Boulevard RIDOT outfall, and all surface water sources that drain to the Moat without relocation of these existing outfalls. However, 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 or removing accumulated sand from the system.

Alternative Location #2: Located immediately north of Memorial Blvd. and west of the existing pump station building. This location offers some protection from storms and shoaling, but requires relocation of the existing gas main for the recommended configuration and vendor. Configurations for some system manufacturers would also require relocation of the sewer mains. The RIDOT Memorial Boulevard and possibly the Pump Station outfalls would also need to be relocated to drain into the UV disinfection system.

Alternative Location #3: This would require installation of two (2) UV disinfection systems, one in each of the western and eastern segments of the Moat. The RIDOT outfall would need to be relocated to one of these two systems requiring extensive excavation and work adjacent to the Moat and Pump Station. Configurations for some system manufacturers would also require relocation of the sewer mains.

The following table summarizes advantages and disadvantages for each the alternative locations.

Table 10
Summary of Alternative Location Options

Alternative Location	Pros	Cons
#1	▪ Ability to treat water from each source without reconstruction of either. ▪ No relocation of gas or sewer lines.	▪ Exposure to storm surges. ▪ Significant potential for shoaling and future maintenance problem. ▪ Located adjacent to the beach area this may be an unattractive nuisance. ▪ May require the partial or full relocation of the skate park. ▪ Would consume some portion of the beach parking lot
#2	▪ Location offers better protection from storms. ▪ Shoaling issue is greatly reduced. ▪ Location is away from the beaches. ▪ Located in a grassed area that would not impact beach parking or views from the beach	▪ Will require some relocation of gas, sewer, and overhead electrical lines depending on final configuration of system ▪ Requires relocation of RIDOT outfall and Pump Station Outfall
#3	▪ Best option for protection from storms and shoaling issue ▪ Location is furthest from the beaches.	▪ Requires two UV disinfection systems ▪ Extensive relocation of RIDOT and Pump Station outfalls ▪ Possible relocation of sewer lines required for western Moat installation

Alternative location #2 is recommended and carried through this preliminary design, as it minimizes utility relocation, reduces negative effects of shoaling, provides some physical protection of the equipment from coastal storms, and provides the ability to treat Moat discharge up to WQV design flows.

5.2 Collimated Beam Sampling

Collimated beam sampling continued to be conducted in support of the process design on stormwater from the Moat to provide additional data and confirm the current process design characteristics. Collimated beam testing provides detailed bench-scale dose response data (bacteria response survival following exposure to UV light) to supplement the data collected in the field during the pilot testing. Samples have been collected for nine (9) storm events, and were sent to TojanUV of London, Ontario, Canada who has performed a total of thirteen (13) collimated beam analyses, results of which are highlighted in Table 11. Collimated beam test reports are included in Appendix J.

Sampling was conducted for precipitation events in which a rainfall of greater than 0.1 inch occurred. On July 5, 2007 a collimated beam sample was taken prior to the start-up of the pilot plant but at the future location of the pilot plant intake. Collimated beam samples were collected on October 27, 2007, November 3, 2007, November 6, 2007, and November 15, 2007 during operation of the pilot plant to provide a direct comparison of on-site pilot results. Four (4) additional collimated beam samples were collected following decommissioning of the pilot plant in order to acquire design data over a wider range of Moat and storm event conditions.

Table 11
Collimated Beam Test Results

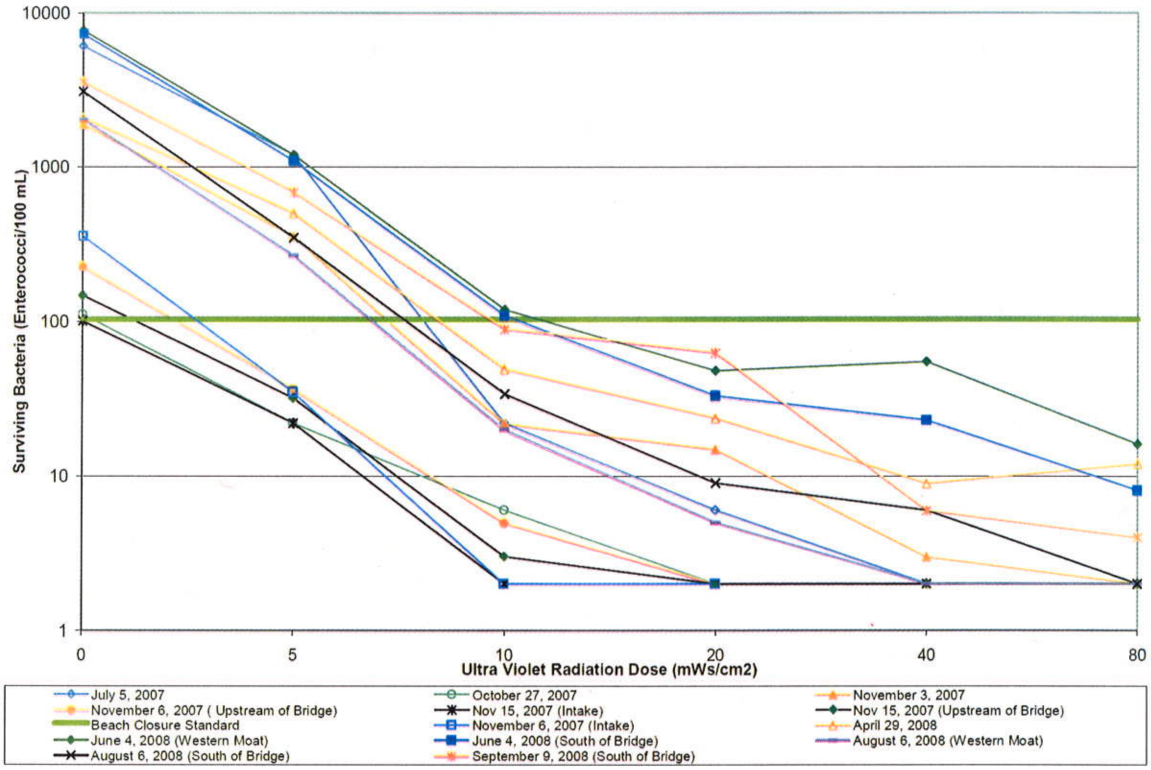
Dose (mWs/cm^2)	UV_T	TSS, mg/L	Enterococci/100mL					
			0	5	10	20	40	80
July 5, 2007 (Pilot Plant Intake)	63	6	6100	1200	22	6	<2	<2
October 27, 2007 (Pilot Plant Intake)	72	Note[1]	112	22	6	<2	<2	<2
November 3, 2007 (Pilot Plant Intake)	66	25	1900	360	22	15	3	2
November 6, 2007 (Upstream of Bridge)	72	12	230	37	5	<2	<2	<2
November 6, 2007 (Pilot Plant Intake)	73	Note[1]	360	35	<2	<2		
November 15, 2007 (Upstream of Bridge)	76	12	148	32	3	<2	<2	<2
November 15, 2007 (Pilot Plant Intake)	76	12	101	22	2	<2	<2	<2
April 29, 2008 (Pilot Plant Intake)	72	41	2100	510	50	24	9	12
June 4, 2008 (Western Moat)	39	44	7700	1200	120	48	55	16
June 4, 2008 (South of Bridge)	41	39	7300	1100	110	33	23	8
August 6, 2008 (Western Moat)	67	6.7	2050	270	20	5	2	<2
August 6, 2008 (South of Bridge)	74	4.3	3100	350	34	9	6	<2
September 9, 2008 (Western Moat)	70	9.8	3600	700	91	64	6	4

Note

1 The volume of sample available for TSS analyses on October 27 and November 6, 2007 were insufficient.

Figure 14 represents the dose response curves generated by plotting the number of surviving *Enterococci* against the UV dose applied during the testing.

Figure 14
Dose Response Curves



The initial Easton Pond dam and Moat Study assumed that 40 mWatt•sec/cm² would be required for a UV system to disinfect the Moat discharge to a geometric mean of 104 colony forming units (cfu)/100 ml. Collimated beam testing results show that a dose of 20 mWatt•sec/cm² reduced *Enterococci* levels to the 104 cfu per 100 ml RIDOH beach closure standard or below; however, in order to obtain manufacturer's guarantee that the system will perform under varied storms, a higher dose will be required. Collimated beam testing required a lower dose than was required during operation of the pilot plant (31 mWatt•sec/cm²), but conditions in the bench-scale laboratory test are ideal and in-field conditions result in more accurate data. Variation from on-site results to the collimated beam testing is potentially due to but not limited to the following:

- interferences with UV light by debris pumped through the pilot plant out of the moat;
- lamp cleanliness or lack thereof in the pilot;

- And ideal laboratory conditions for collimated beam tests (UV cell cleanliness and UV transmittance).

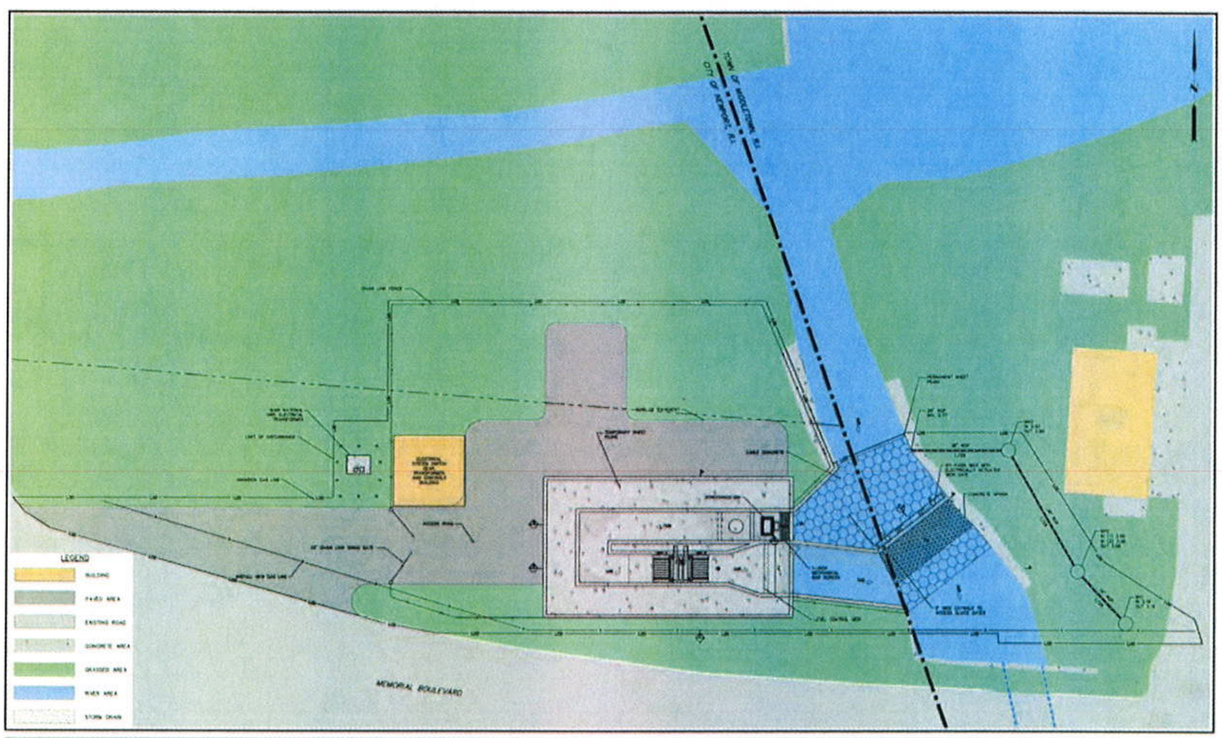
Therefore, collimated beam testing provides useful benchmark data to evaluate pilot plant performance; it does not replace pilot plant operation as a means of acquiring full-scale plant design data.

The minimum design will be at 40 mWatt•sec/cm^2 or vendor recommended dose, to provide approximately 30% contingency for rain events and moat conditions not observed to date.

5.3 Proposed Process Flow Diagram

Figure 15 provides a layout overview of the UV disinfection system that shows the recommended location, Moat, influent screen, pump station, and UV channel. Sheet 9 - Preferred Site Location and System Layout Plan and Sheet 10 - Detail describes the proposed process flow diagram and possible site layout.

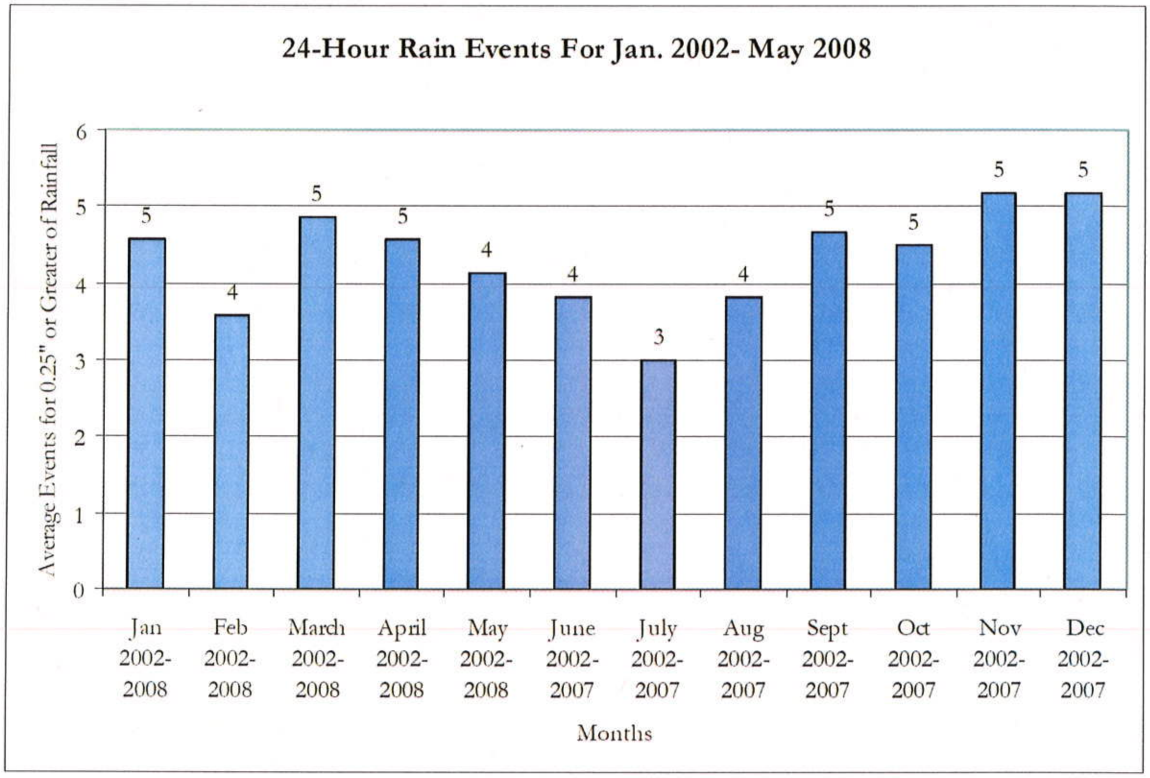
Figure 15
UV System Layout and Flow Diagram



The following sequence describes what the proposed process flow would be.

1. The start of a treatment event will be triggered by a rain gauge using a controller to send a signal to the Master PLC that will then start up the other major operations (UV, Weir Gate, and pump). A minimum amount of rain set point will be determined later that will initiate the start of treatment. 0.25-inches of rainfall would be a starting point since it is the amount of rainfall that started to impact the beach. A minimum run time for the system will be 24 hours initially but may be extended manually should additional treatment be required. The control package will allow the run time to be reduced or extended in the future. See Figure 16 for the past seven years of rainfall totals. As shown, there is an average of 54 rain events each year that equal or exceed 0.25 inches of precipitation. Precipitation data is recorded as 24-hour duration. There is an average of 11 events totaling over 0.25 inches of precipitation for the typical June, July and August swimming season.

Figure 16
Precipitation Data



2. The rain gauge result will trigger the electrically actuated weir gate(s) on the by-pass weir to close and will remain closed until the end of the treatment event.

3. The control system and logic will include a flow sensor that will allow for a manual override (UV disinfection system run) in the event of heavy flows while the by-pass weir is open, e.g. in the event of significant flooding.
4. After the gates have closed the flow of water below the by-pass weir will be diverted to the treatment system. First the water will go through a mechanical bar screen which will remove large particles and debris (trees, braches, shoes, gloves, etc). The mechanical bar screen coordinates its operation with the start of the event through communication of the Master PLC. The mechanical bar screen is an automated system that will, on a set time, remove debris (1" and greater) from the channel and deposit the material in a dumpster to be located at the top of the system. Water that passes through the screen will then travel to the pump chamber.
5. The pump will be activated at the start of a treatment event by receiving a signal from the Master PLC that an event has started. Once activated, a level control sensor in the pump chamber will trigger when the pump turns on and then off depending on the flow rate into chamber based on a high and low set point. The pump will also be equipped with a variable frequency drive to provide a soft ramp up of the pump and allow for lower pump speeds during low flow events.
6. Water will be pumped from the pump chamber up into a concrete channel that will feed by gravity the UV disinfection system. The UV disinfection system will operate under its own PLC, but will be started and shut down from the Master PLC. The UV disinfection system will utilize a level sensor in the channel for determining flow rate that will adjust light intensity. An Ultra Violet Transmittance (UVT) sensor will also monitor lamp intensity and provide the necessary system adjustments to provide a constant dose of UV light needed.
7. From the UV disinfection system, treated water will flow by gravity over a level control weir needed to keep a constant volume of water in the UV disinfection system and out through a concrete channel that will drain back into the existing moat just down stream from the by-pass weir.

The proposed system will require at a minimum the following construction items for a full UV disinfection system:

- Electrical transformer and new service to site
- Rain Gauge and including signal controller
- Flow meters and interlocks with various equipment including the screen, pump and UV disinfection system
- 1-inch Mechanical Screen
- Electrically actuated weir gate structure (installed as part of the by-pass weir)
- Main PLC panel to interconnect equipment

- Pump station
- Concrete channel
- UV disinfection system
- Outlet channel
- Cable concrete to stabilize the upstream and downstream area of the by-pass weir
- Catch basin structures to redirect stormwater flows from the RIDOT and possibly the Pump Station outfalls
- Relocation of the existing 8-inch steel gas main.

5.4 UV Disinfection Process Equipment Review

Fuss & O'Neill requested information from existing UV system vendors in order to collect data required to develop preliminary designs and budgetary cost estimates for various design scenarios. The design scenarios were based on disinfection of either the water quality volume associated with 1.2-inch rain event for the watershed input to the Moat (96 cfs, 62 MGD) and the watershed input to the Moat plus Esplanade flow from Middletown, which was modeled to be 116 cfs (75 MGD), prior to calibration with hydraulic data. Since calibrated model output indicates Moat discharge without Esplanade is just under 96 cfs and with Esplanade is 101.5 cfs, the two design scenarios selected for vendor evaluation (96 and 116 cfs) bracket calibrated Moat flow for the WVQ event.

Additional design flows were evaluated from a hydraulic perspective, but not a disinfection process perspective. Four (4) dilutions of the Moat discharge within Easton's Bay were considered for each flow scenario for a total of eight (8) design scenarios requested of the vendors. Dilutions considered for the evaluation of disinfection equipment were 1:1 (no dilution of Moat discharge by Easton's Bay), 5:1, 10:1, and 50:1 dilutions. Vendor responses to the design scenarios were used to compare system layout, head loss, overall disinfection system footprint and implementation costs.

By involving the vendors at the start of this process, Fuss & O'Neill was able to research the availability of equipment and identify potential suppliers capable of constructing a system that would meet the City of Newport's needs. The vendors were also able to provide information for operating and maintenance for their equipment in order to better understand long-term issues for the City. Our objective was to determine the best technology for this application considering a number of factors such as performance, reliability, maintenance and costs.

5.4.1 UV Disinfection Technology Review

Fuss & O'Neill identified several UV disinfection technologies outside of the traditional UV lamp and ballast systems. These technologies were further researched through a limited internet and publication resources for potential suppliers. The following technologies were reviewed:

- UV Disinfection using Light Emitting Diodes (LED)
- UV Disinfection using Lasers
- UV Disinfection using Microwave Technology

Both the LED and Laser technology are in the initial research and development stage but are not commercially available for water disinfection of this magnitude.

Microwave disinfection does not use microwave radiation to disinfect wastewater, but is used to excite the atoms in a mixture of noble gasses confined at low pressures in a glass lamp. By exciting the gas atom with a particular radio frequency, UV radiation is produced. The UV light generated by microwave excitation is used to disinfect wastewater in the same manner as a conventional system. This method of generating UV radiation has the advantage that the lamp contains no filament, and is not directly connected to a source of electrical energy. Lamp life is comparatively long, and lower amounts of mercury are used in the lamp.

Through this search Fuss & O'Neill has determined that while new technologies exist, or at a research and development stage, they have not become readily available in the United States at the size and scale needed to treat the Moat discharge. The LED and laser technology are really at their infancy stage of development and while showing a promising future, further research and development are needed. The Microwave technology has moved forward and is commercially available but not to the size required for this project.

Fuss & O'Neill contacted the vendor of the Microwave technology, Severn Trent Services, about the proposed project. Severn Trent Services has indicated that at this time they cannot offer a proposed design or budget estimate due to the size limitations in their product offering. A copy of their response is included as <u>Appendix M</u>.

5.4.2 UV Disinfection Vendor Search

Fuss & O'Neill researched the following manufacturers of UV disinfection equipment:

Table 12
UV Disinfection Vendor List

Manufacturer/Vendor	Location
Atlantium Illumination Water Technologies	Hafia (Israel)
American Ultraviolet	Lebanon, IN (USA)
Aquionics, Inc.	Arlanger, KY (USA)
Calgon Carbon Corporation	Pittsburg, PA, (USA)
Hydroxyl Systems, Inc.	Victoria, BC (Canada)
Wedeco UV Technologies, Inc	Charlotte, NC (US office)
Purifics, Inc.	London, Ontario (Canada)
Sentry Ultraviolet, Inc.	Blairsville, GA (USA)
Trojan Technologies, Inc.	London, Ontario (Canada)
UVC Manufacturing and Consulting, Inc.	Minden, NV (USA)
UV Systec Gesellschaft Fuer UV-Strahler-Und Systemtechnik MBH	Jena-Maua (Germany)
Lenntech	Delft (The Netherlands)
Siemens UV (Wallace & Tiernan)	Munich (Germany)
Ecologix Environmental Systems	Rosewell, GA (USA)
Infilco-Degremont, Inc.	Richmond, VA (USA)
Spectral Innovations, LTD	Langley, BC (Canada)
Berson Milieutech BU	Nuenen (The Nethertlands)
Severn-Trent Services, Inc.	Fort Washington, PA (USA)
US Canadian Clear Water, LLC	San Antonio, TX (manuf. in India)
Ryan Process, Inc.	Dayville, CT (USA)

Five of these companies appeared to have the capability and experience needed for this project. A request for additional technical and cost information (RFI) was provided to the following vendors:

1. Aquionics, Inc
2. Wedeco UV Technologies, Inc (Part of ITT)
3. Trojan Technologies
4. Severn Trent Services
5. Calgon Carbon Corporation

As noted above Severn Trent submitted a letter indicating they would not be able to participate at this time due to size limitations on their product line. Responses were received from the four other vendors for the RFI, which is discussed below, and included in Appendix L.

5.4.3 UV Disinfection System Vendor Review

Four UV disinfection system vendors provided response to Fuss & O'Neill's RFI. A summary of these results can be found in Table 16: Summary of Responses for UV Disinfection RFI. Below is a summary of differences between each vendor and items of which potentially impact construction cost:

Aquionics

- The UV disinfection system is installed in a large diameter pipe. A series of these units are piped together to meet the design flow.
- System would require a building to house all equipment.
- Additional structures are needed to convey water to each treatment unit (e.g. long concrete chamber).
- Twelve (12) UV disinfection systems (pipe mounted units) and 252 UV lamps (18 lamps per unit) are needed to treat the water down to 104 *Enterococci* colonies/100 ml.
- Has the lowest system headloss out of the vendors reviewed, but additional headloss will occur due to piping and valves.
- System utilizes a chemical/mechanical system to clean lamps.
- Constant wattage transformers (equivalent to the ballast for other types of UV lamps) can be located 300 feet away from the UV disinfection system.
- UV lamps are warranted for an operating life of 8,000 hours.
- Aquionics has not installed a system of this size, and views this project as a potential way to prove the technology can work for this type of application.

Trojan UV

- The UV disinfection system is installed in a concrete channel that would require additional concrete to be poured around a vendor supplied insert.
- No building is required; panels are design to be exposed to the weather; however an additional structure would most likely be needed to house spare parts and critical electrical components.
- System comes with a mechanical hoist built in to raise and lower UV lamps (other systems require a separate lifting mechanism that need to be supported from above).
- One UV disinfection system (channel) and 336 UV lamps are needed to treat the water down to 104 *Enterococci* colonies/100 ml at the design flow.
- The 16.78-inches of headloss was the second lowest headloss of the four UV disinfection system vendors

- System utilizes a chemical/mechanical system to clean lamps. Chemicals were noted as "Generally safe for Use" and routinely used for public drinking water applications.
- Ballast are located as part of the UV lamp and must remain close to the lamp.
- UV lamps are warranted for an operating life of 5,000 hours, which was the lowest of the vendors reviewed.
- Trojan UV provided large list of references. Many systems were at the same size or larger than that which would be proposed for Newport.
- Trojan UV was the only manufacture to offer a full process guarantee to meet the 104 *Enterococci* colonies/100 ml for the life of the system.

Wedeco

- The UV disinfection system is installed in a concrete channel that allowed for the direct connection of UV disinfection system with out any additional concrete pours.
- System would require a building to house all equipment.
- Wedesco does not provide a mechanical hoist to raise and lower the UV lamps. A separate mechanical hoist will need to be designed and installed for this system.
- Four (4) UV disinfection systems (channels) and 1,944 UV lamps (486 lamps per channel) are needed to treat the water down to 104 *Enterococci* colonies/100 ml.
- The 18.90-inches of headloss is the second highest.
- System utilized a Teflon based mechanical wiper to clean UV lamps. No chemicals are required for cleaning of the lamps. System also utilized a pneumatic device to operate the mechanical wiper (other vendors utilized an oil based system).
- Ballast can be located 50 feet from UV lamps.
- UV lamps are warranted for an operating life of 12,000 hours, which was the highest of the vendors reviewed.
- Wedeco provided a large list of references, close in quantity and system size as that of Trojan UV.
- Would require the relocation of both 20-inch sewer mains.
- System utilized the UV lamps with the lowest kw rating per UV lamp.

Calgon Carbon Corp

- Channel based system similar in size and design to that of Wedeco.
- System would require a building to house all equipment.
- Calgon Carbon Group does not provide a mechanical hoist to raise and lower the UV lamps. A separate mechanical hoist will need to be designed and installed for this system.

- Five (5) UV disinfection systems (channels) and 1,360 UV lamps (272 lamps per channel) are needed to treat the water down to 104 *Enterococci* colonies/100 ml.
- The 29.21-inches of headloss was the highest.
- Calgon did not initially supply information for a process guarantee, but later stated they could offer one, and typically these are for 10 years.
- System utilized a Teflon based mechanical wiper to clean UV lamps. No chemicals are required for cleaning of the lamps.
- UV lamps are warranted for an operating life of 12,000 hours, which was tied with Wedeco for the highest of the vendors reviewed.
- Calgon Corp has not built at the time of this report any system of this size. Their largest system is 12 MGD.
- Would require the relocation of both 20-inch sewer mains.
- System utilized the UV lamps similar to Wedeco.

5.4.4 Quantitative Analysis

Fuss & O'Neill developed a comparison matrix table with a point system to compare the vendor responses based on experience, ability to meet project goals, and equipment cost. The most favorable vendor was that who received the highest score. This matrix is a useful tool which assigns a certain number of points to various system features applied to each vendor in a weighted fashion. Refer to Table 17: UV Disinfection System Qualitative Analysis for this matrix. Points were assigned to a quantifiable unit operation (such as 15 points for having >15 years experience of on going UV disinfection experience). These points were totaled for each vendor and are presented below:

UV Disinfection Systems

- Trojan UV 92.6
- Wedeco 60.5
- Aquionics 58.8
- Calgon Carbon Corp 33.6

Aquionics, Trojan and Wedeco provided information that shows experience at or above the design flow; therefore, each vendor was awarded the same score for that evaluation item. The number of installations were ranked and scored for each vendor by dividing the number of installations in each size range (design flow <10 MGD, 10-50 MGD, and >50 MGD) divided by the total number of each vendor's installations and then multiplied by a factor of 20, i.e. each vendor could receive up to 20 total points for each design flow range. Trojan's installations exceeded all other vendors, and Trojan has 28 installations at or above 50 MGD, while Wedeco has 11, Aquionics has 2, and Calgon offered no feedback on installations.

Aquionics, Wedeco, and Calgon each indicated their UV systems would require an enclosure or building to protect ballasts and other components from weather. Trojan indicated its system may be housed outside; therefore Trojan received positive scoring and the other vendors received negative scoring for that item. Trojan offers a lifetime process performance guarantee that its system will meet the disinfection criteria. No other vendor provided more than a 1-year performance guarantee. Aquionics' guarantee was based on the UV dose, not UV system effluent bacterial count.

5.5 Pretreatment System Evaluation Process

Debris and solids like tree limbs, shoes and trash must be removed from the stormwater to protect the downstream UV disinfection system and pump station. Pretreatment systems include trash racks, mechanical bar screens, and grit removal equipment. The design criterion, for pretreatment, is as follows:

- Water Source - Urban stormwater runoff
- Design Flow Range - 96 cfs to 116 cfs
- Suspended Solids - 30 mg/L
- Channel Width - 96 inches
- Downstream Depth - 103 inches
- 1-inch bar spacing for mechanical screening

The same process used to identify UV disinfection system vendors was undertaken for pretreatment systems in order to assess design issues, power needs, layout of system components, etc. A copy of the RFI sent to vendors is included in Appendix N.

5.5.1 Pretreatment System Vendor Search

Fuss & O'Neill researched the following companies to determine their ability to supply pretreatment system satisfying system requirements, and of their interest in receiving the RFI:

Table 13
Pretreatment System Vendor List

Manufacturer/Vendor	Location
JWC Environmental, Inc.	Costa Mesa, CA
Enviroquip, Inc.	Austin, TX
Parkson Engineering, Inc.	Fort Lauderdale, FL
Smith & Loveless	Lenexa, TX
Westech Engineering, Inc.	Salt Lake City, UT
Headworks, Inc.	Huston, TX
Hydro-Dyne Engineering, Inc.	Oldsmar, FL
Lakeside Equipment Corporation	Bartlett, IL
Hydro International	Portland, ME

Four of these companies appeared to be of the size and experience needed for this project. The following manufacturers received the RFI:

1. Hydro-Dyne Engineering, Inc.
2. Lakeside Equipment Corporation
3. Headworks
4. Hydro International

Hydro-Dyne Engineering, Lakeside Equipment Corporation and Headworks provided information for a 1-inch Mechanical bar screen. Lakeside Equipment Corporation and Hydro International provided information on grit removal. Since the UV disinfection system will be placed upstream of the bridge and shoaling will be minimized, therefore inline grit removal was eliminated from preliminary design. If sediment were to accumulate in the upstream side of the UV disinfection weir, the configuration allows for manual sediment removal from system components downstream of the screen (e.g. the pump station, UV channel, and underneath the lamps) via vactor truck. Pretreatment is limited to screening to 1-inch solids ahead of the pump station and UV disinfection system. Responses were received from all four vendors for the RFI, which is discussed below, and included in Appendix N. Vendor Responses are included in Appendix O.

5.5.2 Pretreatment System Vendor Review

Four pretreatment vendors provided responses to Fuss & O'Neill's RFI. Only three of them provided responses related to mechanical screening. A summary of these results can be found in Table 18: Summary of Responses for Pretreatment Equipment RFI. Below is a summary of differences between each vendor and items of which potentially impact construction cost for the Mechanical Bar Screening only:

Hydro-Dyne Engineering, Inc.

- Mechanical Bar screen to be installed in a channel will have a mechanical scraper.
- Scraper is on a continuous chain which rotates around a bearing that is submerged in the water. This bearing will need to be replaced and greased periodically.
- Hydro-Dyne had 5 units in operation of comparable size to demonstrate their capabilities.
- Hydro-Dyne did offer the lowest capital cost, but included underwater movable parts which need replacement, therefore, not attractive for long term operation.

Lakeside Equipment Corporation

- Mechanical Bar screen to be installed in a channel will have a mechanical scraper arm.
- Scraper is on an extendable arm which reaches into the bottom of the screen and pulls up to clean the screen of debris.
- System has no movable parts located permanently below the water surface.
- Hydro-Dyne offered 29 installations of comparable size to demonstrate their capabilities.
- System has the highest headloss.

Headworks

- Mechanical Bar screen to be installed in a channel will have a mechanical scraper.
- Scraper is on a continuous chain which rotates around a bearing that is submerged in the water. This bearing will need to be replaced and greased periodically.

- Headworks offered the most installations, but did not have the years of experiences as Lakeside Equipment.
- System has the lowest headloss.
- Headworks had the highest capital cost.

Note that Hydro International submitted information for grit removal only. As this item was removed from the design given the preferred treatment system location, no further discussion is provided at this time.

5.5.3 Quantitative Analysis

Fuss & O'Neill developed a comparison matrix table with a point system to compare the vendor responses based on experience, ability to meet project goals, and equipment cost. The most favorable vendor was that who received the highest score. This matrix is a useful tool which assigns a certain number of points to various system features applied to each vendor in a weighted fashion. Refer to Table 19: Pretreatment System Qualitative Analysis for this matrix. Points were assigned to a quantifiable unit operation. These points were totaled for each vendor and are presented below:

Pretreatment Systems (Screening)

- Lakeside Equipment Corporation 31.4
- Hydro-Dyne Engineering, Inc. 24.6
- Headworks 1.5

Pretreatment System (Grit Removal)

- Lakeside Equipment Corporation 43.1
- Hydro International 0.4

Since grit removal will be provided by vactor truck, separate grit removal equipment is not included in the process design. Pretreatment will be by screening only. All three screen vendors indicated they are capable of providing a screen equipment guarantee. Only Hydro-Dyne and Lakeside indicated they would provide performance guarantees. Headworks has the highest number of installations followed by Lakeside and Hydro-Dyne; however, Headworks provided no process guarantee and has less than 25 years of experience. Hydro-Dyne and Headworks each received -10 points for one scoring item, as their systems have moving parts, gears, or chains normally below water surface. Lakeside's system has no moving parts below the water surface, and the screen cleaning mechanism is mounted above the top of the screen; therefore, Lakeside's overall score is higher than the other vendors' scores.

5.6 Summary of Life Cycle Cost

A twenty-year (20-yr) life cycle cost was developed in the qualitative analysis for the four different UV disinfection system vendors for the purposes of comparison. This life cycle cost is based on a budgetary opinion of cost for construction (-30% to +50% accuracy) and operation & maintenance and presented in 2009 dollars. The budgetary opinion of costs are based on construction of the entire system with a 10 percent contingency (based on current 60% design status), and include expected costs for engineering design, environmental permitting and part-time construction administration assistance.

These costs are based on the Alternative #2 location and include, by-pass weir for control of water within the moat, influent screening, pump station, channel to UV disinfection system, and discharge back to the moat. A small structure is included to house electrical switch gear, pump station controls, and instruments (rain gauge, level systems). Configuration and vendors other than those recommended may require complete system housing in a building. A building structure installed over the entire system could be included for this project and based on an assumed unit price of $80 per square foot will add approximately $200,000 to $400,000 to each total budgetary opinion of cost.

Operating costs were estimated based on vendor-supplied unit cost and are estimated using Newport's current electric rate of $0.109 per kilowatt hour with operation of the lamps at 100% intensity over an average of 54 storm events and 48 hours duration each year (i.e. 2,592 hours of operation each year at 100% lamp intensity). UV disinfection lamps will not be operated at 100% intensity for the duration of each storm, and rainfall data for the average annual rain events is based on a 24-hour duration. A total of fifty four (54) rain events of greater than 0.25 inches occur on average each year with 11 events occurring on average during the summer/beach season. Life cycle costs presented in Table 15 are therefore conservative, and the City must decide the premise of operation (e.g. amount of precipitation accumulated prior to UV system startup, duration of UV system operation which may be based on the actual duration of each storm, and the future unit cost of electricity). Table 14 a comparison of life cycle costs based on operating each system at 24 and 48 hour durations at 100% lamp intensity during 54 rain events each year.

Table 14
Life Cycle Cost Comparison

Vendor	1-Year of Operating Cost, 54 Events with 24-hr UV Operation at 100% Lamp Intensity	1-Year of Operating Cost, 54 Events with 48-hr UV Operation at 100% Lamp Intensity

Aquionics	$ 242,889	$ 485,779
Trojan UV	$ 221,391	$ 442,781
Wedeco	$ 198,979	$ 397,958
Calgon	$ 204,149	$ 408,299

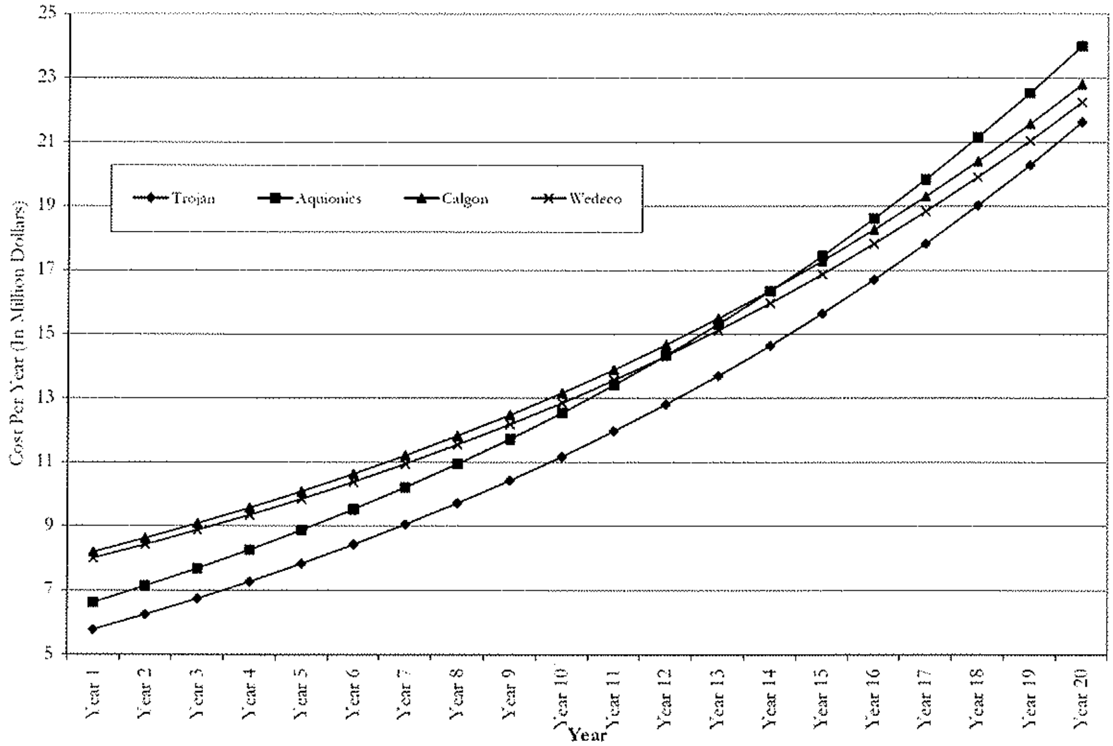
The life cycle cost was based on a 20 year operating life and includes the initial capital cost for construction and operating cost. Each additional year beyond the first year is assumed to equal the operating cost increased at a rate of 6% per year. See Table 18 for a summary of the construction cost, operating cost, and life cycle cost for each vendor at design flow 96 cfs (62 mgd) and no credit taken of dilution of Moat discharge by the bay.

Table 15
Summary of Life Cycle Cost

Vendor	Construction Cost	1-Year of Operating Cost	20-Year Life Cycle Cost	-30% of 20-Year Life Cycle Cost	+50% of 20-Year Life Cycle Cost
Aquionics	$ 6,177,000	$ 485,779	$24,005,762	$16,804,034	$36,008,643
Trojan UV	$ 5,377,000	$ 442,781	$21,624,080	$15,136,856	$ 2,436,120
Wedeco	$ 7,647,000	$ 397,958	$22,245,207	$15,571,645	$33,367,811
Calgon	$ 7,824,000	$ 408,299	$22,802,616	$ 5,961,831	$34,203,923

Again, 1-year operating costs in Table 15 are based on operating the UV disinfection lamps at 100% intensity for 48 hours per rain event and 54 rain events per year. Refer to Appendix P for the Life Cycle cost breakdown for each vendor. A chart showing the cost over time for each of the vendors for the next 20-years is shown in Figure 17. Trojan's system provides the lowest construction and 20-year life-cycle costs.

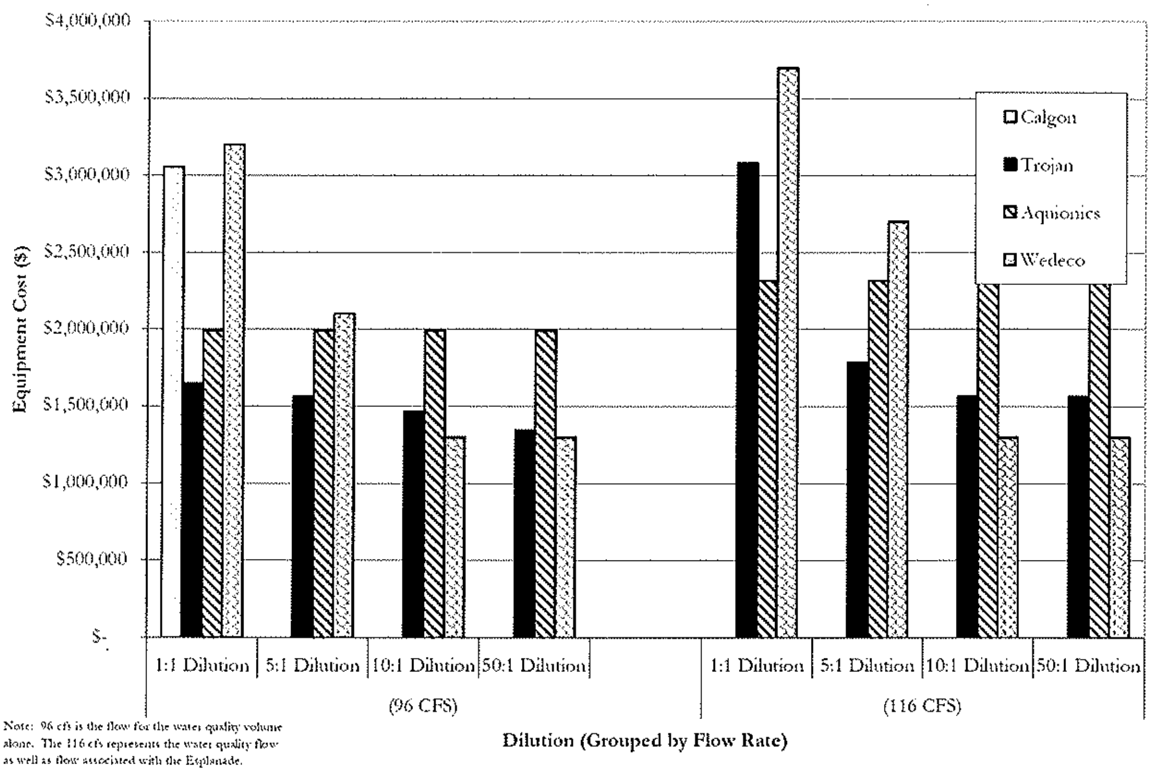
Figure 17
Cumulative Cost for a 20-Year Period



5.7 Effect of Flow and Dilution on Equipment Cost

As part of the request for information from the different vendors, Fuss & O'Neill asked for equipment cost data for different flow rates, and different bacterial colonies to account for potential dilution impacts. The flow rates were for 96 cfs and 116 cfs, and dilutions of 1:1, 1:5, 10:1, and 50:1. Figure 18 shows the effect both flow and dilution has on the equipment cost.

Figure 18
Comparison of Equipment Cost as a Function of Flowrate and Dilution



In general, equipment cost increased as the flow rate increased and decreased with the level of dilution applied. This is a result in the hydraulics and number of lamps needed for disinfection. Each of the systems is limited in the amount of lamps which can be installed in a given channel. As more lamps are installed in a channel to meet a disinfection rate, the amount of headloss through each channel is increased.

An increase in dilution of the Moat discharge by the bay decreases the number of lamps required for disinfection, but after a dilution of approximately 10:1, there does not appear to be a significant economic advantage. Based on a 2:1 dilution provided by the Bay at a distance from the Moat outfall, no credit for dilution was taken in this preliminary design in order to provide some factor of safety.

The UV disinfection system by Wedeco and Calgon incorporates a low pressure high output lamp. Many bulbs are required to provide the same dose as the medium pressure high output system by Trojan, and therefore, both 96 cfs and 116 cfs designs require multiple channel configurations to accommodate the number of lamps required. This increase in the number of channels results in a significant increase in equipment cost.

The Trojan, Wedeco, and Calgon UV disinfection systems are mounted in open channels, while the Aquionics system is mounted in a pipe (verses a channel for the other vendors). This does not impact the systems ability to treat the stormwater, but has the lowest capacity per unit, requiring many units to treat the stormwater design flow of 96 cfs, 62 MGD. An individual Aquionics unit handles a much smaller portion of the total flow rate (5 MGD verses 62 MGD for Trojan UV), which results in a large number of units (12) while maintaining a reasonable headloss through the system. Additionally this system requires additional valves and pipes to connect the many units together which the other vendors would not need. Aquonics 12 units would require an estimated 4,600 square feet to house the UV disinfection system equipment as compared to Trojan UV requires 2,800 square feet in a single channel. The lamps used by Aquionics are different than the other vendors as well (ballast are not used), but the power consumption is similar to the medium pressure high output lamps. Aquionics cost for equipment did not vary by a change in dilution, but changed as the flow rate increased due to the hydraulic limitation noted above.

Under the 96 cfs design condition, Trojan's medium pressure high output lamp system will fit in a single channel configuration, regardless of the dilution of Moat discharge by Eastons Bay. Design peak flow greater than 105 cfs with a 30-day geometric mean discharge standard of 104 cfu/100mL requires a two-channel configuration for the Trojan UV system. At a design flow of 96 cfs and an absolute discharge standard of 104 cfu/100mL, Trojan's system requires three-channel construction. Regardless of design flow, Wedeco and Calgon LPHO systems require multiple channel configurations. Regardless of design flow, Aquionics MPHO system requires multiple units piped in parallel.

5.8 Pump Station

The hydraulic analysis indicated a gravity system is not feasible given the elevation restrictions and current flooding issues. Alternatively, a pump station following the mechanical screening could feed the UV disinfection system and from there flow by gravity back into the existing moat channel. This pump station will be a high volume, low head turbine pump design consistent with an ABS VUP series pump. Additional vendors and manufacturers were not reviewed in depth as done for the UV disinfection system, and final design will need to be completed prior to the construction of the pump station. Refer to Appendix K for manufacturer's information for the ABS VUP series pump as a reference only.

5.9 Electrical Requirements

Electrical service size was based upon UV4000 Plus Trojan System, as the single-channel configuration for the Trojan UV disinfection system appears to best meet project needs. The major component of this system is two power distribution centers that require 568.9 kVA each at 480 volts three phase. In addition to the Trojan System, the water to be treated needs to be pumped into the system. Pump estimates are approximately 200 hp, requiring instruments, screen, gate, panels 110vac, weir gate actuators, etc. This will require 200 kVA at 480 volts three phase.

A work request was filed with National Grid (as they will not review any project without a work request submitted, even for design purposes) on May 23, 2008 (#4665325) for electric service for the proposed site of the UV disinfection system. The service request was for 1,660 kVA or 2,000 amp service at 480 volts, three phases and based on the proposed equipment anticipated to be used for this project. Along with this request, Fuss & O'Neill submitted an Electrical Riser Diagram (See Sheet 10) showing the proposed system.

National Grid responded on May 28, 2008 that there was not enough electrical capacity in the service area to satisfy the work request. National Grid has estimated a cost to the City of $150,000 to $200,000 and an estimated construction of one year from formal service request by the City to provide the proposed electrical service.

5.10 By-Pass Weir

The by-pass weir will need to be constructed in a fashion that it would allow free flow of the Moat during dry weather flow. A combination of 1 to 3 electrically actuated weir gate(s) placed in a concrete structure will be lowered into the channel to direct stormwater to the pump station. The top of the weir(s) will be located at an elevation that will direct flow up to 62 MGD to the UV disinfection channel. Water flow in excess of 62 MGD will continue over the by-pass weir through the existing Moat channel. A single leaf weir gate was used for purposes of estimating budgetary opinions of cost. The preliminary design includes use of cable concrete and a concrete apron to provide a clean lead-up to the gate structure, which will allow self cleaning/flushing of the gate seat. The gate operators are also equipped with proximity switches that re-open the gate if and when debris gets lodged into the seat.

6.0 GEOTECHNICAL EVALUATION

6.1 Introduction

A geotechnical engineering analysis was conducted for the purpose of identifying options for foundation support of the proposed UV disinfection system. The analysis was based on a review of conceptual plans, and on assumptions made concerning the housing structure. Field investigations and data collection were conducted prior to making recommendations for a foundation approach. A complete copy of the Geotechnical Report is attached in Appendix Q (*Geotechnical Engineering Report for the Proposed UV Disinfection System, Newport, Rhode Island* (Geotechnical Report)).

6.2 Field Investigation

The field investigation included borings in order to evaluate soil conditions and groundwater conditions as part of their field investigation. The following sections summarize the findings.

6.2.1 Boring Tests

Historic boring logs were reviewed from C&E Engineering Partners, Inc. at the start of this project. The logs were for borings, located just north of Memorial Boulevard along the alignment for a sewer force main, were completed during the summer of 2006. These borings were advanced to depths from 11 to 17 feet below the ground surface.

The results of a subsurface investigation conducted by Paul B. Aldinger for the construction of a hotel near the project site were also reviewed. This consisted of six test borings in March 2008 that were advanced to depths 31.5 to 49 feet below the ground surface.

Four new test borings were completed in the vicinity of the proposed UV system in June 2008 by Subsurface Drilling, Inc. Borings were advanced to depths between 31 and 49 feet below the ground surface. Information obtained from this investigation provided soil and groundwater information for the geotechnical analysis. All information obtained from the boring tests is contained in the Boring Logs in the Geotechnical Report. Figure 3 – Subsurface Exploration Plan, of the Geotechnical Report, identifies the locations of the individual borings.

6.2.2 Soil Conditions

Soil conditions revealed by the 2008 borings include soil strata information from the ground surface downward. The layers of the soil strata are generally identified as follows:

- Topsoil and Asphalt – Approximately 1 to 2 feet of topsoil at three borings sites and 3 inches of asphalt concrete at one boring site.
- Non-engineered Fill – Encountered at all boring sites and extended to depths between 19 to 22 feet below the ground surface.
- Organic Silt – Encountered thickness of approximately 1 to 5 feet below the non-engineered fill.
- Glacial Outwash – Encountered generally between 21 to 31 feet below the ground surface.
- Glacial Till – Encountered at a depth of 31 to 34 feet below the ground surface at two boring sites.

A grain size analysis was also performed on samples taken from the borings. This analysis served to assess suitability of onsite material for reuse as structural fill.

6.2.3 Groundwater Conditions

The borings made in 2008 also yielded information on groundwater conditions. Although groundwater monitoring wells were not installed for this investigation, groundwater was observed at three of the four borings. During drilling, groundwater was observed at approximate depths between 3 to 6 feet below the ground surface. The groundwater level is likely to fluctuate due to rainfall, seasonal variations, temperature, and tidal changes.

6.3 Geotechnical Analysis

A geotechnical analysis was conducted with the purpose of identifying options for foundation support of the proposed structure that will house the UV disinfection system. The following design assumptions were made prior to analysis discussed in Sections 6.3.1 through 6.3.5. :

- The system will be housed within a tubular steel frame building with an invert approximately 8 feet below the existing grade.