1 The actual water surface elevations obtained from flow depths recorded on May 20th at 8:18PM, the time at which the peak elevations were recorded at the meter locations.
2 The computed water surface elevations represent results obtained using HEC-RAS.
3 The peak flow at Memorial Boulevard was computed using the Continuity Equation.
4 The computed peak flows represent results obtained using HEC-RAS.
5 Refer to Appendix G for summaries of water surface elevations obtained by HEC-RAS for all storm events, including the calibration storm.
6. N/M stands for not measured.

The computed water surface elevations at all three meter locations varied within 8% (or within four inches) of the actual water surface elevations recorded during the May 20th storm event. Additionally, the computed peak flow at the Memorial Boulevard culvert was within 0.5 cfs (or 2%) of the actual peak flow. Therefore, the hydraulic model appears to be relatively accurate in the vicinity of Memorial Boulevard.

3.4 Evaluation of Alternatives

With the hydrologic model calibrated to better represent actual flows experienced within the Moat during storm events, several hydraulic models were developed using HEC-RAS. The models were generated to evaluate and determine the best location and design for the proposed UV system in order to minimize flooding impacts experienced within and adjacent to the Moat during storm events; and to provide an improvement in the quality of stormwater discharged to Easton Bay.

3.4.1 Tidal Conditions

Flows within the Moat are tidally influenced during high tide conditions experienced in Easton Bay. Consequently, the size and layout of the proposed UV light disinfection system is dependent not only on peak flows conveyed by the Moat during storm events, but also tidal conditions experienced within Easton Bay. As a result, the hydraulic models were created in HEC-RAS as "unsteady flow" models assuming the most conservative approach that peak flows conveyed by the Moat (during storm events) occurred at the exact time that peak tidal elevations were experienced within Easton Bay for the following scenarios:

- *Present Day Scenario*: Tidal research of Newport tidal charts for the 2008 calendar year revealed that high tides on June 3, 2008 were expected to yield the greatest high tide elevation of the year. As a result, this elevation of 3.88 feet (NGVD29) was used as the downstream boundary condition (stage hydrograph) during all analyzed storm events. Refer to Appendix H for the 2008 tide charts for Newport, Rhode Island.

- *Sea Rise Scenario*: The rate of sea level rise is accelerating as a result of global warming. Future sea level rise, like the recent rise, is not expected to be globally uniform or linear. Some regions will become more substantially inundated than the global average, and others less. Accounting for regional

isostatic effects, this estimate suggests that by 2100 sea level in Rhode Island could rise approximately 2 to 5 feet. The City must be aware of this concern since rising sea-levels could impact the hydraulics and functionality of the UV disinfection system. Assuming a worst case scenario sea-rise increase of 5 feet, we have approximated that sea levels will rise approximately 0.65 inches on average annual basis. Planning for this potential increase, we have approximated that sea levels could be approximately 16.3 inches higher in 25 years than currently experienced. As a result, a hydraulic model was generated to analyze potential impacts that an increase of 16.3 inches would have on the UV light disinfection system. As a result, the elevation of 5.24 feet (NGVD29) was used as the downstream boundary condition (stage hydrograph) during storm events analyzed to evaluate the UV disinfection system.

Note that this study did not evaluate fluctuations in tidal elevations as a result of storm surges since such storm events would be of a larger magnitude or have a return frequency that would be less than the target storm events (i.e. the Water Quality Storm).

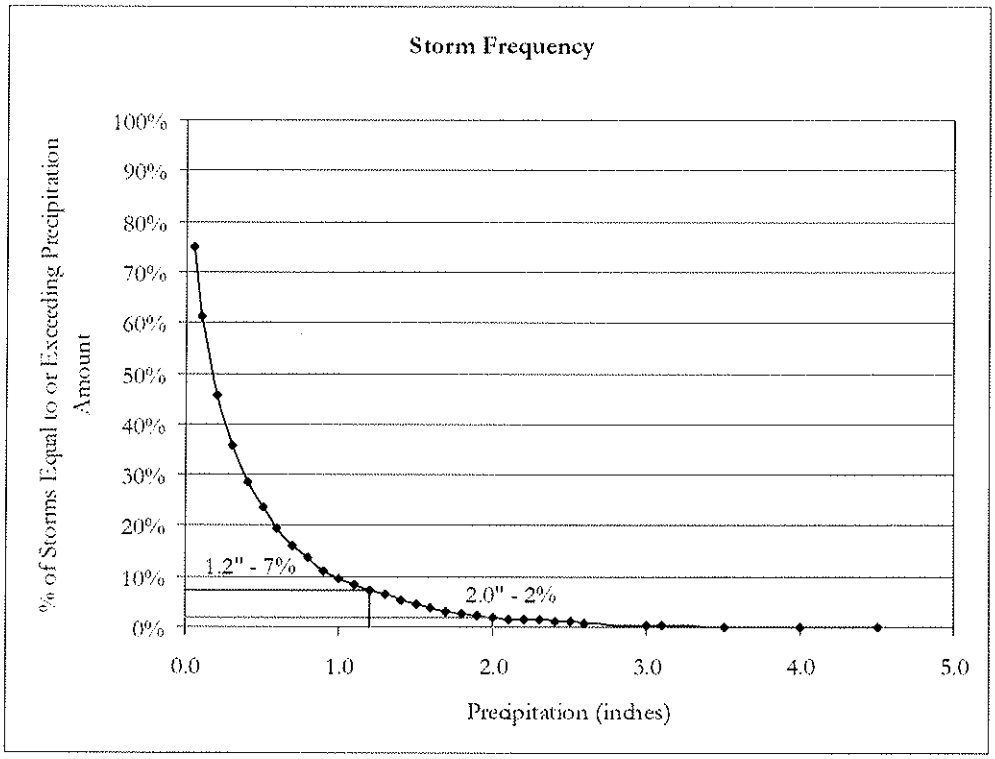
3.4.2 Storm Event Size

In order to determine which storm events should be used to size the UV disinfection system; daily rainfall data recorded from the Naval Underwater Warfare Center (NUWC) weather station in Middletown between 1992 and 2007 was analyzed. It was concluded that the layout and sizing of the proposed system would be evaluated during the following storm events:

- *Water Quality Storm:* the Rhode Island Stormwater design and Installation Standards Manual defines water quality storm event as that that generates the first inch of runoff from impervious surfaces. This storm event is evaluated as representative of the "first flush" that sweeps most of the pollutants off of impervious surfaces. To generate this volume of runoff, a storm event with 1.2 inches of precipitation was evaluated. In the Northeast, the 93 percent rainfall event is typically considered equivalent to approximately 1.2 inches of rainfall over a 24-hour period as shown in Figure 4. Only seven percent of storms that occur on an annual basis exceed 1.2 inches in rainfall over a 24-hour period.

- *2-Inch, 24-Hour Storm:* The 2-inch, 24-hour storm event is equivalent to 98 percent of all 24-hour storms that occur in Middletown between 1992 and 2007. Therefore, only 2 percent of the storms that occurred within Middletown were of a magnitude of greater than 2 inches.

Figure 4
Storm Frequency Histogram



As documented within Table 4, it was computed that the flows conveyed by the Moat during the Water Quality Storm and 2-Inch, 24-Hour Storm are approximately 96 cfs and 256 cfs, respectively. Based on discussions with UV disinfection system manufacturers, sizing a system to accommodate much more flow than approximately 96 cfs (62 MGD) will require a much larger, more extensive disinfection system. Given the negative cost implications associated with designing a system to treat 256 cfs (as discussed in more detail within the Process Design section of this report), and the limited increase in the number of storms that would be treated in their entirety, preliminary design of the UV disinfection system was evaluated for the Water Quality Storm only. Based on this data, an average of 9 storms per year exceed 1.2 inches of precipitation.

3.4.3 UV System Layout Alternatives

3.4.3.1 UV System Location

Several alterative layouts and locations of the UV disinfection system were evaluated from a hydraulic standpoint.

Hydraulic analyses of the Moat were evaluated to determine which sections of the Moat experienced overtopping or local flooding during selected storm events. Table 6 illustrates calculated water surface elevations experienced throughout the Moat during the more frequent storm events (i.e. the Water Quality Storm and the 2-Inch, 24-Hour Storm) for existing conditions. Table 7 illustrates calculated water surface elevations experienced throughout the Moat during the larger, less frequent storm events (i.e. the 2-, 5-, 10-, and 25-Year Storms) for existing conditions. Bold items within both tables indicate locations where overtopping/flooding of bank areas along the Moat occurs. Bold and italicized items in both tables indicate locations along the Moat where overtopping of the Easton Pond embankment would occur or flooding of adjacent roadways and/or properties would occur.

Table 6
Computed Water Surface Elevations in Moat
During More Frequent Storm Events (Present Tide Conditions)

Cross-Section Location	Cross-Section Description	Channel Left Overbank Elevation	Channel Right Overbank Elevation	Water Quality Storm	2-Inch Storm
Sta.77+65	Downstream of North Easton Pond Secondary Spillway	11.12 feet	8.57 feet	8.59 feet	***9.55 feet***[2]
Sta.72+20	In Vicinity of Kay Boulevard and Ellery Road Intersection	11.54 feet	8.97 feet	8.57 feet	***9.55 feet***[2]
Sta.65+34	In Vicinity of Ellery Road and Daniel Street Intersection	11.28 feet	9.76 feet	8.56 feet	9.54 feet
Sta.62+57	Downstream of 48" Culvert at Northwest Corner of Moat	12.19 feet	11.38 feet	8.55 feet	9.53 feet
Sta.39+28	Old Beach Road	12.02 feet	7.89 feet	6.35 feet	7.23 feet
Sta.33+88	Southwestern Corner of Moat at Old Beach Rd./Memorial Blvd. Intersection	11.63 feet	6.06 feet	6.05 feet	6.85 feet
Sta.19+66	Along Memorial Boulevard	12.06 feet	5.52 feet	5.31 feet	**6.20 feet**[1]
Sta.08+69	Along Memorial Boulevard	12.40 feet	5.10 feet	4.81 feet	**5.67 feet**[1]
Sta.05+74	Upstream of Confluence with Easton Pond Spillway	12.00 feet	5.30 feet	4.53 feet	**5.40 feet**[1]
Sta.05+12	Meter 3 Location	12.00 feet	5.30 feet	4.45 feet	5.27 feet
Sta.03+14	Meter 2 Location	7.30 feet	7.30 feet	4.39 feet	5.24 feet
Sta.02+65	Upstream of Memorial Boulevard Culvert	6.30 feet	7.26 feet	4.37 feet	5.17 feet

Cross-Section Location	Cross-Section Description	Channel Left Overbank Elevation	Channel Right Overbank Elevation	Water Quality Storm	2-Inch Storm
Sta.02+09	Downstream of Memorial Boulevard Culvert	8.00 feet	8.10 feet	4.32 feet	4.98 feet
Sta.01+70	Meter 1 Location	8.00 feet	7.80 feet	4.23 feet	4.79 feet
Sta.00+12	12' Upstream of Discharge to Easton Beach	10.30 feet	8.10 feet	3.90 feet	4.07 feet

Notes:

1 Bold items indicate overtopping/flooding of bank areas along sections of Moat considered as potential locations for the proposed UV disinfection systems.

2 Italicized items indicate locations along the Moat where overtopping of the Easton Pond embankment occurs or flooding of adjacent roadways and/or properties occurs.

3 Refer to Appendix G for complete list of computed water surface elevations at all cross-sections during the selected storm events (including cross-section output and supporting documentation).

4 All elevations listed in table are in reference to National Geodetic Vertical Datum 1929 (NGVD29).

5 Refer to Sheet 3 for a depiction of all cross-section locations.

As illustrated within Table 6, the most practical location (from a hydraulic standpoint) to install the proposed system would be in the section of the Moat between Easton Pond's primary spillway and Easton Beach, *Alternative Locations #1 and #2*. Flow conveyed by the Moat during the more frequent storm events (i.e. the Water Quality Storm and the 2-Inch, 24-Hour Storm) is entirely confined within the banks of the Moat channel at these two locations. Conversely, overtopping of the Moat at *Alternate Location #3* occurs during storm events of a greater magnitude than the Water Quality Storm (i.e. the 2-Inch, 24-Hour Storm).

Another consideration in selecting the location for the proposed system is protecting equipment and structures associated with the UV disinfection system from flood damage. Table 7 illustrates locations where flooding within and along the Moat occurs during the larger, more infrequent storm events.

Table 7
Computed Water Surface Elevations in Moat During Larger, Infrequent Storm Events

Cross-Section Location	Cross-Section Description	Channel Left Overbank Elevation	Channel Right Overbank Elevation	2-Year Storm (feet)	5-Year Storm (feet)	10-Year Storm (feet)	25-Year Storm (feet)
Sta.77+65	Downstream of North Easton Pond Secondary Spillway	11.12 feet	8.57 feet	*10.84 feet*[2]	*11.50 feet*[2]	*11.93 feet*[2]	*12.42 feet*[2]
Sta.72+20	In Vicinity of Kay Boulevard and Ellery Road Intersection	11.54 feet	8.97 feet	*10.84 feet*[2]	*11.50 feet*[2]	*11.92 feet*[2]	*12.42 feet*[2]
Sta.65+34	In Vicinity of Ellery Road and Daniel Street Intersection	11.28 feet	9.76 feet	*10.83 feet*[2]	*11.50 feet*[2]	*11.92 feet*[2]	*12.41 feet*[2]
Sta.62+57	Downstream of 48" Culvert at Northwest Corner of Moat	12.19 feet	11.38 feet	10.83 feet	*11.49 feet*[2]	*11.91 feet*[2]	*12.40 feet*[2]
Sta.39+28	Old Beach Road	12.02 feet	7.89 feet	*8.37 feet*[2]	*8.76 feet*[2]	*9.06 feet*[2]	*9.37 feet*[2]
Sta.33+88	Southwestern Corner of Moat at Old Beach Rd./Memorial Blvd. Intersection	11.63 feet	6.06 feet	7.87 feet	8.29 feet	*8.51 feet*[2]	*8.78 feet*[2]
Sta.19+66	Along Memorial Boulevard	12.06 feet	5.52 feet	**7.22 feet**[1]	**7.66 feet**[1]	***7.84 feet***[1,2]	***8.13 feet***[1,2]
Sta.08+69	Along Memorial Boulevard	12.40 feet	5.10 feet	***6.92 feet***[1,2]	***7.46 feet***[1,2]	***7.70 feet***[1,2]	***8.03 feet***[1,2]
Sta.05+74	Upstream of Confluence with Easton Pond Spillway	12.00 feet	5.30 feet	**6.73 feet**[1]	**7.33 feet**[1]	**7.60 feet**[1]	**7.93 feet**[1]
Sta.05+12	Meter 3 Location	12.00 feet	5.30 feet	**6.67 feet**[1]	**7.28 feet**[1]	**7.55 feet**[1]	**7.89 feet**[1]
Sta.03+14	Meter 2 Location	7.30 feet	7.30 feet	6.65 feet	7.27 feet	**7.55 feet**[1]	**7.88 feet**[1]
Sta.02+65	Upstream of Memorial Boulevard Culvert	6.30 feet	7.26 feet	6.49 feet	7.11 feet	**7.42 feet**[1]	**7.72 feet**[1]
Sta.02+09	Downstream of Memorial Boulevard Culvert	8.00 feet	8.10 feet	5.84 feet	6.13 feet	6.28 feet	6.49 feet
Sta.01+70	Meter 1 Location	8.00 feet	7.80 feet	5.54 feet	5.80 feet	5.92 feet	6.00 feet
Sta.00+12	12' Upstream of Discharge to Easton Beach	10.30 feet	8.10 feet	4.43 feet	4.62 feet	4.70 feet	4.80 feet

Notes:

1 Bold items indicate overtopping/flooding of bank areas along sections of Moat considered as potential locations for the proposed UV disinfection systems.

2 Italicized items indicate locations along the Moat where overtopping of the Easton Pond embankment occurs or flooding of adjacent roadways and/or properties occurs.

3 Refer to Appendix G for complete list of computed water surface elevations at all cross-sections during the selected storm events (including cross-section output and supporting documentation).

4 All elevations listed in table are in reference to National Geodetic Vertical Datum 1929 (NGVD29).

Alternative Locations #1 and #2 are least likely to experience flooding during storm events of a lesser magnitude than the 10-year storm. Although Alternative Location #1 would be the most ideal location to install the UV disinfection system from a hydraulic and flood-protection standpoint, this location would be highly impacted by shoaling and coastal storms, and thereby, could pose a significant future maintenance problem due to damage from severe storms.

Consequently, Alternative Location #2 is the location recommended from a hydraulic standpoint and is carried through this preliminary design. This location reduces negative effects of shoaling on the disinfection system, provides some physical protection of the equipment from storms, and provides the ability to treat flows conveyed by the Moat during the more frequent storm events with minimal Moat embankment improvements.

3.4.3.2 UV System Design

Several gravity layout alternatives for the UV disinfection system were contemplated during the design process. Due to the flatness of the Moat and relatively large flows conveyed by the Moat, water surface elevations within the Moat do not significantly vary between successive cross sections. The slopes of both the water surface profile and energy grade line upstream of Memorial Boulevard are relatively small with values ranging between 0.03±% to 0.06±% during the Water Quality Storm. As a result, there is limited head differential to efficiently convey flow through the UV disinfection system during storm events. Based on hydraulic computations provided by system manufacturers, a by-pass weir would need to be installed within the Moat that could increase water surface elevations upstream of the system by approximately 24 to 30 inches above the water surface elevations downstream of the system based on data supplied by manufacturers. This, however, would adversely impact Moat water surface elevations upstream of the system during storm events and exacerbate flooding issues that are currently experienced in several locations along the Moat (i.e. Memorial Boulevard and Old Beach Road). Therefore, a pump must be incorporated into the design to assure that flooding impacts currently experienced along the Moat would not be exacerbated.

Installing a pump within the diversion channel of the UV disinfection system eliminates the need to create the necessary head differential upstream and downstream of the system since the pump would add the hydraulic energy required to overcome head losses in the UV disinfection system. Consequently, the alternative selected for analysis consists of the installation of an inline gate within the Moat, a diversion channel designed to convey the portion of flow targeted for pretreatment to the UV disinfection system, and a pump station located immediately upstream of the Memorial Boulevard culvert. The inline gate will be open during dry weather conditions and will be closed during wet-weather conditions. The top elevation of

the inline gate (when closed) will be set to an elevation slightly above the elevation necessary to direct the targeted flow through the UV disinfection diversion channel under each high tide scenario. Once the gate is closed, flow will be conveyed by the diversion channel to a pump station. Water flow in excess of the targeted flow will continue over the inline gate (which will function as a by-pass weir) through the existing Moat channel.

The design scenarios were based on flows conveyed by the Moat during the Water Quality Storm under present day and future high tide conditions; with and without the inclusion of water quality flow discharged to the Moat from the Esplanade outfall. One pump capable of delivering a flow rate of 96 cfs (WQV without Esplanade flow), at the total dynamic head (TDH) provided by the UV system, was evaluated. The pump series evaluated is also capable of delivering a flow rate of 101.5 cfs, which is the Water Quality Storm accounting for Esplanade flow.

For modeling purposes, the top of the inline gate (when closed) under present-day high tide conditions was set to elevation of 4.75 feet. The top of the inline gate (when closed) under future high tide conditions was set to elevation of 6.00 feet. Both elevations were set to ensure that overtopping of the gate and backflow from downstream of the gate (as a result of tidal conditions) did not occur during each design scenario.

The results of the analyses have been included in Tables 8 and 9. The water surface elevations listed in parentheses for the 2- through 25-Year Storm indicate values obtained accounting for flow discharged to the Moat from the Esplanade outfall. This analysis is based on a pump station being added to the system to better manage channel hydraulics.

Table 8
Pre-Development versus Post-Development
Water Surface Elevation Comparison (Present-Day Tide Scenario)

Cross-Section Location	Cross-Section Description	Pre-Dev. Water Quality Storm	Post-Dev. Water Quality Storm	2-Year Storm	5-Year Storm	10-Year Storm	25-Year Storm
Sta.77+65	Downstream of North Easton Pond Secondary Spillway	8.59 feet	8.60 ft. (8.60 ft.)	10.85 ft. (10.85 ft.)	11.51 ft. (11.51 ft.)	11.93 ft. (11.93 ft.)	12.42 ft. (12.42 ft.)
Sta.72+20	In Vicinity of Kay Boulevard and Ellery Road Intersection	8.57 feet	8.57 ft. (8.57 ft.)	10.85 ft. (10.85 ft.)	11.51 ft. (11.51 ft.)	11.93 ft. (11.93 ft.)	12.42 ft. (12.42 ft.)
Sta.65+34	In Vicinity of Ellery Road and Daniel Street Intersection	8.56 feet	8.56 ft. (8.56 ft.)	10.84 ft. (10.84 ft.)	11.50 ft. (11.50 ft.)	11.93 ft. (11.93 ft.)	12.41 ft. (12.41 ft.)
Sta.62+57	Downstream of 48" Culvert at Northwest Corner of Moat	8.55 feet	8.55 ft. (8.55 ft.)	10.83 ft. (10.83 ft.)	11.50 ft. (11.50 ft.)	11.92 ft. (11.92 ft.)	12.40 ft. (12.40 ft.)
Sta.39+28	Old Beach Road	6.35 feet	6.35 ft. (6.35 ft.)	8.39 ft. (8.39 ft.)	8.77 ft. (8.77 ft.)	9.07 ft. (9.07 ft.)	9.37 ft. (9.38 ft.)
Sta.33+88	Southwestern Corner of Moat at Old Beach Rd./Memorial Blvd. Intersection	6.05 feet	6.05 ft. (6.05 ft.)	7.89 ft. (7.89 ft.)	8.29 ft. (8.29 ft.)	8.52 ft. (8.52 ft.)	8.78 ft. (8.79 ft.)
Sta.19+66	Along Memorial Boulevard	5.34 feet	5.31 ft. (5.32 ft.)	7.25 ft. (7.28 ft.)	7.66 ft. (7.68 ft.)	7.85 ft. (7.87 ft.)	8.14 ft. (8.16 ft.)
Sta.08+69	Along Memorial Boulevard	4.81 feet	4.72 ft. (4.74 ft.)	6.96 ft. (7.01 ft.)	7.47 ft. (7.51 ft.)	7.71 ft. (7.75 ft.)	8.04 ft. (8.06 ft.)
Sta.05+74	Upstream of Confluence with Easton Pond Spillway	4.53 feet	4.42 ft. (4.46 ft.)	6.78 ft. (6.85 ft.)	7.34 ft. (7.39 ft.)	7.60 ft. (7.64 ft.)	7.93 ft. (7.96 ft.)
Sta.05+12	Meter 3 Location	4.45 feet	4.34 ft. (4.39 ft.)	6.73 ft. (6.80 ft.)	7.29 ft. (7.34 ft.)	7.55 ft. (7.59 ft.)	7.89 ft. (7.93 ft.)
Sta.03+14	Upstream of Inline Gates	4.39 feet	4.45 ft. (4.45 ft.)	6.72 ft. (6.79 ft.)	7.29 ft. (7.34 ft.)	7.56 ft. (7.60 ft.)	7.88 ft. (7.93 ft.)
Sta.02+65	Downstream of Inline Gates	4.37 feet	4.49 ft. (4.51 ft.)	6.52 ft. (6.59 ft.)	7.10 ft. (7.15 ft.)	7.40 ft. (7.43 ft.)	7.76 ft. (7.76 ft.)
Sta.02+09	Downstream of Memorial Boulevard	4.32 feet	4.42 ft. (4.43 ft.)	5.85 ft. (5.88 ft.)	6.14 ft. (6.15 ft.)	6.25 ft. (6.27 ft.)	6.50 ft. (6.50 ft.)
Sta.01+70	Meter 1 Location	4.23 feet	4.31 ft. (4.33 ft.)	5.56 ft. (5.58 ft.)	5.80 ft. (5.81 ft.)	5.90 ft. (5.92 ft.)	6.01 ft. (6.01 ft.)
Sta.00+12	12' Upstream of Discharge to Easton Beach	3.90 feet	3.92 ft. (3.92 ft.)	4.44 ft. (4.46 ft.)	4.62 ft. (4.62 ft.)	4.70 ft. (4.71 ft.)	4.80 ft. (4.80 ft.)

Notes:

[1] Refer to Appendix G for complete list of computed water surface elevations at all cross-sections during the selected storm events (including cross-section output and supporting documentation).

[2] A high tide elevation of 3.88 feet (NGVD29) was input as the downstream boundary condition.

Table 9
Pre-Development versus Post-Development
Water Surface Elevation Comparison (Sea-Rise Tide Scenario)

Cross-Section Location	Cross-Section Description	Pre-Dev. Water Quality Storm	Post-Dev. Water Quality Storm	2-Year Storm	5-Year Storm	10-Year Storm	25-Year Storm
Sta.77+65	Downstream of North Easton Pond Secondary Spillway	8.60 ft.	8.60 ft. (8.60 ft.)	10.85 ft. (10.85 ft.)	11.51 ft. (11.51 ft.)	11.94 ft. (11.94 ft.)	12.42 ft. (12.42 ft.)
Sta.72+20	In Vicinity of Kay Boulevard and Ellery Road Intersection	8.58 ft.	8.58 ft. (8.58 ft.)	10.85 ft. (10.85 ft.)	11.51 ft. (11.51 ft.)	11.93 ft. (11.93 ft.)	12.42 ft. (12.42 ft.)
Sta.65+34	In Vicinity of Ellery Road and Daniel Street Intersection	8.56 ft.	8.56 ft. (8.56 ft.)	10.84 ft. (10.84 ft.)	11.51 ft. (11.51 ft.)	11.93 ft. (11.93 ft.)	12.41 ft. (12.41 ft.)
Sta.62+57	Downstream of 48" Culvert at Northwest Corner of Moat	8.55 ft.	8.55 ft. (8.55 ft.)	10.84 ft. (10.84 ft.)	11.50 ft. (11.50 ft.)	11.92 ft. (11.92 ft.)	12.40 ft. (12.40 ft.)
Sta.39+28	Old Beach Road	6.44 ft.	6.45 ft. (6.46 ft.)	8.40 ft. (8.41 ft.)	8.78 ft. (8.78 ft.)	9.08 ft. (9.08 ft.)	9.38 ft. (9.38 ft.)
Sta.33+88	Southwestern Corner of Moat at Old Beach Rd./Memorial Blvd. Intersection	6.19 ft.	6.20 ft. (6.21 ft.)	7.92 ft. (7.93 ft.)	8.30 ft. (8.30 ft.)	8.53 ft. (8.53 ft.)	8.81 ft. (8.81 ft.)
Sta.19+66	Along Memorial Boulevard	5.71 ft.	5.75 ft. (5.76 ft.)	7.34 ft. (7.38 ft.)	7.71 ft. (7.72 ft.)	7.90 ft. (7.92 ft.)	8.19 ft. (8.20 ft.)
Sta.08+69	Along Memorial Boulevard	5.45 ft.	5.55 ft. (5.55 ft.)	7.09 ft. (7.15 ft.)	7.56 ft. (7.59 ft.)	7.78 ft. (7.82 ft.)	8.09 ft. (8.10 ft.)
Sta.05+74	Upstream of Confluence with Easton Pond Spillway	5.37 ft.	5.51 ft. (5.52 ft.)	6.96 ft. (7.02 ft.)	7.45 ft. (7.49 ft.)	7.69 ft. (7.73 ft.)	8.00 ft. (8.00 ft.)
Sta.05+12	Meter 3 Location	5.34 ft.	5.51 ft. (5.52 ft.)	6.91 ft. (6.97 ft.)	7.40 ft. (7.44 ft.)	7.63 ft. (7.68 ft.)	7.98 ft. (7.98 ft.)
Sta.03+14	Upstream of Inline Gates	5.33 ft.	5.75 ft. (5.75 ft.)	6.91 ft. (6.97 ft.)	7.41 ft. (7.45 ft.)	7.65 ft. (7.69 ft.)	7.97 ft. (7.97 ft.)
Sta.02+65	Downstream of Inline Gates	5.32 ft.	5.49 ft. (5.50 ft.)	6.71 ft. (6.77 ft.)	7.23 ft. (7.27 ft.)	7.48 ft. (7.53 ft.)	7.89 ft. (7.91 ft.)
Sta.02+09	Downstream of Memorial Boulevard	5.30 ft.	5.44 ft. (5.45 ft.)	6.06 ft. (6.08 ft.)	6.25 ft. (6.27 ft.)	6.37 ft. (6.39 ft.)	7.67 ft. (7.68 ft.)
Sta.01+70	Meter 1 Location	5.27 ft.	5.42 ft. (5.43 ft.)	5.83 ft. (5.84 ft.)	5.98 ft. (6.00 ft.)	6.08 ft. (6.10 ft.)	7.08 ft. (7.09 ft.)
Sta.00+12	12' Upstream of Discharge to Easton Beach	5.24 ft.	5.26 ft. (5.26 ft.)	5.28 ft. (5.28 ft.)	5.30 ft. (5.30 ft.)	5.32 ft. (5.32 ft.)	5.52 ft. (5.53 ft.)

Notes:

1 Refer to Appendix G for complete list of computed water surface elevations at all cross-sections during the selected storm events (including cross-section output and supporting documentation).

2 A high tide elevation of 5.24 feet (NGVD29) was input as the downstream boundary condition.

As demonstrated by the results of the hydraulic analyses, water surface elevations within the Moat will not be adversely impacted by the installation of the UV disinfection system or the inclusion of Esplanade flow to the Moat during the smaller, more frequent storm events and current tide conditions when a pump station is added to the system (0.0 to 0.12 foot increase in water surface elevations during a water quality storm event). Similarly, water surface elevations within the western and northern sections of the Moat will not be impacted by the installation of the UV disinfection system (with pumps) or the inclusion of Esplanade flow to the Moat during the larger, infrequent storm events. Increases in water surface elevations of less than 0.01 feet are noted in these locations during the larger, infrequent storms.

Impacts to water surface elevations, however, are expected in the southern portion of the Moat along Memorial Boulevard as a result of the installation of the UV disinfection system or the inclusion of Esplanade flow to the Moat during the larger, infrequent storms. During the 2-year storm, minor increases in water surface elevations ranging up to 0.07 feet will be experienced along the southern portion of the Moat (along Memorial Boulevard) as a result of the installation of the UV disinfection system. An additional increase in water surface elevations ranging between 0.02 feet and 0.07 feet will be experienced as a result of the inclusion of Esplanade flow to the Moat.

Additionally, a comparison of water surface elevations between current and future high tides indicates that water surface elevations within the western and northern sections of the Moat will not be impacted by sea rise. However, water surface elevations within the southern portion of the Moat (along Memorial Boulevard) will be impacted by coastal sea rise. Increases in elevations of up to approximately 0.19 feet will be experienced within the southern portion of the Moat upstream of Memorial Boulevard because of sea rise Increases in elevations of up to approximately 0.82 feet will be experienced within the southern portion of the Moat downstream of Memorial Boulevard.

Water surface profiles generated for each design scenario using HEC-RAS have been included on Figures 5 through 8. Larger scale water surface profiles are also provided on Sheets 4 through 7.

Figure 5
Water Surface Profile of Moat Including Inline Gate and Pump
(Water Quality Storm – Present High Tide – Excluding Esplanade Flow)

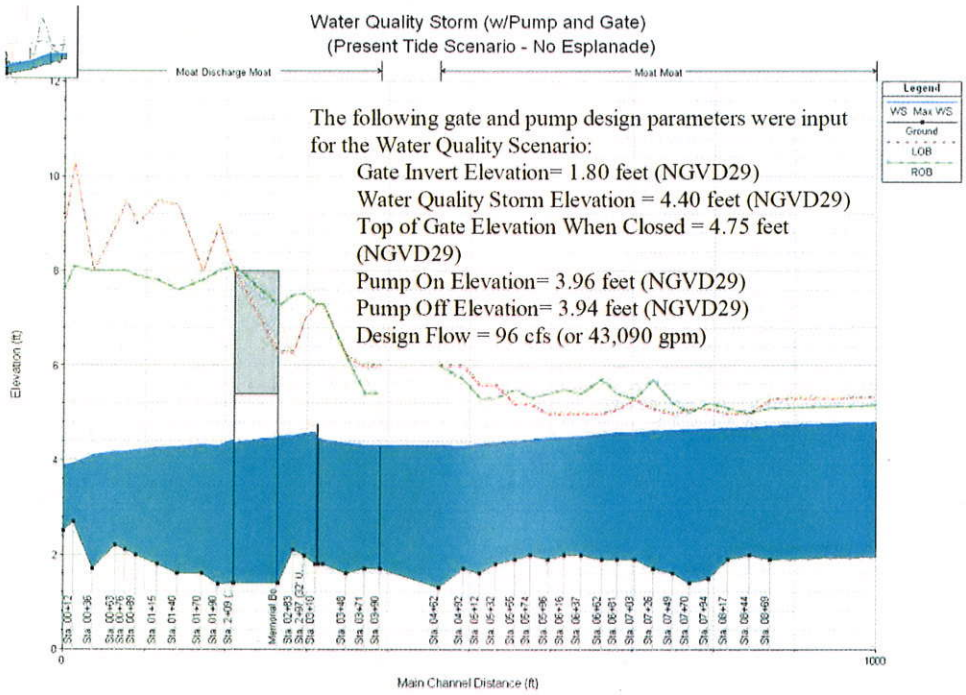


Figure 6
Water Surface Profile of Moat Including Inline Gate and Pump (Water Quality Storm – Present High Tide – Including Esplanade Flow)

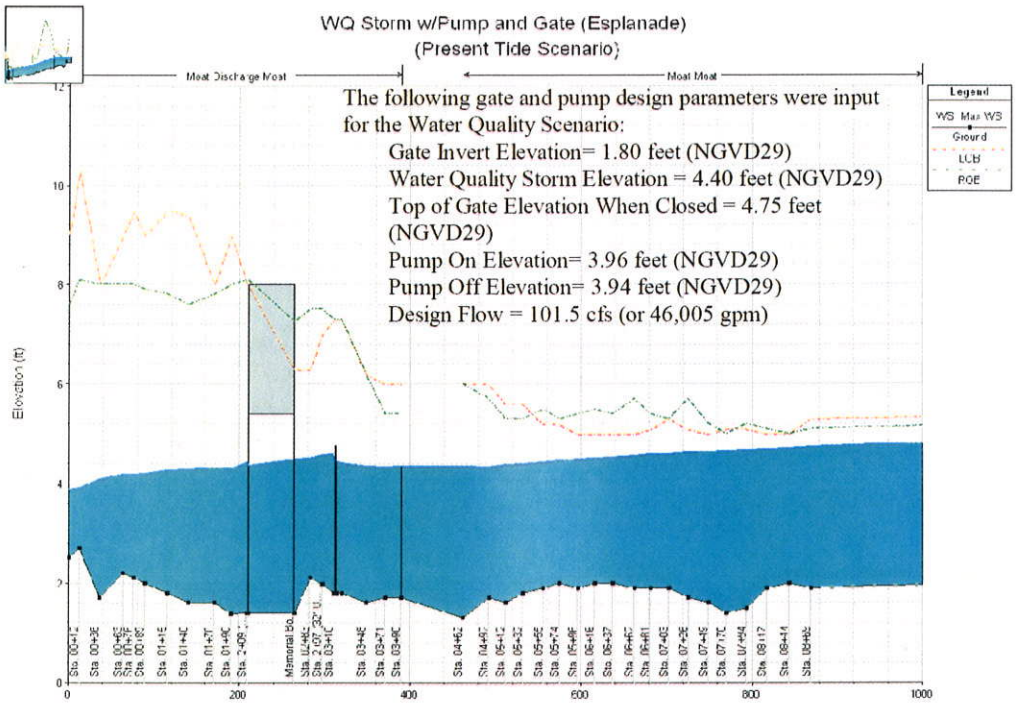


Figure 7
Water Surface Profile of Moat Including Inline Gate and Pump
(Water Quality Storm – Future High Tide – Excluding Esplanade Flow)

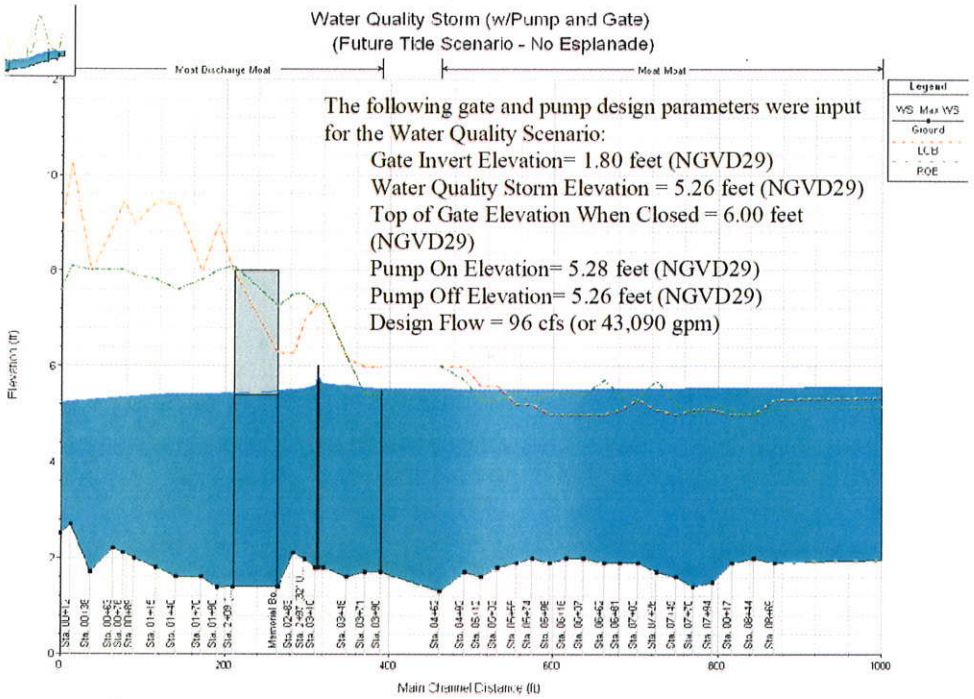
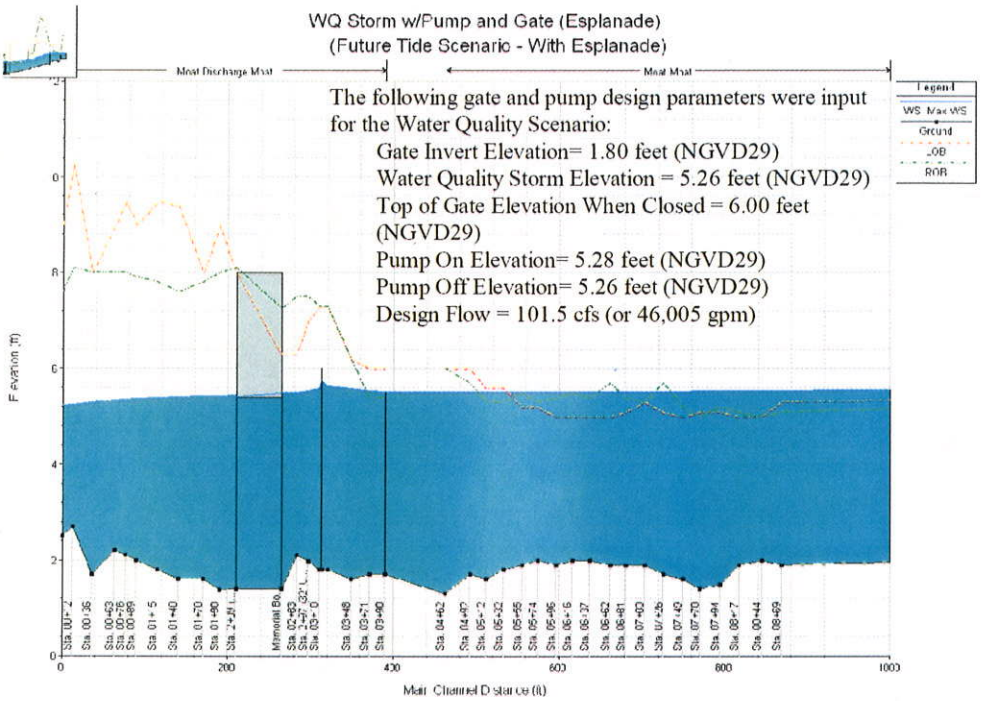


Figure 8
Water Surface Profile of Moat Including Inline Gate and Pump
(Water Quality Storm – Future High Tide – Including Esplanade Flow)



4.0 DILUTION STUDY

A dilution study was conducted to determine the amount of dilution provided by Easton Bay of the Moat discharge that drains the area surrounding South Easton

Pond. A complete copy of the Easton's Pond Moat Dilution Analysis (Dilution Study) is included in Appendix I. This study first conducted a wave analysis using depth and velocity data. CORMIX software was then used to determine dilution rates under two different rates of discharge from the Moat outfall.

4.1 Wave Analysis

The driving physical force in the Easton's Bay nearshore surf zone is likely wave breaking. Wave breaking creates an alongshore momentum flux that results in an alongshore current, which is a function of breaking wave height, local bottom slope and angle of incidence of the breaking wave. The histogram of historic wave heights presented in the Dilution Study indicates that the 50th percentile wave is 2.59 feet high between the months of May and September based on a 20-year (1980-1999) hindcast from the US Army Corps of Engineers Wave Information Study.

Dilution calculations were based on a statistical estimate of low flow, defined as the alongshore current associated with lower wave heights. The alongshore current (v0) associated with the 10th percentile wave height (1.15 feet) was determined to be 0.66 feet/sec.

4.2 Analytical Dilution Modeling

Proposed discharge mixing characteristics were evaluated using Cornell Mixing Zone Expert System (CORMIX) software. CORMIX is a software system for the analysis, prediction, and design of aqueous toxic or conventional pollutant discharges into diverse water bodies. For this project, CORMIX was used to simulate the dilution of effluent discharging from the Moat into Easton Bay. The analysis determined the dilution potential in the nearshore surf zone.

CORMIX requires several input parameters to be defined within the Moat discharge and Easton Bay. The wetted cross section of the Moat was estimated from aerial photography to be 23 feet wide with a depth of 2 feet. The discharge in the Moat was assumed to be fresh water with a density of 1000 kg/m^3. The density of the ambient water in Easton Bay was calculated as 1022 kg/m^3. The dilution, driven by a wave-induced alongshore current based on the Longuet-Higgins Equation, is calculated to be 0.66 feet/sec.

4.3 Dilution Modeling Results and Discussion

Dilution was analyzed for two different Moat discharge scenarios, 96 cfs and 116 cfs that correlate to peak flows associated with the Water Quality Storm (1.2 inches of precipitation over a 24-hour duration) under both existing conditions and if the

Esplanade discharge is diverted to the Moat. The dilution potential is described as the percent of the initial discharge concentration. Therefore, the discharge from the Moat corresponds to 100%, decreasing with distance from the Moat discharge point into Easton Bay and determined by the analytical dilution model. The value at the center line of the discharge plume is used to represent the potential dilution within Easton Bay. Dilution would increase and bacteria levels would decrease as you move away from this centerline of the plume. The plume is oriented in the same direction as the alongshore current, modeled in the direction of the City of Newport to determine worst-case dilution results.

The Easton's Pond Moat Dilution Analysis provides tables and figures related to dilution potential as a function of Moat discharge and distance from the interface between the Moat and Easton Bay. As shown in Figure 9, the model predicts that the effluent dilutes to 60% of its original concentration within 20 feet of the Moat outfall for 96 cfs and 116 cfs flow scenarios. The 116 cfs scenario represents runoff volume for the 1.2-inch storm event including Esplanade flow prior to hydraulic model calibration. The calibrated model indicates Moat flows including Esplanade are 101.5 cfs; therefore, the 116 cfs scenario is conservative and brackets the WQV design

Figure 9
Dilution Calculation Results

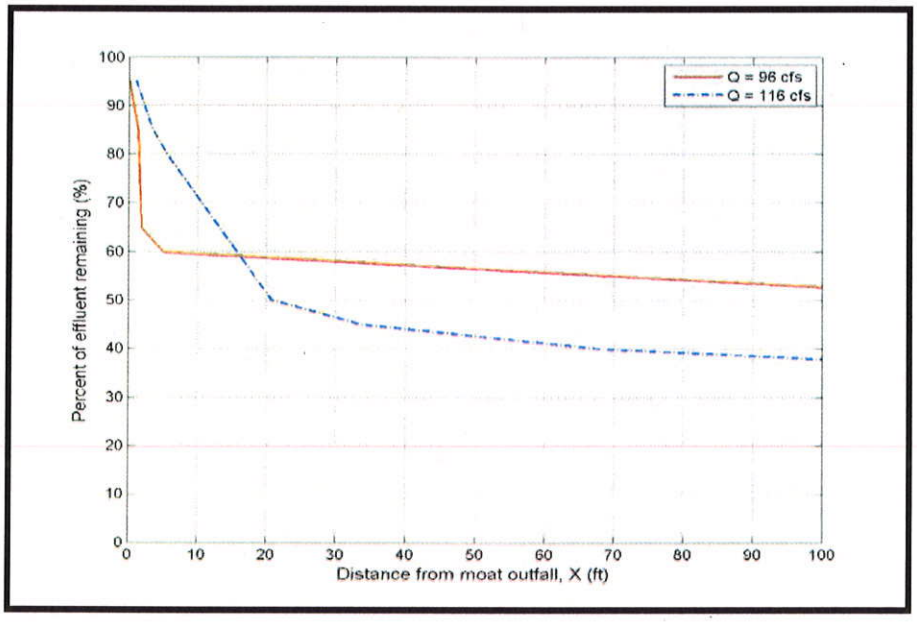
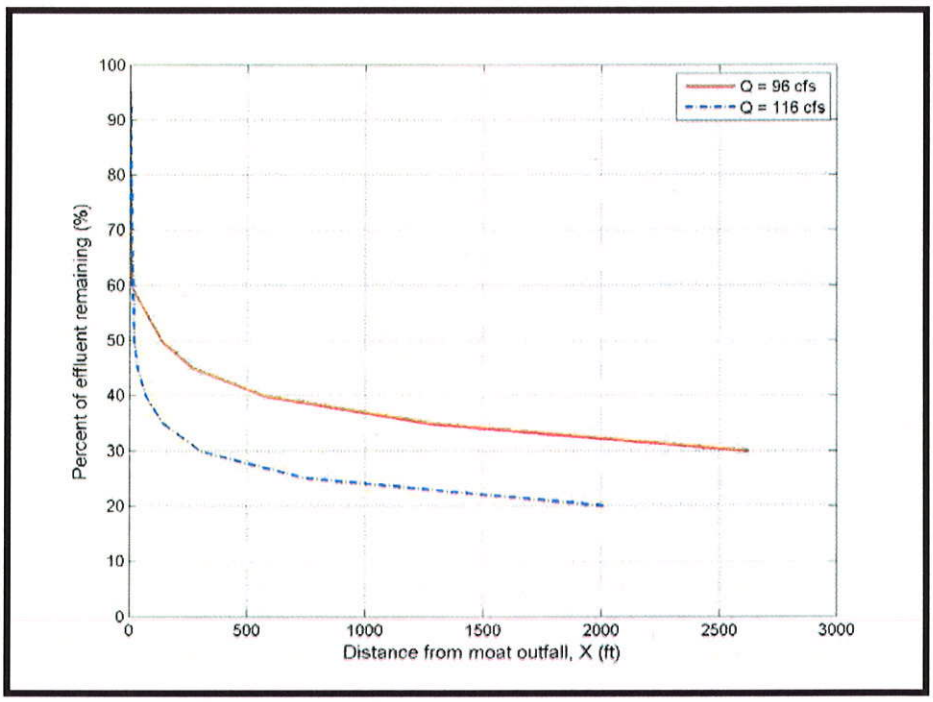


Figure 10 shows that the 96 cfs plume reaches a dilution of 50% within 136 feet of the Moat outfall and at the furthest extent mapped, the plume dilutes to 30%. In contrast, the 116 cfs plume effluent dilutes to less than 30% at 300 feet from the Moat outfall.

Figure 10
Dilution Calculation Results



Figures 11 and 12 provide graphical depictions of plume dilution by Easton's Bay for the 96 and 116 cfs scenarios, respectively.

Figure 11
Moat Effluent Plume for a Discharge Rate of 96 cfs

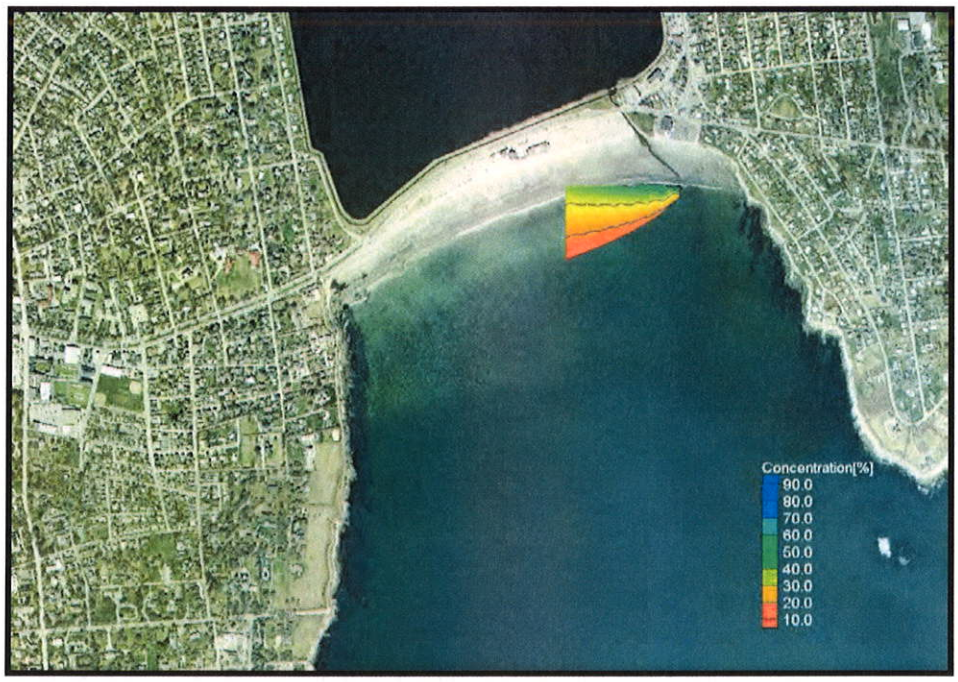
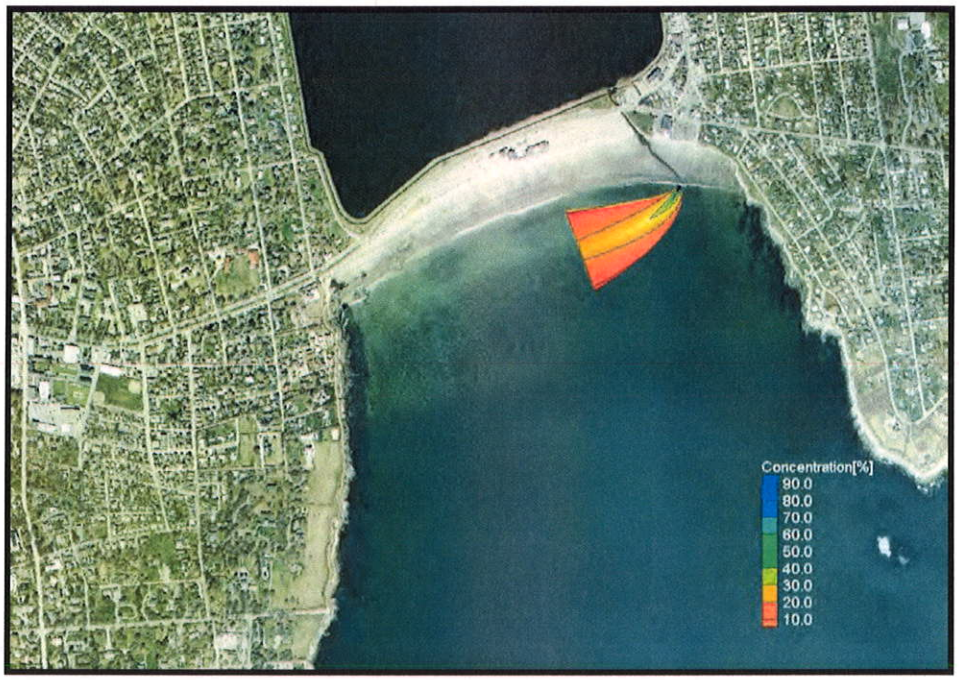


Figure 12
Moat Effluent Plume for a Discharge Rate of 116 cfs



Dilution values were calculated for the center of the plume that appears to flow across the face of the beach. Based on this analysis, about 50% dilution would be expected within 140 feet of the outfall for both 96 and 116 cfs Moat discharge and effluent concentrations would not be diluted to less than 30% of the original concentration in the Moat at even more than 2,500 feet from the Moat discharge. Therefore, a 2:1 dilution is presumed available on the moat discharge at least 90% of the time.

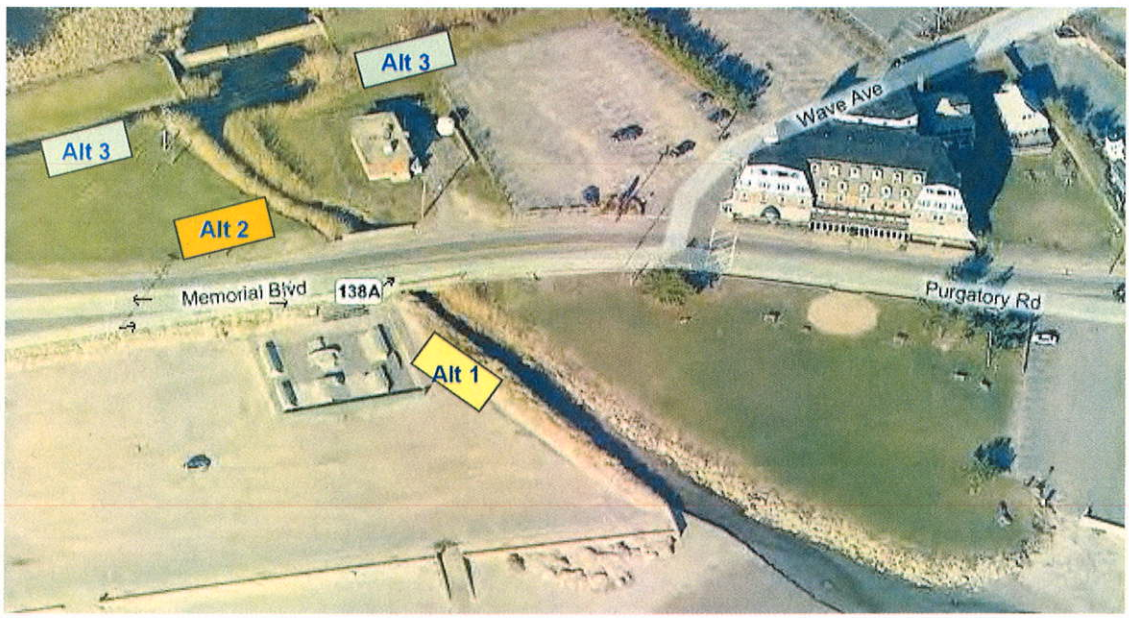
5.0 PROCESS PRELIMINARY DESIGN

The following paragraphs summarize the preliminary design of critical system elements. This includes an assessment of disinfection equipment siting, Moat Hydraulics, UV equipment alternatives, UV disinfection system design flow, dilution available by Easton's Bay, UV system disinfection criteria, capital costs, and long-term operating and maintenance costs.

5.1 UV Disinfection System Alternative Locations

Several alternative locations were reviewed that would provide for an economical as well as beneficial location for the UV disinfection system. These locations were selected for further review based on ability to treat the largest sources of bacteria, while dealing with the physical challenges in the construction area. The following is a description for each of the alternative locations. These alternative locations are indicated on Figure 13 and on Sheet 8.

Figure 13
System Layout Alternatives



Alternative Location #1: This location is near the original UV Pilot Plant located just south of Memorial Blvd. and East of the skate park. The original study suggested placing the UV disinfection system at this location. It allows for treatment of stormwater from City-owned outfalls, the Memorial