EXECUTIVE SUMMARY

The Easton Pond Dam and Moat system is almost 70 years old after being reconstructed in the late-1930s after the 1938 hurricane. The dam infrastructure forms both North and South Easton Pond Dams that are a critical part of the City's water supply reservoir system. There are three areas of concern associated with this infrastructure:

- The aging dam and moat infrastructure has deteriorated over the past 70 years, which is now resulting in soil loss and threatening the future structural stability of the dam.
- The moat system has limited capacity to manage all of the runoff that discharges to it, which results in localized flooding along the moat.
- The runoff from these neighborhoods as well as activities in and around the dam and moat system new generate significant bacteria loadings that lead result in beach closures at Easton Beach.

Our objective is to provide Newport with a comprehensive approach to resolve or mitigate these problems such that the City has a menu of options from which they can implement future actions.

EVALUATION OF EXISTING SYSTEMS

North and South Easton Pond Dams

The Easton Pond Dam is comprised of earthen embankments and a spillway structure enclosing the South Easton Pond (South Pond) as shown on Figure 1. An earthen embankment forms the northern boundary of this impoundment from the adjacent North Easton Pond (North Pond).

A visual inspection of the North Pond and South Pond embankment and spillway structures was conducted on November 21, 2006 to assess current conditions and identify deficiencies. Historic engineering and construction records on these dams were also reviewed and current maintenance staff were interviewed as part of this evaluation. A visual diving inspection of the South Pond spillway structure, South Pond treatment plant intake structure and North Pond treatment plant intake structure was also performed on this date. Some of the significant deficiencies identified during the inspection is provided below:

- Excessive woody vegetation exists on portions of embankment slopes.
- Portions of existing upstream slope protection (stone riprap) will not provide adequate protection during major storm event.
- Portions of upstream slopes are failing and reducing total embankment cross-section.
- Numerous animal burrows were observed and reported on the embankments.
- Moat channel is encroaching on the downstream bench and embankment slope in several locations, reducing total embankment cross-section and stability.
- Concrete spillway structures exhibit moderate deterioration.
- Worn footpath has developed on embankment crests due to foot traffic, resulting in areas where stormwater runoff channelizes and damages embankments.

- Portions of downstream slope and bench are saturated due to the moat channel and seepage through the embankment.
- Mowing equipment has difficulty operating on portions of embankments due to narrow bench, steep slope and saturated conditions leading to excessive woody vegetation exists on portions of embankment slopes.
- Excessive vegetation in the North Pond emergency spillway channel reduces the capacity of this structure to convey flood flows from the North Pond, if required.

Moat Flooding

The Moat is a manmade channel that surrounds the South Pond on its west, south, and east sides. The southern end of the Moat meets the eastern end of the Moat at the spillway to the South Pond. It then flows under Memorial Boulevard, splitting Easton Beach and Atlantic Beach and enters Easton's Bay between these two beaches.

The entire watershed system that drains to the Moat is about 5.3 square miles in size. This watershed includes Bailey Brook that drains into the North Pond. The North Pond drains into the South Pond which overflows into the Moat via a concrete spillway from time to time, mostly during wetter seasons. Subtracting out the Bailey Brook, North and South Pond watersheds, the watershed that drains directly into the Moat is almost one square mile in size. This watershed is largely built-out with significant amounts of connected impervious surfaces with much of the soils being characterized as poorly draining. As a result, this watershed can generate significant amounts of flow.

In order to evaluate the storm water flows that enter this system, a hydrologic model was developed utilizing the NRCS TR-20 method. Based on this model, peak storm water flows during a 2-year frequency, 24-hour storm event would be about 627 cubic feet per second (cfs) just upstream of the Memorial Avenue bridge. A 50-year frequency storm would generate about 1,460 cfs at that location. These flows exceed the hydraulic capacity of the Moat's conveyance system. This is largely due to how very flat the Moat is.

Easton Beach and Watershed

Easton Beach and Atlantic Beach are located in Newport and Middletown, respectively and on the northern side of Easton's Bay. Over the past five years, these beaches have attracted the attention of City residents, beach goers, and State and City officials due to high bacteria levels that have closed the beaches during and just after rainfall events. There have been a number of questions raised over the past couple of years regarding the potential sources of the bacteria causing these closures. The first portion of this study was to better understand the potential sources of bacteria. In order to accomplish that, the following tasks were completed:

- Conduct a comprehensive storm water monitoring program, including DNA testing of the bacteria found at the beach. While there is a significant amount of historic data collected by the Newport and Middletown, the State and others (e.g. Clean Ocean Access), there was very little data on potential sources discharging to the moat as well as no flow data.
- Statistically evaluate current and historic water quality data for clues to potential sources.

- Identify potential nonpoint sources of bacteria to the beach based on monitoring data and field observations.

The following paragraphs summarize our conclusions from the evaluation of this data.

Presence of Sanitary Wastewater

Our review of the data found no specific evidence that sanitary wastewater is a source of the closures. There is a concern with potential illicit discharges are two RIDOT storm water outfalls and the Middletown storm drain outfall draining the Esplanade. Water chemistry and/or visual observations at those outfalls were consistent with what can be an illicit discharge to that outfall such as a sanitary or grey water connection.

Animal Waste

Animal wastes are a potentially significant source of bacteria in runoff. Anecdotal evidence suggests that animals such as raccoons and domestic dogs may be a specific source of *Enterococcus* to the beach. Dog wastes were routinely observed on the pond dam embankments. This represents a very large potential load of bacteria to the beach.

Storm Water

Storm water runoff is the predominant source of bacteria to Easton Beach. Storm water runoff sweeps bacteria from impervious surfaces as well as animal wastes into the moat and storm sewer system. This observation is reinforced by the very strong correlation between beach closures and the levels of bacteria measured at the beach with rainfall. A relative loading evaluation has been completed for the Moat and stormwater outfall sampling stations to better understand these sources.

- Bacteria loadings appear to increase as water flows downstream through the Moat. That is, bacteria loadings are highest at the Moat discharge at the beach and lowest at the upstream end of the Moat. That is consistent with loadings increasing as more storm water enters the Moat.

- Aborn Street outfalls S7 and S8, the RIDOT outfall at the Moat crossing under Memorial Boulevard (S10) and the Middletown 36-inch storm drain outfall from the Esplanade have the greatest potential to contribute bacteria loadings for storm water outfalls. However, these are just parts of the entire storm water problem and only happen to drain more runoff than other outfalls.

Bailey Brook

Although, Bailey Brook is known to be impaired for pathogens, it is probably not a significant source of *Enterococcus* to Easton Beach during beach season because flow from the brook does not reach the beach during most events, especially during the summer when water levels in the ponds are lower. When the Ponds are full, Bailey Brook can represent a significant potential load to the beach.

REMEDIAL ALTERNATIVES

A number of alternatives were identified and developed to address the issues found during our investigations. These alternatives include both short- and long-term alternatives, where long-term alternatives are those that require significant design and capital improvements. Opinions of cost were developed to implement/construct each alternative.

Recommended Dam Improvements

Short-Term Dam Improvement Alternatives

There are no short-term alternatives do not address the most significant deficiencies identified during the inspections, but there are several that can reduce the continuing deterioration of the dam embankment. These present the most available actions for the City to take to begin efforts. These short-term alternatives are described in the table below that also summarizes advantages, disadvantages and implementation issues.

Table 26
Short-Term Dam Alternatives

Dam STA-1 Clear and Grub Vegetation from Embankment Slopes			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Difficult access to portions of embankments • Erosion and sedimentation controls • Permitting	• Allows future mowing as standard maintenance practice (reduced maintenance costs) • Prevents future hazard from overturned trees • Allows effective visual inspection of embankment surfaces • Low engineering cost	• Does not provide slope protection without additional improvements • Permitting required due to stump removal; likely will not qualify as maintenance • Difficult access to some areas	$236,000
Dam STA-2 Clear and Grub North Pond Emergency Spillway Channel			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Coordinate access with normal site activities • Erosion and sedimentation controls • Permitting	• Improves hydraulic capacity of spillway channel • Facilitates visual inspection of spillway structures • Low engineering cost	• Permitting required; likely will not qualify as maintenance • Expense for benefit only realized during relatively rare significant storm events	$21,000

Dam STA-3 Repair North Pond Spillway Concrete Structures			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Erosion and sedimentation controls • Control of water • Permitting	• Relatively low engineering and construction costs • No groundwater dewatering, limited control of surface water required • Limited cost to extend life of existing structures	• Temporary measure to extend life of failing structures	$36,000
Dam STA-4 Conduct Structural Inspection of South Pond Spillway			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Coordinate work with low flows at spillway	• Determine condition of spillway for future repairs or limited/full replacement	• Limited information on actual condition (limited number of samples)	$29,000
Dam STA-5 Repair South Pond Spillway Concrete Structures			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Erosion and sedimentation controls • Control of water • Permitting • Research waterproofing measures	• Limited cost to extend life of existing structures • No groundwater dewatering, limited control of surface water required	• Only delays future need to replace spillway structure	$281,000

Dam STA-6 Construct Stormwater Channel Along East Embankment Slope			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• May require access through adjoining parcel (otherwise adverse access conditions result) • Erosion and sedimentation controls • Control of water • Permitting	• Addresses rilling of embankment and uncontrolled stormwater discharge into impoundment • Removes standing water at toe of embankment slope	• Possible neighbor opposition due to removal of grassed area (property boundary unknown for this study)	$54,000
Dam STA-7 Repair North Pond Embankment Settlement Area			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Erosion and sedimentation controls • Control of water • Permitting	• Limited cost to extend life of existing structure • No groundwater dewatering, limited control of surface water required	• Surficial measure; potentially does not address underlying cause of settlement	$25,000
Dam STA-8 Repair East Embankment Settlement Area and Footpath			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Erosion and sedimentation controls • Control of water • Permitting	• Limited cost to extend life of existing structure • No groundwater dewatering, limited control of surface water required	• Surficial measure; potentially does not address underlying cause of settlement	$14,000
Dam STA-9 Replace Gate Valve in North/South Pond Dividing Embankment			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Dewatering • Possible Shoring	• Restores ability to control discharge to South Pond	• May require excavation controls (dewatering, shoring) depending on depth to valve	$45,000

Dam STA-10 Conduct Slope Stability Evaluation			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Access for drill rig	• Evaluates stability of embankments following filling activities by the City	• Expense	$35,000
Dam STA-11 Place Gravel on Bench / Downstream Slope of Accessible Embankments			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Erosion and sedimentation controls	• Previous construction activity, knowledge of procedures by City • Able to access bench and downstream slopes from opposite side of moat	• Limited measure to address deficiencies (does not address embankment deficiencies)	$167,000
Dam STA-12 Install Inlet Screens for Treatment Plant Intake Structures			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Coordinate access with normal site activities	• Low cost to protect structure and plant facilities • Prevents animals and debris from being drawn into the treatment plant works.	• Requires future maintenance to clear accumulate debris	$10,000
Dam STA-13 Implement Rodent Control Program			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Research and develop program • Public education / community relations • Monitoring and reporting	• Limit damage from burrowing animals • Protect future investment in embankment repairs / improvements	• Public opposition from wildlife enthusiasts opposed to lawful management techniques • Abatement methods need to be selected and / implemented to safeguard public users if public is not prohibited from embankments during the program.	$55,000

Dam STA-14 Prepare Emergency Action Plan			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Research and document resources and contacts • Develop contingency plans for various failure scenarios • Coordination of emergency response agencies • Review and update information periodically	• Provides a prepared plan of action in the event of a failure or unanticipated situation. • Relatively low cost for a measure that could save lives and significant damage to the dam and downstream structures.		$5,000
Dam STA-15 Control Public Access			
Implementation Issues	Advantages	Disadvantages	Opinion of Cost
• Research and develop program • Public education/ community relations • Monitoring and enforcement	• Limit damage from foot traffic and vandalism • Protect public from dangerous structures • future investment in embankment repairs/ improvements	• Public opposition from current users.	$17,500

Long-Term Dam Improvement Alternatives

Long-term alternatives have been developed to address the long-term stability issues of the dam embankments and will generally require more significant efforts for planning, design and permitting, and significant capital planning to fund their implementation. They are more focused on fundamental conditions affecting the overall ability of the embankments and spillways to withstand extreme loadings during significant storm events. These long-term alternatives are listed in the following table with a brief description of each, listing of primary benefits, an order-of-magnitude opinion of cost, and listing of likely implementation issues.

Long-Term Dam Alternatives

Alternative Description	Benefits	Order of Magnitude Costs	Implementation Issues
Dam LTA-1: Realign the East and West Embankments to address significant deficiencies and provide adequate bench width along downstream toe of slopes. Repair upstream slope protection on other embankments.	• Addresses woody vegetation on all slopes and adjacent to embankments. • Repairs significant scarps on embankments. • Replaces deficient slope protection. • Provides 12 'crest width for all embankments for future maintenance/ repair access. • Provides 3H:1V downstream slopes to facilitate mowing equipment. • Provides 10 'wide bench for maintenance access and to facilitate mowing equipment. • Provides toe drains to address saturated slope and bench areas. • Repairs worn footpath, promotes proper surface drainage from embankment crests.	• Cable-Concrete: $7,592,000 • Bare Riprap $4,358,000 • Grouted Riprap: $4,580,000 • Soil-Filled Riprap (vegetated): $4,412,000 • Cellular Confinement: $4,527,000 • Porta-Dam (add-alternate): $750,000 • Watertube (add-alternate): $640,000 • Reinforced Walking Surface (add-alternate): $96,000	• Control of water required by temporarily lowering impoundment or cofferdamming around work areas. • Portion of impoundment storage capacity lost due to relocated embankments. • Significant erosion and sedimentation controls required due to proximity to adjacent water resources. • Difficult access to some portions of embankments. • Significant earth volumes to be handled will require stockpiling areas. • Permits required from CRMC, RIDEM and ACOE.
Dam LTA-2: Replace upstream slope protection on all embankments and widen embankment crest (no horizontal relocation of downstream slopes).	• Addresses woody vegetation on all slopes and adjacent to embankments. • Repairs significant scarps on embankments. • Replaces deficient slope protection. • Provides 12 'crest width for all embankments for future maintenance/ repair access. • Provides toe drains to address saturated slope and bench areas. • Repairs worn footpath, promotes proper surface drainage from embankment crests.	• Cable-Concrete: $5,280,000 • Bare Riprap $2,888,000 • Grouted Riprap: $3,055,000 • Soil-Filled Riprap (vegetated): $2,867,000 • Cellular Confinement: $3,122,000 • Sheetpiling and Cable-Concrete: $7,842,000 • Porta-Dam (add-alternate): $750,000 • Watertube (add-alternate): $640,000	• Control of water required by temporarily lower impoundment or cofferdamming around work areas. • Small portion of impoundment storage capacity lost due to upstream embankment filling. • Erosion and sedimentation controls required due to proximity to adjacent water resources. • Difficult access to some portions of embankments. • Permits required from CRMC, RIDEM and ACOE.

Alternative Description	Benefits	Order of Magnitude Costs	Implementation Issues
		• Reinforced Walking Surface (add-alternate): $96,000	
Dam LTA-3: Demolish and replace South Pond concrete spillway weir.	• Addresses observed deficiencies, does not defer repair. • Extends lifetime of existing spillway structure. • Reduces risk of failure to downstream persons and structures.	• Remove and replace spillway weir: $289,000 • Porta-Dam (add-alternate): $140,000 • Watertube (add-alternate): $120,000	• Control of water required to maintain dry work area and bypass expected storm flows. • Groundwater dewatering system possibly required. • Permits required from CRMC and RIDEM.
Dam LTA-4: Demolish and replace South Pond downstream concrete apron.	• Addresses observed deficiencies, does not defer repair. • Extends lifetime of existing spillway structure. • Reduces risk of failure to downstream persons and structures.	• Remove and replace downstream apron: $234,000	• Control of water required to maintain dry work area and bypass expected storm flows. • Groundwater dewatering system possibly required. • Permits required from CRMC and RIDEM.
Dam LTA-5: Replace North Pond concrete spillway weir.	• Addresses observed deficiencies, does not defer repair. • Extends lifetime of existing spillway structure.	• Remove and replace downstream apron: $205,000	• Control of water required to maintain dry work area and bypass expected storm flows. • Groundwater dewatering system possibly required. • Permits required from CRMC and RIDEM.
Dam LTA-6: Rebuild/Regrade all embankment crests.	• Provides 12 'crest width for all embankments for future maintenance/ repair access. • Repairs worn footpath, promotes proper surface drainage from embankment crests. • Provides reinforced surface for public access	• Rebuild/regrade embankment crests: $303,000	• Erosion and sedimentation controls required due to proximity to adjacent water resources. • Difficult access to some portions of embankments. • Permits required from CRMC, RIDEM and possibly ACOE.

Alternative Description	Benefits	Order of Magnitude Costs	Implementation Issues
Dam LTA-7: Install moat channel scour protection as described in Flood LTA-2 and LTA-6.	• Reinforces moat channel banks to prevent or reduce further encroachment into benches and downstream slopes.	• Install moat channel scour protection (riprap): $2,500,000 • Install moat channel scour protection (concrete): $3,700,000	• Control of water in moat channels required during work. • Difficult access to some portions of moat channel. • Permits required from CRMC, RIDEM and ACOE.
Dam LTA-8: Install embankment toe drains at limited sections of South, West and North Embankments.	• Addresses benches and downstream slopes areas that are wet or saturated.	• Install toe drains: $524,000	• Erosion and sedimentation controls required due to proximity to adjacent water resources. • Difficult access to portions of West Embankment. • Permits required from CRMC and RIDEM.

Dam Evaluation and Improvements Conclusions/Recommendations

Many of the short- and long-term alternatives presented should be implemented in combination or proper sequence in order to be most effective. The short- and long-term alternatives provided above are listed below in a recommended order of priority based on the significance and urgency of the condition being addressed, ease/relative cost of implementation, and contingency relationships.

<u>Short-Term</u>

1. Dam STA-1: Clear and Grub Woody Vegetation from Embankment Slopes
2. Dam STA-4: Conduct Structural Inspection of South Pond Spillway
3. Dam STA-2: Clear and Grub North Pond Emergency Spillway Channel
4. Dam STA-6: Construct Stormwater Channel Along East Embankment Slope
5. Dam STA-13: Implement Rodent Control Program
6. Dam STA-14: Develop an Emergency Action Plan
7. Dam STA-7: Repair North Pond Embankment Settlement Area
8. Dam STA-8: Repair East Embankment Settlement Area and Footpath
9. Dam STA-15: Develop and Implement Program to Control/Prohibit Public Access Onto Embankments
10. Dam STA-5: Repair South Pond Spillway Concrete Structures
11. Dam STA-11: Place Gravel on Bench/Downstream Slope of Accessible Embankments
12. Dam STA-10: Conduct Slope Stability Evaluation
13. Dam STA-9: Replace Gate Valve in North/South Pond Dividing Embankment
14. Dam STA-3: Repair North Pond Spillway Structures
15. Dam STA-12: Install Inlet Screens for Treatment Plant Intake Structures

Long-Term

1. Dam LTA-1: Realign Portions of Embankments
2. Dam LTA-2: Replace Upstream Slope Protection
3. Dam LTA-7: Install Moat Channel Scour Protection
4. Dam LTA-8: Install Embankment Toe Drains
5. Dam LTA-3: Replace South Pond Concrete Spillway Weir
6. Dam LTA-4: Replace South Pond Downstream Concrete Apron
7. Dam LTA-5: Replace North Pond Concrete Spillway Weir
8. Dam LTA-6: Rebuild/Regrade Embankment Crest

Recommended Moat Improvements

Several alternatives to reduce flooding along the northern section of the Moat, specifically within the Ellery Road and Eustis Avenue neighborhoods, were identified in the *1991 USDA Flood Prevention Evaluation for Ellery Road and Eustis Avenue* (1991 USDA Study). While our study expands from the original USDA study by focusing on flooding throughout the entire length of the Moat, we reconsidered the alternatives proposed by the USDA and identified other alternatives to reduce flooding at Memorial Boulevard and at other local roads adjacent to the Moat.

In order to evaluate the anticipated benefits provided by each of our proposed alternatives, we developed a baseline hydraulic model to determine approximate water surface elevations within the Moat during storm events and to identify existing areas of flooding based on different frequency rainfall events. Hydraulic modeling of the Moat was completed using the US Army Corps of Engineer's model HEC-RAS..

Based on the results obtained from our baseline hydraulic model, the hydraulic capacity of the Moat is inadequate. To put the hydraulic inadequacy of the Moat into perspective, the Moat would need to be more than 50 feet wide to contain all storm events up to the 50-year storm within its banks. However, widening the Moat is not possible given existing physical constraints.

Short-Term Flood Management Alternatives

Although short-term alternatives may slightly increase the hydraulic efficiency of the Moat or the adjacent roadway closed-conduit drainage systems, no short-term alternatives proposed will alleviate flooding or significantly reduce water surface elevations within the Moat during storm events. These alternatives will, however, ensure that flooding conditions do not worsen and will also improve stabilization of the Moat bottom to reduce future erosion/scour. The following summarizes each short-term alternative proposed, the approximate cost of each alternative and lists potential implementation issues associated with each.

Short-Term Flood Management Alternatives

Description	Benefit	Order of Magnitude Costs	Relative Cost / Benefit Rating	Implementation Issues
Flood STA-1: Remove areas of sediment deposition within the Moat and install riprap at the outlets of culverts discharging to the Moat.	• Slight improvement of the hydraulic efficiency of the Moat. • Prevents scour at stormwater outlets .	$256,000	Low	• Excavated soil needs to be hauled to an appropriate disposal facility. The material will require testing for contamination. Results could significantly increase disposal costs. • A Maintenance Certificate may be required from the CRMC.
Flood STA-2: Install riprap at the upstream and downstream ends of the Memorial Boulevard culvert	• Stabilized the channel upstream and downstream of the culvert.	$7,000	Low	• Riprap requires little maintenance, but should be inspected periodically for scour or excessive vegetative growth. • Riprap can pose a hazard since children may be tempted to throw small riprap. • A Maintenance Certificate or Council Assent may be required from the CRMC for work below the mean high water level.
Flood STA-3: Install riprap at the upstream and downstream ends of the pedestrian bridge located in the northwestern corner of the Moat	• Stabilized channel upstream and downstream of the pedestrian bridge.	$6,000	Low	• Riprap requires little maintenance, but should be inspected periodically for scour or excessive vegetative growth. • Riprap can pose a hazard since children may be tempted to throw small riprap. • A Maintenance Certificate may be required from the CRMC.
Flood STA-4: Remove hydraulic obstruction within the Moat and install culverts below access path	• Improved moat hydraulics.	$40,000	Low	• Improvements must occur during the dry season/weather since the Moat sustains a base flow. • Dewatering will be necessary. • A Maintenance Certificate may be required from the CRMC.

Flood STA-5: Continue to clean and flush existing drainage structures and pipes that discharge to the Moat along Ellery Rd., Eustis Ave., Old Beach Rd., and Memorial Blvd.	• Reduced roadway flooding during the smaller, more frequent storm events.	$5,000 per Maint. Event	High	• Inspection and maintenance of the closed-conduit drainage systems and components must continue to be performed on a regular basis (e.g., inspect quarterly and maintain twice a year, at minimum).
Flood STA-6: Continue to implement a regular maintenance / mowing program to control the height of vegetation growing within and adjacent to the Moat	• Improved hydraulic capacity of the Moat.	$107,000 per Clearing Event	High	• Due to the instability of the pond embankment and bench in some locations, maintenance needs to be performed by hand. Mow at least twice a year. • A Maintenance Certificate may be required from the CRMC.

Long-Term Flood Management Alternatives

Several long-term alternatives were developed in order to evaluate their effectiveness to reduce flooding. Each of these alternatives was modeled utilizing HEC-RAS and the resulting water surface profiles were compared with the baseline model to evaluate their flood reduction benefits. No alternatives were identified that will substantially reduce flooding along the entire length of the moat. The alternatives described herein will only have localized benefits. The following table summarizes each long-term alternative, the approximate cost of each alternative, and a list of potential implementation issues.

Long-Term Flood Management Alternatives

Alternative Description	Flood Reduction Benefit	Order of Magnitude Costs	Relative Cost / Benefit Rating	Implementation Issues
Flood LTA-1: Excavate existing channel bottom to provide a uniform channel slope in sections of the Moat that are adjacent to the identified areas of flooding.	• Minimal flood reduction benefits in areas adjacent to north portion of moat. • Decreases in water surface elevations of 0.2 feet or less would be expected within northern portion of moat during 2- and 5-year storm events only.	$1.4 Million	Low	• Improvements must occur during dry season and dry weather. • Moat improvements will need to be completed in sections to enable dewatering. • Excavated soil or muck needs to be hauled to an appropriate disposal facility. The material will require testing for contamination. Results could significantly increase disposal costs. • Permits required from RIDOT, CRMC, RIDEM Water Quality, and ACOE.

Flood LTA-2: Excavate and widen the Moat channel throughout its entire length and line the base with riprap.	• Decreases in water surface elevations of 0.3 feet, on average, would be expected for 2- thru 10-year storm events in northern portion of moat. As a result, 2 of the 6 flood-prone houses in this location will be above the flood damage elevation during 2- and 10-year storms. • Minimal to no reduction anticipated for storm events greater than the 10-year storm event in all flood-prone areas.	$2.5 Million	Low	• Improvements must occur during dry season and dry weather. • Moat improvements will need to be completed in sections to enable dewatering. • Excavated soil or muck needs to be hauled to an appropriate disposal facility. The material will require testing for contamination. Results could significantly increase disposal costs. • Permits required from RIDOT, CRMC, RIDEM Water Quality, and ACOE.
Flood LTA-3: Replace existing Memorial Boulevard culvert with three 5-foot by 10-foot box culverts.	• Flood reduction benefits mainly noted within southeastern corner of moat just upstream of Memorial Boulevard. • Decreases in water surface elevations ranging between 0.9 feet (for 2-year storm) to 0.1 feet (for 50-year storm) would be expected in southeastern portion of moat.	$650,000	Low	• Improvements must occur during dry season and dry weather. • Dewatering will be necessary during construction. • Will require coordination with appropriate utility companies. • Demolition and construction work will cause a disruption to on Memorial Boulevard. • Permits required from RIDOT, CRMC, RIDEM Water Quality, and ACOE.
Flood LTA-4: Install a pump station within southern portion of moat (adjacent to Memorial Boulevard culvert).	• Flood reduction benefits noted mainly in area adjacent to southern portion of moat channel along Memorial Boulevard and Old Beach Road. • Decreases in water surface elevations ranging between an average of 1.0 feet (for 2-year storm) to 0.3 feet (for 50-year storm) within section of moat adjacent to Old Beach Road and southwestern portion of moat. • Decreases in water surface elevations ranging between 0.7 feet (for 2-year storm) to 0.0 feet (for 50-year storm) in southeastern portion of moat.	$6.5 Million	Low	• Architectural and landscaping decisions will need to be made in regards to appearance of pump station. • Operation and maintenance of pump stations involves frequent inspection, monitoring, and maintenance. • Will require coordination with appropriate roadway utility companies in addition to cause a disruption to traffic. • Dewatering will be necessary during construction. • Permits required from RIDOT, CRMC, RIDEM Water Quality, and ACOE.

Flood LTA-5: Install 3-5 x8 ' box culverts at southwestern corner of moat (adjacent to Old Beach Road)	• Flood reduction benefits adjacent to the southern portion of the Moat channel along Memorial Boulevard and Old Beach Road. • Decreases in water surface elevations ranging between 10 inches (for the 2-year storm) to 2 inches (for the 50-year storm) expected within the section of the Moat adjacent to Old Beach Road. Decreases in water surface elevations ranging between 30.7 inches (for the 2-year storm) to 4.9 inches (for the 50-year storm) would be expected in the southwestern portion of the Moat. Decreases in water surface elevations ranging between 29.8 inches (for the 2-year storm) to 6.0 inches (for the 50-year storm) would be expected in the southeastern portion of the Moat.	$1.4 Million	Medium	• The channel width at the inlet of the culverts will need to be increased to 30 feet wide. Retaining walls may be required along both sides of the channel at the culverts. • Will require coordination with appropriate utility companies due to potential conflicts with roadway utilities. The installation of the culvert will cause a disruption to traffic as lane closures on Memorial Boulevard will be most likely be required. • Beach area in the western section of Easton Beach will be lost. • Permits required from RIDOT, CRMC, RIDEM Water Quality, and ACOE.
Flood LTA-6: Provide uniform channel slope and cross-section throughout moat and line base of channel with concrete	• Flood reduction benefits in area adjacent to the northern portion of moat. • Decreases in water surface elevations ranging from an average of 1.8 feet (for the 2-year storm) to an average of 0.6 feet (for the 50-year storm) expected in the northern portion of the Moat. • 3 of the 6 flood-prone houses in this location houses will be above the flood damage elevation for storm events up to and including the 10-year storm.	$3.7 Million	Low	• Improvements must occur during dry season and dry weather. • Moat improvements will need to be completed in sections to enable dewatering. • Excavated soil or muck needs to be hauled to an appropriate disposal facility. The material will require testing for contamination. Results could significantly increase disposal costs. • Alternatives such as pre-cast channel sections or shotcrete may be more feasible. • Subdrains or intermittent weepholes may be required to minimize hydrostatic forces on the base and sides of the channel. • Permits required from RIDOT, CRMC, RIDEM Water Quality, and ACOE.

Hydraulic Analysis Conclusions/Recommendations

Flooding along Ellery Road, Old Beach Road, and Memorial Boulevard can be attributed to the insufficient hydraulic capacity of the Moat. Several factors contribute to this deficiency, including:

- The amount of flow discharged to the Moat from numerous closed-conduit storm drain systems and the secondary spillway from North Easton Pond.
- The relatively flat slope of the Moat and restrictive cross-sectional geometry.
- Sediment deposition from scour within the Moat as well as from the interconnected storm drain system, which discharges to the Moat.
- Vegetative growth within the channel of the Moat.

As a result of these factors, no single short-term or long-term alternative that we analyzed will attenuate flooding in all flood-prone areas along the Moat. Each alternative will only have localized effects. For the Memorial Boulevard and Old Beach Road area, the installation of three box culverts in the southwestern corner of the Moat that would span across Memorial Boulevard (Flood LTA-5) did appear to be a moderately cost- effective solution to reduce localized flooding.

Recommended Water Quality Improvements

The Easton Beach watershed has a number of physical limitations that significantly constrain the controls that could be applicable in this watershed. These include significant storm water flows generated in the watershed, little space available to site controls, poor soils available for infiltration and high groundwater which is also prevents use of infiltration. Based on these limitations, a set of potential short- and long-term controls have been identified that could be implemented in the beach-shed to reduce bacteria loads to the beach.

Short-Term Water Quality Alternatives

Several short-term alternatives are available to the City to reduce wet-weather bacteria loadings to the beach. They consist of nonstructural controls and will not require a significant investment or effort to implement. However, none of these short-term alternatives will solve the beach closure problems being currently observed. They would reduce the overall bacteria load discharged.

WQ STA -1 Public Education – The public's behavior has a direct effect on water quality. For example, improperly managed pet waste will contribute significantly to water quality problems. During our fieldwork on Easton Pond Dam, we noted significant quantities of dog waste. We also witnessed dog walking at the beach, where droppings could easily wash into the beach water. In general, this alternative involves adapting existing materials for use at Easton Beach. In part this will involve participation in the Phase II Storm Water Outreach Program that the City has already agreed to participate in this. The opinion of cost for this work is approximately $20,000.

WQ STA-2 Public Participation – Like WQ STA-1, this alternative will also assist the City in complying with Phase II storm water regulations but it will also build public awareness of the water quality problems at the beach and what is contributing to those problems. The City could:

- Continue to work with Clean Ocean Access and wherever possible support their efforts to clean up the beach and conduct water quality sampling.
- The City should also solicit business owner involvement.
- Pet waste is a significant source of bacteria. The City should publicize their existing pet waste ordinance.

The opinion of cost for this work is approximately $10,000.

WQ STA-3 Waste Management at the Beach – Waste management practices at Easton Beach can be improved to reduce sources of bacteria there. Our recommendations are as follows:

- Add trash cans with hoods to prevent seagulls from foraging.
- Develop a regular schedule to remove wrack (i.e., piled-up seaweed) from the beach areas. Wrack is a potential source of bacteria and it has been stockpiled adjacent to the Moat discharge to the beach.

The opinion of cost for this work is approximately $20,000.

WQ STA-4 Illicit Discharge Detection and Elimination (IDDE) – Water quality testing conducted last season showed indications of possible illicit discharges, which could contribute to higher bacteria levels, specifically with three outfalls S9, S10 and S11 that are owned either by RIDOT or the Town of Middletown. The City should coordinate with other entities to remove their illicit discharges. The opinion of cost for this work is approximately $30,000.

WQ STA-5 Wild Animal Management – Urban wildlife can contribute significantly to water quality problems. Animals of concern include birds, raccoons, and rodents.

- Raccoons have been found living in the storm drain system and should be removed.
- The City should also consider developing a waterfowl management plan to control birds around the beach.
- As recommended for the dam, a rodent control plan should be considered.

The opinion of cost for this work is approximately $55,000.

WQ STA-6 Restrict Public Access to Easton Pond Dam –Due to contamination and public health risks, water suppliers do not usually allow public access to or around water supplies. The City should consider prohibiting public access to the dam, especially if efforts to control dog wastes in these areas are not effective. The opinion of cost for this work is approximately $17,500.

Long-Term Water Quality Alternatives

The long-term alternatives proposed herein involve major capital improvements and construction. Long-term alternatives were first screened by reviewing available technologies to identify those that have significant potential to be applied in this watershed. The technologies that were considered have been grouped into filtration/infiltration technologies, disinfection and other technologies and are described below.

- Filtration/infiltration.
  - Infiltration trenches.
  - Disconnected catch basins and proprietary infiltration units.
  - Sand filters.
  - Catch basins with sand filters.
  - Proprietary Filter Media (e.g., Smart Sponge™).
  - Bioretention.
- Disinfection.
  - Chlorination.
  - Ozonation.
  - Ultraviolet disinfection.
- Other Technologies.
  - Stormwater Wetlands.

Long-term alternatives were screened from this list of potential technologies. These alternatives are somewhat unconventional because of the constraints of this watershed. These alternatives are not all equal, they vary significantly with the volumes of storm water they can treat and the areas of runoff that they can manage as well as their treatment efficiency and reliability. As such, long-term alternatives have been organized based on the area that they would be designed to manage. The following table summarizes each potential long-term alternative, which provides size of subwatershed treated, water quality volume treated, treatment efficiency, and cost of alternative in 2007 dollars.

Table 39
Long-Term Water Quality Treatment Alternatives

Treatment Alternative	Subwatershed	Subwatershed Size (acres)	WQV (cubic feet)	Bacteria Removal Efficiency (%)	Cost Benefit Ratio
Easton Beach Parking Lots and Memorial Boulevard					
WQ LTA-1 Infiltration Trenches East Beach Parking Lot	East Beach Parking Lot	4.1	15,078	75-98	$199,000 $13.3-$17.3(/cf)

WQ LTA-2 Infiltration Trenches West Beach Parking Lot	West Beach Parking Lot	2.3	8,600	75-98	$132,000 $15.3-$20.0(/cf)
WQ LTA-3 Infiltration for Memorial Boulevard	Memorial Boulevard	8.6	16,256	75-98	$422,000 $26.5-$34.7(/cf)
WQ LTA-4 Sand Filter East Beach Parking Lot	East Beach Parking Lot Area B	3.1	11,600	40-90	$454,000 $38.8-$50.7(/cf)
Western Residential Neighborhoods Draining to Moat					
WQ LTA-5 Chamber Sand Filters[b]	3-2 3-3 3-4 3-5 3-6 *Total*	232.1 84.6 42.1 21.2 36.6 *416.6*	312,300 143,350 53,060 14,270 24,400 *547,380*	40-90	$4,897,000 $2,109,000 $807,000 $203,000 $351,000 *$8,367,000* $17.8-$40.0(/cf)
WQ LTA-6 Bioretention at Braga Park	3-1 3-2	263.9	335,634	75-98	$2,714,000 $8.2-$10.7(/cf)
WQ LTA-7 Catch Basin Inserts	3-1 3-2 3-3 3-4 3-5 3-6 3-7 3-8 3-9 *Total*	31.8 232.1 84.6 42.1 21.2 36.6 2.2 3.2 4.7 *458.5*	23,300 312,300 143,350 53,060 14,270 24,400 1,200 1,800 2,800 *576,480*	50-75	$14,000 $313,000 $143,000 $58,000 $47,000 $55,000 $5,000 $5,000 $5,000 *$645,000* $1.3-$2/cf
Moat Discharge					
WQ LTA-8 UV Treatment	Easton Beach Watershed[a]	594.3	745,000	99	$3,800,000 $5.1/cf

a. Entire watershed includes flow from Middletown that enters the moat near the discharge point.
b. The sand filters are intended for use in the upland to treat portions of the WQV depending on the length and number installed. Therefore this footprint may be split up amongst several sand filters.
c. The values in the Cost Benefit Ratio column are costs for 2007. The first number is the total cost for the system. The second listing, in BOLD, is the range of dollars per cubic foot of WQV treated, divided by the bacteria removal efficiency (cost/WQV/% removal)

Pilot-Testing of Selected Structural Controls

Several innovative structural controls have been proposed as long-term alternatives. We recommend some pilot testing of the controls before the City makes any significant investment in implementing them. This would allow the City to better understand the relative costs and benefits of the alternatives as a group. The structural controls for which we recommend pilot-testing are:

- Chamber Sand Filters
- Catch Basin Inserts

Pilot testing for these two alternatives would consist of implementing these alternatives on a small scale in the watershed.

In addition to this pilot-testing, more intensive monitoring of both hydraulic and water quality in the Moat area near the Memorial Boulevard bridge is also recommended in order to develop a design for a UV treatment system. The hydraulics in this area is very complicated and need to be better understood in order to ensure that the system will operate without causing additional flooding. Additional water quality testing is recommended in order to define pretreatment needs and sizing of the UV system.

Water Quality Improvements Conclusions/Recommendations

Based on our evaluation, we recommend that the City implement a UV disinfection system for the Moat outfall. This system is the only alternative that could be applied for the entire discharge from the moat. It is also the most reliable in terms of treatment of bacteria and will achieve the greatest reductions in bacteria that are measured at the beach. It is also cost effective compared to other alternatives. Implementation of structural controls such as this is eligible for significant funding opportunities through the Rhode Island Watershed Bond Fund that can provide up to 50% grants for controls such as these. However, this system should be reevaluated after preliminary design to reconfirm expected costs to construct and operate the system and that the system will not significantly impact Moat hydraulics.

Alternatively, the use of catch basin inserts within the watershed to the Moat should be considered if UV disinfection is not implemented. This technology would be the least costly, however, there are many questions regarding its effectiveness. As a result, pilot testing would be recommended for this alternative. Because this technology could only be applied to a portion of the watershed that is draining to the Moat, other structural and non-structural controls will likely be required such as controls for Memorial Boulevard (WQ LTA-3) and removal of dog and animal wastes from the moat and pond dams as a source of bacteria (WQ STA-1, -2, and -5).