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Memorandum

To	George Meservey, Director of Planning & Community Development Michael Domenica, PE, Program Manager
CC	Betsy Shreve, AICP, AECOM Project Director Martin "Reggie" Donoghue, P.E., AECOM Project Engineer
Subject	**Town of Orleans, MA** **Water Quality and Wastewater Planning** **Task Number 10.1.C – Facilities Preliminary Design** **Task 10.1.C.4 - Collection System Preliminary Design Report (25% Design) Downtown Area**
Project Number	60476644
From	Thomas Parece, P.E., AECOM Project Manager
Date	08/22/17

Approvals	Date	Signature / Initials
George Meservey, Orleans, MA Director of Planning & Community Development		
Michael Domenica, PE, Water Resources Associates, Program Manager		

1. Background

The purpose of this Collection System Preliminary Design Report (25% Design) Downtown Area is to identify the types of collection system technologies and to evaluate each of the technologies in order to develop a cost-effective alternative for the proposed Downtown Area wastewater collection area of Orleans. The Collection System Technologies include: (a) Gravity Sewers (GS); (b) Low Pressure Sewers (LPS); (c) Septic Tank Effluent Gravity (STEG); (d) Septic Tank Effluent Pumping (STEP); and (e) Vacuum Sewers (VS). This Technical Memorandum updates previous documents based on supplemental information obtain including topography survey, subsurface investigations and cultural resource evaluations as well as input from the Collection System Working Group.

2. Introduction

A. General

The Orleans Water Quality Advisory Panel (OWQAP) was convened to achieve consensus and build widespread community support for a customized, affordable water quality management plan for the Town of Orleans. The panel consisted of stakeholder representatives (Orleans Selectmen and representatives of engaged citizen constituencies), and liaisons from key town boards and commissions, organizations, neighboring towns, and regional, state, and federal partners. The OWQAP met for twelve half-day meetings starting in July 2014, all of which were open to public attendance and comment. The Project is necessary in order to reduce excessive nitrogen discharges to the Town's ponds, estuaries and embayments. The Project represents the first to implement a "Hybrid" approach under the Cape Cod 208 Water Quality Plan, recently approved by both USEPA and MassDEP.

The Project consists of conceptual and preliminary design to update the Comprehensive Wastewater Management Plan (CWMP) completed by the Town in 2011 to reflect the Consensus Plan (Water Quality Management Plan) developed by the Town in 2015. The Project goal is to minimize the proposed sewered footprint (area of Town and number of properties to be sewered) to the greatest extent possible by maximizing the use of several non-traditional technologies (Coastal Habitat Restoration, Aquaculture, Layered Soil Treatment Areas, and Permeable Reactive Barriers).

The resulting map (Figure. 1), entitled Conceptual Approach to Meet Orleans Water Quality Goals (March 2015) shows the agreed upon water quality management plan and indicates the two proposed areas to be sewered. This map also indicates the number of properties and associated wastewater flows associated with the respective Downtown Area and Meetinghouse Pond Area wastewater collection systems.

The current Project includes two areas proposed for sewering: (1) about 350 parcels encompassing Downtown Area (Average Design Flow of about 234,000 gpd) and (2) about 375 parcels within the Meetinghouse Pond Area (Average Design Flow of about 110,000 gpd) to be treated at a new wastewater treatment facility located on Overland Way and aquifer recharge.

B. Definitions

1) Gravity Sewers (GS)

A Gravity Sewer system two major components: (a) collection system; and (b) a conveyance system. Gravity Sewers have historically been the most popular method used for the collection and conveyance of wastewater in the United States. The pipes are installed on a slope to enable the wastewater to flow by gravity from each property through a series of gravity collector pipes, often to a pumping station, for conveyance to a wastewater treatment facility for treatment and disposal. Pipes are generally 8 inches and larger and they typically are installed at a minimum depth with 5 feet of cover and a maximum depth of about 25 feet. Manholes are located a maximum of 400 feet apart and/or at changes of direction or slope.

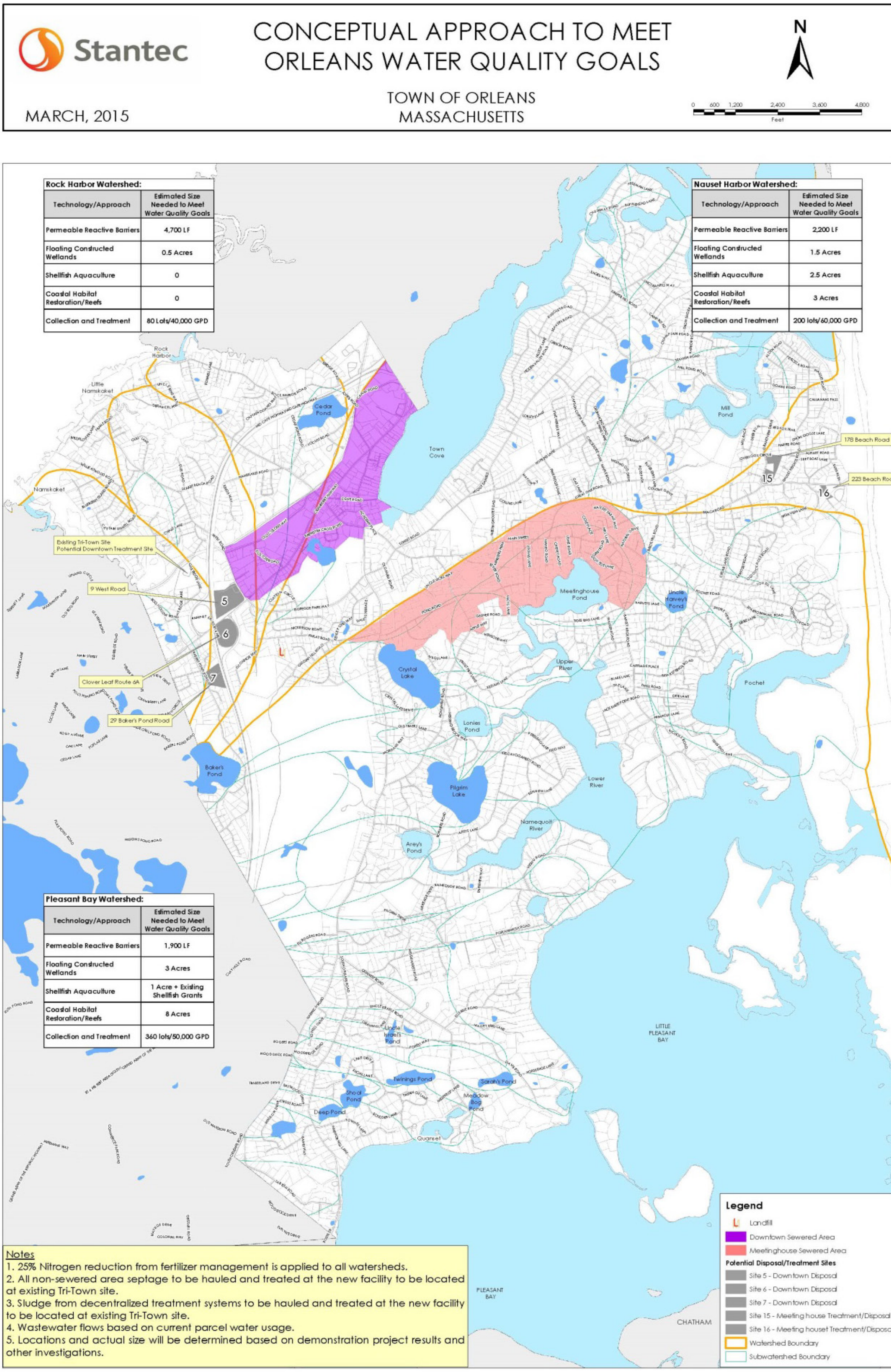
a) Design Considerations

- Most cost effective for areas with topographic relief. Size and slope of pipes are determined by minimum scouring velocity requirements;
- Installation can require deep excavations with large open cut trenches to maintain grade and require dewatering;
- Requires an allowance for infiltration/inflow;
- Operation and maintenance costs and requirements are well known; and
- Typically requires pumping stations in areas of variable topography.

b) Advantages

- Familiarity with the operation and maintenance of the systems;
- Gravity sewer systems typically have large amounts of storage volume;
- Gravity sewers generally can accommodate to future flow;
- Absence of mechanical components reduces the routine operation and maintenance required;
- Operation and maintenance limited to pumping stations; and
- Detention times and the ability to adjust/control pumping operations can shave peak flows at downstream components including wastewater treatment facilities.

Figure 1 – Conceptual Approach to Meet Orleans Water Quality Goals



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c) Disadvantages

- Construction costs are dependent on the depth of construction, and amount of dewatering;
- Deep installation can lead to wide trenches and have a greater impact to the environment and increased restoration cost;
- Reconstructing of entire roadway is typically required;
- May require several pumping stations;
- Ownership of the land and/or easements would be required to site pumping stations and/or to minimize the number of pumping stations; and
- Increased potential infiltration based on the depth, the groundwater table and the system configuration (ie. number of manholes, size of pipes, etc.).

2) Low Pressure Sewers (LPS)

A Low Pressure Sewer system has two major components: (a) private property facilities; and (b) a collection system. Private property facilities consist of a pump chamber and control panel at each property. The pumps are small and are equipped with a grinding mechanism that macerates the solids. Wastewater from the property flows by gravity to the pump chamber. The pumps automatically operate based on water level and discharge into a pressurized pipe system (1-1/2-inch increasing to 4-inches in diameter) terminating at a gravity collection sewer for gravity flow to a wastewater treatment facility for treatment and disposal. In some areas, a pumping station may be required for conveyance to a wastewater treatment facility.

a) Design Considerations

- Used with difficult site conditions including topography, poor soils, high groundwater and narrow roadways;
- Small diameter piping system typically between 1-1/2-inch to 4-inches; and
- Incorporates isolation and cleanout manholes.

b) Advantages

- The depth and width of the trenches are reduced due to small diameter piping;
- Trenchless technologies can be utilized in areas of favorable soils conditions and geography but the advantage decrease as the number of connections increase;
- Smaller pipe size with narrower and shallower trenches can reduce impacts to the environment, reduce construction restoration, and overall construction costs;
- Routine servicing at private grinder pump chamber can be done without exposure to sewage;
- Collection system operation and maintenance requires minimal access to manholes; and
- Infiltration is eliminated by the closed system design throughout the system, thereby reducing the operating and maintenance costs at downstream pumping stations and at the wastewater treatment facility.

c) Disadvantages

- Added operation and maintenance costs for the private property components (pump and controls);
- Storage is in the gravity line and/or pump chamber, and typically provides some emergency storage during a power outages since water usage is reduced.

- Risk of overflows during extended pump shutdown/failure;
- On-site components may not be acceptable to and/or increase the number of complaints from property owners;
- Operation and maintenance risks increase when dealing with seasonal and commercial users;
- Shifting operation and maintenance costs to the property owner may not be acceptable and/or increase the number of complaints particularly when installed in seasonal communities; and
- Small diameter pipe limits the flexibility to accommodate future flows.

3) Septic Tank Effluent Gravity (STEG)

A Septic Tank Effluent Gravity system has three major components: (a) private property facilities; (b) a collection system; and (c) a conveyance system. Gravity Sewers have historically been the most popular method used for the collection and conveyance of wastewater in the United States. The private property facilities consist of a chamber (existing or new septic tank) at each property where solids settle out. The collection sewers are installed on a slope from the septic tank to the collection system to enable the septic tank effluent to flow by gravity from each property. Pipes are generally 8 inches and larger and they typically are installed at a minimum depth with 5 feet of cover and a maximum depth of about 25 feet. Manholes are located a maximum of 400 feet apart and at all changes of direction or slope. In some areas, a pumping station may be required for conveyance to a wastewater treatment facility.

a) Design Considerations

- Most cost effective for areas with topographic relief. Size and slope of pipes determined by minimum scouring velocity requirements;
- Installation can require deep excavations with large open cut trenches to maintain grade and require dewatering;
- Uses the existing or a new on-site septic tank;
- Requires an allowance for infiltration/inflow;
- Operation and maintenance costs and requirements are well known; and
- Typically requires pumping stations.

b) Advantages

- The septic tank reduces the amount of solids in the effluent;
- Familiarity with the operation and maintenance of the systems;
- Gravity sewer systems typically have large amounts of storage volume;
- Gravity sewers generally can be designed to accommodate future flow;
- Absence of mechanical components reduces the routine operation and maintenance required;
- Mechanical operation and maintenance limited to pumping stations;
- Detention times and the ability to adjust/control pumping operations can shave peak flows at downstream components including wastewater treatment facilities.

c) Disadvantages

- Existing septic tank may not meet current TR-16 requirements and/or may not be structurally sound;
- Requires septic tank inspections and pump outs;
- Septage pump-outs require trucking and processing at septage receiving facility;
- Odors may result from improperly maintained septic tanks;
- Increase potential for corrosion in system components;
- Ownership of the land and/or easements would be required to site pumping stations and/or to minimize the number of pumping stations; and
- Increased potential infiltration based on the depth, the groundwater table and the system configuration (ie. number of manholes, size of pipes, etc.).

4) Septic Tank Effluent Pumping (STEP)

A Septic Tank Effluent Pumping system has two major components: (a) private property facilities; and (b) a collection system. Depending upon the distance to the termination point a conveyance system may also be required. Private property facilities consist of two pumps, pump chamber (existing or new septic tank) and control panel at each property. The pumps are small and are designed to pump septic tank effluent, but will not pump raw sewage solids. Wastewater from the property flows by gravity to the pump chamber. The pumps automatically operate based on water level and discharge into a pressurized pipe system (1-1/2-inch increasing to 4-inches in diameter) discharging to the gravity collection sewer, a pumping station for conveyance to a wastewater treatment facility, or directly at a wastewater treatment facility for treatment and disposal.

a) Design Considerations

- Difficult site conditions including varying or little topography, poor soils, rocky conditions, seismically active areas, loose sands, high groundwater, and narrow roadways;
- Septic tank utilized to retain solids from effluent;
- Small diameter piping system typically between 1-1/2-inch to 4-inches;
- Can be utilized in low pressure sewer arrangement for small communities, and
- Effluent pump design requires dual system (primary/back-up) per TR-16.

b) Advantages

- The septic tank reduces the amount of solids in the effluent;
- Pump chamber in new septic tanks can be designed to provide emergency storage volume;
- Trenchless technologies can be utilized in areas of favorable soils conditions and geography but the advantage decrease as the number of connections increase;
- Smaller pipe size with narrower and shallower trenches can reduce impacts to the environment, reduce construction restoration, and overall construction costs;
- Infiltration is reduced and/or eliminated by the closed system effluent piping, thereby reducing the operating and maintenance costs at downstream pumping stations and at the wastewater treatment facility.

c) Disadvantages

- Existing septic tank may not meet current TR-16 requirements and/or may not be structurally sound and are typically required to be replaced thereby increasing capital costs;
- Added operation and maintenance costs for the private property components (pumps, controls and septic tank pump-outs);
- Septage pump-outs require trucking and processing at septage receiving facility;
- Requires monitoring of the septic tank on a regular basis in order to avoid plugging of the pump with solids;
- Odors may result from improperly maintained septic tanks;
- Increase potential for corrosion in system components;
- Risk of overflows during extended pump shutdown/failure;
- On-site components may not be acceptable to and/or increase the number of complaints from property owners;
- Storage is in the gravity line and/or pump chamber, and typically provides up to 8-hour capacity during a power outages since water usage is reduced;
- Operation and maintenance risks increase when dealing with seasonal and commercial users;
- Shifting operation and maintenance costs to the property owner may not be acceptable and/or increase the number of complaints particularly when installed in seasonal communities; and
- Small diameter pipe limits the flexibility to accommodate future flows.

5) Vacuum Sewers (VS)

A Vacuum Sewer system has four major components: (a) gravity property connection to valve pit; (b) a vacuum collector main; (c) a vacuum collection station; and (d) a sewage pump and force main conveyance system. Wastewater from the property flows by gravity to an on-site vacuum interface valve pit/ holding tank. When a specific level has been reached, the vacuum interface valve, which operates automatically using pneumatic controls, opens for a few seconds allowing the wastewater and a volume of air to be sucked through the service pipe and into the vacuum sewer collection system. Vacuum pumps at the central collection station cycle as needed to maintain a constant level of vacuum throughout the service area. When the wastewater in the collection tanks reach a certain level, conventional sewage pumps transmit the wastewater by force main to the wastewater treatment facility for treatment.

a) Design Considerations

- Used with difficult site conditions including; flat or minimal slope topography, poor soils, high groundwater and narrow roadways;
- Vacuum collection chambers include sump and valve pit that must be vented to introduce air for vacuum;
- Vacuum collection chambers can serve multiple properties by gravity connections and be located near street for municipal access;
- Minimum slope of 0.2 percent between lifts and pipeline is installed in a saw tooth profile for lifting flow up an incline and to maintain vacuum level at end of each line;

- Two sets of pumps are required – collection (vacuum) and conveyance (sewage) – with careful selection of pumps required for proper facility operation; and
- One vacuum pumping station can typically pull vacuum in the collection system at a distance of up to 10,000 linear feet.

b) Advantages

- Collection chambers are serviced without exposure to sewage;
- A local power outage is not a factor in service at the property since no power is required at each collection chamber;
- Collection pipe diameters typically range from 8-inches to 10-inches;
- Construction costs, restoration, and environmental impacts are reduced due to smaller pipe size, narrower and shallower trenches;
- The system from private property collection chambers to the vacuum station can be monitored from a control panel located at the vacuum pumping station;
- Emergency power back-up is only needed at the combined vacuum pumps/collection tank and vacuum pumping stations; and
- Infiltration is reduced and/or eliminated by the closed system, thereby reducing the operating and maintenance costs at pumping stations and at the wastewater treatment facility.

c) Disadvantages

- Added operation and maintenance costs for the private property components;
- Requires timely response to low vacuum alarms;
- May require several vacuum stations to serve a large service area;
- Ownership of the land and/or easements would be required to site system vacuum/pumping station and/or to minimize the number of vacuum/pumping stations;
- Limited flexibility regarding future expansion, new vacuum station typical for each added service area;
- Limited storage in the collection system;
- Unsteady flows conveyed to WWTF if the majority of the service area is on vacuum stations that typically run in a batch cycle; and
- Vacuum station requires larger building to house two sets of pumps; vacuum and sewage, which will increases operation and maintenance costs.

C. Design Criteria and Data

Design criteria and data (i.e. minimum pipe sizes and slopes. materials of construction, trench depth and width, private property scope of work, restoration, typical production rates) used as part of the basis of the technologies evaluations and cost estimates are as follows:

1) Gravity Sewers (GS)

- Gravity Sewer Main Layout – Layout the system to allow gravity connections from all properties to be serviced. Pipes shall laid with a uniform slope between manholes and be installed at a minimum of 6 feet below grade in order to prevent freezing and minimize conflicts with other utilities.
- Pipe Size and Material – Pipe diameter sized to provide a cleansing velocity of 2 feet/second when flowing full based on Manning's formula using an "n" value of 0.013 but shall not be less than 8-inches in diameter. Pipe Material to be SDR 35 PVC piping or greater.
- Manholes – Installed at the end of each sewer reach; at all changes in grade, size, or alignment; and at all pipe intersections with a nominal distance of 300 to 400 linear feet. Manhole material to be precast concrete.
- Infiltration/Inflow Allowance: 200 to 500 gpd/inch diameter/mile.
- Minimum Size: Building Sewer at 4-inches; and Municipal Sewer at 8-inches.
- Location to Water Supplies: 10 feet Horizontally and 18-inches Vertically (Unless cased piping is used for necessary crossings).
- Materials: PVC, Ductile Iron, Reinforced Concrete or Other Material Approved by MassDEP.
- Typical Components: Pipe, Fittings, Manholes, Drop Manholes, Chimneys and Cleanout/Check Valve at Property Line.

2) Low Pressure Sewers (LPS)

- Pressure Sewer Main Layout – Layout the system to allow connections to all properties to be services. Pipe routing shall include long radius sweeps but not looped. Pipes shall be installed at a minimum of 5 feet below grade in order to prevent freezing and minimize conflicts with other utilities.
- Pipe Size and Material – Pipe Size diameter sized to provide a cleansing velocity based on the system's average daily flow but not less than 1-1/2-inches in diameter. Sizing shall also consider the retention times of each line segment to provide sufficient wastewater changes to reduce the potential for odor generation. Pipe Material to be Class 200, SDR 21 PVC piping or greater or HDPE SDR 11 to provide the necessary working pressure rating for the system, and to provide durability during installation.
- Isolation Valves and Check Valves – Provide Isolation Valves and Check Valves to allow isolation of individual STEP units, at points where system expansion is projected and at key locations such as property lines. Provide a valve box with a redundant check valve at property lines to protect properties from back-ups and/or flooding.
- Air Release and Vacuum Valves – Provide Automatic Air Release and Vacuum Valves to release air trapped in pressure lines and to prevent system siphoning or vacuum conditions. Provide Air Release and Vacuum Valves at all high points in a system and at least 14 pipe diameters downstream of locations where hydraulic jumps occur. Air Release/Vacuum Valves should be located in a manhole or structure to allow access for repair and maintenance.

- Cleanout Connections – Provide Cleanout Connections as a means for cleaning out pressure mains. Provide Cleanout Connections and valves to conduct required maintenance at terminal ends of branches or zones, intersections, sharp bends, and low and high points. Provide Cleanout Connections at least every 1,500 to 2,000 linear feet in all lines.
- Pump Chamber - Construct each pump chamber of concrete, high density polyethylene, or custom-molded, fiberglass-reinforced polyester resin using a filament wound process, layup and spray technique, or other approved process that will ensure a smooth and resin-rich interior surface designed for structural integrity. Lockable access opening at the ground surface with a minimum inside diameter of 24 inches. Equipped with PVC closet flange or flexible inlet flange suitable for connection to the structure's gravity sewer line. The pump chamber shall be sized to prevent accumulation of solids and designed to promote mixing during pumping actions.
- Pump System
    - Pump Removal - Pump shall be able to be removed without the need for manual disconnection of piping.
    - Grinder - The grinder should be positioned immediately below the pumping elements, securely fastened to the pump motor shaft, and driven directly by the same motor.
    - Pump Opening - The grinder should be capable of reducing all components in normal domestic sewage, including a reasonable number of foreign objects (e.g., paper, wood, plastic, glass, and rubber). Objects should be reduced to finely divided particles that will pass through the passages of the pump and a minimum 1.25 inch diameter discharging pipe.
    - Intake - The grinder should be positioned so solids are fed into it from the bottom in an upward flow, reducing the possibility of overloading or jamming. Sufficient turbulence should be created to keep the tank bottom free of permanent deposits or sludge banks.
    - Check Valve and Anti-Siphon Valve – Provide each pump system with a check valve that is installed in a horizontal position on the discharge pipe. Provide each pump system with a gravity-operated, and integral anti-siphon valve.
    - Ventilation - Provide adequate ventilation as required by State and Local regulations.
    - Controls and Alarms - Provide non-fouling level sensing devices to detect wastewater levels for initiating pump operation and to detect high water levels. Level sensing devices will not be placed near flows entering the well. Alarm indicators should include an audible alarm and a visual light.
    - Electrical Equipment – Provide wiring and electrical connections that are NEMA-rated for the environment in which they are to be placed.
- Materials: Class 200 PVC, Ductile Iron, and HDPE.
- Location to Water Supplies: 10 feet Horizontally and 18-inches Vertically (Unless cased piping is used for necessary crossings).
- Typical Components: Isolation Valves, Air Release Valves, Cleanouts, Check Valve at Property Line, and Electrical – Pumps, Control Panels, Transfer Switches.

3) Septic Tank Effluent Gravity (STEG)

- Gravity Sewer Main Layout – Layout the system to allow gravity connections to all properties to be serviced. Pipes shall be installed at a minimum of 5 feet below grade in order to prevent freezing and minimize conflicts with other utilities.

- Pipe Size and Material – Service pipe from septic tank to street collector shall be minimum 6-inches in diameter. Collector pipe in street sized to provide a cleansing velocity of 2 feet/second when flowing full based on Manning's formula using an "n" value of 0.013 but shall not be less than 8-inches in diameter. Sizing shall also consider the retention times of each line segment to provide sufficient wastewater flushing to reduce the potential for odor generation. All pipe material to be SDR 35 PVC piping or greater.
- Manholes – Installed at the end of each line; at all changes in grade, size, or alignment; and at all pipe intersections with a distance not to exceed 400 linear feet. Manhole material to be precast concrete.
- Septic Tanks – Existing Septic Tanks shall meet current Title 5 Standards. Existing Septic Tanks shall be pumped out, cleaned and pressure tested. Existing Septic Tanks which do not meet current Title 5 Standards or fail the pressure test shall be replaced.
- Infiltration/Inflow Allowance: 200 to 500 gpd/inch diameter/mile.
- Minimum Size: Building Sewer at 4-inches; and Municipal Sewer at 8-inches.
- Location to Water Supplies: 10 feet Horizontally and 18-inches Vertically (Unless cased piping is used for necessary crossings).
- Materials: PVC, Ductile Iron, Reinforced Concrete or Other Material Approved by MassDEP.
- Typical Components: Pipe, Fittings, Manholes, Drop Manholes, Cleanout/Check Valve at Property Line and Septic Tank (1,500 gallon).

4) Septic Tank Effluent Pumping (STEP)

- Pressure Sewer Main Layout – Layout the system to allow connections to all properties to be serviced. Pipe routing shall include long radius sweeps but not be looped. Pipes shall be installed at a minimum of 5 feet below grade in order to prevent freezing and minimize conflicts with other utilities.
- Pipe Size and Material – Pipe diameter sized to provide a cleansing velocity based on the system's average daily flow but not less than 1-1/2-inches in diameter. Sizing shall also consider the retention times of each line segment to provide sufficient wastewater flow-through to reduce the potential for odor generation. Pipe Material to be Class 200, SDR 21 PVC piping or greater or HDPE SDR 11 to provide the necessary working pressure rating for the system, and to provide durability during installation.
- Isolation Valves and Check Valves – Provide Isolation Valves and Check Valves to allow isolation of individual STEP units, at points where system expansion is projected, and at key locations such as property lines. Provide a valve box with a redundant check valve at property lines to protect properties from flooding.
- Air Release and Vacuum Valves – Provide Automatic Air Release and Vacuum Valves to release air trapped in pressure lines and to prevent system siphoning or vacuum conditions. Provide Air Release and Vacuum Valves at all high points in a system and at least 14 pipe diameters downstream of locations where hydraulic jumps occur. Provide Air Release/Vacuum Valves should be located in a manhole or structure to allow access for repair and maintenance.
- Cleanout Connections – Provide Cleanout Connections as a means for cleaning out pressure mains including valves, to conduct required maintenance at terminal ends of branches or zones, intersections, sharp bends, and low and high points. Provide Cleanout Connections at least every 1,500 to 2,000 linear feet in all lines.

- Septic Tanks – Existing Septic Tanks shall meet current Title 5 Standards. Existing Septic Tanks shall be pumped out, cleaned and pressure tested. Existing Septic Tanks which do not meet current Title 5 Standards or fail the pressure test shall be replaced.
- Pumps
  - Dual pump design (lead/stand-by) required per TR-16.
  - Pump design – Provide pump capable of pumping septic tank effluent through the passages of the pump and a minimum 1.25 inch diameter discharging pipe at pressure conditions required for the collection system.
  - Check Valve and Anti-Siphon Valve – Provide each pump system with a check valve that is installed in a horizontal position on the discharge pipe. Provide each pump system with a gravity-operated, and integral anti-siphon valve.
  - Ventilation - Provide adequate ventilation as required by State and Local regulations.
  - Controls and Alarms - Provide non-fouling level sensing devices to detect wastewater levels for initiating pump operation and to detect high water levels. Level sensing devices will not be placed near flows entering the wet well. Alarm indicators should include an audible alarm and a visual light.
  - Electrical Equipment – Provide Wiring and electrical connections that are NEMA-rated for the environment in which they are to be placed.
- Materials: Class 200 PVC, Ductile Iron and HDPE.
- Location to Water Supplies: 10 feet Horizontally and 18-inches Vertically (Unless cased piping is used for necessary crossings).
- Typical Components: Isolation Valves, Air Release Valves, Cleanouts, Check Valve at Property Line, Electrical – Pumps, Control Panels, Transfer Switches and Septic Tank (1,500 gallon).

5) Vacuum Sewers (VS)

- Vacuum Sewer Main Layout – The system layout allow gravity service connections to valve chamber vacuum connections to all properties to be serviced. Pipe routing shall include long radius sweeps in a saw tooth pattern but not looped. Pipes range from 4-inches to 10-inches and shall be installed at a minimum of 5 feet below grade in order to prevent freezing and minimize conflicts with other utilities. Pipe line lengths shall be sized based on static lift and losses with a maximum total head loss of 13 feet.
- Pipe Size and Material – Pipe diameter sized to provide a cleansing velocity using the Hazen-Williams formula for full-bore flow but not less than 1-1/2-inches in diameter. Use a C-factor of 150 for PVC pipe material and a flow that consists of 2 parts of air to 1 part of liquid. Sizing shall also consider the retention times of each line segment to provide sufficient wastewater flow-through to reduce the potential for odor generation. Pipe Material – Pipe Material to be Class 200, SDR 21 PVC piping or greater or HDPE SDR 11 to provide the necessary working pressure rating for the system, and to provide durability during installation.
- Vacuum pumps –Designed as duplex (lead/back-up) to cycle and maintain constant level of vacuum on the entire collection system.
- Collection tank – The total volume of the collection tank shall be 3 times the operating volume with a minimum size of 400 gallons. The operating volume is the sewage accumulation required to restart the discharge pump. Operating volume should be sized so that at minimum design flow, the pump will operate once every 15 minutes.

- Sewage Transfer Pumps
  - Discharge pump capacity shall be 20 percent greater than the peak design flow.
  - Motors are sized using the procedure for force mains plus 25 feet of additional head to pump against the vacuum in a collection tank.
  - Pumps shall be duplex (lead/back-up) design alternating, non-clog type.
- Standby Power - Provide 100 percent standby power at vacuum collection/transmission stations for use during normal power failure.

3. Data Accumulation Survey

A. Introduction

As part of the 25% Preliminary Design Report for the Downtown Area Wastewater Collection System, Coastal Engineering Co., Inc. was engaged by AECOM to perform a Data Accumulation Survey relative to the design of the proposed new wastewater collection system in Orleans, Massachusetts.

This section of the Technical Memorandum outlines the scope of the Aerial Survey and Data Accumulation Survey performed by Coastal Engineering Co., Inc. and their Subconsultant. Refer to Appendix A for the completed survey.

B. Goals and Objectives of the Data Accumulation Survey

The goal of the Data Accumulation Survey was to acquire additional field and aerial survey data necessary for the preparation of the 25% Preliminary Design Report and to supplement the information included in the existing conditions plans prepared by Surveying and Mapping Consultants (SMC) for the Town of Orleans.

1) General

The Data Accumulation Survey included acquiring additional field and aerial survey data in order to supplement the information included in the existing conditions plans prepared by SMC for the Town of Orleans as necessary for the preparation of the 25% Preliminary Design Report. The aerial survey was flown for the Downtown Area as well as the Meetinghouse Pond Area. The imagery acquired for the Meetinghouse Pond Area was not processed and will be saved for future use. The following is the scope of the Data Accumulation Survey:

- Perform an aerial photography fly over and photogrammetric mapping for the subject area (performed by Subconsultant to Subcontractor, with ground control provided by Subcontractor);
- Perform supplemental on-ground detailed existing conditions (strip) survey within the limits of the designated right-of-ways (Approximately 6,500 l.f. including Jones Road, Liberty Lane, Locust Road and a portion of Main Street, portion of West Road and a portion of Eldredge Park Way and portion of Lots Hollow Road);
- Perform a supplemental on-ground detailed existing conditions (strip) survey within the limits of the roundabout at Route 28/Route 6A/Canal Road (to update features since completion of the SMC survey);
- Obtain visible utility/dig-safe evidence at ground level within designated right-of-ways of supplemental strip surveys;
- Obtain pipe invert elevations from available records and via observation for accessible drainage structures within supplemental strip survey roadways;
- Establish vertical benchmarks via differential levelling within designated right-of-ways of supplemental strip surveys;
- Obtain sill elevations for buildings within service area (excepting force main portion);

- Perform field checks/survey of control points as shown on November 28, 2016 SMC survey, and review with AECOM;
- Merge photogrammetric mapping data with route portion ground survey data from SMC and the approximately 6,500 l.f. supplemental detailed strip surveys performed by Subcontractor;
- Prepare an Existing Conditions Topographical Survey for use by AECOM;
- Provide digital files of the base survey in current AutoCAD format (Civil3D 2015 or older version) including one DTM surface, XML file, and a PDF. Base survey plans will be on the Mass State Plane coordinate system and NAVD 1988; and
- Perform a (1”=40’ scale) Aerial Photography Fly Over for the Meetinghouse Pond Area (performed by subcontractor) and retain imagery for future use only.

2) Results of the First Phase of the Data Accumulation Survey

On January 16, 2017, Coastal Engineering provided the following deliverables and relevant technical information associated with the CAD drawings and files for the first phase of the Data Accumulation Survey:

a) PDF Files

- Cover Sheet based on sheet layout of SMC survey plus new supplemental layout locations for data collected from supplemental roadways; and
- Sheets 22-30 showing new supplemental survey layout pages for the 6,500+/- l.f. of new roadway survey.

b) ACAD Files

- Drawing File (generated in Civil3D 2016, saved in v2013 format
- The drawing file contains the following:
    - Edge of Pavement and centerline with elevation points for supplemental roadways;
    - Spot Grades for cross country portion between West Road and Salty Ridge Road;
    - Contours of supplemental areas;
    - Sill elevation labels for entire service area (or thresholds and floor elevations, where appropriate;
    - Point labels and data noting the observation point location of sills/floor/threshold measured;
    - Layout key sheet for service area; and
    - Miscellaneous building footprints and property line data from Mass GIS outside of the limits of the SMC survey area.

c) Data Files

- XML files and ASCII point files for each individual surface of supplemental roadway area;
- Coordinate files of data points used to generate surface/topographical information and building information; and
- Miscellaneous support files generated by ACAD e-transmit export of drawing file information.

3) Results of the Second Phase of the Data Accumulation Survey

Coastal Engineering Co., Inc. delivered the remaining Data Accumulation and Aerial survey on April 21, 2017. The following is a scope of the Second Phase of the Survey:

- An aerial photography fly over and photogrammetric mapping for the Downtown Area was performed by Sewell Mapping with ground control provided by Coastal Engineering Co., Inc.(CEC);
- Supplemental on-ground survey within the limits of Jones Road, Liberty Lane, Locust Road and a portion of Main Street, portion of West Road and Salty Ridge Road, portion of Eldredge Park Way and portion of Lots Hollow Road;
- Supplemental on-ground detailed existing conditions survey within the limits of the roundabout at Route 28/ Route 6A/Canal Road;
- Locating visible utility/dig-safe evidence at ground level within designated right-of-ways of supplemental strip surveys;
- Obtained pipe invert elevations from available records and via observation for accessible drainage structures within supplemental strip survey roadways;
- Established vertical benchmarks via differential levelling within designated right-of-ways of supplemental survey areas;
- Obtained sill elevations for buildings within the Downtown Area service area;
- Perform field checks/survey of surface features in 5 areas of roadways shown on November 28, 2016 SMC survey, and review with AECOM;
- Merged photogrammetric mapping data with route portion ground survey data from SMC and the 6 surveys performed by CEC;
- Prepared an Existing Conditions Topographical Survey for use by AECOM;
- Provided digital files of the base survey in current AutoCAD format (Civil3D 2015 or older version) including one DTM surface, XML file, and a PDF. Base survey plans will be on the Mass State Plane coordinate system and NAVD 1988; and
- Sewell Mapping completed an Aerial Photography Fly Over for the Meetinghouse Pond Area and retained the imagery for future use.

4. Cultural Resource Evaluation

A. Introduction

As part of the 25% Preliminary Design Report for the Downtown Area Wastewater Collection System, AECOM solicited cost proposals from independent licensed and insured professional firms with expertise in conducting Cultural Resource Evaluations. Based on the results of the solicitation, Public Archaeology Laboratory, Inc. (PAL) was engaged to perform a Cultural Resource Evaluation for the proposed new wastewater collection system.

This Technical Memorandum section outlines the Cultural Resource Evaluation prepared by PAL and their recommendations for archaeological monitoring during construction project work. Refer to Appendix B for the Cultural Resource Evaluation.

B. Goals and Objectives of the Cultural Resource Evaluation

The goal of this evaluation was to collect information about known and expected cultural resources within the project area:

- Produce a detailed archaeological sensitivity assessment of the project area; and
- Prepare a technical proposal for archaeological investigations, if necessary.

The evaluation was designed to facilitate project review by the Massachusetts Historical Commission (MHC) and compliance with all applicable federal, state, and local regulations and review including M.G.L. Chapter 9, Sections 26-27c (950 CMR 70-71).

C. Cultural Resources Review

1) General

The cultural resources review included the collection of information about known cultural resources within the project's area of potential effect (APE), including historic and archaeological resources in the Commonwealth of Massachusetts Inventory, and an assessment of existing conditions within the project area. The purpose of the work was to assemble information about previously documented historical resources within and near the project area and provide recommendations about previously documented historical resources within and near the project area and provide recommendations about significant archaeological sites that may be affected by the project.

2) Results of the Background Research

The MHC site files list dozens of historic architectural properties and archaeological sites within the vicinity of the Downtown Area Wastewater Collection System project area.

- The resources were identified through a search of the MHC's Inventory of the Historical and Archaeological Assets of the Commonwealth (MHC Inventory).
- For historic properties, the study area encompassed everything within the project area boundaries.
- For archaeological resources, the study area encompassed everything within one-quarter mile one either side of the project's outer boundaries.
- The evaluation found that there are three historic districts with 73 historic properties within the Downtown Area Wastewater Collection System area. Table 1 of the evaluation includes a list of architectural resources that were identified by the cultural resource review.
- Background research was conducted to assist with the archaeological sensitivity assessment and to develop predictive statements for the types of archaeological resources that may be present within the project area.
- Table 2 of the evaluation includes a list of archaeological resources that were identified by the culture resource review.

3) Results of the Field Assessment

A walkover/drive-over field assessment of the Downtown Area Wastewater Collection System project area was conducted by Dianna Doucette, PAL Senior Archaeologist, on February 8, 2017 to assess the integrity of the ground surface, to collect data about the current environmental setting of each area, and to look for any surface indications of archaeological sites.

- During the field assessment, all the roads that will be impacted by the proposed sewer line construction were accessed as well as the three proposed pump station locations.
- No evidence of archaeological sites was observed on the ground surface during the field assessment.

4) Results of the Sensitivity Assessment

Results of the background research and field assessment were used to develop a sensitivity ranking and predictive statements concerning the potential for the presence of Native American and EuroAmerican cultural resources.

- Overall, the archaeological sensitivity of the Downtown Area Wastewater Collection System project area is high to moderate for Native American sites dating to the Pre-Contact, Contact, and early Post-Contact periods. (ca. 8000 to 300 B.P.).
- The EuroAmerican post-contact archaeology sensitivity for land use is moderate to low.
- The post contact historic period sensitivity of the project area is moderate to low based on the historic nature of Orleans and the possibility of post-contact sites to be present und the current streets.

5) Recommendations

PAL recommends archaeological monitoring in areas assessed as high and moderate archaeological sensitivity, which includes all places where new sewer lines and pump stations will be impacting intact soils during construction (this may include areas between existing utilities).

- PAL also recommends coordinating with the Mashpee Wampanoag and Wampanoag Tribe of Gay Head/Aquinnah regarding the proposed project schedule so that a tribal cultural resource monitor can be present during construction of the project.
- The goal of the archaeological monitoring during construction will be to insure that if any significant archaeological resources, including remains and/or burials are exposed during the construction activities that they are treated appropriately in accordance with the Massachusetts Unmarked Burial Laws.
- The section of Route 28, from Academy Place to where it intersects with Route 6A, the short residential connectors that lie closest to Town Landing (Cottage Street and Cove Road), Cedar Pond (Locust Street and Jones Road), the Old Tote Road, and the three pump station sites have been assessed as having a preliminary high archaeological sensitivity due to the proximity of recorded archaeological sites and general lack of development.
- PAL also recommends a “Post-Review Discoveries” protocol, or, an Unanticipated Discoveries Plan be developed and implemented consistent with the Massachusetts Unmarked Burial Laws.

5. Geotechnical Evaluation

A. Introduction

As part of the Preliminary Design Report (25% Design) for the Downtown Area Wastewater Collection System, New England Geotech, LLC, was engaged by AECOM to perform pre-clearing and drilling for a Geotechnical Evaluation relative to the design of the proposed new wastewater collection system in the Downtown Area.

This section of the Technical Memorandum outlines the scope of the Geotechnical Evaluation performed by AECOM and New England Geotech, LLC. Refer to Appendix C for the Boring Logs.

B. Goals and Objectives of the Geotechnical Evaluation

The goal of the Geotechnical Evaluation was to collect soil data along the proposed sewer alignment necessary for the preparation of the 25% Preliminary Design Report. The data collected included depth of pavement, soil types, depth to groundwater, if encountered, and the recording of any fill or obstructions encountered during the drilling. The information from the geotechnical evaluation was used for the preliminary design of the wastewater collection system. In addition, the information from the soil investigation can be used by prospective sewer system construction bidders to determine the soil conditions in the area of the proposed collection system. The observation wells are available for long term monitoring of groundwater levels and quality.

C. Geotechnical Investigation

The Proposed Collection system in the Downtown Area includes construction of a proposed collection system (gravity sewer, low pressure sewer, STEP/STEG and/or vacuum sewer) within publicly and privately owned rights-of-way and privately owned properties in the Orleans Downtown Area. The Project will provide approximately 30,000 linear feet of pipelines within the publicly and privately owned right of way and sewer service connections within the privately owned properties.

The Geotechnical Evaluation included the drilling 95 borings in the Downtown Area in order to document the soil and groundwater conditions along the proposed Downtown Area sewer collection system route as necessary for the preparation of the 25% Preliminary Design Report. The depth of the borings ranged from 5 feet to 45 feet with an average depth of 15 feet depending upon the depth of the preliminary sewer collection system design profiles. Ten additional borings were constructed as monitor wells. Each location was pre-cleared to a minimum depth of 5-feet using "soft-dig" methods prior to drilling.

1) Prior to performing the borings in the Town roadways, approval from the Town of Orleans Highway Dept. was required. A Road Opening Permit was submitted to the Orleans Highway Dept. by N.E. Geotech, LLC. The Permit application was circulated through town departments for review and comment. On January 23, 2017 a preconstruction conference was held including Frank Nichols of the Orleans Highway Department, Lt. Kevin Higgins of the Orleans Police Department, Dan Regan of N.E. Geotech, LLC, and Reggie Donoghue of AECOM. On February 2, 2017 the Orleans Highway Department issued a Road Opening Permit allowing the geotechnical investigation within the town controlled streets to proceed.
2) An Application for a Permit to Access State Highway was filed with MassDOT in order to perform the borings in the state highway layout of Route 6A and Route 28. On February 3, 2017 representatives of AECOM met with MassDOT officials at the MassDOT Division 5 office in Taunton MA to discuss the proposed Geotechnical Evaluation. On February, 16, 2017 MassDOT issued a Permit to Access State Highway allowing the Geotechnical Investigation to proceed within the State Highway Layouts.
3) Prior to the start of the drilling operations, each boring site was staked or marked in the pavement with paint and Dig Safe was contacted by the drilling contractor to mark out the utilities in the area of the proposed borings. Several of the sites required remarking due to weather and traffic disturbing the marked locations.
4) For work in the roadways, a police detail and cruiser accompanied the drilling and pre-clearing crews for safety and traffic control. A second police detail was employed with the pre-clearing and drilling crews for traffic control along busy sections of the state highways.
5) A trailer mounted Hurricane 500 vacuum unit was used by a two man crew from Strategic Environmental Services to pre-clear the first five feet of excavation using "soft-dig" techniques. The pre-clearing is performed in order to avoid impacting underground utilities during the boring operation. Technical personnel from AECOM accompanied the pre-clearing crew and documented the pre-clearing excavations.

6) Drilling was performed by N.E. Geotech, LLC. A Geoprobe Model 6600 truck mounted direct push drill rig was employed for drilling the borings below the five foot pre-cleared depth. Direct push drilling is a method in which a drill string is advanced by pushing or vibrating. Technical personnel from AECOM accompanied the drill rig and documented the soil information from the borings.

7) In addition to the borings for the Geotechnical Investigation, ten deep observation wells were installed by N.E. Geotech, LLC to allow for sampling of groundwater and the measurement of groundwater levels at the observation well sites.

8) Record boring information from a geotechnical investigation performed for MassDOT during the design of roadway improvements that are underway at the intersections of Main Street and Route 6A, and Main Street and Route 28 was used to supplement the information from the geotechnical evaluation. Borings were not performed at the intersection of Route 6A and West Road, and in the area of the new roundabout at the intersection of Route 6A and Route 28. Borings were not performed in those locations due to a MassDOT prohibition on cutting new pavement, the location of existing utilities, and the proximity of the paving to the limit of the State Highway Layout. Both of the aforementioned projects were treated as overlay projects by MassDOT and no deep borings were performed as part of the design of the roadway improvements.

9) The proposed “Cross Country” portion of the collection system between Canal Road and Route 6A traverses through private property. Permission from the property owner will be required prior to entering onto the property for the Geotechnical Evaluation. The Town of Orleans has been in contact with the property owner and it is anticipate that permission to proceed with the remaining borings will be forthcoming. When the owner has granted permission to enter the property and proceed with the borings, we expect that it will require one day with the pre-clearing crew, and one day with the drilling crew to complete the borings on private property. At that time, four remaining borings in the State Highway Layout will also be completed.

D. Program Status

Boring logs have been prepared by AECOM for the completed borings. The boring locations, depth, and notation as to whether groundwater was encountered have been added to the preliminary sewer profile plans prepared by AECOM to accompany the Preliminary Design Report (25% Design).

When the Town of Orleans has permission from the private property owner to enter onto the property at the Cross-Country portion of the sewer collection system, the remaining eight borings will be completed. Four of the borings are on in the State Highway Layout and four are along the Cross-Country section of the sewer collection system route.

6. Collection System Work Group

A. General

The Collection System Work Group was convened to review the available collection systems technologies for the Downtown Orleans Area. Members of Town boards and committees, concerned citizens, stakeholders, a State Regulator, and representatives of AECOM participated in the Work Group sessions. This section of the Technical Memorandum outlines the Activities of the Collection System Work Group. Work Group Meetings were held on December 20, 2016, January 5, 2017, and March 9, 2017. Refer to Appendix D for the Minutes of Meetings.

B. Goals and Objectives of the Collection System Work Group

The goal of the Work Group was to review the available collection system technologies that were being considered for the Downtown Area and to provide information to the Work Group members so that they would better understand the collection system recommendations that would be included in the 25% Preliminary Design Report prepared by AECOM.

The Work Group provided an opportunity for stakeholders to ask questions and provide their input relative to the Collection System configuration for the Downtown Area. Information obtain was considered and incorporated into the 25% Preliminary Design Report, as applicable.

C. Work Group Participants

The following individuals participated in at least one of the Collection System Work Group meetings:

- Alan McClennan, Orleans Board of Selectman
- Jim Trainor, Citizen
- Gordon Smith, Orleans Taxpayers Association
- Paul Ammann, Orleans Peer Review Panel
- Len Short, Board of Water & Sewer Commissioners
- John Meyer, Board of Water & Sewer Commissioners
- Charles Harris, Eastham Alternate Representative
- Judith Bruce, Orleans Wastewater Management Steering Committee
- Fran McClennen, Pleasant Bay Alliance
- Ed Daley, Orleans Peer Review Panel
- Walter North, Citizen
- Ginia Pati, Orleans Water Alliance
- Dale Fulton, Orleans Taxpayers Association
- Lynn Bruneau, Orleans Finance Committee
- Mike Domenica, Water Resources Associates
- Brian Dudley, MassDEP
- Reggie Donoghue, AECOM
- Jeff Reade, AECOM
- Thomas Parece, AECOM

D. Work Group Meetings

1) Work Group Meeting No. 1 - December 20, 2016

At the first Collection System Work Group Meeting Alan McClennen provided an overview of the Sewer Program and Thomas Parece from AECOM provided a description of the wastewater collection system and treatment systems that were reviewed by AECOM. Participants were allowed to ask questions about a variety to topics from funding to system operation and maintenance. Thomas Parece from AECOM reviewed a collection system cost comparison and selection matrix prepared by AECOM. Work Group members were provided with a Collection System Matrix so that they could complete on their own evaluation of the available collection system technologies.

2) Work Group Meeting No. 2 - January 5, 2017

The second Collection System Work Group meeting included a review of a Downtown Area collection system phasing plan. Refer to Appendix E. Work Group members asked about the impact of construction and there was discussion with regard to the various collection system technologies. Thomas Parece from AECOM provided a description of the various technologies and responded to member’s questions. Bran Dudley from MassDEP attended the meeting and participated in the discussions.

3) **Work Group Meeting No. 3 - March 9, 2017**

The third Collection System Work Group meeting included a question and answer session with regards to the proposed collection system and wastewater treatment facility. Thomas Parece from AECOM provided the regulatory framework and the basis of the collection system design. The cost for Operation and Maintenance of the collection system was discussed. The viability of accepting septage at the treatment facility was also discussed. Jeffrey Reade from AECOM provided a presentation on the available Wastewater Treatment Facility design technologies. The presentation focused on sequencing batch reactors and membrane bioreactor treatment technologies.

7. Enumerate Site Evaluation and Screening Criteria

A. General

As noted above, various types of collection system technologies exist that includes: (a) Gravity Sewers (GS); (b) Low Pressure Sewers (LPS); (c) Septic Tank Effluent Gravity (STEG); (d) Septic Tank Effluent Pumping (STEP); and (e) Vacuum Sewers (VS).. Each technology has been well studied and evaluated by previous consultants to the Town of Orleans. Table 1 summarizes these past studies.

Table 1 – Past Engineering Collection System Evaluations

Project	Engineering Firm	Recommendation / Conclusion
Wastewater System - Mid-1980s	LEA	• Gravity Sewers • Low Pressure Sewers
CWMP - 2010	Wright-Pierce	• Gravity Sewers • Low Pressure Sewers
Technical Review and Cost Analysis of CWMP Options - 2012	Weston & Sampson	• Gravity Sewers and STEP/STEG Similar in Costs
Consensus Planning - 2015	Stantec	• Gravity Sewers • Low Pressure Sewers

Although considerable evaluation had been previously undertaken in the studies, new information has been developed including topographic survey, subsurface investigations, a better defined service area as well as a property-by-property water usage analysis that required another analysis of the collection system technologies.

This analysis identified, defined the technology evaluation and screening criteria for the proposed Collection Systems (GS, LPS, VS, STEP, and STEG), and included: (a) Site Suitability; (b) Environmental Considerations; (c) Financial Considerations; (d) Maintenance Considerations; and (e) Other Considerations.

1) Site Suitability

- Land Ownership - Recognizes that project implementation is likely the most feasible when there is a minimal requirement to negotiate with and obtain access from private property owners, with tendency for risk to increase as the property owners increases.
  - ✓ Favorable scores (+1) are given to those technologies which can be achieved via construction predominantly in public roads and/or public rights-of-way.
  - ✓ Less favorable scores (-1) are given to those technologies which will require construction within or through a substantial number of private roads and/or private properties.
  - ✓ Neutral (0) scores are given to those technologies that contain elements of both public and private construction access, but the number of private properties affected is less than the lowest ranking technology(s).
- Constructability (Method of Installation) - Considers the likely method of installation for the technology, recognizing that conventional construction methods, at nominal depths, typically have lower risks.
  - ✓ Favorable scores (+1) are given to those technologies expected to be constructed with typical cut-and-cover trenching which is well known to the general contractors that would be available for the installation of the collection system.
  - ✓ Less favorable scores (-1) are given to those technologies which require substantial lengths of pipe to be installed by non-conventional means (e.g. horizontal directional drilling) and/or require substantial lengths of pipe to be installed in conventional open cut trenches exceeding 15 feet in depth.
  - ✓ Neutral scores (0) are given to those technologies that contain elements of both favorable (shallow, conventional trenches) and less favorable (deep trenches and/or non-conventional installation technologies), but the length of less favorable segments is less than the lowest ranking technology(s).

2) Environmental Considerations

- Permittability - Considers the potential impacts to natural resources that would occur as a result of constructing the collection system by the given technology, recognizing that the greater the potential adverse effect on natural resources regulated by federal, state, or local agencies, typically corresponds to increasing complexity, and potential uncertainty, in obtaining permits and approvals.
  - ✓ Favorable scores (+1) are given to those technologies anticipated to require the fewest number of permits and have the least adverse impact on natural resources; for example technologies whose alignments allow them to follow almost exclusively previously disturbed corridors (such as roads or rights-of-way).
  - ✓ Less favorable scores (-1) are given to those technologies whose alignments require crossing of environmentally sensitive areas (such as wetlands or woodlands) for which mitigation would likely need to be incorporated into the project in order to obtain regulatory approval.
  - ✓ Neutral scores (0) are given to those technologies that contain elements of both favorable (predominantly constructed through previously developed corridors) but include some construction within natural areas, that require some permitting, but not to the extent of the lowest ranking technology(s).

- Extent of Dewatering - Recognizes that construction in areas where the groundwater table is shallow frequently requires dewatering of the trench/pit in order to safely and efficiently install the collection system. However, as the extent of dewatering increases, there is an increase in the environmental concerns with respect to collecting, storing, treating, and discharging the construction dewatering.
  - ✓ Favorable scores (+1) are given to those technologies likely to generate the lowest volume of construction dewatering effluent, either because of the shallow nature of the trenches or because of the installation technology chosen (e.g. trenchless technologies often generate less construction dewatering because of the smaller excavation areas).
  - ✓ Less favorable scores (-1) are given to those technologies likely to generate the greatest volume of construction dewatering effluent, either because of the deep nature of the trenches or the locations through which trenches must be constructed (e.g. wetlands, areas of shallow groundwater).
  - ✓ Neutral scores (0) are given to those technologies whose construction contains elements of favorable and less favorable considerations with respect to construction dewatering, but do not approach the quantity of the lowest ranking technology(s).
- Sustainability - Considers the extent to which natural resources and/or non-renewable resources would be required to support the construction and operation of the technology. Since the use of non-renewable resources (e.g. fossil fuels) is likely to be similar for construction of any of the technologies, this parameter focuses primarily on the long term demands on non-renewable resources.
  - ✓ Favorable scores (+1) are given to those technologies that require little electricity (presumed to be generated primarily from non-renewable resources) for operation, consume little/no natural resources, and generate little/no solid waste (other than solid waste which can be repurposed for beneficial reuse).
  - ✓ Less favorable scores (-1) are given to those technologies that have high electrical demands for operation, require frequent use/disposal of ‘consumables’, and/or generate substantial non-recyclable waste materials.
  - ✓ Neutral scores (0) are given to those technologies having characteristics of both sustainable-favorable and sustainable-unfavorable categories, but not to the extremes of the highest or lowest ranking technology(s).

3) Financial Considerations

- Construction Costs - Considers the financial burden of constructing the technology. For this criterion, the overall cost of constructing the technology is considered; this evaluation does not attempt to make a distinction between costs borne by the Town versus costs borne by individual property owners but rather looks at the overall financial investment that must be made by the Town and the people of the Town.
  - ✓ Favorable scores (+1) are given to those technologies having the lowest construction costs.
  - ✓ Less favorable scores (-1) are given to those technologies having the highest construction costs. For the purpose of this estimate, technologies having a construction cost within 5 percent of each other are ranked the same.
  - ✓ Neutral scores (0) are assigned to those technologies that fall neither among the highest nor the lowest construction costs.

- Operation and Maintenance Costs - Considers the financial burden of operating the technology. For this criterion, the overall cost of operating the technology (e.g., over a 20 year span) is considered; this evaluation does not attempt to make a distinction between costs borne by the Town versus costs borne by individual property owners but rather looks at the overall financial investment that must be made by the Town and the people of the Town.
  - ✓ Favorable scores (+1) are given to those technologies having the lowest operating costs.
  - ✓ Less favorable scores (-1) are given to those technologies having the highest operating costs. For the purpose of this estimate, technologies having an operating cost within 10 percent of each other are ranked the same.
  - ✓ Neutral scores (0) are assigned to those technologies that fall neither among the highest nor the lowest operation and maintenance costs.

4) Maintenance Considerations

- Level of Maintenance, Homeowner - Considers the anticipated (recommended) amount of maintenance that must be performed by the homeowner (or property owner) for the collection technology; measured by time, convenience, and costs.
  - ✓ Favorable scores (+1) are given to those technologies anticipated to require little to no homeowner intervention on an annual basis.
  - ✓ Less favorable scores (-1) are given to those technologies that have a reasonable probability of requiring service calls (e.g. pump out tanks, reset pumps, replace floats or valves).
  - ✓ Neutral scores (0) are assigned to those technologies that fall neither among the highest nor the lowest with respect to the level of homeowner responsibility for maintaining a fully functioning system.
- Level of Maintenance, Town - Considers the ability of the Town to perform maintenance and the type (routine vs non-routine, frequent vs infrequent) of maintenance required by the collection technology.
  - ✓ Favorable scores (+1) are given to those technologies that are considered reasonably easy for the Town to implement and do not require a substantial investment in equipment or personnel.
  - ✓ Less favorable scores (-1) are given to those technologies that may require a substantial investment in equipment or personnel, or have a greater tendency to require emergency (rather than planned) maintenance.
  - ✓ Neutral scores (0) are assigned to those technologies that fall neither among the highest nor the lowest with respect to demands on the Town for ensuring a fully functioning system.

5) Other Considerations

- Reliability - Considers the track record of the technology in similar locations, including factors such as frequency of unplanned shutdowns and performance in adverse weather conditions, and/or hydraulic conditions.
  - ✓ Favorable scores (+1) are given to those technologies that are considered the most fail-safe (generally those having the least complexity and/or reliance on powered equipment).
  - ✓ Less favorable scores (-1) are given to those technologies that have a record of higher than average malfunctions and/or have a higher risk for backups in the event of a malfunction or weather event (e.g. a power outage).

- ✓ Neutral scores (0) are assigned to those technologies that fall neither among the most or least reliable.

- Ability to Accommodate Expansion - Recognizes that homes, schools, and businesses adjacent to the study area may be added to the collection system at some point in the future in response to evolving planning and zoning, or environmental challenges.
  - ✓ Favorable scores (+1) are given to those technologies that have the greatest flexibility to accommodate additional flows without substantial additional capital investment and/or without making previously capital investments obsolete.
  - ✓ Less favorable (-1) scores are given to those technologies that have the least flexibility to accommodate additional flows without the investment of substantial capital (e.g. laying new/parallel piping; resizing wet wells or pumps, etc.).
  - ✓ Neutral scores (0) are assigned to those technologies that have no strong advantages, nor any strong disadvantages, with respect to their ability to accommodate additional sewage flows in the future.
- Area of Disturbance - Recognizes that construction within a densely developed area has the potential to adversely impact, in the short-term, abutting homes, businesses, and institutions. To the extent that the disturbance can be minimized by the technology selection, the construction anticipated to result in fewer disruptions and thus fewer complaints is desirable.
  - ✓ Favorable scores (+1) are given to those technologies that require the smallest construction footprint to install the collection system.
  - ✓ Less favorable scores (-1) are given to those technologies that require the largest construction footprint (wide, deep trenches that occupy more than 40 percent of a roadway width).
  - ✓ Neutral scores (0) are assigned to those technologies that have an average area of disturbance, and are characterized as having neither the smallest nor the largest construction footprint.
- Use of Property - Recognizes that the completed infrastructure on private property may limit the use of the property
  - ✓ Favorable scores (+1) are given to those technologies that result in less amount of impact on the future use of the property.
  - ✓ Less favorable scores (-1) are given to those technologies that result in the greatest amount of impact on the future use of the property.
  - ✓ Neutral scores (0) are assigned to those technologies that have an average impact on on the future use of the property.
- Duration/Schedule - Recognizes that the public is willing to accept short-term impact for the realization of long-term benefit, but also recognizes that the longer the duration of construction disruption, the greater the potential for impact to the community.
  - ✓ Favorable scores (+1) are given to those technologies anticipated to require the shortest time to install, thereby minimizing disruptions to the community and achieving the public benefit most quickly.
  - ✓ Less favorable scores (-1) are given to those technologies anticipated to require the longest construction schedule.
  - ✓ Neutral scores (0) are assigned to those technologies whose anticipated construction duration falls in between the shortest and longest alternatives.

- Aesthetics - Considers the extent to which the collection technology, after installation, will alter the aesthetic charm of the Town.
  - ✓ Favorable scores (+1) are given to those technologies having little/no aboveground visual structures larger than a utility box.
  - ✓ Less favorable scores (-1) are given to those technologies that require either a considerable number (>3) of aboveground visual structures larger than a utility box (e.g. pump station) or that require a large visual aboveground structure in a prominent location where its presence would not easily blend with the surroundings.
  - ✓ Neutral scores (0) are assigned to those technologies that are not distinctly above the most favorable, nor the least favorable, with respect to potential aesthetic impact.

B. Analysis: Evaluate and Rate Each Technology Based on Criteria

The evaluation criteria were applied to each of the five technologies. In applying each of the criteria to each of the technologies, a consistent three level rating system was used as follows:

- Good = 1 point
- Neutral = 0 points
- Poor = -1 point

An overall rating for each technology was completed based on the criteria and weights assigned to each of the individual criteria. The technologies were ranked using both the weighted and un-weighted criteria. The three level rating system was applied to each collection system technology based on a stand-alone technology for the Downtown Area. It cannot be stressed enough that this evaluation provides a general overall comparison to each technology and that it is not the sole determination in recommending a collection system technology.

A un-weighted technology evaluation matrix for the proposed Collection Systems (GS, LPS, VS, STEP, and STEG) in the proposed Downtown Area was developed and is presented in Table 2. A Criteria Weighting Factor ranging from 1 to 5 was applied. This range avoids mathematical compression of the criteria weighting and helps to allow more discrimination between the criteria.

A weighted technology evaluation matrix for the proposed Collection Systems (GS, LPS, VS, STEP, and STEG) in the proposed Downtown Area was developed and is presented in Table 3.

Table 4 presents the summary results of each technology ranking (weighted and un-weighted) for the Downtown Area.

Table 2 – Downtown Area Collection System Un-Weighted Technology Evaluation Matrix

Criteria	Criteria Weight	Technology A		Technology B		Technology C		Technology D		Technology E	
		Gravity Sewer		STEG		LPS		Vacuum Sewer		STEP	
		Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score
Site Suitability											
Land Ownership	1	-1	-1	-1	-1	0	0	-1	-1	0	0
Constructability (Method of Installation)	1	0	0	0	0	1	1	1	1	1	1
Environmental Considerations											
Permitability	1	0	0	0	0	0	0	0	0	0	0
Extent of Dewatering	1	-1	-1	-1	-1	1	1	1	1	1	1
Sustainability	1	-1	-1	-1	-1	0	0	-1	-1	0	0
Financial Considerations											
Construction Costs	1	-1	-1	-1	-1	1	1	-1	-1	1	1
Operation and Maintenance Costs	1	-1	-1	-1	-1	1	1	-1	-1	1	1
Life Cycle Cost Analysis	1	0	0	-1	-1	1	1	-1	-1	0	0
Maintenance Considerations											
Level of Maintenance - Homeowner	1	1	1	0	0	-1	-1	0	0	-1	-1
Level of Maintenance - Town	1	-1	-1	-1	-1	0	0	-1	-1	-1	-1
Impact to WWTF Operations	1	1	1	-1	-1	1	1	1	1	-1	-1
Other Considerations											
Reliability	1	1	1	1	1	0	0	-1	-1	0	0
Ability to Accommodate Expansion	1	1	1	1	1	-1	-1	-1	-1	-1	-1
Area of Disturbance	1	-1	-1	0	0	1	1	1	1	1	1
Use of Property	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1
Duration/Schedule	1	-1	-1	-1	-1	0	0	0	0	0	0
Aesthetics	1	1	1	1	1	-1	-1	-1	-1	0	0
Total Criteria Points			**(2)**		**(7)**		**3**		**(6)**		**-**
Rank			**3**		**5**		**1**		**4**		**2**

Table 3 – Downtown Area Collection System Weighted Technology Evaluation Matrix

Criteria	Criteria Weight	Technology A Gravity Sewer		Technology B STEG		Technology C LPS		Technology D Vacuum Sewer		Technology E STEP	
		Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score
Site Suitability											
Land Ownership	3	-1	-3	-1	-3	0	0	-1	-3	0	0
Constructability (Method of Installation)	3	0	0	0	0	1	3	1	3	1	3
Environmental Considerations											
Permitability	1	0	0	0	0	0	0	0	0	0	0
Extent of Dewatering	3	-1	-3	-1	-3	1	3	1	3	1	3
Sustainability	4	-1	-4	-1	-4	0	0	-1	-4	0	0
Financial Considerations											
Construction Costs	5	-1	-5	-1	-5	1	5	-1	-5	1	5
Operation and Maintenance Costs	5	-1	-5	-1	-5	1	5	-1	-5	1	5
Life Cycle Cost Analysis	5	0	0	-1	-5	1	5	-1	-5	0	0
Maintenance Considerations											
Level of Maintenance - Homeowner	5	1	5	0	0	-1	-5	0	0	-1	-5
Level of Maintenance - Town	3	-1	-3	-1	-3	0	0	-1	-3	-1	-3
Impact to WWTF Operations	3	1	3	-1	-3	1	3	1	3	-1	-3
Other Considerations											
Reliability	4	1	4	1	4	0	0	-1	-4	0	0
Ability to Accommodate Expansion	3	1	3	1	3	-1	-3	-1	-3	-1	-3
Area of Disturbance	2	-1	-2	0	0	1	2	1	2	1	2
Use of Property	2	1	2	-1	-2	-1	-2	-1	-2	-1	-2
Duration/Schedule	2	-1	-2	-1	-2	0	0	0	0	0	0
Aesthetics	1	1	1	1	1	-1	-1	-1	-1	0	0
Total Criteria Points			**(9)**		**(27)**		**15**		**(24)**		**2**
Rank			**3**		**5**		**1**		**4**		**2**

Table 4 - Downtown Area Collection System

Technology	Weighted		Un-Weighted	
	Number of Evaluation Points	Rank	Number of Evaluation Points	Rank
Gravity Sewers	(9)	3	(2)	3
Septic Tank Effluent Gravity	(27)	5	(7)	5
Low Pressure Sewers	15	1	3	1
Vacuum Sewers	(24)	4	(6))	4
Septic Tank Effluent Pumping	2	2	0	2

C. Findings: Summarize Technology Selection Matrix/Screening Results

As can be seen in the ranking results, the overall ranking of the individual technologies does not change between weighted and un-weighted rank for each system.

- Septic tank effluent pumping (STEP) and low pressure sewer (LPS) are ranked the most favorable;
- Gravity sewers were ranked at 3 of 5;
- Septic tank effluent gravity (STEG) systems ranked at 4 of 5; and
- Vacuum sewers were ranked the least favorable;

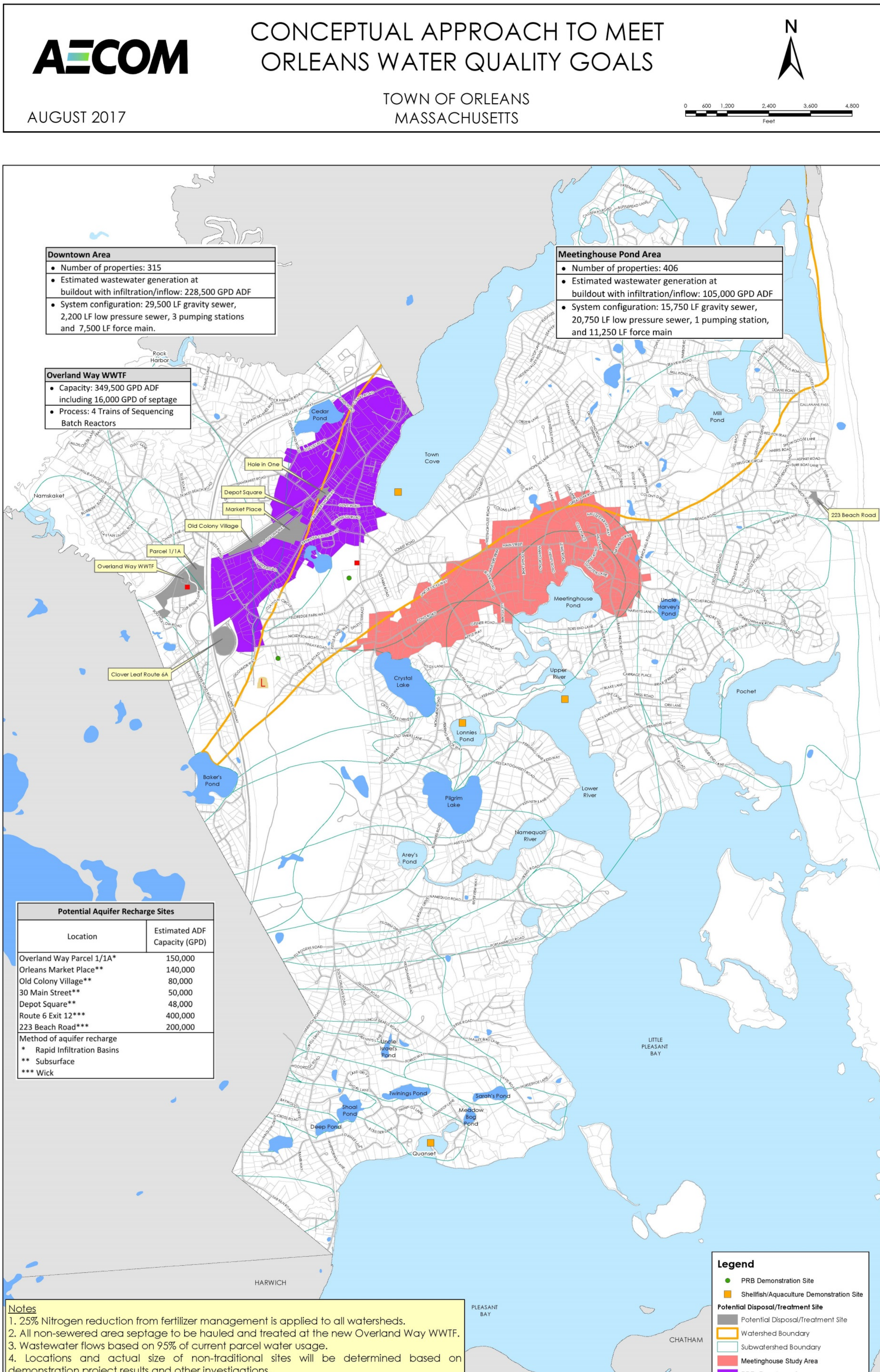
In this analysis, key differentiators were construction impacts related to cost, environmental considerations and restoration. This focus highlights the benefits of utilizing smaller pipes from LPS and STEP systems to collect and transmit sewage flows at a lower cost of construction per service connection. However, these systems are most suitable for expansion of small service areas into an established service area and are less able to provide future expansion capacity within the same collection area due to the use of small diameter pipes.

8. System Layout and Cost Estimates

A. Figure 2 showed the updated map developed as part of the Conceptual Approach to Meet Orleans Water Quality Goals and shows the agreed upon water quality management plan and indicates the two proposed areas to be sewered. The map has been updated to reflect the activities which have occurred over the past two years (see Figure 2). This map includes the following summary of the proposed plan:

- Downtown Area – Number of Properties; Estimate Wastewater Generation at Buildout with Infiltration/Inflow; and System Configuration;
- Overland Way WWTF – Capacity and Process;
- Meetinghouse Pond Area – Number of Properties; Estimate Wastewater Generation at Buildout with Infiltration/Inflow; and System Configuration;
- Potential Effluent Disposal Sites – Location and Estimated Capacity; and
- Permeable Reactive Barriers and Shellfish/Aquaculture – Demonstration Sites.

Figure 2 – Updated Conceptual Approach to Meet Orleans Water Quality Goals



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B. A system layout (plan and profiles) was developed for the Downtown Area. Refer to Appendix F. The preliminary system layouts were developed in accordance with the New England Interstate Water Pollution Control Commission - TR-16, Guides for the Design of Wastewater Treatment Works, 2011 Edition as Revised in 2016. The development of the plan and profiles was based on the following information:

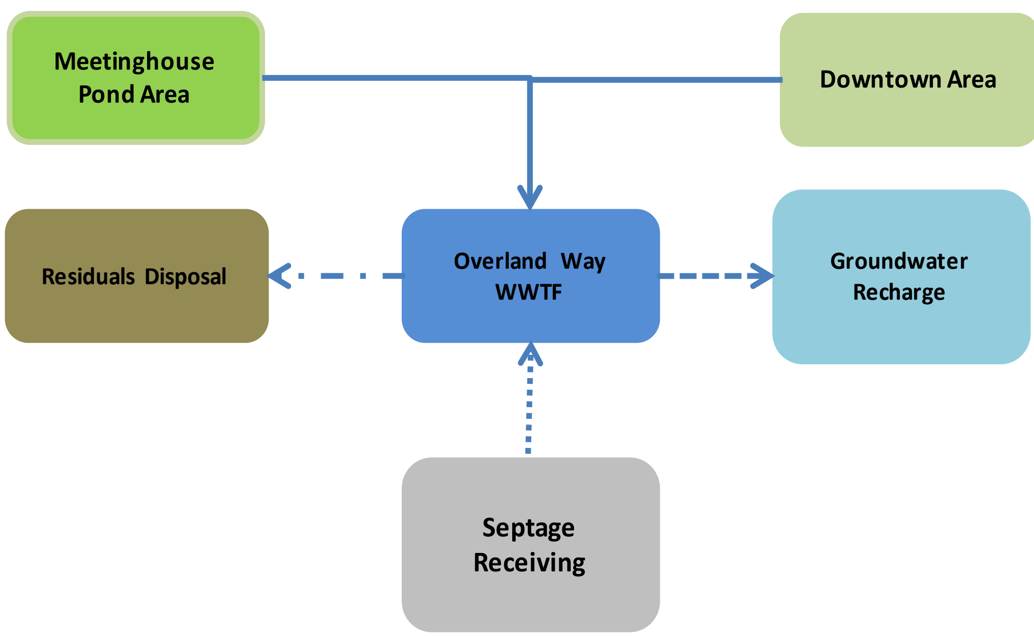
- Town of Orleans Assessors Records;
- USGS topographic survey;
- Town of Orleans Topography Survey by Surveying and Mapping Consultants;
- Town of Orleans Topography Survey by Coastal Engineering Co., Inc.;
- Subsurface Investigations by N.E. Geotech, LLC.;
- Cultural resource evaluations by Public Archaeology Laboratory, Inc.; and
- Supplemental information/input (Collection System Working Group and various manufacturers).

It is anticipated that the final system layouts will be further developed based on various site factors as based on the ability to obtain land and/or easements; and further investigations of existing utilities.

Figure 3 presents a flow schematic for the Downtown Area.

C. Preliminary cost estimates were developed based on the preliminary system layouts and included Project Costs; Annual Operation and Maintenance Costs; Replacement Costs; and Annual Monitoring Cost and is included in the following sections.

Figure 3 - Downtown Area Flow Schematic



9. Development of Program Costs

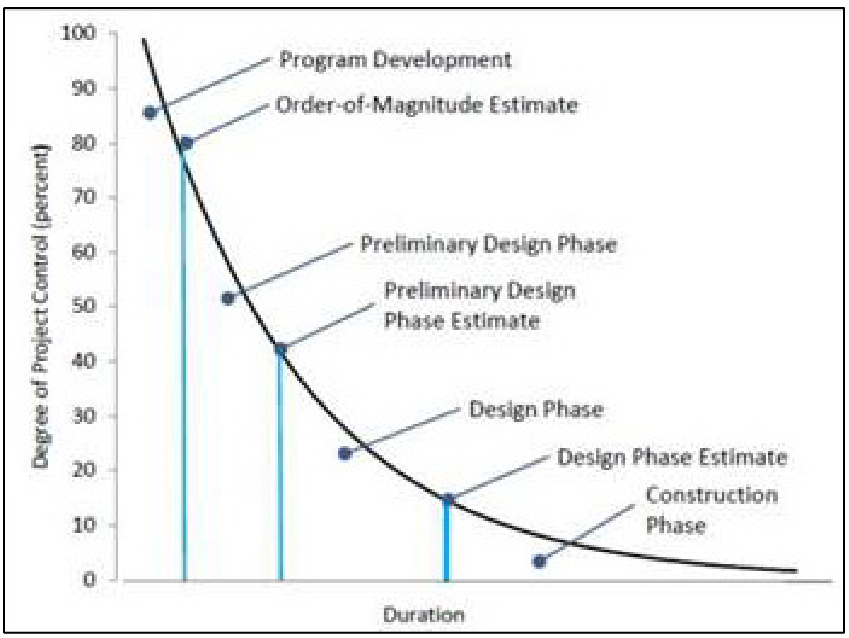
Cost estimating is a critical component of a project evaluation in the early stages of planning and concept design, before selection of a definitive plan and commitment of any funds. As part of the development of this document, order-of-magnitude Program Cost estimates were developed for the Downtown Area wastewater collection system technologies:

- Gravity Sewers;
- Low Pressure Sewers;
- Septic Tank Effluent Gravity;
- Septic Tank Effluent Pumping; and
- Vacuum Sewers.

As can be seen on Figure 4, as the duration of a Program move from "Program Development" to "Construction Phase", the degree of project control or influent on the outcome of the Program diminishes. Making changes in the later phases of a Program typically results in an increase of costs.

The Program Costs for the Downtown Area wastewater collection system were developed with our in-house specialists who prepare cost estimates for construction and operation using industry standards for materials and labor as well as actual bid tabs from a library of projects. Supplemented with information obtained from the Project's interactive workshops, manufacturer's information, other operating facilities, and a collaborative process to fully understand the cost implications of the various alternatives, these comprehensive costs allow for informed decision making.

Figure 4 – Degree of Project Control vs. Project Duration



The Program Costs for the Downtown Area wastewater collection system include Capital Costs, Annual Operation and Maintenance Costs, Replacement Costs and Monitoring Costs. These costs obviously vary with the specific design considerations and layout configuration ultimately selected for each collection system technology. Nonetheless, it is possible to put together an estimate that can be used for Life-Cycle Cost Analysis to determine of the most cost effective technology or combination of technologies.

The Program Costs for the Downtown Area wastewater collection system presented are planning level costs and should be refined as additional informational details are identified and/or determined. For the Downtown Area, this refinement to the project scope has been updated based on completion of topographic survey, subsurface exploration, as well as the development of this 25% Preliminary Design Report for the proposed Downtown Area Collection System. It is recommended that planning level Program Costs be updated just prior to appropriation of funding for the implementation phase of the Program.

The Program Costs for the Downtown Area wastewater collection system are preliminary in nature and contain construction cost, construction contingencies, administrative, legal, construction engineering, environmental and regulatory permitting related costs. The Class 3 opinion of probable construction costs were developed in accordance with "AACE International Recommended Practice No. 18R-97 - Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries" as prepared by the Association for the Advancement of Cost Estimating (AACE) International (www.aacei.org) dated February 2, 2005. Refer to Table 5 for the AACE International Cost Estimating classification system.

Table 5- AACE International Cost Estimating Classification System

Estimate Class	Primary Classification	Secondary Classification			
	Level of Project Definition[1]	End Usage[2]	Methodology[3]	Expected Accuracy Range[4]	Preparation Effort[5]
5	0 to 2 percent	Concept Screening	Capacity Factored, Parametric Models, Judgment or Analogy	L: -20 to -50 percent H: +30 to +100 percent	1
4	1 to 15 percent	Study or Feasibility	Equipment Factored or Parametric Models	L: -15 to -30 percent H: +20 to +50 percent	2 to 4
3	10 to 40 percent	Budget Authorization or Control	Semi-Detailed Unit Costs with Assembly Level Line Items	L: -10 to -20 percent H: +10 to +30 percent	3 to 10
2	30 to 70 percent	Control or Bid Tender	Detailed Unit Cost with Forced Detailed Take-off	L: -5 to -15 percent H: +50 to +20 percent	4 to 20
1	50 to 100 percent	Check Estimate or Bid Tender	Detailed Unit Cost with Detailed Take-off	L: -3 to -10 percent H: +3 to +5 percent	5 to 100

Notes:

1 Expressed as percent of Complete Definition

2 Typical Purpose of Estimate

3 Typical Estimating Method

4 Variation of Low and High Ranges. The state of process technology and availability of applicable reference costs data affect the range market. The +/- value represents percentage variation of actual costs from the cost estimate after application of contingency (typically at a 50 percent level of confidence) for given scope.

5 Typical Degree of Effort Relative to Least Cost Index of 1. If the range index value of "1" represents 0.005 percent of project costs, then an index value of "100" represents 0.5 percent. Estimate preparation effort is highly dependent upon the size of the project and the quality of estimating data and tools.

AECOM has no control over costs of labor, materials, competitive bidding environments and procedures, unidentified field conditions, financial and/or market conditions or other factors likely to affect the opinion of probable project costs all of which are and will unavoidably remain in a state of change. It is further understood that the probable project costs for the Downtown Area wastewater collection system are a “snapshot in time” and that the reliability of this opinion of probable project costs will inherently degrade over time. The probable project costs for the Downtown Area wastewater collection system need to be indexed on a common “baseline”. The construction industry uses the Engineering News Record (ENR) Construction Cost Index (www.enr.com) that is based on construction and materials costs throughout the United States. Therefore, the probable project costs for the Downtown Area wastewater collection system contained herein are based on an ENR Construction Cost Index of 10790 for July 2017.

A. Capital Costs

Capital Costs are those one-time, depreciable costs (i.e. not including any reoccurring annual costs) to construct a wastewater collection and treatment system with a design life greater than 5 years including non-traditional technologies. Capital Costs are generally financed through a loan or bond program. This provides up front funding for construction, with principal and interest payments spread out over time. Estimates have been developed to show Capital Costs by each type of system component. Defining costs by individual system component is essential given the eligibility requirements of different financing programs and revenue sources. Although not a depreciable costs, included in the Capital Costs were land purchases, at $250,000 per acre, required for locations of pumping stations that are not proposed on existing municipally owned land since it is considered an upfront cost.

B. Operation and Maintenance Costs

Operations and Maintenance (O&M) Costs relate to the day-to-day running and upkeep of the non-traditional and traditional technologies. O&M Costs include items such as labor, utilities, chemicals, etc. In order to achieve maximum asset life and reduce O&M costs, the establishment of standardized O&M procedures is critical. Standardized procedures helps personnel operate all assets within acceptable operational levels and ensures that each person is following the same routines. Lack of regular maintenance may result in the deterioration of the system components and result in rapid failure and reduced nitrogen removal from the environment as well as the ability to meet operating permits. O&M Costs are an annual cost generally paid through fee or tax revenues as costs accrue. O&M Costs will vary greatly by technology solution and have been estimated on a technology-by-technology basis.

C. Replacement Costs

In addition to O&M Costs, system components will malfunction and/or fail and therefore Replacement Costs, including Repair Costs, become a necessary part of the overall costs of the wastewater collection system. Replacement Costs are capital costs that will be required in the future when the original equipment has reached its useful life such as a pump at 10 years. Replacement Costs are used to replace components and/or equipment that have failed or malfunctioned such as; failed ejector pumps from LPS or STEP sewer systems, or pump bearings, mixers or control valves installed at conveyance pumping stations. As part of an Asset Management Program, a schedule of assets with their useful life should be developed since understanding the costs for partial replacement and full replacement of an asset will become necessary for sound financial planning. If more funding is spent on a repair to an asset, there will be a decreased need for the replacement of the asset. However, if greater funding is spent to replace the asset, there will be a decreased need for repairs to an asset. Overall there is a balance between how much to fund in each category in order to achieve the most efficient system. Like Capital Costs and unlike Annual O&M Costs, Replacement Costs are generally financed through a loan or bond program. This provides up front funding for construction, with principal and interest payments spread out over time. Estimates have been developed to show Replacement Costs by each type of system component for the Downtown Area wastewater collection system. Defining costs by individual system component is essential given the eligibility requirements of different financing programs and revenue sources.

D. Monitoring Costs

Monitoring is an essential component of adaptive management. Monitoring will assess the effectiveness of implementing the different collection system technologies. The results of monitoring will indicate which technologies are preferred based on long-term performance and which are less successful. This allows adjustments in the phased approach to improve overall performance of the solution. Like O&M Costs, Monitoring Costs are an annual cost generally paid through fee or tax revenues as costs accrue. Monitoring Costs will vary greatly by technology solution and have been estimated on a technology-by-technology basis.

10. Development and Assumptions of Program Costs

The development and assumptions of the Program Costs for the wastewater collection system for both public property and private property installation were estimated from various source of information including past AECOM projects and manufacturers information. The presented above, the Capital Costs for the Downtown Area wastewater collection system includes both public property and private property installation in order to present the entire cost of the Program. It should be noted that the Town has not determined what entity will be responsible for the Capital Costs of the wastewater system components located on private property. In addition, the Capital Costs for Downtown Area wastewater collection system do not include an allowance for any reconfiguration and/or upgrade to existing interior plumbing and/or electrical systems. Refer to Appendix G for the Program Costs estimates.

A. Capital Costs

Capital Costs for the Downtown Area wastewater collection system for both public property and private property installation were estimated by compiling typical unit costs for gravity sewers, vacuum sewers, low pressure sewers, septic tank effluent pumping/gravity and septic tank effluent pumping and, as applicable, pumping stations and force mains. Table 6 presents a Menu of Collection System Construction Unit Costs not including the contractor’s overhead and profit and project contingency.

Table 6 - Menu of Collection System Construction Unit Costs

Description	Unit	Unit Cost
Custom Pump Station	Each	$585,000
Force Main	L.F.	$120
Gravity Sewer	L.F.	$125
Gravity Sewer - Private Property	Each	$7,800
Low Pressure Sewer	L.F.	$100
Low Pressure Sewer - Private Property	Each	$12,000
STEG - Private Property	Each	$7,800
STEG Sewer	L.F.	$125
STEP - Private Property	Each	$16,400
STEP Force Main	L.F.	$100
Submersible Pump Station	Each	$275,000
Vacuum Collection/Transmission Station	Each	$860,000
Vacuum Sewer	L.F.	$110
Vacuum Sewer - Private Property	Each	$10,250
Wet Pit /Dry Pit Pump Station	Each	$470,000

Table 7 presents a Menu of Other Collection System Unit Costs required as part of the Project Costs. The Unit Costs are based on a traditional municipal design-bid-construct process and include the costs for paying minimum wage rates per Massachusetts Prevailing Wage Law for public works projects G.L. c. 149, §§ 26 - 27 ("The Prevailing Wage Law") which establishes minimum wage rates for workers on public construction projects. In addition, review of actual construction costs for other similar projects was reviewed, adjusted for local bidding costs, and utilized to develop these unit costs.

Table 7 - Menu of Other Collection System Costs

Description	Unit	Unit Cost
Overhead and Profit	Percent	22.0
Contingency	Percent	15.0
Project Services	Percent	35.0
Planning/Consultation	Percent	5.0
Design Engineering	Percent	10.0
Construction Engineering	Percent	15.0
Town Administrative	Percent	5.0

B. Operation and Maintenance Costs

Operation and Maintenance Costs for Downtown Area wastewater collection system for both public property and private property installation were estimated by compiling typical scope items and associated costs for gravity sewers, vacuum sewers, low pressure sewers, septic tank effluent pumping/gravity and septic tank effluent pumping and, as applicable, pumping stations and force mains. The following is a summary of the scope of work items. It should be noted that this summary consists of components that should be included in the normal operation and "preventive" and "predictive" maintenance of the wastewater collection system. It should also be noted that the Town has not determined what entity will be responsible for the Operation and Maintenance Costs of the wastewater system component located on private property.

- 1 full time employee for administration, operation and maintenance of each type of technology (Gravity Sewers; Low Pressure Sewers; Septic Tank Effluent Gravity; Septic Tank Effluent Pumping; and Vacuum Sewers) including Private Property Components such as pumps, valves, and vaults/tanks;
- A minimum of 260 hours per year for each type of Pump Station (Custom Pump Station; Submersible Pump Station; Vacuum Pump Station; and Wet Pit /Dry Pit Pump Station);
- Utilities, chemicals, etc. per each type of Pump Station (Custom Pump Station; Submersible Pump Station; Vacuum Pump Station; and Wet Pit /Dry Pit Pump Station) based on 25 horsepower pumps each running an average of 15 minutes per day at $0.15 per kWh; miscellaneous supplies (i.e. fuses, lamps, filters, grease, etc.); and chemicals for odor control.
- Clean and TV 25 percent of sewers per year for Gravity Sewer and STEG technologies;
- Clean 25 percent of pressure/vacuum pipes per year for Low Pressure Sewer, STEP and Vacuum Sewer technologies as well as force mains; and
- Pump-out Septic Tanks Every 3 Years for STEP and STEG technologies in order to avoid septic conditions and plugging of pumps as well as cleaning of the screen/filters in the STEP systems.

- Power costs for private pumps for LPS, or STEP systems based on 0.5-1 HP and 250 hours per year (350 gal/home/45 gal) x (8 pump outs x 5 min = 0.67 hours/day) x 356 d = 250 hours/yr.).

C. Replacement Costs

- Equipment (i.e. pumps or pump parts - impellers and bearings) for each type of Pump Station (Custom Pump Station; Submersible Pump Station; Vacuum Pump Station; and Wet Pit /Dry Pit Pump Station) at 1 percent of original Capital Cost of the Pump Station per year; and
- Equipment (ie. pumps and valves) located on Private Property for Low Pressure Sewer, STEP and Vacuum Sewer technologies at 5 percent of total number connections per year.

D. Monitoring Costs

- Calibration of monitoring equipment at each type of Pump Station (Custom Pump Station; Submersible Pump Station; Vacuum Pump Station; and Wet Pit /Dry Pit Pump Station) at $2,500 per year;
- Monitoring of Private Property Components (i.e. pumps, valves, and vaults/tanks) to verify system integrity estimated at 8 hours per connection per year.

11. Life-Cycle Cost Analysis

A Life-Cycle Costs evaluation of the various collection system alternatives was performed to compare the Program Costs (Project Costs, Annual Operation and Maintenance Costs, Replacement Costs and Monitoring Costs). The assumptions used in the Life-Cycle Cost Analysis are as follows:

- Evaluation Period of 20 Years with a Rate of Return of 3.0 percent.
- Inflation Rate of 3.0 percent annually based on the average ENR Construction Cost Index from January 2005 through February 2016.
- The proposed Downtown Area wastewater collection system consists of only one type of collection system alternative even though it may not be technical feasible in all cases.
- The Program Costs include Capital Costs, Annual Operation and Maintenance Costs, Replacement Costs and Monitoring Costs will vary with the specific design considerations and will change the Life-Cycle Cost Analysis.
- A hybrid system is typically the most cost effective alternative. For comparison, a hybrid system consisting of Gravity Sewer and Low Pressure Sewer was also evaluated for the Downtown Area wastewater collection system.

Based on the estimated quantities developed from the updated system layout, estimated Program Costs and Life-Cycle Cost Analysis Assumptions a Life-Cycle Cost was developed for each of the technologies. The result of the Life-Cycle Cost Analysis is presented in Table 8 for the Downtown Area wastewater collection system. Refer to Appendix H for the Life-Cycle Cost Analysis.

Table 8 - Downtown Area Life-Cycle Cost Analysis (20 Years)

Type of Cost	Gravity Sewers	Septic Tank Effluent Gravity	Low Pressure Sewers	Vacuum Sewers	Septic Tank Effluent Pumping	Hybrid (GS and LPS)	Hybrid (GS and STEP)
Capital	$22.379	$25.934	$17.074	$28.785	$21.833	$20.719	$21.467
O&M, Replacement and Monitoring	$0.656	$0.715	$0.417	$0.814	$0.461	$0.490	$0.497
Present Value	$32.137	$36.572	$23.283	$40.893	$28.699	$28.002	$28.853

Note: Costs in Millions of Dollars

12. Recommendation

A. Type of Collection System

The standalone comparison of the individual technologies would result in the recommendation of a low pressure sewer system for the Downtown area. However, based on the technical evaluation considering system flexibility, greater familiarity of system components, and economic evaluation (Life-Cycle Cost Analyses) it is recommended that a “hybrid” wastewater collection system consisting of gravity sewers and low pressure sewers be constructed in the Downtown Area. The “hybrid” configuration is recommended because of the following:

- The ability to accommodate changes in wastewater flow caused by zoning changes and business dynamics;
- The ability to phase the design and construction particularly when considering the unknown performance of the non-traditional technologies;
- The overall low construction and operations 20-year life cycle cost (longer life cycle cost analysis;
- Proven long term reliability of gravity sewers and low pressure sewer in the New England Area;
- Greater familiarity of system components by General Contractors, Contract Operators and Design-Built-Operate Teams;
- Generally a higher public acceptance;
- Reduced potential for odor generation and corrosion; and
- Reduced risk of operation and maintenance in seasonal communities.

A hybrid system that takes advantage of the newer collection system design strategies to provide services to the individual properties, with a gravity sewer system, designed to eliminate deep excavations and the need for pumping stations as much as possible, that can collect the flows and provide the capacity for long-term expansion and a low pressure sewer system that provided cost-effective service to low laying properties and areas.

A LPS system is recommended for use in the hybrid plan due to the additional cost and maintenance burden of the STEP System from the additional private property components (resulting in about a $850,000 higher life cycle cost over 20 years). Additional factors include added costs for septage management requirements, the higher potential for corrosion and odors from the septic conditions of the STEP system at the property, as well as increase in difficulty in the biological process of the septic effluent and septage at a wastewater treatment facility.

B. Other

a) Utilize similar collection system alternatives in each of the proposed services areas and standardize design details/configurations since this reduces overall project costs.

b) Determine the preferred method of implementation – design-bid-construction; design-build-operate, etc.

c) Utilize the updated information to engage in Public-Private-Partnerships negotiations, as applicable.

d) Utilize the updated information to prepare a Notice of Project Change to the approved CWMP and funding applications in order to obtain grants and loans.

e) Inflate project costs to the year anticipated for implementation. The ENR's Cost Index History Tables can be used for estimating inflation on future cost projections that are then used for development of future Capital Improvement Plans and Financing Plans.

13. Design Data

A. Collection System

The Preliminary Design Data for the collection system located within the Downtown Area is presented in Table 9.

Table 9 - Downtown Area Collection System Preliminary Design Data

Description	Phase 1	Phase 2	Phase 3	Phase 4
Gravity Sewer Length (linear feet)	8,000	9,300	7,300	4,900
Gravity Sewer Size (inches)	8 to 10	8 to 10	8 to 10	8 to 10
Gravity Sewer Material	PVC or DI	PVC or DI	PVC or DI	PVC or DI
Number of Properties	82	64	72	45
LPS Length (linear feet)	1,500	700	---	---
LPS Size (inches)	1.5 to 3	1.5 to 3	---	---
LPS Material	PVC or HDPE	PVC or HDPE	---	---
Number of Properties	23	16	8	5

B. Pump Stations

The Preliminary Design Data for the pump stations located within the Downtown Area is presented in Table 10.

Table 10 – Downtown Area Pump Station Preliminary Design Data

Description	Pump Station		
	Phase 1	Phase 2	Phase 3
Average Daily Flow (gpd)	140,350	76,700	212,100
Average Daily Flow (gpm)	98	54	148
Infiltration/Inflow (gpd)	12,800	9,900	16,800
Infiltration/Inflow (gpm)	9	7	12
Peaking Factor	5.28	5.93	4.91
Peak Daily Flow (gpd)	741,060	454,850	1,041,400
Peak Daily Flow (gpm)	525	325	740
Force Main Length (linear feet)	1,800	2,900	2,250
Force Main Size (inches)	6	6	8
Force Main Material	HDPE	HDPE	HDPE
Velocity (fps)	5.96	3.69	4.72
Number of Pumps	2	2	3
Total Dynamic Head (feet)	80	90	53
Static Head (feet)	39	63	29
Horsepower	30	20	25
Type of Drive	VFD	VFD	VFD

14. Preliminary Plans, Specifications, and Required Permits

A. Plans and Specifications

The Downtown Area Collection System design will require Contract Documents (plans and specifications) for public bidding. The plans will be plotted on 24-inch by 36-inch vellums and the specifications will be printed on 8-1/2 inch by 11-inch paper. The Contract Documents will include the MassDEP requirements for projects funded by the Massachusetts SRF Loan Program.

Table 11 shows a preliminary list of drawings and Table 12 shows a preliminary list of specifications for the Collection System. These lists will be updated as the final design proceeds toward completion.

Table 11 - Preliminary List of Drawings

Drawing No.	Drawing Title	Collection System	Pump Stations
General			
--	Cover and Index of Drawings	X	X
--	Sheet Key Plans	X	X
---	General Notes, Abbreviations and Legends	X	X
Site			
LA-1	Existing Conditions Plan	---	X
LA-2	Layout Plan	---	X
LA-3	Grading and Drainage Plan	---	X
LA-6	Site Construction Details	---	X
LA-7	Environmental Details I	---	X
LA-8	Environmental Details II	---	X
Architectural			
A-1	Abbreviations and Symbols	---	X
A-2	Building Ground Level Plan	---	X
A-3	Building Elevations and Sections	---	X
A-4	Room Finish Schedule, Door Schedule and Details	---	X
A-5	Miscellaneous Schedules and Details	---	X
Structural			
S-1	Building Foundation Plan	---	X
S-2	Roof Framing Plan and Details	---	X
S-3	Building Sections and Details	---	X
S-4	Wetwell Plan, Sections and Details	---	X
GS-1	Notes and Details I	---	X
GS-2	Notes and Details II	---	X
Mechanical			
M-1	Abbreviations and Symbols,	X	X
M-2	Yard Piping	---	X
M-3	Building Plan and Sections	---	X
M-4	Wetwell Plan and Sections	---	X
M-5	General Mechanical Schematics and Details I	X	X
M-6	General Mechanical Schematics and Details II	X	X
M-7	General Mechanical Schematics and Details III	X	X
M-8	General Mechanical Schematics and Details IV	X	X
M-9	General Mechanical Schematics and Details V	X	X
M-10	Gravity Sewer Plan and Profile – No. of Drawings TBD	X	---
M-11	Low Pressure Sewer Plan and Profile – No. of Drawings TBD	X	---
M-12	Force Main Plan and Profile – No. of Drawings TBD	X	---

Drawing No.	Drawing Title	Collection System	Pump Stations
HVAC			
HV-1	Notes, Legends and Abbreviations	---	X
HV-2	Building Floor Plan	---	X
HV-3	Legends, Schedules, and Details	---	X
Plumbing			
P-1	Notes, Legends and Abbreviations	---	X
P-2	Building Floor Plan	---	X
P-3	Legend, Schedule, and Details	---	X
Electrical			
E-1	Legend and General Notes	---	X
E-2	Site Plan (1” = 20’)	---	X
E-3	Single Line Diagrams and Schematics	---	X
E-4	Control Wiring Diagrams and Block Wiring Diagrams	---	X
E-5	Conduit and Panel Board Schedules and Details	---	X
E-6	Fire and Security Riser Diagram	---	X
E-7	Duct Bank Sections and Details	---	X
E-8	Lighting and Power – Building Floor Plan	---	X
E-9	Lighting and Power – Wetwell Plan	---	X
Instrumentation			
I-1	Legend, Symbols and Notes	---	X
I-2	PLC Network Diagrams	---	X
I-3	Instrument Installation Details	---	X

Table 12 - Preliminary List of Specifications

Section	Title
Section 00001	Title Sheet
Section 00003	Table of Contents
BIDDING REQUIREMENTS, CONTRACT FORMS AND CONDITIONS OF THE CONTRACT	
Section 00005	Invitation to Bid
Section 00100	Instructions and Information for Bidders
Section 00300	Form for General Bid
Section 00305	Commonwealth of Massachusetts DCAM Update Statement
Section 00310	Bid Bond
Section 00350	Form for Subbid
Section 00375	Affidavit
Section 00420	Subcontract
Section 00430	Notice of Award
Section 00500	Form for Agreement
Section 00600	Payment Bond
Section 00610	Performance Bond
Section 00650	Notice to Proceed
Section 00700	General Conditions
Section 00852	Special Conditions - General
Section 00855	Special Conditions - Commonwealth of Massachusetts
Section 00858	Special Conditions - Permits and Licenses
Section 00859	Special Conditions – Massachusetts Equal Employment Opportunity
Section 00862	Special Conditions - MassDEP Policy Memoranda
Section 00905	Change Order Form
Section 00945	Certificate of Substantial Completion
Section 00950	Waiver of Liens
Section 00960	Certificate of Final Payment and Completion of Work
Section 00965	Transfer of Title

Section	Title
	TECHNICAL SPECIFICATIONS
DIVISION 1 - GENERAL REQUIREMENTS	
Section 01020	Allowances
Section 01025	Measurement and Payment
Section 01030	Special Requirements
Section 01090	Reference Standards
Section 01140	Environmental Protection
Section 01310	Miscellaneous Testing and Soil Data
Section 01500	Temporary Facilities
Section 01570	Traffic Management and Maintenance
Section 01640	Special Mechanical and Electrical Equipment Requirements
Section 01700	Contract Closeout
DIVISION 2 - SITE WORK	
Section 02100	Site Preparation
Section 02220	Earthwork
Section 02440	Site Improvements
Section 02444	Chain Link Fence and Gates
Section 02483	Planting Operations
Section 02485	Loaming and Seeding
Section 02503	Paving, Curbing and Sidewalks
Section 02620	Insulation and Jacketing
Section 02625	Polyvinyl Chloride Sewer Pipe
Section 02629	Pressure Pipe
Section 02630	Ductile Iron Sewer Pipe
Section 02635	HDPE Force Main
Section 02725	Manholes, Catch Basins, Handholes, and Pull Boxes
DIVISION 3 – CONCRETE	
Section 03100	Concrete Formwork
Section 03200	Concrete Reinforcement
Section 03250	Concrete Specialties
Section 03300	Cast-In-Place Concrete
Section 03305	Concrete Repair and Surfacing Products
Section 03345	Concrete Placing, Curing and Finishing
Section 03604	Non-Shrink Grout

Section	Title
DIVISION 4 – MASONRY – Not Used	
DIVISION 5 – METAL WORK – Not Used	
DIVISION 6 – WOOD AND PLASTIC	
Section 06100	Carpentry
Section 06192	Prefabricated Wood Trusses
Section 06160	Sheathing
Section 06200	Finish Carpentry
Section 06700	Fiberglass Fabrications
DIVISION 7 – THERMAL AND MOISTURE PROTECTION	
Section 07156	Waterproofing and Dampproofing
Section 07210	Building Insulation
Section 07240	Exterior Insulation and Finish System
Section 07311	Asphalt Shingles
Section 07317	Wood Shingles
Section 07400	Metal Roofing, Siding and Flashing
Section 07900	Sealants and Firestopping
DIVISION 8 – DOORS AND WINDOWS	
Section 08100	Metal Doors and Frames
Section 08220	Fiberglass Reinforced Plastic Doors and Frames
Section 08510	Steel Windows
Section 08700	Finish Hardware
Section 08800	Glass and Glazing
DIVISION 9 - FINISHES	
Section 09900	Painting
DIVISION 10 - SPECIALTIES	
Section 10200	Louvers
Section 10440	Signs
Section 10475	Emergency and Miscellaneous Equipment
Section 10520	Fire Extinguishers

Section	Title
DIVISION 11 - EQUIPMENT	
Section 11286	Sluice Gates, Slide Gates and Operators
Section 11300	Submersible Pump Station
Section 11306	Prefabricated LPS Systems
Section 11317	Sump Pumps
Section 11340	Variable Frequency Drives
Section 11348	Odor Control System
DIVISION 12 – FURNISHINGS – Not Used	
DIVISION 13 - SPECIAL CONSTRUCTION	
Section 13300	Instrumentation and Control System
Section 13350	Field Instruments
Section 13400	Supervisory Control and Data Acquisition (SCADA) System
Section 13500	Security Surveillance System
Section 13768	Fiber Optic Media
DIVISION 14 - CONVEYING SYSTEMS – Not Used	
DIVISION 15 - MECHANICAL	
Section 15050	Mechanical General Conditions
Section 15080	Mechanical Insulation
Section 15100	Process Piping
Section 15195	Natural Gas Piping System
Section 15300	Fire Protection
Section 15400	Plumbing Systems
Section 15500	Heating, Ventilating and Air Conditioning
Section 15950	HVAC Testing, Adjusting and Balancing
DIVISION 16 - ELECTRICAL	
Section 16050	Electrical General Conditions
Section 16071	Seismic Controls for Electrical Work
Section 16085	Miscellaneous Equipment
Section 16120	Wires and Cables
Section 16130	Raceways and Fittings
Section 16160	Panelboards
Section 16402	Underground Systems

Section	Title
Section 16426	Metal-Enclosed Drawout Switchgear-Low Voltage
Section 16450	Grounding System
Section 16500	Lighting System
Section 16601	Lighting Protection
Section 16612	Engine Generator
Section 16721	Fire Alarm System
Section 16760	Telecommunication Systems
Section 16920	Motor Control Centers
Section 16921	Switchboards
Section 16922	Electrical Power System Studies
Section 16924	Electrical Power Commissioning
Section 16998	Filed Inspection and Acceptance

B. Permits

Table 13 identifies the permits and approvals that are likely to be required for construction of each Phase of the Downtown Area Collection System. This list will be updated as the final design proceeds toward completion.

Table 13 - Preliminary List of Permits

Agency Name	Permit
Orleans Building Department	Building Permit (by Construction Contractor)
Orleans Site Plan Review Committee	Certificate of Appropriateness
Orleans Conservation Commission	Wetlands Notice of Intent/Order of Conditions *
Massachusetts Historical Commission	Certificate of Appropriateness
Old's Kings Highway Historic District	Certificate of Appropriateness
MassDEP	Water Quality Permit *
MassDEP	Plan and Specification Approval
Massachusetts Natural Heritage	Conservation Permit*
U.S. Army Corps of Engineers	Programmatic General Permit *
U.S. EPA	NPDES Permit for construction dewatering permit *

* By Construction Contractor

C. Preliminary Schedule

Table 14 shows the anticipated schedule to implement the construction of each Phase of the Downtown Area Collection.

Table 14 - Preliminary Schedule

Task		Duration (Months)
Prepare Draft Plans and Specifications		6 to 9
Town and MassDEP Review		3 to 4
Finalize Plans and Specifications		1
Obtain Permits		3 to 7
Construction		12 to 18
Startup and Testing		2 to 3
	Total	27 to 42

15. References

- AACE International - AACE International Recommended Practice No. 18R-97, Cost Estimate Classification System As Applied in Engineering, Procurement and Construction for the Process Industries, 2005
- AIRVAC, Inc. – Vacuum System Design Manual, 2001
- Biological Wastewater Treatment by Grady, Daigger, & Lim
- Cape Cod Commission – Barnstable County Cost Report, Comparison of Costs for Wastewater Management Systems Applicable to Cape Cod, Revised 2014
- Commonwealth of Massachusetts - 310 CMR 15.000: The State Environmental Code, Title 5: Standard Requirements for the Siting, Construction, Upgrade and Expansion of On-Site Sewage Treatment and Disposal Systems and for the Transport and Disposal of Septage
- Commonwealth of Massachusetts, Department of Labor Standards – Topical Outline of Massachusetts Prevailing Wage Law, March 2012
- Guidelines for the Design, Construction, Operation, and Maintenance of Small Wastewater Treatment Facilities with Land Disposal by MassDEP
- Iowa Department of Natural Resources - Alternative Collection Systems Technology Assessment and Design Guidance, August 2007
- Lacey, Washington – 20-Year Life Cycle Analysis of Effluent Sewer (STEP) System, 2013
- New England Interstate Water Pollution Control Commission - The Northeast Guide for Estimating Staffing at Publicly and Privately Owned Wastewater Treatment Plants, 2008
- New England Interstate Water Pollution Control Commission - TR-16, Guides for the Design of Wastewater Treatment Works, 2011 Edition
- Orenco Systems, Inc. – Operational Costs of Two Pressure Sewer Technologies: Effluent (STEP) Sewers and Grinder Sewers, 2014; Small Community Collection Systems: Construction Costs, 2014; and Decentralized Design Considerations and Life Cycle Costs, 2015

- Process Design Manual: Land Treatment of Municipal Wastewater – Supplement on Rapid Infiltration and Overland Flow" by United States EPA (EPA 625/1-81-013a)
- Process Design Manual: Land Treatment of Municipal Wastewater by United States EPA (EPA 625/1-81-013)
- United States Environmental Protection Agency - Decentralized Systems Technology Fact Sheet Low Pressure Pipe Systems, September 1999
- US EPA – Alternative Wastewater Collection System Manual, 1991
- Wastewater Engineering: Treatment, Disposal, and Reuse by AECOM (Metcalf & Eddy)
- Wastewater Treatment Plant Design: Manual of Practice (MOP 8) by Water Environment Federation
- Water Environment Research Foundation (2010)
- Water Reuse: Issues, Technologies, and Applications by AECOM (Metcalf & Eddy)

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Appendix A

Downtown Area Topographic Survey

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Appendix B

Downtown Area Cultural Resource Evaluation

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Appendix C

Downtown Area Geotechnical Evaluation Boring Logs

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Appendix D
Collection System Workgroup Meeting Minutes

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Appendix E

Downtown Area Collection System Phasing Plan

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Appendix F

Downtown Area Collection System 25% Preliminary Design Plan and Profiles

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Appendix G

Downtown Area Collection System Cost Estimate

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Appendix H

Downtown Area Collection System Life Cycle Cost Analysis

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