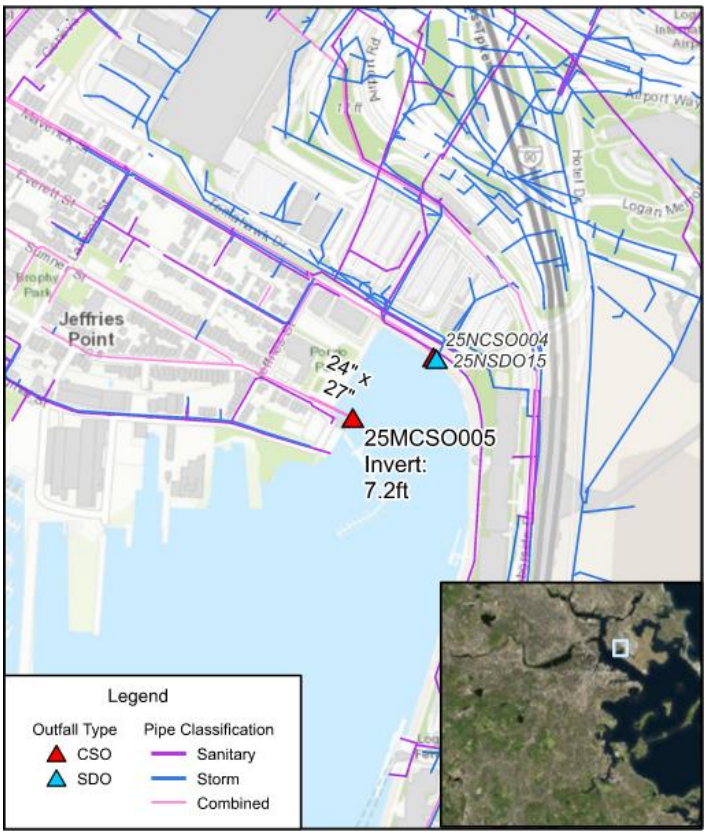
Porzio Park Consolidation and Pump Station



Outfall 25MCSO005
Porzio Park, East Boston
CRB Implementation Date: 2070

Existing Conditions and Recommendations:

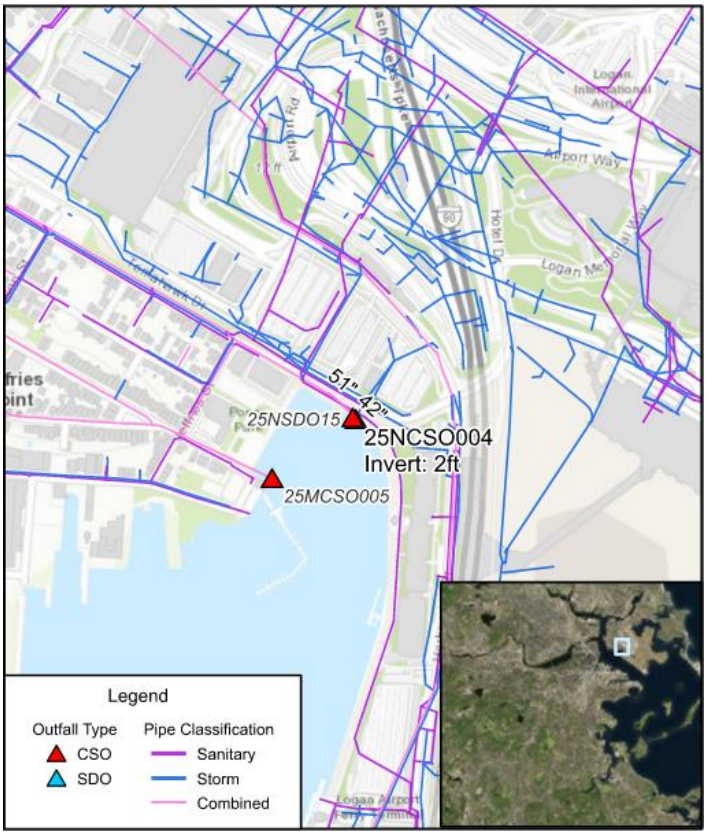
- CRB project type: Elevated waterfront parks and berms
- 24 by 27-inch outfall serves a 0.8-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Divert flow to possible pump station associated with outfall 24NCSO004



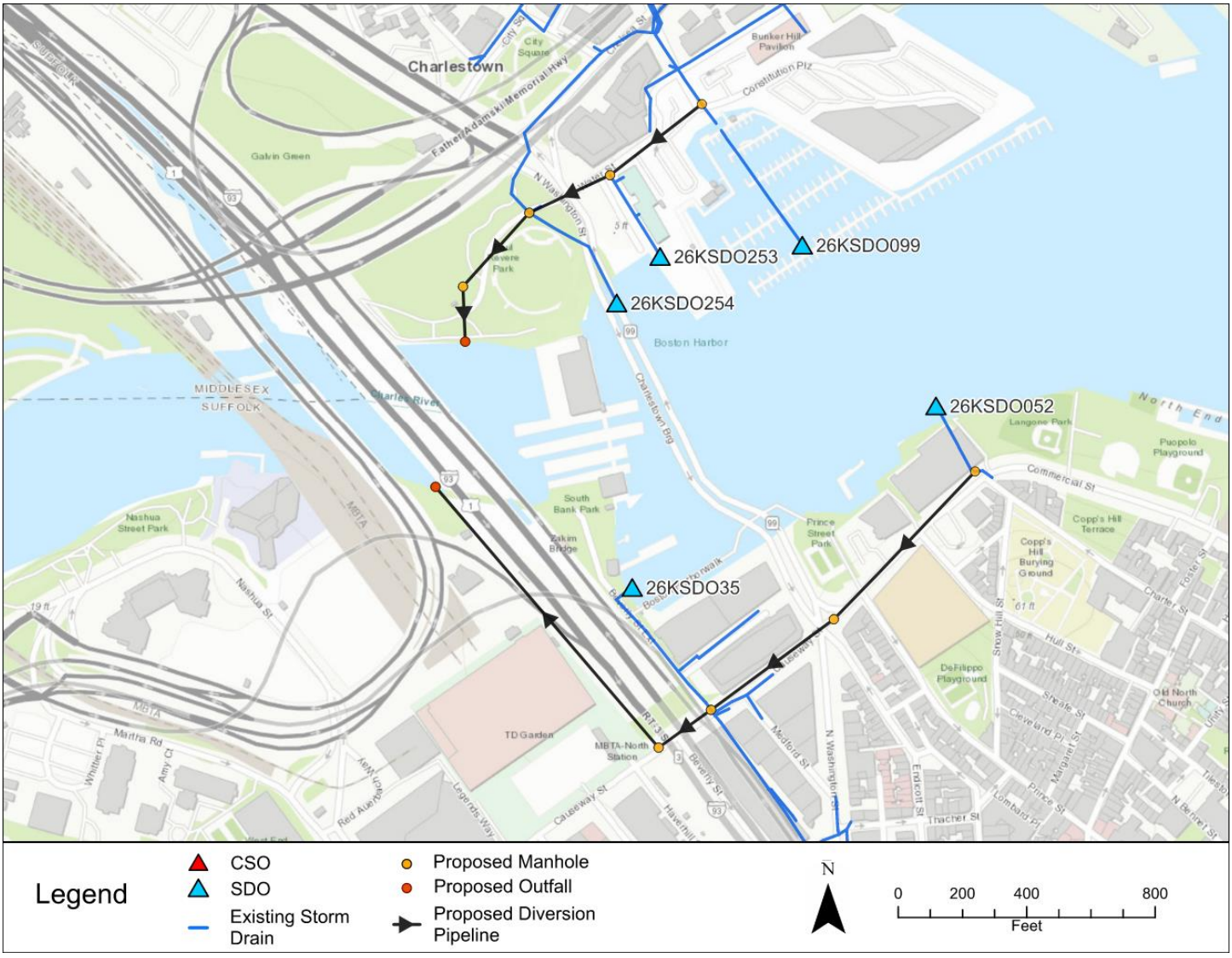
Outfall 25NCSO004
East Boston
CRB Implementation Date: 2070

Existing Conditions and Recommendations:

- CRB project type: TBD
- 42-inch outfall serves a 14.3-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Subsurface storage facility and pump station with outfall 25NSDO15



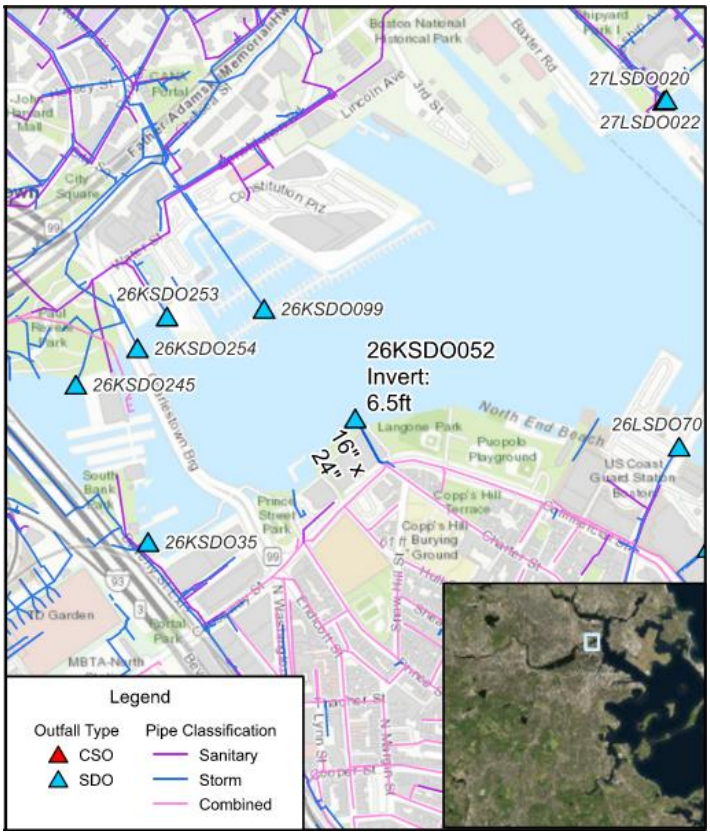
Outfall Diversion to Charles River Basin



Outfall 26KSDO052
Prince Park, North End
CRB Implementation Date: 2070

Existing Conditions and Recommendations:

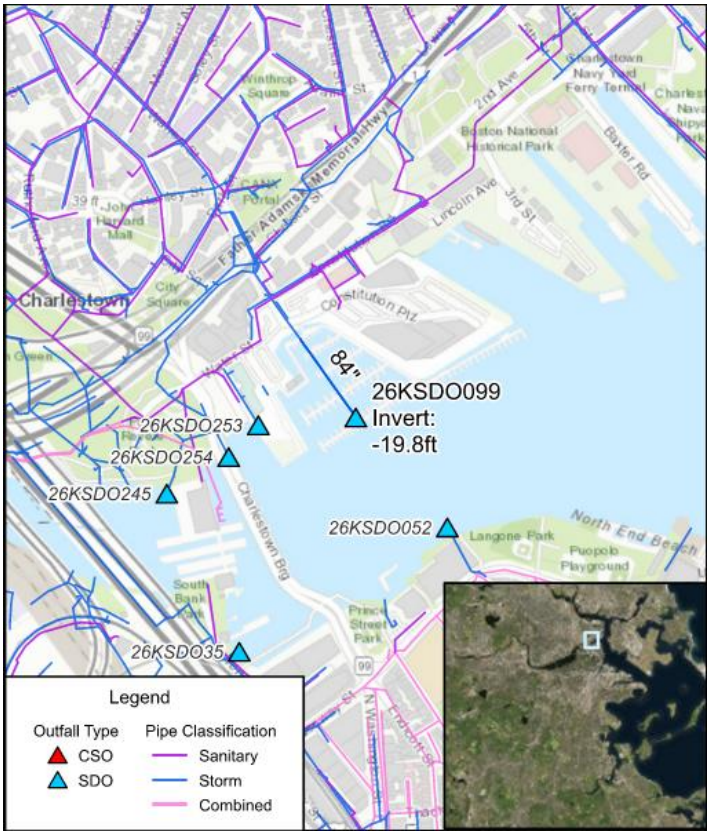
- CRB project type: Raised harborwalk.
- 16 by 24-inch outfall serves an 8.8-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Consolidate flow from this and nearby outfalls to discharge behind the Charles River Dam



Outfall 26KSDO099
Raised Harborwalk to Charles River Dam, Charlestown
CRB Implementation Date: 2050

Existing Conditions and Recommendations:

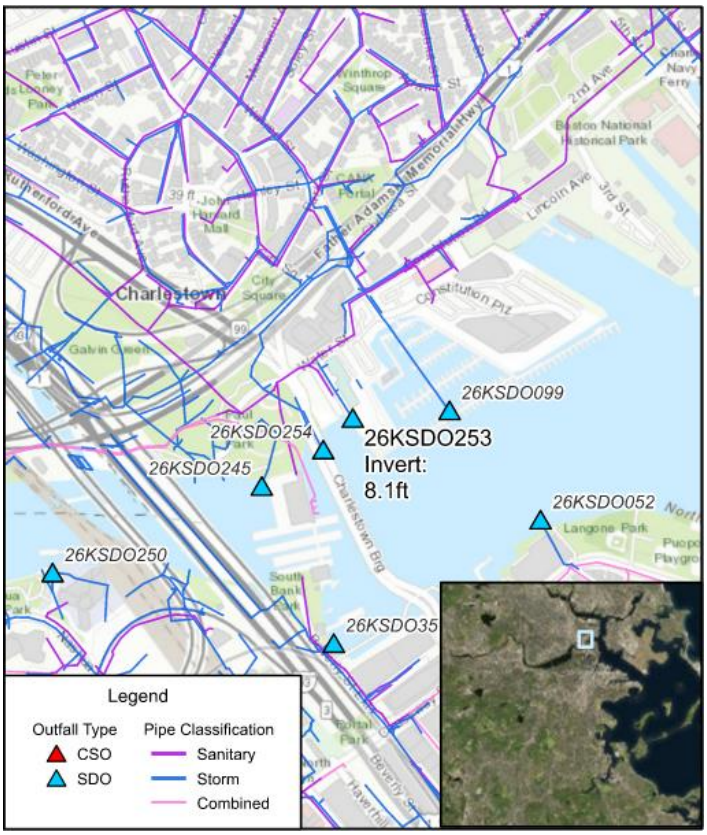
- CRB project type: Raised harborwalk
- 84-inch outfall serves an 84.5-acre tributary area
- Possible stormwater management opportunity on adjacent privately owned land or Mass Port owned land
- Tide gate to prevent backflow during high tide conditions
- Consolidate flow from this and nearby outfalls to discharge behind the Charles River Dam
- Alternatively, a subsurface storage and pump station could be installed to facilitate discharge during high sea levels



Outfall 26KSDO253
Raised Harborwalk to Charles River Dam, Charlestown
CRB Implementation Date: 2050

Existing Conditions and Recommendations:

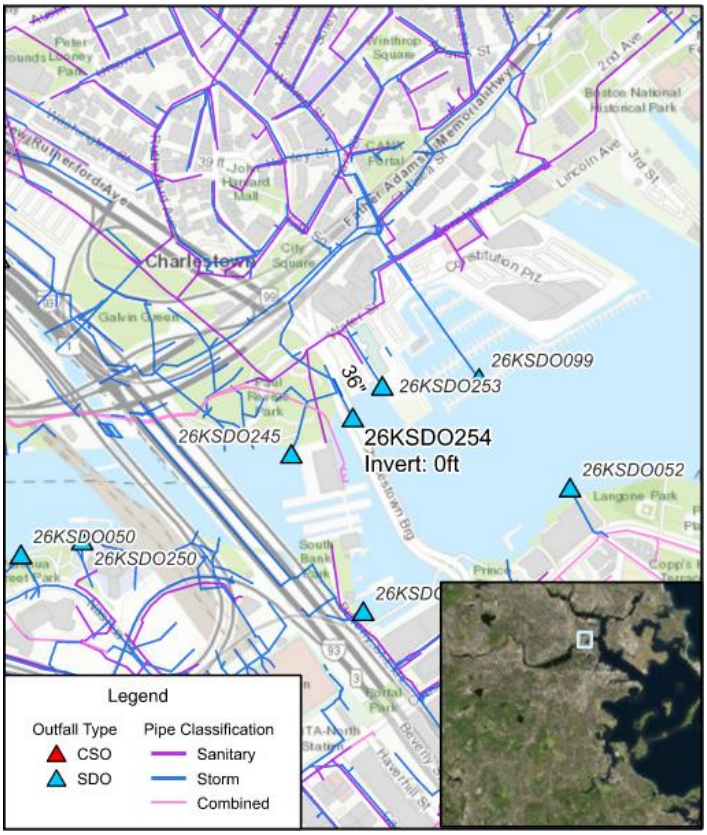
- CRB project type: Raised harborwalk
- Outfall serves a small tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Consolidate flow from this and nearby outfalls to discharge behind the Charles River Dam



Outfall 26KSDO254
Raised Harborwalk to Charles River Dam, Charlestown
CRB Implementation Date: 2050

Existing Conditions and Recommendations:

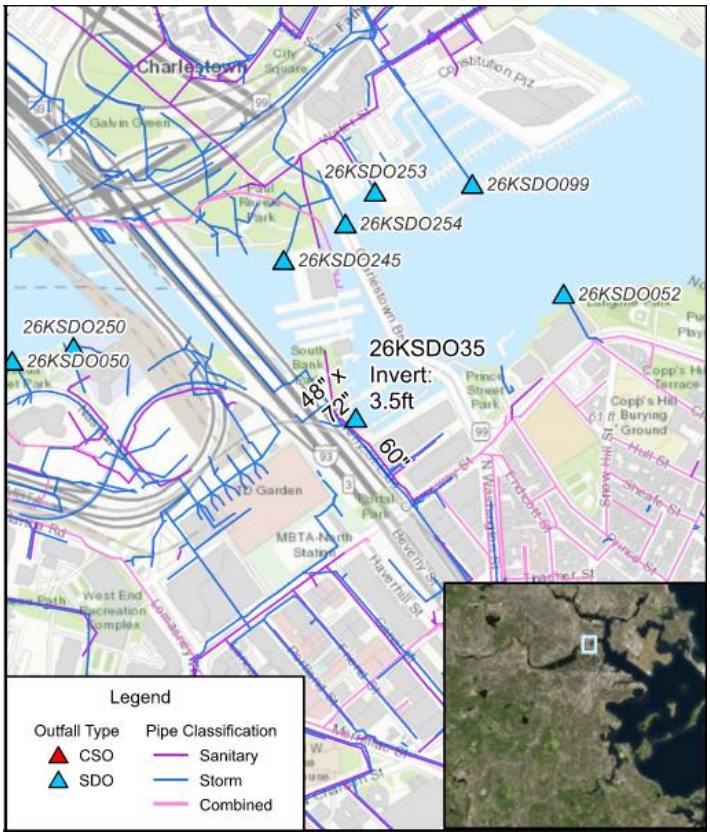
- CRB project type: Raised harborwalk
- 36-inch outfall serves a 2.1-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Consolidate flow from this and nearby outfalls to discharge behind the Charles River Dam



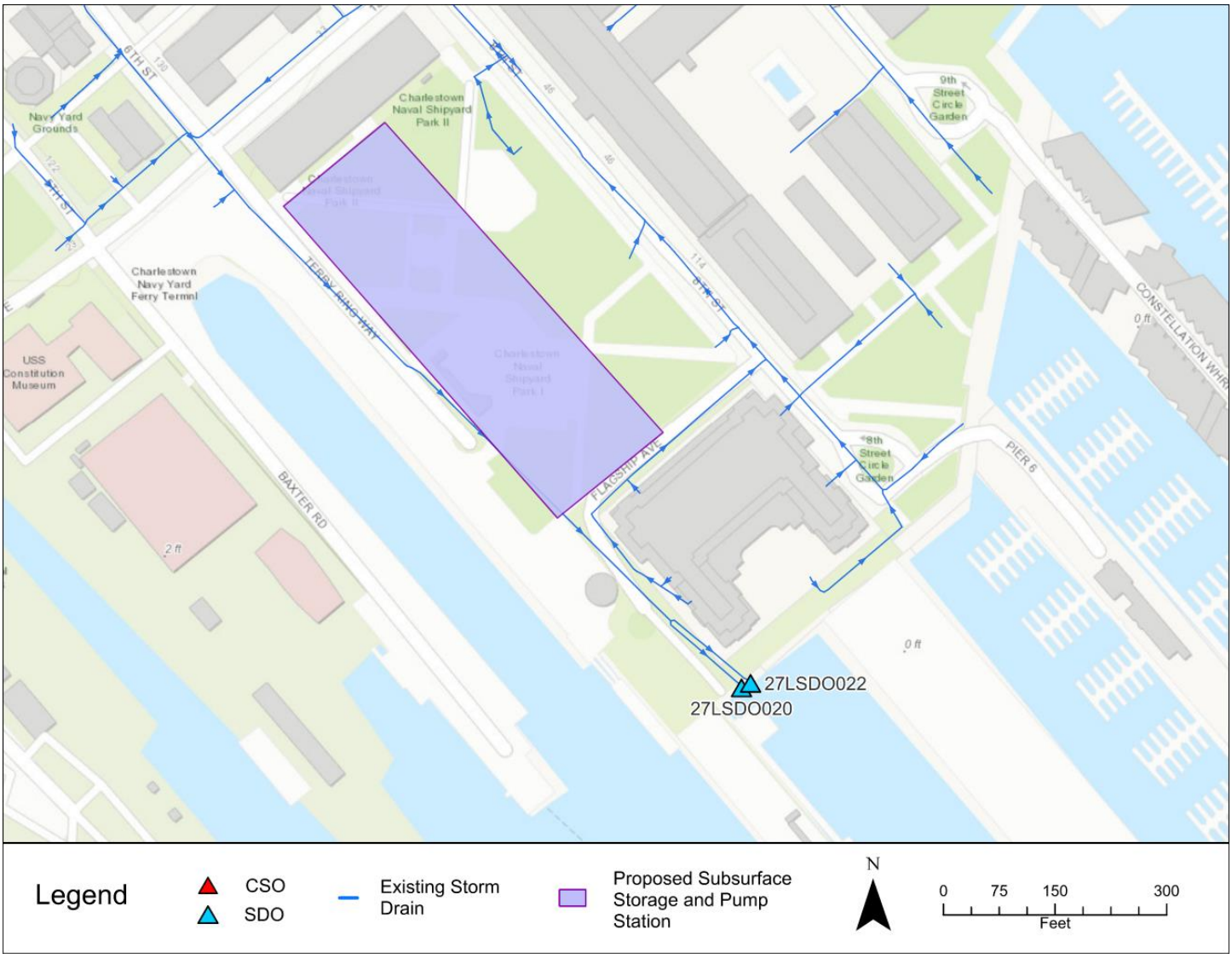
Outfall 26KSDO35
New Charles Dam, West End
CRB Implementation Date: 2050

Existing Conditions and Recommendations:

- CRB project type: Raised harborwalk.
- 48 by 72-inch outfall serves a 12.0-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Consolidate flow from this and nearby outfalls to discharge behind the Charles River Dam



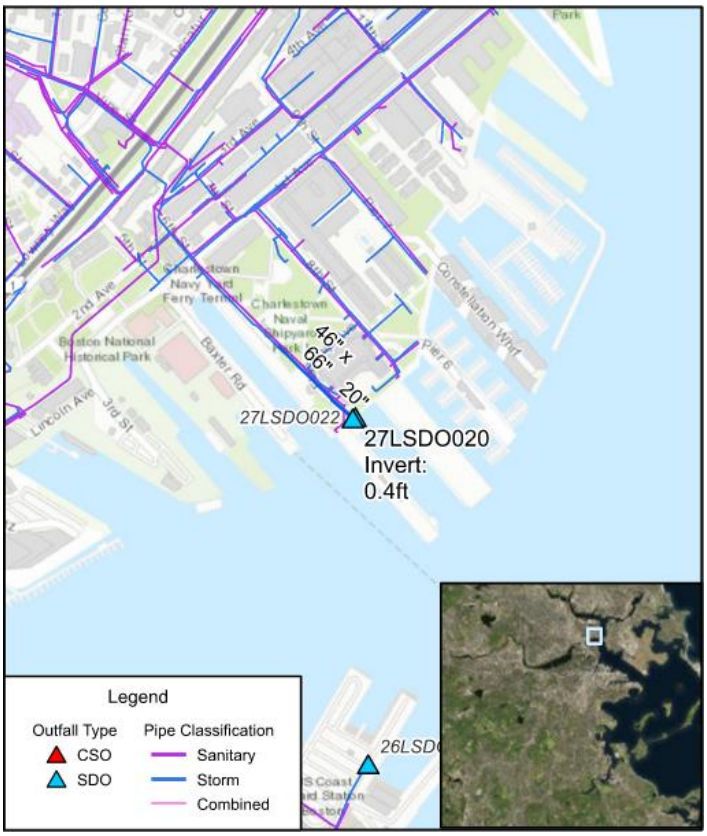
Charlestown Naval Shipyard Park Storage and Pump Station



Outfall 27LSDO020
Raised Harborwalk to Cheslea St Bridge, Charlestown
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

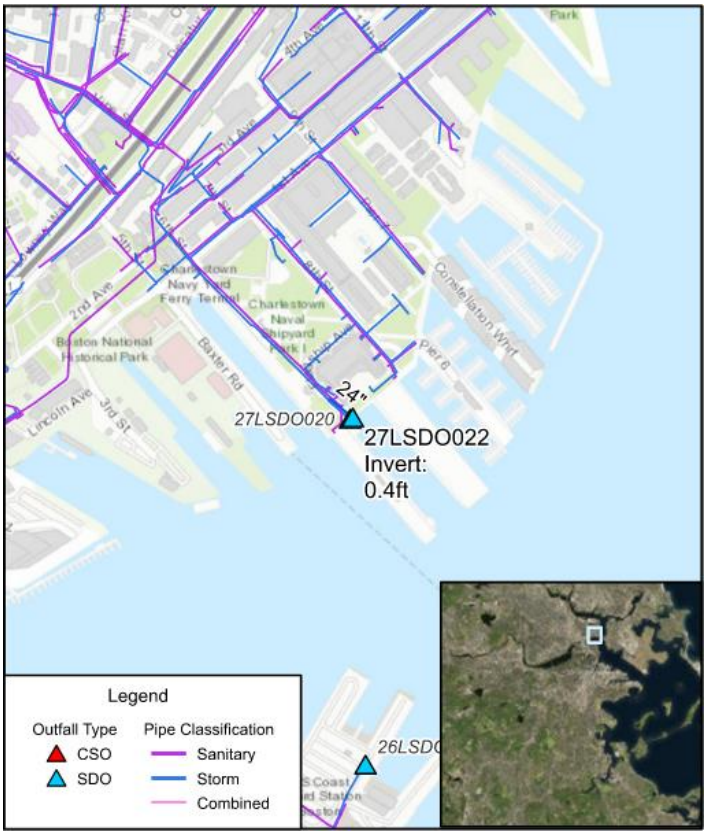
- CRB project type: Raised harborwalk
- 20-inch outfall serves a 45.0-acre tributary area (shared with outfall 27LSDO022)
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Subsurface storage facility and pump station could be installed in the Naval Shipyard to facilitate discharge during high sea levels



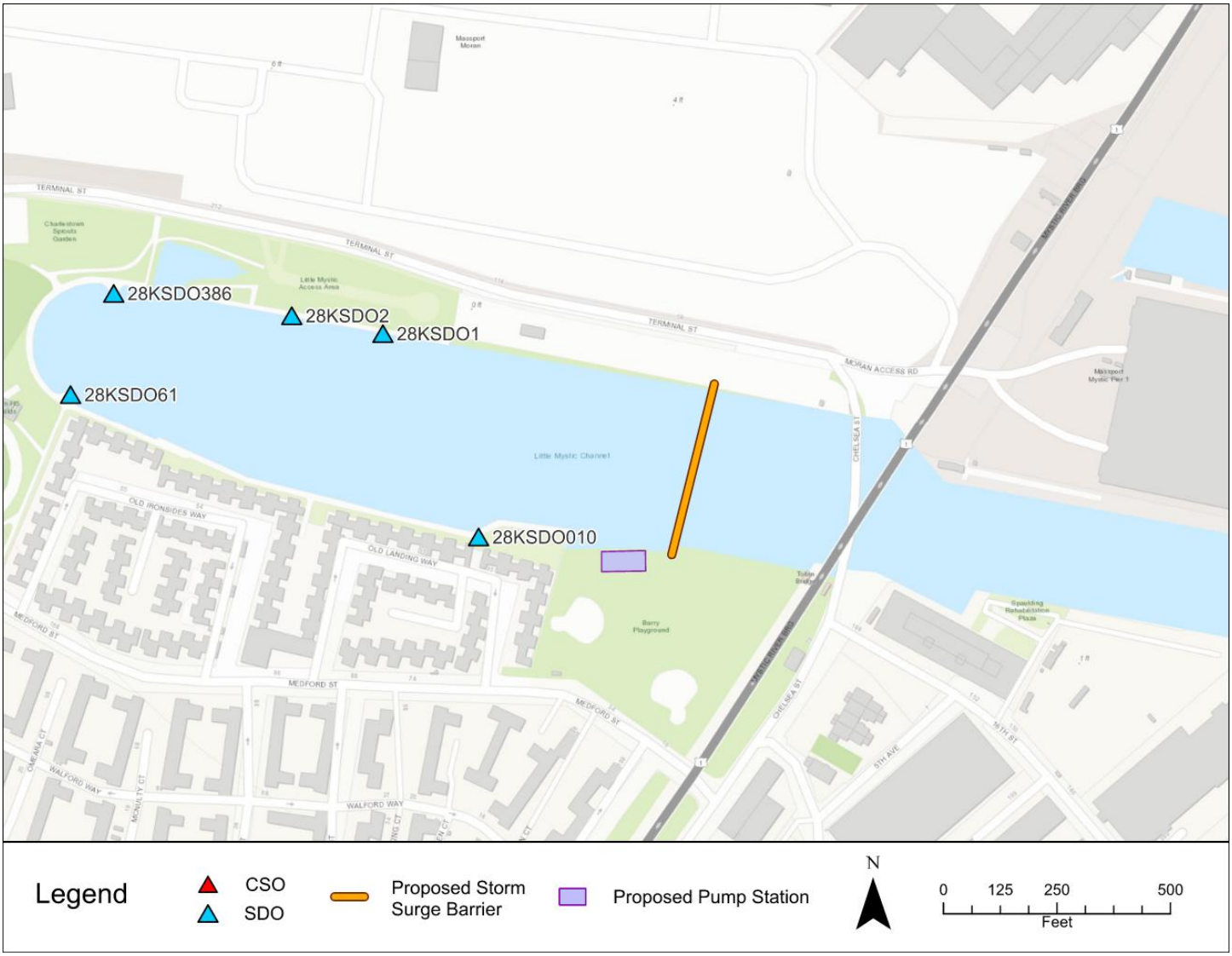
Outfall 27LSDO022
Raised Harborwalk to Chelsea St Bridge, Charlestown
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

- CRB project type: Raised harborwalk.
- 24-inch outfall serves a 45.0-acre tributary area (shared with outfall 27LSDO020)
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Subsurface storage facility and pump station could be installed in the Naval Shipyard to facilitate discharge during high sea levels



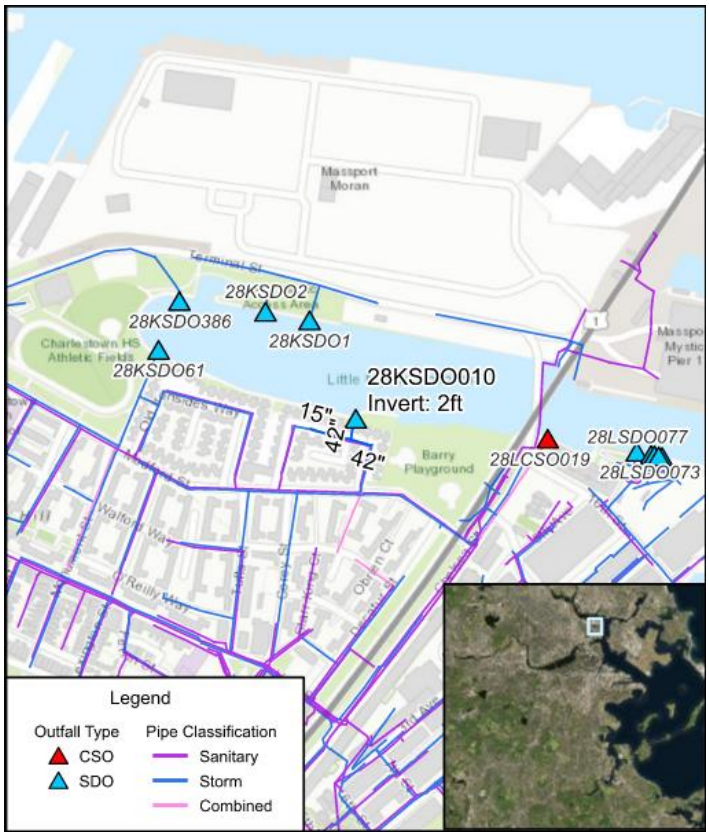
Little Mystic Channel Storm Surge Barrier and Pump Station



Outfall 28KSDO010
Raised Park South of Little Mystic, Charlestown
CRB Implementation Date: 2070

Existing Conditions and Recommendations:

- CRB project type: Raised harborwalk
- 42-inch outfall serves a 24.0-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Storm surge barrier and pump station near the mouth of the Little Mystic Channel could be installed to protect multiple outfalls



Outfall 28KSDO1
Boston Autoport, Charlestown
CRB Implementation Date: 2050

Existing Conditions and Recommendations:

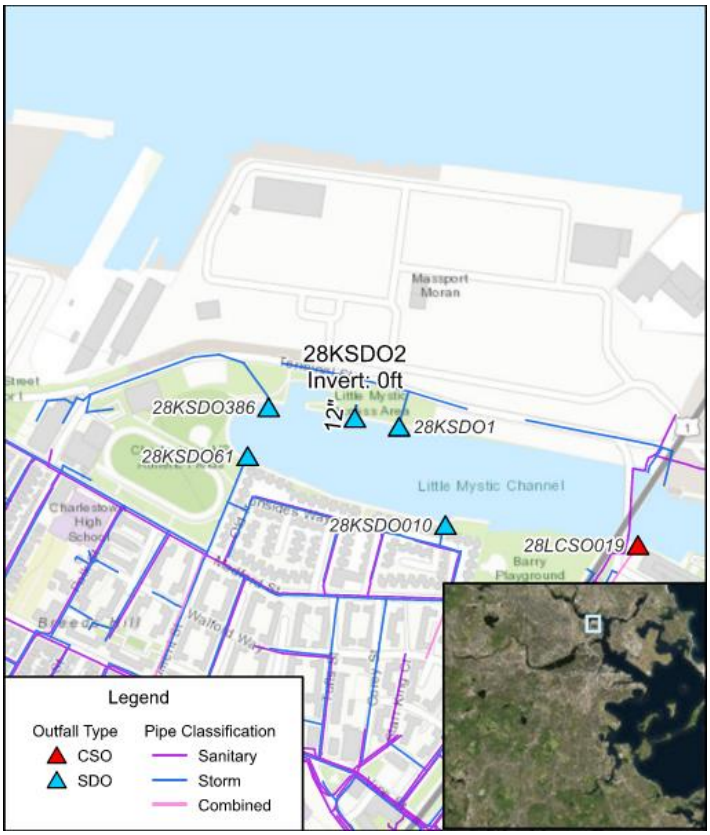
- CRB project type: Building/site scale adaptations
- 24-inch outfall serves a small tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- Storm surge barrier and pump station near the mouth of the Little Mystic Channel could be installed to protect multiple outfalls
- Alternatively, a pump station and/or subsurface storage could be installed in the parking area to prevent surcharging during wet weather



Outfall 28KSDO2
Boston Autoport, Charlestown
CRB Implementation Date: 2050

Existing Conditions and Recommendations:

- CRB project type: Building/site scale adaptations
- 12-inch outfall serves a small tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate could be installed to prevent backflow during high tide conditions
- Storm surge barrier and pump station near the mouth of the Little Mystic Channel could be installed to protect multiple outfalls



Outfall 28KSDO386
Boston Autoport, Charlestown
CRB Implementation Date: 2050

Existing Conditions and Recommendations:

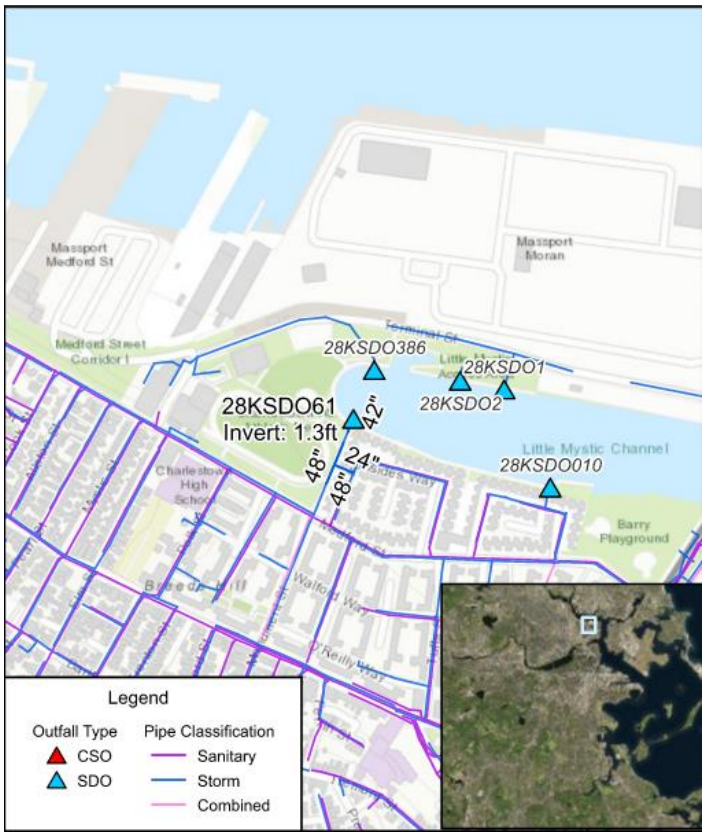
- CRB project type: Building/site scale adaptations
- 30-inch outfall serves a 2.6-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Storm surge barrier and pump station could be installed near the mouth of the Little Mystic Channel to protect multiple outfalls



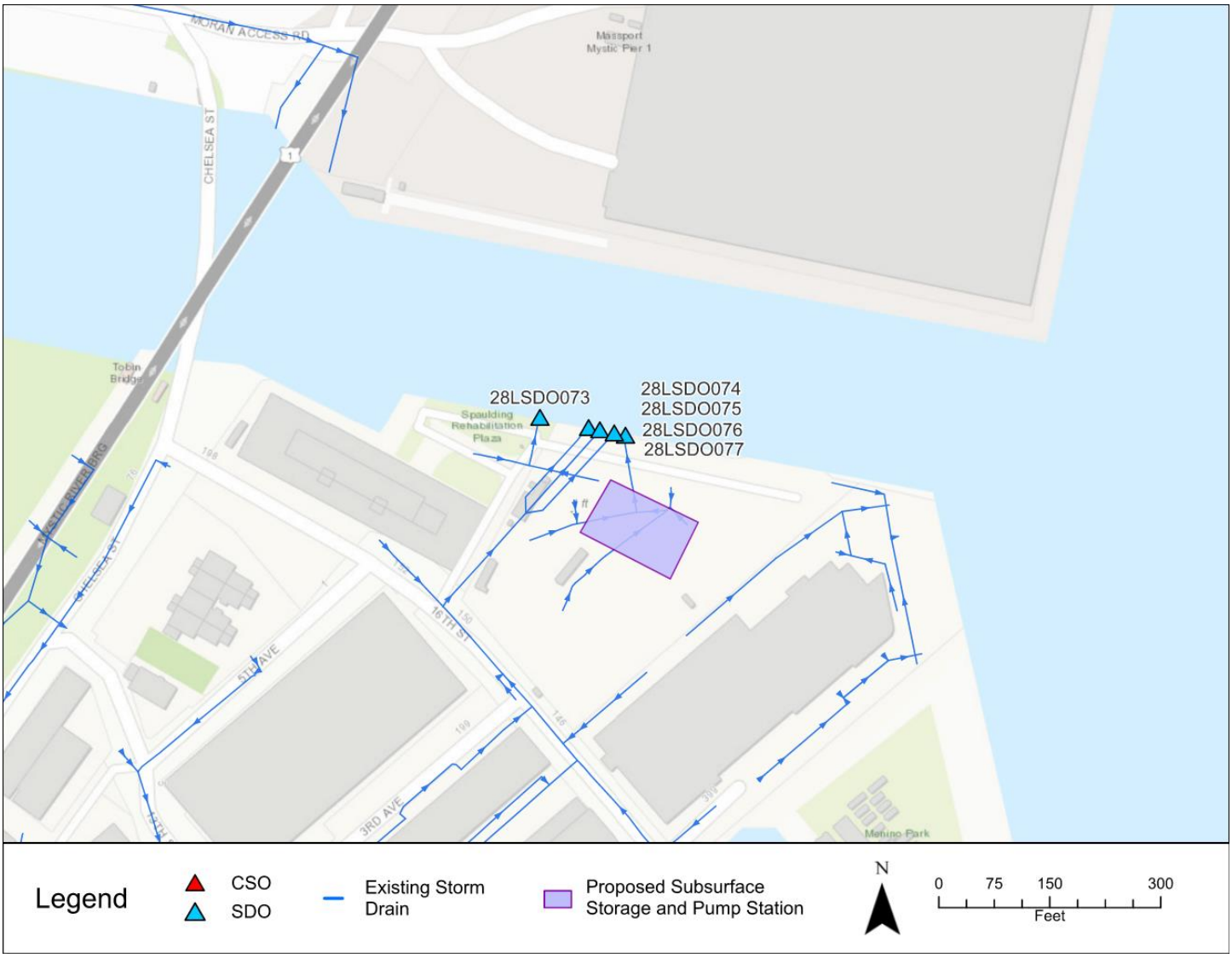
Outfall 28KSDO61
Raised Park South of Little Mystic, Charlestown
CRB Implementation Date: 2070

Existing Conditions and Recommendations:

- CRB project type: Raised harborwalk
- 42-inch outfall serves a 47.8-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate could be installed to prevent backflow during high tide conditions
- Storm surge barrier and pump station could be installed near the mouth of the Little Mystic Channel to protect multiple outfalls



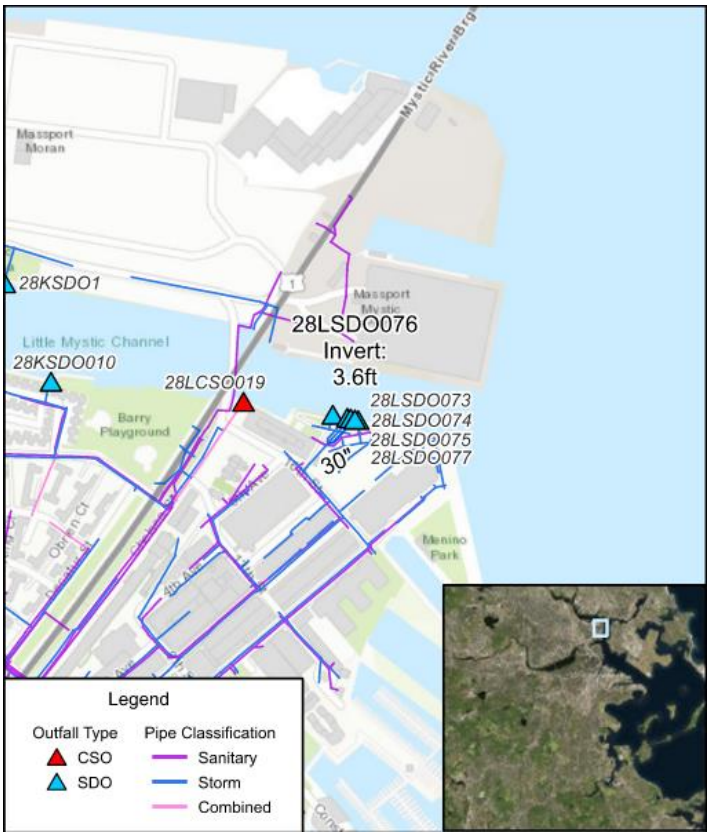
Little Mystic Channel Subsurface Storage and Pump Station



Outfall 28LSDO076
Raised Harborwalk to Chelsea St Bridge, Charlestown
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

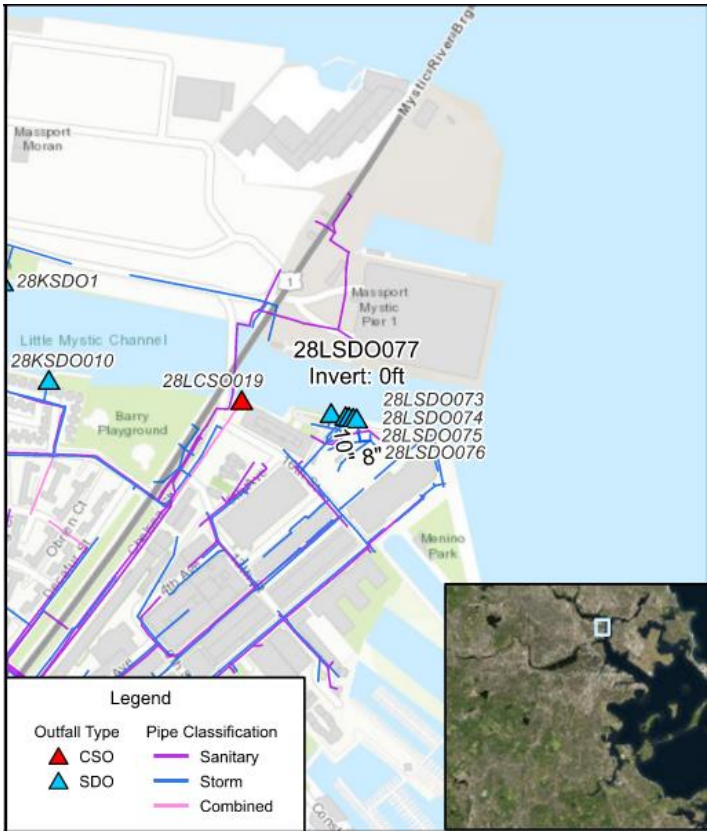
- CRB project type: Raised harborwalk
- 30-inch outfall serves a 46.9-acre tributary area (shared with outfalls 28LSDO074 and 28LSDO075)
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- A subsurface storage and pump station could be installed to facilitate discharge from this and nearby outfalls during high sea levels



Outfall 28LSDO077
Raised Harborwalk to Chelsea St Bridge, Charlestown
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

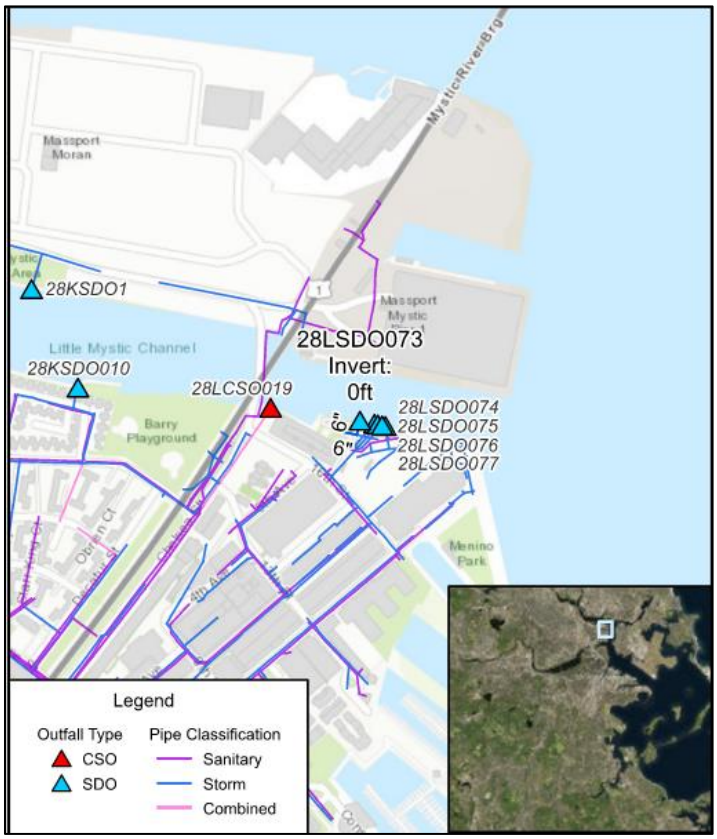
- CRB project type: Raised harborwalk
- 10-inch outfall serves a 0.9-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- A subsurface storage and pump station could be installed to facilitate discharge from this and nearby outfalls during high sea levels



Outfall 28LSDO073
Raised Harborwalk to Chelsea St Bridge, Charlestown
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

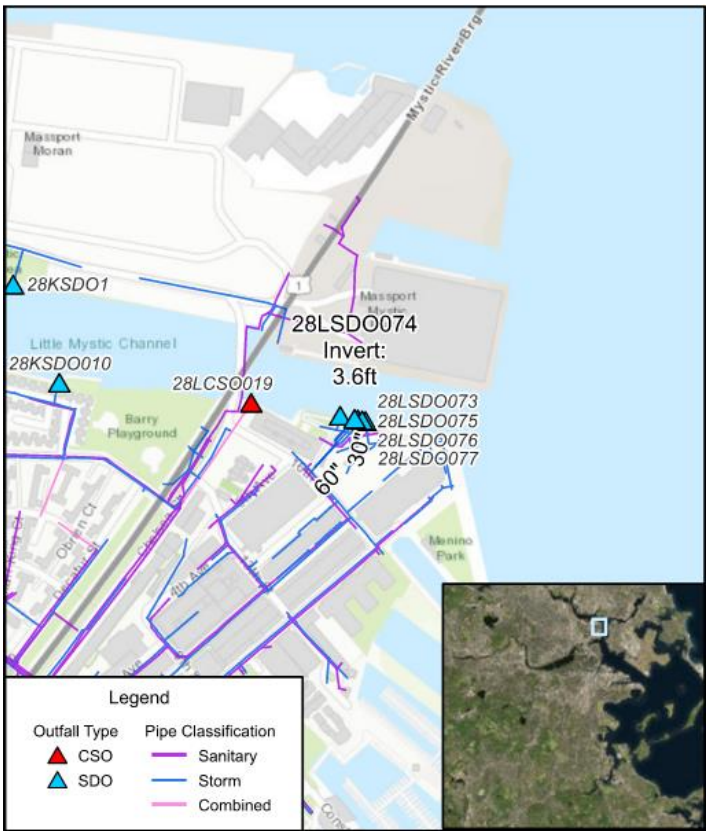
- CRB project type: Raised harborwalk
- 6-inch outfall serves a 0.4-acre tributary area
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- A subsurface storage and pump station could be installed to facilitate discharge from this and nearby outfalls during high sea levels



Outfall 28LSDO074
Raised Harborwalk to Chelsea St Bridge, Charlestown
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

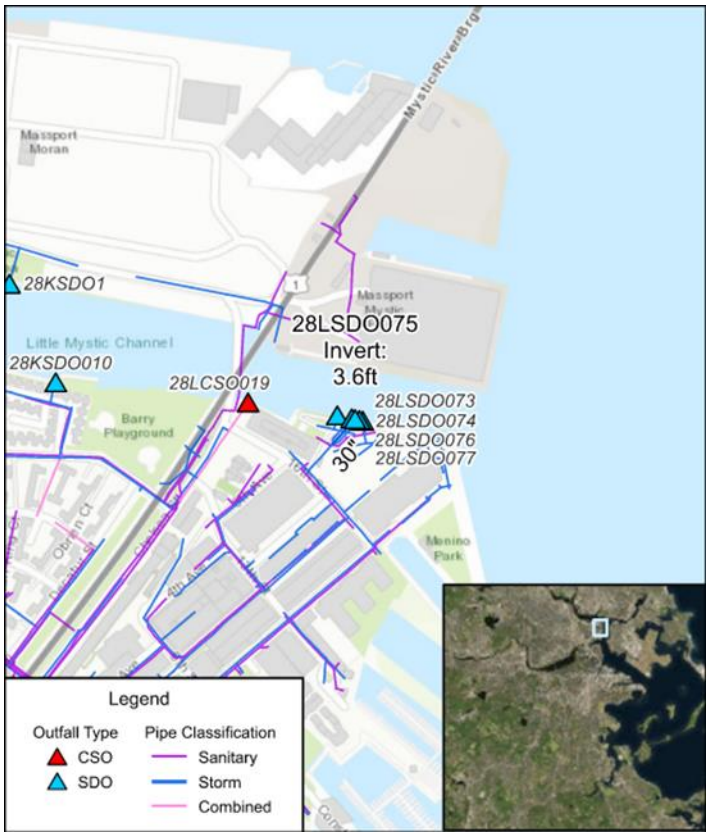
- CRB project type: Raised harborwalk
- 30-inch outfall serves a 46.9-acre tributary area (shared with outfalls 28LSDO075 and 28LSDO076)
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- A subsurface storage and pump station could be installed to facilitate discharge from this and nearby outfalls during high sea levels



Outfall 28LSDO075
Raised Harborwalk to Chelsea St Bridge, Charlestown
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

- CRB project type: Raised harborwalk
- 30-inch outfall serves a 46.9-acre tributary area (shared with outfalls 28LSDO074 and 28LSDO076)
- Publicly owned open space nearby provides opportunities for stormwater management
- Tide gate to prevent backflow during high tide conditions
- A subsurface storage and pump station could be installed to facilitate discharge from this and nearby outfalls during high sea levels



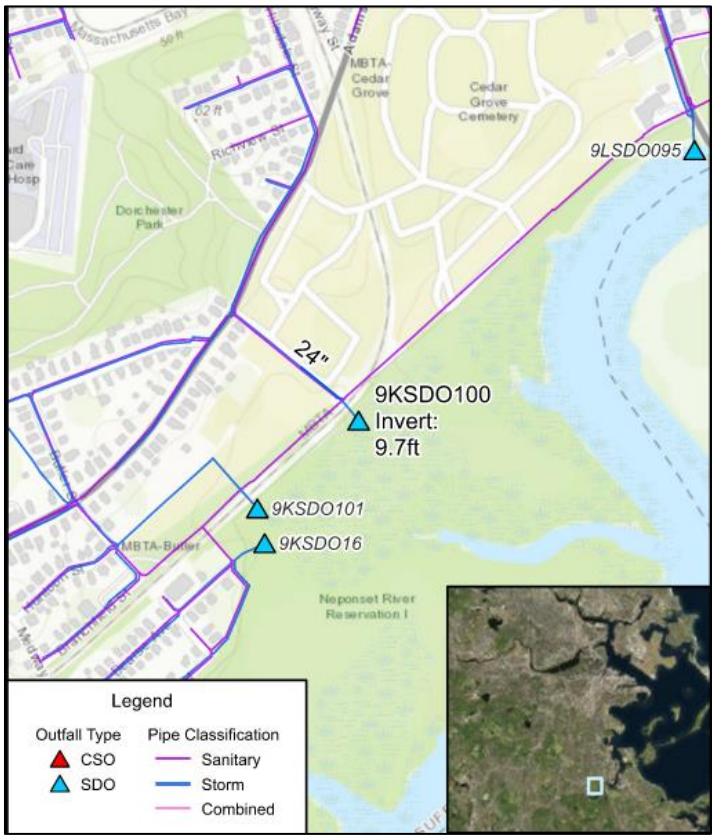
Bearse Avenue Pump Station / Detention Area



Outfall 9KSDO100
Neponset River State Reservation, Dorchester
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

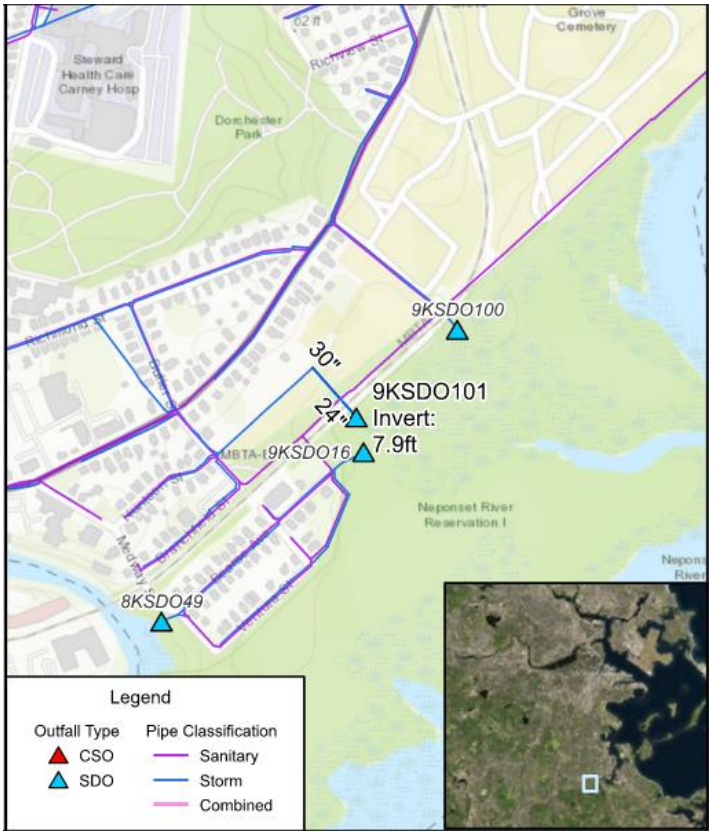
- CRB project type: Nature based solutions
- 24 by 34-inch outfall serves a 53.4-acre tributary area
- Opportunity for storage in nearby reservation
- Permitting challenges due to wetland
- Tide gate to prevent backflow during high tide conditions
- Small pump station or detention pond could be installed off Bearse Avenue accepting flow from nearby outfalls



Outfall 9KSDO101
Mattapan Trolley and Butler Station, Dorchester
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

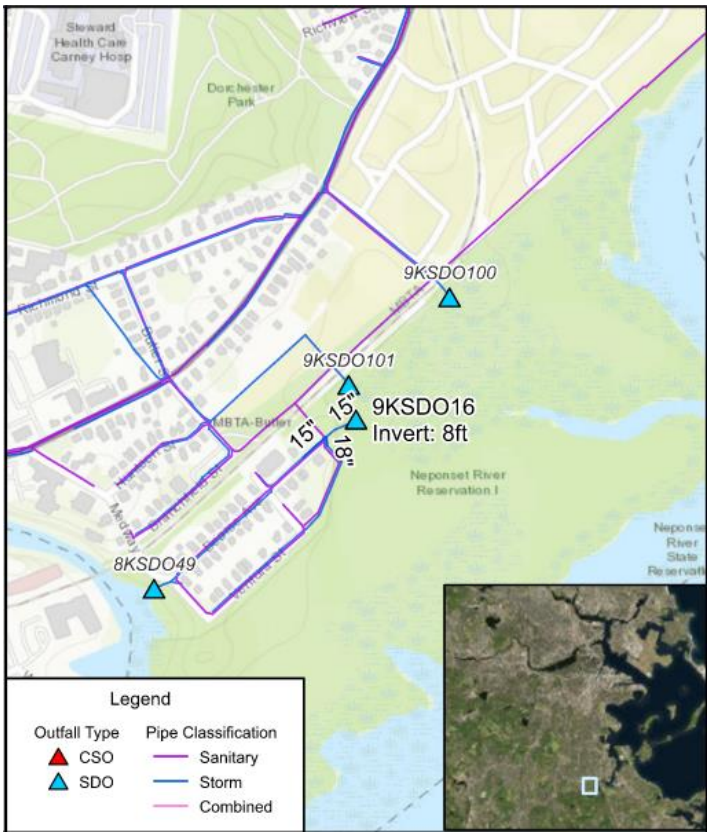
- CRB project type: Elevated roadways
- 24-inch outfall serves a 27.8-acre tributary area
- Opportunity for storage in nearby reservation
- Permitting challenges due to wetland
- Tide gate to prevent backflow during high tide conditions
- Small pump station or detention pond could be installed off Bearse Avenue accepting flow from nearby outfalls



Outfall 9KSDO16
Neponset River State Reservation, Dorchester
CRB Implementation Date: 2030

Existing Conditions and Recommendations:

- CRB project type: Nature based solutions
- 15-inch outfall serves a 6.2-acre tributary area
- Opportunity for storage in nearby reservation
- Permitting challenges due to wetland
- Tide gate to prevent backflow during high tide conditions
- Small pump station or detention pond could be installed off Bearse Avenue accepting flow from nearby outfalls



Appendix F: Outfall Site Summary Sheets



Figure 1: Outfall Sites Visited

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Project Sheet #1

Fort Point Channel

Conceptual Design Candidate ☒

The Fort Point contains multiple high ranking outfalls that were identified during the site screening process. As part of this project, the Commission will evaluate the feasibility of a barrier at the mouth of the Fort Point Channel during the conceptual design phase. This barrier will provide protection against high sea levels, and provide a basin that could be used for stormwater storage. Since several combined sewer outfalls would also be upstream of the barrier, it will be necessary to evaluate permitting related to open air storage of combined sewer overflows. It should also be noted that Climate Ready Boston is currently evaluating shoreline elevation along the eastern shore of the Channel.

High Ranking Outfalls within the Fort Point Channel

Outfall ID	PowerBI Ranking
21KCSO070	1
21KSDO069	17
22KCSO065	5
22KCSO068	22
22KCSO072	24
22LCSO073	37
22LSDO580	42
23LCSO062	16
23LCSO064	27
23LSDO075	45



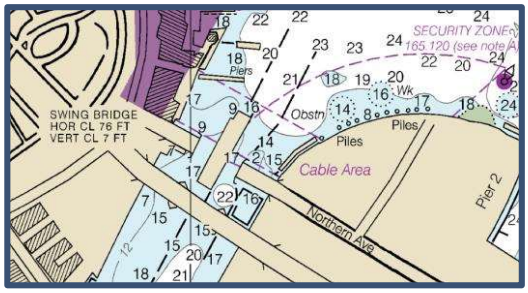
Preliminary Design Considerations

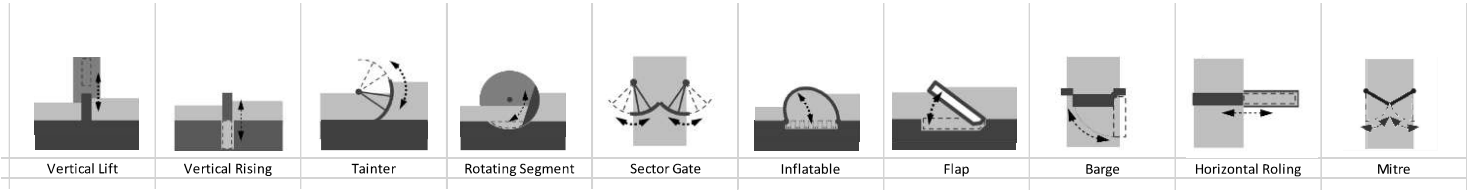
Basin Design:
- Barrier siting study
- Historic character of seawalls and low water levels

Navigable and Auxiliary Flow Gates:
- Size the gate openings for flow and navigation
- Evaluate applicable gate types
- Optimize barrier height

Pump Station Design:
- Preliminarily assess pump capacity and number of pumps

Tie-ins to High Ground:
- Preliminary floodwall height and alignment
- Prevent flanking





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Project Sheet #2

Outfall 16LSDO122

Conceptual Design Candidate ☒

Outfall ID:	**16LSDO122**	**Outfall Size:**	**108 x 96 inches**
Neighborhood:	**Dorchester**	**Outfall Shape:**	**Rectangular**
Discharge Location:	**Savin Hill Cove**	**Invert Elevation (BCB):**	**-2.73 feet**
Tributary Area Size:	**285 acres**	**PowerBI Ranking:**	**2**

Outfall 16LSDO122 is a large stormwater outfall that serves a large drainage area along the Southeast Way, north of Savin Hill. The outfall ranked highly due to a large predicted discharge volume, flood vulnerability, and tributary area characteristics. The outfall is located in close proximity to a large athletic field at Boston College High School. It is recommended that this site be advanced to the conceptual design phase.

Site Notes

- Open space near the side of Morrissey Boulevard within Boston College High School athletic fields
- Adjacent to Patten's Cove and outfall 16LSDO097 (24-inch diameter)
- High public visibility/educational opportunity associated with any adaptation project at this location
- Good location to develop a replicable concept that utilizes large, grassed areas
- Climate Ready Boston Project: Elevated Roadways and Nature Based Solution (Berm) around Pattens Cove

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	31,204
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	4
Population	No. of People	6186
Public Land	Distance in feet to public land	~200
Employment	No. of Employees	8418
Environmental Justice	% Population below Poverty Line	28%
Outfall Size	Dimension (inches)	108 x 96
Invert Elevation	Feet (BCB, NAVD88)	-2.7, -9.2

Site Selection Recommendations

- It is recommended that this site be advanced to the conceptual design phase. This outfall ranked highly in the screening process due to numerous factors, including flood vulnerability, overall system importance, and tributary area characteristics. Any adaptations constructed at this location will also benefit from high public visibility and educational opportunities.
- **Site Selection Rank: 1**

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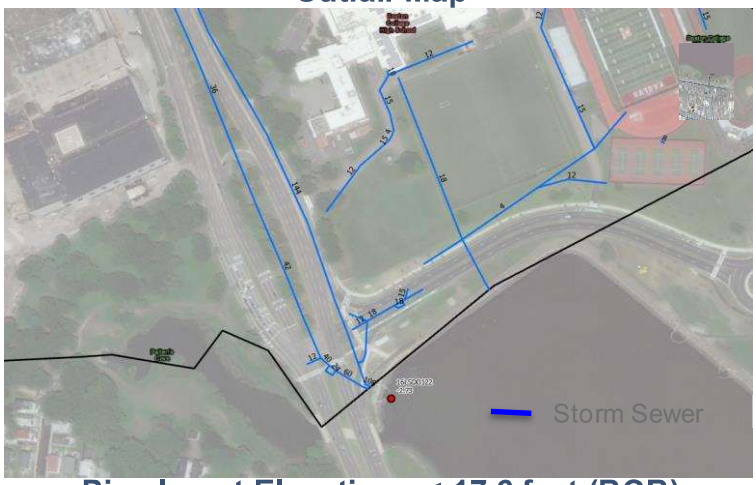
Project Sheet #2

Site Visit Photo



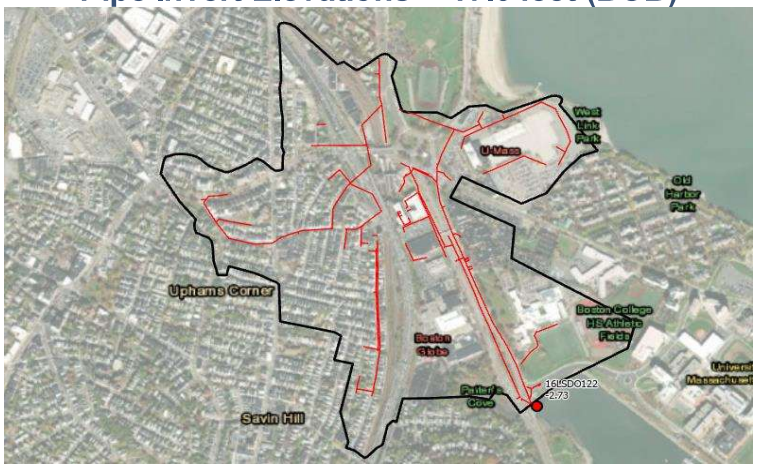
Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



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Project Sheet #3

Outfall 10LSDO094

Conceptual Design Candidate ☒

Outfall ID:	**10LSDO094**	**Outfall Size:**	**74 x 93 inches**
Neighborhood:	**Dorchester**	**Outfall Shape:**	**Unknown**
Discharge Location:	**Neponset River/ Davenport Creek**	**Invert Elevation (BCB):**	**3.44 feet**
Tributary Area Size:	**641 acres**	**PowerBI Rank:**	**13**

Outfall 10LSDO094 is a stormwater outfall that serves a large drainage area in Dorchester. This outfall ranked highly due to its size, discharge volume, flood vulnerability, and tributary area characteri sics. The outfall is located on the eastern side of Hallet Street and discharges into the Davenport Creek which travels under the Neponset Trail and the Southeast Expressway, eventually leading out to the Neponset River. There is ample open space near the outfall. This location is recommended for conceptual design.

Site Notes

- Open space downstream of the outfall, between the Neponset Trail and Southeast Expressway
- Nearby outfalls include 9LSDO095, 10LSDO096, and 11MSDO093
- Significant tidal influence at this location
- Climate Ready Boston Project: Tide Gate at Davenport Creek

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	30,300
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	9
Population	No. of People	12,793
Public Land	Distance in feet to public land	239
Employment	No. of Employees	3,030
Environmental Justice	% Population below Poverty Line	17%
Outfall Size	Dimension (inches)	74 x 93
Invert Elevation	Feet (BCB, NAVD88)	3.4, -3.0

Site Selection Recommendations

- It is recommended that this outfall be advanced to the conceptual design stage. There is sufficient open space to evaluate storage concepts, in concert with upstream flow management strategies, to consider the development of a passive concept (that functions with the planned CRB tide gate) that could be replicated in other locations.
- **Site Selection Rank: 2**

Hazen

Project Sheet #3

Site Visit Photo



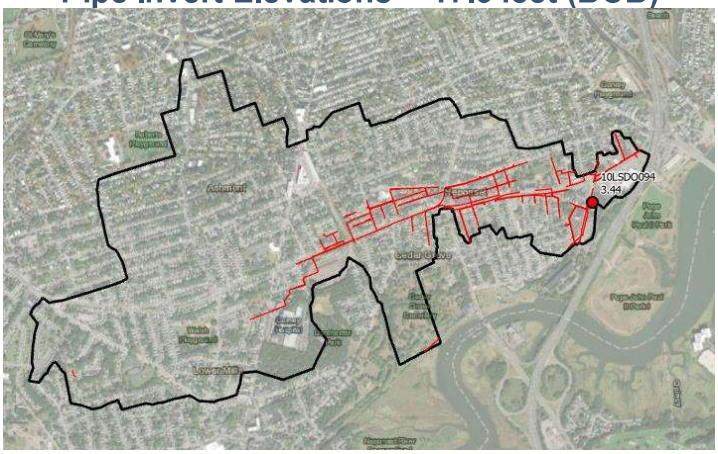
Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



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Project Sheet #4

Outfall 29OSDO001

Conceptual Design Candidate ☒

Outfall ID:	**29OSDO001**	**Outfall Size:**	**66 inches**
Neighborhood:	**East Boston**	**Outfall Shape:**	**Round**
Discharge Location:	**Boston Harbor**	**Invert Elevation (BCB):**	**-13.95 feet**
Tributary Area Size:	**239 acres**	**PowerBI Ranking:**	**8**

Outfall 29OSDO001 is a submerged structure that serves a large drainage area in East Boston. This outfall ranked highly in most of the screening criteria, and provides drainage to a flood vulnerable area with higher social vulnerability. The outfall discharges into the Harbor beneath Constitution Beach. Although East Boston is a prioritized neighborhood for Climate Ready Boston, a specific adaptation strategy at this location has not been identified.

Site Notes

- Open space available upstream of the outfall, between the public walkway and parking lot, within the parking lot, or between the parking lot and the Blue Line rail
- Adjacent outfalls include 29PSDO44 and 28PSDO1
- High public visibility
- High flood vulnerability
- Climate Ready Boston: TBD

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	13,177
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	5
Population	No. of People	3,453
Public Land	Distance in feet to public land	58
Employment	No. of Employees	1,384
Environmental Justice	% Population below Poverty Line	21%
Outfall Size	Dimension (inches)	66
Invert Elevation	Feet (BCB, NAVD88)	-13.9, -20.4

Site Selection Recommendations

- It is recommended that this location be considered for conceptual design. Adaptations at this location should be considered in concert with adjacent outfalls and with shoreline protection strategies from Climate Ready Boston. A project at this location would serve an area with higher social vulnerability and could be paired with other enhancements and provide educational value.
- Identify site a high-priority location as part of coordination with Climate Ready Boston.
- **Site Selection Rank: 3**

Hazen

Project Sheet #4

Site Visit Photo



Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #5

Outfall 13LSDO090

Conceptual Design Candidate ☒

Outfall ID:	**13LSDO090**	**Outfall Size:**	**144 x 180 inches**
Neighborhood:	**Dorchester**	**Outfall Shape:**	**Box**
Discharge Location:	**Neponset River**	**Invert Elevation (BCB):**	**-2.76 feet**
Tributary Area Size:	**821 acres**	**PowerBI Ranking:**	**7**

Outfall 13LSDO090 is a very large structure that provides drainage to extensive area located primarily in Dorchester. This location ranked highly due to flood vulnerability, size, discharge volume, and tributary area characteristics. The outfall discharges near Victory Road Park in a small inlet off of the Neponset River. There is very limited open space between the outfall and the Southeast Expressway. Open space is available in the adjacent Victory Road Park. It is recommended that this location be considered for conceptual design.

Site Notes

- No open space available between expressway and outfall location
- Open space adjacent to the outfall (Victory Road Park)
- Very large outfall and drainage area – high importance to drainage system
- Outfall serves area with higher social vulnerability
- Climate Ready Boston: Nature Based Solution

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	28,537
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	24
Population	No. of People	25,793
Public Land	Distance in feet to public land	930
Employment	No. of Employees	5025
Environmental Justice	% Population below Poverty Line	21%
Outfall Size	Dimension	144 x 180
Invert Elevation	Feet (BCB, NAVD88)	-2.8, -9.2

Site Selection Recommendations

- It is recommended that this location be considered for conceptual design. Design of a facility at this location would be more challenging due to site constraints; a design at this location could be replicated at other challenging locations. This outfall also serves an area with higher social vulnerability and is vulnerable to flooding during higher sea levels.
- **Site Selection Rank: 4**

Hazen

Project Sheet #5

Site Visit Photo



Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #6

Outfall 25LSDO058

Conceptual Design Candidate ☒

Outfall ID:	**25LSDO058**	**Outfall Size:**	**84 inches**
Neighborhood:	**Downtown**	**Outfall Shape:**	**Box**
Discharge Location:	**Boston Harbor**	**Invert Elevation (BCB):**	**-0.1 feet**
Tributary Area Size:	**55 acres**	**Ranking:**	**6**

Outfall 25LSDO058 provides drainage for a large portion of downtown Boston. The outfall is located near and beneath Christopher Columbus Park. This location was highly ranked due to flood vulnerability, system importance, and tributary area characteristics. In addition, Climate Ready Boston adaptations are planned in this area. A project at this location would have high public visibility, but have the potential to create significant public disruptions. It is recommended that this site be considered for conceptual design.

Site Notes

- Open space is developed (park)
- High flood vulnerability
- High public visibility
- Climate Ready Boston: Raised Harborwalk, Enhanced Open Space, and Outboard Options

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	25,191
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	3
Population	No. of People	2,698
Public Land	Distance in feet to public land	32
Employment	No. of Employees	27,818
Environmental Justice	% Population below Poverty Line	16%
Outfall Size	Dimension (inches)	84
Invert Elevation	Feet (BCB, NAVD88)	-0.1, -6.5

Site Selection Recommendations

- It is recommended that this site be considered for advancement to the conceptual design phase. This outfall has high overall importance and serves a flood vulnerable area. As such, efforts should be coordinated with Climate Ready Boston to ensure that coastal flood protection is also provided. Construction in this area may be challenging. A successful concept at this location could be replicated in other highly visible and trafficked areas.
- **Site Selection Ranking: 5**

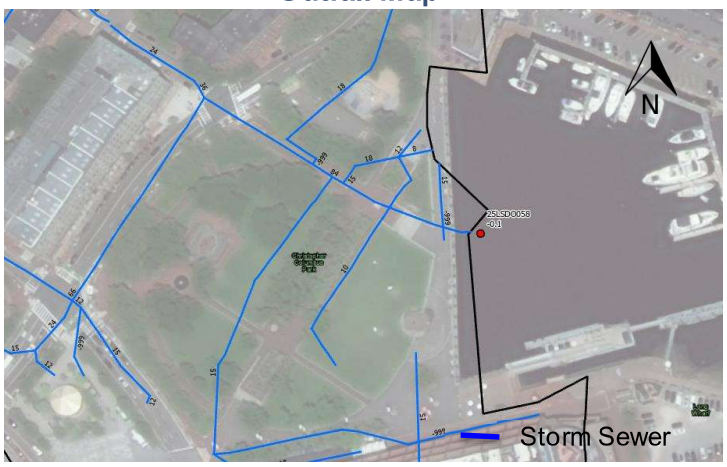
Hazen

Project Sheet #6

Site Visit Photo



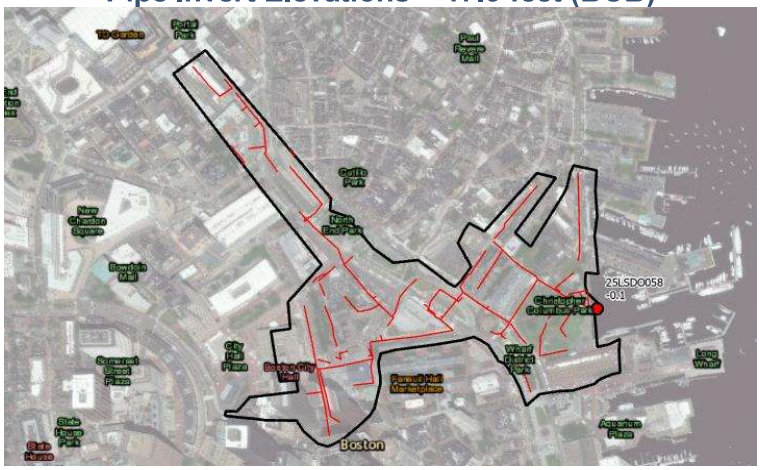
Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #7

Outfall 28LSDO074, 28LSDO075, 28LSDO076

Conceptual Design Candidate ☒

Outfall ID:	**28LSDO074**	**Outfall Size:**	**60 inches**
Neighborhood:	**Charlestown**	**Outfall Shape:**	**Round**
Discharge Location:	**Little Mystic Channel**	**Invert Elevation (BCB):**	**3.59 feet**
Tributary Area Size:	**47 acres**	**PowerBI Ranking:**	**55**

Outfalls 28LSDO074, 28LSDO075, and 28LSDO076 are three 30-inch stormwater outfalls connected to a 60-inch upstream pipe. The outfalls discharges into the Little Mystic Channel. These outfalls received lower rankings in the desktop screening since they are considered to be three separate structures in the Commission's GIS database. Regardless, they function together and a single adaptation project could enhance all three outfalls. The tributary area has high flood vulnerability. There is ample open space along the Harbor Walk and adjacent to it. It is recommended that this location be advanced to the conceptual design phase.

Site Notes

- Open space available in the vicinity of the outfall including a large grass area which is surrounded by the walking path, the Charlestown Navy Yard, 16th Street, and the Spaulding Rehabilitation Hospital
- Three outfalls are all connected to shared upstream pipe
- High flood vulnerability
- Climate Ready Boston: Ongoing Study Area, Completed an Elevated Waterfront Parks and Plaza at Spaulding Rehab Hospital

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	0
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	0
Population	No. of People	868
Public Land	Distance in feet to public land	Adjacent
Employment	No. of Employees	5,308
Environmental Justice	% Population below Poverty Line	32%
Outfall Size	Dimension (inches)	60
Invert Elevation	Feet (BCB, NAVD88)	3.6, -2.9

Site Selection Recommendations

- It is recommended that this location be advanced to the conceptual design phase. There is ample open space to evaluate subsurface storage and pumping and enhance resiliency at all three outfall pipes (shared structure). This area is also a prioritized location for Climate Ready Boston implementation. It should be noted that a barrier could evaluated at the mouth of the Little Mystic Channel. This would reduce coastal flooding risk and provide a significant storage opportunity for the numerous BWSC outfalls within the channel.
- **Site Selection Rank: 6**

Hazen

Project Sheet #7

Site Visit Photo



Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #8

Outfall 24NCSO003

Conceptual Design Candidate ☒

Outfall ID:	**24NCSO003**	**Outfall Size:**	**144 x 120 inches**
Neighborhood:	**East Boston**	**Outfall Shape:**	**Horseshoe**
Discharge Location:	**Boston Harbor**	**Invert Elevation (BCB):**	**-2.68 feet**
Tributary Area Size:	**626 acres**	**PowerBI Ranking:**	**9**

Outfall 24NCSO003 is a large combined sewer outfall located in East Boston. The outfall appears to be located on Logan Airport/Massport property. It was not possible to access the outfall directly during the site visit and evaluate open space. The outfall serves a large flood vulnerable portion of East Boston. Inability to discharge at this location could contribute to sewer backups throughout East Boston. It is recommended that this location be advanced to the conceptual design phase.

Site Notes

- Unable to directly access outfall (located on airport property)
- Large, combined sewer tributary area
- Climate Ready Boston: TBD

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	55,394
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	12
Population	No. of People	13,095
Public Land	Distance in feet to public land	2,133
Employment	No. of Employees	9,501
Environmental Justice	% Population below Poverty Line	16%
Outfall Size	Dimension	144 x 120
Invert Elevation	Feet (BCB, NAVD88)	-2.7, -9.1

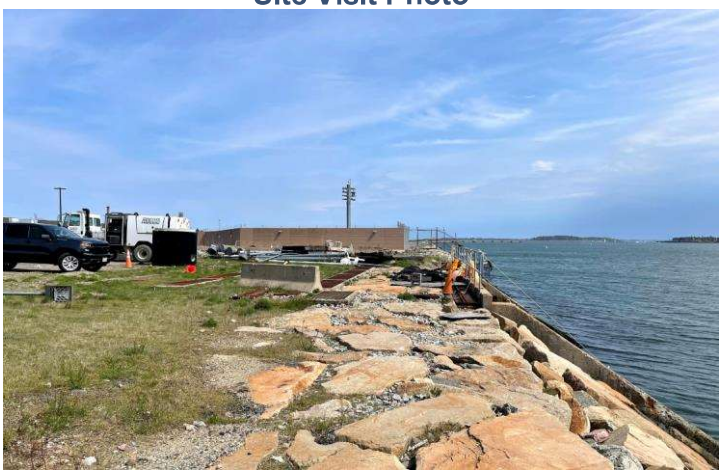
Site Selection Recommendations

- It is recommended that this outfall be advanced to the conceptual design phase. The potential for sewer backups to originate from this location throughout East Boston indicates that it is a high priority location. Sewer separation efforts, and other upstream flow management efforts, could be considered in concert with a discharge project at the outfall to reduce the risk of sewer backups. Coordination with Logan Airport would likely be required to implement any adaptation at this location.
- **Site Selection Rank: 7**

Hazen

Project Sheet #8

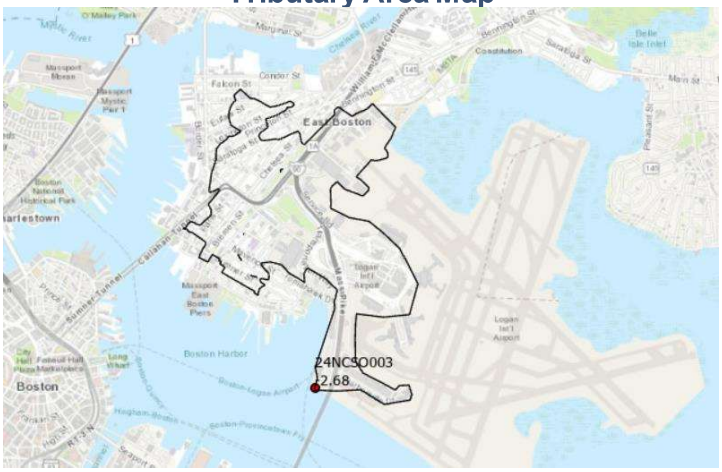
Site Visit Photo



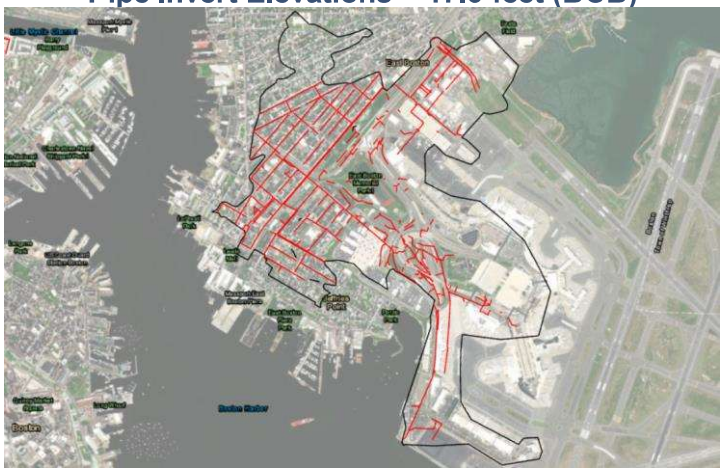
Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #9

Outfall 28NSDO207

Conceptual Design Candidate ☒

Outfall ID:	**28NSDO207**	**Outfall Size:**	**60 inches**
Neighborhood:	**East Boston**	**Outfall Shape:**	**Round**
Discharge Location:	**Boston Harbor**	**Invert Elevation (BCB):**	**3.12 feet**
Tributary Area Size:	**57 acres**	**PowerBI Ranking:**	**47**

Outfall 28NSDO207 is a stormwater outfall that serves a drainage area in East Boston. This location achieved a lower ranking in the screening primarily due to the smaller size of the drainage area compared to other high-priority locations. Regardless, the area is vulnerable to flooding and has higher social vulnerability. East Boston is a priority location for Climate Ready Boston, although a specific adaptation at this location has not been identified. Nature based solutions that utilize the marsh area may be investigated further by Climate Ready Boston. There is ample open space along the East Boston Greenway in this area, and high public visibility.

Site Notes

- Ample open space
- High public visibility along Greenway
- Smaller outfall relative to other priority sites
- Climate Ready Boston: TBD, possible nature-based adaptation in marsh area

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	6,975
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	1
Population	No. of People	1,356
Public Land	Distance in feet to public land	564
Employment	No. of Employees	266
Environmental Justice	% Population below Poverty Line	20%
Outfall Size	Dimension (inches)	60
Invert Elevation	Feet (BCB, NAVD88)	3.1, -3.3

Site Selection Recommendations

- It is recommended that this location be advanced to the conceptual design phase. An adaptation constructed at this location will provide high public visibility and encounter fewer constructability concerns than other similar locations due to ample open space. In addition, the smaller size of this outfall may provide an opportunity to pilot an adaptation strategy that could be replicated at other locations. Coordination should occur with Climate Ready Boston. Permitting related to the marsh should be considered.
- **Site Selection Rank: 8**

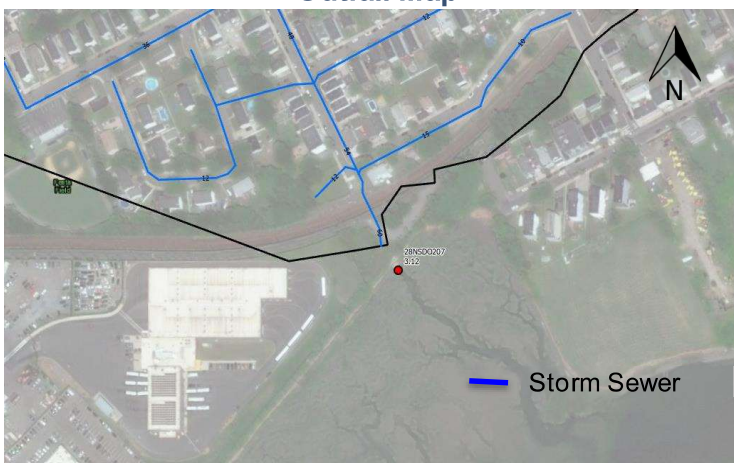
Hazen

Project Sheet #9

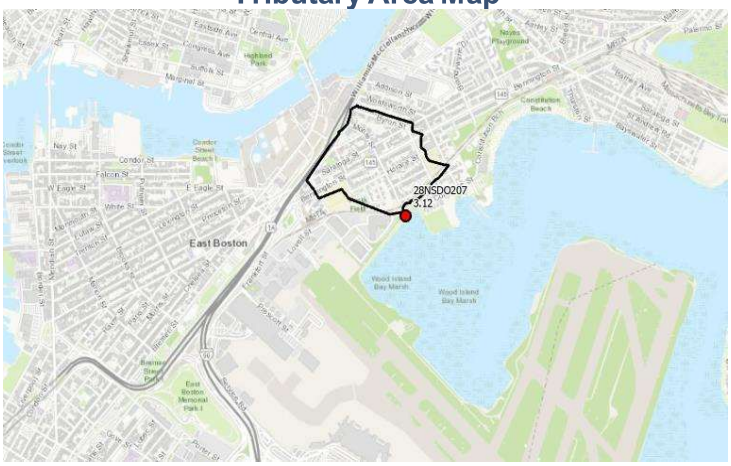
Site Visit Photo



Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #10

Outfall 15LSDO089

Conceptual Design Candidate ☒

Outfall ID:	**15LSDO089**	**Outfall Size:**	**96 x 120 inches**
Neighborhood:	**Neponset**	**Outfall Shape:**	**Box**
Discharge Location:	**Savin Hill Cove**	**Invert Elevation (BCB):**	**-8 feet**
Tributary Area Size:	**79 acres**	**PowerBI Ranking:**	**19**

Outfall 15LSDO089 is a large outfall in Dorchester. This outfall ranked highly due to its size, modeled discharge volume in addition to flood risk and tributary area characteritics. This outfall is located within the privately owned Savin Hill Yacht Club and the tributary area contains the Savin Hill Park and McConnell Park in Dorchester. It should be noted that the delineated tributary area is not accurate as shown; this outfall functions in conjunction with 15LSDO088; as such, the tributary area assigned to that outfall is also tributary to this location.

Site Notes

- Open space is available within the Savin Hill Yacht Club (privately owned)
- Hydraulically linked to 15LSDO088
- Climate Ready Boston: Elevated Roadways

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	4,450
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	0
Population	No. of People	698
Public Land	Distance in feet to public land	865.1
Employment	No. of Employees	447
Environmental Justice	% Population below Poverty Line	11%
Outfall Size	Dimension (inches)	96 x 120
Invert Elevation	Feet (BCB, NAVD88)	-8.0, -14.5

Site Selection Recommendations

- It is recommended that this location be advanced to the conceptual design phase. The outfall serves a large tributary area (currently assigned to 15LSDO088, which only discharges during extreme rain events). As such, a project at this location will benefit a large tributary area.
- **Site Selection Rank: 9**

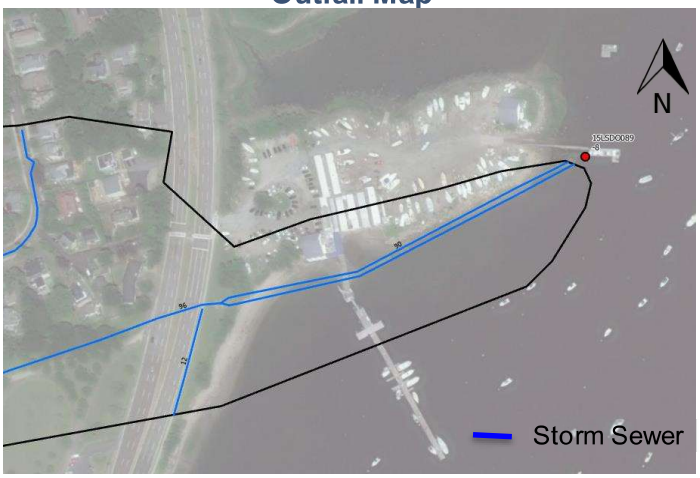
Hazen

Project Sheet #10

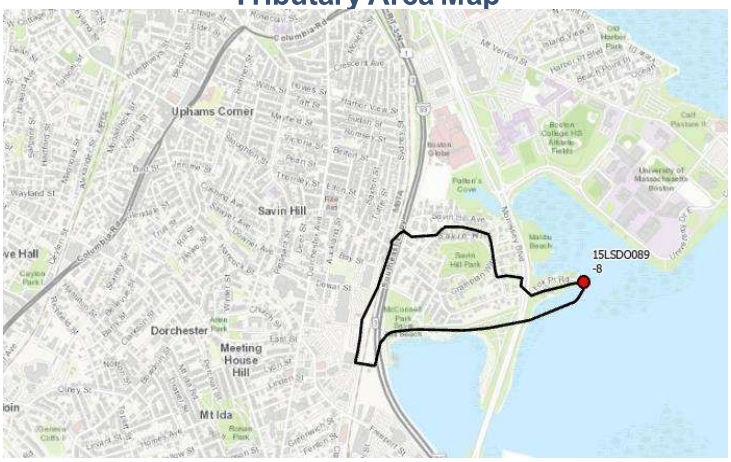
Site Visit Photo



Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #11

Outfall 12LSDO092

Conceptual Design Candidate ☒

Outfall ID:	**12LSDO092**	**Outfall Size:**	**72 inches**
Neighborhood:	**Dorchester**	**Outfall Shape:**	**Round**
Discharge Location:	**Neponset River**	**Invert Elevation (BCB):**	**-1.11 feet**
Tributary Area Size:	**121 acres**	**PowerBI Ranking:**	**10**

Outfall 29OSDO001 discharges to a small inlet near the Neponset River and provides drainage for a large area in Dorchester. This location ranked highly due to flood vulnerability, system importance, and tributary area characteristics. There is limited open space directly around the outfall. A barrier or movable structure could be evaluated at the downstream end of the inlet to provide flood control and stormwater storage opportunities.

Site Notes

- Limited open space directly adjacent to outfall
- Inlet could provide storage opportunity
- Climate Ready Boston: Elevated Waterfront Parks and Plazas, Elevated Roadways, and Deployable Floodwalls

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	9,137
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	2
Population	No. of People	2,110
Public Land	Distance in feet to public land	29
Employment	No. of Employees	1,397
Environmental Justice	% Population below Poverty Line	11%
Outfall Size	Dimension (inches)	72
Invert Elevation	Feet (BCB, NAVD88)	-1.1, -7.6

Site Selection Recommendations

- It is recommended that this location be considered for advancement to the conceptual design phase. This location is vulnerable to flooding and has also been identified by Climate Ready Boston for adaptation efforts. Coordination with the City and Climate Ready Boston could occur to evaluate the feasibility of a barrier or other movable structure at the mouth of the inlet near Tenean Beach.
- **Site Selection Rank: 10**

Hazen

Project Sheet #11

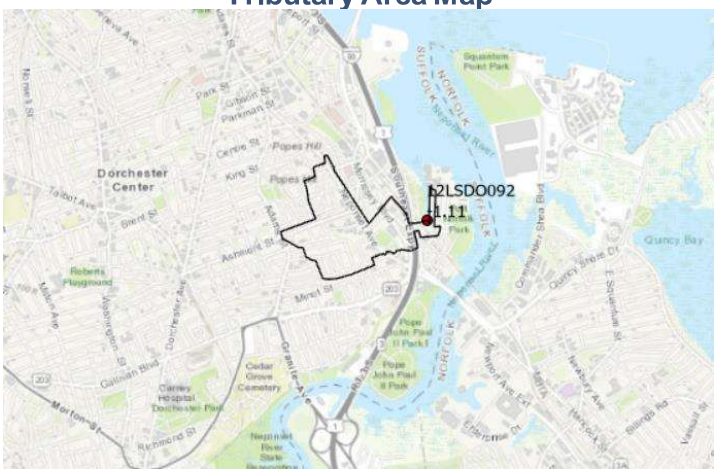
Site Visit Photo



Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #12

Outfall 29JSDO212

Conceptual Design Candidate ☒

Outfall ID:	**29JSDO212**	**Outfall Size:**	**72 inches**
Neighborhood:	**Charlestown**	**Outfall Shape:**	**Round**
Discharge Location:	**Mystic River**	**Invert Elevation (BCB):**	**0.5 feet**
Tributary Area Size:	**96 acres**	**PowerBI Ranking:**	**31**

Outfall 29JSDO212 is stormwater outfall that provides drainage to the Bunker Hill neighborhood in Charlestown. Although the outfall achieved a lower ranking relative to some other locations, it is directly adjacent to combined sewer outfall 29JCSO01. A conceptual design at this location could enhance the resilience of both outfalls. In addition, there is a large parking lot for Schrafft's Center immediately upstream of both outfalls. Climate Ready Boston is planning elevated shorelines at this location. It is recommended that this location be considered for the conceptual design phase.

Site Notes

- Large privately owned parking lot
- Adjacent to outfall 29JCSO017
- Climate Ready Boston: Elevated Waterfront Parks and Plazas
- Most of the tributary area (Bunker Hill neighborhood) has low flood vulnerability

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	2,620
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	4
Population	No. of People	2,648
Public Land	Distance in feet to public land	410
Employment	No. of Employees	2,044
Environmental Justice	% Population below Poverty Line	14%
Outfall Size	Dimension (inches)	7
Invert Elevation	Feet (BCB, NAVD88)	0.5, -5.7

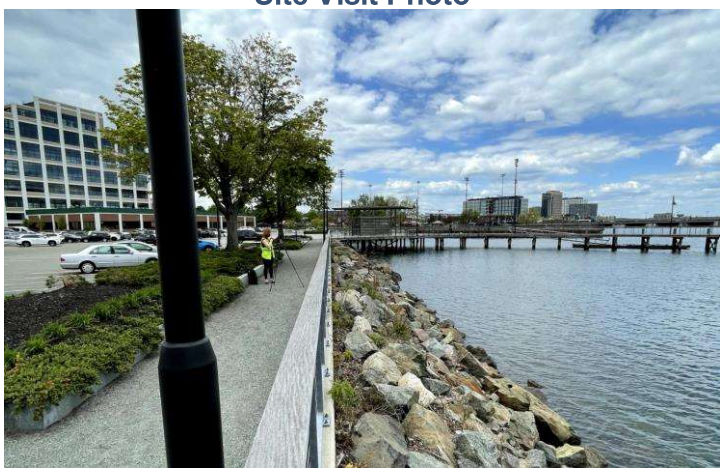
Site Selection Recommendations

- It is recommended that this location be considered for conceptual design given the planned Climate Ready Boston work and the opportunity to enhance two outfalls with one project. In addition, this location could serve as a replicable concept for locations with privately owned parking areas. It should be noted that the upstream drainage area is less flood vulnerable than other high priority areas.
- **Site Selection Rank: 11** (with 29JCSO017)

Hazen

Project Sheet #12

Site Visit Photo



Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #13

Outfall 29JCSO017

Conceptual Design Candidate ☒

Outfall ID:	**29JCSO017**	**Outfall Size:**	**63 inches**
Neighborhood:	**Charlestown**	**Outfall Shape:**	**Round**
Discharge Location:	**Mystic River**	**Invert Elevation (BCB):**	**2.86 feet**
Tributary Area Size:	**48 acres**	**PowerBI Ranking:**	**43**

Outfall 29JCSO017 is a combined sewer outfall that provides service to the Sullivan Square area and part of East Somerville. Although the outfall achieved a lower ranking relative to some other locations, it is directly adjacent to stormwater outfall 29JSDO212. A conceptual design at this location could enhance the resilience of both outfalls. In addition, there is a large parking lot for Schrafft's Center immediately upstream of both outfalls. Climate Ready Boston is planning elevated shorelines at this location. It is recommended that this location be considered for the conceptual design phase.

Site Notes

- Large privately owned parking lot
- Adjacent to outfall 29JSDO212
- Service area includes East Somerville
- Climate Ready Boston: Elevated Waterfront Parks and Plazas

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	8,566
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	0
Population	No. of People	332
Public Land	Distance in feet to public land	416
Employment	No. of Employees	2,274
Environmental Justice	% Population below Poverty Line	7%
Outfall Size	Dimension (inches)	63
Invert Elevation	Feet (BCB, NAVD88)	2.9, -3.6

Site Selection Recommendations

- It is recommended that this location be considered for conceptual design given the planned Climate Ready Boston work and the opportunity to enhance two outfalls with one project. In addition, an adaptation project at these outfalls (in concert with planned CRB work) could provide flood reduction benefits for part of East Somerville. Benefits shared by Somerville could be characterized during the damage analysis and help serve as a case study for implementation of a project with widely shared benefits.
- **Site Selection Rank: 11** (with 29JSDO212)

Hazen

Project Sheet #13

Site Visit Photo



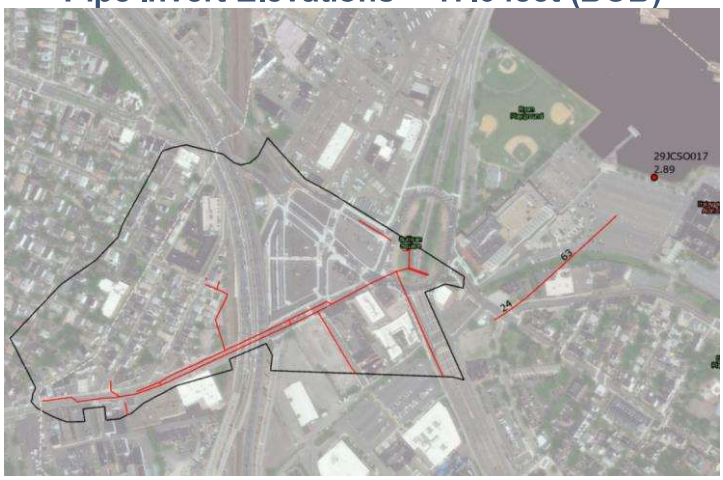
Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #14

Outfall 17MSDO33

Conceptual Design Candidate ☒

Outfall ID:	**17MSDO33**	**Outfall Size:**	**72 inches**
Neighborhood:	**Dorchester**	**Outfall Shape:**	**Round**
Discharge Location:	**Dorchester Bay**	**Invert Elevation (BCB):**	**0.52 feet**
Tributary Area Size:	**81 acres**	**PowerBI Ranking:**	**20**

Outfall 17MSDO33 is a stromwater outfall that serves a flood vulnerable area in Dorchester. The outfall's tributary drainage area includes the Harbor Point apartment complex. The area served by this outfall is significantly more socially vulnerable than other high priority areas. The outfall is located along the Harborwalk, and there is ample open space around the outfall. It is recommended that this location be advanced the conceptual design phase.

Site Notes

- Outfall critical for stormwater drainage in Harbor Point apartment complex
- Located along the Harborwalk, open space available
- High social vulnerability
- Flood vulnerable
- Climate Ready Boston: Integrated Flood Protection is in development and Elevated Waterfront

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	0
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	3
Modeled Discharge	Model Predicted Discharge from Simulated Storms (MG)	15.5
Public Land	Distance in feet to public land	0
Employment	No. of Employees	1963
Environmental Justice	% Population below Poverty Line	48%
Outfall Size	Dimension (inches)	72
Invert Elevation	Feet (BCB, NAVD88)	0.5, -5.9

Site Selection Recommendations

- It is recommended that this location be advanced to the conceptual design phase. In addition to being identified as an area for planned projects by Climate Ready Boston, this location has public visibility and improvement potential. A successful concept at this location could be replicated at other locations along the Harborwalk.
- **Site Selection Rank: 12**

Hazen

Project Sheet #14

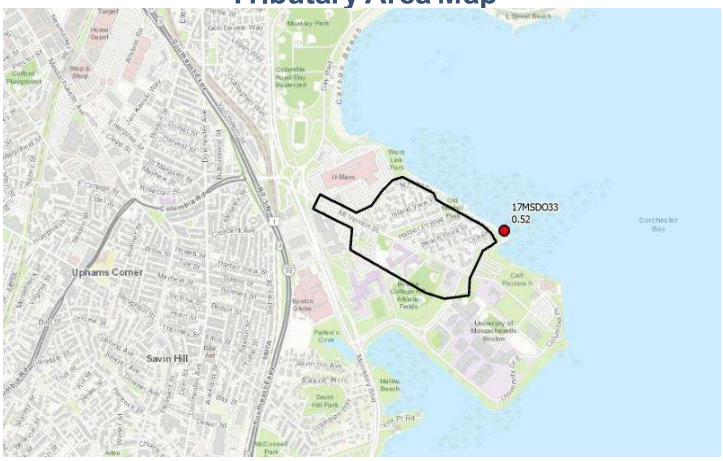
Site Visit Photo



Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #15

Outfall 27LCSO10

Conceptual Design Candidate ☒

Outfall ID:	**27LCSO10**	**Outfall Size:**	**60 inches**
Neighborhood:	**East Boston**	**Outfall Shape:**	**Round**
Discharge Location:	**Boston Harbor**	**Invert Elevation (BCB):**	**1.60 feet**
Tributary Area Size:	**37 acres**	**PowerBI Ranking:**	**55**

Outfall 27LCSO10 is a combined sewer outfall located in East Boston. This outfall serves a highly flood vulnerable area that has been identified by Climate Ready Boston as a priority area for near term adaptation. Although this location achieved a lower rank relative to other locations, this location should be considered for conceptual design given the possibility of combined sewer backups originating from this outfall. In addition, adaptations at this outfall should be incorporated into Climate Ready Boston's planned projects for the shoreline in this area.

Site Notes

- Open space is available in the vicinity of the outfall, containing a large grass area surrounded by the Harbor Walk Border Street, and the EBNHC Wellness Garden.
- Upstream sewer system is low-lying and flood vulnerable
- Climate Ready Boston: Elevated Waterfront Parks and Plazas

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	6,046
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	1
Population	No. of People	1,707
Public Land	Distance in feet to public land	628
Employment	No. of Employees	921
Environmental Justice	% Population below Poverty Line	20%
Outfall Size	Dimension (inches)	60
Invert Elevation	Feet (BCB, NAVD88)	1.6, -4.9

Site Selection Recommendations

- This outfall could be advanced to the conceptual design phase, given the possibility that combined sewer backups could originate from this location. In addition, this area has been identified as a priority area for near term adaptation efforts by Climate Ready Boston; enhancements to this outfall should be coordinated with shoreline elevation and other possible construction projects in the area.
- **Site Selection Rank: 13**

Hazen

Project Sheet #15

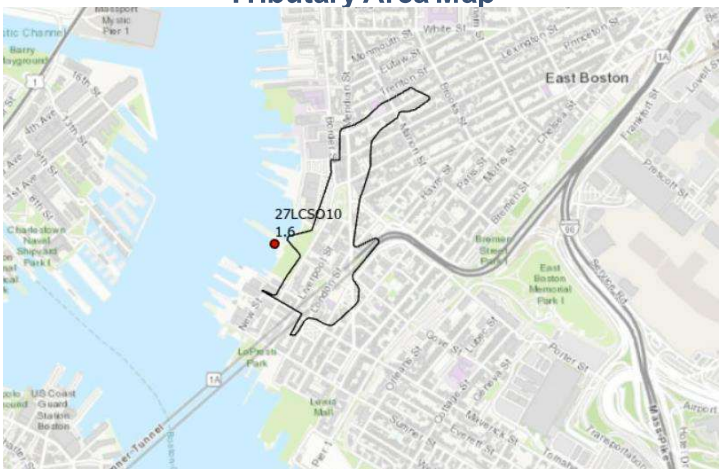
Site Visit Photo



Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #16

Outfall 11MSDO093

Conceptual Design Candidate ☒

Outfall ID:	**11MSDO093**	**Outfall Size:**	**48 inches**
Neighborhood:	**Dorchester**	**Outfall Shape:**	**Round**
Discharge Location:	**Neponset River**	**Invert Elevation (BCB):**	**3.8 feet**
Tributary Area Size:	**49 acres**	**PowerBI Ranking:**	**25**

Outfall 11MSDO093 is a stormwater outfall located along the Neponset Trail directly beneath the Neponset Ave (Route 3A) bridge that discharges into the Neponset River. This outfall achieved a ranking in the top 25 during the screening process due to its flood vulnerability and size. The only "open" space in close proximity to this outfall is a privately owned parking lot. It is recommended that this location be considered for the conceptual design phase.

Site Notes
- High public visibility
- Limited open space
- Climate Ready Boston: Elevated Waterfront Parks and Plazas

Potential Conceptual Design Strategies:



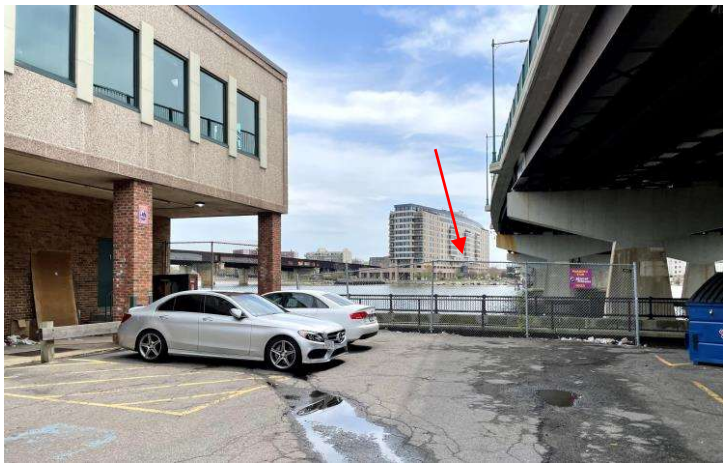
Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	8180
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	2
Population	No. of People	564
Public Land	Distance in feet to public land	112
Employment	No. of Employees	1094
Environmental Justice	% Population below Poverty Line	7%
Outfall Size	Dimension (inches)	48
Invert Elevation	Feet (BCB, NAVD88)	3.8, -2.7

Site Selection Recommendations:
- It is recommended that this location be considered for advancement of the conceptual design phase. Although construction in this location may be challenging, the large privately owned parking lot may provide an opportunity to evaluate strategies for public-private collaboration. A successful project in this location could be replicated in other locations with limited open space and privately owned land.
- **Site Selection Rank: 14**

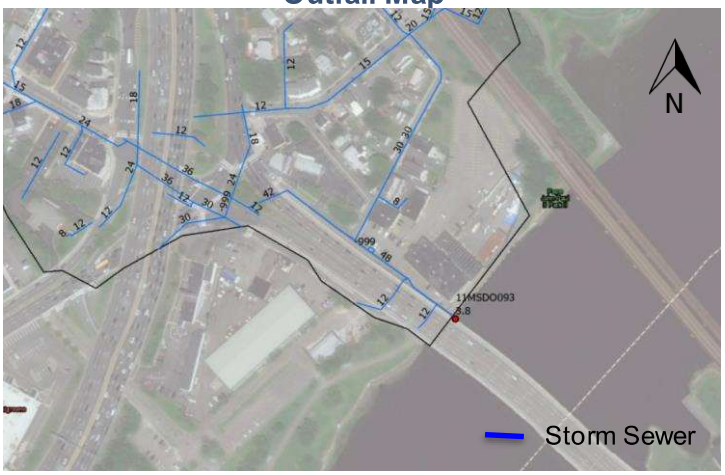
Hazen

Project Sheet #16

Site Visit Photo



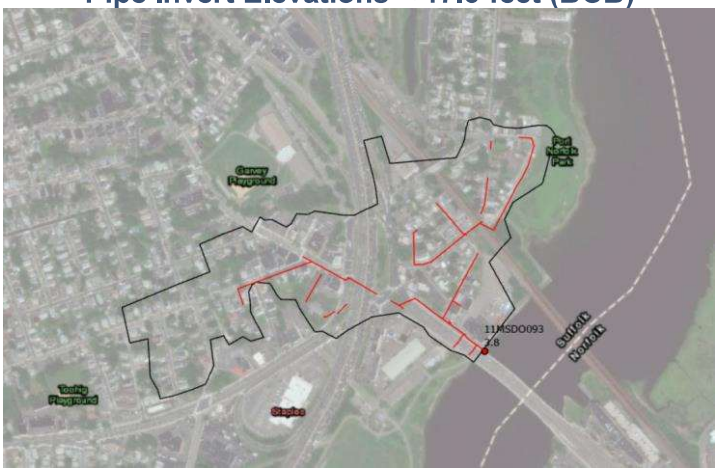
Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #17

Outfall 26LCSO009

Conceptual Design Candidate ☒

Outfall ID:	**26LCSO009**	**Outfall Size:**	**54 inches**
Neighborhood:	**East Boston**	**Outfall Shape:**	**Round**
Discharge Location:	**Boston Harbor**	**Invert Elevation (BCB):**	**2.3 feet**
Tributary Area Size:	**7 acres**	**PowerBI Ranking:**	**32**

Outfall 26LCSO009 is a combined sewer outfall located along the East Boston waterfront near LoPresti Park. This outfall serves an area with high flood and social vulnerability. In addition, this area has been identified as a priority area for near term adaptation by Climate Ready Boston. It is recommended this location be considered for advancement to the conceptual design phase.

Site Notes

- Open space available (LoPresti Park)
- High flood and social vulnerability
- Climate Ready Boston: Elevated Waterfront Parks and Plazas

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	1,415
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	0
Population	No. of People	303
Public Land	Distance in feet to public land	27
Employment	No. of Employees	41
Environmental Justice	% Population below Poverty Line	37%
Outfall Size	Dimension (inches)	54
Invert Elevation	Feet (BCB, NAVD88)	2.3, -4.2

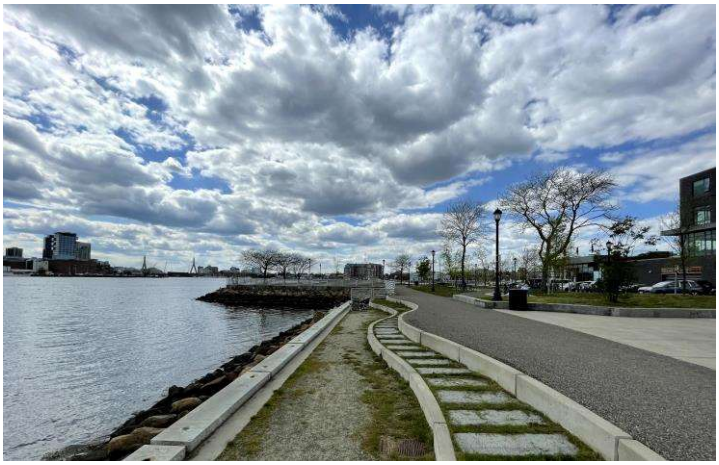
Site Selection Recommendations

- It is recommended that this site be considered for advancement to the conceptual design phase. If the outfall were unable to discharge, sewer backups could result throughout the tributary area, which has higher social vulnerability. In addition, this area has been identified as a priority area for near term adaptation by Climate Ready Boston.
- **Site Selection Rank: 15**

Hazen

Project Sheet #17

Site Visit Photo



Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #18

Outfall 27LSDO020

Conceptual Design Candidate ☒

Outfall ID:	**27LSDO020**	**Outfall Size:**	**46 inches**
Neighborhood:	**Charlestown**	**Outfall Shape:**	**Round**
Discharge Location:	**Boston Harbor**	**Invert Elevation (BCB):**	**0.4 feet**
Tributary Area Size:	**45 acres**	**PowerBI Ranking:**	**32**

Outfall 27LSDO020 is a stormwater outfall located in Charlestown. This outfall serves a flood vulnerable area, and is located in an area that may be prioritized for adaptation by Climate Ready Boston. The outfall is located beneath public park land. Coordination with Climate Ready Boston should occur if shoreline elevation or other adaptations are planned for this area. The immediate upstream pipe to this outfall is a 46-inch pipe that splits into two separate outfalls, 27LSDO020 (20-inch diameter) and 27LSDO022 (24-inch diameter).

Site Notes

- Located beneath public park area
- Upstream pipe network is low-lying and potentially flood vulnerable
- Climate Ready Boston: Ongoing Study Area

Feasible Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	3,624
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	9
Population	No. of People	1,378
Public Land	Distance in feet to public land	0
Employment	No. of Employees	2,293
Environmental Justice	% Population below Poverty Line	20%
Outfall Size	Dimension (inches)	46
Invert Elevation	Feet (BCB, NAVD88)	0.4, -6.1

Site Selection Recommendations

- This location is a lower priority candidate for advancement to conceptual design. Coordination should occur with Climate Ready Boston if shoreline elevation, or other adaptations, are planned for this area.
- **Conceptual Design Rank: 16** (with 26KSDO099)

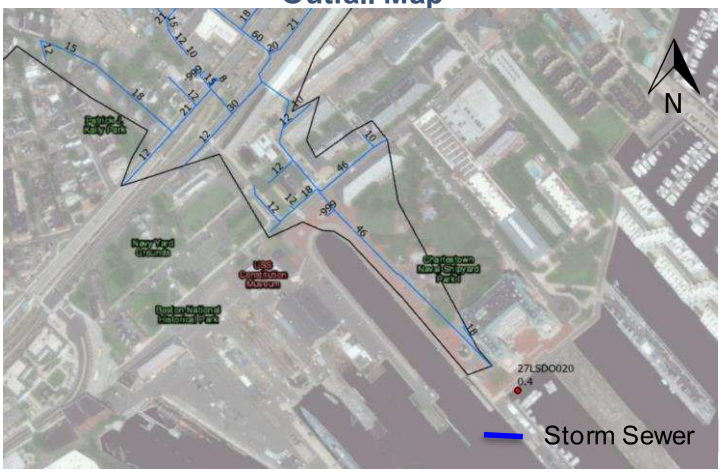
Hazen

Project Sheet #18

Site Visit Photo



Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #19

Outfall 26KSDO099

Conceptual Design Candidate ☒

Outfall ID:	**26KSDO099**	**Outfall Size:**	**84 inches**
Neighborhood:	**Charlestown**	**Outfall Shape:**	**Round**
Discharge Location:	**Boston Harbor**	**Invert Elevation (BCB):**	**-19.75 feet**
Tributary Area Size:	**84 acres**	**PowerBI Ranking:**	**18**

Outfall 26KSDO099 is a submerged outfall beneath a marina that serves a large drainage area in Charlestown. There is a large parking area upstream of the outfall with limited open space. The area upstream of this outfall has a limited number of low-lying pipes that could be vulnerable to backwater during high sea levels.

Site Notes

- Limited open space upstream of outfall in privately owned parking lot
- Large tributary area
- Limited number of low lying pipes in tributary area
- Climate Ready Boston: Ongoing Study Area

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	11,025
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	1
Population	No. of People	2000
Public Land	Distance in feet to public land	306.2
Employment	No. of Employees	2798
Environmental Justice	% Population below Poverty Line	11%
Outfall Size	Dimension (inches)	84
Invert Elevation	Feet (BCB, NAVD88)	-19.8, -26.2

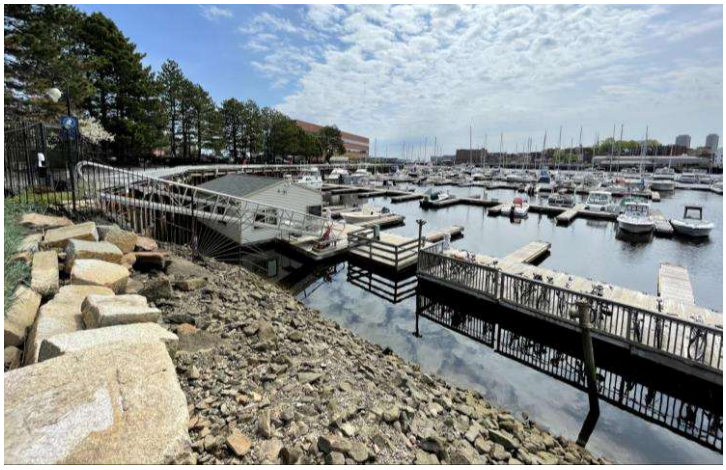
Site Selection Recommendations

- This location is a lower priority candidate for advancement to the conceptual design phase. Coordination with Climate Ready Boston should occur if shoreline elevation projects (or other adaptation measures) are planned for this area.
- **Site Selection Rank: 16** (with 27LSDO020)

Hazen

Project Sheet #19

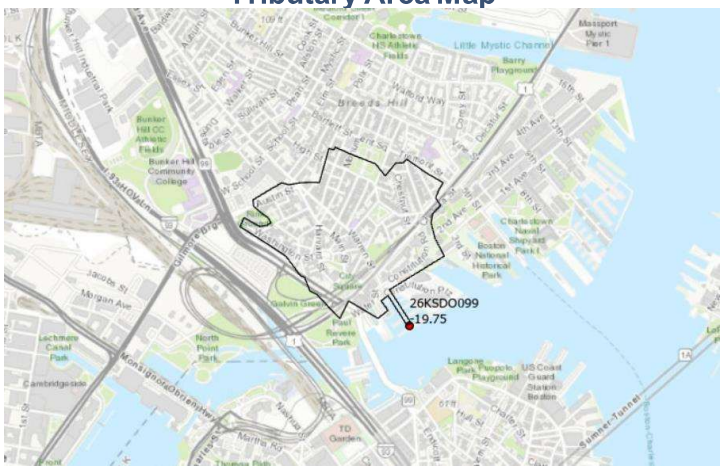
Site Visit Photo



Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #20

Outfall 28LCSO012

Conceptual Design Candidate ☒

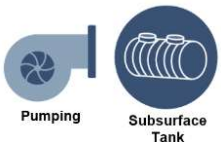
Outfall ID:	**28LCSO012**	**Outfall Size:**	**54 x 36 inches**
Neighborhood:	**East Boston**	**Outfall Shape:**	**Box**
Discharge Location:	**Boston Harbor**	**Invert Elevation (BCB):**	**4.36 feet**
Tributary Area Size:	**47 acres**	**PowerBI Ranking:**	**52**

Outfall 28LCSO012 is a combined sewer outfall located in East Boston. This outfall is in an area that has been identified as a priority for near term adapation by Climate Ready Boston. The outfall achieved a lower rank relative to other vulnerable sites. Regardless, the outfall serves an area with higher social and flood vulnerability. There is open space in close proximity to the outfall. A storm drain outfall is in close proximity to this CSO outfall, indicating that a single adaptation project could enhance both outfalls. This location could be considered for advancement to the conceptual design phase.

Site Notes

- Open space available in the vicinity of the outfall, within the school yard/grassed area
- Adjacent to outfall 28LSDO011
- Flood vulnerable area
- Climate Ready Boston: Elevated Waterfront Parks and Plazas

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	1,189
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	3
Population	No. of People	2,641
Public Land	Distance in feet to public land	641
Employment	No. of Employees	524
Environmental Justice	% Population below Poverty Line	25%
Outfall Size	Dimension (inches)	54 x 36
Invert Elevation	Feet (BCB, NAVD88)	4.4, -2.1

Site Selection Recommendations

- This outfall could be considered for advancement to the conceptual design phase. The possibility of also including storm drain outfall 28LSDO011 in a single project, and the ability to integrate with planned projects by Climate Ready Boston, indicates that this location should be incorporated into the Commission's long term adaptation strategy. However, this outfall ranked lower than some other high priority sites.
- **Conceptual Design Rank: 17**

Hazen

Project Sheet #20

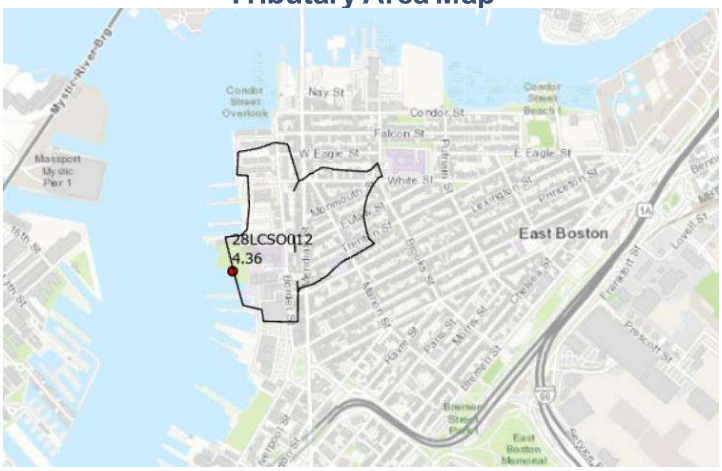
Site Visit Photo



Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #21

Outfall 29NCSO014

Conceptual Design Candidate ☒

Outfall ID:	**29NCSO014**	**Outfall Size:**	**48 x 60 inches**
Neighborhood:	**East Boston**	**Outfall Shape:**	**Egg Shaped**
Discharge Location:	**Chelsea Creek**	**Invert Elevation (BCB):**	**3.0 feet**
Tributary Area Size:	**77 acres**	**PowerBI Ranking:**	**40**

Outfall 29NCSO014 is a large combined sewer outfall that serves a flood vulnerable area in East Boston. The upstream sewer system is low lying, and the inability of the outfall to discharge could contribute to widespread sewer backups during some rain events. The outfall is located in close proximity to the Condor Street Playground, near a site on which Eversource intends to construct a new substation. Coordination with Eversource, and Climate Ready Boston, should occur if construction will occur at this location. It was not possible to directly access the outfall during the site visit.

Site Notes

- Limited open space
- Adjacent to planned Eversource substation construction site
- Upstream pipe network low-lying
- Climate Ready Boston: TBD

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	10,935
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	2
Population	No. of People	2,477
Public Land	Distance in feet to public land	502
Employment	No. of Employees	914
Environmental Justice	% Population below Poverty Line	20%
Outfall Size	Dimension	48 x 60
Invert Elevation	Feet (BCB, NAVD88)	3.0, -3.5

Site Selection Recommendations

- This outfall could be advanced to the conceptual design stage. If the planned Eversource substation construction continues to advance towards construction, coordination should occur to identify opportunities to incorporate a facility to ensure resilient discharge at this location during high sea levels.
- **Site Selection Rank: 18**

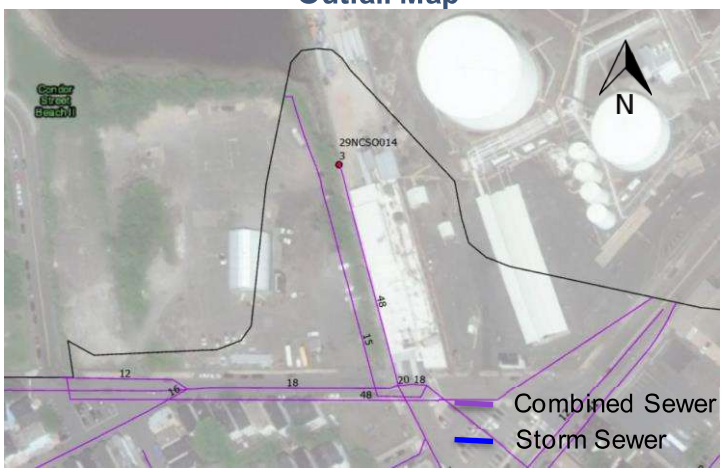
Hazen

Project Sheet #21

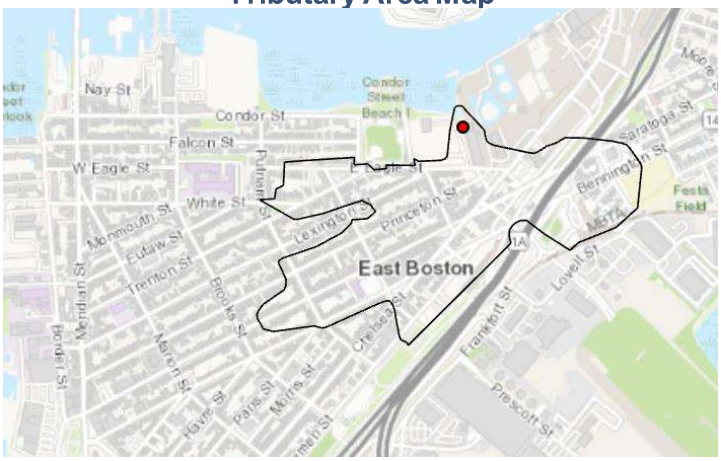
Site Visit Photo



Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #22

Outfall 28KSDO61

Conceptual Design Candidate ☒

Outfall ID:	**28KSDO61**	**Outfall Size:**	**42 inches**
Neighborhood:	**Charlestown**	**Outfall Shape:**	**Round**
Discharge Location:	**Little Mystic Channel**	**Invert Elevation (BCB):**	**1.34 feet**
Tributary Area Size:	**48 acres**	**PowerBI Ranking:**	**87**

Outfall 28KSDO61 is a storm drain outfall that serves a drainage area in Charlestown. A portion of this drainage serves the Old Iron Way Housing Development. This location could be considered for advancement to the conceptual design phase.

Site Notes

- Open space in the vicinity of the outfall
- Could be protected by a barrier or dam at the mouth of the Little Mystic Channel
- Some flood vulnerable (low-lying) pipes upstream of outfall
- Climate Ready Boston: TBD

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	0
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	3
Population	No. of People	2,323
Public Land	Distance in feet to public land	653
Employment	No. of Employees	528
Environmental Justice	% Population below Poverty Line	19%
Outfall Size	Dimension (inches)	42
Invert Elevation	Feet (BCB, NAVD88)	1.3, -5.1

Site Selection Recommendations

- This is a lower priority location that could be considered for advancement to the conceptual design phase. A barrier at the mouth of the Little Mystic Channel would protect this outfall, in addition to several other larger storm drains and combined sewer outfalls.
- **Site Selection Rank: 19**

Hazen

Project Sheet #22

Site Visit Photo



Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #23

Outfall 25NCSO004

Conceptual Design Candidate ☒

Outfall ID:	**25NCSO004**	**Outfall Size:**	**42 inches**
Neighborhood:	**East Boston**	**Outfall Shape:**	**Round**
Discharge Location:	**Boston Harbor**	**Invert Elevation (BCB):**	**2.03 feet**
Tributary Area Size:	**34 acres**	**PowerBI Ranking:**	**89**

Outfall 25NCSO004 is a combined sewer outfall located in East Boston. This is a lower priority site identified for a site visit due to its proximity to other higher priority locations. The tributary pipe network is low-lying and could be vulnerable to surcharging during high sea levels.

Site Notes

- Limited open space available in the vicinity of the outfall along the Harborwalk
- Outfall 25NSDO15 located in close proximity
- Tributary pipe network is low-lying and could be flood vulnerable
- Climate Ready Boston: TBD

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	899
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	0
Population	No. of People	192
Public Land	Distance in feet to public land	561
Employment	No. of Employees	318
Environmental Justice	% Population below Poverty Line	12%
Outfall Size	Dimension (inches)	42
Invert Elevation	Feet (BCB, NAVD88)	2.0, -4.4

Site Selection Recommendations

- This site could be advanced to the conceptual design phase as low priority site. If Climate Ready Boston develops adaptation plans in this area this outfall should be considered.
- **Site Selection Rank: 20**

Hazen

Project Sheet #23

Site Visit Photo



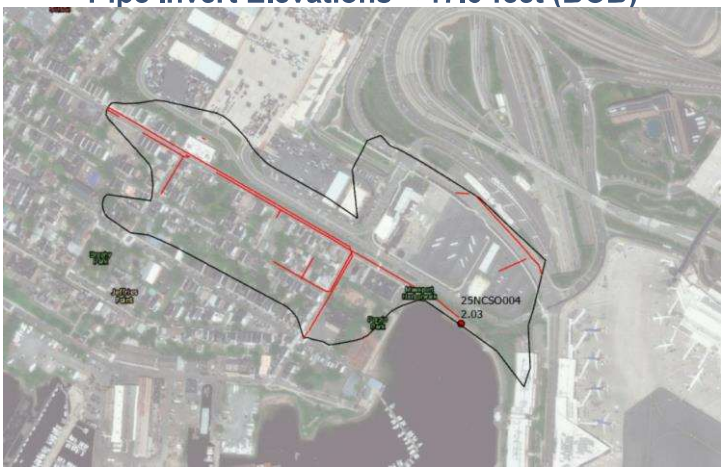
Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #24

Outfall 23HSDO042

Conceptual Design Candidate ☐

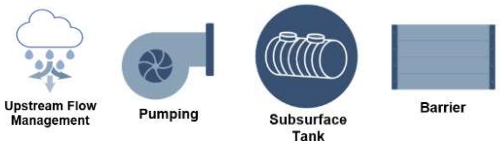
Outfall ID:	**23HSDO042**	**Outfall Size:**	**116 x 120 inches**
Neighborhood:	**Back Bay**	**Outfall Shape:**	**Box**
Discharge Location:	**Charles River**	**Invert Elevation (BCB):**	**-11.7 feet**
Tributary Area Size:	**200 acres**	**PowerBI Ranking:**	**4**

Outfall 23HSDO042 was ranked highly in the screening process due to its large tributary area size, discharge volume, flood vulnerability, and upstream characteristics. The drain system immediately upstream of the outfall is low-lying and vulnerable to surcharging due to flooding and coastal inundation. At present, the outfall is protected by the Charles River Dam. If plans to harden the dam are not developed, this outfall should be prioritized for adaptation.

Site Notes

- Currently protected by Charles River Dam
- Limited open space available in the vicinity of the outfall, on the side of the Esplanade running along Storrow Drive.
- Close proximity to outfall 23HSDO040
- Drainage system upstream of outfall is low-lying and vulnerable to SLR and surge (in the event of dam overtopping or flanking)
- Climate Ready Boston Project: None

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	6,950
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	29
Population	No. of People	8,345
Public Land	Distance in feet to public land	Close Proximity
Employment	No. of Employees	27,090
Social Vulnerability	% Population below Poverty Line	40%
Outfall Size	Dimension (inches)	116 x 120
Invert Elevation	Feet (BCB, NAVD88)	-11.7, -18.2

Site Selection Recommendation

- The outfall is upstream of the Charles River Dam. As such, this location is considered a low priority at present. If the Charles River Dam is not adapted to future conditions, this site should be prioritized for adaptation.
- **Site Selection Rank: N/A**

Hazen

Project Sheet #24

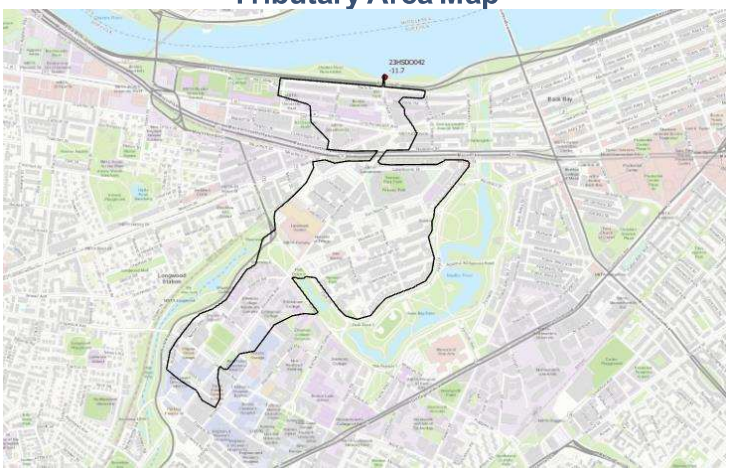
Site Visit Photo



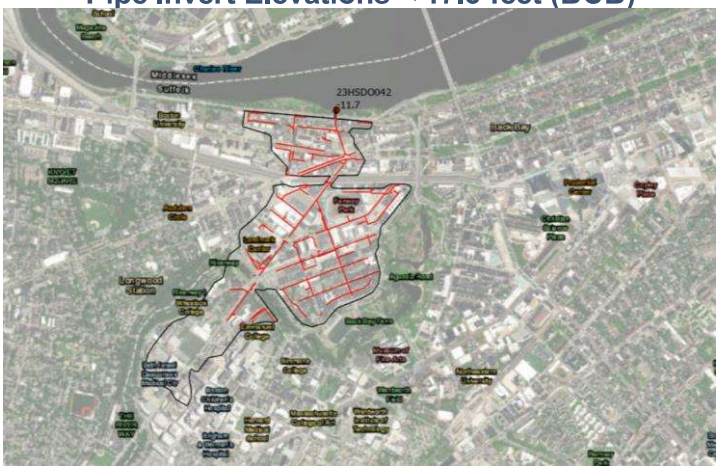
Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #25

Outfall 15LSDO088

Conceptual Design Candidate ☐

Outfall ID:	**15LSDO088**	**Outfall Size:**	**84 inches**
Neighborhood:	**Dorchester**	**Outfall Shape:**	**Round**
Discharge Location:	**Dorchester Bay Basin**	**Invert Elevation (BCB):**	**-0.29 feet**
Tributary Area Size:	**485 acres**	**PowerBI Ranking:**	**11**

Outfall 15LSDO088 is a large stormwater outfall located in Dorchester beneath the northbound lanes of the Southeast Expressway. This outfall functions as an overflow during extreme rain events in conjunction with outfall 15LSDO089. This site ranked highly due to flood vulnerability, tributary area characteristics (served by 15LSDO089), and size. Due to site constraints, conceptual design at this location would be challenging. It is recommended that near term efforts center on outfall 15LSDO089, which is typically responsible for most wet weather discharge from this tributary area. This location could be protected with a backflow prevention device or tide gate to reduce the risk of high sea levels backflowing into the pipe network. It should be noted that the outfall discharges into Dorchester Bay Basin, not directly into Dorchester Bay. If necessary, a barrier beneath Morissey Boulevard could be considered in conjunction with the roadway elevation work being evaluated by Climate Ready Boston. This could protect the outfall from high sea levels, and allow for storage of stormwater discharged from the outfall.

Site Notes

- Directly along Southeast Expressway – no open space
- Functions in conjunction with outfall 15LSDO089
- Climate Ready Boston: Elevated Roadways

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	11,330
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	11
Population	No. of People	16,279
Public Land	Distance in feet to public land	174
Employment	No. of Employees	4,236
Environmental Justice	% Population below Poverty Line	21%
Outfall Size	Dimension (inches)	84
Invert Elevation	Feet (BCB, NAVD88)	-0.3, -6.8

Site Selection Recommendations

- It is not recommended that this location be advanced to conceptual design at this time. Coordination with Climate Ready Boston should occur if adaptations are planned at this location in the future.
- **Site Selection Rank: N/A** (15LSDO089 Rank 9)

Hazen

Project Sheet #25

Site Visit Photo



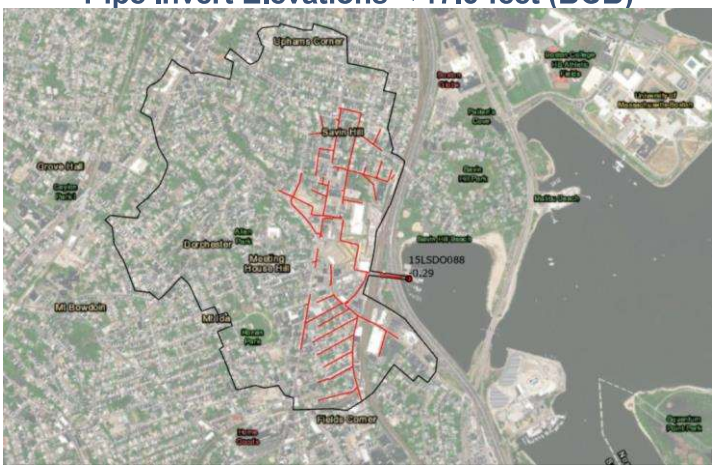
Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #26

Outfall 24LCSO060

Conceptual Design Candidate ☐

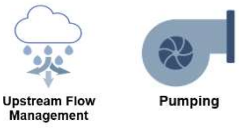
Outfall ID:	**24LCSO060**	**Outfall Size:**	**72 inches**
Neighborhood:	**Downtown**	**Outfall Shape:**	**Round**
Discharge Location:	**Boston Harbor**	**Invert Elevation (BCB):**	**-0.32 feet**
Tributary Area Size:	**72 acres**	**PowerBI Ranking:**	**14**

Outfall 24LCSO060 is a combined sewer outfall that serves the downtown Boston area. This outfall ranked highly due to its size and overall system importance. In addition, the upstream system is relatively low-lying and flood vulnerable. The outfall is located in a highly developed area near the New England Aquarium beneath the Harborwalk and Pier. At present, it is not recommended to advance this location to conceptual design due to site constraints. Coordination with the City should occur if adaptation measures are constructed in this area through Climate Ready Boston.

Site Notes

- Combined sewer runs underneath the Harborwalk and pier, adjacent to the Aquarium
- Highly developed – limited open space
- Adjacent outfalls 25LSDO058 with an 84-inch diameter and 24LSDO233 with a 42-inch diameter
- Low lying upstream system is vulnerable to high sea levels
- Climate Ready Boston Project: Raised Harborwalk, Enhanced Open Space

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	8,710
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	2
Population	No. of People	1,475
Public Land	Distance in feet to public land	Close Proximity
Employment	No. of Employees	78,611
Social Vulnerability	% Population below Poverty Line	18%
Outfall Size	Dimension (inches)	72
Invert Elevation	Feet (BCB, NAVD88)	-0.3, -6.8

Site Selection Recommendation

- At present, the feasibility of construction at this site is limited without major public disruption. If the City constructs facilities at this location as part of the Climate Ready Boston initiative, efforts should be undertaken to evaluate the feasibility of incorporating a facility for stormwater discharge.
- Conceptual designs from other more difficult locations could be replicated at this location.
- **Site Selection Rank: N/A**

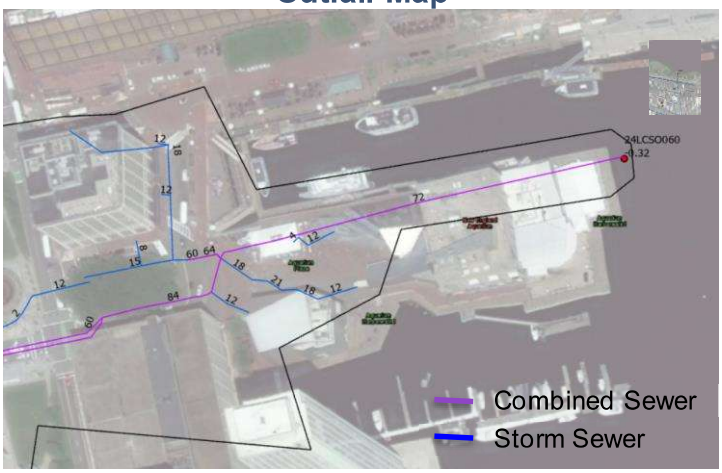
Hazen

Project Sheet #26

Site Visit Photo



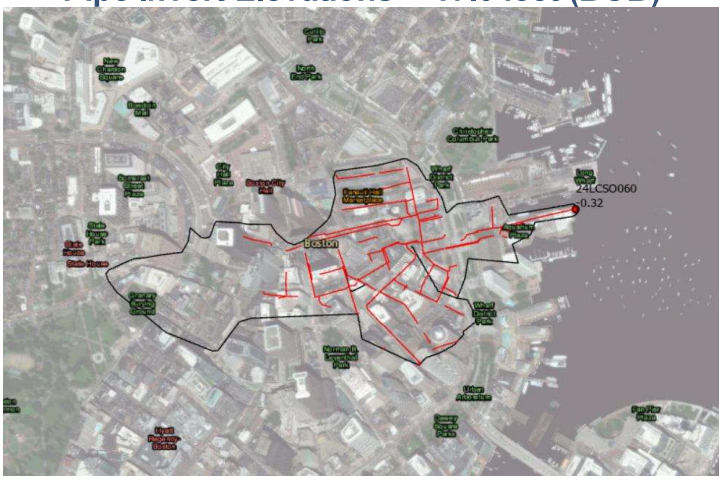
Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #27

Outfall 26JSDO049

Conceptual Design Candidate ☐

Outfall ID:	**26JSDO049**	**Outfall Size:**	**54 inches**
Neighborhood:	**West End**	**Outfall Shape:**	**Round**
Discharge Location:	**Charles River**	**Invert Elevation (BCB):**	**-0.11 feet**
Tributary Area Size:	**179 acres**	**PowerBI Ranking:**	**15**

Outfall 26JSDO049 is a large stormwater outfall located near the Nashua Street Park upstream of the Charles River Dam. This outfall serves an area with flood vulnerable low-lying pipes in the West End area. At present, this outfall is protected by the Charles River Dam. As such, it is not recommended that this location be advanced to conceptual design at this time. However, this outfall has high overall system importance, and provides drainage for a large area of Downtown Boston. If enhancements are not planned to harden the Charles River Dam, this location should be prioritized for adaptation.

Site Notes

- Open area (park)
- Adjacent to outfall 26KSDO050
- Currently protected by the Charles River Dam
- Climate Ready Boston: Raised Harborwalk, Enhanced Open Space, and Outboard Options

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	21,720
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	14
Population	No. of People	7,435
Public Land	Distance in feet to public land	311
Employment	No. of Employees	52,115
Environmental Justice	% Population below Poverty Line	15%
Outfall Size	Dimension (inches)	54
Invert Elevation	Feet (BCB, NAVD88)	-0.1, -6.6

Site Selection Recommendations

- It is not recommended to advance this location to the conceptual design phase at this time as the outfall is currently protected by the Charles River Dam. If an adaption project is not planned to harden the dam as sea level rise continues to increase the risk of dam overtopping and flanking, this outfall should be prioritized for enhancements.
- **Site Selection Rank: N/A**

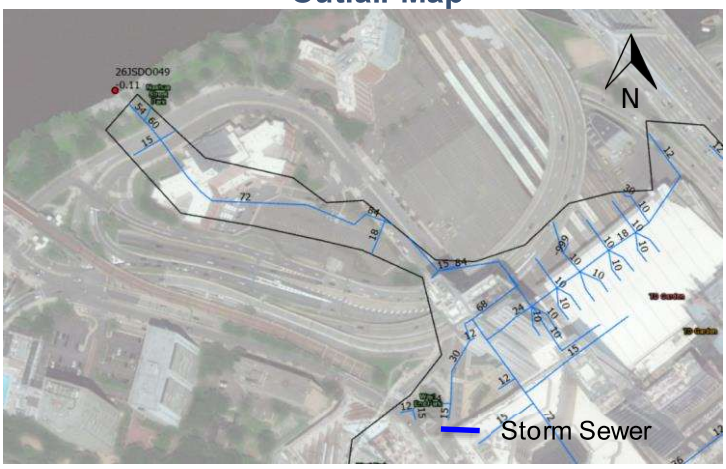
Hazen

Project Sheet #27

Site Visit Photo



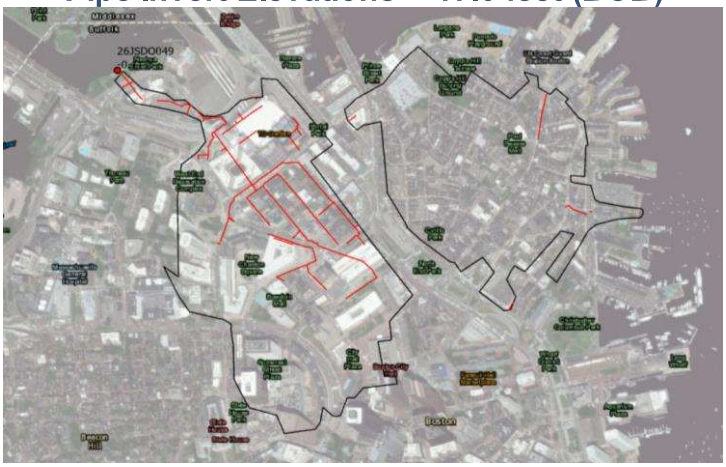
Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #28

Outfall 26LSDO084

Conceptual Design Candidate ☐

Outfall ID:	**26LSDO084**	**Outfall Size:**	**24 inches**
Neighborhood:	**East Boston**	**Outfall Shape:**	**Round**
Discharge Location:	**Boston Harbor**	**Invert Elevation (BCB):**	**5.9 feet**
Tributary Area Size:	**2 acres**	**PowerBI Ranking:**	**50**

Outfall 26LSDO084 is a small stormwater outfall located in East Boston. This location was identified for a site visit due to its close proximity to other higher priority outfalls. It is not recommended that this site be advanced to the conceptual design phase at this time. It should be noted that this outfall should be considered if shoreline elevation, or another adaptation, is planned along East Pier Drive to alleviate flooding during high sea levels along East Pier Drive and Lewis Street.

Site Notes

- Located along East Boston waterfront and Lewis Mall Harbor Park
- Small tributary area with low-lying pipe; backflow through this outfall could contribute to flooding on Lewis Street during high sea level
- Climate Ready Boston: Elevated Waterfront Parks and Plazas

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	0
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	0
Population	No. of People	77
Public Land	Distance in feet to public land	16
Employment	No. of Employees	10
Environmental Justice	% Population below Poverty Line	25%
Outfall Size	Dimension (inches)	24
Invert Elevation	Feet (BCB, NAVD88)	5.9, -0.6

Site Selection Recommendations

- At present, this is a lower priority location not recommended for advancement into the conceptual design phase. It should be noted that backflow through this outfall could contribute to street flooding along Lewis Street and East Pier Drive. If Climate Ready Boston implements a shoreline elevation project in this area, this outfall should be evaluated to further alleviate street flooding.
- **Site Selection Rank: N/A**

Hazen

Project Sheet #28

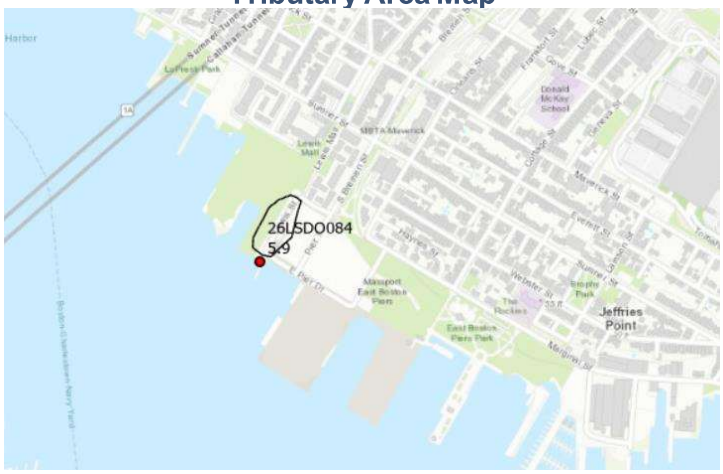
Site Visit Photo



Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #29

Outfall 31PSDO84

Conceptual Design Candidate ☐

Outfall ID:	**31PSDO84**	**Outfall Size:**	**30 inches**
Neighborhood:	**East Boston**	**Outfall Shape:**	**Round**
Discharge Location:	**Belle Isle Marsh**	**Invert Elevation (BCB):**	**6.1 feet**
Tributary Area Size:	**10 acres**	**PowerBI Ranking:**	**55**

Outfall 31PSDO84 is located near the border of Boston and Revere. This outfall was identified for a site visit given its proximity Suffolk Downs and other possible planned adaptations. Regardless, the outfall itself achieved a low rank. The outfall itself appears to be located in Revere. It is not recommended that this location be advanced to the conceptual design phase at this time.

Site Notes
- Outfall structure appears to be located in Reverse
- Adjacent to outfalls 30PSDO107 and 30PSDO62
- Lower flood vulnerability
- Climate Ready Boston: Ongoing Study Area

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	2,143
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	0
Population	No. of People	73
Public Land	Distance in feet to public land	27
Employment	No. of Employees	240
Environmental Justice	% Population below Poverty Line	21%
Outfall Size	Dimension (inches)	30
Invert Elevation	Feet (BCB, NAVD88)	6.1, -0.4

Site Selection Recommendations

- It is not recommended that this site be advanced to the conceptual design phase at this time. If adaptations are implemented by Climate Ready Boston in the Suffolk Downs area, this outfall could be considered for coordination.
- **Site Selection Rank: N/A**

Hazen

Project Sheet #29

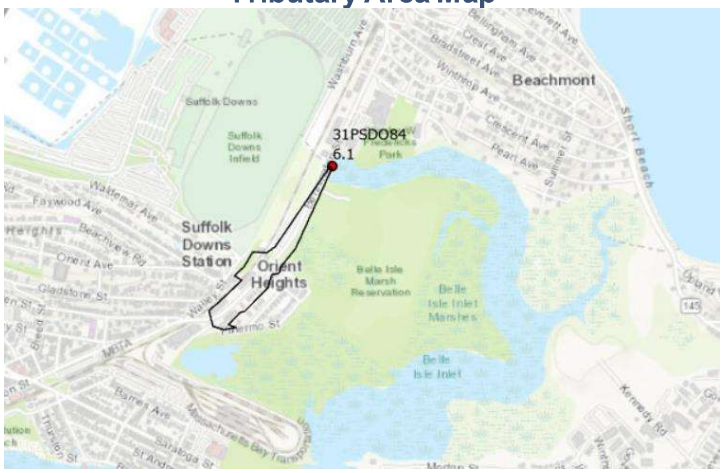
Site Visit Photo



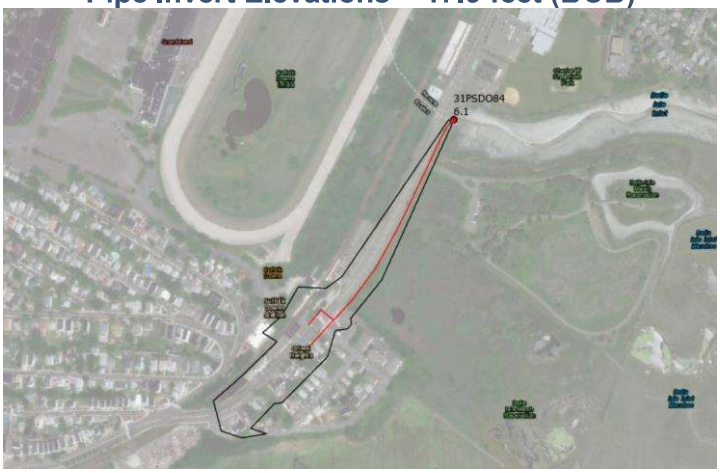
Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #30

Outfall 29NSDO135

Conceptual Design Candidate ☐

Outfall ID:	**29NSDO135**	**Outfall Size:**	**30 x 30 inches**
Neighborhood:	**East Boston**	**Outfall Shape:**	**Box**
Discharge Location:	**Chelsea Creek**	**Invert Elevation (BCB):**	**8.45 feet**
Tributary Area Size:	**16 acres**	**PowerBI Ranking:**	**71**

Outfall 29NSDO135 is a small stormwater outfall that discharges to Chelsea Creek in East Boston. This site was identified for a site visit due to its proximity to other higher priority outfalls. At present, this location is low priority and is not recommended for advancement into the conceptual design phase.

Site Notes
- Limited open space (parking area)
- Small upstream area with low-lying pipes that could be impacted by high sea levels
- Climate Ready Boston: TBD

Potential Conceptual Design Strategies



Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	226
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	0
Population	No. of People	402
Public Land	Distance in feet to public land	534
Employment	No. of Employees	211
Environmental Justice	% Population below Poverty Line	20%
Outfall Size	Dimension (inches)	30 x 30
Invert Elevation	Feet (BCB, NAVD88)	8.5, 2.0

Site Selection Recommendations

- It is not recommended that this site be advanced to the conceptual design phase at this time. If other adaptations in this area are planned by Climate Ready Boston, it should be noted that this outfall could experience backflow during high sea levels and contribute to street level flooding.
- **Site Selection Rank: N/A**

Hazen

Project Sheet #30

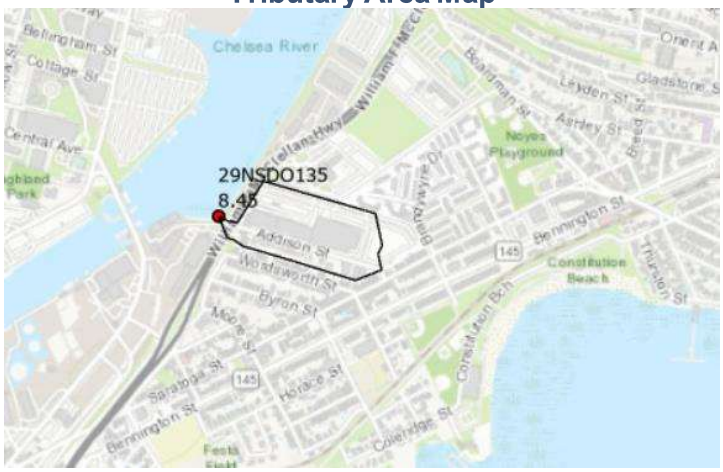
Site Visit Photo



Outfall Map



Tributary Area Map



Pipe Invert Elevations < 17.6 feet (BCB)



Hazen

Project Sheet #31

Outfall 25MCSO005

Conceptual Design Candidate ☐

Outfall ID:	**25MCSO005**	**Outfall Size:**	**24 x 27 inches**
Neighborhood:	**East Boston**	**Outfall Shape:**	**Modified Circle**
Discharge Location:	**Boston Harbor**	**Invert Elevation (BCB):**	**7.2 feet**
Tributary Area Size:	**10 acres**	**PowerBI Ranking:**	**89**

Outfall 25MCSO005 is low priority CSO outfall in East Boston identified for a site visit due to its proximity to other sites. The upstream pipe network has limited flood vulnerability. This site is not recommended for advancement to the conceptual design phase.

Site Notes
- Open space is available within the southern portion of Porzio Park.
- Limited flood vulnerability
- Climate Ready Boston: Elevated Waterfront Parks and Plazas

Potential Conceptual Design Strategies

N/A

Key Tributary Area Characteristics		
Criteria	**Description**	**Amount**
Transportation	Linear Feet of Evacuation roadways and MBTA Rails	0
Critical Facilities	No. of Facilities from BWSC "Contact List of Centers"	0
Population	No. of People	14
Public Land	Distance in feet to public land	113
Employment	No. of Employees	210
Environmental Justice	% Population below Poverty Line	14%
Outfall Size	Dimension (inches)	24 x 27
Invert Elevation	Feet (BCB, NAVD88)	7.2, 0.7

Site Selection Recommendations

- It is not recommended that this site be advanced to the conceptual design phase due to limited vulnerability. If future sea level rise projections increase, this site could be re-evaluated.
- **Site Selection Rank: N/A**

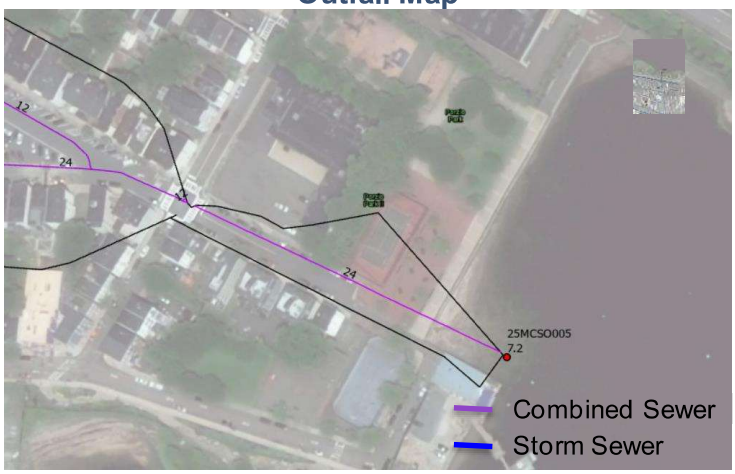
Hazen

Project Sheet #31

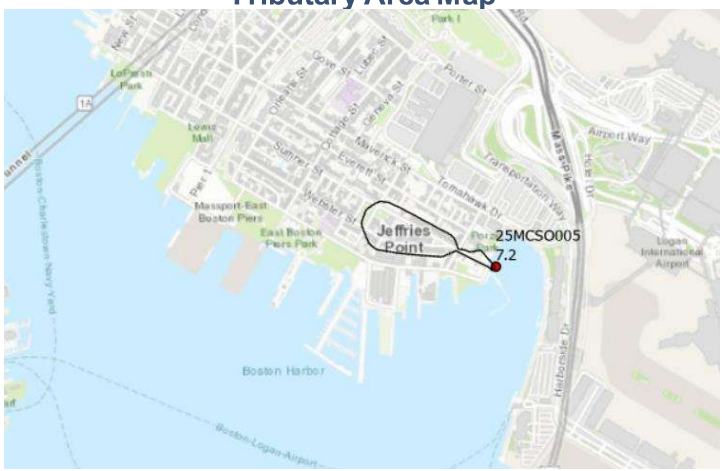
Site Visit Photo



Outfall Map



Tributary Area Map

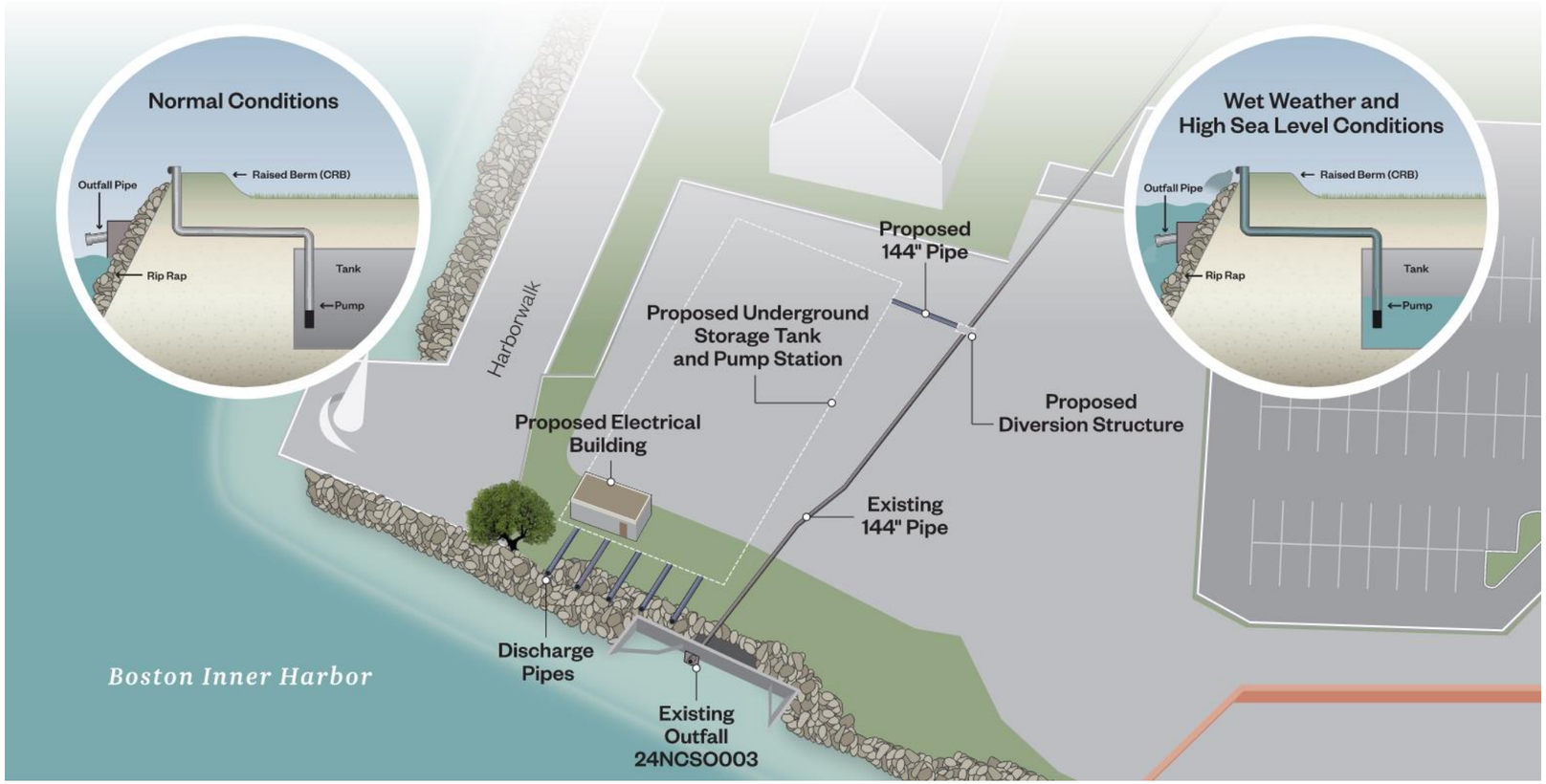


Pipe Invert Elevations < 17.6 feet (BCB)



Appendix G: Concept Design Packages

Airport Pump Station *Concept Overview*





Conceptual Solution

The conceptual solution herein includes a stormwater storage (peak flow shaving) tank and pump station to discharge excess wet weather flow when tide levels are high. The tank and pump station are located at the southwest corner of Boston Logan Airport. If a high tide level begins to reduce the ability of existing outfall 24NCSO003 to discharge by gravity, the existing storm sewer will begin to surcharge. A diversion structure with a static weir directs excess flow from the existing sewer to the storage tank. The storage tank is connected directly to the pump station. The pump station includes four duty and one standby pump. The pump station utilizes electric submersible pumps to minimize the above ground footprint of the station and mitigate negative visual and auditory impacts from diesel engine driven pumps. Each pump is designed with a formed suction inlet and non-manifolded discharge (each pump discharges separately). An additional stormwater outfall owned by the Massachusetts Port Authority (Massport) is located near the existing BWSC owned outfall; the feasibility of adding this outfall to the concept could be evaluated in the future.

Type: Storage and Pumping

Total Drainage Area: 625 acres

Coastal Flood Vulnerable Drainage Area Protected: 598 acres

Concept Elements:

- Subsurface Pump Station
- Subsurface Storage Tank
- Diversion Structure

Outfalls Included in Concept:

- 24NCSO003

Coastal Stormwater Discharge Analysis
Airport Pump Station

Boston Water and Sewer Commission | Hazen

Sheet 1 of 10 | November 2022

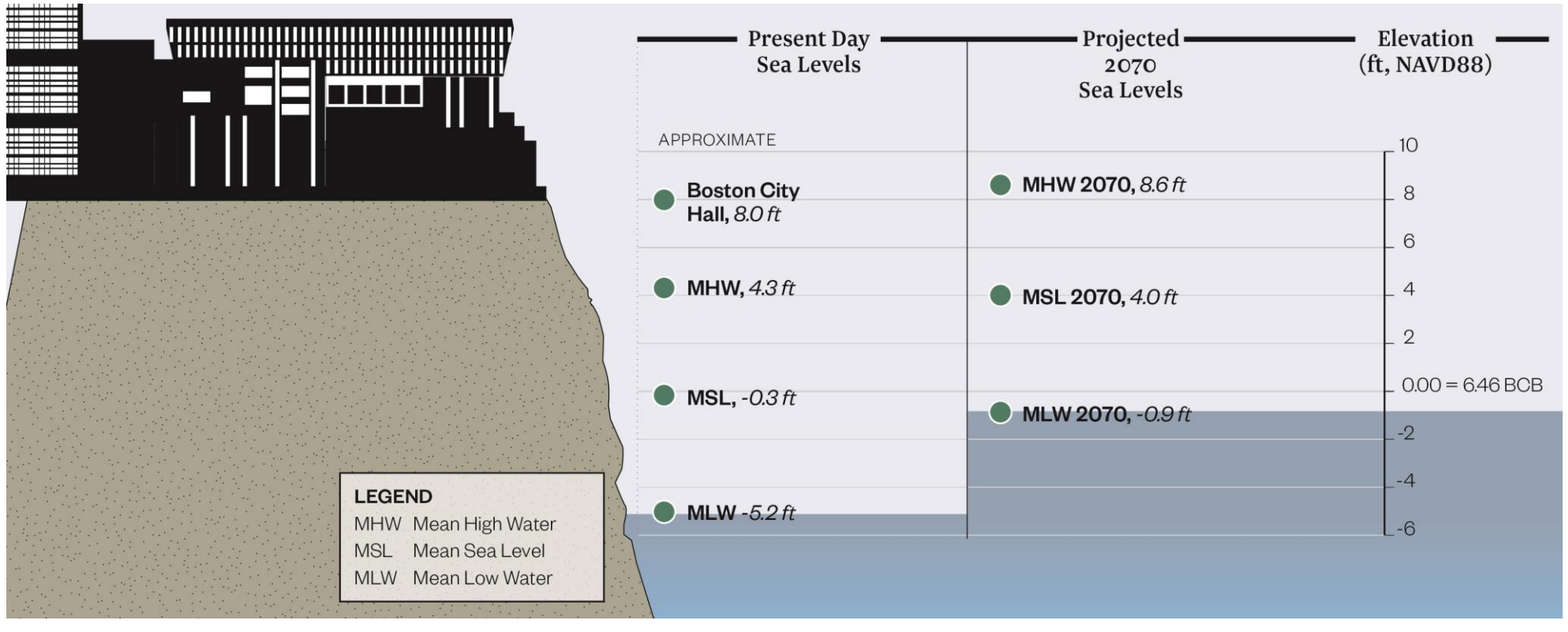
Assumptions

Sea Level Rise and Datum

The Airport Pump Station concept was designed for consistency with Climate Ready Boston (CRB) proposed adaptations and analyzed based on sea level rise (SLR) projections in the Massachusetts Coastal Flood Risk Model (MC-FRM). The SLR values applied in MC-FRM are consistent with the standards for the State of Massachusetts developed by Coastal Zone Management. The MC-FRM utilizes a "High" SLR scenario. This scenario is based on the relative SLR projections under Relative Concentration Pathway (RCP) 8.5 (a "worst case scenario" of increasing atmospheric carbon concentrations) and represents elevations that have a 99.5% probability of not being exceeded within the respective timeframes. In 2030, that amounts to an increase of 1.3 feet in Boston from a baseline condition (2008 centered tidal epoch), and in 2070 that amounts to an increase of 4.3 feet.

The concept developed in this project was analyzed using coastal conditions that include 2070 projected SLR and storm surge resulting from a 100-year tropical storm. The peak water surface elevation (WSE) predicted by the MC-FRM during these conditions is approximately 13.8 feet NAVD88 (varies by location). In mid 2022, the Greater Boston Research Advisory Group (BRAG) issued an updated report with new SLR projections. The report acknowledges that long term SLR projections are associated with significant uncertainty, and that updated projections include less SLR by 2100 (compared to earlier projections in the 2015 BRAG report.) According to the report, the likely range of SLR by 2070 under an RCP 8.5 scenario is 1.4 – 2.8 feet. Based on this information, projections from the MC-FRM that were utilized in this project are conservative and appropriate for long term planning purposes.

Unless otherwise noted, all elevations are based on the NAVD88 vertical datum. Elevations given in NAVD88 can be converted to Boston City Base (BCB) elevation by adding 6.46 feet.



Climate Ready Boston and Shoreline Protection

The Airport Pump Station concept was developed to maintain consistency with possible Climate Ready Boston (CRB) adaptations based on the latest available information at the time they were developed. As the CRB program continues to evolve, it is anticipated that proposed concepts will need to be adapted.

The concept was developed to be consistent with stated neighborhood design flood elevations. In East Boston, where the stated design flood elevation is 16.0 feet, pumps were designed to discharge to a minimum elevation of 16.0 feet.

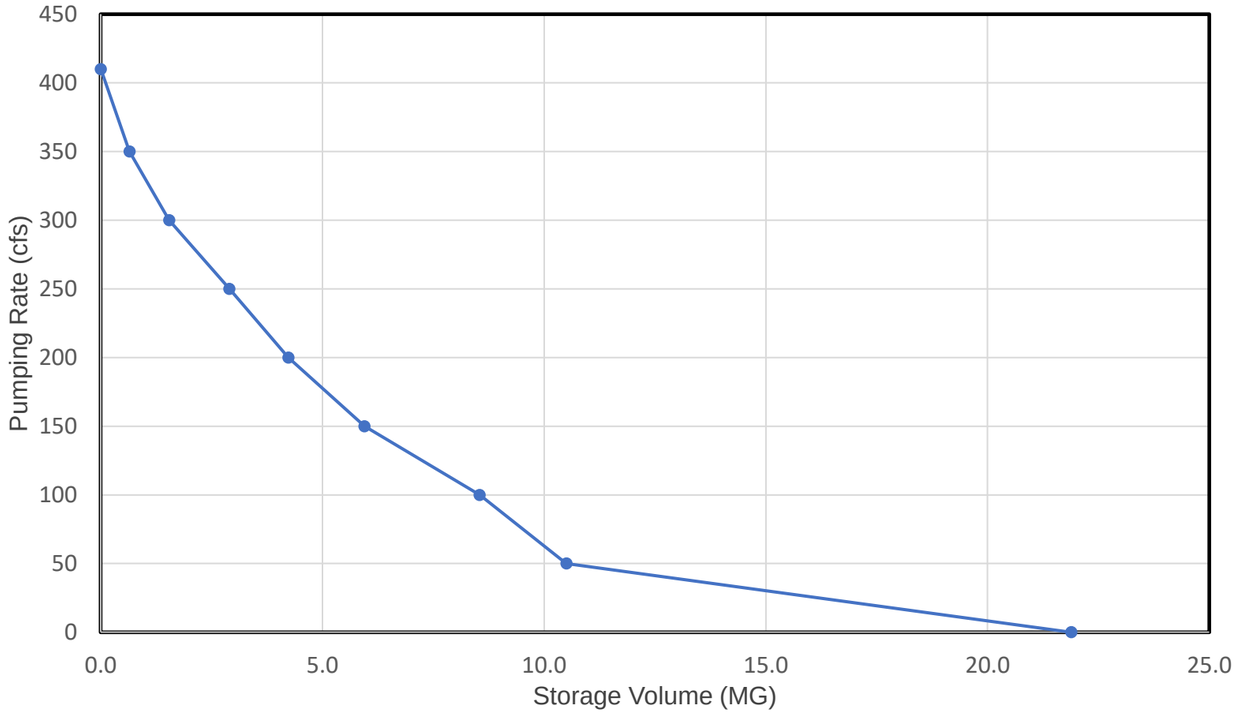
At the time of this project, many CRB concepts were in early planning stages and not fully defined. **In consideration of this, it was assumed the shoreline protection around the City of Boston is 100% effective for all modeling evaluations.** This assumption eliminates overland coastal flooding from model predictions, allowing for isolation of flooding that results only from rainfall and stormwater that cannot be discharged due to high sea levels. It is important to recognize that additional flooding, beyond what is depicted herein, would be expected if 100% effective shoreline protection is not implemented.

Basis of Design

Storage and Pumping

Model simulations were conducted to determine the maximum Hydraulic Grade Line (HGL) that occurs at Outfall 24NCSO003 with the current tide cycle. Analyses were then conducted to determine the acceptable combinations of storage volume and pumping rate required to maintain the existing HGL with 2070 projected sea level rise and 100-year storm surge, as shown in Figure 1. The City of Boston's Parcel database was used to identify publicly owned parcels near the existing outfall. An analysis of the pump station was performed to identify a pump rate and physical dimensions that are hydraulically viable. It was found that a 1.2 MG storage tank ~26 feet deep could fit within the property with a 320 CFS pump station. The pump station and storage tank occupy an area of 8,750 ft^2. The Airport pump station utilizes four duty pumps, one standby pump, and two dewatering pumps. The pump station is configured with vertical, axial electric submersible pumps in parallel bays. The pumps are configured to discharge into individual, non-manifolded force mains, which travel horizontally underground from the pump station to the proposed elevated shoreline project (TBD by CRB), at which point they discharge into the harbor onto an energy dissipation structure.

Figure 1: Pumping vs. Storage



Rainfall and Coastal Conditions

The Commission currently utilizes a 10-year, 24-hour design storm to establish its target level of service. For the purpose of sizing new piping and evaluating storage capacity, a projected 2070 10-year, 24-hour design storm was developed. For consistency with Climate Ready Boston, performance of the Airport pump station concept was also evaluated with projected rainfall from a 100-year tropical event (developed during the Commission's Inundation Model Project. The Airport pump station was evaluated using a 100-year return period coastal boundary condition. Data for this condition were obtained from the MC-FRM. For the purpose of evaluating the effectiveness of the concept, it was further assumed that complete shoreline protection was implemented, preventing flow of water between the Airport pump station tributary area and Boston Harbor. Table 2 contains a summary of the coastal conditions that were analyzed.

Table 1: Rainfall Conditions

Scenario	Purpose	Rainfall Depth (in)	Peak Intensity (in/hr)
Present Day 10-year, 24-hr design storm	Baseline Conditions	5.15	3.32
Projected 2070 10-year, 24-hr design storm	Design Conditions	6.18	4.08
100-year Tropical Storm	Damage Analysis	9.58	0.84

Table 2: Coastal Conditions

Scenario	Purpose	Peak Water Surface Elevation (ft, NAVD88)	Source
Present Day	Baseline Conditions	3.7	BWSC Existing Model (April 2016 Tide Cycle)
2070,100-year Tropical Storm	Damage Analysis	13.8	MC-FRM

Conceptual Design – Not for Construction

Flood Modeling and Damage Analysis

Figure 2: Estimated Replacement Cost

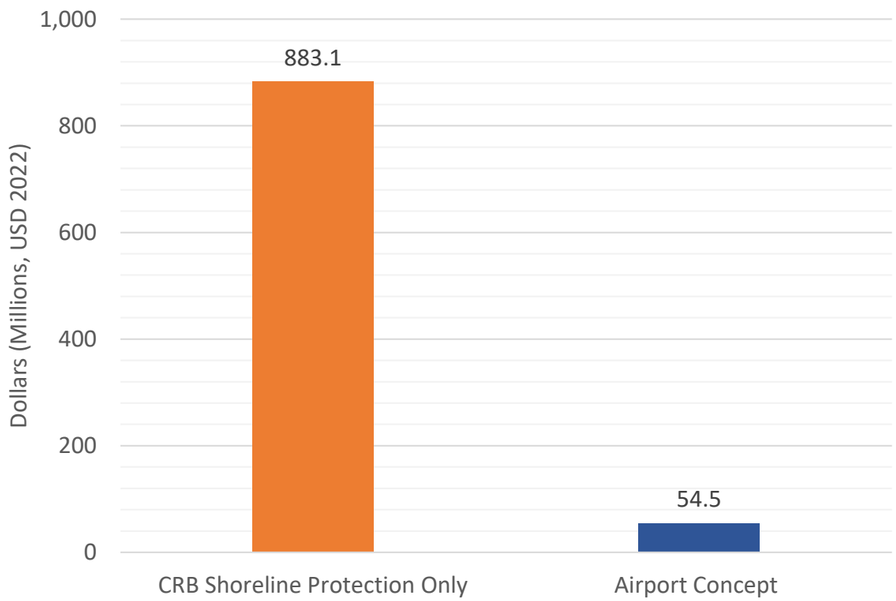


Figure 3: Loss of GDP

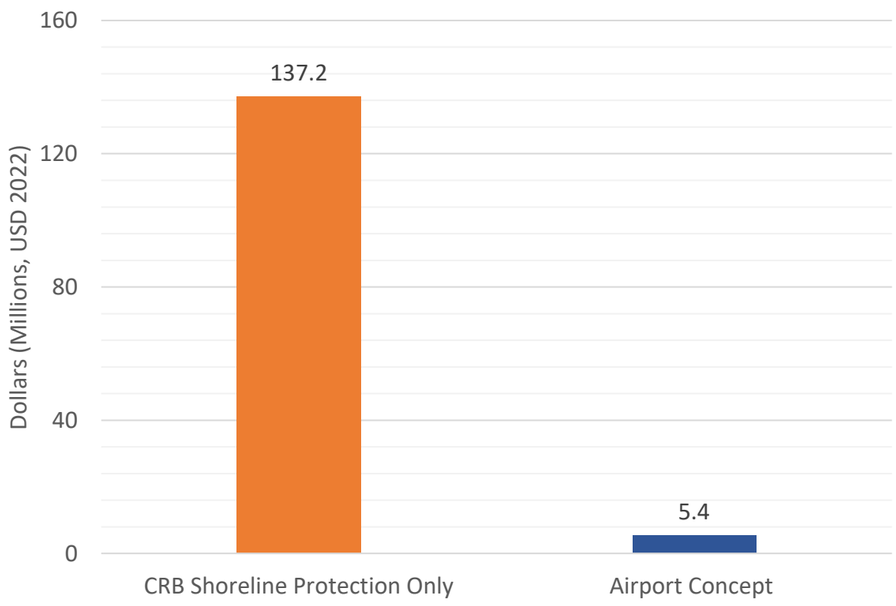
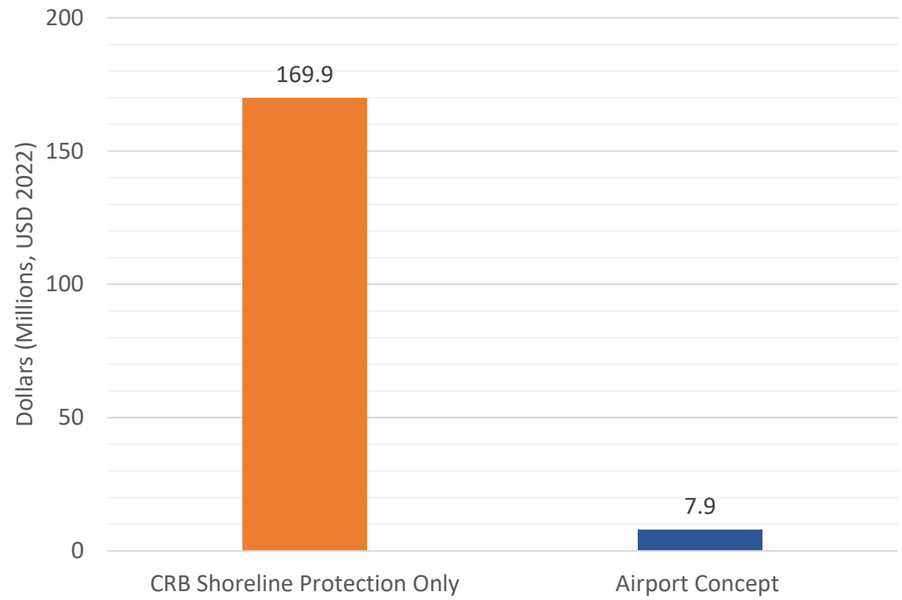


Figure 4: Physical Damage



The flood reduction benefits of the Airport Pump Station concept were evaluated using the Commission's 2D Inundation Model by simulating a 100-year tropical storm event with 2070 SLR and storm surge. The figures on the following page depict the peak flooding that was predicted in the Airport Pump Station drainage area with shoreline protection only and with the pump station and tide gates on all vulnerable BWSC owned outfalls. An analysis of economic losses/physical impacts from flooding under both scenarios was performed by risQ Inc.

Model predictions indicate that the Airport Pump Station concept reduces physical damage by **$162.0 million**, avoids **$828.6 million** in rebuilding costs, and mitigates a GPD loss of **$131.8 million** during a 100-year tropical storm event in 2070.

Note: replacement values include the total value of impacted buildings in flooded areas (e.g., impacted buildings are fully replaced), whereas physical damage includes estimated costs to repair flood damage based on predicted flood depths and building characteristics. The values shown are the average of minimum and maximum calculated losses. Refer to the Project's Final Report for more information.

Conceptual Design – Not for Construction



2070 SLR + 100yr Tropical Storm + Storm Surge

Shoreline Protection Only



2070 SLR + 100yr Tropical Storm + Storm Surge

Airport Pump Station and Tide Gates

Legend

- Flood Depth > 4 in and < 1 ft
- Flood Depth > 1 ft and < 2 ft
- Flood Depth > 2 ft
- Drainage Area Analyzed

Simulation Parameters

Storm Type	100yr Tropical Storm
Rainfall Depth	9.6 inches
Peak WSE 2070 SLR + 100yr Surge	13.8 feet NAVD88

Coastal Stormwater Discharge Analysis
Airport Pump Station

Boston Water and Sewer Commission

Hazen

November 2022

Damage Analysis

Capital Cost Estimate

A construction cost estimate for the Airport Pump Station concept was developed for planning purposes. Assumptions for the cost estimate include 15-year escalation to the mid-point of construction and the inclusion of a 50% design contingency. Utility hookup costs were not included.

Table 3: Airport Pump Station Cost Estimate Subtotals

Remaining Design Development & Construction Administration (*assumed 20% of total less design contingency*)	$3,666,000
Direct Construction Costs	$7,236,248
Indirect Construction Costs	$1,447,250
Mark-Up *(Including 50% design contingency)*	$18,479,502
Total	**$30,829,000**

Social Vulnerability and FEMA BRIC Funding

FEMA BRIC funding prioritizes disadvantaged communities. Table 4 contains a summary of several indicators for the Airport tributary area that could be used help characterize the community for future FEMA funding applications and prioritization of projects that benefit disadvantaged communities.

Table 4: Airport Tributary Area Social Vulnerability Indicators

Low Income & Persistent Poverty	
Per Capita Income	$32,827
Below Poverty Line	12%
High Housing Cost Burden	
Stressed Renters (>40% rent-to-income)	33%
Households With Food Insecurity	14%
Racial and Ethnic Segregation	
Asian Population	3%
Black Population	3%
Hispanic Population	63%
White Population	53%
Education and Employment	
Adults Age 25+ Without High School (or equivalent) Degree	29%
Unemployment Rate (Age 16+)	6%

Data provided by risQ inc. from the US census and American Community Survey

Planting Palette

A planting palette was developed for the Airport concept. The planting palette can be applied to the greenspace surrounding the proposed airport electrical building and discharge pipes. After construction, planting of native plant species could help conceal concept utilities from the public and provide environmental benefits associated with native species.

Trees



Amelanchier arborea
common serviceberry



Juniperus virginiana
eastern red cedar



Magnolia virginiana
sweet bay magnolia



Quercus rubra
northern red oak

Shrubs



Rosa carolina
pasture rose



Rhus copallinum
winged sumac



Aronia melanocarpa
black chokeberry



Morella pensylvanica
bayberry

Herbaceous and Grasses



Panicum virgatum
switchgrass



Schizacharium scoparium
little bluestem



Eutrochium purpureum
Joe-Pye-Weed



Solidago sempervirens
seaside goldenrod

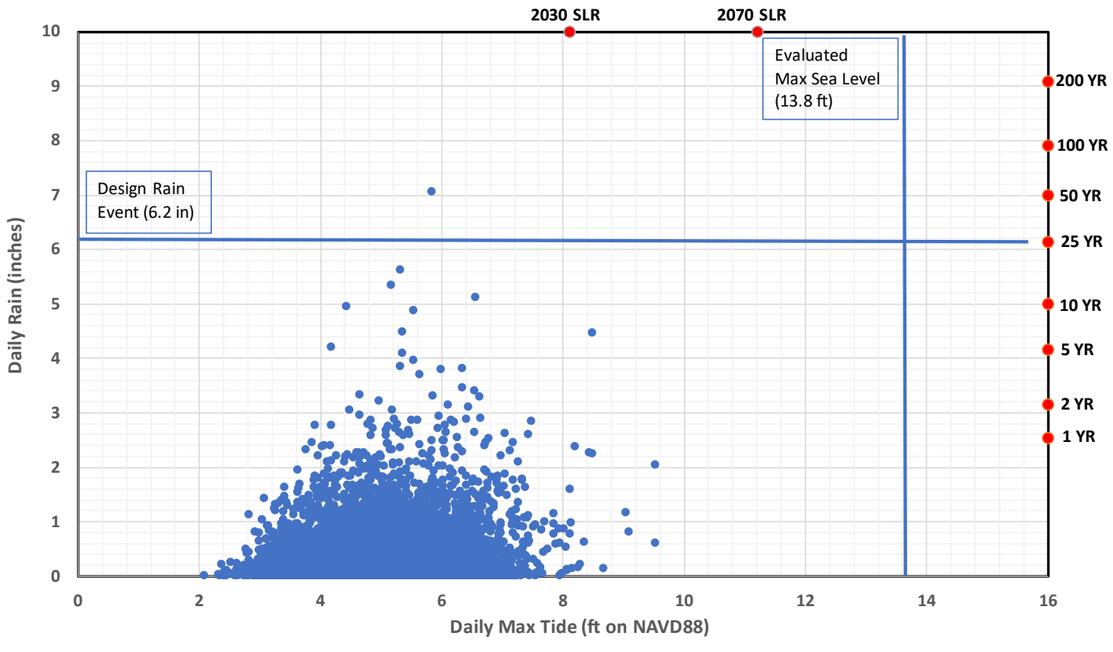
Adaptability and Implementation

Adaptability

Figure 5 below depicts historical daily rainfall totals and tide levels. As shown in this figure, the conditions that were used to design and analyze and design the Airport pump station are conservative and represent more extreme conditions than have occurred historically. Regardless, the following measures could be implemented to adapt the concept to more severe conditions (additional SLR, more intense rainfall, etc.) in the future:

- Increase the size of installed electric submersible pumps.
- Utilize the standby pump as a duty pump during extreme conditions.
- Increase the size of the peak shaving tank.
- Consider construction of a larger storage and pump facility at the large privately owned parking lot nearby.
- Increase the size of the concept to manage wet weather flow from the adjacent outfall owned by Massport.

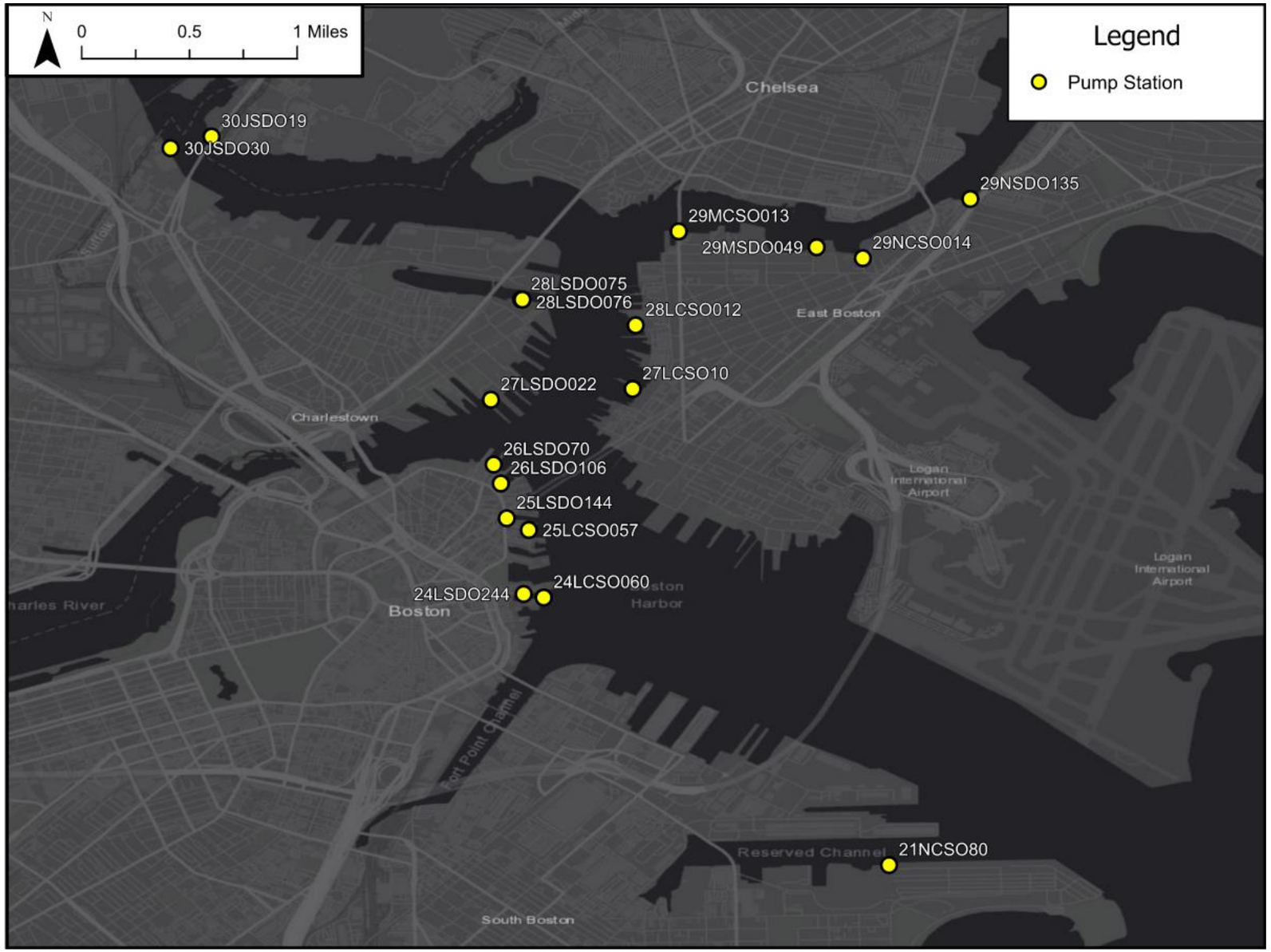
Figure 5: Design and Analysis Conditions vs. Historical Tide and Rainfall



Implementation Considerations

- Coordination with CRB is necessary to implement shoreline protection. The pump station should not be implemented without shoreline protection to prevent coastal flooding within the area tributary to it. The discharge structure may need to be modified depending on the exact nature of the shoreline protection chosen by CRB.
- Community engagement with stakeholders may help build project support by documenting the need for the storage tank and pump station.
- A comprehensive permitting evaluation should be conducted to evaluate possible impacts from construction and operation of the pump station to the receiving water.
- The Airport Pump Station currently serves a CSO outfall. It is the Commission's intention to separate the drainage area and use the outfall for stormwater flow in the future. The size and pump capacity of the facility should be re-evaluated to consider sewer separation in the future.
- Coordination with Massport would be necessary to construct the pump station. The concept could be modified to manage wet weather flow from the adjacent outfall owned by Massport.
- The existing outfall receives flow from a large 144" conduit. Analyses should be conducted to determine if this conduit has excess capacity after planned sewer separation projects are completed. If it is found that there is additional capacity, other storm drains that are connected to coastal flood vulnerable outfalls could be diverted to Outfall 24NCSO003 and the Airport Pump Station.

Replicability and Implementation Timeline



Summary of Similar Concepts

Number of Sites: 18

Vulnerable Area: 422 acres

The map on this sheet depicts other vulnerable outfalls that could be adapted with electric submersible pump stations. In some locations, several outfalls could be consolidated with a new conduit that conveys flow to a single pump station.

Additional detail about these outfalls can be found in the Commission's Coastal Stormwater Discharge Analysis Implementation Timeline.

ATTACHMENT A
AIRPORT PUMP STATION CONCEPTUAL DESIGN DRAWINGS

A-1: Overview Plan and Pump Station Plan
A-2: Pump Station Section View

Coastal Stormwater Discharge Analysis
Airport Pump Station

Boston Water and Sewer Commission

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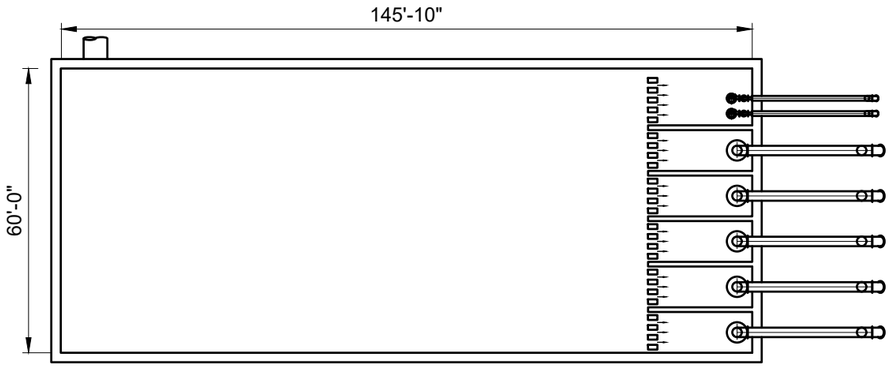
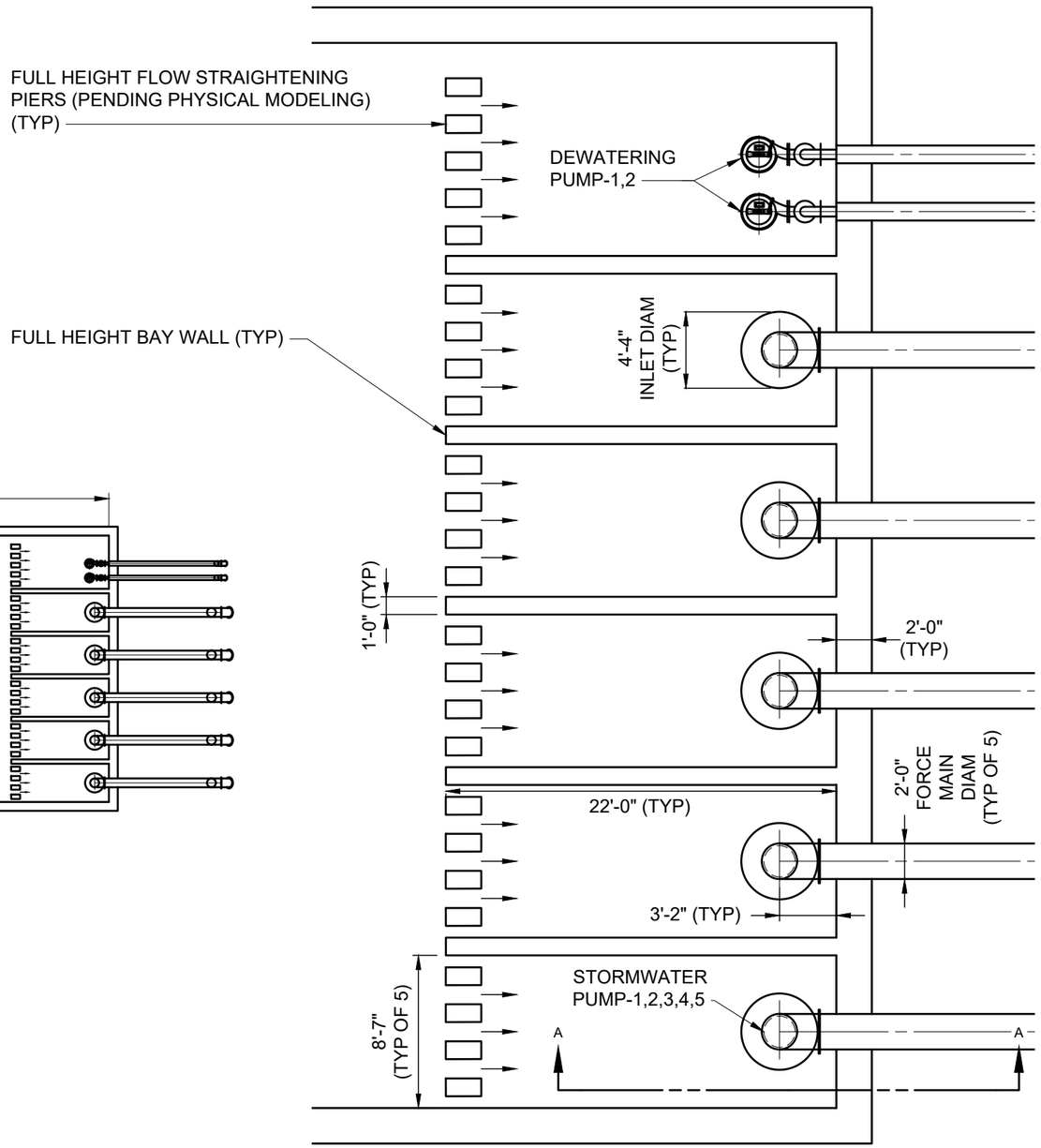
November 2022

Airport Stormwater Pump Station



OVERVIEW PLAN
SCALE: NTS



PUMP STATION PLAN
SCALE: NTS

NOTES

1. FOR WATER SURFACE ELEVATIONS REFER TO OPERATIONAL TABLE.
2. ALL ELEVATIONS USE THE NAVD88 VERTICAL DATUM UNLESS OTHERWISE STATED.
3. CONCEPTUAL DRAWING, NOT FOR CONSTRUCTION.

STORMWATER PUMP-1,2,3,4,5 OPERATIONAL PARAMETERS	
FLOW RATE, CFS	80
STATIC HEAD RANGE, FT	13.3 - 20.5
DESIGN FLOOD ELEVATION, FT	16.0

STORMWATER PUMP-1,2,3,4,5 OPERATIONAL WSE TABLE		
NOTE	OPERATION	ELEVATION, FT
A	HIGH LEVEL ALARM	2.7
B	LAG PUMP ON	1.0
C	LEAD PUMP ON	-0.5
D	LEAD PUMP OFF	-1.5
E	LOW LOW ALARM	-2.5
G	MIN PUMP SUBMERGENCE	-3.5

COASTAL STORMWATER DISCHARGE ANALYSIS

Boston Water and Sewer Commission

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A-1

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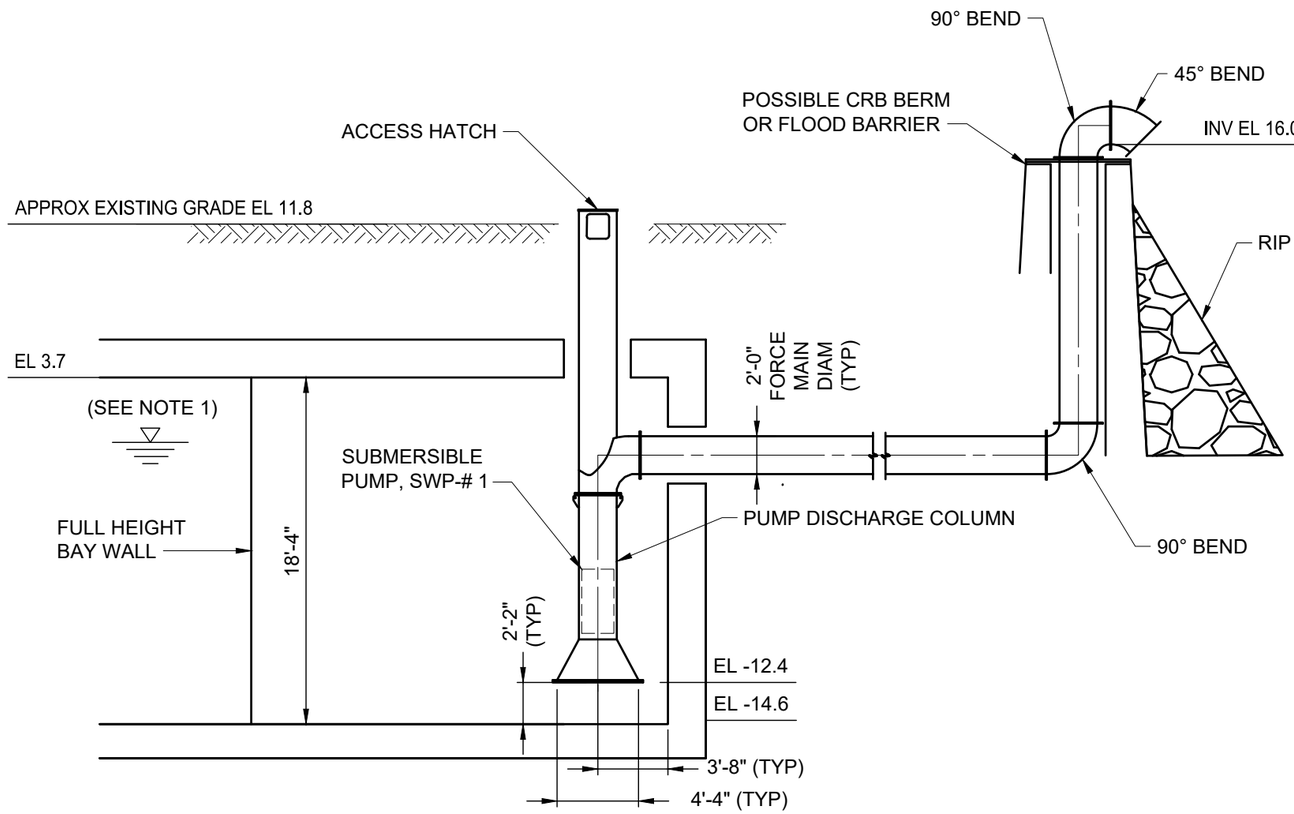
Airport Stormwater Pump Station



SECTION

SCALE: NTS

NOTES

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STORMWATER PUMP-1,2,3,4,5 OPERATIONAL PARAMETERS	
FLOW RATE, CFS	80
STATIC HEAD RANGE, FT	13.3 - 20.5
DESIGN FLOOD ELEVATION, FT	16.0

STORMWATER PUMP-1,2,3,4,5
OPERATIONAL WSE TABLE

NOTE	OPERATION	ELEVATION, FT
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B	LAG PUMP ON	1.0
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D	LEAD PUMP OFF	-1.5
E	LOW LOW ALARM	-2.5
G	MIN PUMP SUBMERGENCE	-3.5

COASTAL STORMWATER
DISCHARGE ANALYSIS

Boston Water and Sewer Commission

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A-2

November 2022

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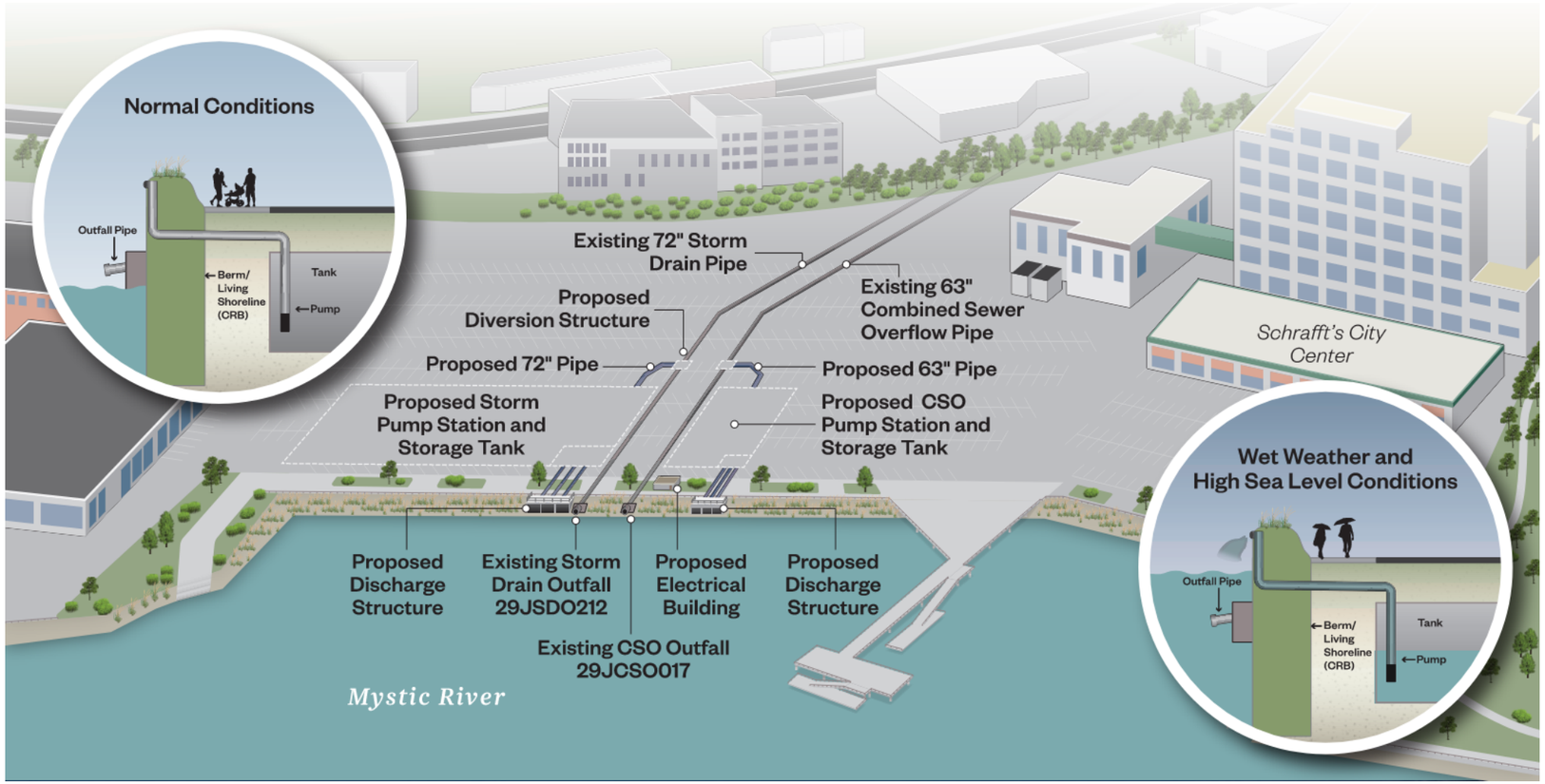
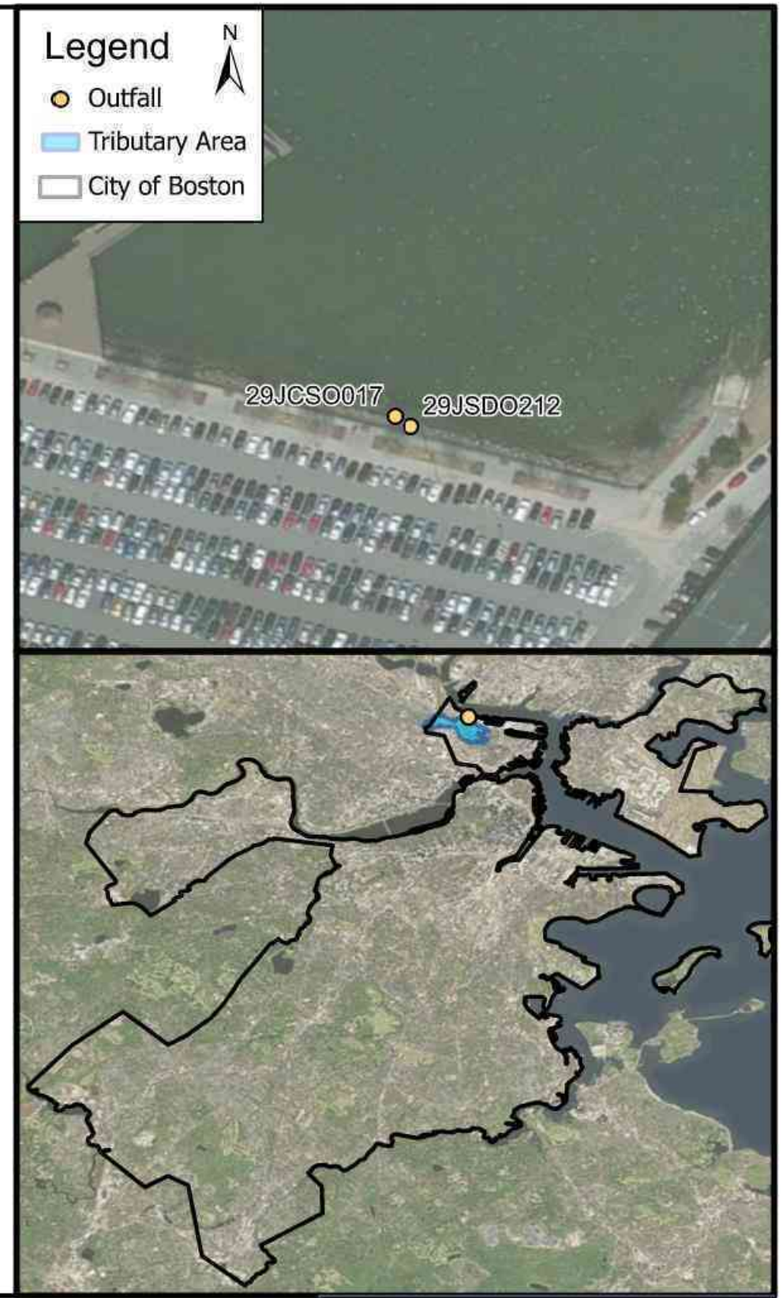
Charlestown Pump Station *Concept Overview*





Conceptual Solution

The conceptual solution herein includes two storage (peak flow shaving) tanks and pump stations to discharge wet weather flow and combined flow when tide levels are high. The tanks and pump stations are located within the Schrafft City Center Parking Lot in Charlestown. This conceptual solution was developed to adapt two adjacent outfalls, 29JSDO212 and 29CSO017. If a high tide level begins to reduce the ability of existing outfalls 29JSDO212 and 29CSO017 to discharge by gravity, the existing storm and combined sewers will begin to surcharge. Both storage tanks are designed with a diversion structure with a static weir to direct excess flow to a storage tank that is connected directly to the pump station. Both pump stations includes two duty and one standby pump. The pump stations utilize electric submersible pumps to minimize the above ground footprint of the station and mitigate negative visual and auditory impacts from diesel engine driven pumps. Each pump is designed with a formed suction inlet and non-manifolded discharge. During extreme storm conditions a portable generator could be parked within the parking lot to provide a backup power supply in the event of a power outage.

Type: Storage and Conveyance

Total Drainage Area: 144 acres

Coastal Vulnerable Drainage Area Protected: 105 acres

Concept Elements:

- Subsurface Pump Stations
- Subsurface storage tanks
- Diversion structures

Outfalls Included in Concept:

- 29JCSO017
- 29JSDO212

Coastal Stormwater Discharge Analysis
Charlestown Pump Station

Boston Water and Sewer Commission | Hazen

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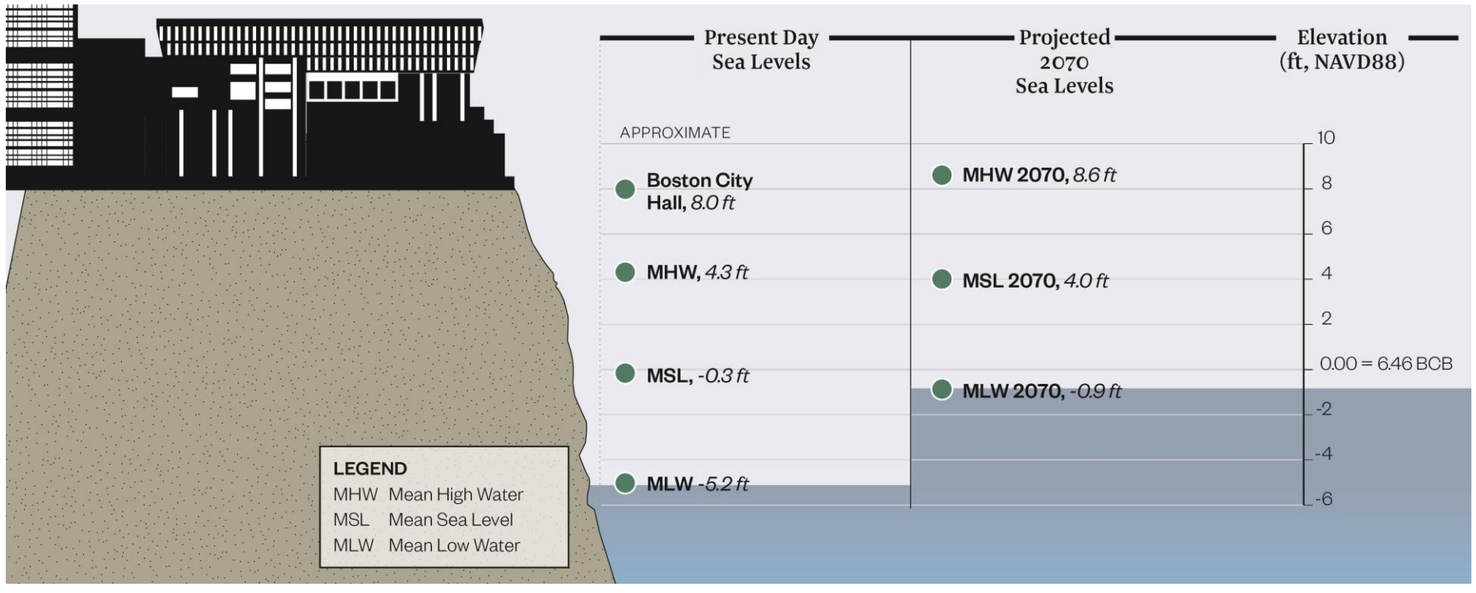
Assumptions

Sea Level Rise and Datum

The Charlestown Pump Station concept was designed for consistency with Climate Ready Boston (CRB) proposed adaptations and analyzed based on sea level rise (SLR) projections in the Massachusetts Coastal Flood Risk Model (MC-FRM). The SLR values applied in MC-FRM are consistent with the standards for the State of Massachusetts developed by Coastal Zone Management. The MC-FRM utilizes a "High" SLR scenario. This scenario is based on the relative SLR projections under Relative Concentration Pathway (RCP) 8.5 (a "worst case scenario" of increasing atmospheric carbon concentrations) and represents elevations that have a 99.5% probability of not being exceeded within the respective timeframes. In 2030, that amounts to an increase of 1.3 feet in Boston from a baseline condition (2008 centered tidal epoch), and in 2070 that amounts to an increase of 4.3 feet.

The concept developed in this project was analyzed using coastal conditions that include 2070 projected SLR and storm surge resulting from a 100-year tropical storm. The peak water surface elevation (WSE) predicted by the MC-FRM during these conditions is approximately 13.8 feet NAVD88 (varies by location). In mid 2022, the Greater Boston Research Advisory Group (BRAG) issued an updated report with new SLR projections. The report acknowledges that long term SLR projections are associated with significant uncertainty, and that updated projections include less SLR by 2100 (compared to earlier projections in the 2015 BRAG Report). According to the report, the likely range of SLR by 2070 under an RCP 8.5 scenario is 1.4 – 2.8 feet. Based on this information, projections from the MC-FRM that were utilized in this project are conservative and appropriate for long term planning purposes.

Unless otherwise noted, all elevations are based on the NAVD88 vertical datum. Elevations given in NAVD88 can be converted to Boston City Base (BCB) elevation by adding 6.46 feet.



Climate Ready Boston and Shoreline Protection

The Charlestown Pump Station concept was developed to maintain consistency with possible Climate Ready Boston (CRB) adaptations based on the latest available information at the time they were developed. As the CRB program continues to evolve, it is anticipated that proposed concepts will need to be adapted.

The concept was developed to be consistent with stated neighborhood design flood elevations. In Charlestown, where the stated design flood elevation is 15.5 feet, pumps were designed to discharge to a minimum elevation of 15.5 feet.

At the time of this project, many CRB concepts were in early planning stages and not fully defined. **In consideration of this, it was assumed the shoreline protection around the City of Boston is 100% effective for all modeling evaluations.** This assumption eliminates overland coastal flooding from model predictions, allowing for isolation of flooding that results only from rainfall and stormwater that cannot be discharged due to high sea levels. It is important to recognize that additional flooding, beyond what is depicted herein, would be expected if 100% effective shoreline protection is not implemented.

Basis of Design

CSO and SDO Pump Stations

Model simulations were conducted to determine the maximum Hydraulic Grade Line (HGL) that occurs at Outfalls 29JCSO017 and 29JSDO212 with the current tide cycle. Analyses were then conducted to determine the acceptable combinations of storage volume and pumping rate required to maintain the existing HGL with 2070 projected sea level rise, as shown in Figures 1 and 2. The City of Boston's Parcel database was used to identify publicly owned parcels near the existing outfall. An analysis of the pump station was performed to identify pump rates and physical dimensions that are hydraulically viable at the outfalls. It was found that Outfall 29JCSO017 would require a 0.5 MG storage tank at ~12 feet deep could fit on the property with a 40 CFS pump station. The CSO pump station and storage tank occupy an area of 5,885 ft^2. It was found that Outfall 29JSDO212 would require a 2.5 MG storage tank at ~15 feet deep could fit on the property with a 200 CFS pump station. The SDO storage tank and pump station occupy an area of 25,500 ft^2. Both stations utilize two duty pumps, one standby pump, and one dewatering pumps and are configured with vertical, axial electric submersible pumps in parallel bays. The storage tanks for both stations could be constructed as a single structure with a dividing wall.

Figure 1: 29JCSO017 Pumping vs. Storage

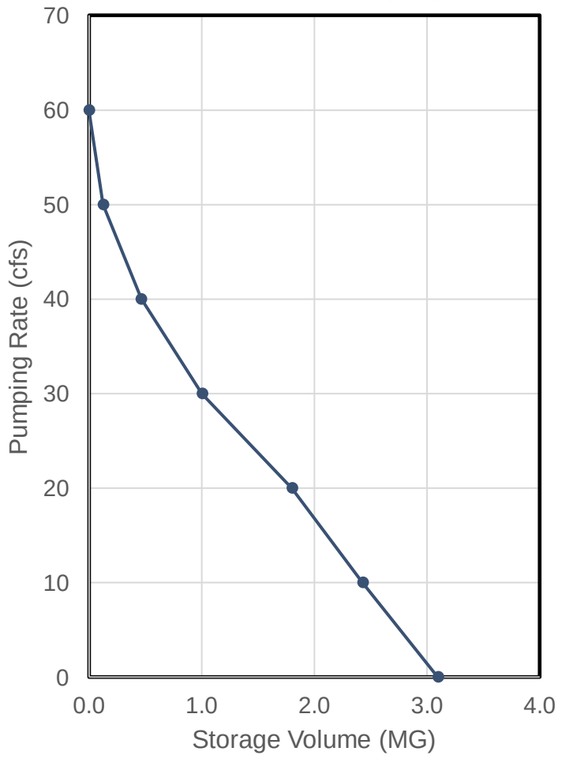
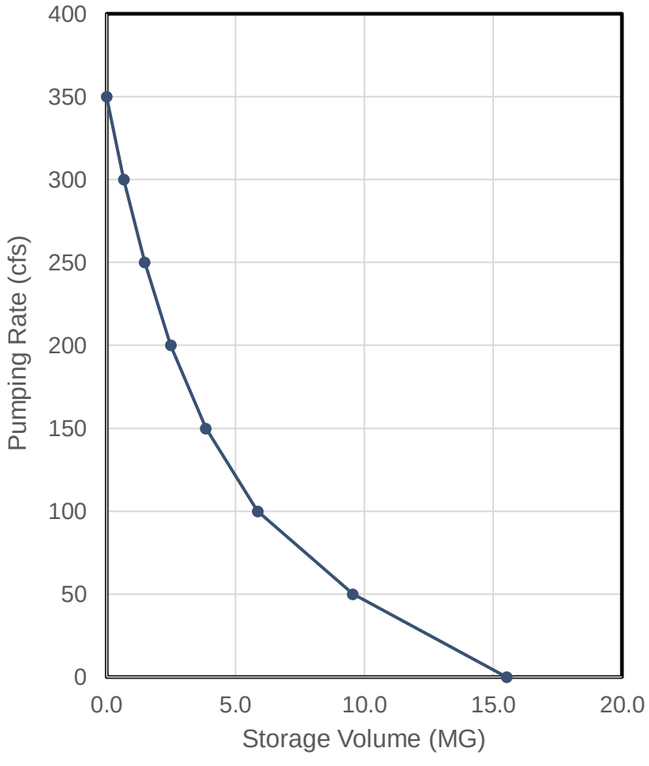


Figure 2: 29JSDO212 Pumping vs. Storage



Rainfall and Coastal Conditions

The Commission currently utilizes a 10-year, 24-hour design storm to establish its target level of service. For the purpose of sizing new piping and evaluating storage capacity, a projected 2070 10-year, 24-hour design storm was developed. For consistency with Climate Ready Boston, performance of the Charlestown Pump Station concept was also evaluated with projected rainfall from a 100-year tropical event (developed during the Commission's Inundation Model Project). The Charlestown Pump Station concept was evaluated using a 100-year return period coastal boundary condition. Data for this condition were obtained from the MC-FRM. For the purpose of evaluating the effectiveness of the concept, it was further assumed that complete shoreline protection was implemented, preventing flow between the Charlestown Pump Station tributary area and the Mystic River. Table 2 contains a summary of the coastal conditions that were analyzed.

Table 1: Rainfall Conditions

Scenario	Purpose	Rainfall Depth (in)	Peak Intensity (in/hr)
Present Day, 10-year, 24-hr design storm	Baseline Conditions	5.15	3.32
Projected 2070, 10-year, 24-hr design storm	Design Conditions	6.18	4.08
100-year Tropical Storm	Damage Analysis	9.58	0.84

Table 2: Coastal Conditions

Scenario	Purpose	Peak Water Surface Elevation (ft, NAVD88)	Source
Present Day	Baseline Conditions	3.7	BWSC Existing Model (April 2016 Tide Cycle)
2070,100-year Tropical Storm	Damage Analysis	13.8	MC-FRM

Conceptual Design – Not for Construction

Flood Modeling and Damage Analysis

Figure 3: Estimated Replacement Cost

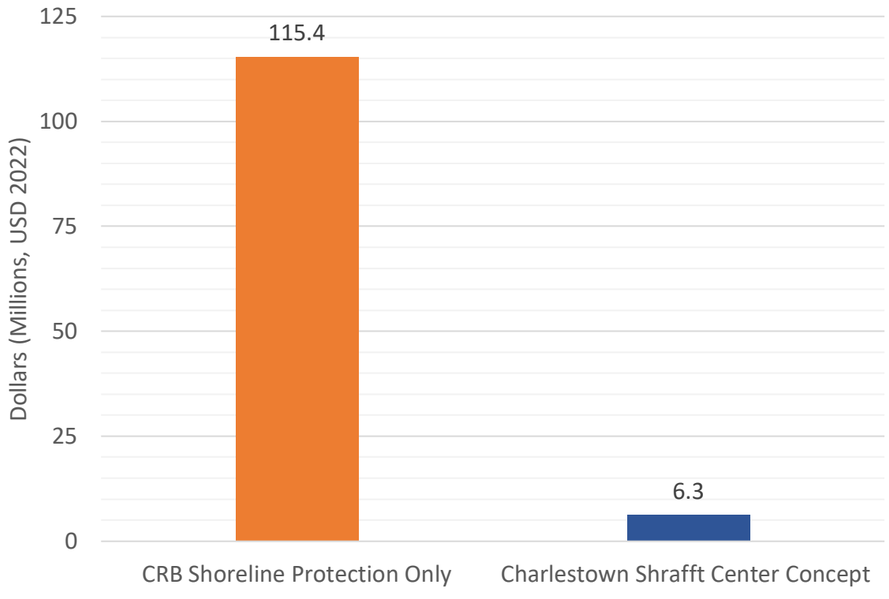


Figure 4: Loss of GDP

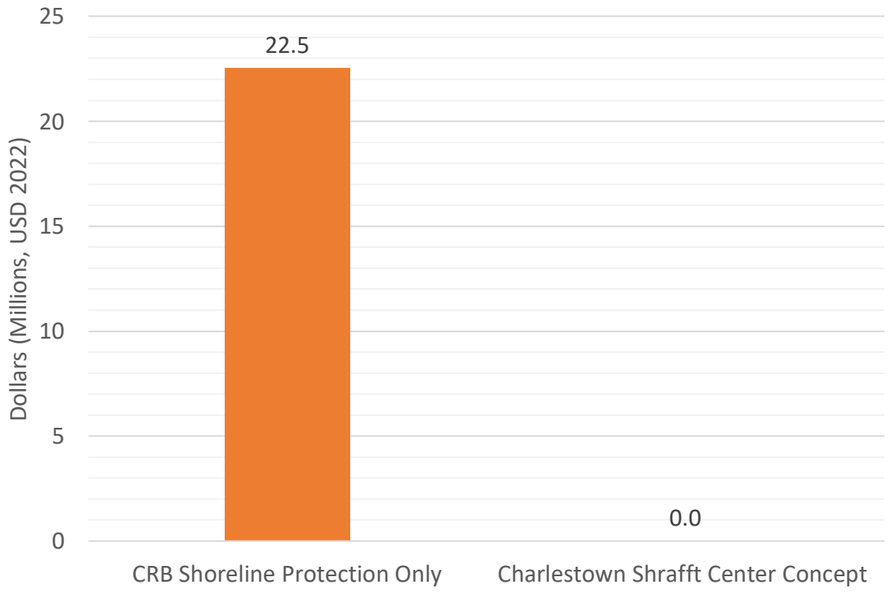
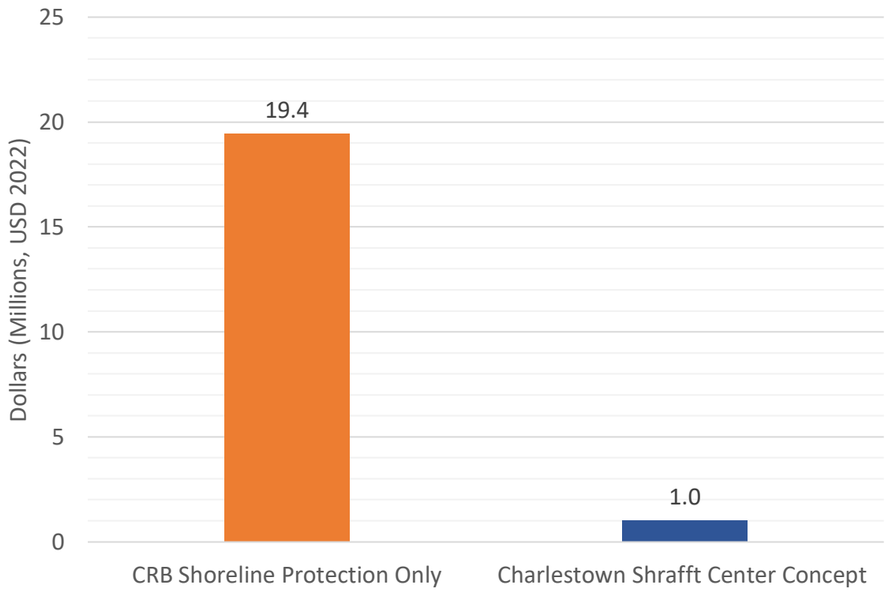


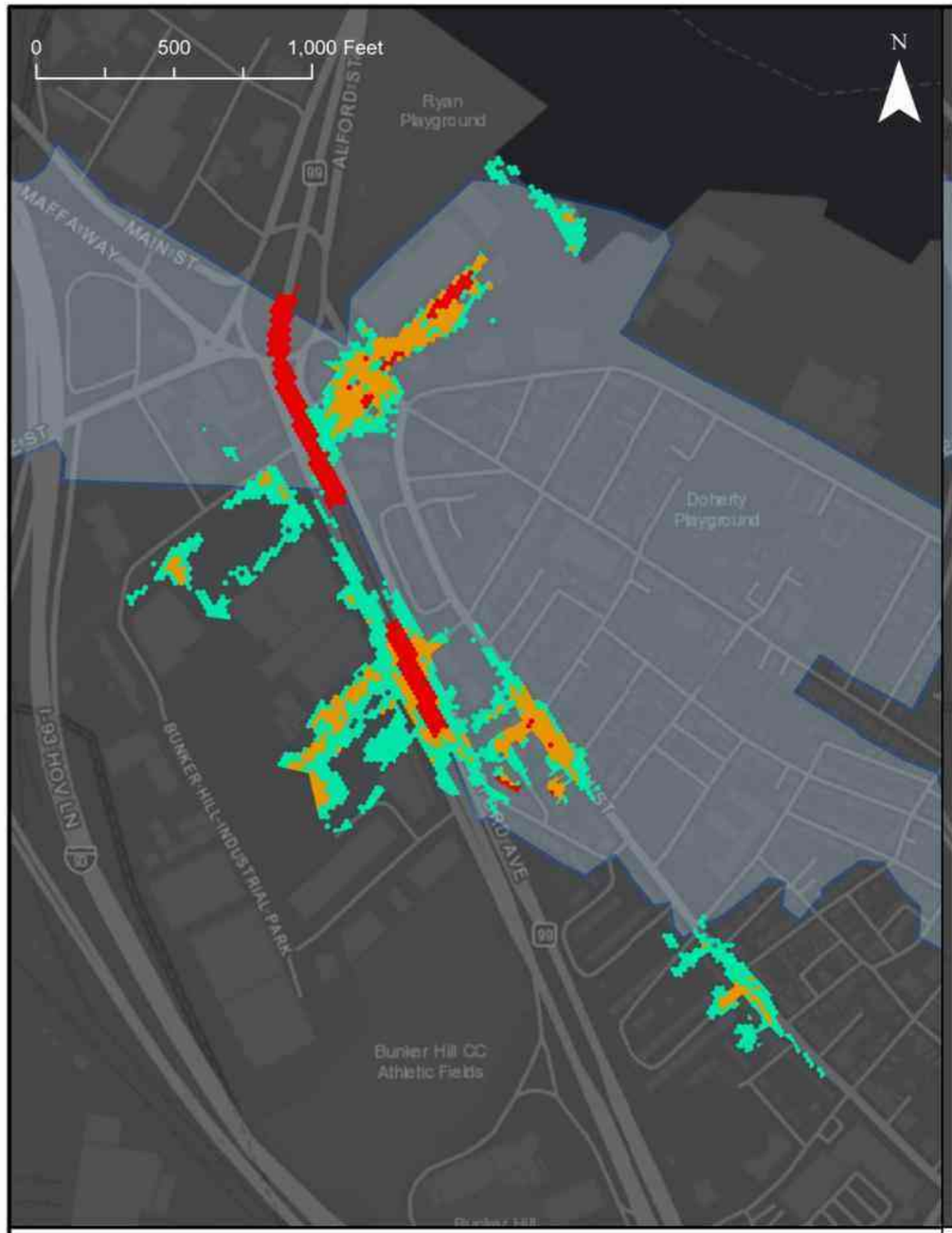
Figure 5: Physical Damage



The flood reduction benefits of the Charlestown Pump Station concept were evaluated using the Commission's 2D Inundation Model by simulating a 100-year tropical storm event with 2070 SLR and storm surge. The figures on the following page depict the peak flooding that was predicted in the Charlestown Schrafft Center drainage area with shoreline protection only and with the pump station and tide gates on all vulnerable BWSC owned outfalls. An analysis of economic losses/physical impacts from flooding under both scenarios was performed by risQ Inc.

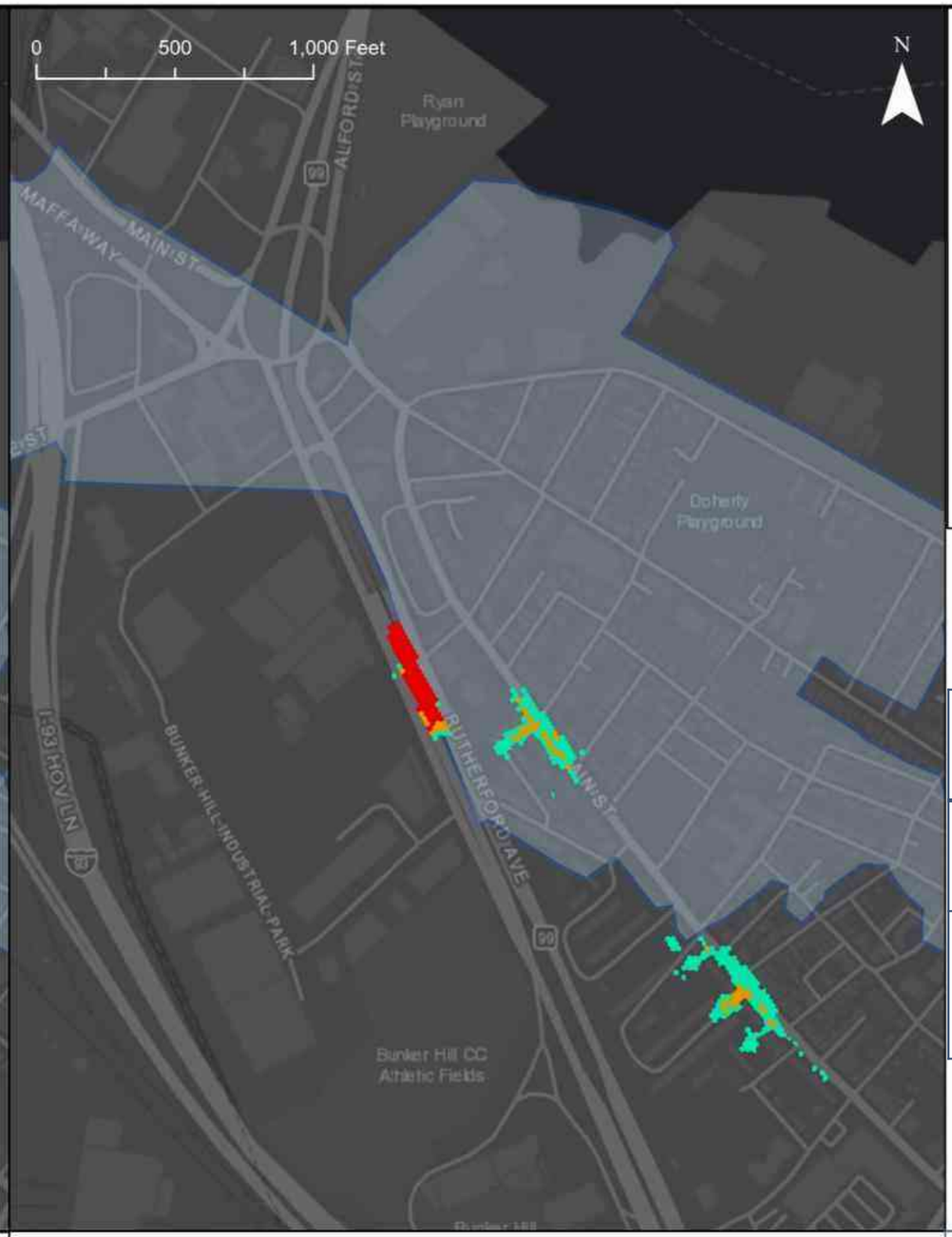
Model predictions indicate that the Charlestown Pump Station concept reduces physical damage by **$18.4 million**, avoids **$109.1 million** in rebuilding costs, and mitigates a GPD loss of **$22.5 million** during a 100-year tropical storm event in 2070 compared to shoreline protection only.

Note: replacement values include the total value of impacted buildings in flooded areas (e.g., impacted buildings are fully replaced), whereas physical damage includes estimated costs to repair flood damage based on predicted flood depths and building characteristics. The values shown are the average of minimum and maximum calculated losses. Refer to the Project's Final Report for more information.



2070 SLR + 100yr Tropical Storm + Storm Surge

Shoreline Protection Only



2070 SLR + 100yr Tropical Storm + Storm Surge

Schrafft Center Pump Stations and Tide Gates

Legend

- Flood Depth > 4 in and < 1 ft
- Flood Depth > 1 ft and < 2 ft
- Flood Depth > 2 ft
- Drainage Area Analyzed

Shared Simulation Parameters

Storm Type	100yr Tropical Storm
Rainfall Depth	9.6 inches
Peak WSE 2070 SLR + 100yr Surge	13.8 feet NAVD88

Coastal Stormwater Discharge Analysis
Charlestown Pump Station

Boston Water and Sewer Commission

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Cost Estimate and FEMA BRIC Considerations

Capital Cost Estimate

A construction cost estimate for the Charlestown Pump Station concept was developed for planning purposes. Assumptions for the cost estimate include 15-year escalation to the mid-point of construction and the inclusion of a 50% design contingency. Utility hookup costs were not included.

Table 3: Charlestown Pump Station Cost Estimate Subtotals

Remaining Design Development & Construction Administration (assumed 20% of total less design contingency)	$5,893,000
Direct Construction Costs	$11,596,079
Indirect Construction Costs	$2,319,216
Mark-Up *(Including 50% design contingency)*	$29,742,705
Total	**$49,551,000**

Social Vulnerability and FEMA BRIC Funding

FEMA BRIC funding prioritizes disadvantaged communities. Table 4 contains a summary of several indicators for the Charlestown Pump Station tributary area that could be used help characterize the community for future FEMA funding applications and prioritization of projects that benefit disadvantaged communities.

Table 4: Charlestown Pump Station Tributary Area Social Vulnerability Indicators

Low Income & Persistent Poverty	
Per Capita Income	$81,062
Below Poverty Line	5%
High Housing Cost Burden	
Stressed Renters (>40% rent-to-income)	26%
Households With Food Insecurity	14%
Racial and Ethnic Segregation	
Asian Population	6%
Black Population	5%
Hispanic Population	5%
White Population	84%
Education and Employment	
Adults Age 25+ Without High School (or equivalent) Degree	3%
Unemployment Rate (Age 16+)	2%

Data provided by risQ inc. from the US census and American Community Survey

Conceptual Design – Not for Construction

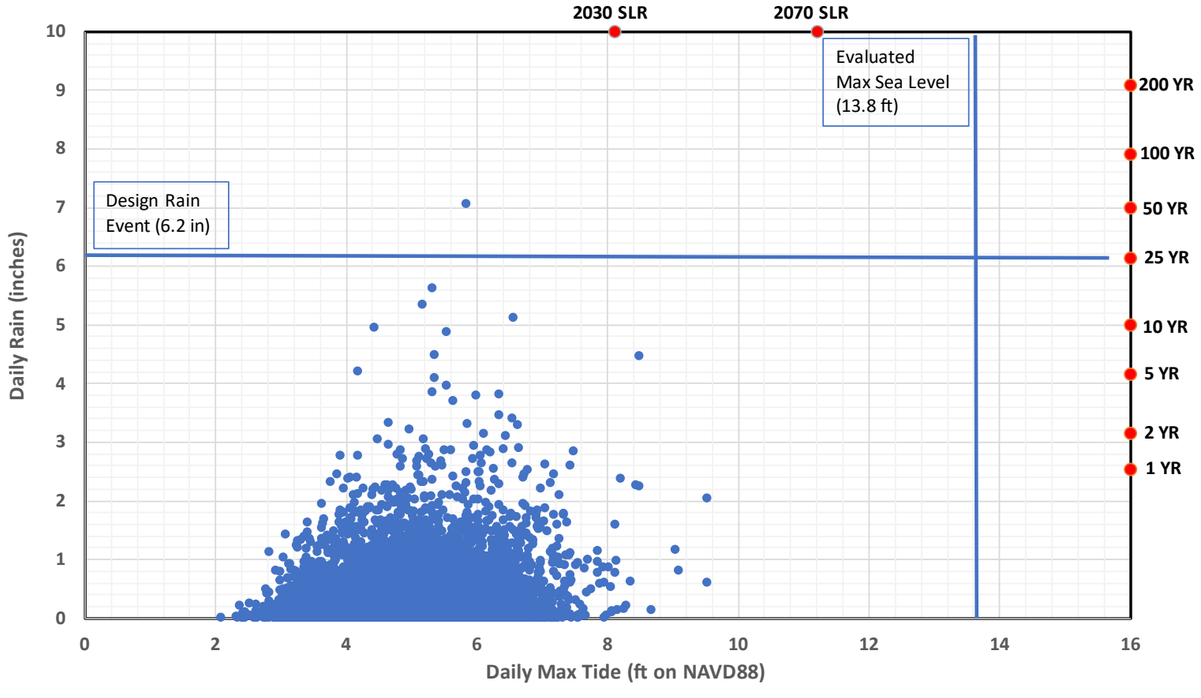
Adaptability and Implementation

Adaptability

Figure 6 below depicts historical daily rainfall totals and tide levels. As shown in this figure, the conditions that were used to design and analyze the Schrafft Center pump station are conservative and represent more extreme conditions than have occurred historically. Regardless, the following measures could be implemented to adapt the concept to more severe conditions (additional SLR, more intense rainfall, etc.) in the future:

- Increase the size of installed electric submersible pumps
- Utilize the standby pumps as a duty pump during extreme conditions
- Increase the size of the peak shaving tanks
- Combine the CSO and SDO pump stations or control flow to each station with active controls to maximize system efficiency

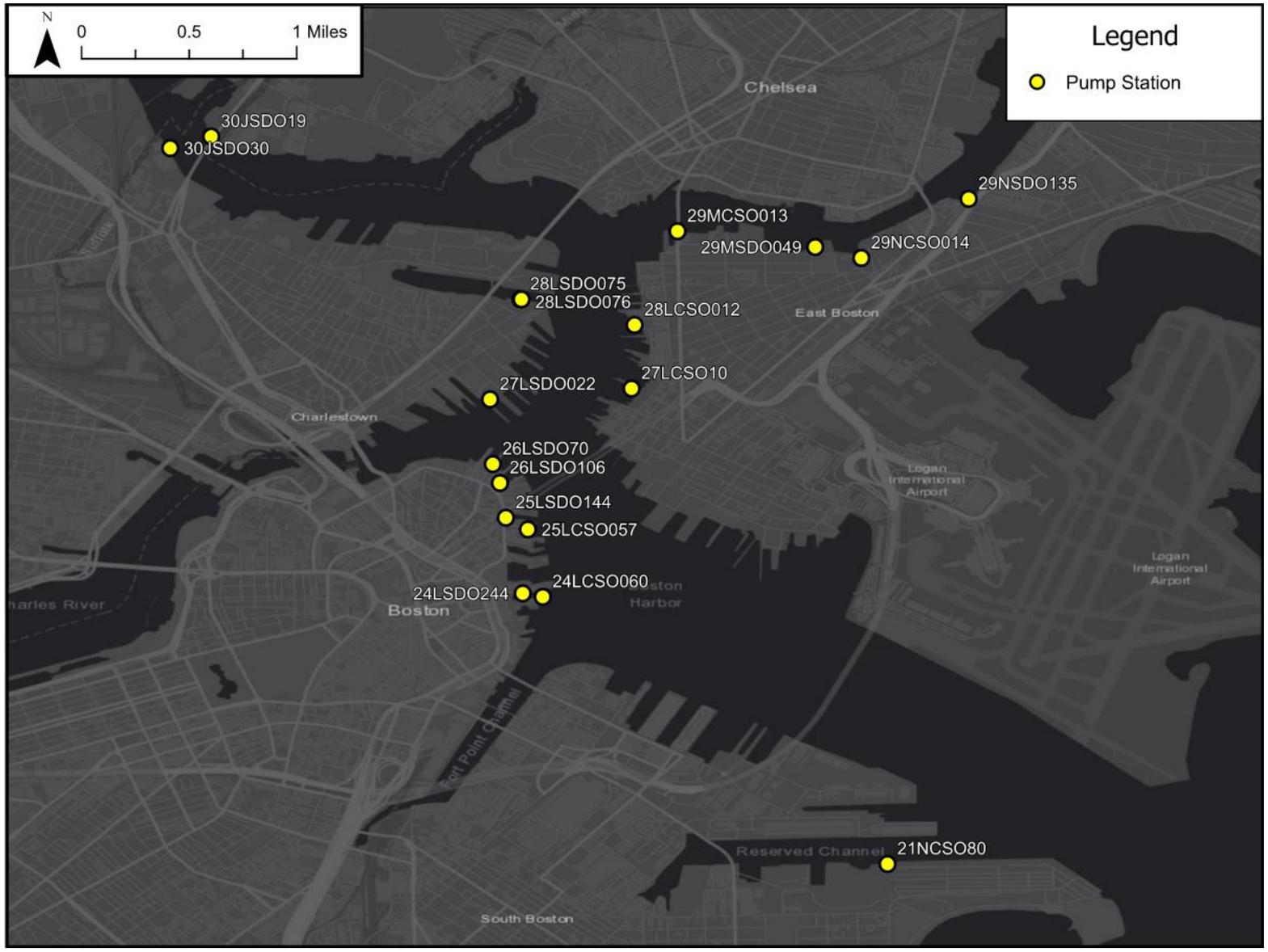
Figure 6: Design and Analysis Conditions vs. Historical Tide and Rainfall



Implementation Considerations

- Coordination with CRB is necessary to implement shoreline protection. The pump station should not be implemented without shoreline protection to prevent coastal flooding within the area tributary to it.
- Community engagement with stakeholders may help build project support by illustrating the flood control benefits of the pump station.
- A comprehensive permitting evaluation should be conducted to evaluate possible impacts from construction and operation of the pump station to the receiving water.
- If sewer separation is planned in the area tributary to the CSO outfall leading to it being converted to a storm drain outfall, a single tank and pump station could be constructed to manage flow from both outfalls.
- Coordination with the property manager at Shrafft Center should be conducted to plan for temporary loss of parking during construction.

Replicability and Implementation Timeline



Summary of Similar Concepts

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Vulnerable Area: 422 acres

The map on this sheet depicts other vulnerable outfalls that could be adapted with electric submersible pump stations. In some locations, several outfalls could be consolidated with a new conduit that conveys flow to a single pump station.

Additional detail about these outfalls can be found in the Commission's Coastal Stormwater Discharge Analysis Implementation Timeline.

ATTACHMENT A
CHARLESTOWN PUMP STATION CONCEPTUAL DESIGN DRAWINGS

A-1: CSO and SDO Overview Plans
A-2: CSO Pump Station Plan
A-3: CSO Pump Station Section View
A-4: SDO Pump Station Plan
A-5: SDO Pump Station Section View

Charlestown Stormwater Pump Station

NOTES

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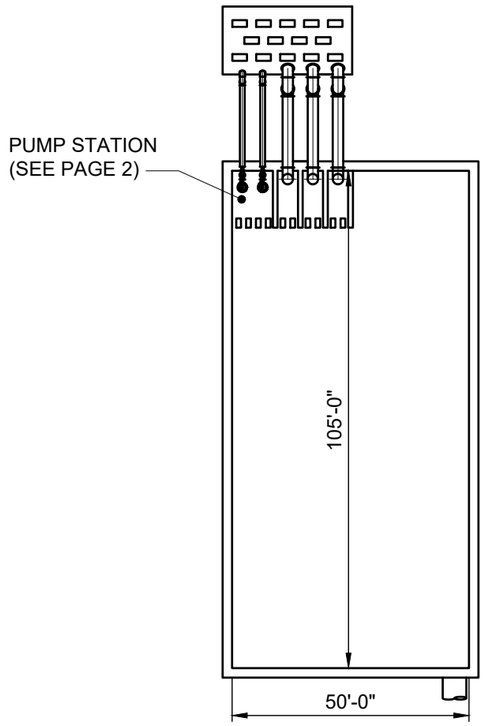
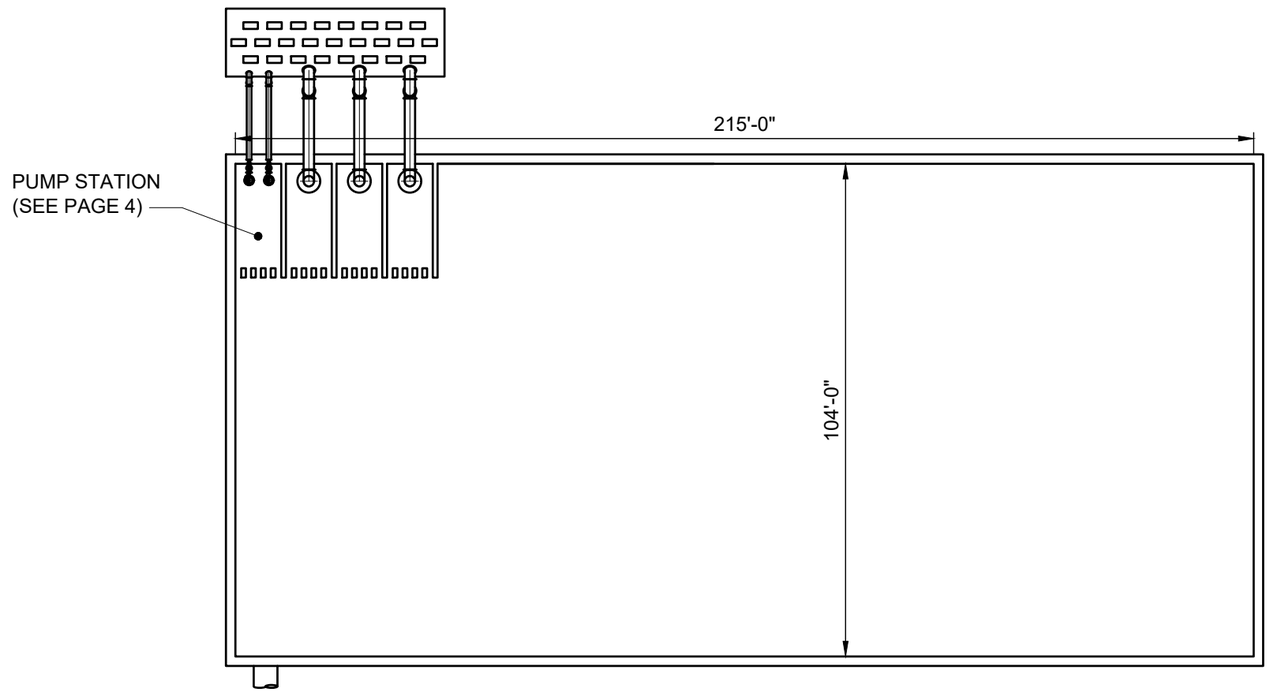


CSO OVERVIEW PLAN

SCALE: NTS



SDO OVERVIEW PLAN

SCALE: NTS

COASTAL STORMWATER
DISCHARGE ANALYSIS

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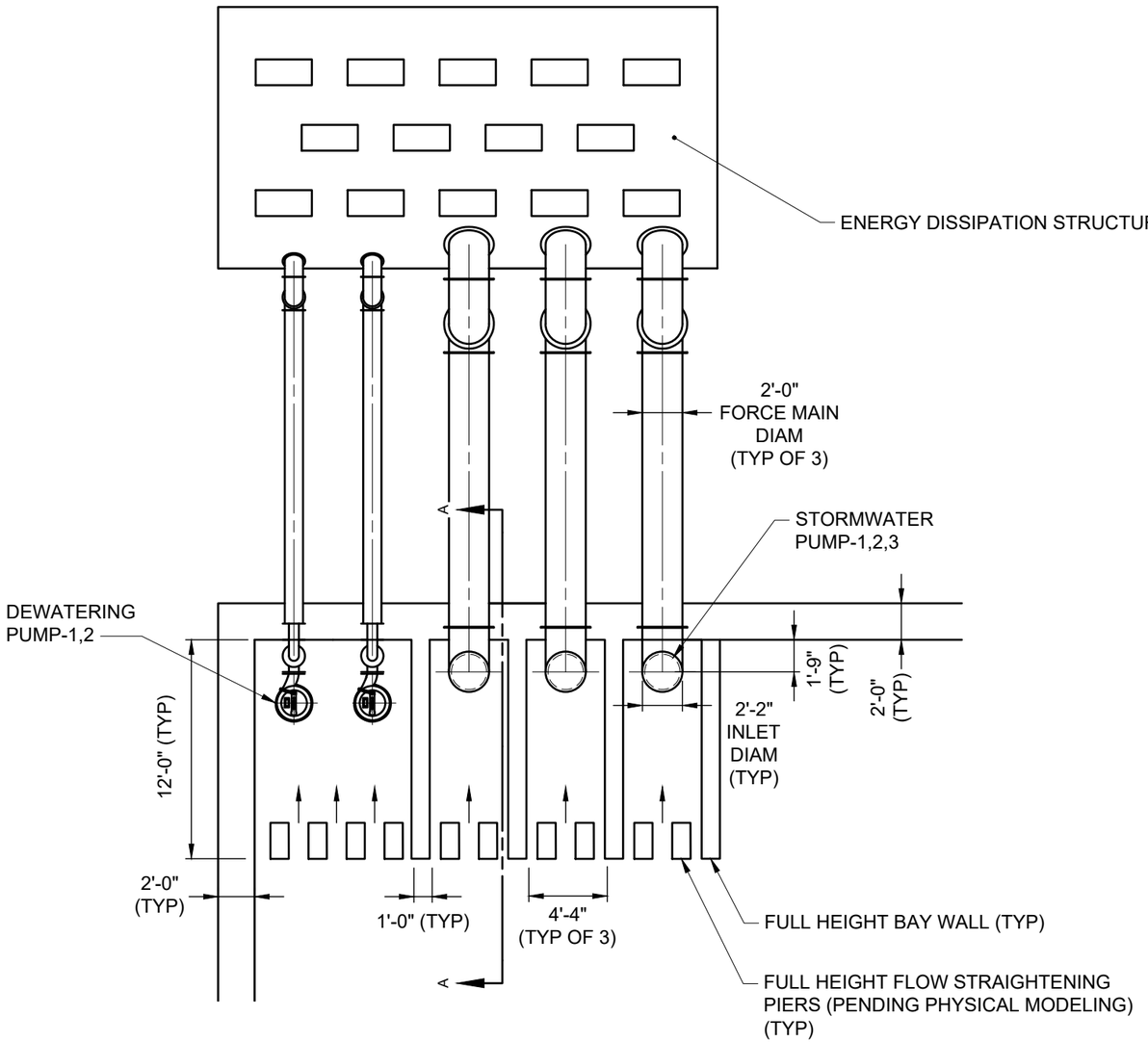
Charlestown Stormwater Pump Station



CSO PUMP STATION PLAN

SCALE: NTS

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STORMWATER PUMP-1,2,3 OPERATIONAL PARAMETERS	
FLOW RATE, CFS	20
STATIC HEAD RANGE, FT	12.6 - 17.2
DESIGN FLOOD ELEVATION, FT	15.5

STORMWATER PUMP-1,2,3 OPERATIONAL WSE TABLE		
NOTE	OPERATION	ELEVATION, FT
A	HIGH LEVEL ALARM	1.9
B	LAG PUMP ON	1.4
C	LEAD PUMP ON	0.9
D	LEAD PUMP OFF	0.4
E	LOW LOW ALARM	-0.1
G	MIN PUMP SUBMERGENCE	-0.6

COASTAL STORMWATER
DISCHARGE ANALYSIS

Boston Water and Sewer Commission

Hazen

A-2

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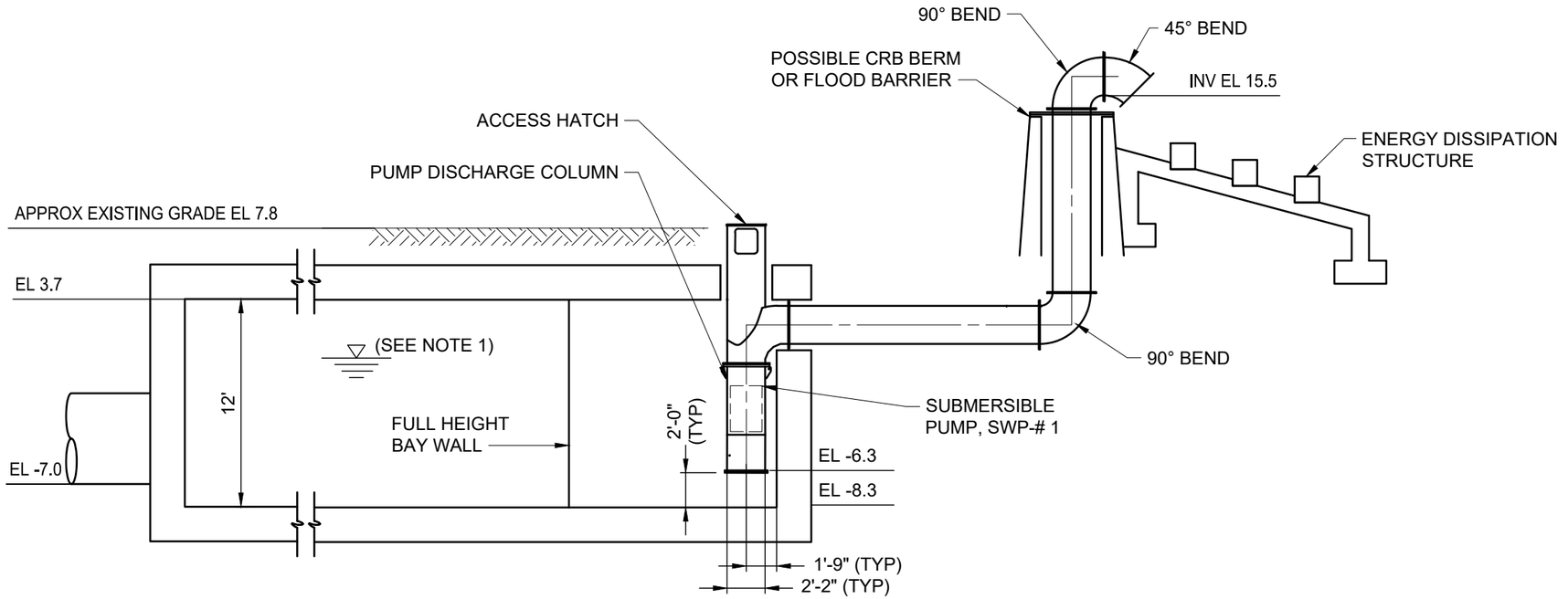
Charlestown Stormwater Pump Station



SECTION A

SCALE: NTS

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STORMWATER PUMP-1,2,3 OPERATIONAL PARAMETERS	
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STATIC HEAD RANGE, FT	12.6 - 17.2
DESIGN FLOOD ELEVATION, FT	15.5

STORMWATER PUMP-1,2,3
OPERATIONAL WSE TABLE

NOTE	OPERATION	ELEVATION, FT
A	HIGH LEVEL ALARM	3.0
B	LAG PUMP ON	2.3
C	LEAD PUMP ON	1.5
D	LEAD PUMP OFF	0.7
E	LOW LOW ALARM	-0.1
G	MIN PUMP SUBMERGENCE	-0.9

COASTAL STORMWATER
DISCHARGE ANALYSIS

Boston Water and Sewer Commission

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A-3

November 2022

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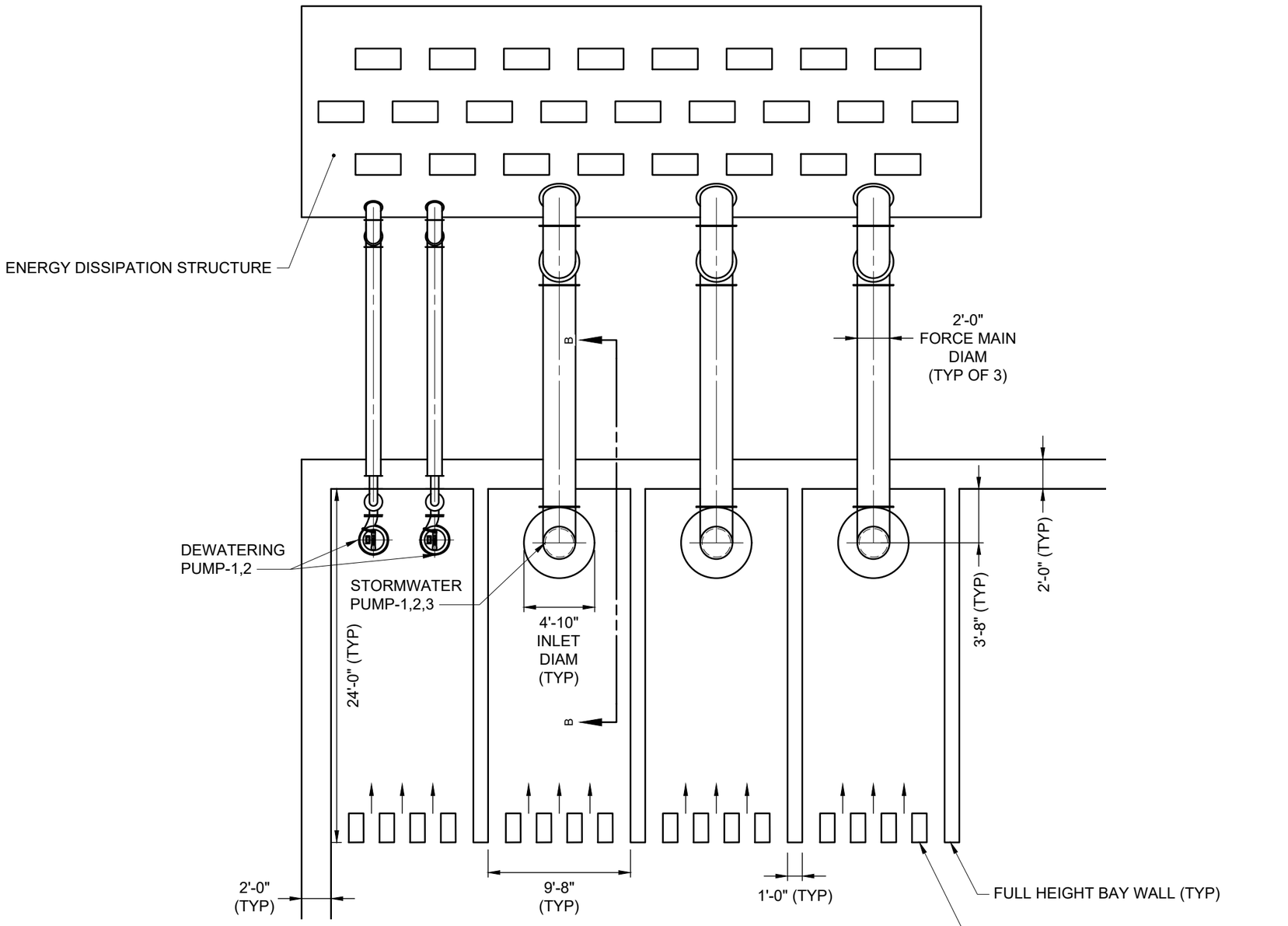
Charlestown Stormwater Pump Station



SDO PUMP STATION PLAN

SCALE: NTS

NOTES

1. FOR WATER SURFACE ELEVATIONS REFER TO OPERATIONAL TABLE.
2. ALL ELEVATIONS USE THE NAVD88 VERTICAL DATUM UNLESS OTHERWISE STATED.
3. CONCEPTUAL DRAWING, NOT FOR CONSTRUCTION.

STORMWATER PUMP-1,2,3 OPERATIONAL PARAMETERS	
FLOW RATE, CFS	100
STATIC HEAD RANGE, FT	12.6 - 17.3
DESIGN FLOOD ELEVATION, FT	15.5

STORMWATER PUMP-1,2,3 OPERATIONAL WSE TABLE

NOTE	OPERATION	ELEVATION, FT
A	HIGH LEVEL ALARM	2.3
B	LAG PUMP ON	1.8
C	LEAD PUMP ON	1.3
D	LEAD PUMP OFF	0.8
E	LOW LOW ALARM	0.3
G	MIN PUMP SUBMERGENCE	-0.7

COASTAL STORMWATER DISCHARGE ANALYSIS

Boston Water and Sewer Commission

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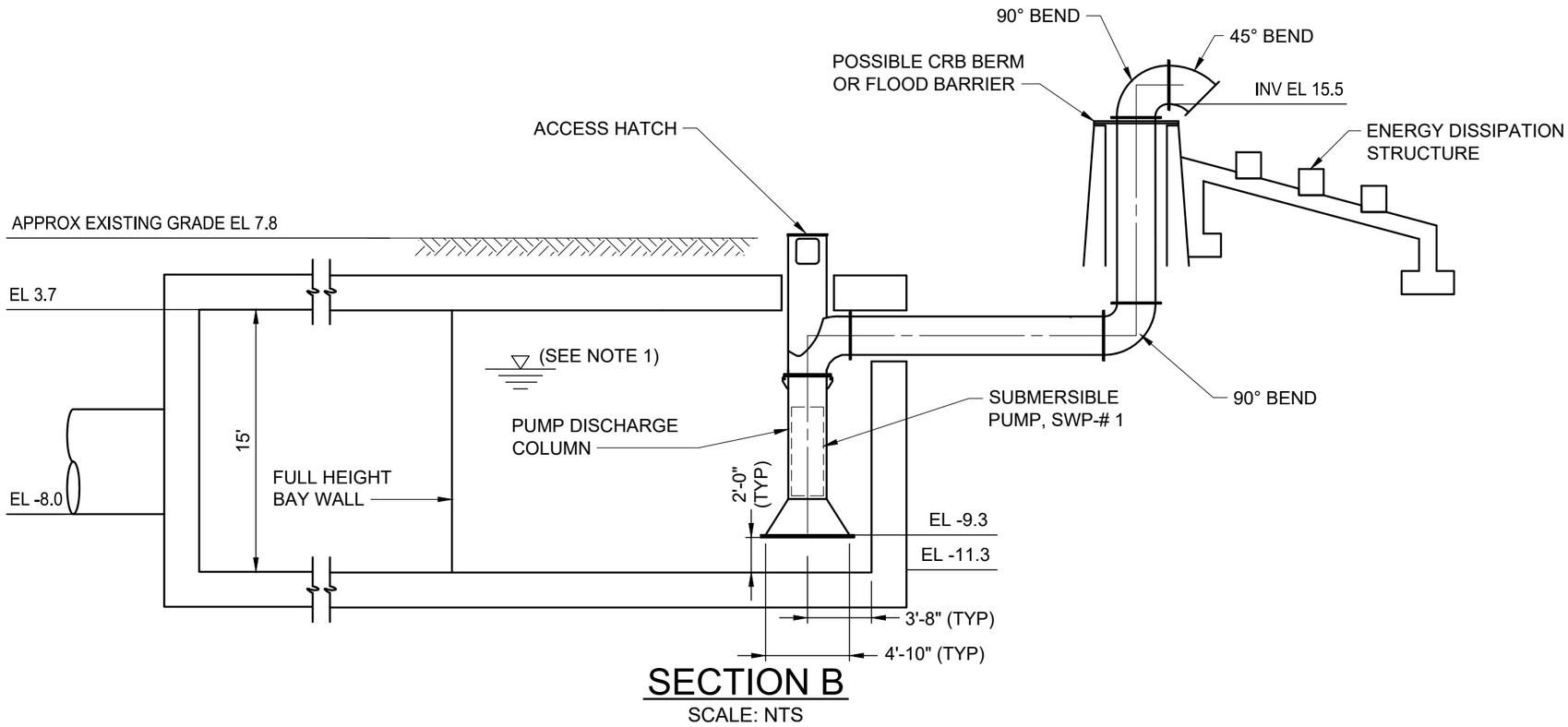
Charlestown Stormwater Pump Station



SECTION B

SCALE: NTS

NOTES

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STORMWATER PUMP-1,2,3 OPERATIONAL PARAMETERS	
FLOW RATE, CFS	100
STATIC HEAD RANGE, FT	12.6 - 17.3
DESIGN FLOOD ELEVATION, FT	15.5

STORMWATER PUMP-1,2,3
OPERATIONAL WSE TABLE

NOTE	OPERATION	ELEVATION, FT
A	HIGH LEVEL ALARM	3.0
B	LAG PUMP ON	2.2
C	LEAD PUMP ON	1.4
D	LEAD PUMP OFF	0.6
E	LOW LOW ALARM	-0.2
G	MIN PUMP SUBMERGENCE	-1.0

COASTAL STORMWATER
DISCHARGE ANALYSIS

Boston Water and Sewer Commission

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November 2022

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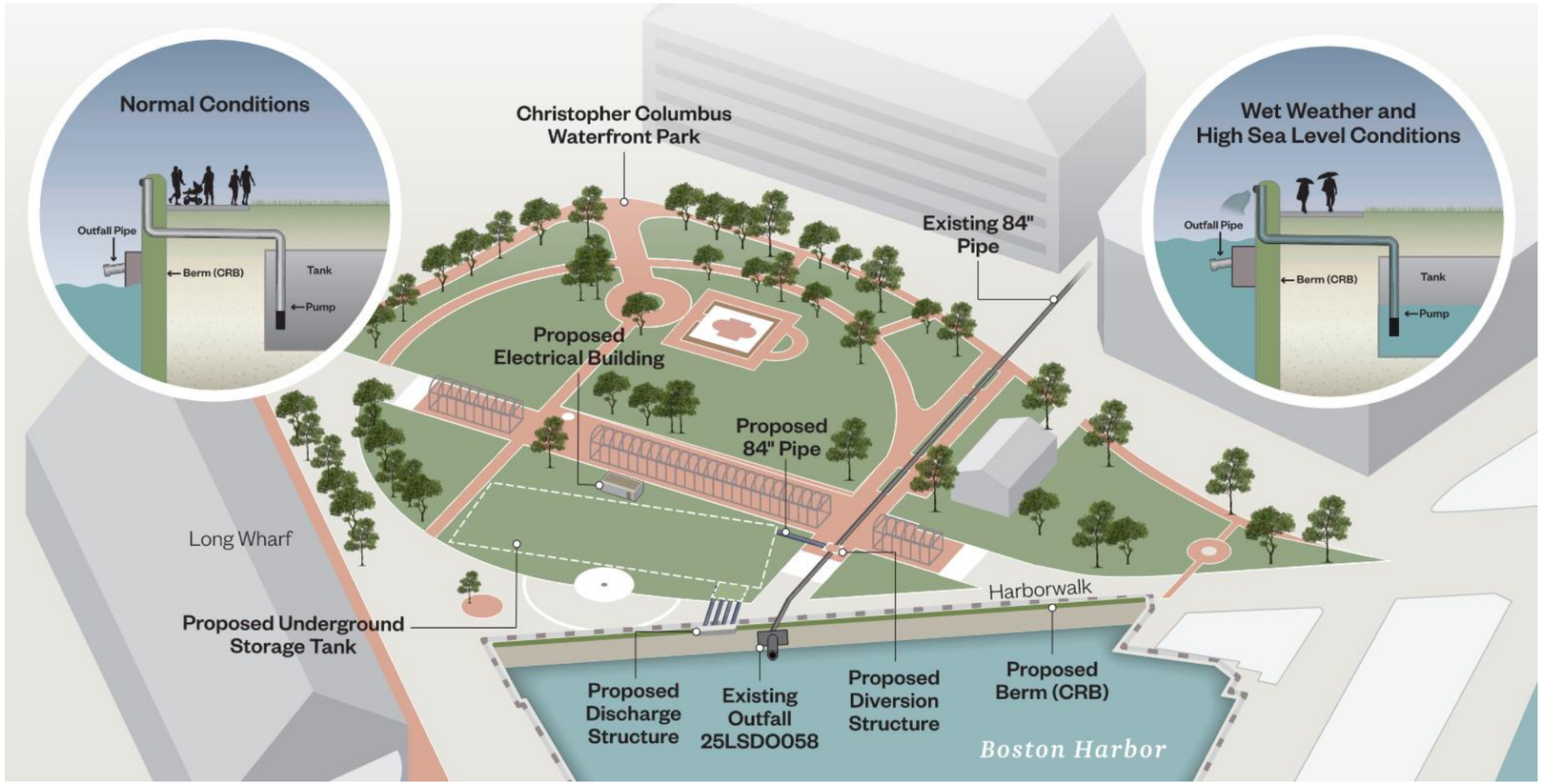
Columbus Park Pump Station *Concept Overview*





Conceptual Solution

The conceptual solution herein includes a stormwater storage (peak shaving) tank and pump station to discharge wet weather flow when water levels are too high in the harbor for the outfall to discharge by gravity. The tank and pump station are located beneath Christopher Columbus Park. If water surface conditions in the harbor prevent the outfall from discharging, a static diversion weir redirects flow to the underground storage tank. The storage tank is directly connected to the pump station. The pump station utilizes one duty pump, one standby pump, and two dewatering pumps. Each pump discharges into an individual force main and then connects to a discharge structure that could be incorporated with a future CRB berm or other shoreline protection adaptation. The pump station utilizes electric submersible pumps to minimize the above ground footprint of the station and mitigate chemical and noise pollution of the park from diesel engine driven pumps.

Type: Storage and Pumping

Total Drainage Area: 55 acres

Coastal Flood Vulnerable Drainage Area Protected: 55 acres

Concept Elements:

- Subsurface Pump Station
- Subsurface Storage Tank
- Diversion Structure

Outfalls Included in Concept:

- 25LSDO058

Coastal Stormwater Discharge Analysis
Columbus Park Pump Station

Boston Water and Sewer Commission | Hazen

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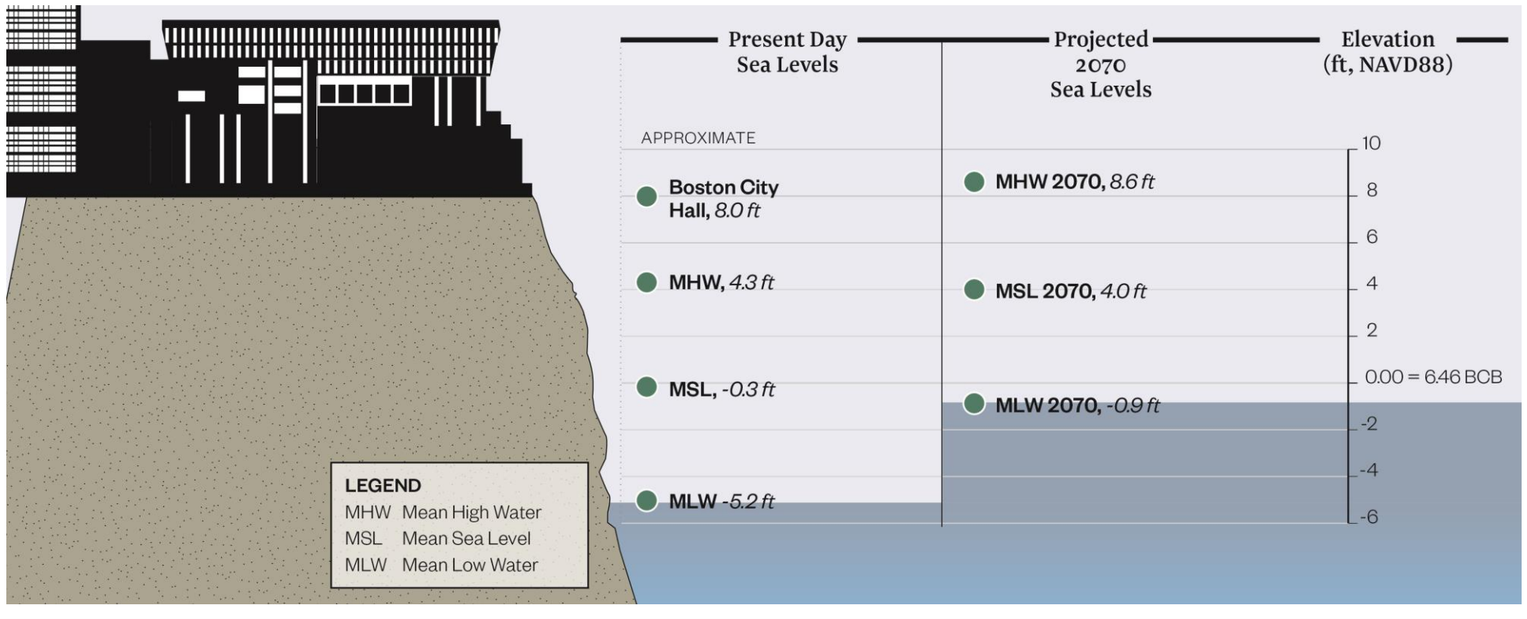
Assumptions

Sea Level Rise and Datum

The Columbus Park Pump Station concept was designed for consistency with Climate Ready Boston (CRB) proposed adaptations and analyzed based on sea level rise (SLR) projections in the Massachusetts Coastal Flood Risk Model (MC-FRM). The SLR values applied in MC-FRM are consistent with the standards for the State of Massachusetts developed by Coastal Zone Management. The MC-FRM utilizes a "High" SLR scenario. This scenario is based on the relative SLR projections under Relative Concentration Pathway (RCP) 8.5 (a "worst case scenario" of increasing atmospheric carbon concentrations) and represents elevations that have a 99.5% probability of not being exceeded within the respective timeframes. In 2030, that amounts to an increase of 1.3 feet in Boston from a baseline condition (2008 centered tidal epoch), and in 2070 that amounts to an increase of 4.3 feet.

The concept developed in this project was analyzed using coastal conditions that include 2070 projected SLR and storm surge resulting from a 100-year tropical storm. The peak water surface elevation (WSE) predicted by the MC-FRM during these conditions is approximately 13.8 feet NAVD88 (varies by location). In mid 2022, the Greater Boston Research Advisory Group (BRAG) issued an updated report with new SLR projections. The report acknowledges that long term SLR projections are associated with significant uncertainty, and that updated projections include less SLR by 2100 (compared to earlier projections in the 2015 BRAG Report). According to the report, the likely range of SLR by 2070 under an RCP 8.5 scenario is 1.4 – 2.8 feet. Based on this information, projections from the MC-FRM that were utilized in this project are conservative and appropriate for long term planning purposes.

Unless otherwise noted, all elevations are based on the NAVD88 vertical datum. Elevations given in NAVD88 can be converted to Boston City Base (BCB) elevation by adding 6.46 feet.



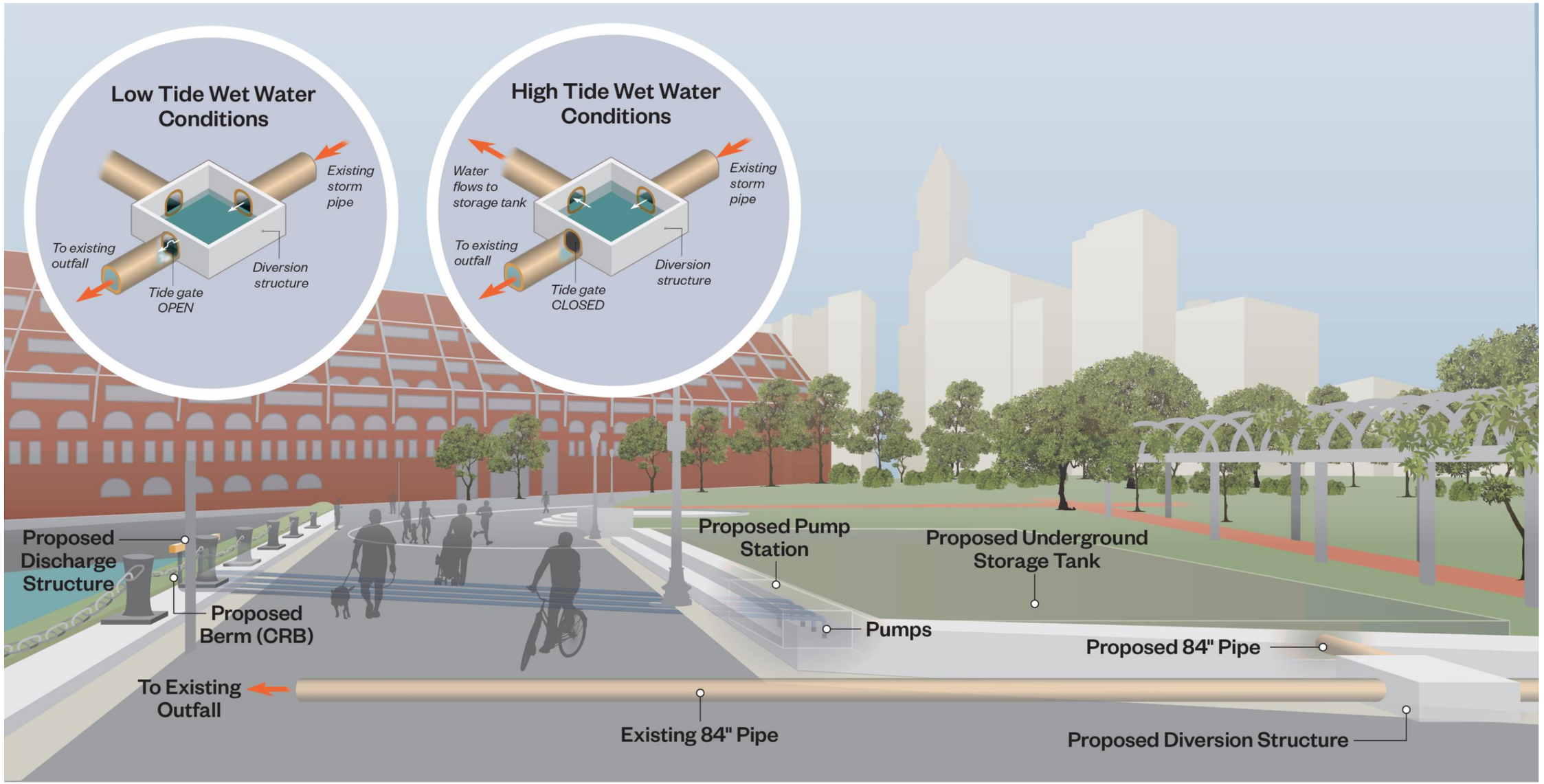
Climate Ready Boston and Shoreline Protection

The Columbus Park Pump Station concept was developed to maintain consistency with possible Climate Ready Boston (CRB) adaptations based on the latest available information at the time they were developed. As the CRB program continues to evolve, it is anticipated that proposed concepts will need to be adapted.

The concept was developed to be consistent with stated neighborhood design flood elevations. In Columbus Park, where the stated target design flood elevation (DFE) is 15.0 feet, pumps were designed to discharge to a minimum elevation of 15.0 feet. The modular (higher) DFE for this location is 16.5 feet.

At the time of this project, many CRB concepts were in early planning stages and not fully defined. **In consideration of this, it was assumed the shoreline protection around the City of Boston is 100% effective for all modeling evaluations.** This assumption eliminates overland coastal flooding from model predictions, allowing for isolation of flooding that results only from rainfall and stormwater that cannot be discharged due to high sea levels. It is important to recognize that additional flooding, beyond what is depicted herein, would be expected if 100% effective shoreline protection is not implemented.

Columbus Park Pump Station *Section View*



Note: This concept also includes an aboveground electrical building, which is not shown in this graphic. Landscaping could be used to lessen the visual impact of the electrical building.

Coastal Stormwater Discharge Analysis
Columbus Park Pump Station

Boston Water and Sewer Commission | Hazen

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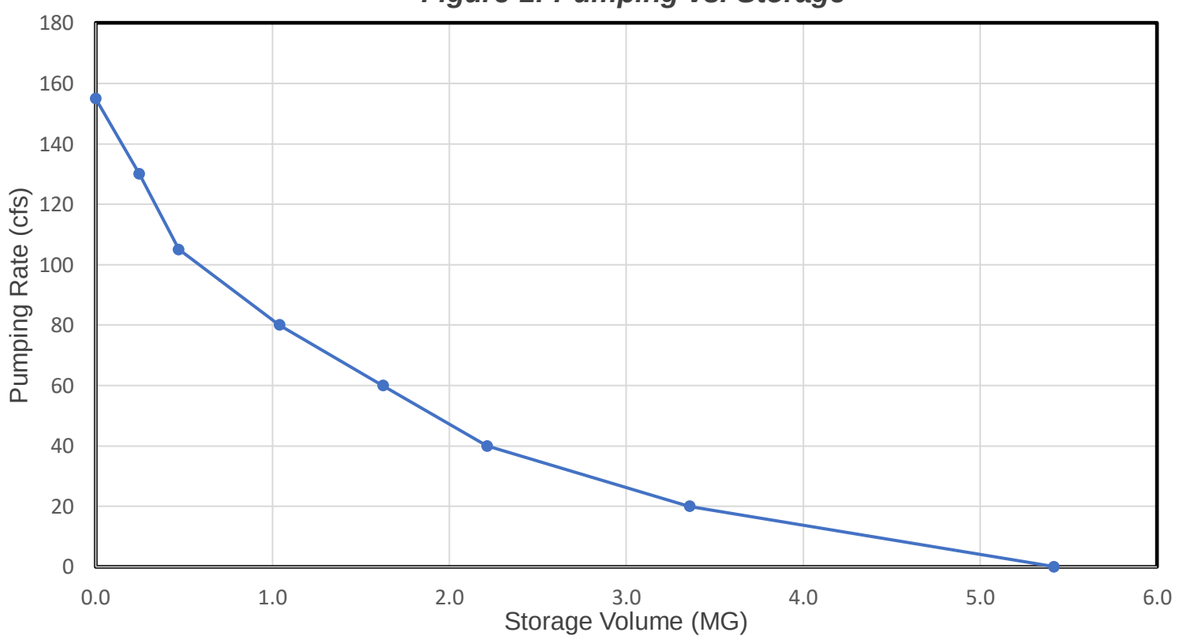
Basis of Design

Storage and Pumping

Model simulations were conducted to determine the maximum Hydraulic Grade Line (HGL) that occurs at Outfall 25LSDO058 with the current tide cycle. Analyses were then conducted to determine the acceptable combinations of storage volume and pumping rate required to maintain the existing HGL with 2070 projected sea level rise and 100-year storm surge, as shown in Figure 1. The City of Boston's Parcel database was used to identify publicly owned parcels near the existing outfall. An analysis of the pump station was performed to identify a pump rate and physical dimensions that are hydraulically viable. It was found that a 1.26 MG, storage tank ~13.3 feet deep could fit within the property with an 80 CFS pump station. The storage tank and pump station occupy and area of approximately 13,000 ft^2. The Columbus Park pump station utilizes one duty pump, one standby pump, and two dewatering pumps. The pump station is configured with vertical, axial electric submersible pumps in parallel bays. The pumps are configured to discharge into individual, non-manifolded force mains, which travel horizontally underground from the pump station to the proposed elevated shoreline project (TBD by CRB), at which point they connect to a singular discharge structure with a fixed weir and discharge into the harbor onto an energy dissipation structure.

Figure 1: Pumping vs. Storage



Rainfall and Coastal Conditions

The Commission currently utilizes a 10-year, 24-hour design storm to establish its target level of service. For the purpose of sizing new piping and evaluating storage capacity, a projected 2070 10-year, 24-hour design storm was developed. For consistency with Climate Ready Boston, performance of the Columbus Park storage concept was also evaluated with projected rainfall from a 100-year tropical event (developed during the Commission's Inundation Model Project). The Columbus Park region was evaluated using a 100-year return period coastal boundary condition. Data for this condition were obtained from the MC-FRM. For the purpose of evaluating the effectiveness of the concept, it was further assumed that complete shoreline protection was implemented, preventing flow of water between land and the harbor. Table 2 contains a summary of the coastal conditions that were analyzed.

Table 1: Rainfall Conditions

Scenario	Purpose	Rainfall Depth (in)	Peak Intensity (in/hr)
Present Day, 10-year, 24-hr design storm	Baseline Conditions	5.15	3.32
Projected 2070, 10-year, 24-hr design storm	Design Conditions	6.18	4.08
100-year Tropical Storm	Damage Analysis	9.58	0.84

Table 2: Coastal Conditions

Scenario	Purpose	Peak Water Surface Elevation (ft, NAVD88)	Source
Present Day	Baseline Conditions	3.7	BWSC Existing Model (April 2016 Tide Cycle)
2070,100-year Tropical Storm	Damage Analysis	13.8	MC-FRM

Flood Modeling and Damage Analysis

Figure 2: Estimated Replacement Cost

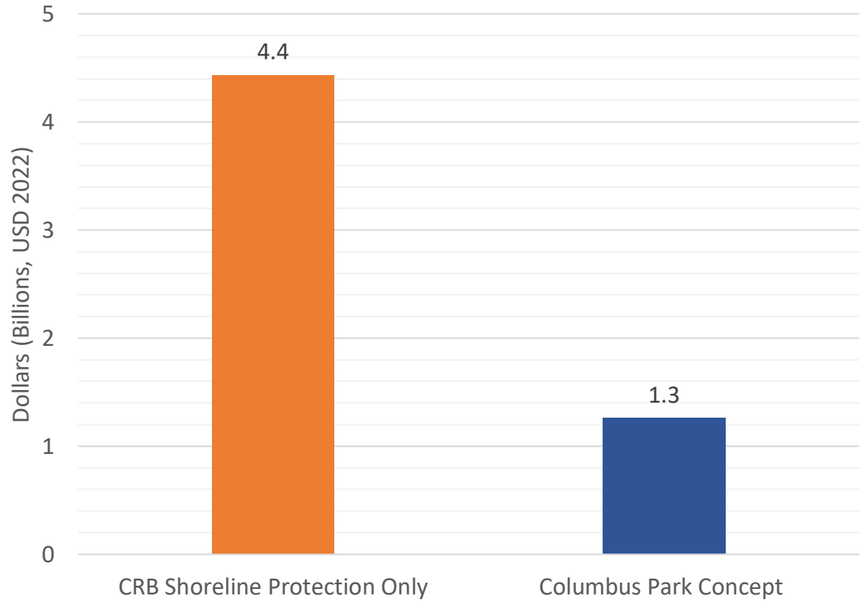


Figure 3: Loss of GDP

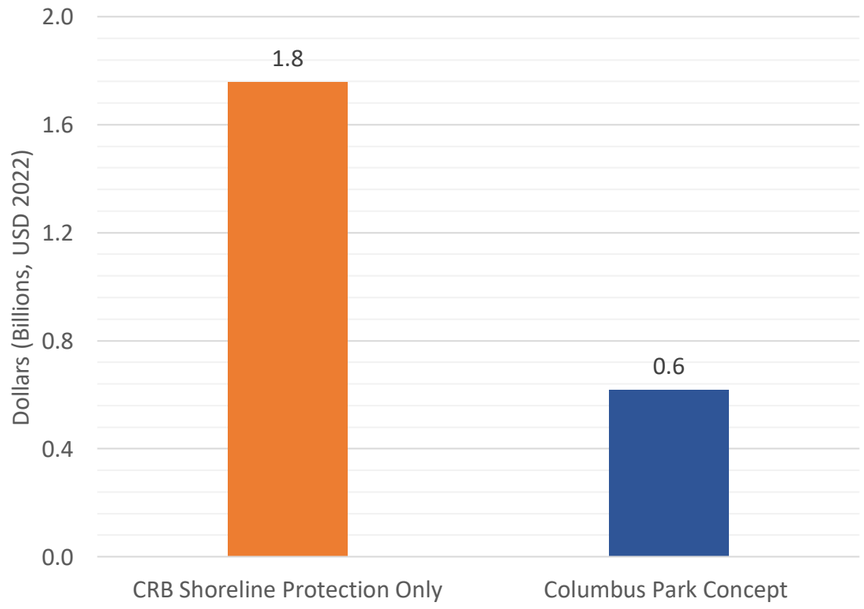
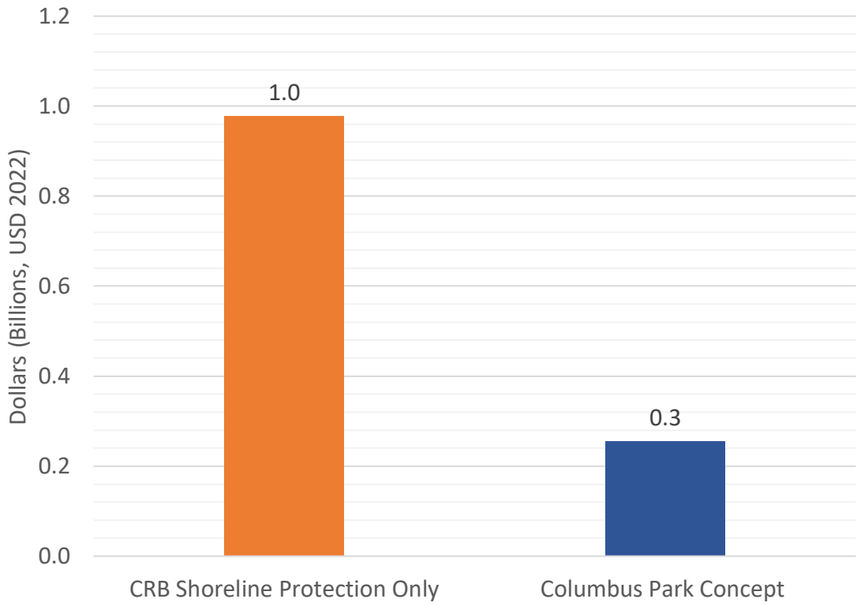


Figure 4: Physical Damage



The flood reduction benefits of the Columbus Park Pump Station concept were evaluated using the Commission's 2D Inundation Model by simulating a 100-year tropical storm event with 2070 SLR and storm surge. The figures on the following page depict the peak flooding that was predicted in the Columbus Park drainage area with shoreline protection only and with the pump station and tide gates on all vulnerable BWSC owned outfalls. An analysis of economic losses/physical impacts from flooding under both scenarios was performed by risQ Inc.

Model predictions indicate that the Columbus Park Pump Station concept reduces physical damage by **$700 million**, avoids **$3.1 billion** in rebuilding costs, and mitigates a GPD loss of **$1.2 billion** during a 100-year tropical storm event in 2070 compared to shoreline protection only.

Note: replacement values include the total value of impacted buildings in flooded areas (e.g., impacted buildings are fully replaced), whereas physical damage includes estimated costs to repair flood damage based on predicted flood depths and building characteristics. The values shown are the average of minimum and maximum calculated losses. Refer to the Project's Final Report for more information.

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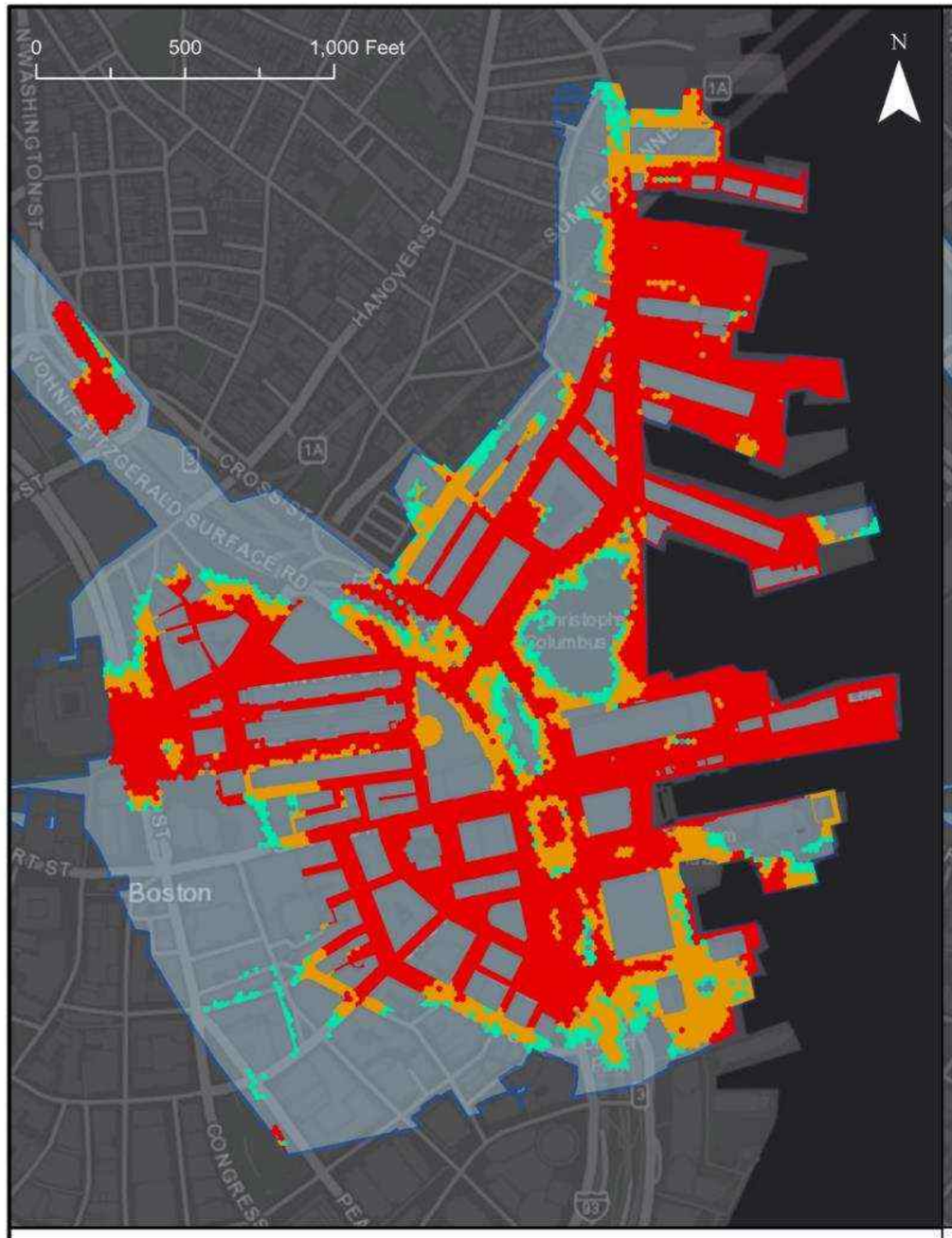

2070 SLR + 100yr Tropical Storm + Storm Surge

Shoreline Protection Only



2070 SLR + 100yr Tropical Storm + Storm Surge

Pump Station and Tide Gates

Legend

- Flood Depth > 4 in and < 1 ft
- Flood Depth > 1 ft and < 2 ft
- Flood Depth > 2 ft
- Drainage Area Analyzed

Simulation Parameters

Storm Type	100yr Tropical Storm
Rainfall Depth	9.6 inches
Peak WSE 2070 SLR + 100yr Surge	13.8 feet NAVD88

Coastal Stormwater Discharge Analysis
Columbus Park Pump Station

Boston Water and Sewer Commission

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Cost Estimate and FEMA BRIC Considerations

Capital Cost Estimate

A construction cost estimate for the Columbus Park Pump Station concept was developed for planning purposes. Assumptions for the cost estimate include 15-year escalation to the mid-point of construction and the inclusion of a 50% design contingency. Utility hookup costs were not included.

Table 3: Columbus Park Pump Station Cost Estimate Subtotals

Remaining Design Development & Construction Administration (assumed 20% of total less design contingency)	$2,409,000
Direct Construction Costs	$4,731,915
Indirect Construction Costs	$946,383
Mark-Up *(Including 50% design contingency)*	$12,170,702
Total	**$20,258,000**

Social Vulnerability and FEMA BRIC Funding

FEMA BRIC funding prioritizes disadvantaged communities. Table 4 contains a summary of several indicators for the Columbus Park tributary area that could be used help characterize the community for future FEMA funding applications and prioritization of projects that benefit disadvantaged communities.

Table 4: Columbus Park Tributary Area Social Vulnerability Indicators

Low Income & Persistent Poverty	
Per Capita Income	$108,521
Below Poverty Line	11%
High Housing Cost Burden	
Stressed Renters (>40% rent-to-income)	26%
Households With Food Insecurity	14%
Racial and Ethnic Segregation	
Asian Population	7%
Black Population	5%
Hispanic Population	5%
White Population	84%
Education and Employment	
Adults Age 25+ Without High School (or equivalent) Degree	3%
Unemployment Rate (Age 16+)	4%

Data provided by risQ inc. from the US census and American Community Survey

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Planting Palette

A planting palette was developed for the Columbus Park concept. Native plant selections create an enhanced, environmentally-beneficial green space. Larger shrubs and trees can conceal concept utilities such as discharge pipes and the electrical building from the public.

Trees



Amelanchier arborea
common serviceberry



Juniperus virginiana
eastern red cedar



Magnolia virginiana
sweet bay magnolia



Quercus rubra
northern red oak

Shrubs



Rosa carolina
pasture rose



Rhus copallinum
winged sumac



Aronia melanocarpa
black chokeberry



Morella pensylvanica
bayberry

Herbaceous and Grasses



Panicum virgatum
switchgrass



Schizacharium scoparium
little bluestem



Eutrochium purpureum
Joe-Pye-Weed



Solidago sempervirens
seaside goldenrod

Coastal Stormwater Discharge Analysis
Columbus Park Pump Station

Boston Water and Sewer Commission | Hazen

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Conceptual Design – Not for Construction

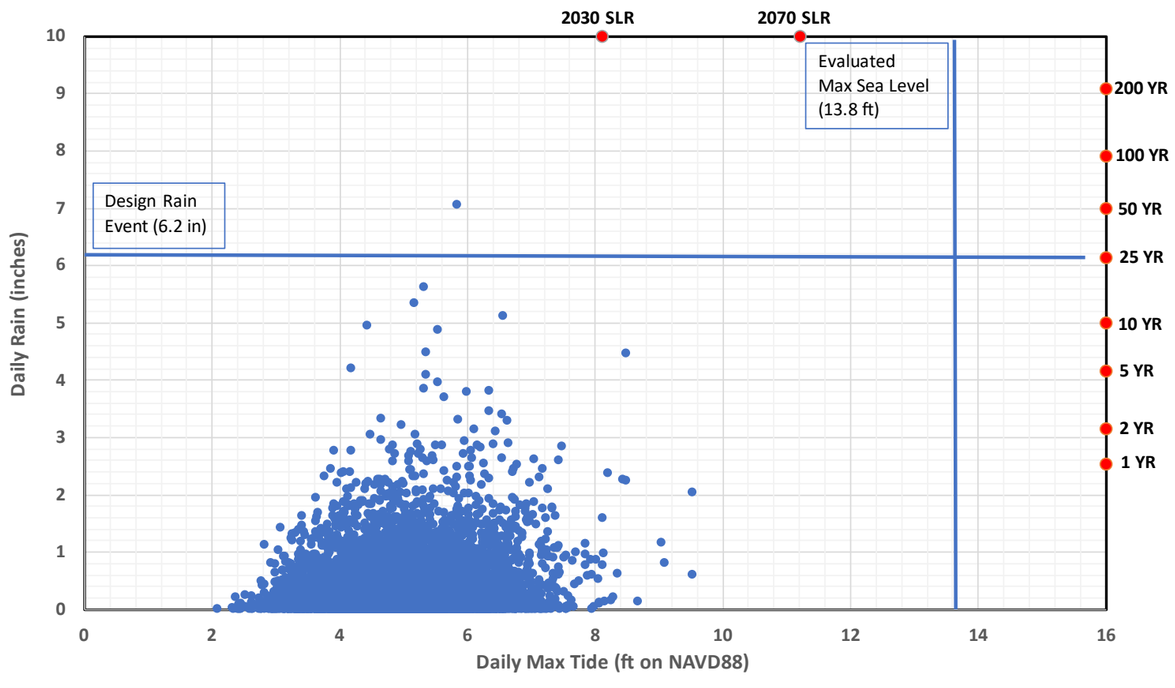
Adaptability and Implementation

Adaptability

Figure 5 below depicts historical daily rainfall totals and tide levels. As shown in this figure, the conditions that were used to design and analyze and design the Columbus Park pump station are conservative and represent more extreme conditions than have occurred historically. Regardless, the following measures could be implemented to adapt the concept to more severe conditions (additional SLR, more intense rainfall, etc.) in the future:

- Increase the size of installed electric submersible pumps
- Utilize the standby pump as a duty pump during extreme conditions
- Increase the size of the peak shaving tank

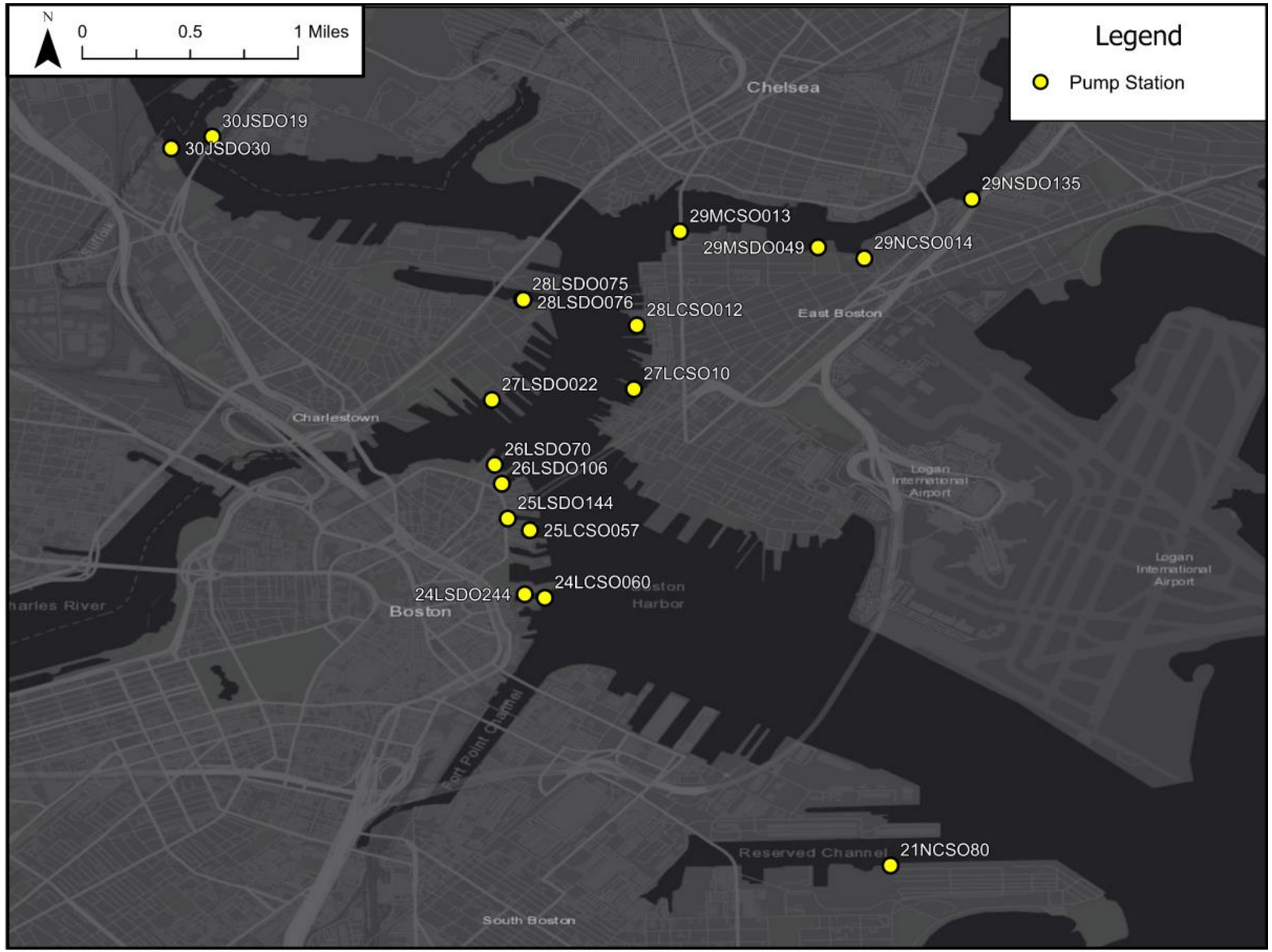
Figure 5: Design and Analysis Conditions vs. Historical Tide and Rainfall



Implementation Considerations

- Coordination with CRB is necessary to implement shoreline protection. The pump station should not be implemented without shoreline protection to prevent coastal flooding within the area tributary to it. The discharge structure may need to be modified depending on the exact nature of the shoreline protection chosen by CRB.
- Community engagement with stakeholders may help build project support by documenting the need for the storage tank and pump station.
- A comprehensive permitting evaluation should be conducted to evaluate possible impacts from construction and operation of the pump station to the receiving water.
- A careful analysis of constructability and sequencing will need to be performed to minimize impacts to the existing park.
- If construction of the storage tank results in modifications to the existing park, the design should be made compliant with the Americans with Disabilities Act to ensure accessibility.
- Given the high public visibility location of this concept, coordination with CRB should occur to construct shoreline adaptations at the same time to avoid separate construction projects.

Replicability and Implementation Timeline



Summary of Similar Concepts

Number of Sites: 18

Vulnerable Area: 422 acres

The map on this sheet depicts other vulnerable outfalls that could be adapted with electric submersible pump stations. In some locations, several outfalls could be consolidated with a new conduit that conveys flow to a single pump station.

Additional detail about these outfalls can be found in the Commission's Coastal Stormwater Discharge Analysis Implementation Timeline.

Coastal Stormwater Discharge Analysis
Columbus Park Pump Station

Boston Water and Sewer Commission | Hazen

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ATTACHMENT A
COLUMBUS PARK PUMP STATION CONCEPTUAL DESIGN DRAWINGS

A-1: Overview Plan
A-2: Pump Station Plan
A-3: Pump Station Section View

Coastal Stormwater Discharge Analysis
Columbus Park Pump Station

Boston Water and Sewer Commission

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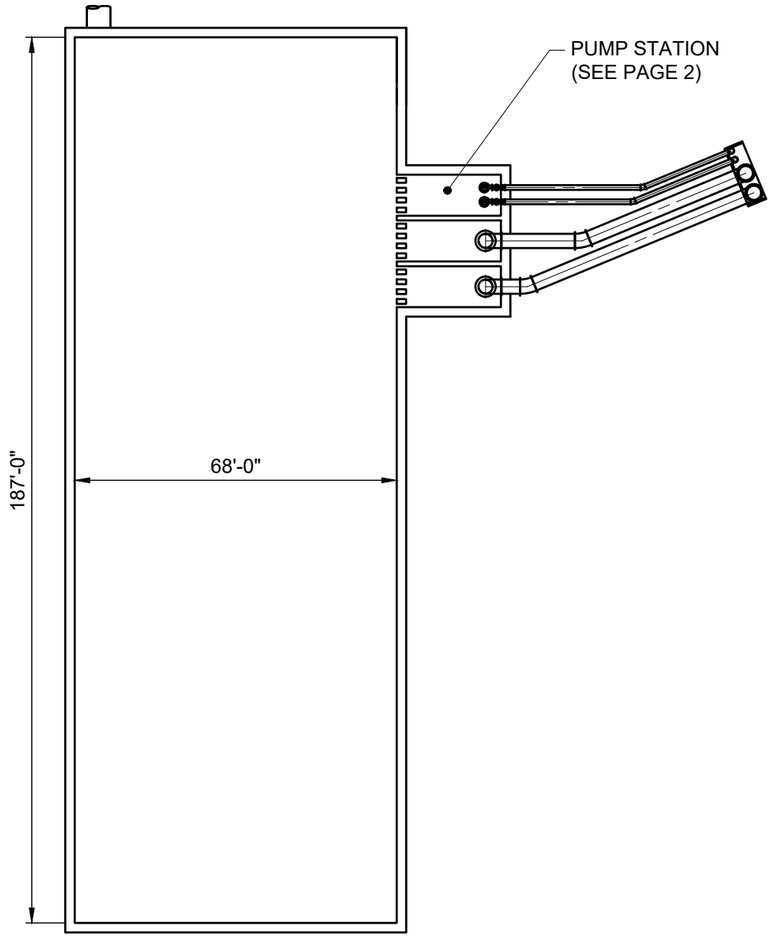
Columbus Park Stormwater Pump Station



OVERVIEW PLAN

SCALE: NTS

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STATIC HEAD RANGE, FT	11.6 - 13.7
DESIGN FLOOD ELEVATION, FT	15.0

STORMWATER PUMP-1,2, OPERATIONAL WSE TABLE		
NOTE	OPERATION	ELEVATION, FT
A	HIGH LEVEL ALARM	3.0
B	LAG PUMP ON	2.7
C	LEAD PUMP ON	2.5
D	LEAD PUMP OFF	2.0
E	LOW LOW ALARM	1.8
G	MIN PUMP SUBMERGENCE	1.6

COASTAL STORMWATER DISCHARGE ANALYSIS

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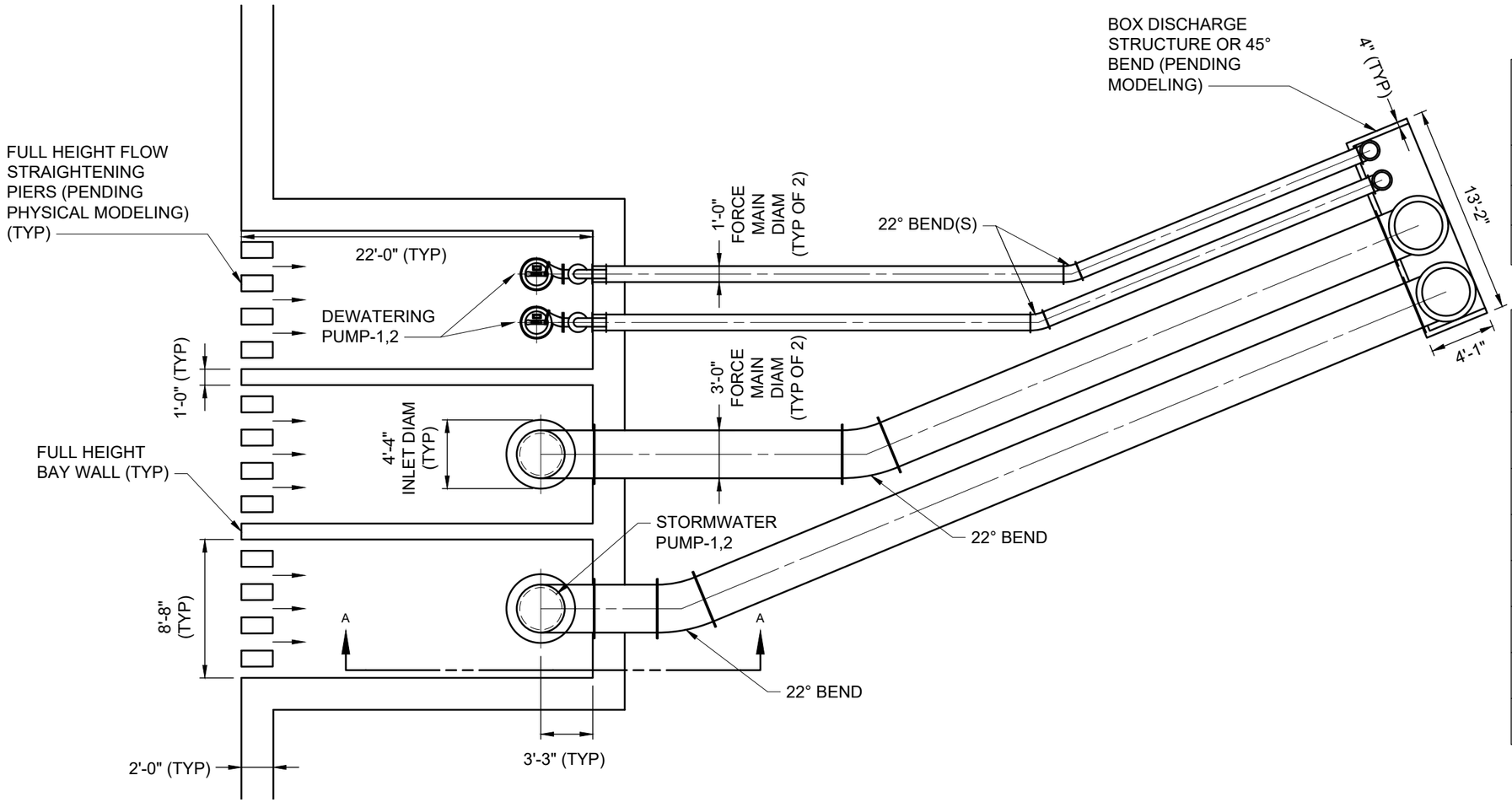
Columbus Park Stormwater Pump Station



PUMP STATION PLAN

SCALE: NTS

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STATIC HEAD RANGE, FT	11.6 - 13.7
DESIGN FLOOD ELEVATION, FT	15.0

STORMWATER PUMP-1,2, OPERATIONAL WSE TABLE		
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A	HIGH LEVEL ALARM	3.0
B	LAG PUMP ON	2.7
C	LEAD PUMP ON	2.5
D	LEAD PUMP OFF	2.0
E	LOW LOW ALARM	1.8
G	MIN PUMP SUBMERGENCE	1.6

COASTAL STORMWATER DISCHARGE ANALYSIS

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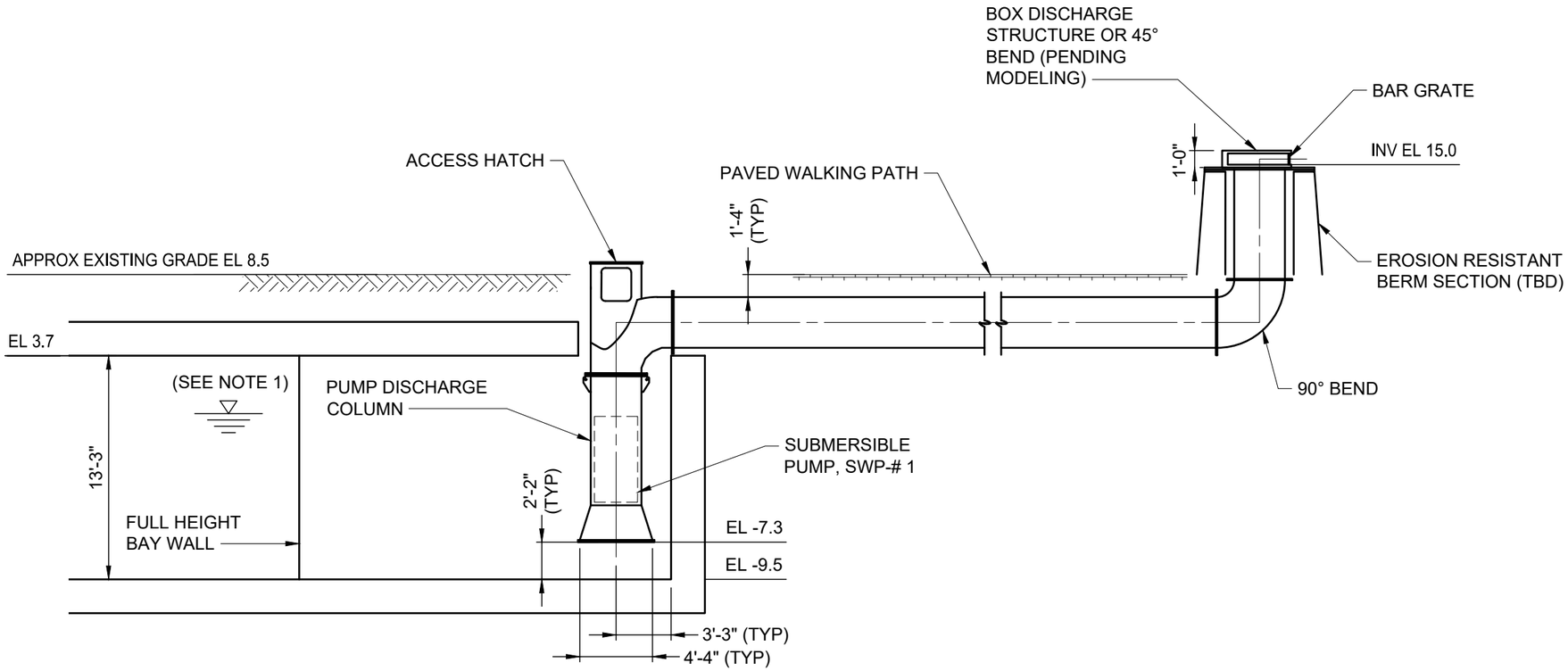
Columbus Park Stormwater Pump Station



SECTION

SCALE: NTS

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DESIGN FLOOD ELEVATION, FT	15.0

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A	HIGH LEVEL ALARM	3.0
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COASTAL STORMWATER DISCHARGE ANALYSIS

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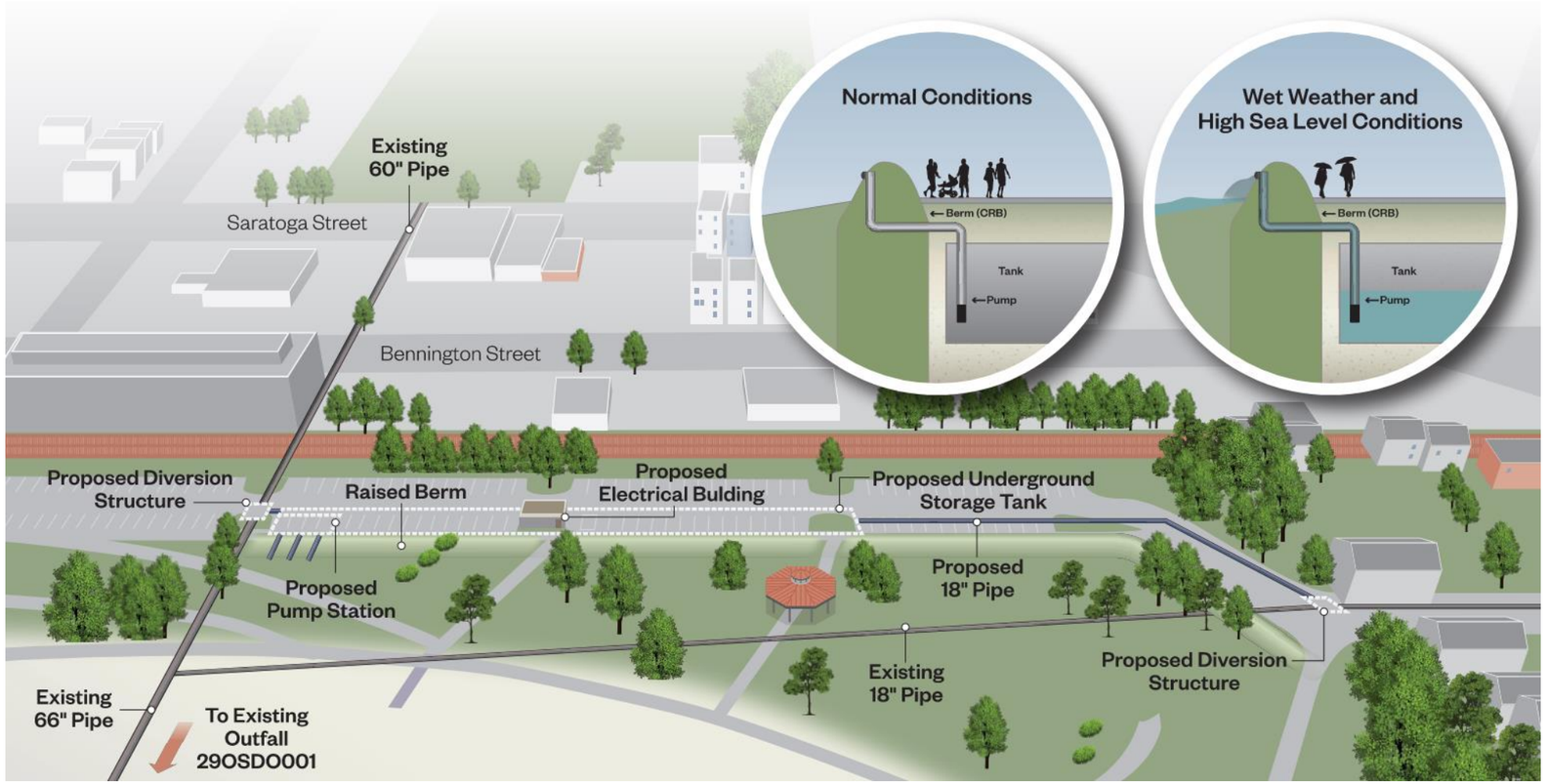
Constitution Beach *Concept Overview*





Conceptual Solution

The Constitution Beach concept design includes a subsurface stormwater storage tank and an underground stormwater pump station to discharge wet weather flow from outfalls 29OSDO001, 29PSDO44, and 28PSDO1 when sea levels are too high for the outfalls to discharge by gravity. Flow to the storage tank is diverted from existing sewers with passive diversion weirs, where proposed pipes then convey the flow to the storage tank. The storage tank is connected directly to the pump station. The pump stations utilizes electric submersible pumps to minimize the above ground footprint of the station and mitigate negative visual and auditory impacts from diesel engine driven pumps. Each pump is designed with its own, non-manifolded, discharge. During extreme storm conditions a portable generator could be parked within the parking lot to provide a backup power supply in the event of a power outage.

The location of the pump station discharge at this location is determined primarily by preliminary CRB adaptation plans, which include shoreline elevation and berms along the outer perimeter of the parking lot. During an extreme storm condition, it is anticipated that any area not protected by the berm would be flooded.

Type: Pumping and Storage

Total Drainage Area: 251 acres

Coastal Flood Vulnerable Drainage Area Protected: 239 acres

Concept Elements:

- Subsurface Storage Tank
- Subsurface Pump Station
- Diversion structures
- New conveyance

Outfalls Included in Concept:

- 29OSDO001
- 29PSDO44
- 28PSDO1

Coastal Stormwater Discharge Analysis
Constitution Beach

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Assumptions

Sea Level Rise and Datum

The Constitution Beach Pump Station concept was designed for consistency with Climate Ready Boston (CRB) proposed adaptations and analyzed based on sea level rise (SLR) projections in the Massachusetts Coastal Flood Risk Model (MC-FRM). The SLR values applied in MC-FRM are consistent with the standards for the State of Massachusetts developed by Coastal Zone Management. The MC-FRM utilizes a "High" SLR scenario. This scenario is based on the relative SLR projections under Relative Concentration Pathway (RCP) 8.5 (a "worst case scenario" of increasing atmospheric carbon concentrations) and represents elevations that have a 99.5% probability of not being exceeded within the respective timeframes. In 2030 that amounts to an increase of 1.3 feet in Boston from a baseline condition (2008 centered tidal epoch), and in 2070 that amounts to an increase of 4.3 feet.

The concept developed in this project was analyzed using coastal conditions that include 2070 projected SLR and storm surge resulting from a 100-year tropical storm. The peak water surface elevation (WSE) predicted by the MC-FRM during these conditions is approximately 13.8 feet NAVD88 (varies by location). In mid 2022, the Greater Boston Research Advisory Group (BRAG) issued an updated report with new SLR projections. The report acknowledges that long term SLR projections are associated with significant uncertainty, and that updated projections include less SLR by 2100 (compared to earlier projections in the 2015 BRAG Report). According to the report, the likely range of SLR by 2070 under an RCP 8.5 scenario is 1.4 – 2.8 feet. Based on this information, projections from the MC-FRM that were utilized in this project are conservative and appropriate for long term planning purposes.

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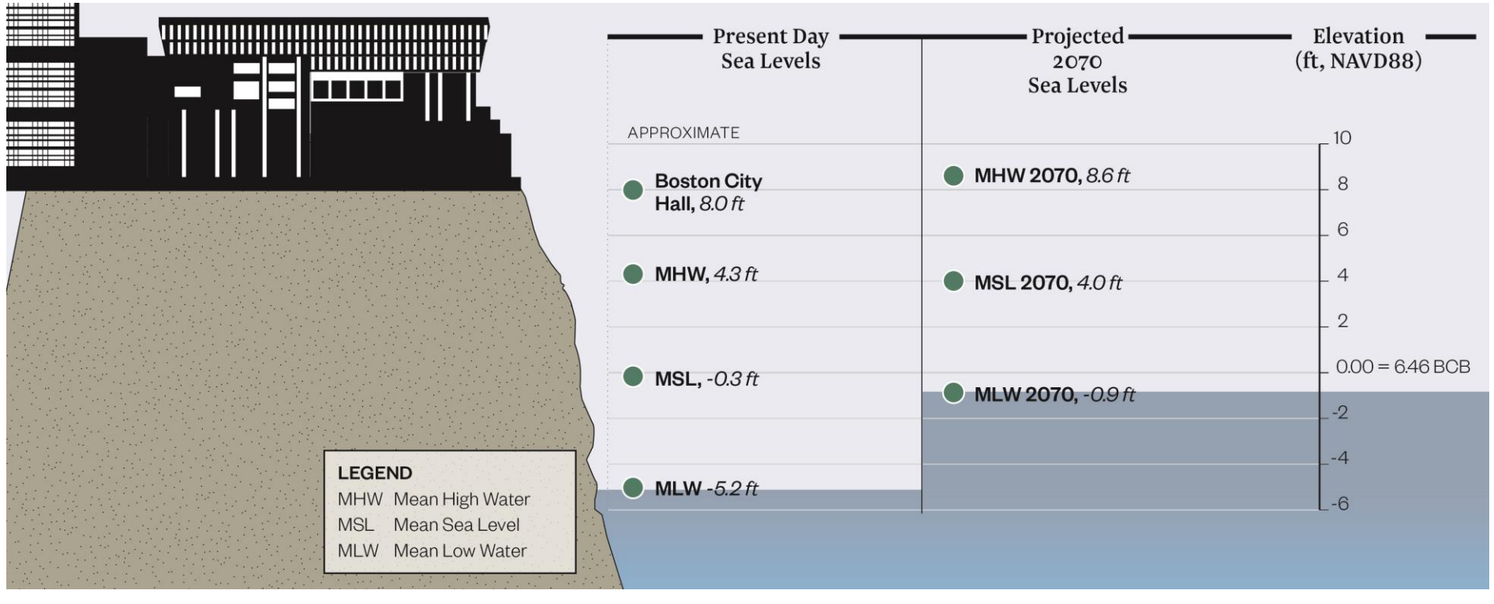


Climate Ready Boston and Shoreline Protection

The Constitution Beach Pump Station concept was developed to maintain consistency with possible Climate Ready Boston (CRB) adaptations based on the latest available information at the time they were developed. As the CRB program continues to evolve, it is anticipated that proposed concepts will need to be adapted.

The concept was developed to be consistent with stated neighborhood design flood elevations. In East Boston, where the stated design flood elevation is 16.0 feet, pumps were designed to discharge to a minimum elevation of 16.0 feet.

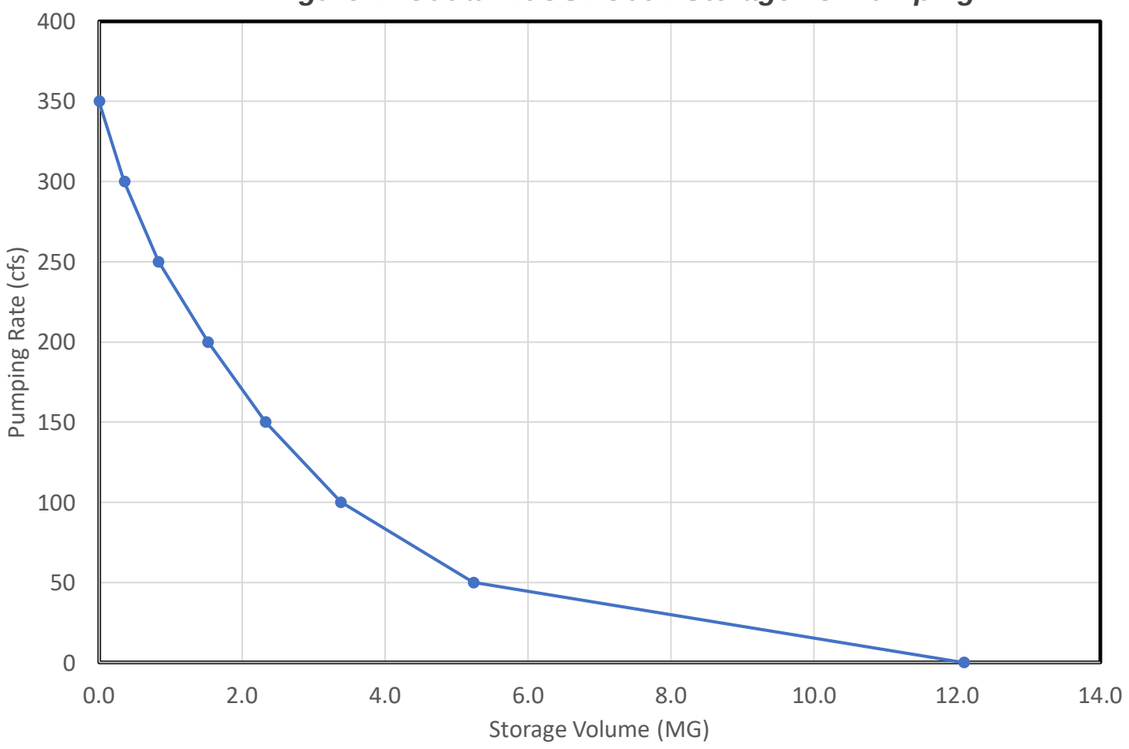
At the time of this project, many CRB concepts were in early planning stages and not fully defined. **In consideration of this, it was assumed the shoreline protection around the City of Boston is 100% effective for all modeling evaluations.** This assumption eliminates overland coastal flooding from model predictions, allowing for isolation of flooding that results only from rainfall and stormwater that cannot be discharged due to high sea levels. It is important to recognize that additional flooding, beyond what is depicted herein, would be expected if 100% effective shoreline protection is not implemented.

Basis of Design

Storage and Pumping

Model simulations were conducted to determine the maximum Hydraulic Grade Line (HGL) that occurs at Outfalls 29OSDO001, 29PSDO44, and 28PSDO1 with the current tide cycle. Analyses were then conducted to determine the acceptable combinations of storage volume and pumping rate required to maintain the existing HGL with 2070 projected sea level rise and 100-year storm surge, as shown in Figure 1. The City of Boston's Parcel database was used to identify publicly owned parcels near the existing outfall. An analysis of the pump station was performed to identify a pump rate and physical dimensions that are hydraulically viable. It was found that a 1.4 MG storage tank ~23 feet deep could fit within the parking lot of the property with a 150 CFS pump station. The storage tank and pump station occupy an area of 11,935 ft^2. Each pump has a separate discharge force main which carries water to the proposed CRB berm, currently planned to be placed next to the parking lot, where the discharge structure will be placed. The Constitution Beach pump station utilizes two duty pumps, one standby pump, and two dewatering pumps. The pump station is configured with vertical, axial electric submersible pumps in parallel bays.

Figure 1: Outfall 29OSDO001 Storage vs. Pumping



Rainfall and Coastal Conditions

The Commission currently utilizes a 10-year, 24-hour design storm to establish its target level of service. For the purpose of sizing new piping and evaluating storage capacity, a projected 2070 10-year, 24-hour design storm was developed. For consistency with Climate Ready Boston, performance of the DBB storage concept was also evaluated with projected rainfall from a 100-year tropical event (developed during the Commission's Inundation Model Project). The DBB was evaluated using a 100-year return period coastal boundary condition. Data for this condition were obtained from the MC-FRM. For the purpose of evaluating the effectiveness of the concept, it was further assumed that complete shoreline protection was implemented, preventing flow of water between land and the harbor/Neponset River. Table 2 contains a summary of the coastal conditions that were analyzed.

Table 1: Rainfall Conditions

Scenario	Purpose	Rainfall Depth (in)	Peak Intensity (in/hr)
Present Day, 10-year, 24-hr design storm	Baseline Conditions	5.15	3.32
Projected 2070, 10-year, 24-hr design storm	Design Conditions	6.18	4.08
100-year Tropical Storm	Damage Analysis	9.58	0.84

Table 2: Coastal Conditions

Scenario	Purpose	Peak Water Surface Elevation (ft, NAVD88)	Source
Present Day	Baseline Conditions	3.7	BWSC Existing Model (April 2016 Tide Cycle)
2070,100-year Tropical Storm	Damage Analysis	13.8	MC-FRM

Flood Modeling and Damage Analysis

Figure 2: Estimated Replacement Cost

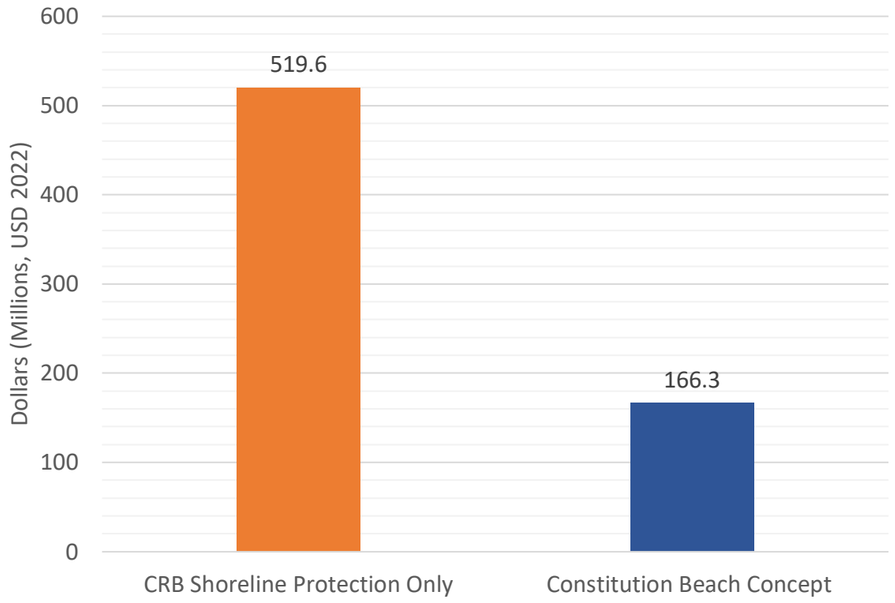


Figure 3: Loss of GDP

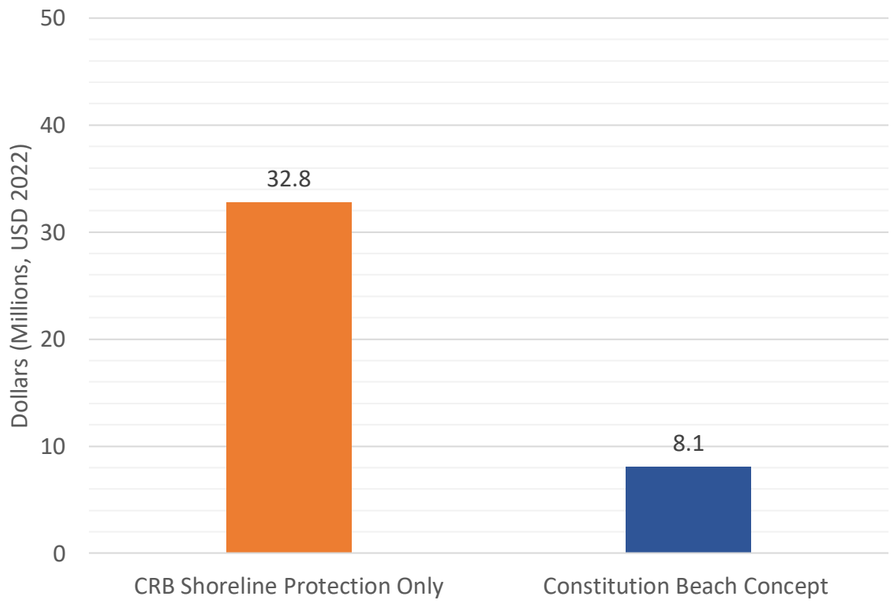
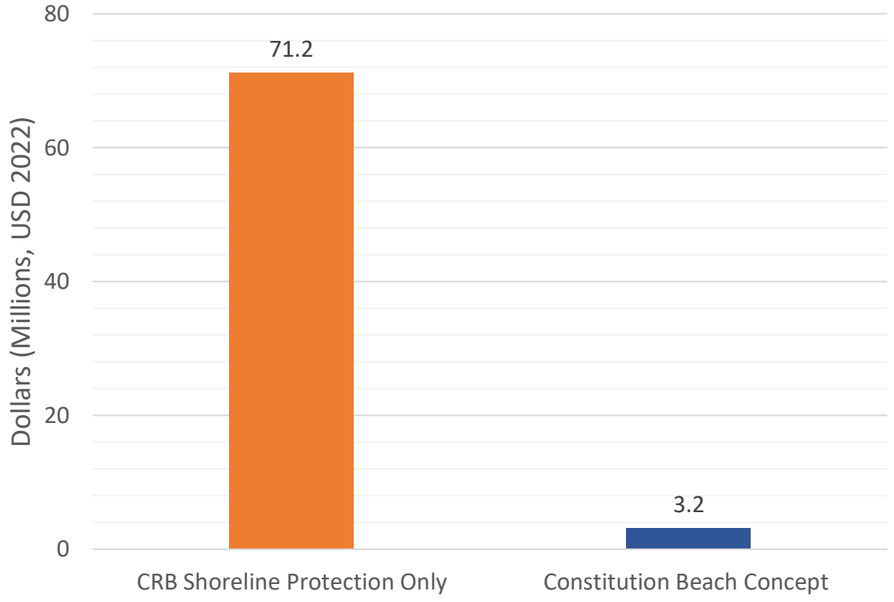


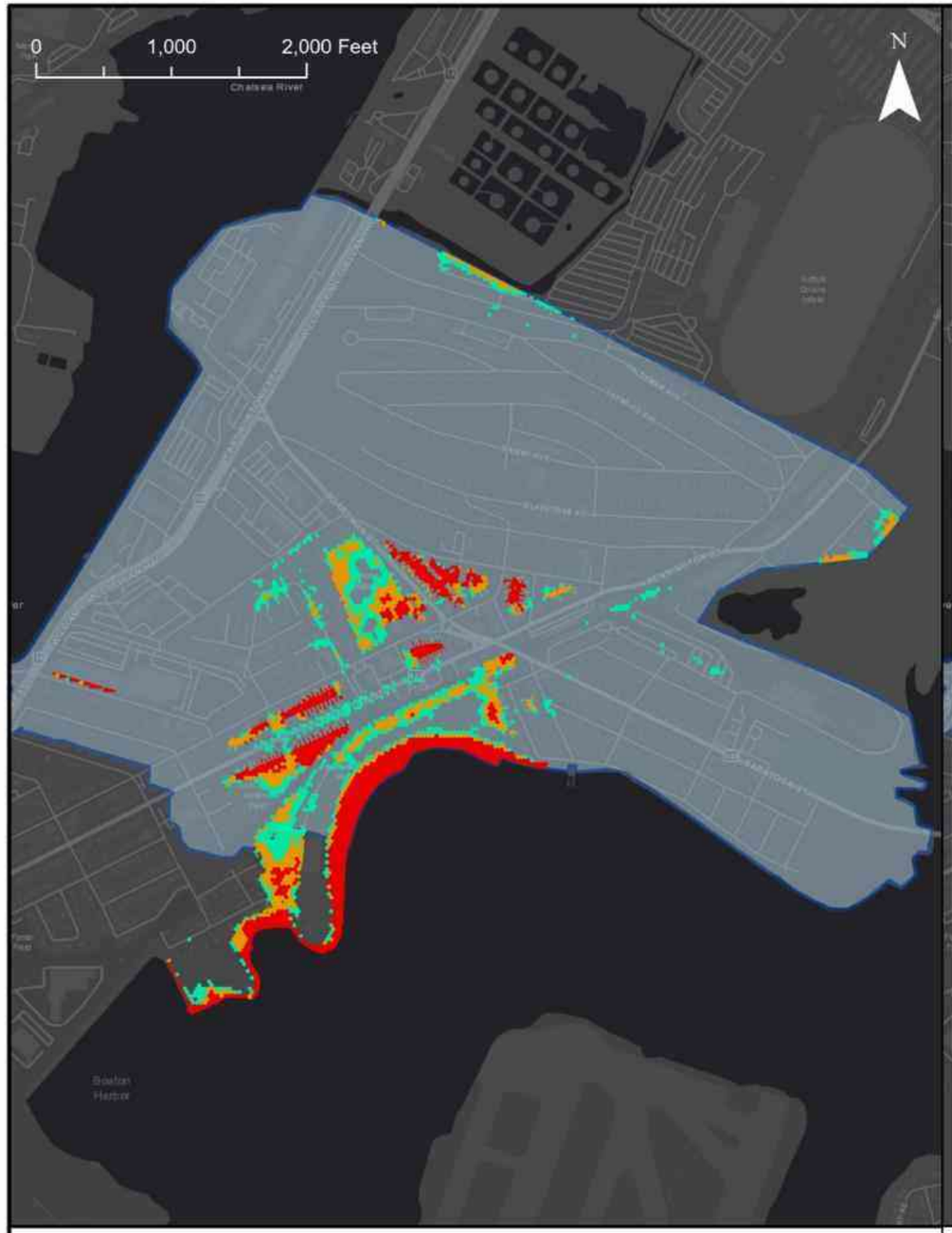
Figure 4: Physical Damage



The flood reduction benefits of the Constitution Beach concept were evaluated using the Commission's 2D Inundation Model by simulating a 100-year tropical storm event with 2070 SLR and storm surge. The figures on the following page depict the peak flooding that was predicted in the Constitution Beach drainage area with shoreline protection only and with the pump station and tide gates on all vulnerable BWSC owned outfalls. An analysis of economic losses/physical impacts from flooding under both scenarios was performed by risQ Inc.

Model predictions indicate that the Constitution Beach Pump Station concept reduces physical damage by **$68 million**, avoids **$353.3 million** in rebuilding costs, and mitigates a GPD loss of **$24.7 million** during a 100-year tropical storm event in 2070 compared to shoreline protection only.

Note: replacement values include the total value of impacted buildings in flooded areas (e.g., impacted buildings are fully replaced), whereas physical damage includes estimated costs to repair flood damage based on predicted flood depths and building characteristics. The values shown are the average of minimum and maximum calculated losses. Refer to the Project's Final Report for more information.



2070 SLR + 100yr Tropical Storm + Storm Surge

Shoreline Protection Only



2070 SLR + 100yr Tropical Storm + Storm Surge

Constitution Beach Pump Station and Tide Gates

Legend

- Flood Depth > 4 in and < 1 ft
- Flood Depth > 1 ft and < 2 ft
- Flood Depth > 2 ft
- Drainage Area Analyzed

Simulation Parameters

Storm Type	100yr Tropical Storm
Rainfall Depth	9.6 inches
Peak WSE 2070 SLR + 100yr Surge	13.8 feet NAVD88

Coastal Stormwater Discharge Analysis
Constitution Beach

Boston Water and Sewer Commission

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Cost Estimate and FEMA BRIC Considerations

Capital Cost Estimate

A construction cost estimate for the Constitution Beach concept was developed for planning purposes. Assumptions for the cost estimate include 15-year escalation to the mid-point of construction and the inclusion of a 50% design contingency. Utility hookup costs were not included.

Table 3: Constitution Beach Cost Estimate Subtotals

Remaining Design Development & Construction Administration (assumed 20% of total less design contingency)	$3,870,000
Direct Construction Costs	$7,615,841
Indirect Construction Costs	$1,523,168
Mark-Up *(Including 50% design contingency)*	$19,533,991
Total	**$32,543,000**

Social Vulnerability and FEMA BRIC Funding

FEMA BRIC funding prioritizes disadvantaged communities. Table 4 contains a summary of several indicators for the Constitution Beach tributary area that could be used help characterize the community for future FEMA funding applications and prioritization of projects that benefit disadvantaged communities.

Table 4: Constitution Beach Tributary Area Social Vulnerability Indicators

Low Income & Persistent Poverty	
Per Capita Income	$32,899
Below Poverty Line	16%
High Housing Cost Burden	
Stressed Renters (>40% rent-to-income)	18%
Households With Food Insecurity	14%
Racial and Ethnic Segregation	
Asian Population	4%
Black Population	3%
Hispanic Population	48%
White Population	67%
Education and Employment	
Adults Age 25+ Without High School (or equivalent) Degree	19%
Unemployment Rate (Age 16+)	11%

Data provided by risQ inc. from the US census and American Community Survey

Conceptual Design – Not for Construction

Planting Palette

A planting palette was developed for the greenspace bordering Constitution Beach. After construction, planting of native plant species could provide a public amenity with new green space and environmental benefits associated with native plant species.

Shrubs



Baccharis halimifolia
groundsel tree



Iva frutescens
saltmarsh elder



Prunus maritima
beach plum



Morella pensylvanica
bayberry

Herbaceous and Grasses



Spartina alterniflora
smooth cordgrass



Spartina patens
saltmeadow grass



Distichlis spicata
coastal salt grass



Solidago sempervirens
seaside goldenrod

Coastal Stormwater Discharge Analysis
Constitution Beach

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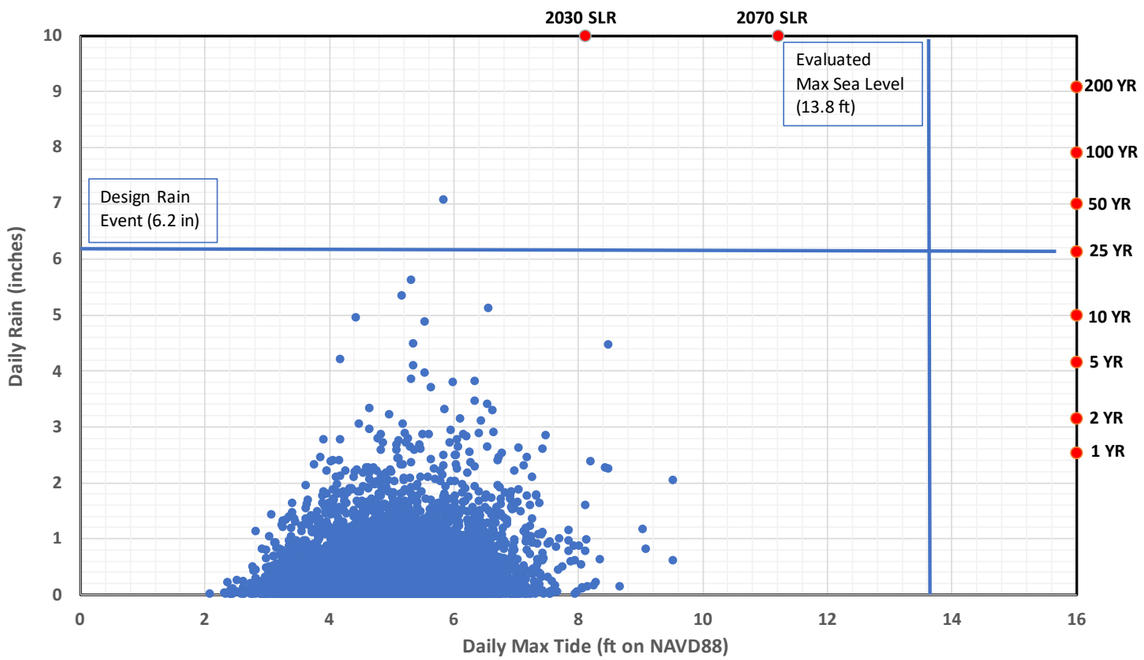
Adaptability and Implementation

Adaptability

Figure 5 below depicts historical daily rainfall totals and tide levels. As shown in this figure, the conditions that were used to design and analyze the Constitution Beach pump station are conservative and represent more extreme conditions than have occurred historically. Regardless, the following measures could be implemented to adapt the concept to more severe conditions (additional SLR, more intense rainfall, etc.) in the future:

- Increase the size of installed electric submersible pumps
- Utilize the standby pump as a duty pump during extreme conditions
- Increase the size of peak shaving tank

Figure 5: Design and Analysis Conditions vs. Historical Tide and Rainfall



Implementation Considerations

- Coordination with CRB is necessary to implement shoreline protection. The pump station should not be implemented without shoreline protection to prevent coastal flooding within the area tributary to it.
- Planting of native plant species and other green features will provide an improved public amenity and preserve the “look and feel” of the parking lot and surrounding park.
- Community engagement with stakeholders may help build project support by illustrating the flood control benefits of the pump station.
- A comprehensive permitting evaluation should be conducted to evaluate possible impacts from construction and operation of the pump station to the receiving water.
- The location of the pump station and discharge should be adapted based as CRB continues to evolve its plan for shoreline protection in this area. The pump station should be located in the “protected” area behind the shoreline adaptation, and the pump station discharge should be incorporated with the shoreline project.
- At present, CRB planning documents indicate that a berm could be constructed between the beach and parking lot. Based on this, the current concept includes a discharge in the same area. It is anticipated that the pump station would only be operated during extreme storm events when the beach is flooded. If the pump station were operated during a on-flood condition, discharge from the pump station would create beach erosion and be a hazard to beach occupants.

Replicability and Implementation Timeline



Summary of Similar Concepts

Number of Sites: 24

Vulnerable Area: 464 acres

The map on this sheet depicts other vulnerable outfalls that could be adapted with electric submersible pump stations. In some locations, several outfalls could be consolidated with a new conduit that conveys flow to a single pump station.

Additional detail about these outfalls can be found in the Commission's Coastal Stormwater Discharge Analysis Implementation Timeline.

ATTACHMENT A

CONSTITUTION BEACH PUMP STATION CONCEPTUAL DESIGN DRAWINGS

A-1: Overview Plan and Pump Station Plan

A-2: Pump Station Section View

Coastal Stormwater Discharge Analysis
Constitution Beach

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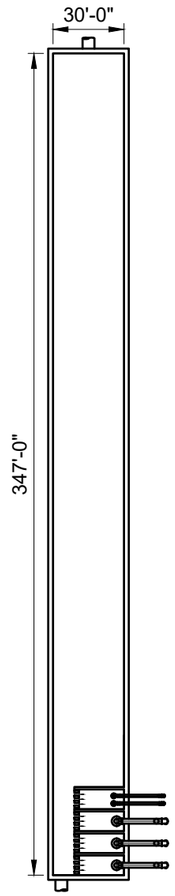
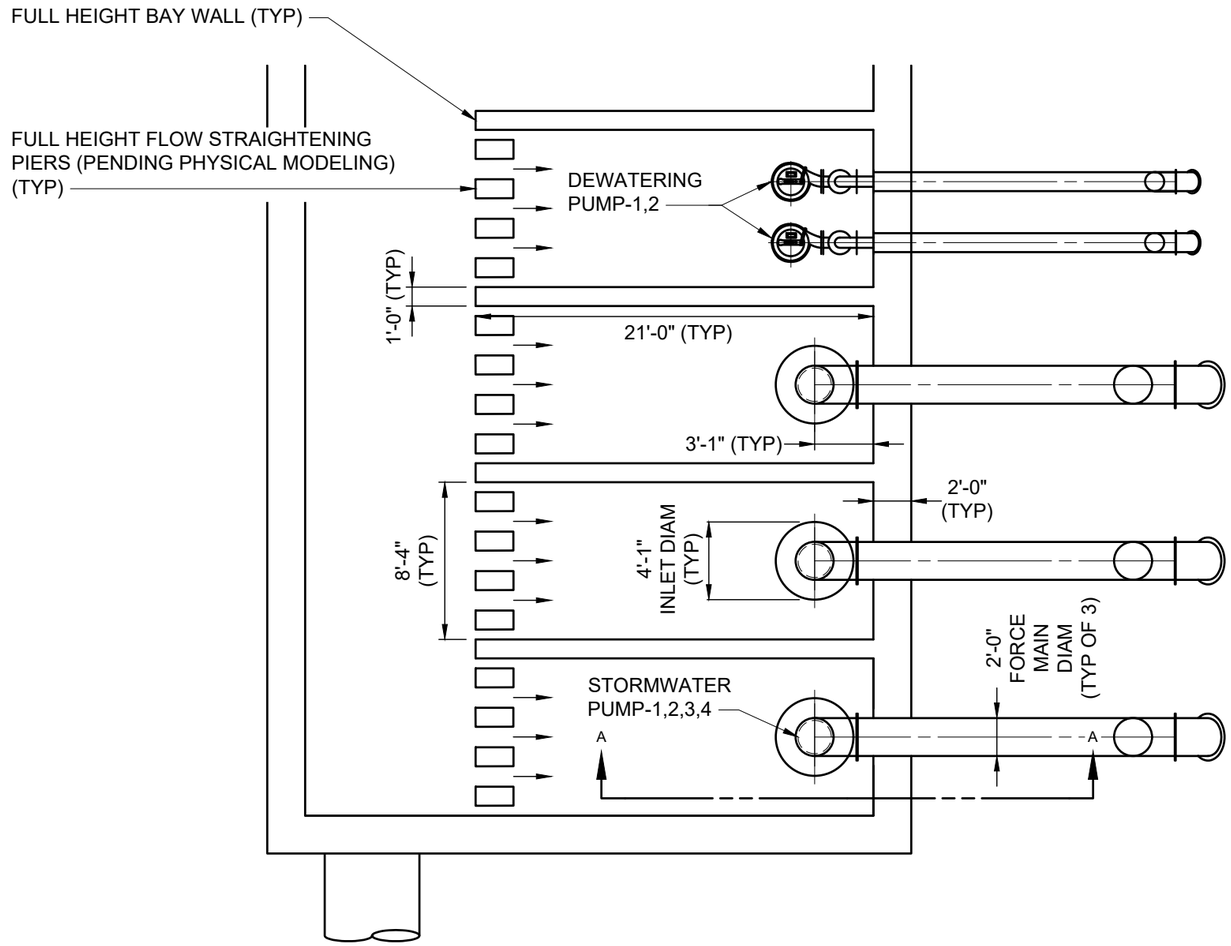
Constitution Beach Stormwater Pump Station



OVERVIEW PLAN
SCALE: NTS



PUMP STATION PLAN
SCALE: NTS

NOTES

1. FOR WATER SURFACE ELEVATIONS REFER TO OPERATIONAL TABLE.
2. ALL ELEVATIONS USE THE NAVD88 VERTICAL DATUM UNLESS OTHERWISE STATED.
3. CONCEPTUAL DRAWING, NOT FOR CONSTRUCTION.

STORMWATER PUMP-1,2,3 OPERATIONAL PARAMETERS	
FLOW RATE, CFS	74
STATIC HEAD RANGE, FT	13.3 - 20.5
DESIGN FLOOD ELEVATION, FT	16.0

STORMWATER PUMP-1,2,3 OPERATIONAL WSE TABLE

NOTE	OPERATION	ELEVATION, FT
A	HIGH LEVEL ALARM	2.7
B	LAG PUMP ON	1.0
C	LEAD PUMP ON	-0.5
D	LEAD PUMP OFF	-1.5
E	LOW LOW ALARM	-2.5
G	MIN PUMP SUBMERGENCE	-3.5

COASTAL STORMWATER DISCHARGE ANALYSIS

Boston Water and Sewer Commission

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November 2022

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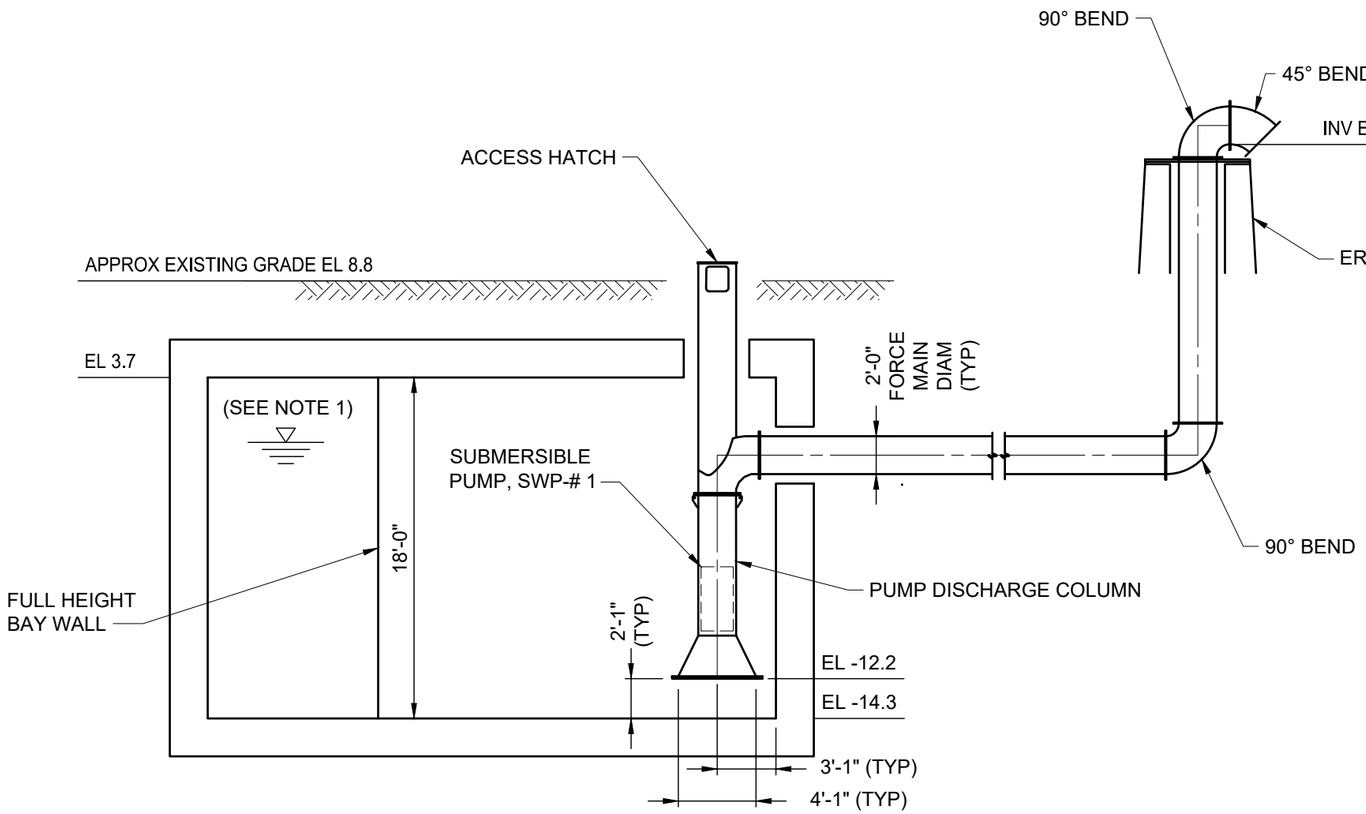
Constitution Beach Stormwater Pump Station



SECTION

SCALE: NTS

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COASTAL STORMWATER DISCHARGE ANALYSIS

Boston Water and Sewer Commission

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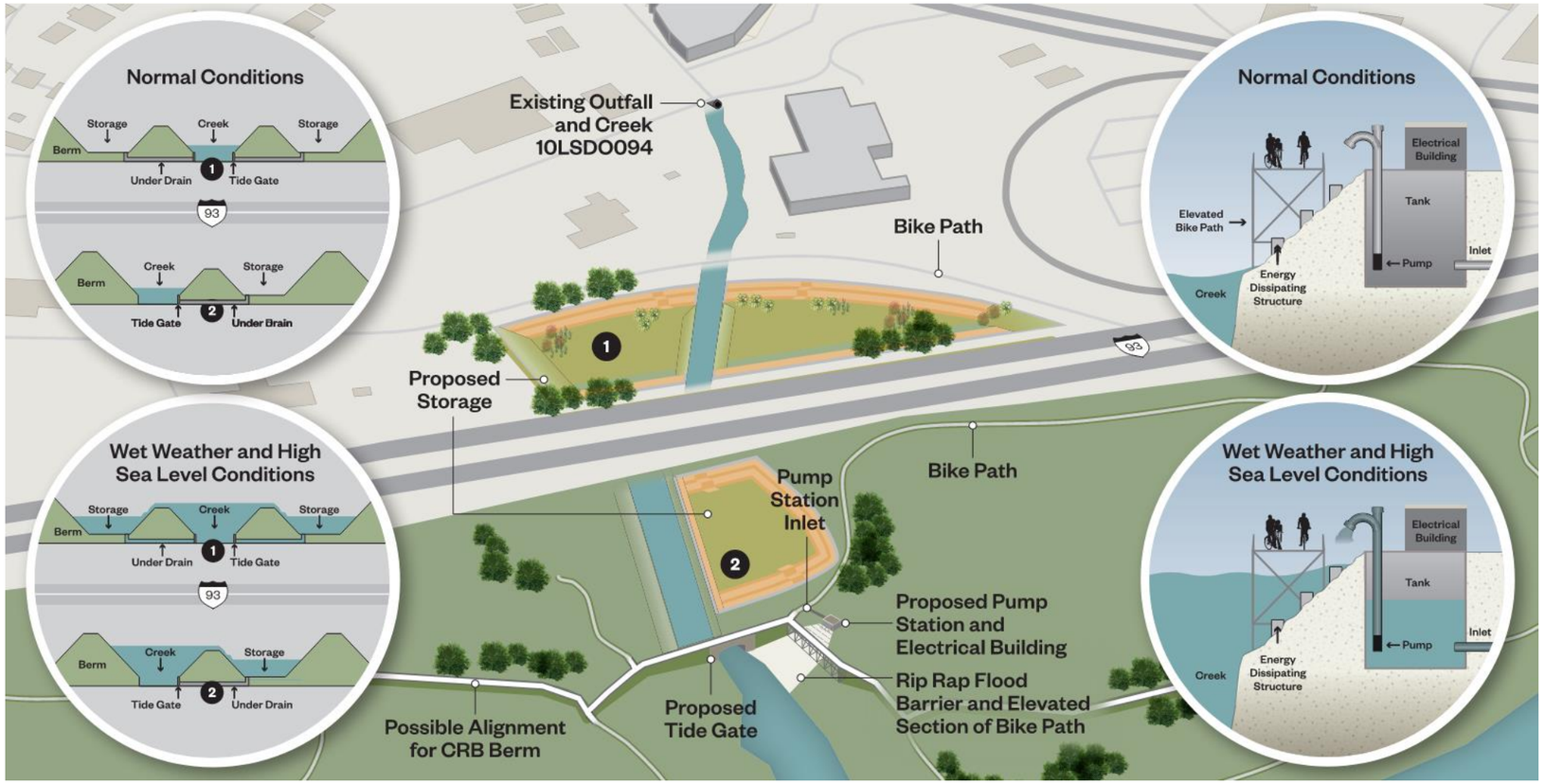
Davenport Creek Stormwater Park *Concept Overview*





Conceptual Solution

The Davenport Creek Stormwater Park includes a "natural" (surface) storage system with a pump station that can be used during larger storm events. This concept is designed to maintain sufficiently low water levels at Outfall 10LSDO094 by isolating the outfall from high tide levels with a tide gate and providing a large storage area for temporary detention of stormwater in an above ground area. During rain events which occur at high tide (triggering closure of a tide gate installed to the west of Interstate 93) stormwater discharged from Outfall 10LSDO094 can overflow proposed berms alongside Davenport Creek into the above ground storage areas. These storage areas would typically remain dry during normal conditions, and feature water tolerant native plant species and public access along the existing Neponset Trail. During larger storm events flow exceeding the capacity of the storage areas can enter a stormwater pump station that discharges into Davenport Creek near its confluence with the Neponset River. Due to the high flood vulnerability of this location, it is essential that berms (or other shoreline protection measures) be constructed around the pump station and storage areas to prevent coastal flooding. In addition to constructing the storage area and pump station, proposed storm water conveyance piping is required to divert higher elevation areas upstream directly to existing outfall 9LSDO095 (see Sheet 4).

Type: Storage and Pumping

Total Drainage Area: 641 acres

Coastal Flood Vulnerable Drainage Area Protected: 244 acres

Concept Elements:

- Above ground "nature based" storage basin
- Improved public amenity/park
- New pipeline for high elevation drainage
- Subsurface pump station and tide gate

Outfalls Included in Concept:

- 10LSDO094

Coastal Stormwater Discharge Analysis
Davenport Creek

Boston Water and Sewer Commission | Hazen

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Assumptions

Sea Level Rise and Datum

The Davenport Creek Stormwater Park was designed for consistency with Climate Ready Boston (CRB) proposed adaptations and analyzed based on sea level rise (SLR) projections in the Massachusetts Coastal Flood Risk Model (MC-FRM). The SLR values applied in MC-FRM are consistent with the standards for the State of Massachusetts developed by Coastal Zone Management. The MC-FRM utilizes a "High" SLR scenario. This scenario is based on the relative SLR projections under Relative Concentration Pathway (RCP) 8.5 (a "worst case scenario" of increasing atmospheric carbon concentrations) and represents elevations that have a 99.5% probability of not being exceeded within the respective timeframes. In 2030, that amounts to an increase of 1.3 feet in Boston from a baseline condition (2008 centered tidal epoch), and in 2070 that amounts to an increase of 4.3 feet.

The concept developed in this project was analyzed using coastal conditions that include 2070 projected SLR and storm surge resulting from a 100-year tropical storm. The peak water surface elevation (WSE) predicted by the MC-FRM during these conditions is approximately 13.8 feet NAVD88 (varies by location). In mid 2022, the Greater Boston Research Advisory Group (BRAG) issued an updated report with new SLR projections. The report acknowledges that long term SLR projections are associated with significant uncertainty, and that updated projections include less SLR by 2100 (compared to earlier projections in the 2015 BRAG Report). According to the report, the likely range of SLR by 2070 under an RCP 8.5 scenario is 1.4 – 2.8 feet. Based on this information, projections from the MC-FRM that were utilized in this project are conservative and appropriate for long term planning purposes.

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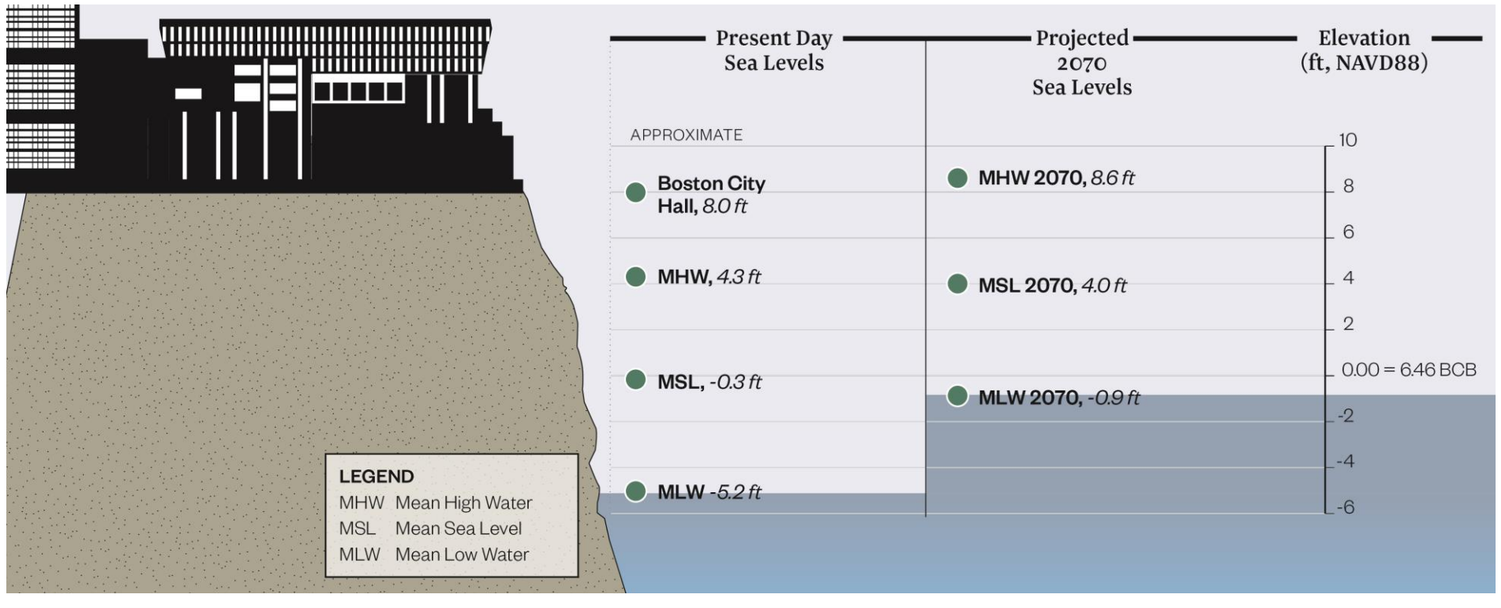

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At the time of this project, many CRB concepts were in early planning stages and not fully defined. **In consideration of this, it was assumed the shoreline protection around the City of Boston is 100% effective for all modeling evaluations.** This assumption eliminates overland coastal flooding from model predictions, allowing for isolation of flooding that results only from rainfall and stormwater that cannot be discharged due to high sea levels. It is important to recognize that additional flooding, beyond what is depicted herein, would be expected if 100% effective shoreline protection is not implemented.

Basis of Design

Storage and Pumping

Model simulations were conducted to determine the maximum Hydraulic Grade Line (HGL) that occurs at Outfall 10LSDO094 with the current tide cycle. Analyses were then conducted to determine the required volume of storage and rate of pumping required to maintain the existing HGL with 2070 projected sea level rise, as shown in Figure 1. The City of Boston's Parcel database was used to identify publicly owned parcels near the existing outfall. It was assumed that flow from the higher elevation portion of the Davenport Creek tributary area will be diverted as shown on the next page. Based on a maximum acceptable depth of 7.5 feet in the above ground storage areas (depicted on the next page), it was found that the above ground storage areas can detain approximately 6 million gallons, requiring a 250 CFS pump station. The storage tank and pump station occupy an area of 2,465 ft^2. After a wet weather event when the tide level recedes, the storage areas are designed to drain by gravity into Davenport Creek via underdrains. The pump station utilizes three duty pumps, one standby pump, and two dewatering pumps. All pumps are axial electric submersible pumps, arranged in parallel bays. The pump station discharges onto an energy dissipation structure located underneath a raised section of mixed-use path (a “bike bridge”).

Figure 1: Pumping vs. Storage

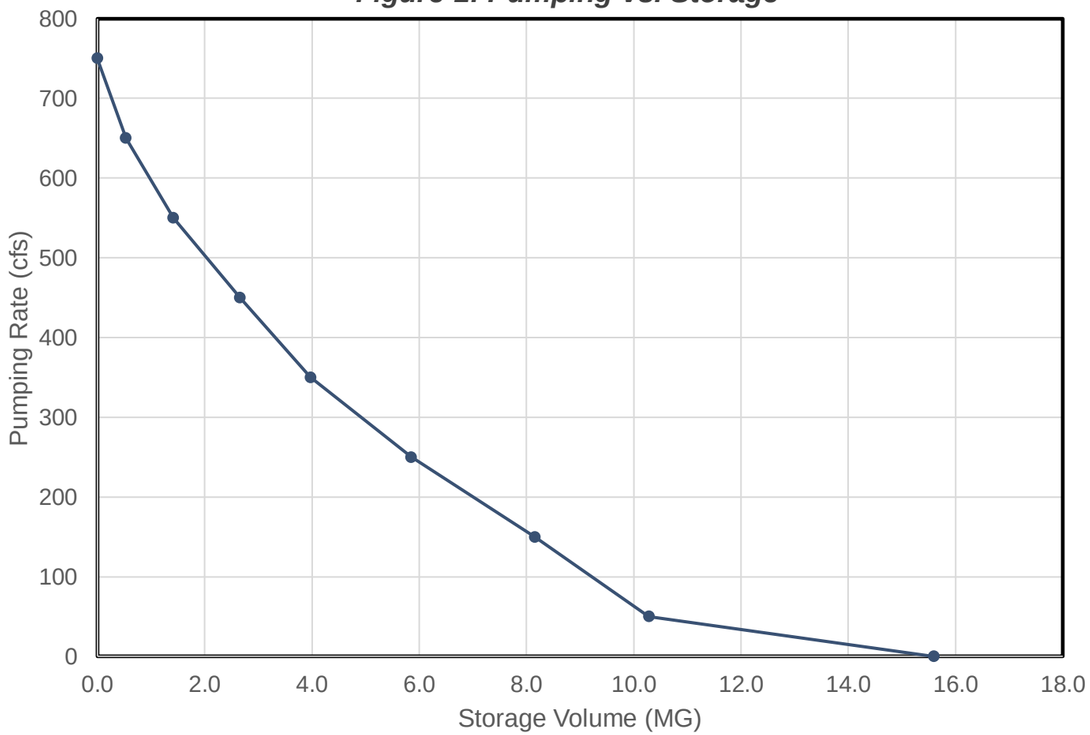

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Table 1: Rainfall Conditions

Scenario	Purpose	Rainfall Depth (in)	Peak Intensity (in/hr)
Present Day, 10-year, 24-hr design storm	Baseline Conditions	5.15	3.32
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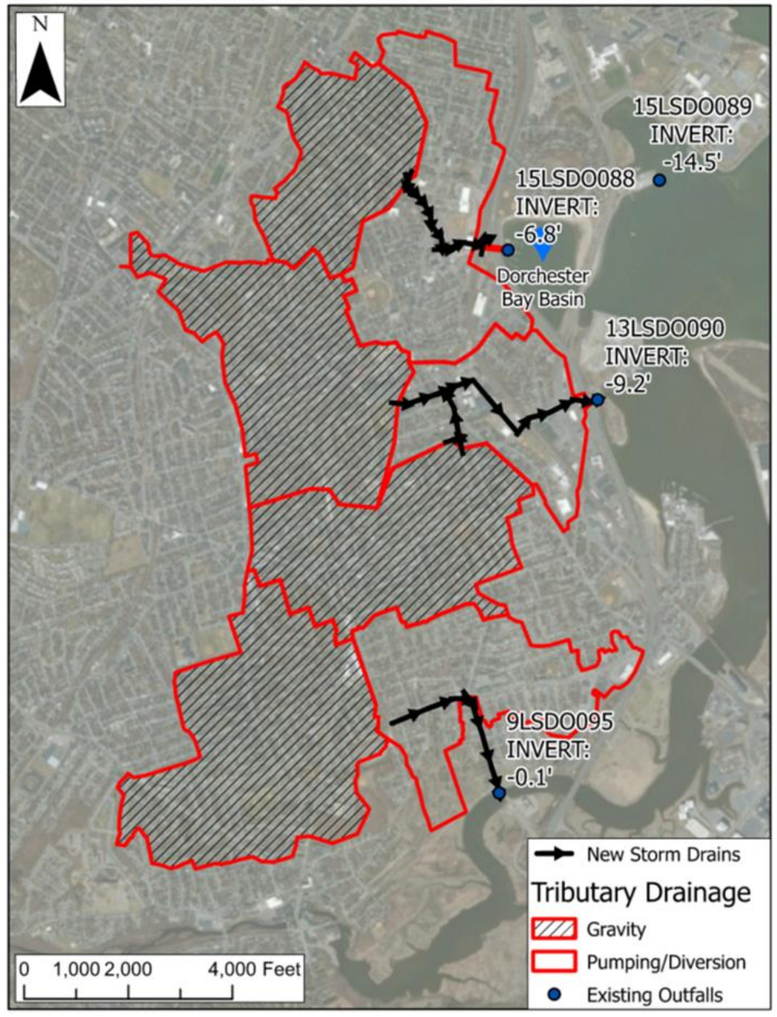
2070,100-year Tropical Storm	Damage Analysis	13.8	MC-FRM

Conceptual Design – Not for Construction

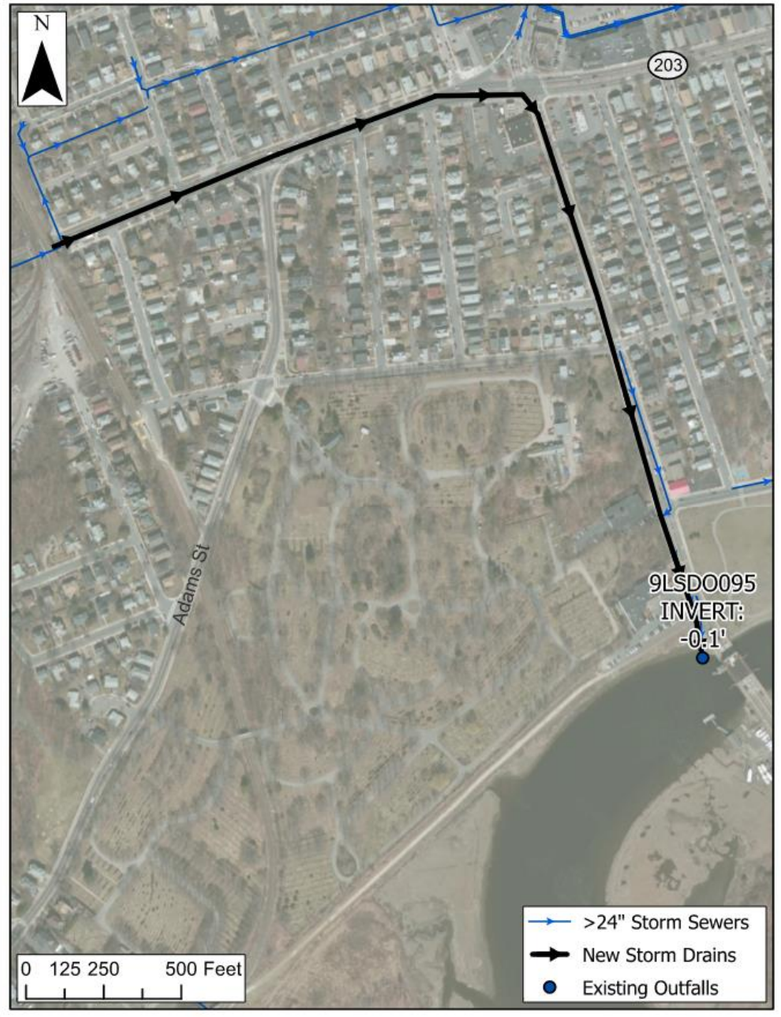
Proposed Storage and Pipelines



6 MG Proposed Storage Areas and Pump Station



New Pipelines for High Elevation Flow Diversion



High Elevation Flow Diversion Pipeline
(in 10LSDO094 Drainage Area)

Coastal Stormwater Discharge Analysis
Davenport Creek

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Davenport Creek Stormwater Park

High Elevation Diversion Pipeline

Coastal Stormwater Discharge Analysis
Davenport Creek

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November 2022

Flood Modeling and Damage Analysis

Figure 2: Estimated Replacement Cost

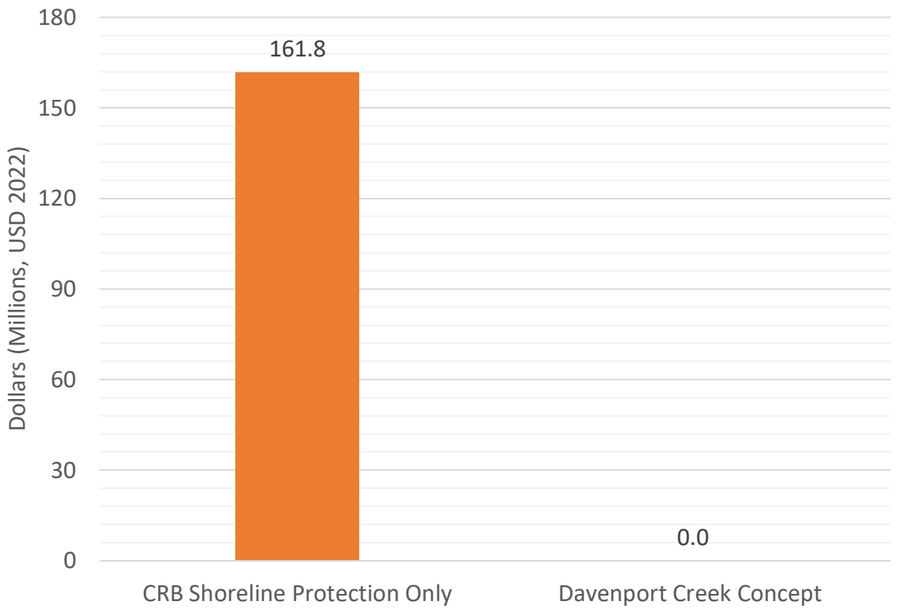


Figure 3: Loss of GDP

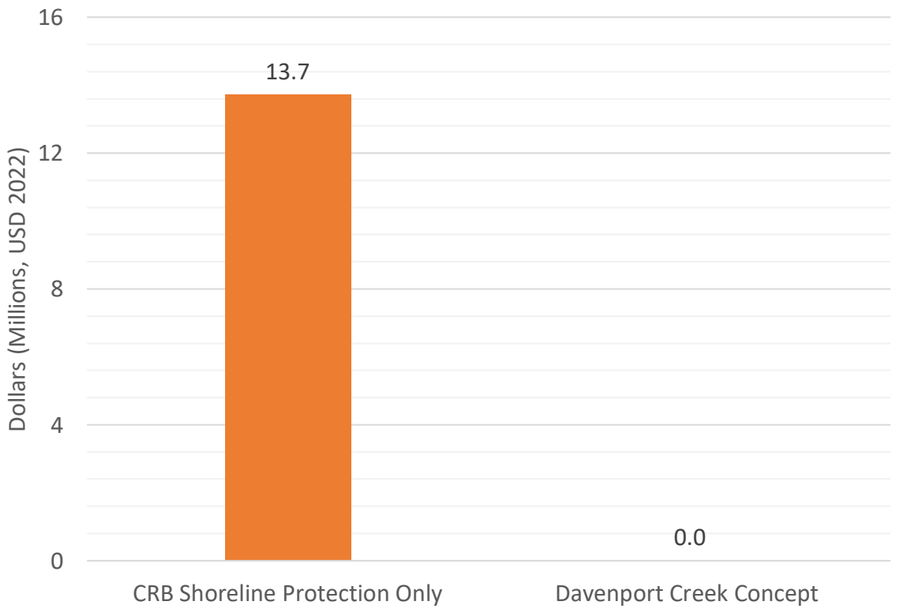
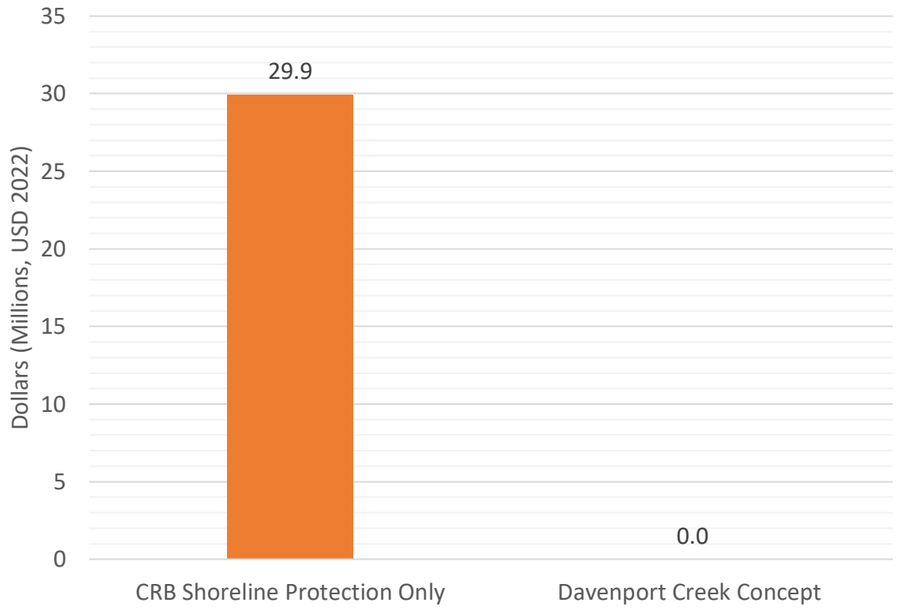


Figure 4: Physical Damage



The flood reduction benefits of the Davenport Creek Stormwater Park concept were evaluated using the Commission's 2D Inundation Model by simulating a 100-year tropical storm event with 2070 SLR and storm surge. The figures on the following page depict the peak flooding that was predicted in the drainage area tributary to Davenport Creek with shoreline protection only and with the concept implemented. An analysis of economic losses/physical impacts from flooding under both scenarios was performed by risQ Inc.

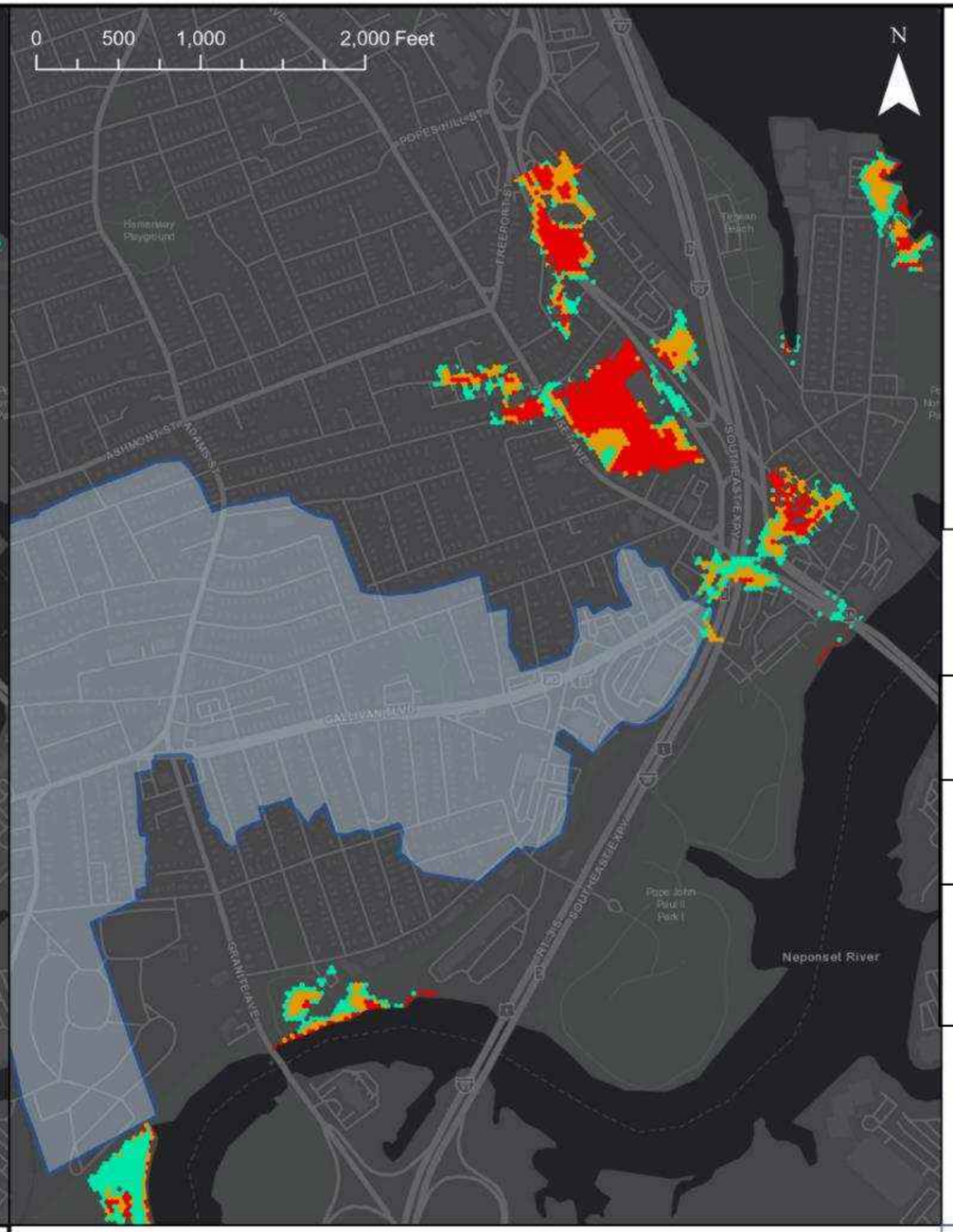
*Model predictions indicate that the Davenport Creek concept reduces physical damage by **$29.9 million**, avoids **$161.8 million** in rebuilding costs, and mitigates a GPD loss of **$13.7 million** during a 100-year tropical storm event in 2070.*

Note: replacement values include the total value of impacted buildings in flooded areas (e.g., impacted buildings are fully replaced), whereas physical damage includes estimated costs to repair flood damage based on predicted flood depths and building characteristics. The values shown are the average of minimum and maximum calculated losses. Refer to the Project's Final Report for more information.



2070 SLR + 100yr Tropical Storm + Storm Surge

Shoreline Protection Only



2070 SLR + 100yr Tropical Storm + Storm Surge

Davenport Creek Stormwater Park and Tide Gates

Legend

- Flood Depth > 4 in and < 1 ft
- Flood Depth > 1 ft and < 2 ft
- Flood Depth > 2 ft
- Drainage Area Analyzed

Simulation Parameters

Storm Type	100yr Tropical Storm
Rainfall Depth	9.6 inches
Peak WSE 2070 SLR + 100yr Surge	13.8 feet NAVD88

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Davenport Creek

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Damage Analysis

Capital Cost Estimate

A construction cost estimate for the Davenport Creek Stormwater Park concept was developed for planning purposes. Assumptions for the cost estimate include 15-year escalation to the mid-point of construction and the inclusion of a 50% design contingency. Additionally, for this estimate electrical duct bank allowances were based on their distance to the closest street. The cost of piles below storm drainage runs and structures as well as hookup costs to existing electrical services were not included in this estimate.

Table 3: Davenport Creek Cost Estimate Subtotals

Remaining Design Development & Construction Administration (assumed 20% of total less design contingency)	$9,119,000
Direct Construction Costs	$17,902,197
Indirect Construction Costs	$3,580,439
Mark-Up *(Including 50% design contingency)*	$46,173,364
Total	**$76,775,000**

Social Vulnerability and FEMA BRIC Funding

FEMA BRIC funding prioritizes disadvantaged communities. Table 5 contains a summary of several indicators for the Davenport Creek tributary area that could be used help characterize the community for future FEMA funding applications and prioritization of projects that benefit disadvantaged communities.

Table 4: Davenport Creek Tributary Area Social Vulnerability Indicators

Low Income & Persistent Poverty	
Per Capita Income	$40,556
Below Poverty Line	18%
High Housing Cost Burden	
Stressed Renters (>40% rent-to-income)	41%
Households With Food Insecurity	14%
Racial and Ethnic Segregation	
Asian Population	6%
Black Population	39%
Hispanic Population	15%
White Population	44%
Education and Employment	
Adults Age 25+ Without High School (or equivalent) Degree	12%
Unemployment Rate (Age 16+)	5%

Data provided by risQ inc. from the US census and American Community Survey

“Dry” Planting Palette

A planting palette was developed for the “dry” areas surrounding the stormwater storage zones. After construction, planting of native plant species could provide a public amenity with new green space and environmental benefits associated with native plant species.

Trees



Amelanchier arborea
common serviceberry



Juniperus virginiana
eastern red cedar



Nyssa sylvatica
black gum



Quercus alba
white oak

Shrubs



Rosa carolina
pasture rose



Rhus copallinum
winged sumac



Aronia melanocarpa
black chokeberry



Morella pensylvanica
bayberry

Herbaceous and Grasses



Panicum virgatum
switchgrass



Schizacharium scoparium
little bluestem



Eutrochium purpureum
Joe-Pye-Weed



Solidago sempervirens
seaside goldenrod

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Davenport Creek

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Conceptual Design – Not for Construction

Stormwater Storage Area Planting Palette

A planting palette was developed for stormwater storage areas that are designed to temporarily flood during intense storm events. The selected plant species are tolerant of occasional temporary flooding. After construction, planting of native plant species could provide a public amenity with new green space and environmental benefits associated with native plant species.

Trees



Amelanchier canadensis
Canadian serviceberry



Juniperus virginiana
eastern red cedar



Betula populifolia
gray birch



Celtis occidentalis
hackberry

Shrubs



Spirea tomentosa
steeplebush



Aronia arbutifolia
red chokeberry



Clethra alnifolia
sweet pepperbush



Lindera benzoin
spicebush

Herbaceous and Grasses



Eupatorium album
white throughwart



Schizacharium scoparium
little bluestem



Symphyotrichum novi-belgi
New York aster



Euthamia graminofolia
grass-leaved goldenrod

Coastal Stormwater Discharge Analysis
Davenport Creek

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Conceptual Design – Not for Construction

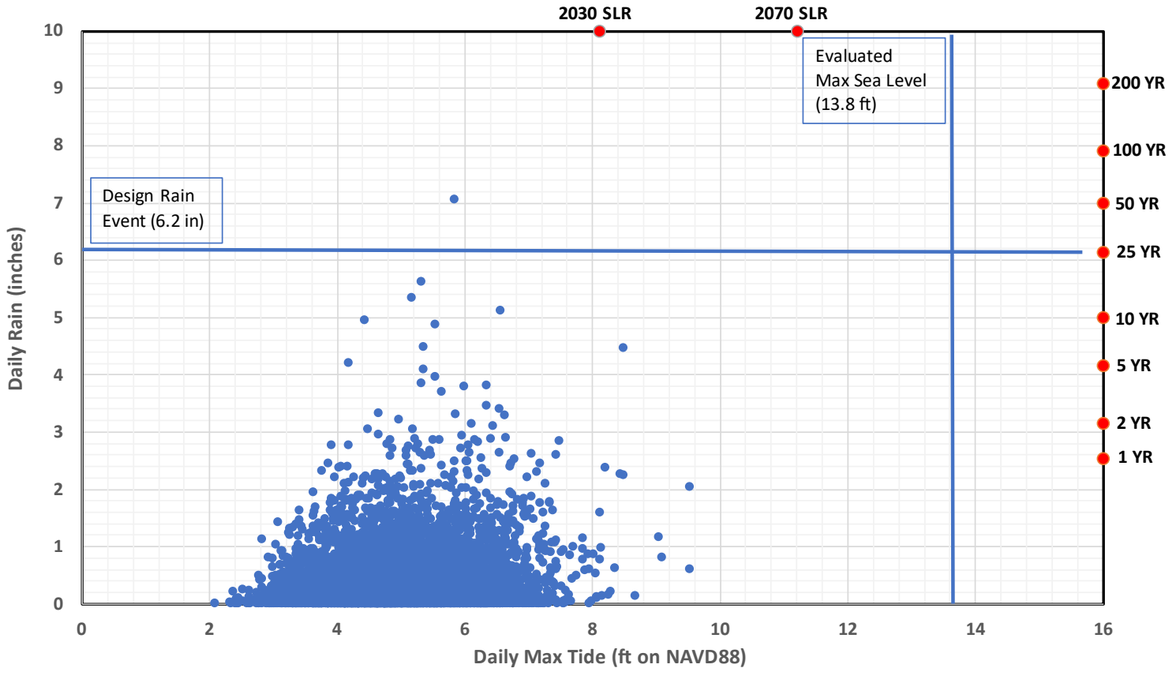
Adaptability and Implementation

Adaptability

Figure 5 below depicts historical daily rainfall totals and tide levels. As shown in this figure, the conditions that were used to design and analyze and design the Davenport Creek Stormwater Park are conservative and represent more extreme conditions than have occurred historically. Considering this, it is expected that the Davenport Creek Stormwater Park will function as a storage only facility (not requiring pumping) during most storm events. Regardless, if additional storage or pumping capacity is required in the future, the following options could be considered:

- The pump station could be expanded to increase pumping capacity if more intense rainfall causes larger than predicted inflows.
- The storage area could be expanded into the adjacent athletic fields in Pope John Paul II Park. If this larger storage area is implemented flow from other adjacent outfalls could be diverted into the storage area.

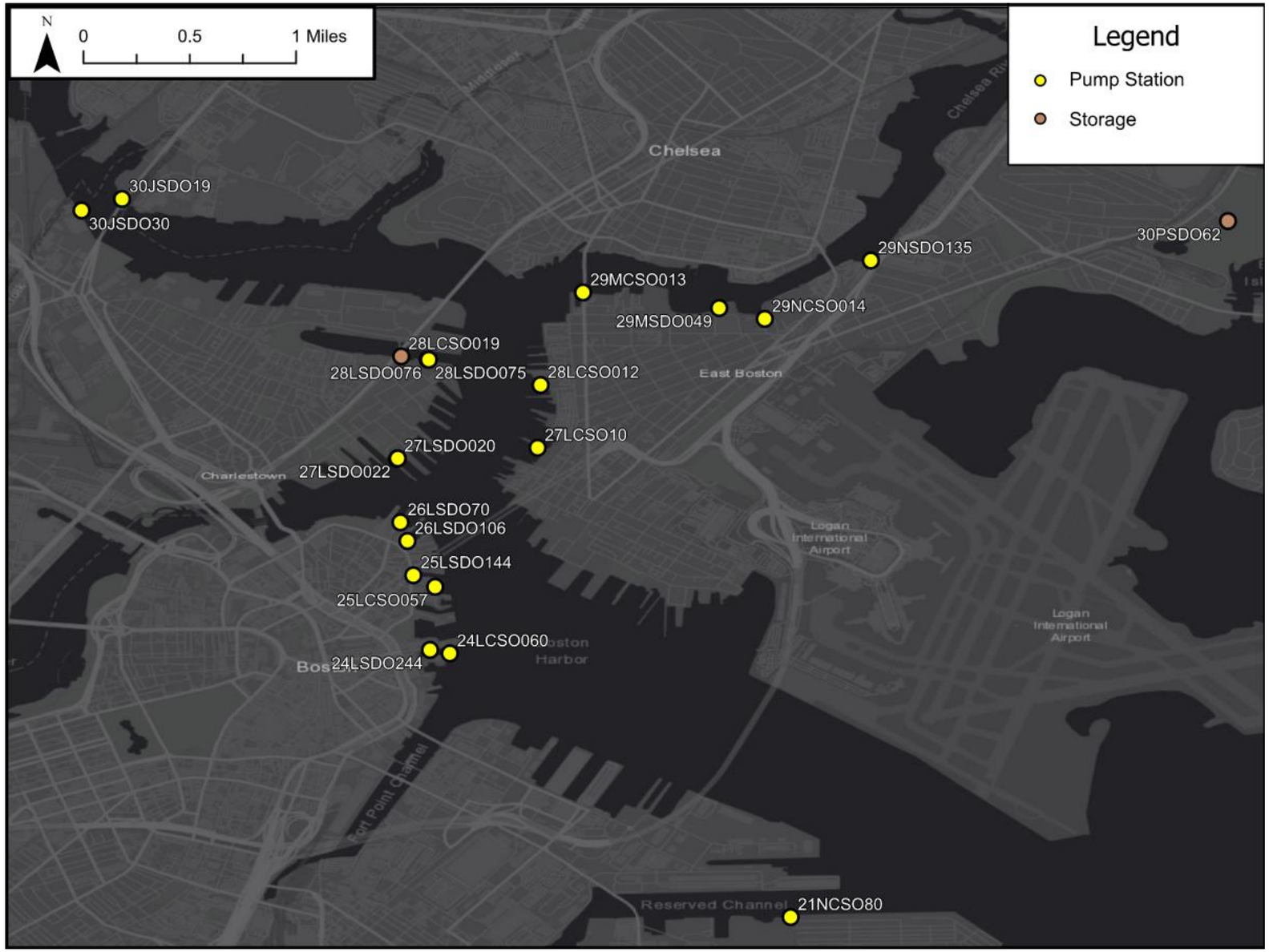
Figure 5: Design and Analysis Conditions vs. Historical Tide and Rainfall



Implementation Considerations

- Coordination with CRB (and other relevant stakeholders) to construct adequate shoreline protection around the Davenport Creek Stormwater Park is essential for successful implementation of this concept.
- The new pipelines that drain higher elevation portions of the tributary areas are designed only to convey flow from areas upstream of their origin. Lower elevation areas with higher flood vulnerability along these pipelines should not be connected to the new pipelines.
- The Neponset River is federally designated superfund site. A survey of hazardous materials, and detailed list of required permits, should be developed before beginning the final design process.
- Before beginning the final design process geotechnical investigations should be conducted to determine the groundwater elevation in the proposed storage areas; high groundwater levels could significantly reduce the usable storage volume.
- Coordination with residents and stakeholders could be conducted to determine preferences for features to be included in the above ground storage areas.

Replicability and Implementation Timeline



Summary of Similar Concepts

Number of Sites: 21

Vulnerable Area: 462 acres

The Davenport Creek Stormwater Park is a unique solution that is not directly replicable in other locations. The design of the pump station could be replicated at other locations in the City. Additional detail about outfalls that could be protected with a similar pump station can be found in the Commission's Coastal Stormwater Discharge Analysis Implementation Timeline.

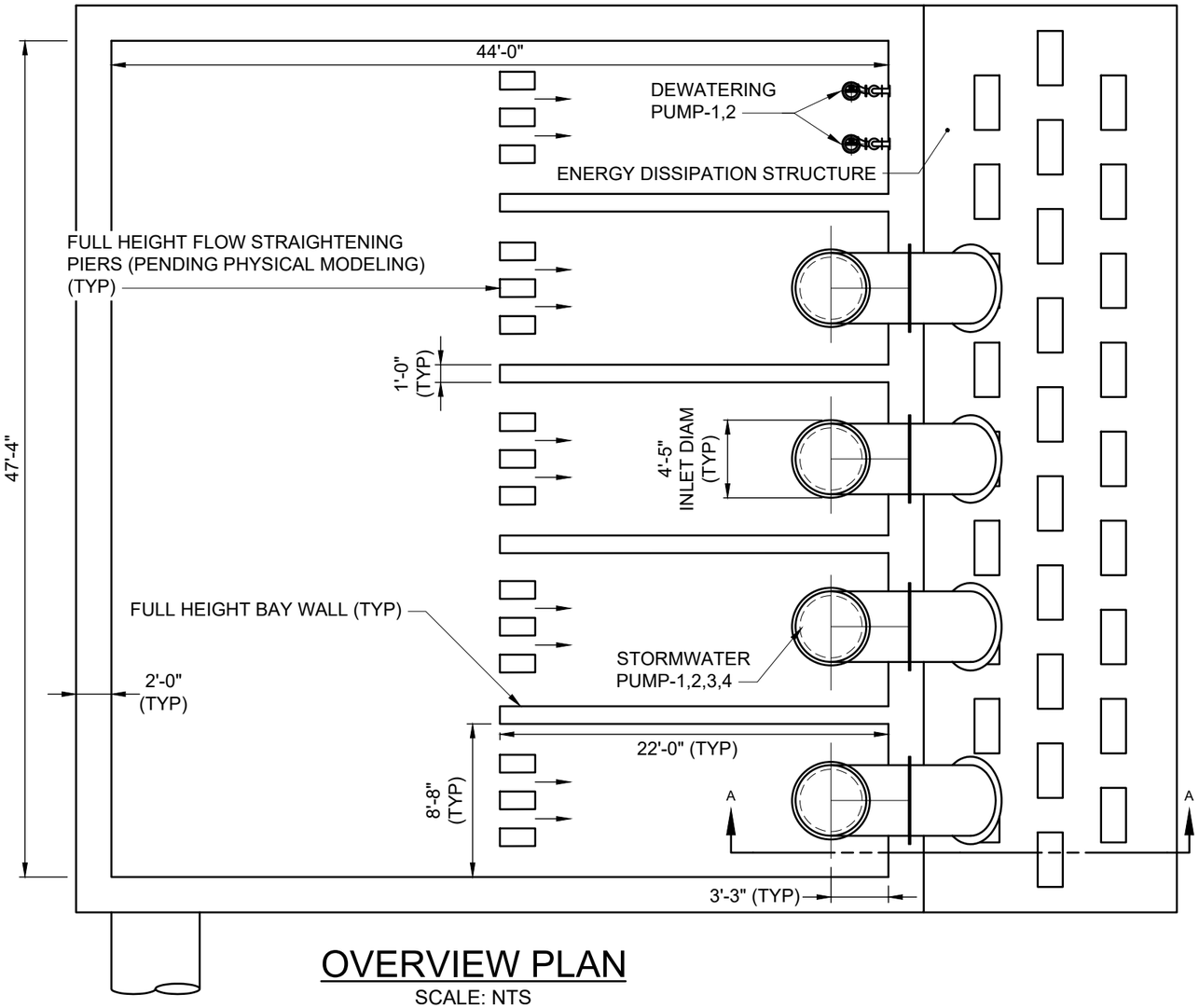
ATTACHMENT A

DAVENPORT CREEK STORMWATER PARK CONCEPTUAL DESIGN DRAWINGS

A-1: Pump Station Overview Plan

A-2: Pump Station Section View

Davenport Creek Stormwater Pump Station



OVERVIEW PLAN

SCALE: NTS

NOTES

1. FOR WATER SURFACE ELEVATIONS REFER TO OPERATIONAL TABLE.
2. ALL ELEVATIONS USE THE NAVD88 VERTICAL DATUM UNLESS OTHERWISE STATED.
3. CONCEPTUAL DRAWING, NOT FOR CONSTRUCTION.

STORMWATER PUMP-1,2,3,4 OPERATIONAL PARAMETERS	
FLOW RATE, CFS	83
STATIC HEAD RANGE, FT	14.7 - 22.7
DESIGN FLOOD ELEVATION, FT	16.5

STORMWATER PUMP-1,2,3,4 OPERATIONAL WSE TABLE

NOTE	OPERATION	ELEVATION, FT
A	HIGH LEVEL ALARM	2.8
B	LAG PUMP ON	0.8
C	LEAD PUMP ON	-1.2
D	LEAD PUMP OFF	-2.2
E	LOW LOW ALARM	-3.2
G	MIN PUMP SUBMERGENCE	-4.2

COASTAL STORMWATER DISCHARGE ANALYSIS

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A-1

November 2022

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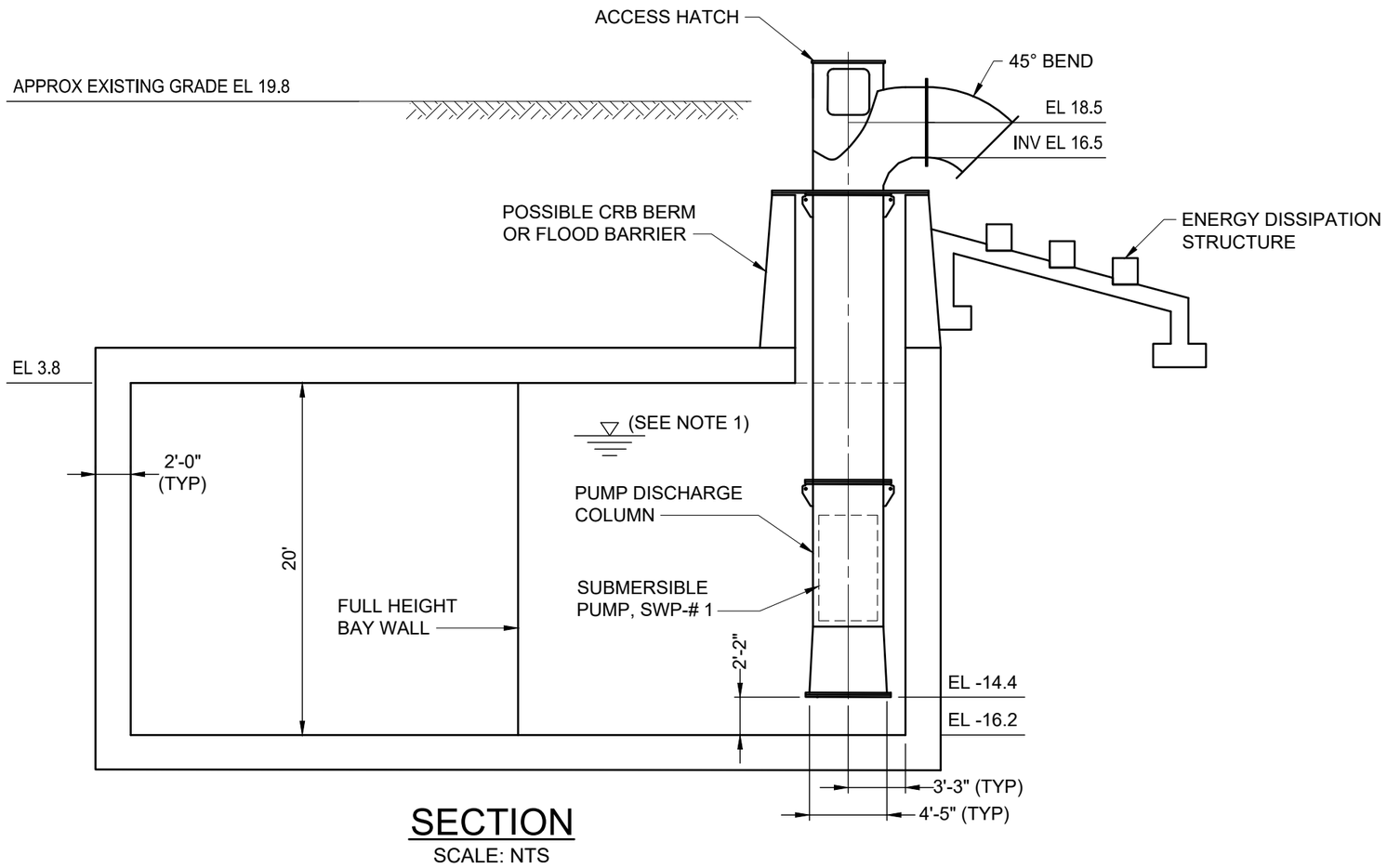
Davenport Creek Stormwater Pump Station



SECTION
SCALE: NTS

NOTES

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STORMWATER PUMP-1,2,3,4 OPERATIONAL PARAMETERS	
FLOW RATE, CFS	83
STATIC HEAD RANGE, FT	14.7 - 22.7
DESIGN FLOOD ELEVATION, FT	16.5

STORMWATER PUMP-1,2,3,4 OPERATIONAL WSE TABLE

NOTE	OPERATION	ELEVATION, FT
A	HIGH LEVEL ALARM	2.8
B	LAG PUMP ON	0.8
C	LEAD PUMP ON	-1.2
D	LEAD PUMP OFF	-2.2
E	LOW LOW ALARM	-3.2
G	MIN PUMP SUBMERGENCE	-4.2

COASTAL STORMWATER DISCHARGE ANALYSIS

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ATTACHMENT B
DAVENPORT CREEK STORMWATER PARK DIVERSION PIPELINE ALIGNMENT DRAWINGS

B-1: Pipe Alignment Drawings

Coastal Stormwater Discharge Analysis
Davenport Creek

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Davenport Creek Stormwater Park

High Elevation Diversion Pipeline

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PROP-PIPE-21



Plan
1"= 30'

0 30 60 120 Feet

PRELIMINARY
DO NOT USE FOR CONSTRUCTION

ASSUMPTIONS, DEFINITIONS, AND DISCLAIMERS

-EXISTING PIPE ALIGNMENTS AND ELEVATION DATA PROVIDED BY BWSC ON 12/21/2020
-ALL ELEVATIONS THROUGHOUT ARE REFERENCED TO NAVD88 DATUM
-PROPOSED PIPE AND MANHOLE ALIGNMENTS ARE PRELIMINARY AND CONCEPTUAL
-DETAILED SURVEY AND AN EVALUATION FOR SUBSURFACE CONFLICTS SHOULD BE PERFORMED BEFORE ADVANCEMENT OF THESE CONCEPTS

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N

PROP-PIPE-22



Plan
1"= 30'

0 30 60 120 Feet

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PROP-PIPE-32



0 20 40 80 Feet

Plan
1"= 20'

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PROP-PIPE-23

Plan
1"= 10'

0 10 20 40 Feet

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N

Z

PROP-PIPE-24



Plan
1"= 30'

0 30 60 120 Feet

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-EXISTING PIPE ALIGNMENTS AND ELEVATION DATA PROVIDED BY BWSC ON 12/21/2020
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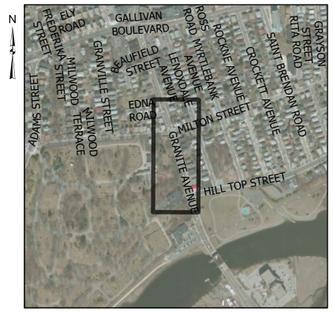

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PROP-PIPE-25



Plan
1"= 30'

0 30 60 120
Feet

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CONSTRUCTION

ASSUMPTIONS, DEFINITIONS, AND DISCLAIMERS

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PROP-PIPE-26



Plan
1"= 20'

0 20 40 80 Feet

PRELIMINARY
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ASSUMPTIONS, DEFINITIONS, AND DISCLAIMERS

-EXISTING PIPE ALIGNMENTS AND ELEVATION DATA PROVIDED BY BWSC ON 12/21/2020
-ALL ELEVATIONS THROUGHOUT ARE REFERENCED TO NAVD88 DATUM
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Plan
1"= 20'

PRELIMINARY
DO NOT USE FOR
CONSTRUCTION

ASSUMPTIONS, DEFINITIONS, AND DISCLAIMERS

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PROP-PIPE-33

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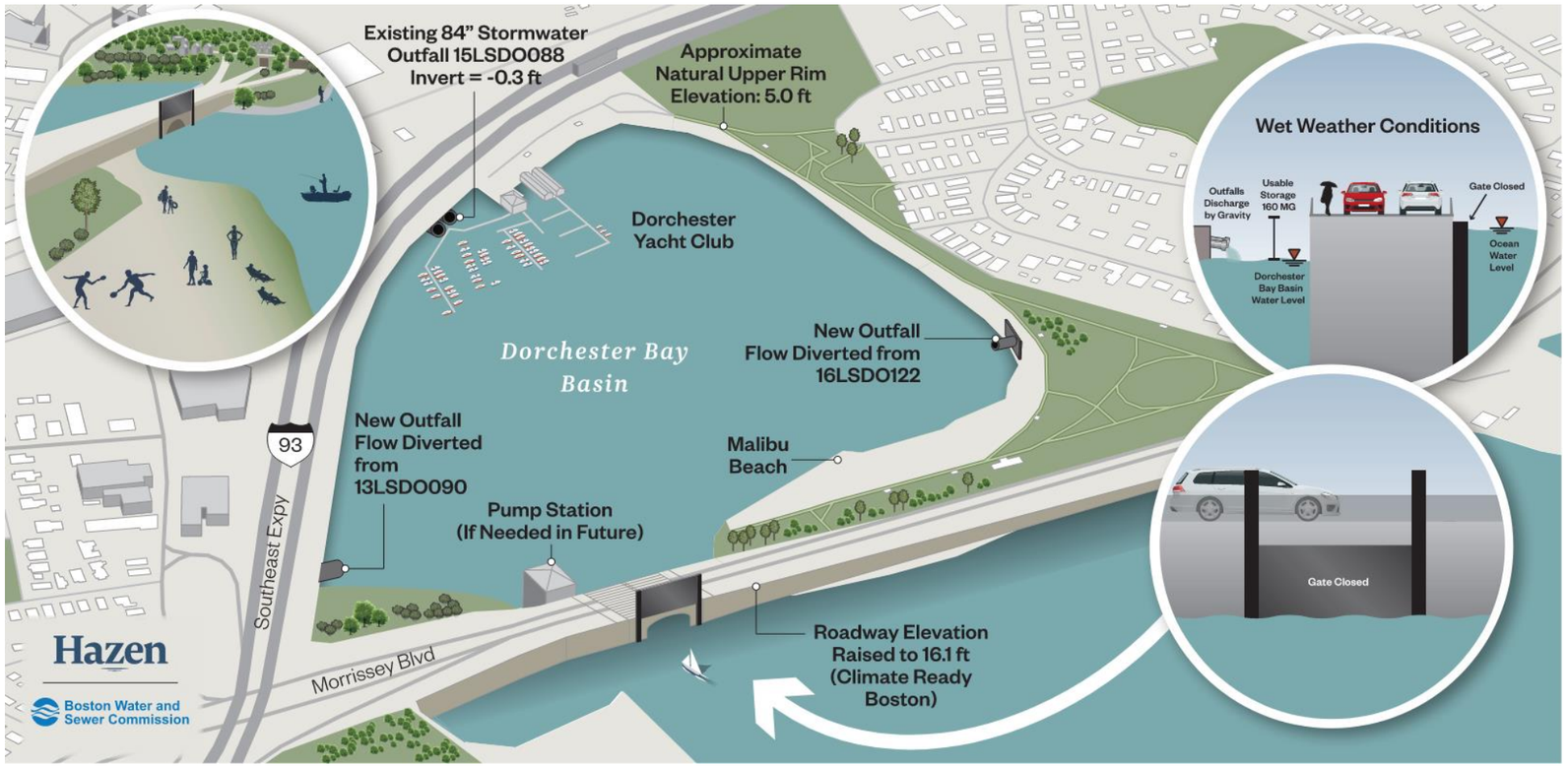
Dorchester Bay Basin *Concept Overview*





Conceptual Solution

The conceptual solution herein utilizes the existing shoreline geometry to store stormwater in the Dorchester Bay Basin (DBB). By utilizing a vertical lift gate, the DBB could be closed at low tide before a predicted coastal storm event. Under present day conditions, the basin could store approximately 160 million gallons (MG) before overflowing; by 2070 (assuming 4.3' of sea level rise) the basin's storage capacity would be reduced to 100 million gallons.

In addition to protecting outfalls 15LSDO088 and 15LSDO089, this concept protects outfalls 13LSDO090 and 16LSDO0122 with diversion structures that can redirect flow to the basin by gravity through new conduits. Higher elevation portions of the areas tributary to these outfalls are not vulnerable to flooding from rising sea levels; thus, this concept also includes new pipelines to separately drain these higher elevation areas directly to the receiving waters. By providing separate drainage conduits for these high elevation areas, flow into the DBB is reduced sufficiently to avoid the need for a pump station under the conditions analyzed. A pump station could be constructed in the future if necessary to help maintain sufficiently low water surface elevations in the basin, if conditions change in the future.

Type: Storage and Conveyance

Total Drainage Area: 1305 acres

Coastal Flood Vulnerable Drainage Area Protected: 473 acres

Concept Elements:

- Nature based storage basin
- Gravity drainage via new conveyance for high elevation areas
- Diversion structures
- Navigable storm surge barrier and gate structure

Outfalls Included in Concept:

- 16LSDO122
- 15LSDO089
- 15LSDO088
- 13LSDO090

Coastal Stormwater Discharge Analysis
Dorchester Bay Basin

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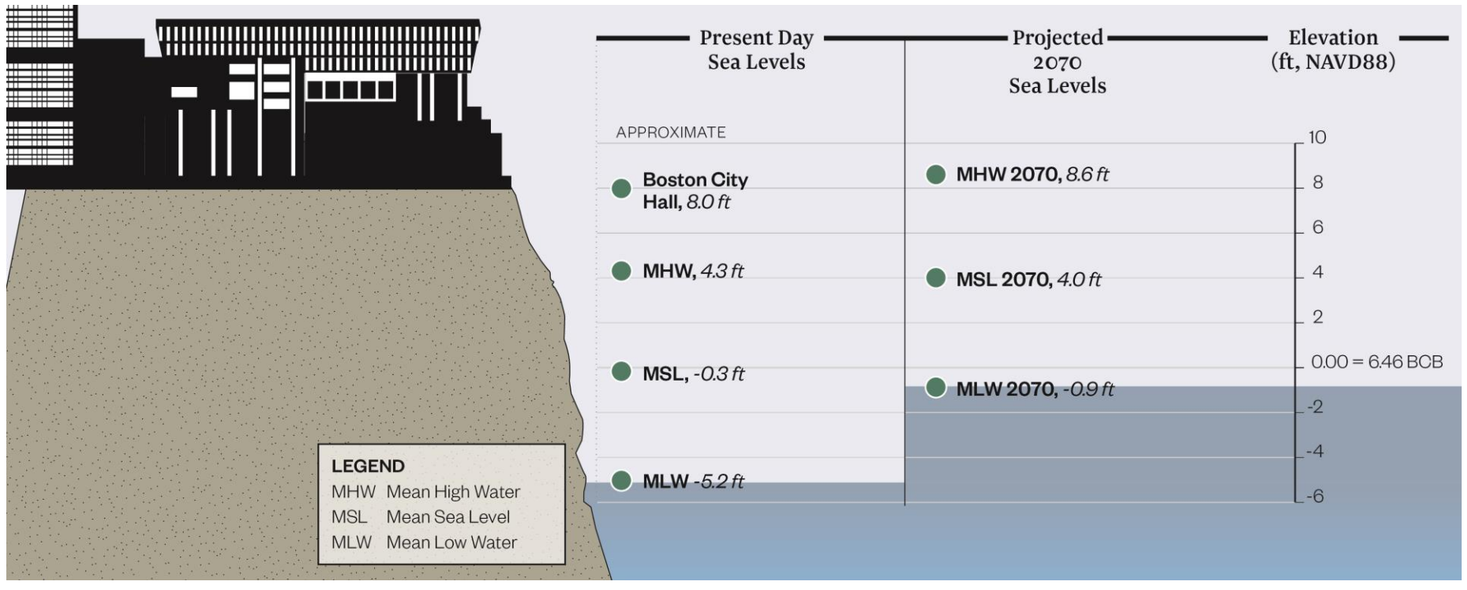
Assumptions

Sea Level Rise and Datum

The Dorchester Bay Basin concept was designed for consistency with Climate Ready Boston (CRB) proposed adaptations and analyzed based on sea level rise (SLR) projections in the Massachusetts Coastal Flood Risk Model (MC-FRM). The SLR values applied in MC-FRM are consistent with the standards for the State of Massachusetts developed by Coastal Zone Management. The MC-FRM utilizes a "High" SLR scenario. This scenario is based on the relative SLR projections under Relative Concentration Pathway (RCP) 8.5 (a "worst case scenario" of increasing atmospheric carbon concentrations) and represents elevations that have a 99.5% probability of not being exceeded within the respective timeframes. In 2030, that amounts to an increase of 1.3 feet in Boston from a baseline condition (2008 centered tidal epoch), and in 2070 that amounts to an increase of 4.3 feet.

The concept developed in this project was analyzed using coastal conditions that include 2070 projected SLR and storm surge resulting from a 100-year tropical storm. The peak water surface elevation (WSE) predicted by the MC-FRM during these conditions is approximately 13.8 feet NAVD88 (varies by location). In mid 2022, the Greater Boston Research Advisory Group (BRAG) issued an updated report with new SLR projections. The report acknowledges that long term SLR projections are associated with significant uncertainty, and that updated projections include less SLR by 2100 (compared to earlier projections in the 2015 BRAG Report). According to the report, the likely range of SLR by 2070 under an RCP 8.5 scenario is 1.4 – 2.8 feet. Based on this information, projections from the MC-FRM that were utilized in this project are conservative and appropriate for long term planning purposes.

Unless otherwise noted, all elevations are based on the NAVD88 vertical datum. Elevations given in NAVD88 can be converted to Boston City Base (BCB) elevation by adding 6.46 feet.



Climate Ready Boston and Shoreline Protection

The Dorchester Bay Basin concept was developed to maintain consistency with possible Climate Ready Boston (CRB) adaptations based on the latest available information at the time they were developed. As the CRB program continues to evolve, it is anticipated that proposed concepts will need to be adapted.

The concept was developed to be consistent with stated neighborhood design flood elevations. In the Columbia Point and Morrissey Boulevard Zone (location of the Dorchester Bay Basin), where the stated CRB design flood elevation is 16.1 feet, pumps would be designed to discharge to a minimum elevation of 16.1 feet.

At the time of this project, many CRB concepts were in early planning stages and not fully defined. **In consideration of this, it was assumed the shoreline protection around the City of Boston is 100% effective for all modeling evaluations.** This assumption eliminates overland coastal flooding from model predictions, allowing for isolation of flooding that results only from rainfall and stormwater that cannot be discharged due to high sea levels. It is important to recognize that additional flooding, beyond what is depicted herein, would be expected if 100% effective shoreline protection is not implemented.

Basis of Design

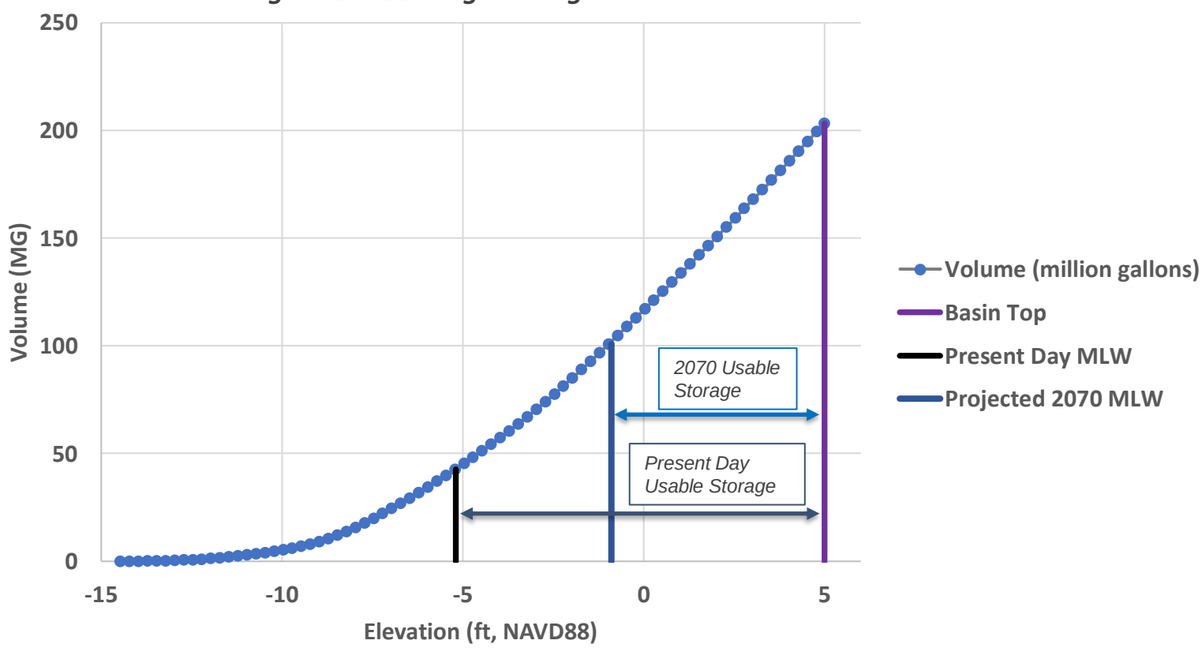
Basin Storage Capacity

The storage capacity of the DBB was analyzed under present day and 2070 conditions based on 4.3 feet of sea level rise projected in the MC-FRM. The usable storage volume was calculated by developing a stage storage curve from a topobathymetric DEM obtained for the DBB from the Continuously Updated Digital Elevation Model (CUDEM) project from NOAA and determining the volume between Mean Low Water (MLW) and the approximate upper rim elevation of the existing DBB (5.0 feet, NAVD88). Table 1 contains a summary of the present day and projected usable DBB storage volume. Figure 1 depicts the stage storage curve that was developed to determine the DBB storage capacity. For conceptual design purposes, a usable storage volume of 100 MG (2070 conditions) was assumed.

Table 1: Present Day and 2070 Projected Estimated DBB Storage Capacity

Scenario	Mean Low Water (ft, NAVD88)	Mean High Water (ft, NAVD88)	Usable DBB Storage Capacity (million gallons)
Present Day	-5.2	4.3	160
Projected 2070 SLR	-0.9	8.6	100

Figure 1: DBB Stage Storage Curve



Rainfall and Coastal Conditions

The Commission currently utilizes a 10-year, 24-hour design storm to establish its target level of service. For the purpose of sizing new piping and evaluating storage capacity, a projected 2070 10-year, 24-hour design storm was developed. For consistency with Climate Ready Boston, performance of the DBB storage concept was also evaluated with projected rainfall from a 100-year tropical event (developed during the Commission's Inundation Model Project). The DBB was evaluated using a 100-year return period coastal boundary condition. Data for this condition were obtained from the MC-FRM. For the purpose of evaluating the effectiveness of the concept, it was further assumed that complete shoreline protection was implemented, preventing flow of water between land and the Harbor/Neponset River. Table 3 contains a summary of the coastal conditions that were analyzed.

Table 2: Rainfall Conditions

Scenario	Purpose	Rainfall Depth (in)	Peak Intensity (in/hr)
Present Day, 10-year, 24-hr design storm	Baseline Conditions	5.15	3.32
Projected 2070, 10-year, 24-hr design storm	Design Conditions	6.18	4.08
100-year Tropical Storm	Damage Analysis	9.58	0.84

Table 3: Coastal Conditions

Scenario	Purpose	Peak Water Surface Elevation (ft, NAVD88)	Source
Present Day	Baseline Conditions	3.7	BWSC Existing Model (April 2016 Tide Cycle)
2070,100-year Tropical Storm	Damage Analysis	13.8	MC-FRM

Basis of Design Summary

Pumping Evaluation and Storage Capacity

A series of simulations were conducted using the Commission's Inundation Model to determine the volume of water discharged into the DBB during the 10-year, 24-hour design storm and 100-year tropical storm under 2070 conditions. This analysis was conducted to evaluate the potential for the basin to overflow (exceed elevation 5.0' NAVD88) and determine if pumping is required to prevent the basin from overflowing. The simulation included the high elevation gravity diversions shown on Sheet 5 and it was assumed that the basin was isolated from the Neponset River for the duration of the simulation (water was not discharged from the basin). Figure 2 depicts the WSE in the basin during the projected 10-year, 24-hour design storm event.

Based on the results of these simulations, it was determined that the DBB Storage Concept does not require a pump station under the conditions simulated. During the final design process, detailed survey should be conducted to verify the available storage volume in the basin with more accuracy. A pump station could be added to the concept in the future if larger storm events result in inflow volumes that exceed the storage capacity of the basin. It should be noted that these simulations utilized a MLW elevation based on projections for 4.3 feet of SLR by 2070; under present day conditions the basin has approximately 60% more storage capacity than this projected 2070 condition.

Figure 2: Model Predicted WSE in DBB
(2070 Projected 10-year, 24-hour Design Storm)

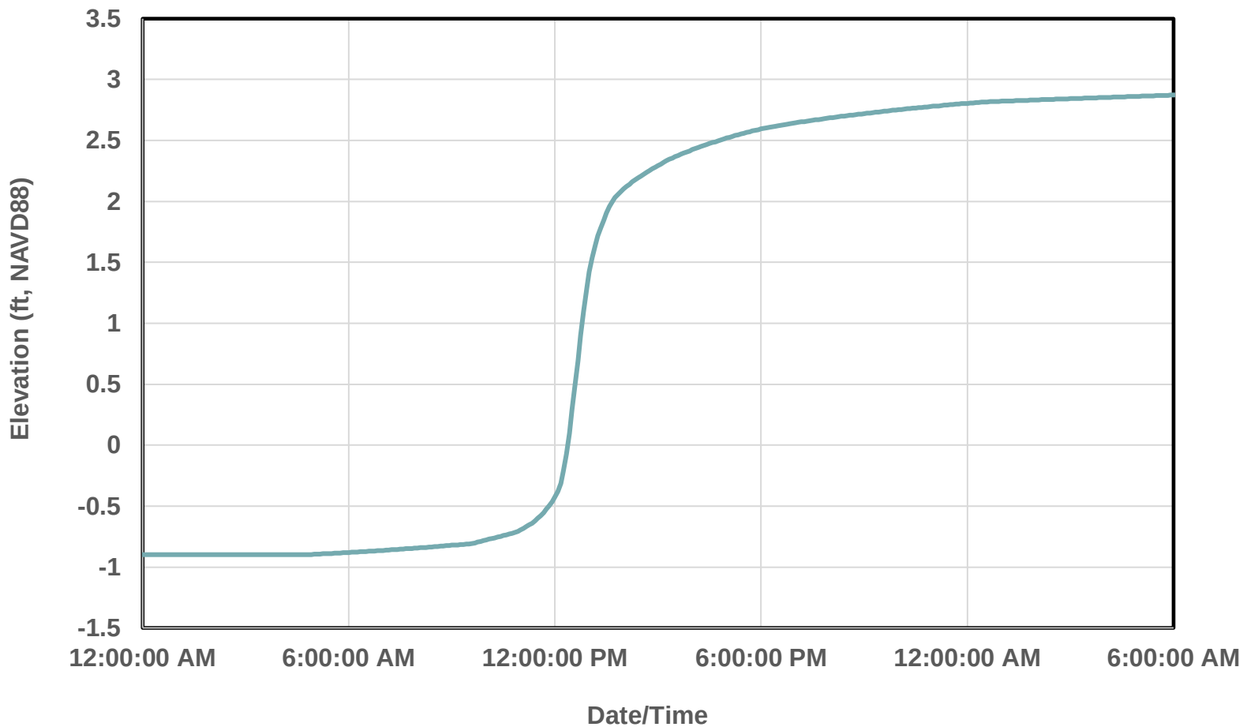


Table 4: DBB Storage Simulation

Scenario	Initial WSE (ft, NAVD88)	Final WSE (ft, NAVD88)	Volume Stored (MG)	Percent Full
10-year, 24-hr Design Storm (2070)	-0.9	2.9	64	64%
100-year Tropical Storm (2070)	-0.9	4.7	97	97%

Conceptual Design – Not for Construction

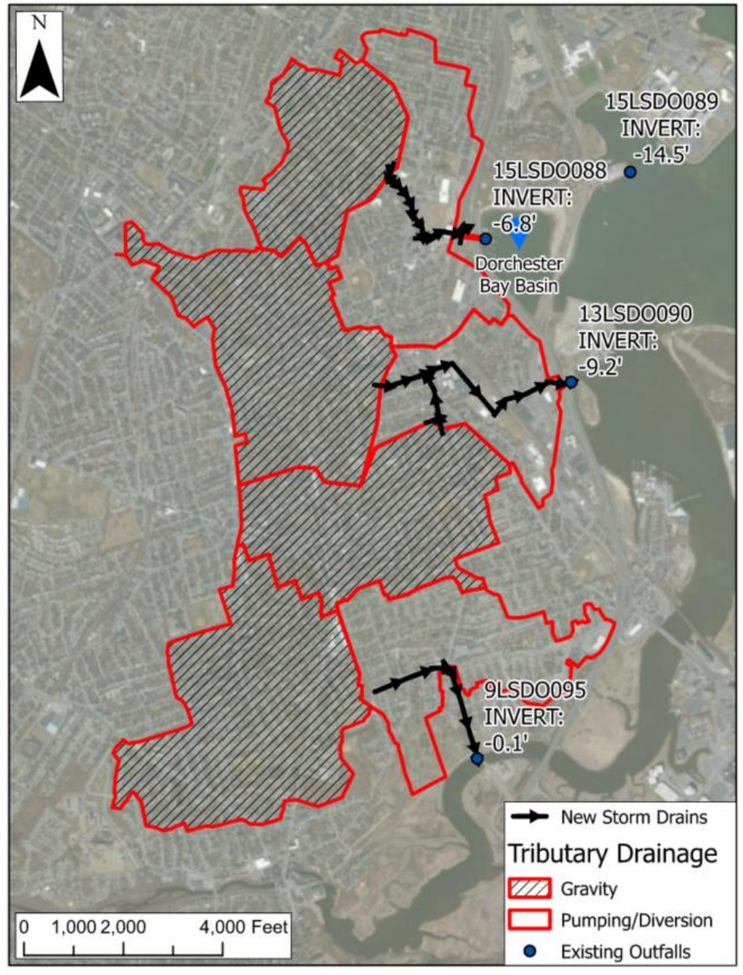
Proposed Pipelines



New pipeline to direct flow from 16LSDO0122 to the DBB



New pipeline to direct flow from 13LSDO090 to the DBB



New pipelines for drainage of high elevation areas

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Dorchester Bay Basin

High Elevation Diversion – New Pipeline 1

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Dorchester Bay Basin

High Elevation Diversion – New Pipeline 2

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Dorchester Bay Basin

Outfall 13LSDO090 Diversion to Dorchester Bay Basin

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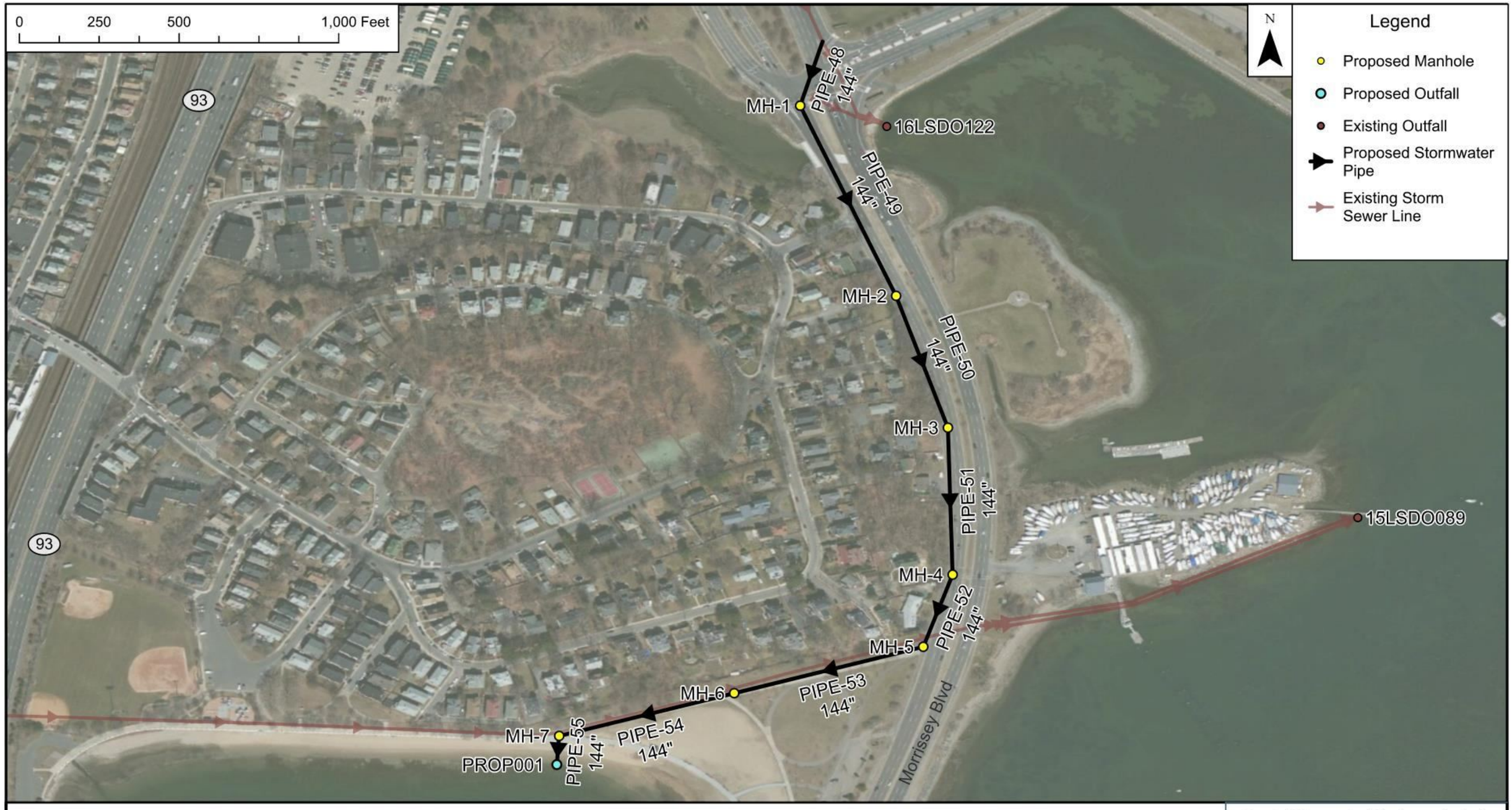

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Outfall 16LSDO122 Diversion to Dorchester Bay Basin

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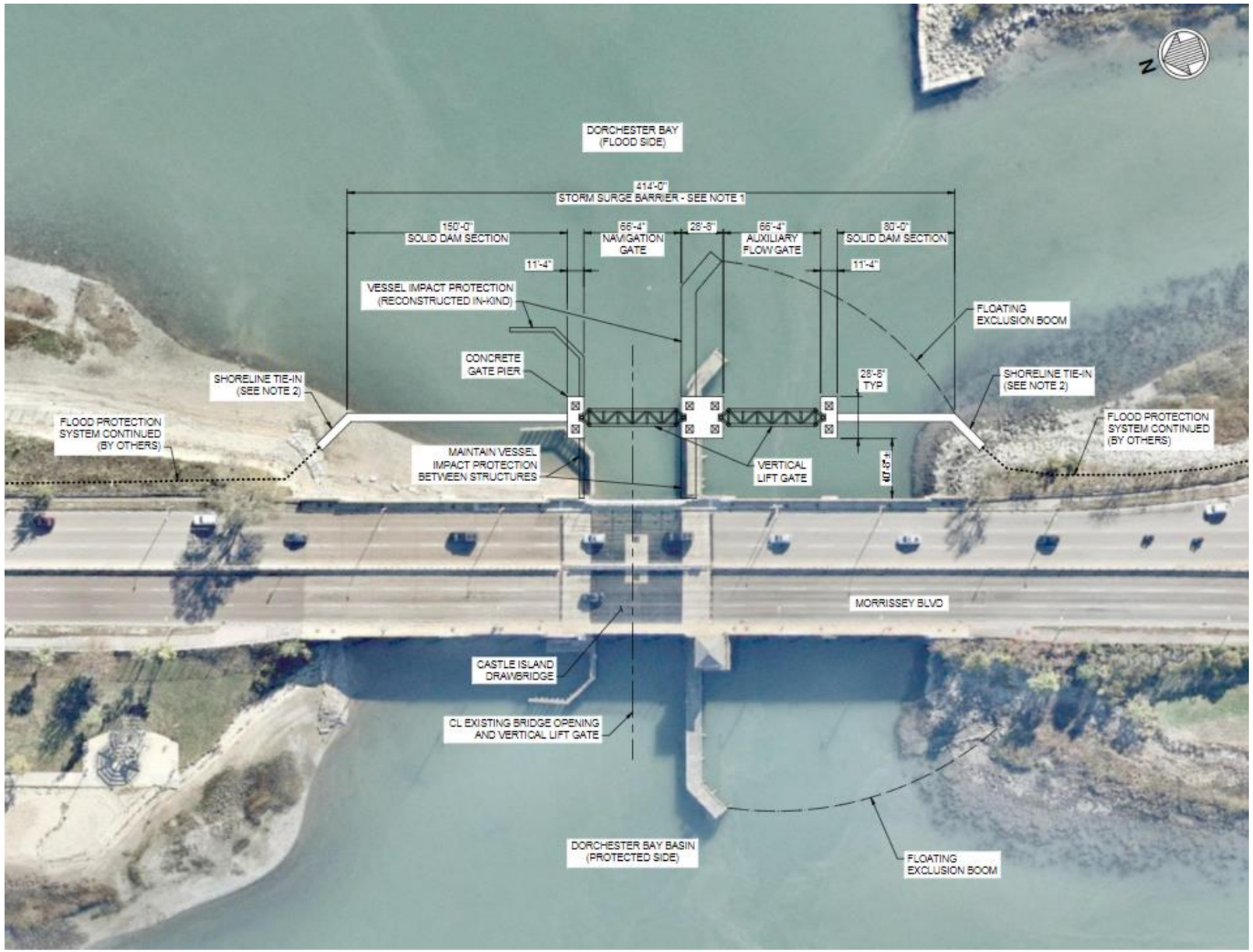
Storm Surge Barrier and Navigable Gate



Storm Surge Barrier and Gates

The SSB concept at the DBB utilizes a single 66' navigation gate and an additional auxiliary flow gate. The gates, when open, are stored above the storm surge barrier superstructure. When open, the storm surge barrier does not impede existing navigation or flow between the DBB and Harbor. The gates can be lowered into the "closed" position ahead of an extreme storm event to isolate the DBB.

Flood Modeling and Damage Analysis

Figure 3: Estimated Replacement Cost

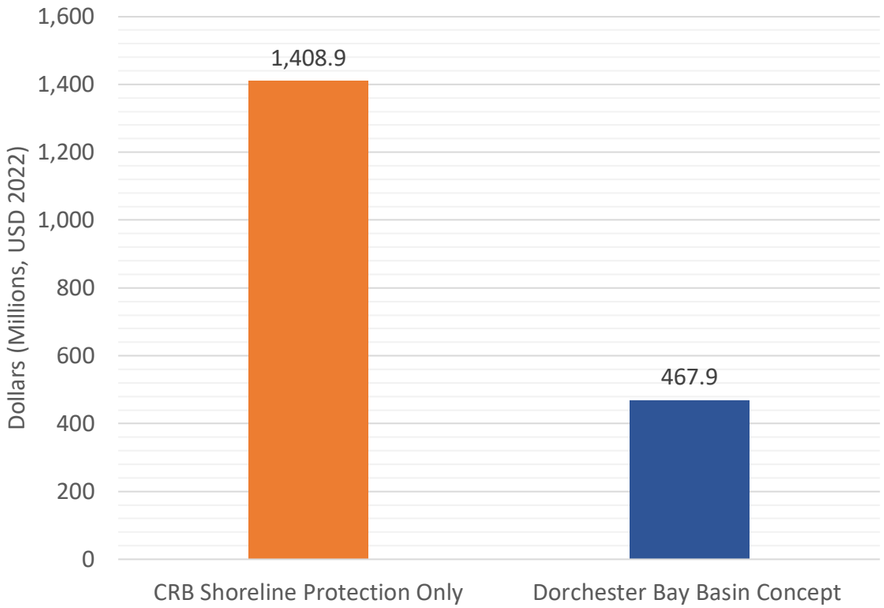


Figure 4: Loss of GDP

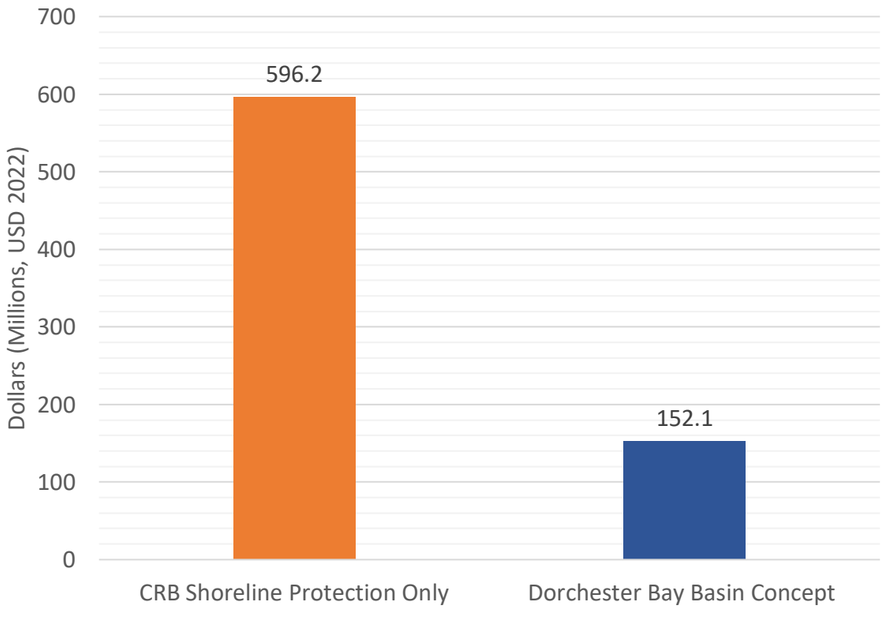
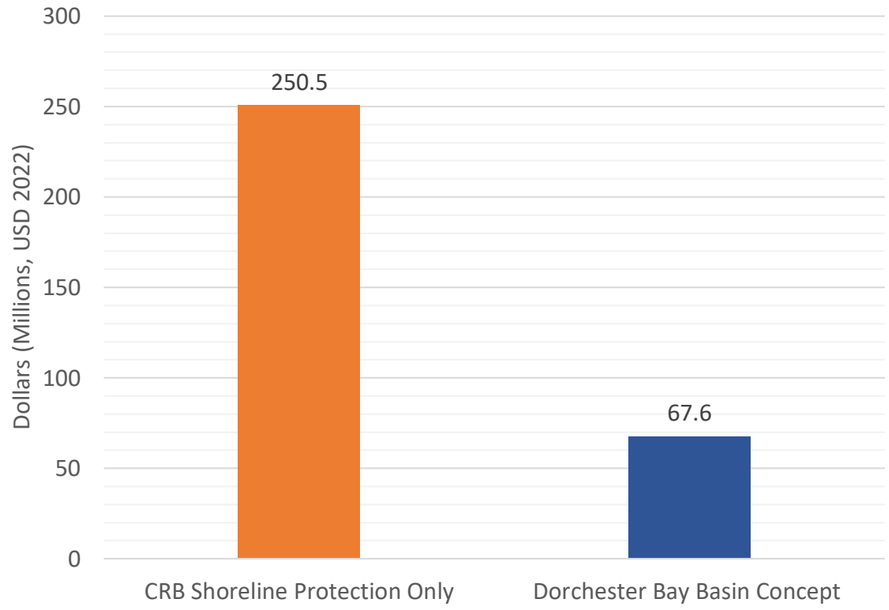


Figure 5: Physical Damage



The flood reduction benefits of the DBB concept were evaluated using the Commission's 2D Inundation Model by simulating a 100-year tropical storm event with 2070 SLR and storm surge. The figures on the following page depict the peak flooding that was predicted in the drainage area tributary to the DBB with shoreline protection only and with the DBB concept implemented. An analysis of economic losses/physical impacts from flooding under both scenarios was performed by risQ Inc.

Model predictions indicate that the Dorchester Bay Basin concept reduces physical damage by **$182.9 million**, avoids **$941 million** in rebuilding costs, and mitigates a GPD loss of **$444.1 million** during a 100-year tropical storm event in 2070 compared to shoreline protection only.

Note: replacement values include the total value of impacted buildings in flooded areas (e.g., impacted buildings are fully replaced), whereas physical damage includes estimated costs to repair flood damage based on predicted flood depths and building characteristics. The values shown are the average of minimum and maximum calculated losses. Refer to the Project's Final Report for more information.

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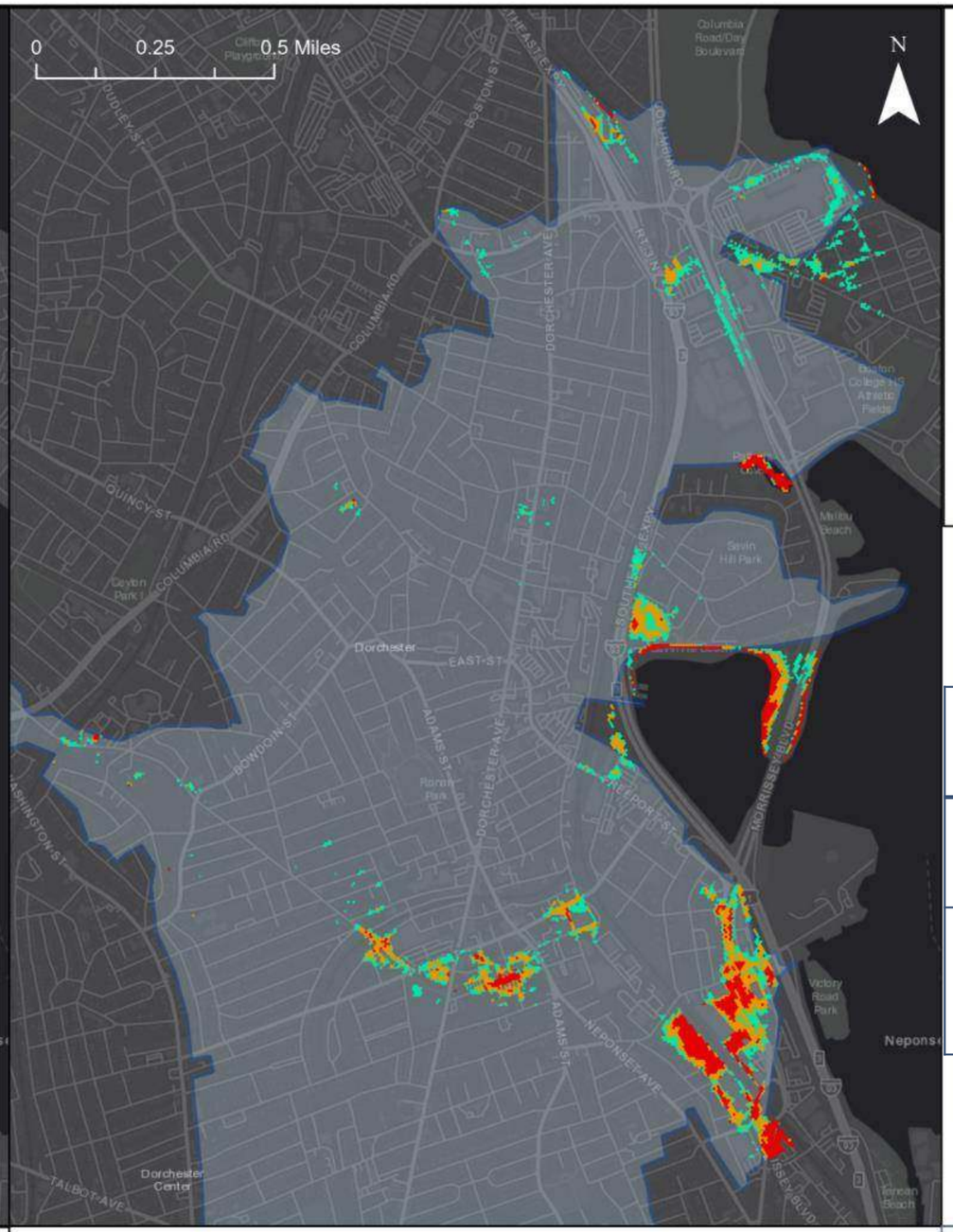

Legend

- Flood Depth > 4 in and < 1 ft
- Flood Depth > 1 ft and < 2 ft
- Flood Depth > 2 ft
- Drainage Area Analyzed

Simulation Parameters

Storm Type	100yr Tropical Storm
Rainfall Depth	9.6 inches
Peak WSE 2070 SLR + 100yr Surge	13.8 feet NAVD88

2070 SLR + 100yr Tropical Storm + Storm Surge

Shoreline Protection Only

2070 SLR + 100yr Tropical Storm + Storm Surge

Dorchester Bay Basin Storage and Tide Gates

Coastal Stormwater Discharge Analysis
Dorchester Bay Basin

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Cost Estimate and FEMA BRIC Considerations

Capital Cost Estimate

A construction cost estimate for the Dorchester Bay Basin concept was developed for planning purposes. Assumptions for the cost estimate include 15-year escalation to the mid-point of construction and the inclusion of a 50% design contingency. Additionally, for this estimate electrical duct bank allowances were based on their distance to the closest street. The cost of piles below storm drainage runs and structures, hookup costs to existing electrical services, and the cost of microtunneling and jacking were not included in this estimate.

Table 5: Dorchester Bay Basin Cost Estimate Subtotals

Remaining Design Development & Construction Administration (assumed 20% of total less design contingency)	$24,845,000
Direct Construction Costs	$48,774,375
Indirect Construction Costs	$9,754,875
Mark-Up *(Including 50% design contingency)*	$125,628,750
Total	**$209,004,000**

Table 6: Dorchester Bay Basin Marine Work Cost Estimate Subtotals

	Vertical Lift Gate
Remaining Design Development & Construction Administration	$14,169,000
Direct & Indirect Construction Costs Total (Marked-Up)	$76,917,000
Escalation (15 years)	$56,078,000
Design Contingency (35%)	$31,881,000
Total	**$179,045,000**
* Marked-up costs includes contractor overhead, profit, fees, bond, insurance.	

Social Vulnerability and FEMA BRIC Funding

FEMA BRIC funding prioritizes disadvantaged communities. Table 7 contains a summary of several indicators for the Dorchester Bay Basin tributary area that could be used help characterize the community for future FEMA funding applications and prioritization of projects that benefit disadvantaged communities.

Table 7: Dorchester Bay Basin Tributary Area Social Vulnerability Indicators

Low Income & Persistent Poverty	
Per Capita Income	$33,671
Below Poverty Line	17%
High Housing Cost Burden	
Stressed Renters (>40% rent-to-income)	39%
Households With Food Insecurity	14%
Racial and Ethnic Segregation	
Asian Population	17%
Black Population	36%
Hispanic Population	17%
White Population	31%
Education and Employment	
Adults Age 25+ Without High School (or equivalent) Degree	18%
Unemployment Rate (Age 16+)	7%

Data provided by risQ inc. from the US census and American Community Survey

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Planting Palette

A planting palette was developed for the embankment around the Dorchester Bay Basin. After construction, planting of native plant species could provide a public amenity with new green space and environmental benefits associated with native plant species.

Shrubs



Baccharis halimifolia
groundsel tree



Iva frutescens
saltmarsh elder



Prunus maritima
beach plum



Morella pensylvanica
bayberry

Herbaceous and Grasses



Spartina alterniflora
smooth cordgrass



Spartina patens
saltmeadow grass



Distichlis spicata
coastal salt grass



Solidago sempervirens
seaside goldenrod

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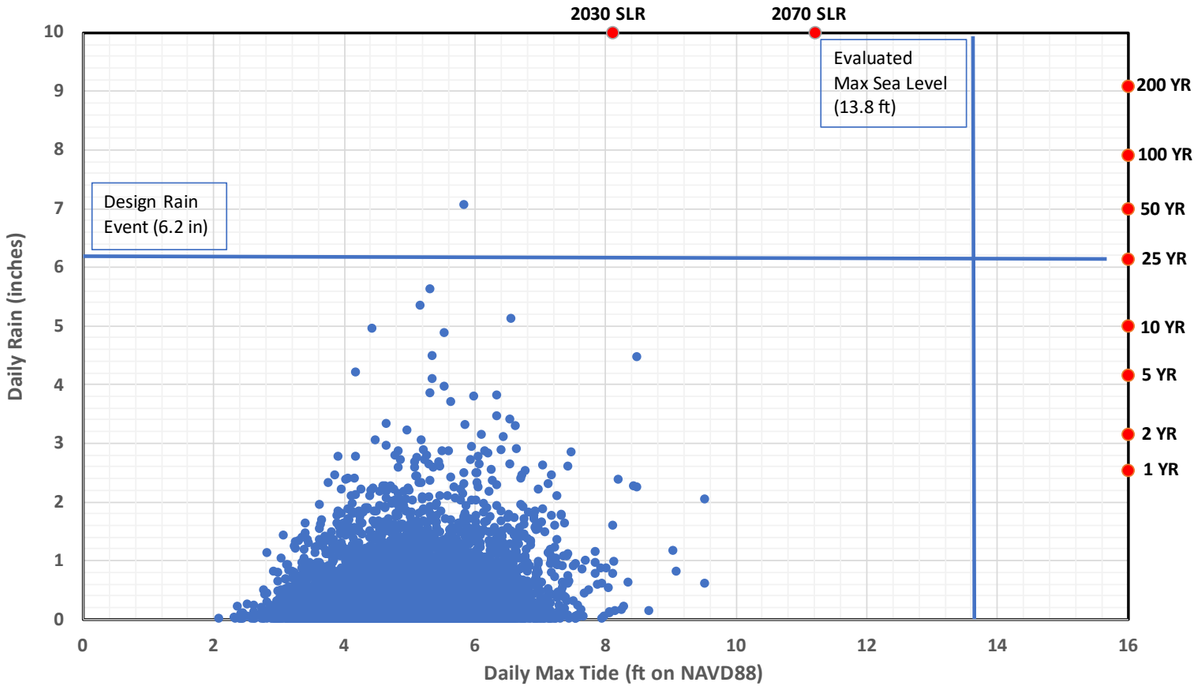
Adaptability and Implementation

Adaptability

Figure 6 below depicts historical daily rainfall totals and tide levels. As shown in this figure, the conditions that were used to design and analyze the DBB storage concept are conservative and represent more extreme conditions than have occurred historically. As such, it is likely that the DBB storage concept will function without the need for a pump station in the future under many conditions. Regardless, the following measures could be implemented to adapt the concept to more severe conditions (additional SLR, more intense rainfall, etc.) in the future:

- Construct a pump station to maintain lower water levels during a storm event
- Construct a pump station to draw down water levels (maximize storage capacity) in DBB before a forecast storm event
- In conjunction with a pump station, dredge DBB to obtain additional usable storage

Figure 6: Design and Analysis Conditions vs. Historical Tide and Rainfall



Implementation Considerations

- Coordination with CRB (and other relevant stakeholders) to construct adequate shoreline protection around the DBB is essential for successful implementation of this concept. To function as designed, the DBB must be fully isolated from high sea levels when the gate is closed; as such, careful coordination with CRB is essential at this location.
- Coordination with the Dorchester Yacht Club should be conducted to ensure gates are sufficiently large to accommodate all anticipated boat traffic.
- The new pipelines that convey flow from adjacent outfalls to the DBB are designed to surcharge. As such, under design conditions, it is important that manhole covers are watertight and securely bolted or fastened in place to prevent flooding.
- The new pipelines that drain higher elevation portions of the tributary areas are designed only to convey flow from areas upstream of their origin. Lower elevation areas with higher flood vulnerability along these pipelines should not be connected to the new pipelines.
- The Neponset River is federally designated superfund site. A survey of hazardous materials, and detailed list of required permits, should be developed before beginning the final design process.
- Active flow control gates at proposed diversion structures could be used to periodically divert flow into the DBB during “normal” tide conditions; this could help prevent sediment deposition in the pipelines.

Replicability and Implementation Timeline



Summary of Similar Concepts

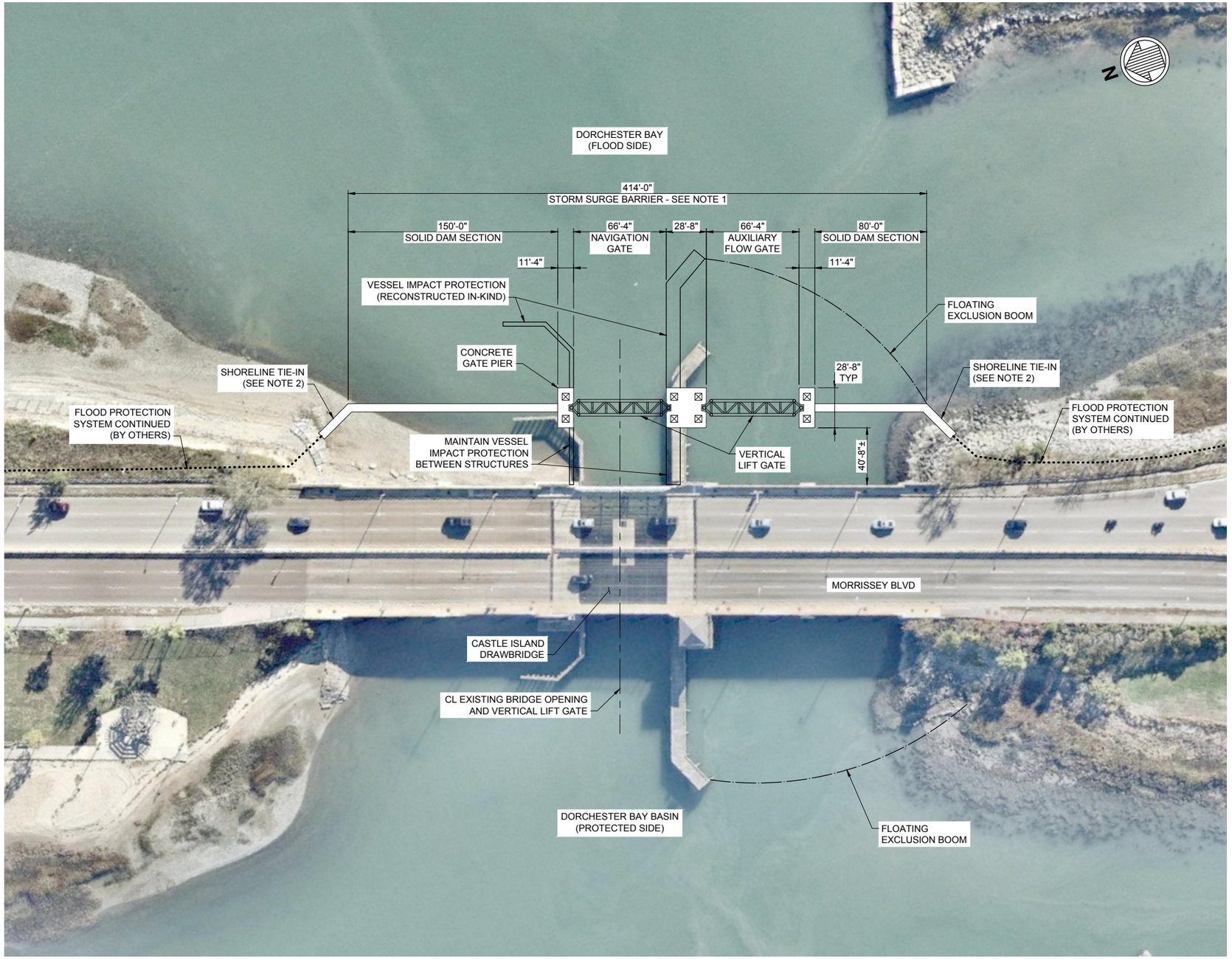
Number of Sites: 27

Vulnerable Area: 499 acres

The map on this sheet depicts other vulnerable outfalls that could utilize elements of the DBB solution including storage, storm surge barriers, and tide gates. Additional detail about these outfalls can be found in the Commission's Coastal Stormwater Discharge Analysis Implementation Timeline.

ATTACHMENT A
DORCHESTER BAY BASIN STORM SURGE BARRIER CONCEPTUAL DESIGN DRAWINGS
VERTICAL LIFT GATE

A-1: Vertical Lift Gate Overview Plan
A-2: Vertical Lift Gate Foundation and Elevation Plans



NOTES:

1. THE CONCEPT PLAN VIEWS SHOW PORTIONS OF STORM SURGE BARRIER STRUCTURE THAT PROJECT ABOVE DAILY HIGH WATER LINE. SEE S-400 SERIES SHEETS FOR MULTIVIEWS AND DETAILS ASSOCIATED WITH BELOW WATER AND CHANNEL BED FEATURES (FOUNDATION, SCOUR PROTECTION).

2. SHORELINE INTERFACES, TRANSITIONS, AND TIE-INS SHALL BE DETERMINED DURING DETAILED DESIGN.

A1 / S-101 PLAN - STORM SURGE BARRIER - VERTICAL LIFT GATE
SCALE: 1" = 40'

40'-0" 0'-0" 40'-0" 80'-0"
SCALE: 1"=40'

PRELIMINARY - CONCEPT LEVEL

No.	Mark	Description	Date	Appr
01		DBB SSB DRAFT CONCEPT - FOR CLIENT REVIEW	11-21-2022	MK

BOSTON WATER AND SEWER COMMISSION
STORM SURGE BARRIER
DORCHESTER BAY BASIN
BOSTON, MA

PLAN - STORM SURGE BARRIER - VERTICAL LIFT GATE

Date: 2022-11-21 | Rev: -
M&N Project No: 11167
Drawing code:
Drawing Scale:
Plot scale: 1:1 (D SHEET)

Designed by: NBJ
Drawn by: CMI | Det by: JCS
Reviewed by: MK
Submitted by: MOFFATT & NICHOL

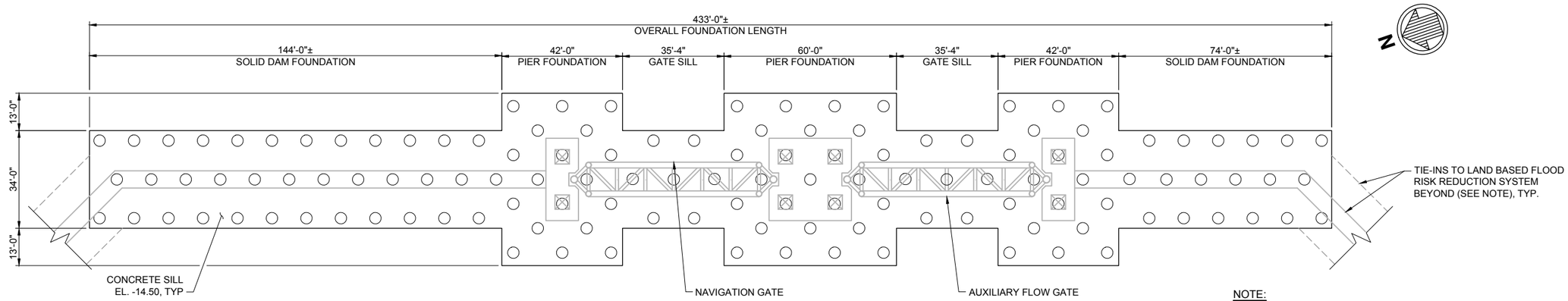
MOFFATT & NICHOL
180 WELLS AVE, SUITE #302
NEWTON, MA 02459
moffatt & nichol

SEAL

Sheet Reference No.
S-101
INDEX: 1 OF 2

DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING

File: Q:\BOS\Projects\11167 BWSC\600_CADD_Active_Exhibits\Dorchester Bay\11167025-101 - Plotted: 11/21/2022 8:47 PM by MOYA IGLESIAS, CRISTIAN - Saved: 11/21/2022 8:32 PM by CMOYAGLESIAS



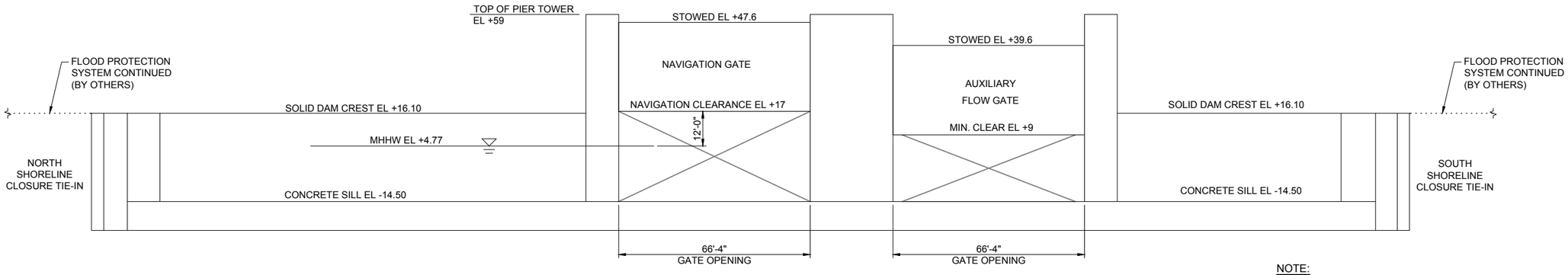
LEGEND:

○ 4'-0" DIA. DRILLED SHAFT

NOTE:

1. SHORELINE INTERFACES, TRANSITIONS, AND TIE-INS SHALL BE DETERMINED DURING DETAIL DESIGN.

D1 / S-401 PLAN - FOUNDATION - VERTICAL LIFT GATE STORM SURGE BARRIER
SCALE: 1" = 20'



NOTE:

1. ALL ELEVATIONS SHOWN IN FT NAVD88.

A1 / S-401 ELEVATION - VERTICAL LIFT GATE STORM SURGE BARRIER - LOOKING TOWARDS EAST
SCALE: 1" = 20'

20'-0" 0'-0" 20'-0" 40'-0"

SCALE: 1"=20'

PRELIMINARY - CONCEPT LEVEL

Mark	Description	Date	Appr
01	DBB SSB DRAFT CONCEPT - FOR CLIENT REVIEW	11-21-2022	MK

BOSTON WATER AND SEWER COMMISSION
STORM SURGE BARRIER
DORCHESTER BAY BASIN
BOSTON, MA

MULTIVIEWS - VERTICAL LIFT GATE

Designed by: NBJ
Drawn by: CMI
Cad by: JCS
Reviewed by: MK
Submitted by: MOFFATT & NICHOL
Date: 2022-11-21
M&N Project No. 11167
Drawing code:
Drawing Scale: Plot scale: 1:1 (D SHEET)
Rev: -

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NEWTON, MA 02459
moffatt & nichol

SEAL

Sheet Reference No.
S-102
INDEX: 2 OF 2

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DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING

ATTACHMENT B
PROPOSED STORM DIVERSION PIPE ALIGNMENT DRAWINGS

High Elevation Diversion 1: B-1 – B-8, B-27 -- B-31
High Elevation Diversion 2: B-9 – B20, B34 – B35
Outfall 13LSDO090 Diversion: B36 – B47
Outfall 16LSDO122 Diversion: B48 – B55



Dorchester Bay Basin

High Elevation Diversion – New Pipeline 1

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B-1

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N

PROP-PIPE-1



Plan
1"= 10'

0 10 20 40
Feet

PRELIMINARY
DO NOT USE FOR CONSTRUCTION

ASSUMPTIONS, DEFINITIONS, AND DISCLAIMERS

-EXISTING PIPE ALIGNMENTS AND ELEVATION DATA PROVIDED BY BWSC ON 12/21/2020
-ALL ELEVATIONS THROUGHOUT ARE REFERENCED TO NAVD88 DATUM
-PROPOSED PIPE AND MANHOLE ALIGNMENTS ARE PRELIMINARY AND CONCEPTUAL
-DETAILED SURVEY AND AN EVALUATION FOR SUBSURFACE CONFLICTS SHOULD BE PERFORMED BEFORE ADVANCEMENT OF THESE CONCEPTS

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N

PROP-PIPE-2



Plan
1"= 10'

0 10 20 40
Feet

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N

PROP-PIPE-3



Plan
1"= 20'

0 20 40 80 Feet

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N

PROP-PIPE-4



Plan
1"= 20'

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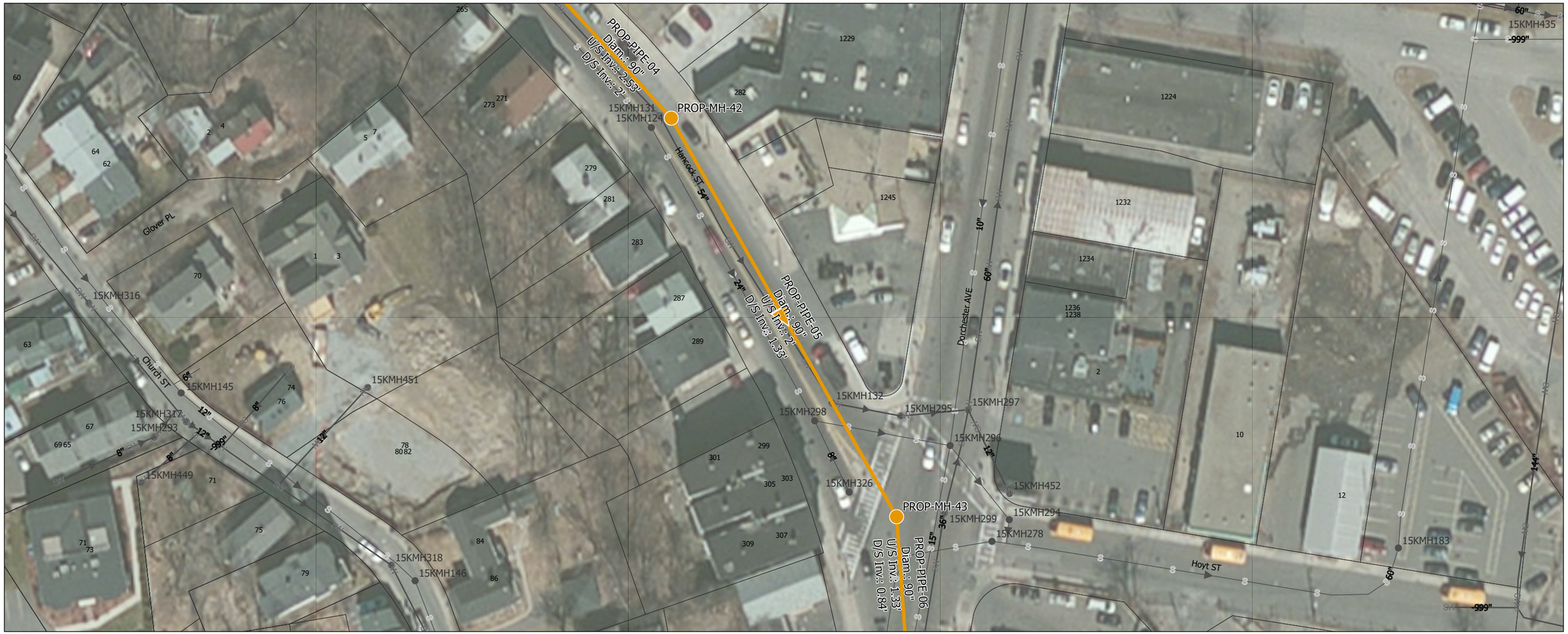
N

PROP-PIPE-5



Plan
1"= 30'

0 30 60 120 Feet

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CONSTRUCTION

ASSUMPTIONS, DEFINITIONS, AND DISCLAIMERS

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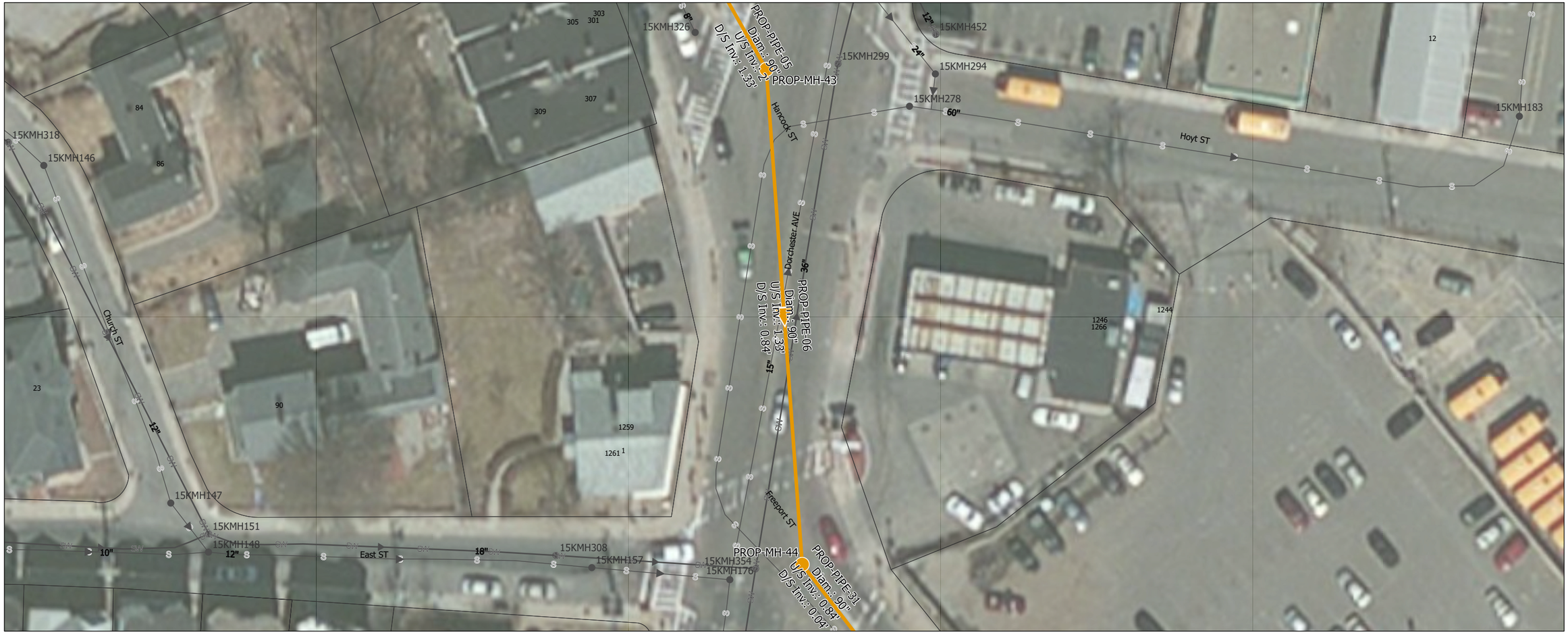
N

PROP-PIPE-6



0 20 40 80 Feet

Plan

1"= 20'

PRELIMINARY
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-EXISTING PIPE ALIGNMENTS AND ELEVATION DATA PROVIDED BY BWSC ON 12/21/2020
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PROP-PIPE-31



0 30 60 120 Feet

Plan
1"= 30'

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Z

PROP-PIPE-30



Plan
1"= 20'

0 20 40 80 Feet

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-EXISTING PIPE ALIGNMENTS AND ELEVATION DATA PROVIDED BY BWSC ON 12/21/2020
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PROP-PIPE-29



N



Plan
1"= 20'

0 20 40 80 Feet

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N

PROP-PIPE-7



Plan
1"= 20'

0 20 40 80 Feet

PRELIMINARY
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CONSTRUCTION

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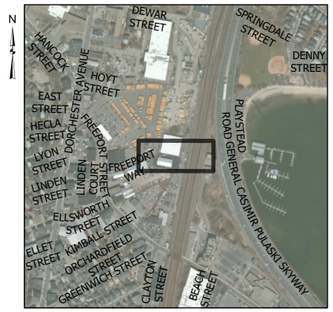

N

PROP-PIPE-28

PROP-MH-48
15KMH232
PROP-PIPE-07
Diam.: 90"
U/S Inv.: -0.77'
D/S Inv.: -1.56'
15KMH457
Freeport WAY
-999"
144"
PROP-PIPE-28
Diam.: 90"
U/S Inv.: -1.56'
D/S Inv.: -2.56'
15KMH233
84"
168"
PROP-MH-49
PROP-MH-50
PROP-MH-51
PROP-PIPE-08
Diam.: 90"
U/S Inv.: -2.77'
D/S Inv.: -2.98'
-999"
PROP-PIPE-27
Diam.: 90"
U/S Inv.: -2.56'
D/S Inv.: -2.77'
96"
6"
15KMH253
15KMH234
8"
78"
15KMH254
10
35
15
17
170

0 20 40 80 Feet

Plan
1"= 20'

PRELIMINARY
DO NOT USE FOR
CONSTRUCTION

ASSUMPTIONS, DEFINITIONS, AND DISCLAIMERS

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Coastal Stormwater Discharge Analysis
Dorchester Bay Basin

Boston Water and Sewer Commission | Hazen

B-12 | November 2022



N

PROP-PIPE-27



0 10 20 40 Feet

Plan
1"= 10'

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Dorchester Bay Basin

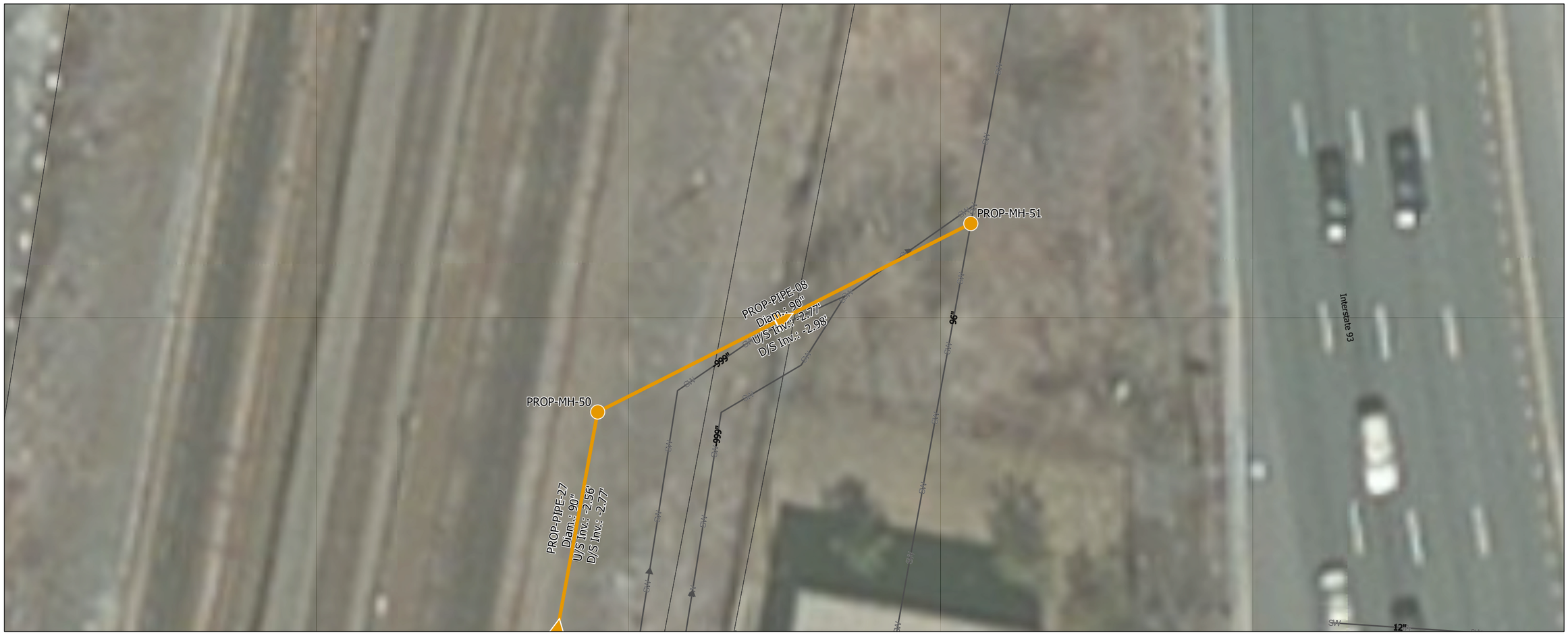
Boston Water and Sewer Commission | Hazen

B-13 | November 2022



N

PROP-PIPE-8



Plan
1"= 10'

PRELIMINARY
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Dorchester Bay Basin

Boston Water and Sewer Commission | Hazen

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Dorchester Bay Basin

High Elevation Diversion – New Pipeline 2

Coastal Stormwater Discharge Analysis
Dorchester Bay Basin

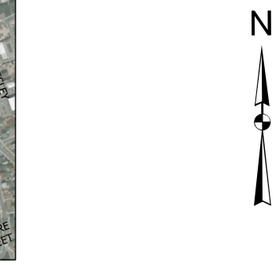
Boston Water and Sewer Commission

Hazen

B-15

November 2022





PROP-PIPE-9



Plan
1"= 20'

0 20 40 80 Feet

PRELIMINARY
DO NOT USE FOR
CONSTRUCTION

ASSUMPTIONS, DEFINITIONS, AND DISCLAIMERS

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Coastal Stormwater Discharge Analysis
Dorchester Bay Basin

Boston Water and Sewer Commission

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November 2022

PROP-PIPE-10



N



0 30 60 120 Feet

Plan
1"= 30'

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Dorchester Bay Basin

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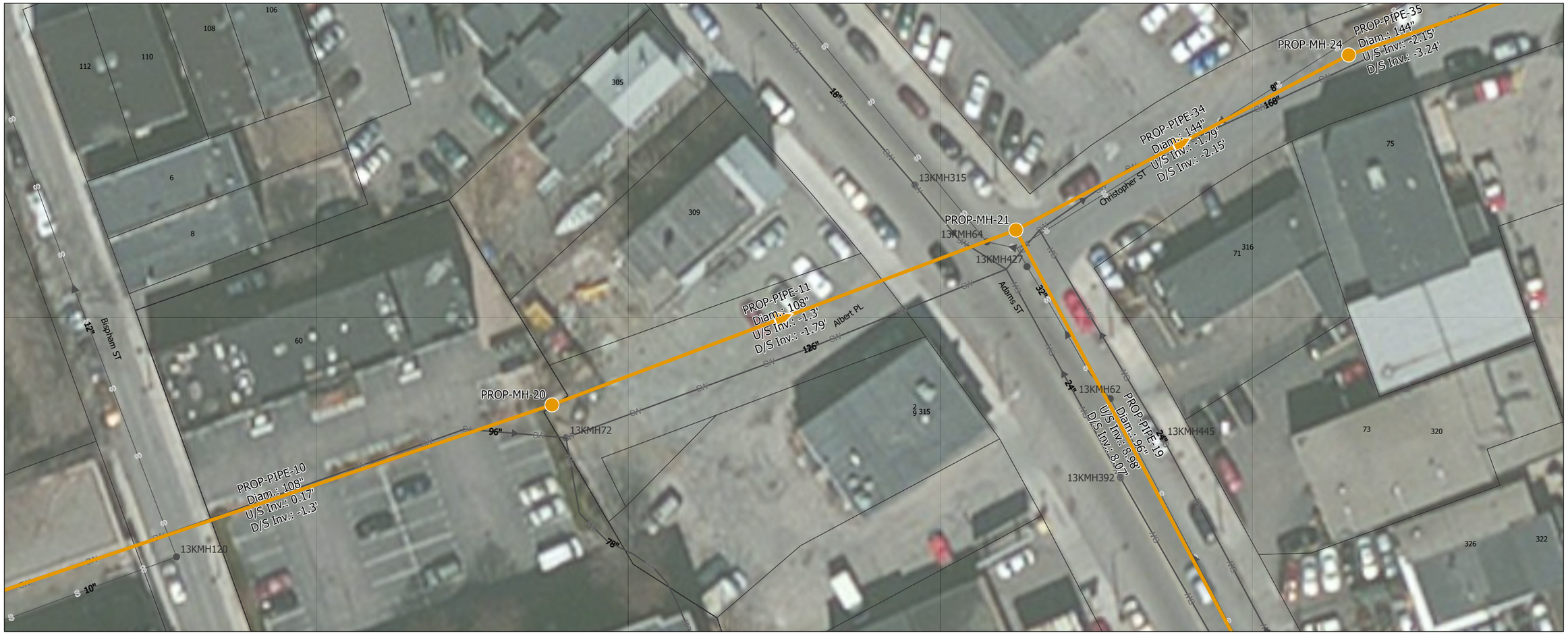
PROP-PIPE-11



0 20 40 80 Feet

Plan

1"= 20'

PRELIMINARY
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Dorchester Bay Basin

Boston Water and Sewer Commission

Hazen

B-18

November 2022



N

PROP-PIPE-34



0 20 40 80 Feet

Plan
1"= 20'

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Dorchester Bay Basin

Boston Water and Sewer Commission

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N

PROP-PIPE-35



Plan
1"= 30'

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Coastal Stormwater Discharge Analysis
Dorchester Bay Basin

Boston Water and Sewer Commission

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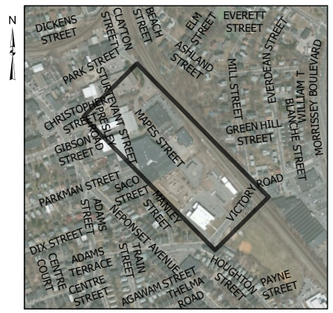
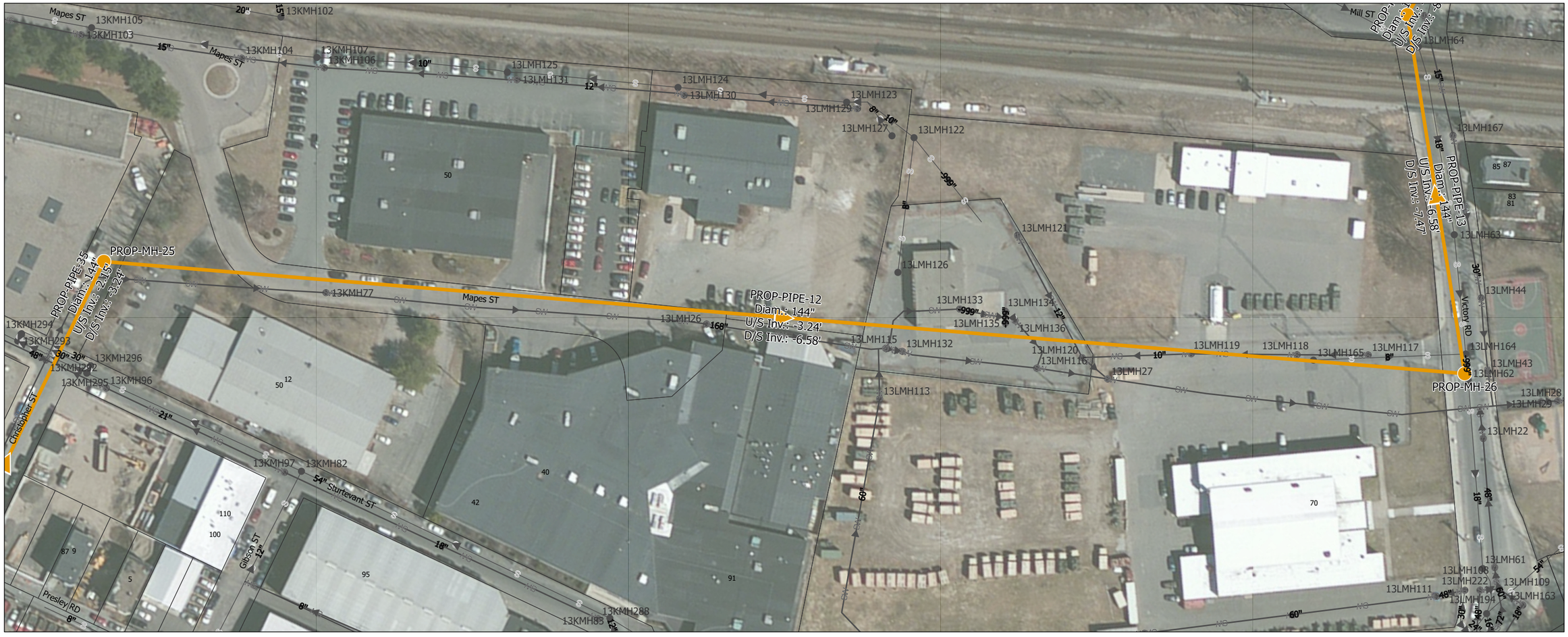
B-20

November 2022



PROP-PIPE-12



Plan
1"= 50'

0 50 100 200 Feet

PRELIMINARY
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Coastal Stormwater Discharge Analysis
Dorchester Bay Basin

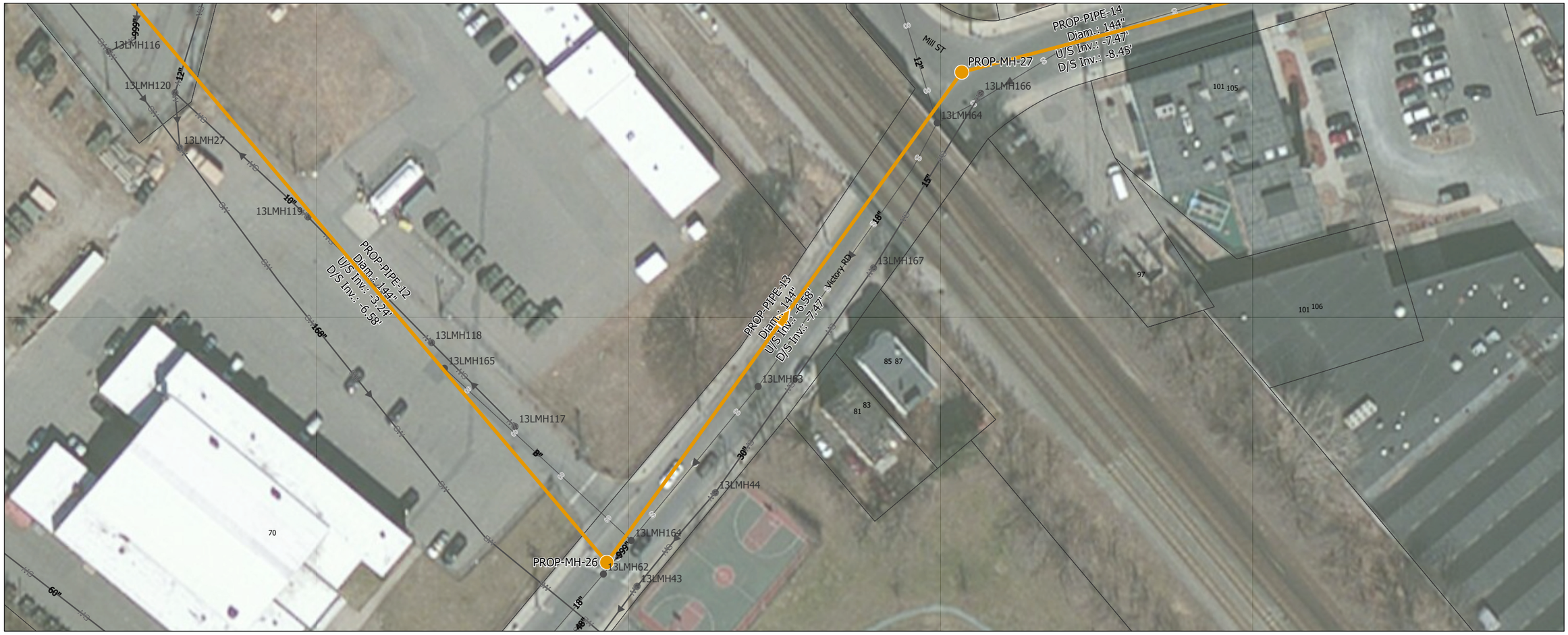
Boston Water and Sewer Commission | Hazen

B-21 | November 2022



N

PROP-PIPE-13



Plan
1"= 30'

PRELIMINARY
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Coastal Stormwater Discharge Analysis
Dorchester Bay Basin

Boston Water and Sewer Commission

Hazen

B-22

November 2022



N

PROP-PIPE-14



Plan
1"= 20'

0 20 40 80
Feet

PRELIMINARY
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Coastal Stormwater Discharge Analysis
Dorchester Bay Basin

Boston Water and Sewer Commission

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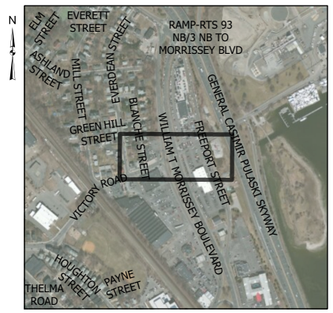
November 2022

PROP-PIPE-15



N



Plan
1"= 30'

0 30 60 120
Feet

PRELIMINARY
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Coastal Stormwater Discharge Analysis
Dorchester Bay Basin

Boston Water and Sewer Commission | Hazen

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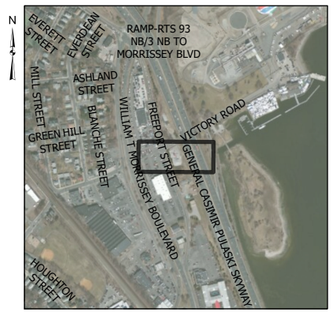

N

PROP-PIPE-16



0 20 40 80 Feet

Plan
1"= 20'

PRELIMINARY
DO NOT USE FOR CONSTRUCTION

ASSUMPTIONS, DEFINITIONS, AND DISCLAIMERS

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Coastal Stormwater Discharge Analysis
Dorchester Bay Basin

Boston Water and Sewer Commission | Hazen

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PROP-PIPE-17



Plan
1"= 20'

0 20 40 80 Feet

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CONSTRUCTION

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Coastal Stormwater Discharge Analysis
Dorchester Bay Basin

Boston Water and Sewer Commission

Hazen

B-26

November 2022



N

PROP-PIPE-20



Plan
1"= 20'

0 20 40 80
Feet

PRELIMINARY
DO NOT USE FOR
CONSTRUCTION

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Coastal Stormwater Discharge Analysis
Dorchester Bay Basin

Boston Water and Sewer Commission

Hazen

B-27

November 2022



N

Z

PROP-PIPE-18



0 30 60 120 Feet

Plan
1"= 30'

PRELIMINARY
DO NOT USE FOR
CONSTRUCTION

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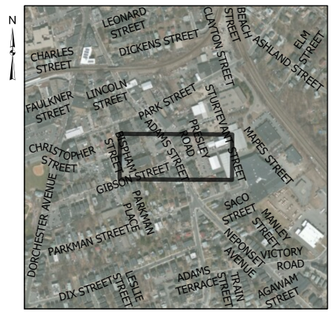
Coastal Stormwater Discharge Analysis
Dorchester Bay Basin

Boston Water and Sewer Commission

Hazen

B-28

November 2022





Plan
1"= 30'

0 30 60 120 Feet

PRELIMINARY
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PROP-PIPE-19

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Dorchester Bay Basin

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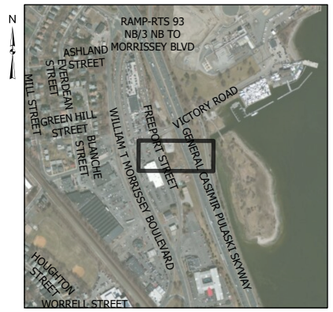
Dorchester Bay Basin

Outfall 13LSDO090 Diversion to Dorchester Bay Basin

Coastal Stormwater Discharge Analysis
Dorchester Bay Basin

Boston Water and Sewer Commission | Hazen

B-30 | November 2022



N

PROP-PIPE-36



0 20 40 80 Feet

Plan
1"= 20'

PRELIMINARY
DO NOT USE FOR
CONSTRUCTION

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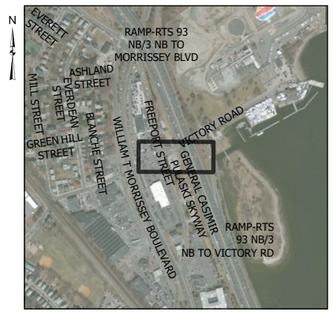
Coastal Stormwater Discharge Analysis
Dorchester Bay Basin

Boston Water and Sewer Commission

Hazen

B-31

November 2022



N

PROP-PIPE-37



Plan
1"= 20'

0 20 40 80 Feet

PRELIMINARY
DO NOT USE FOR CONSTRUCTION

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Coastal Stormwater Discharge Analysis
Dorchester Bay Basin

Boston Water and Sewer Commission | Hazen

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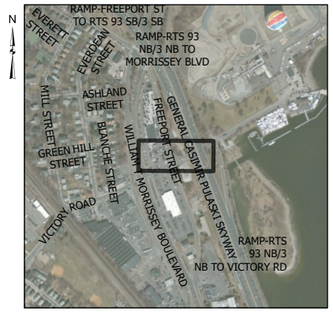

N

PROP-PIPE-38



0 20 40 80 Feet

Plan
1"= 20'

PRELIMINARY
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Coastal Stormwater Discharge Analysis
Dorchester Bay Basin

Boston Water and Sewer Commission | Hazen

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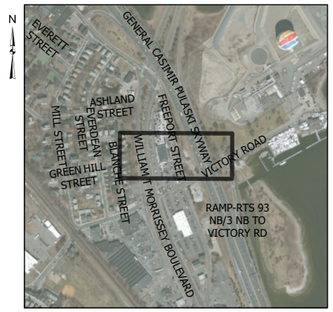

N

PROP-PIPE-39



0 30 60 120 Feet

Plan
1"= 30'

PRELIMINARY
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Dorchester Bay Basin

Boston Water and Sewer Commission | Hazen

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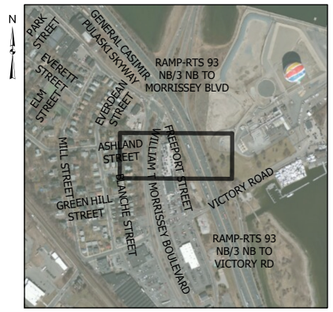

N

PROP-PIPE-40



Plan
1"= 30'

0 30 60 120 Feet

PRELIMINARY
DO NOT USE FOR CONSTRUCTION

ASSUMPTIONS, DEFINITIONS, AND DISCLAIMERS

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Coastal Stormwater Discharge Analysis
Dorchester Bay Basin

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N

PROP-PIPE-41



Plan
1"= 20'

PRELIMINARY
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CONSTRUCTION

ASSUMPTIONS, DEFINITIONS, AND DISCLAIMERS

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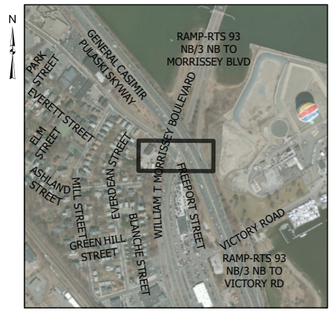
Coastal Stormwater Discharge Analysis
Dorchester Bay Basin

Boston Water and Sewer Commission

Hazen

B-36

November 2022



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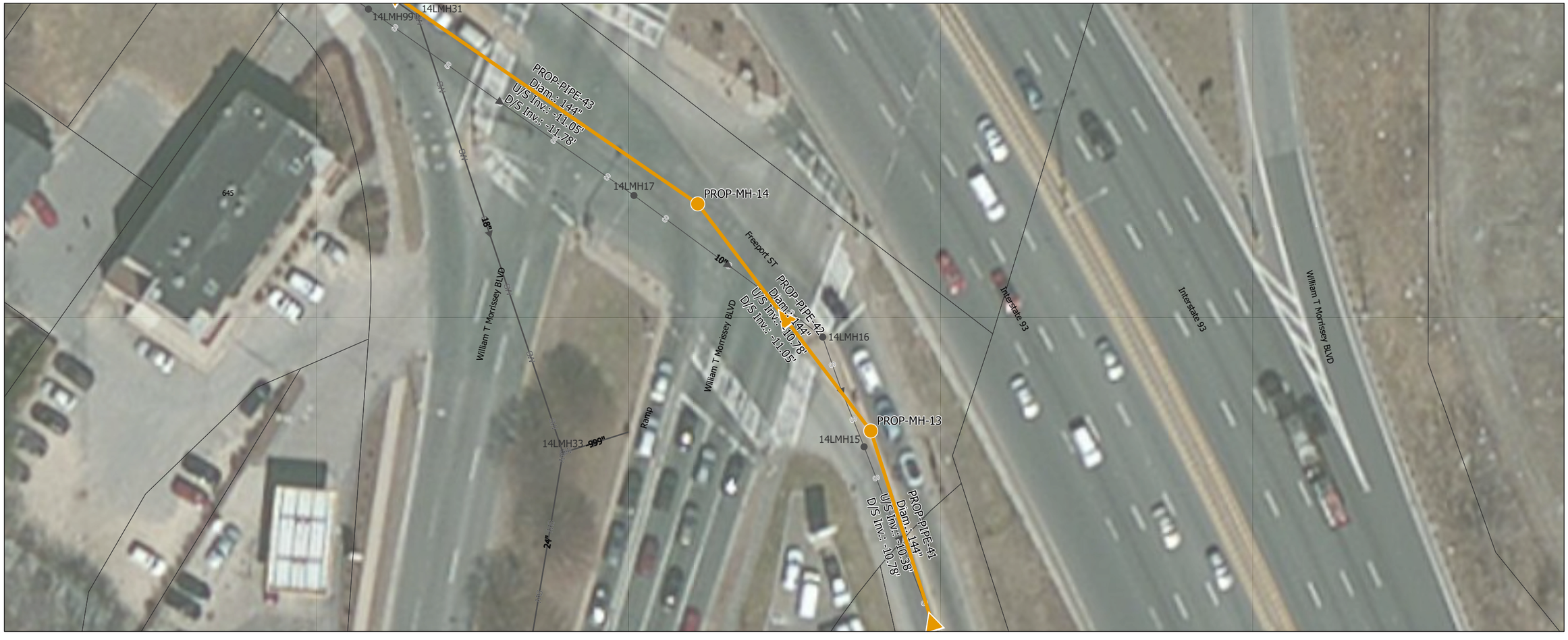
PROP-PIPE-42



Plan
1"= 20'

0 20 40 80 Feet

PRELIMINARY
DO NOT USE FOR
CONSTRUCTION

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Coastal Stormwater Discharge Analysis
Dorchester Bay Basin

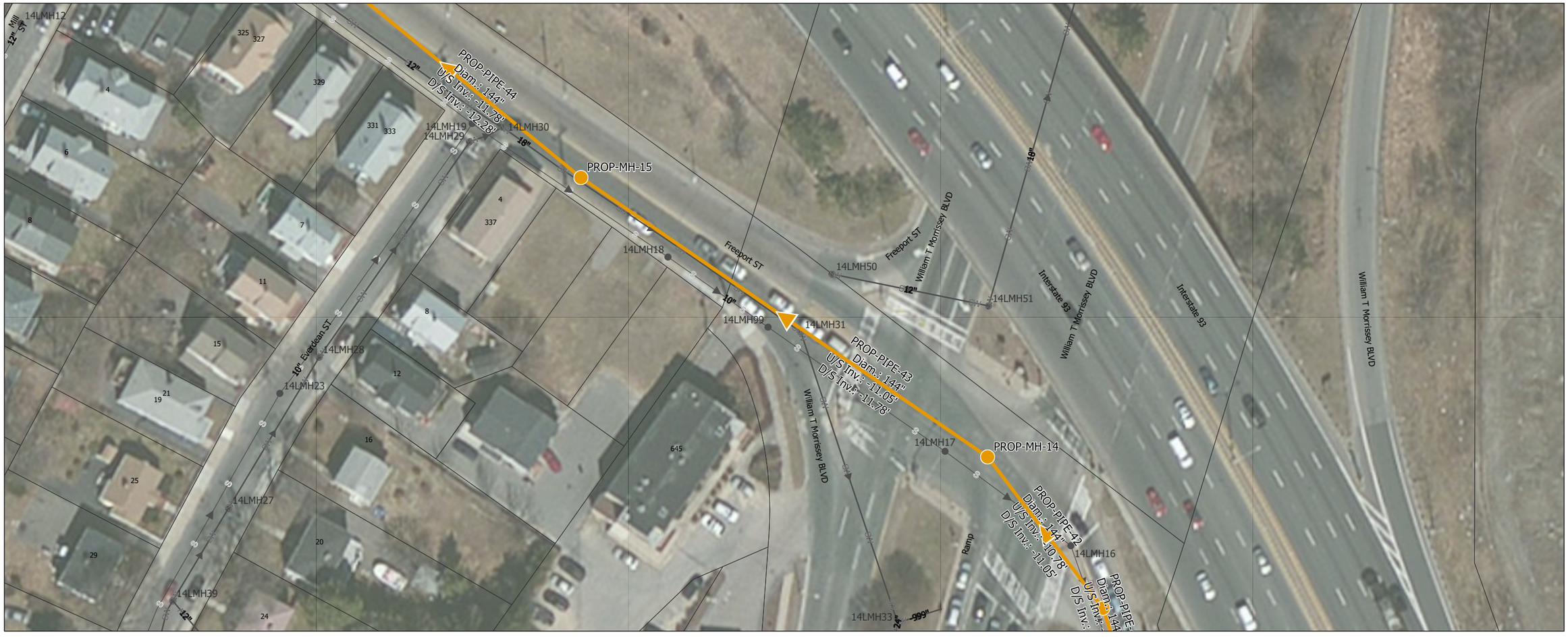
Boston Water and Sewer Commission | Hazen

B-37 | November 2022



N

PROP-PIPE-43



Plan
1"= 30'

PRELIMINARY
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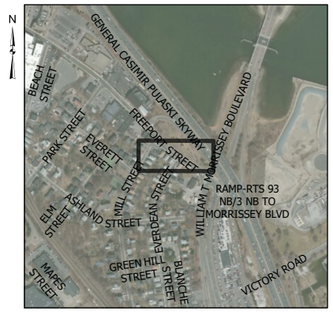
Coastal Stormwater Discharge Analysis
Dorchester Bay Basin

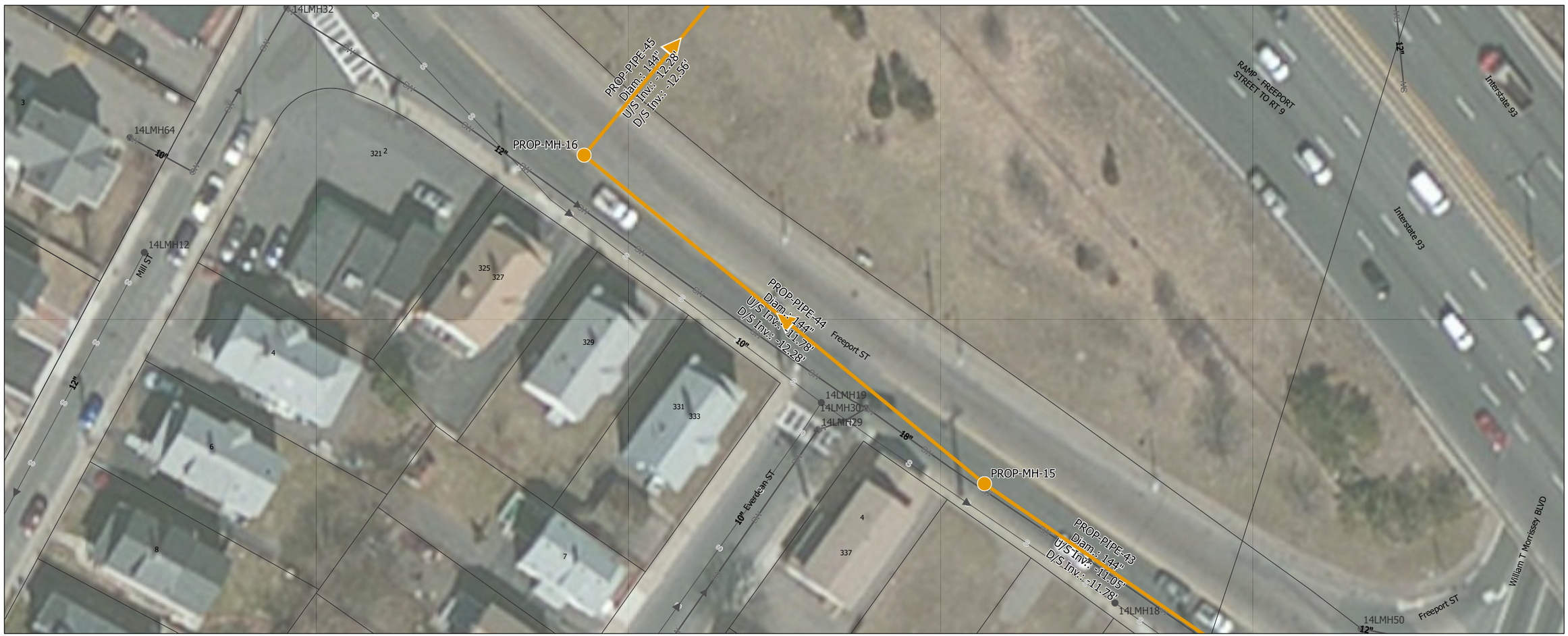
Boston Water and Sewer Commission

Hazen

B-38

November 2022





PROP-PIPE-44

Plan
1"= 20'

0 20 40 80 Feet

PRELIMINARY
DO NOT USE FOR
CONSTRUCTION

ASSUMPTIONS, DEFINITIONS, AND DISCLAIMERS

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Dorchester Bay Basin

Boston Water and Sewer Commission | Hazen

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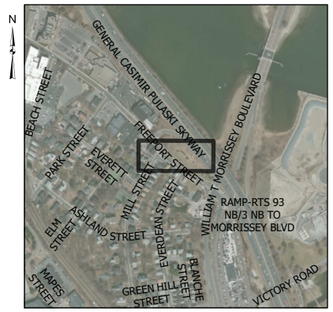

N

PROP-PIPE-45



0 20 40 80 Feet

Plan
1"= 20'

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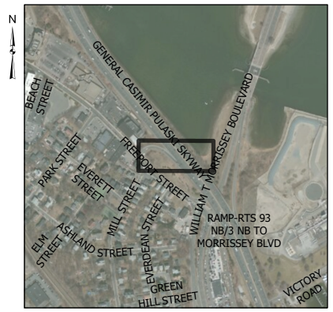

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PROP-PIPE-46



0 20 40 80 Feet

Plan
1"= 20'

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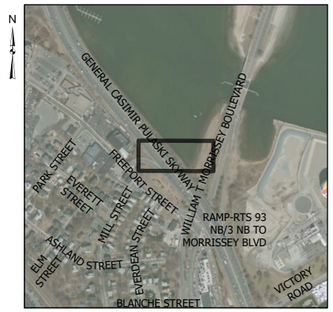



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PROP-PIPE-47

0 20 40 80 Feet

Plan
1"= 20'

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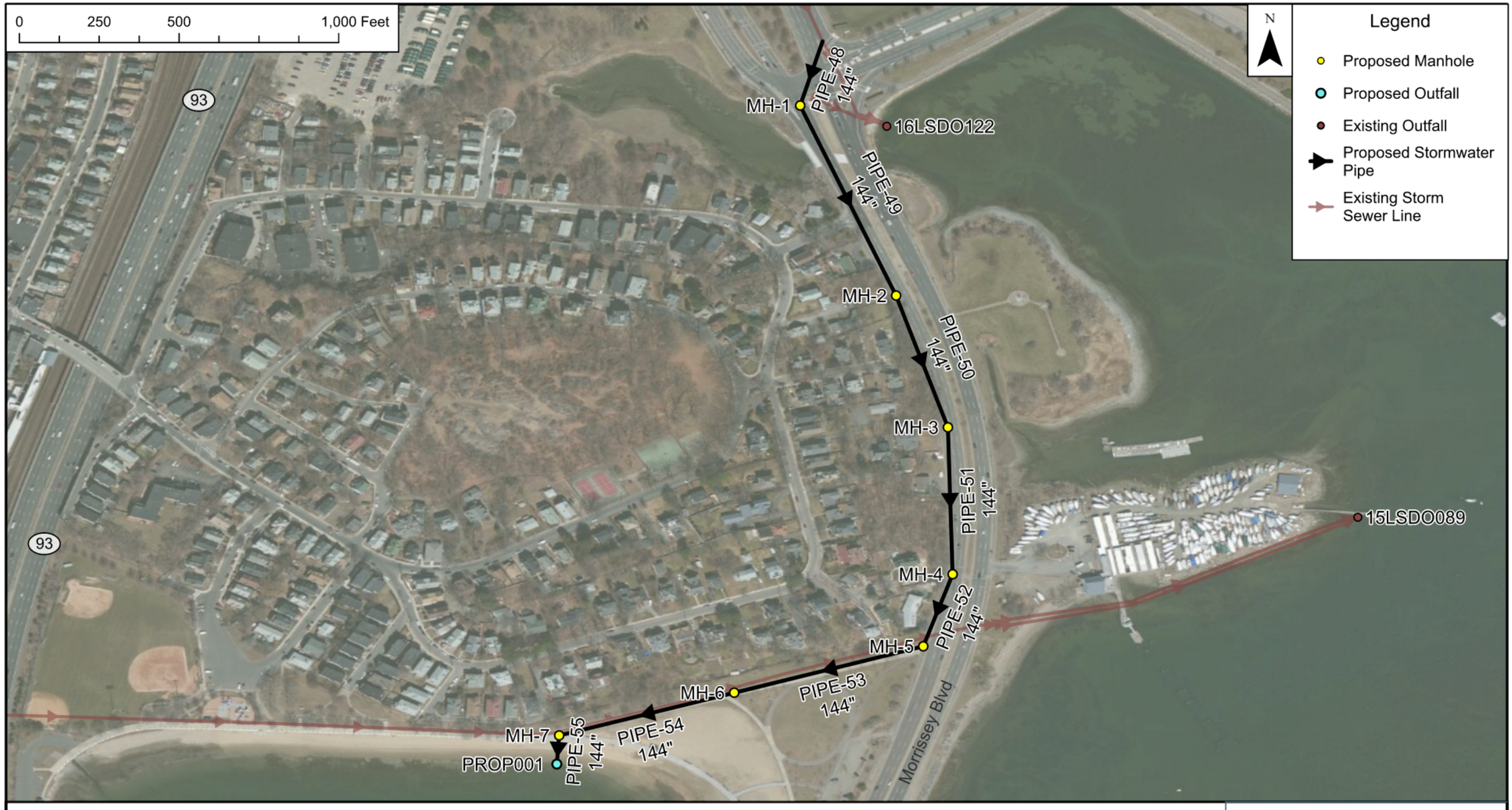

Dorchester Bay Basin

Outfall 16LSDO122 Diversion to Dorchester Bay Basin

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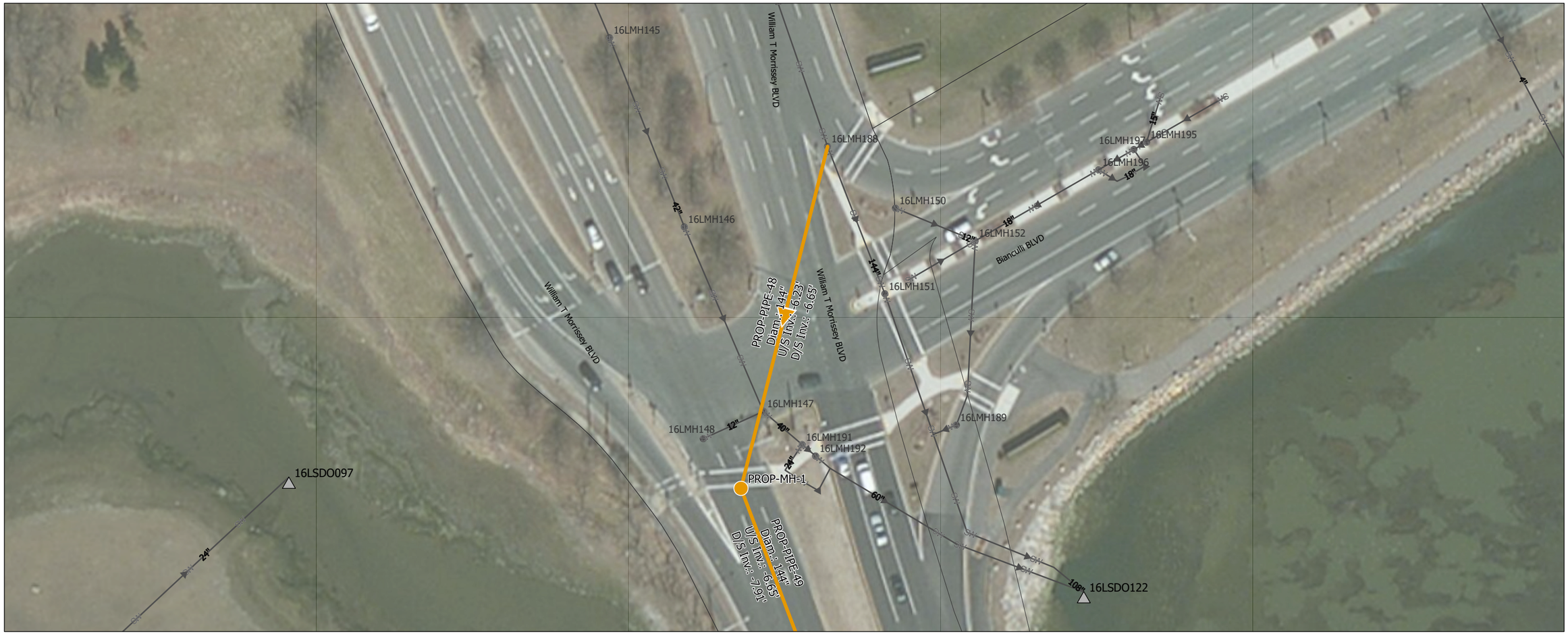
N

PROP-PIPE-48



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1"= 30'

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PROP-PIPE-49



Plan
1"= 30'

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PROP-PIPE-50





Plan
1"= 30'

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N

PROP-PIPE-51



Plan
1"= 30'

0 30 60 120
Feet

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PROP-PIPE-52



N



Plan
1"= 30'

0 30 60 120 Feet

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Plan
1"= 30'

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PROP-PIPE-54



Plan
1"= 30'

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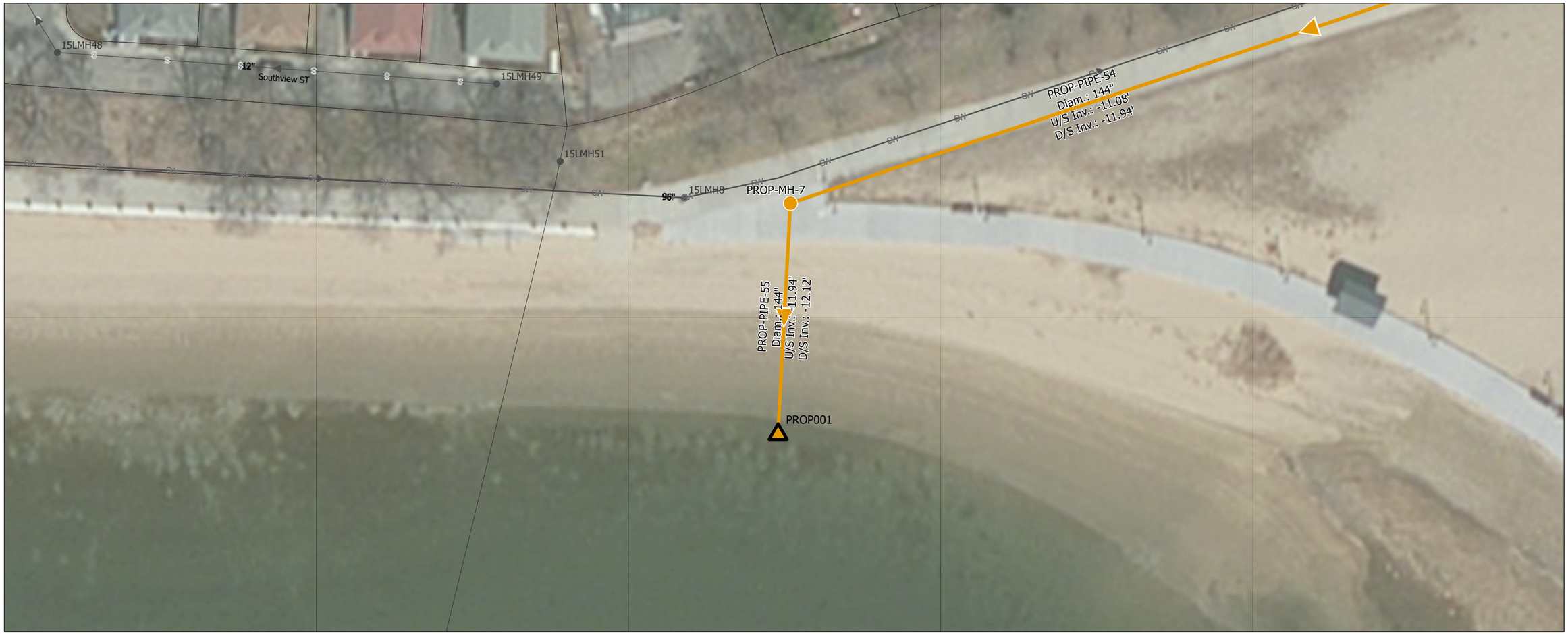
PROP-PIPE-55



Plan
1"= 20'

0 20 40 80
Feet

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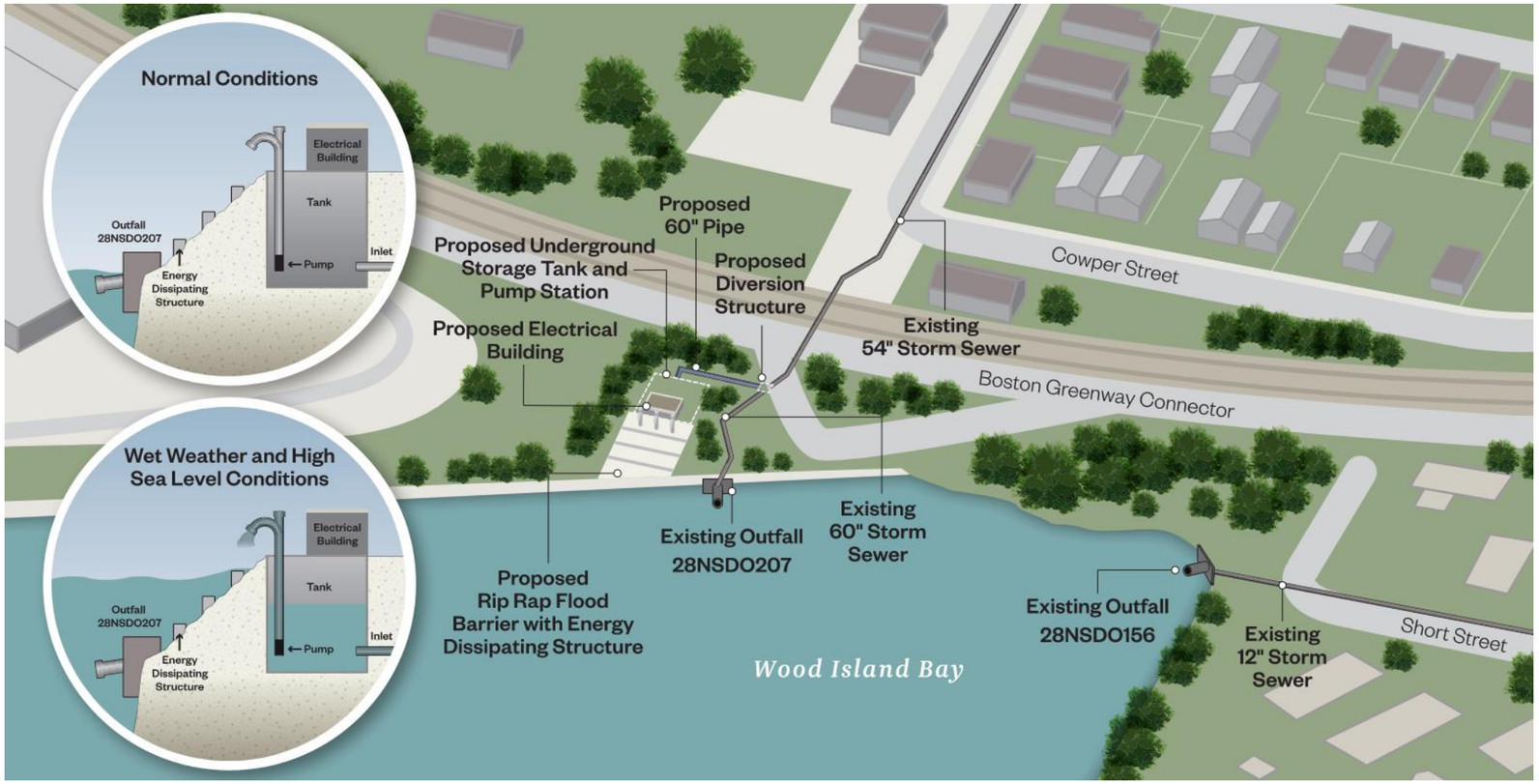
East Boston Greenway *Concept Overview*





Conceptual Solution

The conceptual solution herein includes a small stormwater storage (peak flow shaving) tank and pump station to discharge wet weather flow when tide levels are high. The tank and pump station are located along the East Boston Greenway in close proximity to the Wood Island Bay Edge Park. If a high tide level begins to reduce the ability of existing outfall 28NSDO207 to discharge by gravity the existing storm sewer will begin to surcharge. A diversion structure with a static weir directs excess flow to a small storage tank that is connected directly to the pump station. The pump station utilizes electric submersible pumps to minimize the above ground footprint of the station and mitigate negative visual and auditory impacts from diesel engine driven pumps. During extreme storm conditions a portable generator could be parked along the Greenway to provide a backup power supply in the event of a power outage. Given the high public visibility of this location, this solution could provide educational opportunities about resilient stormwater infrastructure and incorporate nature-based features (such as native plantings) to minimize the impact of new infrastructure.

Type: Storage and Pumping

Total Drainage Area: 57 acres

Coastal Flood Vulnerable Drainage Area Protected: 57 acres

Concept Elements:

- Subsurface Pump Station
- Subsurface Storage Tank
- Diversion Structure

Outfalls Included in Concept:

- 28NSDO207
- 28NSDO156

Coastal Stormwater Discharge Analysis
East Boston Greenway

Boston Water and Sewer Commission | Hazen

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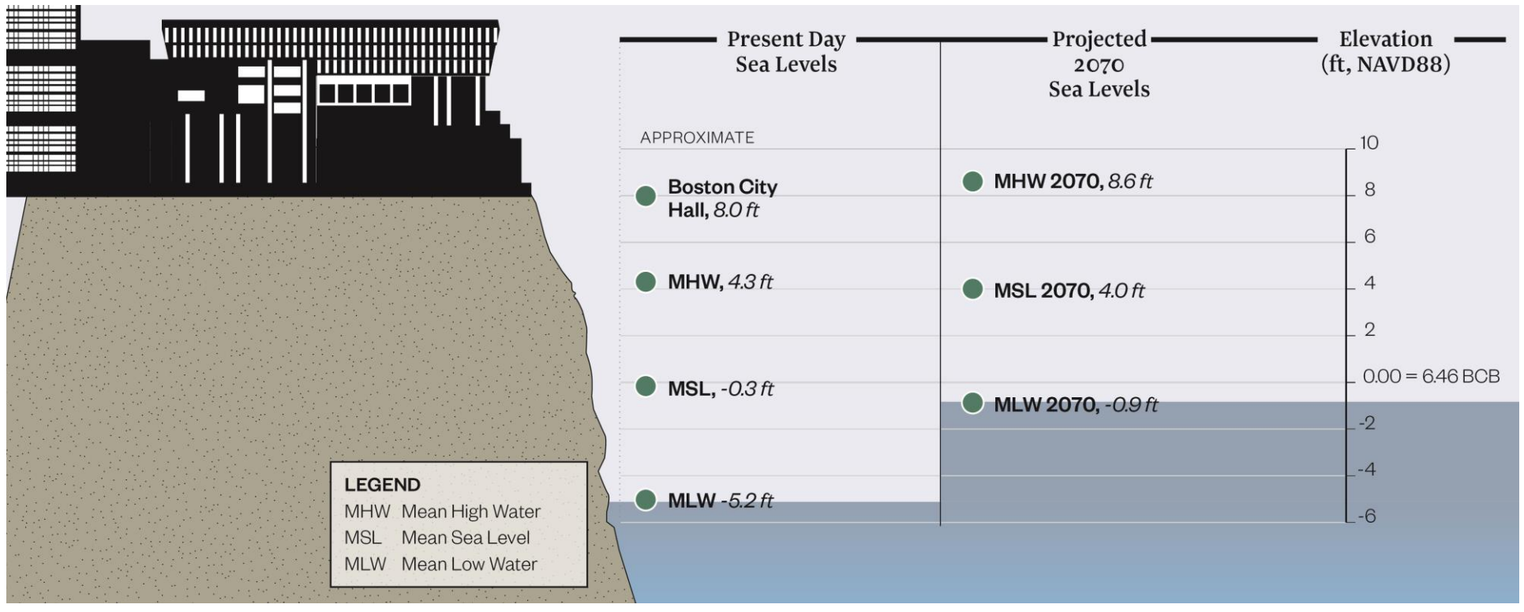
Assumptions

Sea Level Rise and Datum

The East Boston Greenway Pump Station concept was designed for consistency with Climate Ready Boston (CRB) proposed adaptations and analyzed based on sea level rise (SLR) projections in the Massachusetts Coastal Flood Risk Model (MC-FRM). The SLR values applied in MC-FRM are consistent with the standards for the State of Massachusetts developed by Coastal Zone Management. The MC-FRM utilizes a "High" SLR scenario. This scenario is based on the relative SLR projections under Relative Concentration Pathway (RCP) 8.5 (a "worst case scenario" of increasing atmospheric carbon concentrations) and represents elevations that have a 99.5% probability of not being exceeded within the respective timeframes. In 2030, that amounts to an increase of 1.3 feet in Boston from a baseline condition (2008 centered tidal epoch), and in 2070 that amounts to an increase of 4.3 feet.

The concept developed in this project was analyzed using coastal conditions that include 2070 projected SLR and storm surge resulting from a 100-year tropical storm. The peak water surface elevation (WSE) predicted by the MC-FRM during these conditions is approximately 13.8 feet NAVD88 (varies by location). In mid 2022, the Greater Boston Research Advisory Group (BRAG) issued an updated report with new SLR projections. The report acknowledges that long term SLR projections are associated with significant uncertainty, and that updated projections include less SLR by 2100 (compared to earlier projections in the 2015 BRAG Report). According to the report, the likely range of SLR by 2070 under an RCP 8.5 scenario is 1.4 – 2.8 feet. Based on this information, projections from the MC-FRM that were utilized in this project are conservative and appropriate for long term planning purposes.

Unless otherwise noted, all elevations are based on the NAVD88 vertical datum. Elevations given in NAVD88 can be converted to Boston City Base (BCB) elevation by adding 6.46 feet.



Climate Ready Boston and Shoreline Protection

The East Boston Greenway Pump Station concept was developed to maintain consistency with possible Climate Ready Boston (CRB) adaptations based on the latest available information at the time they were developed. As the CRB program continues to evolve, it is anticipated that proposed concepts will need to be adapted.

The concept was developed to be consistent with stated neighborhood design flood elevations. In East Boston, where the stated design flood elevation is 16.0 feet, pumps were designed to discharge to a minimum elevation of 16.0 feet.

At the time of this project, many CRB concepts were in early planning stages and not fully defined. **In consideration of this, it was assumed the shoreline protection around the City of Boston is 100% effective for all modeling evaluations.** This assumption eliminates overland coastal flooding from model predictions, allowing for isolation of flooding that results only from rainfall and stormwater that cannot be discharged due to high sea levels. It is important to recognize that additional flooding, beyond what is depicted herein, would be expected if 100% effective shoreline protection is not implemented

Basis of Design

Storage and Pumping

Model simulations were conducted to determine the maximum Hydraulic Grade Line (HGL) that occurs at Outfall 28NSDO207 with the current tide cycle. Analyses were then conducted to determine the acceptable combinations of storage volume and pumping rate required to maintain the existing HGL with 2070 projected sea level rise and 100-year storm surge, as shown in Figure 1. The City of Boston's Parcel database was used to identify publicly owned parcels near the existing outfall. An analysis of the pump station was performed to identify a pump rate and physical dimensions that are hydraulically viable. It was found that a 0.35 MG storage tank ~26 feet deep could fit within the property with a 130 CFS pump station The pump station and storage tank occupy an area of 2,865 ft^2. The East Boston Greenway pump station utilizes two duty pumps, one standby pump, and two dewatering pumps. The pump station is configured with vertical, axial electric submersible pumps in parallel bays.

Figure 1: Pumping vs. Storage

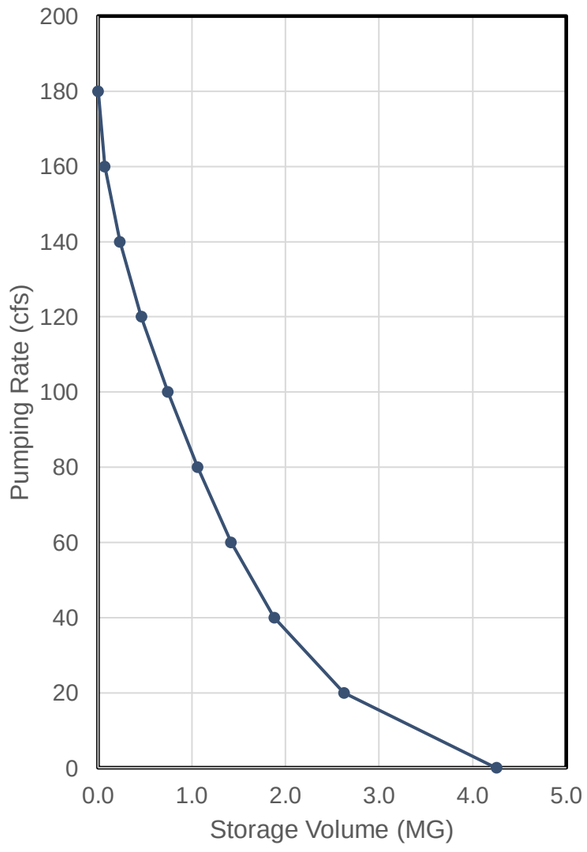


Figure 2: Peak Shaving Tank and Pump Station



Rainfall and Coastal Conditions

The Commission currently utilizes a 10-year, 24-hour design storm to establish its target level of service. For the purpose of sizing new piping and evaluating storage capacity, a projected 2070 10-year, 24-hour design storm was developed. For consistency with Climate Ready Boston, performance of the East Boston pump station concept was also evaluated with projected rainfall from a 100-year tropical event (developed during the Commission's Inundation Model Project. The East Boston pump station was evaluated using a 100-year return period coastal boundary condition. Data for this condition were obtained from the MC-FRM. For the purpose of evaluating the effectiveness of the concept, it was further assumed that complete shoreline protection was implemented, preventing flow of water between the East Boston pump station tributary area and Boston Harbor. Table 2 contains a summary of the coastal conditions that were analyzed.

Table 1: Rainfall Conditions

Scenario	Purpose	Rainfall Depth (in)	Peak Intensity (in/hr)
Present Day, 10-year, 24-hr design storm	Baseline Conditions	5.15	3.32
Projected 2070, 10-year, 24-hr design storm	Design Conditions	6.18	4.08
100-year Tropical Storm	Damage Analysis	9.58	0.84

Table 2: Coastal Conditions

Scenario	Purpose	Peak Water Surface Elevation (ft, NAVD88)	Source
Present Day	Baseline Conditions	3.7	BWSC Existing Model (April 2016 Tide Cycle)
2070,100-year Tropical Storm	Damage Analysis	13.8	MC-FRM

Conceptual Design – Not for Construction

Flood Modeling and Damage Analysis

Figure 3: Estimated Replacement Cost

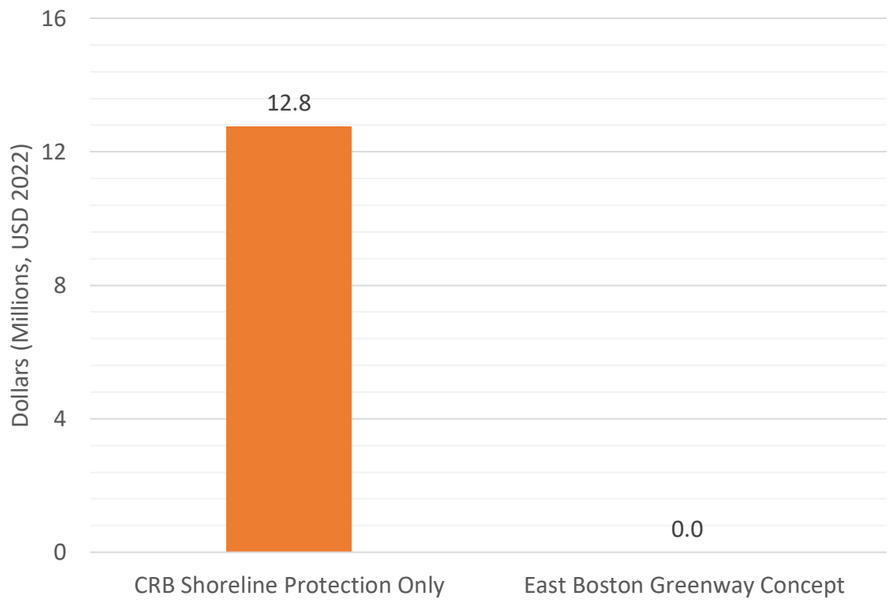


Figure 4: Loss of GDP

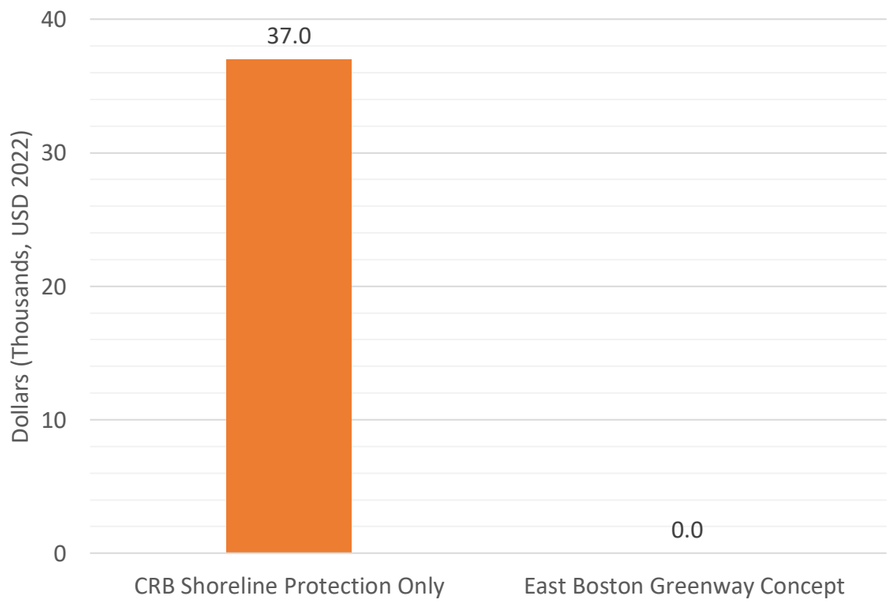
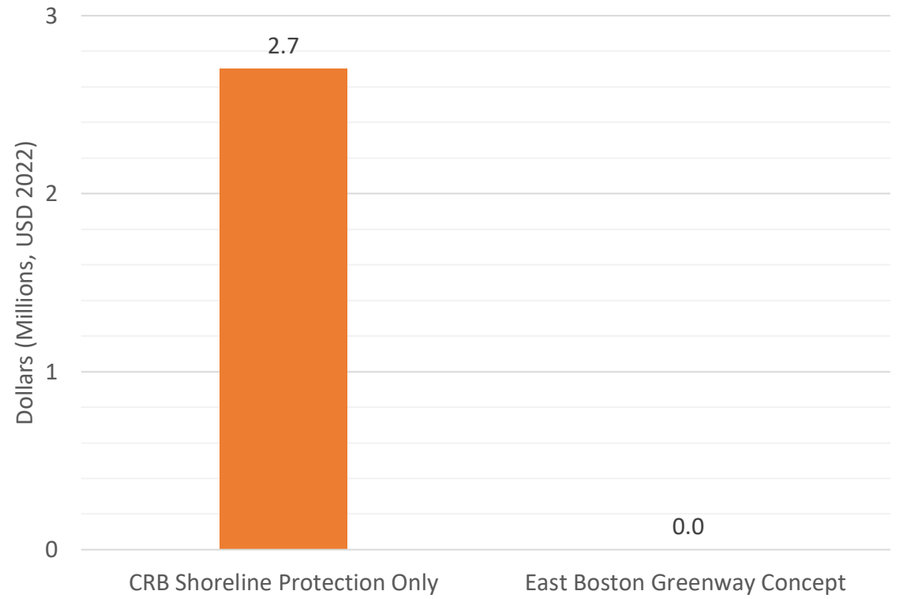


Figure 5: Physical Damage



The flood reduction benefits of the East Boston Greenway pump station were evaluated using the Commission's 2D Inundation Model by simulating a 100-year tropical storm event with 2070 SLR and storm surge. The figures on the following page depict the peak flooding that was predicted in the drainage area tributary to the East Boston Greenway pump station with shoreline protection only and with the pump station concept implemented. An analysis of economic losses/physical impacts from flooding under both scenarios was performed by risQ Inc.

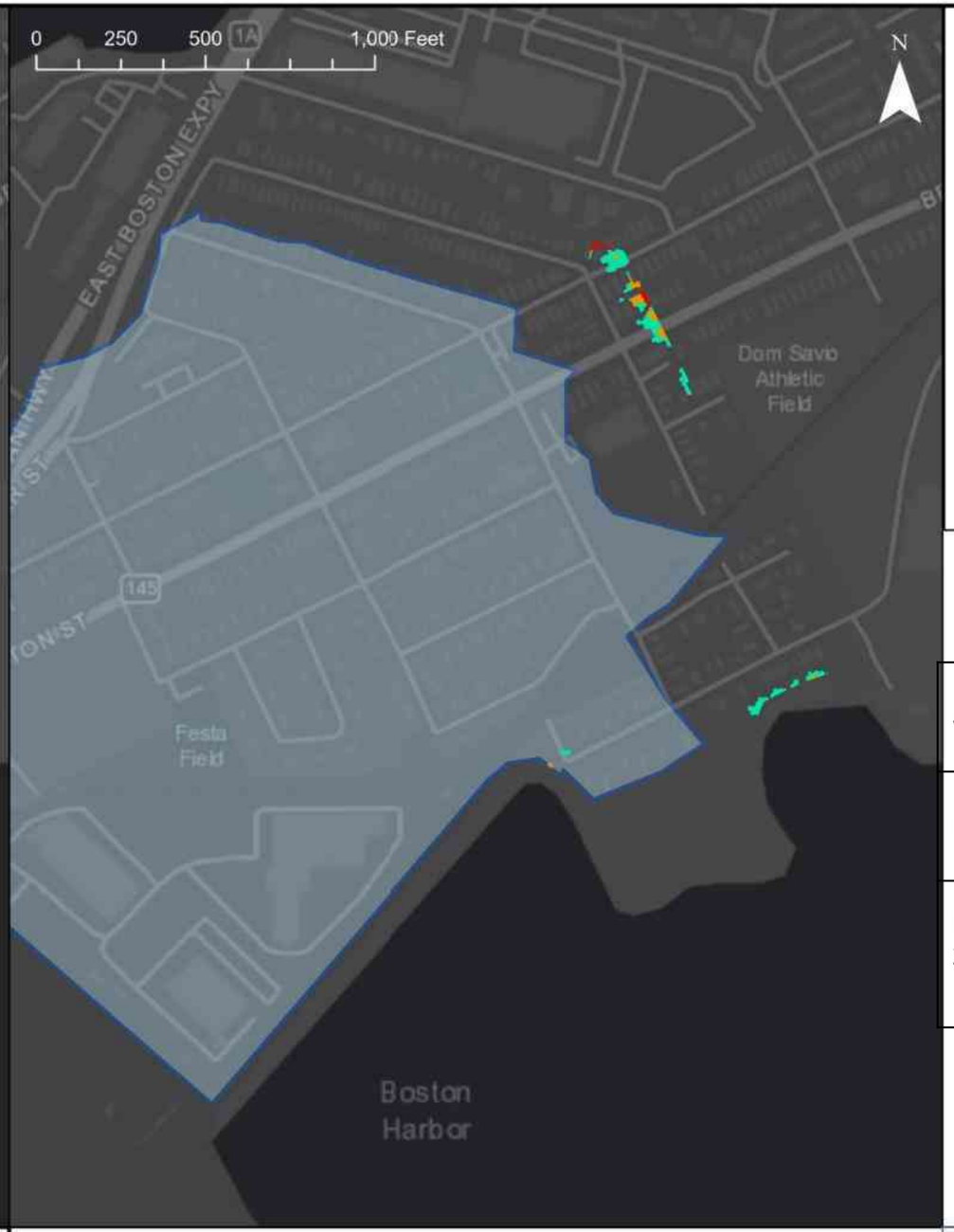
*Model predictions indicate that the East Boston pump station reduces physical damage by **$2.7 million**, avoids **$12.8 million** in rebuilding costs, and mitigates a GPD loss of **$37 thousand** during a 100-year tropical storm event in 2070.*

Note: replacement values include the total value of impacted buildings in flooded areas (e.g., impacted buildings are fully replaced), whereas physical damage includes estimated costs to repair flood damage based on predicted flood depths and building characteristics. The values shown are the average of minimum and maximum calculated losses. Refer to the Project's Final Report for more information.



2070 SLR + 100yr Tropical Storm + Storm Surge

Shoreline Protection Only



2070 SLR + 100yr Tropical Storm + Storm Surge

East Boston Greenway Pump Station and Tide Gates

Legend

- Flood Depth > 4 in and < 1 ft
- Flood Depth > 1 ft and < 2 ft
- Flood Depth > 2 ft
- Drainage Area Analyzed

Simulation Parameters

Storm Type	100yr Tropical Storm
Rainfall Depth	9.6 inches
Peak WSE 2070 SLR + 100yr Surge	13.8 feet NAVD88

Coastal Stormwater Discharge Analysis
East Boston Greenway

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November 2022

Damage Analysis

Capital Cost Estimate

A construction cost estimate for the East Boston Greenway Pump Station concept was developed for planning purposes. Assumptions made for the Davenport Creek Stormwater Park cost estimate include 15-year escalation to the mid-point of construction and the inclusion of a 50% design contingency. Hookup costs to existing electrical services were not included in this estimate.

Table 3: East Boston Greenway Cost Estimate Subtotals

Remaining Design Development & Construction Administration (assumed 20% of total less design contingency)	$1,491,000
Direct Construction Costs	$2,936,938
Indirect Construction Costs	$587,388
Mark-Up *(Including 50% design contingency)*	$7,517,674
Total	**$12,533,000**

Social Vulnerability and FEMA BRIC Funding

FEMA BRIC funding prioritizes disadvantaged communities. Table 4 contains a summary of several indicators for the East Boston Greenway tributary area that could be used help characterize the community for future FEMA funding applications and prioritization of projects that benefit disadvantaged communities.

Table 4: East Boston Greenway Tributary Area Social Vulnerability Indicators

Low Income & Persistent Poverty	
Per Capita Income	$37,917
Below Poverty Line	16%
High Housing Cost Burden	
Stressed Renters (>40% rent-to-income)	33%
Households With Food Insecurity	14%
Racial and Ethnic Segregation	
Asian Population	5%
Black Population	4%
Latino Population	46%
White Population	61%
Education and Employment	
Adults Age 25+ Without High School (or equivalent) Degree	14%
Unemployment (Age 16+)	5%

Data provided by risQ inc. from the US census and American Community Survey

Conceptual Design – Not for Construction

Planting Palette

A planting palette was developed for the park area near the pump station along the East Boston Greenway. After construction, planting of native plant species could provide a public amenity with new green space and environmental benefits associated with native plant species and conceal concept utilities such as the electrical building.

Trees



Amelanchier arborea
common serviceberry



Juniperus virginiana
eastern red cedar



Magnolia virginiana
sweet bay magnolia



Quercus rubra
northern red oak

Shrubs



Rosa carolina
pasture rose



Rhus copallinum
winged sumac



Aronia melanocarpa
black chokeberry



Morella pensylvanica
bayberry

Herbaceous and Grasses



Panicum virgatum
switchgrass



Schizacharium scoparium
little bluestem



Eutrochium purpureum
Joe-Pye-Weed



Solidago sempervirens
seaside goldenrod

Coastal Stormwater Discharge Analysis
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Conceptual Design – Not for Construction

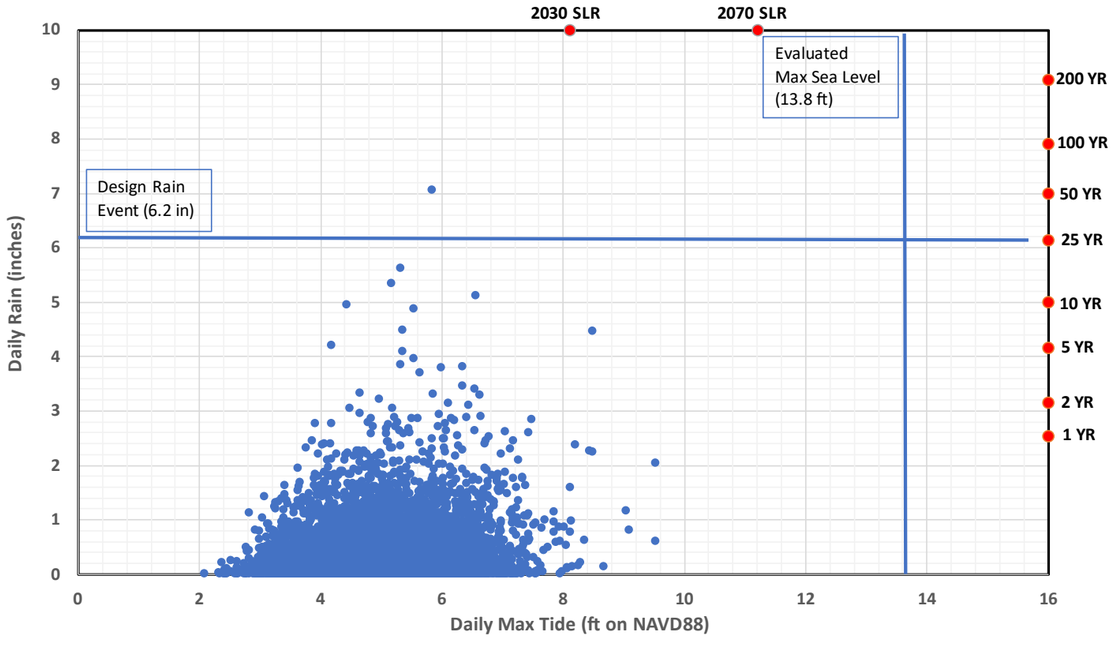
Adaptability and Implementation

Adaptability

Figure 6 below depicts historical daily rainfall totals and tide levels. As shown in this figure, the conditions that were used to design and analyze the East Boston Greenway pump station are conservative and represent more extreme conditions than have occurred historically. Regardless, the following measures could be implemented to adapt the concept to more severe conditions (additional SLR, more intense rainfall, etc.) in the future:

- Increase the size of installed electric submersible pumps
- Utilize the standby pump as a duty pump during extreme conditions
- Increase the size of peak shaving tank
- Consider construction of a larger storage and pump facility at the large privately owned vacant parcel between Short Street and Byron Street.
- Flow from Outfall 28NSDO206 could be redirected to the pump station if it is found that the existing outfall is a source of flooding. The East Boston greenway pump station concept is designed to accommodate this additional flow.

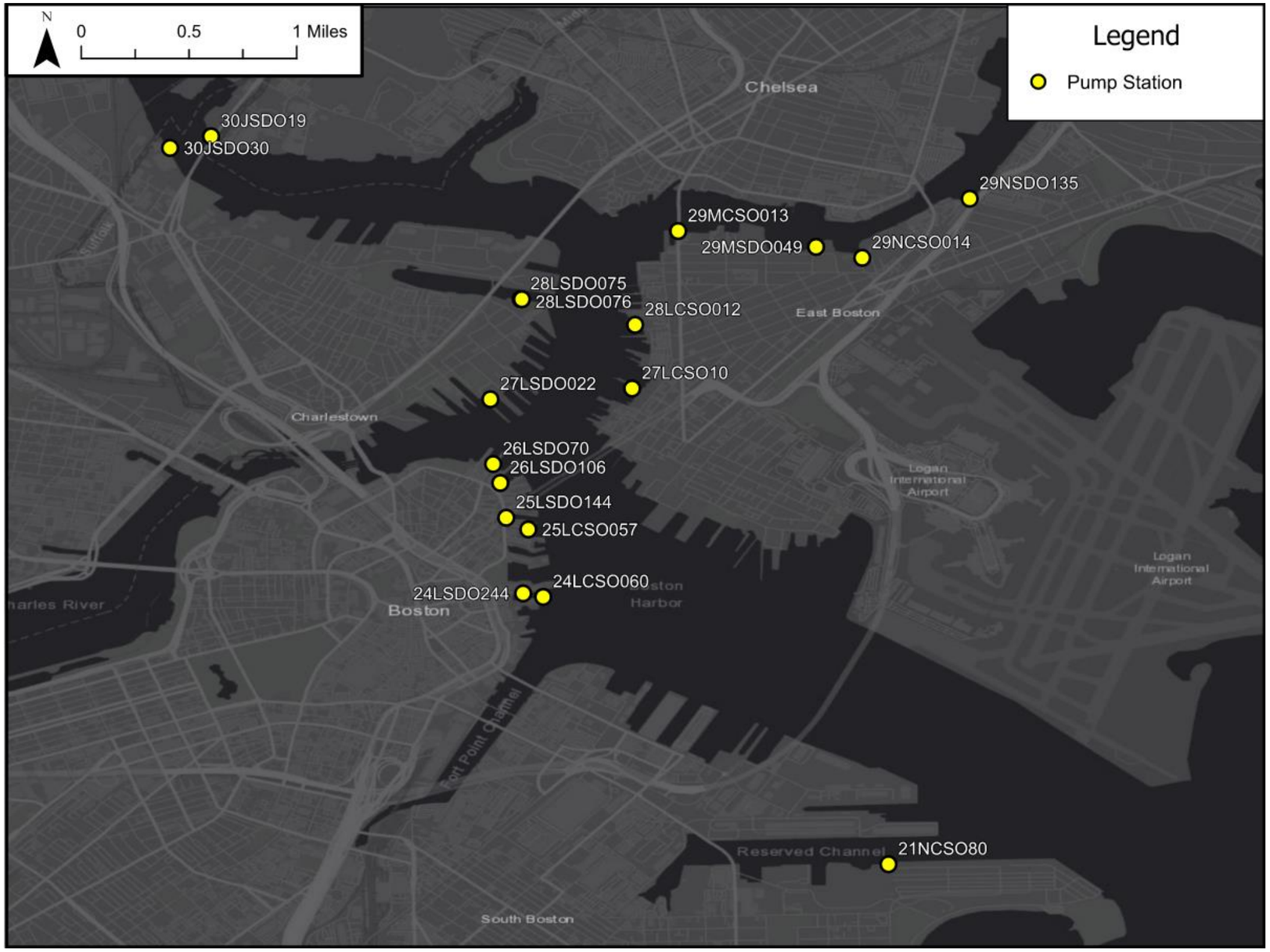
Figure 6: Design and Analysis Conditions vs. Historical Tide and Rainfall



Implementation Considerations

- Compared to other coastal stormwater concepts, the East Boston Greenway Pump station is smaller in size and cost. This project could provide a “pilot” opportunity to implement a coastal stormwater project and shoreline adaptation in parallel.
- Coordination with CRB is necessary to implement shoreline protection. The pump station should not be implemented without shoreline protection to prevent coastal flooding within the area tributary to it.
- Planting of native plant species and other green features will provide an improved public amenity and preserve the “look and feel” of the greenway.
- Community engagement with stakeholders may help build project support by illustrating the flood control benefits of the pump station.
- A comprehensive permitting evaluation should be conducted to evaluate possible impacts from construction and operation of the pump station to the receiving water (marsh area).
- Constructability of the currently proposed concept should be analyzed in greater detail to determine possible impacts to the Greenway. If necessary, the design could be modified to mitigate potential impacts to Greenway users.

Replicability and Implementation Timeline



Summary of Similar Concepts

Number of Sites: 18

Vulnerable Area: 422 acres

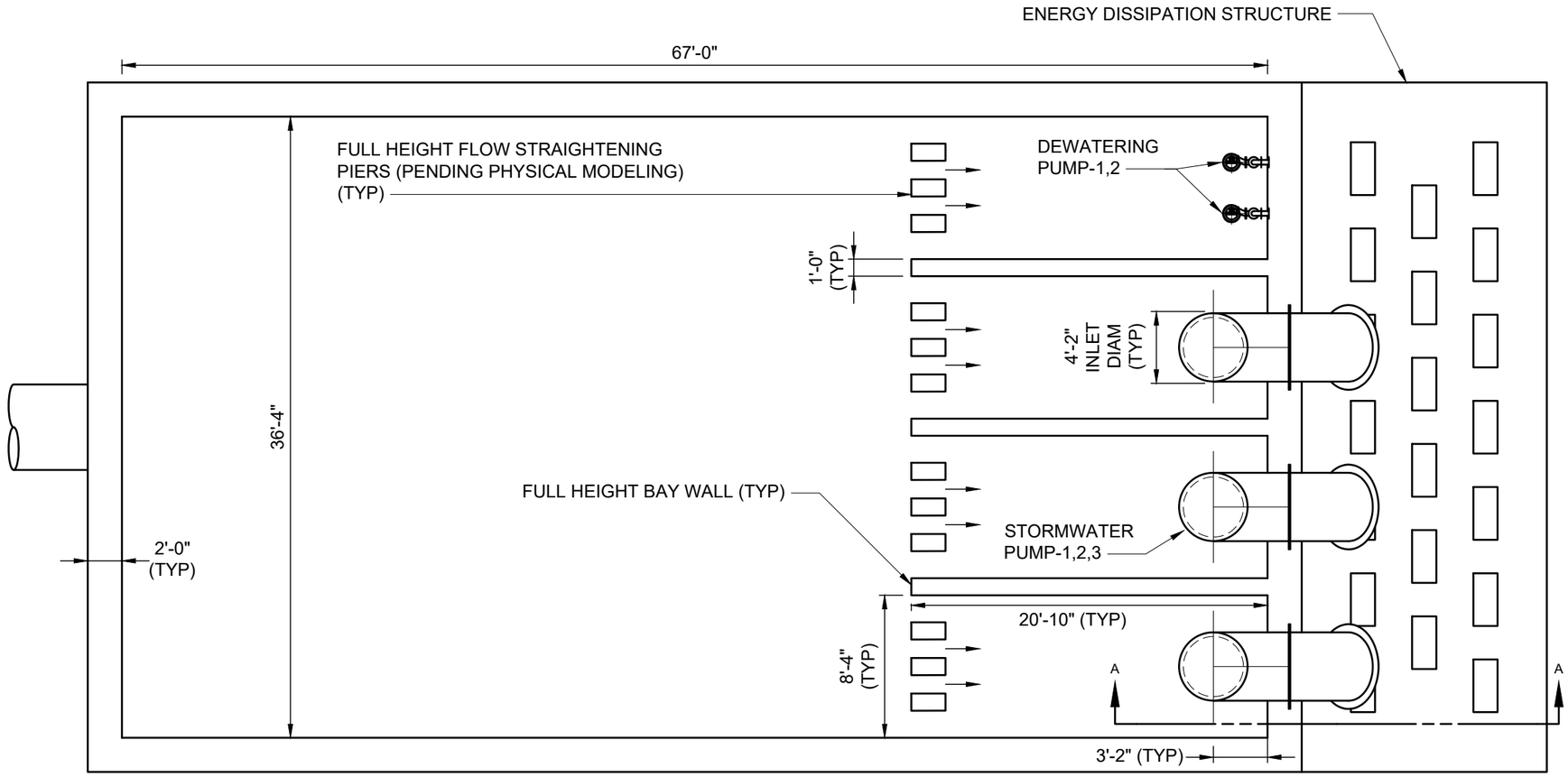
The map on this sheet depicts other vulnerable outfalls that could be adapted with electric submersible pump stations. In some locations, several outfalls could be consolidated with a new conduit that conveys flow to a single pump station.

Additional detail about these outfalls can be found in the Commission's Coastal Stormwater Discharge Analysis Implementation Timeline.

ATTACHMENT A
EAST BOSTON GREENWAY CONCEPTUAL DESIGN DRAWINGS

A-1: Pump Station Overview Plan
A-2: Pump Station Section View

East Boston Stormwater Pump Station



OVERVIEW PLAN

SCALE: NTS

NOTES

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2. ALL ELEVATIONS USE THE NAVD88 VERTICAL DATUM UNLESS OTHERWISE STATED.
3. CONCEPTUAL DRAWING, NOT FOR CONSTRUCTION.

STORMWATER PUMP-1,2,3 OPERATIONAL PARAMETERS	
FLOW RATE, CFS	67
STATIC HEAD RANGE, FT	14.8 - 23.8
DESIGN FLOOD ELEVATION, FT	16.0

STORMWATER PUMP-1,2,3 OPERATIONAL WSE TABLE

NOTE	OPERATION	ELEVATION, FT
A	HIGH LEVEL ALARM	2.7
B	LAG PUMP ON	1.7
C	LEAD PUMP ON	-2.3
D	LEAD PUMP OFF	-3.3
E	LOW LOW ALARM	-4.3
G	MIN PUMP SUBMERGENCE	-5.3

COASTAL STORMWATER DISCHARGE ANALYSIS

Boston Water and Sewer Commission

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A-1

November 2022

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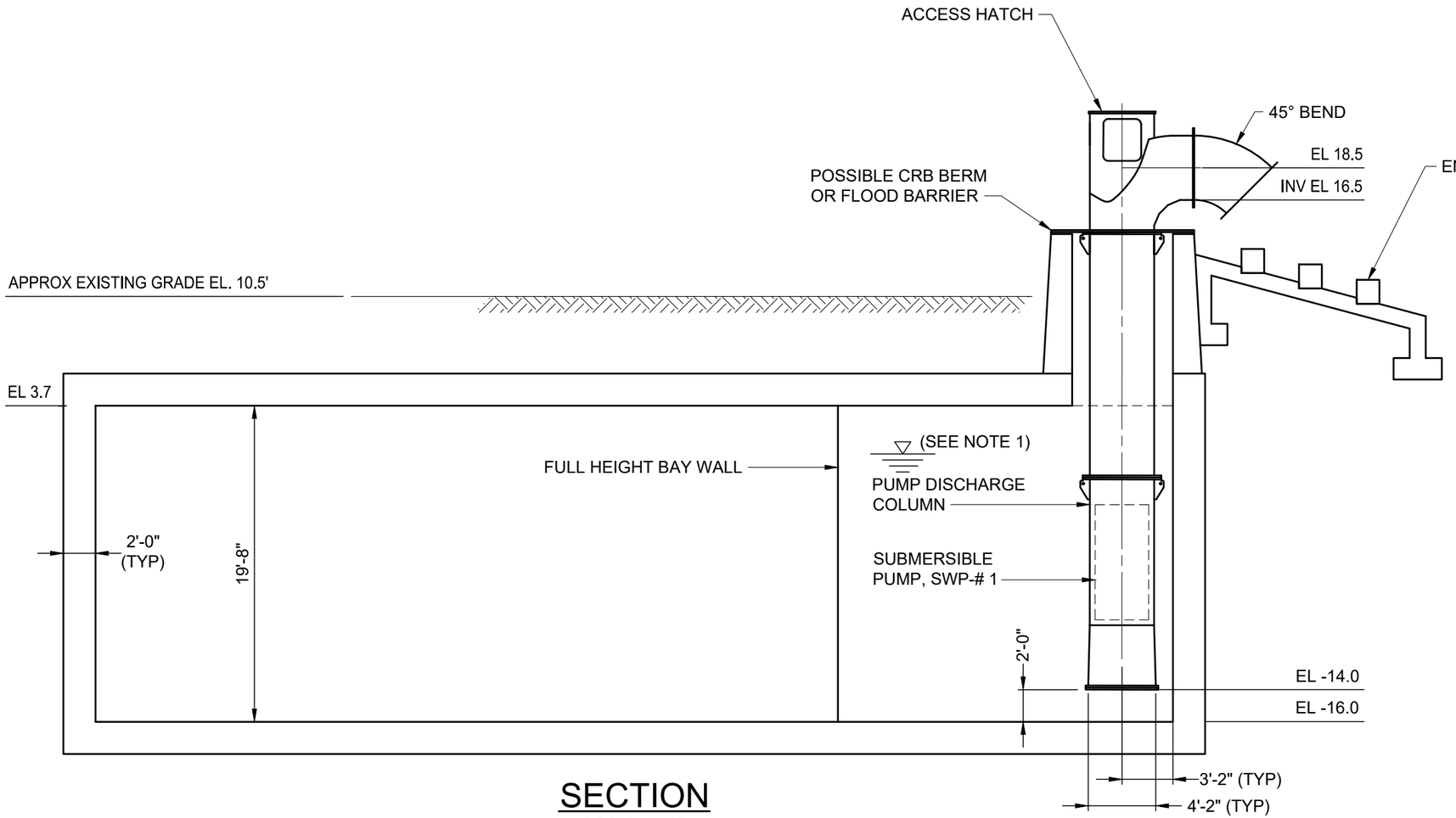
East Boston Stormwater Pump Station



SECTION
SCALE: NTS

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COASTAL STORMWATER
DISCHARGE ANALYSIS

Boston Water and Sewer Commission

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A-2 | November 2022

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ATTACHMENT B
EAST BOSTON GREENWAY DIVERSION PIPELINE ALIGNMENT DRAWINGS

B-1: Pipe Alignment Drawings



East Boston Greenway

Flow from existing outfalls 28NSDO207 and 28NSDO156 is diverted to the East Boston Greenway concept.

Coastal Stormwater Discharge Analysis
East Boston Greenway

Boston Water and Sewer Commission

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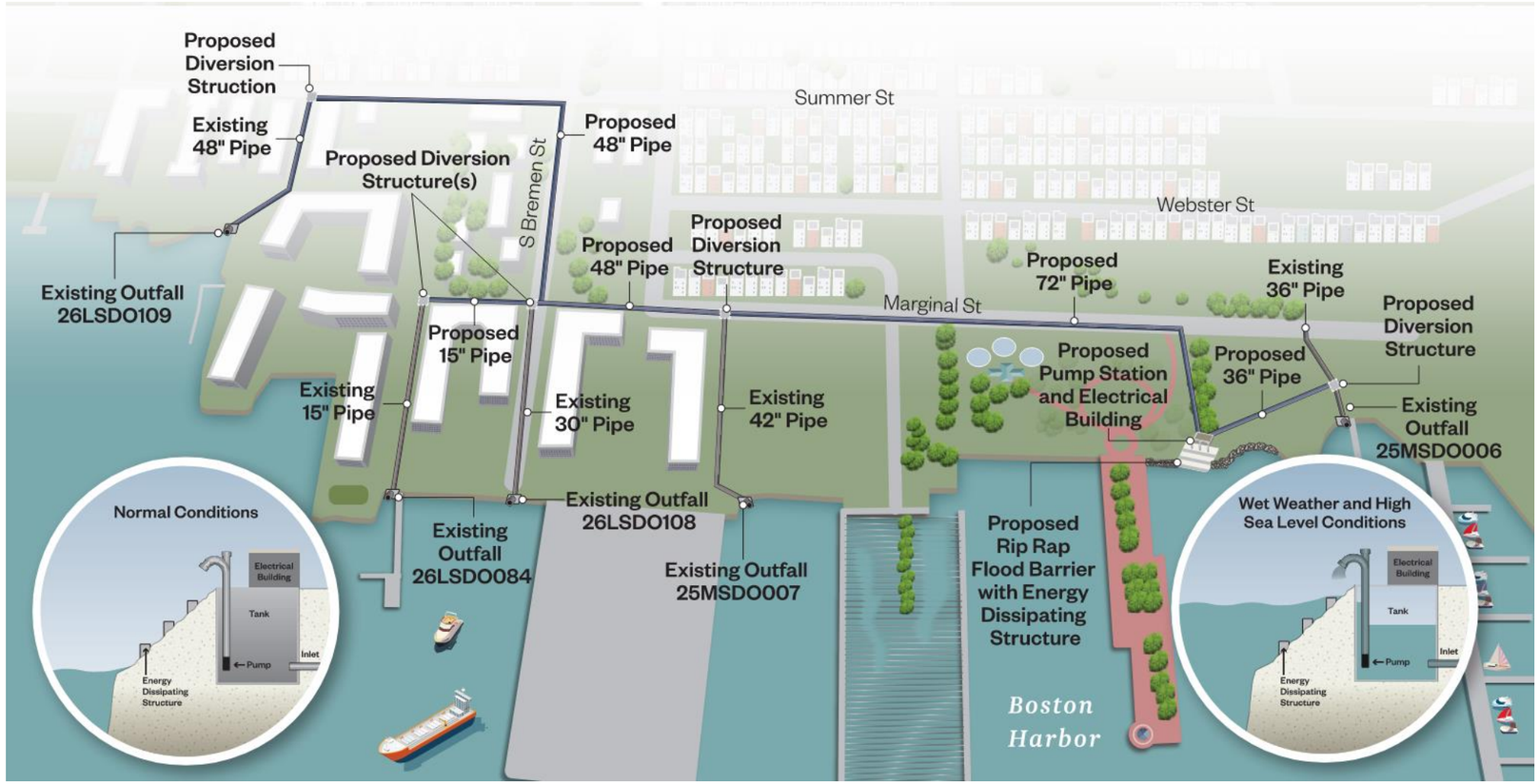
East Boston Waterfront *Concept Overview*





Conceptual Solution

The East Boston Waterfront concept is a stormwater outfall consolidation project with proposed pipes and a pump station. The proposed pipes collect excess wet weather flow from Outfalls 26LSDO109, 26LSDO084, 26LSDO108, 25MSDO007, and 25MSDO006, using passive weirs to divert flow into a new conduit for conveyance to a pump station. The pump station utilizes one duty pump and one standby pump. The pump station is underground and utilizes electric submersible pumps to minimize the aboveground footprint of the concept and mitigate noise pollution. The pump station discharges directly into Boston Harbor, with an energy dissipating structure along that section of coastline to prevent erosion.

Type: Consolidation and Pumping

Total Drainage Area: 43 acres

Coastal Flood Vulnerable Drainage Area Protected: 43 acres

Concept Elements:

- Outfall consolidation
- New conveyance
- Tide gates
- Subsurface Storage Tank
- Subsurface Pump Station

Outfalls Included in Concept:

- 26LSDO109
- 26LSDO084
- 26LSDO108
- 25MSDO007
- 25MSDO006

Coastal Stormwater Discharge Analysis
East Boston Waterfront

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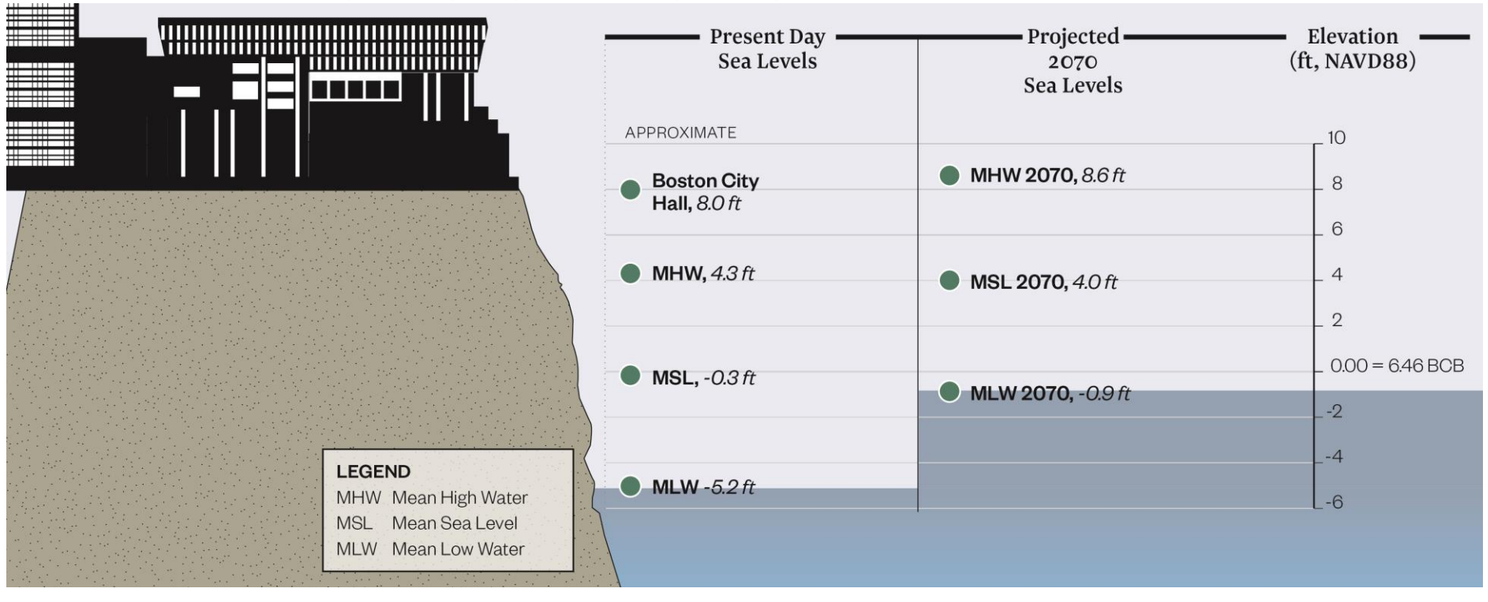
Assumptions

Sea Level Rise and Datum

The East Boston Waterfront Pump Station concept was designed for consistency with Climate Ready Boston (CRB) proposed adaptations and analyzed based on sea level rise (SLR) projections in the Massachusetts Coastal Flood Risk Model (MC-FRM). The SLR values applied in MC-FRM are consistent with the standards for the State of Massachusetts developed by Coastal Zone Management. The MC-FRM utilizes a "High" SLR scenario. This scenario is based on the relative SLR projections under Relative Concentration Pathway (RCP) 8.5 (a "worst case scenario" of increasing atmospheric carbon concentrations) and represents elevations that have a 99.5% probability of not being exceeded within the respective timeframes. In 2030, that amounts to an increase of 1.3 feet in Boston from a baseline condition (2008 centered tidal epoch), and in 2070 that amounts to an increase of 4.3 feet.

The concept developed in this project was analyzed using coastal conditions that include 2070 projected SLR and storm surge resulting from a 100-year tropical storm. The peak water surface elevation (WSE) predicted by the MC-FRM during these conditions is approximately 13.8 feet NAVD88 (varies by location). In mid 2022, the Greater Boston Research Advisory Group (BRAG) issued an updated report with new SLR projections. The report acknowledges that long term SLR projections are associated with significant uncertainty, and that updated projections include less SLR by 2100 (compared to earlier projections in the 2015 BRAG Report). According to the report, the likely range of SLR by 2070 under an RCP 8.5 scenario is 1.4 – 2.8 feet. Based on this information, projections from the MC-FRM that were utilized in this project are conservative and appropriate for long term planning purposes.

Unless otherwise noted, all elevations are based on the NAVD88 vertical datum. Elevations given in NAVD88 can be converted to Boston City Base (BCB) elevation by adding 6.46 feet.



Climate Ready Boston and Shoreline Protection

The East Boston Waterfront Pump Station concept was developed to maintain consistency with possible Climate Ready Boston (CRB) adaptations based on the latest available information at the time they were developed. As the CRB program continues to evolve, it is anticipated that proposed concepts will need to be adapted.

The concept was developed to be consistent with stated neighborhood design flood elevations. In East Boston, where the stated design flood elevation is 16.0 feet, pumps were designed to discharge to a minimum elevation of 16.0 feet.

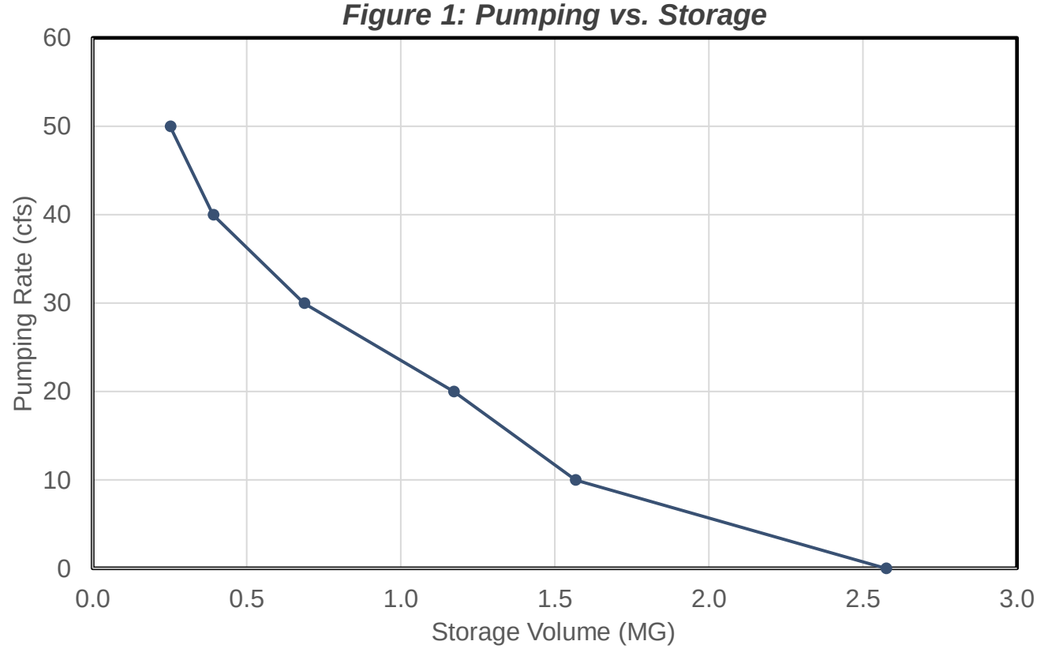
At the time of this project, many CRB concepts were in early planning stages and not fully defined. **In consideration of this, it was assumed the shoreline protection around the City of Boston is 100% effective for all modeling evaluations.** This assumption eliminates overland coastal flooding from model predictions, allowing for isolation of flooding that results only from rainfall and stormwater that cannot be discharged due to high sea levels. It is important to recognize that additional flooding, beyond what is depicted herein, would be expected if 100% effective shoreline protection is not implemented.

Basis of Design

Storage and Pumping

Model simulations were conducted to determine the maximum Hydraulic Grade Line (HGL) that occurs at Outfalls 26LSDO109, 26LSDO084, 26LSDO108, 25MSDO007, and 25MSDO006 with the current tide cycle. Analyses were then conducted to determine the acceptable combinations of storage volume and pumping rate required to maintain the existing HGL with 2070 projected sea level rise and 100-year storm surge, as shown in Figure 1. The City of Boston's Parcel database was used to identify publicly owned parcels near the existing outfalls. A suitable location was not available for all outfalls, so an outfall consolidation approach was used. A suitable location on a publicly owned parcel was located for one pump station, and a pipe alignment was designed to transfer flow from all five outfalls to the pump station. An analysis of the pump station was performed to identify a pump rate and physical dimensions that are hydraulically viable. It was found that a significant storage tank is not required, as the proposed pipes needed to divert flow from the outfalls would have sufficient storage when combined with a 40 CFS pump station. The pump station and storage tank occupy an area of 635 ft^2. The proposed pipes have a storage volume of 0.44 MG. The pump station has one duty pump and one standby pump. Each pump has a separate discharge force main which carries water to the harbor. The pump station is configured with vertical, axial electric submersible pumps in parallel bays.

Figure 1: Pumping vs. Storage



Rainfall and Coastal Conditions

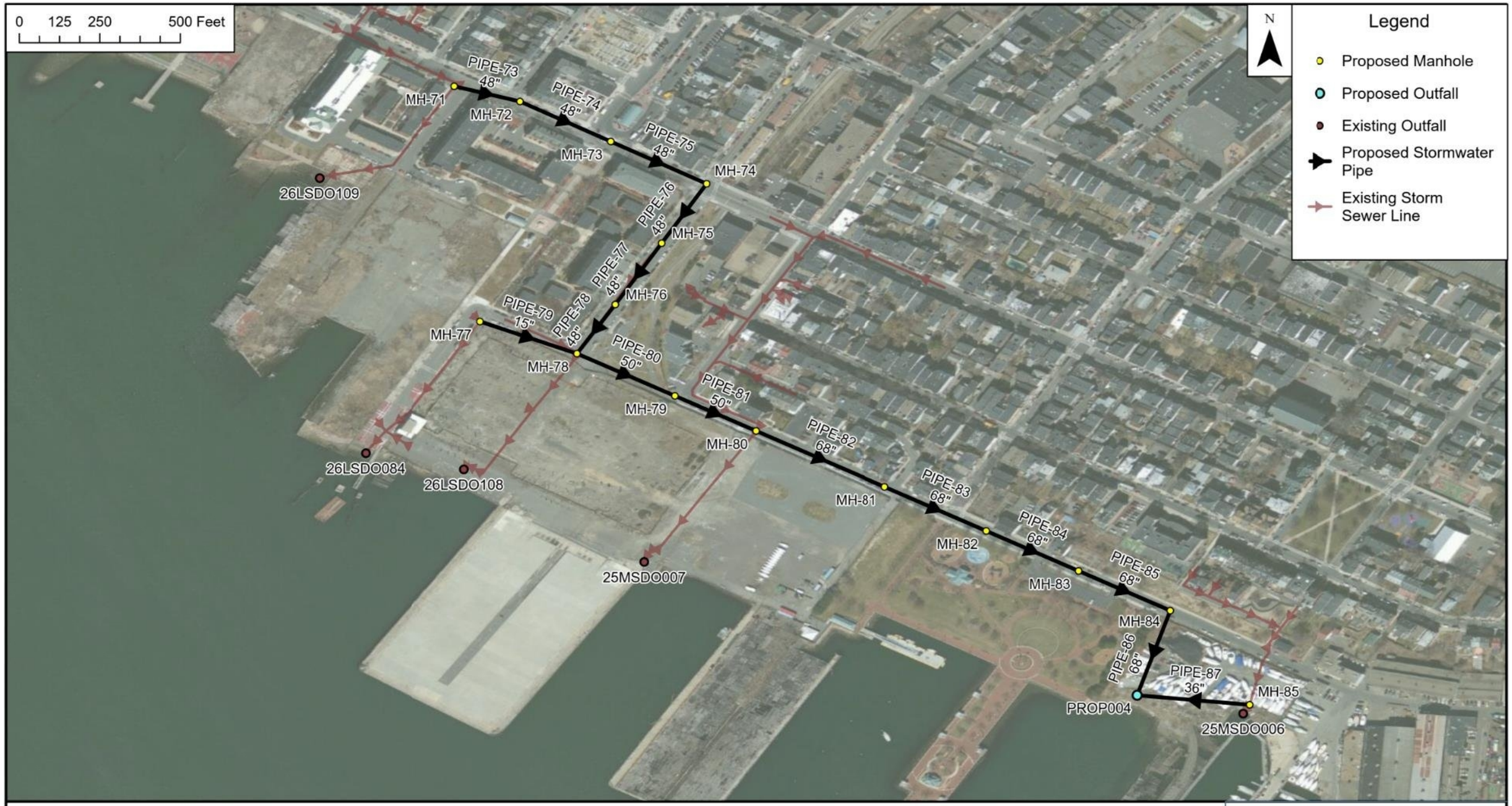
The Commission currently utilizes a 10-year, 24-hour design storm to establish its target level of service. For the purpose of sizing new piping and evaluating storage capacity, a projected 2070 10-year, 24-hour design storm was developed. For consistency with Climate Ready Boston, performance of the DBB storage concept was also evaluated with projected rainfall from a 100-year tropical event (developed during the Commission's Inundation Model Project). The DBB was evaluated using a 100-year return period coastal boundary condition. Data for this condition were obtained from the MC-FRM. For the purpose of evaluating the effectiveness of the concept, it was further assumed that complete shoreline protection was implemented, preventing flow of water between land and the harbor/Neponset River. Table 2 contains a summary of the coastal conditions that were analyzed.

Table 1: Rainfall Conditions

Scenario	Purpose	Rainfall Depth (in)	Peak Intensity (in/hr)
Present Day, 10-year, 24-hr design storm	Baseline Conditions	5.15	3.32
Projected 2070, 10-year, 24-hr design storm	Design Conditions	6.18	4.08
100-year Tropical Storm	Damage Analysis	9.58	0.84

Table 2: Coastal Conditions

Scenario	Purpose	Peak Water Surface Elevation (ft, NAVD88)	Source
Present Day	Baseline Conditions	3.7	BWSC Existing Model (April 2016 Tide Cycle)
2070,100-year Tropical Storm	Damage Analysis	13.8	MC-FRM



East Boston Waterfront

Outfall Diversion – New Pipeline

Coastal Stormwater Discharge Analysis
East Boston Waterfront

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Flood Modeling and Damage Analysis

Figure 2: Estimated Replacement Cost

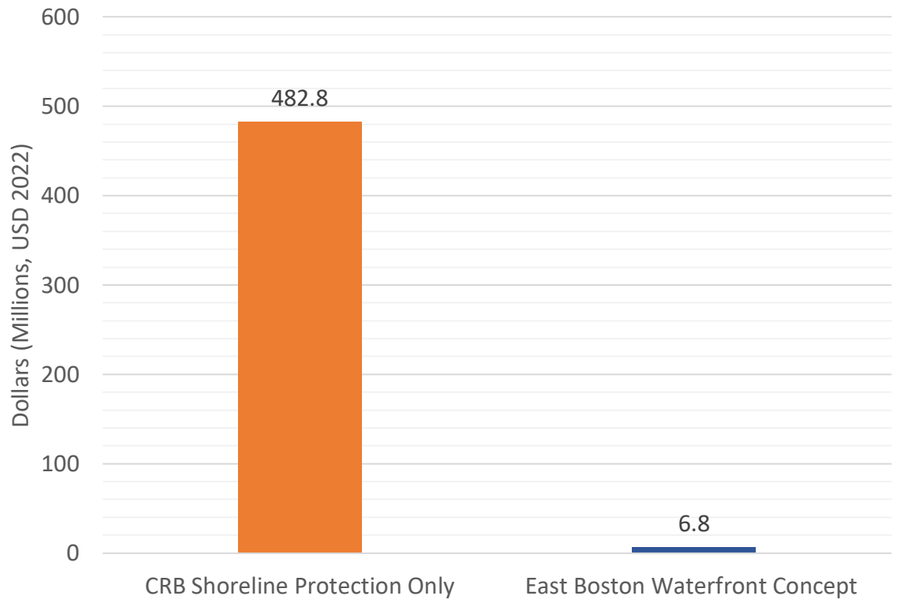


Figure 3: Loss of GDP

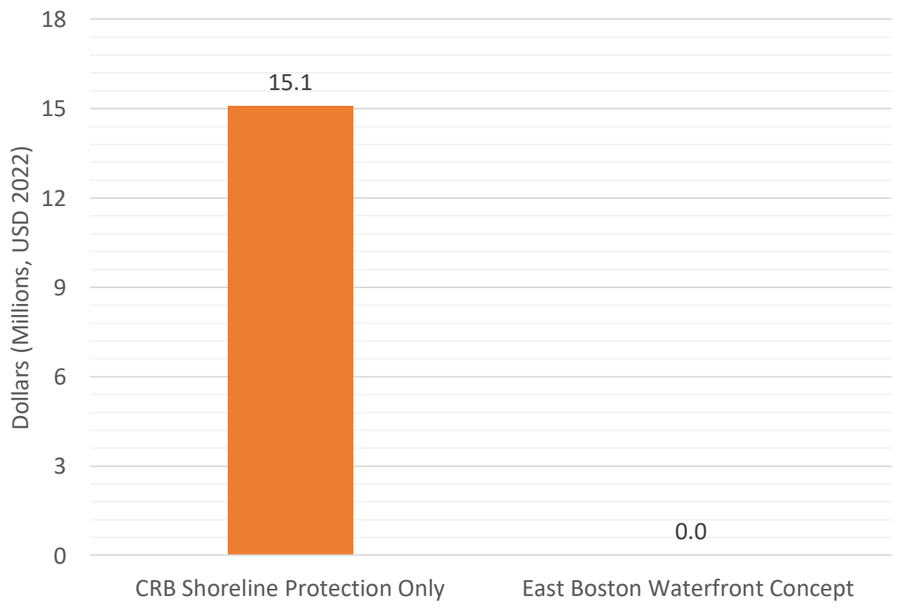
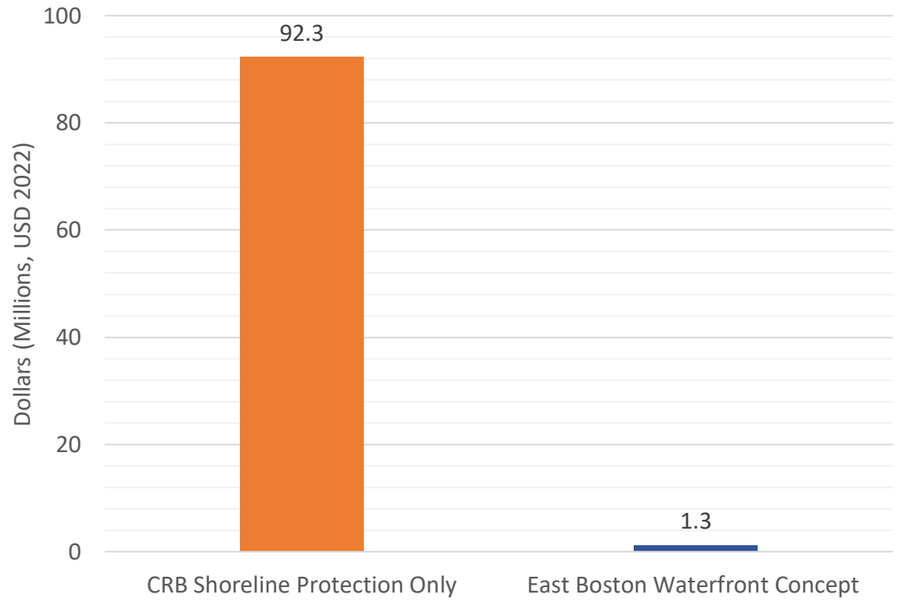


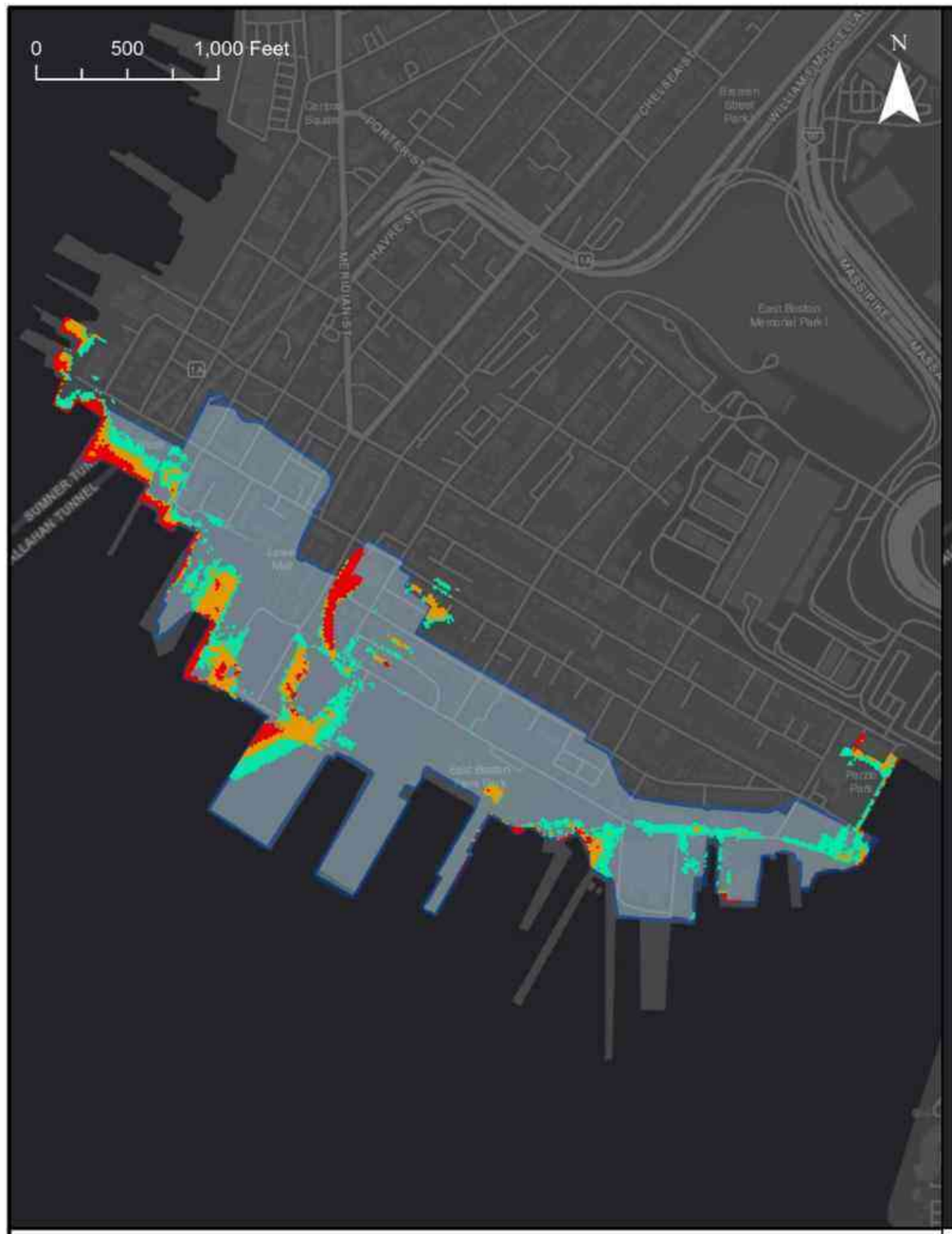
Figure 4: Physical Damage



The flood reduction benefits of the East Boston Waterfront concept were evaluated using the Commission's 2D Inundation Model by simulating a 100-year tropical storm event with 2070 SLR and storm surge. The figures on the following page depict the peak flooding that was predicted in the East Boston Waterfront drainage area with shoreline protection only and with the concept implemented. An analysis of economic losses/physical impacts from flooding under both scenarios was performed by risQ Inc.

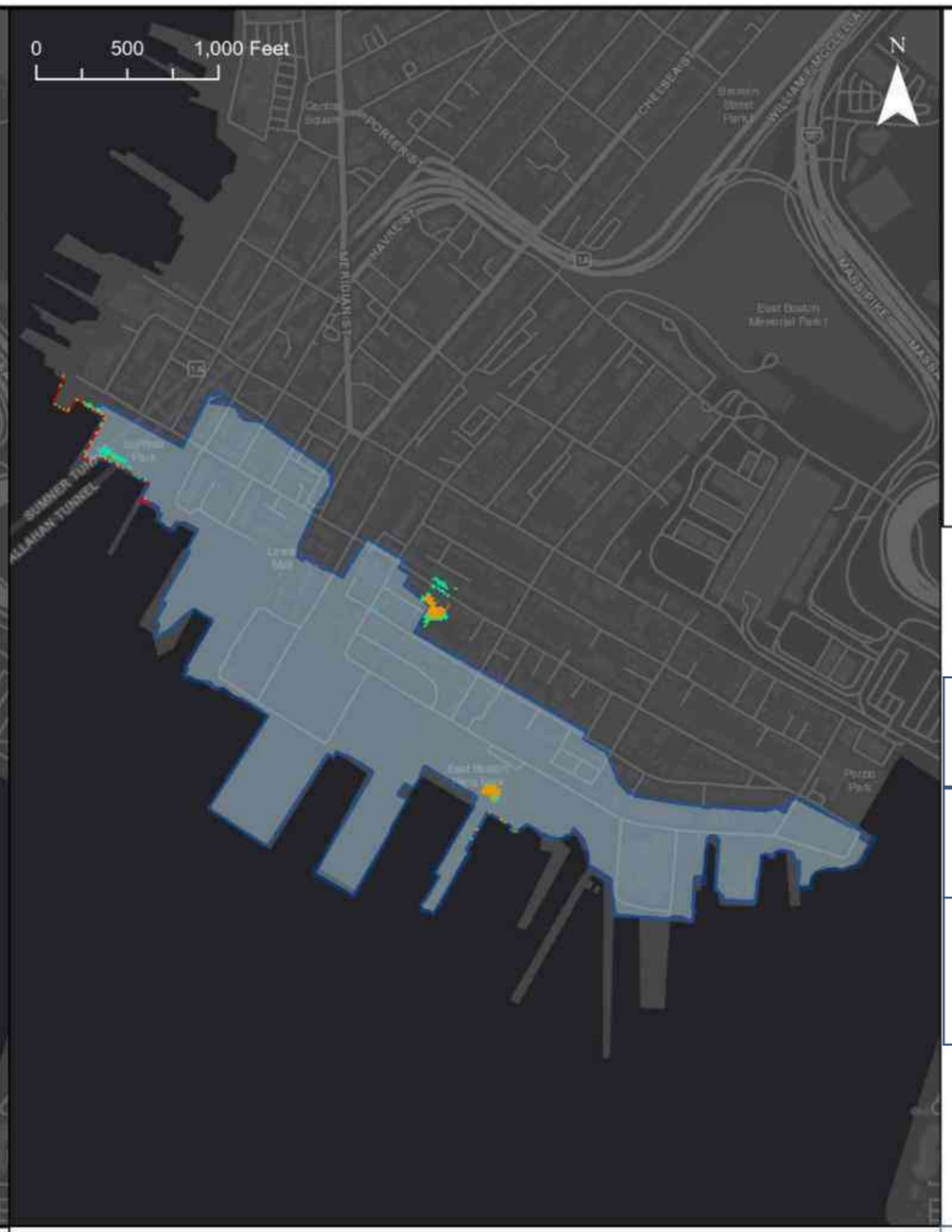
Model predictions indicate that the East Boston Waterfront concept reduces physical damage by **$91 million**, avoids **$476 million** in rebuilding costs, and mitigates a GPD loss of **$15.1 million** during a 100-year tropical storm event in 2070.

Note: replacement values include the total value of impacted buildings in flooded areas (e.g., impacted buildings are fully replaced), whereas physical damage includes estimated costs to repair flood damage based on predicted flood depths and building characteristics. The values shown are the average of minimum and maximum calculated losses. Refer to the Project's Final Report for more information.



2070 SLR + 100yr Tropical Storm + Storm Surge

Shoreline Protection Only



2070 SLR + 100yr Tropical Storm + Storm Surge

East Boston Waterfront Stormwater Consolidation

Legend

- Flood Depth > 4 in and < 1 ft
- Flood Depth > 1 ft and < 2 ft
- Flood Depth > 2 ft
- Drainage Area Analyzed

Simulation Parameters

Storm Type	100yr Tropical Storm
Rainfall Depth	9.6 inches
Peak WSE 2070 SLR + 100yr Surge	13.8 feet NAVD88

Coastal Stormwater Discharge Analysis
East Boston Waterfront

Boston Water and Sewer Commission

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Cost Estimate and FEMA BRIC Considerations

Capital Cost Estimate

A construction cost estimate for the East Boston Waterfront concept was developed for planning purposes. Assumptions for the cost estimate include 15-year escalation to the mid-point of construction and the inclusion of a 50% design contingency. Utility hookup costs were not included.

Table 4: East Boston Waterfront Cost Estimate Subtotals

Remaining Design Development & Construction Administration (assumed 20% of total less design contingency)	$3,177,000
Direct Construction Costs	$6,256,022
Indirect Construction Costs	$1,251,204
Mark-Up *(Including 50% design contingency)*	$16,026,774
Total	**$26,711,000**

Social Vulnerability and FEMA BRIC Funding

FEMA BRIC funding prioritizes disadvantaged communities. Table 4 contains a summary of several indicators for the East Boston Waterfront tributary area that could be used help characterize the community for future FEMA funding applications and prioritization of projects that benefit disadvantaged communities.

Table 4: East Boston Waterfront Tributary Area Social Vulnerability Indicators

Low Income & Persistent Poverty	
Per Capita Income	$39,098
Below Poverty Line	19%
High Housing Cost Burden	
Stressed Renters (>40% rent-to-income)	25%
Households With Food Insecurity	14%
Racial and Ethnic Segregation	
Asian Population	8%
Black Population	5%
Hispanic Population	43%
White Population	69%
Education and Employment	
Adults Age 25+ Without High School (or equivalent) Degree	20%
Unemployment Rate (Age 16+)	6%

Data provided by risQ inc. from the US census and American Community Survey

Planting Palette

A planting palette was developed for the park area near the proposed pump station along the East Boston Waterfront. After construction, planting of native plant species could provide a public amenity with new green space and environmental benefits associated with native plant species. The palette can also be used to conceal concept utilities such as the pump station and electrical building from the public.

Trees



Amelanchier arborea
common serviceberry



Juniperus virginiana
eastern red cedar



Magnolia virginiana
sweet bay magnolia



Quercus rubra
northern red oak

Shrubs



Rosa carolina
pasture rose



Rhus copallinum
winged sumac



Aronia melanocarpa
black chokeberry



Morella pensylvanica
bayberry

Herbaceous and Grasses



Panicum virgatum
switchgrass



Schizacharium scoparium
little bluestem



Eutrochium purpureum
Joe-Pye-Weed



Solidago sempervirens
seaside goldenrod

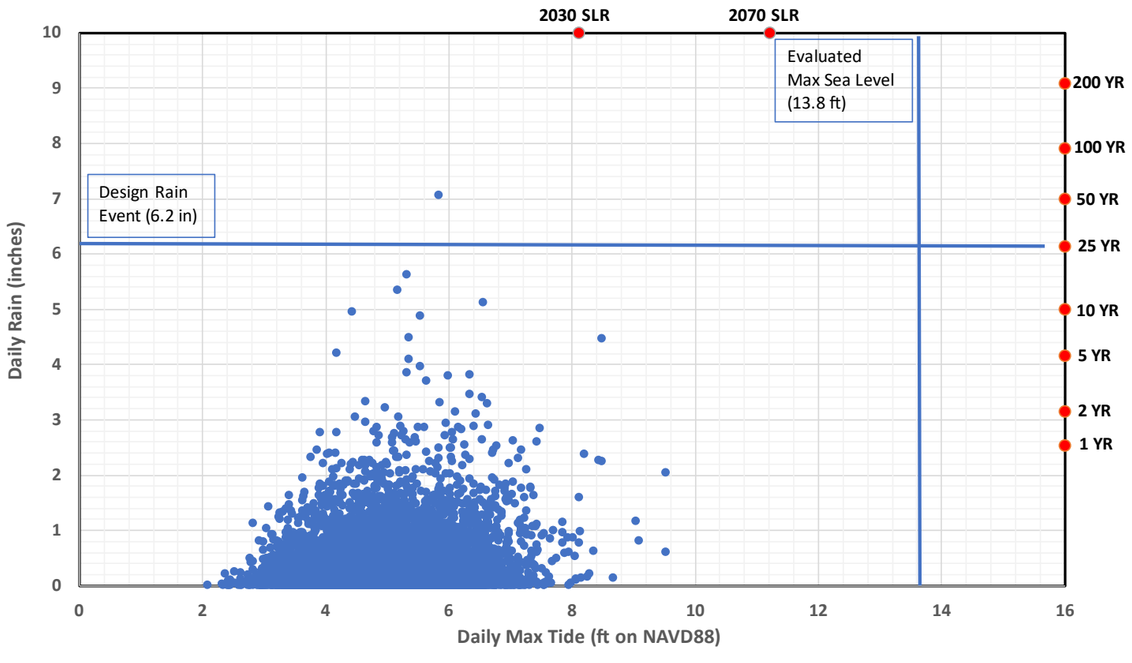
Adaptability and Implementation

Adaptability

Figure 5 below depicts historical daily rainfall totals and tide levels. As shown in this figure, the conditions that were used to design and analyze the East Boston Waterfront pump station are conservative and represent more extreme conditions than have occurred historically. Regardless, the following measures could be implemented to adapt the concept to more severe conditions (additional SLR, more intense rainfall, etc.) in the future:

- Increase the size of installed electric submersible pumps
- Utilize the standby pump as a duty pump during extreme conditions
- Increase the size of the pump station to increase pumping capacity
- Increase the size of the pump station to add more peak-shaving storage volume
- Divert additional flow into the new consolidation conduit

Figure 5: Design and Analysis Conditions vs. Historical Tide and Rainfall



Implementation Considerations

- Coordination with CRB (and other relevant stakeholders) to construct adequate shoreline protection around the East Boston Waterfront is essential for successful implementation of this concept. To function as designed, the region must be fully isolated from high sea levels; as such, careful coordination with CRB is essential at this location.
- The portions of existing pipelines downstream from the proposed diversion structures are designed to surcharge to allow flow to back up enough to be diverted at the diversion structures. As such, under design conditions, it is important that manhole covers along those portions of the existing pipelines are watertight and securely bolted or fastened in place to prevent flooding.
- Regional stormwater pipes should not be directly connected to the diversion pipeline, as there is currently no way for flow within the pipeline to be discharged without the pump station; therefore, the diversion pipeline should only be configured to accept flow from stormwater outfall pipes that are surcharging, unless a large pump station is provided.
- A careful analysis of constructability, and design efforts to minimize disruptions from large diameter pipe construction, should be completed.
- Tide gates could be added on the included outfalls a near term measure to prevent backflow during higher tide conditions.

Replicability and Implementation Timeline



Summary of Similar Concepts

Number of Sites: 6

Vulnerable Area: 41 acres

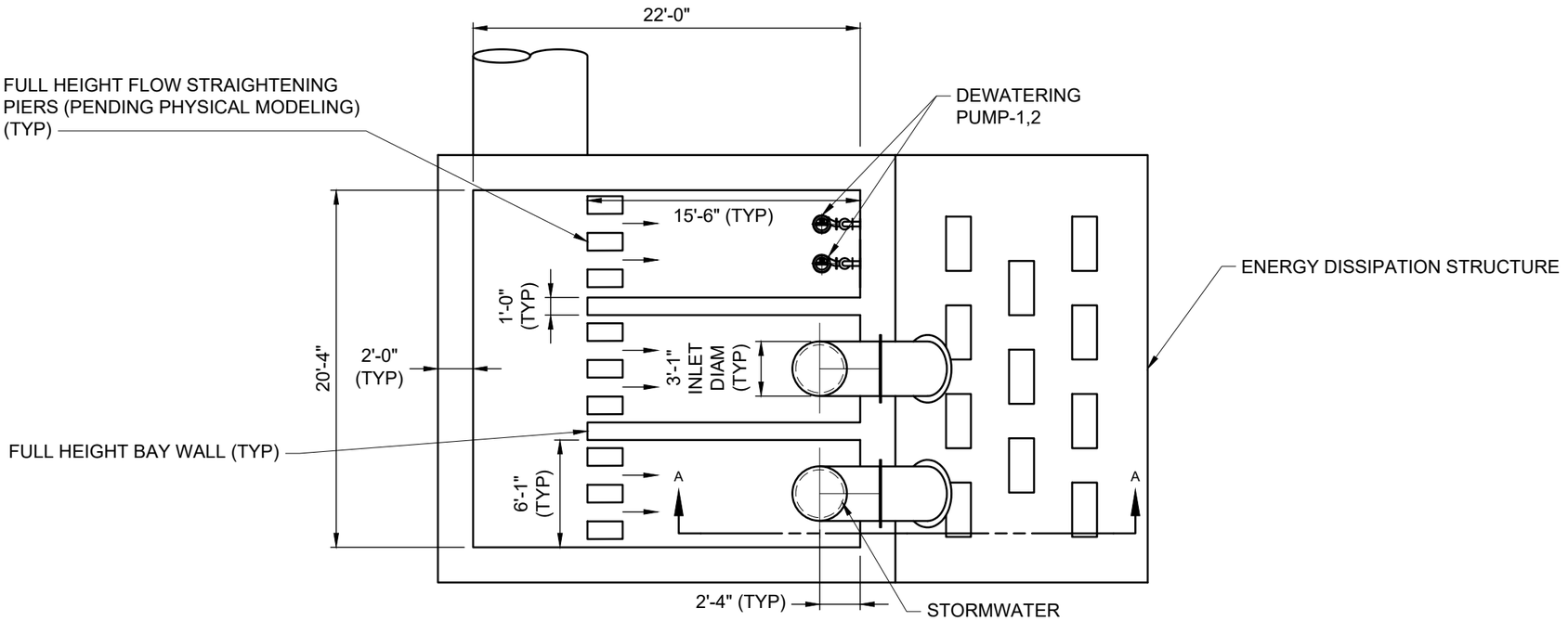
The map on this sheet depicts other vulnerable outfalls that could be consolidated with a new conduit that conveys flow to a single pump station.

Additional detail about these outfalls can be found in the Commission's Coastal Stormwater Discharge Analysis Implementation Timeline.

ATTACHMENT A
EAST BOSTON WATERFRONT PUMP STATION CONCEPTUAL DESIGN DRAWINGS

A-1: Overview Plan and Pump Station Plan
A-2: Pump Station Section View

East Boston Waterfront Stormwater Pump Station



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STORMWATER PUMP-1,2
OPERATIONAL WSE TABLE

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C	LEAD PUMP ON	0.7
D	LEAD PUMP OFF	-0.3
E	LOW LOW ALARM	-1.3
G	MIN PUMP SUBMERGENCE	-2.3

COASTAL STORMWATER
DISCHARGE ANALYSIS

Boston Water and Sewer Commission

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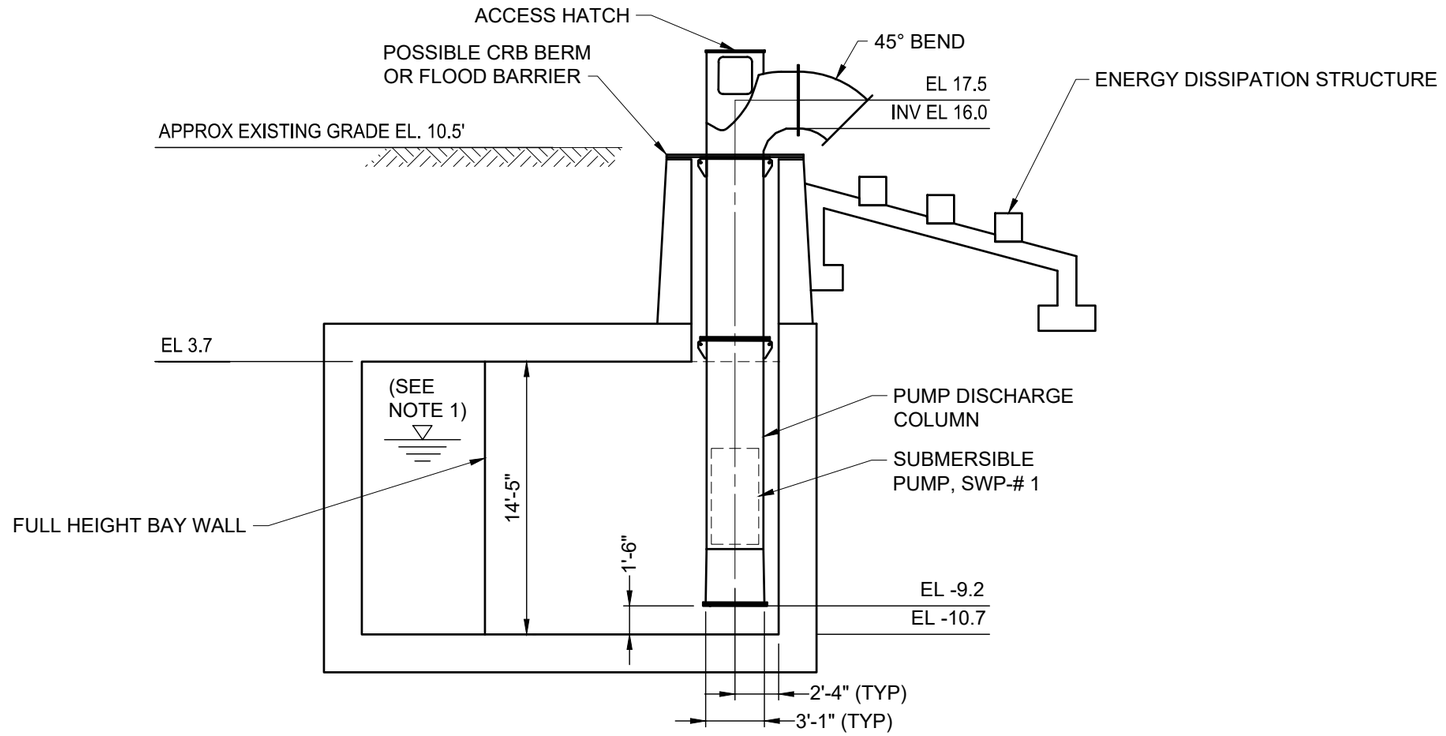
East Boston Waterfront Stormwater Pump Station



SECTION

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COASTAL STORMWATER
DISCHARGE ANALYSIS

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ATTACHMENT B
EAST BOSTON WATERFRONT CONSOLIDATION CONDUIT ALIGNMENT DRAWINGS

B-1: Pipe Alignment Drawings

Conceptual Design – Not for Construction



East Boston Waterfront

Outfall Diversion – New Pipeline

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East Boston Waterfront

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PROP-PIPE-73



Plan
1"= 20'

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ASSUMPTIONS, DEFINITIONS, AND DISCLAIMERS

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-ALL ELEVATIONS THROUGHOUT ARE REFERENCED TO NAVD88 DATUM
-PROPOSED PIPE AND MANHOLE ALIGNMENTS ARE PRELIMINARY AND CONCEPTUAL
-DETAILED SURVEY AND AN EVALUATION FOR SUBSURFACE CONFLICTS SHOULD BE PERFORMED BEFORE ADVANCEMENT OF THESE CONCEPTS

Coastal Stormwater Discharge Analysis
East Boston Waterfront

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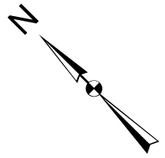

PROP-PIPE-74



Plan
1"= 20'

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Coastal Stormwater Discharge Analysis
East Boston Waterfront

Boston Water and Sewer Commission

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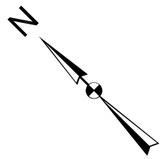

PROP-PIPE-75



Plan
1"= 20'

0 20 40 80 Feet

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Coastal Stormwater Discharge Analysis
East Boston Waterfront

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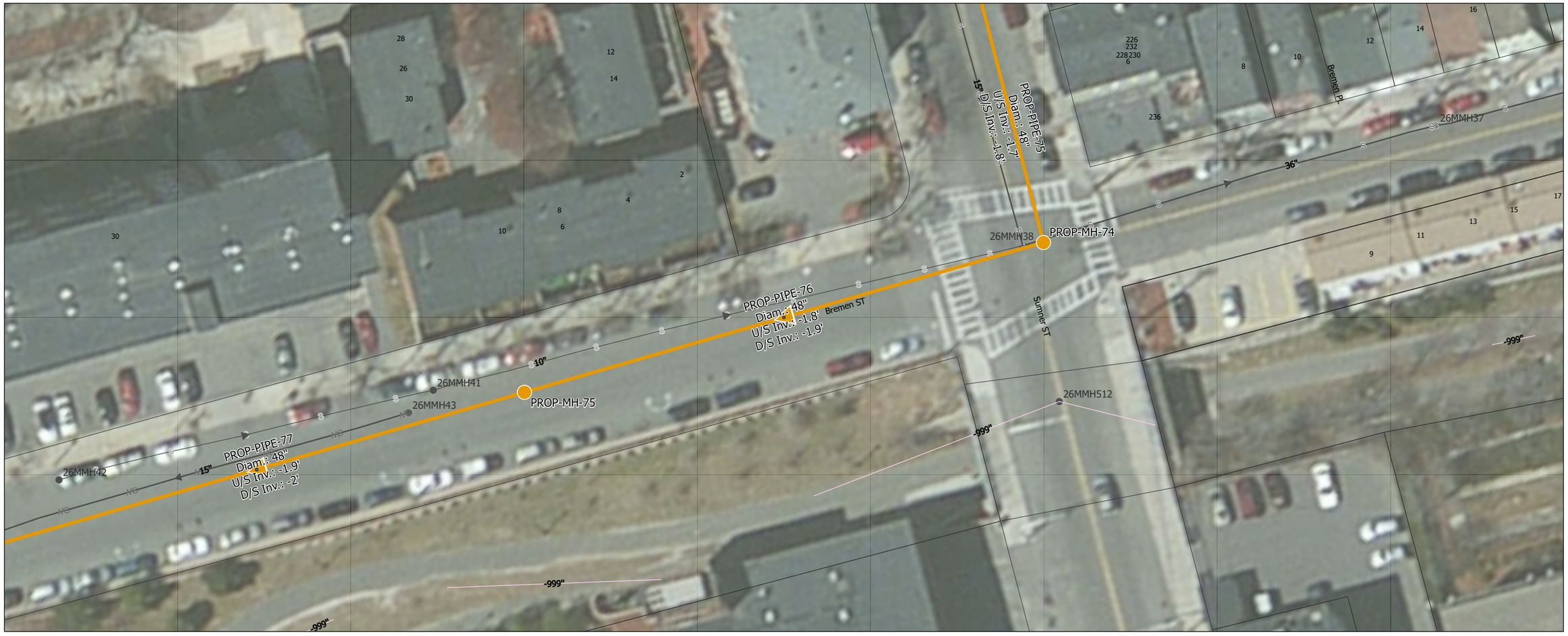
PROP-PIPE-76





Plan
1"= 20'

0 20 40 80 Feet

PRELIMINARY
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Coastal Stormwater Discharge Analysis
East Boston Waterfront

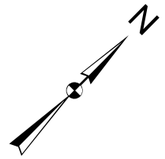
Boston Water and Sewer Commission

Hazen

B-5

November 2022





PROP-PIPE-77



Plan
1"= 20'

0 20 40 80
Feet

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Coastal Stormwater Discharge Analysis
East Boston Waterfront

Boston Water and Sewer Commission | Hazen

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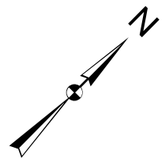

PROP-PIPE-78



0 20 40 80 Feet

Plan
1"= 20'

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Coastal Stormwater Discharge Analysis
East Boston Waterfront

Boston Water and Sewer Commission | Hazen

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PROP-PIPE-79





0 20 40 80 Feet

Plan
1"= 20'

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Coastal Stormwater Discharge Analysis
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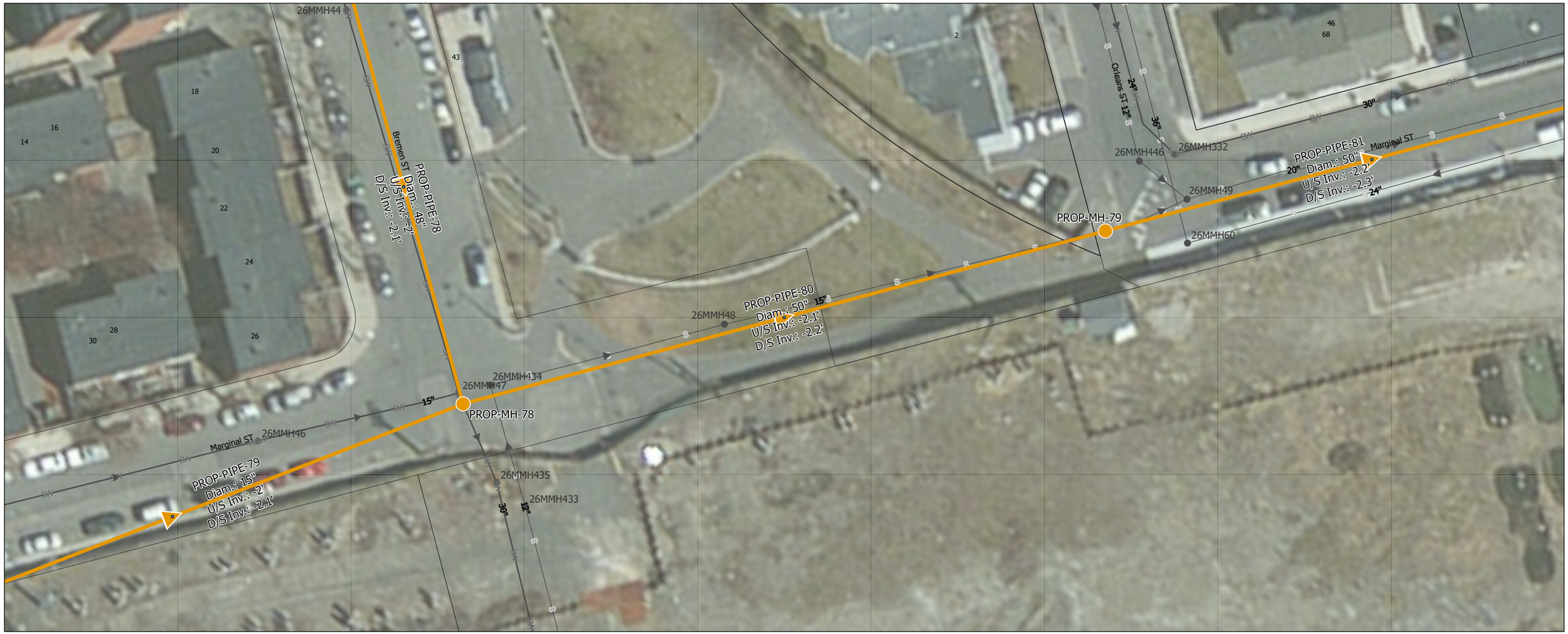
November 2022

PROP-PIPE-80





Plan
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Coastal Stormwater Discharge Analysis
East Boston Waterfront

Boston Water and Sewer Commission

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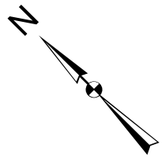
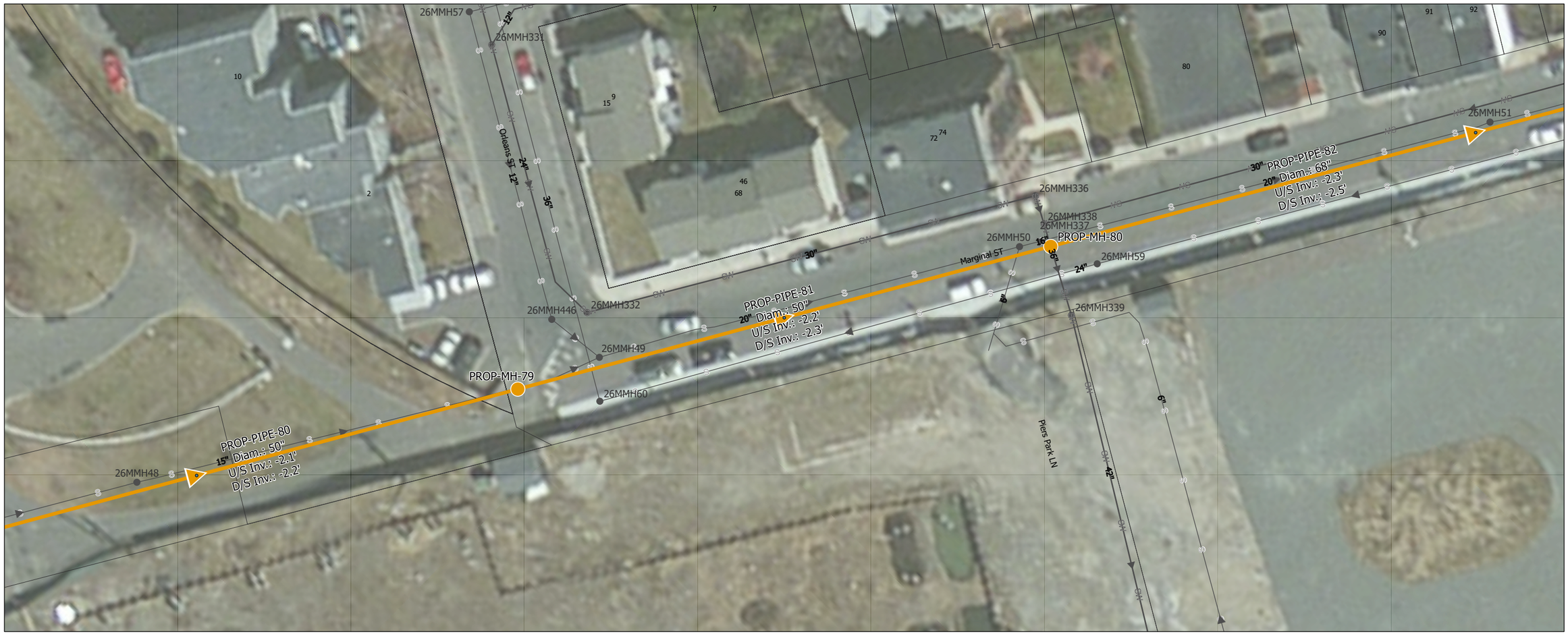


PROP-PIPE-81



Plan
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Feet

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Coastal Stormwater Discharge Analysis
East Boston Waterfront

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PROP-PIPE-82

Plan
1"= 20'

0 20 40 80 Feet

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Coastal Stormwater Discharge Analysis
East Boston Waterfront

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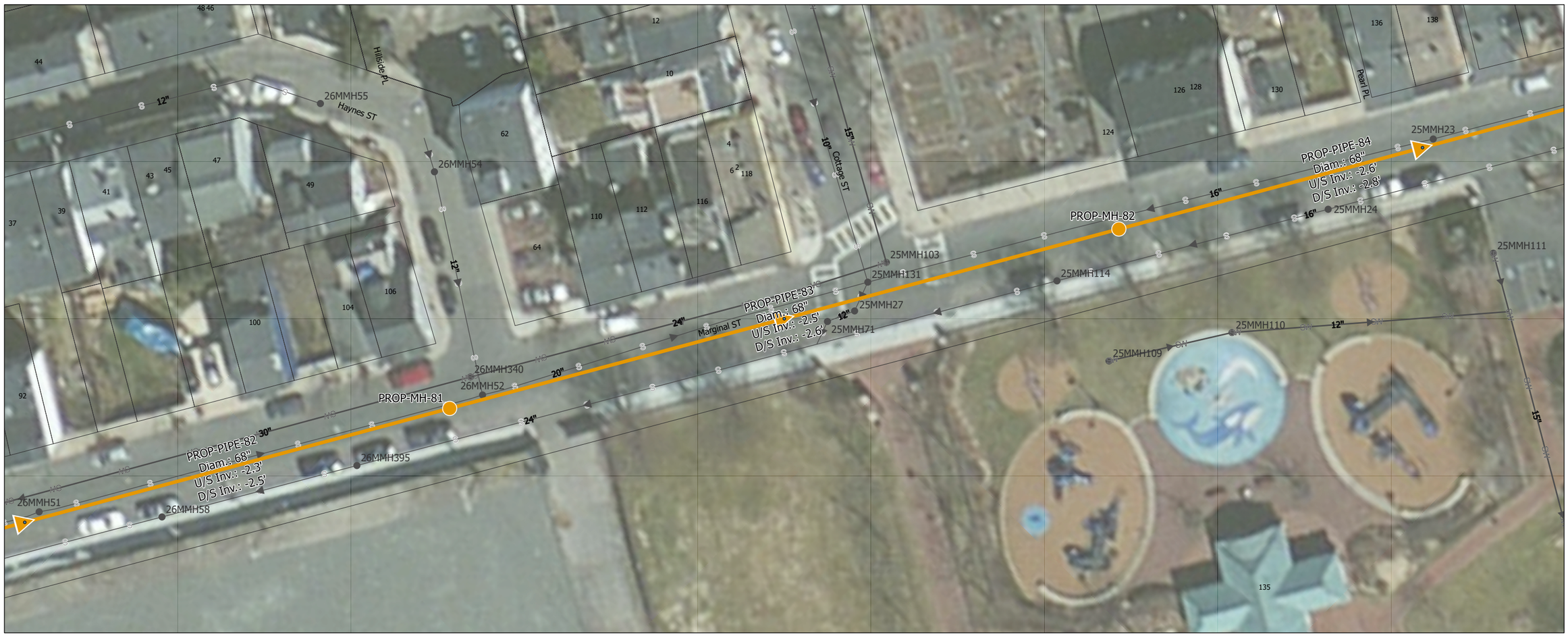
PROP-PIPE-83





Plan
1"= 20'

0 20 40 80 Feet

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Coastal Stormwater Discharge Analysis
East Boston Waterfront

Boston Water and Sewer Commission | Hazen

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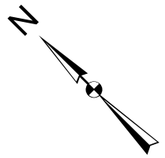

PROP-PIPE-84



Plan
1"= 20'

0 20 40 80
Feet

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Coastal Stormwater Discharge Analysis
East Boston Waterfront

Boston Water and Sewer Commission

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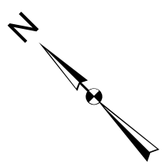
November 2022





PROP-PIPE-85



0 20 40 80 Feet

Plan
1"= 20'

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Coastal Stormwater Discharge Analysis
East Boston Waterfront

Boston Water and Sewer Commission | Hazen

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PROP-PIPE-86



Plan
1"= 20'

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Coastal Stormwater Discharge Analysis
East Boston Waterfront

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N

PROP-PIPE-87



Plan
1"= 20'

0 20 40 80 Feet

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East Boston Waterfront

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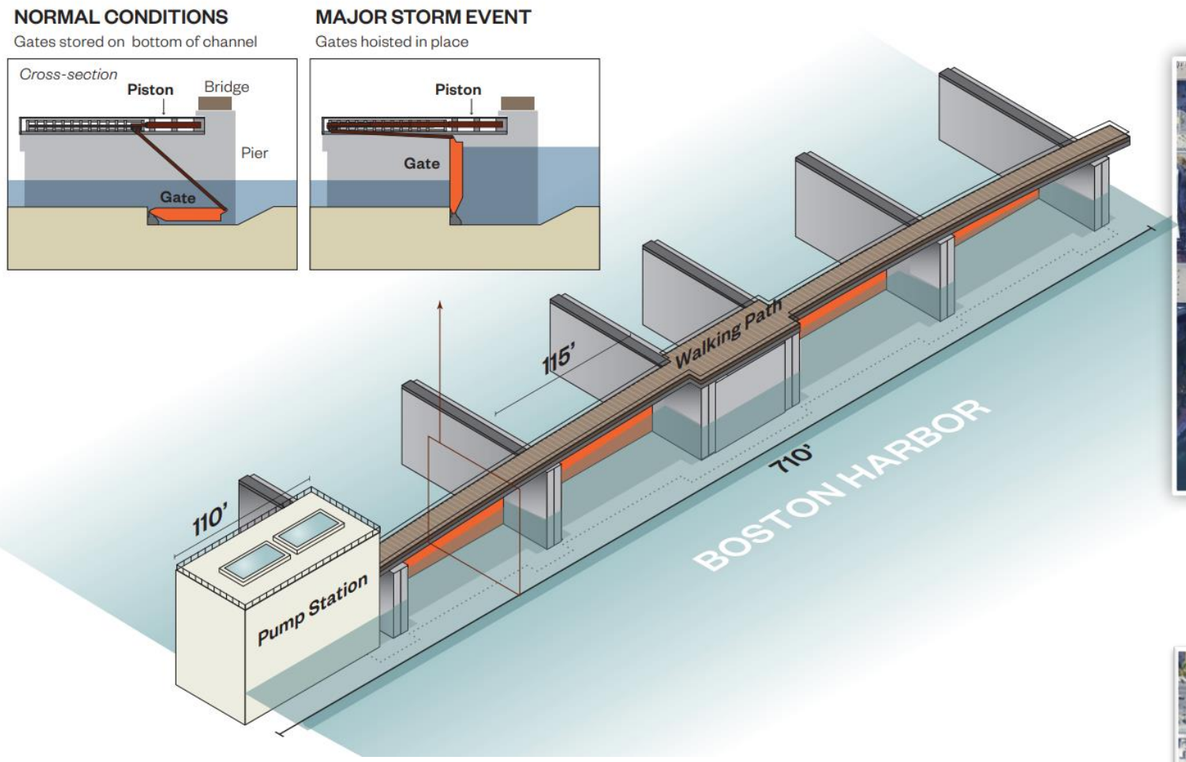
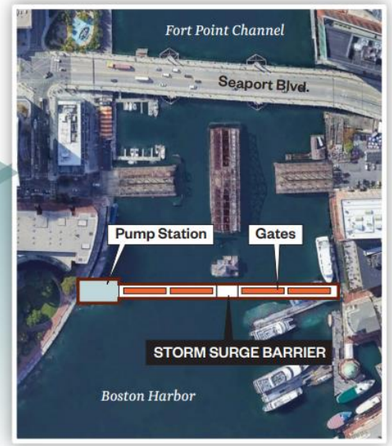
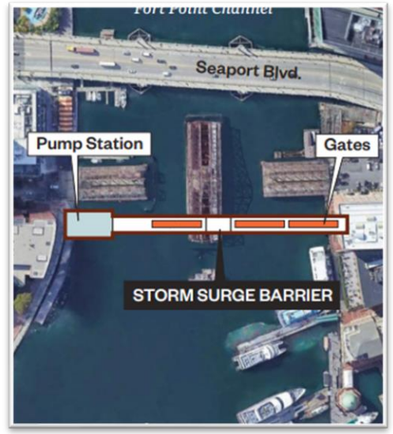
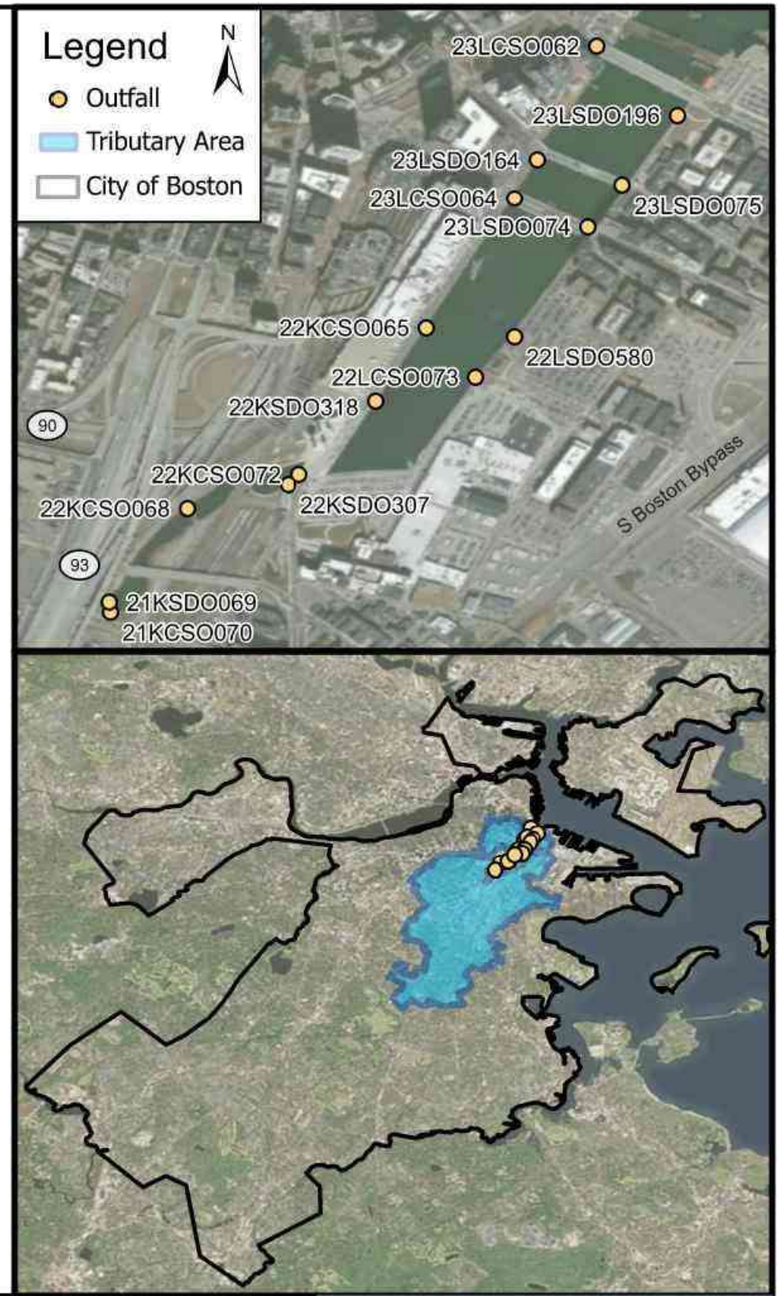
Fort Point Channel Storm Surge Barrier *Concept Overview*







Alternative SSB location – concept in development



Conceptual Solution

The Fort Point Channel (FPC) Storm Surge Barrier (SSB) is a concept that utilizes that natural storage capacity of the Fort Point Channel, in combination with a pump station, to isolate outfalls from high sea levels. The storm surge barrier and navigable gate structure would remain open under typical conditions. In the open position, normal tidal flow into and out of the channel and marine traffic are not impeded. If a large storm event with high sea levels is expected, the gate structures could be closed at low tide, effectively isolating the FPC from higher sea levels. A pump station utilizing electric submersible pumps is incorporated with the SSB. The pump station can help prevent the FPC from overflowing or causing backups into combined sewer and stormwater conduits that drain into the channel.

Type: Storm Surge Barrier and Pump Station
Total Drainage Area: 2653 acres
Coastal Flood Vulnerable Drainage Area Protected: 842 acres

Concept Elements:

- Navigable storm surge barrier (vertical lift gate and submerged axis flap gate alternatives)
- 500 CFS pump station utilizing electric submersible pumps with formed suction inlets
- 160 MG storage capacity within the FPC basin currently with SSB closed low tide
- ~100 MG storage capacity within the FPC basin in 2070 with SSB closed at projected low tide

Coastal Stormwater Discharge Analysis
Fort Point Channel

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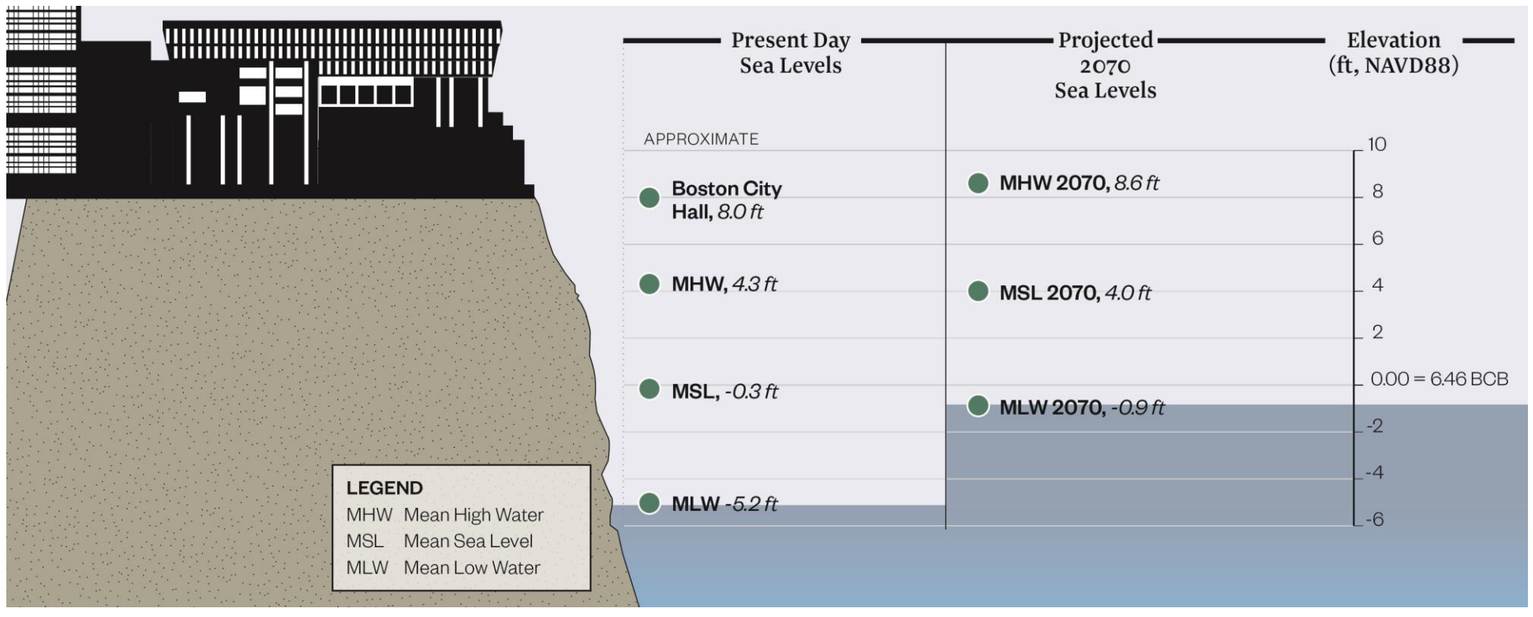
Assumptions

Sea Level Rise and Datum

The Fort Point Channel Storm Surge Barrier concept was designed for consistency with Climate Ready Boston (CRB) proposed adaptations and analyzed based on sea level rise (SLR) projections in the Massachusetts Coastal Flood Risk Model (MC-FRM). The SLR values applied in MC-FRM are consistent with the standards for the State of Massachusetts developed by Coastal Zone Management. The MC-FRM utilizes a "High" SLR scenario. This scenario is based on the relative SLR projections under Relative Concentration Pathway (RCP) 8.5 (a "worst case scenario" of increasing atmospheric carbon concentrations) and represents elevations that have a 99.5% probability of not being exceeded within the respective timeframes. In 2030, that amounts to an increase of 1.3 feet in Boston from a baseline condition (2008 centered tidal epoch), and in 2070 that amounts to an increase of 4.3 feet.

The concept developed in this project was analyzed using coastal conditions that include 2070 projected SLR and storm surge resulting from a 100-year tropical storm. The peak water surface elevation (WSE) predicted by the MC-FRM during these conditions is approximately 13.8 feet NAVD88 (varies by location). In mid 2022, the Greater Boston Research Advisory Group (BRAG) issued an updated report with new SLR projections. The report acknowledges that long term SLR projections are associated with significant uncertainty, and that updated projections include less SLR by 2100 (compared to earlier projections in the 2015 BRAG Report). According to the report, the likely range of SLR by 2070 under an RCP 8.5 scenario is 1.4 – 2.8 feet. Based on this information, projections from the MC-FRM that were utilized in this project are conservative and appropriate for long term planning purposes.

Unless otherwise noted, all elevations are based on the NAVD88 vertical datum. Elevations given in NAVD88 can be converted to Boston City Base (BCB) elevation by adding 6.46 feet.



Climate Ready Boston and Shoreline Protection

The Fort Point Channel Storm Surge Barrier concept was developed to maintain consistency with possible Climate Ready Boston (CRB) adaptations based on the latest available information at the time they were developed. As the CRB program continues to evolve, it is anticipated that proposed concepts will need to be adapted.

The concept was developed to be consistent with stated neighborhood design flood elevations. In the Fort Point Channel, where the stated design flood elevation is 15.5 feet, pumps and the storm surge barrier were designed to a minimum elevation of 15.5 feet.

At the time of this project, many CRB concepts were in early planning stages and not fully defined. **In consideration of this, it was assumed the shoreline protection around the City of Boston is 100% effective for all modeling evaluations.** This assumption eliminates overland coastal flooding from model predictions, allowing for isolation of flooding that results only from rainfall and stormwater that cannot be discharged due to high sea levels. It is important to recognize that additional flooding, beyond what is depicted herein, would be expected if 100% effective shoreline protection is not implemented.

Basis of Design

Storm Surge Barrier and Pump Station

The storage capacity of the FPC was estimated under present day and 2070 conditions based on 4.3 feet of sea level rise projected in the MC-FRM. The usable storage volume was calculated by developing a stage storage curve provided by BWSC and determining the volume between Mean Low Water (MLW) and the approximate upper rim elevation of the FPC (approximately 7.0 feet, NAVD88). For design and analysis purposes, a usable storage volume of 100 MG (2070 conditions) was assumed, based on previous bathymetric data provided by BWSC. Additional storage could be obtained by drawing down the water level (below the future low tide level) with the pumps. The present-day usable storage is approximately 160 MG. For the purpose of this analysis, it was assumed that the current-day mean low water is the lowest water surface elevation allowable within the channel; future geotechnical analysis may indicate that it is possible to pump to even lower water levels if needed.

The concept includes a storm surge barrier to isolate the Fort Point Channel with navigable gate structures. Two alternative navigable gate concepts were designed:

1. Vertical lift gate alternative: Lower cost alternative, but higher visual impacts (see sheet 5).

2. Submerged axis flap gate alternative: Higher cost alternative with minimal visual impacts (see sheet 6).

Rainfall and Coastal Conditions

The Commission currently utilizes a 10-year, 24-hour design storm to establish its target level of service. For the purpose of sizing new piping and evaluating storage capacity, a projected 2070 10-year, 24-hour design storm was developed. For consistency with Climate Ready Boston, performance of the FPC SSC concept was also evaluated with projected rainfall from a 100-year tropical event (developed during the Commission's Inundation Model Project, as shown in Table 2. The FPC SSB was evaluated using a 100-year return period coastal boundary condition. Data for this condition were obtained from the MC-FRM. For the purpose of evaluating the effectiveness of the concept, it was further assumed that complete shoreline protection was implemented, preventing flow of water between the FPC tributary area and Boston Harbor. Table 3 contains a summary of the coastal conditions that were analyzed.

Table 2: Rainfall Conditions

Scenario	Purpose	Rainfall Depth (in)	Peak Intensity (in/hr)
Present Day, 10-year, 24-hr design storm	Baseline Conditions	5.15	3.32
Projected 2070, 10-year, 24-hr design storm	Design Conditions	6.18	4.08
100-year Tropical Storm	Damage Analysis	9.58	0.84

Table 3: Coastal Conditions

Scenario	Purpose	Peak Water Surface Elevation (ft, NAVD88)	Source
Present Day	Baseline Conditions	3.7	BWSC Existing Model (April 2016 Tide Cycle)
2070,100-year Tropical Storm	Damage Analysis	13.8	MC-FRM

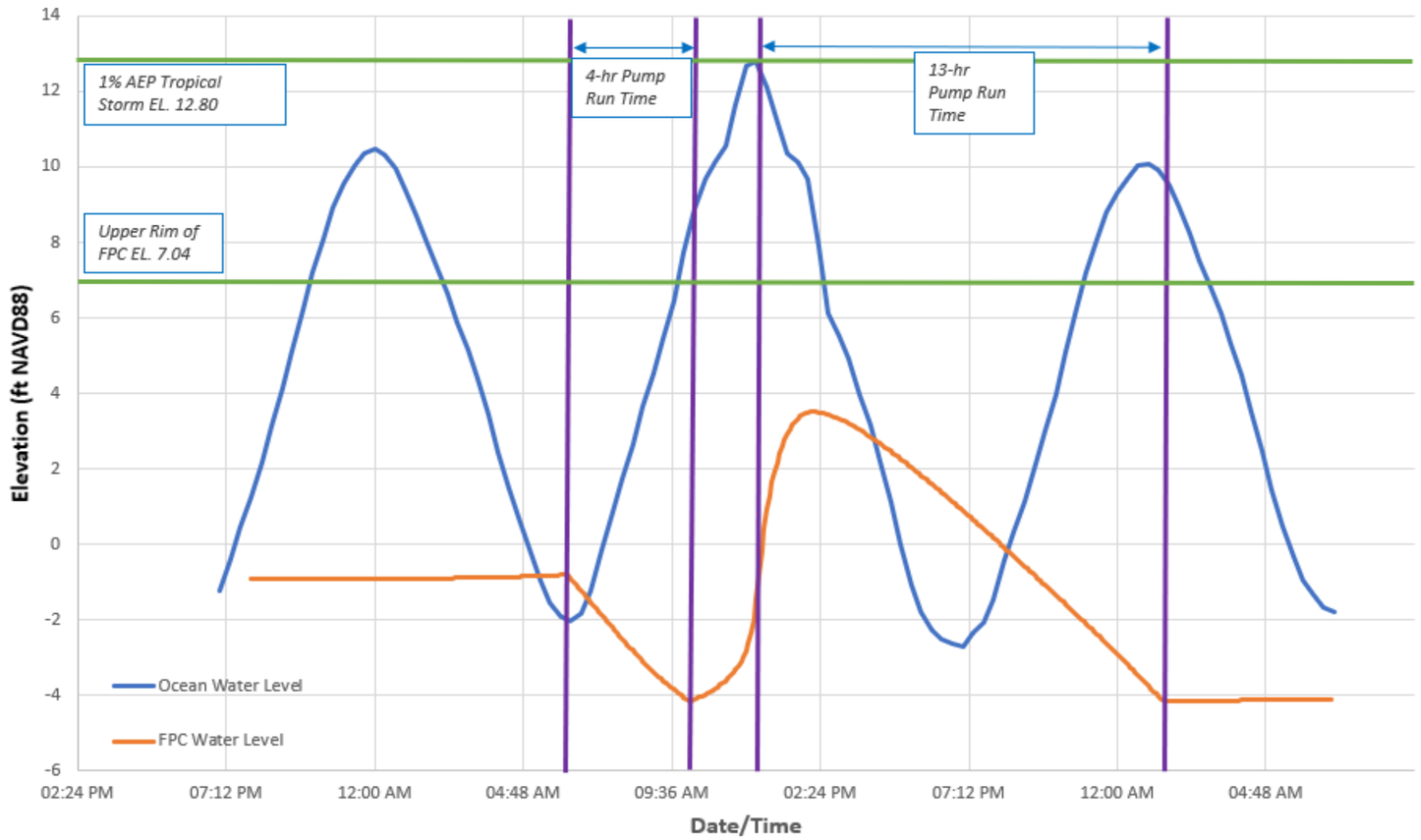
Conceptual Design – Not for Construction

Basis of Design

Pump Station

An analysis was conducted to determine required pumping capacity by simulating the 10-year, 24-hour design storm with 100-year tropical storm surge under 2070 conditions. The model was used to characterize the Hydraulic Grade Line (HGL) in tributary pipelines under existing conditions and evaluate different size pumps under the conditions described above. It was found that 500 CFS of pumping capacity is sufficient to maintain a WSE of 3.7 or less within the FPC during these conditions as shown in Figure 1.

Figure 1: Water Surface Elevation in FPC with 500 CFS Pumping Capacity
(2070 Projected 10-year, 24-hour Design Storm with 100-year Storm Surge)

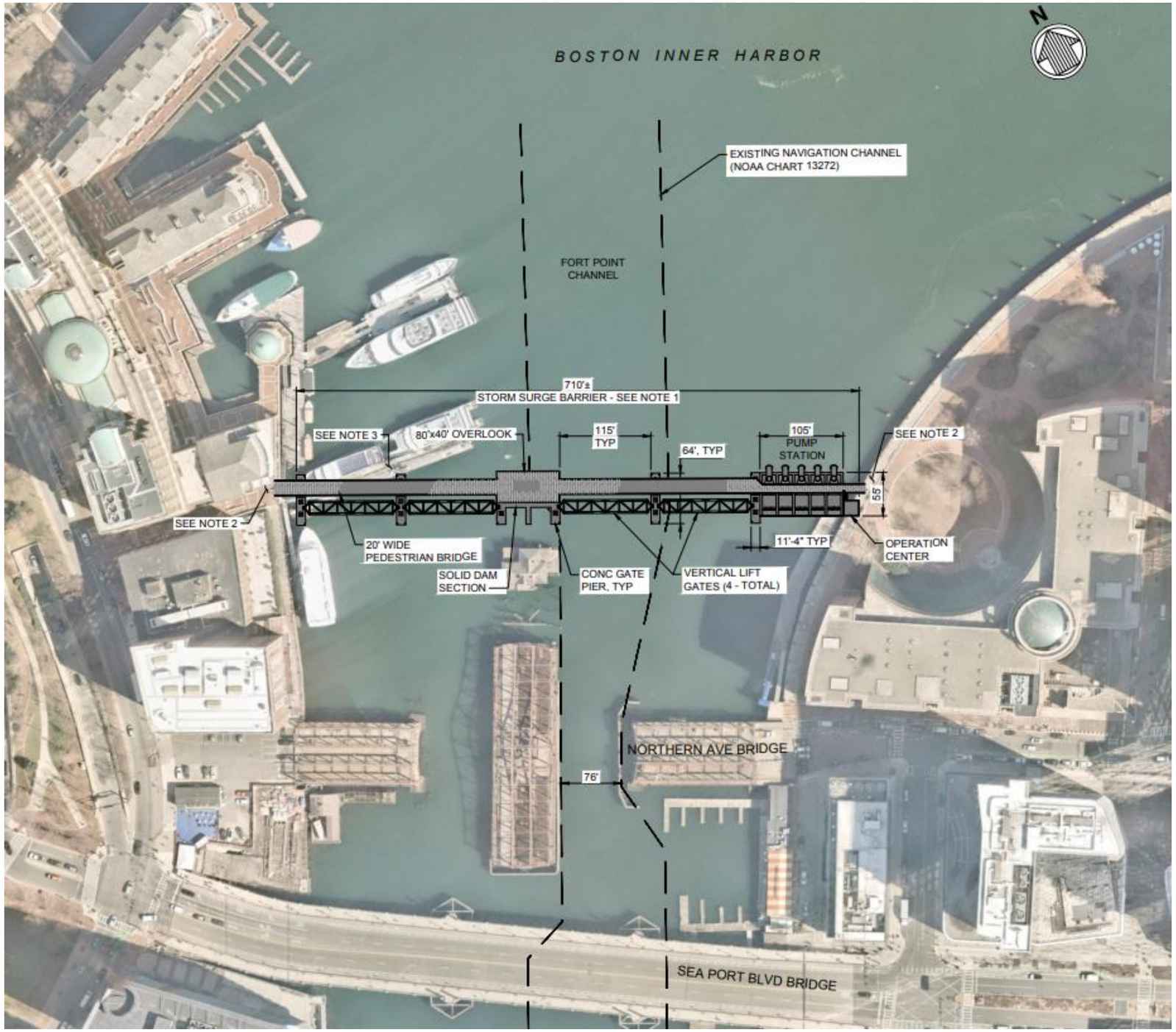


For the purpose of this evaluation, it was assumed that SSB gates were closed at low tide before the storm event and that the pumps were run to draw down the water level from the projected 2070 MLW elevation to the current MLW elevation to maximize storage. It was further assumed that gates remained closed throughout the storm event. During an actual storm event it may be possible to open the SSB gates when the exterior tide level drops below the water level in the basin.

Pumps were sized based on the SSB (and surrounding CRB flood barriers) having a crest elevation of 15.5 feet NAVD88 (for consistency with CRB), with a discharge centerline at 17.0 feet NAVD88. The pump station utilizes 3 duty and 2 standby pumps, each with a capacity of approximately 167 CFS and static head range of 21 feet (low water level) to 4 feet (high-high water level, basin overflowing).The area of the pump station is 5,700 ft^2.

Several alternatives for the FPC pump station were analyzed including use of diesel engine driven pumps, electric submersible pumps, electric non-submersible pumps, and construction of an offsite station. The concept herein utilizes electric submersible pumps with a temporary offsite emergency power supply on the basis of minimized visual impacts and minimized permitting challenges.

Storm Surge Barrier and Navigation Gates

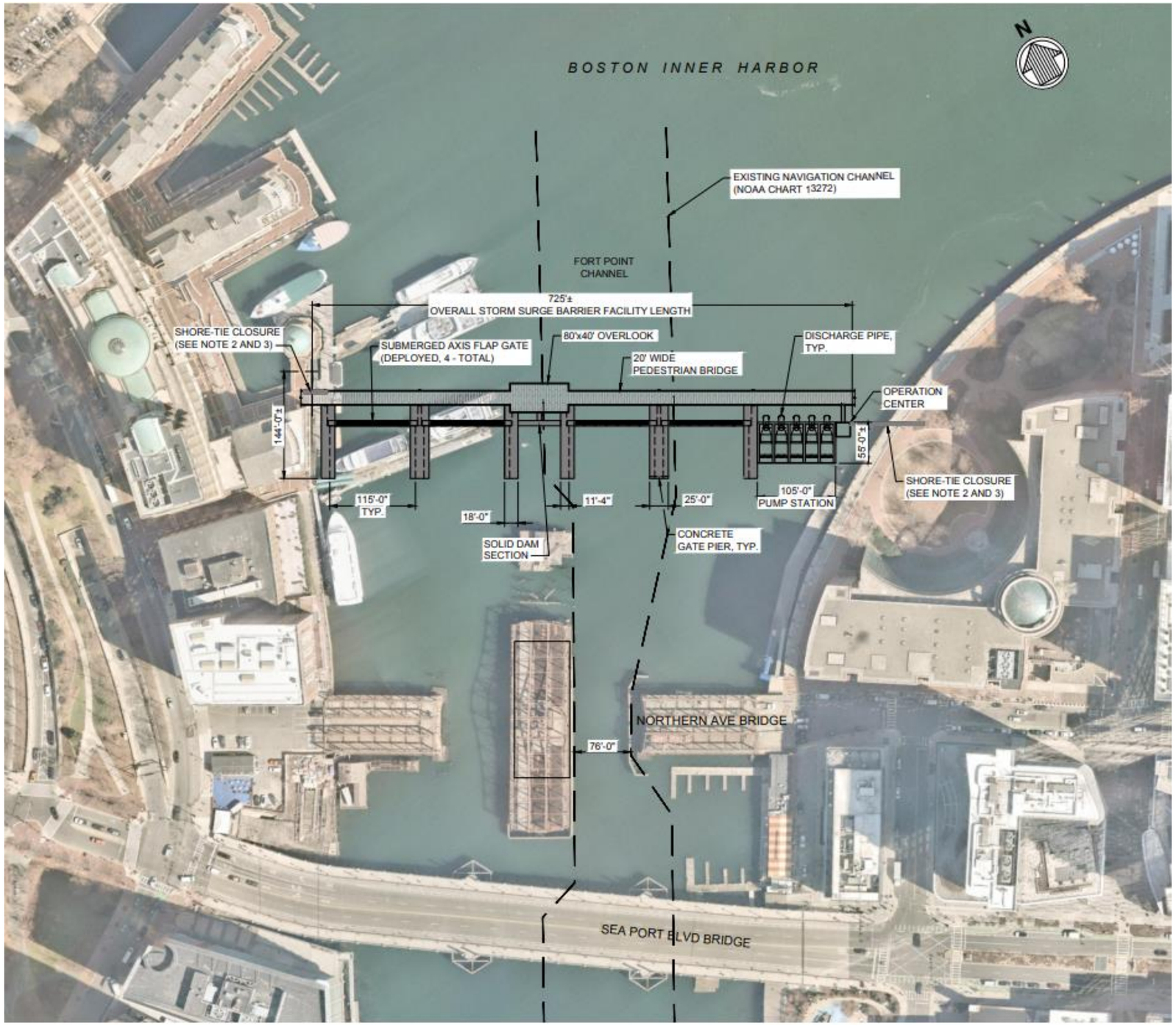


Vertical Lift Gate Alternative

The vertical lift gate alternative utilizes four 115' wide gate sections that are stowed in the air (above the storm surge barrier superstructure) when in the open position. A navigable passage is provided in addition to three auxiliary flow gates. When open, the storm surge barrier does not impede existing navigation. The gates can be lowered into the "closed" position ahead of an extreme storm event to isolate the FPC.

The vertical lift gate alternative is associated with high visual impacts and lower cost compared with the submerged axis flap gate alternative.

Storm Surge Barrier and Navigation Gates



Submerged Axis Flap Gate Alternative

The submerged axis flap gate alternative utilizes four 115' wide gate sections that are stored on the channel bottom recessed in a reinforced concrete pier foundation/sill. A navigable passage is provided in addition to three auxiliary flow gates. When open, the storm surge barrier does not impede existing navigation. The gates can be lifted into the "closed" position with telescoping hydraulic drive cylinders and trolley attached to the gate arm before an extreme storm event to isolate the FPC.

The submerged axis flap gate offers minimized viewshed impacts compared to the vertical lift gate alternative, but is associated with a greater O&M burden, additional complexity, and higher cost.

Flood Modeling and Damage Analysis

Figure 2: Estimated Replacement Cost

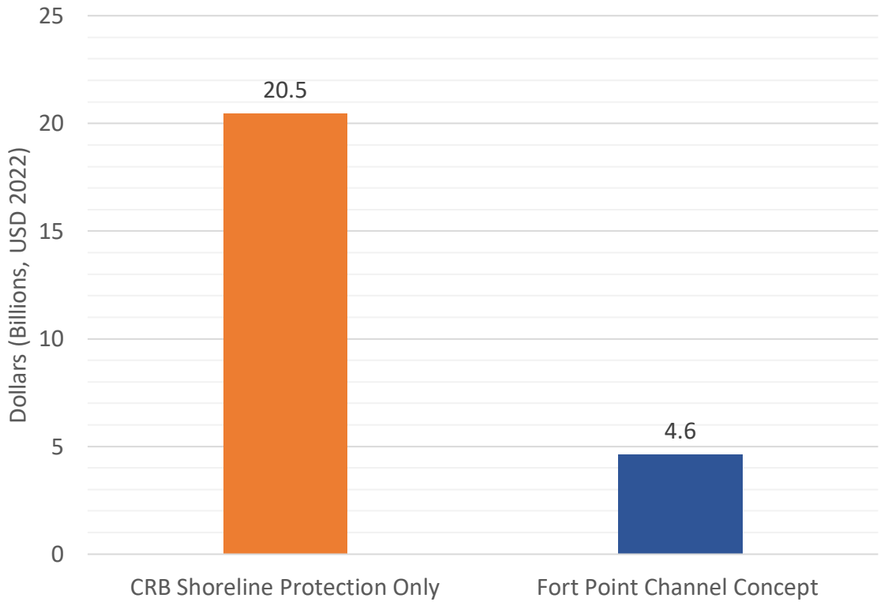


Figure 3: Loss of GDP

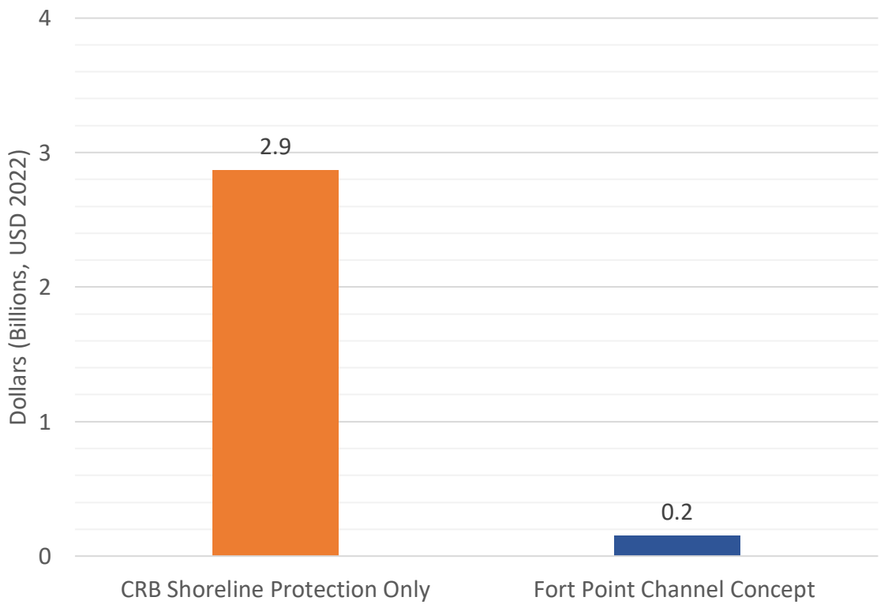
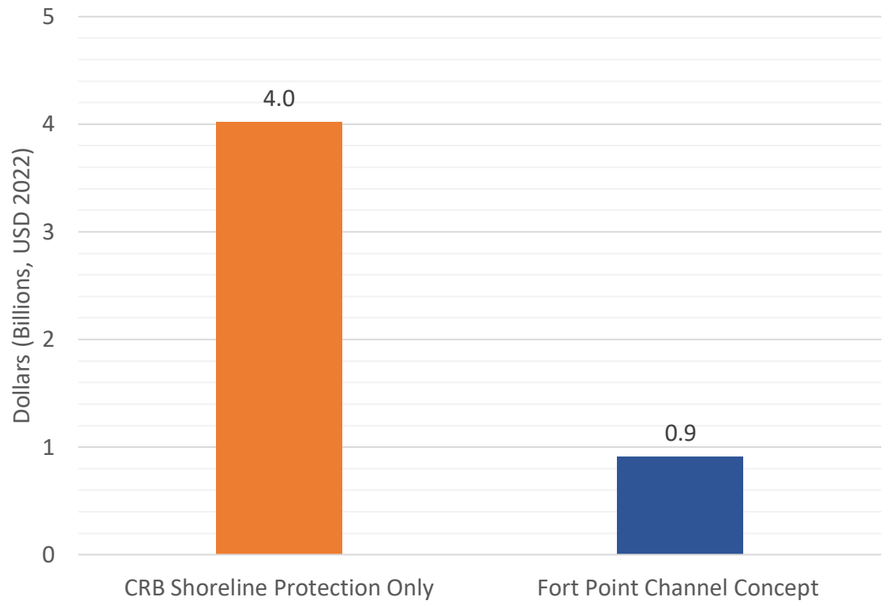


Figure 4: Physical Damage

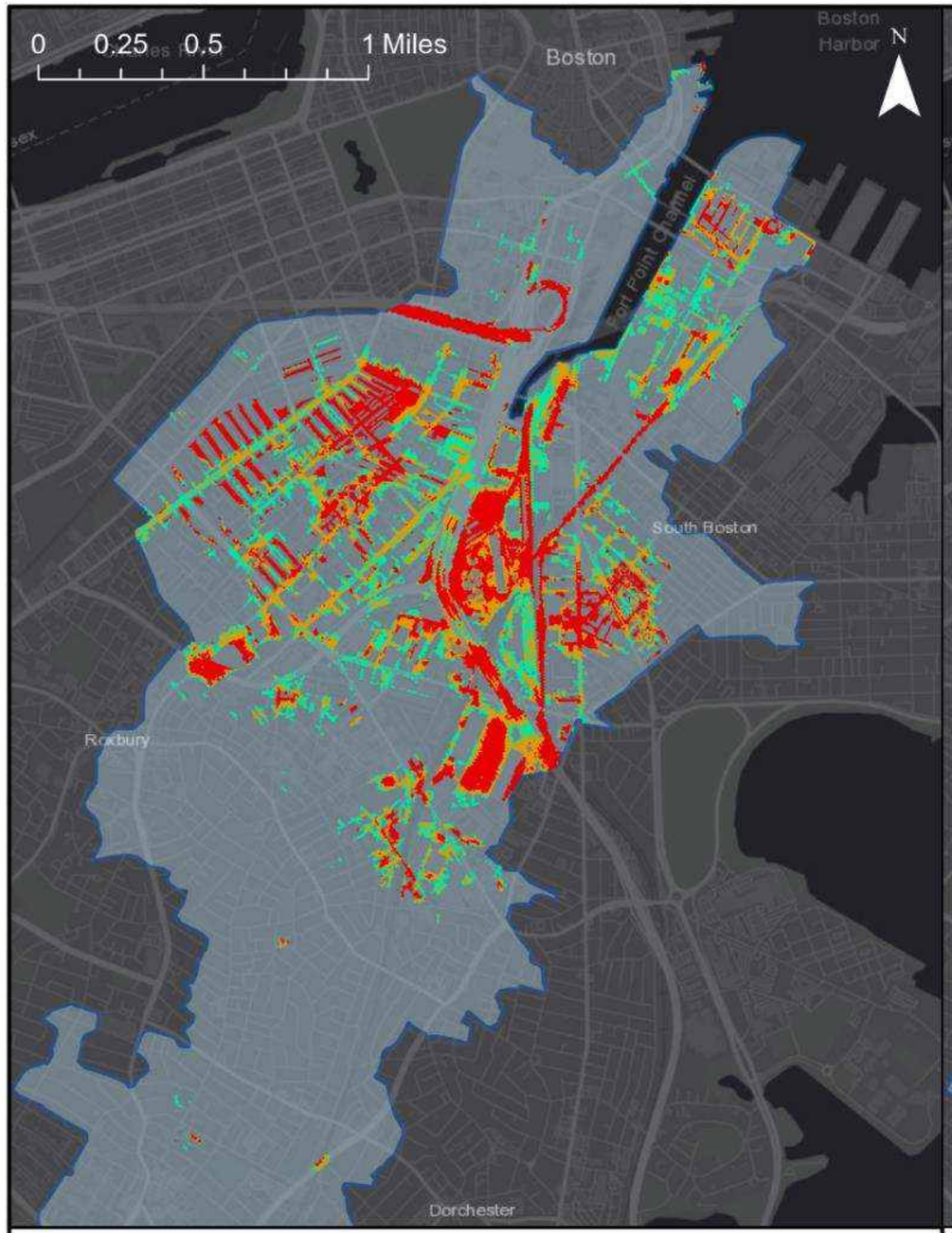


The flood reduction benefits of the FPC SSB concept were evaluated using the Commission's 2D Inundation Model by simulating a 100-year tropical storm event with 2070 SLR and storm surge. The figures on the following page depict the peak flooding that was predicted in the drainage area tributary to the FPC with shoreline protection only and with the FPC SSB and tide gates on all vulnerable BWSC owned outfalls. An analysis of economic losses/physical impacts from flooding under both scenarios was performed by risQ Inc.

Model predictions indicate that the FPC SSB concept reduces physical damage by **$3.1 billion**, avoids **$15.9 billion** in rebuilding costs, and mitigates a GPD loss of **$2.7 billion** during a 100-year tropical storm event in 2070 compared to shoreline protection only.

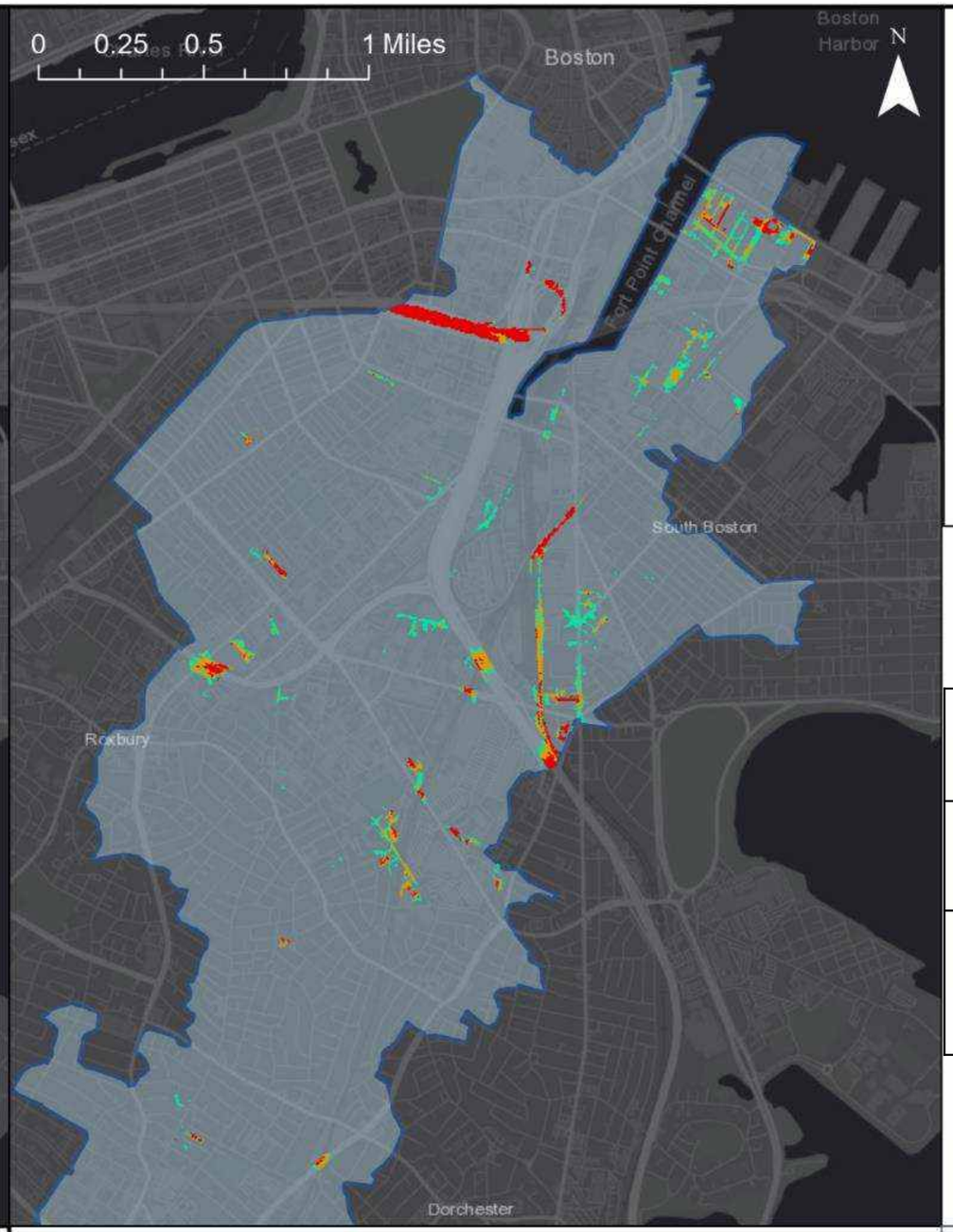
Note: replacement values include the total value of impacted buildings in flooded areas (e.g., impacted buildings are fully replaced), whereas physical damage includes estimated costs to repair flood damage based on predicted flood depths and building characteristics. The values shown are the average of minimum and maximum calculated losses. Refer to the Project's Final Report for more information.

Conceptual Design – Not for Construction



2070 SLR + 100yr Tropical Storm + Storm Surge

CRB Shoreline Protection Only



2070 SLR + 100yr Tropical Storm + Storm Surge

FPC SSB and Pump Station and Tide Gates

Legend

- Flood Depth > 4 in and < 1 ft
- Flood Depth > 1 ft and < 2 ft
- Flood Depth > 2 ft
- Drainage Area Analyzed

Simulation Parameters

Storm Type	100yr Tropical Storm
Rainfall Depth	9.6 inches
Peak WSE 2070 SLR + 100yr Surge	13.8 feet NAVD88

Coastal Stormwater Discharge Analysis
Fort Point Channel

Boston Water and Sewer Commission

Hazen

November 2022

Cost Estimate and FEMA BRIC Considerations

Capital Cost Estimate

A construction cost estimate for the FPC SSB and pump station concept was developed for planning purposes. Assumptions made for the cost estimate include 15-year escalation to the mid-point of construction and the inclusion of a 50% design contingency. Installation and labor costs for the portable generator as well as hookup costs to existing electrical services were not included in this estimate.

Table 4: Fort Point Channel Pump Station Cost Estimate Subtotals

Remaining Design Development & Construction Administration (*assumed 20% of total less design contingency*)	$4,524,000
Direct Construction Costs	$8,968,000
Indirect Construction Costs	$1,794,000
Mark-Up *(Including 50% design contingency)*	$22,760,000
Total	**$38,045,000**

Table 5: Fort Point Channel Marine Work Alternatives Cost Estimate Subtotals

	Submerged Axis Flap Gate	Submerged Axis Flap Gate – South Location	Vertical Lift Gate
Remaining Design Development & BWSC Construction Administration	$60,553,000	$49,851,000	$36,350,000
Direct & Indirect Construction Costs Total (Marked-up)*	$329,465,000	$271,236,000	$197,328,000
Escalation (15 Years)	$240,119,000	$197,682,000	$143,867,000
Design Contingency (35%)	$136,506,000	$112,381,000	$81,788,000
Total	**$766,643,000**	**$631,150,000**	**$459,333,000**
* Marked-up cost includes contractor overhead, profit, fees, bond, insurance.			

Social Vulnerability and FEMA BRIC Funding

FEMA BRIC funding prioritizes disadvantaged communities. Table 6 contains a summary of several indicators for the Fort Point Channel tributary area that could be used help characterize the community for future FEMA funding applications and prioritization of projects that benefit disadvantaged communities.

Table 6: Fort Point Channel Tributary Area Social Vulnerability Indicators

Low Income & Persistent Poverty	
Per Capita Income	$58,326
Below Poverty Line	23%
High Housing Cost Burden	
Stressed Renters (>40% rent-to-income)	34%
Households With Food Insecurity	14%
Racial and Ethnic Segregation	
Asian Population	13%
Black Population	30%
Latino Population	20%
White Population	41%
Employment	
Adults Age 25+ Without High School (or equivalent) Degree	16%
Unemployment Rate (Age 16+)	8%

Data provided by risQ inc. from the US census and American Community Survey

Conceptual Design – Not for Construction

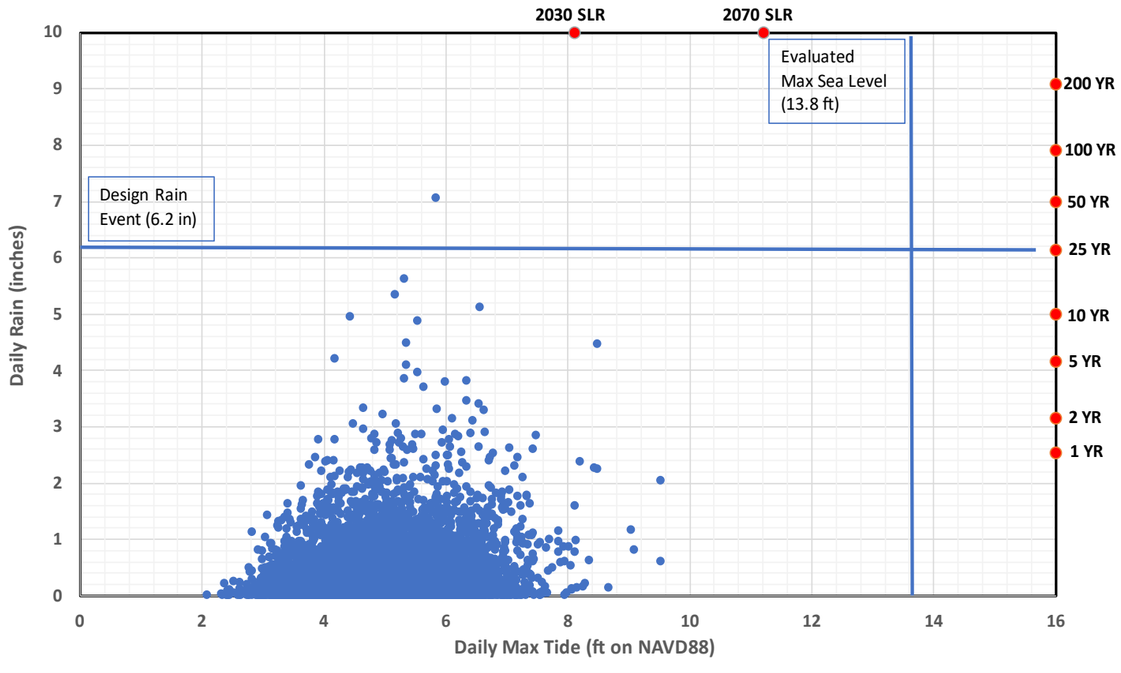
Adaptability and Implementation

Adaptability

Figure 5 below depicts historical daily rainfall totals and tide levels. As shown in this figure, the conditions that were used to design and analyze the FPC concept are conservative and represent more extreme conditions than have occurred historically. It is important to note that the design storm generates higher intensity rainfall than is typically associated with tropical and nor'easter storm events. As such, it is likely that the FPC pump station is sufficiently large to discharge flows from most future rain events. Regardless, the following measures could be implemented to adapt the concept to more severe conditions (additional SLR, more intense rainfall, etc.) in the future:

- Convert a standby pump to a duty pump for additional capacity
- Increase the size of each FPC pump unit
- Redirect additional vulnerable outfalls to discharge into the FPC behind the SSB

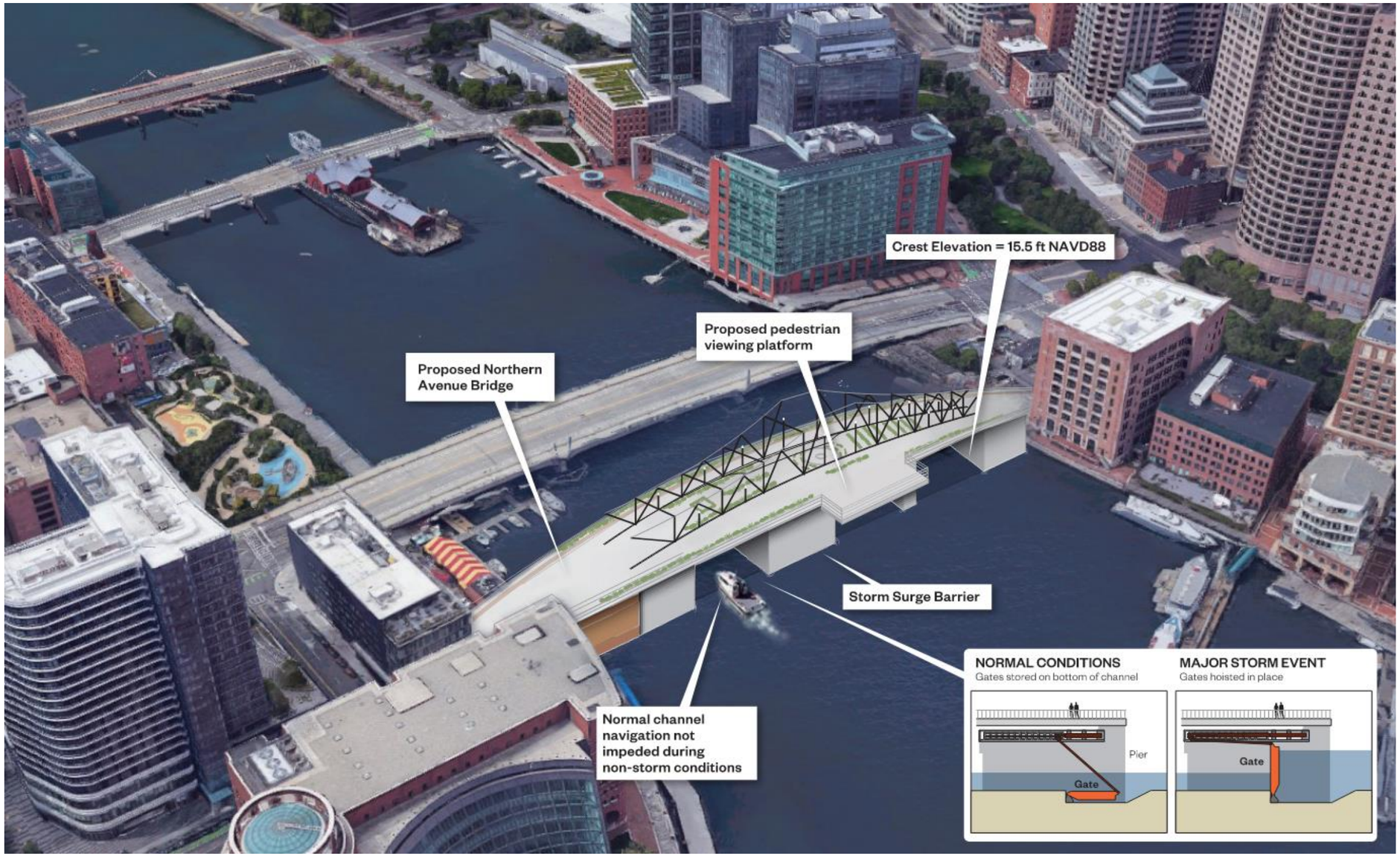
Figure 5: Design and Analysis Conditions vs. Historical Tide and Rainfall



Implementation Considerations

- Coordination with CRB (and other relevant stakeholders) to construct adequate shoreline protection to prevent flanking of the SSB.
- Shoreline elevation projects along the interior of the FPC should still be evaluated since the FBC SSB is not designed to isolate the basin from "day-to-day" high tide levels.
- A thorough permitting evaluation of the FPC SSB should be conducted. Although the SSB concept was developed to maximize tidal exchange between the FPC and Boston Harbor, a thorough environmental impact assessment should be conducted to evaluate possible impacts of constructing a SSB.
- Coordination with the Northern Avenue Bridge replacement team could facilitate integration of these structures. Construction of an "integrated" structure could reduce construction costs, minimize viewshed impacts, and provide additional public amenities.
- The FPC SSB pump station uses a temporary backup power supply; as such, it is important to coordinate availability of backup power several days before an anticipated extreme storm event
- Deauthorization of the federally authorized navigation channel would be a significant undertaking. It is recommended that future development of this concept preserve the existing navigation function.
- Additional outfalls could be redirected to discharge behind the FPC SSB and pump station to mitigate the effect of higher sea levels – this would increase the regional utility and benefits of the concept in the future
- 2D modeling was conducted to evaluate the incremental benefit of adding tide gates to all BWSC owned outfalls that discharge into the FPC in addition to shoreline elevation. It was found that additional tide gates have a substantial flood reduction benefit compared to shoreline elevation alone. Installation of tide gates on all BWSC owned outfalls could be considered as an interim measure before construction of the SSB and pump station.
- At a further stage of the design process, consideration should be given to mitigating the possible hazard caused by the high-flow discharges of the pump station to small boats, swimmers, and other harbor users.

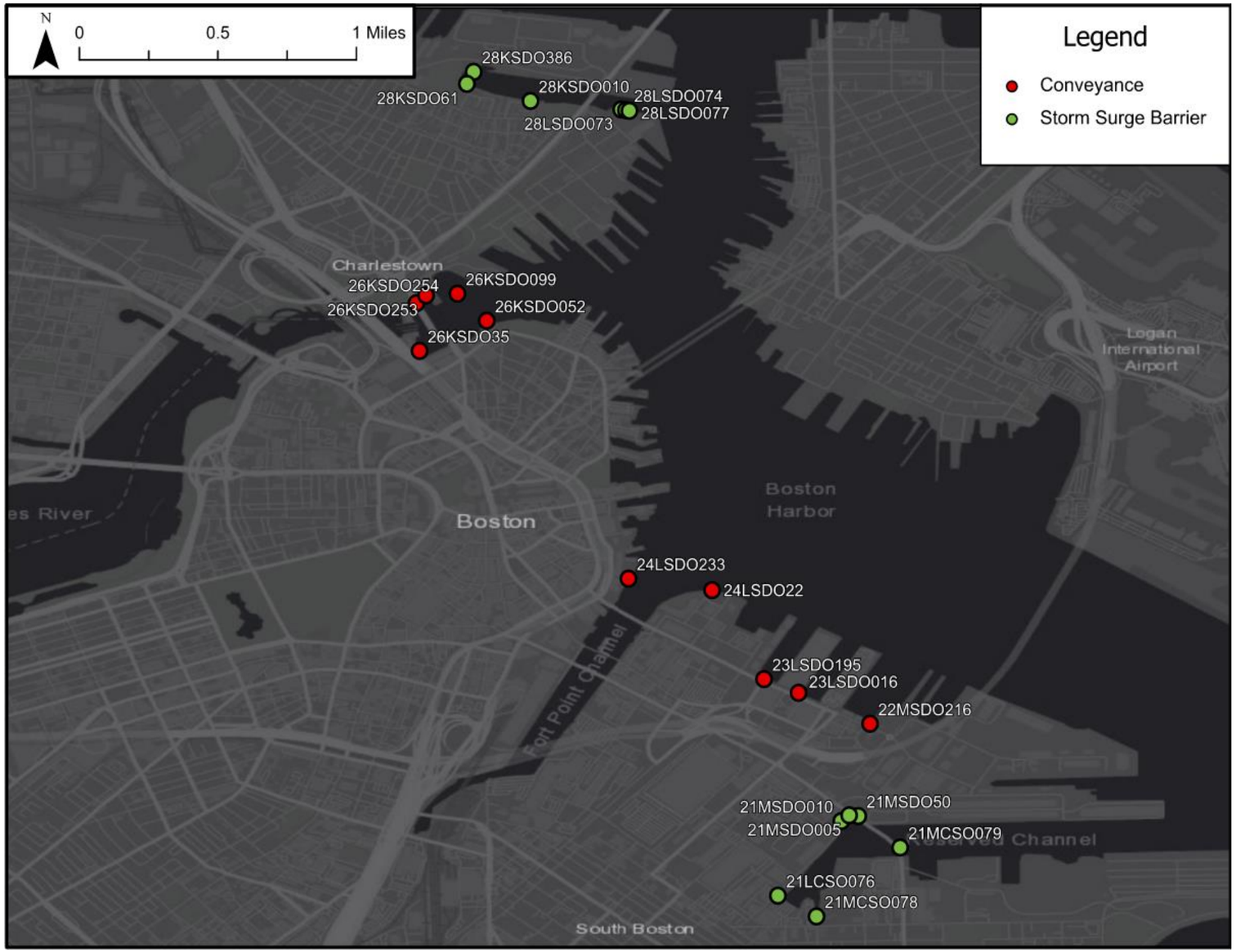
Storm Surge Barrier *Northern Avenue Bridge Integrated Alternative*



Conceptual Solution – Alternate Location

The above graphic depicts an alternate concept for the FPC SSB that is integrated with the planned Northern Avenue Bridge Replacement. The mechanical systems are similar to the other concepts shown previously. This alternate location combines planned renovations to the Northern Avenue Pedestrian Bridge with the FPC SSB into one project. This alternative mitigates the viewshed impact of the SSB on the planned viewing platform of the bridge. Although this concept has not been advanced to the design stage at this time, and it is anticipated that both structures would need to be significantly redesigned, integration of these structures would reduce construction impacts from separate projects. In addition, an integrated project would offer an opportunity for Boston and the Commission to implement an iconic adaption project, with multiple community benefits, that could catalyze funding and coordination for further adaptation efforts.

Replicability and Implementation Timeline



Summary of Similar Concepts

Number of Outfalls: 22

Vulnerable Area: 573 acres

The map on this sheet depicts other vulnerable outfalls that could utilize elements of the FPC SSB solution including the following:

- Several outfalls along the South Boston Waterfront could be consolidated with a new conduit and redirected to a new outfall behind the FPC SSB.
- Outfalls near the Charles River Dam could be consolidated with new conduits and redirected to new outfalls behind the dam.
- Outfalls at the “back” of the Reserved Channel (west of Summer Street) could be protected with a SSB.
- Outfalls within the Little Mystic Channel could be protected with a SSB.

Additional information about these outfalls can be found in the Commission’s Coastal Stormwater Discharge Analysis Implementation Timeline.

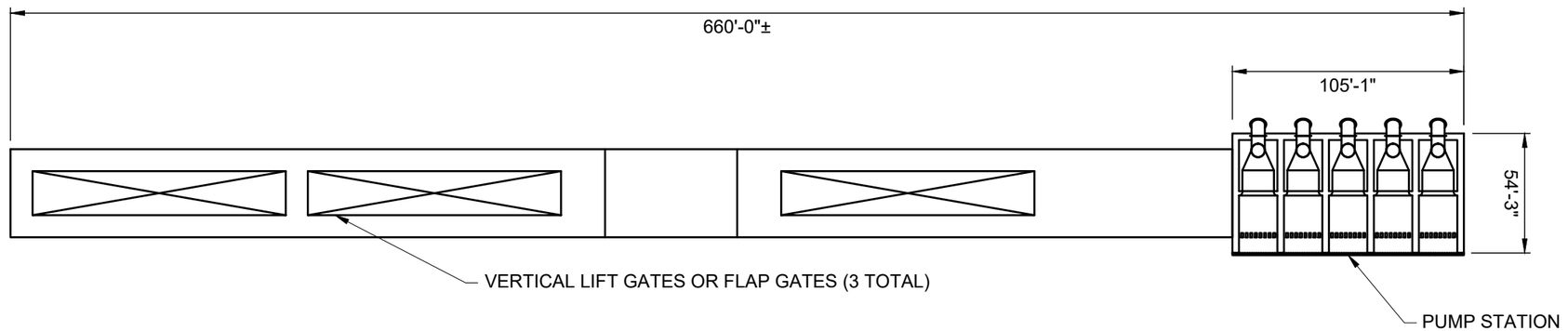
ATTACHMENT A
FORT POINT CHANNEL PUMP STATION CONCEPTUAL DESIGN DRAWINGS

A-1: Storm Surge Barrier Overview Plan
A-2: Pump Station Plan
A-3: Pump Station Section View
A-4: Electrical Single Line Diagram (Three Gate Alternative)
A-5: Electrical Single Line Diagram (Four Gate Alternative)

Fort Point Channel Pump Station

NOTES

1. FOR WATER SURFACE ELEVATIONS REFER TO OPERATIONAL TABLE.
2. ALL ELEVATIONS USE THE NAVD88 VERTICAL DATUM UNLESS OTHERWISE STATED.
3. CONCEPTUAL DRAWING, NOT FOR CONSTRUCTION.



OVERVIEW DRAFT PLAN

SCALE: NTS

COASTAL STORMWATER
DISCHARGE ANALYSIS

Boston Water and Sewer Commission

Hazen

A-1	November 2022

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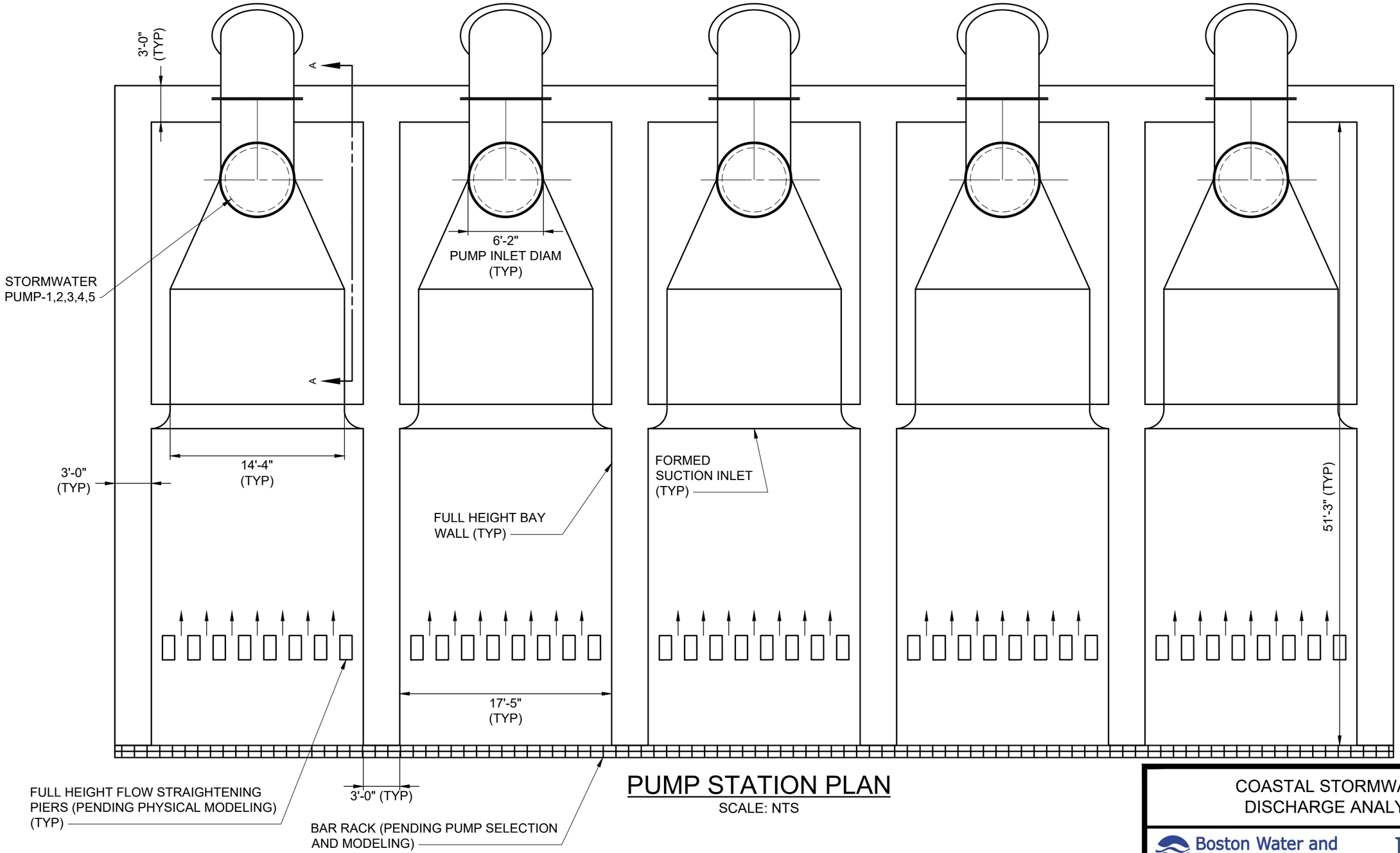
Fort Point Channel Pump Station



PUMP STATION PLAN

SCALE: NTS

COASTAL STORMWATER
DISCHARGE ANALYSIS

Boston Water and Sewer Commission

Hazen

A-2

November 2022

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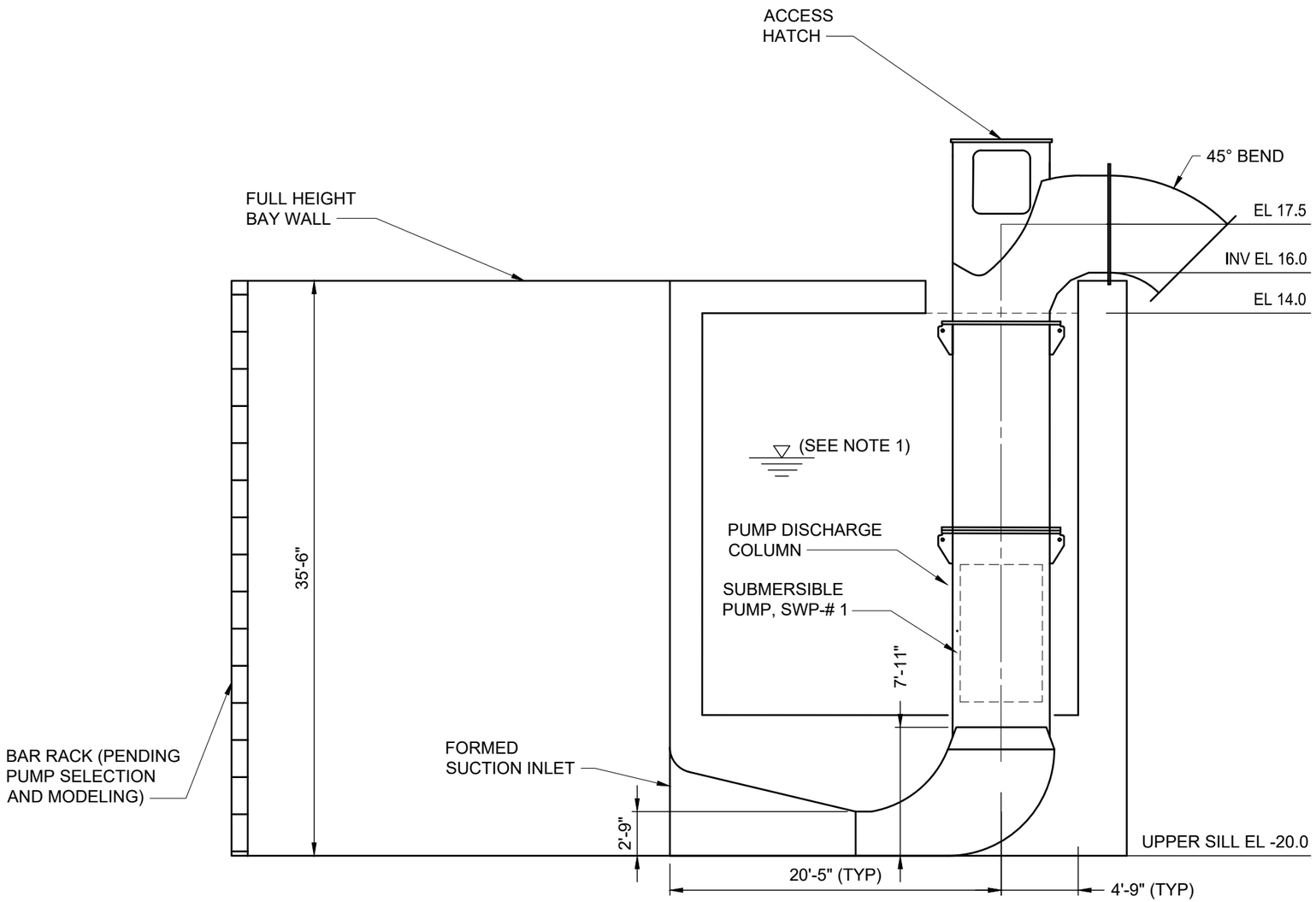
Fort Point Channel Pump Station



SECTION

SCALE: NTS

NOTES

1. FOR WATER SURFACE ELEVATIONS REFER TO OPERATIONAL TABLE.
2. ALL ELEVATIONS USE THE NAVD88 VERTICAL DATUM UNLESS OTHERWISE STATED.
3. CONCEPTUAL DRAWING, NOT FOR CONSTRUCTION.

STORMWATER PUMP-1,2,3,4,5 OPERATIONAL PARAMETERS	
FLOW RATE, CFS	167
STATIC HEAD RANGE, FT	3.5 - 23.0
DESIGN FLOOD ELEVATION, FT	15.5

STORMWATER PUMP-1,2,3,4,5 OPERATIONAL WSE TABLE

NOTE	OPERATION	ELEVATION, FT
A	HIGH LEVEL ALARM	13
B	LAG PUMP ON	5.0
C	LEAD PUMP ON	-2.6
D	LEAD PUMP OFF	-3.6
E	LOW LOW ALARM	-4.6
G	MIN PUMP SUBMERGENCE	-5.6

COASTAL STORMWATER DISCHARGE ANALYSIS

Boston Water and Sewer Commission

Hazen

A-3 | November 2022

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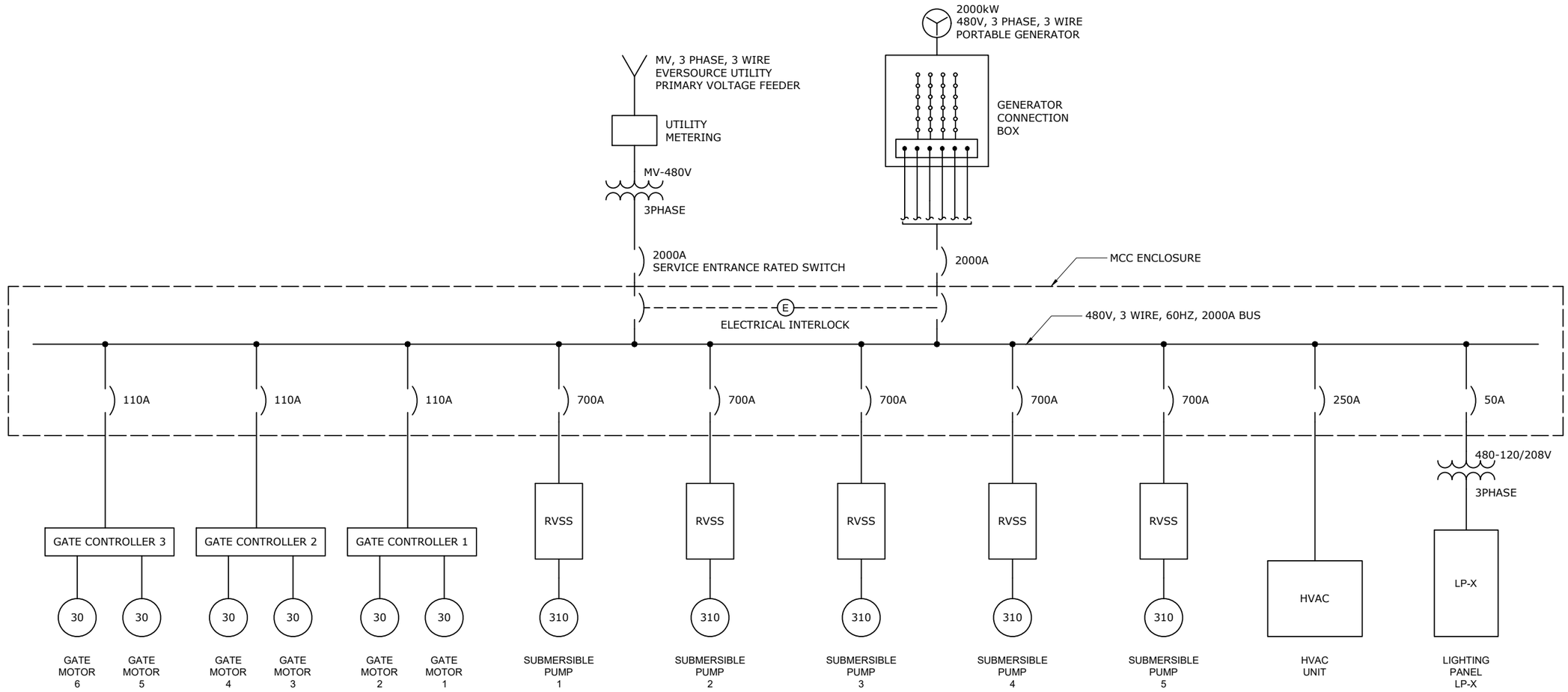
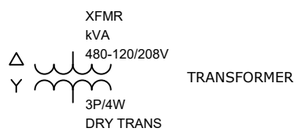
FPC SSB Pump Station Three Gate Alternative



LEGENDS AND SYMBOLS



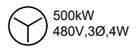
TRANSFORMER



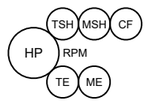
PROTECTIVE RELAY:
NUMBER DENOTES IEEE DEVICE FUNCTION



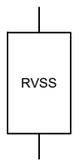
LOW VOLTAGE MOLDED CASE CIRCUIT BREAKER
LEFT: THERMAL-MAGNETIC TRIP UNIT
RIGHT: ELECTRONIC TRIP UNIT



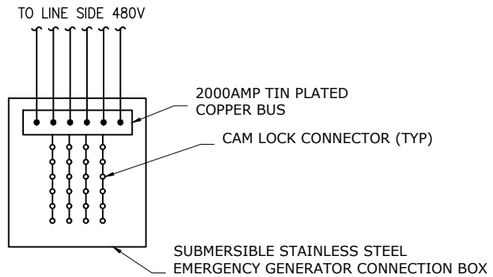
GENERATOR



MOTOR AND TYPICAL ADDITIONAL DEVICES:
TSH: TEMPERATURE SWITCH
MSH: MOTOR SPACE HEATER
CF: COOLING FAN
TE: TEMPERATURE ELEMENT
ME: MOISTURE DETECTOR



RVSS



ELECTRICAL
FLOOD WATER PUMP STATION
PROPOSED SINGLE LINE DIAGRAM

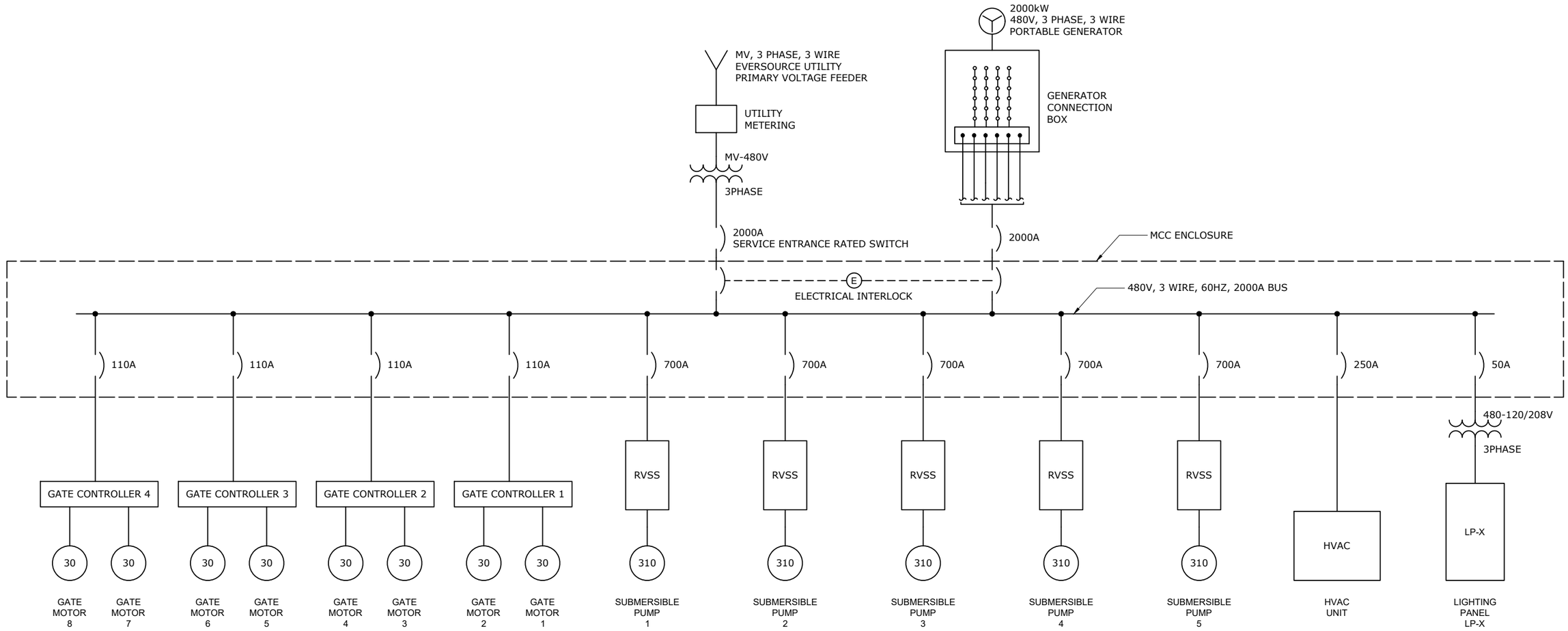
COASTAL STORMWATER
DISCHARGE ANALYSIS

Boston Water and Sewer Commission

Hazen

A-4	November 2022

FPC SSB Pump Station Four Gate Alternative



LEGENDS AND SYMBOLS

XFMR
kVA
480-120/208V
3P/4W
DRY TRANS

TRANSFORMER

500kW
480V,3Ø,4W

GENERATOR

TSH MSH CF
HP RPM
TE ME

MOTOR AND TYPICAL ADDITIONAL DEVICES:
TSH: TEMPERATURE SWITCH
MSH: MOTOR SPACE HEATER
CF: COOLING FAN
TE: TEMPERATURE ELEMENT
ME: MOISTURE DETECTOR

#

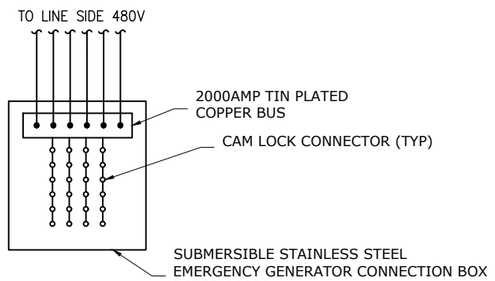
PROTECTIVE RELAY:
NUMBER DENOTES IEEE DEVICE FUNCTION

100AF
100AT
ETU
800AF
800AP
800AT
LSIG

LOW VOLTAGE MOLDED CASE CIRCUIT BREAKER
LEFT: THERMAL-MAGNETIC TRIP UNIT
RIGHT: ELECTRONIC TRIP UNIT

RVSS

RVSS



ELECTRICAL
FLOOD WATER PUMP STATION
PROPOSED SINGLE LINE DIAGRAM

COASTAL STORMWATER
DISCHARGE ANALYSIS

Boston Water and Sewer Commission

Hazen

A-5	November 2022

ATTACHMENT B
FORT POINT CHANNEL STORM SURGE BARRIER CONCEPTUAL DESIGN DRAWINGS
VERTICAL LIFT GATE ALTERNATIVE

B-1: Vertical Lift Gate Plan
B-2: Vertical Lift Gate Phase 1 Plan
B-3: Vertical Lift Gate Phase 2 Plan
B-4: Vertical Lift Gate Phase 3 Plan
B-4: Vertical Lift Gate Phase 4 Plan
B-5: Vertical Lift Gate Phase 5 Plan
B-6: Vertical Lift Gate Top Surface and Foundation Plans
B-7: Vertical Lift Gate Elevations
B-8: Vertical Lift Gate Pier Section
B-9: Vertical Lift Gate Sections and Details



NOTES:

1. THE CONCEPT PLAN VIEWS SHOW PORTIONS OF STORM SURGE BARRIER STRUCTURE THAT PROJECT ABOVE DAILY HIGH WATER LINE. SEE S-400 SERIES SHEETS FOR MULTIVIEWS AND DETAILS ASSOCIATED WITH BELOW WATER AND CHANNEL BED FEATURES (FOUNDATION, SCOUR PROTECTION).
2. SHORELINE INTERFACES, TRANSITIONS, AND TIE-INS SHALL BE DETERMINED DURING DETAILED DESIGN.
3. EXISTING SHORELINE STRUCTURES AND OBSTRUCTIONS TO BE REMOVED SHALL BE DETERMINED DURING DETAILED DESIGN.

A1 / FIG-1 PLAN - STORM SURGE BARRIER - VERTICAL LIFT GATE ALTERNATE
SCALE: 1" = 80'

80' 0' 80' 160'
SCALE: 1"=80'

PRELIMINARY - CONCEPT LEVEL

Mark	Description	Date	Appr
01	FPC LIFT GATE DRAFT - CLIENT REVIEW	10-26-2022	MK
02	FPC FLAP GATE DRAFT - CLIENT REVIEW	11-21-2022	MK

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
VERTICAL LIFT GATE CONCEPT DESIGN
BOSTON, MA

PLAN - STORM SURGE BARRIER VERTICAL LIFT GATE ALTERNATE

Date: 2022-11-21
Rev: -
M&N Project No.: 11167
Drawing code:
Drawing Scale:
Plot scale: 1:1 (D SHEET)

Designed by: NBJ
Drawn by: M&N BAL
Checked by: JCS
Reviewed by: MK
Submitted by: MOFFATT & NICHOL

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NEWTON, MA 02459
moffatt & nichol

SEAL

Sheet Reference No.
S-101
INDEX: 1 OF 10

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DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING



NOTES - PHASE 1:

1. THIS CONCEPT PHASING PLAN REPRESENTS ONE POSSIBLE CONFIGURATION THE CONTRACTOR COULD UTILIZE TO ESTABLISH IN-THE-DRY CONDITIONS TO CONSTRUCT THE SILL, PIERS, GATES, AND BALANCE OF SUPERSTRUCTURE. ACTUAL PHASING PROGRESSION, EXTENTS, AND INTERFACES SHALL BE DETERMINED BY THE FINAL DESIGN OF THE SURGE BARRIER AND CONTRACTOR'S COFFERDAM SYSTEM.
2. CONTRACTOR SHALL DREDGE TEMPORARY NAVIGATION CHANNEL AND PROVIDE TEMPORARY NAVIGATION AIDS PRIOR TO CONSTRUCTING PHASE 1 TEMPORARY COFFERDAM.

A1 / S-102 PLAN - STORM SURGE BARRIER - VERTICAL LIFT GATE - PHASE 1
SCALE: 1" = 80'

80' 0' 80' 160'
SCALE: 1"=80'

PRELIMINARY - CONCEPT LEVEL

Mark	Description	Date	Appr
02	PPC FLAP GATE DRAFT - CLIENT REVIEW	11-21-2022	MK
01	PPC LIFT GATE DRAFT - CLIENT REVIEW	10-26-2022	MK

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
VERTICAL LIFT GATE CONCEPT DESIGN
BOSTON, MA

PLAN - STORM SURGE BARRIER
VERTICAL LIFT GATE - PHASE 1

Date: 2022-11-21
Rev: -
M&N Project No: 11167
Drawing code:
Drawing Scale:
Plot scale: 1:1 (D SHEET)
Designed by: NBJ
Drawn by: M&N BAL
Checked by: JCS
Reviewed by: MK
Submitted by: MOFFATT & NICHOL

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DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING



NOTES - PHASE 2:

1. THIS CONCEPT PHASING PLAN REPRESENTS ONE POSSIBLE CONFIGURATION THE CONTRACTOR COULD UTILIZE TO ESTABLISH IN-THE-DRY CONDITIONS TO CONSTRUCT THE SILL, PIERS, GATES, AND BALANCE OF SUPERSTRUCTURE. ACTUAL PHASING PROGRESSION, EXTENTS, AND INTERFACES SHALL BE DETERMINED BY THE FINAL DESIGN OF THE SURGE BARRIER AND CONTRACTOR'S COFFERDAM SYSTEM.

2. EXISTING SHORELINE STRUCTURES AND OBSTRUCTIONS TO BE REMOVED SHALL BE DETERMINED DURING DETAILED DESIGN.

A1 / S-103 PLAN - STORM SURGE BARRIER - VERTICAL LIFT GATE - PHASE 2
SCALE: 1" = 80'

80' 0' 80' 160'
SCALE: 1"=80'

PRELIMINARY - CONCEPT LEVEL

Mark	Description	Date	Appr
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01	PPC LIFT GATE DRAFT - CLIENT REVIEW	10-26-2022	MK

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
VERTICAL LIFT GATE CONCEPT DESIGN
BOSTON, MA

PLAN - STORM SURGE BARRIER
VERTICAL LIFT GATE - PHASE 2

Designed by: NBJ
Drawn by: M&N BAL
Checked by: JCS
Reviewed by: MK
Submitted by: MOFFATT & NICHOL
Date: 2022-11-21
M&N Project No.: 11167
Drawing scale:
Plot scale: 1:1 (D SHEET)
Rev: -

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S-103
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DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING



NOTES - PHASE 3:

1. THIS CONCEPT PHASING PLAN REPRESENTS ONE POSSIBLE CONFIGURATION THE CONTRACTOR COULD UTILIZE TO ESTABLISH IN-THE-DRY CONDITIONS TO CONSTRUCT THE SILL, PIERS, GATES, AND BALANCE OF SUPERSTRUCTURE. ACTUAL PHASING PROGRESSION, EXTENTS, AND INTERFACES SHALL BE DETERMINED BY THE FINAL DESIGN OF THE SURGE BARRIER AND CONTRACTOR'S COFFERDAM SYSTEM.
2. EXISTING SHORELINE STRUCTURES AND OBSTRUCTIONS TO BE REMOVED SHALL BE DETERMINED DURING DETAILED DESIGN.

A1 / S-104 PLAN - STORM SURGE BARRIER - VERTICAL LIFT GATE - PHASE 3
SCALE: 1" = 80'

80' 0' 80' 160'
SCALE: 1"=80'

PRELIMINARY - CONCEPT LEVEL

Mark	Description	Date	Appr
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01	PPC LIFT GATE DRAFT - CLIENT REVIEW	10-26-2022	MK

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
VERTICAL LIFT GATE CONCEPT DESIGN
BOSTON, MA

PLAN - STORM SURGE BARRIER
VERTICAL LIFT GATE - PHASE 3

Date: 2022-11-21 | Rev: -
M&N Project No.: 11167
Drawing scale:
Plot scale: 1:1 (D SHEET)
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Drawing Scale:

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S-104
INDEX: 4 OF 10

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DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING



A1
S-105
PLAN - STORM SURGE BARRIER - VERTICAL LIFT GATE - PHASE 4
SCALE: 1" = 80'

NOTES - PHASE 4:

1. THIS CONCEPT PHASING PLAN REPRESENTS ONE POSSIBLE CONFIGURATION THE CONTRACTOR COULD UTILIZE TO ESTABLISH IN-THE-DRY CONDITIONS TO CONSTRUCT THE SILL, PIERS, GATES, AND BALANCE OF SUPERSTRUCTURE. ACTUAL PHASING PROGRESSION, EXTENTS, AND INTERFACES SHALL BE DETERMINED BY THE FINAL DESIGN OF THE SURGE BARRIER AND CONTRACTOR'S COFFERDAM SYSTEM.
2. EXISTING SHORELINE STRUCTURES AND OBSTRUCTIONS TO BE REMOVED SHALL BE DETERMINED DURING DETAILED DESIGN.

80' 0' 80' 160'
SCALE: 1"=80'

PRELIMINARY - CONCEPT LEVEL

Mark	Description	Date	Appr
02	PPC FLAP GATE DRAFT - CLIENT REVIEW	11-21-2022	MK
01	PPC LIFT GATE DRAFT - CLIENT REVIEW	10-26-2022	MK

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
VERTICAL LIFT GATE CONCEPT DESIGN
BOSTON, MA

PLAN - STORM SURGE BARRIER
VERTICAL LIFT GATE - PHASE 4

Designed by: NBJ
Drawn by: M&N BAL
Checked by: MK
Submitted by: MOFFATT & NICHOL
Cad by: JCS
M&N Project No. 11167
Drawing code:
Drawing Scale: Plot scale: 1:1 (0 SHEET)
Date: 2022-11-21
Rev: -

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180 WELLS AVE, SUITE #302
NEWTON, MA 02459
moffatt & nichol

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Sheet
Reference No.
S-105
INDEX: 5 OF 10

DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING

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NOTES - PHASE 5:

1. THIS CONCEPT PHASING PLAN REPRESENTS ONE POSSIBLE CONFIGURATION THE CONTRACTOR COULD UTILIZE TO ESTABLISH IN-THE-DRY CONDITIONS TO CONSTRUCT THE SILL, PIERS, GATES, AND BALANCE OF SUPERSTRUCTURE. ACTUAL PHASING PROGRESSION, EXTENTS, AND INTERFACES SHALL BE DETERMINED BY THE FINAL DESIGN OF THE SURGE BARRIER AND CONTRACTOR'S COFFERDAM SYSTEM.
2. EXISTING SHORELINE STRUCTURES AND OBSTRUCTIONS TO BE REMOVED SHALL BE DETERMINED DURING DETAILED DESIGN.

A1 / S-105 PLAN - STORM SURGE BARRIER - VERTICAL LIFT GATE - PHASE 5
SCALE: 1" = 80'

80' 0' 80' 160'
SCALE: 1"=80'

PRELIMINARY - CONCEPT LEVEL

Mark	Description	Date	Appr
02	PPC FLAP GATE DRAFT - CLIENT REVIEW	11-21-2022	MK
01	PPC LIFT GATE DRAFT - CLIENT REVIEW	10-26-2022	MK

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
VERTICAL LIFT GATE CONCEPT DESIGN
BOSTON, MA

PLAN - STORM SURGE BARRIER
VERTICAL LIFT GATE - PHASE 5

Designed by: NBJ
Drawn by: M&N BAL
Checked by: JCS
Reviewed by: MK
Submitted by: MOFFATT & NICHOL
Date: 2022-11-21
M&N Project No.: 11167
Drawing code:
Drawing Scale:
Plot scale: 1:1 (D SHEET)
Rev: -

MOFFATT & NICHOL
180 WELLS AVE, SUITE #302
NEWTON, MA 02459
moffatt & nichol

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Sheet Reference No.
S-106
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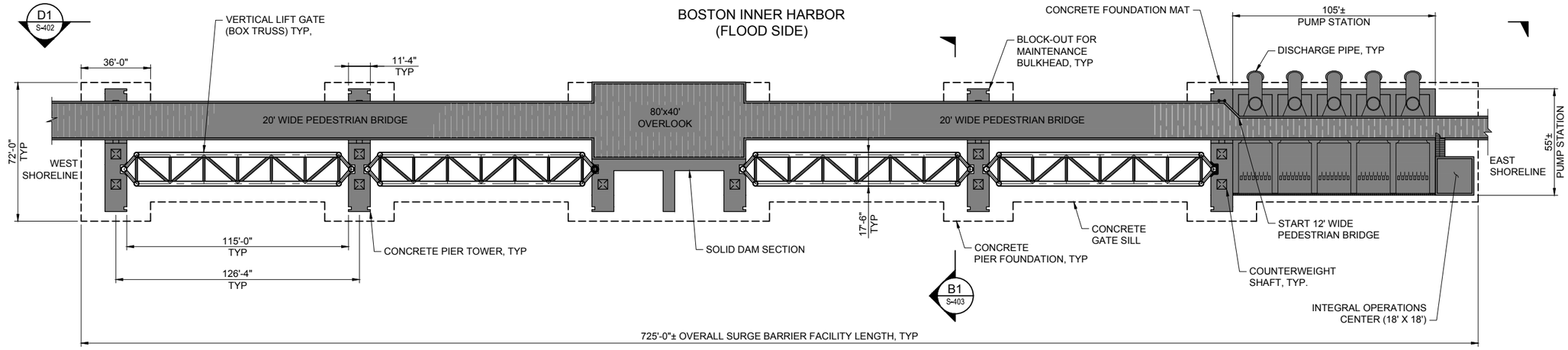
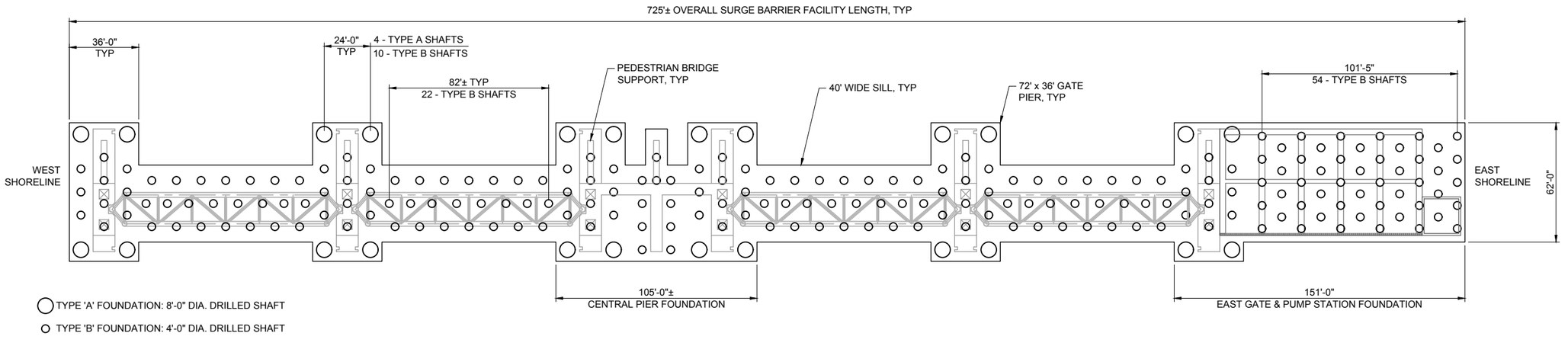
DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING



D1 S-401 PLAN - TOP SURFACE - VERTICAL LIFT GATE STORM SURGE BARRIER
SCALE: 1" = 30'



B1 S-401 PLAN - FOUNDATION - VERTICAL LIFT GATE STORM SURGE BARRIER
SCALE: 1" = 30"

30' 0' 30' 60'
SCALE: 1"=30'

PRELIMINARY - CONCEPT LEVEL

Mark	Description	Date	Appr
02	FPC FLAP GATE DRAFT - CLIENT REVIEW	11-21-2022	MK
01	FPC LIFT GATE DRAFT - CLIENT REVIEW	10-26-2022	MK

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
VERTICAL LIFT GATE CONCEPT DESIGN
BOSTON, MA

DETAIL - VERTICAL LIFT GATE SURGE BARRIER

MOFFATT & NICHOL
180 WELLS AVE, SUITE #302
NEWTON, MA 02459

Designed by:	NBJ
Drawn by:	M&N BAL
Checked by:	JCS
Reviewed by:	MK
Submitted by:	MOFFATT & NICHOL
Date:	2022-11-21
M&N Project No.	11167
Drawing code:	
Drawing Scale:	
Plot scale:	1:1 (D SHEET)
Rev.	-

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Reference No.
S-401
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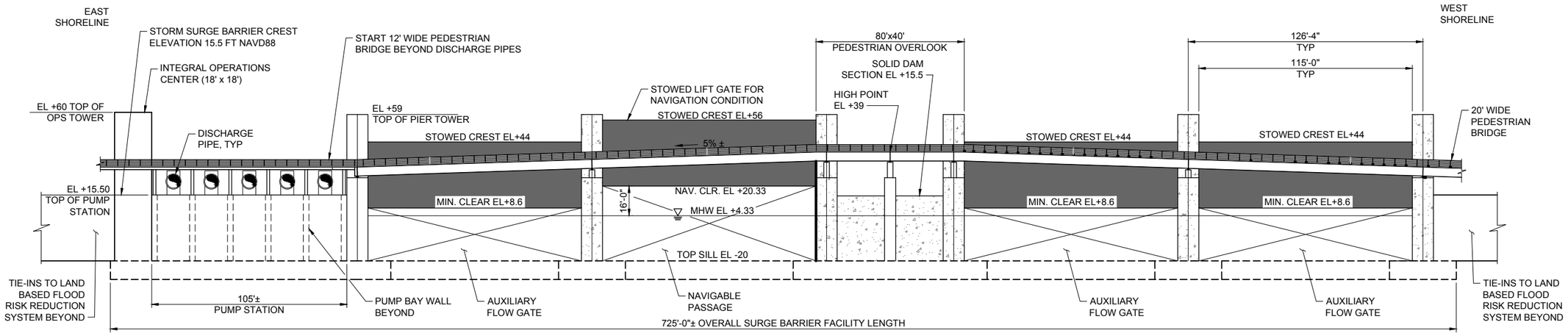

D1 / S-401 ELEVATION - VERTICAL LIFT GATE STORM SURGE BARRIER - LOOKING TOWARDS FPC

SCALE: 1" = 30'

NOTE:

1. SHORELINE INTERFACES, TRANSITIONS, AND TIE-INS SHALL BE DETERMINED DURING DETAILED DESIGN.

30' 0' 30' 60'

SCALE: 1"=30'

PRELIMINARY - CONCEPT LEVEL

No.	Description	Date	Appr
02	FPC FLAP GATE DRAFT - CLIENT REVIEW	11-21-2022	MK
01	FPC LIFT GATE DRAFT - CLIENT REVIEW	10-26-2022	MK
Mark			

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
VERTICAL LIFT GATE CONCEPT DESIGN
BOSTON, MA

ELEVATION - VERTICAL LIFT GATE
SURGE BARRIER - LOOKING TOWARD FP

MOFFATT & NICHOL
180 WELLS AVE, SUITE #302
NEWTON, MA 02459
moffatt & nichol

Designed by: NBJ	Date: 2022-11-21
Drwn by: M&N BAL	Qcd by: JCS
Reviewed by: MK	M&N Project No. 11167
Submitted by: MOFFATT & NICHOL	Drawing code:
	Drawing Scale: Plot scale: 1:1 (D SHEET)
	Rev: -

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Sheet Reference No.
S-402
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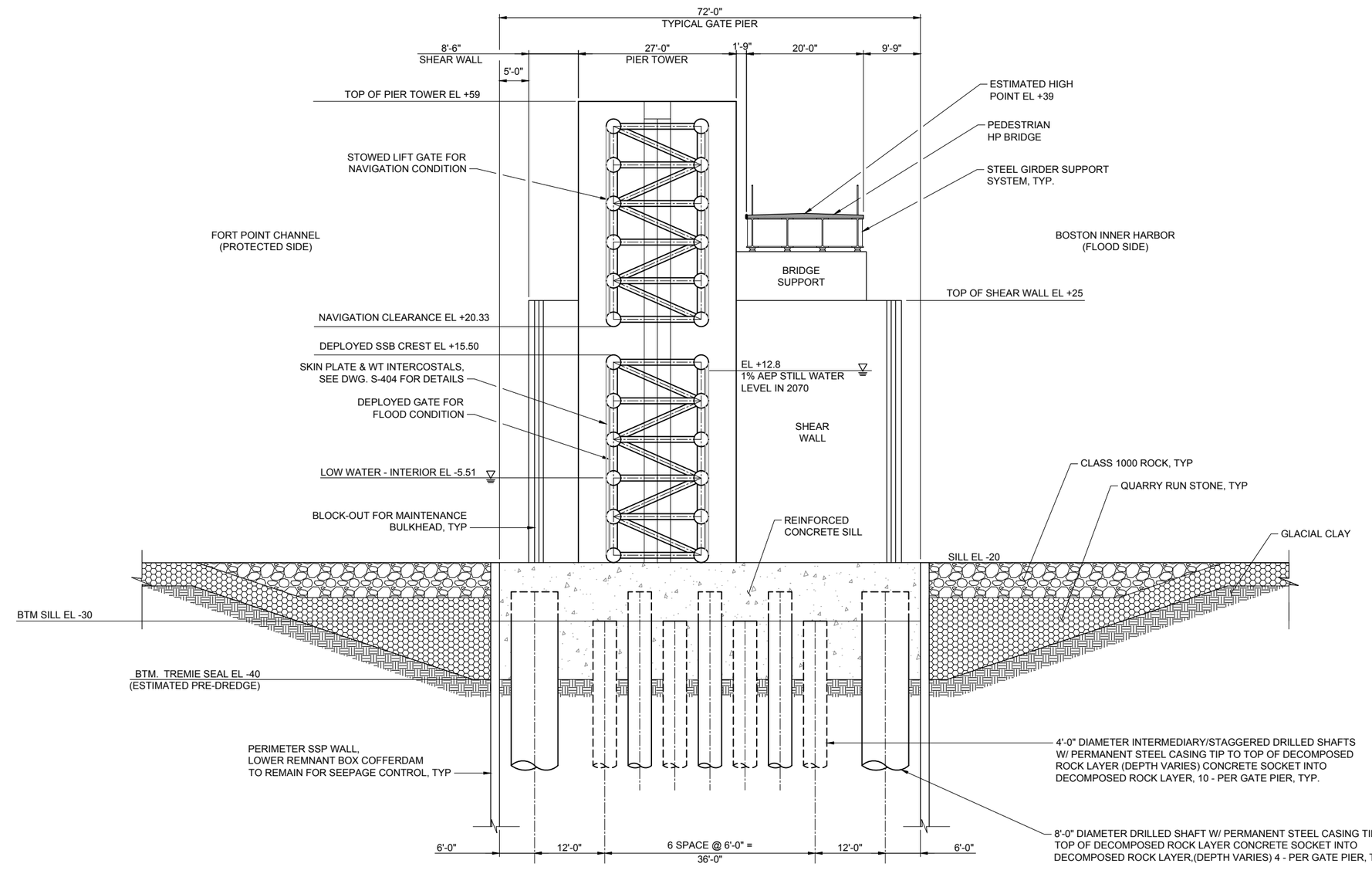
DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING



B1 / S-403 SECTION - VERTICAL LIFT GATE PIER

SCALE: 1" = 10'

10'-0" 0'-0" 10'-0" 20'-0"

SCALE: 1"=10'

PRELIMINARY - CONCEPT LEVEL

No.	Mark	Description	Date	Appr
02		FPC FLAP GATE DRAFT - CLIENT REVIEW	11-21-2022	MK
01		FPC LIFT GATE DRAFT - CLIENT REVIEW	10-26-2022	MK

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
VERTICAL LIFT GATE CONCEPT DESIGN
BOSTON, MA

DETAIL - VERTICAL LIFT GATE

Designed by: NBJ
Drawn by: M&N BAL
Checked by: JCS
Reviewed by: MK
Submitted by: MOFFATT & NICHOL
Date: 2022-11-21
M&N Project No. 11167
Drawing code:
Drawing Scale:
Plot scale: 1:1 (D SHEET)
Rev: -

MOFFATT & NICHOL
180 WELLS AVE, SUITE #302
NEWTON, MA 02459

SEAL

Sheet Reference No.
S-403
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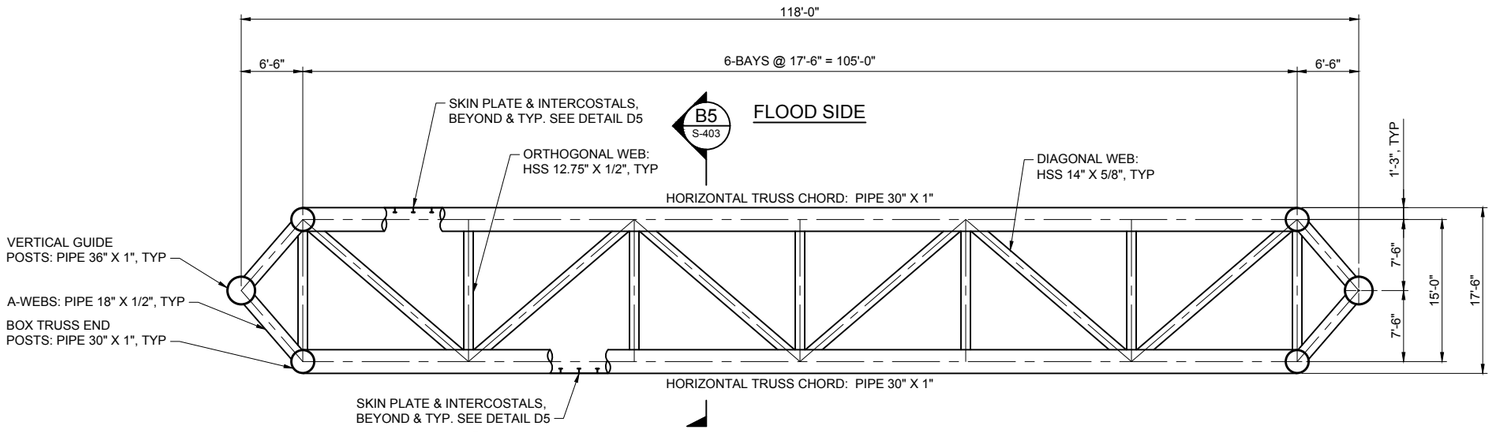
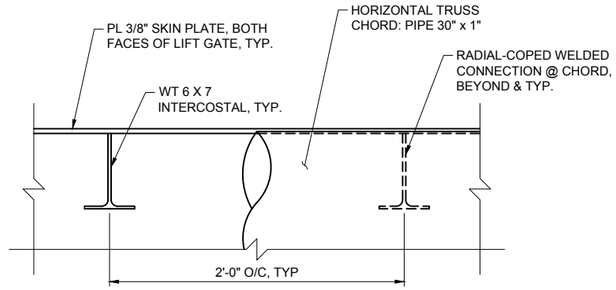
File: Q:\BOS\Projects\11167 BWSC\500_CADD_Active_Exhibits\11167005-403 - Plotted: 11/21/2022 3:47 PM by MOYA IGLESIAS, CRISTIAN - Saved: 11/21/2022 2:28 PM by

DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING



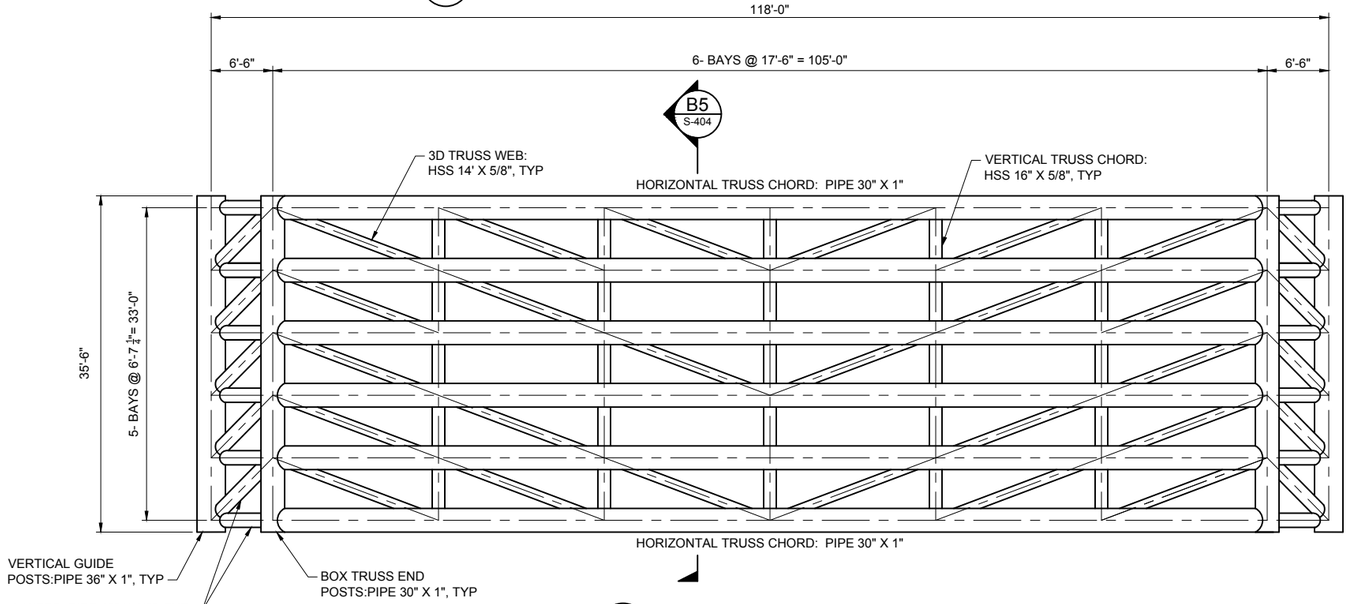
D1 S-404 PLAN - VERTICAL LIFT GATE - TYPICAL HORIZONTAL TRUSS SECTION

SCALE: 1/8" = 1'-0"



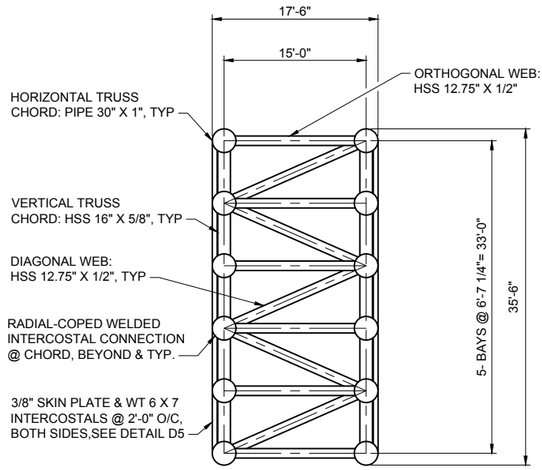
D5 S-404 DETAIL - INTERCOSTAL & SKIN PLATE

N.T.S.



B1 S-404 ELEVATION - VERTICAL LIFT GATE

SCALE: 1/8" = 1'-0"



B5 S-403 SECTION - VERTICAL LIFT GATE

SCALE: 1/8" = 1'-0"

8'-0" 0'-0" 8'-0" 16'-0"

SCALE: 1/8"=1'-0"

PRELIMINARY - CONCEPT LEVEL

Mark	Description	Date	Appr
02	PPC FLAP GATE DRAFT - CLIENT REVIEW	11-21-2022	MK
01	PPC LIFT GATE DRAFT - CLIENT REVIEW	10-26-2022	MK

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
VERTICAL LIFT GATE CONCEPT DESIGN
BOSTON, MA

MULTI VIEWS - VERTICAL LIFT GATE SURGE BARRIER

Designed by: NBJ
Drawn by: M&N BAL
Checked by: JCS
Reviewed by: MK
Submitted by: MOFFATT & NICHOL
Date: 2022-11-21
M&N Project No: 11167
Drawing scale:
Drawing Scale:
Plot scale: 1:1 (D SHEET)
Rev: -

MOFFATT & NICHOL
180 WELLS AVE, SUITE #302
NEWTON, MA 02459

moffatt & nichol

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Sheet Reference No.
S-404
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DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING

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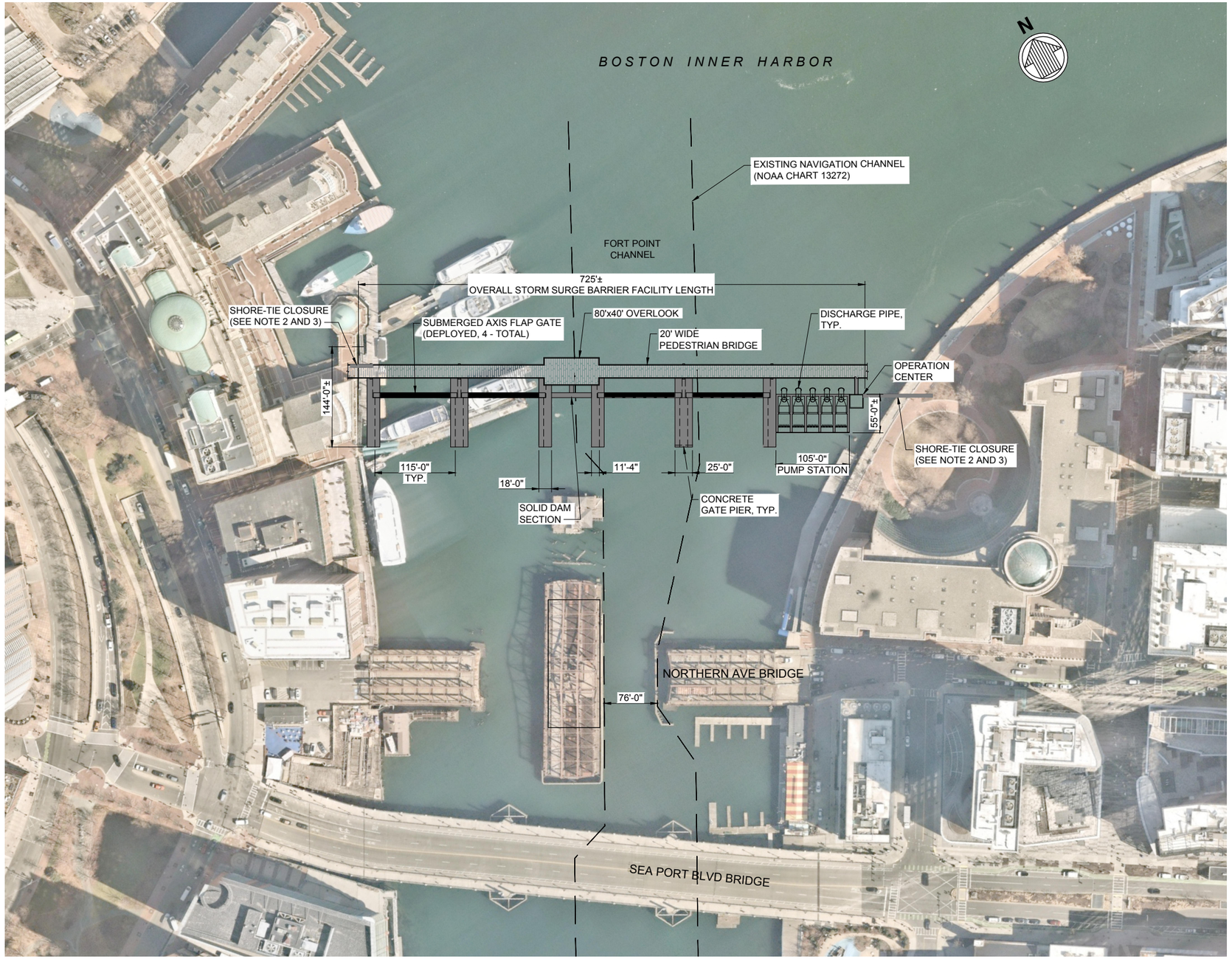
ATTACHMENT C
FORT POINT CHANNEL STORM SURGE BARRIER CONCEPTUAL DESIGN DRAWINGS
SUBMERGED AXIS FLAP GATE ALTERNATIVE

C-1: Submerged Axis Flap Gate Plan
C-2: Submerged Axis Flap Gate Phase 1 Plan
C-3: Submerged Axis Flap Gate Phase 2 Plan
C-4: Submerged Axis Flap Gate Top Surface and Foundation Plans
C-5: Submerged Axis Flap Gate Elevations
C-6: Submerged Axis Flap Gate (Stowed) Section
C-7: Submerged Axis Flap Gate (Deployed) Section
C-8: Submerged Axis Flap Gate Plan – South Location Alternative
C-9: Submerged Axis Flap Gate Phase 1 Plan – South Location Alternative
C-10: Submerged Axis Flap Gate Phase 2 Plan – South Location Alternative
C-11: Submerged Axis Flap Gate Top Surface and Foundation Plans – South Location Alternative
C-12: Submerged Axis Flap Gate Elevations – South Location Alternative
C-13: Submerged Axis Flap Gate (Stowed) Section – South Location Alternative
C-14: Submerged Axis Flap Gate (Deployed) Section – South Location Alternative



NOTES:

1. THE CONCEPT PLAN VIEWS SHOWS PORTIONS OF STORM SURGE BARRIER STRUCTURE THAT PROJECT ABOVE DAILY HIGH WATER LINE. SEE S-400 SERIES SHEETS FOR MULTIVIEWS AND DETAILS ASSOCIATED WITH BELOW WATER AND CHANNEL BED FEATURES (FOUNDATION, SCOUR PROTECTION).
2. SHORELINE INTERFACES, TRANSITIONS, AND TIE-INS SHALL BE DETERMINED DURING DETAILED DESIGN.
3. EXISTING SHORELINE STRUCTURES AND OBSTRUCTIONS TO BE REMOVED SHALL BE DETERMINED DURING DETAILED DESIGN.

A1 / S-101 PLAN - STORM SURGE BARRIER - SUBMERGED AXIS FLAP GATE ALTERNATE
SCALE: 1" = 80'

80' 0' 80' 160'
SCALE: 1"=80'

PRELIMINARY - CONCEPT LEVEL

No.	Description	Date	Appr.
02	PPC FLAP GATE DRAFT - CLIENT REVIEW	11-21-2022	MK
01	PPC FLAP GATE DRAFT - CLIENT REVIEW	10-26-2022	MK
Mark			

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
SUBMERGED AXIS FLAP GATE CONCEPT
BOSTON, MA

PLAN - STORM SURGE BARRIER - SUBMERGED AXIS FLAP GATE ALTERNATE

Date: 2022-11-21 | Rev: -
M&N Project No.: 11167
Drawing code:
Drawing Scale:
Plot scale: 1:1 (D SHEET)

Designed by: NBJ
Drawn by: CMI
Dot by: JCS
Reviewed by: MK
Submitted by: MOFFATT & NICHOL

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NEWTON, MA 02459
moffatt & nichol

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Sheet Reference No.
S-101
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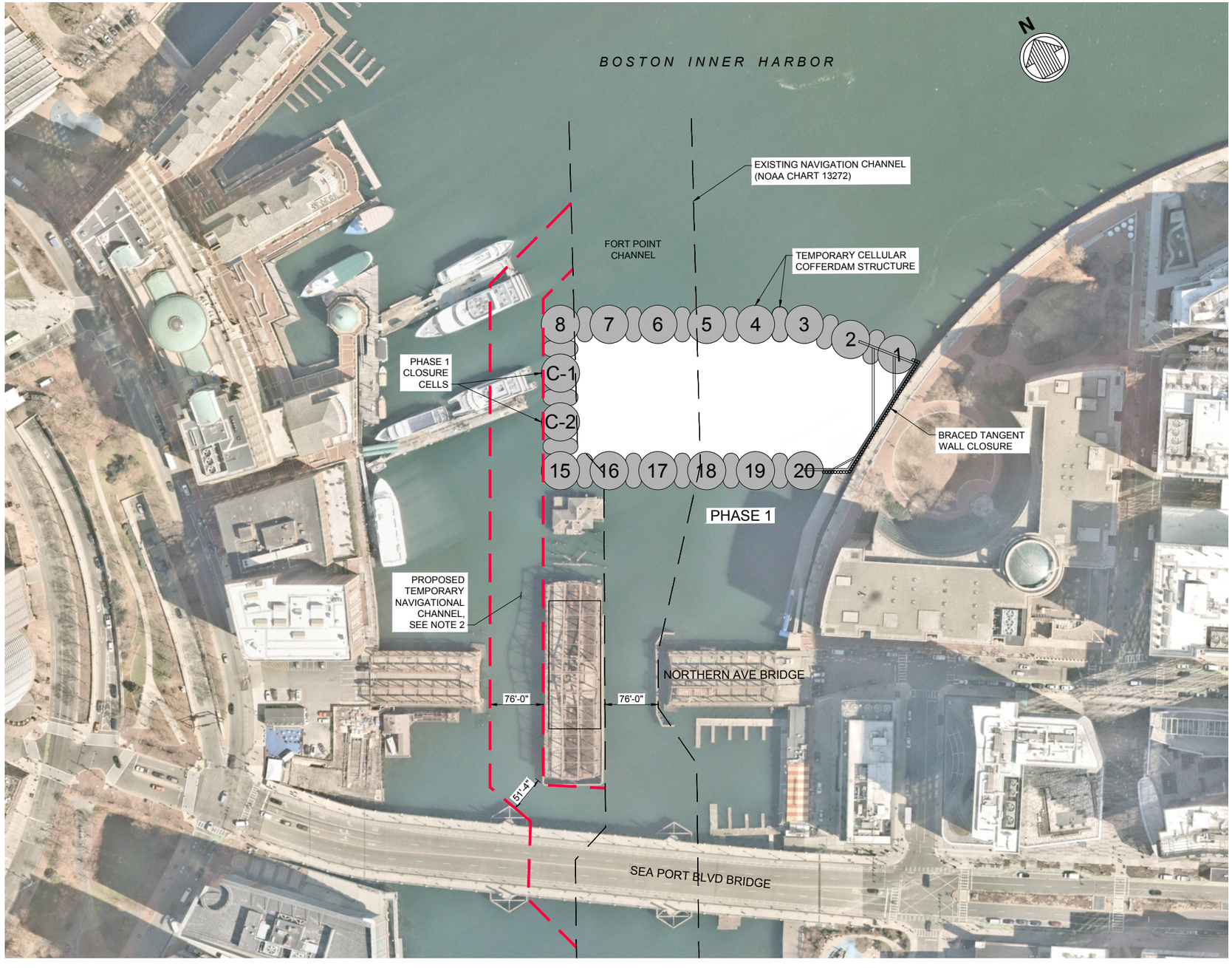
DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING



NOTES - PHASE 1:

1. THIS CONCEPT PHASING PLAN REPRESENTS ONE POSSIBLE CONFIGURATION THE CONTRACTOR COULD UTILIZE TO ESTABLISH IN-THE-DRY CONDITIONS TO CONSTRUCT THE SILL, PIERS, GATES, AND BALANCE OF SUPERSTRUCTURE. ACTUAL PHASING PROGRESSION, EXTENTS, AND INTERFACES SHALL BE DETERMINED BY THE FINAL DESIGN OF THE SURGE BARRIER AND CONTRACTOR'S COFFERDAM SYSTEM.
2. CONTRACTOR SHALL DREDGE TEMPORARY NAVIGATION CHANNEL AND PROVIDE TEMPORARY NAVIGATION AIDS PRIOR TO CONSTRUCTING PHASE 1 COFFERDAM.

A1 / S-102 PLAN - STORM SURGE BARRIER - SUBMERGED AXIS FLAP GATE ALTERNATE - PHASE 1
SCALE: 1" = 80'

80' 0' 80' 160'
SCALE: 1"=80'

PRELIMINARY - CONCEPT LEVEL

No.	Description	Date	Appr.
02	PPC FLAP GATE DRAFT - CLIENT REVIEW	11-21-2022	MK
01	PPC FLAP GATE DRAFT - CLIENT REVIEW	10-26-2022	MK
Mark			

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
SUBMERGED AXIS FLAP GATE CONCEPT
BOSTON, MA

PLAN - STORM SURGE BARRIER
SUBMERGED AXIS FLAP GATE -
PHASE 1

MOFFATT & NICHOL
180 WELLS AVE, SUITE #302
NEWTON, MA 02459
moffatt & nichol

Designed by: NBJ
Drawn by: CMI
Checked by: JCS
Reviewed by: MK
Submitted by: MOFFATT & NICHOL
Date: 2022-11-21
M&N Project No. 11167
Drawing code:
Drawing Scale:
Plot scale: 1:1 (D SHEET)
Rev: -

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Sheet Reference No.
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DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING

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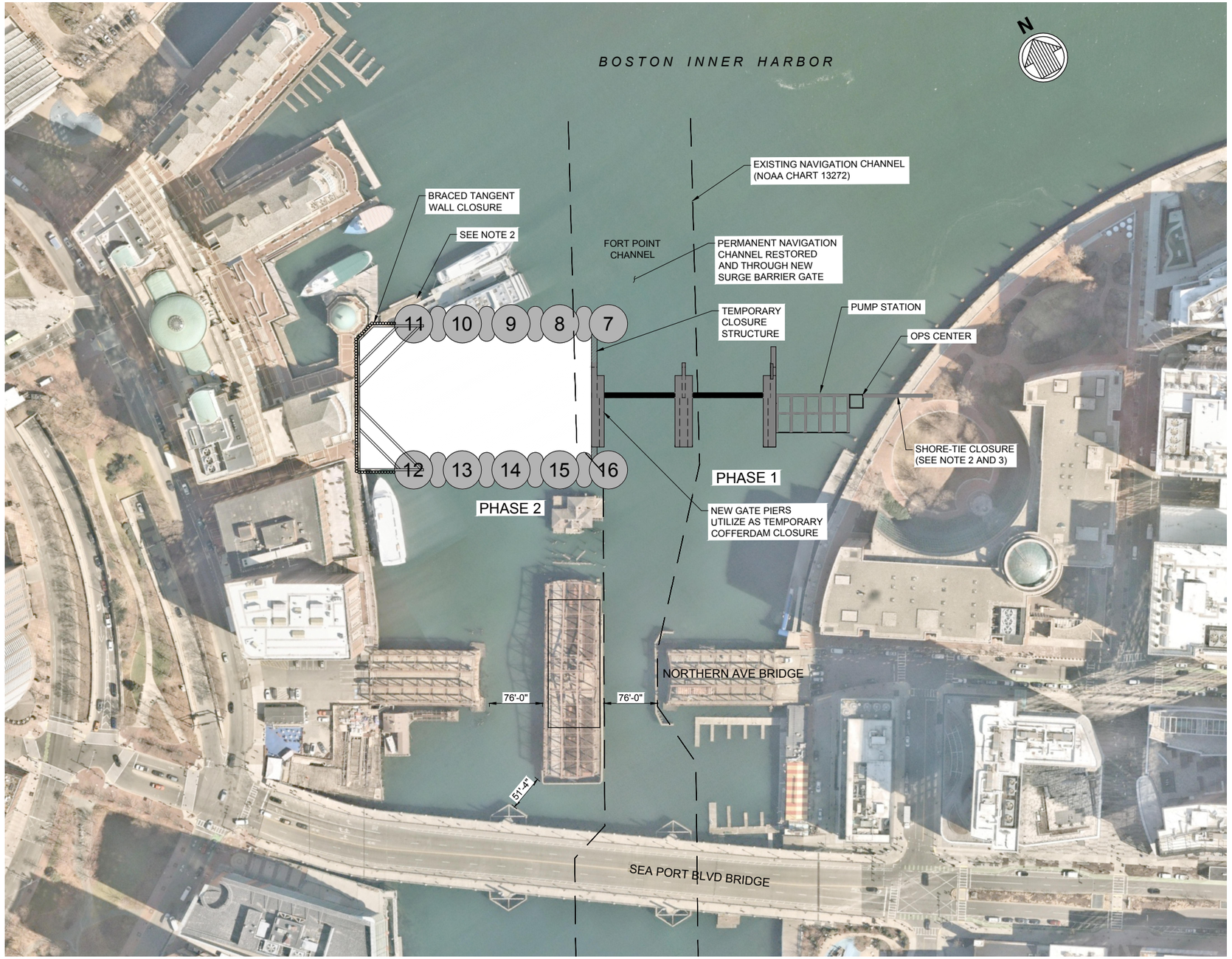

NOTES - PHASE 2:

1. THIS CONCEPT PHASING PLAN REPRESENTS ONE POSSIBLE CONFIGURATION THE CONTRACTOR COULD UTILIZE TO ESTABLISH IN-THE-DRY CONDITIONS TO CONSTRUCT THE SILL, PIERS, GATES, AND BALANCE OF SUPERSTRUCTURE. ACTUAL PHASING PROGRESSION, EXTENTS, AND INTERFACES SHALL BE DETERMINED BY THE FINAL DESIGN OF THE SURGE BARRIER AND CONTRACTOR'S COFFERDAM SYSTEM.
2. SHORELINE INTERFACES, TRANSITIONS, AND TIE-INS SHALL BE DETERMINED DURING DETAILED DESIGN.
3. EXISTING SHORELINE STRUCTURES AND OBSTRUCTIONS TO BE REMOVED SHALL BE DETERMINED DURING DETAILED DESIGN .

A1 / S-103 PLAN - STORM SURGE BARRIER - SUBMERGED AXIS FLAP GATE ALTERNATE - PHASE 2
SCALE: 1" = 80'

80' 0' 80' 160'
SCALE: 1"=80'

PRELIMINARY - CONCEPT LEVEL

No.	Description	Date	Appr.
02	PPC FLAP GATE DRAFT - CLIENT REVIEW	11-21-2022	MK
01	PPC FLAP GATE DRAFT - CLIENT REVIEW	10-26-2022	MK
Mark			

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
SUBMERGED AXIS FLAP GATE CONCEPT
BOSTON, MA

PLAN - STORM SURGE BARRIER
SUBMERGED AXIS FLAP GATE -
PHASE 2

Date: 2022-11-21 | Rev: -
M&N Project No.: 11167
Drawing code:
Drawing Scale:
Plot scale: 1:1 (D SHEET)
Designed by: NBJ
Drawn by: CMI | Det by: JCS
Reviewed by: MK
Submitted by: MOFFATT & NICHOL

MOFFATT & NICHOL
180 WELLS AVE, SUITE #302
NEWTON, MA 02459
moffatt & nichol

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Sheet Reference No.
S-103
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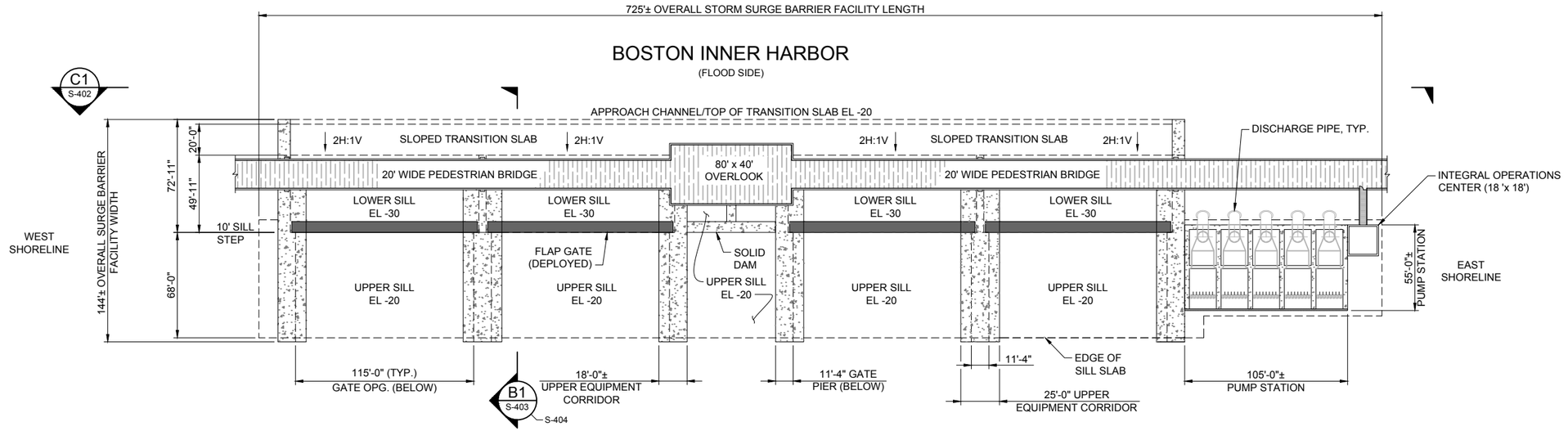
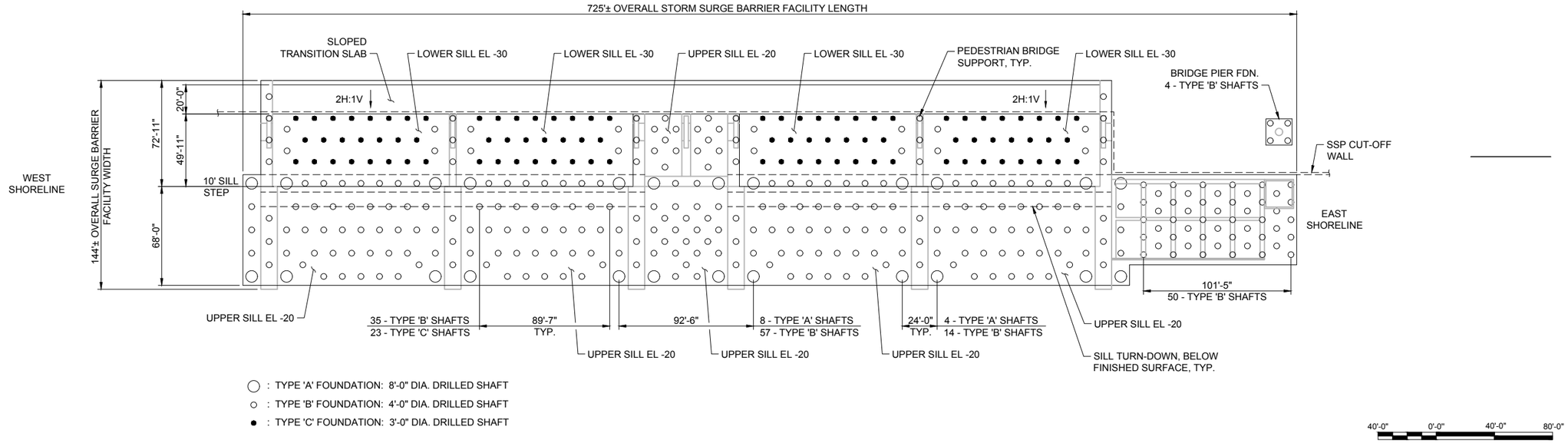
DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING



C1 / S-401 PLAN - TOP SURFACE - SUBMERGED AXIS FLAP GATE STORM SURGE BARRIER
SCALE: 1" = 40'



A1 / S-401 PLAN - FOUNDATION - SUBMERGED AXIS FLAP GATE STORM SURGE BARRIER
SCALE: 1" = 40'

40'-0" 0'-0" 40'-0" 80'-0"
SCALE: 1"=40'

PRELIMINARY - CONCEPT LEVEL

No.	Description	Date	Appr.
02	PPC FLAP GATE DRAFT - CLIENT REVIEW	11-21-2022	MK
01	PPC FLAP GATE DRAFT - CLIENT REVIEW	10-26-2022	MK
-	Kiosk		

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
SUBMERGED AXIS FLAP GATE CONCEPT
BOSTON, MA

PLAN VIEWS - STORM SURGE BARRIER - SUBMERGED AXIS FLAP GATE

Designed by: NBJ
Drawn by: CMI
Checked by: JCS
Reviewed by: MK
Submitted by: MOFFATT & NICHOL
Date: 2022-11-21
M&N Project No. 11167
Drawing code:
Drawing Scale:
Plot scale: 1:1 (D SHEET)
Rev. -

MOFFATT & NICHOL
180 WELLS AVE, SUITE #302
NEWTON, MA 02459

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Sheet Reference No.
S-401
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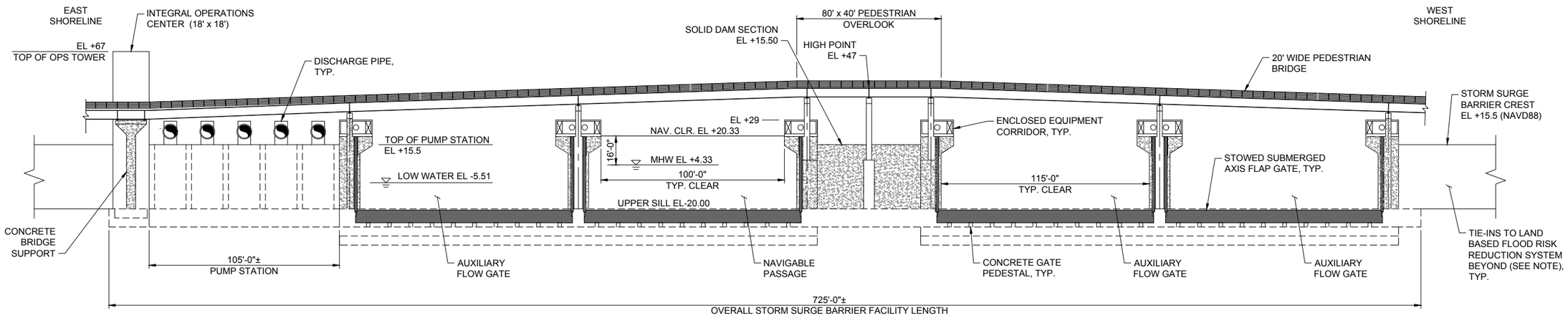
DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING



C1 S-401 ELEVATION - SUBMERGED AXIS FLAP GATE STORM SURGE BARRIER - LOOKING TOWARDS FPC (GATES IN STOWED POSITION)
SCALE: 1 = 30

NOTE:

1. SHORELINE INTERFACES, TRANSITIONS, AND TIE-INS SHALL BE DETERMINED DURING DETAILED DESIGN.

30'-0" 0'-0" 30'-0" 60'-0"
SCALE: 1"=30'

PRELIMINARY - CONCEPT LEVEL

Mark	Description	Date	Appr.
02	FPC FLAP GATE DRAFT - CLIENT REVIEW	11-21-2022	MK
01	FPC FLAP GATE DRAFT - CLIENT REVIEW	10-26-2022	MK

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
SUBMERGED AXIS FLAP GATE CONCEPT
BOSTON, MA

ELEVATION - STORM SURGE BARRIER - SUBMERGED AXIS FLAP GATE

Designed by: NBJ
Dwn by: CMI
Ckd by: JCS
Reviewed by: MK
Submitted by: MOFFATT & NICHOL
Date: 2022-11-21
Rev. -
M&N Project No. 11167
Drawing code:
Drawing Scale:
Plot scale: 1:1 (D SHEET)

moffatt & nichol
MOFFATT & NICHOL
180 WELLS AVE, SUITE #302
NEWTON, MA 02459

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Sheet Reference No.
S-402
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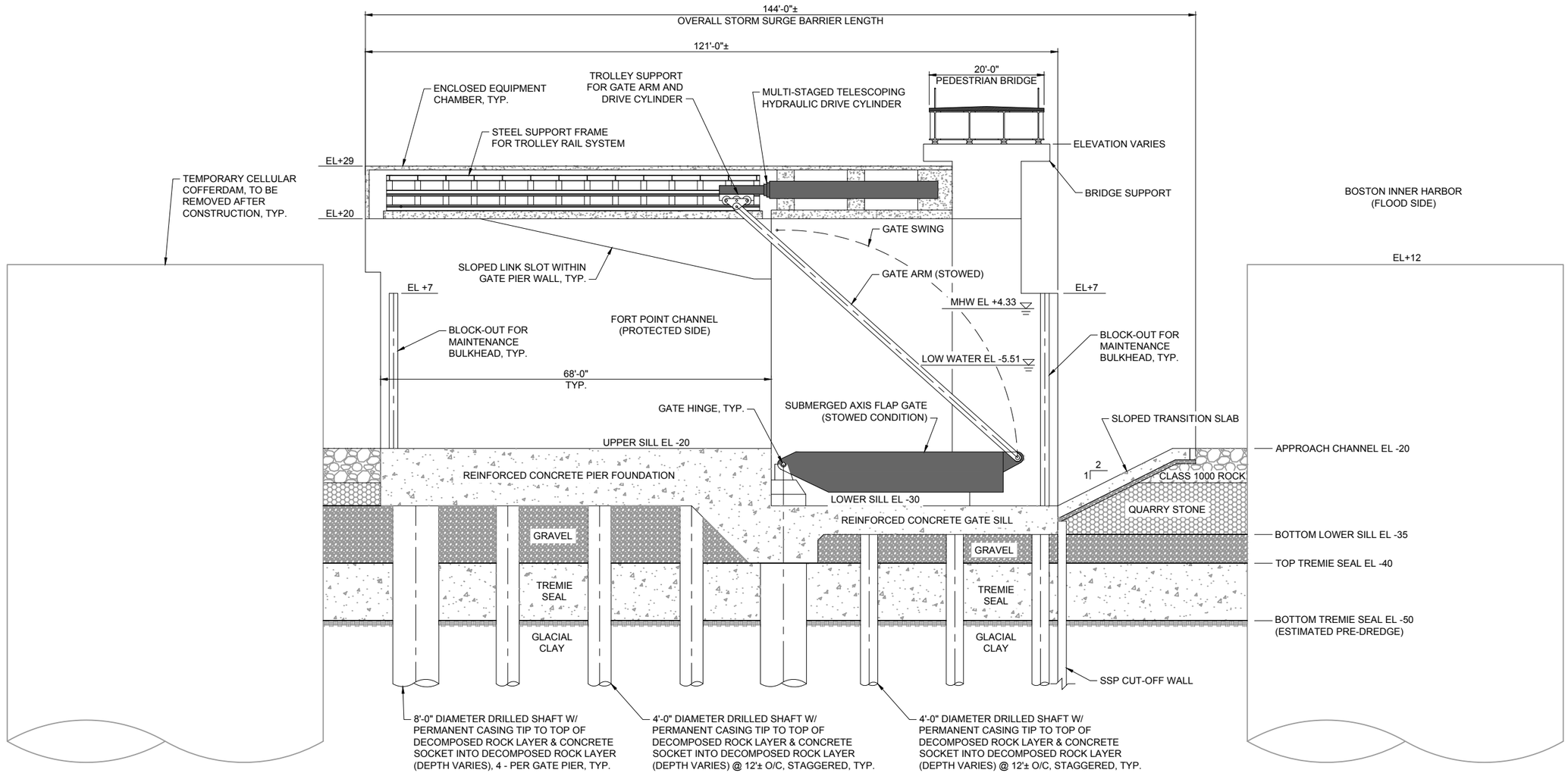
File: Q:\BOS\Projects\11167 BWSC\500_CADD_Active_Exhibits\Flap Gate\11167015-402 ; Plotted: 11/21/2022 2:51 PM by MOYA IGLESIAS, CRISTIAN ; Saved: 10/26/2022 10:15 PM by CMOYAIGLESIAS

DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING



B1 / S-401 SECTION - SUBMERGED AXIS FLAP GATE STORM SURGE BARRIER (STOWED)
SCALE: 1" = 10'

10'-0" 0'-0" 10'-0" 20'-0"
SCALE: 1"=10'

PRELIMINARY - CONCEPT LEVEL

No.	Mark	Description	Date	Appr.
02	PPC FLAP GATE DRAFT - CLIENT REVIEW		11-21-2022	MK
01	PPC FLAP GATE DRAFT - CLIENT REVIEW		10-26-2022	MK

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
SUBMERGED AXIS FLAP GATE CONCEPT
BOSTON, MA

SECTION - STORM SURGE BARRIER - SUBMERGED AXIS FLAP GATE (STOWED)

Rev: -
Date: 2022-11-21
M&N Project No.: 11167
Drawing code:
Drawing Scale:
Plot scale: 1:1 (D SHEET)

Designed by: NBJ
Drawn by: CMI
Checked by: JCS
Reviewed by: MK
Submitted by: MOFFATT & NICHOL

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SEAL

Sheet Reference No.
S-403
INDEX: 6 OF 7

File: Q:\BOS\Projects\11167 BWSC\500_CADD_Active_Exhibits\Flap Gate\11167015-403 ; Plotted: 11/21/2022 2:51 PM by MOYA IGLESIAS, CRISTIAN ; Saved: 11/21/2022 2:17 PM by CMOYAIGLESIAS

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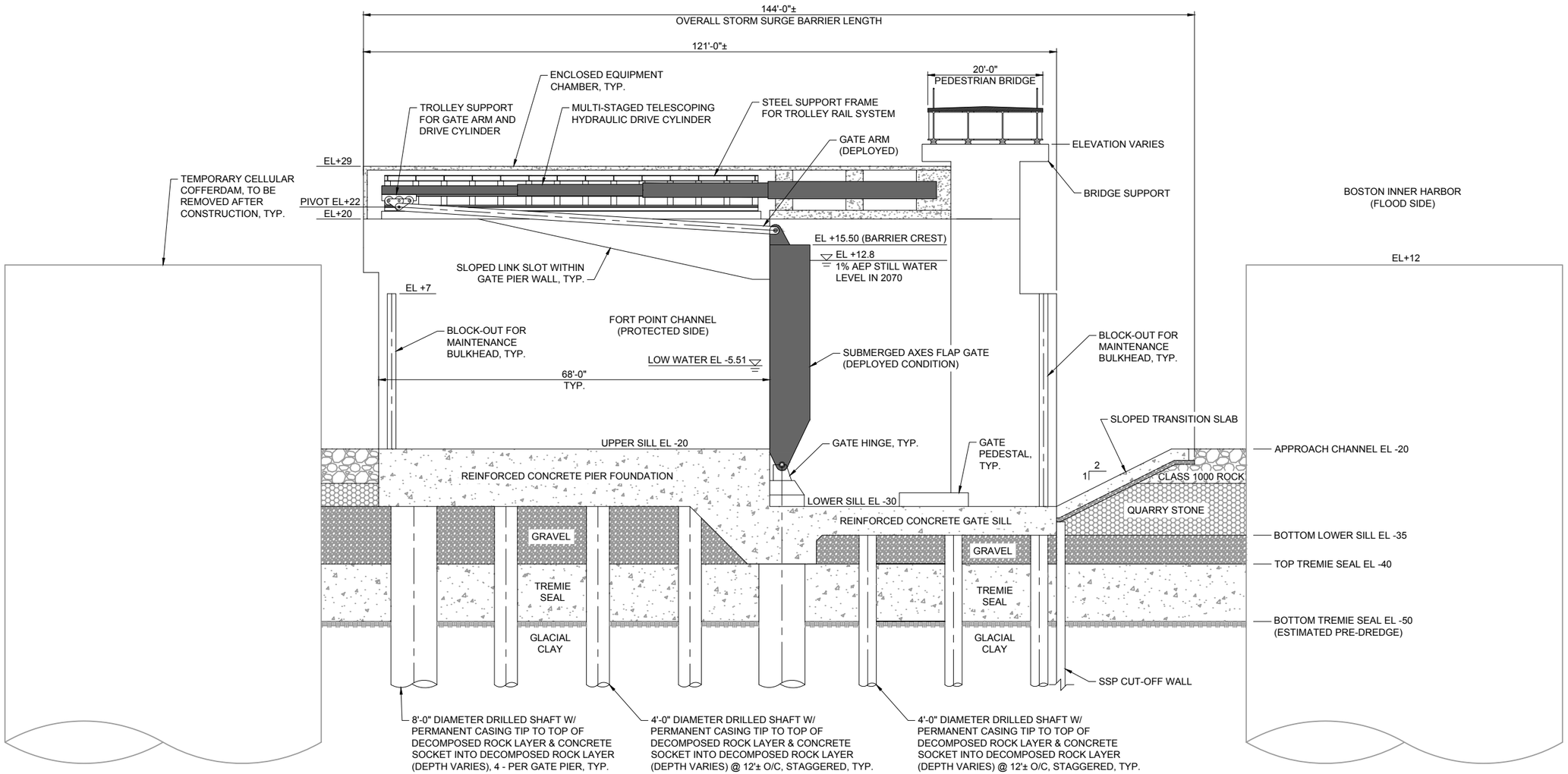

B1 / S-401 SECTION - SUBMERGED AXIS FLAP GATE STORM SURGE BARRIER (DEPLOYED)
SCALE: 1" = 10'

10'-0" 0'-0" 10'-0" 20'-0"
SCALE: 1"=10'

PRELIMINARY - CONCEPT LEVEL

No.	Description	Date	Appr.
02	FPC FLAP GATE DRAFT - CLIENT REVIEW	11-21-2022	MK
01	FPC FLAP GATE DRAFT - CLIENT REVIEW	10-26-2022	MK
Mark			

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
SUBMERGED AXIS FLAP GATE CONCEPT
BOSTON, MA

SECTION - STORM SURGE BARRIER - SUBMERGED AXIS FLAP GATE (DEPLOYED)

Rev: -
Date: 2022-11-21
M&N Project No: 11167
Drawing code:
Drawing Scale:
Plot scale: 1:1 (D SHEET)

Designed by: NBJ
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Sheet Reference No.
S-404
INDEX: 7 OF 7

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DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING



A1
S-101
PLAN - STORM SURGE BARRIER - SUBMERGED AXIS FLAP GATE - SOUTH LOCATION ALTERNATE
SCALE: 1" = 80'

NOTES:

1. THE CONCEPT PLAN VIEWS SHOWS PORTIONS OF THE STORM SURGE BARRIER STRUCTURE THAT PROJECT ABOVE DAILY HIGH WATER LINE. SEE S-400 SERIES SHEETS FOR MULTIVIEWS AND DETAILS ASSOCIATED WITH BELOW WATER AND CHANNEL BED FEATURES (FOUNDATION, SCOUR PROTECTION).
2. SHORELINE INTERFACES, TRANSITIONS, AND TIE-INS SHALL BE DETERMINED DURING DETAILED DESIGN.
3. EXISTING SHORELINE STRUCTURES AND OBSTRUCTIONS TO BE REMOVED SHALL BE DETERMINED DURING DETAILED DESIGN.

80' 0' 80' 160'
SCALE: 1"=80'

PRELIMINARY - CONCEPT LEVEL

Mark	Description	Date	Appr
01	FPC FLAP GATE (SOUTH) DRAFT - CLIENT REVIEW	12-15-2022	MK

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
SUBMERGED AXIS FLAP GATE - 3 GATE CONCEPT
BOSTON, MA

PLAN - STORM SURGE BARRIER - SUBMERGED AXIS FLAP GATE - SOUTH LOCATION ALTERNATE

Date: 2022-12-15 | Rev: -
M&N Project No.: 11167
Drawing scale:
Drawing Scale:
Plot scale: 1:1 (D SHEET)
Designed by: NBJ
Drawn by: CMI
Chkd by: JCS
Reviewed by: MK
Submitted by: MOFFATT & NICHOL

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SEAL

Sheet Reference No.
S-101
INDEX: 1 OF 7

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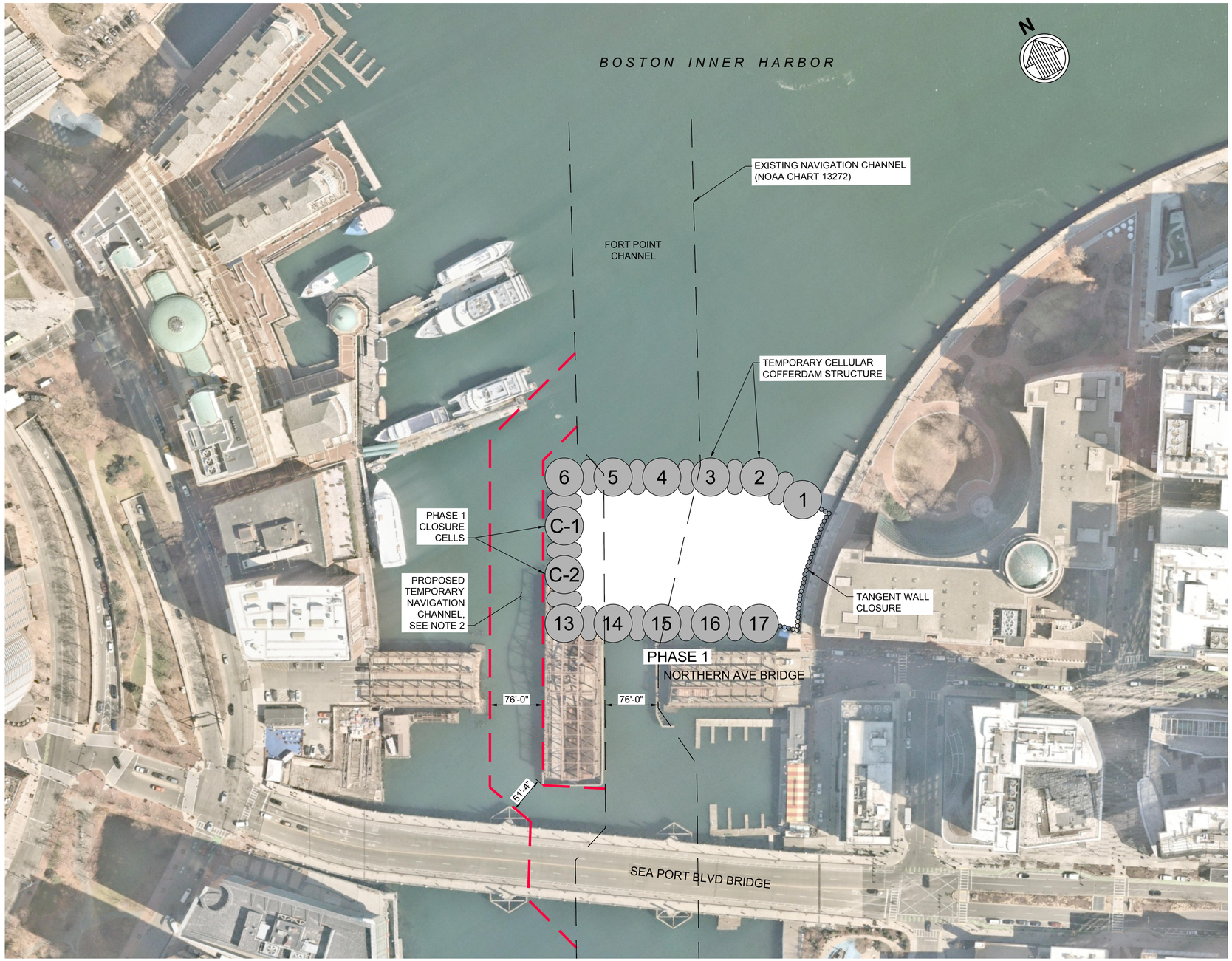
DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING



NOTES - PHASE 1:

1. THIS CONCEPT PHASING PLAN REPRESENTS ONE POSSIBLE CONFIGURATION THE CONTRACTOR COULD UTILIZE TO ESTABLISH IN-THE-DRY CONDITIONS TO CONSTRUCT THE SILL, PIERS, GATES, AND BALANCE OF SUPERSTRUCTURE. ACTUAL PHASING PROGRESSION, EXTENTS, AND INTERFACES SHALL BE DETERMINED BY THE FINAL DESIGN OF THE STORM SURGE BARRIER AND CONTRACTOR'S COFFERDAM SYSTEM.
2. CONTRACTOR SHALL DREDGE TEMPORARY NAVIGATION CHANNEL AND PROVIDE TEMPORARY NAVIGATION AIDS PRIOR TO CONSTRUCTING PHASE 1 COFFERDAM.

A1 / S-102 PLAN - STORM SURGE BARRIER - SUBMERGED AXIS FLAP GATE - SOUTH LOCATION ALTERNATE - PHASE 1
SCALE: 1" = 80'

80' 0' 80' 160'
SCALE: 1"=80'

PRELIMINARY - CONCEPT LEVEL

Mark	Description	Date	Appr
01	FPC FLAP GATE (SOUTH) DRAFT - CLIENT REVIEW	12-15-2022	MK

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
SUBMERGED AXIS FLAP GATE - 3 GATE CONCEPT
BOSTON, MA

PLAN - STORM SURGE BARRIER SUBMERGED AXIS FLAP GATE - SOUTH LOCATION ALTERNATE - PHASE 1

Designed by: NBJ
Drawn by: CMI
Cad by: JCS
Reviewed by: MK
Submitted by: MOFFATT & NICHOL
Date: 2022-12-15
M&N Project No. 11167
Drawing code:
Drawing Scale:
Plot scale: 1:1 (D SHEET)

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Sheet Reference No.
S-102
INDEX: 2 OF 7

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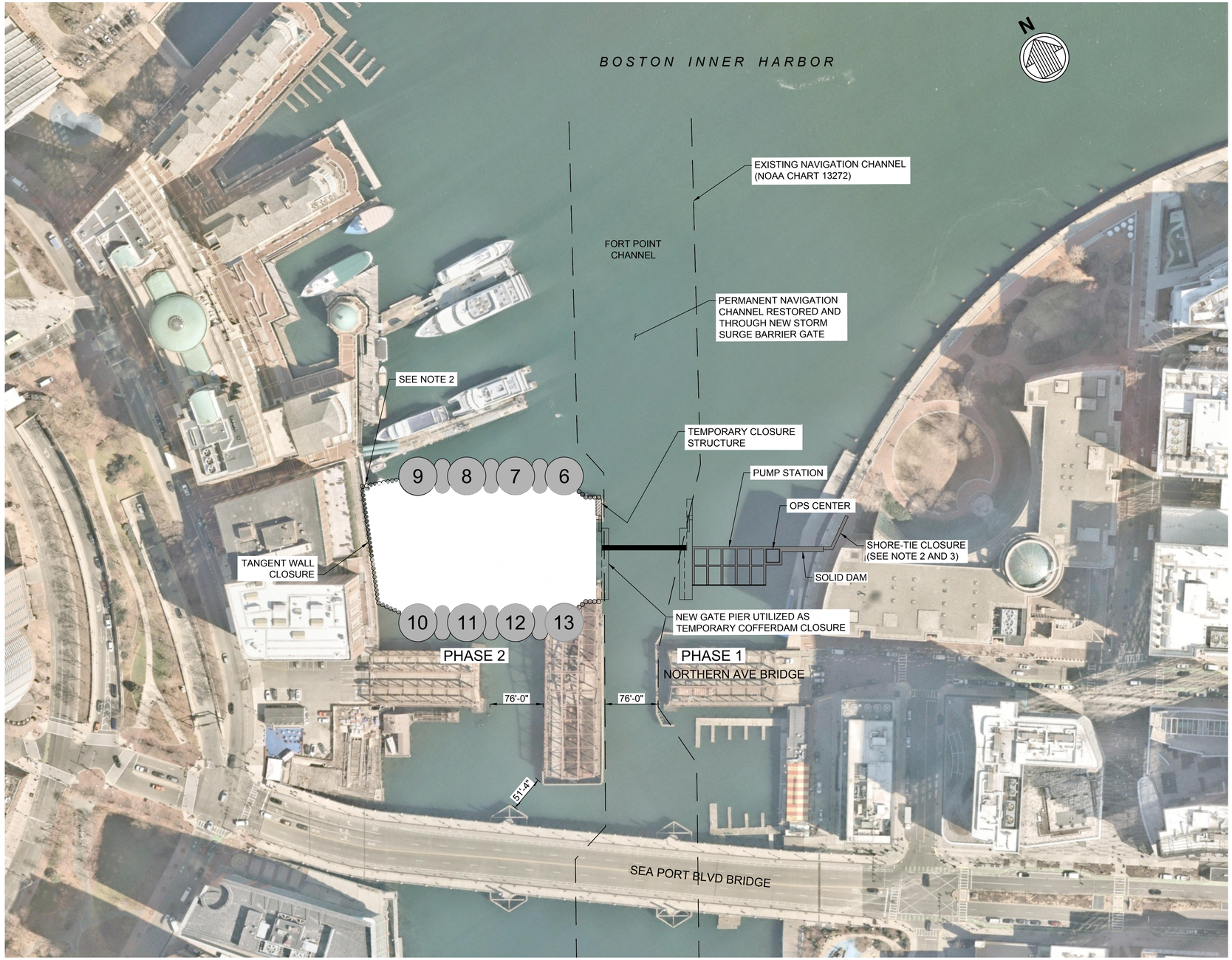
DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING



NOTES - PHASE 2:

1. THIS CONCEPT PHASING PLAN REPRESENTS ONE POSSIBLE CONFIGURATION THE CONTRACTOR COULD UTILIZE TO ESTABLISH IN-THE-DRY CONDITIONS TO CONSTRUCT THE SILL, PIERS, GATES, AND BALANCE OF SUPERSTRUCTURE. ACTUAL PHASING PROGRESSION, EXTENTS, AND INTERFACES SHALL BE DETERMINED BY THE FINAL DESIGN OF THE STORM SURGE BARRIER AND CONTRACTOR'S COFFERDAM SYSTEM.
2. SHORELINE INTERFACES, TRANSITIONS, AND TIE-INS SHALL BE DETERMINED DURING DETAILED DESIGN.
3. EXISTING SHORELINE STRUCTURES AND OBSTRUCTIONS TO BE REMOVED SHALL BE DETERMINED DURING DETAILED DESIGN .

A1 / S-103 PLAN - STORM SURGE BARRIER - SUBMERGED AXIS FLAP GATE - SOUTH LOCATION ALTERNATE - PHASE 2
SCALE: 1" = 80'

80' 0' 80' 160'
SCALE: 1"=80'

PRELIMINARY - CONCEPT LEVEL

Mark	Description	Date	Appr
01	FPC FLAP GATE (SOUTH) DRAFT - CLIENT REVIEW	12-15-2022	MK

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
SUBMERGED AXIS FLAP GATE - 3 GATE CONCEPT
BOSTON, MA

PLAN - STORM SURGE BARRIER
SUBMERGED AXIS FLAP GATE -
SOUTH LOCATION ALTERNATE -
PHASE 2

Date: 2022-12-15 | Rev: -
M&N Project No.: 11167
Drawing scale:
Drawing Scale:
Plot scale: 1:1 (D SHEET)
Designed by: NBJ | Drawn by: CMI | Chkd by: JCS
Reviewed by: MK
Submitted by: MOFFATT & NICHOL

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Sheet Reference No.
S-103
INDEX: 3 OF 7

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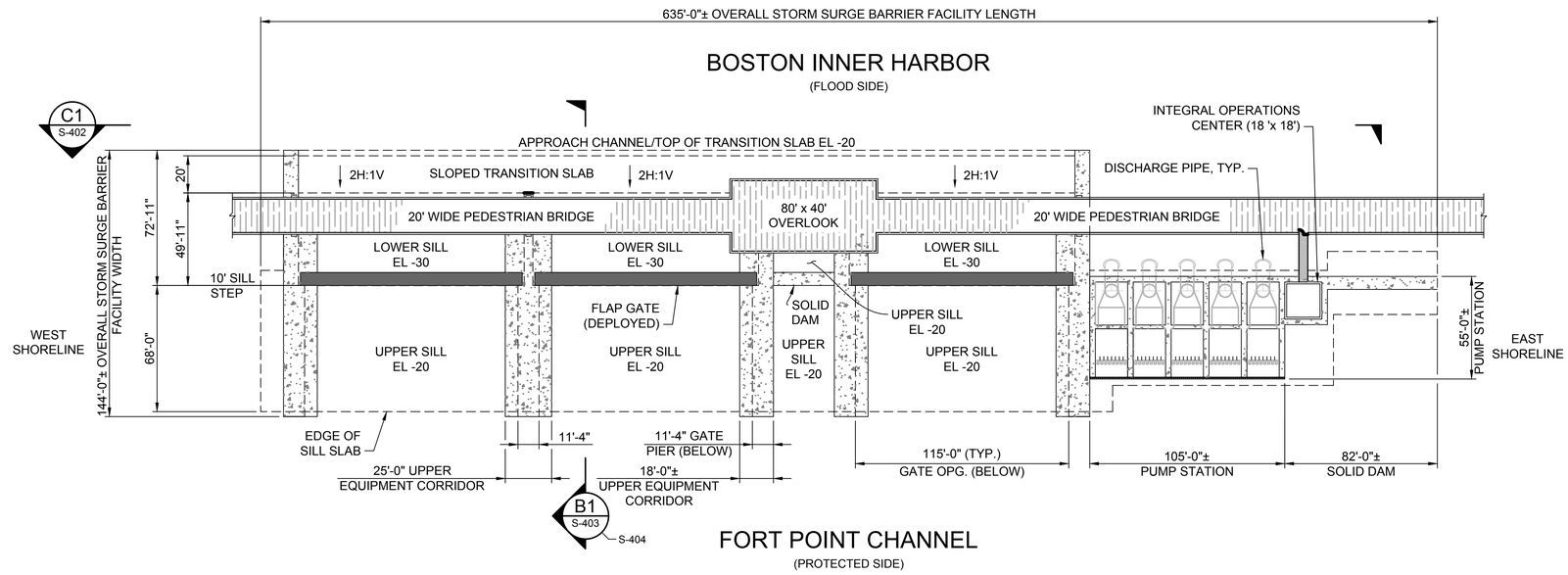
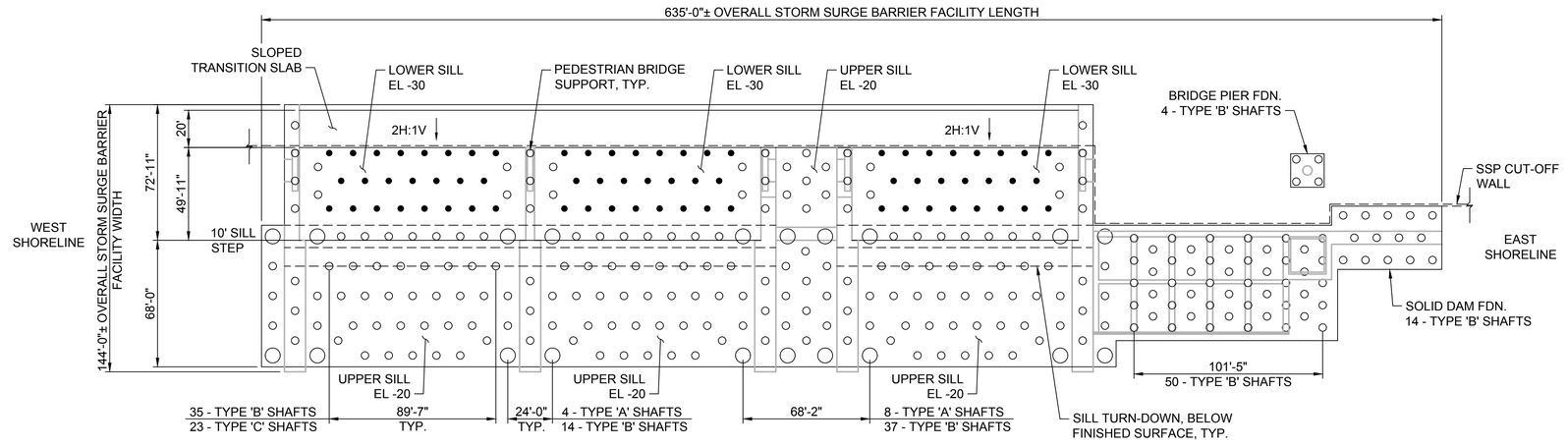
DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING



C1 S-401 PLAN - TOP SURFACE - SUBMERGED AXIS FLAP GATE STORM SURGE BARRIER - SOUTH LOCATION ALTERNATE

SCALE: 1" = 40'



◯ : TYPE 'A' FOUNDATION: 8'-0" DIA. DRILLED SHAFT

○ : TYPE 'B' FOUNDATION: 4'-0" DIA. DRILLED SHAFT

● : TYPE 'C' FOUNDATION: 3'-0" DIA. DRILLED SHAFT

A1 S-401 PLAN - FOUNDATION - SUBMERGED AXIS FLAP GATE STORM SURGE BARRIER - SOUTH LOCATION ALTERNATE

SCALE: 1" = 40'

40'-0" 0'-0" 40'-0" 80'-0"

SCALE: 1"=40'

PRELIMINARY - CONCEPT LEVEL

Rev.	Description	Date	Appr
01	FPC FLAP GATE (SOUTH) DRAFT - CLIENT REVIEW	12-15-2022	MK

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
SUBMERGED AXIS FLAP GATE - 3 GATE CONCEPT
BOSTON, MA

PLAN VIEWS - STORM SURGE BARRIER - SUBMERGED AXIS FLAP GATE - SOUTH LOCATION ALTERNATE

Designed by: NBJ
Drawn by: CMI
Ckd by: JCS
Reviewed by: MK
Submitted by: MOFFATT & NICHOL
Date: 2022-12-15
M&N Project No. 11167
Drawing code:
Drawing Scale:
Plot scale: 1:1 (D SHEET)

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Sheet Reference No.
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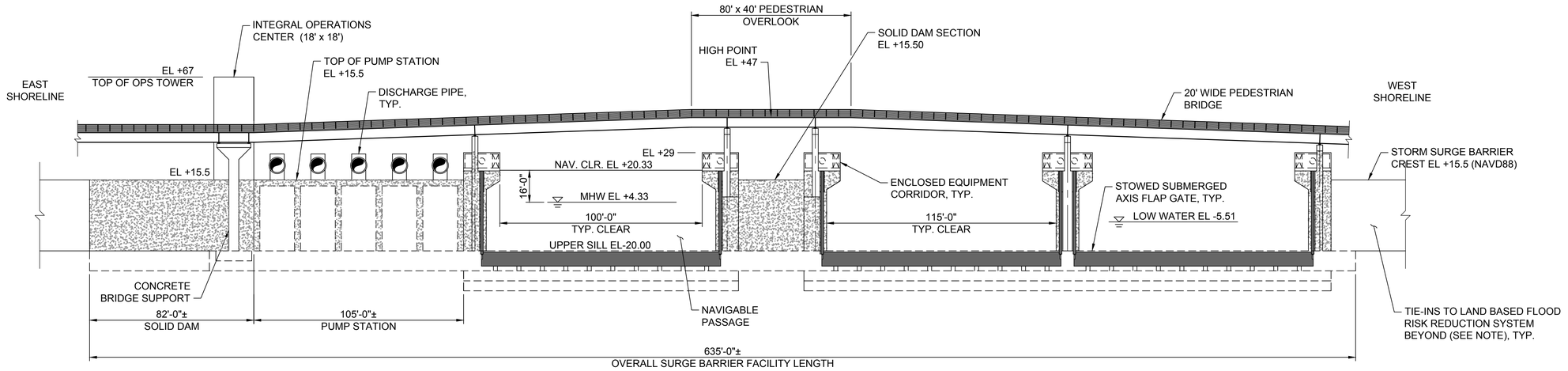
DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING



C1 / S-401 ELEVATION - SUBMERGED AXIS FLAP GATE STORM SURGE BARRIER - SOUTH LOCATION ALTERNATE - LOOKING TOWARDS FPC (GATES IN STOWED POSITION)

SCALE: 1 = 30

NOTE:

1. SHORELINE INTERFACES, TRANSITIONS, AND TIE-INS SHALL BE DETERMINED DURING DETAILED DESIGN.

30'-0" 0'-0" 30'-0" 60'-0"

SCALE: 1"=30'

PRELIMINARY - CONCEPT LEVEL

No.	Mark	Description	Date	Appr
01		FPC FLAP GATE (SOUTH) DRAFT - CLIENT REVIEW	12-15-2022	MK

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
SUBMERGED AXIS FLAP GATE - 3 GATE CONCEPT
BOSTON, MA

ELEVATION - STORM SURGE BARRIER - SUBMERGED AXIS FLAP GATE - SOUTH LOCATION ALTERNATE

Designed by: NBJ
Drawn by: CMI
Cad by: JCS
Reviewed by: MK
Submitted by: MOFFATT & NICHOL
Date: 2022-12-15
Rev. -
M&N Project No. 11167
Drawing code:
Drawing Scale:
Plot scale: 1:1 (D SHEET)

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SEAL

Sheet Reference No.
S-402
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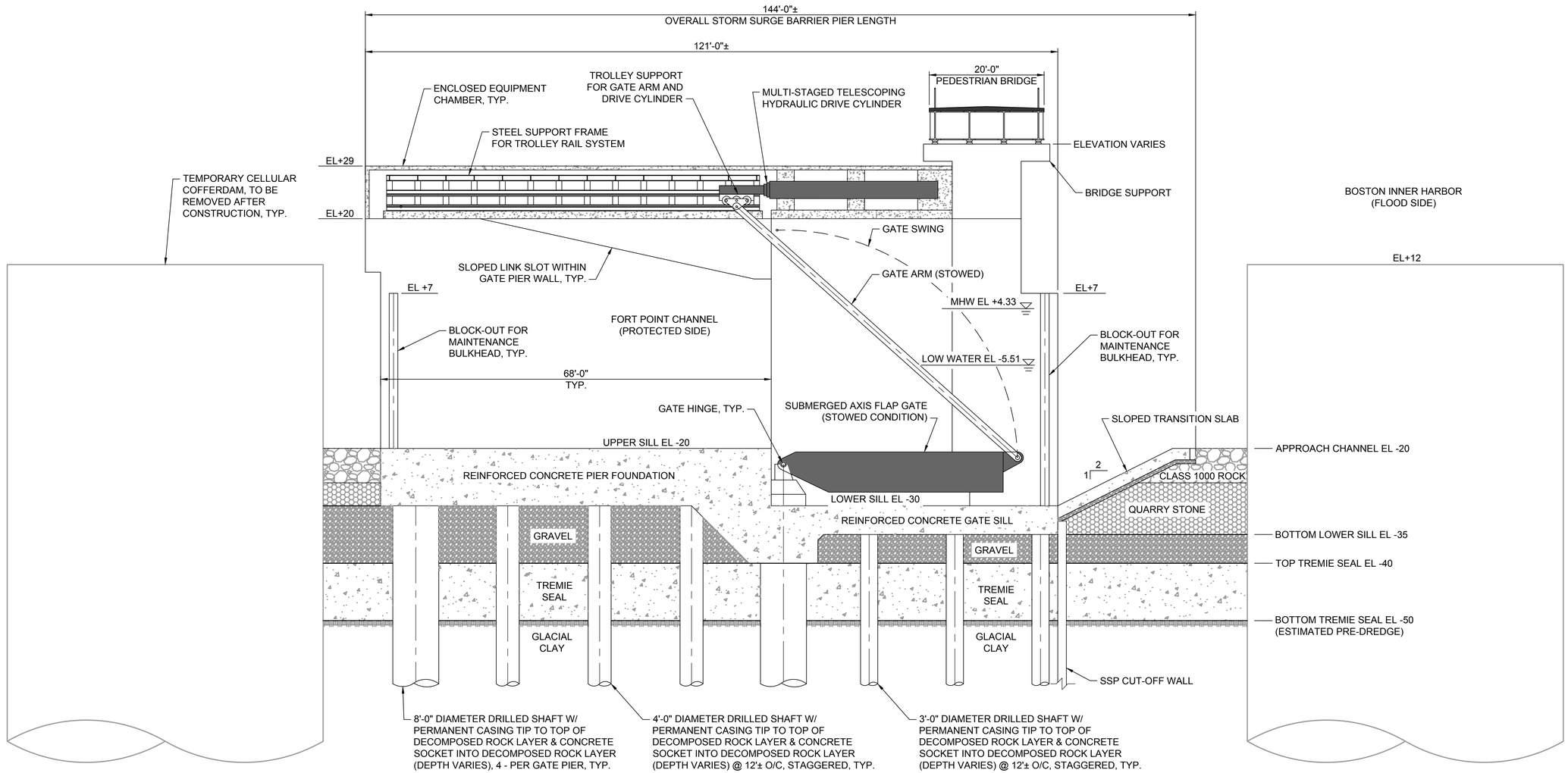

B1 / S-401 SECTION - SUBMERGED AXIS FLAP GATE STORM SURGE BARRIER (STOWED) - SOUTH LOCATION ALTERNATE
SCALE: 1" = 10'

10'-0" 0'-0" 10'-0" 20'-0"
SCALE: 1"=10'

PRELIMINARY - CONCEPT LEVEL

No.	Description	Date	Appr
01	FPC FLAP GATE (SOUTH) DRAFT - CLIENT REVIEW	12-15-2022	MK

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
SUBMERGED AXIS FLAP GATE - 3 GATE CONCEPT
BOSTON, MA

SECTION - STORM SURGE BARRIER - SUBMERGED AXIS FLAP GATE - SOUTH LOCATION ALTERNATE (STOWED)

Rev.: -
Date: 2022-12-15
M&N Project No.: 11167
Drawing scale:
Drawing Scale: 1:1 (D SHEET)
Plot scale: 1:1 (D SHEET)
Designed by: NBJ
Drawn by: CMI
Chd by: JCS
Reviewed by: MK
Submitted by: MOFFATT & NICHOL

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Sheet Reference No.
S-403
INDEX: 6 OF 7

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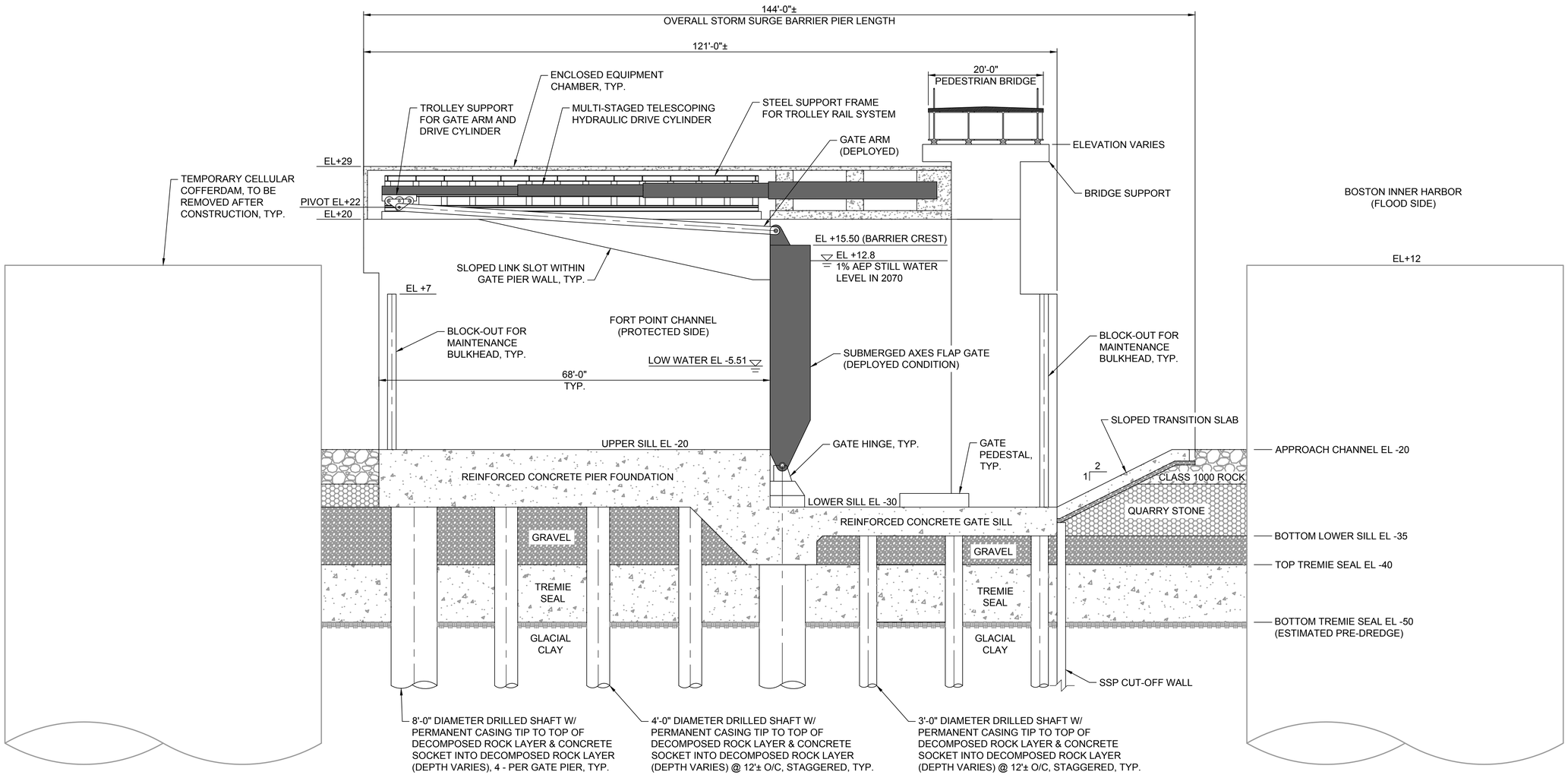
DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING



B1 / S-401 SECTION - SUBMERGED AXIS FLAP GATE STORM SURGE BARRIER (DEPLOYED) - SOUTH LOCATION ALTERNATE

SCALE: 1" = 10'

10'-0" 0'-0" 10'-0" 20'-0"

SCALE: 1"=10'

PRELIMINARY - CONCEPT LEVEL

No.	Mark	Description	Date	Appr
01	FPC FLAP GATE (SOUTH) DRAFT - CLIENT REVIEW		12-15-2022	MK

BOSTON WATER AND SEWER COMMISSION
FORT POINT CHANNEL STORM SURGE BARRIER
SUBMERGED AXIS FLAP GATE - 3 GATE CONCEPT
BOSTON, MA

SECTION - STORM SURGE BARRIER - SUBMERGED AXIS FLAP GATE - SOUTH LOCATION ALTERNATE (DEPLOYED)

Designed by: NBJ
Drawn by: CMI
Checked by: JCS
Reviewed by: MK
Submitted by: MOFFATT & NICHOL
Date: 2022-12-15
M&N Project No. 11167
Drawing scale:
Drawing Scale:
Plot scale: 1:1 (D SHEET)
Rev. -

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Sheet Reference No.
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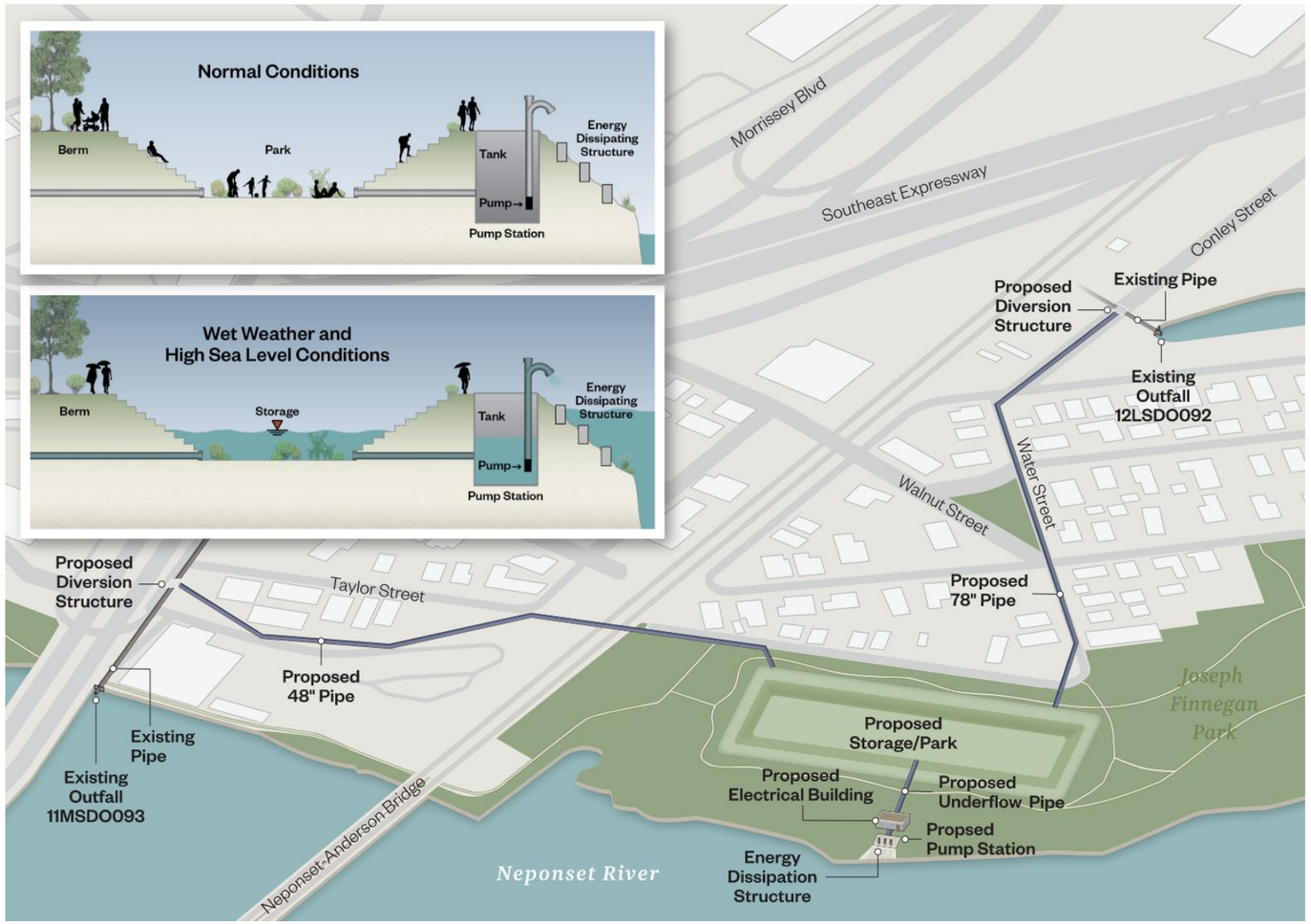
DRAWING SCALES SHOWN BASED ON 22"x34" DRAWING

Joseph Finnegan Park *Concept Overview*





Conceptual Solution

The Joseph Finnegan Park storage basin is a hybrid “natural” (above ground) storage system with a pump station that can be used during larger storm events. The basin and pump station are located inside Joseph Finnegan Park and next to the Neponset River. The basin has a rectangular perimeter and walls that slope inward at a 1:4 slope. During dry weather or low tide rain events, the basin functions as walkable recreation space. During rain events, if a high tide level begins to reduce the ability of existing outfalls 12LSDO092 and 11MSDO093 to discharge by gravity, then a diversion structure with a static weir directs excess flow to the park storage basin. The storage basin is connected to the pump station, which sits near the shoreline and can pump water into the Neponset River. The pump station includes one duty and one standby pump.

Type: Storage and Pumping
Total Drainage Area: 170 acres
Coastal Flood Vulnerable Drainage Area Protected: 170 acres

Concept Elements:

- Above ground “nature based” storage basin
- Improved public amenity/park
- Diversion Structures
- Subsurface Pump Station

Outfalls Included in Concept:

- 12LSDO092
- 11MSDO093

Coastal Stormwater Discharge Analysis
Joseph Finnegan Park

Boston Water and Sewer Commission | Hazen

November 2022

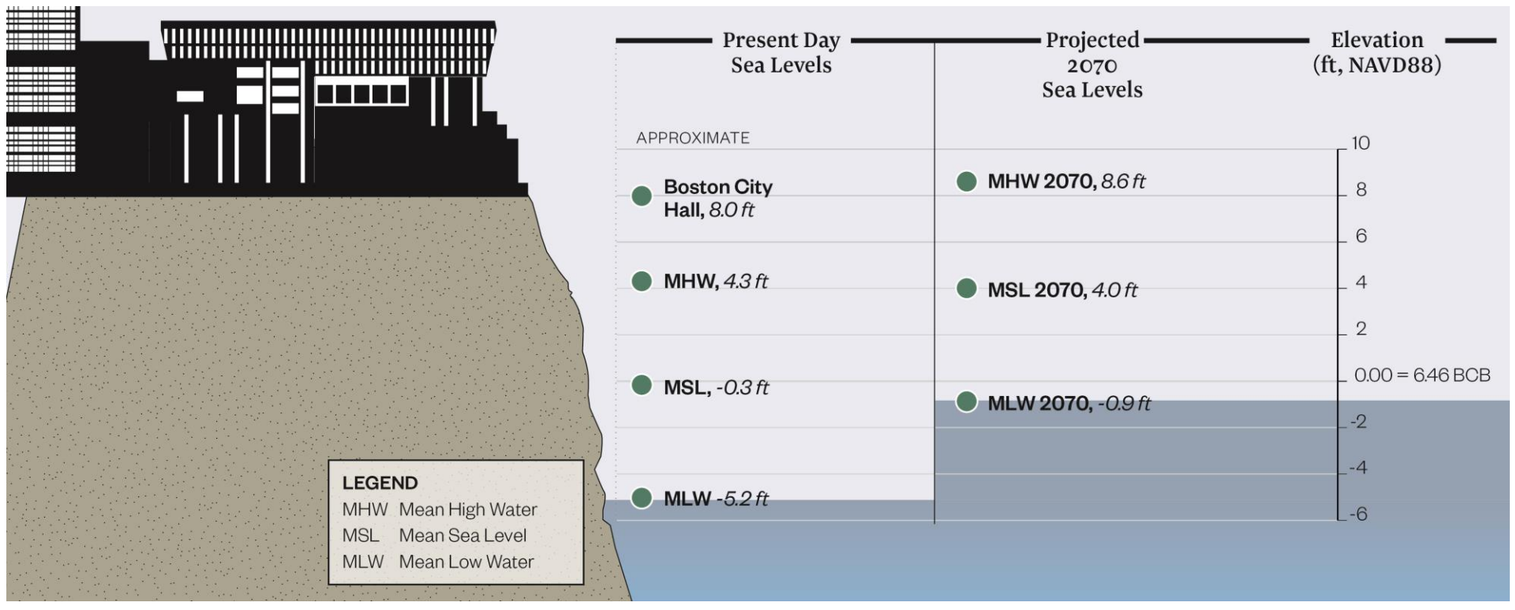
Assumptions

Sea Level Rise and Datum

The Finnegan Park Pump Station concept was designed for consistency with Climate Ready Boston (CRB) proposed adaptations and analyzed based on sea level rise (SLR) projections in the Massachusetts Coastal Flood Risk Model (MC-FRM). The SLR values applied in MC-FRM are consistent with the standards for the State of Massachusetts developed by Coastal Zone Management. The MC-FRM utilizes a "High" SLR scenario. This scenario is based on the relative SLR projections under Relative Concentration Pathway (RCP) 8.5 (a "worst case scenario" of increasing atmospheric carbon concentrations) and represents elevations that have a 99.5% probability of not being exceeded within the respective timeframes. In 2030, that amounts to an increase of 1.3 feet in Boston from a baseline condition (2008 centered tidal epoch), and in 2070 that amounts to an increase of 4.3 feet.

The concept developed in this project was analyzed using coastal conditions that include 2070 projected SLR and storm surge resulting from a 100-year tropical storm. The peak water surface elevation (WSE) predicted by the MC-FRM during these conditions is approximately 13.8 feet NAVD88 (varies by location). In mid 2022, the Greater Boston Research Advisory Group (BRAG) issued an updated report with new SLR projections. The report acknowledges that long term SLR projections are associated with significant uncertainty, and that updated projections include less SLR by 2100 (according to earlier projections in the 2015 BRAG Report). According to the report, the likely range of SLR by 2070 under an RCP 8.5 scenario is 1.4 – 2.8 feet. Based on this information, projections from the MC-FRM that were utilized in this project are conservative and appropriate for long term planning purposes.

Unless otherwise noted, all elevations are based on the NAVD88 vertical datum. Elevations given in NAVD88 can be converted to Boston City Base (BCB) elevation by adding 6.46 feet.



Climate Ready Boston and Shoreline Protection

The Finnegan Park Pump Station concept was developed to maintain consistency with possible Climate Ready Boston (CRB) adaptations based on the latest available information at the time they were developed. As the CRB program continues to evolve, it is anticipated that proposed concepts will need to be adapted.

The concept was developed to be consistent with stated neighborhood design flood elevations. In the Neponset River Waterfront Zone (location of Finnegan Park), where the stated design flood elevation is 14.4 feet, pumps would be designed to discharge to a minimum elevation of 14.4 feet.

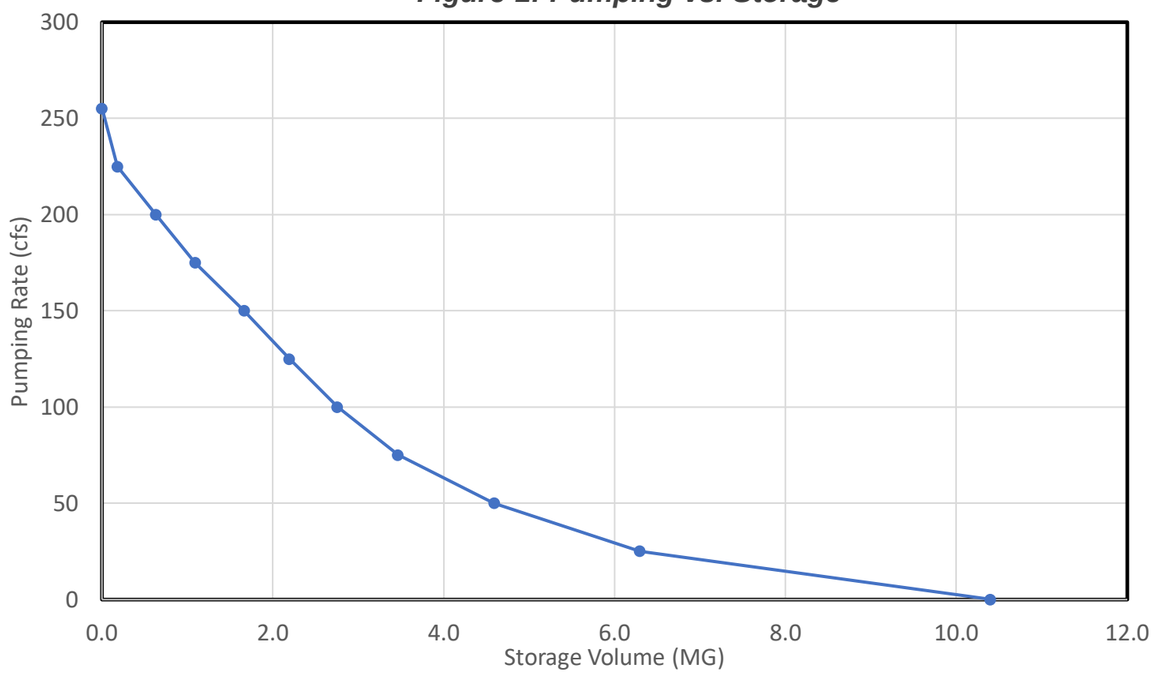
At the time of this project, many CRB concepts were in early planning stages and not fully defined. **In consideration of this, it was assumed the shoreline protection around the City of Boston is 100% effective for all modeling evaluations.** This assumption eliminates overland coastal flooding from model predictions, allowing for isolation of flooding that results only from rainfall and stormwater that cannot be discharged due to high sea levels. It is important to recognize that additional flooding, beyond what is depicted herein, would be expected if 100% effective shoreline protection is not implemented.

Basis of Design

Storage and Pumping

Model simulations were conducted to determine the maximum Hydraulic Grade Line (HGL) that occurs at Outfalls 12LSDO092 and 11MSDO093 with the current tide cycle. Analyses were then conducted to determine the acceptable combinations of storage volume and pumping rate required to maintain the existing HGL with 2070 projected sea level rise and 100-year storm surge, as shown in Figure 1. The City of Boston's Parcel database was used to identify publicly owned parcels near the existing outfall. An analysis of the pump station was performed to identify a pump rate and physical dimensions that are hydraulically viable. It was found that a 10 MG storage basin and a 50 cfs pump station ~20.5 feet deep could fit within the property. The storage tank and pump station occupy an area of 133,020 ft^2. The storage basin has a rectangular perimeter and walls that slope inward at a 1:4 slope. During dry weather or low tide rain events, the basin functions as walkable recreation space. During rain events, if a high tide level begins to reduce the ability of existing outfalls 12LSDO092 and 11MSDO093 to discharge by gravity, then a diversion structure with a static weir directs excess flow to the park storage basin. The storage basin is connected to the pump station, which sits near the shoreline and can pump water into the Neponset river. The Finnegan park pump station utilizes one duty pump, one standby pump, and two dewatering pumps. The pump station is configured with vertical, axial electric submersible pumps in parallel bays.

Figure 1: Pumping vs. Storage



Rainfall and Coastal Conditions

The Commission currently utilizes a 10-year, 24-hour design storm to establish its target level of service. For the purpose of sizing new piping and evaluating storage capacity, a projected 2070 10-year, 24-hour design storm was developed. For consistency with Climate Ready Boston, performance of the DBB storage concept was also evaluated with projected rainfall from a 100-year tropical event (developed during the Commission's Inundation Model Project). The DBB was evaluated using a 100-year return period coastal boundary condition. Data for this condition were obtained from the MC-FRM. For the purpose of evaluating the effectiveness of the concept, it was further assumed that complete shoreline protection was implemented, preventing flow of water between land and the harbor/Neponset River. Table 2 contains a summary of the coastal conditions that were analyzed.

Table 1: Rainfall Conditions

Scenario	Purpose	Rainfall Depth (in)	Peak Intensity (in/hr)
Present Day 10-year, 24-hr design storm	Baseline Conditions	5.15	3.32
Projected 2070 10-year, 24-hr design storm	Design Conditions	6.18	4.08
100-year Tropical Storm	Damage Analysis	9.58	0.84

Table 2: Coastal Conditions

Scenario	Purpose	Peak Water Surface Elevation (ft, NAVD88)	Source
Present Day	Baseline Conditions	3.7	BWSC Existing Model (April 2016 Tide Cycle)
2070,100-year Tropical Storm	Damage Analysis	13.8	MC-FRM



Joseph Finnegan Park

Outfalls 12LSDO092 and 11MSDO093 Diversion to Storage Area and Neponset River

Coastal Stormwater Discharge Analysis
Joseph Finnegan Park

Boston Water and Sewer Commission

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November 2022

Flood Modeling and Damage Analysis

Figure 2: Estimated Replacement Cost

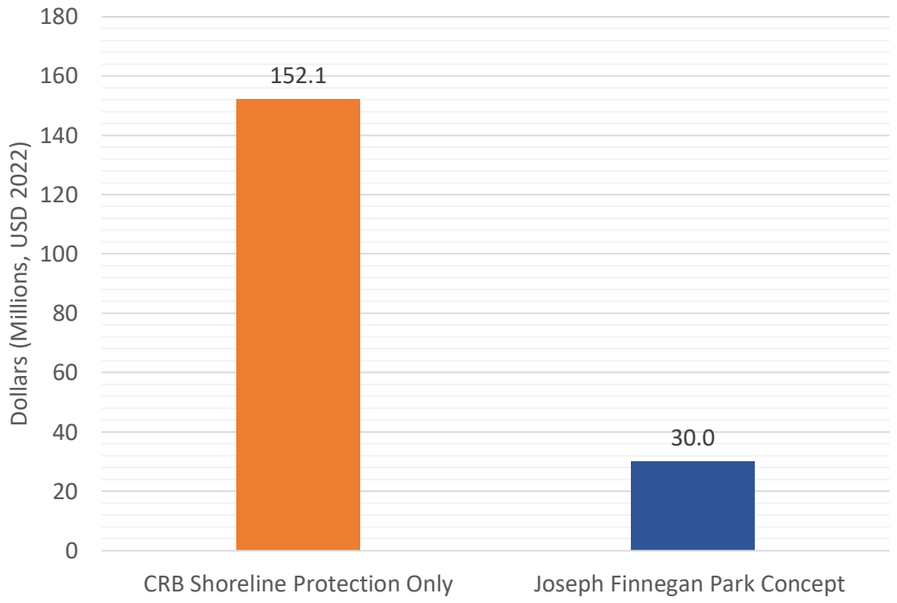


Figure 3: Loss of GDP

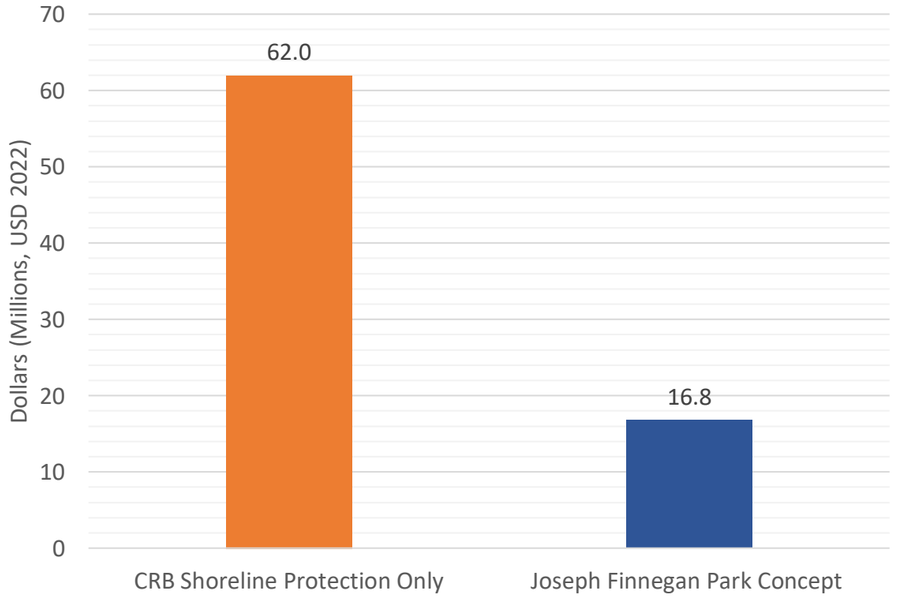
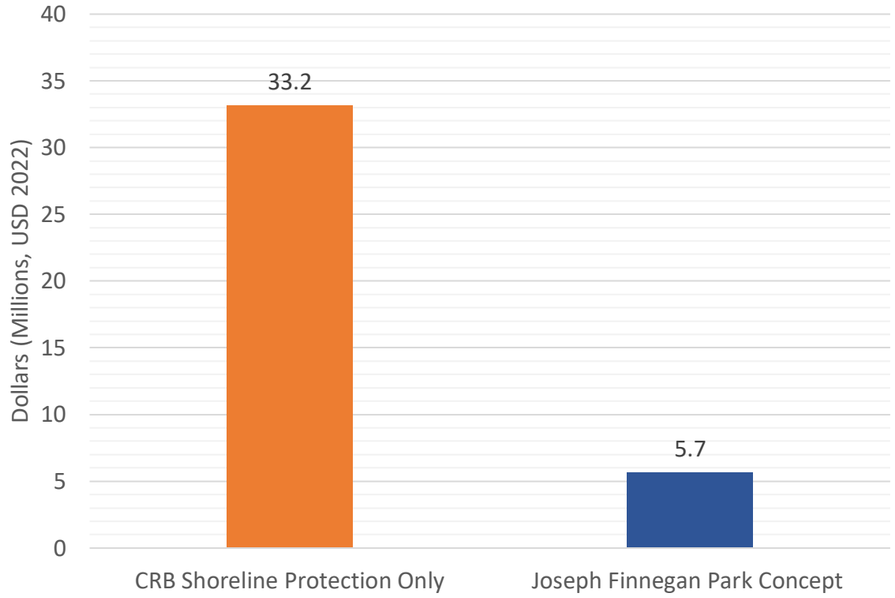


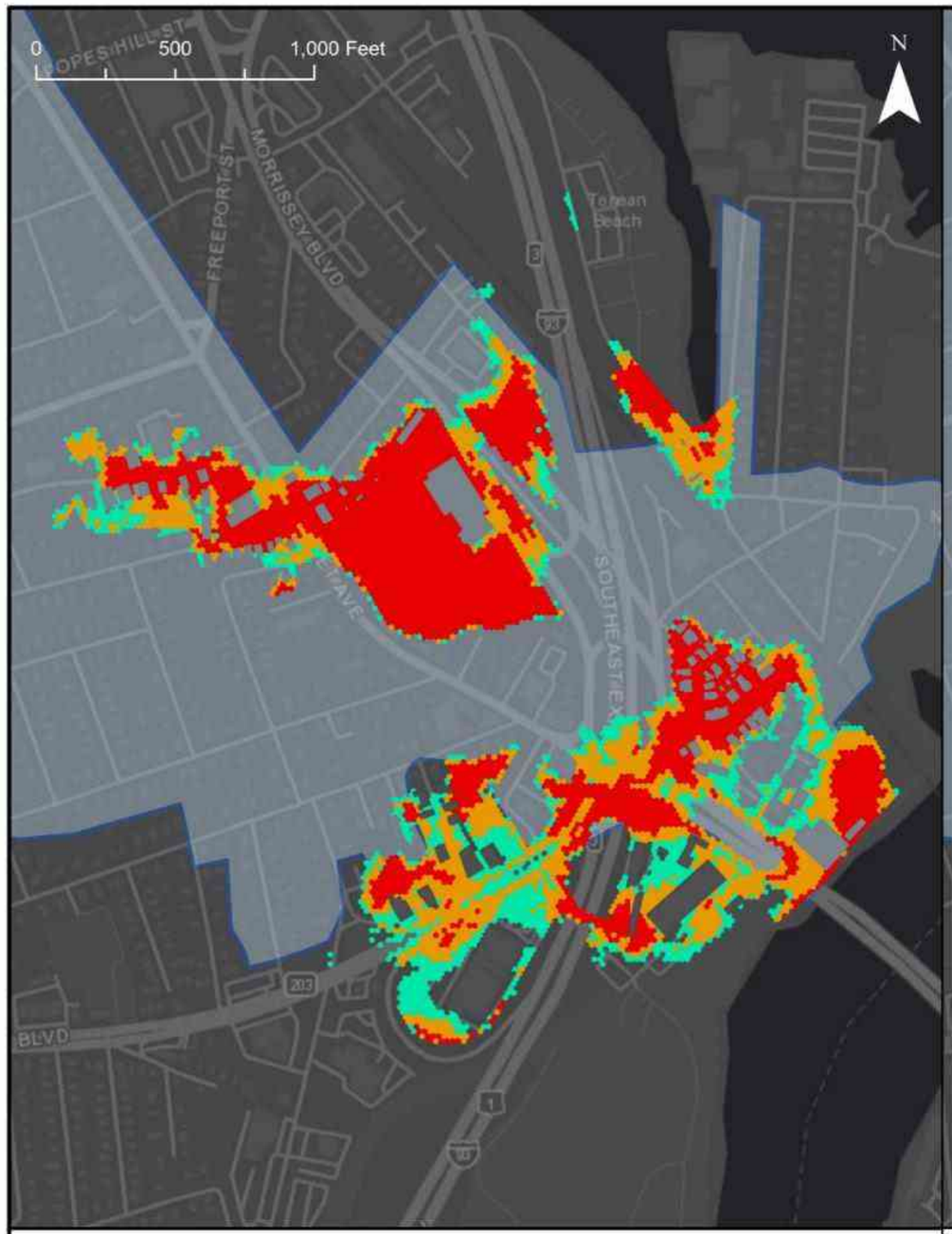
Figure 4: Physical Damage



The flood reduction benefits of the Joseph Finnegan Park concept were evaluated using the Commission's 2D Inundation Model by simulating a 100-year tropical storm event with 2070 SLR and storm surge. The figures on the following page depict the peak flooding that was predicted in the Joseph Finnegan Park drainage area with shoreline protection only and with the pump station and tide gates on all vulnerable BWSC owned outfalls. An analysis of economic losses/physical impacts from flooding under both scenarios was performed by risQ Inc.

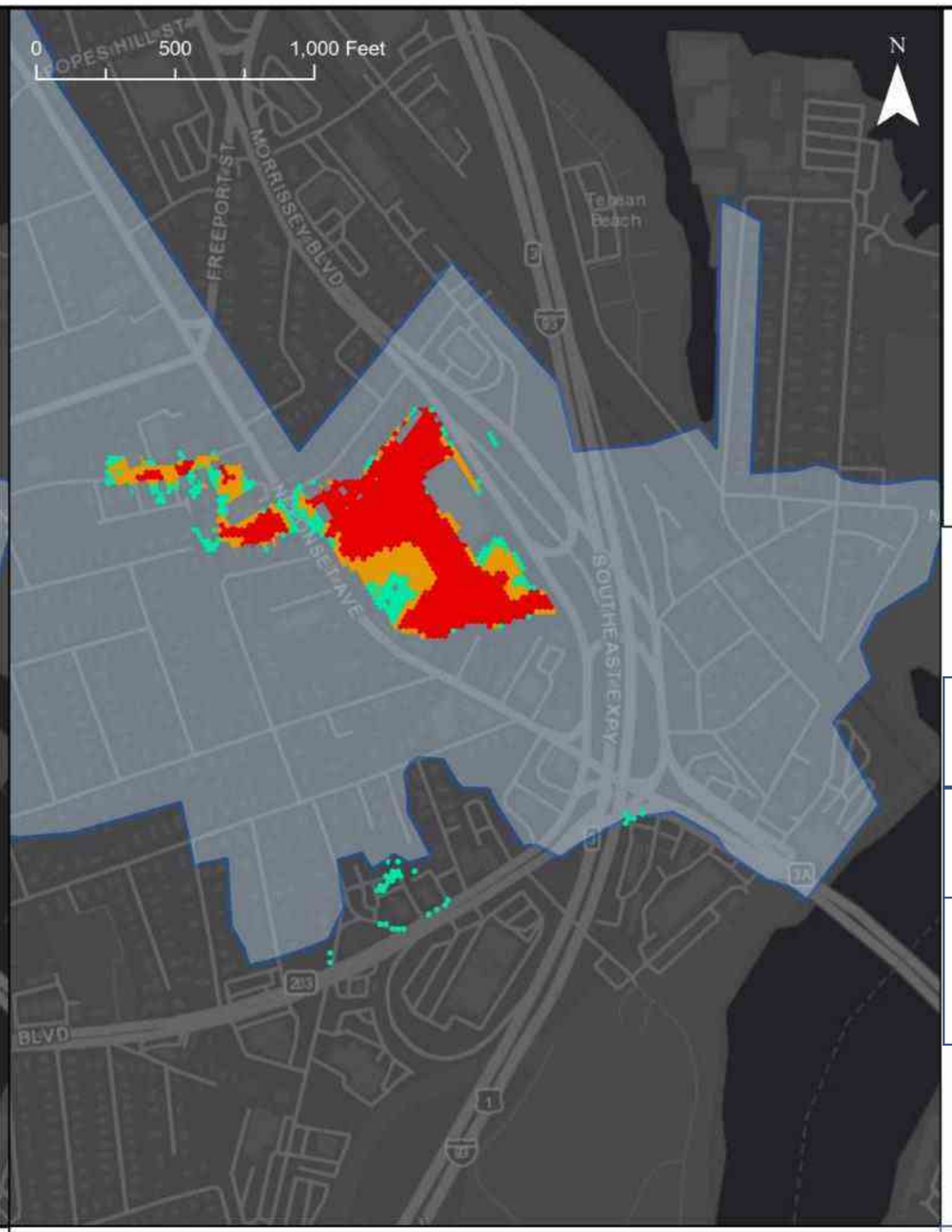
Model predictions indicate that the Joseph Finnegan Park concept reduces physical damage by **$27.5 million**, avoids **$122.1 million** in rebuilding costs, and mitigates a GPD loss of **$45.2 million** during a 100-year tropical storm event in 2070.

Note: replacement values include the total value of impacted buildings in flooded areas (e.g., impacted buildings are fully replaced), whereas physical damage includes estimated costs to repair flood damage based on predicted flood depths and building characteristics. The values shown are the average of minimum and maximum calculated losses. Refer to the Project's Final Report for more information.



2070 SLR + 100yr Tropical Storm + Storm Surge

Shoreline Protection Only



2070 SLR + 100yr Tropical Storm + Storm Surge

Joseph Finnegan Park Pump Station

Legend

- Flood Depth > 4 in and < 1 ft
- Flood Depth > 1 ft and < 2 ft
- Flood Depth > 2 ft
- Drainage Area Analyzed

Simulation Parameters

Storm Type	100yr Tropical Storm
Rainfall Depth	9.6 inches
Peak WSE 2070 SLR + 100yr Surge	13.8 feet NAVD88

Coastal Stormwater Discharge Analysis
Joseph Finnegan Park

Boston Water and Sewer Commission

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Cost Estimate and FEMA BRIC Considerations

Capital Cost Estimate

A construction cost estimate for the Joseph Finnegan Park concept was developed for planning purposes. Assumptions for the cost estimate include 15-year escalation to the mid-point of construction and the inclusion of a 50% design contingency. Utility hookup costs were not included.

Table 3: Joseph Finnegan Park Cost Estimate Subtotals

Remaining Design Development & Construction Administration (assumed 20% of total less design contingency)	$4,708,000
Direct Construction Costs	$9,246,000
Indirect Construction Costs	$1,849,000
Mark-Up *(Including 50% design contingency)*	$23,787,000
Total	**$39,590,000**

Social Vulnerability and FEMA BRIC Funding

FEMA BRIC funding prioritizes disadvantaged communities. Table 4 contains a summary of several indicators for the Joseph Finnegan Park tributary area that could be used help characterize the community for future FEMA funding applications and prioritization of projects that benefit disadvantaged communities.

Table 4: Joseph Finnegan Park Tributary Area Social Vulnerability Indicators

Low Income & Persistent Poverty	
Per Capita Income	$50,749
Below Poverty Line	6%
High Housing Cost Burden	
Stressed Renters (>40% rent-to-income)	25%
Households With Food Insecurity	14%
Racial and Ethnic Segregation	
Asian Population	9%
Black Population	10%
Hispanic Population	4%
White Population	75%
Education and Employment	
Adults Age 25+ Without High School (or equivalent) Degree	8%
Unemployment Rate (Age 16+)	4%

Data provided by risQ inc. from the US census and American Community Survey

Conceptual Design – Not for Construction

Planting Palette

A planting palette was developed for the stormwater storage areas at Joseph Finnegan Park. Parts of the concept are designed to temporarily flood during intense storm events. The selected plant species are tolerant of occasional temporary flooding. After construction, planting of native plant species could provide a public amenity with new green space and environmental benefits associated with native plant species.

Trees



Amelanchier canadensis
Canadian serviceberry



Juniperus virginiana
eastern red cedar



Betula populifolia
gray birch



Celtis occidentalis
hackberry

Shrubs



Spirea tomentosa
steeplebush



Aronia arbutifolia
red chokeberry



Clethra alnifolia
sweet pepperbush



Lindera benzoin
spicebush

Herbaceous and Grasses



Eupatorium album
white throughwart



Schizacharium scoparium
little bluestem



Symphyotrichum novi-belgi
New York aster



Euthamia graminofolia
grass-leaved goldenrod

Coastal Stormwater Discharge Analysis
Joseph Finnegan Park

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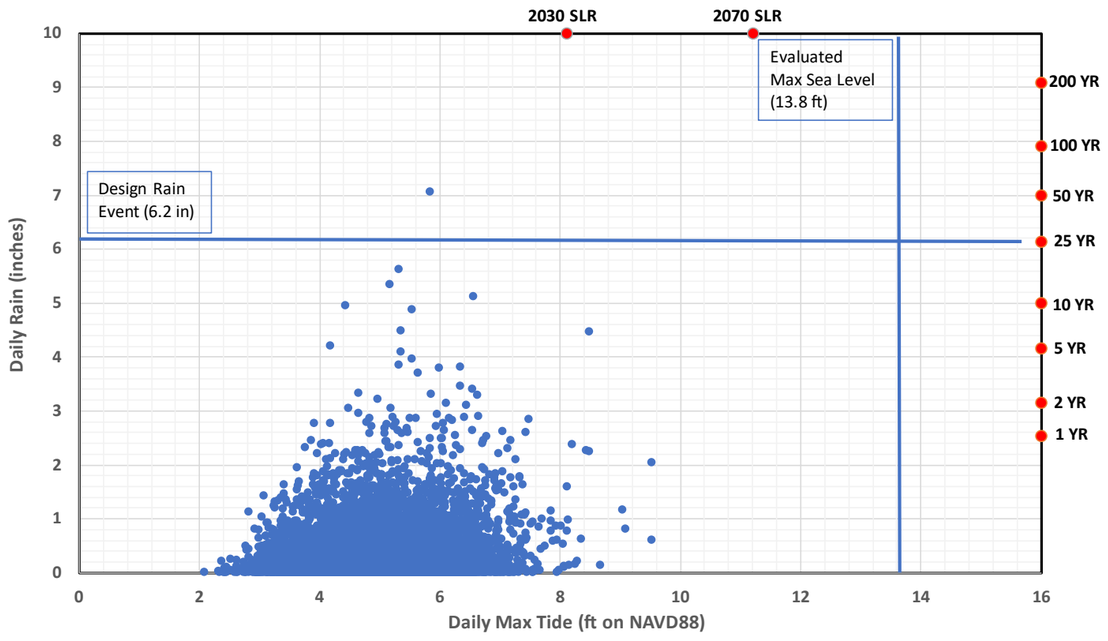
Adaptability and Implementation

Adaptability

Figure 4 below depicts historical daily rainfall totals and tide levels. As shown in this figure, the conditions that were used to design and analyze and design the Finnegan Park storage concept are conservative and represent more extreme conditions than have occurred historically. As such, it is likely that the Finnegan Park storage concept will function even without the need for significant pumping in the future under many conditions. Regardless, the following measures could be implemented to adapt the concept to more severe conditions (additional SLR, more intense rainfall, etc.) in the future:

- Expand the pump station to maintain lower water levels during a storm event
- Deepen the storage basin and redesign the pump station to obtain additional usable storage
- Other interior drainage improvements could be made to convey additional flow to the Finnegan Park storage concept

Figure 4: Design and Analysis Conditions vs. Historical Tide and Rainfall



Implementation Considerations

- Coordination with CRB (and other relevant stakeholders) to construct adequate shoreline protection around Finnegan Park is essential for successful implementation of this concept. To function as designed, Finnegan park must be fully isolated from high sea levels; as such, careful coordination with CRB is essential at this location.
- Coordination with park planners and users of the park should be conducted to ensure that risks associated with having significant topographic variation are mitigated, such as determining locations where activities such as throwing frisbees and balls is discouraged. The design should be modified as necessary to ensure the park area is compliant with the Americans with Disabilities Act and fully accessible.
- On-site signage and community outreach will be required to adequately inform the public that the park will be a drowning hazard for children and people with physical disabilities during wet weather events.
- A portion of the Neponset River is federally designated as a superfund site. A survey of hazardous materials, and detailed list of required permits, should be developed before beginning the final design process.
- Active flow control gates at proposed diversion structures could be used to divert flow into Finnegan Park during low-intensity rain events; this could help prevent sediment deposition in the pipelines.
- Planting of native plant species and other green features will provide an improved public amenity and preserve the “look and feel” of the park.
- A comprehensive permitting evaluation should be conducted to evaluate possible impacts from construction and operation of the pump station to the receiving water.
- Community engagement with stakeholders may help build project support by illustrating the flood control benefits of the storage basin and pump station.

Replicability and Implementation Timeline



Summary of Similar Concepts

Number of Sites: 21

Vulnerable Area: 462 acres

The Finnegan Park solution unique and not directly replicable in other locations. The design of the pump station could be replicated at other locations in the City. Additional detail about outfalls that could be protected with a similar pump station can be found in the Commission's Coastal Stormwater Discharge Analysis Implementation Timeline.

ATTACHMENT A
JOSEPH FINNEGAN PARK CONCEPTUAL DESIGN DRAWINGS

A-1: Overview Plan and Storage Section Views
A-2: Pump Station Plan and Section View

Coastal Stormwater Discharge Analysis
Joseph Finnegan Park

Boston Water and Sewer Commission

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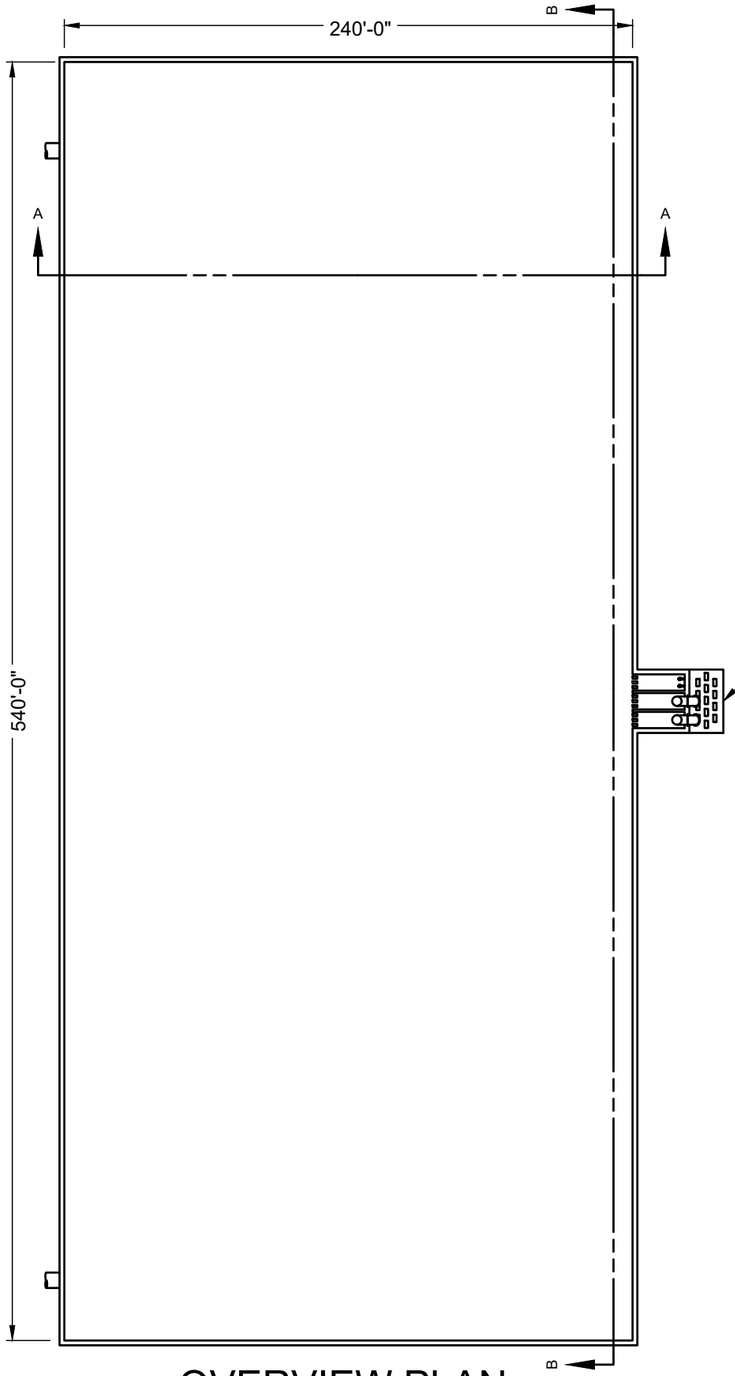
Finnegan Park Stormwater Management Concept

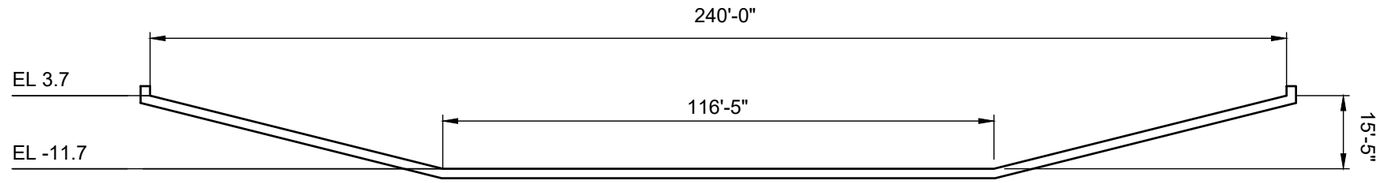


OVERVIEW PLAN

SCALE: NTS

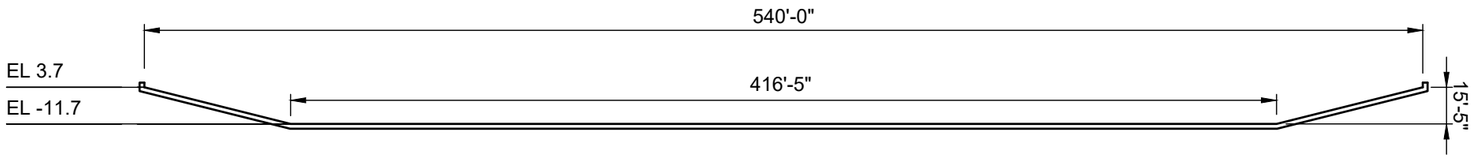
NOTES

1. FOR WATER SURFACE ELEVATIONS REFER TO OPERATIONAL TABLE.
2. ALL ELEVATIONS USE THE NAVD88 VERTICAL DATUM UNLESS OTHERWISE STATED.
3. CONCEPTUAL DRAWING, NOT FOR CONSTRUCTION.



SECTION A

SCALE: NTS



SECTION B

SCALE: NTS

COASTAL STORMWATER DISCHARGE ANALYSIS

Boston Water and Sewer Commission

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A-1

November 2022

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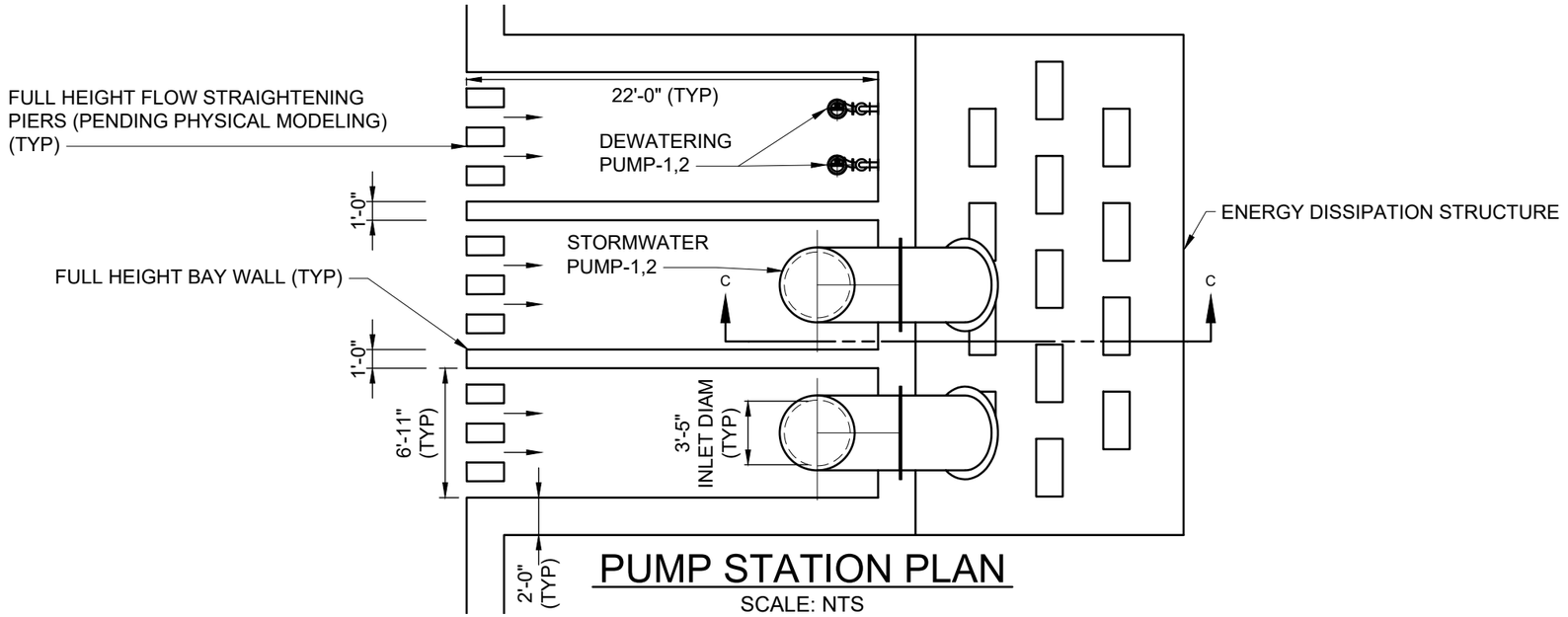
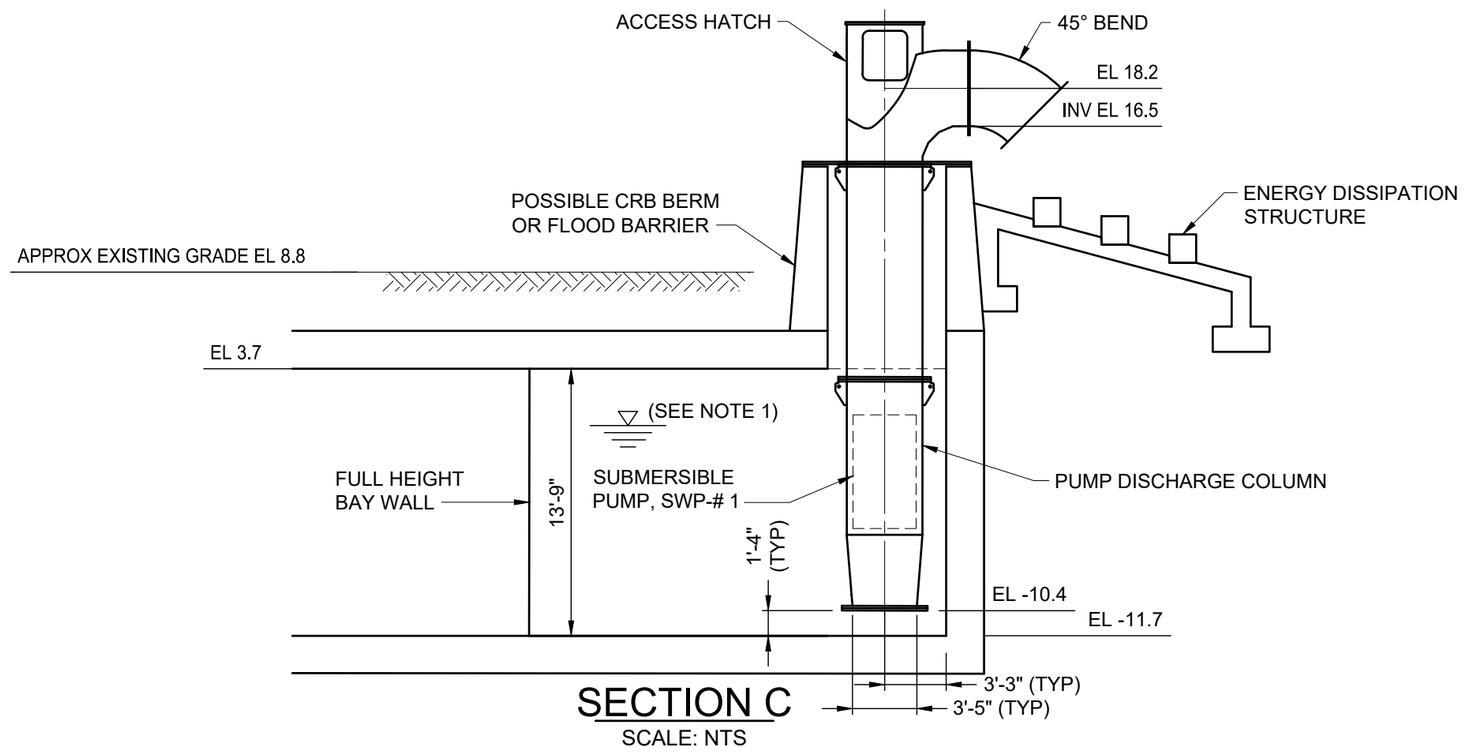
Finnegan Park Stormwater Management Concept



PUMP STATION PLAN

SCALE: NTS



SECTION C

SCALE: NTS

NOTES

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STORMWATER PUMP-1,2 OPERATIONAL PARAMETERS	
FLOW RATE, CFS	50
STATIC HEAD RANGE, FT	14.5 - 22.1
DESIGN FLOOD ELEVATION, FT	15.5

STORMWATER PUMP-1,2 OPERATIONAL WSE TABLE		
NOTE	OPERATION	ELEVATION, FT
A	HIGH LEVEL ALARM	2.7
B	LAG PUMP ON	1.9
C	LEAD PUMP ON	-0.9
D	LEAD PUMP OFF	-1.9
E	LOW LOW ALARM	-2.9
G	MIN PUMP SUBMERGENCE	-3.9

COASTAL STORMWATER DISCHARGE ANALYSIS

Boston Water and Sewer Commission

Hazen

A-2

November 2022

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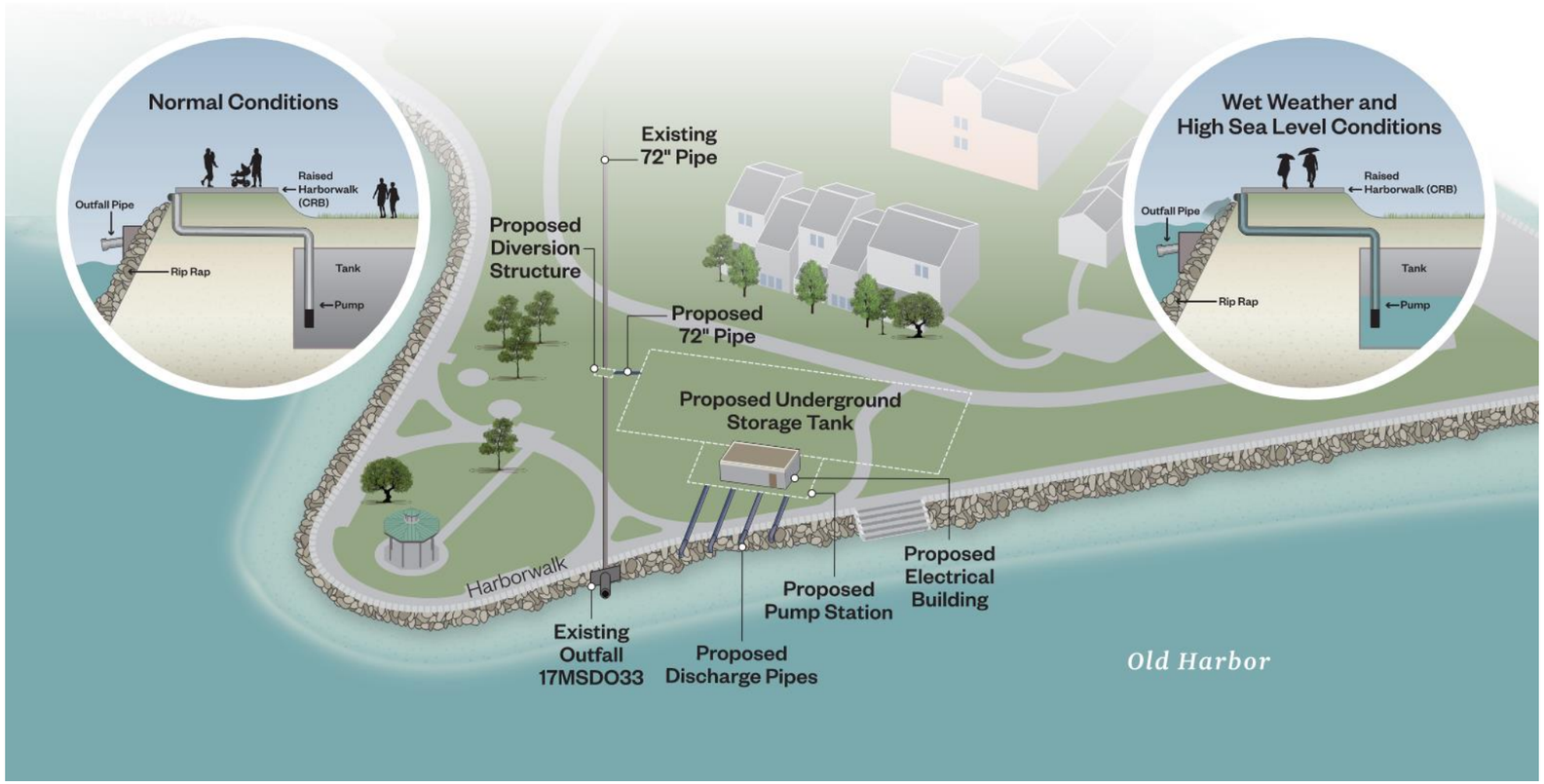
Old Harbor Park Pump Station *Concept Overview*





Conceptual Solution

The conceptual solution herein includes a stormwater storage (peak flow shaving) tank and pump station to discharge wet weather flow when tide levels are high. The tank and pump station are located at Old Harbor Park. If a high tide level begins to reduce the ability of existing outfall 17MSDO33 to discharge by gravity the existing storm sewer will begin to surcharge. A diversion structure with a static weir directs excess flow from the existing sewer to the storage tank. The storage tank is connected directly to the pump station. The pump station includes three duty, one standby, and two dewatering pumps. The pump station utilizes electric submersible pumps to minimize the above ground footprint of the station and mitigate negative visual and auditory impacts from diesel engine driven pumps. Each pump discharges into a force main that travels horizontally underground from the pump station to a potential shoreline elevation project (TBD by CRB), at which point they discharge into the harbor onto an energy dissipation structure.

Type: Storage and Pumping

Total Drainage Area: 81 acres

Coastal Flood Vulnerable Drainage Area Protected: 81 acres

Concept Elements:

- Subsurface Pump Station
- Subsurface Storage Tank
- Diversion Structure

Outfalls Included in Concept:

- 17MSDO33

Coastal Stormwater Discharge Analysis
Old Harbor Park Pump Station

Boston Water and Sewer Commission | Hazen

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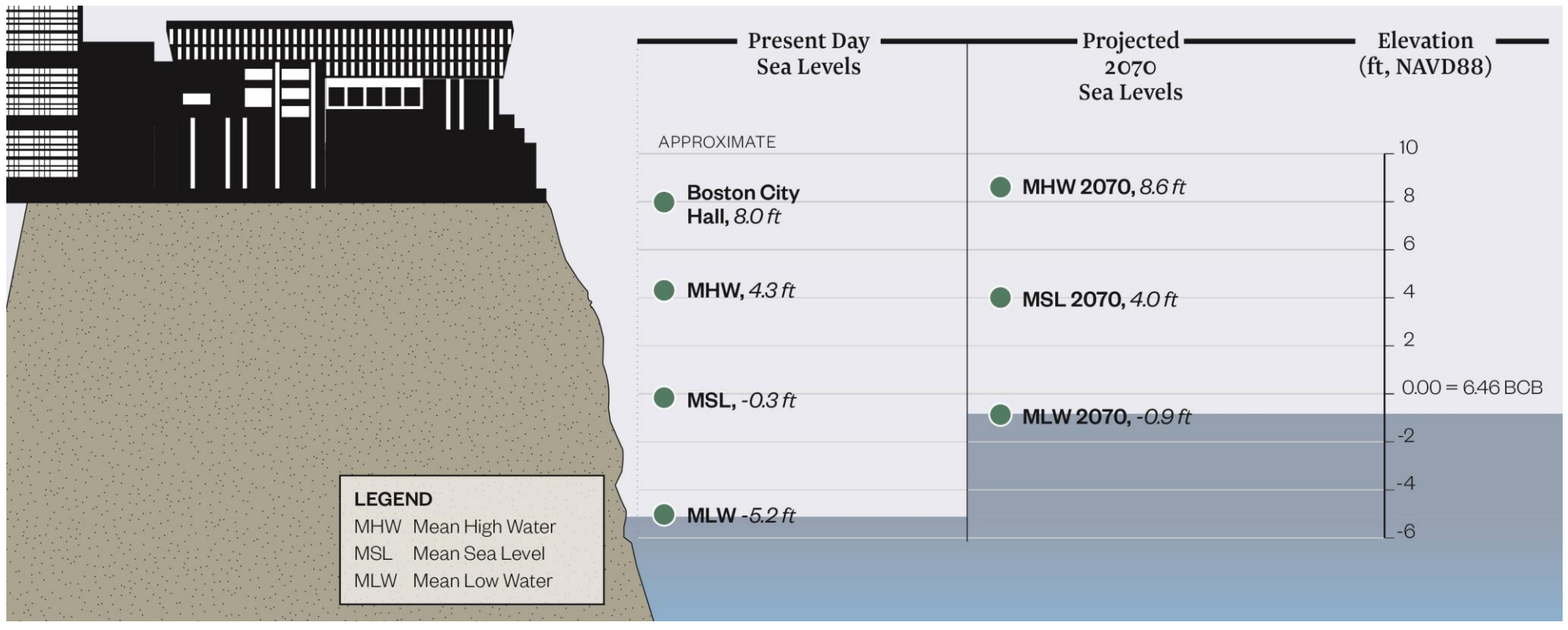
Assumptions

Sea Level Rise and Datum

The Old Harbor Park Pump Station concept was designed for consistency with Climate Ready Boston (CRB) proposed adaptations and analyzed based on sea level rise (SLR) projections in the Massachusetts Coastal Flood Risk Model (MC-FRM). The SLR values applied in MC-FRM are consistent with the standards for the State of Massachusetts developed by Coastal Zone Management. The MC-FRM utilizes a "High" SLR scenario. This scenario is based on the relative SLR projections under Relative Concentration Pathway (RCP) 8.5 (a "worst case scenario" of increasing atmospheric carbon concentrations) and represents elevations that have a 99.5% probability of not being exceeded within the respective timeframes. In 2030, that amounts to an increase of 1.3 feet in Boston from a baseline condition (2008 centered tidal epoch), and in 2070 that amounts to an increase of 4.3 feet.

The concept developed in this project was analyzed using coastal conditions that include 2070 projected SLR and storm surge resulting from a 100-year tropical storm. The peak water surface elevation (WSE) predicted by the MC-FRM during these conditions is approximately 13.8 feet NAVD88 (varies by location). In mid 2022, the Greater Boston Research Advisory Group (BRAG) issued an updated report with new SLR projections. The report acknowledges that long term SLR projections are associated with significant uncertainty, and that updated projections include less SLR by 2100 (compared to earlier projections in the 2015 BRAG Report). According to the report, the likely range of SLR by 2070 under an RCP 8.5 scenario is 1.4 – 2.8 feet. Based on this information, projections from the MC-FRM that were utilized in this project are conservative and appropriate for long term planning purposes.

Unless otherwise noted, all elevations are based on the NAVD88 vertical datum. Elevations given in NAVD88 can be converted to Boston City Base (BCB) elevation by adding 6.46 feet.



Climate Ready Boston and Shoreline Protection

The Old Harbor Park Pump Station concept was developed to maintain consistency with possible Climate Ready Boston (CRB) adaptations based on the latest available information at the time they were developed. As the CRB program continues to evolve, it is anticipated that proposed concepts will need to be adapted.

The concept was developed to be consistent with stated neighborhood design flood elevations. In the Columbia Point and Morrissey Boulevard Zone (location of Old Harbor Point Park), where the stated design flood elevation is 16.2 feet, pumps would be designed to discharge to a minimum elevation of 16.2 feet.

At the time of this project, many CRB concepts were in early planning stages and not fully defined. **In consideration of this, it was assumed the shoreline protection around the City of Boston is 100% effective for all modeling evaluations.** This assumption eliminates overland coastal flooding from model predictions, allowing for isolation of flooding that results only from rainfall and stormwater that cannot be discharged due to high sea levels. It is important to recognize that additional flooding, beyond what is depicted herein, would be expected if 100% effective shoreline protection is not implemented.

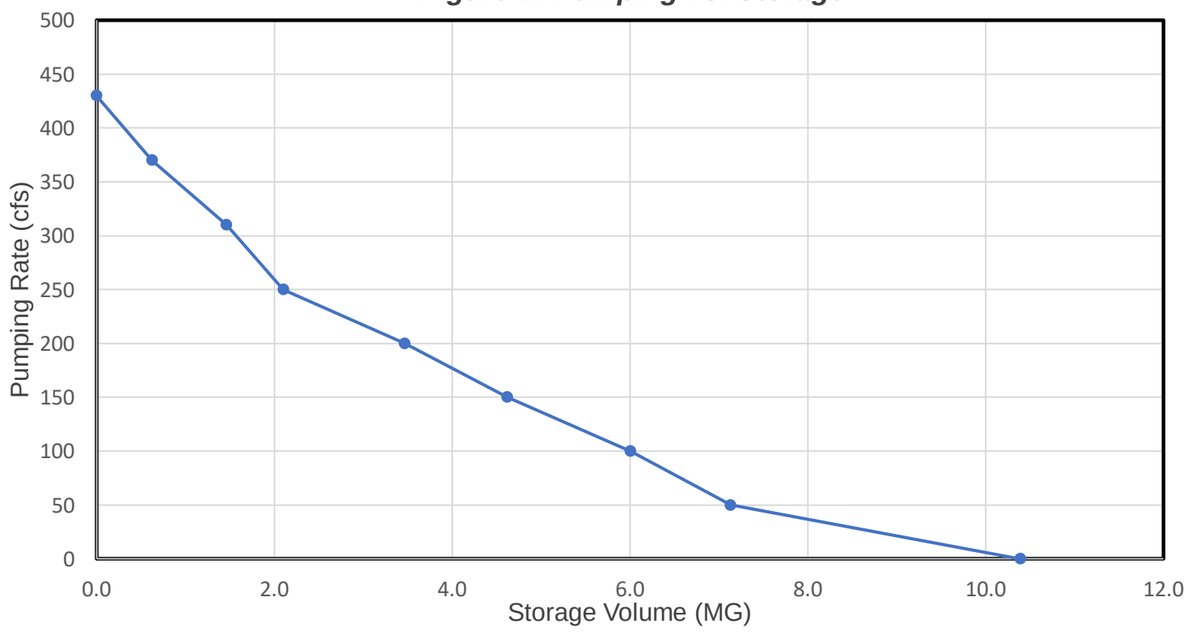
Conceptual Design – Not for Construction

Basis of Design

Storage and Pumping

Model simulations were conducted to determine the maximum Hydraulic Grade Line (HGL) that occurs at Outfall 17MSDO033 with the current tide cycle. Analyses were then conducted to determine the acceptable combinations of storage volume and pumping rate required to maintain the existing HGL with 2070 projected sea level rise and 100-year storm surge, as shown in Figure 1. The City of Boston's Parcel database was used to identify publicly owned parcels near the existing outfall. An analysis of the pump station was performed to identify a pump rate and physical dimensions that are hydraulically viable. It was found that a 1.4 MG storage tank ~25 feet deep could fit within the property with a 306 CFS pump station. The pump station and storage tank occupy an area of 11,260 ft^2. The Old Harbor Park Pump station utilizes three duty pumps, one standby pump, and two dewatering pumps. The pump Station is configured with vertical, axial electric submersible pumps in parallel bays. The pumps are configured to discharge into individual, non-manifolded force mains, which travel horizontally underground from the pump station to the proposed elevated shoreline project (TBD by CRB), at which point they discharge into the harbor onto an energy dissipation structure.

Figure 1: Pumping vs. Storage



Rainfall and Coastal Conditions

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Conceptual Design – Not for Construction

Flood Modeling and Damage Analysis

Figure 2: Estimated Replacement Cost

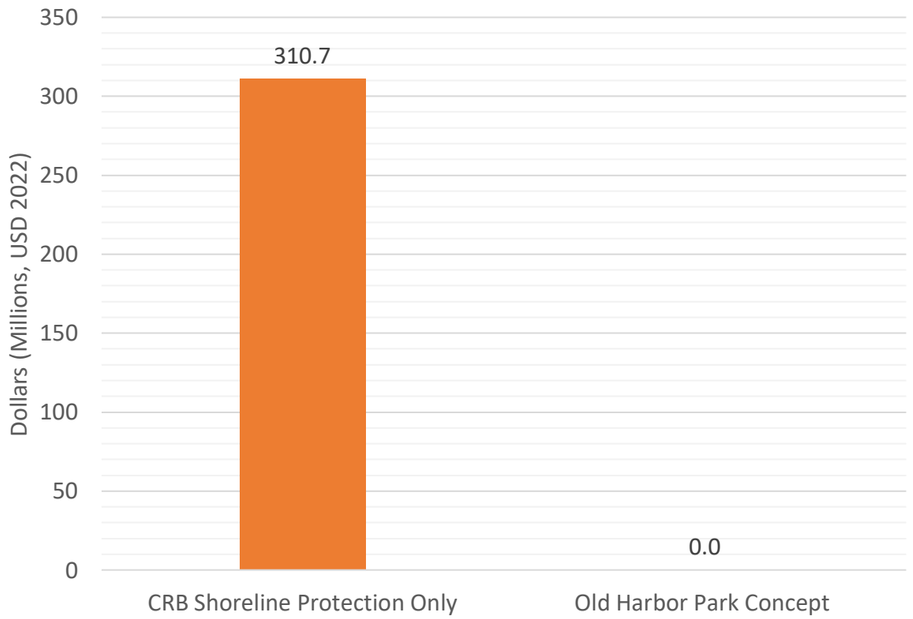


Figure 3: Loss of GDP

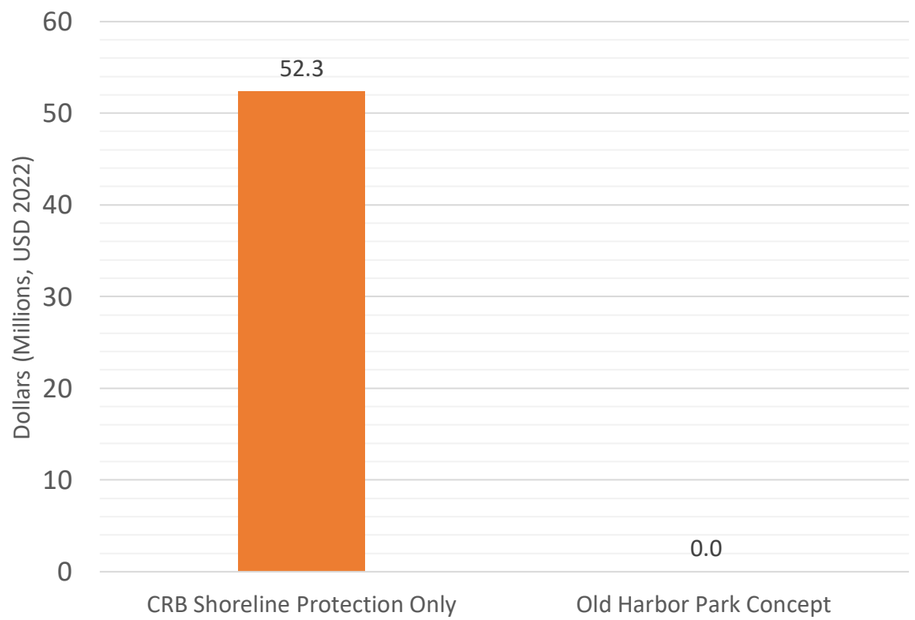
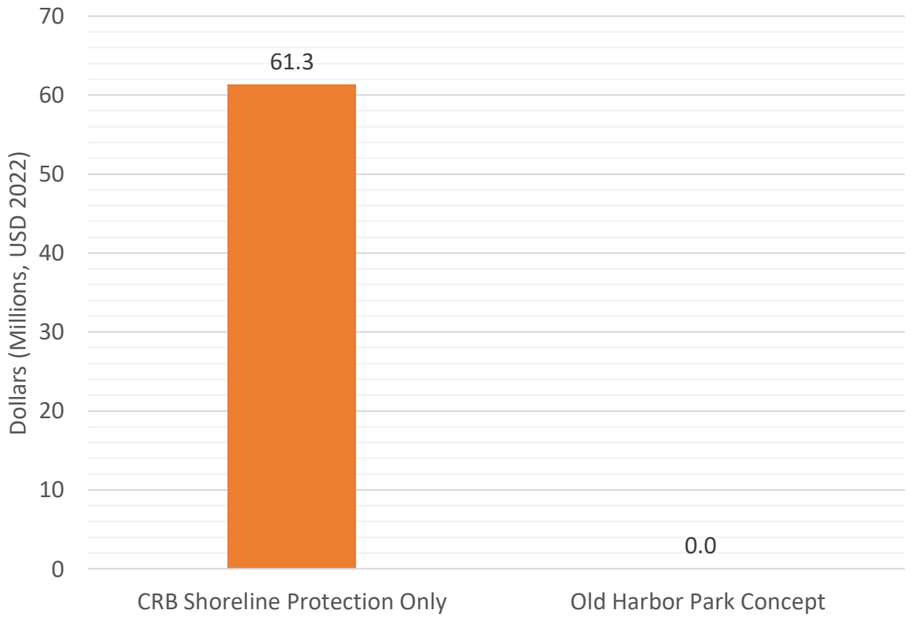


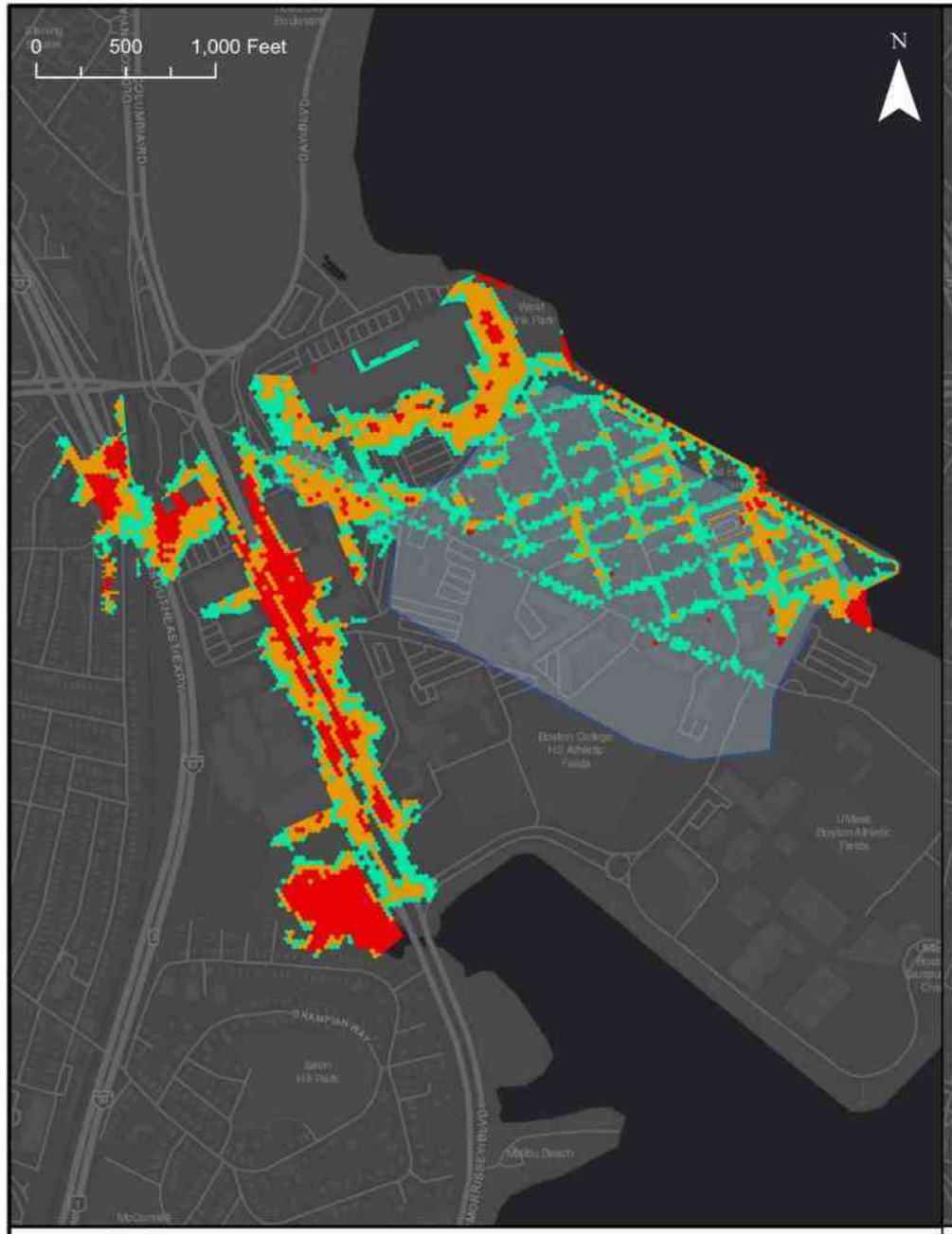
Figure 4: Physical Damage



The flood reduction benefits of the Old Harbor Park Pump Station concept were evaluated using the Commission's 2D Inundation Model by simulating a 100-year tropical storm event with 2070 SLR and storm surge. The figures on the following page depict the peak flooding that was predicted in the Old Harbor Park drainage area with shoreline protection only and with the pump station and tide gates on all vulnerable BWSC owned outfalls. An analysis of economic losses/physical impacts from flooding under both scenarios was performed by risQ Inc.

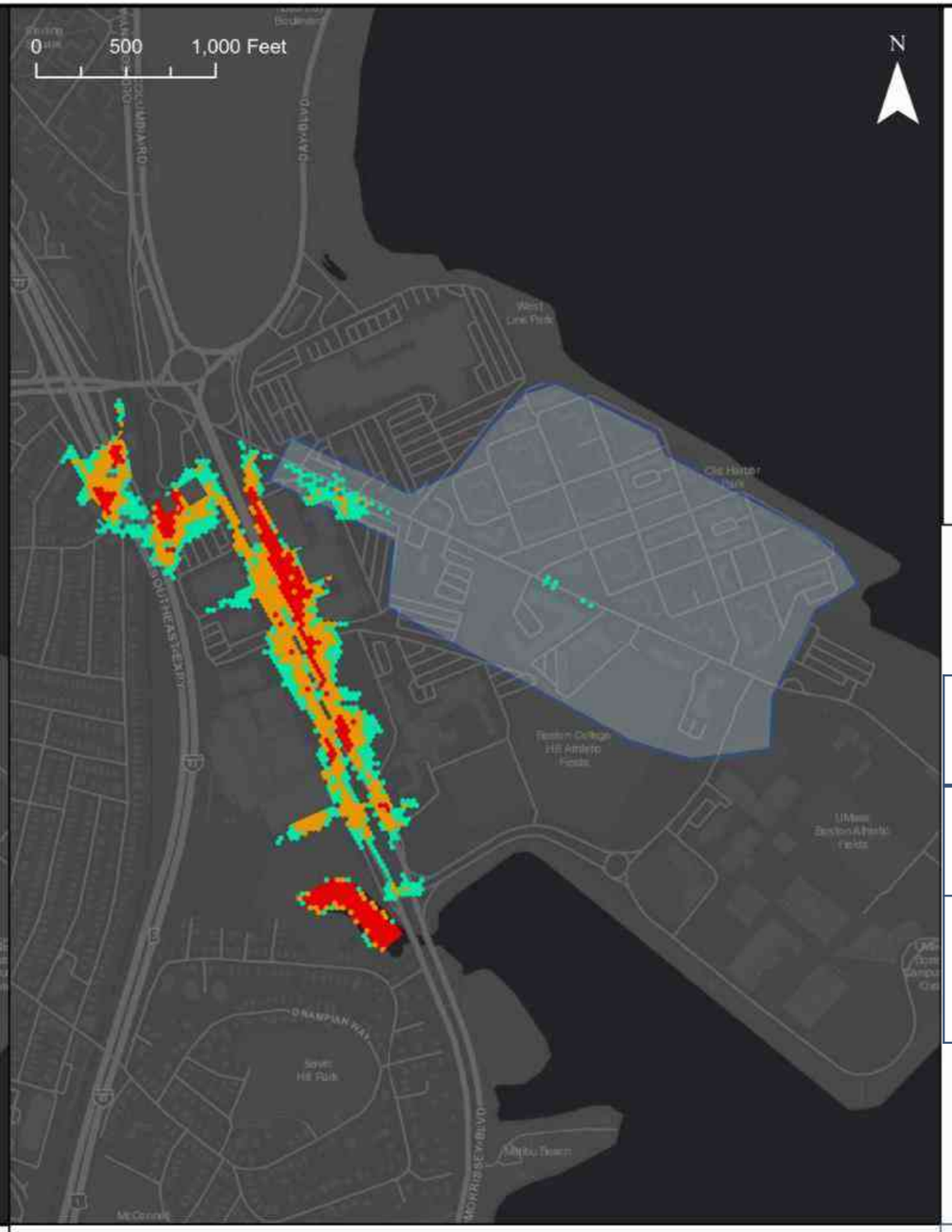
Model predictions indicate that the Old Harbor Park Pump Station concept reduces physical damage by **$61.3 million**, avoids **$310.7 million** in rebuilding costs, and mitigates a GPD loss of **$52.3 million** during a 100-year tropical storm event in 2070 compared to shoreline protection only.

Note: replacement values include the total value of impacted buildings in flooded areas (e.g., impacted buildings are fully replaced), whereas physical damage includes estimated costs to repair flood damage based on predicted flood depths and building characteristics. The values shown are the average of minimum and maximum calculated losses. Refer to the Project's Final Report for more information.



2070 SLR + 100yr Tropical Storm + Storm Surge

Shoreline Protection Only



2070 SLR + 100yr Tropical Storm + Storm Surge

Harbor Park Pump Station

Legend

- Flood Depth > 4 in and < 1 ft
- Flood Depth > 1 ft and < 2 ft
- Flood Depth > 2 ft
- Drainage Area Analyzed

Simulation Parameters

Storm Type	100yr Tropical Storm
Rainfall Depth	9.6 inches
Peak WSE 2070 SLR + 100yr Surge	13.8 feet NAVD88

Coastal Stormwater Discharge Analysis
Old Harbor Park Pump Station

Boston Water and Sewer Commission

Hazen

November 2022

Cost Estimate and FEMA BRIC Considerations

Capital Cost Estimate

A construction cost estimate for the Old Harbor Park Pump Station concept was developed for planning purposes. Assumptions for the cost estimate include 15-year escalation to the mid-point of construction and the inclusion of a 50% design contingency. Utility hookup costs were not included.

Table 3: Old Harbor Park Pump Station Cost Estimate Subtotals

Remaining Design Development & Construction Administration (assumed 20% of total less design contingency)	$3,547,000
Direct Construction Costs	$7,012,000
Indirect Construction Costs	$1,402,000
Mark-Up *(Including 50% design contingency)*	$17,865,000
Total	**$29,826,000**

Social Vulnerability and FEMA BRIC Funding

FEMA BRIC funding prioritizes disadvantaged communities. Table 4 contains a summary of several indicators for the Old Harbor Park Pump Station tributary area that could be used help characterize the community for future FEMA funding applications and prioritization of projects that benefit disadvantaged communities.

Table 4: Old Harbor Park Pump Station Tributary Area Social Vulnerability Indicators

Low Income & Persistent Poverty	
Per Capita Income	$19,522
Below Poverty Line	49%
High Housing Cost Burden	
Stressed Renters (>40% rent-to-income)	52%
Households With Food Insecurity	14%
Racial and Ethnic Segregation	
Asian Population	29%
Black Population	14%
Hispanic Population	29%
White Population	36%
Education and Employment	
Adults Age 25+ Without High School (or equivalent) Degree	12%
Unemployment Rate (Age 16+)	6%

Data provided by risQ inc. from the US census and American Community Survey

Conceptual Design – Not for Construction

Planting Palette

A planting palette was developed for the Old Harbor Park concept. After construction, planting of native plant species could create an enhanced green space with the associated environmental benefits of native plants and conceal concept utilities such as the electrical building.

Trees



Amelanchier arborea
common serviceberry



Juniperus virginiana
eastern red cedar



Magnolia virginiana
sweet bay magnolia



Quercus rubra
northern red oak

Shrubs



Rosa carolina
pasture rose



Rhus copallinum
winged sumac



Aronia melanocarpa
black chokeberry



Morella pensylvanica
bayberry

Herbaceous and Grasses



Panicum virgatum
switchgrass



Schizacharium scoparium
little bluestem



Eutrochium purpureum
Joe-Pye-Weed



Solidago sempervirens
seaside goldenrod

Coastal Stormwater Discharge Analysis
Old Harbor Park Pump Station

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Conceptual Design – Not for Construction

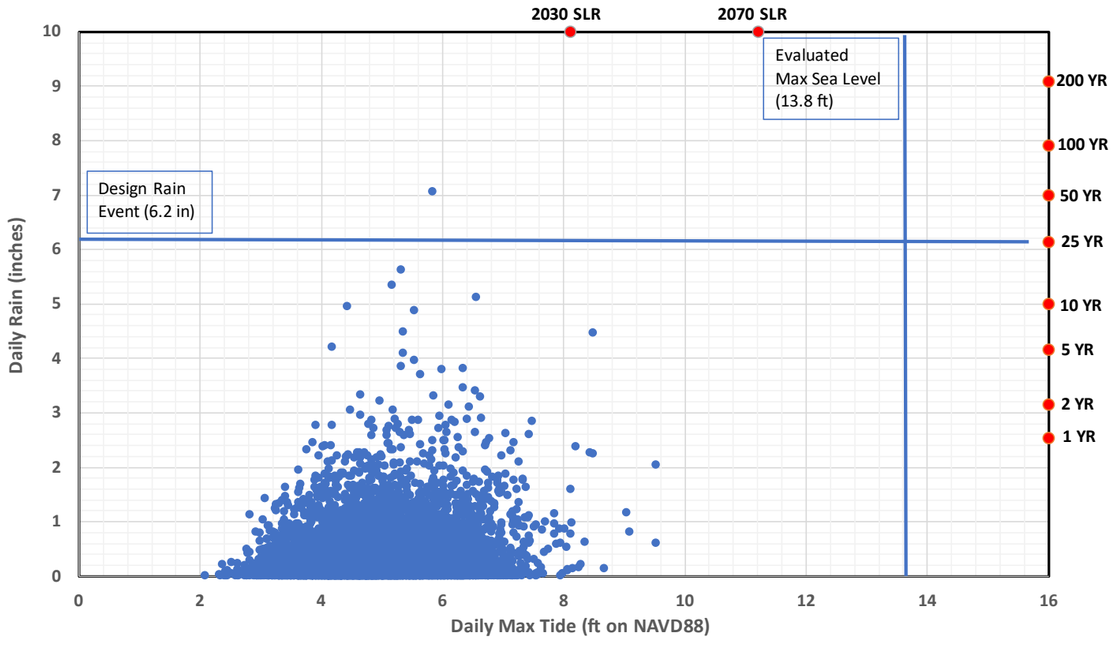
Adaptability and Implementation

Adaptability

Figure 5 below depicts historical daily rainfall totals and tide levels. As shown in this figure, the conditions that were used to design and analyze the Harbor Park pump station are conservative and represent more extreme conditions than have occurred historically. Regardless, the following measures could be implemented to adapt the concept to more severe conditions (additional SLR, more intense rainfall, etc.) in the future:

- Increase the size of installed electric submersible pumps
- Utilize the standby pump as a duty pump during extreme conditions
- Increase the size of peak shaving tank

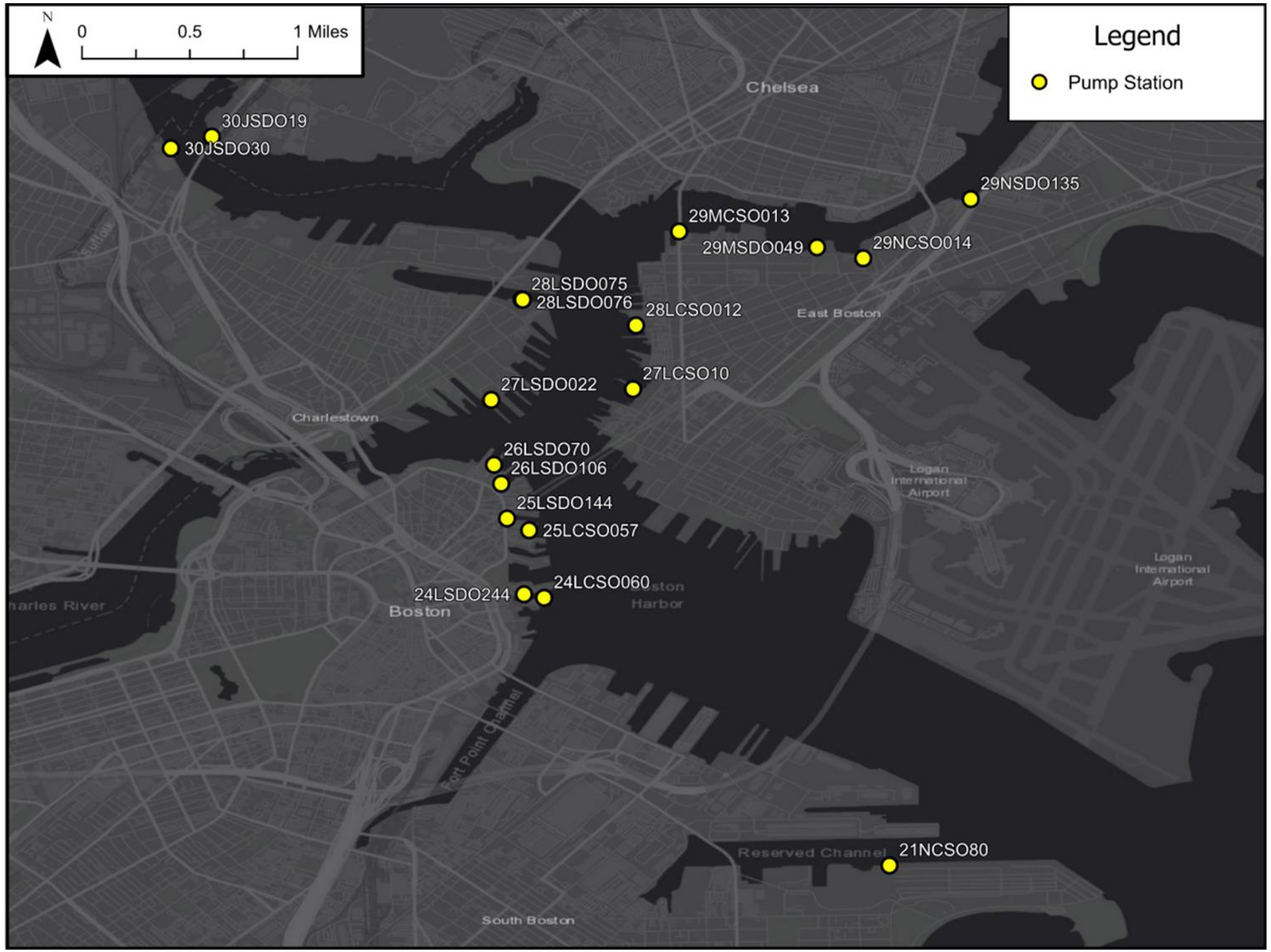
Figure 5: Design and Analysis Conditions vs. Historical Tide and Rainfall



Implementation Considerations

- Coordination with CRB is necessary to implement shoreline protection. The pump station should not be implemented without shoreline protection to prevent coastal flooding within the area tributary to it.
- Planting of native plant species and other green features will provide an improved public amenity and preserve the “look and feel” of the greenway.
- Community engagement with stakeholders may help build project support by illustrating the flood control benefits of the pump station.
- A comprehensive permitting evaluation should be conducted to evaluate possible impacts from construction and operation of the pump station to the receiving water (recreation area).
- A thorough analysis of constructability should be conducted at this location. Methods to minimize disruptions to residents should be considered during the design process.

Replicability and Implementation Timeline



Summary of Similar Concepts

Number of Sites: 18

Vulnerable Area: 422 acres

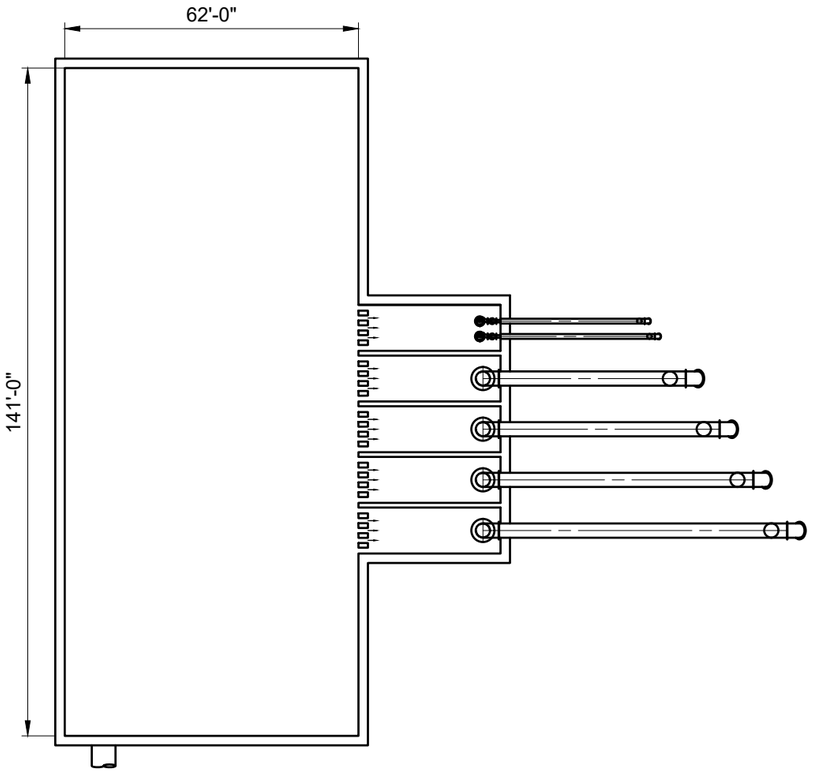
The map on this sheet depicts other vulnerable outfalls that could be adapted with electric submersible pump stations. In some locations, several outfalls could be consolidated with a new conduit that conveys flow to a single pump station.

Additional detail about these outfalls can be found in the Commission's Coastal Stormwater Discharge Analysis Implementation Timeline.

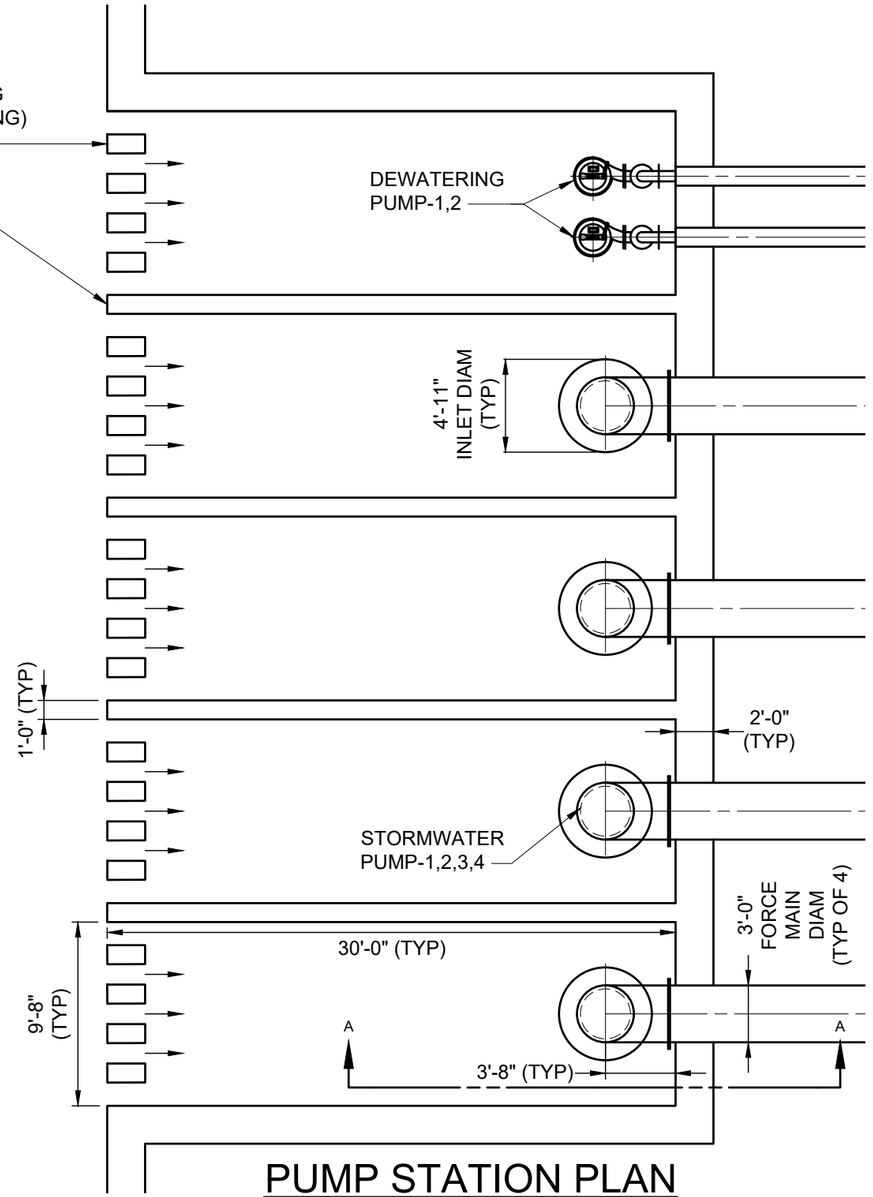
ATTACHMENT A
OLD HARBOR PARK PUMP STATION CONCEPTUAL DESIGN DRAWINGS

A-1: Overview Plan and Pump Station Plans
A-2: Pump Station Section View

Old Harbor Park Stormwater Pump Station



OVERVIEW PLAN
SCALE: NTS



PUMP STATION PLAN
SCALE: NTS

NOTES

1. FOR WATER SURFACE ELEVATIONS REFER TO OPERATIONAL TABLE.
2. ALL ELEVATIONS USE THE NAVD88 VERTICAL DATUM UNLESS OTHERWISE STATED.
3. CONCEPTUAL DRAWING, NOT FOR CONSTRUCTION.

STORMWATER PUMP-1,2,3,4 OPERATIONAL PARAMETERS	
FLOW RATE, CFS	102
STATIC HEAD RANGE, FT	14.3 - 20.2
DESIGN FLOOD ELEVATION, FT	16.5

STORMWATER PUMP-1,2,3,4 OPERATIONAL WSE TABLE		
NOTE	OPERATION	ELEVATION, FT
A	HIGH LEVEL ALARM	2.8
B	LAG PUMP ON	1.8
C	LEAD PUMP ON	0.8
D	LEAD PUMP OFF	-0.2
E	LOW LOW ALARM	-1.2
G	MIN PUMP SUBMERGENCE	-2.2

COASTAL STORMWATER DISCHARGE ANALYSIS

Boston Water and Sewer Commission

Hazen

A-1

November 2022

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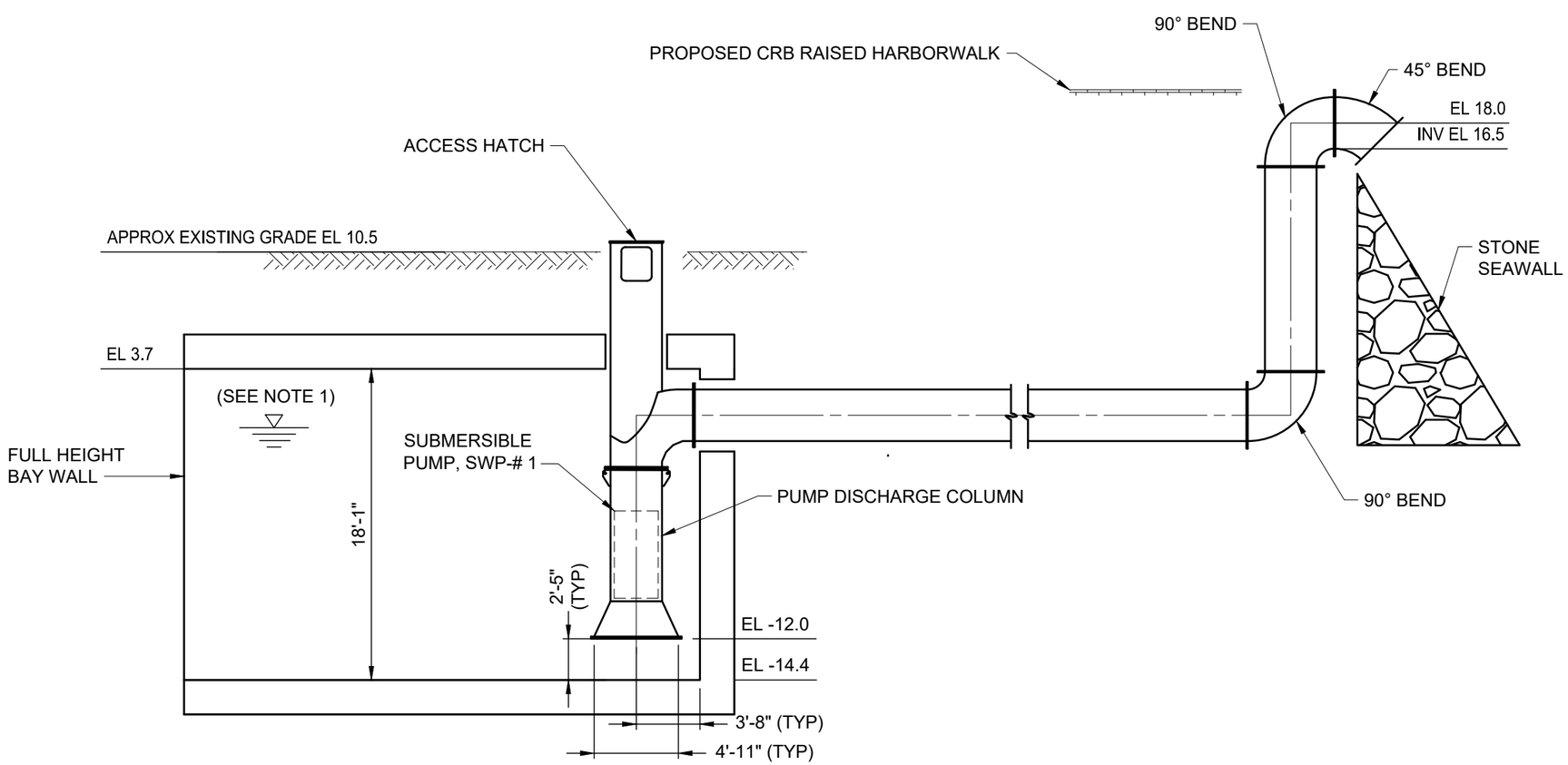
Old Harbor Park Stormwater Pump Station



SECTION

SCALE: NTS

NOTES

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COASTAL STORMWATER DISCHARGE ANALYSIS

Boston Water and Sewer Commission

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A-2

November 2022

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Appendix H: Concept Design Calculations

1. The primary design objective at each location was to maintain the existing HGL in the system (starting at the outfall(s) included in the concept) despite additional SLR and storm surge due to a projected 100-year tropical storm in 2070. The maximum water surface elevation (at each outfall) was chosen to be 3.7 ft NAVD88, or 10.2 ft BCB based on a representative 2016 tidal dataset included in the Commission's existing PCSWMM model. Modeling of the 2070 projected 10-year, 24-hour design storm was conducted to determine the required rates of pumping and volume of storage necessary to maintain the maximum acceptable water surface elevation (3.7 ft, at each outfall). A curve of required pumping (rate) was developed based on this modeling.
2. A tank footprint (in square feet) was selected considering the space constraints of the site and other special conditions (existing trees, property lines, topography, etc). Generally, the horizontal footprint was maximized as much as reasonable, as deeper construction is generally more expensive and complicated for a given excavation volume. Consideration was not given to the approach flow patterns of the inlet to the storage tank based on the orientation of the storage tank to existing pipes and how such flow regimes may or may not impact the pumping of the water. Additional analysis of the inlet(s) of the storage tank is required before final design.
3. A tank depth was selected to correspond with a point along the storage-pumping curve. The top elevation was chosen to be 3.7 ft NAVD88, as described in step 1. Generally, operating the tank in a "storage-only" configuration was preferred; if such a configuration was not possible or practical given the required depth or size of the tank, the preferred design was a volume that intersects roughly with the knee of the storage-pumping curve.
4. The volume of the tank was calculated given the footprint and depth.
5. The required pump rate for the chosen storage volume was calculated by interpolating the pumping vs. storage curve.
6. The number of active pumps was selected to utilize as few pumps as reasonable. All pumps specified for this project are axial-flow propeller, electric, submersible, column pumps. Some manufacturer outreach was performed for the project, particularly for the FPC concept, to confirm that the general ranges of pump rates and pressures required were possible for several manufacturers to produce. Generally, this meant limiting pump rate to below 120 CFS. For most concepts, pump rates were chosen at around 80 CFS or lower, as larger pump rates generally require deeper tanks to accommodate the additional required submergence of the pump. The number of standby pumps was selected to reflect the relative criticality of the particular concept. All concepts including pumping except for the FPC concept were selected to have one standby pump.
7. Minimum pump submergence was calculated using Hydraulic Institute Standard 9.8-2018. All concepts have been designed with a depth sufficient for HI standards, but additional tank depth may be required for some concepts, depending on the specific NPSH requirements of the pumps available on the market.
    a. It was checked whether the selected tank depth could provide the necessary minimum submergence and usable height (active storage). Generally, a usable height of at least 6 feet was preferred, to allow for alarms and pump controls to function without overlap. Here, the usable height is defined as the height of the tank minus the height of the minimum submergence required for proper pump function. If the tank depth did not meet the requirements for minimum submergence and usable height, the design process began again at step 2 with a

deeper tank and repeated until an appropriate combination of tank depth and pumps were found, except for some concepts where space constraints dictated a smaller usable height. Such concepts will need to be considered further to evaluate potentially needing to use an alternative controls schema versus making the tank deeper. Tank heights may need to be adjusted to comply with specific manufacturers' requirements for pump controls and instrumentation in further design phases.

8. The Hydraulic Institute Standard 9.8 was followed to calculate pump intake design dimensions for the pump bays. All pumping concepts were designed to have partitioned pump bays instead of a single intake structure, as recommended by HI 9.8-2018. (See Figures 9.8.3.1.4a and 9.8.3.1.4b.)

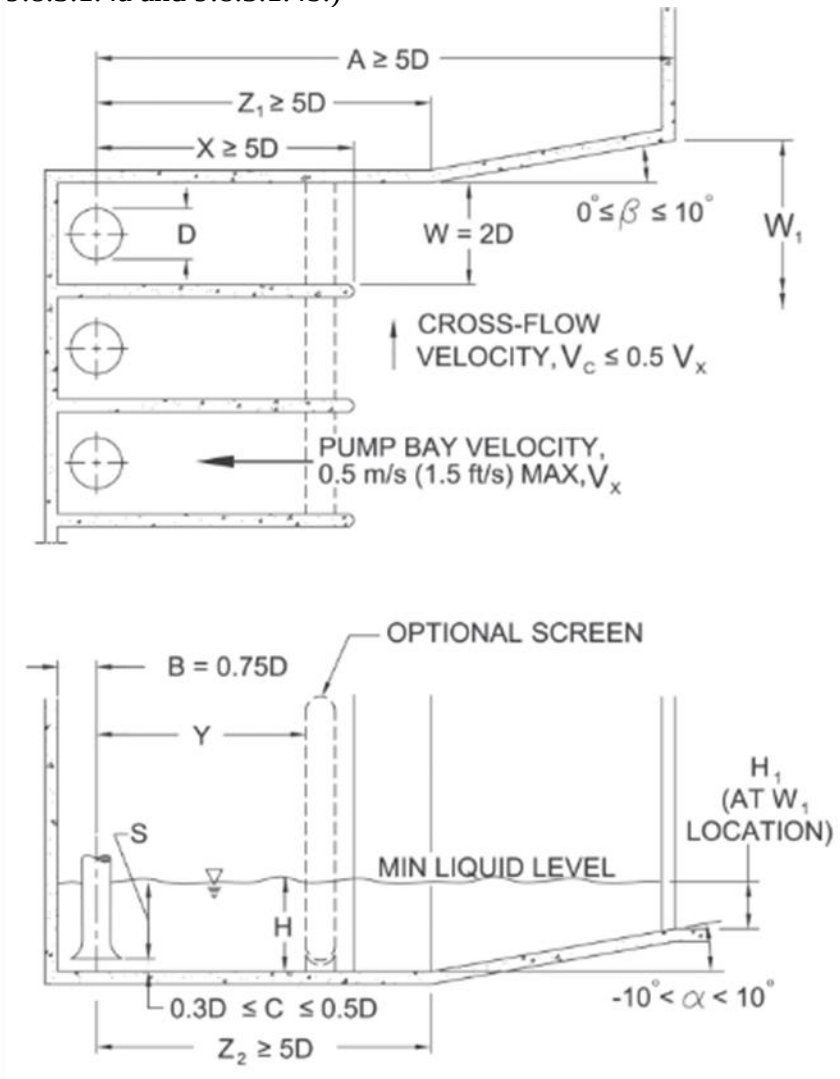


Figure 9.8.3.1.4a Rectangular intake structure layout

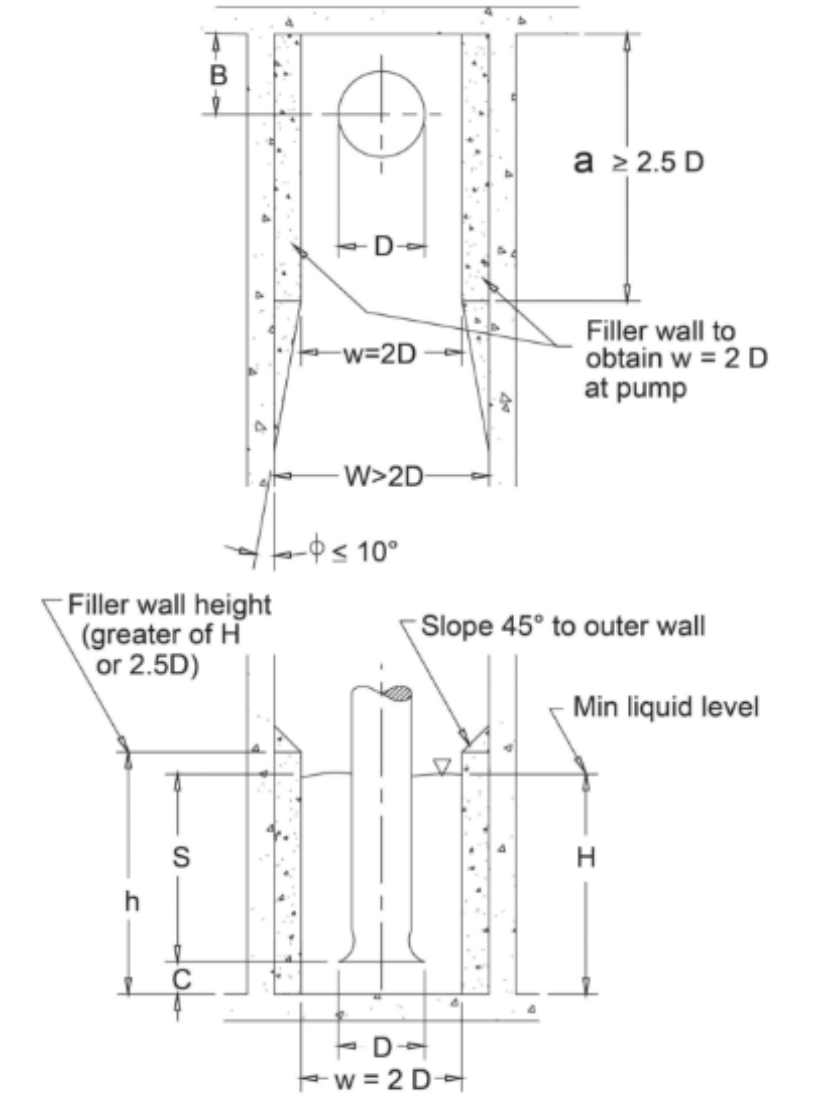


Figure 9.8.3.1.4b Filler wall details for proper bay width

a. It was checked whether the pump bays could be accommodated inside the tank footprint or on site. If no, the design process began again until this constraint could be met.

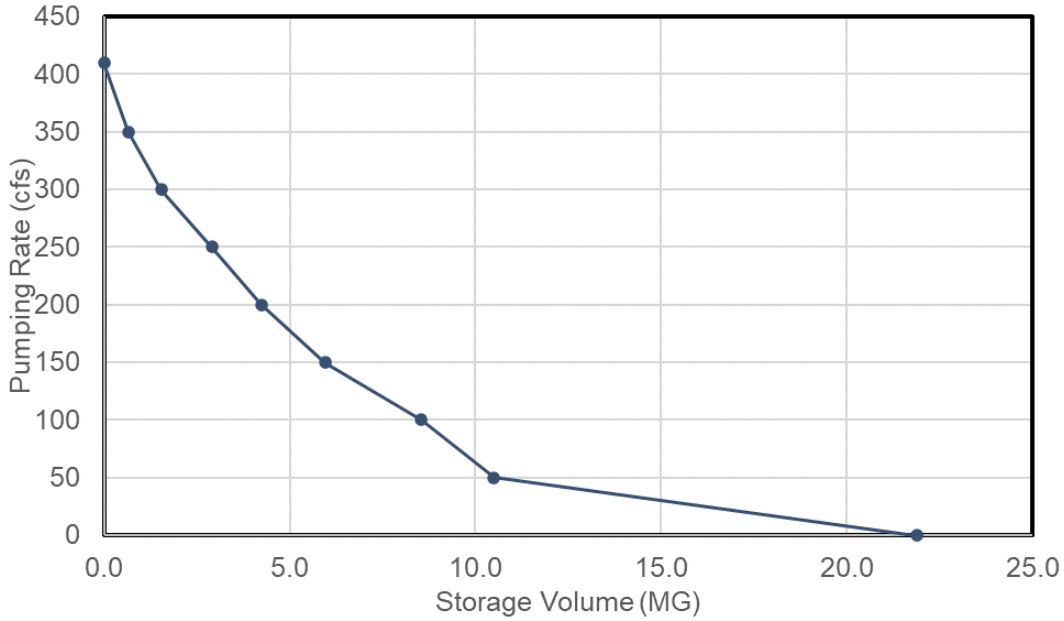
9. A conservative pump rate for the dewatering pumps was calculated: each of the two dewatering pumps was designed to dewater the tank from full to empty in 6 hours. Two dewatering pumps were selected for redundancy. Additional hydraulic modeling at each location may indicate that lower pump rates are acceptable for some concepts. Due to the uncertainty involved with the required dewatering rate, the dewatering pump sump was not designed for any of the pumping concepts. The exact size and shape of the dewatering pump bay sump will have to be calculated at a further stage of the design process. All concepts are expected to have small dewatering pumps less than 20 CFS.
10. Wherever feasible, pump stations were designed to be as close as possible to the discharge location, to minimize the discharge pipe length. At such sites, smaller discharge pipe diameters can be used without excessive head losses, generally assumed to

be equal to the size of the pipes that the pumps are each located inside. For sites that utilized force mains for discharge:

a. A diameter of discharge pipe was selected.
b. The Hazen Williams Equation was used to calculate the slope of the energy line "s" (head loss per length of pipe). Discharge pipes were assumed to be made of galvanized iron with a friction factor, C, of 120.
c. Head loss was calculated for the assumed length of pipe.
    i. If head loss was found to be too large (greater than 5ft) a new diameter of pipe was selected and the process began again at step 9a.

11. For sites that utilized force mains for discharge, step 10 a-c was repeated to size the discharge pipes for the dewatering pumps.

Airport Design Calculations



1.
2. $A_{surf} = 8{,}750 ft^2$
3. $H = 18.3\ ft$
4. $V = A_{surf} * H = 160{,}125 ft^3 \approx 1.2\ MG$
5. $Q_{tot} \approx 320\ cfs$
6. *4 duty and 1 standby pump ->* $Q_{pump} = 80\ cfs$
7. *Min submergence = 8.9 -> OK.*
8. *Pump bay dimensions:*

Max flow per pump	35904	gpm
Max flow per pump	80	cfs
D	4.3	ft
H, Min Liquid Level	11.1	ft
W, Bay Width	8.6	ft
B, 0.75D	3.2	ft
a, >2.5D	10.8	ft
X, 5D min	21.5	ft
Vx, 1.5ft/s max	0.84	ft/s
C, 0.3 to 0.5D	2.2	ft
S	8.9	ft
FD	0.47	
X/D ratio	5	

9. *Dewatering pumps sized to empty tank in 6 hrs ->* $Q_{pump} = \frac{V}{6hrs} \approx 7.4\ cfs$
10. *Discharge pipe calculations:*
    a. $D = 2.0 ft$

b. $k = 1.318,\ C = 120, R_h = \frac{D}{4}, v = \frac{Q_{pump}}{\pi\left(\frac{D}{2}\right)^2}$

$v = kCR_h^{0.67}s^{0.54}$

$s = 0.0803\frac{ft}{ft}$

c. $Length_{pipe} = 50\ ft \rightarrow Head\ loss = Length_{pipe} * s = 4.0ft$ -> *OK.*

11. *Dewatering pump discharge pipe calculations:*

a. $D = 1\ ft$

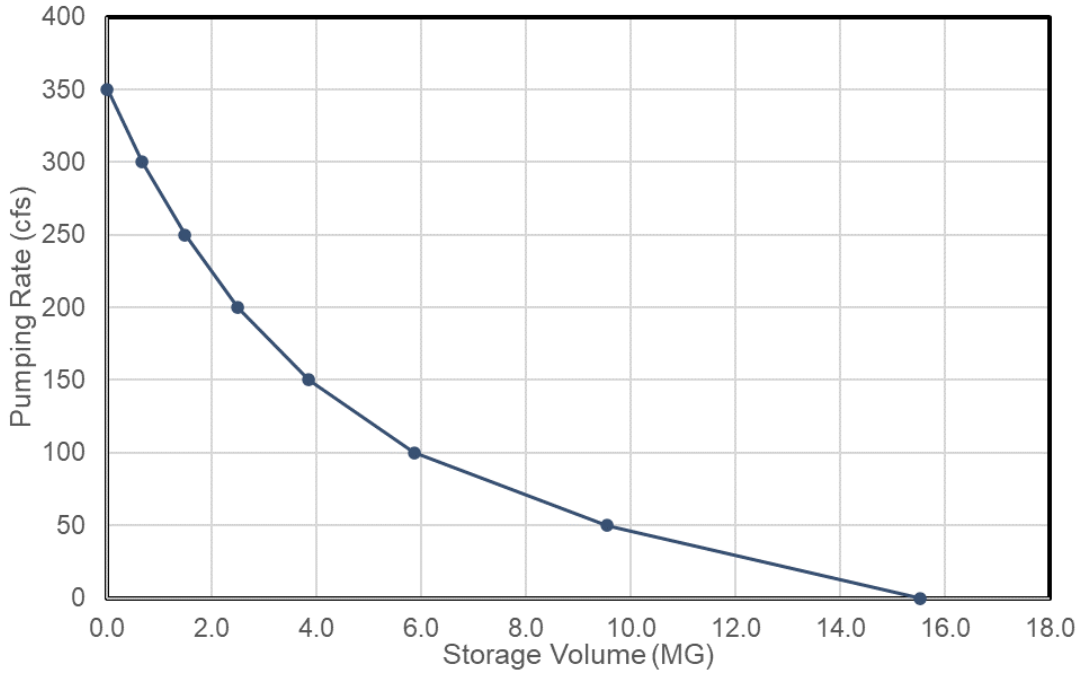
b. $k = 1.318,\ C = 120, R_h = \frac{D}{4}, v = \frac{Q_{pump}}{\pi\left(\frac{D}{2}\right)^2}$

$v = kCR_h^{0.67}s^{0.54}$

$s = 0.030\frac{ft}{ft}$

c. $Length_{pipe} = 50\ ft \rightarrow Head\ loss = Length_{pipe} * s = 1.5\ ft$ -> *OK.*

Charlestown CSO Design Calculations

1. 

2. $A_{surf} = 5{,}250 ft^2$
3. $H = 12\ ft$
4. $V = A_{surf} * H = 63{,}000 ft^3 \approx 0.47\ MG$
5. $Q_{tot} \approx 40\ cfs$
6. *2 duty and 1 standby pump ->* $Q_{pump} = 20\ cfs$
7. *Min submergence = 5.4 -> OK.*
8. *Pump bay dimensions:*

Max flow per pump	8976	gpm
Max flow per pump	20	cfs
D	2.2	ft
H, Min Liquid Level	6.5	ft
W, Bay Width	4.3	ft
B, 0.75D	1.6	ft
a, >2.5D	5.4	ft
X, 5D min	10.8	ft
Vx, 1.5ft/s max	0.71	ft/s
C, 0.3 to 0.5D	1.1	ft
S	5.4	ft
FD	0.66	
X/D ratio	5	

9. *Dewatering pumps sized to empty tank in 6 hrs ->* $Q_{pump} = \frac{V}{6hrs} \approx 2.9\ cfs$
10. *Discharge pipe calculations:*

a. $D = 2.0ft$

b. $k = 1.318,\ C = 120, R_h = \frac{D}{4}, v = \frac{Q_{pump}}{\pi\left(\frac{D}{2}\right)^2}$

$v = kCR_h^{0.67}s^{0.54}$

$s = 0.006\frac{ft}{ft}$

c. $Length_{pipe} = 35\ ft \rightarrow Head\ loss = Length_{pipe} * s = 0.2ft$ -> *OK.*

11. *Dewatering pump discharge pipe calculations:*

a. $D = 1\ ft$

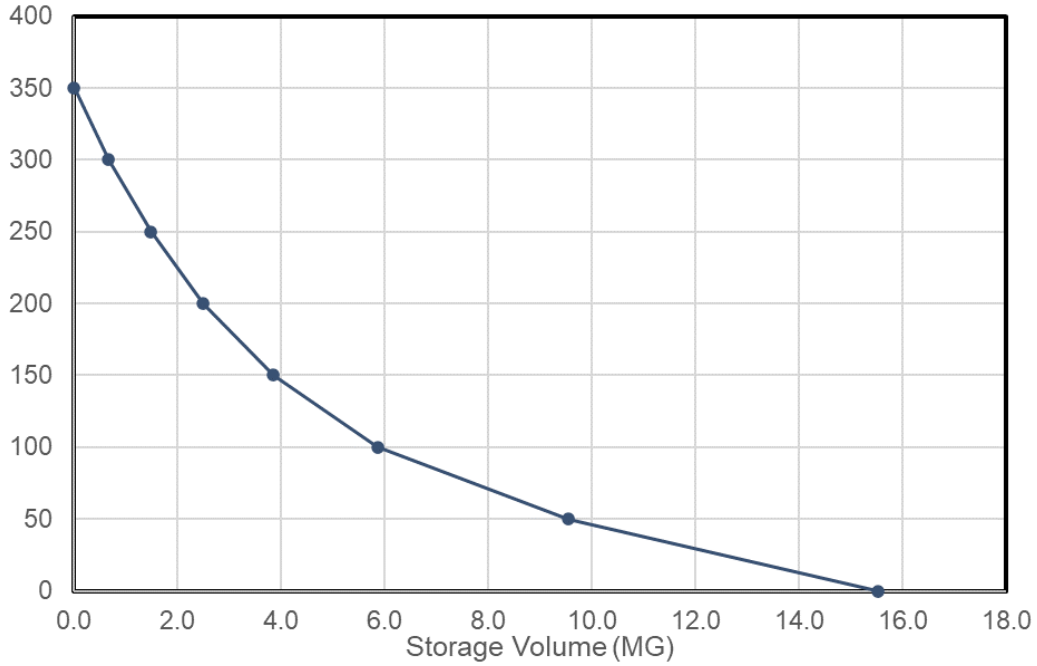
b. $k = 1.318,\ C = 120, R_h = \frac{D}{4}, v = \frac{Q_{pump}}{\pi\left(\frac{D}{2}\right)^2}$

$v = kCR_h^{0.67}s^{0.54}$

$s = 0.005\frac{ft}{ft}$

c. $Length_{pipe} = 35\ ft \rightarrow Head\ loss = Length_{pipe} * s = 0.2\ ft$ -> *OK.*

Charlestown SDO Design Calculations

1. 

2. $A_{surf} = 22{,}360 ft^2$
3. $H = 15\ ft$
4. $V = A_{surf} * H = 335{,}400 ft^3 \approx 2.5\ MG$
5. $Q_{tot} \approx 200\ cfs$
6. *2 duty and 1 standby pump ->* $Q_{pump} = 100\ cfs$
7. *Min submergence = 8.3 -> OK.*
8. *Pump bay dimensions:*

Max flow per pump	44880	gpm
Max flow per pump	100	cfs
D	4.8	ft
H, Min Liquid Level	12.1	ft
W, Bay Width	9.6	ft
B, 0.75D	3.6	ft
a, >2.5D	12.0	ft
X, 5D min	24.1	ft
Vx, 1.5ft/s max	0.86	ft/s
C, 0.3 to 0.5D	2.4	ft
S	9.7	ft
FD	0.44	
X/D ratio	5	

9. *Dewatering pumps sized to empty tank in 6 hrs ->* $Q_{pump} = \frac{V}{6hrs} \approx 15.5\ cfs$
10. *Discharge pipe calculations:*
    a. $D = 2.0 ft$

b. $k = 1.318,\ C = 120, R_h = \frac{D}{4}, v = \frac{Q_{pump}}{\pi\left(\frac{D}{2}\right)^2}$

$v = kCR_h^{0.67}s^{0.54}$

$s = 0.121\frac{ft}{ft}$

c. $Length_{pipe} = 35\ ft \rightarrow Head\ loss = Length_{pipe} * s = 4.2ft$ -> *OK.*

11. *Dewatering pump discharge pipe calculations:*

a. $D = 1\ ft$

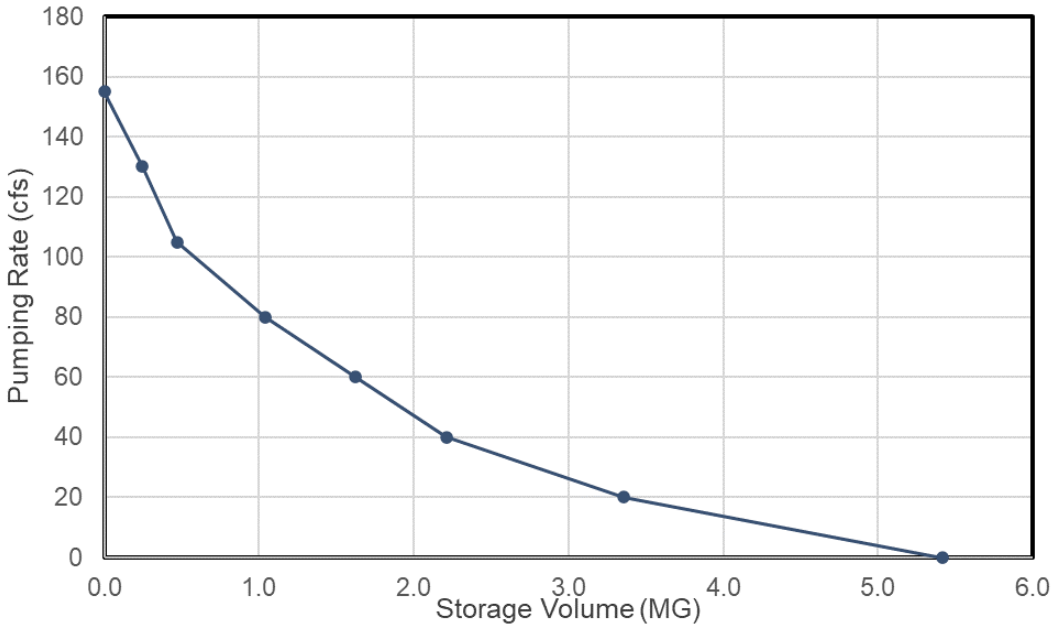
b. $k = 1.318,\ C = 120, R_h = \frac{D}{4}, v = \frac{Q_{pump}}{\pi\left(\frac{D}{2}\right)^2}$

$v = kCR_h^{0.67}s^{0.54}$

$s = 0.118\frac{ft}{ft}$

c. $Length_{pipe} = 35\ ft \rightarrow Head\ loss = Length_{pipe} * s = 4.1\ ft$ -> *OK.*

Columbus Park Design Calculations

1. 

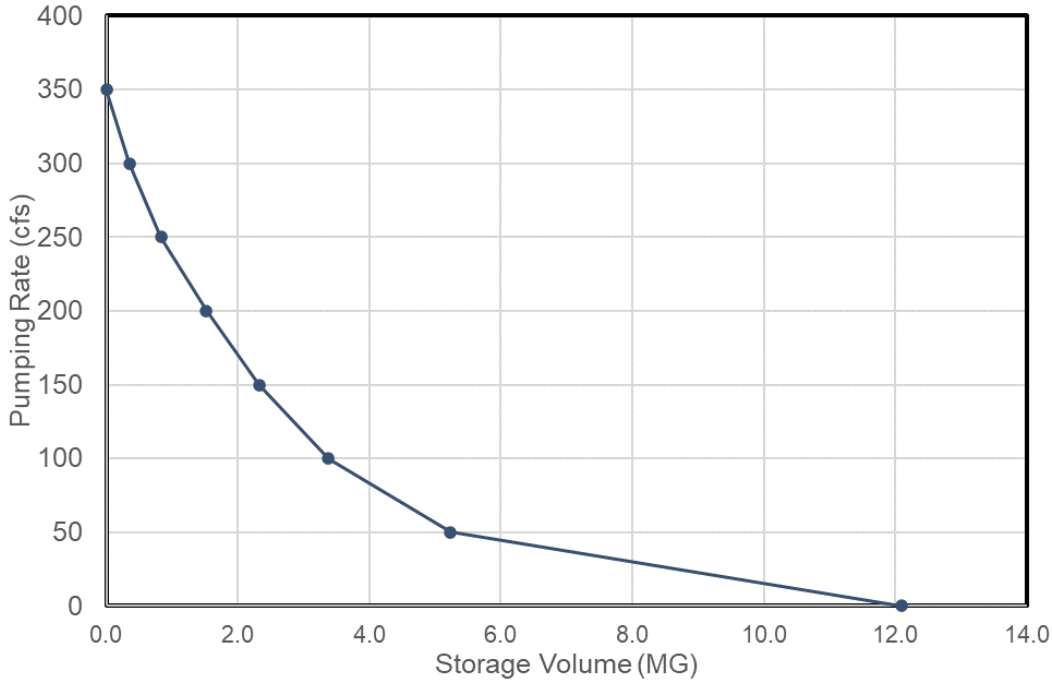
2. $A_{surf} = 187ft * 68ft = 12{,}716ft^2$
3. $H = 13.3\ ft.$ Note: This concept was intentionally made shallower than other concepts, as it is suspected that there is existing underground infrastructure, possibly including parts of the structure of the Callahan tunnel. To advance the design, additional information about the subsurface is required.
4. $V = A_{surf} * H = 169{,}123ft^3 \approx 1.15\ MG$
5. $Q_{tot} \approx 80\ cfs$
6. *1 duty and 1 standby pump -> $Q_{pump} = 80\ cfs$*
7. *Min submergence = 8.9 -> OK.*
8. *Pump bay dimensions:*

Max flow per pump	35904	gpm
Max flow per pump	80	cfs
D	4.3	ft
H, Min Liquid Level	11.1	ft
W, Bay Width	8.6	ft
B, 0.75D	3.2	ft
a, >2.5D	10.8	ft
X, 5D min	21.5	ft
Vx, 1.5ft/s max	0.84	ft/s
C, 0.3 to 0.5D	2.2	ft
S	8.9	ft
FD	0.47	
X/D ratio	5	

9. *Dewatering pumps sized to empty tank in 6 hrs -> $Q_{pump} = \frac{V}{6hrs} \approx 6.4\ cfs$*

10. *Discharge pipe calculations:*
    a. $D = 2.5ft$
    b. $k = 1.318,\ C = 120, R_h = \frac{D}{4}$
       $v = kCR_h^{0.67}s^{0.54}$
       $s = 0.0257\frac{ft}{ft}$
    c. $Length_{pipe} = 118\ ft \rightarrow Head\ loss = Length_{pipe} * s = 3.03$ -> *OK.*
11. *Dewatering pump discharge pipe calculations:*
    a. $D = 1\ ft$
    b. $k = 1.318,\ C = 120, R_h = \frac{D}{4}, v = \frac{Q_{pump}}{\pi\left(\frac{D}{2}\right)^2}$
       $v = kCR_h^{0.67}s^{0.54}$
       $s = 0.023\frac{ft}{ft}$
    c. $Length_{pipe} = 120\ ft \rightarrow Head\ loss = Length_{pipe} * s = 2.8ft$ -> *OK.*
12. *Discharge structure design:*
    a. $Structure\ fed\ by\ two\ (2)2.5ft\ pipes\ and\ two\ (2)1ft\ pipes\ \rightarrow$ $min\ discharge\ surface\ area\ =\ 5.7\ ft^2$.
    b. $Selected\ grate\ structure\ dimensions$: $8ft\ (L)\ x\ 1ft\ (H)$. Four separate pipe discharges could also be used. Co-ordination with CRB is required, as the discharge will need to be integrated into the seawall/berm.

Constitution Beach Design Calculations

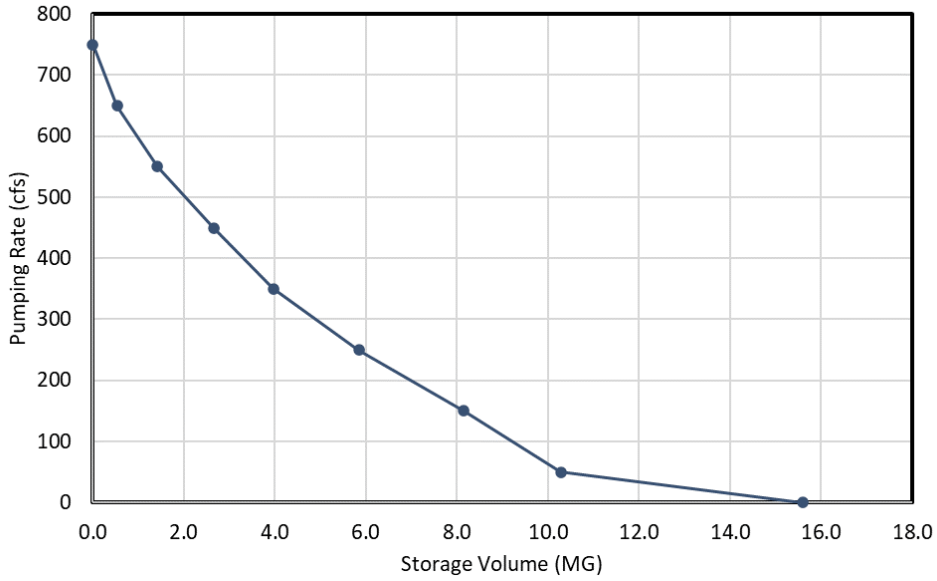


1.
2. $A_{surf} = 10{,}410 ft^2$
3. $H = 18.0\ ft$
4. $V = A_{surf} * H = 187{,}380 ft^3 \approx 1.4\ MG$
5. $Q_{tot} \approx 145\ cfs$
6. *2 duty and 1 standby pump -> $Q_{pump} = 75\ cfs$*
7. *Min submergence = 8.7 -> OK.*
8. *Pump bay dimensions:*

Max flow per pump	33660	gpm
Max flow per pump	75	cfs
D	4.2	ft
H, Min Liquid Level	10.8	ft
W, Bay Width	8.3	ft
B, 0.75D	3.1	ft
a, >2.5D	10.4	ft
X, 5D min	20.8	ft
Vx, 1.5ft/s max	0.83	ft/s
C, 0.3 to 0.5D	2.1	ft
S	8.7	ft
FD	0.47	
X/D ratio	5	

9. *Dewatering pumps sized to empty tank in 6 hrs -> $Q_{pump} = \frac{V}{6hrs} \approx 8.7\ cfs$*

Davenport Creek Design Calculations

1. 

2. $A_{surf\ tank} = 2{,}083 ft^2$
3. $H_{tank} = 20.0\ ft$
4. $V_{tank} = 41{,}653\ ft^3$. $V_{storage\ basins} \approx 6\ MG$. Storage basin volume was calculated in AutoCAD Civil 3D using volume dashboard. The surface shape of the storage basins was selected, and it was assumed that the walls sloped inward at a 1:1 slope until the basin reached a depth of 7.5 feet. This volume does not include the volume of the pump station tank.
5. $Q_{tot} \approx 249\ cfs$
6. *3 duty and 1 standby pump ->* $Q_{pump} = 83\ cfs$
7. *Min submergence = 9.0 -> OK.*
8. *Pump bay dimensions:*

Max flow per pump	37250	gpm
Max flow per pump	83	cfs
D	4.4	ft
H, Min Liquid Level	11.2	ft
W, Bay Width	8.8	ft
B, 0.75D	3.3	ft
a, >2.5D	11.0	ft
X, 5D min	21.9	ft
Vx, 1.5ft/s max	0.84	ft/s
C, 0.3 to 0.5D	2.2	ft
S	9.0	ft
FD	0.46	
X/D ratio	5	

9. *Dewatering pumps sized to empty tank in 6 hrs ->* $Q_{pump} = \frac{V_{tank}}{6hrs} \approx 1.9\ cfs$

Dorchester Bay Basin Design Calculations

Using the NOAA interactive data downloader, a Digital Elevation Model (DEM) was downloaded for the region surrounding both study regions in a TIFF format. From this DEM, the Contour geoprocessing tool was run to create a polyline feature of elevation contours. The contour lines were used to define approximate bounding regions for the basins. For the purposes of this preliminary investigation, the upper rim (bounding region) of the basin was defined as the highest contour line which stayed within the boundary of the intertidal zone of the basin and did not interfere with buildings or roads. For the DBB, this was approximately 5 feet NAVD88, close to the mean higher high-water level of 4.77 feet. Landscaping and/or building a seawall would allow for a higher "upper rim" to the basin (i.e., additional storage volume within the basin). See Figure 1 below, for an illustration of the contour chosen as the upper rim elevation for the DBB.



Figure 1 - DBB, Bounded by 5-Foot Contour

The 5-foot contour was then used to create a boundary polygon to represent the upper rim of the basin, including a vertical lift gate underneath Morrissey Blvd.

The DEM was then clipped to the upper rim polygon. The summary statistics of this DEM raster can be used to calculate the total volume of the DBB between the sea floor and 5 feet NAVD88 within the boundary polygon. With an arithmetic mean value of -6.0 feet and a "ceiling" of 5.0 feet, the total volume of the basin can be approximated as 11.0 feet multiplied by the surface area of the bounding polygon, which had an area of 2.46 million square feet. This results in a volume of 27.11 million cubic feet, or 202.8 million gallons.

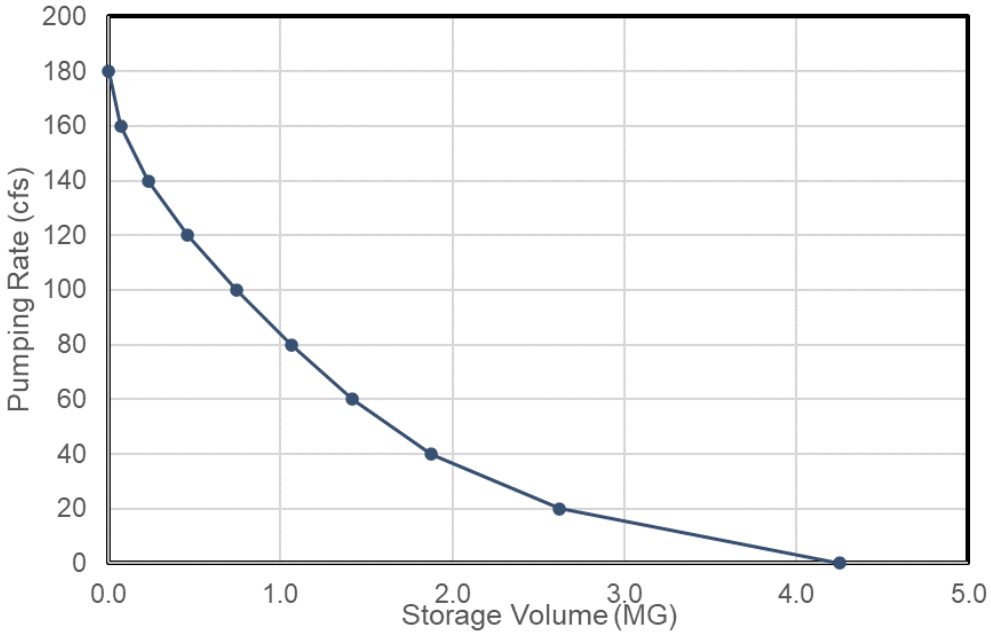
Since a portion of the basin will always be filled (based on the tide level) some of this volume is not usable for stormwater storage. The unusable portion of the basin was approximated as being the volume between the sea floor and the mean low water level (MLW). For this analysis, MLW was taken to be -5.2 feet NAVD88 (based on data from NOAA buoy 8443970).

The volume of the DBB between the sea floor and the contour line at -5.2 feet NAVD88 was then calculated using the same process used to find the total volume of the basin. This analysis found that the volume of water below the level of the MLW was 5.74 million cubic feet, or 42.98 million gallons.

The usable volume of the basin was then calculated by subtracting the volume that is below the mean low water level from the full volume of the basin, yielding a usable basin volume of 21.37 million cubic feet, or 159.9 million gallons. This analysis was repeated for 2070 sea level conditions. See Table 1, below.

Metric	Present Day Sea Levels	2070 Sea Levels
Upper Rim Elevation (ft NAVD88)	5.0	5.0
Mean Basin Depth from Upper Rim (ft)	11.0	11.0
Surface Area of Upper Rim (Million sqft)	2.5	2.5
Total Volume (Million cubic ft)	27.1	27.1
Total Volume (Million gal)	202.8	202.8
Mean Low Water Elevation (ft NAVD88)	-5.2	-0.9
Mean Basin Depth below MLW Level (ft)	3.8	6.4
Surface Area of MLW Contour (Million sqft)	1.5	2.1
Volume Below MLW (Million cubic ft)	5.7	13.6
Volume Below MLW (Million gal)	43.0	102.0
Usable Basin Volume (Million cuft)	21.4	13.5
Usable Basin Volume (Million gal)	159.9	100.8

East Boston Greenway Design Calculations

1. 

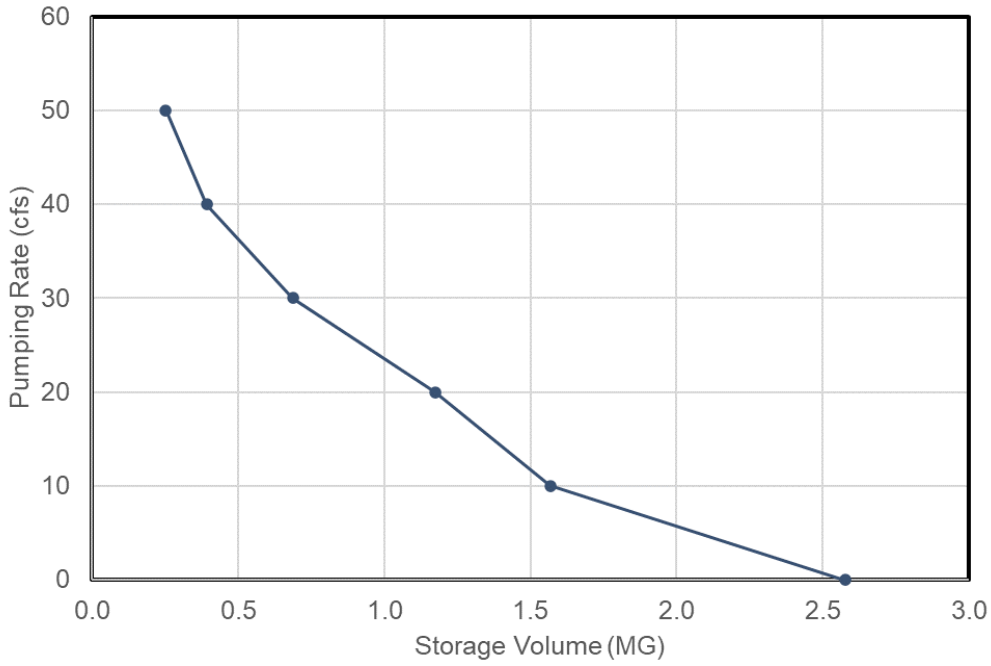
2. $A_{surf} = 2{,}424 ft^2$
3. $H = 14.7 ft$
4. $V = A_{surf} * H = 47{,}515 ft^3 \approx 0.355\ MG$
5. $Q_{tot} \approx 133\ cfs$
6. *2 duty and 1 standby pump -> $Q_{pump} = 67\ cfs$*
7. *Min submergence = 8.7 -> OK.*
8. *Pump bay dimensions:*

Max flow per pump	30070	gpm
Max flow per pump	67	cfs
D	3.9	ft
H, Min Liquid Level	10.3	ft
W, Bay Width	7.9	ft
B, 0.75D	3.0	ft
a, >2.5D	9.9	ft
X, 5D min	19.7	ft
Vx, 1.5ft/s max	0.82	ft/s
C, 0.3 to 0.5D	2.0	ft
S	8.4	ft
FD	0.49	
X/D ratio	5	

To accommodate additional flow from nearby outfalls and/or unexpected future flow intensity, and given the size constraints of the site, the pump bays were made as big as possible, larger than required, to allow for larger pumps to be more easily retrofit if needed. The pump station was designed to accommodate flow of 150 CFS.

9. *Dewatering pumps sized to empty tank in 6 hrs -> $Q_{pump} = \frac{V}{6hrs} \approx 2.2\ cfs$*

East Boston Waterfront Design Calculations

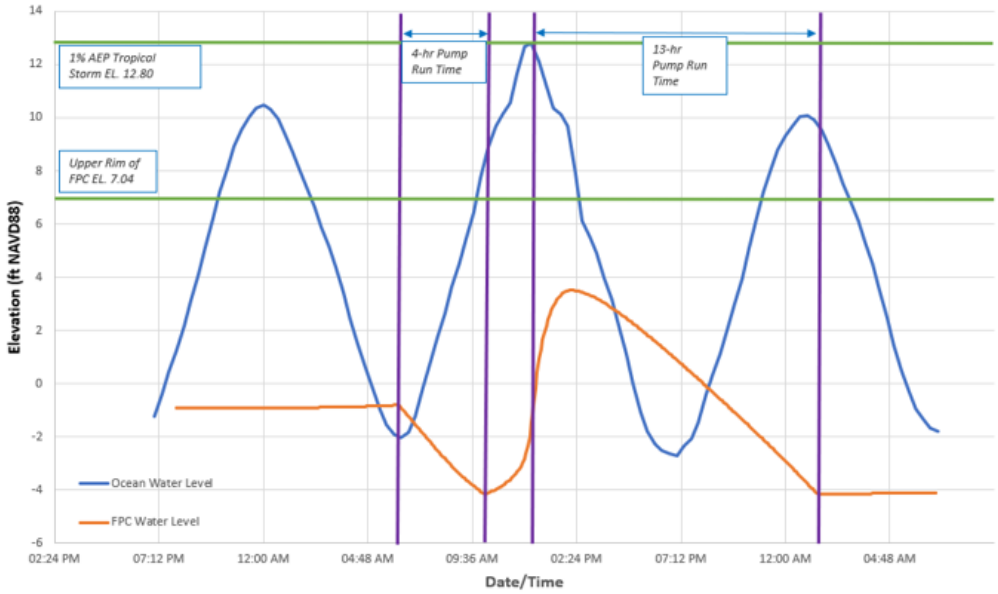


1.
2. $A_{surf\ tank} = 2{,}424 ft^2$
3. $H_{tank} = 14.7 ft$
    a. Bottom of tank selected to be -10.7 NAVD 88 to allow proposed pipes to feed the tank by gravity. All proposed pipes have a 0.05% slope.
4. $V_{tank} = 447\ ft^3$. $V_{pipes} = 59{,}244 ft^3 \approx 1.4\ MG$. Volume of pipes was calculated as cross-sectional area multiplied by length of pipe for all proposed pipes.
5. $Q_{tot} \approx 40\ cfs$
6. *1 duty and 1 standby pump -> $Q_{pump} = 40\ cfs$*
7. *Min submergence = 6.9 -> OK.*
8. *Pump bay dimensions:*

Max flow per pump	17952	gpm
Max flow per pump	40	cfs
D	3.0	ft
H, Min Liquid Level	8.5	ft
W, Bay Width	6.1	ft
B, 0.75D	2.3	ft
a, >2.5D	7.6	ft
X, 5D min	15.2	ft
Vx, 1.5ft/s max	0.78	ft/s
C, 0.3 to 0.5D	1.5	ft
S	6.9	ft
FD	0.55	
X/D ratio	5	

9. *Dewatering pumps sized to empty tank in 6 hrs -> $Q_{pump} = \frac{V}{6hrs} \approx 0.02\ cfs$*
10. *Tank inlet diameter = equivalent diameter of 2 inlet pipes -> 68" and 36" => 78"*

Fort Point Channel Design Calculations



1.
2. Surface area not relevant
3. $H = 35.5ft$
4. $V = 100\ MG$. The usable storage volume was calculated by developing a stage storage curve provided by BWSC and determining the volume between Mean Low Water (MLW) and the approximate upper rim elevation of the FPC (approximately 7.0 feet, NAVD88).
5. $Q_{tot} \approx 500\ cfs$
6. *3 duty and 2 standby pumps -> $Q_{pump} = 167\ cfs$*
7. *Min submergence = 11.8 -> OK.*
8. *Pump bay dimensions:*

Max flow per pump	75000	gpm
Max flow per pump	167	cfs
D	6.2	ft
H, Min Liquid Level	7	ft
W, Bay Width	12.4	ft
Spacing between Pumps	6	ft
B, 0.75D	4.7	ft
a, >2.5D	15.6	ft
X, 5D min	31.1	ft
Vx, 1.5ft/s max	0.90	ft/s
C, 0.3 to 0.5D	3.1	ft
S	11.8	ft
FD	0.39	
X/D ratio	5	

The Fort Point Channel concept pump station includes pumps with formed suction intakes. HI standards were followed (see Figure 9.8.3.2.2) in selecting the dimensions of the formed suction intakes.

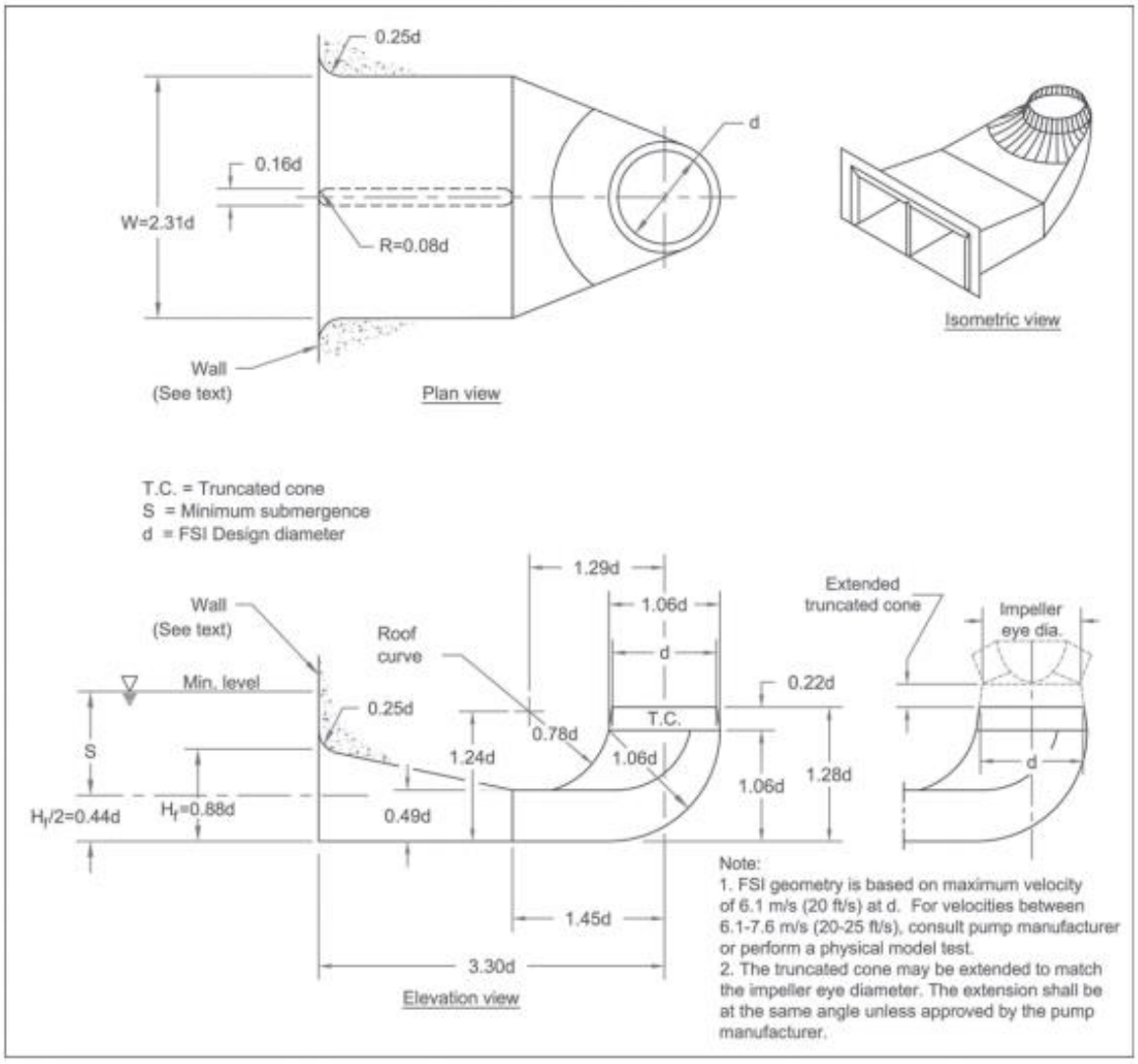
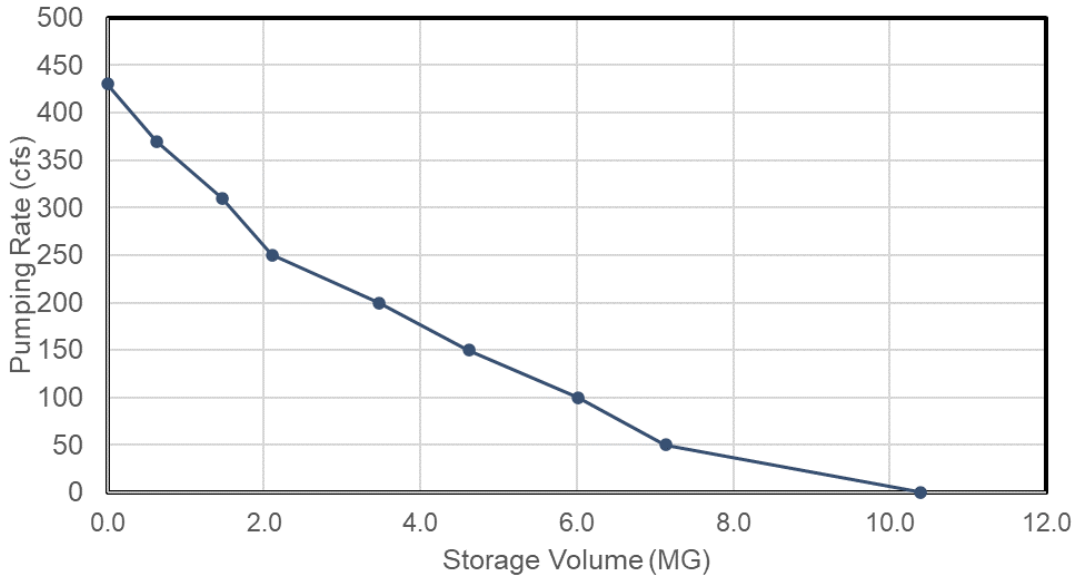


Figure 9.8.3.2.2 Formed suction intake

Formed suction intake dimensions:

d	5.8	ft
Hf	5.1	ft
W	13.5	ft

Old Harbor Park Design Calculations



1.
2. $A_{surf} = 10{,}311 ft^2$
3. $H = 18.3\ ft$
4. $V = A_{surf} * H = 188{,}691 ft^3 \approx 1.4\ MG$
5. $Q_{tot} \approx 306\ cfs$
6. *3 duty and 1 standby pump ->* $Q_{pump} = 102\ cfs$
7. *Min submergence = 10.3 -> OK.*
8. *Pump bay dimensions:*

Max flow per pump	45778	gpm
Max flow per pump	102	cfs
D	4.9	ft
H, Min Liquid Level	12.2	ft
W, Bay Width	9.7	ft
B, 0.75D	3.6	ft
a, >2.5D	12.2	ft
X, 5D min	24.3	ft
Vx, 1.5ft/s max	0.86	ft/s
C, 0.3 to 0.5D	2.4	ft
S	9.8	ft
FD	0.44	
X/D ratio	5	

9. *Dewatering pumps sized to empty tank in 6 hrs ->* $Q_{pump} = \frac{V}{6hrs} \approx 8.7\ cfs$
10. *Discharge pipe calculations:*
    a. $D = 3.0 ft$
    b. $k = 1.318,\ C = 120, R_h = \frac{D}{4}, v = \frac{Q_{pump}}{\pi\left(\frac{D}{2}\right)^2}$

$v = kCR_h^{0.67}s^{0.54}$

$s = 0.0170\frac{ft}{ft}$

c. $Length_{pipe} = 80\ ft \rightarrow Head\ loss = Length_{pipe} * s = 1.4ft$ -> *OK.*

11. *Dewatering pump discharge pipe calculations:*

a. $D = 1.0ft$

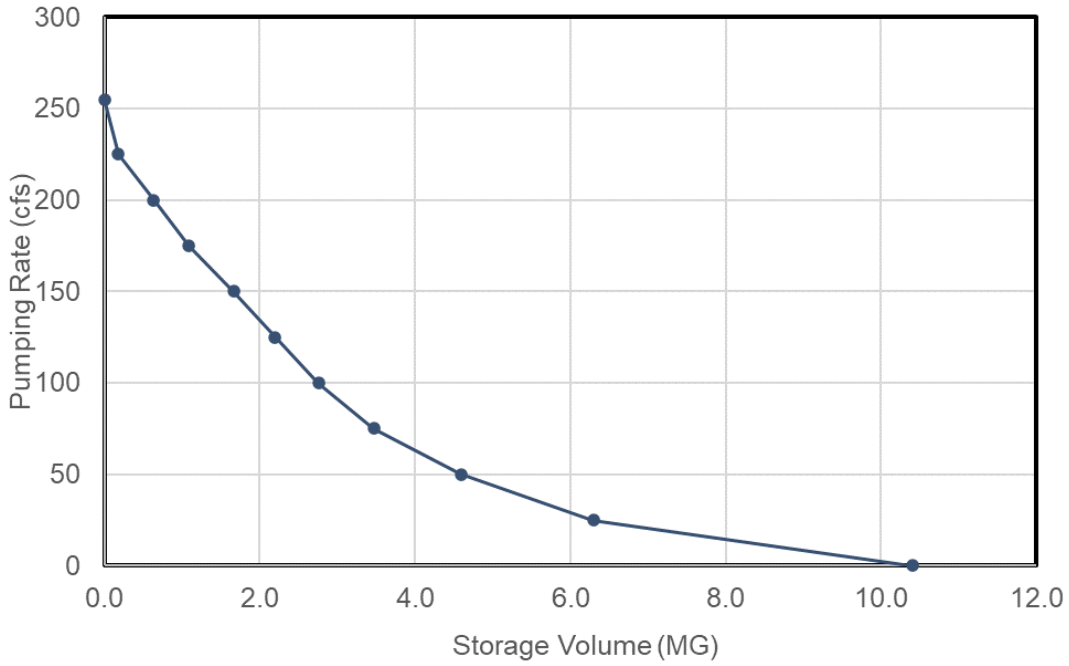
b. $k = 1.318,\ C = 120, R_h = \frac{D}{4}, v = \frac{Q_{pump}}{\pi\left(\frac{D}{2}\right)^2}$

$v = kCR_h^{0.67}s^{0.54}$

$s = 0.041\frac{ft}{ft}$

c. $Length_{pipe} = 80\ ft \rightarrow Head\ loss = Length_{pipe} * s = 3.2ft$ -> *OK.*

Joseph Finnegan Park Calculations

1. 

2. $A_{surfPump\ station} = 501\ ft^2$. $A_{surfbasin} = 129{,}600 ft^2$
3. $H = 13.75\ ft$
4. $V_{Pump\ station} = 6{,}888\ ft^3$. Basin walls slope inward with 1:4 slope, volume calculated in AutoCAD Civil 3D $V \approx 10\ MG$
5. $Q_{tot} \approx 0\ cfs$
6. *1 duty and 1 standby pump -> $Q_{pump} = 50\ cfs$*
7. *Min submergence = 6.5 -> OK.*
8. *Pump bay dimensions:*

Max flow per pump	22440	gpm
Max flow per pump	50	cfs
D	3.4	ft
H, Min Liquid Level	9.2	ft
W, Bay Width	6.8	ft
B, 0.75D	2.6	ft
a, >2.5D	8.5	ft
X, 5D min	17.0	ft
Vx, 1.5ft/s max	0.80	ft/s
C, 0.3 to 0.5D	1.7	ft
S	7.5	ft
FD	0.52	
X/D ratio	5	

9. *Dewatering pumps sized to empty pump station in 6 hrs -> $Q_{pump} = \frac{V_{ps}}{6hrs} \approx 0.3\ cfs$*

Appendix I: Moffatt & Nichol Fort Point Channel Report

Boston Water and Sewer Commission

DRAFT REPORT

Coastal Stormwater Discharge Analysis

Fort Point Channel Storm Surge Barrier

Conceptual Design

December 2022

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Coastal Stormwater Discharge Analysis

Fort Point Channel Storm Surge Barrier

Conceptual Design

DOCUMENT VERIFICATION

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1 INTRODUCTION

1.1 Introduction

The Boston Water and Sewer Commission (Commission) has undertaken the Coastal Stormwater Discharge Analysis project to continue its efforts to prepare for the effects of climate change. As preliminary strategies to respond to climate change are developed, including alternatives developed by the City of Boston (City) and other agencies, it is essential that the Commission's ability to discharge stormwater is preserved despite the challenges posed by sea level rise and storm surge. In addition, the adaptations being planned and designed by other agencies have the potential to influence the Commission's infrastructure. The Coastal Stormwater Discharge Analysis will establish strategies and conceptual designs that will ensure that the Commission maintains its ability to discharge stormwater under varied circumstances, despite the impact of these dynamic challenges.

As such, the Coastal Stormwater Discharge Analysis includes a conceptual design of a facility for resilient stormwater management at the downstream end of the Fort Point Channel (FPC). Specifically, this facility is envisioned to be a storm surge barrier that can be closed during the combined conditions of storm tides and heavy rainfall, thereby effectively changing the FPC into a managed storm water discharge basin.

1.2 Purpose

The gates of a Storm Surge Barrier (SSB) are a major element of any SSB as they provide for both exclusion of surge during a storm event, and the passage of flow under non-event conditions. In addition, as required, SSB's may be required to afford passage of vessel traffic. The SSB consists of gates that are the movable parts within an otherwise static structure; therefore, an SSB requires an operation plan. The evaluation and selection of a gate type, or gate types, for the FPC SSB are the subjects of this report.

1.3 Methodology

The intent is to review the characteristics, application and proven concepts of several constructed storm surge barriers and associated gate types to facilitate screening for selection of gate types for the FPC SSB. Screening will be completed at a level of detail commensurate to a feasibility study.

SSB's and systematic overviews of constructed storm surge barriers around the world inclusive of the characterization of hydraulic gate types and functions have been discussed by various authors. Amongst others, relevant publications include: (USACE-ERDC, 2007), (PIANC, 2006), (Mooyaart L. F., Jonkman, de Vries, van der Toorn, & van Ledden, 2014), (Mooyaart & Jonkman, 2017), (Dircke, Jongeling, & Jansen, 2012), (van Ledden, Lansen, de Ridder, & Edge, 2012) and (Dijk, 2010). This document does not intend to reproduce or summarize the body of work that has been produced by these authors and others; rather, a brief overview of commonly used gate types in storm surge barriers and water control structures is provided. This overview provides a general

characterization of gate types that have been successfully applied elsewhere; from this, screening for applicability is performed for the FPC SSB.

1.4 Readers Guide:

This interim report is structured as follows: Section 2 provides an overview of the Fort Point Channel site conditions, Section 3 provides a general overview of gate types for storm surge barrier, Section 4 discusses the gate type screening and selection of a gate type for conceptual design of the FPC SSB and Section 5 provides a brief synopsis of the study insights thus far and elaborates on next steps. It should be noted that this is a Draft Interim Report. This report will be updated in the future to include additional evaluations that document more detailed conceptual design development of alternative FPC SSB structures and their probable costs.

2 FORT POINT CHANNEL STORM SURGE BARRIER – ABBREVIATED DESIGN CRITERIA

2.1 Introduction

Key characteristics of the FPC SSB site location and the structure's intended function need to be summarized in order to assess the feasibility of various gate types for the structure. Box 1 includes a general description of a storm surge barrier with navigable passage to introduce typical storm surge barrier nomenclature prior to providing the FPC project characteristics.

Box 1: General Description of a Storm Surge Barrier with Navigable Passage

Mooyaart & Jonkman, 2017 provide an overview of and general design considerations for storm surge barriers based on data and design documentation review of a select set of constructed barriers throughout the world. (Mooyaart & Jonkman, 2017) provide a general description of a navigable storm surge barrier. A typical layout of a storm surge barrier contains three elements: a gated section, a dam section and a navigable passage. A navigable passage can either be established with a lock or with a gated navigable opening. The difference is that the gates of a navigable passage are seldom in use, but must operate reliably during floods, while lock gates are frequently in use and must operate reliably during day-to-day lock operations and during floods. Figure 2-1 below provides a schematic plan view that identifies the principal components of a navigable storm surge barrier. The navigable passage is schematically shown as a gated navigable opening, not as a lock, since the Fort Point Channel storm surge requires maximization of the flow area and minimization of interruptions for maritime traffic during transit.

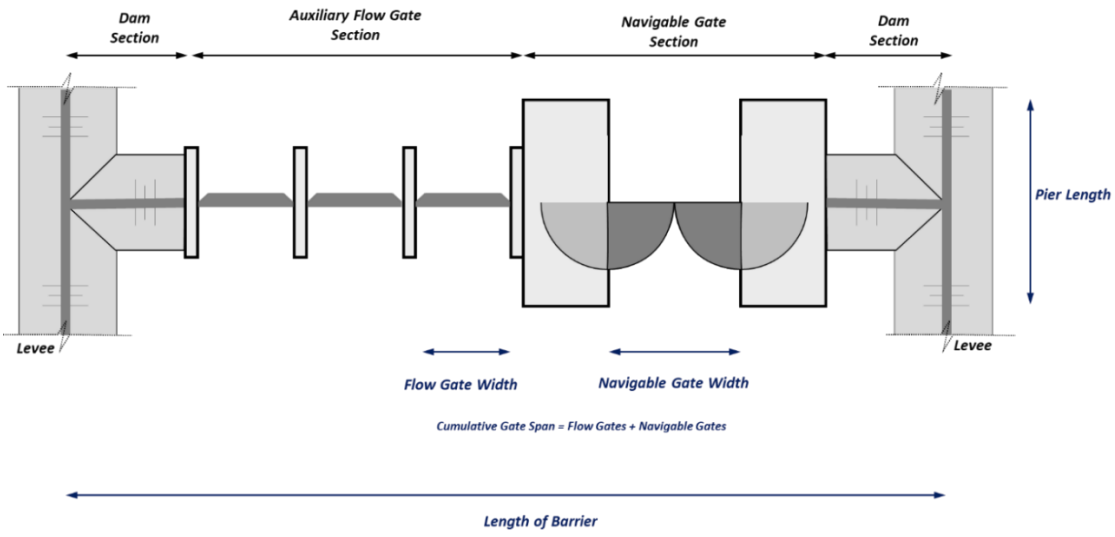


Figure 2-1: Schematic plan view of a storm surge barrier (modified after Mooyaart and Jonkman, 2017).

2.2 Location and Scope

The Fort Point Channel Storm Surge Barrier location is proposed to be just north of the Northern Avenue Bridge as shown in Figure 2-2.

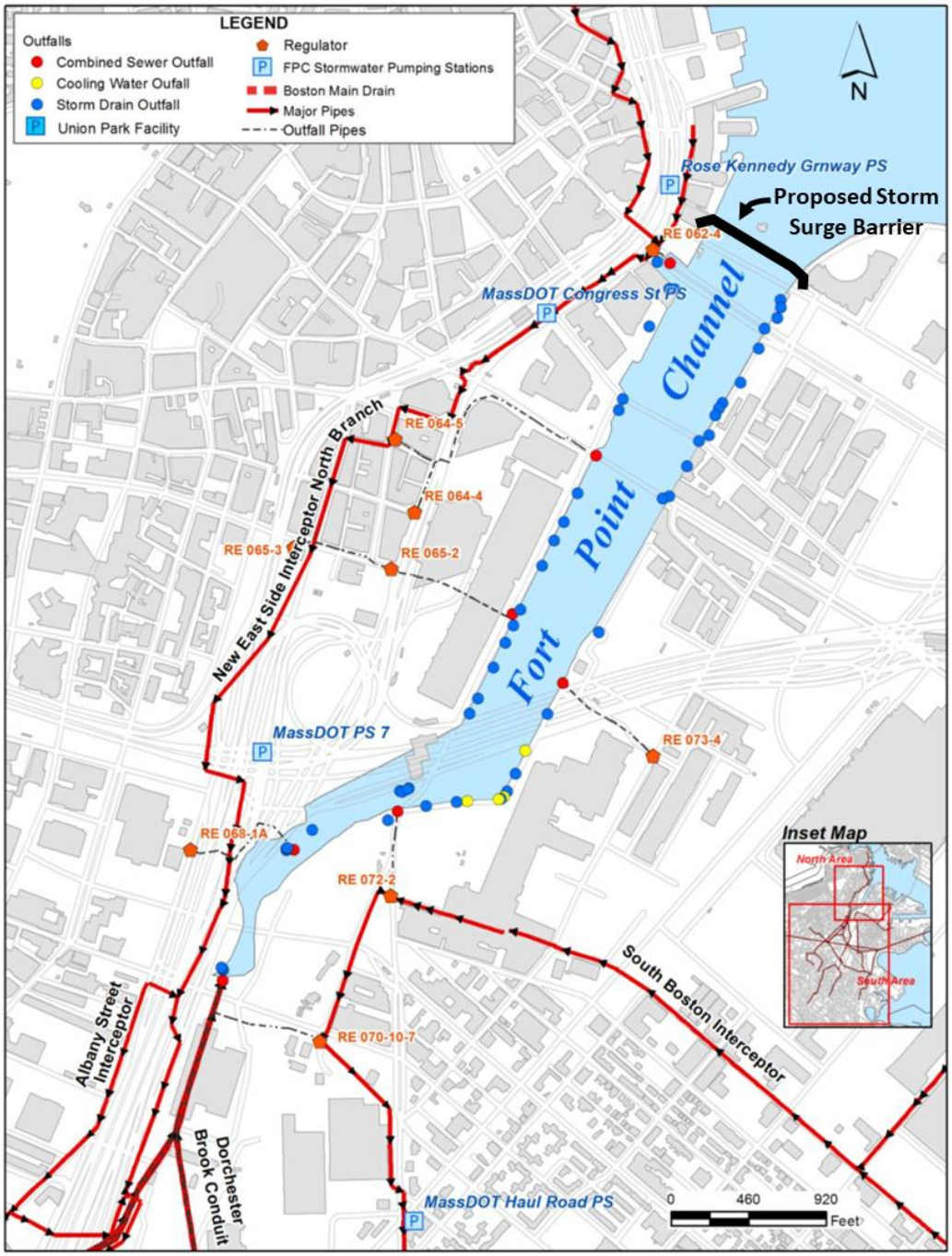


Figure 2-2: Fort Point Channel environs showing; proposed storm surge barrier location, outfalls and major drainage infrastructure in the immediate vicinity.

The SSB is the civil works complex that spans the Fort Point Channel, provides for flood risk reduction by blocking storm surge from entering the channel. The SSB ties to natural high ground elevations on both the west and east side of the FPC. In addition, the SSB is a gated structure and allows for the passage of flow and vessel traffic. Functional requirements are further defined in the next section.

2.3 Basic Functional Requirements

The following basic functional requirements have been identified for the conceptual design of the storm surge barrier consistent with the overall objectives of the Study:

- The storm surge barrier will provide a reliable structural measure to reduce the risk of coastal storm damage to the coastal region adjacent to and upstream of the FPC.
- The storm surge barrier will provide a reliable structural measure to retain storm water and rainfall runoff within the FPC during conditions when the barrier is closed.
- The storm surge barrier will minimize impact to navigation and waterborne commerce; and
- The storm surge barriers will minimize impact on the water exchange through the opening during normal operation (non-storm conditions) in order to minimize impacts on the inner basin environmental conditions.

As a result of the above requirements the storm surge barrier concept will at its simplest consist of two principal parts: 1) moveable gates (both navigable gates and flow control gates) with associated gate support structures and 2) tie-in structures. For any system of movable gates, including navigable gates and flow control gates, there are three basic functional requirements:

- The moveable gates of the storm surge barrier will be able to open and close with a high degree of reliability.
- The gates will be sized and provide a range of motion suitable for purpose (e.g. navigation, flow control); and,
- The moveable gates and gate structures will be an integral part of the overall storm surge barrier structure and be designed such that they impede the coastal storm flood levels and minimize the risk of coastal storm damage to the region behind it.

2.4 Service Life

The FPC SSB will have various project components for which Life Cycle Design should be considered. At this stage of the project (feasibility study stage) no such analysis has been performed. A minimum project service life of 100 years is preliminarily recommended as a result of the size and nature of the project. For certain project components a shorter service life may be applicable.

For the storm surge barrier to meet the functional requirements regarding flood risk reduction (see section 2.6.2) a period of analysis of 50 years has been established. The project will perform to meet the design criteria related to flood risk reduction in this document for a 50-year period spanning the years between 2020 and 2070s. The project is to be designed for sea level rise,

regional subsidence, and local settlement occurring for a 50-year planning horizon (to the year 2070). After such a time, to achieve the same level of risk reduction, the structures may have to be modified or improved (i.e., adaptive management may be necessary or structural improvements may be needed if the observed sea level rise exceeds the planning criteria). Design provisions will be required to accommodate such improvements if and when needed, and adaptability to future improvements will be part of the gate type selection process.

2.5 Site Conditions

2.5.1 Federal Navigation Project

The FPC SSB intersects with a federally authorized navigation channel. The FPC is part of the Boston Harbor Navigation Project and extends from Boston Harbor to the Northern Avenue Bridge, a distance of about 1,000 ft and is 23 ft deep and 175 ft wide. However, at the location of the Northern Avenue Bridge (see also section 0) the channel narrows due to the physical constrictions imposed by the bridge piers. The characteristics of the FPC at the SSB are summarized in Table 2-1.

Table 2-1: Federal Navigation Project Characteristics

		Authorized Project				
Name	Reach of Federal Channel	Width	Length	Depth		Approx. Width at proposed location[1]
		ft	ft	ft below MLLW	ft NAVD88	Ft
Boston Harbor Navigation Project	Fort Point Channel	175	1,000	23	-28.5	76

Note:

1. *As a result of the existing Northern Avenue Bridge the navigation channel has a localized restricted width*

2.5.2 Northern Avenue Bridge

A replacement design for the Northern Avenue Bridge, led by the City of Boston Public Works Project Team, is currently (2022) being completed and the team has final plans and specifications ready[1]. The construction phase of the project is expected to start in 2023. Due to the close proximity of the proposed FPC SSB to the redesigned Northern Avenue Bridge, it is expected that

[1] https://www.northernavebridgebos.com

there will be multiple items to coordinate during the design process. At this feasibility-level design stage for the SSB, two items of the replacement bridge impacts are considered: 1) the navigable clearances and 2) elevations for viewing platforms and potential view shed impacts.

Compared to the existing structure, the replacement structure raises the ends of the bridge approximately 5 feet; the main navigation span is raised approximately 6 feet, thereby providing 16 feet of navigable clearance above MHW. This clearance matches the clearance of the Moakley Bridge to the south. The horizontal clearance remains unchanged at 76 feet and the navigable channel remains east of the center bridge pier. From the project design drawings, the lowest elevation of the bridge span across the navigation channel will be El. 20.3 ft NAVD88. Characteristics are summarized in Table 2-2.

Table 2-2: Characteristics of Northern Avenue Bridge

Bridge Name	Characteristics for Navigation Span			
	Horizontal Clearance (ft)	Vertical Clearance (ft from MHW)	Bridge Type	Notes
Northern Avenue Bridge	76	16	Fixed	Active civil works project

The redesigned Northern Avenue bridge aims to improve mobility, honor history, strengthen resiliency and create a new destination along Boston's shore (https://www.northernavebridgebos.com). The bridge will provide a pedestrian promenade and amenities to experience views of the City and the harbor. The bridge deck will be varying between an elevation of +19 ft NAVD88 at the first pier to an elevation of +30ft NAVD88 at the center piers (piers no. 3 and 4). In addition, a promenade deck and viewing platform will be constructed at an elevation of +18 ft NAVD88 as shown in Figure 2-3 below.

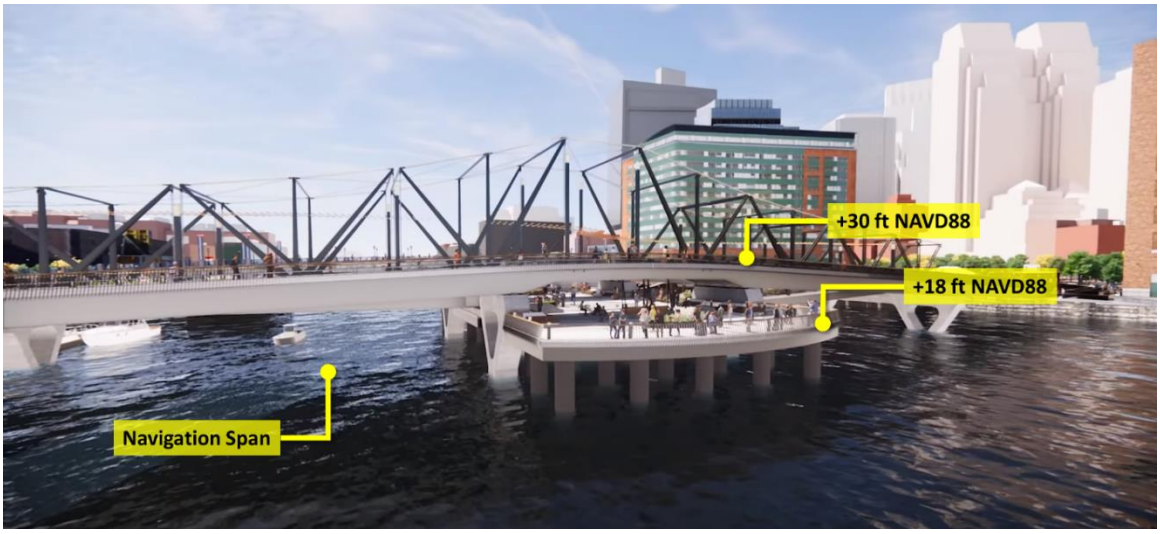


Figure 2-3: Annotated rendering of proposed redesign of the Northern Avenue Bridge with promenade platform and bridge deck at pier 3 and 4 at the elevation of +18 ft and +30ft NAVD88 respectively.

2.5.3 Bathymetry and Topography

Deepest soundings within the centerline of Fort Point Channel are 26 ft and 5-15 ft near the bulkhead. Soundings are referenced to Mean Lower-Low Water and shown in the nautical chart from NOAA (NOAA, National Oceanic and Atmospheric Administration, 2020) below (Figure 2-4). A bathymetric survey completed specifically for the Fort Point Channel was provided by BWSC and a depiction of surveyed depths is shown in Figure 2-5.

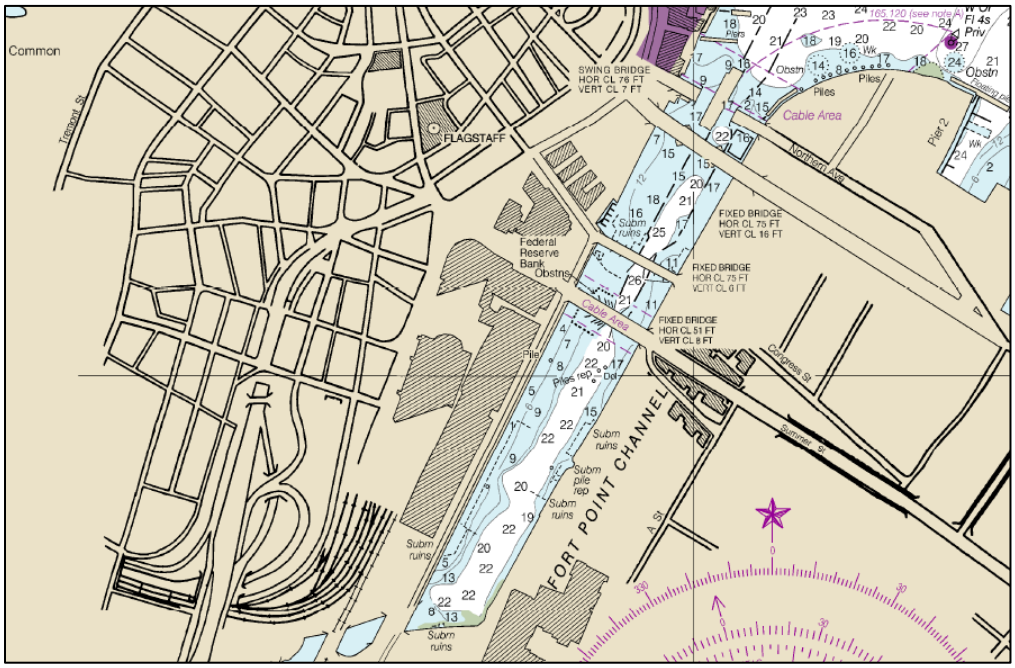


Figure 2-4: Soundings in Fort Point Channel in Feet (datum: Mean Lower-Low Water)

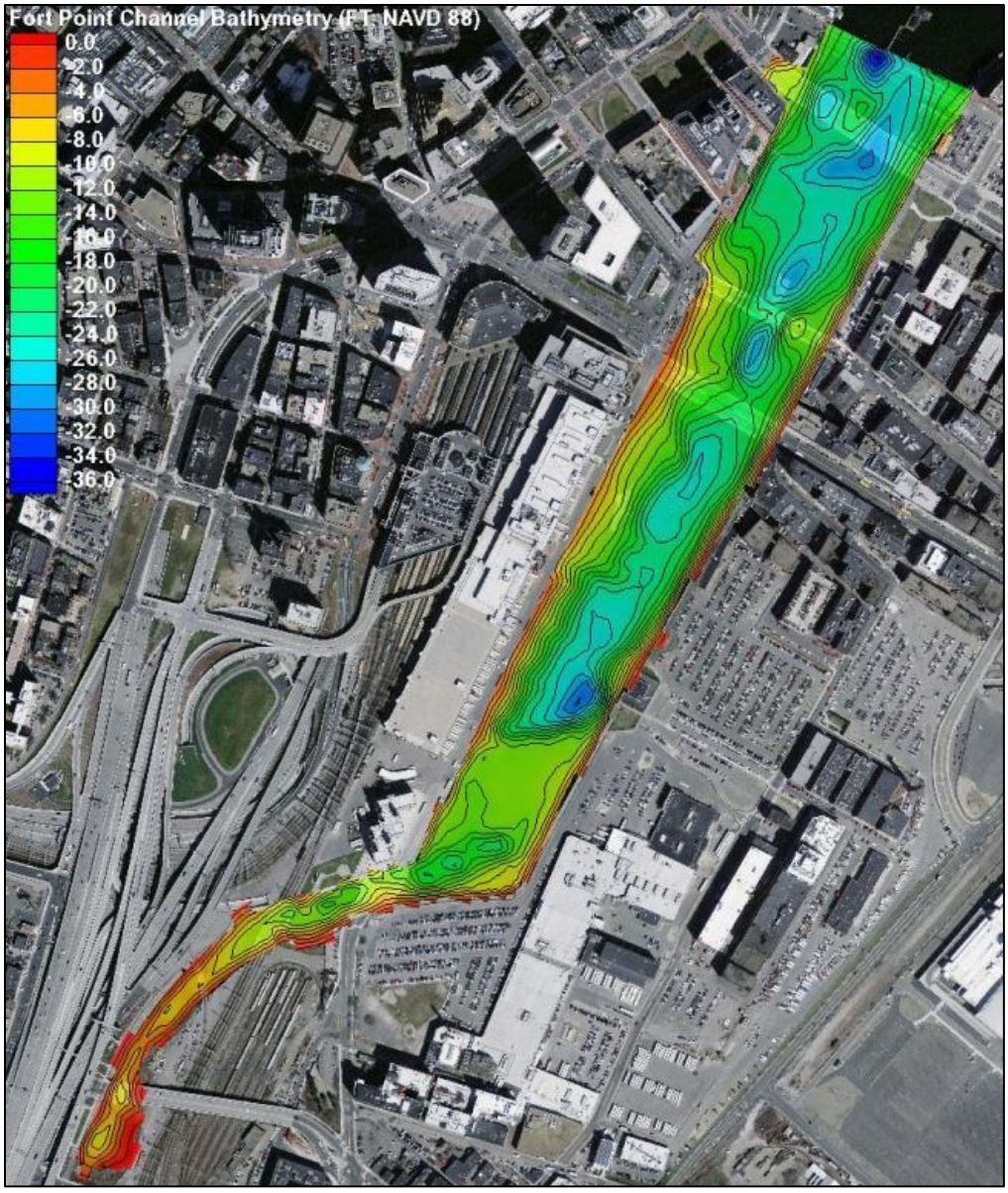


Figure 2-5: Bathymetry of the Point Channel in Feet (datum: NAVD88). Source: BWSC

2.5.4 Subaqueous Utilities

Buried utilities, including cables, cross the project area as shown in Figure 2-4. Further exploration will be needed to identify marked and unmarked utilities. At this phase of the study, it is assumed that the utilities will have to be relocated prior to construction of the proposed FPC SSB. Further site investigations are recommended at later stages of the study and future phases of the design process.

2.6 Hydraulic Conditions

Refer to Technical Memorandum #1 for a detailed description of hydraulic conditions. A brief summary of relevant parameters is provided herein.

2.6.1 Operational Hydraulic Conditions

2.6.1.1 Sea Level Rise

Sea Level Rise is based on information provided in Climate Ready Boston (2018) and tabulated below.

Table 2-3: Sea Level Rise from base year (2013 centered tidal epoch)

Year	Source	Inch	Feet
2030	Climate Ready Boston	9	0.75
2070	Climate Ready Boston	40	3.33

2.6.1.2 Tidal Datums

Tidal Datums are obtained from NOAA (NOAA, 2020) and shown in Table 2-4. The water-level observation station closest to the project site is the NOAA tide gauge sensor "Boston, MA" (Station ID: 8443970), which is located at the project site. Future tidal datums are provided as well and include a linear adjustment to account for 3.33ft (40 inches) of SLR for the year 2070.

Table 2-4: Tidal Datums referenced to NAVD88

Description	Abbreviation	Current tidal epoch[1]	Year 2070
Mean Higher-High Water	MHHW	4.77	9.06
Mean High Water	MHW	4.33	8.62
Mean Sea Level	MSL	-0.3	3.99
Mean Low Water	MLW	-5.16	-0.87
Mean Lower-Low Water	MLLW	-5.51	-1.22
Notes: 1) Datum Elevation for NOAA Station 8443970, Boston, MA (ft, NAVD88)			

The mean tidal range for the Fort Point Channel area is 9.49 feet (NOAA, 2020).

2.6.1.3 Tidal Flow Regime

No detailed flow records were readily available for the Fort Point Channel at the time of this study. Hydraulic design data was obtained from the hydraulic report (Dated 9/21/2020) developed for the re-design of the Northern Avenue Bridge.

Table 2-5: 10-year Return Period Flow data

Description	Value	Unit
Flood Discharge	4,510	ft3/s
Flood Frequency	10	Years
Design Flood Velocity (riverine)	1.03	ft/sec

2.6.2 Extreme Hydraulic Conditions

In the event that the SSB gates are closed, hydraulic conditions are governed by extreme water levels on the exterior resulting from storm surge in combination with low or high water levels within FPC.

2.6.2.1 Extreme Water Levels

For the conceptual design of the SSB the 100-year Return Period extreme water level, inclusive of SLR up to the year 2070 is to be used. Extreme water levels are taken from the Boston Climate Ready Study (2018) presented in Table 2-5 and SLR in the next section.

Table 2-6: Extreme Water Levels

Average Return Period (years)	Expected Value Extreme Water levels (ft NAVD88)
100	9.5

2.6.2.2 Design Water Level (exterior)

Following the data in the preceding sections the design water level is +12.8 ft NAVD88 and represents the 100-year Return Period extreme water level, inclusive of 3.3 ft (40 inches) of SLR up to the year 2070.

Table 2-7: Design Water Levels

Year	100-year RP water level	SLR	Design Water Level
	ft NAVD88	ft	ft NAVD88
2070	9.5	3.3	12.8

2.6.2.3 Waves

The 100-year RP wave conditions for the flood side of the SSB are based on NACCS data and are provided in the table below.

Table 2-8: Wave Characteristics from NACCS Point 1900

Average Return Period (years)	Wave Heights (ft)	Wave Period (sec)
100 years	4.3	3.6

2.6.2.4 Design Water Level (interior)

The FPC SSB will also function as a water control structure at the head of the newly created FPC basin, i.e., the FPC will be a basin when the SSB is closed. The design anticipates the FPC basin to accommodate water storage between an elevation of approximately -5.5 ft NAVD88 and 7.0 ft NAVD88 per the summary presented in Table 2-9

Table 2-9: Design Water Levels for FPC Basin

Water Level	Elevation (ft NAVD88)	Notes
Low water level interior	-5.51	Based on current epoch MLLW
High water level interior	7.04	Top of bank elevation

It is preliminarily assumed that maximum reverse head loading conditions can occur when gate operations fail following a storm closure, resulting in maximum interior water levels and low tide levels on the exterior. This situation will yield a 12.55 ft head difference with -5.51 ft NAVD88 exterior water levels.

2.7 Geotechnical Conditions

Boring data is available from the Northern Avenue Bridge Project. Boring data indicates argillite at an elevation of approximately -75 ft NAVD88.

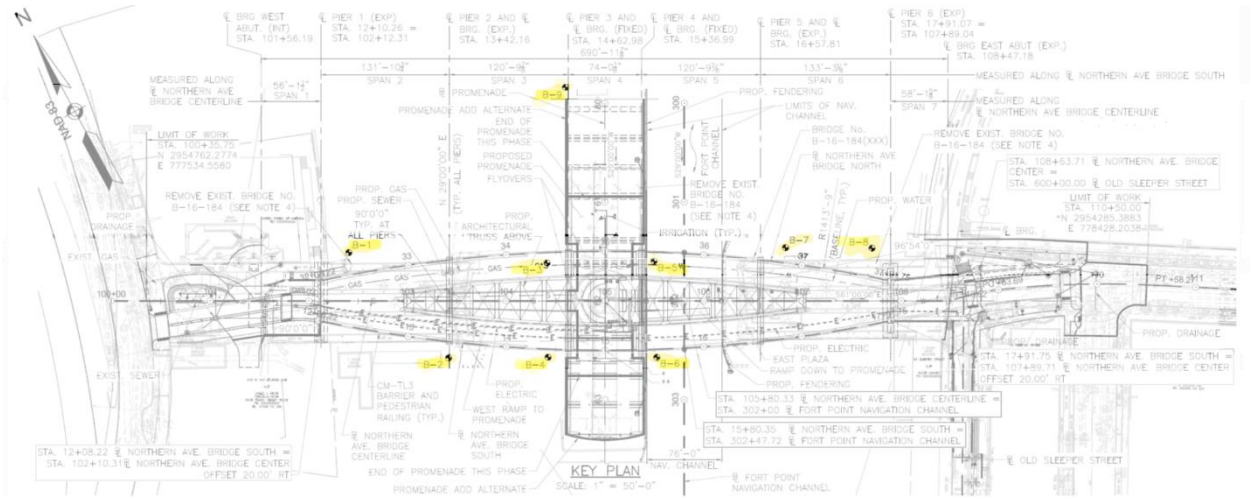


Figure 2-6: Plan view of proposed Northern Avenue Bridge with boring locations highlighted.

Geotechnical information is preliminary and will be reviewed further during later stages of the study.

2.8 Navigation Criteria

2.8.1 Navigation Safety

The proposed storm surge barriers will cross one federal navigation channel, and cross currents or excessive head-on and helping currents at the navigable passage could adversely impact navigation. The storm surge barrier and gate layout should be optimized to minimize adverse influence on vessels transiting the storm surge barrier. Additionally, the provision of vessel guides, aids-to-navigation, and protective structures at the navigable channel entrance and exits will be considered to increase navigational safety and potentially protect the storm surge barrier from aberrant vessel impact.

2.8.2 Design Vessels / Fleet

This section will be completed after a more in-depth review of the FPC federal channel authorization, and the fleet that currently uses the channel.

2.9 Viewshed Criteria

Due consideration is given to redesign of the Northern Avenue Bridge which is located just south of the proposed FPC SSB. The promenade and viewing platform are located at an elevation of +18ft (see section 0). The conceptual SSB design will, where reasonably possible, minimize the crest elevation to minimize potential viewshed impacts.

2.10 Design Criteria Yet to be Specified

2.10.1 Design Criteria

For the feasibility study, design criteria are limited to those elaborated in the previous sections. The scope of this report is too broad to evaluate and establish the minimum criteria requirements for the gated portion of the structure. The documentation provided within the previous sections is the first step in an iterative design approach.

The general design criteria within the previous sections are not complete and many criteria are yet to be specified. Such criteria can include but are not limited to:

- Constructability Criteria
- Geotechnical and Foundation Criteria
- Seismic Design Criteria
- Structural Loading and Associated Criteria
- Mechanical Design Criteria
- Electrical and Control Systems Design Criteria
- Civil Design Criteria
- Dredging and Earthwork Design Criteria
- Infrastructure and Transportation Criteria
- Operational and Maintenance Assessments
- Materials
- Aesthetics criteria
- Risk (assessments would occur across a broad range of structures, environmental, and operations evaluations)
- Extreme event loadings (seismic, vessel collision, force protection)
- Serviceability and design life assessments

In addition, environmental criteria other than those identified in the preceding sections are only qualitatively considered when appropriate and will need to be further evaluated during subsequent design phases. Such criteria, amongst others, include:

- Criteria related to the impacts on bed morphology and sediment transport
- Criteria related to water quality
- Criteria related to marine habitats, flora and fauna (e.g., fish passage) – ecology
- Criteria related to environmental impacts during construction and upon completion of the project)
- Hazardous materials
- Sedimentation, maintenance dredging, impacts to navigable depths, localized scour

2.10.2 Operational Criteria

For the feasibility study, design criteria related to the operation of the storm surge barrier are limited to functional requirements as listed in Section 2.3. However more detailed requirements with respect to many aspects of the structure, its function and its operation will need to be addressed in later phases of the study. Such criteria include, but are not limited to:

- Machinery and controls requirements and criteria,
- Auxiliary pump requirements,
- Maintenance requirements (access, inspection, and maintenance for the gates, machinery controls, abutments, piers, dam section, bulkheads, stoplogs, etc.),
- Operational requirements (optimum closure frequency, timescale for deployment and recovery, operational forecast and triggers),
- Redundancy requirements,
- Navigation criteria (vessel traffic service, advisory, control, limitations on passage, restrictions, etc.).

3 GATE TYPES FOR STORM SURGE BARRIERS, INCLUDING GATES FOR NAVIGABLE PASSAGES

3.1 Introduction

The gates are a major element of any SSB as they provide for both the passage of flow and, as required, vessel traffic. The gates are the movable parts within an otherwise static structure and the selection of a gate type affects the overall shape, form, and operation of the structure. This section introduces various gate types, also referred to as hydraulic steel structures, and describes typical advantages and disadvantages for each.

3.2 Hydraulic Steel Structures

USACE designs, constructs, and operates many types of projects, and for many of them the primary project purpose is flood control (dams), navigation, water supply (reservoirs), and local flood protection (or a combination thereof). Many of these projects include the use of Hydraulic Steel Structures (HSS), also referred to as hydraulic gates, to control the flow of water in various ways. EM 1110-2-2107 (USACE, 2022) prescribes guidance for designing new hydraulic steel structures and includes an overview of the most commonly gate types. It includes lock gates, tainter gates and lift gates.

For the FPC SSB study, the gate types suitable for a storm surge barrier as reported by (Mooyaart & Jonkman, 2017) are used as a starting point, which is inclusive of the commonly used gate types above, but more comprehensive and specifically tailored to the application of hydraulic gates in constructed storm surge barriers. Refer to (Mooyaart & Jonkman, 2017) for a full overview of gate types and a description of the constructed storm surge barriers, but in general the gate types can be categorized by their direction of movement (e.g., vertical axes – horizontally rotating or horizontal axes – vertical motion). The following is a list of hydraulic gate types evaluated:

- Horizontal rolling gates (horizontal lateral movement)
- Sector gate (vertical axes)
- Floating Sector Gate (ball joint)
- Rotating Segment Gate (horizontal axes)
- Flap Gates (horizontal axes)
- Barge Gate (vertical axes)
- Miter Gate (vertical axes)
- Vertical Lift Gates (vertical movement)
- Vertical Rising Gates (submerged, vertical movement)
- Tainter Gates (Horizontal axes, both submerged and exposed)

It is recognized that other hydraulic gate types exist (e.g., drum gate, visor gate), which have application to riverine and upland water control structures. However, those gate types are not known to be used in a coastal setting or in constructed storm surge barriers, and as such are omitted for preliminary design considerations for the FPC SSB Study.

3.3 Gate Type Overview

The application of hydraulic gates in storm surge barriers should first evaluate the specific use of the gate. As discussed, storm surge barriers typically contain gate structures that accommodate three distinct functions: blocking surge, passage of vessels and passage of flow. Surge is blocked when all gates are closed. Vessels are accommodated through the navigable gate passage and the passage of flow is accommodated through one or more auxiliary flow gates. In the instances where the navigation is not locked through the storm surge barrier, the gated opening of the navigable passage also provides flow exchange. Certain gate types have fewer limitations for navigation, while others have more. The air clearance restriction associated with tainter gates and lift gates is a typical example of a limitation for navigation. Second, while all hydraulic gate types require a foundation, gate types like the vertical rising or inflatable gate require relatively more complex sill structures which effectively limit the gate height and thereby the depth of the navigable passage. Other limitations for navigation result from the feasible span of the gate types. Based on the dataset of constructed navigable storm surge barriers, floating sector gates provide the largest navigable openings (over 1,200 ft) while rotary segment gates for example have so far been limited to a span of 200 ft.

The following pages provide a brief summary of the gate types and lists advantages and disadvantages of each gate types when considered for navigable storm surge barriers based on and modified after (USACE, 2014), (Dircke, Jongeling, & Jansen, 2012) and (PIANC, 2006).

Vertical Lift Gate

Vertical lift gates are moved vertically from the sill. A tower supports the gate during its operation. Overhead cables, sheaves and bull wheels can enable lifting or hydraulic cylinders lift the gate (e.g., Seabrook Barrier, USA)



Cross Section

Pros	Cons
• Large gate span (up to 300 feet) possible • Little upland space required • Controlled operation under flow and wave conditions • Raised gate accessible for maintenance • Proven concept • Vertical closure (gravity assisted) • Straightforward release of excess water from inner basin • Overflow and reverse flow acceptable • Relatively less complex underwater sill structures	• Limited clearance height for maritime traffic • Raised gate subject to wind load can result in cost increase • Water depth, and required clearance determines tower and gate height • Sensitive to vibrations • Gates with wheels are a known weak spot and subject to wearing • Smooth glide and vertical motion of gate can be impeded by marine growth in gate recess

Examples: Seabrook (USA), IHNC (USA), Eastern Scheldt (NL), Hollandse Ijssel (NL), Ems (GER)

Vertical Rising Gate

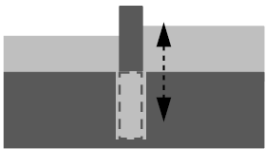
Vertical rising gates are stored beneath the sill in open position. The gates are lifted vertically to close the barrier. Both in open and in closed position the gates are positioned largely under water. In most applications, gates can be lifted above water to allow for maintenance.

Pros

- Large gate span possible
- Unrestricted air-draft clearance for maritime traffic
- Little upland space required
- Controlled operation under flow and wave conditions
- Proven concept
- Straightforward release of excess water from inner basin
- Overflow and reverse flow acceptable

Cons

- Inspection and Maintenance is challenging
- Large, deep and complex underwater sill structures
- Water depth determines sill structure depth
- Sensitive to vibrations
- Smooth glide and vertical motion of gate can be impeded by marine growth in gate recess



Cross Section

St. Petersburg Barrier (RU)

Tainter Gate (Conventional)

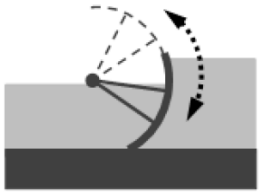
The tainter gate rotates around a horizontal axis, which passes through the bearing center. In closed position, the tainter gate rests on the sill and in open position it is lifted and locked. It is also referred to as a radial or segment gate.

Pros

- Large gate span feasible
- Proven Concept
- Controlled operation during flow and wave conditions
- Little space required
- Inspection and maintenance in the dry
- Limited horizontal flow contraction
- Straightforward release of excess water from inner basin
- Suitable for reverse head and flow

Cons

- Limited clearance height for maritime traffic
- Generally, not used for vessel passage (Exception Fox Point Barrier, RI and Eider Barrier in Germany)
- Raised gate subject to wind load
- Relatively stringent tolerance criteria for the sill structure



Cross Section

St. Petersburg Barrier, Eider (GER), Thames (UK), Ems (GER)

Submerged Tainter Gate

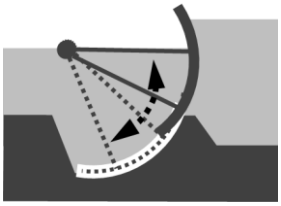
The submerged tainter gate rotates around a horizontal axis, which passes through the bearing center. In closed position, the tainter gate is recessed in a submerged gate bay below the channel bottom. In open position it is lifted, partially emergent and locked into position. It is also referred to as a submerged radial or segment gate.

Pros

- Large gate span feasible
- Unlimited clearance height for maritime traffic
- Proven Concept
- Controlled operation during flow and wave conditions
- Little space required
- Limited horizontal flow contraction
- Straightforward release of excess water from inner basin
- Suitable for reverse head and flow

Cons

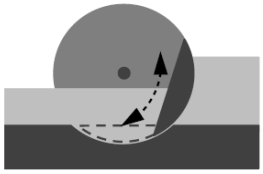
- Complex design with relatively low tolerances
- Sill structure is vulnerable to silting, objects and corrosion
- Large, deep and complex underwater sill structures
- Water depth determines sill structure depth
- Access to and maintenance of gate body can be challenging



Cross Section

Rotating Segment Gate

	Pros	Cons
Similar to a tainter gate the rotary segment gate has a horizontal axis. However, in recess, it lies in a concrete sill in the bed of the river. Thus, it is possible to sail over the gate in opened position. Operation of the gate is achieved by approximately 90deg rotation to raise the gate to the active flood protection position. An additional 90deg of rotation places the gate in the top raised position ready for inspection or maintenance.	• Large gate span feasible • Unrestricted vertical clearance for maritime traffic • Controlled operation during flow and wave conditions • Little space required • No wind loads during open position • Inspection and maintenance in the dry • Limited horizontal flow contraction • Suitable for reverse head and flow • Deployment and recovery time is relatively short	• Load transfer and concentration is complex • Complex design with relatively low tolerances • Sill structure is vulnerable to silting, objects and corrosion • Access to and maintenance of hollow gate body can be challenging • Complex mechanical operating system



Cross Section

Thames (UK), Ems (GER)

Sector Gate (Vertical Axis)

A sector gate consists of a double gate complex. Each gate has a circular shape, transferring forces through a steel frame to the hinges at each side of the opening. It operates by rotating around two vertical axes. During operation the gates will rest on the riverbed. In non-operational condition, each gate is stored in a gate housing or recess besides the waterway.

Pros

- Large gate span feasible
- Unrestricted clearance for maritime traffic
- Relatively low wind loads in open and closed position
- Suitable for deep waters
- Immediately ready for operation
- Simple sill structures
- Stable structure; no load concentration
- Gate housing/recess can be converted to dry docks to perform maintenance
- Gates are stored in the recesses; small collision hazards
- Suitable for reverse head and flow
- Relatively low susceptibility to flow vibrations

Cons

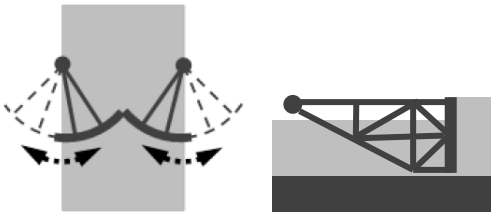
- Large space and deep excavation required for gate housing
- Flat and smooth slide way required
- Siltation may hamper operation
- Load transfer to hinges, maintenance, corrosion and marine growth are a concern
- Potential for ship collision
- Potential for siltation within gate housing



Seabrook (USA), New Bedford (USA), IHNC (USA), Harvey Canal (USA), West Closure (USA)

Floating Sector Gate

	Pros	Cons
A floating sector gate consists of a double gate. Each gate has a circular shape, rotates around a spherical hinge at each side of the opening transferring forces through a steel frame to the hinges and to the foundation. The gate leaves are buoyant and float into place. During operation the gates will rest on the riverbed. In non-operational condition, the doors are stored in a gate housing (dry dock) besides the waterway in the riverbanks	• Large gate span possible • Unrestricted overhead clearance for maritime traffic • Shallow dry dock: easy inspection and maintenance and collision protection • Can be operated even if sill is covered with silt • Flatness of sill is not critical for operation • Vertical closure of flow opening (no strong horizontal flow contraction) • Separate sluice openings may be applied to reduce differential head and discharge excess water during reverse head conditions	• Large space required • Operation complicated; in-flowing water may be difficult to control • Loads are concentrated on the hinges • Reverse head conditions may cause unexpected loads on the spherical hinges • Objects on sill can cause damage • Deployment and recovery time is relatively extensive due to filling time of dry docks • Sensitivity to flow-induced oscillations • Sensitive to dynamic wave forces • Limited resistance to negative differential head



Plan view Cross-section

Maeslant Barrier (NL), St. Petersburg Barrier (RU)

Inflatable Gate or Dam

An inflatable gate is basically a sealed tube made of a flexible material, such as synthetic fiber, rubber, or laminated plastics. It is anchored to the sill and walls by means of anchor bolts and an air- and watertight clamping system. The gate is inflated with air, water, or a combination of both.



Cross Section

Ramspol Barrier (NL)

Pros

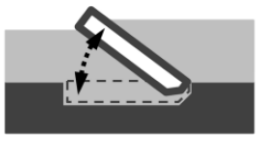
- Comparatively fewer limitations on total span
- Unrestricted overhead clearance for maritime traffic
- Marginal to wind loads
- Little space required
- Direct transfer of hydraulic load to foundation
- Invisible when not in use
- No need for hinges and driving system
- Vertical closure of the flow opening possible in adverse wave and current conditions
- Not sensitive to sediment deposition on the sill

Cons

- Relatively slow deployment/closure speeds
- Internal pressure determines stability
- Control of storage and immersion of rubber sheet can be challenging
- Not suitable for deep water (max height built today is 27ft)
- Difficult inspection, maintenance and replacement of rubber sheet
- Potentially vulnerable to vandalism and debris abrasion
- Flexible structure, low frequencies, small stiffness, great mass
- Considerable response to wave loads
- No spill of excess water; overflow vibrations

Flap Gate

	Pros	Cons
Flap gates consist of a straight or curved gate leaf surface, pivoted on a fixed horizontal axis. In Venice, the gates are operated by filling or emptying them with air. At Venice and Stamford, the gates pivot around an axis at the sill, while at the Billwerder Bucht the axis is positioned above the mean water level.	• Relative few limitations on the total span if constructed in series • Separate flaps; reduced failure risk • Unrestricted overhead clearance for maritime traffic • Little space required • Suitable for deep waters • Controlled operation under flow and wave conditions • Not subjected to wind loads • Invisible when not in use • No strong confinement of horizontal flow with alternate gates deployment • Vertical closure, single flap • Excess water through lowering the gate crest or a single flap gate	• Limitations on suitability for conditions with reverse head • Pneumatic operation is not always fully controlled • Underwater storage of flap gates makes inspection and maintenance challenging and may lead to corrosion or excessive marine growth • Abrasion of underwater hinges due to contact with granular suspended sediments • Sensitivity to vibrations • Natural frequencies low; small stiffness, large mass • Relatively more expensive structure

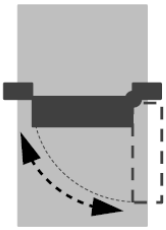


Cross Section

MOSE Venice (IT), Stamford (USA), Billwerder Bucht (GER)

Barge Gate

	Pros	Cons
A barge gate is a caisson stored on one side of a waterway, pivoting around a vertical axis to close. A barge gate may be buoyant or equipped with gated openings to reduce hinge and operating forces. This type of gate is also referred to as a swing gate or caisson gate.	• Large gate span feasible • Unrestricted overhead clearance for maritime traffic • Relatively simple design concept as a result of its similarities with shipping barge designs • Possibility to perform maintenance offsite	• Very slow deployment/closure speeds • Not well suited for reverse head or flow • Difficult to control during opening and closing (especially in current and wave conditions) • Increase in size increases difficulties in control - not well suited for deep waters • Specialized operating equipment needed and back up tug to provide assistance • Maintenance of hollow gate body can be challenging • Not well suited to deal with sedimentation at the sill

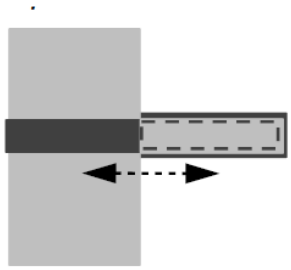


Plan view

IHNC Barrier (USA)

Horizontal Rolling Gate

Rolling gates are sliding panels or caissons stored adjacent to the waterway. They are rolled into position in anticipation of a flood event. The new Panama locks are equipped with rolling gates. Alternative designs for the Maeslant barrier and for a barrier near Hamburg included rolling gates. For these designs the gates were equipped with gated openings to reduce the lateral loads during closure.



Plan view

Pros

- Large gate span feasible
- Unrestricted overhead clearance for maritime traffic
- Gate housing/recess can be converted to dry docks to perform maintenance
- Gates are stored in the recesses; small collision hazards
- Suitable for reverse head and flow
- Relatively low susceptibility to flow vibrations
- Stored adjacent to the channel (no impacts to flow or navigation)

Cons

- Very slow deployment/closure speeds
- Difficult to control during opening and closing (especially in current and wave conditions)
- Specialized operating equipment needed
- Large upland area needed to “dock” gate and as such impractical as auxiliary flow gates
- Susceptible to siltation on the sill and in gate recess
- Maintenance of hollow gate body can be challenging

Miter Gate

	Pros	Cons
Miter gates consist of two leaves mounted on the lock walls. These gates are fairly simple in construction and operation and can be opened or closed more rapidly than other types of gates. The two leaves of a miter gate form a shallow three-hinged arch angled upstream. In the closed position, under head, each leaf bears on a lock wall and on the other leaf at the center of the lock. This arch shape is very efficient for spanning larger distances between lock walls.	• Proven concept • Unrestricted overhead clearance for maritime traffic • Relatively low susceptibility to flow vibrations • Subjected only to marginal wind loads • Stored adjacent to the channel (no impacts to flow or navigation) • Little upland space required • Gates are stored in the recesses; relatively small collision hazards • Suited for application in relatively deep waters	• Only relatively small gate spans are economically feasible (up to 110ft) • Not suitable for operation in reverse head conditions or waves • It is extremely hard to close this gate type during an emergency situation with appreciable flow through the opening • Sensitive to vibrations when operated in flow conditions



Plan view

Eastern Scheldt (NL), Eider Barrier (GER) and applied in many locks throughout the world

4 GATE TYPE SELECTION FOR THE FORT POINT CHANNEL STORM SURGE BARRIER

4.1 Geometric Constraints

This section presents a summary of some of the basic geometric constraints for the FPC SSB conceptual design. Geometric constraints follow from the site conditions and hydraulic conditions as presented in section 2. Four gate bays are proposed for the SSB structure such that gates align with the openings between the bridge piers of the re-designed Northern Avenue Bridge. One gate structure will align with the federal channel and function as a gated navigable passage and the three other gates will allow for water control through the auxiliary flow openings.

The FPC SSB geometric constraints are summarized in three tables; Table 4-1 summarizes key geometric characteristics of the overall SSB complex, where Table 4-2 and Table 4-3 provide key geometric characteristics for the navigable passage and the auxiliary flow gates. One should note that based on discussion with BWSC uniformity of gate type is preferred and as such the sill elevation of the structure is set at a constant elevation across. It should further be noted that the provided data is preliminary and future refinements are anticipated as the design progresses

Table 4-1: Geometric Characteristics of the FPC SSB Complex Site Conditions

Item	Value	Source/Reference	Notes
Span(ft)	610 ft		Shore to Shore span measured just north of the Northern Avenue Bridge
Existing Bathymetry Deepest point	-21ft NAVD88	Bathymetric survey	
Existing Bathymetry Shallowest Point	-5 ft NAVD88	Bathymetric survey	Mudline at bulkhead north side
Minimum Height of Barrier	+15.5 ft NAVD88		Based on Design Water Level and Climate Ready Boston
Ideal Height of Barrier (during normal day-to-day conditions)	+18 ft NAVD88		Minimizing viewshed impacts based on viewing platform elevation of proposed Northern Avenue Bridge

Table 4-2: Geometric Characteristics of the FPC SSB Navigable Opening

Item	Value	Based on	Notes
Minimum Horizontal Clearance	76 ft	Northern Avenue Bridge	Navigation Channel width at bridge
Minimum Vertical Clearance Elevation	+20.33 ft NAVD88	Northern Avenue Bridge	Fixed Bridge 16ft clearance from MHW
Sill Elevation	-20 ft NAVD88	Uniformity of sill depths	Navigation Channel authorized depth is -28.5 ft NAVD88 (-23ft MLLW)
Location of Nav. Channel	East of center	Navigation Chart	

Table 4-3: Geometric Characteristics of the FPC SSB Auxiliary Flow Openings

Item	Value	Based on	Notes
Horizontal Clearance	110 ft	Northern Avenue Bridge	Approximate value and based on span between bridge piers
Minimum Vertical Clearance	8.5 ft NAVD88	MHHW and SLR	To allow for free flow (no orifice flow) during normal hydrometeorological conditions at the end of the service life
Sill Elevation	-20 ft NAVD88	Upstream and downstream bathymetry and preferred uniformity of sill depth	To allow for sufficient flow

4.2 Selection of a Suitable Set of Gate Types

The screening of gate types is presented in this and the following section and contains a first phase in which the full list of gate types is reduced to a limited set based on a high-level evaluation. The second phase includes the screening of gate types based on a multi criteria analysis. The screening and evaluation include the screening of the navigable gate and auxiliary flow gates jointly. It is assumed herein that due to the existing navigational constrictions (bridge span clearance) and the relatively small vessels present within the FPC, the navigation function can be jointly screened with flow function.

A cursory evaluation of gate types and their suitability for the navigable passage and auxiliary flow opening is presented in Table 4-4. The table includes two columns with a brief evaluation of suitability of a gate type for the navigation function and flow function of the FPC SSB.

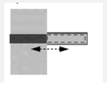
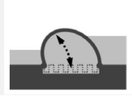
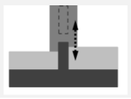
The evaluation follows the requirements for the navigable passage and auxiliary flow opening in the previous section and the information provided in section 2. The screening of gate types is a qualitative evaluation of each gate type where one considers: 1) The basic functional requirements, 2) Design criteria, and 3) Geometric constraints and site-specific characteristics.

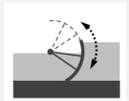
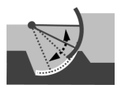
Based on Table 4-4 below the following gate types will be evaluated in the multi criteria analysis (see section 4.3)

- Vertical Lift Gate
- Vertical Rising Gate
- Tainter Gate (Conventional)
- Submerged Tainter Gate
- Rotating Segment Gate
- Flap Gate with submerged axes
- Flap Gate with emerged axes

The multi criteria analysis is presented in the next section.

Table 4-4: Cursory Review of Hydraulic Gate Types for Application Within the Navigable Passage and Auxiliary Flow Gate of the Fort Point Channel Storm Surge Barrier

	GATE TYPE	FPC SSB – Suitability for Main Navigation Gate	FPC SSB – Suitability for the Auxiliary Flow Gates	Moved on for screening
	Horizontal Rolling Gate	Impractical due to area needed to dock the gate	Impractical due to area needed to dock the gate	No
	Sector Gate (Vertical Axis)	**Possible**, proven concept, but the area needed to dock the gate would reduce the overall flow area	Impractical due to area needed to dock the gate and the preference by BWSC to keep gate types uniform for the FPC SSB	No
	Floating Sector Gate	Not suitable, relatively expensive and too complex system for a relatively small opening	Impractical due to area needed to dock the gate and too complex a system for auxiliary flow	No
	Rotating Segment Gate	**Possible**, but relatively expensive and complex system. Potential for sediment built-up as a result of the sediment exchange between FPC and Boston Harbor	**Possible**, but no need for unrestricted air clearance, furthermore, relative expensive and complex system for auxiliary flow	Yes
	Inflatable Gate or Dam	Not suitable, only one proven concept available in riverine area with small tidal range. In addition, considered a relatively complex system with relatively slow deployment/closure speeds	Not suitable,only one proven concept available in riverine area with small tidal range. In addition, considered a relatively complex system with relatively slow deployment/closure speeds.	No
	Flap Gate	With submerged (under water axes): **Possible**, but not well suited for reverse head conditions and challenging from a maintenance perspective With emerged (above water axes): Not suitable since the required air clearance would prohibitively increase gate costs and the required height would have impacts on viewsheds	With submerged (under water) axes: **Possible**, but not well suited for reverse head conditions and challenging from a maintenance perspective With emerged (above water) axes: **Possible**, proven concept.	Yes
	Barge Gate	Not suitable, too challenging to operate under reverse head conditions or under wave and current conditions	Impractical due to area needed to dock the gate and relatively slow deployment/closure speeds	No
	Miter Gate	Not suitable for reverse head conditions	Not suitable for reverse head conditions	No
	Vertical Lift Gate	**Possible**, but the required air clearance would prohibitively increase gate costs and the required height would have impacts on viewsheds	**Possible**, proven concept, however the required height would have impacts on viewsheds.	Yes
	Vertical Rising Gate	**Possible**, however very challenging from a maintenance perspective. Potential for sediment built-up as a result of the sediment exchange between FPC and Boston Harbor	**Possible**, proven concept, however very challenging from a maintenance perspective. Potential for sediment built-up as a result of the sediment exchange between FPC and Boston Harbor.	Yes

	GATE TYPE	FPC SSB – Suitability for Main Navigation Gate	FPC SSB – Suitability for the Auxiliary Flow Gates	Moved on for screening
	Tainter Gate	Not suitable since the required air clearance could prohibitively increase gate costs and the required height would have impacts on viewsheds	**Possible**, proven concept, however the required height would have impacts on viewsheds	Yes
	Submerged Tainter Gate	**Possible**, but challenging from a maintenance perspective	**Possible**, proven concept, but challenging from a maintenance perspective.	Yes

4.3 Multi Criteria Analysis and Gate Type Selection

4.3.1 Screening Criteria, Scoring and Weight

Six gate types for the FPC SSB are presented herein. Presented are several issues that the BWSC and stakeholders might consider should a project be pursued beyond this conceptual study. As introduced in section 3, each gate type offers advantages and disadvantages. Section 3 further identified potential constraints and challenges that add to the overall complexities involved in adopting a storm surge barrier system as part of the City's overall approach to flood risk reduction and resiliency. These issues have been discussed with the BWSC during meetings in the Fall of 2021.

The multicriteria analysis takes a high-level review of the concept gate options and compares how they perform against various criteria[2]. Based on discussion with BWSC a list of screening criteria was established. The screening criteria were grouped into five categories and are listed below in Table 4-5.

Table 4-5: Multi-Criteria Analysis Screening Criteria

Category	Criterion	Notes (It is a positive if ..)
Cost	Relatively Low Construction Cost	.. the selected gate type results in relatively low overall construction cost for the gate complex when compared to the other options
	Relatively Low Life Cycle Cost	.. the selected gate type results in relatively low life cycle costs when compared to the other options
Navigation	Minimize Navigation Impacts	.. the selected gate type accommodates navigation through the structure without any special provisions
Implementation	Improved Aesthetics / minimize viewshed impacts	.. the selected gate type reduces or minimizes viewsheds impact and is readily suitable to accommodate aesthetic improvements when compared to the other options
	Public Access possible	.. the selected gate type and pier structures can easily accommodate and supported public access walkways

[2] It should be noted that without a complete gate type study and evaluation of gate alternatives for the storm surge barrier (inclusive of preliminary cost estimates) this can only be viewed as a preliminary screening which will have to be verified at a later stage. The evaluation of gate types is to establish a reasonable preliminary selection of gate types such that a geometry of the conceptual gate structure design can be established.

Category	Criterion	Notes (It is a positive if ..)
Hydraulic Function	Operation under reverse head, currents and waves	.. the selected gate type is suitable to operate under adverse hydraulic conditions
Reliability	Proven Technology	.. the selected gate type has seen many proven and successful applications elsewhere for similar conditions
	Adaptability to Future Conditions	.. the selected gate type and pier structures can be easily adapted to continue to provide its function with increased SLR or frequency of operation

At this screening stage, the numerical criterion scoring is relative to other gate types and is based on preliminary analysis and quantification of historical gate information, as well as the team's professional experience. The rational for scoring each gate type is then largely based in the information presented in section 3 in combination with the project's geometric constraints and site characteristics. The criteria scoring is provided on a 5-point scale (with 5 being positive) for each gate type; scoring is presented in Table 4-6.

Weights are assigned to each criterion to differentiate between the importance of the criteria. Relative importance is subjective and was discussed during meetings with the BWSC. In these deliberations cost and viewshed impacts were frequently brought forward as important topics. During the meeting of November 29th, 2021 several weight sets were discussed where either cost or viewsheds would be weighted most heavily. Ultimately two weight sets were agreed upon:

1) Weight Set 1: The emphasis and highest weight is placed on construction and life cycle cost.
2) Weight Set 2: The emphasis and highest weight is placed on minimizing viewshed impacts.

The criteria other than cost or viewshed are included but are equally weighted amongst the two sets. The weight of each criterion for the two weight sets is listed in Table 4-6.

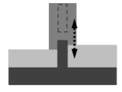
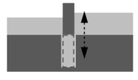
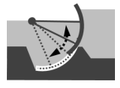
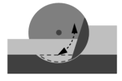
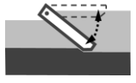
4.3.2 Multi Criteria Analysis Result

The gate types were screened using the criteria, the criteria scoring and the established weights per the two weight sets and the interim results are presented in Table 4-6. Based on the multi criteria analysis, discussions with the BWSC, and feedback from the BWSC, the following two gate types were selected:

1) Vertical lift gate
2) Flap gate with submerged axes

These two gate types are the preferred option and will be used to develop a conceptual design for the FPC SSB complex.

Table 4-6: Multi Criteria Analysis Results

Category	CRITERION									
		Weight set 1	Weight set 2	Vertical Lift Gate	Vertical Rising Gate	Conventional Tainter Gate	Submerged Tainter Gate	Rotating Segment Gate	Flap Gate (submerged axes)	Flap Gate (emerged axes)
Cost	Relatively Low Construction Cost	**20**	**10**	5	2	5	2	1	2	3
Cost	Relatively Low Life Cycle Cost	**20**	**10**	5	1	4	2	2	2	3
Navigation	Minimize Navigation Impacts	**10**	**10**	3	5	1	5	5	5	1
Implementation	Improved Aesthetics / minimize viewshed impacts	**10**	**30**	1	4	1	3	3	5	3
Implementation	Public Access possible	**10**	**10**	4	1	3	1	1	1	4
Hydraulic Function	Operation under reverse head, currents and waves	**10**	**10**	4	4	5	5	4	2	5
Reliability	Proven Technology	**5**	**5**	5	3	5	3	4	3	3
Reliability	Adaptability to Future Conditions	**5**	**5**	5	2	5	2	2	2	2
	Total Weighted Average Score (weight set 1)			**4.1**	2.5	3.7	2.7	2.4	2.6	3.1
	Total Weighted Average Score (weight set 2)			3.2	3.1	2.9	2.9	2.8	**3.3**	3.1

5 CONCEPTUAL DESIGN FOR LIFT GATE ALTERNATE

5.1 Introduction

A preliminary geometry for the storm surge barrier with lift gates has been established and is shown in Figure 5-1. This geometry has been established based on the basis of design criteria as provided in the previous sections and includes one navigable opening to accommodate navigation and three auxiliary flow gates to maintain tidal exchange to the fullest extent possible. The reader is referred to the plan set titled "Boston Water and Sewer Commission Fort Point Channel Storm Surge Barrier Vertical Lift Gate Concept Design, Boston, MA" Rev 02, dated November 21, 2022. for a complete overview of the conceptual design.

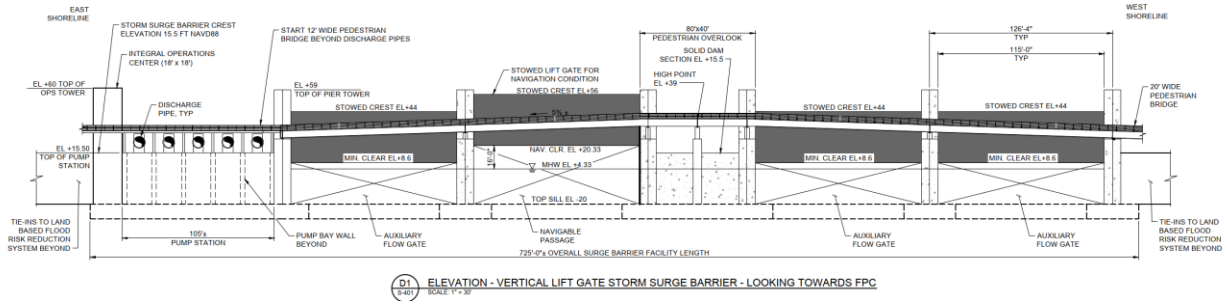


Figure 5-1: Fort Point Channel storm surge barrier lift gate, elevation view

Table 5-1 lists the gate series and shows that 4 gates are included. The gate series are provided a lettered ID to indicate each gate from north to south.

Table 5-1: Summary of the Storm Surge Barrier Geometry – Lift Gate Alternate

Gate ID	Sill Elevation in ft NAVD88 (and in ft MLLW in parentheses)	Gate Width (ft)	Span[1] (ft)	Notes	Top of storm surge barrier[2] (ft, NAVD88)	Gate Height (ft)	Top of Lift Gate in Raised Position (ft, NAVD88)
A	-20	115	126.3	Auxiliary Flow Gate	+15.5	35.5	44
B	-20 (-14.5)	115	126.3	Navigable Passage	+15.5	35.5	56
C	-20	115	126.3	Auxiliary Flow Gate	+15.5	35.5	44
D	-20	115	126.3	Auxiliary Flow Gate	+15.5	35.5	44

Note:

1. *Span is measured from the center of the pier to center of the pier*
2. *Storm surge barrier with gates closed to provide flood risk reduction function*

The storm surge barrier complex also includes a pump station. The pump station is not discussed herein, the reader is referred to main report that discuss the overarching Coastal Storm Water Analysis project.

5.2 General Project Phasing, Sequence of Construction, and Constructability Considerations

General phasing of construction for the Fort Point Channel Lift Gate Alternative is indicated in the plan set "Boston Water and Sewer Commission Fort Point Channel Storm Surge Barrier Vertical Lift Gate Concept Design, Boston, MA" Rev 02, dated November 21, 2022. This proposed phasing considers the maintenance of navigation and hydraulic flow/conveyance area for the duration of the construction process. The phasing is schematic in nature, and alternate phasing scenarios can be considered as design development occurs.

Project phasing considers the incremental completion of major systems, portions, and/or subsets of the overall project, and often considers the influence of construction activities upon factors external to construction itself, such as the accommodation of traffic or hydraulic flow through or around the construction site.

The following elements are considered in the phased construction process:

1. Dredging a temporary navigation channel west of the Northern Avenue Bridge swing span pier. This temporary channel will accommodate vessels during construction of the Phase 1 gate complex at the existing navigation channel.
2. Construction of the Phase 1 gate complex, located within Fort Point Channel at the existing navigation channel. All work for each phase of the gated barrier construction is expected to occur within the confines of a steel sheet pile, braced, box-type cofferdam. Construction sequences for each phase are described in greater detail in the sections that follow.
3. Upon completion of the Phase 1 gate, navigation will revert to the existing (authorized) channel location.
4. Work will then progress with phased construction, with Phase 2 involving the westernmost gate complex. Phase 2 can also include construction of the landside abutment and/or dam section tie-in that provides the line of protection for the gated barrier system.
5. Phase 3 involves construction of the gate complex east of Phase 2, plus construction of the solid dam located coincident with the center (swing span) pier.
6. Phase 4 accomplishes construction of the gate complex east of the Phase 1 work, east of the navigation channel.
7. Phase 5 is related to the construction of the pump station located near the eastern bank of Fort Point Channel. Phase 5 also includes construction of the landside abutment and/or dam section tie-in structures
8. Additional phases of construction, not depicted within the plan set, will be required after completion of each gate complex and the pump station. This will include construction of

the pedestrian bridge and overlook, construction of the operations building, and completion of mechanical, electrical, operating, and control systems. The final phase will include operational testing, and commissioning of the project.

The term "constructability," in its most general sense, is defined as the ability of a structure to be constructed. For the purposes of this narrative, the term constructability also encompasses the location, extents, and physical and environmental conditions in which the project will be constructed. Constructability considers the nature of the work, contractor capabilities, equipment, and means and methods a given contractor might employ to accomplish the work. Constructability also considers site access, special material and work requirements, difficult or unusual environmental conditions, strict tolerances, complexities of mechanized and automated interfaces, exceptional loads and load handling requirements, risk, and many other specific impacts that the construction methods and processes.

Constructability considerations influence sequence of construction and the means and methods that will likely be used to accomplish construction activities; in turn constructability and site constraints will impact both cost and schedule for construction.

The following constructability considerations were assessed when evaluating project phasing, sequence of construction, and their resulting impact on costs:

1. The site is located in a high-density urban area, and lands in immediate proximity to the site for construction staging and laydown appear to be very limited.
2. Work occurs primarily in Fort Point Channel, excepting the construction of the landside abutments and/or dam section tie-ins. It is assumed that the majority of the work will involve floating plant and equipment and waterborne transport of personnel, materials, and equipment to the worksite.
3. Due to spatial requirements, it was assumed that phased construction using box-type cofferdams would be most advantageous for the Vertical Lift Gate concept.
4. It is anticipated that larger components (e.g., lift gates) will be fabricated off-site and will be lift into place.
5. Concrete deliveries and the ability to use ready-mix concrete sources are uncertain. It is anticipated that either a floating concrete batch plant or shuttle barges will be used for concrete deliveries.
6. Cofferdams are anticipated to remain in a near-dry condition for the majority of each phase of construction. Provisions will need to be made for re-watering and subsequent dewatering and clean-up should extreme flood and/or weather events occur.
7. A space should be identified for near-site construction office trailer(s) and small tool and equipment storage. If necessary, these may be located on barges.
8. Due to the possibility of offsite staging, fabrication, and laydown areas, a modest amount of barges and other waterborne transportation will be generated by construction activities. This will need to be coordinated with maritime agencies, including but not limited to the DHS (US Coast Guard) and other Federal, commonwealth, and local agencies.

9. Due to the variability in climate, special procedures may be required to provide continual construction activities (e.g., hot weather concrete, cold weather concrete). It may also be necessary to suspend construction activities for a portion of the year (e.g., winter shutdown).
10. Best practices are necessary to achieve the required service life of the structure (anticipated to be 100 years, without the need to major reconstruction or retrofit). This includes requirements for steel and concrete protection and corrosion control. While evaluation of these systems is beyond the current scope, they can affect both constructability and cost of construction. Corrosion protection systems to be considered in the future include but are not limited to: increased concrete cover, densified concrete, other concrete additives ad admixtures (e.g., calcium nitrite), reinforcing corrosion protection (e.g., hot-dipped galvanized, epoxy coated, glass-fiber reinforced polymer, stainless, clad systems), cathodic protection systems (e.g., sacrificial anodes, impressed current), high quality steel coatings, and numerous other potential systems, either alone or in combination.

Sequence of construction considers the logical and orderly arrangement of construction activities to provide for an efficient completion of project construction. Sequence involves prescribing predecessor activities (those that must be undertaken and at least partially completed before subsequent construction occurs) and successor activities (those that must be delayed until such time at least a portion of the predecessor activity is complete). From the sequence, duration of activities, consideration of external influence, and interrelationship of predecessor and successor activities, a construction schedule is formulated.

The anticipated sequence of construction for the gated barrier is provided in the section that follows. Sequence of construction for each phase is similar, and is not repeated for each subsequent phase, unless otherwise noted.

1. Dredge temporary navigation channel. Dredging is one-time, and is expected to include:
   a. Mobilization and Demobilization
   b. Pre-Dredge Hydrographic Survey
   c. Provision of Environmental Protection, Sediment and Erosion Control
   d. Probe channel bottom to identify potential obstructions and remove as necessary.
   e. Treatment and disposal of impacted silts above threshold, if any, at a facility approved to receive such material
   f. Disposal of non-impacted silts and non-impacted sand and gravel at a permitted facility
2. Perform survey and stake-out
3. Fabricate and install cofferdam template using spud piles
4. Fabricate and install cofferdam sheet piling
5. Fabricate and install upper level of sheet pile bracing
6. Remove by (clamshell) dredging channel bottom materials to the level of the bottom of the proposed tremie seam

7. Install driven / drilled foundation elements within the cofferdam, including permanent steel casings, reinforcing, and concrete. Drilled shafts are likely the preferred foundation components, based on review of available geotechnical information and the anticipated loads imposed on the foundations by the gated structures. Drilled shaft foundation installation includes:
    a. Mobilization and Demobilization
    b. Survey and Stake-out
    c. Provision permanent steel shaft casings, including fabrication, coating (as needed), installation (vibrating and seating into rock), and casing cut-off to the required elevation.
    d. Material removal and disposal from the casing, performed via augering.
    e. Drilling and disposal of rock material from the socket.
    f. Placing reinforcing cages
    g. Placement of drilled shaft concrete via tremie methods.
    h. Providing Pile Load Tests (e.g., statnamic tests, Osterburg tests, full scale load tests)
    i. Verification Surveys
    j. Bracing or otherwise stabilizing foundation elements from excessive movement, as needed, until such time the tremie seal is placed.
8. Provide concrete seal placed by tremie methods.
9. Upon curing of the seal, dewater cofferdam. Provide pumps necessary to maintain the cofferdam in a dewatered condition.
10. Cut off residual/upper casings, and prepare top of tremie to receive reinforced concrete footing and sill elements.
11. Construct reinforced concrete vertical elements, including pier towers, shear walls, bridge supports, including gate recesses, bulkhead recess, armor, anchorages, galleries, chases, conduits, seals, and other embedded devices.
12. When concrete vertical element (pier) construction has advanced sufficiently, the cofferdam can be re-watered and the upper reaches of the steel sheet pile cofferdam removed. The lower portion of the sheet piling will remain in place for seepage control.
13. Install sill protection, including quarry stone and armor (rip-rap) rock.
14. Construct navigation span pier protection/guard and guide fender systems
15. Install mechanical, electrical, instrumentation, and control systems to the extent practicable for the phased construction approach.
16. Install pre-fabricated lift gate, and maintain in the open (elevated) position through the point where testing and commissioning begins.
17. At the completion of all phases of construction for the vertical lift gates and pump station construct the pedestrian bridge and overlook. This may be done in parallel with construction of the operations building, and any remaining mechanical, electrical, instrumentation, and control systems requiring completion.

5.3 Vertical Lift Gates

The first configuration of gates considered for Fort Point Channel are overhead vertical lift gates. This gate type uses pier-type towers with overhead cables, sheaves, and bullwheels to support the gate during its operation and counterweights to assist hoisting machinery. The tower height is governed by the lift required to accommodate both navigation traffic and hydraulic flow.

The structural configuration of vertical lift gates can be plate girder, horizontal tied arch, or horizontal truss. The structural framing type selected for the Fort Point Channel gate complex is horizontal truss, with skin plates provided on both the harbor and channel sides of the gate, as a means of accounting for the frequent reverse head conditions that could be encountered though the service life of the project.

It is relatively common for gates of this type to be used as tide or hurricane gates along the seacoast, with a lesser frequency of use as gate structures for inland navigation locks. When used as hurricane barriers, they are normally raised to permit normal water traffic to pass underneath and lowered to protect channels and harbors from tidal storm surges. This type of gate is applicable for use as a hurricane or tide gate when it is subject to reverse hydrostatic or hydrodynamic loadings.

The type of gate hoisting system will be based on economics and governing criteria for closure times under emergency conditions, including mechanical pulley and wire rope systems, tractor systems, and hydraulic arms. The hoisting system for wire ropes may be deck mounted or placed in recesses above the high pool elevation. Cylinders for the hydraulic system are mounted below the deck in the intake gate slot. When gates must be capable of operating under full head and flowing water, tractor type gates are often used to reduce friction.

End supports for vertical lift gates are classified according to the method used to transfer the loads to the gate guides; these include fixed wheel, tractor, and slide supports. The gate guides receive the main reaction component from horizontal loads.

Fixed wheel provides wheels that revolve on fixed axles, which are either cantilevered from the body of the gate or supported at each end by the web of a vertical girder(s) attached to the gate frame. The wheels may also be mounted by pairs in trucks that carry the wheel loads through center pins to end girders attached to the gate frame. When gate hoisting occurs with no static head, this type of end support will usually be most economical.

Tractor end supports, also referred to as caterpillar, has at each side of the gate endless trains of small rollers mounted either directly on members attached to or on the vertical end girder. These are more commonly found on emergency closure gates or gates that control flow under high head. Because load transfer is achieved by uniformly distributed bearing through the small rollers, they are able to withstand large horizontal loads while being lowered under full hydrostatic head. Their main advantages over fixed wheels are a lower friction component while hoisting under load, lower bearing stresses transferred to the guides and gate framing, and shear and bending not transferred to the gate through the axle. When compared to slide gates, the main advantage is reduced friction,

which reduces the hoisting effort required for controlling flow. This reduced friction also reduces the wear and maintenance compared with those of slide gate seal surfaces.

Slide gates use metal to metal contact for end support. A machined surface that is mounted to the front face of the gate bears directly against a machined guide surface in the gate slot. The two bearing surfaces also serve as the gate seal. Materials for the gate seal surface may include aluminum, bronze, or stainless steel. They can be used for high heads; however, the head during flow control in combination with the width and height of the inlet/outlet works will determine the feasibility for using slide gates. The bearing surfaces of the guides and slide bearings must be machined to tight tolerances to maintain a seal for the gate. It is expected that slide gates will not be applicable for the Fort Point Channel gated barrier design.

The effective use of overhead lift gates is based on economics, flow conditions, operational criteria, and navigation requirements. Some of the main advantages of using vertical lift gates are ease of fabrication, considerably shortened erection time, and in most cases, relatively small and easier to construct pier towers. The loads from the gate to the supporting pier is in one direction, simplifying the design of the supports. One main disadvantage when using vertical lift gates that are under constant cyclic loading is that the main load resisting frame relies on a tension flange or, where fatigue plays a primary role in their design. For this reason, skin plates are provided on both sides of the gate frame.

Almost all lift gates use a horizontal framing system, since vertical framing systems are not structurally efficient in transferring loads to the side bearing surfaces and require special framing to accommodate roller guides for hoisting operations.

Trusses are the selected framing type, as for long-span elements they are expected to weigh less and be more economical than plate girders. Common members used for the trusses are wide flanges, structural tubing and pipe sections, and structural T's. The main trusses frame into an end post supported by an end bearing similar to a stiffened plate girder. Special framing requirements need to be considered for the roller guides in the upstream/ downstream and lateral directions. As with girders, other framing members include intercostals, diaphragms, end posts, stiffeners, and skin plates.

Framing arrangements for the gate trusses are shown in the plan set titled: "Boston Water and Sewer Commission Fort Point Channel Storm Surge Barrier Vertical Lift Gate Concept Design, Boston, MA" Rev 02, dated November 21, 2022.

Gate system corrosion damage will occur over time and can impair structural and operational capacity of vertical lift gates. To minimize future structural problems and high maintenance and rehabilitation costs, resistance to corrosion will need to be considered in the design process. Vertical lift gates are subject primarily to localized corrosion (i.e., crevice corrosion or pitting corrosion), general atmospheric corrosion, and mechanically assisted corrosion.

Prudent design and maintenance practices can minimize these types of corrosion. Corrosion of vertical lift gates is best controlled by application of protective coatings but is also effectively

controlled by proper selection of materials, cathodic protection, and proper design of details. The selection of corrosion protection alternatives is highly dependent on the particular environment in which the gate will function.

5.4 Dam sections and tie-ins

The solid dam section that would be constructed in Phase 3 (under the current construction phasing scenario) is a mass concrete, monolith-type structure that extends from the top of the footing/sill location to Elevation +15.5, the same elevation as the top of the vertical lift gates in their deployed (lowered) positions. The central dam section encompasses the gap between the two easterly and two westerly gate areas, and serves to maintain a line of protection between these gate elements. The dam is expected to be of reinforced cast-in-place concrete construction, and would be provided with supplemental structures as needed, including dam buttresses and piers that would serve to support the pedestrian bridge and overlook areas.

Tie-ins would occur at the western and eastern ends of the surge barrier complex, and transition to shore-based measures that are provided to afford flooding of adjacent land-based areas. Alternately, tie-ins could extend to existing lands that are situated above the anticipated flood elevation. Under both scenarios, tie-ins are required to prevent flood waters from flanking the surge barrier complex.

There are numerous potential configurations of tie-in structures, including walls, levees, cellular structures, movable barriers, and combinations thereof. The identification of alternatives required extents, and development of the preferred configuration and limits of tie-ins is beyond the current scope of the project. Hence, for cost budgeting efforts an assumed continuous pile-supported inversed "T-Wall" constructed of reinforced concrete is the assumed configuration of the tie-ins.

5.5 Maintenance Bulkheads

Maintenance bulkheads (stoplogs) will be required to provide access to, and inspection and maintenance of the submerged areas of each gate. Bulkheads would be provided in sufficient quantity to allow dewatering and service on one gate; bulkheads are required on both the harbor side and the channel side of the gate. Bulkheads can also be used for short-duration emergency closure, if one (or up to two) gates become inoperable.

Bulkheads are typically constructed of steel truss elements with a skin plate on one side. Bulkheads span the entire width of the gate opening, and are installed and restrained by slots (recesses) provided in the pier towers. Bulkheads are often modular, and are provided in heights that usually range from four to six feet. Bulkhead units are positioned and lowered on each other, stacked, with seals provided between each layer to lessen water intrusion. Once bulkheads are fully installed the gate area is dewatered using pumps, thereby allowing access for inspection and maintenance in-the-dry. Once that work is complete the gate area is re-watered, and the bulkheads are removed. Bulkheads are typically stored near the site, but could be stored remotely if

necessary. Regardless, they should be readily accessible, particularly if required for emergency closure.

Bulkheads can be installed using barge-mounted equipment (crane), and this is the assumed scenario for bulkhead installation and removal for the Fort Point Channel gate complex.

The other option for bulkhead installation involves lifting components into place using a mobile crane located on a service bridge. For this scenario the service bridge would need to be designed for crane loads. It may be possible to configure the proposed pedestrian bridge to also work as a service bridge for equipment access and bulkhead installation. However, this concept would significantly increase the cost of the bridge due to the much greater loads. Likewise, the bridge approach structures and embankments require consideration, as vehicle and equipment access and allowable grades would differ from those required for pedestrian access. This concept could be evaluated further as the bridge systems are assessed in more detail.

5.6 Pedestrian bridge

A pedestrian bridge and pedestrian overlook have been incorporated into the vertical lift gate surge barrier system. Relatively little effort has been expended in evaluating alternative bridge structural configurations, but the spans (115 feet) appear conducive for considering several potential bridge types, including:

1. Prestressed concrete girders, including Bulb Tee girders
2. Prestressed and post-tensioned box girders
3. Steel beam and concrete slab systems
4. Through-arch and through-truss spans, either prefabricated or site-assembled
5. Cable stayed spans
6. Other arrangements, and combinations of those listed

A definitive bridge type has not been established, nor are recommendations made in this regard. Further study is suggested, which could also explore the potential for combining service access with pedestrian access.

From a costing standpoint, historic bid tabulations were used to identify a potential unit cost for the pedestrian bridge structure. This anticipates a modest degree of enhancements and pedestrian amenities, such as decorative paving/deck surface, architectural railings, signage and wayfinding, and similar features.

5.7 Pump Station

A pump station is integrated within the storm surge barrier complex as shown on the plan set titled: "Boston Water and Sewer Commission Fort Point Channel Storm Surge Barrier Vertical Lift Gate Concept Design, Boston, MA" Rev 02, dated November 21, 2022. The pump station is not discussed herein, as this document focusses on the gated storm surge barrier facility. The reader is

referred to the main report describing all projects that are part of the "Coastal Stormwater Discharge Analysis" for a description of the pump station.

5.8 Cost Estimate

An Opinion of Probable Cost has been prepared for the Lift Gate Alternate based on the Conceptual Design Drawings titled "Boston Water and Sewer Commission Fort Point Channel Storm Surge Barrier Vertical Lift Gate Concept Design, Boston, MA" Rev 02, dated November 21, 2022. This Opinion of Probable Cost is a Class 4 level estimate as defined by AACE International. The level of Project definition, expressed as percent of complete definition, for a Class 4 estimate is from 1 percent to 15 percent. The estimate is developed based on take-offs, parametric estimates and engineering judgement. The reader is referred to the main report describing all projects that are part of the "Coastal Stormwater Discharge Analysis" for an overview of the cost estimate. The cost estimate is not included herein as it should be viewed in conjunction with the pump station cost estimate to understand the cost of the storm surge barrier project in its totality.

6 CONCEPTUAL DESIGN FOR SUBMERGED AXIS FLAP GATE ALTERNATE

6.1 Introduction

A preliminary geometry for the storm surge barrier with submerged axis flap gates has been established and is shown in Figure 6-1. This geometry has been established based on the basis of design criteria as provided in the previous sections and includes one navigable opening to accommodate navigation and three auxiliary flow gates to maintain tidal exchange to the fullest extent possible. The reader is referred to the plan set titled: "Boston Water and Sewer Commission Fort Point Channel Storm Surge Barrier Submerged Axis Flap Gate Concept Design, Boston, MA" Rev 02, dated November 21, 2022. for a complete overview of the conceptual design.

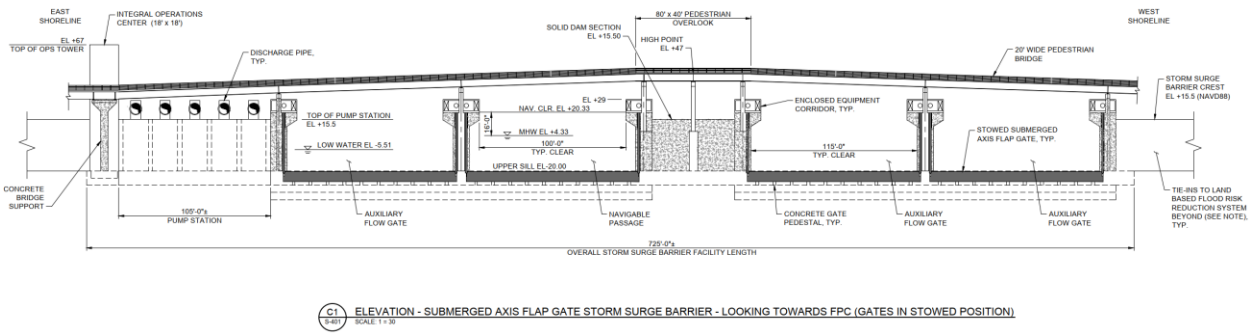


Figure 6-1: Fort Point Channel storm surge barrier submerged axis flap gate , elevation view

Table 6-1 lists the gate series and shows that 4 gates are included. The gate series are provided a lettered ID to indicate each gate from north to south.

Table 6-1: Summary of the Storm Surge Barrier Geometry – submerged axis flap gate alternate

Gate ID	Sill Elevation in ft NAVD88 (and in ft MLLW in parentheses)	Gate Width (ft)	Span[1] (ft)	Notes	Top of storm surge barrier[2] (ft, NAVD88)	Gate Height (ft)
A	-20	115	126.3	Auxiliary Flow Gate	15.5	35.5
B	-20 (-14.5)	115	126.3	Navigable Passage	15.5	35.5
C	-20	115	126.3	Auxiliary Flow Gate	15.5	35.5
D	-20	115	126.3	Auxiliary Flow Gate	15.5	35.5

Note:

1. *Span is measured from the center of the pier to center of the pier*
2. *Storm surge barrier with gates closed to provide flood risk reduction function*

The storm surge barrier complex also includes a pump station. The pump station is not discussed herein, the reader is referred to main report that discuss the overarching Coastal Storm Water Analysis project.

6.2 General Project Phasing, Sequence of Construction, and Constructability Considerations

General phasing of construction for the Fort Point Channel Submerged Axis Flap Gate alternative is indicated in "Boston Water and Sewer Commission Fort Point Channel Storm Surge Barrier Submerged Axis Flap Gate Concept Design, Boston, MA" Rev 02, dated November 21, 2022. This proposed phasing considers the maintenance of navigation and hydraulic flow/conveyance area for the duration of the construction process. The phasing is schematic in nature, and alternate phasing scenarios can be considered as design development occurs.

Project phasing considers the incremental completion of major systems, portions, and/or subsets of the overall project. The following elements are considered in the phased construction process:

1. Dredging a temporary navigation channel west of the Northern Avenue Bridge swing span pier. This temporary channel will accommodate vessels during construction of the Phase 1 gate complex at the existing navigation channel.
2. Construction of the Phase 1 cellular cofferdam, and the braced tangent wall cofferdam at the eastern shore tie-in location. All work for both phases of the submerged axis gate barrier construction is expected to occur in the dry within the confines of the cellular cofferdam. Construction sequences for each phase are described in greater detail in the sections that follow.
3. Phase 1 construction includes completion of the Phase 1 cofferdam, construction of the submerged axis flap gate at the existing navigation channel, construction of the auxiliary flow gate east of the navigation channel, construction of the pump station, and construction of the eastern landside tie-in.
4. Once Phase 1 work is complete the Phase 1 cofferdam will be re-watered and then deconstructed, salvaging materials and components for reinstallation for the Phase 2 cofferdam. The Phase 2 cofferdam includes beneficial use of the western pier components of the navigable gate bay.
5. Phase 2 construction includes completion of the Phase 2 cofferdam, construction of two westernmost auxiliary flow gates, and construction of the solid dam located near the center of the channel, at the center (swing span) pier.
6. Additional phases of construction, not depicted within the plan set, will be required after completion of each both main phases of construction. This will include construction of the pedestrian bridge and overlook, construction of the operations building, and completion of

mechanical, electrical, operating, and control systems. The final phase will include operational testing, and commissioning of the project.

The term "constructability," in its most general sense, is defined as the ability of a structure to be constructed. For the purposes of this narrative, the term constructability also encompasses the location, extents, and physical and environmental conditions in which the project will be constructed. Constructability also considers site access, special material and work requirements, difficult or unusual environmental conditions, strict tolerances, complexities of mechanized equipment, risk, and many other impacts to the construction methods and processes.

Constructability considerations influence sequence of construction and the means and methods that will likely be used to accomplish construction activities; in turn constructability and site constraints will impact both cost and schedule for construction.

The following constructability considerations were assessed when evaluating project phasing, sequence of construction, and their resulting impact on costs:

1. The use of a braced, box-type cofferdam, as was considered for the Fort Point Channel Vertical Lift Gate concept, was considered inappropriate for the Submerged Axis Flap Gate concept. This is due to the spatial constraints within the box cofferdam, the depth of excavation required for the foundations and submerged sill, and complexities of the submerged gate, and the need for precision alignment of pintles, slots, seals, and operating machinery.
2. The site is located in a high-density urban area, and lands in immediate proximity to the site for construction staging and laydown appear to be very limited.
3. It is assumed that the majority of the work will occur within the dewatered cofferdam(s), with materials and equipment shuttled to the site using floating plant and equipment.
4. Depending on spatial constraints, it may be possible to have equipment and small vehicle (personnel) access into the cofferdam, using haul road(s) constructed within the interior periphery of the cofferdam. Otherwise, it is expected that crawler cranes and/or tower cranes would be located within (on top of) the cofferdam footprint, and be used to lift materials and equipment delivered by barge into the dewatered cofferdam.
5. It is anticipated that larger components (e.g., submerged axis flap gates) will be fabricated off-site and will be lift into place.
6. Concrete deliveries and the ability to use ready-mix concrete sources are uncertain. It is anticipated that either a floating concrete batch plant or shuttle barges will be used for concrete deliveries.
7. Cofferdams are anticipated to remain in a near-dry condition for the majority of each phase of construction. Provisions will need to be made for re-watering and subsequent dewatering and clean-up should extreme flood and/or weather events occur.
8. A space should be identified for near-site construction office trailer(s) and small tool and equipment storage. If necessary, these may be located on barges.

9. Due to the possibility of offsite staging, fabrication, and laydown areas, a modest amount of barges and other waterborne transportation will be generated by construction activities. This will need to be coordinated with maritime agencies, including but not limited to the DHS (US Coast Guard) and other Federal, commonwealth, and local agencies.
10. Due to the variability in climate, special procedures may be required to provide continual construction activities (e.g., hot weather concrete, cold weather concrete). It may also be necessary to suspend construction activities for a portion of the year (e.g., winter shutdown).
11. Best practices are necessary to achieve the required service life of the structure (anticipated to be 100 years, without the need to major reconstruction or retrofit). This includes requirements for steel and concrete protection and corrosion control. While evaluation of these systems is beyond the current scope, they can affect both constructability and cost of construction. Corrosion protection systems to be considered in the future include but are not limited to: increased concrete cover, densified concrete, other concrete additives ad admixtures (e.g., calcium nitrite), reinforcing corrosion protection (e.g., hot-dipped galvanized, epoxy coated, glass-fiber reinforced polymer, stainless, clad systems), cathodic protection systems (e.g., sacrificial anodes, impressed current), high quality steel coatings, and numerous other potential systems, either alone or in combination.

Sequence of construction considers the logical and orderly arrangement of construction activities to provide for an efficient completion of project construction. Sequence involves prescribing predecessor activities (those that must be undertaken and at least partially completed before subsequent construction occurs) and successor activities (those that must be delayed until such time at least a portion of the predecessor activity is complete).

The anticipated sequence of construction for the gated barrier using submerged axis flap gates is provided in the section that follows. Sequence of construction for each phase is similar, and is not repeated for each subsequent phase, unless otherwise noted.

1. Dredge temporary navigation channel. Dredging is one-time, and is expected to include:
    a. Mobilization and Demobilization
    b. Pre-Dredge Hydrographic Survey
    c. Provision of Environmental Protection, Sediment and Erosion Control
    d. Probe channel bottom to identify potential obstructions and remove as necessary.
    e. Treatment and disposal of impacted silts above threshold, if any, at a facility approved to receive such material
    f. Disposal of non-impacted silts and non-impacted sand and gravel at a permitted facility
2. Perform survey and stake-out
3. Construct the cellular cofferdam, with general considerations and construction sequencing as described in the sections that follow:
    a. Cellular structures are frequently used for large structures that involve heavy civil works, such as cofferdams, weirs, dams, and walls. Properly designed, cellular structures can support significant vertical and lateral loads, can be configured to berth

a variety vessels (including barges), and accommodate the transfer of materials and equipment from those vessels to the work area within the cofferdam.

b. Among the several types of sheet pile cellular structures, including circular cells, diaphragm cells, and cloverleaf cells, it appears that circular cells would be most applicable for the cofferdams at Fort Point Channel.



c. Circular cells consist of flat webbed hot-rolled steel sheet piling placed in a cylindrical configuration, represented by large circles in plan view. The equally-spaced circular cells are connected with smaller semi-circles of flat webbed sheet piling; the two shaped are connected by specially fabricated wyes, and typically intersect at either a 30 degree or 45 degree angle.

d. Both the fully circular cells and arc areas are filled with granular material to complete the form of the gravity structure. Once the individual cells are filled, they are generally considered stable and can resist all reasonably conceived loading conditions. See "Boston Water and Sewer Commission Fort Point Channel Storm Surge Barrier Submerged Axis Flap Gate Concept Design, Boston, MA" Rev 02, dated November 21, 2022 for a concept level plan arrangement of circular cells developed for the FPC site.

e. The general methodology and sequence of construction for sheet pile cellular retaining structures is as follows:

   1) Perform subgrade preparation, using dredging methods, to remove all loose, compressible, and otherwise unsuitable material from within the footprint of the cellular structure. Material that is characterized as competent, such as glacial till, need not be removed, provided that it remains fully consolidated and undisturbed. Removal of unsuitable material can occur on a general area-wide basis prior to installation of the sheet pile cells; alternately unsuitable material can be removed after sheet pile installation using conventional excavation and dredging techniques (e.g. clamshell).

   2) Survey, position, and install sheet pile template. Sheet pile templates are usually configured with structural steel framing, with spuds or pipe piles used to support its weight and maintain position during sheet pile installation. Templates are configured with a minimum of one level of bracing, although two and three level templates are far more common.



3) Sheet piling is provided pre-prepared, with as-needed fabrications, driving shoes, and coatings (as needed) pre-installed. With the template positioned and secured, individual flat-webbed sheets are lifted with a crane, and placed around the template, threading interlocks with the previously placed sheet. This process is repeated until the circle of sheets is complete, with all sheets extending an approximately equal distance above the template.

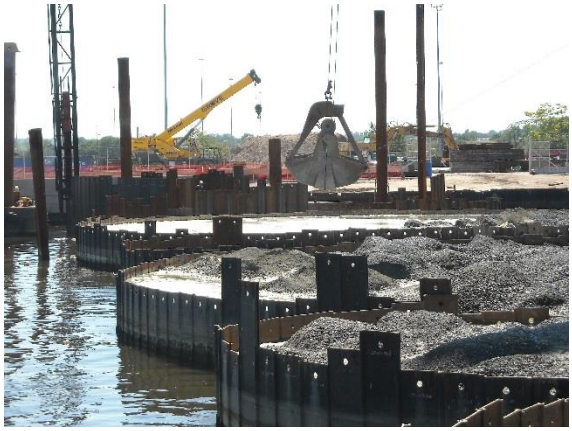


4) With sheets positioned around the template, individual sheets are incrementally lowered using a vibratory hammer to "drive" the sheets in position. Where necessary for the design, the sheets can be further driven and seated into the founding level (e.g. dense alluvium, or bedrock) using an impact hammer.

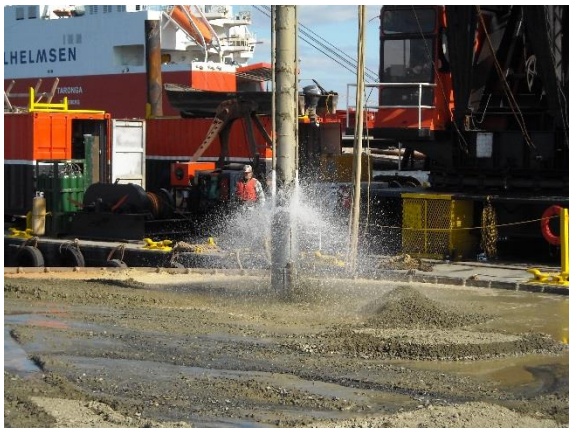


5) The template for the interconnecting arcs is positioned, set down, and the arc sheet piling installed in a manner similar to that of the circular cells.

6) Once the individual circular cell sheet piling is installed to the required elevation, the template is removed, and the cell filled with granular material. Once both sides of the arc sheeting is complete, the area between the circular cells is ready for filling. Both operations can be done using conveyor, clamshell, or a variety of other bulk material handling equipment methods.



7) Depending on the design requirements and nature of the fill material, performance characteristics of the structure can be enhanced by way of fill consolidation within the cells. Vibro-compaction is one method that is commonly employed to consolidate material within the cells.



8) Once the cells are complete, they are ready to accept any of a number of additional structures and features necessary to support required function of the cofferdam, including provision of mooring devices, breasting and fender systems, concrete caps, pavements, drainage features, and utilities. If desired, spread foundations, non-displacement piles (e.g. H-piles, steel pipe piles), and sheet piling may be installed within the cell fill to support concentrated loads (such as a tower crane, or a pad for a crawler crane, generally without effect to the overall structure.

4. Muck out the cofferdam using a clamshell to the level of the bottom of the tremie concrete seal.
5. Install driven / drilled foundation elements within the cofferdam, including permanent steel casings, reinforcing, and concrete. Drilled shafts are likely the preferred foundation components, based on review of available geotechnical information and the anticipated loads imposed on the foundations by the gated structures. Drilled shaft foundation installation includes:
   a. Mobilization and Demobilization
   b. Survey and Stake-out
   c. Provision permanent steel shaft casings, including fabrication, coating (as needed), installation (vibrating and seating into rock), and casing cut-off to the required elevation.
   d. Material removal and disposal from the casing, performed via augering.
   e. Drilling and disposal of rock material from the socket.
   f. Placing reinforcing cages
   g. Placement of drilled shaft concrete via tremie methods.
   h. Providing Pile Load Tests (e.g., statnamic tests, Osterburg tests, full scale load tests)
   i. Verification Surveys
   j. Bracing or otherwise stabilizing foundation elements from excessive movement, as needed, until such time the tremie seal is placed.
6. Install the steel sheet pile seepage cutoff wall
7. Provide concrete seal placed by tremie methods.
8. Upon curing of the seal, dewater the entire cofferdam. Provide pumps necessary to maintain the cofferdam in a dewatered condition.

9. Provide gravel bedding layers at pier foundation and gate sill locations.
10. Cut off residual/upper casings and prepare top of tremie to receive reinforced concrete footing and sill elements.
11. Cut off upper reaches of the sheet pile seepage cutoff wall.
12. Construct reinforced concrete horizontal elements, including pier foundations, gate sill, and transition slab.
13. Construct reinforced concrete vertical elements, including pier towers, shear walls, bridge supports, including gate slot recesses, bulkhead recesses, armor, gate anchorages, galleries, chases, conduits, seals, and other embedded devices.
14. Install sill protection, including quarry stone and armor (rip-rap) rock.
15. Install pre-fabricated submerged axis flap gate, gate lift arms and linkages, and maintain in the open (lowered) position through the point where testing and commissioning begins.
16. When lower work is complete (e.g., concrete pier construction, gate installation) is complete the cofferdam can be re-watered, and the cofferdam components salvaged for reinstallation at the Phase 2 location.
17. Construct navigation span pier protection/guard and guide fender systems
18. Install mechanical, electrical, instrumentation, operation, and control systems to the extent practicable for the phased construction approach.
19. At the completion of all phases of construction for the submerged axis flap gates and pump station construct the pedestrian bridge and overlook. This may be done in parallel with construction of the operations building, and any remaining mechanical, electrical, instrumentation, and control systems requiring completion.

6.3 Submerged Axis Flap Gates

The second configuration of gates considered for Fort Point Channel are submerged axis flap gates. This gate type is typically stored in a submerged position within a receded sill; unless deployed only the pier-type gate guide towers are exposed above the channel surface. Additionally, since the pier towers only need to support the submerged gate rotation to its deployed height, and support mechanical and operating equipment at the top of the towers, the tower heights are approximately 20 feet less than the vertical lift gate option.

The mechanical operating system for each submerged axis flap gate is a pair of articulated gate arm linkages, with one located at each end of the gate. Gate arms will be moved through the required range for gate opening and closing by one of several types of operating systems, including chain drive, tractor-type, and hydraulic cylinder systems. Due to advantages of simplicity and reliability, the hydraulic cylinder system was selected at this level of concept design.

The structural configuration of submerged axis flap gate is anticipated to be horizontally framed steel plate girders, vertical framing and intercostals as required to adequately support and distribute loads imparted to the surrounding skin plates.

The lower reach of the submerged axis flap gate is supported by and rotates about a series of hinge assemblies. The gate hinge pins rest in a cast steel or steel alloy hinge assembly that are anchored to the gate foundation pedestals, through an embedded steel grillage and high-capacity rock-type anchors.

Gate arms are tubular steel, with cast or fabricated linkages provided at each end to provide articulation at both the lifting ear at the top of the gate, and at the connection to the trolley support and hydraulic drive cylinder.

Fort Point Channel Submerged Axis Flap Gate alternative is indicated in See "Boston Water and Sewer Commission Fort Point Channel Storm Surge Barrier Submerged Axis Flap Gate Concept Design, Boston, MA" Rev 02, dated November 21, 2022 for the general configuration of the Fort Point Channel Submerged Axis Flap Gate alternative.

Mechanically actuated submerged axis flap gates are rare, and there is only one known instance of this gate type currently in use as a tide or hurricane barrier along the Eastern Seaboard. The Stamford (Connecticut) Hurricane Barrier East Branch Navigation Gate is a submerged axis flap gate, and is operated and maintained by the US Army Corps of Engineers New England District (USACE NAE). There is one gate at the Stamford Hurricane Barrier, with a navigable opening (gate width) of 90 feet (comparable to the 115 foot width of Fort Point Channel) and an overall height of 37’-9” (measured from center of hinge pin to top of gate), which is virtually identical to the height of the Fort Point Channel submerged axis flap gate. Hence, while rare, there is good precedence for an operable gate configuration of this type used for both storm surge and tide protection, and also serve to accommodate navigation. The Stamford barrier has been in place and in operation since 1969.

6.4 Dam sections and tie-ins

The solid dam section that would be constructed in Phase 1 (under the current construction phasing scenario) is a mass concrete, monolith-type structure that extends from the top of the footing/sill location to Elevation +15.5, the same elevation as the top of the gates in their deployed (raised) positions. The central dam section encompasses the gap between the two easterly and two westerly gate areas, and serves to maintain a line of protection between these gate elements. The dam is expected to be of reinforced cast-in-place concrete construction, and would be provided with supplemental structures as needed, including dam buttresses and piers that would serve to support the pedestrian bridge and overlook areas.

Tie-ins would occur at the western and eastern ends of the surge barrier complex, and transition to shore-based measures that are provided to afford flooding of adjacent land-based areas. Alternately, tie-ins could extend to existing lands that are situated above the anticipated flood elevation. Under both scenarios, tie-ins are required to prevent flood waters from flanking the surge barrier complex.

There are numerous potential configurations of tie-in structures, including walls, levees, cellular structures, movable barriers, and combinations thereof. The identification of alternatives required extents, and development of the preferred configuration and limits of tie-ins is beyond the current scope of the project. Hence, for cost budgeting efforts an assumed continuous pile-supported inversed "T-Wall" constructed of reinforced concrete is the assumed configuration of the tie-ins.

6.5 Maintenance Bulkheads

Maintenance bulkheads (stoplogs) will be required to provide access to, and inspection and maintenance of the submerged areas of each gate. Bulkheads would be provided in sufficient quantity to allow dewatering and service on one gate; bulkheads are required on both the harbor side and the channel side of the gate. Bulkheads can also be used for short-duration emergency closure, if one (or up to two) gates become inoperable.

Bulkheads are typically constructed of steel truss elements with a skin plate on one side. Bulkheads span the entire width of the gate opening, and are installed and restrained by slots (recesses) provided in the pier towers. Bulkheads are often modular, and are provided in heights that usually range from four to six feet. Bulkhead units are positioned and lowered on each other, stacked, with seals provided between each layer to lessen water intrusion. Once bulkheads are fully installed the gate area is dewatered using pumps, thereby allowing access for inspection and maintenance in-the-dry. Once that work is complete the gate area is re-watered, and the bulkheads are removed. Bulkheads are typically stored near the site, but could be stored remotely if necessary. Regardless, they should be readily accessible, particularly if required for emergency closure.

Bulkheads can be installed using barge-mounted equipment (crane), and this is the assumed scenario for bulkhead installation and removal for the Fort Point Channel gate complex.

The other option for bulkhead installation involves lifting components into place using a mobile crane located on a service bridge. For this scenario the service bridge would need to be designed for crane loads. It may be possible to configure the proposed pedestrian bridge to also work as a service bridge for equipment access and bulkhead installation. However, this concept would significantly increase the cost of the bridge due to the much greater loads. Likewise, the bridge approach structures and embankments require consideration, as vehicle and equipment access and allowable grades would differ from those required for pedestrian access. This concept could be evaluated further as the bridge systems are assessed in more detail.

6.6 Pedestrian bridge

A pedestrian bridge and pedestrian overlook have been incorporated into the vertical lift gate surge barrier system. Relatively little effort has been expended in evaluating alternative bridge structural

configurations, but the spans (115 feet) appear conducive for considering several potential bridge types, including:

1. Prestressed concrete girders, including Bulb Tee girders
2. Prestressed and post-tensioned box girders
3. Steel beam and concrete slab systems
4. Through-arch and through-truss spans, either prefabricated or site-assembled
5. Cable stayed spans
6. Other arrangements, and combinations of those listed

A definitive bridge type has not been established, nor are recommendations made in this regard. Further study is suggested, which could also explore the potential for combining service access with pedestrian access.

From a costing standpoint, historic bid tabulations were used to identify a potential unit cost for the pedestrian bridge structure. This anticipates a modest degree of enhancements and pedestrian amenities, such as decorative paving/deck surface, architectural railings, signage and wayfinding, and similar features.

6.7 Pump Station

A pump station is integrated within the storm surge barrier complex as shown on the plan set titled: "Boston Water and Sewer Commission Fort Point Channel Storm Surge Barrier Submerged Axis Flap Gate Concept Design, Boston, MA" Rev 02, dated November 21, 2022. The pump station is not discussed herein, as this document focusses on the gated storm surge barrier facility. The reader is referred to the main report describing all projects that are part of the "Coastal Stormwater Discharge Analysis" for a description of the pump station.

6.8 Cost Estimate

An Opinion of Probable Cost has been prepared for the Submerged Axis Flap Gate Alternate based on the Conceptual Design Drawings titled "Boston Water and Sewer Commission Fort Point Channel Storm Surge Barrier Submerged Axis Flap Gate Concept Design, Boston, MA" Rev 02, dated November 21, 2022. This Opinion of Probable Cost is a Class 4 level estimate as defined by AACE International. The level of Project definition, expressed as percent of complete definition, for a Class 4 estimate is from 1 percent to 15 percent. The estimate is developed based on take-offs, parametric estimates and engineering judgement. The reader is referred to the main report describing all projects that are part of the "Coastal Stormwater Discharge Analysis" for an overview of the cost estimate. The cost estimate is not included herein as it should be viewed in conjunction with the pump station cost estimate to understand the cost of the storm surge barrier project in its totality.

7 NEXT STEPS

7.1 Synopsis

This document provides a brief overview of the site conditions, design parameters and geometric constraints for the Fort Point Channel Storm Surge Barrier. This document further provides a brief overview of gate types used in navigable storm surge barriers. This document does not intend to reproduce or summarize the body of work that has been produced by others, instead it summarizes and briefly expands upon the content and supplemental data of others to get a better understanding of gate types that have been successfully applied elsewhere.

The gate types are compared and an overview of advantages and disadvantages for each gate type were provided in context of the FPC SSB Feasibility Study. A multi criteria analysis was completed in coordination with the BWSC and two gate types were selected such that concept designs for the FPC SSB could be advanced. The selected gate types are:

1. Vertical lift gate
2. Flap gate with submerged axis

Using these two gate types the engineering team developed two conceptual designs and associated budgetary-level costs for the FPC SSB; one design will involve a complex of vertical lift gates, with the other using submerged axes flap gates. These conceptual designs provided sufficient level of detail for a class 4 cost estimate, which allowed BWSC to compare cost, function and geometry, and other considerations for a SSB complex that include either submerged or emergent gates.

Finally, past experience developing and implementing barrier designs tells us that there are often compromises required, and that an "ideal" gate type often does not exist. It should also be recognized that for civil work projects comparable to the FPC SSB, custom designs and features can be developed that select or combine some of the most favorable aspects of different gate types, in order to mitigate potentially unfavorable characteristics.

7.2 Next Steps

Following the evaluation described within this report there are several topics that may warrant further investigation and are could be considered logical next steps as part of an iterative design process. For completeness these topics are summarized here.

1. Site-specific geotechnical evaluation, including site exploration, material testing, and reporting,
2. Evaluation of "Lands and Damages" associated with the provision of shoreline and upland transition structures and tie-ins. This should include evaluation of potential property takings, alternate locations, and related mitigation measures that can lessen impact.
3. Evaluation of "Relocations" that may be required for each of the alternatives, including both land-based and marine oriented elements. This should include evaluation of water-

dependent uses being impacted, and identify potential mitigation measures that can lessen impact.

4. Advanced hydraulic modeling to assess flows, currents, eddies, cross current, rates of sediment accretion, scour potential, and similar impacts to both the gate complex itself (e.g., loads, design development, maintenance requirements) and external interests (e.g., navigation).
5. Perform a navigation study to determine both existing and potential future navigable impacts of the gated barrier, and integrate those findings with future design
6. A bridge-type study, to assess pedestrian/combined pedestrian and service bridge concepts. This should also include evaluation of bridge geometry, span arrangements, widths, structural framing and type. Pedestrian (and potentially vehicular or service equipment) access and approach geometry should be investigated.
7. Site-specific material sampling and testing, to evaluate in-situ channel bed materials, as a means of identifying the possible presence of hazardous or toxic waste, including but not limited to PCB's, heavy metals, pesticides, and similar undesirable substances.
8. Preliminary, concept level design of mechanical, electrical, operating, and control systems.
9. Architectural design and space planning for operations building.
10. Planning and layout for future maintenance shops and associated maintenance facilities.
11. Construction planning, including identification of a Work Breakdown Structure, staging and laydown areas, work packages and sequence of work, material transport logistics, production rates, equipment requirements, labor participation requirements, identification of special components, long-lead materials, and specialty equipment, develop project scheduling, and establish cashflow/expenditure/funding stream requirements.
12. Initiate engagement with the USACE NAE, and other Federal, commonwealth, and local stakeholders.
13. Initiate a public involvement process for project communication, and local stakeholder input.
14. Provide initial engagement of environmental/permitting stakeholders (e.g., USACE, MARAD, NOAA Marine Fisheries, EPA, MassDEP) to identify very early in the process potential concerns, obstacles, and to develop lines of communication and dialogue with these agencies
15. Perform a corrosion study to assess in better detail the means and methods required to achieve project service life. This can include cost/benefit and life-cycle cost evaluations.
16. Study to assesses the viability of "innovative" construction means and methods (e.g., float-in, lift-in) and the potential impact of such concepts on constructability, cost, and schedule.
17. Other studies that may be desired to assess issues and answer questions that arise throughout the phased design development process.

8 REFERENCES

Dijk, A. a. (2010). *Multifunctionele beweegbare waterkeringen [Multifunctional movable flood gates]*. Delft, The Netherlands. Retrieved from http://www.tudelft.nl/fileadmin/UD/MenC/Support/Internet/TU_Website/TU_Delft_portal/Onderzoek/Infrastructure/Engineering_challenges/open_en_afsluitbaar_Rijnmond/doc/AOR_Multifunctionele_beweegbare_keringen_FvdZiel_ADijk,_TUD,RCP,KvK_Definitief.pdf

Dircke, P., Jongeling, T., & Jansen, P. (2012). Navigable storm surge barriers for coastal cities: An overview and comparison. In J. Aerts, W. Botzen, M. Bowman, P. Ward, & P. Dircke, *Climate Adaptation and Flood Risk in Coastal Cities* (pp. 201-223). New York: Earthscan.

Mooyaart, L. F., & Jonkman, S. N. (2017). Overview and Design Considerations of Storm Surge Barriers. *ASCE Journal of Waterway, Port, Coastal and Ocean Engineering*.

Mooyaart, L. F., Jonkman, S. N., de Vries, P. A., van der Toorn, A., & van Ledden, M. (2014). Storm Surge Barrier: Overview And Design Considerations. In P. J. Lynett (Ed.), *Coastal Engineering Proceedings* (p. 808). Seoul, Korea: Coastal Engineering Research Council.

NOAA. (2020). *NOAA.gov*. Retrieved from Tides & Currents: https://www.tidesandcurrents.noaa.gov

NOAA, National Oceanic and Atmospheric Administration. (2020). *NOAA.gov*. Retrieved from Office of Coast Survey: https://www.charts.noaa.gov/OnLineViewer/13272.shtml

PIANC. (2006). *Design of Movable Weirs and Storm Surge Barriers.* Brussels, Belgium: PIANC.

USACE. (2014). *Design of Hydraulic Steel Structures.* Washington, DC: USACE.

USACE-ERDC. (2007). *Hurricane Barriers in New England and New Jersey - History and Status after Four Decades.* USACE, ERDC. Vicksburg, MS: USACE.

van Ledden, M., Lansen, A., de Ridder, H., & Edge, B. (2012). Reconnaissance level study Mississippi storm surge barrier. In P. L. Smith (Ed.), *Proceedings of 33rd Conference on Coastal Engineering.* Santander, Spain: Coastal Engineering Research Council.

Appendix J: Moffatt & Nichol Dorchester Bay Basin Report

Boston Water and Sewer Commission

DRAFT REPORT

Coastal Stormwater Discharge Analysis

Dorchester Bay Basin Storm Surge Barrier

Conceptual Design

December 2022

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Coastal Stormwater Discharge Analysis

Dorchester Bay Basin Storm Surge Barrier

Conceptual Design

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1 INTRODUCTION

1.1 Introduction

The Boston Water and Sewer Commission (Commission) has undertaken the Coastal Stormwater Discharge Analysis project to continue its efforts to prepare for the effects of climate change. As preliminary strategies to respond to climate change are developed, including alternatives developed by the City of Boston (City) and other agencies, it is essential that the Commission's ability to discharge stormwater is preserved despite the challenges posed by sea level rise and storm surge. In addition, the adaptations being planned and designed by other agencies have the potential to influence the Commission's infrastructure. The Coastal Stormwater Discharge Analysis will establish strategies and conceptual designs that will ensure that the Commission maintains its ability to discharge stormwater under varied circumstances, despite the impact of these dynamic challenges.

As such, the Coastal Stormwater Discharge Analysis includes a conceptual design of a facility for resilient stormwater management at the entrance to the Dorchester Bay Basin. Specifically, this facility is envisioned to be a storm surge barrier that can be closed during the combined conditions of storm tides and heavy rainfall, thereby effectively changing the Dorchester Bay Basin into a managed storm water discharge basin.

1.2 Purpose

The gates of a Storm Surge Barrier (SSB) are a major element of any SSB as they provide for both exclusion of surge during a storm event, and the passage of flow under non-event conditions. In addition, as required, SSB's may be required to afford passage of vessel traffic. The SSB consists of gates that are the movable parts within an otherwise static structure; therefore, an SSB requires an operation plan. The conceptual design of the gated storm surge barrier structure for the Dorchester Bay Basin is the subject of this report.

1.3 Readers Guide:

This interim report is structured as follows: Section 2 provides an overview of the Dorchester Bay Basin design criteria and Section 3 provides a description of the proposed storm surge barrier site conditions. Section 4 discusses the gate type selection and the geometric characteristics of the gated portion of the storm surge barrier. Section 5 provides a description of the conceptual design development of the proposed storm surge barrier structure. Lastly, section 6 provides a brief synopsis of the work described herein and provides an outline of next steps if the proposed concept were to be studied further and/or brought to a refined level of design.

2 DORCHESTER BAY BASIN STORM SURGE BARRIER – ABBREVIATED DESIGN CRITERIA

2.1 Introduction

This report provides a brief review and compilation of existing relevant information on the Dorchester Bay Basin (DBB), with a focus on the feasibility of construction of a SSB at the mouth of the Basin. The function of the SSB would be twofold; 1) provide flood risk reduction for the low-lying areas adjacent to and upstream of the DBB SSB in the event of a coastal storm event and 2) by closure of the SSB provide storage capacity within the DBB during extreme rainfall events that coincide with elevated tides and thereby reduce flood risk in the DBB connected sewersheds during pluvial storm events.

For a general description of a storm surge barrier and its elements the reader is referred to the Fort Point Channel storm surge barrier report .

2.2 Alignment of the Storm Surge Barrier

The assumed SSB alignment is informed by the Coastal Resilience Solutions for Dorchester (Cook, et al., 2020), which is part of Climate Ready Boston study. The pink line on the harbor side of the Castle Island Drawbridge, which is part of Morrisey Blvd (Figure 2-1), placed the SSB in close vicinity to the bridge. Placement of the SSB at the mouth of the bay is a logical alternative as it is the shortest in-water span versus the longer all land-based perimeter option.

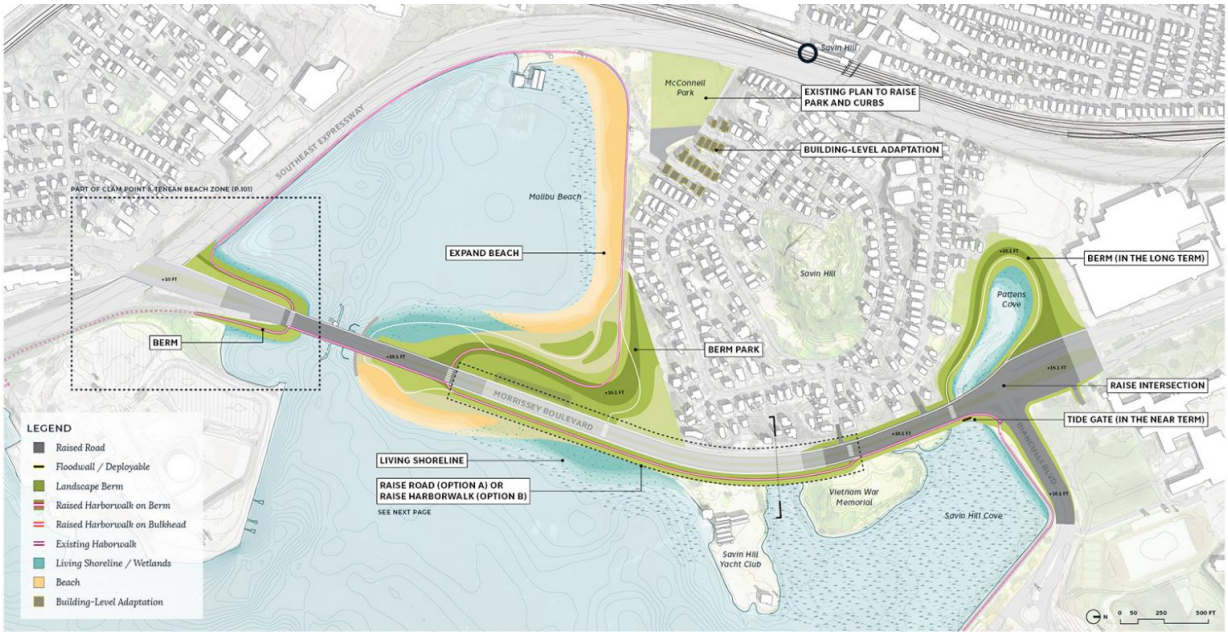

Figure 2-1: Area of Dorchester Storm Surge Barrier as presented in Coastal Resilience Solutions for Dorchester

2.3 Location and Scope

The Dorchester Bay Basin (DBB) is located south of South Boston, MA, between the I-93 Southeast Expressway and Morrissey Blvd. (Figure 2-2). Dorchester Yacht Club is located within DBB and is connected to the Neponset River via a dredged channel within the basin. The Castle Island Drawbridge allows vessels to navigate in and out of the basin past Morrisey Blvd.

Multiple hazards are located in the vicinity of the future SSB, including three underwater awash rock points, a pipeline area, and a nearby anchorage area (Figure 2-2).

To assist in the evaluation of the SSB at the mouth of the Dorchester Bay Basin, several metocean and environmental site characteristics are summarized in section 2. Section 3 provides additional detail regarding some site-specific considerations.

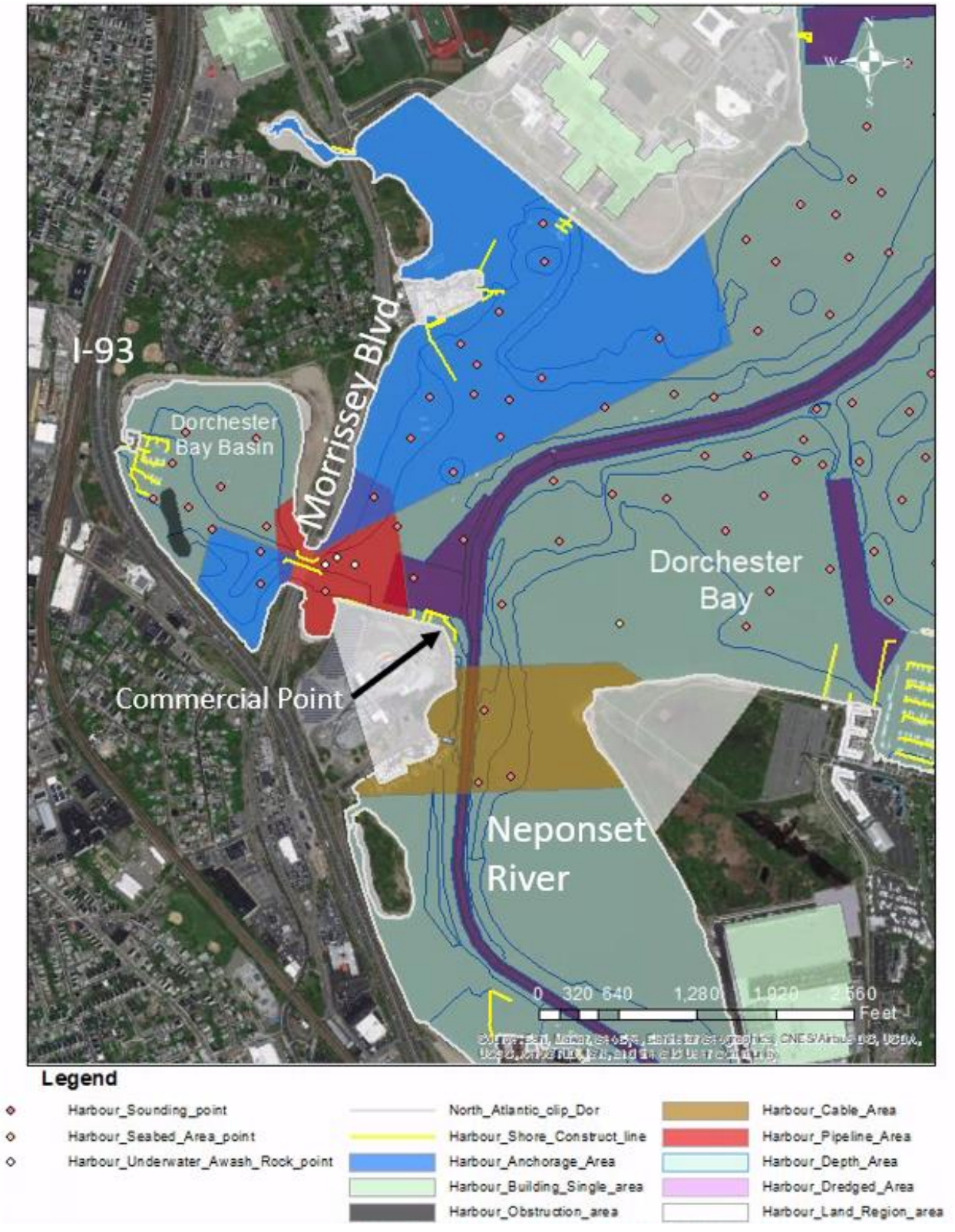

Figure 2-2: Dorchester Bay Basin and Surrounding Hazard Areas

2.4 Basic Functional Requirements

The following basic functional requirements have been identified for the conceptual design of the storm surge barrier consistent with the overall objectives of the Study:

- The storm surge barrier will provide a reliable structural measure to reduce the risk of coastal storm damage within the Dorchester Bay Basin.
- The storm surge barrier will provide a reliable structural measure to retain storm water and rainfall runoff within the DBB during conditions when the barrier is closed.
- The storm surge barrier will minimize impact to navigation and waterborne commerce; and
- The storm surge barrier will minimize impact on the water exchange through the opening during normal operation (non-storm conditions) in order to minimize impacts on the inner basin environmental conditions.

As a result of the above requirements the storm surge barrier concept will at its simplest consist of two principal parts: 1) moveable gates (both navigable gates and flow control gates) with associated gate support structures and 2) tie-in structures. For any system of movable gates, including navigable gates and flow control gates, there are three basic functional requirements:

- The moveable gates of the storm surge barrier will be able to open and close with a high degree of reliability.
- The gates will be sized and provide a range of motion suitable for purpose (e.g. navigation, flow control); and,
- The moveable gates and gate structures will be an integral part of the overall storm surge barrier structure and be designed such that they impede the coastal storm flood levels and minimize the risk of coastal storm damage to the region behind it.

2.5 Service Life

The Dorchester Bay Basin SSB will have various project components for which Life Cycle Design should be considered. At this stage of the project (feasibility study stage) no such analysis has been performed. A minimum project service life of 100 years is preliminarily recommended as a result of the size and nature of the project. For certain project components a shorter service life may be applicable.

For the storm surge barrier to meet the functional requirements regarding flood risk reduction (see section 2.7.2) a period of analysis has been established that is shorter than the recommended project service life. The project will perform to meet the design criteria related to flood risk reduction in this document for a 50-year period spanning the years between 2020 and 2070s. The project is to be designed for sea level rise, regional subsidence, and local settlement occurring for a 50-year planning horizon (to the year 2070). After such a time, to achieve the same level of risk reduction, the structures may have to be modified or improved (i.e., adaptive management may be necessary or structural improvements may be needed if the observed sea level rise exceeds the planning criteria). Design provisions will be required to accommodate such improvements if and

when needed, and adaptability to future improvements will be part of the gate type selection process.

2.6 Site Conditions

2.6.1 Bathymetry and Topography

Deepest soundings within the centerline of the dredged channel of Dorchester Bay Basin are approximately 13 ft and deepest soundings in the harbor near the draw bridge are 8 ft. Soundings are referenced to Mean Lower-Low Water and shown in a partial image of nautical chart 13270 (NOAA, 2016) (Figure 2-3). A Digital Elevation Model (DEM) completed for the New England Region States of New York, Connecticut, Rhode Island and Massachusetts with data collected from 1887 to 2016 (Figure 2-4) was used to derive cross-sectional profiles of flow areas near the draw bridge (Section 3.4) (NOAA, 2016).

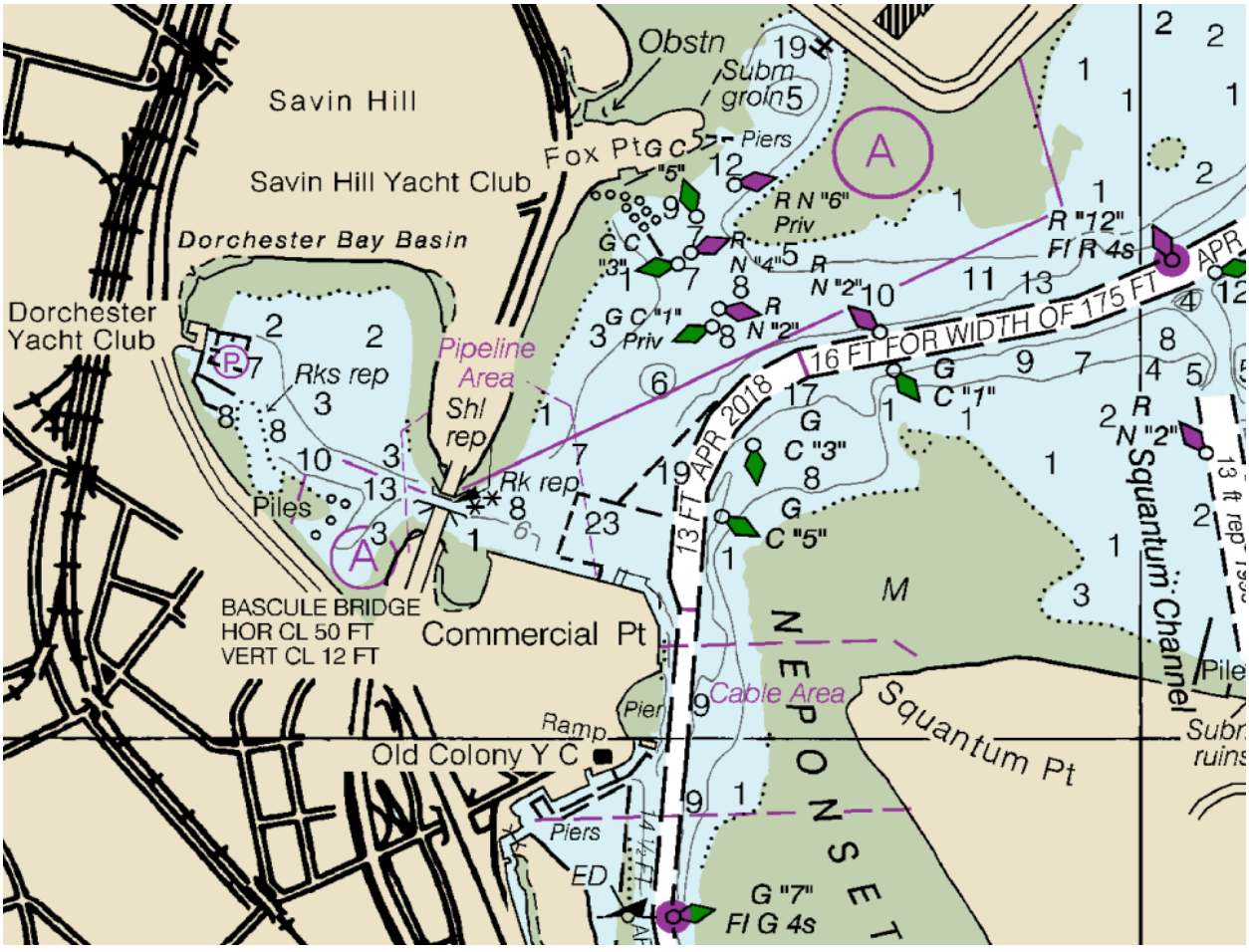

Figure 2-3: Soundings in Dorchester Bay Basin in Feet (datum: Mean Lower-Low Water) from Nautical Chart 13270



Figure 2-4: Bathymetry of Dorchester Bay Basin and Dorchester Bay in meters (datum: NAVD88). Source: (USGS, 2016)

2.6.2 Subaqueous Utilities

Buried utilities, including cables, cross the project area as shown in Figure 2-2. Further exploration will be needed to identify marked and unmarked utilities. At this phase of the study, it is assumed that the utilities will have to be relocated prior to construction of the proposed Dorchester Bay Basin SSB. Further site investigations are recommended at later stages of the study and future phases of the design process.

2.7 Hydraulic Conditions

2.7.1 Operational Hydraulic Conditions

2.7.1.1 Sea Level Rise

This design includes 40 inches of sea-level rise by the 2070's. For additional information on sea level rise in this area and values used for conceptual design of the storm surge barrier structures, see FPC channel memo M&N dated 12/23/20 (Moffatt & Nichol, 2022).

2.7.1.2 Tidal Datums

Tidal Datums at Dorchester Bay Basin are referenced to the same gauge as for the Four Point Channel analysis. Therefore, see FPC channel memo M&N dated December 2022 for tide datums (Moffatt & Nichol, 2022).

2.7.1.1 Winds

Both normal and extreme wind conditions were sourced from the same Logan International Airport Station as for the Four Point Channel analysis. Therefore, see FPC channel memo M&N dated December 2022 for the wind analysis (Moffatt & Nichol, 2022).

2.7.2 Extreme Hydraulic Conditions

In the event that the SSB gates are closed, hydraulic conditions are governed by extreme water levels on the exterior side of the Dorchester Bay Basin SSB resulting from storm surge in combination with low or high water levels within the basin.

2.7.2.1 Extreme Water Levels

Coastal storm surge data is presented in FEMA's 2020 Preliminary Flood Insurance Study of Suffolk County, MA (FEMA, 2020) and is available from the 2015 USACE North Atlantic Coast Comprehensive Study (NACCS) (USACE, 2015). The still water flood elevations for these two sources are shown in Figure 2-5 and listed in Table 2-1 for the 10%, 2%, 1%, 0.2%, 0.1% annual exceedance probability (AEP) floods (10-, 50-, 100-, 500-, and 1000-year average return periods (RPs) respectively). For this study, the AEP from the nearest NACCS point, 9592 (Figure 2-6),

will be used. For projections of future extreme water levels sea level rise will need to be accounted for[1] and is further discussed in section 2.7.1.1.

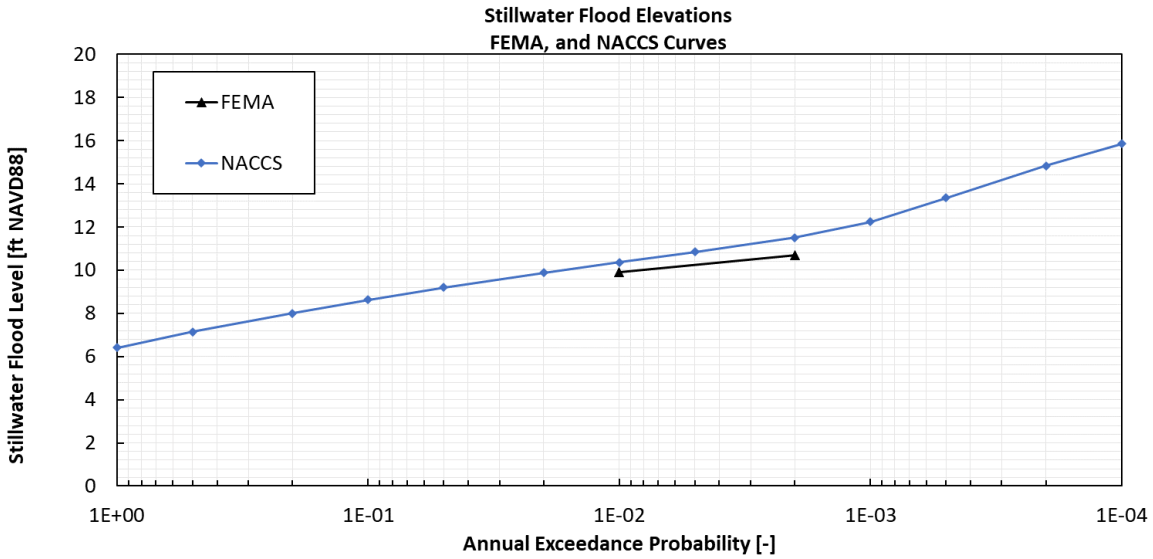

Figure 2-5: Stillwater Flood Elevations for Various AEP Floods

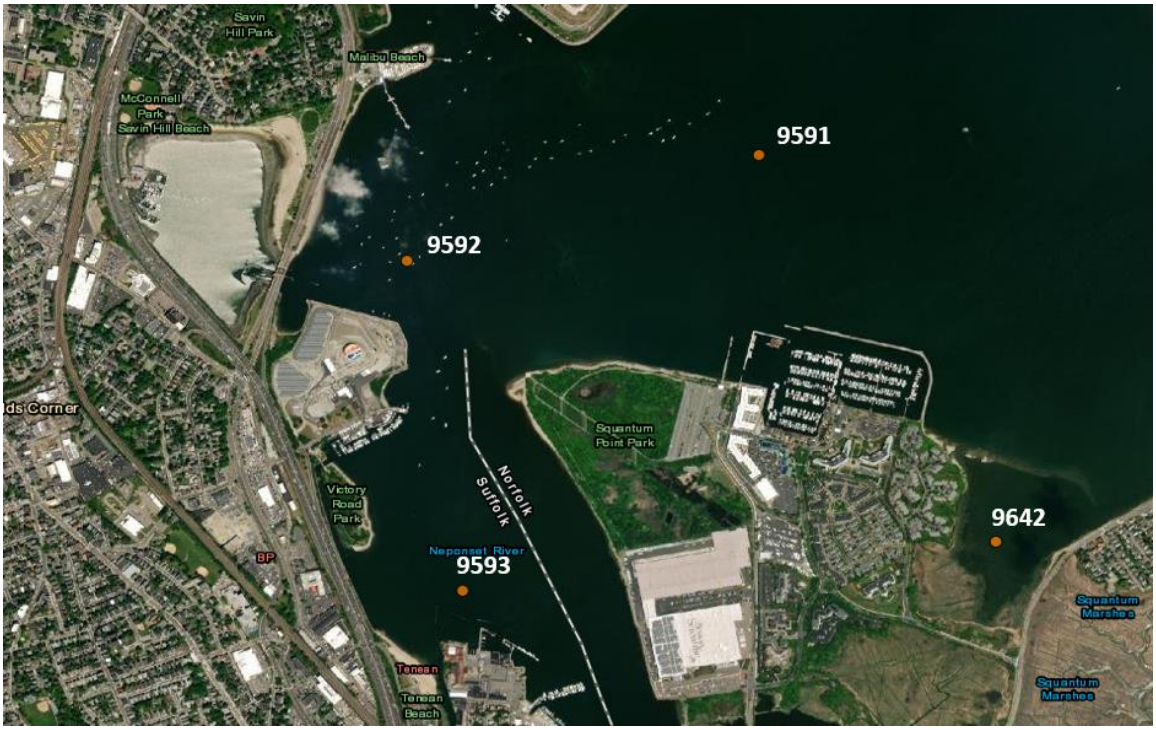

Figure 2-6: NACCS Points located near Dorchester Bay Basin

[1] Extreme water level values are based on the current tidal epoch. When accounting for sea level rise the year 1992, the middle of the tidal epoch, is used as the base year

Table 2-1: Extreme Water Levels at the Dorchester Bay Basin SSB Project Site

Average Return Period	Expected Value AEP based on		
	FEMA	NACCS	Used for this study
years	ft, NAVD88	ft, NAVD88	ft, NAVD88
10	-	8.6	8.6
50	-	9.9	9.9
100	9.9	10.4	10.4
500	10.7	11.5	11.5
1000	-	12.2	12.2

2.7.2.2 Design Water Level (exterior)

Following the data in the preceding sections the design water level is +13.7 ft NAVD88 and represents the 100-year Return Period extreme water level, inclusive of 3.3 ft (40 inches) of SLR up to the year 2070.

Table 2-2: Design Water Levels

Year	100-year RP water level	SLR	Design Water Level
	ft NAVD88	ft	ft NAVD88
2070	10.4	3.3	13.7

2.7.2.3 Waves

The 100-year RP wave conditions for the flood side of the barrier are based on NACCS data and are provided in the table below. Table 2-3.

Table 2-3: Extreme Wave Heights and Peak Wave Periods from NACCS points show in Figure 2-6

Average Return Period (years)	Wave Heights from (ft)	Peak wave period (s)
100 years	5.3	4.9

2.7.2.4 Design Water Level (interior)

The Dorchester Bay Basin SSB will also function as a water control structure at the head of the newly created DBB basin, i.e., the DBB will be a basin when the SSB is closed. As a conservative estimate the conceptual design is based on the assumption that the DBB basin may accommodate water storage between the same elevations as the FPC SSB (this is a range between approximately -5.5 ft NAVD88 and 7.0 ft NAVD88. This is a conservative assumption and can be further refined

during later phases of the design. It is preliminarily assumed that maximum reverse head loading conditions can occur when gate operations fail following a storm closure, resulting in maximum interior water levels and low tide levels on the exterior. This situation will yield a 12.55 ft head difference with -5.51 ft NAVD88 exterior water levels.

2.8 Geotechnical Conditions

Boring data is available from the Proposed Widening of Bridge over Dorchester Bay Project, which contains boring locations and data from M.D.C. drawing No 2 dated May 5, 1927.

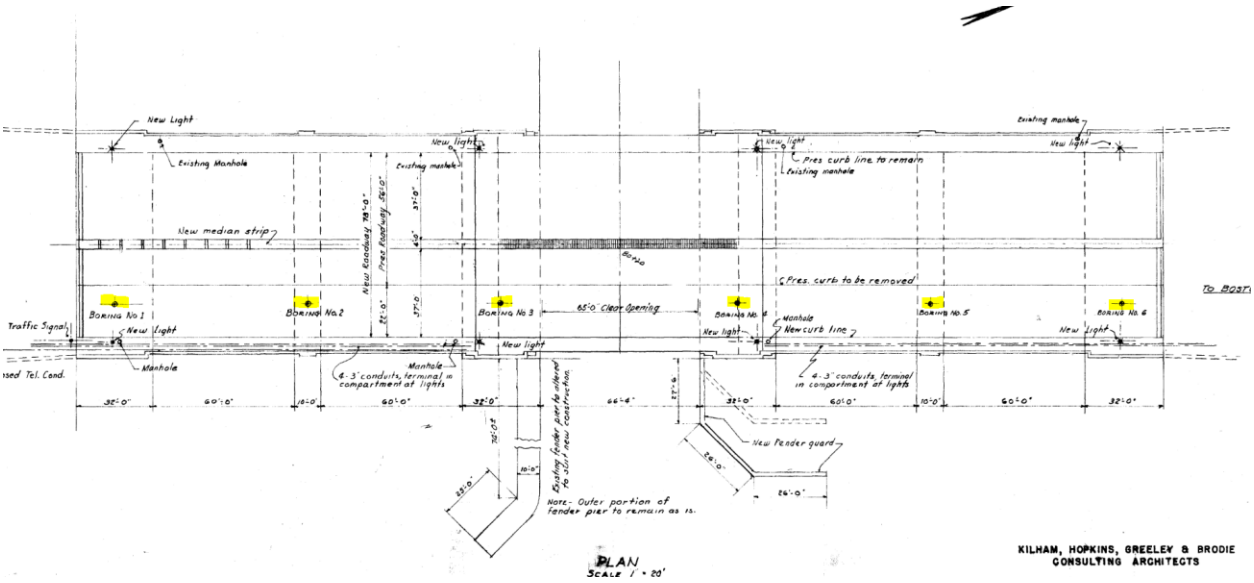

Figure 2-7: Plan view of Bridge over Dorchester Bay (1927) with boring locations highlighted.

Geotechnical information is preliminary and will be reviewed further during later stages of the study.

2.9 Navigation Criteria

2.9.1 Navigation Safety

Cross currents or excessive head-on and helping currents at the navigable passage could adversely impact navigation. The storm surge barrier and gate layout should be optimized to minimize adverse influence on vessels transiting the storm surge barrier. Additionally, the provision of vessel guides, aids-to-navigation, and protective structures at the navigable channel entrance and exits will be considered to increase navigational safety and potentially protect the storm surge barrier from aberrant vessel impact.

2.9.2 Design Vessels / Fleet

No detailed analyses related to design vessels has been completed at this conceptual design stage. Instead, the minimum navigable dimensions for the navigable passage of the storm surge barrier

structure are derived from the minimum clearances provided for the Castle Island Drawbridge (Morrissey Blvd) on the navigation chart. See further discussion in section 3.2 and 4.1.

2.10 Design Criteria Yet to be Specified

2.10.1 Design Criteria

For the feasibility study, design criteria are limited to those elaborated in the previous sections. The scope of this report is too broad to evaluate and establish the minimum criteria requirements for the gated portion of the structure. The documentation provided within the previous sections is the first step in an iterative design approach.

The general design criteria within the previous sections are not complete and many criteria are yet to be specified. Such criteria can include but are not limited to:

- Constructability Criteria
- Geotechnical and Foundation Criteria
- Seismic Design Criteria
- Structural Loading and Associated Criteria
- Mechanical Design Criteria
- Electrical and Control Systems Design Criteria
- Civil Design Criteria
- Dredging and Earthwork Design Criteria
- Infrastructure and Transportation Criteria
- Operational and Maintenance Assessments
- Materials
- Aesthetics and viewshed criteria
- Risk (assessments would occur across a broad range of structures, environmental, and operations evaluations)
- Extreme event loadings (seismic, vessel collision, force protection)
- Serviceability and design life assessments

In addition, environmental criteria other than those identified in the preceding sections are only qualitatively considered when appropriate and will need to be further evaluated during subsequent design phases. Such criteria, amongst others, include:

- Criteria related to the impacts on bed morphology and sediment transport
- Criteria related to water quality
- Criteria related to marine habitats, flora and fauna (e.g., fish passage) – ecology
- Criteria related to environmental impacts during construction and upon completion of the project)
- Hazardous materials

- Sedimentation, maintenance dredging, impacts to navigable depths and potential for localized scour

2.10.2 Operational Criteria

For the feasibility study design criteria related to the operation of the storm surge barrier are limited to functional requirements as listed in Section 2.4. However more detailed requirements with respect to many aspects of the structure, its function and its operation will need to be addressed in later phases of the study. Such criteria include, but are not limited to:

- Machinery and controls requirements and criteria,
- Auxiliary pump requirements,
- Maintenance requirements (access, inspection, and maintenance for the gates, machinery controls, abutments, piers, dam section, bulkheads, stoplogs, etc.),
- Operational requirements (optimum closure frequency, timescale for deployment and recovery, operational forecast and triggers),
- Redundancy requirements,
- Navigation criteria (vessel traffic service, advisory, control, limitations on passage, restrictions, etc.).

3 PROJECT SITE ENVIRONS

For the feasibility study of a storm surge barrier at the mouth of the Dorchester Bay Basin it is important to make note of authorized, ongoing or planned construction projects in the storm surge barrier vicinity.

3.1 Navigation Channels

The Dorchester Bay Basin and is not part of a federal navigation project.

3.1.1 Dorchester Bay Access Channel

The access channel for Dorchester Bay Basin is periodically maintained to allow for access to the Dorchester Bay Yacht Club. The project depth is -9ft MLLW (which includes 1ft of over dredge).

3.1.2 Dorchester Bay and Neponset River Navigation Project

The Dorchester Bay Basin is located near the U.S. Army Corps (USACE) Dorchester Bay and Neponset River Navigation Project (USACE, 2022). That project includes a channel that branches off from the main ship channel in Boston Harbor and extends through Dorchester Bay and up the Neponset River. The Channel depth is 18 ft, MLLW and 175 ft wide from the main ship channel to Commercial Point, near the SSB site (Figure 2-2, Figure 2-3).

3.2 Bridges

Data for the Castle Island Drawbridges located adjacent to the proposed DBB SSB are tabulated below. Bridge dimensions may inform gate dimensions for the storm surge barrier to maintain or accommodate small craft navigation.

Table 3-1: Characteristics of bridges just upstream of proposed SSB location

Bridge Name	Bridge Characteristics		
	Horizontal Clearance (ft)	Vertical Clearance (ft from MHHW)	Bridge Type
Castle Island Drawbridge	62	12	Fixed

3.3 Tax Lot and Land Ownership

For construction of civil works and flood risk reduction alignments there is a general preference to minimize land use conflicts and utilize public lands, i.e., lands not privately owned, when available.

There is public property located on both sides of a potential alignment at the inlet of the DBB thereby reducing the risk of encountering private property. The neighboring lot to the south of the is owned by the utility company National Grid.

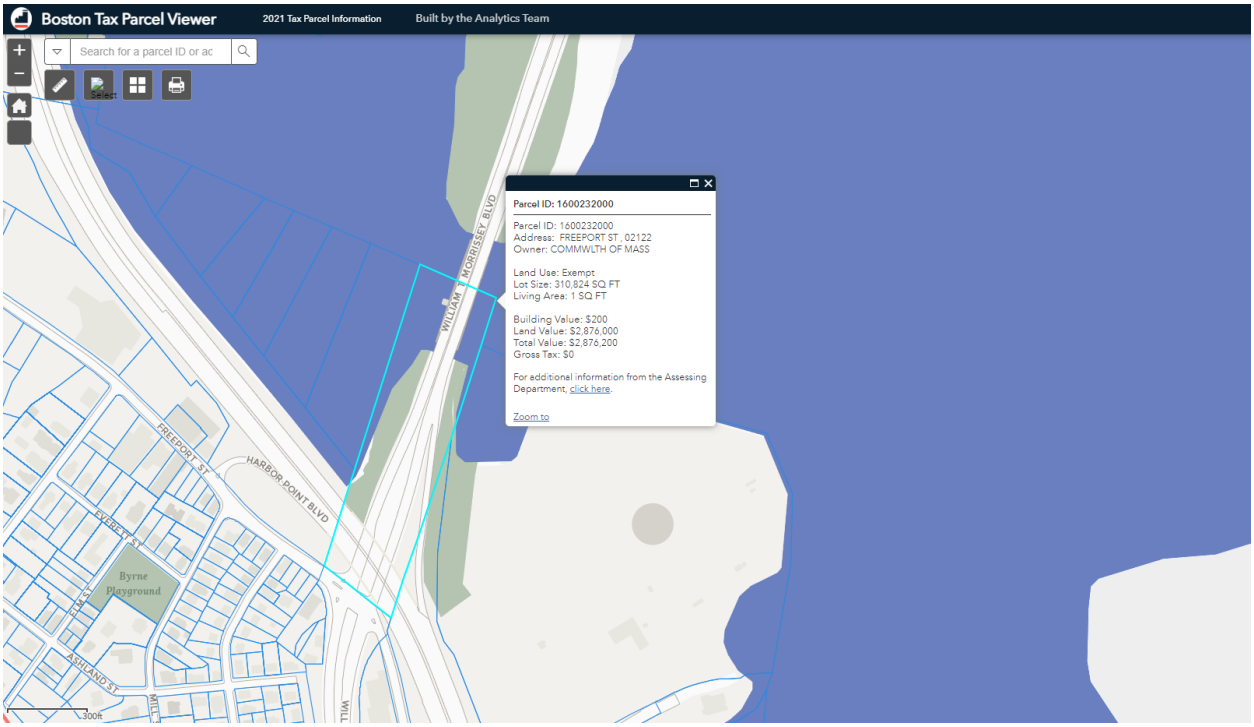

Figure 3-1: Screenshot from Boston Tax Parcel Viewer highlighting tax lot under public ownership

3.4 Channel Cross-Sectional Area

A cross-sectional profile was extracted from the DEM data to inform the preliminary design of the storm surge barrier. It is located approximately 45 ft east of the Castle Island Drawbridge (Morrissey Blvd) (Figure 3-2). The original flow area, the flow area of the planned SSB bays, and the ratio of the SSB bays flow area / original flow area was calculated for this cross-sectional profile with the water level at 0 ft, NAVD88 (Table 2-3).

It is good practice to initially assume that little change to tidal flow exchange is preferred with the implementation of a SSB. No detailed hydraulic analysis or a study of gate geometry has yet been completed. For illustrative purposes we show the outline of the gated open flow area in the figures below with two gates, each with a width of 66ft and a sill elevation of -14.5ft NAVD88 (see section 4 and 5 for further details). The existing flow area of the narrowest cross-section would be reduced to approximately 65% of the original flow if such a geometry would be implemented.



Figure 3-2: Locations of Cross-Sectional Profiles over and adjacent to Castle Island Drawbridge, which is part of Morrisey Blvd. Red boxes indicate SSB opening location (m, NAVD88)

Table 3-2: Profile 1 and Profile 2 Cross-section Statistics

	Profile 1
Existing flow area (sq ft)	2,686
Gated flow area (120*14.5) (sq ft)	1,740
Gated flow area as percentage of existing flow area (%)	65

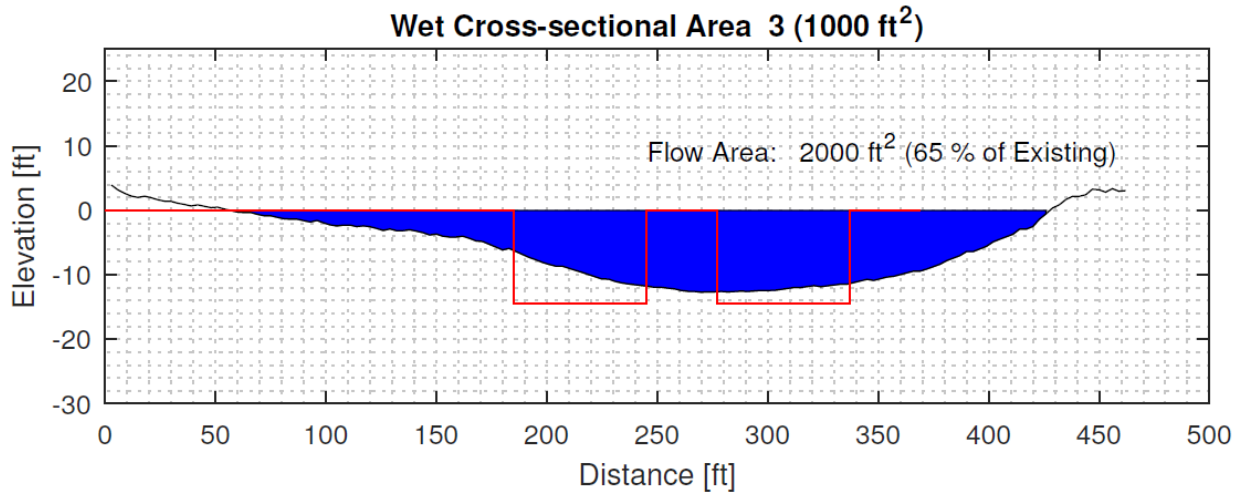

Figure 3-3: Cross-sectional Profile 2.

4 GATE TYPE AND GEOMETRIC CHARACTERISTICS OF THE DORCHESTER BAY BASIN STORM SURGE BARRIER

4.1 Geometric Constraints

This section presents a summary of some of the basic geometric constraints for the DBB SSB conceptual design. Geometric constraints follow from the site conditions and hydraulic conditions as presented in section 2. Two gate bays are proposed for the SSB structure such that gates align with two of the five openings between the existing bridge piers. One gate structure will align with the navigation channel and function as a gated navigable passage and the other gate will allow for water control through the auxiliary flow opening.

The DBB SSB geometric constraints are summarized in three tables; Table 4-1, Table 4-2 and Table 4-3 summarizes key geometric characteristics of the overall SSB complex, where Table 4-2 and Table 4-3 provide key geometric characteristics for the navigable passage and the auxiliary flow gate. Uniformity of gate type is preferred for constructability and as such the sill elevation of the structure is set at a constant elevation across. It should further be noted that the provided data is preliminary and future refinements are anticipated as the design progresses.

Table 4-1: Geometric Characteristics of the DBB SSB Complex Site Conditions

Item	Value	Source/Reference	Notes
Span(ft)	414 ft		Shore to Shore span measured just north of the Castle Island Drawbridge (Morrissey Blvd)
Existing Bathymetry Deepest point	-25ft NAVD88	Bathymetric survey	Located at the center under the bridge scour hole
Existing Bathymetry Shallowest Point	-10 ft NAVD88	Bathymetric survey	Approx. 45 ft east of Castle Island Drawbridge (Morrissey Blvd)
Minimum Height of Barrier	+16.1 ft NAVD88		Based on Design Water Level and Climate Ready Boston

Table 4-2: Geometric Characteristics of the DBB SSB Navigable Opening

Item	Value	Based on	Notes
Minimum Horizontal Clearance	66.3 ft	Castle Island Drawbridge (Morrissey Blvd) bridge span	Navigation Channel width at bridge
Minimum Vertical Clearance Elevation	+17 ft NAVD88	Castle Island Drawbridge (Morrissey Blvd)	Fixed Bridge 12ft clearance from MHW
Sill Elevation	-14.5 ft NAVD88	Existing Channel Depth	-
Location of Nav. Channel	Center	Navigation Chart	-

Table 4-3: Geometric Characteristics of the DBB SSB Auxiliary Flow Openings

Item	Value	Based on	Notes
Horizontal Clearance	66.3 ft	Castle Island Drawbridge (Morrissey Blvd)	Approximate value and based on span between bridge piers
Minimum Vertical Clearance	9.0 ft NAVD88	MHHW and SLR	To allow for free flow (no orifice flow) during normal hydrometeorological conditions at the end of the service life
Sill Elevation	-14.5 ft NAVD88	Existing channel depth	

4.2 Selection of a Suitable Set of Gate Types

For the Dorchester Bay Basin storm surge barrier complex, no detailed evaluation of gate types was completed. Instead, the gate type evaluations and gate type selection for the Fort Point Channel SSB were reviewed and for conceptual design one single gate type was selected. The lift gate was selected for both the navigable and auxiliary flow gate as basis to develop a conceptual design and cost estimate for the storm surge barrier structure.

5 CONCEPTUAL DESIGN FOR DBB SSB

5.1 Introduction

A preliminary geometry for the storm surge barrier with lift gates has been established and is shown in Figure 5-1. This geometry has been established based on the basis of design criteria as provided in the previous sections and includes one navigable opening to accommodate navigation and three auxiliary flow gates to maintain tidal exchange to the fullest extent possible. The reader is referred to the plan set titled: "Storm Surge Barrier Dorchester Bay Basin, Boston, MA" dated "11-21-2022" for a complete overview of the conceptual design.

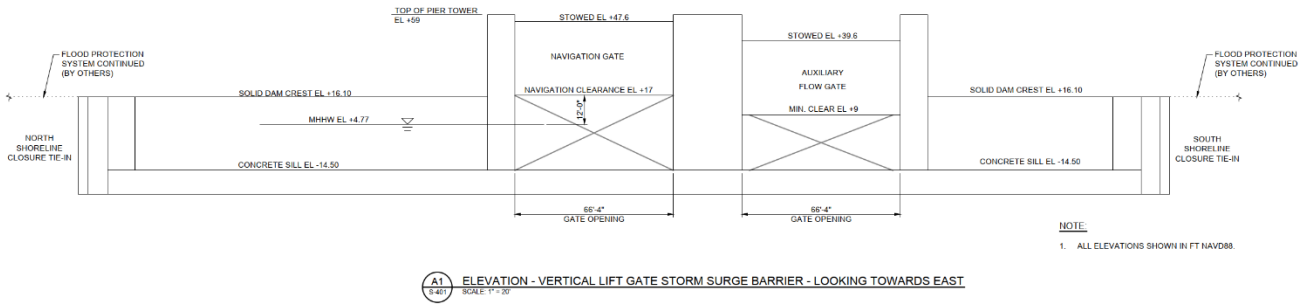

Figure 5-1: Dorchester Bay storm surge barrier lift gate, elevation view

Table 5-1 lists the gate series and shows that 4 gates are included. The gate series are provided a lettered ID to indicate each gate from north to south.

Table 5-1: Summary of the Storm Surge Barrier Geometry – Lift Gate

Gate ID	Sill Elevation in ft NAVD88 (and in ft MLLW in parentheses)	Gate Width (ft)	Span[1] (ft)	Notes	Top of storm surge barrier[2] (ft, NAVD88)	Gate Height (ft)	Top of Lift Gate in Raised Position (ft, NAVD88)
A	-14.5	66.3	86.3	Auxiliary Flow Gate	+16.1	30.6	39.6
B	-14.5 (-9.0)	66.3	86.3	Navigable Passage	+16.1	30.6	47.6

Note:

1. *Span is measured from the center of the pier to center of the pier*
2. *Storm surge barrier with gates closed to provide flood risk reduction function*

5.2 General Project Phasing, Sequence of Construction, and Constructability Considerations

The proposed phasing considers maintaining the hydraulic flow/conveyance area for the duration of the construction process. However, it appears difficult (if not impossible) to maintain navigation through the entire construction period. This is because the navigable gate is aligned with the navigable bridge opening (Castle Island Drawbridge, a bascule span) along the William T. Morrissey Boulevard.

When the navigable gate of the SSB is constructed, the cofferdam will completely block the Dorchester Bay entrance/navigation channel. It may be possible that some vessels could gain access to the channel at the bridge's fix span locations under low tide conditions; however, airdraft will be restricted to a height less than that provided by the drawbridge location.

Hence, it may be necessary to partially or fully restrict navigable passage of boats into and out of Dorchester Bay. This could impact temporarily the Dorchester Yacht Club, and the boater's use of the facilities. Temporary relocations of boats to an alternate facility, or other forms of restitution (e.g., financial compensation) may be necessary to offset the loss of use.

The phasing described herein is schematic in nature, and alternate phasing scenarios and offsets for channel disruption can be considered as design development occurs.

Project phasing considers the incremental completion of major systems, portions, and/or subsets of the overall project, and often considers the influence of construction activities upon factors external to construction itself, such as the accommodation of traffic or hydraulic flow through or around the construction site.

The following elements are considered in the phased construction process:

1. Construction of the Phase 1 gate complex, located within the entrance/navigation channel at Dorchester Bay. All work for both phases of the gated barrier construction is expected to occur within the confines of a steel sheet pile, braced, box-type cofferdam. Construction sequences for each phase are described in greater detail in the sections that follow.
2. Upon completion of the Phase 1 gate, navigation again gain access to the Bay through the existing entrance/navigation channel location.
3. Work will then progress with phased construction, with Phase 2 involving the southerly auxiliary flow gate complex.
4. Phase 3 will include construction of the two (northerly and southerly) solid-type dam section tie-ins that provides the continuous line of protection for the gated barrier system.
5. Additional phases of construction will be required after completion of each gate complex. This will include construction of the operations building, and completion of mechanical, electrical, operating, and control systems. The final phase will include operational testing, and commissioning of the project.

The term "constructability," in its most general sense, is defined as the ability of a structure to be constructed. For the purposes of this narrative, the term constructability also encompasses the location, extents, and physical and environmental conditions in which the project will be constructed. Constructability considers the nature of the work, contractor capabilities, equipment, and means and methods a given contractor might employ to accomplish the work. Constructability also considers site access, special material and work requirements, difficult or unusual environmental conditions, strict tolerances, complexities of mechanized and automated interfaces, exceptional loads and load handling requirements, risk, and many other specific impacts that the construction methods and processes.

Constructability considerations influence sequence of construction and the means and methods that will likely be used to accomplish construction activities; in turn constructability and site constraints will impact both cost and schedule for construction.

The following constructability considerations were assessed when evaluating project phasing, sequence of construction, and their resulting impact on costs:

1. The site is in a moderate-density urban area, and lands in immediate proximity to the site for construction staging and laydown may be limited.
2. Work occurs just outside Dorchester Bay, near Commercial Point and the Neponset River. It is assumed that most of the work will involve floating plant and equipment and land-based transport of personnel, materials, and equipment to the worksite.
3. Due to spatial requirements and the need to phase construction to allow for tidal flow exchange, it was assumed that phased construction using box-type cofferdams would be most advantageous for the Vertical Lift Gate concept.
4. It is anticipated that larger components (e.g., lift gates) will be fabricated off-site and will be lift into place.
5. Concrete deliveries and the ability to use ready-mix concrete sources are uncertain. It is anticipated that shuttle barges will be used for concrete deliveries.
6. Cofferdams are anticipated to remain in a near-dry condition for the majority of each phase of construction. Provisions will need to be made for re-watering and subsequent dewatering and clean-up should extreme flood and/or weather events occur.
7. A space should be identified for near-site construction office trailer(s) and small tool and equipment storage. If necessary, these may be located on barges.
8. Due to the possibility of offsite staging, fabrication, and laydown areas, a modest amount of barges and other waterborne transportation will be generated by construction activities. This will need to be coordinated with maritime agencies, including but not limited to the DHS (US Coast Guard) and other Federal, commonwealth, and local agencies.
9. Due to the variability in climate, special procedures may be required to provide continual construction activities (e.g., hot weather concrete, cold weather concrete). It may also be necessary to suspend construction activities for a portion of the year (e.g., winter shutdown).

10. Best practices are necessary to achieve the required service life of the structure (anticipated to be 100 years, without the need to major reconstruction or retrofit). This includes requirements for steel and concrete protection and corrosion control. While evaluation of these systems is beyond the current scope, they can affect both constructability and cost of construction. Corrosion protection systems to be considered in the future include but are not limited to: increased concrete cover, densified concrete, other concrete additives ad admixtures (e.g., calcium nitrite), reinforcing corrosion protection (e.g., hot-dipped galvanized, epoxy coated, glass-fiber reinforced polymer, stainless, clad systems), cathodic protection systems (e.g., sacrificial anodes, impressed current), high quality steel coatings, and numerous other potential systems, either alone or in combination.

Sequence of construction considers the logical and orderly arrangement of construction activities to provide for an efficient completion of project construction. Sequence involves prescribing predecessor activities (those that must be undertaken and at least partially completed before subsequent construction occurs) and successor activities (those that must be delayed until such time at least a portion of the predecessor activity is complete). From the sequence, duration of activities, consideration of external influence, and interrelationship of predecessor and successor activities, a construction schedule is formulated.

The anticipated sequence of construction for the gated barrier is provided in the section that follows. Sequence of construction for each phase is similar, and is not repeated for each subsequent phase, unless otherwise noted.

1. Perform survey and stake-out
2. Fabricate and install cofferdam template using spud piles
3. Fabricate and install cofferdam sheet piling
4. Fabricate and install upper level of sheet pile bracing
5. Remove by (clamshell) dredging harbor bottom materials to the level of the bottom of the proposed tremie seam
6. Install driven / drilled foundation elements within the cofferdam, including permanent steel casings, reinforcing, and concrete. Drilled shafts are likely the preferred foundation components, although driven piles may also be considered. Drilled shaft foundation installation includes:
    a. Mobilization and Demobilization
    b. Survey and Stake-out
    c. Provision permanent steel shaft casings, including fabrication, coating (as needed), installation (vibrating and seating into rock), and casing cut-off to the required elevation.
    d. Material removal and disposal from the casing, performed via augering.
    e. Drilling and disposal of rock material from the socket.
    f. Placing reinforcing cages
    g. Placement of drilled shaft concrete via tremie methods.

h. Providing Pile Load Tests (e.g., statnamic tests, Osterburg tests, full scale load tests)
i. Verification Surveys
j. Bracing or otherwise stabilizing foundation elements from excessive movement, as needed, until such time the tremie seal is placed.

7. Provide concrete seal placed by tremie methods.
8. Upon curing of the seal, dewater cofferdam. Provide pumps necessary to maintain the cofferdam in a dewatered condition.
9. Cut off residual/upper casings and prepare top of tremie to receive reinforced concrete footing and sill elements.
10. Construct reinforced concrete vertical elements, including pier towers, shear walls, gate recesses, bulkhead recess, armor, anchorages, galleries, chases, conduits, seals, and other embedded devices.
11. When concrete vertical element (pier) construction has advanced sufficiently, the cofferdam can be re-watered, and the upper reaches of the steel sheet pile cofferdam removed. The lower portion of the sheet piling will remain in place for seepage control.
12. Install sill protection, including quarry stone and armor (riprap) rock.
13. Construct navigation span pier protection/guard and guide fender systems
14. Install mechanical, electrical, instrumentation, and control systems to the extent practicable for the phased construction approach.
15. Install prefabricated lift gate and maintain in the open (elevated) position through the point where testing and commissioning begins.

5.3 Vertical Lift Gates

The selected configuration of gates for Dorchester Bay are overhead vertical lift gates. This gate type uses pier-type towers with overhead cables, sheaves, and bullwheels to support the gate during its operation and counterweights to assist hoisting machinery. The tower height is governed by the lift required to accommodate both navigation traffic and hydraulic flow.

The structural configuration of vertical lift gates can be plate girder, horizontal tied arch, or horizontal truss. The structural framing type selected for the Dorchester Bay gate complex is horizontal truss, with skin plates provided on both the harbor and channel sides of the gate, as a means of accounting for the frequent reverse head conditions that could be encountered though the service life of the project.

It is relatively common for gates of this type to be used as tide or hurricane gates along the seacoast, with a lesser frequency of use as gate structures for inland navigation locks. When used as hurricane barriers, they are normally raised to permit normal water traffic to pass underneath and lowered to protect channels and harbors from tidal storm surges. This type of gate is applicable for use as a hurricane or tide gate when it is subject to reverse hydrostatic or hydrodynamic loadings.

The type of gate hoisting system will be based on economics and governing criteria for closure times under emergency conditions, including mechanical pulley and wire rope systems, tractor systems, and hydraulic arms. The hoisting system for wire ropes may be deck mounted or placed in recesses above the high pool elevation. Cylinders for the hydraulic system are mounted below the deck in the intake gate slot. When gates must be capable of operating under full head and flowing water, tractor type gates are often used to reduce friction.

End supports for vertical lift gates are classified according to the method used to transfer the loads to the gate guides; these include fixed wheel, tractor, and slide supports. The gate guides receive the main reaction component from horizontal loads.

Fixed wheel provides wheels that revolve on fixed axles, which are either cantilevered from the body of the gate or supported at each end by the web of a vertical girder(s) attached to the gate frame. The wheels may also be mounted by pairs in trucks that carry the wheel loads through center pins to end girders attached to the gate frame. When gate hoisting occurs with no static head, this type of end support will usually be most economical.

Tractor end supports, also referred to as caterpillar, has at each side of the gate endless trains of small rollers mounted either directly on members attached to or on the vertical end girder. These are more commonly found on emergency closure gates or gates that control flow under high head. Because load transfer is achieved by uniformly distributed bearing through the small rollers, they are able to withstand large horizontal loads while being lowered under full hydrostatic head. Their main advantages over fixed wheels are a lower friction component while hoisting under load, lower bearing stresses transferred to the guides and gate framing, and shear and bending not transferred to the gate through the axle. When compared to slide gates, the main advantage is reduced friction, which reduces the hoisting effort required for controlling flow. This reduced friction also reduces the wear and maintenance compared with those of slide gate seal surfaces.

Slide gates use metal to metal contact for end support. A machined surface that is mounted to the front face of the gate bears directly against a machined guide surface in the gate slot. The two bearing surfaces also serve as the gate seal. Materials for the gate seal surface may include aluminum, bronze, or stainless steel. They can be used for high heads; however, the head during flow control in combination with the width and height of the inlet/outlet works will determine the feasibility for using slide gates. The bearing surfaces of the guides and slide bearings must be machined to tight tolerances to maintain a seal for the gate. It is expected that slide gates will not be applicable for the Dorchester Bay gated barrier design.

The effective use of overhead lift gates is based on economics, flow conditions, operational criteria, and navigation requirements. Some of the main advantages of using vertical lift gates are ease of fabrication, considerably shortened erection time, and in most cases, relatively small and easier to construct pier towers. The loads from the gate to the supporting pier is in one direction, simplifying the design of the supports. One main disadvantage when using vertical lift gates that are under constant cyclic loading is that the main load resisting frame relies on a tension flange or,

where fatigue plays a primary role in their design. For this reason, skin plates are provided on both sides of the gate frame.

Almost all lift gates use a horizontal framing system, since vertical framing systems are not structurally efficient in transferring loads to the side bearing surfaces and require special framing to accommodate roller guides for hoisting operations.

Trusses are the selected framing type, as for long-span elements they are expected to weigh less and be more economical than plate girders. Common members used for the trusses are wide flanges, structural tubing and pipe sections, and structural T's. The main trusses frame into an end post supported by an end bearing similar to a stiffened plate girder. Special framing requirements need to be considered for the roller guides in the upstream/ downstream and lateral directions. As with girders, other framing members include intercostals, diaphragms, end posts, stiffeners, and skin plates.

Gate system corrosion damage will occur over time and can impair structural and operational capacity of vertical lift gates. To minimize future structural problems and high maintenance and rehabilitation costs, resistance to corrosion will need to be considered in the design process. Vertical lift gates are subject primarily to localized corrosion (i.e., crevice corrosion or pitting corrosion), general atmospheric corrosion, and mechanically assisted corrosion.

Prudent design and maintenance practices can minimize these types of corrosion. Corrosion of vertical lift gates is best controlled by application of protective coatings but is also effectively controlled by proper selection of materials, cathodic protection, and proper design of details. The selection of corrosion protection alternatives is highly dependent on the particular environment in which the gate will function.

5.4 Dam section and tie-ins

The solid dam section that would be constructed in Phase 1 (under the current construction phasing scenario) is essentially the central pier shared by the northerly and southerly gates. This will be a mass concrete, monolith-type structure that extends from the top of the footing/sill location to Elevation +59.0. The central dam section serves to maintain a line of protection between these gate elements. The dam is expected to be of reinforced cast-in-place concrete construction.

Tie-ins would occur at the northern and southern ends of the surge barrier complex, and transition to shore-based measures that are provided to afford flooding of adjacent land-based areas. Alternately, tie-ins could extend to existing lands that are situated above the anticipated flood elevation. Under both scenarios, tie-ins are required to prevent flood waters from flanking the surge barrier complex.

There are numerous potential configurations of tie-in structures, including walls, levees, cellular structures, movable barriers, and combinations thereof. The identification of alternatives required extents, and development of the preferred configuration and limits of tie-ins is beyond the current

scope of the project. Hence, for cost budgeting efforts an assumed continuous pile-supported inversed "T-Wall" constructed of reinforced concrete is the assumed configuration of the tie-ins.

5.5 Maintenance Bulkheads

Maintenance bulkheads (stoplogs) will be required to provide access to, and inspection and maintenance of the submerged areas of each gate. Bulkheads would be provided in sufficient quantity to allow dewatering and service on one gate; bulkheads are required on both the harbor side and the channel side of the gate. Bulkheads can also be used for short-duration emergency closure, if one (or both) gates become inoperable.

Bulkheads are typically constructed of steel truss elements with a skin plate on one side. Bulkheads span the entire width of the gate opening and are installed and restrained by slots (recesses) provided in the pier towers. Bulkheads are often modular and are provided in heights that usually range from four to six feet. Bulkhead units are positioned and lowered on each other, stacked, with seals provided between each layer to lessen water intrusion. Once bulkheads are fully installed the gate area is dewatered using pumps, thereby allowing access for inspection and maintenance in-the-dry. Once that work is complete the gate area is re-watered, and the bulkheads are removed. Bulkheads are typically stored near the site but could be stored remotely if necessary. Regardless, they should be readily accessible, particularly if required for emergency closure.

Bulkheads can be installed using barge-mounted equipment (crane), and this is the assumed scenario for bulkhead installation and removal for the Dorchester Bay gate complex.

5.6 Cost Estimate

An Opinion of Probable Cost has been prepared for the Lift Gate Alternate based on the Conceptual Design Drawings titled "Boston Water and Sewer Commission Dorchester Bay Storm Surge Barrier Vertical Lift Gate Concept Design, Boston, MA" Rev 02, dated November 21, 2022. This Opinion of Probable Cost is a Class 4 level estimate as defined by AACE International. The level of Project definition, expressed as percent of complete definition, for a Class 4 estimate is from 1 percent to 15 percent. The estimate is developed based on take-offs, parametric estimates and engineering judgement and was scaled from the lift gate concept developed for the Fort Point Channel storm surge barrier (a different project also part of this study). The reader is referred to the main report describing all projects that are part of the "Coastal Stormwater Discharge Analysis" for an overview of the cost estimate.

6 NEXT STEPS

6.1 Synopsis

This document provides a brief overview of the site conditions, design parameters and geometric constraints for the Dorchester Bay Basin storm surge barrier. The engineering team developed a conceptual design and associated budgetary-level costs for the DBB SSB, which involves a pair of vertical lift gates. This conceptual design provides a level of detail for a class 4 cost estimate, which will allow BWSC to compare cost, function and geometry, and other considerations for a SSB complex.

Finally, past experience developing and implementing barrier designs tells us that there are often compromises required, and that an "ideal" gate type often does not exist. It should also be recognized that for civil work projects comparable to the DBB SSB, custom designs and features can be developed that select or combine some of the most favorable aspects of different gate types, in order to mitigate potentially unfavorable characteristics.

6.2 Next Steps

Following the evaluation described within this report there are several topics that may warrant further investigation and are could be considered logical next steps as part of an iterative design process. For completeness these topics are summarized here.

1. Site-specific geotechnical evaluation, including site exploration, material testing, and reporting,
2. Utility locations: the NOAA navigation chart indicates the presence of a submerged pipeline, and the exact location of this site feature needs to be determined; it could impact the location and alignment of the SSB, or otherwise determine the potential need for pipeline relocation.
3. Evaluation of "Lands and Damages" associated with the provision of shoreline and upland transition structures and tie-ins. This should include evaluation of potential property takings, alternate locations, and related mitigation measures that can lessen impact.
4. Evaluation of "Relocations" that may be required including both land-based and marine oriented elements (e.g., Dorchester Yacht Club patrons). This should include evaluation of water-dependent uses being impacted and identify potential mitigation measures that can lessen impact.
5. Coordinate the Dorchester Bay SSB configuration with surge mitigation measures beyond the scope of this project, particularly with the raising of Morrissey Boulevard.
6. Perform a navigation study to determine both existing and potential future navigable impacts of the gated barrier and integrate those findings with future design.
7. Advanced hydraulic modeling to assess flows, currents, eddies, cross current, rates of sediment accretion, scour potential, and similar impacts to both the gate complex itself

(e.g., loads, design development, maintenance requirements) and external interests (e.g., navigation).

8. Site-specific material sampling and testing, to evaluate in-situ channel bed materials, as a means of identifying the possible presence of hazardous or toxic waste, including but not limited to PCB's, heavy metals, pesticides, and similar undesirable substances.
9. Preliminary, concept level design of mechanical, electrical, operating, and control systems.
10. Architectural design and space planning for operations building; this could include beneficial use of the existing operations building for the Castle Island Drawbridge for operations and control of the gated barrier complex. Other options could include separate operations facilities for bridge and gates, or a new operations facility with combined use.
11. Planning and layout for future maintenance shops and associated maintenance facilities.
12. Construction planning, including identification of a Work Breakdown Structure, staging and laydown areas, work packages and sequence of work, material transport logistics, production rates, equipment requirements, labor participation requirements, identification of special components, long-lead materials, and specialty equipment, develop project scheduling, and establish cashflow/expenditure/funding stream requirements.
13. Initiate engagement with the USACE NAE, and other Federal, commonwealth, and local stakeholders.
14. Initiate a public involvement process for project communication, and local stakeholder input.
15. Provide initial engagement of environmental/permitting stakeholders (e.g., USACE, MARAD, NOAA Marine Fisheries, EPA, MassDEP) to identify very early in the process potential concerns, obstacles, and to develop lines of communication and dialogue with these agencies
16. Perform a corrosion study to assess in better detail the means and methods required to achieve project service life. This can include cost/benefit and life-cycle cost evaluations.
17. Study to assesses the viability of "innovative" construction means and methods (e.g., float-in, lift-in) and the potential impact of such concepts on constructability, cost, and schedule.
18. Other studies that may be desired to assess issues and answer questions that arise throughout the phased design development process.

7 REFERENCES

Cook, C., Spector, C., Brizius, A., Zones, P. S., Davis, Z., McGuinness, R., . . . Ris, B. (2020). *Coastal Resilience Solutions for Dorchester.* Boston: City of Boston.

Dijk, A. a. (2010). *Multifunctionele beweegbare waterkeringen [Multifunctional movable flood gates]*. Delft, The Netherlands. Retrieved from http://www.tudelft.nl/fileadmin/UD/MenC/Support/Internet/TU_Website/TU_Delft_portal/Onderzoek/Infrastructure/Engineering_challenges/open_en_afsluitbaar_Rijnmond/doc/AOR_Multifunctionele_beweegbare_keringen_FvdZiel_ADijk,_TUD,RCP,KvK_Definitief.pdf

Dircke, P., Jongeling, T., & Jansen, P. (2012). Navigable storm surge barriers for coastal cities: An overview and comparison. In J. Aerts, W. Botzen, M. Bowman, P. Ward, & P. Dircke, *Climate Adaptation and Flood Risk in Coastal Cities* (pp. 201-223). New York: Earthscan.

FEMA. (2020). *Preliminary Flood Insurance Study Number 25025CV000C.* New York: Federal Emergency Management Agency.

Moffatt & Nichol. (2022). *Coastal Stormwater Discharge Analysis: Fort Point Channel Storm Surge Barrier Conceptual Design.* Boston: Boston Water and Sewer Commission.

Mooyaart, L. F., & Jonkman, S. N. (2017). Overview and Design Considerations of Storm Surge Barriers. *ASCE Journal of Waterway, Port, Coastal and Ocean Engineering*.

Mooyaart, L. F., Jonkman, S. N., de Vries, P. A., van der Toorn, A., & van Ledden, M. (2014). Storm Surge Barrier: Overview And Design Considerations. In P. J. Lynett (Ed.), *Coastal Engineering Proceedings* (p. 808). Seoul, Korea: Coastal Engineering Research Council.

NOAA. (2016). *NOAA.gov*. Retrieved from Office of Coast Survey: https://charts.noaa.gov/PDFs/13270.pdf

NOAA. (2020). *NOAA.gov*. Retrieved from Tides & Currents: https://www.tidesandcurrents.noaa.gov

NOAA, National Oceanic and Atmospheric Administration. (2020). *NOAA.gov*. Retrieved from Office of Coast Survey: https://www.charts.noaa.gov/OnLineViewer/13272.shtml

PIANC. (2006). *Design of Movable Weirs and Storm Surge Barriers.* Brussels, Belgium: PIANC.

USACE. (2014). *Design of Hydraulic Steel Structures.* Washington, DC: USACE.

USACE. (2022, 10 17). *Dorchester Bay and Neponset River Navigation Project*. Retrieved from US Army Corps of Engineers New England District Website: https://www.nae.usace.army.mil/Missions/Civil-Works/Navigation/Massachusetts/Dorchester-Bay/

USACE, C. M. (2015). *North Atlantic Coast Comprehensive Study (NACCS).* Vicksburg, MS: Engineer Research and Development Center Vicksburg MS Coastal and Hydraulics Lab.

USACE-ERDC. (2007). *Hurricane Barriers in New England and New Jersey - History and Status after Four Decades.* USACE, ERDC. Vicksburg, MS: USACE.

USGS. (2016). *CoNED Viewer*. Retrieved from https://topotools.cr.usgs.gov/topobathy_viewer/?downloadBbox=42.26695,42.33985,-71.07420,-70.95541

van Ledden, M., Lansen, A., de Ridder, H., & Edge, B. (2012). Reconnaissance level study Mississippi storm surge barrier. In P. L. Smith (Ed.), *Proceedings of 33rd Conference on Coastal Engineering.* Santander, Spain: Coastal Engineering Research Council.

Appendix K: risQ Damage and Economic Analysis



Coastal Stormwater Discharge Analysis

Damage and Economic Analyses for Boston Water and Sewer Commission

Work carried out in conjunction with Hazen and Sawyer

December 5th, 2022

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Coastal Stormwater Discharge Analysis

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Executive Summary

This document describes the methodology used to evaluate financial damages resulting from modeled storm surge events for various flood mitigation scenarios versus baseline scenarios impacting the Boston metropolitan area. The scenarios cover hypothetical 100-year return period storm events, under climate scenarios for the year 2070, coupled with estimates of tide heights accounting for sea level rise. In total, 22 discrete areas of interest are modeled, with direct financial impacts to the built environment and gross domestic product (GDP) presented individually and aggregated geographically to specific regions.

Using the model storm event simulations provided, estimates of the impact to the physical environment across multiple social dimensions, including property damage and GDP impairment based on estimates of business interruption are calculated. These metrics facilitate comparisons between existing conditions versus conceptual design scenarios and could be used to estimate the net present value of different conceptual design alternatives. Results of these analyses are presented in Table 5.

A database of building locations and their physical attributes was created for the areas of interest impacted by the simulated storm events. To enable data sharing, open-source data obtain from the Boston Planning and Development Agency, (BPDA), together with data from the City of Boston Tax Assessor Department were used.

Modeling of flood induced damage to buildings accounted for foundation type and the presence or absence of a basement, which were key drivers of resulting damage. Various modeling techniques were used in allocating the physical building attributes, which required validation via random sampling and manual inspection.

The modeled output from the storm surge simulations included gridded physical flood parameters such as ground surface water elevations, flow velocity, and depths. The horizontal spatial resolution of the hexagonal grids was approximately 10 meters.

Damage was estimated by applying standard physical risk loss modeling techniques, where hazard intensities are linked to building damages using vulnerability functions. The vulnerability functions provide potential individual building damage estimates as percentages of a building's replacement costs for a given flood intensity. The functions used accounted for both flood depth and velocity, and distinguish damage by building occupancy, height, and foundation type.

Uncertainty in the calculation of building replacement costs and flood parameters impacting each building are also accounted for in the damage estimates. This approach enables a range of loss estimates for each area of interest's flood mitigation scenario and baseline scenario.

Although location level individual building data were used to model damages for each scenario, it should be made clear that the approach, and vulnerability functions used in the modeling process, can only provide typical expected losses. For more accurate,

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actual building specific loss to be calculated much more detail in terms of the individual buildings physical characteristics would be required. This statement is particularly true for the engineered mid-and high-rise structures, and structures servicing more complex occupancies within the areas of interest.

Damage to infrastructure including bridges, roads, train tracks & stations, utility infrastructure e.g., power lines, substations, communication networks, and water treatment plants were not included.

Besides monetary loss and impairment metrics, social demographic data are highlighted in Table 4 to support hazard mitigation grant applications such as FEMA's Building Resilient Infrastructure and Communities (BRIC) grant program.

Data files containing direct physical damage loss estimates, gross domestic product impairment and BRIC social data metrics are included.

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Areas of Interest & Flooding Scenarios

Hazard Data for Each Modeled Scenario Explained

Hazen was responsible for modeling storm surge from 100-year return period level intensity storms under 2070 climate scenarios and sea level rise conditions for several areas of interest, (AOI), within the Boston metropolitan area. There are 11 AOI with several subareas within each. A base case scenario was developed for each area as well as at least one mitigation scenario that entailed the installation of a flood mitigation solution such as a protective wall or pumps.

A summary of the data and associated areas of interest can be seen in Table 1.

Area of Interest (AOI)	Scenario Type (1 = No action, 2 = With action)	AOI Abbreviation	AOI Name	Original scenario file name
1	1	FPC	Fort Point Channel	Tropical_100yr_2070SLR 100yr Surge_With Wall.shp
2	2	FPC	Fort Point Channel	Tropical_100yr_2070SLR 100yr Surge_Storage+500 cfs Pumping.shp
3	1	JFP	Joseph Finnegan Park	JFP_wall.shp
4	2	JFP	Joseph Finnegan Park	JFP_sol.shp
5	1	HARP	Old Harbor Park	HARP_wall.shp
6	2	HARP	Old Harbor Park	HARP_sol.shp
7	1	EBWF	East Boston Waterfront	EBWF_wall.shp
8	2	EBWF	East Boston Waterfront	EBWF_sol.shp
9	1	EBCB	Constitution Beach	EBCB_wall.shp
10	2	EBCB	Constitution Beach	EBCB_sol.shp
11	1	EB	East Boston	EB_Tropical_100yr_Surge_w_Wall.shp
12	2	EB	East Boston	EB_Tropical_100yr_Surge_w_Pump.shp
13	1	DBB	Dorchester Bay Basin	DBB_Tropical_100yr_Surge_w_Wall.shp
14	2	DBB	Dorchester Bay Basin	DBB_Tropical_100yr_Surge_w_Pump.shp
15	1	DAV	Davenport Creek	Dav_Tropical_100yr_Surge_w_Wall.shp
16	2	DAV	Davenport Creek	Dav_Tropical_100yr_Surge_w_Pump.shp
17	1	COLP	Columbus Park	COLP_wall.shp
18	2	COLP	Columbus Park	COLP_sol.shp
19	1	CHAR	Charlestown Schrafft Center	CHAR_wall.shp
20	2	CHAR	Charlestown Schrafft Center	CHAR_sol.shp
21	1	AIRP	Boston Logan Airport	AIRP_wall.shp
22	2	AIRP	Boston Logan Airport	AIRP_sol.shp

Table 1: Details of geographic areas of interest for which storm simulations were carried out.

The data for each scenario were provided as ESRI Shapefile format. These files consisted of spatial geometries and 68 associated attribute data fields for each unique geometry. The grid cells were typically hexagonal in shape with a vertex-to-vertex horizontal spatial

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resolution of approximately 10 meters. The data was in a standard Boston, Massachusetts specific geographic projection, EPSG code 2249, named "NAD83/Massachusetts Mainland (ftus)".

The modeled grids contained holes where buildings were assumed to be located. An example of a typical AOI region, with and without grid overlain, can be seen in Figure 1.



Figure 1: Example urban area, with and without modeled storm event grid overlain.

Before the analysis could be performed, polygon extents for each AOI were developed from the model grids and used to calculate building statistics and an understanding of the built environment within each AOI. This was used to inform the development of an exposures database that could be used to model financial impacts to each AOI for the individual storm events.

Building Level Exposures Database Development

A database of building locations was developed to calculate financial impairment to both the physical built environment and subsequence economic impacts.

The key characteristics of each individual building define the building's vulnerability to flooding, and hence the levels of damage from storm surge induced flooding include the following:

(1) Occupancy type, or at a minimum distinction between residential, commercial, and industrial types
(2) Representation of the individual building location. Either building centroid or building footprint
(3) Building height, or numbers of stories
(4) Building square footage
(5) Type of foundation, or at a minimum presence or not of a basement
(6) Construction type

These building characteristics required to be sourced from data or modeled based on available statistics of the general building stock. In general, assigning foundation type to an individual building without onsite inspection is the most problematic.

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The three primary sources of building location level exposures data representing the Boston metropolitan area used in the study are listed below:

(1) Boston Planning & Development Agency (BPDA) 3D Building data; http://www.bostonplans.org/3d-data-maps/3d-smart-model/3d-data-download
(2) Boston Tax Assessor data; https://data.boston.gov/dataset/property-assessment
(3) HAZUS; Hazus | FEMA.gov

The BPDA data offered building footprints and dimension data. For instance, the square foot area representing the building footprints and height. Building attributes such as general occupancy, construction type, and presence of basements were also available.

The Tax Assessor data was used to augment the building level data from the BPDA. Where possible the two data sets were merged and the best data representing an individual building was used.

The HAZUS dataset, which stands for "**Hazards United States** (FEMA)", is a nationally standardized risk modeling methodology. It is distributed as free GIS-based desktop software with a collection of inventory databases for every U.S. state and territory. The inventory data includes county and regional estimates of various building level attributes statistics such as construction and foundation type.

The general method for developing the exposures database used in the project is outlined below.

(1) BPDA was assumed to represent the universe of individual buildings within the Boston metropolitan area
    a. Spatial geometries were cleaned to remove duplicates and any irregularities such as nonconforming geometries
    b. Non-building structures such as docks, and walls were removed
    c. Building level square footage was calculated based on developing an estimate of the number of stories for each building and multiplying by the building plan area square footage
    d. Foundation type of basement or no basement was assigned based on the ground elevation compared to the building grade level
(2) Boston Tax Assessor (BTA) data representing individual taxable lots by ownership was merged with the BPDA data based on parcel identification numbers. BTA data was prioritized over that of the BPDA data where both existed
    a. Occupancy and building square footage were key data fields used from the BTA data
(3) Overall validation/calibration metrics were developed to ensure that the augmented BPDA data was consistent with the BTA data at aggregate levels.
(4) HAZUS data was used to assign appropriate construction type based on occupancy type and height
(5) Building replacement costs were calculated using statistics from industry data sources on the cost of construction within Boston. Due to the uncertainty in construction costs, low and high estimates were obtained. Table 2 below presents the range of per square footage replacement cost by occupancy type and building height class (i.e., Low, Mid, High).

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Dollars per Sqft	Low Costs per Building Height			High Costs per Building Height		
	Low	Mid	High	Low	Mid	High
Residential Single Family	$ 150			$ 250		
Residential Apartment	$ 150	$ 300	$ 500	$ 200	$ 500	$ 700
Commercial	$ 150	$ 300	$ 500	$ 200	$ 500	$ 700
Industrial	$ 100	$ 200	$ 350	$ 250	$ 350	$ 600

Table 2: Square foot building replacement cost estimates.

Building replacement costs were informed by consulting reports from RSMeans and Cumming. Building costs can vary widely from the most basic of construction practices to utilizing luxury materials, such as granite counter tops and hardwood floors. The range of costs chosen for this analysis represent an average quality of construction for the Northeast region.

Example images highlighting the flood event simulation grid with and without building exposures overlain is shown in Figure 2.

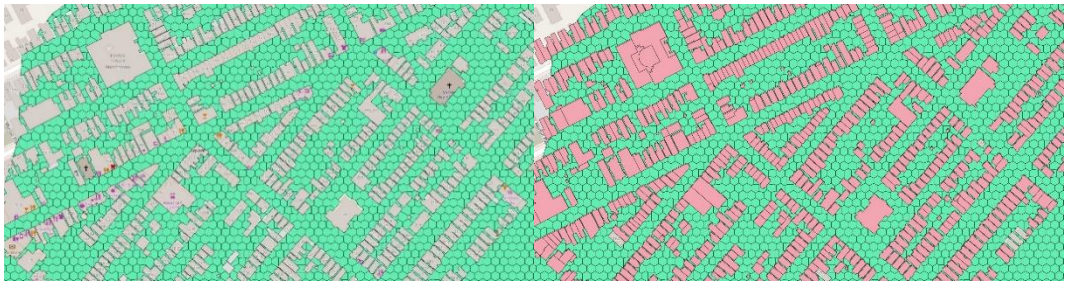

Figure 2: Example simulation grid overlain with building exposure polygons.

Statistics of the building types for each AOI are highlighted in the next section, which discusses each AOI in more detail.

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Overview of the General Built Environment for Each Area of Interest

The project analyses included 11 distinct areas throughout the Boston metropolitan area: Boston Logan Airport, Charlestown Schrafft Center, Columbus Park, Constitution Beach, Davenport Creek, Dorchester Bay Basin, East Boston, East Boston Waterfront, Fort Point Channel, Joseph Finnegan Park, and Old Harbor Park. The location of the areas relative to their position within the city is shown in Figure 3 below. The subsequent sections include characteristics of the areas such as the size of the AOI, the types of properties (based on the land use classification from property tax assessor data), and the financial impacts of the baseline and mitigated flood scenarios. The estimated building damages are presented as a min to max range which is based on minimum flood depths and minimum construction costs as well as maximum flood depths and maximum constructions costs.

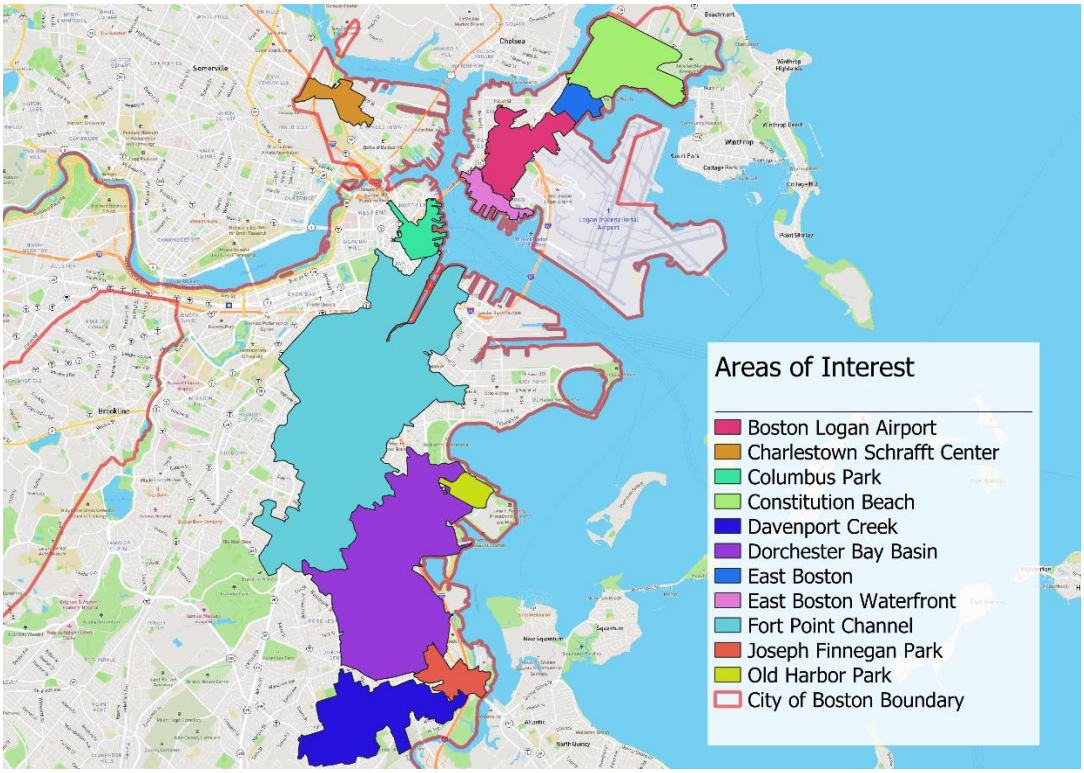

Figure 3: Eleven analysis areas.

Boston Logan Airport

The Boston Logan Airport (AIRP) is in East Boston on the northwest side of the airport. The area of interest covers 0.55 square miles and contains ~2,700 properties. The structural composite is predominately duplexes and triplexes (50%), commercial use buildings (12%), single-family homes (10%), condominiums (10%), and multi-unit apartments (8%). The largest property owner is Massachusetts Port Authority which owns 106 properties.

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AIRP contains a diverse mix of small businesses and tenant-occupied properties. It is served by the MBTA's Maverick, Airport and Wood Island T-stops, several bus stops, and the 1A Expressway. Some notable buildings in this area include East Boston High School, Excel Academy, and facilities associated with the airport. The East Boston Memorial Park and Bremen Street Park as also situated in this area.

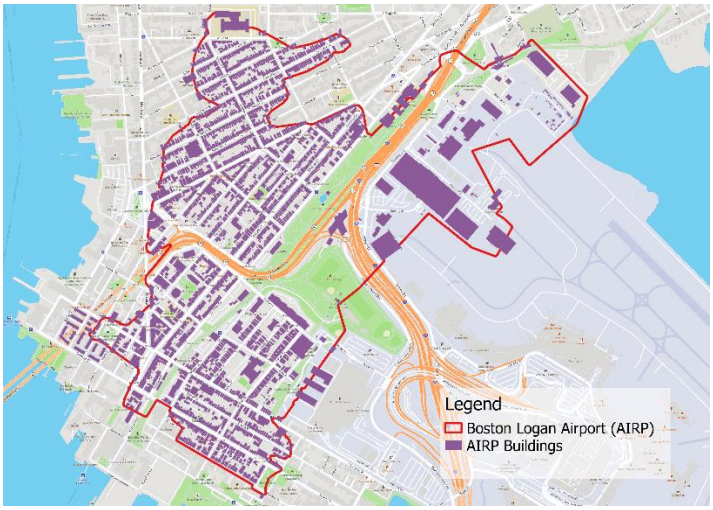

Figure 4: Boston Logan Airport (red) contains ~2,700 properties (purple).

Comparing Flood Scenarios



Figure 5: Baseline flood scenario (left) impacts 563 properties and covers 2.6 million square feet; the yellow circle denotes the flooded area in front of MBTA's Airport station. Mitigated flood scenario (right) impacts 36 properties and covers 156,000 square feet.

Under the baseline flooding scenario shown in Figure 5, the majority of the flooding occurs along the 1A Expressway, including the road in front of the MBTA's Airport T station (denoted in the image with a yellow circle). By comparison, under the mitigated flood scenario nearly all the flooding along 1A Expressway is avoided. The estimated building damage in the baseline scenario ranges from $125 million to $215 million and in the mitigated scenario ranges from $6 million to $10 million.

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Charlestown Schrafft Center

The Charlestown Schrafft Center (CHAR) is in the northwestern portion of the Charlestown neighborhood. The area of interest covers 0.2 square miles and contains ~1,200 properties. Within CHAR, 41% of the properties are single-family homes, 23% are condominiums, 18% are duplexes and triplexes, and 7% are commercial buildings. The largest property owner is Rise Development LLC which owns 14 properties.

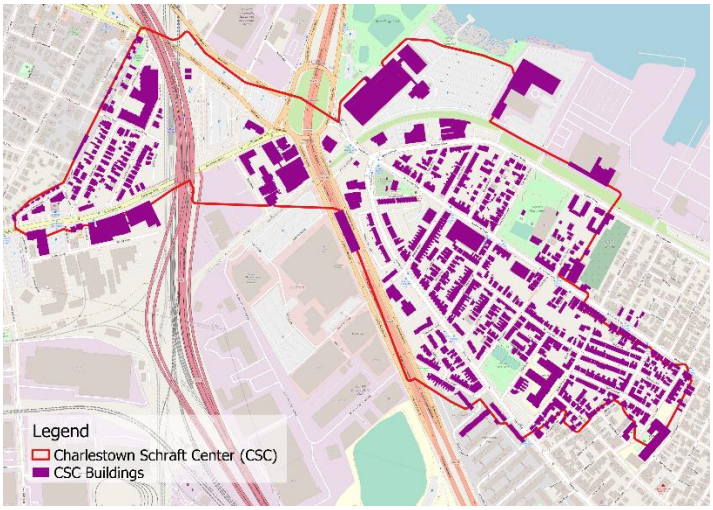

Figure 6: Charlestown Schrafft Center (red) contains ~1,200 properties (purple).

Comparing Flood Scenarios

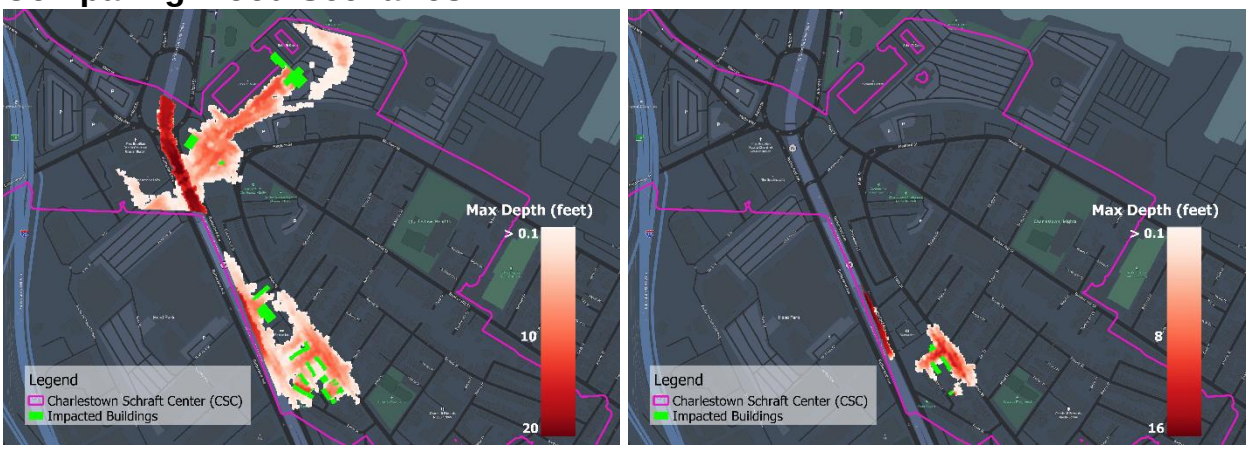

Figure 7: Baseline flood scenario (left) impacts 90 properties and covers 581,000 square feet. Mitigated flood scenario (right) impacts 10 properties and covers 69,000 square feet.

Under the baseline flood scenario shown in Figure 7, the worst flooding occurs along MA-99 and inundates the underpass. The flooding impacts 90 properties, many of which are concentrated in the southwestern corner of CHAR; these properties include single-family homes as well as property owned by Boston Public Housing Authority along Lyndeboro and Main Street. The estimated building damage under this scenario ranges from $14 million to $25 million.

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Under the mitigated flood scenario, a smaller portion of MA-99 is inundated but still causes flooding in the underpass. 10 buildings are impacted which includes properties owned by Boston Public Housing Authority along Lyndeboro and Main Street; an example of these properties is shown in Figure 8. The estimated building damage under this scenario ranges from $760K to $1.3 million.



Figure 8: Example of properties owned by Boston Public Housing Authority which are impacted under both flood scenarios.

Columbus Park

Columbus Park (COLP) sits in the heart of Boston and includes portions of the Financial District, the North End, Quincy Market, and the waterfront areas surrounding Christopher Columbus Park. It is a culturally and historically significant portion of the city that draws in tourism year-round. The analysis area covered 0.23 square miles and contained ~200 properties. The lion share of properties are commercial buildings (68%) while condominiums make up 20%.

Some notable buildings in COLP include Faneuil Hall, the Custom House, and the New England Aquarium. Within COLP there are several hotels, restaurants, boat marinas, and tourism attractions such as the Duck Boats and Harbor City Cruises. COLP includes the Long Wharf Ferry terminal, Aquarium T-stop, and a portion of the Rose Kennedy Greenway Park.

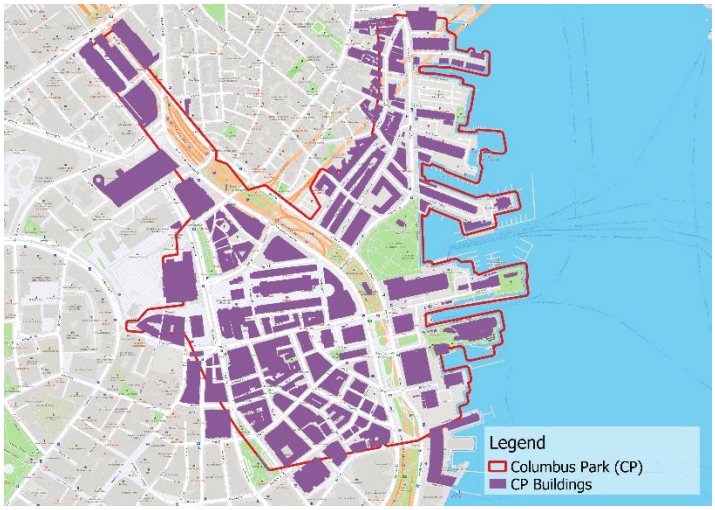

Figure 9: Columbus Park (red) contains ~200 properties (purple).

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Comparing Flood Scenarios

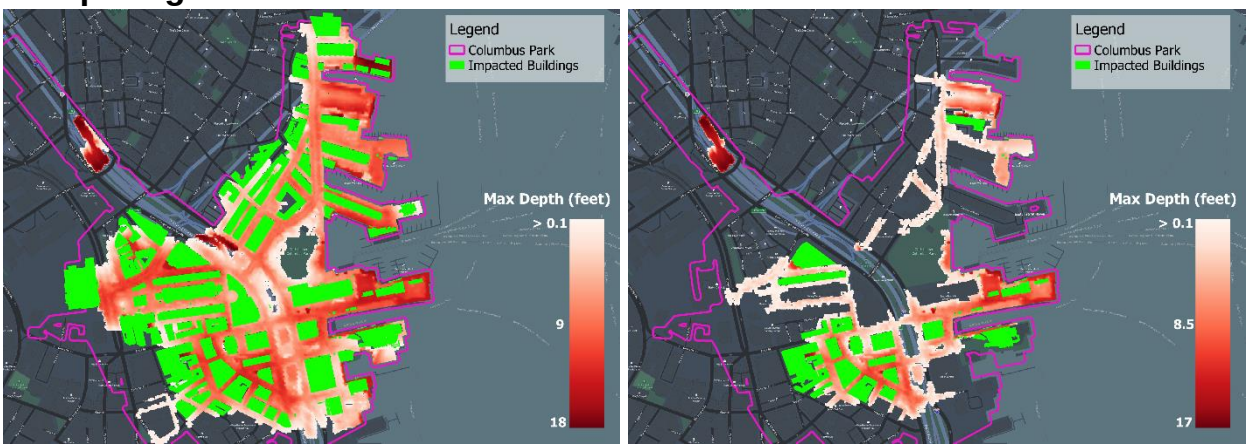

Figure 10: Baseline flood scenario (left) impacts 142 properties and covers 4.5 million square feet. Mitigated flood scenario (right) impacts 44 properties and covers 1.7 million square feet.

Under the baseline flooding scenario shown in Figure 10, nearly all roads in the Columbus Park analysis area experience flooding. 142 properties are impacted and the deepest flooding along Union Wharf and Long Wharf reaches 18 feet. The estimated building damage ranges from $715 million to $1.2 billion.

The mitigated flood scenario results in 44 properties affected, but still includes notable buildings such as the Custom House, portions of Quincy Market, and the New England Aquarium. The estimated building damage ranges from $187 million to $324 million.

Constitution Beach

Constitution Beach (EBCB) sits in East Boston north of Logan Airport. It covers 0.78 square miles and contains 2,100 properties; 46% of the properties are duplexes and triplexes, 23% are single-family, 12% are commercial, and 8% are apartments. The largest property owner, Brandywyne Village Co, operates dozens of subsidized housing properties near Noyes Playground. The area includes two hotels, Manassah Bradley and Curtis Guild Schools, and is served by MBTA's Orient Heights and Suffolk Downs T-stops.



Figure 11: Constitution Beach (red) contains ~2,100 properties (purple).

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Comparing Flood Scenarios

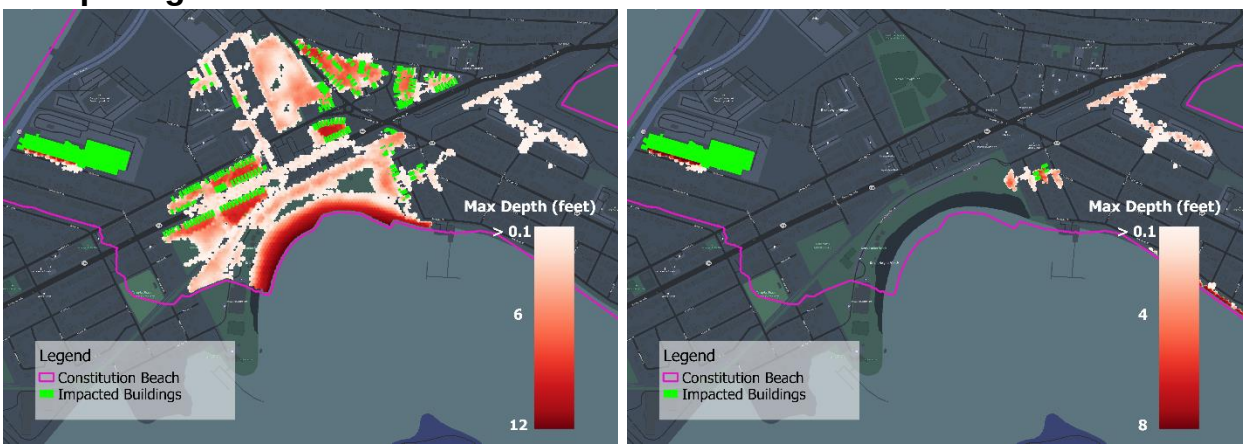

Figure 12: Baseline flood scenario (left) impacts 226 properties and covers 2.9 million square feet. Mitigated flood scenario (right) impacts 9 properties and covers 560,000 square feet.

Under the baseline flooding scenario shown in Figure 12, the flooding pushes it way up Orient Heights Beach reaching a max depth of ~12 feet and impacts 226 properties. Most of the damage properties are duplexes/ triplexes and single-family homes along Benning St., Saratoga St., Boardman St., and Ashley St.; there is also flooding next to the Planet Fitness facility along the Chelsea River. The estimated building damage ranges from $53 million to $89 million.

The mitigated flood scenario results in only 9 properties affected and the estimated building damage ranges from $2 million to $4 million.

Davenport Creek

Davenport Creek (DAV) is in the southern end of the Dorchester neighborhood. The 1 square mile area of interest contains ~4,600 properties of which 46% are single-family homes and 39% are duplexes and triplexes. Notable properties in DAV include Carney Hospital, Charles H. Taylor School, and Thomas J. Kenny School. Boston Housing Authority, the largest property owner in DAV, owns 66 properties. MBTA's Ashmount / Peabody Square T-stop serve Davenport Creek.

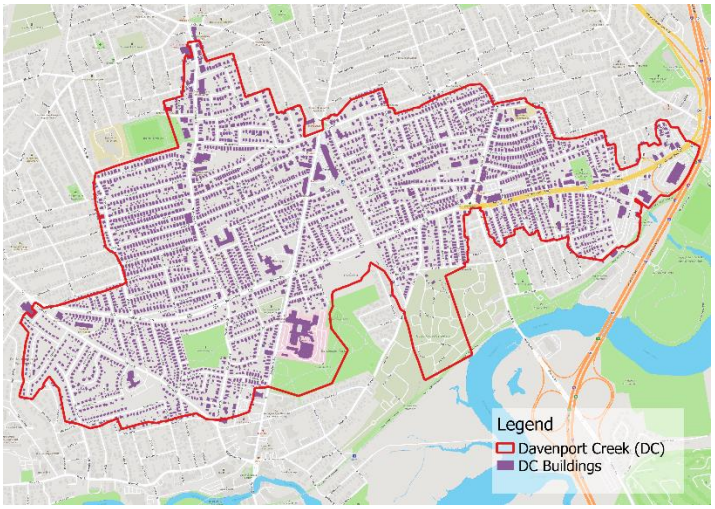

Figure 13: Davenport Creek (red) contains ~4,600 properties (purple).

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Comparing Flood Scenarios

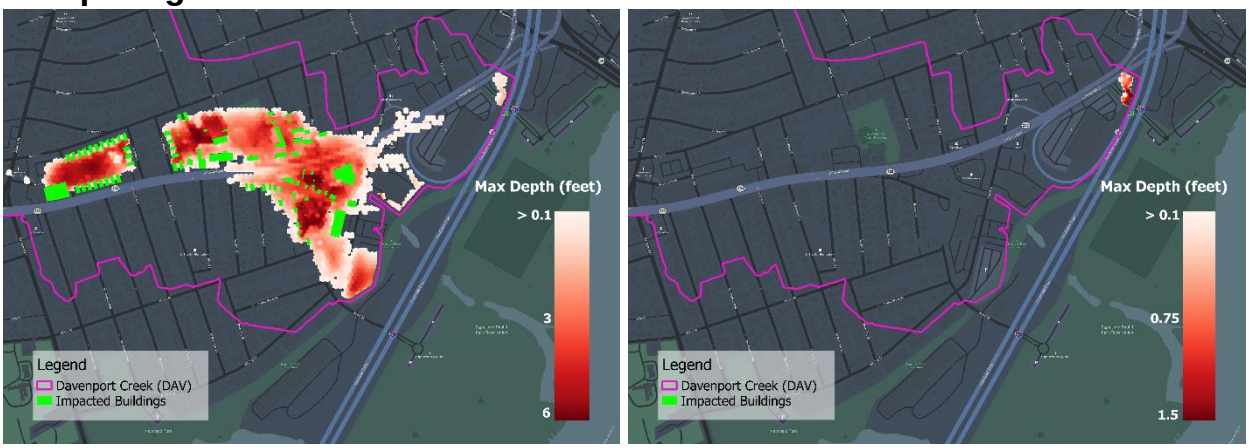

Figure 14: Baseline flood scenario (left) impacts 135 properties and covers 1.1 million square feet. Under the mitigated flood scenario (right), flooding covers 12,000 square feet and no properties are impacted.

In the baseline flooding scenario, shown in Figure 14, 135 properties are impacted. The flooding occurs on the eastern side of DAV along Gallivan Blvd and impacts residential buildings and small businesses. The estimated building damage ranges from $22 million to $37 million. By comparison, under the mitigated flood scenario no buildings are impacted.

Dorchester Bay Basin

Dorchester Bay Basin (DBB) contains ~10,200 properties which are a mix of residential and commercial buildings. This area of interest covers 2.6 square miles and includes approximately two thirds of the Dorchester neighborhood.

DBB is served by several MBTA Red Line stations, multiple bus routes, as well as commuter rail stations. Along DBB's eastern border is Interstate 93 which is a major transit route to and from Boston. The area of interest is primarily residential buildings and includes more than seven schools (Boston College High School, Boston Collegiate Charter School, St. Kevin Elementary, Mather School, Harbor School, John Marshall School, Richard J Murphy School, and Boston Latin Academy).



Figure 15: Dorchester Bay Basin (red) contains ~10,200 properties (purple).

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Comparing Flood Scenarios



Figure 16: Baseline flood scenario (left) impacts 347 properties and covers an area of 9.9 million square feet. Mitigated flood scenario (right) impacts 140 properties and covers 4.7 million square feet.

Under the baseline flooding scenario shown in Figure 16, most of the flooding occurs along the western side of I-93. There are areas of flooding around MBTA's JFK/Mass, Savin Hill, and Field's Corner T stations. In total, 347 properties are impacted and flood depths reach ~8 feet. The estimated building damage ranges from $186 million to $315 million. Under the mitigated flood scenario, flooding is reduced by 53% and the estimated building damage ranges from $51 million to $84 million. Flooding still occurs near the previously mentioned T-stops, but the total surface area and depths are reduced.

East Boston

The East Boston (EB) area of interest is a 0.19 square mile region located in East Boston near Logan Airport. It contains ~566 properties which are mostly single-family and multi-family residential buildings (85% in total). The largest property owner in EB is Massachusetts Port Authority which owns 33 properties.

In terms of major transit routes, the EB is served by the MBTA's Wood Island T-stop and two main thruways—Saratoga and Bennington Street—cut through the center of the area of interest. Additionally, the 1A Expressway runs along the EB's northwestern border. EB is home to Excel Academy and Brooke Charter School, as well as several airport facilities.



Figure 17: East Boston (red) contains ~566 properties (purple)

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Comparing Flooding Scenarios

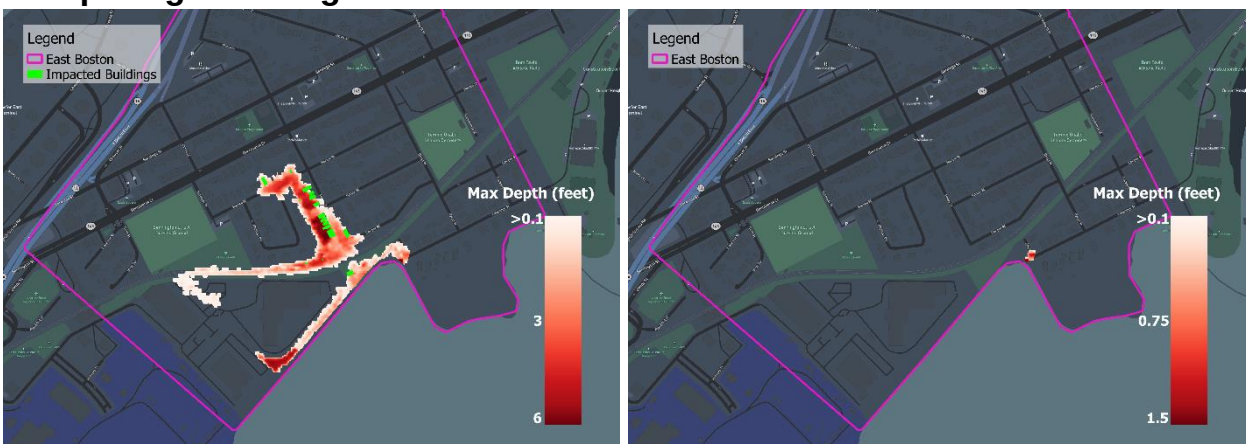

Figure 18: Baseline flood scenario (left) impacts 16 properties and covers an area of 230,000 square feet. Mitigated flood scenario (right) impacts zero properties and reduces flooding to 3,100 square feet.

Under the baseline flooding scenario shown in Figure 18, the southwestern corner of East Boston is impacted. The flooded area covers 230,000 square feet and encroaches up Moore Street and inundates MBTA train tracks near the Wood Island T-stop. The flooded area reaches a maximum flood depth of 6.25 feet and 16 properties are affected in total, all of which are residential homes, such as those in Figure 19. The estimated building damage ranges from $2 million to $3.4 million.

By contrast, under the mitigated flood scenario zero buildings are impacted, and the flooding extent is trivial: 3,100 square feet (about the area of a tennis court) with a maximum depth of 1.6 feet. Because no properties are impacted under this scenario the estimated building damage is zero dollars.



Figure 19: Residential buildings that are damaged under the baseline flood scenario.

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East Boston Waterfront

East Boston Waterfront (EBWF) is located on the western part of East Boston and covers 0.16 square miles. The area of interest contains ~457 properties including many high-rise apartment developments along the waterfront. The structural composite of EBWF is 73% residential and 23% commercial; many of the commercial buildings are operated by the marinas in the area.

EBWF is served by MBTA's Maverick T station. Some notable buildings of interest include ICA Watershed Museum, Downeast Cider House, and the Boston Harbor Shipyard and East Boston Yacht Clubs. The largest property owner is Boston Marine Work which owns 16 properties, followed by Massachusetts Port Authority which owns 15.

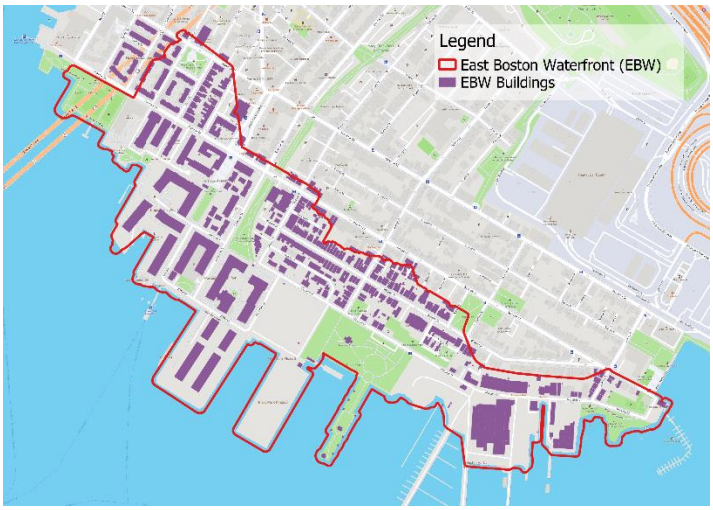

Figure 20: East Boston Waterfront (red) contains ~457 properties (purple).

Comparing Flood Scenarios

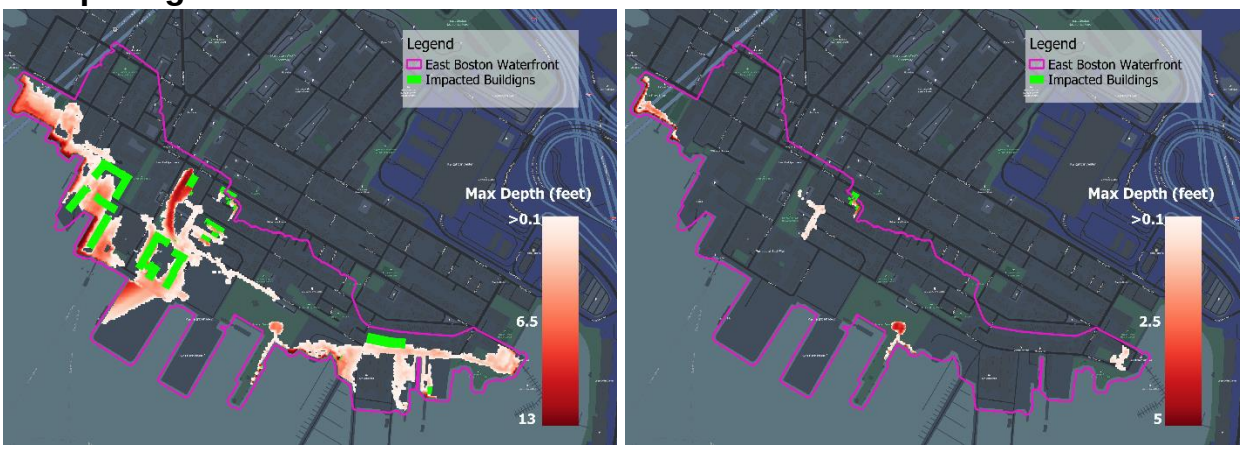

Figure 21: Baseline flood scenario (left) impacts 39 properties and covers 1.2 million square feet. The mitigated flood scenario (right) impacts 6 properties and reduces flooding to 100,000 square feet.

Under the baseline flood scenario shown in Figure 21, 39 properties are impacted, and flooding covers 1.2 million square feet. Some of the notable buildings affected by this flooding include the high-rise apartments along Marginal St. in the western portion of

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EBWF and Downeast Cider House. The estimated building damage ranges from $69 million to $115 million. By comparison, the mitigated flood scenario impacts 6 properties and the estimated building damage ranges from $1 million to $1.7 million; the flood footprint is reduced to 100,000 square feet.

Fort Point Channel

The Fort Point Channel (FPC) is the largest analysis area. FPC includes parts of the South End, Chinatown, Seaport, South Boston, Roxbury, and Dorchester neighborhoods, more than 10,000 properties, and covers 4.4 square miles. Within FPC, duplexes and triplexes account for 26% of the building stock, commercial buildings are 21%, condominiums are 18%, single-family homes are 15%, and apartments account for 10%. Some notable buildings within FPC include the Boston Convention Center, Boston University Medical Center, and the Children's Museum.

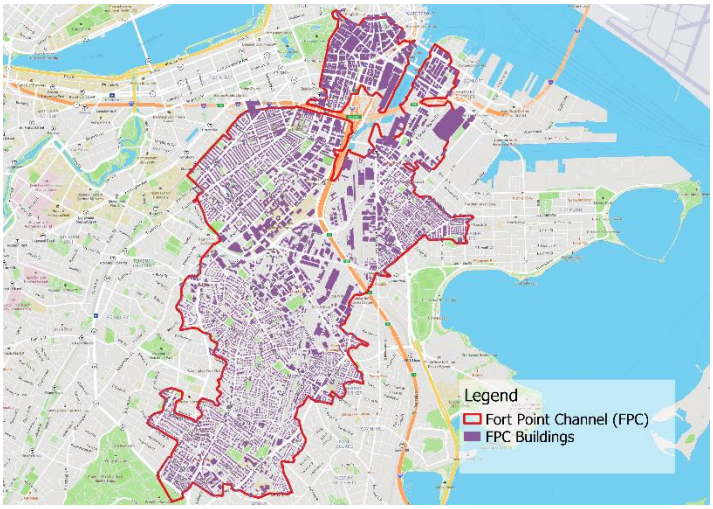

Figure 22: Fort Point Channel (red) contains ~10,000 properties (purple).

Comparing Flooding Scenarios

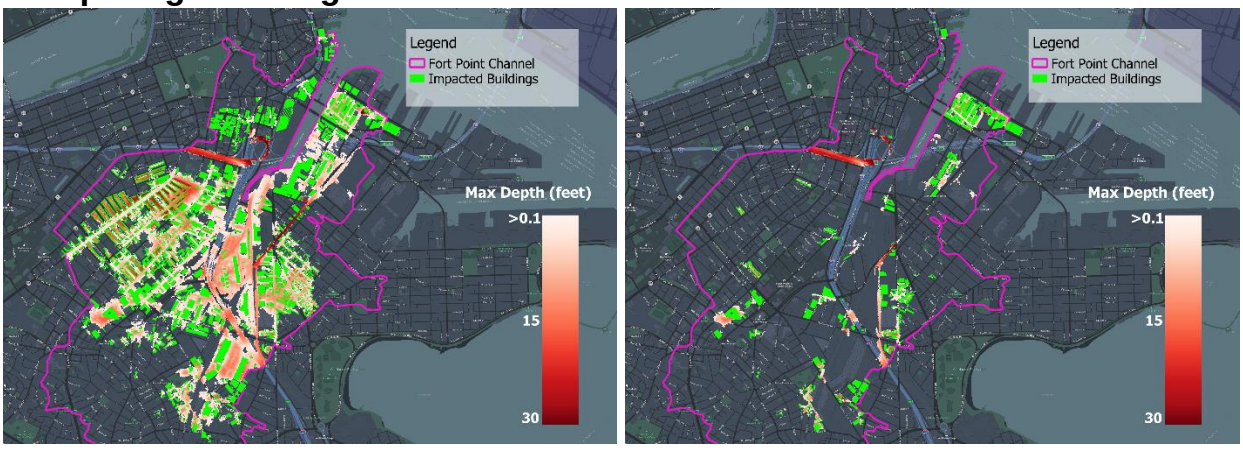

Figure 23: Baseline flood scenario (left) impacts ~4,400 properties and covers 1.7 square miles. Mitigated flood scenario (right) impacts ~700 properties and covers 0.3 square miles.

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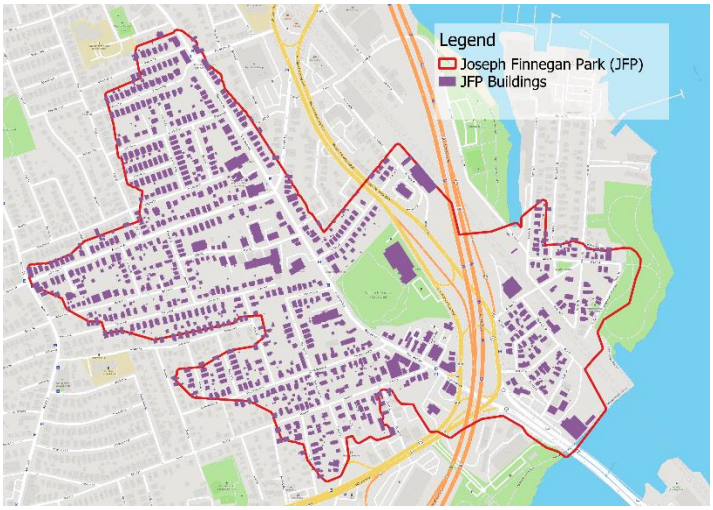
Under the baseline flooding scenario shown in Figure 23, more than 4,400 buildings are impacted and the estimated building damage ranges from $2.9 billion to $5.1 billion. Flooding is concentrated in the South End, South Boston, Seaport, and northern Dorchester neighborhoods. One area of the city that is particularly impacted by this flooding event is Boston's South End neighborhood, which harbors hundreds of iconic brownstone homes. Under this scenario the maximum flood depths reach 30 feet along I-90 and cover an area of more than 1.7 square miles.

Under the mitigated flood scenario, the area of the flood extent is drastically reduced from 1.7 to 0.3 square miles. Under this scenario, ~700 properties are impacted. The flooding in this scenario primarily occurs in Dorchester and Seaport; the estimated building damage ranges from $677 million to $1.1 billion.

Joseph Finnegan Park



Joseph Finnegan Park (JFP) is in the southeastern corner of Dorchester and covers 0.25 square miles. Within JFP there are ~1,000 properties and approximately 6% are commercial buildings while the rest are residential.

Figure 24: Joseph Finnegan Park (red) contains ~1,000 properties (purple).

Comparing Flood Scenarios

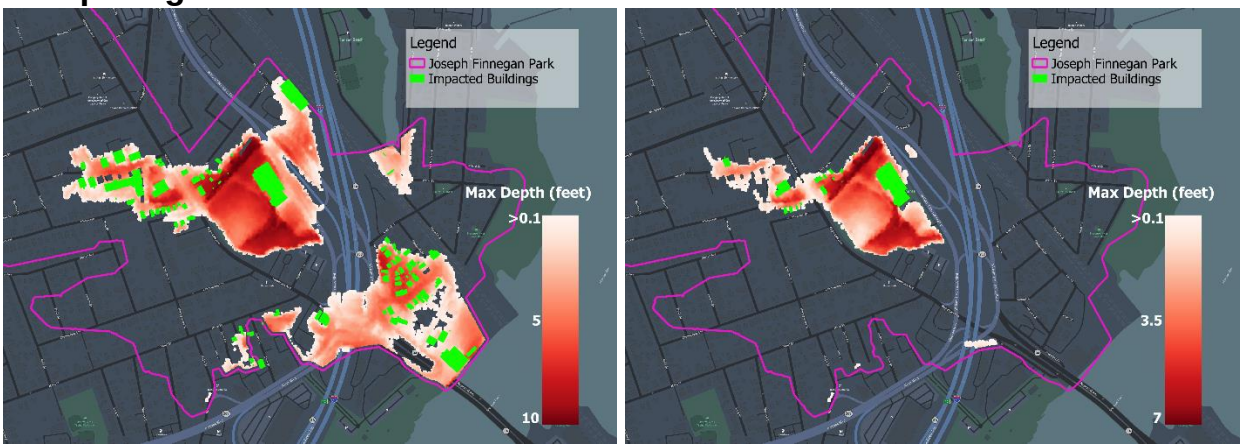


Figure 25: Baseline flood scenario (left) impacts 97 properties and covers 1.8 million square feet. Mitigated flood scenario (right) impacts 16 properties and covers 553,000 square feet.

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Under the baseline flood scenario shown in Figure 25, water encroaches from the Neponset River up Neponset Ave and damages commercial buildings near the riverbank. The deepest flooding occurs around the Dorchester Shores Reservation further inland. In total 97 properties are impacted, and the estimated building damage ranges from $25 million to $42 million. The mitigated flood scenario reduces flooding along Neponset Ave near the river, but Dorchester Shores Reservation still is impacted by flooding. In total 16 properties are impacted under the mitigated flood scenario and the estimated building damage ranges from $4 million to $7 million.

Old Harbor Park

Old Harbor Park (HARP) is in the northeastern portion of Dorchester near University of Massachusetts - Boston and sits on the coastline. It is the smallest analysis area for this study and covers 0.14 square miles. HARP contains 241 properties and 215 of them are owned by Harbor Point Apartments. Within the area of interest is John W. McCormack Middle School as well as athletic fields owned by Boston College High School.

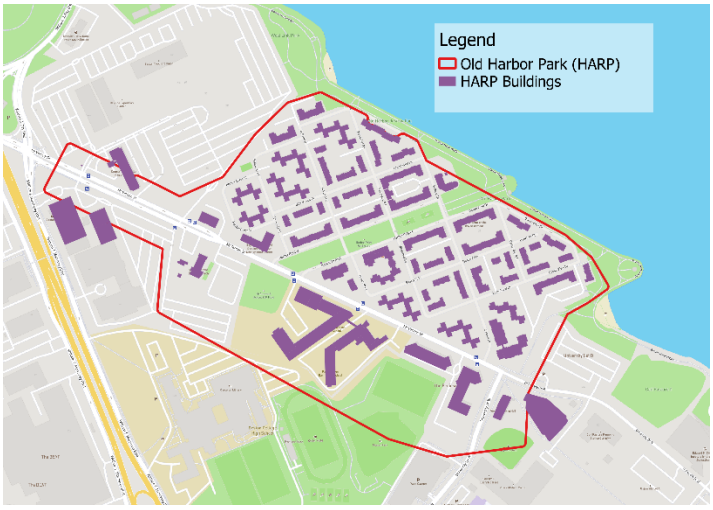

Figure 26: Old Harbor Park (red) contains ~240 properties (purple).

Comparing Flood Scenarios

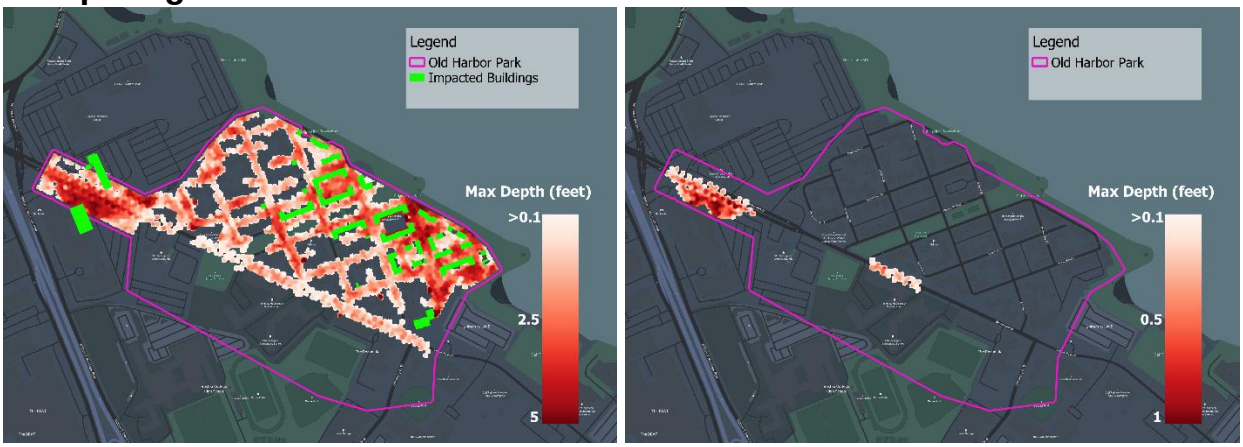

Figure 27: Baseline flood scenario (left) impacts 78 properties and covers 2.2 million square feet. Mitigated flood scenario (right) impacts zero properties and covers 107,000 square feet.

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The baseline flood scenario, as shown in Figure 27, inundates all the roads within HARP and covers 2.2 million square feet. In total 78 properties are impacted, most of which are owned by Harbor Point Apartments. The estimated building damage ranges from $46 million to $77 million. The mitigated flood scenario results in no properties impacted by flooding; the maximum flood depth is ~1 foot which occurs along Mt. Vernon Street.

Physical Loss Model Methodology

Direct Building Structure Physical Damage Model

The direct physical damage due to storm surge depth and velocity are modeled using a standard catastrophe modeling framework, where for an individual building location:

Monetary loss = (Damage ratio at depth x) * Building replacement cost

The total loss per event scenario being the sum of loss from each impacted building location.

The vulnerability functions linking depth/velocity to expected damage ratio were derived from the HAZUS modeling software and have been calibrated and updated independently. Vulnerability functions vary by occupancy, material of construction, height, and foundation type. Velocity impacts have been included in the base functions and are not applied as separate modifiers.

Typical damage functions for residential single-family homes of various construction types with basement are shown in Figure 28.

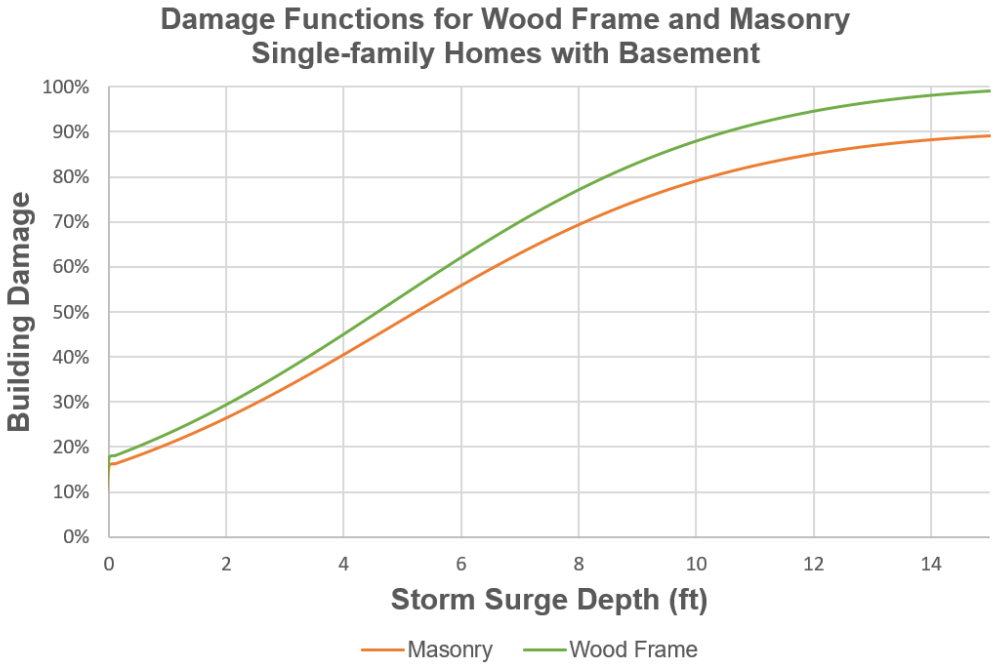

Figure 28: Damage function for single-family homes by construction type.

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In all, vulnerability functions are used covering thirty-three occupancies, three height categories and five material-based construction types, for multiple foundation types.

Building down time, or time to recover and rebuild, is modeled using HAZUS recovery duration curves. These curves offer estimates of recovery time based on depth of flooding experienced. These offer the primary input to the gross domestic product impairment calculation i.e., days to recover.

Location Level Building Structure Intensity Calculation

As stated previously and highlighted in many graphics, storm surge intensities are presented for multiple areas of interest by event scenario. The event is specified as storm surge 100-year return period for year 2070 and each area of interest has a mitigation scenario, e.g., pumps, and a baseline scenario.

For each AOI and event scenario, spatial data were supplied including relevant metrics from the event flood simulations, such as flood depth, surface water and ground elevation. Where building locations were known, estimates of the minimum, mean and maximum likely flood depths over each building footprint were calculated. Allowances were made to account for buildings having a threshold above grade level elevation, as few buildings allow entry/exit exactly at the ground surface elevation.

The scenario level flood simulation output was in vector format, represented by approximately 10-meter hexagonal shapes, with each shape having multiple attributes. The key attributes of interest for each were elevation (ground surface) and maximum surface water elevation (maximum water height above datum). To assign the relevant flood metrics to each building in an efficient manner it was necessary to reformat this data to raster grid format for both elevation and maximum water surface elevation, here in referred to as ELEV and MAXWSE.

The process for creating these metrics, and assigning the requisite flooding intensity to each building location is outlined below:

(1) For each area of interest, a polygon representing the extent of each storm surge event was created. These AOI flood extent polygons as they are called, were used to define a 5 ft raster grid template. Many of these polygons have been shown in previous sections
(2) The raster grid templates were used to create grids for both ELEV and MAXSWE, by rasterizing the vector shape data for these attributes
(3) Building footprints from the exposures database were converted to spatial polygons, and each polygon was externally buffered by 7.5 ft. Using standard spatial modeling techniques, estimates of ELEV were calculated for each building.

Standard output for steps (1) through (3) is highlighted in Figure 29

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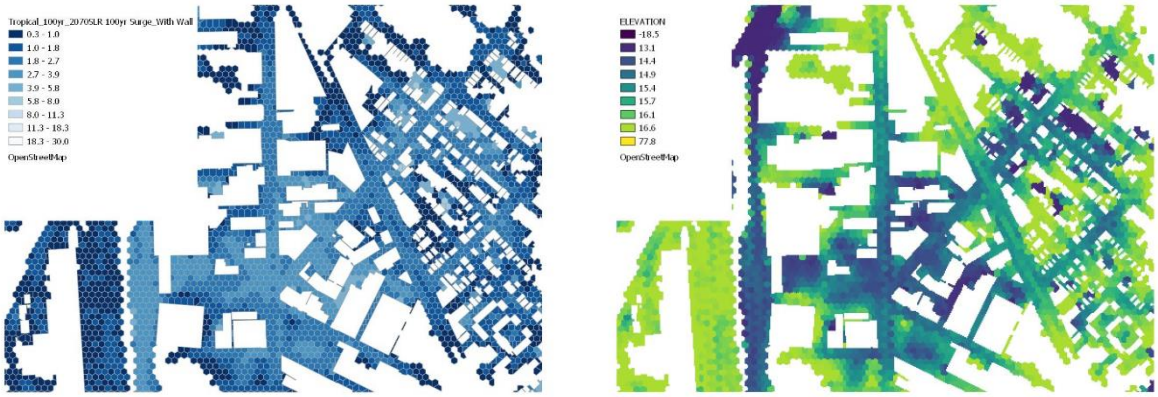

Figure 29: Elevation data converted from vector format (left) to raster format (right).

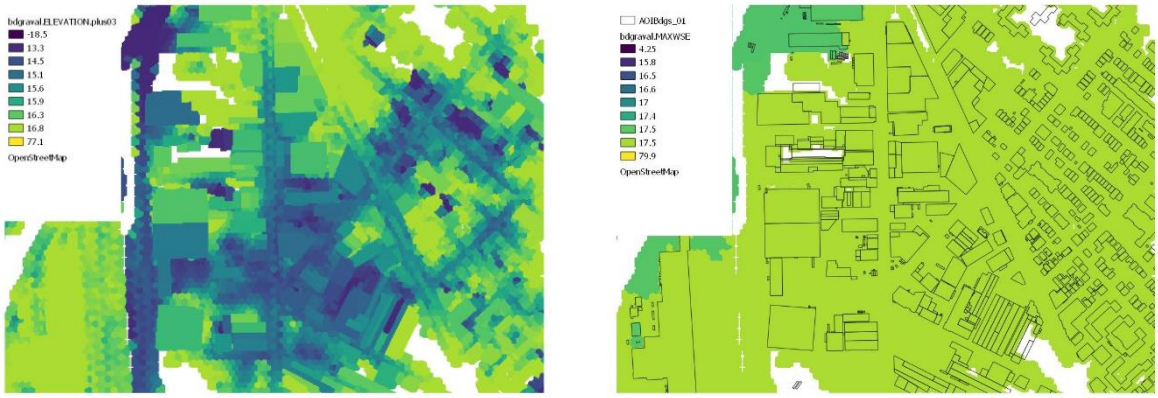

Figure 30: Final elevation (ELEV) raster on left and surface water height (MAXWSE) raster on right.

(4) From step (3), the elevation estimates for each building were raised by 0.3 ft to account for the standard level of threshold, or step up, a typical building is likely to have. These building level elevation grade estimates were then burnt into the rasters from step (3)
(5) Rasters representing estimated flood depth were created by subtracting the "thresholded" ELEV raster from the MAXSWE raster
(6) For each building, using the buffered building polygon data, minimum, mean, and maximum threshold flood depths were calculated. These metrics were used as the event specific flood depth for each impacted building for modeling the physical damages

Standard output for steps (4) through (6) is highlighted in Figure 30

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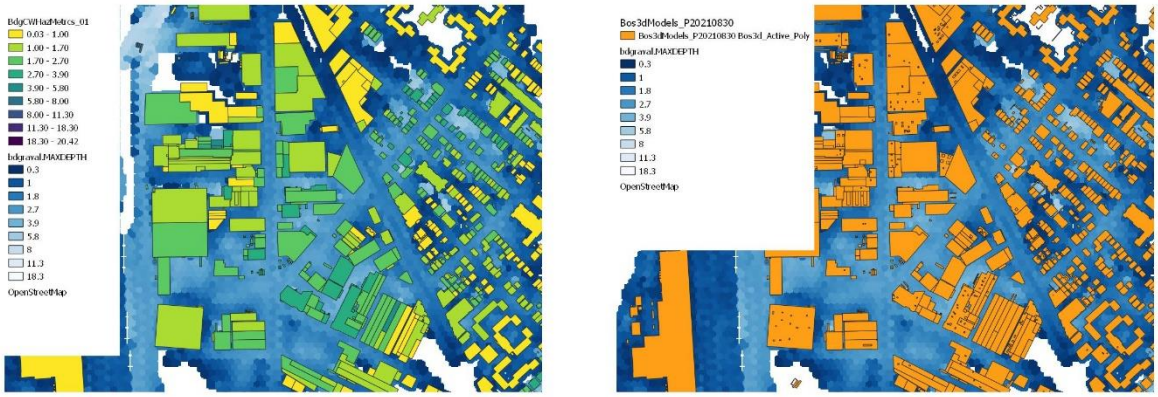

Figure 31: Example of building level mean elevation on cleaned building polygon data (left) and starting building polygon data (right).

The processed building data derived from the above process estimated many statistics. Only the minimum, mean and maximum depths per building were used in the final physical damage calculations.

Validating Damage Assumptions

Critical variables to the resulting flood damage are the building's structure (i.e., wood frame, brick, steel, etc.) and the presence of a basement. The former information was collected via the Boston Tax Assessor database while the latter required additional investigation. To confirm the presence of basements for impacted buildings we reviewed Google Street images. Below is an example of an indicator to determine if the structure had a basement, primarily if there were windows below the ground floor.



Figure 32: *windows below the ground flood, highlighted in yellow, indicate the presence of a basement.*

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Estimating Gross Domestic Product Impairment from Flood Damage

In addition to replacement cost estimates to repair flood damage, lost revenue from the lost building usage was also modeled and presented in Table 5. This included business interruption for commercial and industrial occupancies and lost rental income for residential properties. Additionally, loss estimates included potential property tax abatements and refunds for properties damaged by a natural disaster, as described under Massachusetts' General Laws.[1]

Business interruption is modelled using the estimated number of days to repair the flood damage. Regional GDP, from the Bureau of Economic Analysis, is distributed down to individual commercial properties, weighted by their estimated replacement values. To estimate GDP loss, the damaged buildings have their annual GDP prorated down by the number of days to repair over 365 days in a year.

Estimates of rental income loss were derived by using the estimated number of days to repair the flood damage and then applying an average rental income for apartments of $2 per square foot per month.

Property tax loss is estimated from an assumption of $2.80 per square foot per year for the single-family home tax rate, and $2.10 per square foot per year for apartments. These factors were estimated from averages from the 2022 City of Boston Tax Assessor dataset.

Building Resilient Infrastructure and Communities (BRIC) Grant Opportunity

To help fund flood mitigation efforts, Boston Water and Sewer Commission could pursue grant opportunities. FEMA's Building Resilient Infrastructure and Communities (BRIC) grant program provides states, local communities, tribes, and territories funding to address natural disasters risks, including wildfires, drought, hurricanes, earthquakes, extreme heat, and flooding. In 2022, FEMA made $2.3 billion available through the BRIC hazard mitigation assistance grant program.

One of the guiding principles of the program is to promote equity and prioritize 40% of the available funding to disadvantaged communities. Per BRIC's Qualitative Evaluation Criteria, "a disadvantaged community may be characterized by variables including, but not limited to: low income, high and/or persistent poverty, high unemployment and underemployment, racial and ethnic segregation, linguistic isolation, high housing cost burden and substandard housing, distressed neighborhoods, high transportation cost burden and/or low transportation access, disproportionate environmental burden and high cumulative impacts, limited water and sanitation access and affordability,

[1] https://malegislature.gov/Laws/GeneralLaws/PartI/TitleIX/Chapter59/Section2D

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disproportionate climate impacts, high energy cost burden and low energy access, and all geographic areas within Tribal jurisdictions." To quantify these variables, applicants are encouraged to provide documentation that defines the disadvantaged community (e.g., Centers for Disease Control and Prevention and U.S. Census data). To this end, below is data from the U.S. Census and the American Community Survey which can provide relevant metrics to support BRIC grant applications.

The metrics were derived through a dasymetric mapping technique where the original census tract level survey data was downscaled onto a 100-meter grid. The downscaling process makes use of auxiliary spatial data (e.g., residential, and commercial building locations) to determine the necessary weights per grid cell. Once the data is downscaled to the 100-meter grid, it is re-aggregated up to each of the eleven flood analysis areas.

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Social Demographic Metrics to Support Grant Application

Variable	Definition	Data Source
Per Capita Income	Per capita income in U.S. dollars	American Community Survey
Racial Gap in Income	Non-white average household income as a percent of white household income	American Community Survey
Below Poverty Line	Percent of households below federal poverty line	American Community Survey
Median Monthly Housing Costs	Median monthly housing costs in U.S. dollars	American Community Survey
Rent Burdened Population	Percentage of stressed renters (40%+ rent-to-income ratio)	American Community Survey
Food Insecure	Percentage of households with food insecurity (3-year average)	U.S. Dept. of Agriculture (2017)
Unemployment Rate	Unemployment rate, ages 16+	American Community Survey
Working Poor	Percentage of working population living below the poverty line	American Community Survey
Childhood Poverty	Percentage of children living below the poverty line	American Community Survey
Early Education	Percentage of population aged 3-4 enrolled in school	American Community Survey
No High School Degree	Percentage of U.S. adults ≥25 without a high school diploma or equivalent degree	American Community Survey
Mental Health Challenges	Percentage of ≥18 years old who report 14 or more days in the past 30 days which their mental health was not good	Centers of Disease Control
Health Insurance Coverage	Percent of population with health insurance	American Community Survey
Safe Drinking Water Violation	Percent of population served by a water system with ≥1 Safe Drinking Water Act violation in the preceding 5 years	Environmental Protection Agency
Asian Popl	Percent of population. Individuals may identify as more than one race	American Community Survey
Black Popl.	Percent of population. Individuals may identify as more than one race	American Community Survey
Latinx Popl.	Percent of population. Individuals may identify as more than one race	American Community Survey
Native American Popl.	Percent of population. Individuals may identify as more than one race	American Community Survey
Native Islander Popl.	Percent of population. Individuals may identify as more than one race	American Community Survey
White Popl.	Percent of population. Individuals may identify as more than one race	American Community Survey

Table 3: Variable definitions and source of data. Data is 2020 vintage unless otherwise noted.

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BRIC Variable	Boston Logan Airport	Charlestown Schrafft Center	Columbus Park	Constitution Beach	Davenport Creek	Dorchester Bay Basin	East Boston	East Boston Waterfront	Fort Point Channel	Joseph Finnegan Park	Old Harbor Park
Per Capita Income	$ 32,827.0	$ 81,062	$ 108,521	$ 32,899	$ 40,556	$ 33,671	$ 37,917	$ 39,098	$ 58,326	$ 50,749	$ 19,522
Racial Gap in Income	86%	57%	67%	77%	57%	80%	69%	74%	60%	57%	100%
Below Poverty Line	12%	5%	11%	16%	18%	17%	16%	19%	23%	6%	49%
Median Monthly Housing Costs	$ 1,683	$ 2,502	$ 2,635	$ 1,342	$ 1,655	$ 1,662	$ 1,559	$ 1,481	$ 1,778	$ 1,816	$ 2,076
Rent Burdened Population	33%	26%	26%	18%	41%	39%	33%	25%	34%	25%	52%
Food Insecure	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%
Unemployment Rate	6%	2%	4%	11%	5%	7%	5%	6%	8%	4%	6%
Working Poor	8%	4%	0%	7%	13%	10%	5%	12%	13%	2%	25%
Childhood Poverty	19%	5%	5%	32%	29%	23%	22%	26%	27%	5%	52%
Early Education	37%	66%	38%	56%	25%	22%	40%	39%	31%	41%	0%
No High School Degree	29%	3%	3%	19%	12%	18%	14%	20%	16%	8%	12%
Mental Health Challenges	17%	10%	11%	15%	14%	16%	14%	16%	15%	12%	19%
Health Insurance Coverage	91%	99%	98%	92%	98%	95%	93%	94%	96%	98%	96%
Safe Drinking Water Violation	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Asian Popl	3%	6%	7%	4%	6%	17%	5%	8%	13%	9%	29%
Black Popl.	3%	5%	5%	3%	39%	36%	4%	5%	30%	10%	14%
Latinx Popl.	63%	5%	5%	48%	15%	17%	46%	43%	20%	4%	29%
Native American Popl.	1%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%
Native Islander Popl.	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%
White Popl.	53%	84%	84%	67%	44%	31%	61%	69%	41%	75%	36%

Table 4: Socioeconomic variables to support FEMA's BRIC grant application.

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Coastal Stormwater Discharge Analysis Project Results

Monetary losses from physical building damage and direct gross domestic product impairment are presented in Table 5 for each area of interest and event scenario. The methodologies for these calculations are previously discussed in the Physical Loss Model Methodology and Estimating Gross Domestic Product Impairment from Flood Damage sections, respectively. In the table below, *replacement value of impacted buildings* is the total value of the impacted buildings, based on the buildings' replacement cost estimates, if a full rebuild were necessary. The *min/max physical damages* are estimates to repair the actual flood damage factoring in flood depths, building characteristics, and the square foot construction cost estimates. The *min/max GDP loss* estimates reflect the value of lost economic activity while impacted buildings are repaired.

Area	Scenario	Replacement Value of Impacted Buildings	Min Physical Damage	Max Physical Damage	Min GDP Loss	Max GDP Loss
Fort Point Channel	Wall	$ 20,470,236	$ 2,938,938	$ 5,105,728	$ 1,842,013	$ 3,894,824
Fort Point Channel	Solution	$ 4,616,728	$ 676,619	$ 1,145,390	$ 86,588	$ 225,193
Joseph Finnegan Park	Wall	$ 152,077	$ 24,789	$ 41,516	$ 46,119	$ 77,888
Joseph Finnegan Park	Solution	$ 30,029	$ 4,290	$ 7,025	$ 12,606	$ 21,034
Old Harbor Park	Wall	$ 310,681	$ 45,805	$ 76,698	$ 27,815	$ 76,874
Old Harbor Park	Solution	$ -	$ -	$ -	$ -	$ -
East Boston Waterfront	Wall	$ 482,821	$ 69,255	$ 115,439	$ 7,805	$ 22,399
East Boston Waterfront	Solution	$ 6,789	$ 987	$ 1,665	$ 8	$ 29
Constitution Beach	Wall	$ 519,621	$ 52,906	$ 89,495	$ 22,837	$ 42,692
Constitution Beach	Solution	$ 166,283	$ 2,382	$ 3,991	$ 6,055	$ 10,115
East Boston	Wall	$ 12,754	$ 2,008	$ 3,392	$ 20	$ 54
East Boston	Solution	$ -	$ -	$ -	$ -	$ -
Dorchester Bay Basin	Wall	$ 1,408,902	$ 186,031	$ 315,066	$ 326,320	$ 866,024
Dorchester Bay Basin	Solution	$ 467,912	$ 50,691	$ 84,433	$ 78,449	$ 225,660
Davenport Creek	Wall	$ 161,816	$ 22,380	$ 37,466	$ 10,053	$ 17,382
Davenport Creek	Solution	$ -	$ -	$ -	$ -	$ -
Columbus Park	Wall	$ 4,432,483	$ 714,699	$ 1,239,409	$ 1,232,970	$ 2,281,389
Columbus Park	Solution	$ 1,258,120	$ 186,800	$ 324,124	$ 370,274	$ 867,807
Charlestown Schrafft Center	Wall	$ 115,431	$ 14,032	$ 24,831	$ 8,625	$ 36,397
Charlestown Schrafft Center	Solution	$ 6,281	$ 757	$ 1,262	$ -	$ 2
Boston Logan Airport	Wall	$ 883,069	$ 125,137	$ 214,588	$ 74,862	$ 199,502
Boston Logan Airport	Solution	$ 54,545	$ 5,787	$ 10,028	$ 2,490	$ 8,319

Table 5: All values are in $1,000s USD.

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For each AOI, the delta between the “wall” and “solution” scenarios quantifies the direct benefit derived from implementing the proposed improvements.

The largest delta observed between the “wall” and “solution” scenarios occurs in the Fort Point Channel (FPC) AOI; looking at the max physical damage estimates, the FPC mitigation solution results in nearly $4 billion in avoided property damage and avoids $3.7 billion in GDP impairment. Results also show that three “solution” scenarios—Old Harbor Park, East Boston, and Davenport Creek—prevented all property loss and GDP impairment.

Beyond the financial benefits of the proposed mitigation efforts, one may also consider the population demographic these measures would serve. To that point, demographic data for each AOI is included in Table 4. For instance, the populations living in Charlestown Schrafft Center and Columbus Park have higher per capita incomes, fewer rent burdened occupants, and a lower percentage of people living below the poverty line than in Old Harbor Park. Other metrics related to the AOI’s population by race, educational attainment, etc., may highlight several AOIs where mitigation measures may have more pronounced effects on the general population.

The use and application of this demographic data related to the BRIC program is relatively recent but offers a means of addressing equity in the decision-making process. Ideally creating some form of index encapsulating the pertinent social metrics would be ideal.

Data Availability

Analysis results as shown above, are included in Excel workbooks accompanying this document. The file name for reference is:

V3_Hazen_data_delivery_loss_metrics_and_BRIC.xlsx

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Appendix L: Cost Backup for Pumping Storage and Conveyance Solutions

Hazen

Boston Water and Sewer Commission
Coastal Stormwater Discharge Analysis
Conceptual
Estimate Summary - CSI Division by WBS

10/21/2022
10/5/2022

	Description			Fort Point Channel	Dorchester Bay Basin	Davenport Creek	East Boston	Total
Div 02	*Existing Conditions*			*$ 20,176*	*$ 171,683*	*$ 40,877*	*$ -*	*$ 232,735*
Div 03	*Concrete*			*$ 44,618*	*$ -*	*$ 636,359*	*$ 612,818*	*$ 1,293,795*
Div 04	*Masonry*			*$ 250,409*	*$ -*	*$ 44,716*	*$ 44,716*	*$ 339,841*
Div 05	*Metals*			*$ 9,720*	*$ -*	*$ 419,808*	*$ -*	*$ 429,528*
Div 06	*Wood, Plastics, and Composites*			*$ 28,954*	*$ -*	*$ -*	*$ -*	*$ 28,954*
Div 07	*Thermal and Moisture Protection*			*$ 60,664*	*$ -*	*$ 6,276*	*$ 6,276*	*$ 73,217*
Div 08	*Openings*			*$ 43,828*	*$ -*	*$ 29,190*	*$ 29,190*	*$ 102,207*
Div 09	*Finishes*			*$ 6,707*	*$ -*	*$ 4,007*	*$ 4,007*	*$ 14,722*
Div 10	*Specialties*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 11	*Equipment*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 12	*Furnishings*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 13	*Special Construction*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 14	*Conveying Systems*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 21	*Fire Suppression*			*$ 17,307*	*$ -*	*$ 10,846*	*$ 10,846*	*$ 38,998*
Div 22	*Plumbing*			*$ 27,307*	*$ -*	*$ 22,307*	*$ 22,307*	*$ 71,921*
Div 23	*Heating, Ventilating, and Air Conditioning (HVAC)*			*$ 89,133*	*$ -*	*$ 22,711*	*$ 22,711*	*$ 134,555*
Div 25	*Integrated Automation*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 26	*Electrical*			*$ 1,930,015*	*$ -*	*$ 1,030,551*	*$ 514,085*	*$ 3,474,651*
Div 27	*Communications*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 28	*Electronic Safety and Security*			*$ 20,365*	*$ -*	*$ -*	*$ -*	*$ 20,365*
Div 31	*Earthwork*			*$ 30,652*	*$ 10,630,600*	*$ 3,586,104*	*$ 403,380*	*$ 14,650,736*
Div 32	*Exterior Improvements*			*$ 166,510*	*$ 873,171*	*$ 444,129*	*$ -*	*$ 1,483,809*
Div 33	*Utilities*			*$ 5,740,611*	*$ 33,976,778*	*$ 10,466,314*	*$ 1,091,578*	*$ 51,275,281*
Div 34	*Transportation*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 35	*Waterway and Marine Construction*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 40	*Process Interconnections*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 40P	*Process Monitoring and Control System*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 41	*Material Processing and Handling Equipment*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 42	*Process Heating, Cooling, and Drying Equipment*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 43	*Process Gas and Liquid Handling, Purification and Storage Equipment*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 44	*Pollution and Waste Control Equipment*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 45	*Industry-Specific Manufacturing Equipment*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 46	*Water and Wastewater Equipment*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 48	*Electrical Power Generation*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
	Subtotal:			**$ 8,486,977**	**$ 45,652,231**	**$ 16,764,195**	**$ 2,761,914**	**$ 73,665,316**
	Special Conditions	*5.0%*	*on*	*$ 8,486,977*	*$ 45,652,231*	*$ 16,764,195*	*$ 2,761,914*	
	Special Conditions Total:			$ 424,349	$ 2,282,612	$ 838,210	$ 138,096	$ 3,683,266
	Small Tools (Applied on Labor)	*2.0%*	*on*	*$ 804,914*	*$ 11,993,319*	*$ 4,282,749*	*$ 527,545*	
	Small Tools (Applied on Labor) Total:			$ 16,098	$ 239,866	$ 85,655	$ 10,551	$ 352,171
	Incidental Overtime (Applied on Labor)	*5.0%*	*on*	*$ 804,914*	*$ 11,993,319*	*$ 4,282,749*	*$ 527,545*	
	Incidental Overtime (Applied on Labor) Total:			$ 40,246	$ 599,666	$ 214,137	$ 26,377	$ 880,426
	Direct Costs Subtotal:			**$ 8,967,670**	**$ 48,774,375**	**$ 17,902,197**	**$ 2,936,938**	**$ 78,581,179**
	General Conditions	*20.0%*	*on*	*$ 8,967,670*	*$ 48,774,375*	*$ 17,902,197*	*$ 2,936,938*	
	General Conditions Total:			$ 1,793,534	$ 9,754,875	$ 3,580,439	$ 587,388	$ 15,716,236
	Indirect Costs Subtotal:			**$ 1,793,534**	**$ 9,754,875**	**$ 3,580,439**	**$ 587,388**	**$ 15,716,236**
	Direct and Indirect Costs Total:			**$ 10,761,204**	**$ 58,529,250**	**$ 21,482,636**	**$ 3,524,325**	**$ 94,297,415**

Hazen

Boston Water and Sewer Commission
Coastal Stormwater Discharge Analysis
Conceptual
Estimate Summary - CSI Division by WBS

10/21/2022
10/5/2022

	Description			Fort Point Channel	Dorchester Bay Basin	Davenport Creek	East Boston	Total
	Add-On / Mark-Up							
	Labor Escalation at 3.5% annually	*67.5%*	*on*	*$ 2,508,572*	*$ 21,621,100*	*$ 7,810,873*	*$ 1,098,035*	
	Labor Escalation Total:			$ 1,694,161	$ 14,601,784	$ 5,275,064	$ 741,556	$ 22,312,566
	Material/Equipment Escalation at 3% annually	*55.8%*	*on*	*$ 8,252,632*	*$ 36,908,146*	*$ 13,671,760*	*$ 2,426,287*	
	Material/Equipment Escalation Total:			$ 4,604,700	$ 20,593,543	$ 7,628,396	$ 1,353,789	$ 34,180,428
	Subtotal:			**$ 17,060,065**	**$ 93,724,577**	**$ 34,386,097**	**$ 5,619,671**	**$ 150,790,409**
	Subcontractor Overhead, Profit and Fee	*25.0%*	*on*	*$ 5,118,019*	*$ 28,117,373*	*$ 10,315,829*	*$ 1,685,901*	
	Subcontractor Overhead, Profit and Fee Total:			$ 1,279,505	$ 7,029,343	$ 2,578,957	$ 421,475	$ 11,309,281
	Subtotal:			**$ 18,339,570**	**$ 100,753,920**	**$ 36,965,054**	**$ 6,041,146**	**$ 162,099,690**
	Prime Contractor Overhead	*10.0%*	*on*	*$ 11,942,045*	*$ 65,607,204*	*$ 24,070,268*	*$ 3,933,770*	
	Prime Contractor Overhead Total:			$ 1,194,205	$ 6,560,720	$ 2,407,027	$ 393,377	$ 10,555,329
	Subtotal:			**$ 19,533,774**	**$ 107,314,641**	**$ 39,372,081**	**$ 6,434,523**	**$ 172,655,018**
	Prime Contractor Profit	*10.0%*	*on*	*$ 13,136,250*	*$ 72,167,924*	*$ 26,477,294*	*$ 4,327,147*	
	Prime Contractor Profit:			$ 1,313,625	$ 7,216,792	$ 2,647,729	$ 432,715	$ 11,610,861
	Subtotal:			**$ 20,847,399**	**$ 114,531,433**	**$ 42,019,810**	**$ 6,867,238**	**$ 184,265,880**
	Prime Profit on Subcontracted Work	*5.0%*	*on*	*$ 6,397,524*	*$ 35,146,716*	*$ 12,894,786*	*$ 2,107,377*	
	Prime Profit on Subcontracted Work Total:			$ 319,876	$ 1,757,336	$ 644,739	$ 105,369	$ 2,827,320
	Subtotal:			**$ 21,167,275**	**$ 116,288,769**	**$ 42,664,549**	**$ 6,972,607**	**$ 187,093,200**
	Bond and Insurance	*3.0%*		*$ 635,018*	*$ 3,488,663*	*$ 1,279,936*	*$ 209,178*	$ 5,612,796
	Subtotal:			**$ 21,802,294**	**$ 119,777,432**	**$ 43,944,486**	**$ 7,181,785**	**$ 192,705,996**
	Design Contingency	*50.0%*		*$ 10,901,147*	*$ 59,888,716*	*$ 21,972,243*	*$ 3,590,892*	$ 96,352,998
	Subtotal:			**$ 32,703,440**	**$ 179,666,148**	**$ 65,916,729**	**$ 10,772,677**	**$ 289,058,994**
	Contract Allowances and Unit Prices	*2.5%*		*$ 817,586*	*$ 4,491,654*	*$ 1,647,918*	*$ 269,317*	*$ 7,226,475*
	Total (rounded):			**$ 33,521,000**	**$ 184,158,000**	**$ 67,565,000**	**$ 11,042,000**	**$ 296,285,000**

Note: Project Assumptions NTP: 10/1/32, 1825 CCD (60 months)

Location Code	CSI Div.	Description	Quantity	Unit	Notes	Labor Unit Cost	Equipment Unit Cost	Material Unit Cost	Total Unit Cost	Total Amount
						$0.00	$0.00		$ -	$ -
Airport		**AIRPORT PUMP STATION**				$0.00	$0.00		$ -	$ -
Airport		**Sitework & Removals**				$0.00	$0.00		$ -	$ -
Airport	Div 02	Surface removal, mixed dirt & gravel	2,000	sy	allow 9" removal across entire site area	$3.29	$1.86	$0.00	$ 5.15	$ 10,297
Airport	Div 02	Haul & dispose	600	lcy		$12.62	$11.80	$5.00	$ 29	$ 17,649
Airport	Div 02	Haul off misc. trailers & equipment	1	ls	approx. 6 pcs of static equipment identified on Google Earth	$8,023.55	$4,103.25	$0.00	$ 12,127	$ 12,127
Airport						$0.00	$0.00		$ -	$ -
Airport	Div 32	Surface restore, subbase, 6" aggregate	2,000	sy	allow paving of disturbed area	$1.09	$1.47	$3.79	$ 6.35	$ 12,696
Airport	Div 32	Surface restore, asphalt, 1.5" binder	2,000	sy		$7.19	$5.93	$5.45	$ 19	$ 37,150
Airport	Div 32	Surface restore, asphalt, 1.5" wearing	2,000	sy		$7.19	$5.93	$6.10	$ 19	$ 38,450
Airport						$0.00	$0.00		$ -	$ -
Airport		**Proposed Pipelines**				$0.00	$0.00		$ -	$ -
Airport	Div 33	RCP, 144"dia	30	lf	distance btwn exist pipeline and storage tank not specified	$446.16	$161.03	$1,900.00	$ 2,507	$ 75,216
Airport	Div 31	Trench excavation	880	cy	combined qty for RCP and diversion structure	$3.45	$4.03	$0.00	$ 7.48	$ 6,583
Airport	Div 31	Haul & dispose	1,060	lcy		$12.62	$11.80	$5.00	$ 29	$ 31,180
Airport	Div 33	SOE, trench sheeting	6,100	sf		$1.26	$0.31	$0.75	$ 2.31	$ 14,109
Airport	Div 31	Screened gravel, backfill, 6-8" lifts	600	cy		$6.69	$3.20	$0.00	$ 9.89	$ 5,936
Airport	Div 31	Haul borrow material	600	cy		$12.62	$11.80	$30.00	$ 54	$ 32,649
Airport	Div 33	Diversion Structure	1	ea	allow cast-in-place chamber	$46,876.93	$16,102.50	$50,000.00	$ 112,979	$ 112,979
Airport	Div 33	Bypass pumping allowance @ existing 144" main	14	day	calendar days (full time 24/7 pumping) - allow 2 weeks	$1,770.61	$526.03	$1,500.00	$ 3,797	$ 53,153
Airport	Div 02	Cut & remove existing RCP @ diversion structure/tie-in	15	lf		$647.99	$396.68	$0.00	$ 1,045	$ 15,670
Airport						$0.00	$0.00		$ -	$ -
Airport		**Pumps & Discharge Piping**				$0.00	$0.00		$ -	$ -
Airport	Div 33	Dewatering Pumps	2	ea		$13,300.05	$4,879.55	$25,000.00	$ 43,180	$ 86,359
Airport	Div 33	Stormwater Pumps - 320 CFS pump station (4 duty + 1 standby)	5	ea	allow based on quote for 167CFS pumps - 80 CFS per duty	$14,633.31	$6,441.00	$500,000.00	$ 521,074	$ 2,605,372
Airport						$0.00	$0.00		$ -	$ -
Airport	Div 33	Stormwater pump discharge, 2ft dia, DIP	300	lf	allow mech joint DIP, allow 60 lf per discharge (5 ea discharges)	$58.82	$21.71	$258.62	$ 339	$ 101,747
Airport	Div 33	Fittings, 2ft dia, DIP	20	ea	4 ea per discharge	$625.79	$230.99	$8,810.00	$ 9,667	$ 193,335
Airport						$0.00	$0.00		$ -	$ -
Airport	Div 33	Dewater pump discharge, 1ft dia, DIP	120	lf	allow mech joint DIP, allow pipe dia (not specified)	$28.01	$10.34	$223.10	$ 261	$ 31,374
Airport	Div 33	Fittings, 1ft dia, DIP	8	ea		$280.11	$103.40	$2,060.00	$ 2,444	$ 19,548
Airport						$0.00	$0.00		$ -	$ -
Airport		**Storage Tank - 1.2 MG**				$0.00	$0.00		$ -	$ -
Airport	Div 31	Temporary SOE - sheet pile wall, drive, extract & salvage	290	ton	allow around perimeter of pump station	$468.24	$455.95	$530.00	$ 1,454	$ 421,715
Airport	Div 31	Structure excavation	8,890	bcy		$4.61	$3.17	$0.00	$ 7.78	$ 69,164
Airport	Div 31	Bedding stone, 6", including grading	180	cy		$20.08	$4.93	$30.00	$ 55	$ 9,901
Airport	Div 31	Structure backfill	2,140	bcy		$26.34	$14.27	$0.00	$ 41	$ 86,906
Airport	Div 31	Haul & dispose excess dirt	8,100	lcy		$12.62	$11.80	$5.00	$ 29	$ 238,265
Airport						$0.00	$0.00		$ -	$ -
Airport	Div 03	Tank, floor slab, 24" th	720	cy		$21.09	$0.00	$145.00	$ 166	$ 119,582
Airport	Div 03	Formwork, slab edge	860	sfca		$6.54	$0.00	$6.72	$ 13	$ 11,404
Airport	Div 03	Rebar	72	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 268,429
Airport	Div 03	Tank, exterior and bay walls	670	cy	2ft thick exterior walls; 1ft thick bay wall	$33.39	$0.00	$145.00	$ 178	$ 119,519
Airport	Div 03	Formwork, wall	19,910	sfca		$6.54	$0.00	$6.72	$ 13	$ 264,011
Airport	Div 03	Rebar	60	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 223,691
Airport	Div 03	Tank, flow straightening piers, 12" th	40	cy		$66.77	$0.00	$145.00	$ 212	$ 8,471
Airport	Div 03	Formwork, column	2,775	sfca		$6.54	$0.00	$6.72	$ 13	$ 36,797
Airport	Div 03	Rebar	6	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 22,369
Airport	Div 03	Tank, support columns, 12" th	70	cy	none shown, carry as allowance (20 ft grid spacing)	$66.77	$0.00	$145.00	$ 212	$ 14,824
Airport	Div 03	Formwork, column	3,552	sfca		$6.54	$0.00	$6.72	$ 13	$ 47,100
Airport	Div 03	Rebar	11	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 39,146
Airport	Div 03	Tank, support beams, 12" th	60	cy	none shown, carry as allowance (20 ft spacing)	$66.77	$0.00	$145.00	$ 212	$ 12,706
Airport	Div 03	Formwork, beam	2,880	sfca		$6.54	$0.00	$6.72	$ 13	$ 38,190
Airport	Div 03	Rebar	5	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 20,132
Airport	Div 03	Tank, roof slab, 12" th	360	cy		$42.17	$0.00	$145.00	$ 187	$ 67,382
Airport	Div 03	Formwork, slab edge	430	sfca		$6.54	$0.00	$6.72	$ 13	$ 5,702
Airport	Div 03	Formwork, supported slab	9,600	sfca		$5.53	$0.00	$6.72	$ 12	$ 117,639
Airport	Div 03	Rebar	36	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 134,215
Airport						$0.00	$0.00		$ -	$ -
Airport		**Electrical House**				$0.00	$0.00		$ -	$ -
Airport	Div 03	House, floor slab, 12" th	10	cy		$44.51	$0.00	$145.00	$ 190	$ 1,895
Airport	Div 03	Formwork, slab edge	60	sfca		$6.54	$0.00	$6.72	$ 13	$ 796
Airport	Div 03	Rebar	1	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 3,728
Airport	Div 04	CMU, 8" th	900	sf	for pump station house or shed. Allow 10 x 20 building	$13.41	$1.29	$3.78	$ 18	$ 16,634
Airport	Div 07	Rigid insulation, wall, 2" th	900	sf		$0.82	$0.00	$1.67	$ 2.49	$ 2,242
Airport	Div 04	Brick veneer	900	sf		$16.09	$1.55	$13.56	$ 31	$ 28,082
Airport	Div 07	Roofing, preformed metal	200	sf		$7.42	$1.14	$5.00	$ 14	$ 2,712
Airport	Div 07	Rigid insulation, roof, 2" th	200	sf		$1.85	$0.00	$1.67	$ 3.52	$ 704
Airport	Div 07	Snow guard	8	ea	1 per 25 sf	$58.54	$0.00	$18.80	$ 77	$ 619
Airport	Div 08	Doors, single	1	ea	allow hollow metal, 3' x 7'	$1,143.08	$494.89	$5,000.00	$ 6,638	$ 6,638
Airport	Div 08	Door, overhead	1	ea		$2,286.15	$989.78	$12,000.00	$ 15,276	$ 15,276
Airport	Div 08	Windows	2	ea		$1,143.08	$494.89	$2,000.00	$ 3,638	$ 7,276
Airport	Div 09	Paint interior	900	sf		$1.45	$0.00	$3.00	$ 4.45	$ 4,007
Airport						$0.00	$0.00		$ -	$ -
Airport		Allowances for undefined services				$0.00	$0.00		$ -	$ -
Airport	Div 21	Fire suppression allowance	1	ls		$5,845.51	$0.00	$5,000.00	$ 10,846	$ 10,846
Airport	Div 22	Plumbing allowance	1	ls		$7,306.89	$0.00	$15,000.00	$ 22,307	$ 22,307
Airport	Div 23	HVAC allowance	1	ls		$6,888.00	$822.95	$15,000.00	$ 22,711	$ 22,711
Airport	Div 26	Electrical allowance	1	ls	utility hookup not included	$14,084.80	$0.00	$500,000.00	$ 514,085	$ 514,085
Airport	Div 26	Duct bank allowance	350	lf	allowance length to potential nearby power hookup	$259.39	$36.19	$350.00	$ 646	$ 225,954
						$0.00	$0.00		$ -	$ -
						$0.00	$0.00		$ -	$ -
Schrafft		**CHARLESTOWN SCHRAFFT CENTER**				$0.00	$0.00		$ -	$ -
Schrafft		**Sitework & Removals**				$0.00	$0.00		$ -	$ -
Schrafft	Div 02	Surface removal, asphalt parking lot	5,600	sy	allow 9" removal across entire site area	$8.15	$4.06	$0.00	$ 12	$ 68,376
Schrafft	Div 02	Haul & dispose	1,670	lcy		$12.62	$11.80	$20.00	$ 44	$ 74,174
Schrafft						$0.00	$0.00		$ -	$ -
Schrafft	Div 32	Surface restore, subbase, 6" aggregate	5,600	sy		$1.09	$1.47	$3.79	$ 6.35	$ 35,550
Schrafft	Div 32	Surface restore, asphalt, 1.5" binder	5,600	sy		$7.19	$5.93	$5.45	$ 19	$ 104,019
Schrafft	Div 32	Surface restore, asphalt, 1.5" wearing	5,600	sy		$7.19	$5.93	$6.10	$ 19	$ 107,659
Schrafft	Div 32	Pavement marking, parking lot	3,000	lf	restore to current condition	$0.00	$0.00	$5.00	$ 5.00	$ 15,000
Schrafft						$0.00	$0.00		$ -	$ -
Schrafft		**Proposed Pipelines**				$0.00	$0.00		$ -	$ -
Schrafft	Div 33	RCP, 72"dia	30	lf	distance btwn exist pipeline and storage tank not specified	$74.36	$55.24	$625.25	$ 755	$ 22,646
Schrafft	Div 33	Fittings, RCP, 72"dia	2	ea		$2,788.50	$2,071.61	$17,052.00	$ 21,912	$ 43,824
Schrafft	Div 31	Trench excavation	340	cy	combined qty for RCP and diversion structure	$3.45	$2.38	$0.00	$ 5.83	$ 1,984
Schrafft	Div 31	Haul & dispose	410	lcy		$12.62	$11.80	$5.00	$ 29	$ 12,060
Schrafft	Div 33	SOE, trench sheeting	3,600	sf		$1.26	$0.31	$0.75	$ 2.31	$ 8,327
Schrafft	Div 31	Screened gravel, backfill, 6-8" lifts	300	cy		$6.69	$3.20	$0.00	$ 9.89	$ 2,968
Schrafft	Div 31	Haul borrow material	300	cy		$12.62	$11.80	$30.00	$ 54	$ 16,325
Schrafft	Div 33	RCP, 63"dia	30	lf	distance btwn exist pipeline and storage tank not specified	$74.36	$55.24	$550.00	$ 680	$ 20,388
Schrafft	Div 33	Fittings, RCP, 63"dia	2	ea		$2,788.50	$2,071.61	$13,000.00	$ 17,860	$ 35,720
Schrafft	Div 31	Trench excavation	270	cy	combined qty for RCP and diversion structure	$3.45	$2.38	$0.00	$ 5.83	$ 1,575
Schrafft	Div 31	Haul & dispose	330	lcy		$12.62	$11.80	$5.00	$ 29	$ 9,707
Schrafft	Div 33	SOE, trench sheeting	3,000	sf		$1.26	$0.31	$0.75	$ 2.31	$ 6,939
Schrafft	Div 31	Screened gravel, backfill, 6-8" lifts	200	cy		$6.69	$3.20	$0.00	$ 9.89	$ 1,979
Schrafft	Div 31	Haul borrow material	200	cy		$12.62	$11.80	$30.00	$ 54	$ 10,883
Schrafft	Div 33	Diversion Structure	2	ea	allow cast-in-place chamber	$26,928.35	$11,048.59	$35,000.00	$ 72,977	$ 145,954
Schrafft	Div 33	Bypass pumping allowance @ existing pipeline	28	day	calendar days (full time 24/7 pumping) - allow 2 weeks per	$1,770.61	$526.03	$1,500.00	$ 3,797	$ 106,306
Schrafft	Div 02	Cut & remove existing RCP @ diversion structure/tie-in	20	lf		$647.99	$396.68	$0.00	$ 1,045	$ 20,893
Schrafft						$0.00	$0.00		$ -	$ -
Schrafft		**Pumps & Discharge Piping**				$0.00	$0.00		$ -	$ -
Schrafft	Div 33	Dewatering Pumps	2	ea		$13,300.05	$4,879.55	$25,000.00	$ 43,180	$ 86,359
Schrafft	Div 33	Stormwater Pumps - 200 CFS pump station (2 duty + 1 standby)	3	ea	allow based on quote for 167CFS pumps - 100 CFS per duty	$14,633.31	$6,441.00	$640,000.00	$ 661,074	$ 1,983,223
Schrafft	Div 33	Stormwater Pumps - 40 CFS pump station (2 duty + 1 standby)	3	ea	allow based on quote for 167CFS station - 20 CFS per duty pump	$14,633.31	$6,441.00	$240,000.00	$ 261,074	$ 783,223
Schrafft						$0.00	$0.00		$ -	$ -
Schrafft	Div 33	Stormwater pump discharge, 2ft dia, DIP	360	lf	allow mech joint DIP, allow 60 lf per discharge	$58.82	$21.71	$258.62	$ 339	$ 122,096
Schrafft	Div 33	Fittings, 2ft dia, DIP	24	ea	4 ea per discharge	$625.79	$230.99	$8,810.00	$ 9,667	$ 232,003
Schrafft						$0.00	$0.00		$ -	$ -
Schrafft	Div 33	Dewater pump discharge, 1ft dia, DIP	120	lf	allow mech joint DIP, allow pipe dia (not specified)	$28.01	$10.34	$223.10	$ 261	$ 31,374
Schrafft	Div 33	Fittings, 1ft dia, DIP	8	ea		$280.11	$103.40	$2,060.00	$ 2,444	$ 19,548
Schrafft						$0.00	$0.00		$ -	$ -
Schrafft		**Storage Tank - 0.5 MG**				$0.00	$0.00		$ -	$ -
Schrafft	Div 31	Temporary SOE - sheet pile wall, drive, extract & salvage	140	ton	allow around perimeter of pump station	$468.24	$455.95	$530.00	$ 1,454	$ 203,587
Schrafft	Div 31	Structure excavation	3,120	bcy		$4.61	$3.17	$0.00	$ 7.78	$ 24,273
Schrafft	Div 31	Bedding stone, 6", including grading	100	cy		$20.08	$4.93	$30.00	$ 55	$ 5,501

Location Code	CSI Div.	Description	Quantity	Unit	Notes	Labor Unit Cost	Equipment Unit Cost	Material Unit Cost	Total Unit Cost	Total Amount
Schrafft	Div 31	Structure backfill	690	bcy		$26.34	$14.27	$0.00	$ 41	$ 28,021
Schrafft	Div 31	Haul & dispose excess dirt	2,920	lcy		$12.62	$11.80	$5.00	$ 29	$ 85,893
Schrafft						$0.00	$0.00		$ -	$ -
Schrafft	Div 03	Tank, floor slab, 24" th	390	cy		$21.09	$0.00	$145.00	$ 166	$ 64,774
Schrafft	Div 03	Formwork, slab edge	620	sfca		$6.54	$0.00	$6.72	$ 13	$ 8,221
Schrafft	Div 03	Rebar	39	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 145,399
Schrafft	Div 03	Tank, exterior and bay walls	300	cy	2ft thick exterior walls; 1ft thick bay wall	$33.39	$0.00	$145.00	$ 178	$ 53,516
Schrafft	Div 03	Formwork, wall	8,600	sfca		$6.54	$0.00	$6.72	$ 13	$ 114,038
Schrafft	Div 03	Rebar	30	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 111,845
Schrafft	Div 03	Tank, flow straightening piers, 12" th	10	cy		$66.77	$0.00	$145.00	$ 212	$ 2,118
Schrafft	Div 03	Formwork, column	576	sfca		$6.54	$0.00	$6.72	$ 13	$ 7,638
Schrafft	Div 03	Rebar	2	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 5,592
Schrafft	Div 03	Tank, support columns, 12" th	30	cy	none shown, carry as allowance (20 ft grid spacing)	$66.77	$0.00	$145.00	$ 212	$ 6,353
Schrafft	Div 03	Formwork, column	1,260	sfca		$6.54	$0.00	$6.72	$ 13	$ 16,708
Schrafft	Div 03	Rebar	5	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 16,777
Schrafft	Div 03	Tank, support beams, 12" th	50	cy	none shown, carry as allowance (20 ft spacing)	$66.77	$0.00	$145.00	$ 212	$ 10,589
Schrafft	Div 03	Formwork, beam	2,250	sfca		$6.54	$0.00	$6.72	$ 13	$ 29,836
Schrafft	Div 03	Rebar	5	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 16,777
Schrafft	Div 03	Tank, roof slab, 12" th	195	cy		$42.17	$0.00	$145.00	$ 187	$ 36,499
Schrafft	Div 03	Formwork, slab edge	310	sfca		$6.54	$0.00	$6.72	$ 13	$ 4,111
Schrafft	Div 03	Formwork, supported slab	5,250	sfca		$5.53	$0.00	$6.72	$ 12	$ 64,334
Schrafft	Div 03	Rebar	20	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 72,700
Schrafft	Div 03	Energy dissipation structure	60	cy	allow dimensions	$80.13	$0.00	$145.00	$ 225	$ 13,508
Schrafft	Div 03	Formwork, slab edge	500	sfca	allow extra form area for dissipation blocks	$11.51	$0.00	$6.72	$ 18	$ 9,115
Schrafft	Div 03	Rebar	6	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 22,369
Schrafft						$0.00	$0.00		$ -	$ -
Schrafft		**Storage Tank - 2 MG**				$0.00	$0.00		$ -	$ -
Schrafft	Div 31	Temporary SOE - sheet pile wall, drive, extract & salvage	340	ton	allow around perimeter of pump station	$468.24	$455.95	$530.00	$ 1,454	$ 494,425
Schrafft	Div 31	Structure excavation	16,570	bcy		$4.61	$3.17	$0.00	$ 7.78	$ 128,914
Schrafft	Div 31	Bedding stone, 6", including grading	420	cy		$20.08	$4.93	$30.00	$ 55	$ 23,103
Schrafft	Div 31	Structure backfill	3,730	bcy		$26.34	$14.27	$0.00	$ 41	$ 151,477
Schrafft	Div 31	Haul & dispose excess dirt	15,410	lcy		$12.62	$11.80	$5.00	$ 29	$ 453,291
Schrafft						$0.00	$0.00		$ -	$ -
Schrafft	Div 03	Tank, floor slab, 24" th	1,660	cy		$21.09	$0.00	$145.00	$ 166	$ 275,703
Schrafft	Div 03	Formwork, slab edge	1,280	sfca		$6.54	$0.00	$6.72	$ 13	$ 16,973
Schrafft	Div 03	Rebar	166	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 618,878
Schrafft	Div 03	Tank, exterior and bay walls	770	cy	2ft thick exterior walls; 1ft thick bay wall	$33.39	$0.00	$145.00	$ 178	$ 137,357
Schrafft	Div 03	Formwork, wall	22,020	sfca		$6.54	$0.00	$6.72	$ 13	$ 291,991
Schrafft	Div 03	Rebar	70	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 260,973
Schrafft	Div 03	Tank, flow straightening piers, 12" th	20	cy		$66.77	$0.00	$145.00	$ 212	$ 4,235
Schrafft	Div 03	Formwork, column	1,440	sfca		$6.54	$0.00	$6.72	$ 13	$ 19,095
Schrafft	Div 03	Rebar	3	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 11,185
Schrafft	Div 03	Tank, support columns, 12" th	130	cy	none shown, carry as allowance (20 ft grid spacing)	$66.77	$0.00	$145.00	$ 212	$ 27,530
Schrafft	Div 03	Formwork, column	6,708	sfca		$6.54	$0.00	$6.72	$ 13	$ 88,950
Schrafft	Div 03	Rebar	20	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 72,700
Schrafft	Div 03	Tank, support beams, 12" th	180	cy	none shown, carry as allowance (20 ft spacing)	$66.77	$0.00	$145.00	$ 212	$ 38,119
Schrafft	Div 03	Formwork, beam	9,360	sfca		$6.54	$0.00	$6.72	$ 13	$ 124,116
Schrafft	Div 03	Rebar	16	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 60,397
Schrafft	Div 03	Tank, roof slab, 12" th	830	cy		$42.17	$0.00	$145.00	$ 187	$ 155,353
Schrafft	Div 03	Formwork, slab edge	640	sfca		$6.54	$0.00	$6.72	$ 13	$ 8,487
Schrafft	Div 03	Formwork, supported slab	22,360	sfca		$5.53	$0.00	$6.72	$ 12	$ 274,001
Schrafft	Div 03	Rebar	83	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 309,439
Schrafft	Div 03	Energy dissipation structure	60	cy	allow dimensions	$80.13	$0.00	$145.00	$ 225	$ 13,508
Schrafft	Div 03	Formwork, slab edge	500	sfca	allow extra form area for dissipation blocks	$11.51	$0.00	$6.72	$ 18	$ 9,115
Schrafft	Div 03	Rebar	6	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 22,369
Schrafft						$0.00	$0.00		$ -	$ -
Schrafft		**Electrical House**				$0.00	$0.00		$ -	$ -
Schrafft	Div 03	House, floor slab, 12" th	20	cy		$44.51	$0.00	$145.00	$ 190	$ 3,790
Schrafft	Div 03	Formwork, slab edge	80	sfca		$6.54	$0.00	$6.72	$ 13	$ 1,061
Schrafft	Div 03	Rebar	2	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 7,456
Schrafft	Div 04	CMU, 8" th	1,200	sf	for pump station house or shed. Allow 20 x 20 building (serves both pump stations)	$13.41	$1.29	$3.78	$ 18	$ 22,178
Schrafft	Div 07	Rigid insulation, wall, 2" th	1,200	sf		$0.82	$0.00	$1.67	$ 2.49	$ 2,990
Schrafft	Div 04	Brick veneer	1,200	sf		$16.09	$1.55	$13.56	$ 31	$ 37,443
Schrafft	Div 07	Roofing, preformed metal	400	sf		$7.42	$1.14	$5.00	$ 14	$ 5,424
Schrafft	Div 07	Rigid insulation, roof, 2" th	400	sf		$1.85	$0.00	$1.67	$ 3.52	$ 1,407
Schrafft	Div 07	Snow guard	16	ea	1 per 25 sf	$58.54	$0.00	$18.80	$ 77	$ 1,237
Schrafft	Div 08	Doors, single	1	ea	allow hollow metal, 3' x 7'	$1,143.08	$494.89	$5,000.00	$ 6,638	$ 6,638
Schrafft	Div 08	Door, overhead	1	ea		$2,286.15	$989.78	$12,000.00	$ 15,276	$ 15,276
Schrafft	Div 08	Windows	2	ea		$1,143.08	$494.89	$2,000.00	$ 3,638	$ 7,276
Schrafft	Div 09	Paint interior	1,200	sf		$1.45	$0.00	$3.00	$ 4.45	$ 5,343
Schrafft						$0.00	$0.00		$ -	$ -
Schrafft		Allowances for undefined services				$0.00	$0.00		$ -	$ -
Schrafft	Div 21	Fire suppression allowance	1	ls		$5,845.51	$0.00	$5,000.00	$ 10,846	$ 10,846
Schrafft	Div 22	Plumbing allowance	1	ls		$7,306.89	$0.00	$15,000.00	$ 22,307	$ 22,307
Schrafft	Div 23	HVAC allowance	1	ls		$6,888.00	$822.95	$15,000.00	$ 22,711	$ 22,711
Schrafft	Div 26	Electrical allowance	1	ls	utility hookup not included	$14,084.80	$0.00	$750,000.00	$ 764,085	$ 764,085
Schrafft	Div 26	Duct bank allowance	800	lf	allowance length to both tanks & potential nearby power hookup	$259.39	$36.19	$350.00	$ 646	$ 516,466
						$0.00	$0.00		$ -	$ -
						$0.00	$0.00		$ -	$ -
Columbus		**COLUMBUS PARK**				$0.00	$0.00		$ -	$ -
Columbus		**Sitework & Removals**				$0.00	$0.00		$ -	$ -
Columbus	Div 02	Remove & store existing light poles	2	ea		$1,395.21	$1,247.91	$0.00	$ 2,643	$ 5,286
Columbus	Div 02	Clear & grub @ tank area	18,500	sf		$0.22	$0.04	$0.00	$ 0.25	$ 4,671
Columbus	Div 02	Remove brick walkway	1,100	sf		$6.96	$0.00	$0.00	$ 6.96	$ 7,653
Columbus						$0.00	$0.00		$ -	$ -
Columbus	Div 32	Sodding, 1" depth	18,500	sf	restore disturbed lawm area	$0.32	$0.05	$0.32	$ 0.70	$ 12,889
Columbus	Div 32	Additional landscaping restoration allowance	1	ls		$8,032.38	$1,310.37	$10,000.00	$ 19,343	$ 19,343
Columbus	Div 32	Reinstall light poles	2	ea		$1,395.21	$1,247.91	$0.00	$ 2,643	$ 5,286
Columbus	Div 32	Restore brick walkway	1,100	sf		$20.66	$0.00	$7.19	$ 28	$ 30,634
Columbus						$0.00	$0.00		$ -	$ -
Columbus		**Proposed Pipelines**				$0.00	$0.00		$ -	$ -
Columbus	Div 33	RCP, 84"dia	40	lf	distance btwn exist pipeline and storage tank not specified	$111.54	$82.86	$809.97	$ 1,004	$ 40,175
Columbus	Div 31	Trench excavation	360	cy	combined qty for RCP and diversion structure	$3.45	$2.38	$0.00	$ 5.83	$ 2,101
Columbus	Div 31	Haul & dispose	440	lcy		$12.62	$11.80	$5.00	$ 29	$ 12,943
Columbus	Div 33	SOE, trench sheeting	3,700	sf		$1.26	$0.31	$0.75	$ 2.31	$ 8,558
Columbus	Div 31	Screened gravel, backfill, 6-8" lifts	300	cy		$6.69	$3.20	$0.00	$ 9.89	$ 2,968
Columbus	Div 31	Haul borrow material	300	cy		$12.62	$11.80	$30.00	$ 54	$ 16,325
Columbus	Div 33	Diversion Structure	1	ea	allow cast-in-place chamber	$26,928.35	$11,048.59	$35,000.00	$ 72,977	$ 72,977
Columbus	Div 33	Bypass pumping allowance @ existing pipeline	14	day	calendar days (full time 24/7 pumping) - allow 2 weeks per	$1,770.61	$526.03	$1,500.00	$ 3,797	$ 53,153
Columbus	Div 02	Cut & remove existing RCP @ diversion structure/tie-in	10	lf		$647.99	$396.68	$0.00	$ 1,045	$ 10,447
Columbus						$0.00	$0.00		$ -	$ -
Columbus		**Pumps & Discharge Piping**				$0.00	$0.00		$ -	$ -
Columbus	Div 33	Dewatering Pumps	2	ea		$13,300.05	$4,879.55	$25,000.00	$ 43,180	$ 86,359
Columbus	Div 33	Stormwater Pumps - 80 CFS pump station (2 duty + 1 standby)	2	ea	allow based on quote for 167CFS pumps - 40 CFS per duty	$14,633.31	$6,441.00	$350,000.00	$ 371,074	$ 742,149
Columbus						$0.00	$0.00		$ -	$ -
Columbus	Div 33	Stormwater pump discharge, 3ft dia, DIP	120	lf	allow mech joint DIP, allow 60 lf per discharge	$98.04	$36.19	$364.49	$ 499	$ 59,846
Columbus	Div 33	Fittings, 3ft dia, DIP	8	ea	4 ea per discharge	$980.40	$361.88	$13,215.00	$ 14,557	$ 116,458
Columbus						$0.00	$0.00		$ -	$ -
Columbus	Div 33	Dewater pump discharge, 1ft dia, DIP	120	lf	allow mech joint DIP	$28.01	$10.34	$223.10	$ 261	$ 31,374
Columbus	Div 33	Fittings, 1ft dia, DIP	8	ea		$280.11	$103.40	$2,060.00	$ 2,444	$ 19,548
Columbus						$0.00	$0.00		$ -	$ -
Columbus	Div 33	Box discharge structure	1	ls	allowance	$11,764.77	$4,342.60	$20,000.00	$ 36,107	$ 36,107
Columbus						$0.00	$0.00		$ -	$ -
Columbus		**Storage Tank - 1.26 MG**				$0.00	$0.00		$ -	$ -
Columbus	Div 31	Temporary SOE - sheet pile wall, drive, extract & salvage	250	ton	allow around perimeter of pump station	$468.24	$455.95	$530.00	$ 1,454	$ 363,548
Columbus	Div 31	Structure excavation	8,480	bcy		$4.61	$3.17	$0.00	$ 7.78	$ 65,974
Columbus	Div 31	Bedding stone, 6", including grading	240	cy		$20.08	$4.93	$30.00	$ 55	$ 13,202
Columbus	Div 31	Structure backfill	2,000	bcy		$26.34	$14.27	$0.00	$ 41	$ 81,221
Columbus	Div 31	Haul & dispose excess dirt	7,780	lcy		$12.62	$11.80	$5.00	$ 29	$ 228,852
Columbus						$0.00	$0.00		$ -	$ -
Columbus	Div 03	Tank, floor slab, 24" th	950	cy		$21.09	$0.00	$145.00	$ 166	$ 157,782
Columbus	Div 03	Formwork, slab edge	1,020	sfca		$6.54	$0.00	$6.72	$ 13	$ 13,525
Columbus	Div 03	Rebar	95	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 354,177
Columbus	Div 03	Tank, exterior and bay walls	550	cy	2ft thick exterior walls; 1ft thick bay wall	$33.39	$0.00	$145.00	$ 178	$ 98,112
Columbus	Div 03	Formwork, wall	15,850	sfca		$6.54	$0.00	$6.72	$ 13	$ 210,175

Location Code	CSI Div.	Description	Quantity	Unit	Notes	Labor Unit Cost	Equipment Unit Cost	Material Unit Cost	Total Unit Cost	Total Amount
Columbus	Div 03	Rebar	50	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 186,409
Columbus	Div 03	Tank, flow straightening piers, 12" th	20	cy		$66.77	$0.00	$145.00	$ 212	$ 4,235
Columbus	Div 03	Formwork, column	954	sfca		$6.54	$0.00	$6.72	$ 13	$ 12,650
Columbus	Div 03	Rebar	3	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 11,185
Columbus	Div 03	Tank, support columns, 12" th	70	cy	none shown, carry as allowance (20 ft grid spacing)	$66.77	$0.00	$145.00	$ 212	$ 14,824
Columbus	Div 03	Formwork, column	3,370	sfca		$6.54	$0.00	$6.72	$ 13	$ 44,684
Columbus	Div 03	Rebar	11	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 39,146
Columbus	Div 03	Tank, support beams, 12" th	60	cy	none shown, carry as allowance (20 ft spacing)	$66.77	$0.00	$145.00	$ 212	$ 12,706
Columbus	Div 03	Formwork, beam	3,060	sfca		$6.54	$0.00	$6.72	$ 13	$ 40,576
Columbus	Div 03	Rebar	5	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 20,132
Columbus	Div 03	Tank, roof slab, 12" th	475	cy		$42.17	$0.00	$145.00	$ 187	$ 88,907
Columbus	Div 03	Formwork, slab edge	510	sfca		$6.54	$0.00	$6.72	$ 13	$ 6,763
Columbus	Div 03	Formwork, supported slab	12,716	sfca		$5.53	$0.00	$6.72	$ 12	$ 155,823
Columbus	Div 03	Rebar	48	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 177,089
Columbus						$0.00	$0.00		$ -	$ -
Columbus		**Electrical House**				$0.00	$0.00		$ -	$ -
Columbus	Div 03	House, floor slab, 12" th	10	cy		$44.51	$0.00	$145.00	$ 190	$ 1,895
Columbus	Div 03	Formwork, slab edge	60	sfca		$6.54	$0.00	$6.72	$ 13	$ 796
Columbus	Div 03	Rebar	1	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 3,728
Columbus	Div 04	CMU, 8" th	900	sf	for pump station house or shed. Allow 10 x 20 building	$13.41	$1.29	$3.78	$ 18	$ 16,634
Columbus	Div 07	Rigid insulation, wall, 2" th	900	sf		$0.82	$0.00	$1.67	$ 2.49	$ 2,242
Columbus	Div 04	Brick veneer	900	sf		$16.09	$1.55	$13.56	$ 31	$ 28,082
Columbus	Div 07	Roofing, preformed metal	200	sf		$7.42	$1.14	$5.00	$ 14	$ 2,712
Columbus	Div 07	Rigid insulation, roof, 2" th	200	sf		$1.85	$0.00	$1.67	$ 3.52	$ 704
Columbus	Div 07	Snow guard	8	ea	1 per 25 sf	$58.54	$0.00	$18.80	$ 77	$ 619
Columbus	Div 08	Doors, single	1	ea	allow hollow metal, 3' x 7'	$1,143.08	$494.89	$5,000.00	$ 6,638	$ 6,638
Columbus	Div 08	Door, overhead	1	ea		$2,286.15	$989.78	$12,000.00	$ 15,276	$ 15,276
Columbus	Div 08	Windows	2	ea		$1,143.08	$494.89	$2,000.00	$ 3,638	$ 7,276
Columbus	Div 09	Paint interior	900	sf		$1.45	$0.00	$3.00	$ 4.45	$ 4,007
Columbus						$0.00	$0.00		$ -	$ -
Columbus		Allowances for undefined services				$0.00	$0.00		$ -	$ -
Columbus	Div 21	Fire suppression allowance	1	ls		$5,845.51	$0.00	$5,000.00	$ 10,846	$ 10,846
Columbus	Div 22	Plumbing allowance	1	ls		$7,306.89	$0.00	$15,000.00	$ 22,307	$ 22,307
Columbus	Div 23	HVAC allowance	1	ls		$6,888.00	$822.95	$15,000.00	$ 22,711	$ 22,711
Columbus	Div 26	Electrical allowance	1	ls	utility hookup not included	$14,084.80	$0.00	$300,000.00	$ 314,085	$ 314,085
Columbus	Div 26	Duct bank allowance	250	lf	allowance length to potential nearby power hookup	$259.39	$36.19	$350.00	$ 646	$ 161,396
						$0.00	$0.00		$ -	$ -
						$0.00	$0.00		$ -	$ -
Constitution		**CONSTITUTION BEACH**				$0.00	$0.00		$ -	$ -
Constitution		**Sitework & Removals**				$0.00	$0.00		$ -	$ -
Constitution	Div 02	Surface removal, asphalt parking lot / pathways	2,400	sy	allow 9" removal across entire site area	$8.15	$4.06	$0.00	$ 12	$ 29,304
Constitution	Div 02	Haul & dispose	700	lcy		$12.62	$11.80	$20.00	$ 44	$ 31,091
Constitution						$0.00	$0.00		$ -	$ -
Constitution	Div 32	Surface restore, subbase, 6" aggregate	2,400	sy		$1.09	$1.47	$3.79	$ 6.35	$ 15,236
Constitution	Div 32	Surface restore, asphalt, 1.5" binder	2,400	sy		$7.19	$5.93	$5.45	$ 19	$ 44,580
Constitution	Div 32	Surface restore, asphalt, 1.5" wearing	2,400	sy		$7.19	$5.93	$6.10	$ 19	$ 46,140
Constitution	Div 32	Pavement marking, parking lot	1,000	lf	restore to current condition	$0.00	$0.00	$5.00	$ 5.00	$ 5,000
Constitution	Div 32	Sodding, 1" depth	10,000	sf	restore disturbed lawn area	$0.32	$0.05	$0.32	$ 0.70	$ 6,967
Constitution	Div 32	Additional landscaping restoration allowance	1	ls		$8,032.38	$1,310.37	$7,500.00	$ 16,843	$ 16,843
Constitution						$0.00	$0.00		$ -	$ -
Constitution		**Proposed Pipelines**				$0.00	$0.00		$ -	$ -
Constitution	Div 33	RCP, 18"dia	220	lf	distance btwn exist pipeline and storage tank not specified	$34.32	$25.50	$145.00	$ 205	$ 45,060
Constitution	Div 31	Trench excavation	960	cy	combined qty for RCP and diversion structure	$3.45	$2.38	$0.00	$ 5.83	$ 5,602
Constitution	Div 31	Haul & dispose	1,160	lcy		$12.62	$11.80	$5.00	$ 29	$ 34,122
Constitution	Div 33	SOE, trench sheeting	18,600	sf		$1.26	$0.31	$0.75	$ 2.31	$ 43,021
Constitution	Div 31	Screened gravel, backfill, 6-8" lifts	1,000	cy		$6.69	$3.20	$0.00	$ 9.89	$ 9,893
Constitution	Div 31	Haul borrow material	1,000	cy		$12.62	$11.80	$30.00	$ 54	$ 54,415
Constitution	Div 33	Diversion Structure	2	ea	allow cast-in-place chamber	$26,928.35	$11,048.59	$25,000.00	$ 62,977	$ 125,954
Constitution	Div 33	Bypass pumping allowance @ existing pipeline	28	day	calendar days (full time 24/7 pumping) - allow 2 weeks per	$1,770.61	$526.03	$1,500.00	$ 3,797	$ 106,306
Constitution	Div 02	Cut & remove existing RCP @ diversion structure/tie-in	14	lf		$647.99	$396.68	$0.00	$ 1,045	$ 14,625
Constitution						$0.00	$0.00		$ -	$ -
Constitution		**Pumps & Discharge Piping**				$0.00	$0.00		$ -	$ -
Constitution	Div 33	Dewatering Pumps	2	ea		$13,300.05	$4,879.55	$25,000.00	$ 43,180	$ 86,359
Constitution	Div 33	Stormwater Pumps - 150 CFS pump station (2 duty + 1 standby)	3	ea	allow based on quote for 167CFS pumps - 75 CFS per duty	$14,633.31	$6,441.00	$500,000.00	$ 521,074	$ 1,563,223
Constitution						$0.00	$0.00		$ -	$ -
Constitution	Div 33	Stormwater pump discharge, 2ft dia, DIP	1,050	lf	allow mech joint DIP, allow 350 lf per discharge (to beach)	$58.82	$21.71	$258.62	$ 339	$ 356,115
Constitution	Div 33	Fittings, 2ft dia, DIP	12	ea	4 ea per discharge	$625.79	$230.99	$8,810.00	$ 9,667	$ 116,001
Constitution						$0.00	$0.00		$ -	$ -
Constitution	Div 33	Dewater pump discharge, 1ft dia, DIP	700	lf	allow mech joint DIP	$28.01	$10.34	$223.10	$ 261	$ 183,016
Constitution	Div 33	Fittings, 1ft dia, DIP	8	ea		$280.11	$103.40	$2,060.00	$ 2,444	$ 19,548
Constitution						$0.00	$0.00		$ -	$ -
Constitution	Div 33	Box discharge structure	1	ls	not shown, include due to beachside discharge location	$11,764.77	$4,342.60	$20,000.00	$ 36,107	$ 36,107
Constitution						$0.00	$0.00		$ -	$ -
Constitution		**Storage Tank - 1.4 MG**				$0.00	$0.00		$ -	$ -
Constitution	Div 31	Temporary SOE - sheet pile wall, drive, extract & salvage	490	ton	allow around perimeter of pump station	$468.24	$455.95	$530.00	$ 1,454	$ 712,554
Constitution	Div 31	Structure excavation	9,640	bcy		$4.61	$3.17	$0.00	$ 7.78	$ 74,999
Constitution	Div 31	Bedding stone, 6", including grading	200	cy		$20.08	$4.93	$30.00	$ 55	$ 11,001
Constitution	Div 31	Structure backfill	2,500	bcy		$26.34	$14.27	$0.00	$ 41	$ 101,526
Constitution	Div 31	Haul & dispose excess dirt	8,570	lcy		$12.62	$11.80	$5.00	$ 29	$ 252,090
Constitution						$0.00	$0.00		$ -	$ -
Constitution	Div 03	Tank, floor slab, 24" th	780	cy		$21.09	$0.00	$145.00	$ 166	$ 129,547
Constitution	Div 03	Formwork, slab edge	1,510	sfca		$6.54	$0.00	$6.72	$ 13	$ 20,023
Constitution	Div 03	Rebar	78	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 290,798
Constitution	Div 03	Tank, exterior and bay walls	1,070	cy	2ft thick exterior walls; 1ft thick bay wall	$33.39	$0.00	$145.00	$ 178	$ 190,873
Constitution	Div 03	Formwork, wall	30,170	sfca		$6.54	$0.00	$6.72	$ 13	$ 400,062
Constitution	Div 03	Rebar	90	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 335,536
Constitution	Div 03	Tank, flow straightening piers, 12" th	30	cy		$66.77	$0.00	$145.00	$ 212	$ 6,353
Constitution	Div 03	Formwork, column	1,728	sfca		$6.54	$0.00	$6.72	$ 13	$ 22,914
Constitution	Div 03	Rebar	5	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 16,777
Constitution	Div 03	Tank, support columns, 12" th	70	cy	none shown, carry as allowance (20 ft grid spacing)	$66.77	$0.00	$145.00	$ 212	$ 14,824
Constitution	Div 03	Formwork, column	3,748	sfca		$6.54	$0.00	$6.72	$ 13	$ 49,694
Constitution	Div 03	Rebar	11	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 39,146
Constitution	Div 03	Tank, support beams, 12" th	50	cy	none shown, carry as allowance (20 ft spacing)	$66.77	$0.00	$145.00	$ 212	$ 10,589
Constitution	Div 03	Formwork, beam	2,700	sfca		$6.54	$0.00	$6.72	$ 13	$ 35,803
Constitution	Div 03	Rebar	5	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 16,777
Constitution	Div 03	Tank, roof slab, 12" th	390	cy		$42.17	$0.00	$145.00	$ 187	$ 72,997
Constitution	Div 03	Formwork, slab edge	755	sfca		$6.54	$0.00	$6.72	$ 13	$ 10,011
Constitution	Div 03	Formwork, supported slab	10,410	sfca		$5.53	$0.00	$6.72	$ 12	$ 127,565
Constitution	Div 03	Rebar	39	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 145,399
Constitution						$0.00	$0.00		$ -	$ -
Constitution		**Electrical House**				$0.00	$0.00		$ -	$ -
Constitution	Div 03	House, floor slab, 12" th	10	cy		$44.51	$0.00	$145.00	$ 190	$ 1,895
Constitution	Div 03	Formwork, slab edge	60	sfca		$6.54	$0.00	$6.72	$ 13	$ 796
Constitution	Div 03	Rebar	1	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 3,728
Constitution	Div 04	CMU, 8" th	900	sf	for pump station house or shed. Allow 10 x 20 building	$13.41	$1.29	$3.78	$ 18	$ 16,634
Constitution	Div 07	Rigid insulation, wall, 2" th	900	sf		$0.82	$0.00	$1.67	$ 2.49	$ 2,242
Constitution	Div 04	Brick veneer	900	sf		$16.09	$1.55	$13.56	$ 31	$ 28,082
Constitution	Div 07	Roofing, preformed metal	200	sf		$7.42	$1.14	$5.00	$ 14	$ 2,712
Constitution	Div 07	Rigid insulation, roof, 2" th	200	sf		$1.85	$0.00	$1.67	$ 3.52	$ 704
Constitution	Div 07	Snow guard	8	ea	1 per 25 sf	$58.54	$0.00	$18.80	$ 77	$ 619
Constitution	Div 08	Doors, single	1	ea	allow hollow metal, 3' x 7'	$1,143.08	$494.89	$5,000.00	$ 6,638	$ 6,638
Constitution	Div 08	Door, overhead	1	ea		$2,286.15	$989.78	$12,000.00	$ 15,276	$ 15,276
Constitution	Div 08	Windows	2	ea		$1,143.08	$494.89	$2,000.00	$ 3,638	$ 7,276
Constitution	Div 09	Paint interior	900	sf		$1.45	$0.00	$3.00	$ 4.45	$ 4,007
Constitution						$0.00	$0.00		$ -	$ -
Constitution		Allowances for undefined services				$0.00	$0.00		$ -	$ -
Constitution	Div 21	Fire suppression allowance	1	ls		$5,845.51	$0.00	$5,000.00	$ 10,846	$ 10,846
Constitution	Div 22	Plumbing allowance	1	ls		$7,306.89	$0.00	$15,000.00	$ 22,307	$ 22,307
Constitution	Div 23	HVAC allowance	1	ls		$6,888.00	$822.95	$15,000.00	$ 22,711	$ 22,711
Constitution	Div 26	Electrical allowance	1	ls	utility hookup not included	$14,084.80	$0.00	$500,000.00	$ 514,085	$ 514,085
Constitution	Div 26	Duct bank allowance	600	lf	allowance length to potential nearby power hookup	$259.39	$36.19	$350.00	$ 646	$ 387,349
						$0.00	$0.00		$ -	$ -
						$0.00	$0.00		$ -	$ -
E. Boston		**EAST BOSTON WATERFRONT**				$0.00	$0.00		$ -	$ -
E. Boston		**Proposed Pipelines**				$0.00	$0.00		$ -	$ -
E. Boston	Div 33	RCP, 15"dia	250	lf		$23.24	$17.26	$145.00	$ 186	$ 46,375

Location Code	CSI Div.	Description	Quantity	Unit	Notes	Labor Unit Cost	Equipment Unit Cost	Material Unit Cost	Total Unit Cost	Total Amount
E. Boston	Div 33	RCP, 36"dia	260	lf		$46.48	$34.53	$224.00	$ 305	$ 79,300
E. Boston	Div 33	RCP, 48"dia	1,270	lf		$69.71	$51.79	$320.00	$ 442	$ 560,709
E. Boston	Div 33	RCP, 50"dia	480	lf		$69.71	$51.79	$320.00	$ 442	$ 211,921
E. Boston	Div 33	RCP, 68"dia	1,380	lf		$74.36	$55.24	$625.00	$ 755	$ 1,041,352
E. Boston	Div 31	Trench excavation	12,710	bcy		$3.45	$2.38	$0.00	$ 5.83	$ 74,162
E. Boston	Div 31	Haul & dispose	15,260	lcy		$12.62	$11.80	$5.00	$ 29	$ 448,879
E. Boston	Div 33	SOE, trench sheeting	80,640	sf		$0.63	$0.15	$0.75	$ 1.53	$ 123,498
E. Boston	Div 31	Screened gravel, backfill, 6-8" lifts	10,580	cy		$6.69	$3.20	$0.00	$ 9.89	$ 104,665
E. Boston	Div 31	Haul borrow material	10,580	cy		$12.62	$11.80	$30.00	$ 54	$ 575,715
E. Boston	Div 33	Manhole, precast, storm	9	ea		$2,019.63	$828.64	$3,000.00	$ 5,848	$ 52,634
E. Boston	Div 33	Manhole cover	9	ea		$360.31	$67.85	$750.00	$ 1,178	$ 10,603
E. Boston	Div 33	Diversion Structures	4	ea	allow cast-in-place chamber	$20,196.26	$8,286.45	$30,000.00	$ 58,483	$ 233,931
E. Boston	Div 33	Bypass pumping allowance @ existing pipeline	56	day	calendar days (full time 24/7 pumping) - allow 2 weeks per	$1,770.61	$526.03	$1,500.00	$ 3,797	$ 212,612
E. Boston	Div 02	Cut & remove existing RCP @ diversion structure/tie-in	40	lf		$647.99	$396.68	$0.00	$ 1,045	$ 41,787
E. Boston	Div 02	Surface removal, asphalt road, 3" th	4,500	sy		$4.96	$2.47	$0.00	$ 7.43	$ 33,445
E. Boston	Div 32	Surface restore, asphalt road, 1.5" binder	4,500	sy	subbase will be covered by trench backfill (gravel per BWSC std)	$7.19	$5.93	$5.45	$ 19	$ 83,587
E. Boston	Div 32	Surface restore, asphalt road, 1.5" wearing	4,500	sy		$7.19	$5.93	$6.10	$ 19	$ 86,512
E. Boston	Div 33	Traffic Protection	150	shifts	total duration of trench & RCP work, include cost for MPT	$762.23	$186.70	$60.00	$ 1,009	$ 151,339
E. Boston										
E. Boston		**Pumps & Discharge Piping**				$0.00	$0.00			
E. Boston	Div 33	Dewatering Pumps	2	ea		$13,300.05	$4,879.55	$25,000.00		
E. Boston	Div 33	Stormwater Pumps - 40 CFS pump station (1 duty + 1 standby)	2	ea	allow based on quote for 167CFS station - 40 CFS per duty pump	$14,633.31	$6,441.00	$350,000.00	$ 371,074	$ 742,149
E. Boston						$0.00	$0.00		$ -	$ -
E. Boston	Div 33	Stormwater pump discharge, 2ft dia, DIP	40	lf	allow mech joint DIP, allow 20 lf per discharge	$58.82	$21.71	$258.62	$ 339	$ 13,566
E. Boston	Div 33	Fittings, 2ft dia, DIP	4	ea	2 ea per discharge	$625.79	$230.99	$8,810.00	$ 9,667	$ 38,667
E. Boston						$0.00	$0.00		$ -	$ -
E. Boston	Div 33	Dewater pump discharge, 1ft dia, DIP	40	lf	allow mech joint DIP	$28.01	$10.34	$223.10	$ 261	$ 10,458
E. Boston	Div 33	Fittings, 1ft dia, DIP	4	ea		$280.11	$103.40	$2,060.00	$ 2,444	$ 9,774
E. Boston						$0.00	$0.00		$ -	$ -
E. Boston		**Pump Station Tank**			not for storage, only houses pump intakes	$0.00	$0.00		$ -	$ -
E. Boston	Div 31	Temporary SOE - sheet pile wall, drive, extract & salvage	60	ton	allow around perimeter of pump station	$468.24	$455.95	$530.00	$ 1,454	$ 87,251
E. Boston	Div 31	Structure excavation	370	bcy		$4.61	$3.17	$0.00	$ 7.78	$ 2,879
E. Boston	Div 31	Bedding stone, 6", including grading	10	cy		$20.08	$4.93	$30.00	$ 55	$ 550
E. Boston	Div 31	Structure backfill	120	bcy		$26.34	$14.27	$0.00	$ 41	$ 4,873
E. Boston	Div 31	Haul & dispose excess dirt	300	lcy		$12.62	$11.80	$5.00	$ 29	$ 8,825
E. Boston						$0.00	$0.00		$ -	$ -
E. Boston	Div 03	Tank, floor slab, 24" th	40	cy		$21.09	$0.00	$145.00	$ 166	$ 6,643
E. Boston	Div 03	Formwork, slab edge	170	sfca		$6.54	$0.00	$6.72	$ 13	$ 2,254
E. Boston	Div 03	Rebar	4	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 14,913
E. Boston	Div 03	Tank, exterior and bay walls	120	cy	2ft thick exterior walls; 1ft thick bay wall	$33.39	$0.00	$145.00	$ 178	$ 21,406
E. Boston	Div 03	Formwork, wall	3,510	sfca		$6.54	$0.00	$6.72	$ 13	$ 46,543
E. Boston	Div 03	Rebar	10	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 37,282
E. Boston	Div 03	Tank, flow straightening piers, 12" th	10	cy		$66.77	$0.00	$145.00	$ 212	$ 2,118
E. Boston	Div 03	Formwork, column	783	sfca		$6.54	$0.00	$6.72	$ 13	$ 10,383
E. Boston	Div 03	Rebar	2	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 5,592
E. Boston	Div 03	Tank, roof slab, 12" th	20	cy		$42.17	$0.00	$145.00	$ 187	$ 3,743
E. Boston	Div 03	Formwork, slab edge	85	sfca		$6.54	$0.00	$6.72	$ 13	$ 1,127
E. Boston	Div 03	Formwork, supported slab	451	sfca		$5.53	$0.00	$6.72	$ 12	$ 5,527
E. Boston	Div 03	Rebar	2	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 7,456
E. Boston	Div 03	Energy dissipation structure	20	cy	allow dimensions	$80.13	$0.00	$145.00	$ 225	$ 4,503
E. Boston	Div 03	Formwork, slab edge	220	sfca	allow extra form area for dissipation blocks	$11.51	$0.00	$6.72	$ 18	$ 4,011
E. Boston	Div 03	Rebar	2	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 7,456
E. Boston						$0.00	$0.00		$ -	$ -
E. Boston		**Electrical House**				$0.00	$0.00		$ -	$ -
E. Boston	Div 03	House, floor slab, 12" th	10	cy		$44.51	$0.00	$145.00	$ 190	$ 1,895
E. Boston	Div 03	Formwork, slab edge	60	sfca		$6.54	$0.00	$6.72	$ 13	$ 796
E. Boston	Div 03	Rebar	1	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 3,728
E. Boston	Div 04	CMU, 8" th	900	sf	for pump station house or shed. Allow 10 x 20 building	$13.41	$1.29	$3.78	$ 18	$ 16,634
E. Boston	Div 07	Rigid insulation, wall, 2" th	900	sf		$0.82	$0.00	$1.67	$ 2.49	$ 2,242
E. Boston	Div 04	Brick veneer	900	sf		$16.09	$1.55	$13.56	$ 31	$ 28,082
E. Boston	Div 07	Roofing, preformed metal	200	sf		$7.42	$1.14	$5.00	$ 14	$ 2,712
E. Boston	Div 07	Rigid insulation, roof, 2" th	200	sf		$1.85	$0.00	$1.67	$ 3.52	$ 704
E. Boston	Div 07	Snow guard	8	ea	1 per 25 sf	$58.54	$0.00	$18.80	$ 77	$ 619
E. Boston	Div 08	Doors, single	1	ea	allow hollow metal, 3' x 7'	$1,143.08	$494.89	$5,000.00	$ 6,638	$ 6,638
E. Boston	Div 08	Door, overhead	1	ea		$2,286.15	$989.78	$12,000.00	$ 15,276	$ 15,276
E. Boston	Div 08	Windows	2	ea		$1,143.08	$494.89	$2,000.00	$ 3,638	$ 7,276
E. Boston	Div 09	Paint interior	900	sf		$1.45	$0.00	$3.00	$ 4.45	$ 4,007
E. Boston						$0.00	$0.00		$ -	$ -
E. Boston		Allowances for undefined services				$0.00	$0.00		$ -	$ -
E. Boston	Div 21	Fire suppression allowance	1	ls		$5,845.51	$0.00	$5,000.00	$ 10,846	$ 10,846
E. Boston	Div 22	Plumbing allowance	1	ls		$7,306.89	$0.00	$15,000.00	$ 22,307	$ 22,307
E. Boston	Div 23	HVAC allowance	1	ls		$6,888.00	$822.95	$15,000.00	$ 22,711	$ 22,711
E. Boston	Div 26	Electrical allowance	1	ls	utility hookup not included	$14,084.80	$0.00	$300,000.00	$ 314,085	$ 314,085
E. Boston	Div 26	Duct bank allowance	200	lf	allowance length to potential nearby power hookup	$259.39	$36.19	$350.00	$ 646	$ 129,116
						$0.00	$0.00		$ -	$ -
						$0.00	$0.00		$ -	$ -
Harbor		**HARBOR PARK**				$0.00	$0.00		$ -	$ -
Harbor		**Proposed Pipelines**				$0.00	$0.00		$ -	$ -
Harbor	Div 33	RCP, 72"dia	20	lf	distance btwn exist pipeline and storage tank not specified	$74.36	$55.24	$625.25	$ 755	$ 15,097
Harbor	Div 31	Trench excavation	210	cy	combined qty for RCP and diversion structure	$3.45	$2.38	$0.00	$ 5.83	$ 1,225
Harbor	Div 31	Haul & dispose	260	lcy		$12.62	$11.80	$5.00	$ 29	$ 7,648
Harbor	Div 33	SOE, trench sheeting	2,400	sf		$1.26	$0.31	$0.75	$ 2.31	$ 5,551
Harbor	Div 31	Screened gravel, backfill, 6-8" lifts	200	cy		$6.69	$3.20	$0.00	$ 9.89	$ 1,979
Harbor	Div 31	Haul borrow material	200	cy		$12.62	$11.80	$30.00	$ 54	$ 10,883
Harbor	Div 33	Diversion Structure	1	ea	allow cast-in-place chamber	$26,928.35	$11,048.59	$35,000.00	$ 72,977	$ 72,977
Harbor	Div 33	Bypass pumping allowance @ existing pipeline	14	day	calendar days (full time 24/7 pumping) - allow 2 weeks per	$1,770.61	$526.03	$1,500.00	$ 3,797	$ 53,153
Harbor	Div 02	Cut & remove existing RCP @ diversion structure/tie-in	10	lf		$647.99	$396.68	$0.00	$ 1,045	$ 10,447
Harbor						$0.00	$0.00		$ -	$ -
Harbor		**Pumps & Discharge Piping**				$0.00	$0.00		$ -	$ -
Harbor	Div 33	Dewatering Pumps	2	ea		$13,300.05	$4,879.55	$25,000.00	$ 43,180	$ 86,359
Harbor	Div 33	Stormwater Pumps - 200 CFS pump station (3 duty + 1 standby)	4	ea	allow based on quote for 167CFS pumps - 100 CFS per duty	$14,633.31	$6,441.00	$640,000.00	$ 661,074	$ 2,644,297
Harbor						$0.00	$0.00		$ -	$ -
Harbor	Div 33	Stormwater pump discharge, 3ft dia, DIP	240	lf	allow mech joint DIP, allow 60 lf per discharge	$98.04	$36.19	$364.49	$ 499	$ 119,691
Harbor	Div 33	Fittings, 3ft dia, DIP	16	ea	4 ea per discharge	$980.40	$361.88	$13,215.00	$ 14,557	$ 232,916
Harbor						$0.00	$0.00		$ -	$ -
Harbor	Div 33	Dewater pump discharge, 1ft dia, DIP	120	lf	allow mech joint DIP, allow pipe dia (not specified)	$28.01	$10.34	$223.10	$ 261	$ 31,374
Harbor	Div 33	Fittings, 1ft dia, DIP	8	ea		$280.11	$103.40	$2,060.00	$ 2,444	$ 19,548
Harbor						$0.00	$0.00		$ -	$ -
Harbor		**Storage Tank - 1.4 MG**				$0.00	$0.00		$ -	$ -
Harbor	Div 31	Temporary SOE - sheet pile wall, drive, extract & salvage	270	ton	allow around perimeter of pump station	$468.24	$455.95	$530.00	$ 1,454	$ 392,632
Harbor	Div 31	Structure excavation	8,100	bcy		$4.61	$3.17	$0.00	$ 7.78	$ 63,018
Harbor	Div 31	Bedding stone, 6", including grading	170	cy		$20.08	$4.93	$30.00	$ 55	$ 9,351
Harbor	Div 31	Structure backfill	2,110	bcy		$26.34	$14.27	$0.00	$ 41	$ 85,688
Harbor	Div 31	Haul & dispose excess dirt	7,190	lcy		$12.62	$11.80	$5.00	$ 29	$ 211,497
Harbor						$0.00	$0.00		$ -	$ -
Harbor	Div 03	Tank, floor slab, 24" th	650	cy		$21.09	$0.00	$145.00	$ 166	$ 107,956
Harbor	Div 03	Formwork, slab edge	820	sfca		$6.54	$0.00	$6.72	$ 13	$ 10,873
Harbor	Div 03	Rebar	65	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 242,332
Harbor	Div 03	Tank, exterior and bay walls	670	cy	2ft thick exterior walls; 1ft thick bay wall	$33.39	$0.00	$145.00	$ 178	$ 119,519
Harbor	Div 03	Formwork, wall	21,100	sfca		$6.54	$0.00	$6.72	$ 13	$ 279,791
Harbor	Div 03	Rebar	60	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 223,691
Harbor	Div 03	Tank, flow straightening piers, 12" th	30	cy		$66.77	$0.00	$145.00	$ 212	$ 6,353
Harbor	Div 03	Formwork, column	1,728	sfca		$6.54	$0.00	$6.72	$ 13	$ 22,914
Harbor	Div 03	Rebar	5	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 16,777
Harbor	Div 03	Tank, support columns, 12" th	60	cy	none shown, carry as allowance (20 ft grid spacing)	$66.77	$0.00	$145.00	$ 212	$ 12,706
Harbor	Div 03	Formwork, column	3,147	sfca		$6.54	$0.00	$6.72	$ 13	$ 41,732
Harbor	Div 03	Rebar	9	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 33,554
Harbor	Div 03	Tank, support beams, 12" th	60	cy	none shown, carry as allowance (20 ft spacing)	$66.77	$0.00	$145.00	$ 212	$ 12,706
Harbor	Div 03	Formwork, beam	2,790	sfca		$6.54	$0.00	$6.72	$ 13	$ 36,996
Harbor	Div 03	Rebar	5	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 20,132
Harbor	Div 03	Tank, roof slab, 12" th	325	cy		$42.17	$0.00	$145.00	$ 187	$ 60,831
Harbor	Div 03	Formwork, slab edge	410	sfca		$6.54	$0.00	$6.72	$ 13	$ 5,437
Harbor	Div 03	Formwork, supported slab	8,742	sfca		$5.53	$0.00	$6.72	$ 12	$ 107,125
Harbor	Div 03	Rebar	33	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 121,166
Harbor						$0.00	$0.00		$ -	$ -
Harbor		**Electrical House**				$0.00	$0.00		$ -	$ -

Location Code	CSI Div.	Description	Quantity	Unit	Notes	Labor Unit Cost	Equipment Unit Cost	Material Unit Cost	Total Unit Cost	Total Amount
Harbor	Div 03	House, floor slab, 12" th	10	cy		$44.51	$0.00	$145.00	$ 190	$ 1,895
Harbor	Div 03	Formwork, slab edge	60	sfca		$6.54	$0.00	$6.72	$ 13	$ 796
Harbor	Div 03	Rebar	1	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 3,728
Harbor	Div 04	CMU, 8" th	900	sf	for pump station house or shed. Allow 10 x 20 building	$13.41	$1.29	$3.78	$ 18	$ 16,634
Harbor	Div 07	Rigid insulation, wall, 2" th	900	sf		$0.82	$0.00	$1.67	$ 2.49	$ 2,242
Harbor	Div 04	Brick veneer	900	sf		$16.09	$1.55	$13.56	$ 31	$ 28,082
Harbor	Div 07	Roofing, preformed metal	200	sf		$7.42	$1.14	$5.00	$ 14	$ 2,712
Harbor	Div 07	Rigid insulation, roof, 2" th	200	sf		$1.85	$0.00	$1.67	$ 3.52	$ 704
Harbor	Div 07	Snow guard	8	ea	1 per 25 sf	$58.54	$0.00	$18.80	$ 77	$ 619
Harbor	Div 08	Doors, single	1	ea	allow hollow metal, 3' x 7'	$1,143.08	$494.89	$5,000.00	$ 6,638	$ 6,638
Harbor	Div 08	Door, overhead	1	ea		$2,286.15	$989.78	$12,000.00	$ 15,276	$ 15,276
Harbor	Div 08	Windows	2	ea		$1,143.08	$494.89	$2,000.00	$ 3,638	$ 7,276
Harbor	Div 09	Paint interior	900	sf		$1.45	$0.00	$3.00	$ 4.45	$ 4,007
Harbor						$0.00	$0.00		$ -	$ -
Harbor		Allowances for undefined services				$0.00	$0.00		$ -	$ -
Harbor	Div 21	Fire suppression allowance	1	ls		$5,845.51	$0.00	$5,000.00	$ 10,846	$ 10,846
Harbor	Div 22	Plumbing allowance	1	ls		$7,306.89	$0.00	$15,000.00	$ 22,307	$ 22,307
Harbor	Div 23	HVAC allowance	1	ls		$6,888.00	$822.95	$15,000.00	$ 22,711	$ 22,711
Harbor	Div 26	Electrical allowance	1	ls	utility hookup not included	$14,084.80	$0.00	$750,000.00	$ 764,085	$ 764,085
Harbor	Div 26	Duct bank allowance	200	lf	allowance length to potential nearby power hookup	$259.39	$36.19	$350.00	$ 646	$ 129,116
						$0.00	$0.00		$ -	$ -
						$0.00	$0.00		$ -	$ -
Finnegan		**JOSEPH FINNEGAN PARK**				$0.00	$0.00		$ -	$ -
Finnegan		**Proposed Pipelines**				$0.00	$0.00		$ -	$ -
Finnegan	Div 33	RCP, 48"dia	960	lf		$69.71	$51.79	$320.00	$ 442	$ 423,843
Finnegan	Div 33	RCP, 78"dia	1,011	lf		$89.23	$66.29	$910.00	$ 1,066	$ 1,077,244
Finnegan	Div 33	RCP, 90"dia	90	lf		$111.54	$82.86	$1,186.50	$ 1,381	$ 124,281
Finnegan	Div 31	Trench excavation	8,580	bcy		$3.45	$2.38	$0.00	$ 5.83	$ 50,064
Finnegan	Div 31	Haul & dispose	10,300	lcy		$12.62	$11.80	$5.00	$ 29	$ 302,979
Finnegan	Div 33	SOE, trench sheeting	49,380	sf		$0.63	$0.15	$0.75	$ 1.53	$ 75,624
Finnegan	Div 31	Screened gravel, backfill, 6-8" lifts	6,750	cy		$6.69	$3.20	$0.00	$ 9.89	$ 66,776
Finnegan	Div 31	Haul borrow material	6,750	cy		$12.62	$11.80	$30.00	$ 54	$ 367,304
Finnegan	Div 33	Manhole, precast, storm	6	ea		$2,019.63	$828.64	$3,000.00	$ 5,848	$ 35,090
Finnegan	Div 33	Manhole cover	6	ea		$360.31	$67.85	$750.00	$ 1,178	$ 7,069
Finnegan	Div 33	Diversion Structures	2	ea	allow cast-in-place chamber	$20,196.26	$8,286.45	$30,000.00	$ 58,483	$ 116,965
Finnegan	Div 33	Bypass pumping allowance @ existing pipeline	28	day	calendar days (full time 24/7 pumping) - allow 2 weeks per	$1,770.61	$526.03	$1,500.00	$ 3,797	$ 106,306
Finnegan	Div 02	Cut & remove existing RCP @ diversion structure/tie-in	20	lf		$647.99	$396.68	$0.00	$ 1,045	$ 20,893
Finnegan	Div 02	Surface removal, asphalt road, 3" th	3,000	sy		$4.96	$2.47	$0.00	$ 7.43	$ 22,296
Finnegan	Div 32	Surface restore, asphalt road, 1.5" binder	3,000	sy	subbase will be covered by trench backfill (gravel per BWSC std)	$7.19	$5.93	$5.45	$ 19	$ 55,724
Finnegan	Div 32	Surface restore, asphalt road, 1.5" wearing	3,000	sy		$7.19	$5.93	$6.10	$ 19	$ 57,674
Finnegan	Div 33	Traffic Protection	100	shifts	total duration of trench & RCP work, include cost for MPT	$762.23	$186.70	$60.00	$ 1,009	$ 100,893
Finnegan						$0.00	$0.00		$ -	$ -
Finnegan		**Stormwater Storage Basins**	2	ea	areas as indicated in concept slideshow	$0.00	$0.00		$ -	$ -
Finnegan	Div 31	Clearing & grubbing, tree removal allowance	5	acre	180,000 sf approximate basins area	$4,187.72	$5,082.76	$0.00	$ 9,270	$ 46,352
Finnegan	Div 31	Excavation	74,100	bcy	per concept details; 20.5ft max excavation depth, sloped basin (no SOE)	$2.67	$4.19	$0.00	$ 6.87	$ 508,730
Finnegan	Div 31	Haul & dispose	88,920	lcy	allow full haul-off and dispose	$12.62	$11.80	$5.00	$ 29	$ 2,615,618
Finnegan	Div 32	Landscaping allowance	1	ls	allow topsoil and plantings @ storage basins	$52,684.85	$33,546.19	$200,000.00	$ 286,231	$ 286,231
Finnegan						$0.00	$0.00		$ -	$ -
Finnegan		**Pumps & Discharge Piping**				$0.00	$0.00		$ -	$ -
Finnegan	Div 33	Dewatering Pumps	2	ea		$13,300.05	$4,879.55	$25,000.00	$ 43,180	$ 86,359
Finnegan	Div 33	Stormwater Pumps - 50 CFS pump station (1 duty + 1 standby)	2	ea	allow based on quote for 167CFS station - 50 CFS per duty pump	$14,633.31	$6,441.00	$400,000.00	$ 421,074	$ 842,149
Finnegan						$0.00	$0.00		$ -	$ -
Finnegan	Div 33	Stormwater pump discharge, 3.5ft dia, DIP	40	lf	allow mech joint DIP, allow 20 lf per discharge	$98.04	$36.19	$400.00	$ 534	$ 21,369
Finnegan	Div 33	Fittings, 3.5ft dia, DIP	4	ea	2 ea per discharge	$980.40	$361.88	$15,000.00	$ 16,342	$ 65,369
Finnegan						$0.00	$0.00		$ -	$ -
Finnegan	Div 33	Dewater pump discharge, 1ft dia, DIP	40	lf	allow mech joint DIP	$28.01	$10.34	$223.10	$ 261	$ 10,458
Finnegan	Div 33	Fittings, 1ft dia, DIP	4	ea		$280.11	$103.40	$2,060.00	$ 2,444	$ 9,774
Finnegan						$0.00	$0.00		$ -	$ -
Finnegan		**Pump Station Tank**			not for storage, only houses pump intakes	$0.00	$0.00		$ -	$ -
Finnegan	Div 31	Temporary SOE - sheet pile wall, drive, extract & salvage	60	ton	allow around perimeter of pump station	$468.24	$455.95	$530.00	$ 1,454	$ 87,251
Finnegan	Div 31	Structure excavation	370	bcy		$4.61	$3.17	$0.00	$ 7.78	$ 2,879
Finnegan	Div 31	Bedding stone, 6", including grading	10	cy		$20.08	$4.93	$30.00	$ 55	$ 550
Finnegan	Div 31	Structure backfill	120	bcy		$26.34	$14.27	$0.00	$ 41	$ 4,873
Finnegan	Div 31	Haul & dispose excess dirt	300	lcy		$12.62	$11.80	$5.00	$ 29	$ 8,825
Finnegan						$0.00	$0.00		$ -	$ -
Finnegan	Div 03	Tank, floor slab, 24" th	40	cy		$21.09	$0.00	$145.00	$ 166	$ 6,643
Finnegan	Div 03	Formwork, slab edge	170	sfca		$6.54	$0.00	$6.72	$ 13	$ 2,254
Finnegan	Div 03	Rebar	4	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 14,913
Finnegan	Div 03	Tank, exterior and bay walls	120	cy	2ft thick exterior walls; 1ft thick bay wall	$33.39	$0.00	$145.00	$ 178	$ 21,406
Finnegan	Div 03	Formwork, wall	3,510	sfca		$6.54	$0.00	$6.72	$ 13	$ 46,543
Finnegan	Div 03	Rebar	10	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 37,282
Finnegan	Div 03	Tank, flow straightening piers, 12" th	10	cy		$66.77	$0.00	$145.00	$ 212	$ 2,118
Finnegan	Div 03	Formwork, column	783	sfca		$6.54	$0.00	$6.72	$ 13	$ 10,383
Finnegan	Div 03	Rebar	2	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 5,592
Finnegan	Div 03	Tank, roof slab, 12" th	20	cy		$42.17	$0.00	$145.00	$ 187	$ 3,743
Finnegan	Div 03	Formwork, slab edge	85	sfca		$6.54	$0.00	$6.72	$ 13	$ 1,127
Finnegan	Div 03	Formwork, supported slab	451	sfca		$5.53	$0.00	$6.72	$ 12	$ 5,527
Finnegan	Div 03	Rebar	2	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 7,456
Finnegan	Div 03	Energy dissipation structure	20	cy	allow dimensions	$80.13	$0.00	$145.00	$ 225	$ 4,503
Finnegan	Div 03	Formwork, slab edge	220	sfca	allow extra form area for dissipation blocks	$11.51	$0.00	$6.72	$ 18	$ 4,011
Finnegan	Div 03	Rebar	2	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 7,456
Finnegan						$0.00	$0.00		$ -	$ -
Finnegan		**Electrical House**				$0.00	$0.00		$ -	$ -
Finnegan	Div 03	House, floor slab, 12" th	10	cy		$44.51	$0.00	$145.00	$ 190	$ 1,895
Finnegan	Div 03	Formwork, slab edge	60	sfca		$6.54	$0.00	$6.72	$ 13	$ 796
Finnegan	Div 03	Rebar	1	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 3,728
Finnegan	Div 04	CMU, 8" th	900	sf	for pump station house or shed. Allow 10 x 20 building	$13.41	$1.29	$3.78	$ 18	$ 16,634
Finnegan	Div 07	Rigid insulation, wall, 2" th	900	sf		$0.82	$0.00	$1.67	$ 2.49	$ 2,242
Finnegan	Div 04	Brick veneer	900	sf		$16.09	$1.55	$13.56	$ 31	$ 28,082
Finnegan	Div 07	Roofing, preformed metal	200	sf		$7.42	$1.14	$5.00	$ 14	$ 2,712
Finnegan	Div 07	Rigid insulation, roof, 2" th	200	sf		$1.85	$0.00	$1.67	$ 3.52	$ 704
Finnegan	Div 07	Snow guard	8	ea	1 per 25 sf	$58.54	$0.00	$18.80	$ 77	$ 619
Finnegan	Div 08	Doors, single	1	ea	allow hollow metal, 3' x 7'	$1,143.08	$494.89	$5,000.00	$ 6,638	$ 6,638
Finnegan	Div 08	Door, overhead	1	ea		$2,286.15	$989.78	$12,000.00	$ 15,276	$ 15,276
Finnegan	Div 08	Windows	2	ea		$1,143.08	$494.89	$2,000.00	$ 3,638	$ 7,276
Finnegan	Div 09	Paint interior	900	sf		$1.45	$0.00	$3.00	$ 4.45	$ 4,007
Finnegan						$0.00	$0.00		$ -	$ -
Finnegan		Allowances for undefined services				$0.00	$0.00		$ -	$ -
Finnegan	Div 21	Fire suppression allowance	1	ls		$5,845.51	$0.00	$5,000.00	$ 10,846	$ 10,846
Finnegan	Div 22	Plumbing allowance	1	ls		$7,306.89	$0.00	$15,000.00	$ 22,307	$ 22,307
Finnegan	Div 23	HVAC allowance	1	ls		$6,888.00	$822.95	$15,000.00	$ 22,711	$ 22,711
Finnegan	Div 26	Electrical allowance	1	ls	utility hookup not included	$14,084.80	$0.00	$300,000.00	$ 314,085	$ 314,085
Finnegan	Div 26	Duct bank allowance	600	lf	allowance length to potential nearby power hookup	$259.39	$36.19	$350.00	$ 646	$ 387,349
						$0.00	$0.00		$ -	$ -

Hazen

Boston Water and Sewer Commission
Coastal Stormwater Discharge Analysis
Conceptual - Phase 2
Estimate Summary - CSI Division by WBS

11/17/2022
11/11/2022

	Description			Airport	Charlestown Schrafft Center	Columbus Park	Constitution Beach	East Boston Waterfront	Harbor Park	Joseph Finnegan Park	Total
Div 02	*Existing Conditions*			*$ 55,743*	*$ 163,443*	*$ 28,057*	*$ 75,020*	*$ 75,231*	*$ 10,447*	*$ 43,190*	*$ 451,131*
Div 03	*Concrete*			*$ 1,577,727*	*$ 3,685,593*	*$ 1,655,319*	*$ 1,942,106*	*$ 187,377*	*$ 1,489,009*	*$ 187,377*	*$ 10,724,508*
Div 04	*Masonry*			*$ 44,716*	*$ 59,621*	*$ 44,716*	*$ 44,716*	*$ 44,716*	*$ 44,716*	*$ 44,716*	*$ 327,917*
Div 05	*Metals*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 06	*Wood, Plastics, and Composites*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 07	*Thermal and Moisture Protection*			*$ 6,276*	*$ 11,058*	*$ 6,276*	*$ 6,276*	*$ 6,276*	*$ 6,276*	*$ 6,276*	*$ 48,717*
Div 08	*Openings*			*$ 29,190*	*$ 29,190*	*$ 29,190*	*$ 29,190*	*$ 29,190*	*$ 29,190*	*$ 29,190*	*$ 204,329*
Div 09	*Finishes*			*$ 4,007*	*$ 5,343*	*$ 4,007*	*$ 4,007*	*$ 4,007*	*$ 4,007*	*$ 4,007*	*$ 29,388*
Div 10	*Specialties*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 11	*Equipment*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 12	*Furnishings*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 13	*Special Construction*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 14	*Conveying Systems*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 21	*Fire Suppression*			*$ 10,846*	*$ 10,846*	*$ 10,846*	*$ 10,846*	*$ 10,846*	*$ 10,846*	*$ 10,846*	*$ 75,919*
Div 22	*Plumbing*			*$ 22,307*	*$ 22,307*	*$ 22,307*	*$ 22,307*	*$ 22,307*	*$ 22,307*	*$ 22,307*	*$ 156,148*
Div 23	*Heating, Ventilating, and Air Conditioning (HVAC)*			*$ 22,711*	*$ 22,711*	*$ 22,711*	*$ 22,711*	*$ 22,711*	*$ 22,711*	*$ 22,711*	*$ 158,977*
Div 25	*Integrated Automation*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 26	*Electrical*			*$ 740,039*	*$ 1,280,551*	*$ 475,480*	*$ 901,434*	*$ 443,201*	*$ 893,201*	*$ 701,434*	*$ 5,435,341*
Div 27	*Communications*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 28	*Electronic Safety and Security*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 31	*Earthwork*			*$ 902,300*	*$ 1,655,966*	*$ 787,132*	*$ 1,256,202*	*$ 1,307,799*	*$ 783,920*	*$ 4,062,201*	*$ 10,755,520*
Div 32	*Exterior Improvements*			*$ 88,296*	*$ 262,228*	*$ 68,152*	*$ 134,765*	*$ 170,098*	*$ -*	*$ 399,630*	*$ 1,123,168*
Div 33	*Utilities*			*$ 3,293,192*	*$ 3,647,930*	*$ 1,266,704*	*$ 2,680,710*	*$ 3,538,890*	*$ 3,280,964*	*$ 3,102,794*	*$ 20,811,183*
Div 34	*Transportation*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
Div 35	*Waterway and Marine Construction*			*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*	*$ -*
	Subtotal:			**$ 6,797,350**	**$ 10,856,786**	**$ 4,420,897**	**$ 7,130,289**	**$ 5,862,650**	**$ 6,597,594**	**$ 8,636,678**	**$ 50,302,245**
	Special Conditions	*5.0%*	*on*	*$ 6,797,350*	*$ 10,856,786*	*$ 4,420,897*	*$ 7,130,289*	*$ 5,862,650*	*$ 6,597,594*	*$ 8,636,678*	
	Special Conditions Total:			$ 339,867	$ 542,839	$ 221,045	$ 356,514	$ 293,132	$ 329,880	$ 431,834	$ 2,515,112
	Small Tools (Applied on Labor)	*2.0%*	*on*	*$ 1,414,731*	*$ 2,806,468*	*$ 1,285,323*	*$ 1,843,382*	*$ 1,432,002*	*$ 1,200,365*	*$ 2,536,049*	
	Small Tools (Applied on Labor) Total:			$ 28,295	$ 56,129	$ 25,706	$ 36,868	$ 28,640	$ 24,007	$ 50,721	$ 250,366
	Incidental Overtime (Applied on Labor)	*5.0%*	*on*	*$ 1,414,731*	*$ 2,806,468*	*$ 1,285,323*	*$ 1,843,382*	*$ 1,432,002*	*$ 1,200,365*	*$ 2,536,049*	

Hazen

Boston Water and Sewer Commission
Coastal Stormwater Discharge Analysis
Conceptual - Phase 2
Estimate Summary - CSI Division by WBS

11/17/2022
11/11/2022

Description			Airport	Charlestown Schrafft Center	Columbus Park	Constitution Beach	East Boston Waterfront	Harbor Park	Joseph Finnegan Park	Total
Incidental Overtime (Applied on Labor) Total:			$ 70,737	$ 140,323	$ 64,266	$ 92,169	$ 71,600	$ 60,018	$ 126,802	$ 625,916
Direct Costs Subtotal:			**$ 7,236,248**	**$ 11,596,079**	**$ 4,731,915**	**$ 7,615,841**	**$ 6,256,022**	**$ 7,011,500**	**$ 9,246,035**	**$ 53,693,640**
General Conditions	*20.0%*	*on*	*$ 7,236,248*	*$ 11,596,079*	*$ 4,731,915*	*$ 7,615,841*	*$ 6,256,022*	*$ 7,011,500*	*$ 9,246,035*	
General Conditions Total:			$ 1,447,250	$ 2,319,216	$ 946,383	$ 1,523,168	$ 1,251,204	$ 1,402,300	$ 1,849,207	$ 10,738,728
Indirect Costs Subtotal:			**$ 1,447,250**	**$ 2,319,216**	**$ 946,383**	**$ 1,523,168**	**$ 1,251,204**	**$ 1,402,300**	**$ 1,849,207**	**$ 10,738,728**
Direct and Indirect Costs Total:			**$ 8,683,498**	**$ 13,915,294**	**$ 5,678,298**	**$ 9,139,009**	**$ 7,507,227**	**$ 8,413,800**	**$ 11,095,242**	**$ 64,432,368**
Add-On / Mark-Up										
Labor Escalation at 3.5% annually	*67.1%*	*on*	*$ 2,825,805*	*$ 5,093,333*	*$ 2,225,160*	*$ 3,345,313*	*$ 2,661,855*	*$ 2,559,518*	*$ 4,373,632*	
Labor Escalation Total:			$ 1,894,852	$ 3,415,349	$ 1,492,087	$ 2,243,209	$ 1,784,914	$ 1,716,292	$ 2,932,751	$ 15,479,455
Material/Equipment Escalation at 3% annually	*55.4%*	*on*	*$ 5,857,694*	*$ 8,821,965*	*$ 3,453,137*	*$ 5,793,695*	*$ 4,845,371*	*$ 5,854,282*	*$ 6,721,610*	
Material/Equipment Escalation Total:			$ 3,245,950	$ 4,888,555	$ 1,913,502	$ 3,210,486	$ 2,684,987	$ 3,244,060	$ 3,724,676	$ 22,912,217
Subtotal:			**$ 13,824,300**	**$ 22,219,198**	**$ 9,083,887**	**$ 14,592,704**	**$ 11,977,128**	**$ 13,374,151**	**$ 17,752,670**	**$ 102,824,039**
Subcontractor Overhead, Profit and Fee	*25.0%*	*on*	*$ 4,147,290*	*$ 6,665,759*	*$ 2,725,166*	*$ 4,377,811*	*$ 3,593,139*	*$ 4,012,245*	*$ 5,325,801*	
Subcontractor Overhead, Profit and Fee Total:			$ 1,036,823	$ 1,666,440	$ 681,292	$ 1,094,453	$ 898,285	$ 1,003,061	$ 1,331,450	$ 7,711,803
Subtotal:			**$ 14,861,123**	**$ 23,885,638**	**$ 9,765,179**	**$ 15,687,157**	**$ 12,875,413**	**$ 14,377,213**	**$ 19,084,120**	**$ 110,535,842**
Prime Contractor Overhead	*10.0%*	*on*	*$ 9,677,010*	*$ 15,553,438*	*$ 6,358,721*	*$ 10,214,893*	*$ 8,383,990*	*$ 9,361,906*	*$ 12,426,869*	
Prime Contractor Overhead Total:			$ 967,701	$ 1,555,344	$ 635,872	$ 1,021,489	$ 838,399	$ 936,191	$ 1,242,687	$ 7,197,683
Subtotal:			**$ 15,828,824**	**$ 25,440,982**	**$ 10,401,051**	**$ 16,708,646**	**$ 13,713,812**	**$ 15,313,403**	**$ 20,326,807**	**$ 117,733,525**
Prime Contractor Profit	*10.0%*	*on*	*$ 10,644,711*	*$ 17,108,782*	*$ 6,994,593*	*$ 11,236,382*	*$ 9,222,389*	*$ 10,298,096*	*$ 13,669,556*	
Prime Contractor Profit:			$ 1,064,471	$ 1,710,878	$ 699,459	$ 1,123,638	$ 922,239	$ 1,029,810	$ 1,366,956	$ 7,917,451
Subtotal:			**$ 16,893,295**	**$ 27,151,860**	**$ 11,100,510**	**$ 17,832,284**	**$ 14,636,051**	**$ 16,343,213**	**$ 21,693,763**	**$ 125,650,976**
Prime Profit on Subcontracted Work	*5.0%*	*on*	*$ 5,184,113*	*$ 8,332,199*	*$ 3,406,458*	*$ 5,472,264*	*$ 4,491,423*	*$ 5,015,307*	*$ 6,657,251*	
Prime Profit on Subcontracted Work Total:			$ 259,206	$ 416,610	$ 170,323	$ 273,613	$ 224,571	$ 250,765	$ 332,863	$ 1,927,951
Subtotal:			**$ 17,152,501**	**$ 27,568,470**	**$ 11,270,833**	**$ 18,105,898**	**$ 14,860,622**	**$ 16,593,978**	**$ 22,026,625**	**$ 127,578,927**
Bond and Insurance	*3.0%*		*$ 514,575*	*$ 827,054*	*$ 338,125*	*$ 543,177*	*$ 445,819*	*$ 497,819*	*$ 660,799*	$ 3,827,368
Subtotal:			**$ 17,667,076**	**$ 28,395,524**	**$ 11,608,958**	**$ 18,649,074**	**$ 15,306,441**	**$ 17,091,798**	**$ 22,687,424**	**$ 131,406,294**
Design Contingency	*50.0%*		*$ 8,833,538*	*$ 14,197,762*	*$ 5,804,479*	*$ 9,324,537*	*$ 7,653,220*	*$ 8,545,899*	*$ 11,343,712*	$ 65,703,147
Subtotal:			**$ 26,500,613**	**$ 42,593,286**	**$ 17,413,437**	**$ 27,973,612**	**$ 22,959,661**	**$ 25,637,696**	**$ 34,031,136**	**$ 197,109,442**
Contract Allowances and Unit Prices	*2.5%*		*$ 662,515*	*$ 1,064,832*	*$ 435,336*	*$ 699,340*	*$ 573,992*	*$ 640,942*	*$ 850,778*	*$ 4,927,736*
Total (rounded):			**$ 27,163,000**	**$ 43,658,000**	**$ 17,849,000**	**$ 28,673,000**	**$ 23,534,000**	**$ 26,279,000**	**$ 34,882,000**	**$ 202,037,000**

Note: Project Assumptions NTP: 4/1/35, 1825 CCD (60 months)

Location Code	CSI Div.	sub*	Description	Quantity	Unit	Notes	Labor Unit Cost	Equipment Unit Cost	Material Unit Cost	Total Unit Cost	Total Amount
							$0.00	$0.00		$ -	$ -
			FORT POINT CHANNEL			M&N estimate to cover storm surge barr	$0.00	$0.00		$ -	$ -
FPC			**Flood Barrier - Pumps w/ enclosure**	1	ea	M&N to cover PS foundation conc	$0.00	$0.00		$ -	$ -
FPC	Div 33		Pumps, storm, duty & standby, 167 CFS (total flow = 500 CFS)	5	ea	Budget quote for Patterson pump #54af-a (76000 gpm @ 18ft)	$24,650.50	$21,701.39	$950,000.00	$ 996,352	$ 4,981,759
FPC	Div 33		Contingency - additional pump hardware or different pump selection	5	ea	allow extra 15% of cost	$4,930.10	$4,340.28	$142,500.00	$ 151,770	$ 758,852
FPC	Div 26		Conduit, 3"dia, PVC-coated RGS, for pumps	500	lf	allow conduit and wiring material - conduit to be cast into structure	$28.17	$0.00	$70.00	$ 98	$ 49,085
FPC	Div 26		Wiring, 480V, for pumps	20	clf	allow 4 wires per pump	$201.21	$0.00	$750.00	$ 951	$ 19,024
FPC	Div 26		Conduit, 2"dia, PVC-coated RGS, for flood barrier motors	2,400	lf	allow 2 conduit per lift gate	$20.12	$0.00	$40.00	$ 60	$ 144,291
FPC	Div 26		Wiring, 480V, for flood barrier motors	96	clf	allow 4 wires per pump	$201.21	$0.00	$750.00	$ 951	$ 91,316
FPC							$0.00	$0.00		$ -	$ -
FPC	Div 04		Enclosure, CMU 8" th	3,240	sf	allow 25ft x 110ft x 15ft (to enclose pumps) w/ openings for discharge	$13.41	$1.29	$3.78	$ 18	$ 59,882
FPC	Div 04		Brick veneer	3,240	sf		$16.09	$1.55	$13.56	$ 31	$ 101,096
FPC	Div 07		Roofing, preformed metal	2,750	sf		$7.42	$1.14	$5.00	$ 14	$ 37,289
FPC	Div 08		Doors, single	1	ea	allow hollow metal, 3' x 7'	$1,143.08	$494.89	$5,000.00	$ 6,638	$ 6,638
FPC	Div 23		Motorized louvers	10	ea	allow 2 ea per pump	$1,377.60	$164.59	$5,000.00	$ 6,542	$ 65,422
FPC	Div 26		Lighting allowance	1	ls		$5,633.92	$0.00	$5,000.00	$ 10,634	$ 10,634
FPC							$0.00	$0.00		$ -	$ -
FPC			**Landside Electrical House - Civil & Sitework**			covers landside work along Harborwalk and nearby plaza	$0.00	$0.00		$ -	$ -
FPC	Div 02		Surface removal (building) - brick/pavers	800	sf	allow 20' x 40' building at nearby court house plaza	$6.96	$0.00	$0.00	$ 6.96	$ 5,566
FPC	Div 31		Excavation (building)	90	bcy		$9.21	$6.35	$0.00	$ 16	$ 1,400
FPC	Div 31		Haul & dispose	110	lcy		$12.62	$11.80	$10.00	$ 34	$ 3,786
FPC	Div 02		Surface removal (duct bank trench) - brick/pavers	2,100	sf	allow 300 ft duct bank to start of barrier	$6.96	$0.00	$0.00	$ 6.96	$ 14,610
FPC	Div 31		Trench excavation	390	bcy	allow 5ft depth	$9.21	$6.35	$0.00	$ 16	$ 6,068
FPC	Div 31		Bedding stone	30	bcy		$22.31	$5.47	$30.00	$ 58	$ 1,734
FPC	Div 31		Backfill & compaction	270	bcy		$26.34	$14.27	$0.00	$ 41	$ 10,965
FPC	Div 31		Haul & dispose excess dirt	150	lcy		$12.62	$11.80	$10.00	$ 34	$ 5,162
FPC	Div 26		Duct bank - concrete	90	cy		$44.51	$0.00	$145.00	$ 190	$ 17,056
FPC	Div 26		Duct bank formwork	1,200	sfca		$6.54	$0.00	$6.72	$ 13	$ 15,912
FPC	Div 26		Duct bank rebar	9	ton		$1,530.36	$0.00	$2,270.70	$ 3,801	$ 34,209
FPC	Div 26		Duct bank conduits, 3"dia, PVC	3,000	lf	allow 10 ea PVC conduits @ 3"dia	$5.87	$0.00	$4.06	$ 9.93	$ 29,786
FPC	Div 26		Duct bank wire	120	clf	wire for 4 ea pairs of 30hp motors + 5 ea 310hp pumps	$201.21	$0.00	$750.00	$ 951	$ 114,145
FPC	Div 26		Hand holes	4	ea		$313.07	$0.00	$455.84	$ 769	$ 3,076
FPC	Div 32		Surface restoration (duct bank) - brick/pavers	2,100	sf		$40.77	$0.00	$28.91	$ 70	$ 146,334
FPC	Div 32		Landscaping allowance	1	ls		$6,520.78	$655.19	$13,000.00	$ 20,176	$ 20,176
FPC							$0.00	$0.00		$ -	$ -
FPC			**Landside Electrical House - Structural & Architectural**			not detailed - allowance line items based on similar pump station est	$0.00	$0.00		$ -	$ -
FPC	Div 03		Foundation slab-on-grade, 24" th	60	cy		$44.51	$0.00	$145.00	$ 190	$ 11,371
FPC	Div 03		Formwork, slab edge	240	sfca		$6.54	$0.00	$6.72	$ 13	$ 3,182
FPC	Div 03		Rebar	6	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 22,369
FPC	Div 31		Bedding stone, 6", including grading	20	cy		$34.55	$12.32	$30.00	$ 77	$ 1,537
FPC							$0.00	$0.00		$ -	$ -
FPC	Div 03		Equipment pads, 6" th	3	cy		$801.27	$0.00	$145.00	$ 946	$ 2,839
FPC	Div 03		Formwork, slab edge	50	sfca		$14.39	$0.00	$6.72	$ 21	$ 1,055
FPC	Div 03		Rebar	1	ton		$1,530.36	$0.00	$2,270.70	$ 3,801	$ 3,801
FPC							$0.00	$0.00		$ -	$ -
FPC	Div 04	*	CMU, 8" th	1,800	sf	backup wall for brick veneer	$13.41	$1.29	$3.78	$ 18	$ 33,268
FPC	Div 07	*	Rigid insulation, wall, 2" th	1,800	sf		$1.01	$0.00	$1.67	$ 2.68	$ 4,829
FPC	Div 04	*	Brick veneer	1,800	sf		$16.09	$1.55	$13.56	$ 31	$ 56,164
FPC							$0.00	$0.00		$ -	$ -
FPC	Div 06	*	Roof truss, 20ft span, 2ft spacing	21	ea		$822.11	$356.55	$200.11	$ 1,379	$ 28,954
FPC	Div 05	*	Decking	800	sf		$6.41	$0.57	$5.17	$ 12	$ 9,720
FPC							$0.00	$0.00		$ -	$ -
FPC	Div 07	*	Roofing, shingles, asphalt	8	sq	1 sq = 100 sf	$1,125.63	$210.14	$167.33	$ 1,503	$ 12,025
FPC	Div 07	*	Roofing, underlayment	800	sf		$1.88	$0.35	$1.32	$ 3.55	$ 2,837
FPC	Div 07	*	Rigid insulation, roof, 2" th	800	sf		$1.01	$0.00	$1.67	$ 2.68	$ 2,146
FPC	Div 07	*	Snow guard	32	ea	1 per 25 sf	$29.27	$0.00	$18.80	$ 48	$ 1,538
FPC							$0.00	$0.00		$ -	$ -
FPC	Div 08	*	Doors, single	1	ea	allow hollow metal, 3' x 7'	$1,143.08	$494.89	$5,000.00	$ 6,638	$ 6,638
FPC	Div 08	*	Door, overhead	1	ea		$2,286.15	$989.78	$12,000.00	$ 15,276	$ 15,276
FPC	Div 08	*	Windows	6	ea		$381.03	$164.96	$2,000.00	$ 2,546	$ 15,276
FPC							$0.00	$0.00		$ -	$ -
FPC	Div 09	*	Paint interior	1,800	sf		$0.73	$0.00	$3.00	$ 3.73	$ 6,707
FPC							$0.00	$0.00		$ -	$ -
FPC			**Landside Electrical House - Services**			not detailed - allowance line items based on similar pump station est	$0.00	$0.00		$ -	$ -
FPC	Div 21	*	Fire suppression allowance	1	ls		$7,306.89	$0.00	$10,000.00	$ 17,307	$ 17,307
FPC							$0.00	$0.00		$ -	$ -
FPC	Div 22	*	Plumbing allowance	1	ls	allow for water service, hose bibs, floor drain, etc	$7,306.89	$0.00	$20,000.00	$ 27,307	$ 27,307
FPC							$0.00	$0.00		$ -	$ -
FPC	Div 23	*	Air handling unit	1	ea		$1,377.60	$164.59	$5,000.00	$ 6,542	$ 6,542
FPC	Div 23	*	Air cooled condensing unit	1	ea		$1,377.60	$164.59	$3,000.00	$ 4,542	$ 4,542
FPC	Div 23	*	Louver	2	ea		$688.80	$82.30	$2,000.00	$ 2,771	$ 5,542
FPC	Div 23	*	Damper	2	ea		$688.80	$82.30	$500.00	$ 1,271	$ 2,542
FPC	Div 23	*	Fan	1	ea		$1,377.60	$164.59	$3,000.00	$ 4,542	$ 4,542
FPC						equipment per single line diagram	$0.00	$0.00		$ -	$ -
FPC	Div 26	*	Transformer, MV to 480V	1	ea	allow 2000 kva	$9,080.58	$2,474.45	$91,000.00	$ 102,555	$ 102,555
FPC	Div 26	*	Transformer, 480V to 120/208V	1	ea	for lighting panel; allow 50 kva	$2,012.11	$0.00	$6,000.00	$ 8,012	$ 8,012
FPC	Div 26	*	Portable generator, 2000kW, 480V	1	ea	no install needed. Allow purchase price only. found used 2008 model for sale in BC, Canada for $218K	$0.00	$0.00	$650,000.00	$ 650,000	$ 650,000
FPC	Div 26	*	Transfer switch	1	ea	Allow 500A	$1,408.48	$0.00	$3,750.00	$ 5,158	$ 5,158
FPC	Div 26	*	Generator connection box	1	ea		$2,816.96	$0.00	$7,500.00	$ 10,317	$ 10,317
FPC	Div 26	*	MCC, 2000A bus, 12 sections	1	ea		$9,080.58	$2,474.45	$130,000.00	$ 141,555	$ 141,555
FPC	Div 26	*	Circuit breaker, low voltage, molded case, 110A	5	ea		$306.19	$0.00	$1,000.00	$ 1,306	$ 6,531
FPC	Div 26	*	Circuit breaker, low voltage, molded case, 250A	1	ea		$563.39	$0.00	$1,750.00	$ 2,313	$ 2,313
FPC	Div 26	*	Circuit breaker, low voltage, molded case, 700A	5	ea		$1,482.61	$0.00	$12,500.00	$ 13,983	$ 69,913
FPC	Div 26	*	Service entrance rate switch, 2000A	2	ea		$2,347.47	$0.00	$30,000.00	$ 32,347	$ 64,695
FPC	Div 26	*	Disconnect switch, gate motor, 30hp	8	ea		$306.19	$0.00	$1,420.00	$ 1,726	$ 13,810
FPC	Div 26	*	Disconnect switch, pumps, 310hp	5	ea		$1,408.48	$0.00	$20,000.00	$ 21,408	$ 107,042
FPC	Div 26	*	Receptacles w/ enclosure	10	ea		$26.08	$0.00	$40.00	$ 66	$ 661
FPC	Div 26	*	Meter, rainproof	1	ea		$1,408.48	$0.00	$4,000.00	$ 5,408	$ 5,408
FPC	Div 26	*	Lighting allowance	1	ls	incl. lighting panel, ceiling and wall mount lights plus wire and conduit	$7,042.40	$822.95	$12,500.00	$ 20,365	$ 20,365
FPC	Div 26	*	Grounding allowance	1	ls	incl. ground rod, conductor, grounding bar	$2,816.96	$0.00	$1,000.00	$ 3,817	$ 3,817
FPC	Div 26	*	Wiring & conduit allowance - within pump station	1	ls	conduit/wire in duct bank and on barrier covered seperately	$35,212.01	$4,114.76	$150,000.00	$ 189,327	$ 189,327
FPC	Div 28	*	Security allowance	1	ls		$7,042.40	$822.95	$12,500.00	$ 20,365	$ 20,365
							$0.00	$0.00		$ -	$ -

Location Code	CSI Div.	sub*	Description	Quantity	Unit	Notes	Labor Unit Cost	Equipment Unit Cost	Material Unit Cost	Total Unit Cost	Total Amount
			DAVENPORT CREEK				$0.00	$0.00		$ -	$ -
DC			**Proposed Pipelines**			allow depths	$0.00	$0.00		$ -	$ -
DC	Div 33		RCP, 108"dia	3,500	lf		$191.77	$165.73	$1,120.00	$ 1,478	$ 5,171,256
DC	Div 33		Trench excavation	21,900	bcy		$3.45	$2.38	$0.00	$ 5.83	$ 127,786
DC	Div 33		Haul & dispose	26,280	lcy		$12.62	$11.80	$5.00	$ 29	$ 773,037
DC	Div 33		SOE, trench sheeting	90,800	sf		$0.63	$0.15	$0.75	$ 1.53	$ 139,058
DC	Div 33		Screened gravel, backfill, 6-8" lifts	13,700	cy	per BWSC std detail for RCP sewer trench	$6.69	$3.20	$0.00	$ 9.89	$ 135,530
DC	Div 33		Haul borrow material	13,700	cy		$12.62	$11.80	$30.00	$ 54	$ 745,491
DC	Div 33		Chamber/manhole, cast-in-place, storm	8	ea	allow 13ft depth, 12' x 12' chamber x 10 ft high. Roughly 30 cy/chamber	$20,196.26	$8,286.45	$25,000.00	$ 53,483	$ 427,862
DC	Div 33		Manhole cover	8	ea		$360.31	$67.85	$750.00	$ 1,178	$ 9,425
DC	Div 33		Outfall	1	ea		$12,725.49	$10,044.18	$13,500.00	$ 36,270	$ 36,270
DC	Div 02		Surface removal, asphalt road, 3" th	5,500	sy		$4.96	$2.47	$0.00	$ 7.43	$ 40,877
DC	Div 32		Surface restore, asphalt road, 1.5" binder	5,500	sy		$7.19	$5.93	$5.45	$ 19	$ 102,161
DC	Div 32		Surface restore, asphalt road, 1.5" wearing	5,500	sy		$7.19	$5.93	$6.10	$ 19	$ 105,736
DC							$0.00	$0.00		$ -	$ -
DC	Div 33		Traffic Protection	380	shifts	total duration of trench & RCP work, include cost for MPT materials	$762.23	$186.70	$60.00	$ 1,009	$ 383,392
DC	Div 31		Dewatering allowance	380	shifts	allowoperator/pump time plus consumables	$590.20	$420.83	$200.00	$ 1,211	$ 460,191
DC							$0.00	$0.00		$ -	$ -
DC			**Pump Station & Storage Tank**	1	ea	250 CFS	$0.00	$0.00		$ -	$ -
DC	Div 33		Dewatering Pumps	2	ea		$12,974.72	$6,576.18	$25,000.00	$ 44,551	$ 89,102
DC	Div 33		Stormwater Pumps	4	ea	allow cost based on pump quote for 500CFS station	$24,650.50	$21,701.39	$500,000.00	$ 546,352	$ 2,185,408
DC	Div 33		Tide Gate, unknown size	1	ls	installed near pump station under pedestrian bridge	$20,997.05	$21,701.39	$200,000.00	$ 242,698	$ 242,698
DC							$0.00	$0.00		$ -	$ -
DC			Civil, Structural & Architectural				$0.00	$0.00		$ -	$ -
DC	Div 31		Temporary SOE - sheet pile wall, drive, extract & salvage	200	ton	allow around perimeter of pump station	$702.36	$683.92	$530.00	$ 1,916	$ 383,257
DC	Div 31		Structure excavation	2,270	bcy		$4.61	$3.17	$0.00	$ 7.78	$ 17,660
DC	Div 31		Bedding stone, 6", including grading	50	cy		$20.08	$4.93	$30.00	$ 55	$ 2,750
DC	Div 31		Structure backfill	410	bcy		$26.34	$14.27	$0.00	$ 41	$ 16,650
DC	Div 31		Haul & dispose excess dirt	2,240	lcy		$12.62	$11.80	$10.00	$ 34	$ 77,091
DC	Div 31		Dewatering allowance	90	shifts	allowoperator/pump time plus consumables	$590.20	$420.83	$200.00	$ 1,211	$ 108,993
DC							$0.00	$0.00		$ -	$ -
DC	Div 05		Elevated pedestrian walkway, steel members	1,940	lf	over dissipation structure, btwn house and creek	$7.13	$4.59	$35.00	$ 47	$ 90,640
DC	Div 05		Walkway, metal railing	700	lf	both sides, allow aluminum 3-rail, 1-1/4"dia pipe, clear anodized	$22.59	$1.29	$145.00	$ 169	$ 118,217
DC	Div 05		Walkway, metal grating	3,500	sf	allow heavy duty aluminum, 1-1/4" th	$3.09	$0.18	$57.00	$ 60	$ 210,951
DC	Div 03		Walkway, concrete support pedestals	10	cy		$221.76	$0.00	$350.00	$ 572	$ 5,718
DC							$0.00	$0.00		$ -	$ -
DC	Div 03		Tank, floor slab, 24" th	190	cy		$21.09	$0.00	$145.00	$ 166	$ 31,556
DC	Div 03		Formwork, slab edge	400	sfca		$6.54	$0.00	$6.72	$ 13	$ 5,304
DC	Div 03		Rebar	19	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 70,835
DC	Div 03		Tank, exterior and bay walls	360	cy	2ft thick exterior walls; 1ft thick bay wall	$33.39	$0.00	$145.00	$ 178	$ 64,219
DC	Div 03		Formwork, wall	11,440	sfca		$6.54	$0.00	$6.72	$ 13	$ 151,697
DC	Div 03		Rebar	30	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 111,845
DC	Div 03		Tank, flow straightening piers, 12" th	30	cy		$66.77	$0.00	$145.00	$ 212	$ 6,353
DC	Div 03		Formwork, column	1,800	sfca		$6.54	$0.00	$6.72	$ 13	$ 23,868
DC	Div 03		Rebar	5	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 16,777
DC	Div 03		Tank, roof slab, 12" th	95	cy		$42.17	$0.00	$145.00	$ 187	$ 17,781
DC	Div 03		Formwork, slab edge	200	sfca		$6.54	$0.00	$6.72	$ 13	$ 2,652
DC	Div 03		Formwork, supported slab	3,080	sfca		$5.53	$0.00	$6.72	$ 12	$ 37,742
DC	Div 03		Rebar	10	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 35,418
DC	Div 03		Energy dissipation structure	50	cy	allow dimensions	$80.13	$0.00	$145.00	$ 225	$ 11,256
DC	Div 03		Formwork, slab edge	400	sfca	allow extra form area for dissipation blocks	$11.51	$0.00	$6.72	$ 18	$ 7,292
DC	Div 03		Rebar	5	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 18,641
DC	Div 03		Haul & place rip rap	100	ton		$43.56	$36.27	$30.00	$ 110	$ 10,984
DC							$0.00	$0.00		$ -	$ -
DC	Div 03		House, floor slab, 12" th	10	cy		$44.51	$0.00	$145.00	$ 190	$ 1,895
DC	Div 03		Formwork, slab edge	60	sfca		$6.54	$0.00	$6.72	$ 13	$ 796
DC	Div 03		Rebar	1	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 3,728
DC	Div 04	*	CMU, 8" th	900	sf	for pump station house or shed. Allow 10 x 20 building	$13.41	$1.29	$3.78	$ 18	$ 16,634
DC	Div 07	*	Rigid insulation, wall, 2" th	900	sf		$0.82	$0.00	$1.67	$ 2.49	$ 2,242
DC	Div 04	*	Brick veneer	900	sf		$16.09	$1.55	$13.56	$ 31	$ 28,082
DC	Div 07	*	Roofing, preformed metal	200	sf		$7.42	$1.14	$5.00	$ 14	$ 2,712
DC	Div 07	*	Rigid insulation, roof, 2" th	200	sf		$1.85	$0.00	$1.67	$ 3.52	$ 704
DC	Div 07	*	Snow guard	8	ea	1 per 25 sf	$58.54	$0.00	$18.80	$ 77	$ 619
DC	Div 08	*	Doors, single	1	ea	allow hollow metal, 3' x 7'	$1,143.08	$494.89	$5,000.00	$ 6,638	$ 6,638
DC	Div 08	*	Door, overhead	1	ea		$2,286.15	$989.78	$12,000.00	$ 15,276	$ 15,276
DC	Div 08	*	Windows	2	ea		$1,143.08	$494.89	$2,000.00	$ 3,638	$ 7,276
DC	Div 09	*	Paint interior	900	sf		$1.45	$0.00	$3.00	$ 4.45	$ 4,007
DC							$0.00	$0.00		$ -	$ -
DC			Allowances for undefined services				$0.00	$0.00		$ -	$ -
DC	Div 21	*	Fire suppression allowance	1	ls		$5,845.51	$0.00	$5,000.00	$ 10,846	$ 10,846
DC	Div 22	*	Plumbing allowance	1	ls		$7,306.89	$0.00	$15,000.00	$ 22,307	$ 22,307
DC	Div 23	*	HVAC allowance	1	ls		$6,888.00	$822.95	$15,000.00	$ 22,711	$ 22,711
DC	Div 26	*	Electrical allowance	1	ls	utility hookup not included	$14,084.80	$0.00	$500,000.00	$ 514,085	$ 514,085
DC	Div 26		Duct bank allowance	800	lf	allowance length to potential nearby power hookup	$259.39	$36.19	$350.00	$ 646	$ 516,466
DC							$0.00	$0.00		$ -	$ -
DC			**Stormwater Storage Basins**	2	ea	areas as indicated in concept slideshow	$0.00	$0.00		$ -	$ -
DC	Div 31	*	Clearing & grubbing, tree removal allowance	3	acre	120,000 sf approximate basins area	$4,187.72	$5,082.76	$0.00	$ 9,270	$ 27,811
DC	Div 31		Excavation	54,500	bcy	per concept details; 24ft max excavation depth, sloped basin (no	$2.67	$4.19	$0.00	$ 6.87	$ 374,167
DC	Div 31		Haul & dispose	65,400	lcy	allow full haul-off and dispose	$12.62	$11.80	$5.00	$ 29	$ 1,923,767
DC	Div 32	*	Landscaping allowance	1	ls	allow topsoil and plantings @ storage basins	$52,684.85	$33,546.19	$150,000.00	$ 236,231	$ 236,231
DC	Div 31		Dewatering allowance	160	shifts	allowoperator/pump time plus consumables	$590.20	$420.83	$200.00	$ 1,211	$ 193,765
							$0.00	$0.00		$ -	$ -

Location Code	CSI Div.	sub*	Description	Quantity	Unit	Notes	Labor Unit Cost	Equipment Unit Cost	Material Unit Cost	Total Unit Cost	Total Amount
			EAST BOSTON				$0.00	$0.00		$ -	$ -
EB			**Pump Station & Storage Tank**	1	ea	150 CFS	$0.00	$0.00		$ -	$ -
EB	Div 33		Dewatering Pumps	2	ea		$12,974.72	$6,576.18	$25,000.00	$ 44,551	$ 89,102
EB	Div 33		Stormwater Pumps	3	ea	allow based on pump quote for 500CFS station	$16,797.64	$17,361.12	$300,000.00	$ 334,159	$ 1,002,476
EB							$0.00	$0.00		$ -	$ -
EB			Civil, Structural & Architectural				$0.00	$0.00		$ -	$ -
EB	Div 31		Temporary SOE - sheet pile wall, drive, extract & salvage	200	ton	allow around perimeter of pump station	$468.24	$455.95	$530.00	$ 1,454	$ 290,838
EB	Div 31		Structure excavation	2,240	bcy		$4.61	$3.17	$0.00	$ 7.78	$ 17,427
EB	Div 31		Bedding stone, 6", including grading	50	cy		$20.08	$4.93	$30.00	$ 55	$ 2,750
EB	Div 31		Structure backfill	410	bcy		$26.34	$14.27	$0.00	$ 41	$ 16,650
EB	Div 31		Haul & dispose excess dirt	2,200	lcy		$12.62	$11.80	$10.00	$ 34	$ 75,714
EB							$0.00	$0.00		$ -	$ -
EB	Div 03		Tank, floor slab, 24" th	180	cy		$21.09	$0.00	$145.00	$ 166	$ 29,895
EB	Div 03		Formwork, slab edge	420	sfca		$6.54	$0.00	$6.72	$ 13	$ 5,569
EB	Div 03		Rebar	18	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 67,107
EB	Div 03		Tank, exterior and bay walls	360	cy	2ft thick exterior walls; 1ft thick bay wall	$33.39	$0.00	$145.00	$ 178	$ 64,219
EB	Div 03		Formwork, wall	10,880	sfca		$6.54	$0.00	$6.72	$ 13	$ 144,271
EB	Div 03		Rebar	30	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 111,845
EB	Div 03		Tank, flow straightening piers, 12" th	20	cy		$66.77	$0.00	$145.00	$ 212	$ 4,235
EB	Div 03		Formwork, column	1,440	sfca		$6.54	$0.00	$6.72	$ 13	$ 19,095
EB	Div 03		Rebar	3	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 11,185
EB	Div 03		Tank, roof slab, 12" th	90	cy		$42.17	$0.00	$145.00	$ 187	$ 16,845
EB	Div 03		Formwork, slab edge	210	sfca		$6.54	$0.00	$6.72	$ 13	$ 2,785
EB	Div 03		Formwork, supported slab	3,070	sfca		$5.53	$0.00	$6.72	$ 12	$ 37,620
EB	Div 03		Rebar	9	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 33,554
EB	Div 03		Energy dissipation structure	60	cy	allow dimensions	$80.13	$0.00	$145.00	$ 225	$ 13,508
EB	Div 03		Formwork, slab edge	500	sfca	allow extra form area for dissipation blocks	$11.51	$0.00	$6.72	$ 18	$ 9,115
EB	Div 03		Rebar	6	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 22,369
EB	Div 03		Haul & place rip rap	120	ton		$43.56	$36.27	$30.00	$ 110	$ 13,181
EB							$0.00	$0.00		$ -	$ -
EB	Div 03		House, floor slab, 12" th	10	cy		$44.51	$0.00	$145.00	$ 190	$ 1,895
EB	Div 03		Formwork, slab edge	60	sfca		$6.54	$0.00	$6.72	$ 13	$ 796
EB	Div 03		Rebar	1	ton		$1,457.48	$0.00	$2,270.70	$ 3,728	$ 3,728
EB	Div 04	*	CMU, 8" th	900	sf	for pump station house or shed. Allow 10 x 20 building	$13.41	$1.29	$3.78	$ 18	$ 16,634
EB	Div 07	*	Rigid insulation, wall, 2" th	900	sf		$0.82	$0.00	$1.67	$ 2.49	$ 2,242
EB	Div 04	*	Brick veneer	900	sf		$16.09	$1.55	$13.56	$ 31	$ 28,082
EB	Div 07	*	Roofing, preformed metal	200	sf		$7.42	$1.14	$5.00	$ 14	$ 2,712
EB	Div 07	*	Rigid insulation, roof, 2" th	200	sf		$1.85	$0.00	$1.67	$ 3.52	$ 704
EB	Div 07	*	Snow guard	8	ea	1 per 25 sf	$58.54	$0.00	$18.80	$ 77	$ 619
EB	Div 08	*	Doors, single	1	ea	allow hollow metal, 3' x 7'	$1,143.08	$494.89	$5,000.00	$ 6,638	$ 6,638
EB	Div 08	*	Door, overhead	1	ea		$2,286.15	$989.78	$12,000.00	$ 15,276	$ 15,276
EB	Div 08	*	Windows	2	ea		$1,143.08	$494.89	$2,000.00	$ 3,638	$ 7,276
EB	Div 09	*	Paint interior	900	sf		$1.45	$0.00	$3.00	$ 4.45	$ 4,007
EB							$0.00	$0.00		$ -	$ -
EB			Allowances for undefined services				$0.00	$0.00		$ -	$ -
EB	Div 21	*	Fire suppression allowance	1	ls		$5,845.51	$0.00	$5,000.00	$ 10,846	$ 10,846
EB	Div 22	*	Plumbing allowance	1	ls		$7,306.89	$0.00	$15,000.00	$ 22,307	$ 22,307
EB	Div 23	*	HVAC allowance	1	ls		$6,888.00	$822.95	$15,000.00	$ 22,711	$ 22,711
EB	Div 26	*	Electrical allowance	1	ls	utility hookup not included	$14,084.80	$0.00	$500,000.00	$ 514,085	$ 514,085
	Div 26		Duct bank allowance	500	lf	allowance length to potential nearby power hookup	$259.39	$36.19	$350.00	$ 646	$ 322,791
							$0.00	$0.00		$ -	$ -

Location Code	CSI Div.	sub*	Description	Quantity	Unit	Notes	Labor Unit Cost	Equipment Unit Cost	Material Unit Cost	Total Unit Cost	Total Amount
			DORCHESTER BAY BASIN			M&N estimate to cover tide gate	$0.00	$0.00		$ -	$ -
DBB			**Proposed Pipelines**				$0.00	$0.00		$ -	$ -
DBB			Pipeline 1				$0.00	$0.00		$ -	$ -
DBB	Div 33		RCP, 90"dia	2,600	lf		$159.34	$118.38	$820.00	$ 1,098	$ 2,854,074
DBB	Div 31		Trench excavation	13,590	bcy		$3.45	$2.38	$0.00	$ 5.83	$ 79,297
DBB	Div 31		Haul & dispose	16,310	lcy		$12.62	$11.80	$5.00	$ 29	$ 479,765
DBB	Div 33		SOE, trench sheeting	61,140	sf		$0.63	$0.15	$0.75	$ 1.53	$ 93,634
DBB	Div 31		Screened gravel, backfill, 6-8" lifts	9,420	cy		$6.69	$3.20	$0.00	$ 9.89	$ 93,189
DBB	Div 31		Haul borrow material	9,420	cy		$12.62	$11.80	$30.00	$ 54	$ 512,593
DBB	Div 33		Chamber/manhole, cast-in-place, storm	13	ea		$20,196.26	$8,286.45	$25,000.00	$ 53,483	$ 695,275
DBB	Div 33		Manhole cover	13	ea		$360.31	$67.85	$750.00	$ 1,178	$ 15,316
DBB	Div 02		Surface removal, asphalt road, 3" th	3,800	sy		$4.96	$2.47	$0.00	$ 7.43	$ 28,242
DBB	Div 32		Surface restore, asphalt road, 1.5" binder	3,800	sy		$7.19	$5.93	$5.45	$ 19	$ 70,584
DBB	Div 32		Surface restore, asphalt road, 1.5" wearing	3,800	sy		$7.19	$5.93	$6.10	$ 19	$ 73,054
DBB	Div 33		Traffic Protection	250	shifts	total duration of trench & RCP work, include cost for MPT materials	$762.23	$186.70	$60.00	$ 1,009	$ 252,231
DBB	Div 31		Dewatering allowance	250	shifts	allowoperator/pump time plus consumables	$590.20	$420.83	$200.00	$ 1,211	$ 302,757
DBB							$0.00	$0.00		$ -	$ -
DBB			Pipeline 2				$0.00	$0.00		$ -	$ -
DBB	Div 33		RCP, 48"dia	300	lf		$69.71	$51.79	$260.00	$ 382	$ 114,451
DBB	Div 33		RCP, 84"dia	200	lf		$139.43	$103.58	$750.00	$ 993	$ 198,601
DBB	Div 33		RCP, 96"dia	1,000	lf		$185.90	$138.11	$880.00	$ 1,204	$ 1,204,008
DBB	Div 33		RCP, 108"dia	1,000	lf		$223.08	$165.73	$1,120.00	$ 1,509	$ 1,508,809
DBB	Div 33		RCP, 144"dia	3,500	lf		$446.16	$331.46	$1,900.00	$ 2,678	$ 9,371,664
DBB	Div 31		Trench excavation	45,060	bcy		$3.45	$2.38	$0.00	$ 5.83	$ 262,924
DBB	Div 31		Haul & dispose	54,080	lcy		$12.62	$11.80	$5.00	$ 29	$ 1,590,785
DBB	Div 33		SOE, trench sheeting	166,060	sf		$0.63	$0.15	$0.75	$ 1.53	$ 254,317
DBB	Div 31		Screened gravel, backfill, 6-8" lifts	26,360	cy		$6.69	$3.20	$0.00	$ 9.89	$ 260,771
DBB	Div 31		Haul borrow material	26,360	cy		$12.62	$11.80	$30.00	$ 54	$ 1,434,390
DBB	Div 33		Chamber/manhole, cast-in-place, storm	11	ea		$20,196.26	$8,286.45	$25,000.00	$ 53,483	$ 588,310
DBB	Div 33		Manhole cover	11	ea		$360.31	$67.85	$750.00	$ 1,178	$ 12,960
DBB	Div 02		Surface removal, asphalt road, 3" th	9,400	sy		$4.96	$2.47	$0.00	$ 7.43	$ 69,862
DBB	Div 32		Surface restore, asphalt road, 1.5" binder	9,400	sy		$7.19	$5.93	$5.45	$ 19	$ 174,603
DBB	Div 32		Surface restore, asphalt road, 1.5" wearing	9,400	sy		$7.19	$5.93	$6.10	$ 19	$ 180,713
DBB	Div 33		Traffic Protection	710	shifts	total duration of trench & RCP work, include cost for MPT materials	$762.23	$186.70	$60.00	$ 1,009	$ 716,337
DBB	Div 31		Dewatering allowance	710	shifts	allowoperator/pump time plus consumables	$590.20	$420.83	$200.00	$ 1,211	$ 859,831
DBB							$0.00	$0.00		$ -	$ -
DBB			Pipeline 3				$0.00	$0.00		$ -	$ -
DBB	Div 33		RCP, 144"dia	2,200	lf		$446.16	$331.46	$1,900.00	$ 2,678	$ 5,890,760
DBB	Div 31		Trench excavation	20,290	bcy		$3.45	$2.38	$0.00	$ 5.83	$ 118,391
DBB	Div 31		Haul & dispose	24,350	lcy		$12.62	$11.80	$5.00	$ 29	$ 716,265
DBB	Div 33		SOE, trench sheeting	68,470	sf		$0.63	$0.15	$0.75	$ 1.53	$ 104,860
DBB	Div 31		Screened gravel, backfill, 6-8" lifts	11,330	cy		$6.69	$3.20	$0.00	$ 9.89	$ 112,084
DBB	Div 31		Haul borrow material	11,330	cy		$12.62	$11.80	$30.00	$ 54	$ 616,527
DBB	Div 33		Chamber/manhole, cast-in-place, storm	11	ea		$20,196.26	$8,286.45	$25,000.00	$ 53,483	$ 588,310
DBB	Div 33		Manhole cover	11	ea		$360.31	$67.85	$750.00	$ 1,178	$ 12,960
DBB	Div 33		Outfall	1	ea		$12,725.49	$10,044.18	$13,500.00	$ 36,270	$ 36,270
DBB	Div 02		Surface removal, asphalt road, 3" th	4,200	sy		$4.96	$2.47	$0.00	$ 7.43	$ 31,215
DBB	Div 32		Surface restore, asphalt road, 1.5" binder	4,200	sy		$7.19	$5.93	$5.45	$ 19	$ 78,014
DBB	Div 32		Surface restore, asphalt road, 1.5" wearing	4,200	sy		$7.19	$5.93	$6.10	$ 19	$ 80,744
DBB	Div 33		Traffic Protection	390	shifts	total duration of trench & RCP work, include cost for MPT materials	$762.23	$186.70	$60.00	$ 1,009	$ 393,481
DBB	Div 31		Dewatering allowance	390	shifts	allowoperator/pump time plus consumables	$590.20	$420.83	$200.00	$ 1,211	$ 472,302
DBB							$0.00	$0.00		$ -	$ -
DBB			Pipeline 4				$0.00	$0.00		$ -	$ -
DBB	Div 33		RCP, 144"dia	3,000	lf		$446.16	$331.46	$1,900.00	$ 2,678	$ 8,032,855
DBB	Div 31		Trench excavation	27,900	bcy		$3.45	$2.38	$0.00	$ 5.83	$ 162,796
DBB	Div 31		Haul & dispose	33,480	lcy		$12.62	$11.80	$5.00	$ 29	$ 984,828
DBB	Div 33		SOE, trench sheeting	94,160	sf		$0.63	$0.15	$0.75	$ 1.53	$ 144,204
DBB	Div 31		Screened gravel, backfill, 6-8" lifts	15,580	cy		$6.69	$3.20	$0.00	$ 9.89	$ 154,128
DBB	Div 31		Haul borrow material	15,580	cy		$12.62	$11.80	$30.00	$ 54	$ 847,792
DBB	Div 33		Chamber/manhole, cast-in-place, storm	7	ea		$20,196.26	$8,286.45	$25,000.00	$ 53,483	$ 374,379
DBB	Div 33		Manhole cover	7	ea		$360.31	$67.85	$750.00	$ 1,178	$ 8,247
DBB	Div 33		Outfall	1	ea		$12,725.49	$10,044.18	$13,500.00	$ 36,270	$ 36,270
DBB	Div 02		Surface removal, asphalt road, 3" th	5,700	sy		$4.96	$2.47	$0.00	$ 7.43	$ 42,363
DBB	Div 32		Surface restore, asphalt road, 1.5" binder	5,700	sy		$7.19	$5.93	$5.45	$ 19	$ 105,876
DBB	Div 32		Surface restore, asphalt road, 1.5" wearing	5,700	sy		$7.19	$5.93	$6.10	$ 19	$ 109,581
DBB	Div 33		Traffic Protection	470	shifts	total duration of trench & RCP work, include cost for MPT materials	$762.23	$186.70	$60.00	$ 1,009	$ 474,195
DBB	Div 31		Dewatering allowance	470	shifts	allowoperator/pump time plus consumables	$590.20	$420.83	$200.00	$ 1,211	$ 569,184
							$0.00	$0.00		$ -	$ -

Appendix M: Cost Backup for Storm Surge Barriers

OPINION OF PROBABLE COST	DATE PREPARED 22-Nov-22	SHEET 1 OF 2
ACTIVITY AND LOCATION Boston, MA - Dorchester Bay Basin	CONSTRUCTION CONTRACT NO. N/A	
	ESTIMATED BY Moffatt & Nichol	
PROJECT TITLE Dorchester Bay Basin Storm Surge Barrier Vertical Lift Gate	STATUS OF DESIGN Conceptual Design	M&N PROJECT NUMBER 11167

This Opinion of Probable Cost has been prepared for the subject project based on the Conceptual Design Drawings entitled "Boston Water and Sewer Commission Storm Surge Barrier - Dorchester Bay Basin - Boston, MA" Rev 01, dated November 21, 2022. The scope of work for the project includes construction of a gated, navigable water control structure located eastward-adjacent of the Castle Island Drawbridge, and consists of two (2) vertical lift gates. (1) Navigation Gate and (1) Auxiliary Flow Gate. The remainder of the in-water span of the surge barrier system is comprised of a solid dam structure.

Estimating Procedures and Standards and key assumptions

This Opinion of Probable Cost is a Class 4 level estimate as defined by AACE International. The level of Project definition, expressed as percent of complete definition, for a Class 4 estimate is from 1 percent to 15 percent. The estimate is developed based on take-offs, parametric estimates and engineering judgement. The following assumptions/exclusions shall be noted when reviewing the attached:

- Contingency for this level of cost estimate is set at 35% due to, amongst other factors, the complexity of the project, limited reference cost estimating data and locale of the project
· Unencumbered access to the site will be provided to the Contractor.
- This estimate covers the storm surge barrier structure only.
- estimate for Engineering and Design, MEP controls
· Staging and storage areas will be available for use by the Contractor. No allowances have been included for third party leases.
· In general, the estimate utilized one of 3 sources for unit pricing: current or updated prices from projects with similar scope and complexity, historical costs adjusted for regional variations or material and installation costs from RS Means.
· Work hours assumed to be 8 hours per day, Monday to Friday, occurring between the hours of 7am and 6pm. No overtime has been included.
· In estimating Construction Management and Supervision Services, a percentage of the construction cost has been assumed.
· Mid-Point Escalation is based on a projected 15-year horizon from October 2022, at an annual escalation rate of 3.25% applied to all OPC items presented in current dollars.
· No weather delays are included.
· Estimate assumes market conditions are such that Contractors have availability and are actively seeking to bid new projects.

This cost estimate is an 'Opinion of Probable construction Cost' made by a consultant. In providing opinions of construction cost, it is recognized that neither the client nor the consultant has control over the cost of labor, equipment, materials, or the contractor's means and methods of determining constructability, pricing, or schedule. This opinion of construction cost is based on the consultant's reasonable professional judgement and experience and does not constitute a warranty, expressed or implied, that contractor's bids or negotiated prices for the work will not vary from the client's.

Opinion of Probable Cost: Dorchester Bay Basin - Vertical Lift Gate					
Preliminary & Administrative Work					
Item No.	**Description**	**Unit**	**Estimated Quantity**	**Unit Price**	**Total Price**
1	Site Exploration/Testing (1% of Construction Cost)	AL	1	$674,710	$674,710
2	Engineering/Design Development/Permitting (8% of Construction Cost)	AL	1	$5,397,680	$5,397,680
3	Construction Administration/Inspection/Testing (12% of Construction Cost)	AL	1	$8,096,520	$8,096,520
4	Construction Bonds and Insurance (4% of Construction Cost)	AL	1	$2,698,840	$2,698,840
5	Mobilization & Demobilization (10% of Construction Cost)	LS	1	$6,747,100	$6,747,100
Construct Surge Barrier Foundations					
6	Dredge Sill & Approach Channel Recess	CY	30,070	$40	$1,202,800
7	Furnish & Install Temporary Box Cofferdams	TN	1,919	$3,800	$7,292,557
8	Furnish 48-in Diameter Steel Casings	VLF	14,771	$372	$5,494,626
9	Provide Cast-In-Place Cofferdam Tremie Seals In-Place	CY	6,230	$450	$2,803,406
10	Provide & Maintain Cofferdam Dewatering System	AL	1	$500,000	$500,000
11	Provide Quarry Run Stone In-Place	TN	22,080	$125	$2,760,000
12	Provide Class 1,000 Rock In-Place	TN	16,740	$175	$2,929,500
13	48-in Diameter Steel Casing Cut-Offs	EA	129	$2,200	$283,800
14	48-in Diameter Steel Casing Splices	EA	3	$25,000	$64,500
15	Install 48-in Diameter Drilled Shaft Foundation	VLF	12,400	$1,060	$13,144,000
16	Cast-In-Place Concrete Sill & Pier Mat	CY	6,530	$1,200	$7,835,984
17	Construct Shoreline Tie-In Structures	AL	1	$5,900,000	$5,900,000
Construct Surge Barrier Gates & Superstructures					
18	Cast-In-Place Pier Towers	CY	3,246	$1,885	$6,118,417
19	Cast-In-Place Solid Dam	CY	1,303	$1,885	$2,456,783
20	Concrete Armor, Embedded Metals, Seals	TN	95	$7,000	$665,000
21	Furnish & Fabricate Vertical Lift Gate Elements In-Place	TN	330	$8,700	$2,871,000
22	Provide Surge Barrier Gate Cathodic Protection System (Coatings & Anodes)	AL	1	$287,100	$287,100
23	Extract & Salvage Upper Box Cofferdams	TN	602	$500	$300,923
24	Provide MEP Systems In-Place	AL	1	$717,750	$717,750
25	Provide Vessel Impact Protection In-Place	AL	1	$1,500,000	$1,500,000
26	Operations Building	AL	1	$300,000	$300,000
27	Furnish Maintenance Bulkheads	TN	255	$8,000	$2,042,857
Subtotal Cost of Work Item Costs (Includes Contractor Overhead & Profit), Items 1 through 27 Inclusive:					**$91,085,855**
35% Class IV Design Level Contingency:					**$31,880,049**
Escalation - Average Annual Rate of 3.25% to Mid-Point of Construction, Year 2037:					**$56,078,233**
Total Opinion of Probable Cost, Say:					**$180,000,000**

OPINION OF PROBABLE COST	DATE PREPARED 22-Nov-22	SHEET 1 OF 2

ACTIVITY AND LOCATION Boston, MA - Fort Point Channel	CONSTRUCTION CONTRACT NO. N/A	
	ESTIMATED BY Moffatt & Nichol	
PROJECT TITLE Fort Point Channel Storm Surge Barrier Submerged Axis Flap Gate Alternate	STATUS OF DESIGN Conceptual Design	M&N PROJECT NUMBER 11167

This Opinion of Probable Cost has been prepared for the subject project based on the Conceptual Design Drawings entitled "Boston Water and Sewer Commission Fort Point Channel Storm Surge Barrier Submerged Axis Flap Gate Concept Design, Boston, MA" Rev 02, dated November 21, 2022. The scope of work for the project includes construction of a gated, navigable water control structure at the Boston Harbor side of the Fort Point Channel (north of the Northern Avenue Bridge). This concept includes four (4) submerged axis flap gates.

Estimating Procedures and Standards and key assumptions

This Opinion of Probable Cost is a Class 4 level estimate as defined by AACE International. The level of Project definition, expressed as percent of complete definition, for a Class 4 estimate is from 1 percent to 15 percent. The estimate is developed based on take-offs, parametric estimates and engineering judgement. The following assumptions/exclusions shall be noted when reviewing the attached:

- Contingency for this level of cost estimate is set at 35% due to, amongst other factors, the complexity of the project, limited reference cost estimating data and locale of the project

· Unencumbered access to the site will be provided to the Contractor.

- this estimate covers the storm surge barrier structure only, a cost estimate for the integrated pump station is not included herein.

- estimate for Engineering and Design, MEP controls

· Staging and storage areas will be available for use by the Contractor. No allowances have been included for third party leases.

· In general, the estimate utilized one of 3 sources for unit pricing: current or updated prices from projects with similar scope and complexity, historical costs adjusted for regional variations or material and installation costs from RS Means.

· Work hours assumed to be 8 hours per day, Monday to Friday, occurring between the hours of 7am and 6pm. No overtime has been included.

· In estimating Construction Management and Supervision Services, a percentage of the construction cost has been assumed.

· Mid-Point Escalation is based on a projected 15-year horizon from October 2022, at an annual escalation rate of 3.25% applied to all OPC items presented in current dollars.

· No weather delays are included.

· Estimate assumes market conditions are such that Contractors have availability and are actively seeking to bid new projects.

This cost estimate is an 'Opinion of Probable construction Cost' made by a consultant. In providing opinions of construction cost, it is recognized that neither the client nor the consultant has control over the cost of labor, equipment, materials, or the contractor's means and methods of determining constructability, pricing, or schedule. This opinion of construction cost is based on the consultant's reasonable professional judgement and experience and does not constitute a warranty, expressed or implied, that contractor's bids or negotiated prices for the work will not vary from the client's.

Opinion of Probable Cost: Fort Point Channel Surge Barrier - Submerged Axis Flap Gate					
Preliminary Work					
Item No.	**Description**	**Unit**	**Estimated Quantity**	**Unit Price**	**Total Price**
1	Site Exploration/Testing (1% of Cost)	AL	1	$2,891,055	$2,891,055
2	Engineering/Design Development/Permitting (8% of Cost)	AL	1	$22,968,444	$22,968,444
3	Construction Administration/Inspection/Testing (12% of Cost)	AL	1	$34,692,666	$34,692,666
4	Construction Bonds & Insurance (4% of Cost)	AL	1	$11,448,542	$11,448,542
5	Mobilization & Demobilization	LS	1	$28,910,555	$28,910,555
6	Dredge Temporary Navigation Channel	CY	22300	$40	$892,000
7	Remove Structures and Obstructions at Shoreline Tie-ins	AL	1	$2,000,000	$2,000,000
Construct Surge Barrier Foundations					
8	Dredge Sill & Approach Channel Recess	CY	191,875	$40	$7,675,000
9	Furnish & Salvage Temporary Cellular Cofferdam Sheet Piles & Wyes	TN	5158	$1,100	$5,673,800
10	Install & Remove Temporary Cellular Cofferdam Sheet Piles & Wyes	TN	7127	$3,200	$22,806,400
11	Cofferdam Template	AL	1	$3,500,000	$3,500,000
12	Furnish Granular Cell Fill Material	CY	135048	$50	$6,752,393
13	Place Granular Cell Fill Material	CY	135048	$25	$3,376,196
14	Removal & Hauling of Temporary Cell Fill Material	CY	83106	$50	$4,155,319
15	Furnish & Salvage Temporary Tangent Wall Pipes & Braces	TN	2829	$1,100	$3,111,900
16	Install & Remove Temporary Tangent Wall Pipes & Braces	TN	2781	$3,200	$8,899,200
17	Furnish 96-in Diameter Steel Casings	VLF	2280	$1,161	$2,647,080
18	Furnish 48-in Diameter Steel Casings	VLF	23370	$372	$8,693,640
19	Furnish 36-in Diameter Steel Casings	VLF	8740	$227	$1,983,980
20	Furnish & Install Permanent Steel Sheet Pile Cut-off Wall	TN	550	$3,800	$2,090,000
21	Provide Cast-In-Place Cofferdam Tremie Seals In-Place	CY	41047	$450	$18,471,150
22	Provide & Maintain Cofferdam Dewatering System	AL	1	$3,215,127	$3,215,127
23	Provide Quarry Run Stone In-Place	TN	56610	$125	$7,076,250
24	Provide Class 1,000 Rock In-Place	TN	6070	$175	$1,062,250
25	Provide Bedding Gravel above Tremie	TN	43340	$50	$2,167,000
26	96-in Diameter Steel Casing Cut-Offs	EA	24	$7,500	$180,000
27	48-in Diameter Steel Casing Cut-Offs	EA	246	$2,200	$541,200
28	36-in Diameter Steel Casing Cut-Offs	EA	92	$1,500	$138,000
29	96-in Diameter Steel Casing Splices	EA	1	$80,000	$80,000
30	48-in Diameter Steel Casing Splices	EA	5	$25,000	$125,000
31	36-in Diameter Steel Casing Splices	EA	2	$18,750	$37,500
32	Install 96-in Diameter Concrete Shafts	VLF	2280	$4,516	$10,296,480
33	Install 48-in Diameter Concrete Shafts	VLF	23370	$1,398	$32,671,260

34	Install 36-in Diameter Concrete Shafts	VLF	8740	$1,219	$10,654,060
35	Cast-In-Place Concrete Sill & Pier Mat (Includes Pump Station Mat, Support Block Pedestals)	CY	29215	$1,200	$35,058,000
36	Cast-In-Place Gate Hinge	CY	672	$2,600	$1,747,200
37	Construct Shoreline Tie-In Structures	AL	2	$1,500,000	$3,000,000
Construct Surge Barrier Gates & Superstructures					
38	Cast-In-Place Pier Towers, Shear Walls, & Bridge Supports (Includes Pump Station Shear Walls)	CY	17233	$1,885	$32,484,205
39	Cast-In-Place Solid Dam & Counterforts	CY	981	$1,885	$1,849,185
40	Concrete Armor, Embedded Metals, Seals	TN	370	$7,000	$2,590,000
41	Furnish & Fabricate Submerged Axis Gate Elements In-Place	TN	1091	$12,325	$13,446,500
42	Provide Surge Barrier Gate Cathodic Protection System (Coatings & Anodes)	AL	1	$1,344,650	$1,344,650
43	Furnish & Install Gate to Pier Latching System	AL	1	$3,361,625	$3,361,625
44	Furnish & Install Trolley Support Framing System	TN	110	$8,100	$891,000
45	Provide Pedestrian Bridge & Overlook In-Place	SF	16580	$450	$7,461,000
46	Provide MEP Systems In-Place	AL	1	$6,700,000	$6,700,000
47	Provide Vessel Impact Protection In-Place	AL	1	$1,500,000	$1,500,000
48	Operations Building	AL	1	$1,500,000	$1,500,000
49	Furnish Maintenance Bulkheads	TN	650	$8,000	$5,200,000
Subtotal Cost of Work Item Costs (Includes Contractor Overhead & Profit), Items 1 through 49 Inclusive:					**$390,016,812**
35% Class IV Design Level Contingency:					**$136,505,884**
Escalation - Average Annual Rate of 3.25% to Mid-Point of Construction, Year 2037:					**$240,119,103**
Total Opinion of Probable Cost, Say:					**$767,000,000**

OPINION OF PROBABLE COST	DATE PREPARED 22-Nov-22	SHEET 1 OF 2
ACTIVITY AND LOCATION Boston, MA - Fort Point Channel	CONSTRUCTION CONTRACT NO. N/A	
	ESTIMATED BY Moffatt & Nichol	
PROJECT TITLE Fort Point Channel Storm Surge Barrier Vertical Lift Gate Alternate	STATUS OF DESIGN Conceptual Design	M&N PROJECT NUMBER 11167

This Opinion of Probable Cost has been prepared for the subject project based on the Conceptual Design Drawings entitled "Boston Water and Sewer Commission Fort Point Channel Storm Surge Barrier Vertical Lift Gate Concept Design, Boston, MA" Rev 02, dated November 21, 2022. The scope of work for the project includes construction of a gated, navigable water control structure at the Boston Harbor side of the Fort Point Channel (north of the Northern Avenue Bridge). This concept include four (4) vertical lift gates.

Estimating Procedures and Standards, and key assumptions

This Opinion of Probable Cost is a Class 4 level estimate as defined by AACE International. The level of Project definition, expressed as percent of complete definition, for a Class 4 estimate is from 1 percent to 15 percent. The estimate is developed based on take-offs, parametric estimates and engineering judgement. The following assumptions/exclusions shall be noted when reviewing the attached:

- Contingency for this level of cost estimate is set at 35% due to, amongst other factors, the complexity of the project, limited reference cost estimating data and locale of the project

· Unencumbered access to the site will be provided to the Contractor.

- this estimate covers the storm surge barrier structure only, a cost estimate for the integrated pump station is not included herein.

- estimate for Engineering and Design, MEP controls

· Staging and storage areas will be available for use by the Contractor. No allowances have been included for third party leases.

· In general, the estimate utilized one of 3 sources for unit pricing: current or updated prices from projects with similar scope and complexity, historical costs adjusted for regional variations or material and installation costs from RS Means.

· Work hours assumed to be 8 hours per day, Monday to Friday, occurring between the hours of 7am and 6pm. No overtime has been included.

· In estimating Construction Management and Supervision Services, a percentage of the construction cost has been assumed.

· Mid-Point Escalation is based on a projected 15-year horizon from October 2022, at an annual escalation rate of 3.25% applied to all OPC items presented in current dollars.

· No weather delays are included.

· Estimate assumes market conditions are such that Contractors have availability and are actively seeking to bid new projects.

This cost estimate is an 'Opinion of Probable construction Cost' made by a consultant. In providing opinions of construction cost, it is recognized that neither the client nor the consultant has control over the cost of labor, equipment, materials, or the contractor's means and methods of determining constructability, pricing, or schedule. This opinion of construction cost is based on the consultant's reasonable professional judgement and experience and does not constitute a warranty, expressed or implied, that contractor's bids or negotiated prices for the work will not vary from the client's.

Opinion of Probable Cost: Fort Point Channel Surge Barrier - Vertical Lift Gate					
Preliminary & Administrative Work					
Item No.	**Description**	**Unit**	**Estimated Quantity**	**Unit Price**	**Total Price**
1	Site Exploration/Testing (1% of Construction Cost)	AL	1	$1,730,947	$1,730,947
2	Engineering/Design Development/Permitting (8% of Construction Cost)	AL	1	$13,847,576	$13,847,576
3	Construction Administration/Inspection/Testing (12% of Construction Cost)	AL	1	$20,771,364	$20,771,364
4	Construction Bonds and Insurance (4% of Construction Cost)	AL	1	$6,923,788	$6,923,788
5	Mobilization & Demobilization (10% of Construction Cost)	LS	1	$17,309,470	$17,309,470
6	Dredge Temporary Navigation Channel	CY	20233	$40	$809,320
7	Remove Structures & Obstructions at Shoreline Tie-ins	AL	1	$2,000,000	$2,000,000
Construct Surge Barrier Foundations					
8	Dredge Sill & Approach Channel Recess	CY	112,214	$40	$4,488,560
9	Furnish & Install Temporary Box Cofferdams	TN	4,823	$3,800	$18,327,400
10	Furnish 96-in Diameter Steel Casings	VLF	2,280	$1,161	$2,647,080
11	Furnish 48-in Diameter Steel Casings	VLF	19,760	$372	$7,350,720
12	Provide Cast-In-Place Cofferdam Tremie Seals In-Place	CY	13,022	$450	$5,859,900
13	Provide & Maintain Cofferdam Dewatering System	AL	1	$2,200,000	$2,200,000
14	Provide Quarry Run Stone In-Place	TN	49,250	$125	$6,156,250
15	Provide Class 1,000 Rock In-Place	TN	28,520	$175	$4,991,000
16	96-in Diameter Steel Casing Cut-Offs	EA	24	$7,500	$180,000
17	48-in Diameter Steel Casing Cut-Offs	EA	208	$2,200	$457,600
18	96-in Diameter Steel Casing Splices	EA	1	$80,000	$80,000
19	Furnish 48-in Diameter Steel Casings	EA	4	$25,000	$100,000
20	Install 96-in Diameter Drilled Shaft Foundation	VLF	2,400	$4,516	$10,838,400
21	Install 48-in Diameter Drilled Shaft Foundation	VLF	17,264	$1,398	$24,135,072
22	Cast-In-Place Concrete Sill & Pier Mat (Includes Pump Station Mat)	CY	13,729	$1,200	$16,474,800
23	Construct Shoreline Tie-In Structures	AL	2	$2,000,000	$4,000,000
Construct Surge Barrier Gates & Superstructures					
24	Cast-In-Place Pier Towers & Shear Walls (Includes Pump Station Shear Walls)	CY	12,937	$1,885	$24,386,245
25	Cast-In-Place Solid Dam & Counterforts	CY	863	$1,885	$1,626,755
26	Concrete Armor, Embedded Metals, Seals	TN	270	$7,000	$1,890,000
27	Furnish & Fabricate Vertical Lift Gate Elements In-Place	TN	1,700	$8,700	$14,790,000
28	Extract & Salvage Upper Box Cofferdams	TN	1,838	$500	$919,000
29	Provide Pedestrian Bridge & Overlook In-Place	SF	13,748	$450	$6,186,600
30	Provide MEP Systems In-Place	AL	1	$4,000,000	$4,000,000
31	Provide Vessel Impact Protection In-Place	AL	1	$1,500,000	$1,500,000
32	Operations Building	AL	1	$1,500,000	$1,500,000
33	Furnish Maintenance Bulkheads	TN	650	$8,000	$5,200,000

Subtotal Cost of Work Item Costs (Includes Contractor Overhead & Profit), Items 1 through 33 Inclusive:	**$233,677,848**
35% Class IV Design Level Contingency:	**$81,787,247**
Escalation - Average Annual Rate of 3.25% to Mid-Point of Construction, Year 2037:	**$143,866,914**
Total Opinion of Probable Cost, Say:	**$460,000,000**

OPINION OF PROBABLE COST	DATE PREPARED 16-Dec-22	SHEET 1 OF 2
ACTIVITY AND LOCATION Boston, MA - Fort Point Channel	CONSTRUCTION CONTRACT NO. N/A	
PROJECT TITLE Fort Point Channel Storm Surge Barrier Submerged Axis Flap Gate Alternate	ESTIMATED BY Moffatt & Nichol	
	STATUS OF DESIGN Conceptual Design	M&N PROJECT NUMBER 11167

This Opinion of Probable Cost has been prepared for the subject project based on the Conceptual Design Drawings entitled "Boston Water and Sewer Commission Fort Point Channel Storm Surge Barrier Submerged Axis Flap Gate Concept Design - South Location Alternate, Boston, MA" Rev 01, dated December 15, 2022. The scope of work for the project includes construction of a gated, navigable water control structure at the Boston Harbor side of the Fort Point Channel (north of the Northern Avenue Bridge). This concept includes three (3) submerged axis flap gates.

Estimating Procedures and Standards and key assumptions

This Opinion of Probable Cost is a Class 4 level estimate as defined by AACE International. The level of Project definition, expressed as percent of complete definition, for a Class 4 estimate is from 1 percent to 15 percent. The estimate is developed based on take-offs, parametric estimates and engineering judgement. The following assumptions/exclusions shall be noted when reviewing the attached:

- Contingency for this level of cost estimate is set at 35% due to, amongst other factors, the complexity of the project, limited reference cost estimating data and locale of the project
· Unencumbered access to the site will be provided to the Contractor.
- this estimate covers the storm surge barrier structure only, a cost estimate for the integrated pump station is not included herein.
- estimate for Engineering and Design, MEP controls
· Staging and storage areas will be available for use by the Contractor. No allowances have been included for third party leases.
· In general, the estimate utilized one of 3 sources for unit pricing: current or updated prices from projects with similar scope and complexity, historical costs adjusted for regional variations or material and installation costs from RS Means.
· Work hours assumed to be 8 hours per day, Monday to Friday, occurring between the hours of 7am and 6pm. No overtime has been included.
· In estimating Construction Management and Supervision Services, a percentage of the construction cost has been assumed.
· Mid-Point Escalation is based on a projected 15-year horizon from October 2022, at an annual escalation rate of 3.25% applied to all OPC items presented in current dollars.
· No weather delays are included.
· Estimate assumes market conditions are such that Contractors have availability and are actively seeking to bid new projects.

This cost estimate is an 'Opinion of Probable construction Cost' made by a consultant. In providing opinions of construction cost, it is recognized that neither the client nor the consultant has control over the cost of labor, equipment, materials, or the contractor's means and methods of determining constructability, pricing, or schedule. This opinion of construction cost is based on the consultant's reasonable professional judgement and experience and does not constitute a warranty, expressed or implied, that contractor's bids or negotiated prices for the work will not vary from the client's.

Opinion of Probable Cost: Fort Point Channel Surge Barrier - Submerged Axis Flap Gate - South Location Alternate					
Preliminary Work					
Item No.	**Description**	**Unit**	**Estimated Quantity**	**Unit Price**	**Total Price**
1	Site Exploration/Testing (1% of Cost)	AL	1	$2,378,421	$2,378,421
2	Engineering/Design Development/Permitting (8% of Cost)	AL	1	$19,027,366	$19,027,366
3	Construction Administration/Inspection/Testing (12% of Cost)	AL	1	$28,541,049	$28,541,049
4	Construction Bonds & Insurance (4% of Cost)	AL	1	$9,513,683	$9,513,683
5	Mobilization & Demobilization	LS	1	$23,784,208	$23,784,208
6	Dredge Temporary Navigation Channel	CY	20233	$40	$809,320
7	Remove Structures and Obstructions at Shoreline Tie-ins	AL	1	$2,000,000	$2,000,000
Construct Surge Barrier Foundations					
8	Dredge Sill & Approach Channel Recess	CY	160,916	$40	$6,436,640
9	Furnish & Salvage Temporary Cellular Cofferdam Sheet Piles & Wyes	TN	4174	$1,100	$4,591,400
10	Install & Remove Temporary Cellular Cofferdam Sheet Piles & Wyes	TN	6143	$3,200	$19,657,600
11	Cofferdam Template	AL	1	$3,500,000	$3,500,000
12	Furnish Granular Cell Fill Material	CY	116403	$50	$5,820,150
13	Place Granular Cell Fill Material	CY	116403	$25	$2,910,075
14	Removal & Hauling of Temporary Cell Fill Material	CY	71633	$50	$3,581,630
15	Furnish & Salvage Temporary Tangent Wall Pipes & Braces	TN	1137	$1,100	$1,250,700
16	Install & Remove Temporary Tangent Wall Pipes & Braces	TN	2151	$3,200	$6,883,200
17	Furnish 96-in Diameter Steel Casings	VLF	1900	$1,161	$2,205,900
18	Furnish 48-in Diameter Steel Casings	VLF	23940	$372	$8,905,680
19	Furnish 36-in Diameter Steel Casings	VLF	6555	$227	$1,487,985
20	Furnish & Install Permanent Steel Sheet Pile Cut-off Wall	TN	481	$3,800	$1,827,800
21	Provide Cast-In-Place Cofferdam Tremie Seals In-Place	CY	38716	$450	$17,422,200
22	Provide & Maintain Cofferdam Dewatering System	AL	1	$2,500,000	$2,500,000
23	Provide Quarry Run Stone In-Place	TN	10565	$125	$1,320,625
24	Provide Class 1,000 Rock In-Place	TN	4832	$175	$845,600
25	Provide Bedding Gravel above Tremie	TN	37180	$50	$1,859,000
26	96-in Diameter Steel Casing Cut-Offs	EA	20	$7,500	$150,000
27	48-in Diameter Steel Casing Cut-Offs	EA	252	$2,200	$554,400
28	36-in Diameter Steel Casing Cut-Offs	EA	69	$1,500	$103,500
29	96-in Diameter Steel Casing Splices	EA	1	$80,000	$80,000
30	48-in Diameter Steel Casing Splices	EA	6	$25,000	$150,000
31	36-in Diameter Steel Casing Splices	EA	2	$18,750	$37,500
32	Install 96-in Diameter Concrete Shafts	VLF	1910	$4,516	$8,625,560
33	Install 48-in Diameter Concrete Shafts	VLF	20916	$1,398	$29,240,568

34	Install 36-in Diameter Concrete Shafts	VLF	5106	$1,219	$6,224,214
35	Cast-In-Place Concrete Sill & Pier Mat (Includes Pump Station Mat, Support Block Pedestals)	CY	21831	$1,200	$26,197,200
36	Cast-In-Place Gate Hinge	CY	588	$2,600	$1,528,800
37	Construct Shoreline Tie-In Structures	AL	2	$1,500,000	$3,000,000
Construct Surge Barrier Gates & Superstructures					
38	Cast-In-Place Pier Towers, Shear Walls, & Bridge Supports (Includes Pump Station Shear Walls)	CY	14453	$1,885	$27,243,905
39	Cast-In-Place Solid Dam & Counterforts	CY	849	$1,885	$1,600,365
40	Concrete Armor, Embedded Metals, Seals	TN	292	$7,000	$2,044,000
41	Furnish & Fabricate Submerged Axis Gate Elements In-Place	TN	819	$12,325	$10,094,119
42	Provide Surge Barrier Gate Cathodic Protection System (Coatings & Anodes)	AL	1	$1,009,412	$1,009,412
43	Furnish & Install Gate to Pier Latching System	AL	1	$2,523,530	$2,523,530
44	Furnish & Install Trolley Support Framing System	TN	90	$8,100	$729,000
45	Provide Pedestrian Bridge & Overlook In-Place	SF	17090	$450	$7,690,500
46	Provide MEP Systems In-Place	AL	1	$5,000,000	$5,000,000
47	Provide Vessel Impact Protection In-Place	AL	1	$1,500,000	$1,500,000
48	Operations Building	AL	1	$1,500,000	$1,500,000
49	Furnish Maintenance Bulkheads	TN	650	$8,000	$5,200,000
Subtotal Cost of Work Item Costs (Includes Contractor Overhead & Profit), Items 1 through 49 Inclusive:					**$321,086,804**
35% Class IV Design Level Contingency:					**$112,380,382**
Escalation - Average Annual Rate of 3.25% to Mid-Point of Construction, Year 2037:					**$197,681,415**
Total Opinion of Probable Cost, Say:					**$632,000,000**