TOWN OF ORLEANS, MASSACHUSETTS

"DRAFT"

Preliminary Design Report on the Technical Review and Cost Analysis of Comprehensive Wastewater Management Plan Options

June 2012

Weston & Sampson Engineers, Inc.

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1.0 INTRODUCTION

The Town of Orleans has been very active in pursuing all reasonable options to address its wastewater management needs for the past decade or more. With the completion of the Comprehensive Wastewater Management Plan (CWMP) the Town has established a sound foundation to protect its groundwater, freshwater ponds, and marine receiving waters for the foreseeable future. As with most Cape Cod communities, Orleans has been a participant in the Massachusetts Estuaries Project and looking to address the nitrogen total maximum daily loads (TMDLs) for its coastal waters.

Orleans is a bit unique in that it has an existing septage treatment facility located in the Town that is owned by the Orleans Brewster Eastham Groundwater Protection District. In addition there are possible regional implications of the wastewater planning, with many of Orleans' watersheds tributary to Pleasant Bay extending well into the Town of Brewster. As such there are real opportunities for regional collaboration with Brewster (and to a lesser extent with Eastham) on watershed issues going forward.

An independent review of the CWMP process has been completed by and through the Cape Cod Wastewater Protection Collaborative, in support of the Orleans CWMP development process. That review presented an independent evaluation of critical elements of the CWMP. The report that resulted from that review highlights where the CWMP could be enhanced including the development of updated and refined cost estimates.

As stated in the Request for Qualifications (RFQ), the main goals of this project are 1) to develop and/or refine the centralized sewage collection, treatment and disposal system as outlined in the CWMP, 2) develop an alternative system based on Septic Tank Effluent (STE) collection, treatment and disposal concepts, and 3) develop comprehensive cost estimates for each of the above established design options for comparison purposes and for use in moving the plan forward.

The specific project scope was defined as the following eight (8) tasks:

- Task 1 - Conduct a public presentation at a Board of Selectmen's meeting that outlines the Designer's approach to completing each aspect of the study as outlined in the Scope of Services.

- Task 2 - Preliminary engineering design of a centralized, gravity based, sewage collection network with a centralized treatment and disposal system as outlined in the Town's CWMP.

- Task 3 - Preliminary engineering design of an alternative system based on Septic Tank Effluent (STE) collection with sewage treatment and disposal, using cluster or satellite facilities, if and where appropriate.

- Task 4 - Conduct a public presentation at a Board of Selectmen's meeting to demonstrate that the two preliminary engineering design options have progressed sufficiently in detail to proceed to the cost estimating phase.

- Task 5 - Develop comprehensive cost estimates for each of the two design options being studied utilizing the services of an independent professional cost estimator.

- Task 6 - Conduct a public presentation at a Board of Selectmen's meeting to review the results of the cost estimates that were developed in Task 5.

- Task 7 - Conduct a public presentation at a Board of Selectmen's meeting that details the draft final report and the Designer's recommended option.

- Task 8 - Conduct a public presentation of the final report at a Board of Selectmen's meeting.

Completion of these tasks is described in detail in subsequent sections of this report.

2.0 TASK 1

Under Task 1, an initial public presentation was conducted at the November 16, 2011 Board of Selectmen's meeting. The purpose of this initial presentation was to introduce Weston & Sampson to the Board and to outline our approach to completing each aspect of the study as outlined in the Scope of Services.

Prior to the presentation, a kick-off meeting was conducted with Town staff to 1) establish the primary lines of communication; 2) confirm goals and expectations of the project; 3) compile/review existing information; and 4) identify key issues.

The project goals as previously discussed were confirmed as follows:

- Perform preliminary engineering and detailed cost analysis to determine the most cost effective way to address the wastewater management needs of the Town.
- Develop and or refine the conceptual centralized sewage collection, treatment and disposal system associated with the recommended option of the CWMP (Plan 2 – Figure 11-1).
- Develop an alternative system based on Septic Tank Effluent (STE) collection, treatment and disposal concepts.
- Develop comprehensive cost estimates for each of the above established design options for comparison purposes and for use in moving the plan forward.

The key issues surrounding completion of the project were identified as 1) establishing well defined system layouts for the two options, and 2) providing a clear basis of the cost estimates. Emphasis was made on providing transparency in the evaluation and 'apples to apples' comparisons of costs, specifically with regard to TMDL equivalence and private property costs.

A complete copy of the PowerPoint presentation from the November 16th meeting is included in Appendix A.

3.0 TASK 2

As mentioned above, Task 2 involved the preliminary engineering design of a centralized, gravity based, sewage collection network with a centralized treatment and disposal system. The specific goal was to develop and or refine the conceptual centralized system associated with the recommended option of the CWMP (Plan 2 – Figure 11-1), working toward the following:

- Development of a detailed collection network sufficient to form the basis of a unit priced comprehensive estimate.
- Identification of general locations of pump stations and "cross country" branches, if necessary.
- Preliminary design of a sewage treatment and disposal facility, incorporating the latest technological advances and energy efficiency, to be located on the existing Tri-Town Septage Treatment Facility Site as described in the CWMP.

In preparing the preliminary design for the centralized system, we separated our analysis into the two basic elements of wastewater management: 1) collection; and 2) treatment and disposal.

3.1 Collection System

The collection portion of a centralized system can consist of the following conventional technologies for conveyance of the wastewater to the centralized treatment and disposal site:

- Conventional gravity sewers, pump stations, and force mains
- Individual grinder pumps and low-pressure sewers
- Some combination of these technologies (a hybrid system)

Conventional Gravity Sewers

A conventional gravity sewer system consists of sewer lines that allow residential, commercial, and industrial customers to discharge into a sanitary system consisting of gravity pipes, which flow downhill, and are not pressurized. Extremely flat or hilly terrain poses a problem to gravity sewer installations since the gravity sewers must continually slope downward. This results in the sewer becoming increasingly deep or the need for a wastewater pump station. Pump stations are located at low points to collect and pump the wastewater to the WWTF or to the nearest high point in the collection system, where the process of gravity flow continues. Pump stations may also be required where wastewater must be transported between drainage basins. Wastewater is pumped from the pump stations to the centralized treatment and disposal site (or to the closest gravity manhole that flows to the centralized treatment and disposal site) via a pressurized pipe called a force main.

Pump Stations

Different types of pump stations include similar components; however their configuration, site orientation, size, above or below ground location, etc. will vary depending on the type of pump station. The most typical pump stations include:

Custom pump stations are typically appropriate for high flows at centralized and/or main pump station locations. Components are usually located in multi-level above and below grade cast-in-place concrete structures. Finish above grade structures are often brick buildings with ventilation for enclosed equipment including a standby generator. All components including pumps, piping, valves, channels, comminuters, motors, and controls are often located within the building at various levels of the structure. Some custom stations are equipped with odor control facilities.

Package pump stations are generally appropriate for mid-range flows as part of neighborhood collection and conveyance systems. Above ground components often include an electric service cabinet and standby generator, each housed in separate weather proof enclosures, and access hatches to the below ground chambers. Below ground components typically include the wetwell and the packaged dry-pit pump enclosure complete with pumps, valves, piping, and controls. Some package pump stations include smaller, above ground buildings to house the generator, electric cabinet and access hatch.

Submersible pump stations are usually appropriate for lower flows as part of smaller neighborhood collection and conveyance systems. Above ground components often include an electric service cabinet and standby generator, each housed in separate weather proof enclosures, and access hatches to the below ground chambers. Below ground components typically include the submersible pumps within the wetwell and a separate valve vault. In this type of design, the entire pump and motor are immersed in the wastewater. The pump sits close to the wet well floor and the liquid enters directly into the volute; there is no suction piping. The motor is attached directly to the top of the pump. Some submersible pump stations use above ground buildings to house the generator, electric cabinet and access hatch. This arrangement requires that a crane be used to remove the pump(s) from the wet well for operation and maintenance checks.

Low-Pressure Sewers

A low-pressure sewer system has proven to be a viable alternative where implementation of gravity sewer systems is impractical and/or uneconomical. A low-pressure sewer system includes small diameter pressure sewers fed by individual grinder pumps at each source. A pressure sewer system makes use of small diameter piping, buried at a relatively shallow depth (typically five feet deep) following the profile of the ground. Standard manholes are not required in a pressure sewer system. Instead, flushing connections/drain manholes are installed at the end of branches and where major changes in directions or size of pipe occurs.

In a low-pressure sewer system, each customer will utilize an individual grinder pump for discharge of sewerage into the main. Each grinder pump unit is equipped with a grinder pump, check valve, tank, and all necessary controls. The units can be located outdoors close to each customer’s existing septic tank or cesspool so that the connection to the existing service pipe exiting the building can be made easily. The units can also be located inside the building if permissible under local plumbing codes.

A low-pressure sewer system collects and transports the wastewater from each customer located in low points to the nearest gravity sewer. Within the right-of-way, air relief manholes with air and vacuum valves would be installed at all high points and terminal flushing manholes would be installed at end runs. In addition, cleanouts and drain manholes would be installed at all low points and approximately every 1,000 feet to provide access for periodic maintenance.

Hybrid System

A hybrid system is a combination of conventional wastewater collection system components, grinder pumps, and pressure sewers. These combined systems are designed to maximize the use of gravity sewers, however, where the topography or subsurface conditions (ledge, groundwater, coastal areas, etc.) warrant, grinder pumps and low-pressure sewers are utilized to reduce capital construction costs and to reduce long term I/I in the system.

Preliminary Design

The general layout provided in the CWMP depicts a gravity collection system with approximately 60 wastewater pump stations and the associated force mains. Based on this high number of pump stations, the general topography of the area, and our experience with similar communities, we feel strongly that a centralized sewer system for Orleans lends itself well to a hybrid system that maximizes the use of gravity sewers where they are determined to be cost effective and makes use of low-pressure sewer systems with on-lot grinder pumps in limited areas where topography warrants it and their use is advisable. Based on this, we moved forward with refinement of the recommended CWMP layout to be a hybrid system.

Understanding that the linear nature of a collection system leads to significant cost implications in the overall wastewater management process, we approached the hybrid design with consideration of the following primary cost drivers:

- The size and depth of the pipe
- Number of manholes and other structures
- Number and size of municipal pump stations
- Number of individual on-lot pumps
- Subsurface conditions
- Method of Installation
- Surface Restoration

Consideration of these factors is covered in more detail later in the report. In general, the focus of the preliminary design was to provide gravity sewers where they could be installed at depths less than 12 feet. Depths between 12 and 20 feet were only considered along the spine of the system (i.e. interceptor type sewers) where a significant number of properties would benefit from the deeper gravity sewers and low-lying isolated neighborhoods would have a nearby gravity option, thereby minimizing the number of homes on any given low-pressure system. Individual on-lot grinder pumps and low-pressure sewers were considered for low-lying homes and neighborhoods with too few homes to establish the cost effectiveness of a municipal pump station. In the preliminary layouts of the low-pressure systems, efforts were made to minimize the number of pumps connected to any one system, thereby reducing the size of the low-pressure sewer lines and the hydraulic complexity of the individual systems.

Our general approach to the preliminary design of the centralized hybrid collection system was as follows:

- Prepared a base map of the project area using available GIS mapping. The base map includes available information pertinent to the preliminary design including, but not limited to, topography, existing buildings/structures, roads, wetland resource areas, property lines and street right of ways.
- Performed field reconnaissance in support of the initial system layout, using the CWMP conceptual layout as a starting point and incorporating the hybrid system discussed above as appropriate.
- Generated selected street profiles and preliminary proposed sewer profiles from the existing contours to "fine tune" the layout.
- Performed further field reconnaissance to better define proposed pump station sites and cross country branches and to finalize the proposed layout of the collection system.

The final recommended layout of the centralized hybrid wastewater collection system is depicted in Figure 3-1. A detailed breakdown of the steps taken and data compiled during the preliminary design, including critical criteria and/or assumptions used in developing the layout is as follows:

- The CWMP presented a recommended option of a centralized sewer system with a conceptual layout for the Town of Orleans. The centralized sewer system would ultimately flow to a new wastewater treatment facility to be located at the site of the existing septage treatment facility. The purpose of our work was to start with this conceptual layout and generate a preliminary design layout of a hybrid centralized sewer system (i.e. – combination of gravity sewers, low-pressure sewers, and pump stations) using our knowledge of the area and expertise in wastewater collection system design.

- As stated above, a base map of the project area was created using the available GIS mapping that was provided by the town. The base map included 2-foot contours interpolated from 4-foot contours of the topography of the town. These contours were adequate to prepare a preliminary design of the proposed sewers. Additional survey with more accurate contour lines, however, will be required for final design.

- With 200-foot scale maps of the town, a windshield survey was performed by driving all streets included in the CWMP recommended plan. This survey allowed us to see the topography of the land. High and low spots in the topography were identified to assist us in determining what streets could flow by gravity into central collection areas (i.e. – pump station tributary areas) and what streets would require low-pressure sewers with individual on-lot grinder pump units. We also identified potential pump station locations, environmentally sensitive areas, and potential cross-country easements. In addition, we identified specific streets where profiles would be necessary to further assist in the layout of the hybrid collection system.

- Upon completion of the windshield survey, we created a draft preliminary layout of the proposed hybrid collection system identifying locations of gravity sewers, low-pressure sewers and pump stations. Our analysis determined 19 proposed pump station locations with subsequent hybrid sewer collection tributary systems.

- In order to “fine-tune” our preliminary layout and in accordance with our windshield survey, we created street profiles of 18 different streets (approximately 13.5 miles) to help further define the proposed preliminary sewer layout presented in Figure 3-1. The profiles helped to determine direction of gravity flow in some areas and areas where deeper excavations (i.e. – greater than 12-vertical feet) would be required to eliminate additional or unnecessary pump stations or low-pressure sewer systems. The following table (Table 3-1) presents a summary of the streets where we generated profiles.

Table 3-1
Street Profiles and Lengths

STREET	DESCRIPTION	LENGTH (LF)
Winslow Drive	in its entirety	1,410
South Orleans Road	Towhee Lane to Route 6A	21,130
Harwich Road	South Orleans Road to the Brewster Line	3,425
Namequoit Road	South Orleans Road to Duck Marsh Lane	5,110
Monument Road	in its entirety	7,910
Pond Road	in its entirety	2,450
Kettle Pond Way	Finlay Road to Nickerson Road	610
Nickerson Road	in its entirety	2,790
Route 6A	#169 to #192	1,480
School Road	Monument Road to River Road	910
River Road	in its entirety	1,250
Locust Road	in its entirety	2,610
Main Street / Beach Road	Lewis Road to #121 Beach Road	3,490
Brick Hill Road	Beach Road to Harbor View Road	2,260
Tonset Road	#90 Tonset Road to Gibson Road	6,130
Rock Harbor Road	Bay View Drive to Bridge Street	4,850
Meetinghouse Road	in its entirety	2,140
Finlay Road	Kettle Pond Way to South Orleans Road	1,280
		71,235

- Based on the street profiles, we finalized our proposed preliminary layout of the centralized hybrid collection system. Based on this layout, we then determined the following information on a street by street basis for each of the 19 pump stations and their respective tributary areas in the overall project area:
    - Approximate length of gravity sewer
    - Approximate length of low-pressure sewer
    - Number of houses
    - Number of vacant lots
    - Approximate number of gravity sewer manholes
    - Approximate number low-pressure sewer system manholes
    - Approximate number of on-lot grinder pump units

All of the above information is presented in Table 3-2.

- Once the number of houses and vacant lots were tabulated, it was necessary to calculate the sizes of the gravity sewer and low-pressure sewer pipes, sizes of the force mains from the pump stations, and the pump station sizes and types. All pipes were sized based on "peak" future wastewater flows. Future wastewater flows for the town in the project area were broken down by the following three watershed areas – Pleasant Bay, Cape Cod Bay and Nauset. Table 4-2 of the CWMP presented the anticipated future average daily wastewater flows for each watershed. Based on the information in this table, we determined the approximate average daily wastewater flow per parcel for each watershed area. These wastewater flow rates were then used to size our wastewater collection system. The following is a summary of wastewater flow rates used in our preliminary design:

    - Pleasant Bay – 200 gallons per day (gpd) per lot
    - Cape Cod Bay – 600 gpd per lot
    - Nauset – 275 gpd per lot

  For each pump station tributary area, the total number of properties (including vacant lots) were calculated and then multiplied by the average daily wastewater flow rate depending on which watershed the street was located within. This average daily wastewater flow was then peaked using *Figure 2-1, Ratio of Extreme Flow to Average Daily Flow, from <u>TR-16 Guides for the Design of Wastewater Treatment Wastewater Treatment Works (TR-16)</u>, 1998 edition.*

  Based on the length of gravity sewers in a tributary area, we also carried an allowance for infiltration and inflow (I/I) when determining the size of the gravity sewer pipes and force mains. In accordance with TR-16, we used an allowance of 500 gallons per day per inch-mile (gpdim) for I/I when sizing the gravity pipes. An allowance for I/I is not included for low-pressure sewers since the pipes are smaller and installed at shallower depths and are less susceptible to I/I.

  Gravity sewers were then sized based on the peak wastewater flow plus the allowance for I/I. I/I allowances were not peaked when determining the pipe sizes. The minimum pipe size for gravity sewer mains is 8-inch.

  Detailed calculations for pipe sizing for the 19 pump stations and their respective tributary areas can be found in Appendix B.

- Once the pipe sizes of the gravity sewers were determined, we used the profiles that were generated to determine where the gravity sewers would exceed 12-vertical feet. As previously discussed, the focus of the preliminary design was to provide gravity sewers where they could be installed at depths less than 12 feet. Depths between 12 and 20 feet were only considered along the spine of the system (i.e. interceptor type sewers) where a significant number of properties would benefit from the deeper gravity sewers and low-lying isolated neighborhoods would have a nearby gravity option, thereby minimizing the number of homes on any given low-pressure system. These locations are depicted on Figure 3-1 and presented in Table 3-3.

- The following is a summary of the gravity sewer component of the hybrid wastewater collection system:

    - Approximately 175,000 linear feet (lf) of gravity sewers between 8 and 21-inches
        - Approximately 159,000 lf of 8-inch sewer
        - Approximately 1,000 lf of 10-inch sewer
        - Approximately 7,000 lf of 12-inch sewer
        - Approximately 7,500 lf of 15-inch sewer
        - Approximately 500 lf of 21-inch sewer
    - Approximately 830 sewer manholes
    - Only 6,000 lf of gravity sewer at depths greater than 12-vertical feet (vf)
    - No sewers at depths over 20 vf

- Low-pressure sewer systems typically range in size from 1 ½- to 3-inches in diameter. In order to determine the pipe sizes for the low-pressure sewer system component of the hybrid wastewater collection system as shown on Figure 3-1, we used the following criteria from *Table 2.2 from Alternative Sewer Systems – WEF Manual of Practice No. FD-12, 2nd edition*:

    - 1 to 3 lots served = 1 ½-inch pipe
    - 4 to 10 lots served = 2-inch pipe
    - 11 to 30 lots served = 3-inch pipe
    - 31 to 150 lots served = 4-inch pipe

  All of the low-pressure sewer system branches, as shown on Figure 3-1, were independently examined based on the number of lots along each branch and where it discharged (i.e – directly to a gravity sewer or into another branch of the low-pressure sewer before discharging to a gravity sewer) to determine the low-pressure sewer pipe size.

  Table 3-4 presents a summary of the low-pressure sewer pipe sizes. Calculations depicting how the pipe sizes were determined based on the number of lots can be found in Appendix B.

- The following is a summary of the low-pressure sewer component of the hybrid wastewater collection system:

    - Approximately 116,000 lf of low-pressure sewers between 1 1/2- and 3-inches
        - Approximately 10,000 lf of 1 ½-inch pipe
        - Approximately 86,000 lf of 2-inch pipe
        - Approximately 20,000 lf of 3-inch pipe
    - Approximately 290 manholes structures (in-line and terminal)
    - Approximately 1,100 on-lot grinder pump units

- As previously stated, we identified 19 pump station locations and their respective wastewater collection tributary area. The information included in Appendix B was used to estimate the size of the discharge force main and the type of pump station. In accordance with industry standards, force mains were sized to produce velocities of 3 to 5-feet per second (fps) within the pipe. The following criteria was used to determine the pump station type:

    - Submersible (grinder) Pump Station – Flows less than 100 gallons per minute (gpm)
    - Submersible (non-clog) Pump Station – Flows from 100 gpm to 250 gpm
    - Self-priming Pump Station – Flows from 250 gpm to 700 gpm
    - Custom-built Pump Station – Flows greater than 700 gpm

  Table 3-5 presents a summary of the pump stations and their respective force main sizes and lengths.

  Figure 3-2 depicts a schematic of the pump stations and their interrelation to one another.

  Appendix C provides more information on proposed pump station locations.

- The following is a summary of the pump station types and force mains:

    - 13 submersible pump stations
    - 5 self-priming pump stations
    - 1 custom pump station
    - Approximately 50,000 lf of force mains between 2 and 15-inches
        - Approximately 2,500 lf of 2-inch force main
        - Approximately 5,000 lf of 3-inch force main
        - Approximately 18,000 lf of 4-inch force main
        - Approximately 7,000 lf of 6-inch force main
        - Approximately 9,000 lf of 8-inch force main
        - Approximately 8,500 lf of 15-inch force main
    - Approximately 100 force main cleanout manholes
        - Cleanout manholes are typically installed every 500-feet along the force main route

- Table 3-6 below is a comparison of the CWMP recommended plan and the proposed hybrid system described herein:

Table 3-6
CWMP Layout vs. Proposed Hybrid Collection System

	CWMP Recommended Plan	Proposed Hybrid System
Properties Served	2,830	2,830
Total Pipe Length	390,000	341,000
Pump Stations	61	19
Grinder Pumps	78	1,050

3.2 Treatment & Disposal System

As per the scope of services, Weston & Sampson has provided preliminary design information for a proposed centralized wastewater treatment facility (WWTF) and its associated effluent disposal system, all to be located at the site of the existing Tri-Town Septage Treatment Facility, which will provide advanced levels of treatment for the "Core Program" service area, as defined in the CWMP. Also as per the CWMP, the approximate volume to be treated is an average daily flow of 640,000 gpd and a maximum daily flow of 1,440,000 gpd. As part of the preliminary design we investigated Sequencing Batch Reactor (SBR) and Membrane BioReactor (MBR) technologies, each of which are biological processes that will provide treated effluent of a quality consistent with groundwater discharge requirements.

We have noticed through conversations with regulators, operating several plants on the cape, and our involvement with the design of wastewater treatment systems that permitted effluent nitrogen limits are being continually driven lower. Based on our experience, we feel that it would be most prudent to develop the design of the proposed wastewater treatment facility such that it can consistently meet a target effluent nitrogen limit of 3 mg/l, instead of the 10 mg/l noted in the CWMP. We have incorporated this approach in our conceptual design.

Prior to developing our conceptual design, we performed a cursory in-house evaluation of both of these treatment technologies, with respect to the technology selection criteria listed in the CWMP. These criteria are:

1. Relative Capital Cost
2. Relative Operating Cost
3. Ease of Operation
4. Process Scalability
5. Limited Site Footprint
6. Level 2 Treatment/Reliability

MBRs combine activated sludge treatment with a membrane liquid-solid separation process. The membrane component uses low pressure microfiltration or ultrafiltration membranes and eliminates the need for secondary clarification and tertiary filtration. The membranes are typically immersed in the aeration tank; however, some applications utilize a separate membrane tank. One of the key benefits of an MBR system is that it effectively overcomes the limitations associated with poor settling of sludge in conventional activated sludge (CAS) processes. The technology permits bioreactor operation with considerably higher mixed liquor suspended solids (MLSS) concentration than CAS systems, which are limited by sludge settling. The process is typically operated at MLSS in the range of 8,000–12,000 mg/L, while CAS are operated in the range of 2,000–3,000 mg/L. The elevated biomass concentration in the MBR process allows for very effective removal of both soluble and particulate biodegradable materials at higher loading rates. Iincreased sludge retention times, usually exceeding 15 days, ensure complete nitrification even in extremely cold weather. The cost of building and operating an MBR is usually higher than conventional wastewater treatment, and they are more difficult to operate. Membrane filters can be easliy blinded with grease or abraded by suspended grit and lack a clarifier's flexibility to pass peak flows. The technology has become increasingly popular for reliably pretreated waste streams and has gained wider acceptance where infiltration and inflow have been controlled. The smaller footprint of MBR systems, and the high quality effluent produced, make them particularly useful for water reuse applications.

SBRs treat wastewater in batches with a biological process similar to the CAS process. While there are several configurations of SBR, the basic process is similar for each. The installation consists of at least two identically equipped tanks with a common inlet, which can be switched between them. The tanks have a "flow through" system, with raw wastewater (influent) coming in at one end and treated water (effluent) flowing out the other. While one tank is in settle/decant mode the other is aerating and filling. At the inlet is a section of the tank known as the bio-selector. This consists of a series of walls or baffles which direct the flow either from side to side of the tank or under and over consecutive baffles. This helps to mix the incoming influent and the returned activated sludge, beginning the biological digestion process before the liquor enters the main part of the tank. The process is typically operated at MLSS in the range of 2,000–3,000 mg/L, similar to the CAS process. Because SBR's can cycle between anoxic and aerated phases in the same treatment batch, they provide the functions of several process tanks commonly found in the CAS process. A properly configured SBR treatment system is able to meet the proposed 3 mg/l total nitrogen effluent limit.

We found that, while both technologies provide the level of treatment required to achieve project goals, the SBR technology is more attractive for the following reasons:

1. less costly to construct
2. lower operational costs (has a lower anticipated power consumption)
3. lower level of operational effort required (less mechanical, simpler controls)
4. greater process flexibility (SBR tank cycles can be easily modified to enhance treatment)
5. no primary settling or microscreening needed (MBR's require much finer screening, as the treatment tank is only for soluable BOD)
6. greater equalization capacity in the event of equipment failure

In short, the SBR process has a lower life cycle cost and provides greater operational flexibility.

For this conceptual design we propose the following sequence of treatment processes to achieve the target effluent quality:

1. Preliminary treatment (screening and grit removal)
2. SBR (biological treatment)
3. Methanol addition (at the SBR) as a carbon source for bioligical nitrogen removal
4. Effluent equalization
5. Pressurized UV disinfection
6. Sludge dewatering

The conceptual flow diagram and site plan are shown on Figures 3-3 & 3-4 respectively.

Final effluent discharge will be to a network of ten (10) rapid infiltration basins, similar in design to what currently exists at the Septage Treatment Facility.

4.0 TASK 3

Task 3 involved the preliminary engineering design of an alternative system based on Septic Tank Effluent (STE) collection with sewage treatment and disposal. The basic goals of this task were as follows:

1. Development of a detailed STE collection network sufficient to form the basis of a unit priced comprehensive estimate.
2. Identification of general locations for treatment plant and discharge sites, pump stations, and "cross country" branches if necessary.
3. Preliminary design of sewage treatment and disposal facilities, incorporating the latest technological advances and energy efficiency, to be located either on the existing Tri-Town Septage Treatment Plant Site or at other potential sites as identified in the CWMP.
4. Provide evidence of investigations as to how other communities of similar size and geographic characteristics have implemented STE Programs and their experiences with these systems to date.

As with Task 2, in preparing the preliminary design for the STE system, we separated our analysis into the two basic elements of wastewater management: 1) collection; and 2) treatment and disposal.

4.1 Collection System (including siting of wastewater treatment and disposal sites)

In addition to the conventional collection system technologies discussed above in section 3.1, there are also innovative/alternative technologies that can be considered for certain applications. The scope of this project specifically requires investigation of Septic Tank Effluent (STE) collection systems as an alternative to the conventional collection system. STE systems consist of the following:

- Septic Tank Effluent Pump (STEP) systems
- Septic Tank Effluent Gravity (STEG) systems (a.k.a. small diameter variable slope gravity sewer systems)

<u>STEP Systems</u>
STEP systems are similar in overall construction, operation, and maintenance to grinder pumps with low-pressure sewers. The difference with STEP systems is solids and grease are removed from the wastewater at each residence or commercial/industrial establishment utilizing a conventional septic tank prior to pumping. This system employs a combination of on-site/off-site system technologies. Preliminary treatment takes place on each individual property and secondary treatment takes place at a wastewater treatment facility.

STEP systems require the installation of watertight septic tanks at each home to remove solids and grease followed by an effluent pump that conveys the wastewater to a low-pressure sewer system. A screen is typically installed between the septic tank and the effluent pump to prevent solids from entering the piping system. The STEP pressure sewer system requires the same integral components as the grinder pump low-pressure sewer system. Since a majority of the solids are removed in the septic tank, velocities of only 0.5 fps are required in the pipelines.

Therefore, slightly longer mainline pressure sewers may be utilized as compared to grinder pump pressure sewers. Wastewater delivered to the treatment system from a STEP system typically has 30% lower biochemical oxygen demand (BOD), and can therefore be easier to treat. The septic wastewater does, however, have a higher potential for generating odors and can cause corrosion in collection system structures. Due to the anaerobic nature of the effluent, STEP systems are not typically utilized where a conventional treatment facility exists or is proposed to provide treatment. Also for this reason, STEP systems may tend to experience more odor nuisance problems.

STEP systems require periodic pump outs to remove accumulated solids (septage) and grease from the septic tank to protect the effluent pumps. The removed solids must be conveyed for disposal to an approved facility. The recommended pump out interval varies widely within the industry but the *Water Environment Federation Manual of Practice FD-12, Alternative Sewer Systems* states that for residential systems, the septage is typically removed at an interval of approximately five to ten years, depending on system usage. This interval is more frequent for certain commercial establishments.

STEG Systems

STEG systems work on the same principle as conventional gravity sewers. That is the wastewater is conveyed through the sewer pipeline by gravity. The small diameter gravity sewer does not, however, conform to a continuous downward sloping grade, instead generally following the ground contours with both upward and downward sloping sections. Actual flow in the small diameter gravity sewer therefore varies between pressurized conduit flow and open channel (gravity pipe) flow. The small diameter gravity sewer discharges into either a conventional gravity interceptor or a pump station.

Like STEP systems, the STEG systems utilize a septic tank at each individual home to collect and retain solids, which could clog the small sewer lines. The main design requirement for these systems is that each individual home septic tank discharge be located at an elevation sufficiently above the sewer outlet to induce flow in the sewer line (above the hydraulic grade line for the sewer). For this reason they are dependent on the terrain in the area, although somewhat less so than conventional gravity sewers. Because the hydraulic grade line is critical in the design of STEG systems, detailed survey data typically associated with a final design is required to properly analyze the potential extent of a STEG system.

STEG systems have the pipeline cost advantages of low-pressure or STEP systems (i.e. small pipe, shallow installation depth and narrow trench widths). They have the additional advantage, however, of not requiring pumping for conveyance of the wastewater. Therefore STEG systems are less costly to construct, operate and maintain. Unfortunately, due to topography of the service area, STEG systems are often not feasible where low-pressure and STEP systems would be. Also, in many areas where STEG systems are feasible, conventional gravity sewers are also feasible, and are usually recommended.

Centralized vs. Decentralized Treatment

Task 3 was performed in parallel to Task 2, following the same general approach to preliminary design. A significant difference with the layout of this system, however, was the need to determine the number and location of treatment and disposal sites. Under Task 2 it was pre-determined that one centralized treatment facility would be located at the Tri-Town Septage Treatment Facility. A major consideration under Task 3 was to determine the appropriate conceptual approach to wastewater treatment, specifically one ‘centralized’ treatment facility versus multiple ‘decentralized’ treatment facilities.

Research indicates that most STE installations are in independent cluster developments or targeted areas in urban and suburban areas. Although there are some large STE systems (comparable in size to the Orleans core program) with one centralized treatment plant in place, our experience is that in general, STE systems are typically smaller, more manageable systems with shallow, small diameter pipe, low horsepower effluent pumps, and limited municipal pump stations. The larger the service area, the larger and more complex the STE system and components become.

Another consideration is the length of transmission lines and the effects of odor and corrosion on the lines. As previously discussed, the septic wastewater associated with an STE system has a higher potential for generating odors and can cause corrosion in collection system structures. The issues of odor and corrosion are more easily mitigated with the shorter distance from source to treatment associated with decentralized treatment options.

From the standpoint of cost, it is safe to say the capital and operation and maintenance cost of treatment will be cheaper with one facility and discharge area as opposed to multiple sites throughout town. The collection system itself, however, would be more costly under a centralized STE scenario as the pipes and pumps would get larger and the hydraulic complexity of the system would increase.

In our opinion, a centralized STE system will get away from the concepts of “small pipe” typically associated with these systems. For this reason and the reasons discussed above, we recommended and moved forward with a decentralized approach to wastewater treatment in conjunction with the STE collection system.

Preliminary Design

The final recommended layout of the decentralized STE wastewater collection system is depicted in Figure 4-1. A detailed breakdown of the steps taken and data compiled during the preliminary design, including critical criteria and/or assumptions used in developing the layout is as follows:

- The CWMP developed one decentralized treatment option for the final evaluation of the three (3) best composite wastewater plans. To make best use of available information, that option (Plan 1 – Figure 6-3) was used as a starting point for layout of an STE system. This plan identified the following sites as suitable wastewater treatment sites, effluent disposal sites, or both:

<u>Wastewater Treatment Sites</u> –

- Site 163 – Private property

<u>Effluent Disposal Sites</u> –

- Site 112 – Town-owned property
- Site 172 – Private property
- Site 173 – Private property
- Site 181 – Private property
- Site 322 – Town-owned property

<u>Both</u> –

- Site 241 – Existing septage treatment facility site (Town-owned property)
- Site 111 – Private property
- Site 321 – Private property

- Further analysis of the potential treatment and disposal sites revealed the following:
  - Site 111, although viable for location of a treatment plant, was no longer acceptable as an effluent disposal site based on its proximity to Meetinghouse Pond.
  - Site 321, based on its location in relation to the service area, did not present itself as a logical site for a treatment facility.
- Based on this additional information, the proposed STE system was broken into three decentralized wastewater treatment facilities, each with one or more effluent disposal sites as follows:
  - Site #163 – Effluent Disposal Sites #172, #173, and #181
  - Site #111 – Effluent Disposal Sites #112, Site #321, and #322
  - Site #241 – its own Effluent Disposal Site

Table 4-1 is a summary of the projected wastewater flows to each of the three decentralized wastewater treatment facilities:

Table 4-1
Treatment and Disposal Site Wastewater Flow Limits

TREATMENT SITES	DISPOSAL SITES (1)
<u>Site #163</u> – • 165,000 gpd Average Daily Flow • 330,000 gpd Maximum Daily Flow	Site #172 – 140,000 gpd Site #173 – 50,000 gpd Site #181 – 140,000 gpd
<u>Site #111</u> – • 230,000 gpd Average Daily Flow • 460,000 gpd Maximum Daily Flow	Site #112 – 75,000 gpd Site #321 – 235,000 gpd Site #322 – 150,000 gpd
<u>Site #241</u> - • 150,000 gpd Average Daily Flow • 300,000 gpd Maximum Daily Flow	Site #241 – 300,000 gpd

(1) *– Source: Table 5-5 of the CWMP*

The wastewater treatment plant sites and the effluent disposal sites were also screened by Weston & Sampson for environmental, human, and hydrogeological constraints. Based on certain assumptions, all treatment plant sites and effluent disposal sites were determined capable of handling the flows presented in Table 4-1. Refer to Appendix D for additional information.

- Having identified the proposed treatment sites and corresponding disposal sites for the decentralized system, the base map of the project area that was used for the centralized option presented in Section 3 was also used as the starting point for this alternative. Again, the base map included 4-foot contours that were interpolated to 2-foot contours. Although adequate to prepare a preliminary design of the proposed STE collection system, additional survey with more accurate contour lines will be required for final design, especially for development of hydraulic grade lines in conjunction with the proposed STEG systems.

- A big component of the CWMP is meeting total maximum daily loads (TMDLs) with regard to the watersheds. Of particular concern on Cape Cod is nitrogen loading and its impacts on the coastal resource areas. Considering that the centralized hybrid system included one discharge site, the entire discharge was to one watershed. Due to the multiple discharge sites in three different watersheds under the decentralized STE system and the need to maintain TMDLs for nitrogen, the service area of this alternative was modified consistent with Plan 1 – Figure 6-3 of the CWMP to maintain total required nitrogen removal levels in each of the watersheds. The modified service areas are identified on Figure 4-1.

- Utilizing the centralized hybrid collection system layout, we started our layout by assuming that all gravity sewers could become STEG systems and all low-pressure sewers would become STEP systems. In some cases, however, it was more cost-effective to eliminate a pump station and convert a tributary area to STEP systems rather than a STEG system with a pump station. Based on this criteria, we initially identified eight STEG system tributary areas with eight pump stations throughout the project area and 15 STEP system tributary areas. As we "fine-tuned" the proposed design, we eliminated two pump stations and changed those tributary areas from STEG to STEP based on the limited number of lots being served in the tributary area. The final conceptual decentralized STE collection system layout was based on 17 STEP system tributary areas and six (6) STEG system tributary areas.

- Based on their location in the project area, the amount of flow each wastewater treatment facility could handle, and the amount of flow each effluent disposal site could handle, the STEP and STEG areas were directed to one of the following three wastewater treatment sites– Site #163, Site #111, and Site #241, as presented in Tables 4-2 and 4-3.

- Similar to the centralized option, we then determined the following information on a street by street basis for each of the STEP/STEG tributary areas in the overall project area:

    - Approximate length of gravity STEG sewer

- Approximate length of low-pressure STEP sewer
- Number of houses
- Number of vacant lots
- Approximate number of on-lot STEP units

- Once the number of houses and vacant lots were tabulated for each STEG and STEP area, it was necessary to calculate the sizes of the STEG and STEP mainline pipes. Low-pressure STEP sewer systems typically range in size from 1 ½- to 4-inches in diameter.

  In order to determine the pipe sizes for the low-pressure STEP sewer system component of the decentralized collection system as shown on Figure 4-1, we used the following criteria from *Orenco Systems, Inc.'s* Effluent Sewer Design Manual:

  - Less than 100 lots served = 1 ½-inch pipe
  - 100 to 500 lots served = 2-inch pipe
  - Over 500 lots served = 4-inch pipe

  According to *Alternative Sewer Systems – WEF Manual of Practice No. FD-12*, *2nd edition*, the most commonly used minimum pipe size for STEG systems is 4-inch. For the STEG sewer system pipe sizing, we used this information from *Alternative Sewer Systems* and the following criteria similar to Orenco Systems, Inc.'s criteria for STEP pipe sizes:

  - Less than 100 lots served = 4-inch pipe
  - 100 to 500 lots served = 6-inch pipe
  - Over 500 lots served = 8-inch pipe

  All of the low-pressure STEP sewer system branches and STEG sewer system branches, as shown on Figure 4-1, were independently examined based on the number of lots along each branch and where it discharged (i.e – directly to another STEP or STEG system or into another branch of a STEP sewer before discharging to a STEG system) to determine the pipe sizes.

  Appendix E and Tables 4-2 and 4-3 present a summary of the STEP and STEG pipe sizes, lengths and which wastewater treatment facility each STEP/STEG system is tributary to.

- The following is a summary of the STEP and STEG components of the decentralized wastewater collection system:

  - Approximately 237,000 lf of low-pressure STEP sewers
    - Approximately 215,000 lf of 1 ½-inch pipe
    - Approximately 22,000 lf of 2-inch pipe
  - Approximately 240 cleanout structures (in-line and terminal)
  - Approximately 2,300 on-lot STEP units

  - Approximately 80,000 lf of gravity STEG sewers
    - Approximately 58,000 lf of 4-inch pipe

        - Approximately 20,000 lf of 6-inch pipe
        - Approximately 2,000 lf of 8-inch pipe
    - Approximately 85 cleanout structures (in-line and terminal)
    - Approximately 230 on-lot STEG tanks
- Information included in Appendix E was used to estimate the size of the discharge force mains and the types of pump stations. The following is a summary of the six pump station and force mains necessary for the STEG systems under the decentralized wastewater collection system:

    - 2 submersible pump stations
    - 3 self-priming pump stations
    - 1 custom pump station
    - Approximately 21,000 lf of force mains between 4- and 12-inches
        - Approximately 7,000 lf of 4-inch force main
        - Approximately 2,000 lf of 6-inch force main
        - Approximately 4,000 lf of 8-inch force main
        - Approximately 8,000 lf of 12-inch force main
    - Approximately 45 force main cleanout manholes
        - Cleanout manholes are typically installed every 500-feet along the force main route

- Figures 4-2, 4-3, and 4-4 present schematic flow diagrams of each wastewater treatment site, the STEP and STEG systems (including pump stations) that are tributary to the treatment sites, and the effluent disposal sites.

4.2 Treatment & Disposal Systems

Similar to the centralized option under Task 2, Weston & Sampson has provided preliminary design information for proposed decentralized WWTFs and their associated effluent disposal systems, to be located as shown on Figure 4-1 and as described above.

Decentralized wastewater systems consist of an on-site or cluster-type wastewater system that is used to treat and dispose of relatively small volumes of wastewater, generally originating from individual or groups of dwellings and/or businesses that are in close proximity to one another. Some of the reasons for developing decentralized wastewater systems, as opposed to centralized system as described in Task 2, are:

- Allows for different technologies to be used at different locations, instead of a one-size fits all treatment facility (i.e.: residential wastes vs. commercial/industrial)
- Allows for phasing of construction so that system costs increase over time to match growth
- Provides for primary treatment at the individual residences by the use of septic tanks
- Avoids a large transfer of water from one watershed to another
- Allows for installation of smaller diameter piping to convey septic tank effluent

Some commonly discussed disadvantages of decentralized wastewater systems are:

- The community needs to inspect and maintain numerous STEP pumps (in areas where STEG is not feasible)
- Conventional gravity sewers aerate wastewater to a degree, and convey raw wastewater which has not gone septic. Septic tank effluent pumping systems convey an already septic fluid, and maintain this flow in an oxygen free environment. When the septic tank effluent is discharged to open tankage sulfides are released creating a subsequent odor release.
- High sulfide concentrations create corrosive atmospheres in wastewater process tankage and can reduce the useful life of the equipment.

Most of the wastewater in the proposed service area is domestic, therefore it is not necessary to implement different treatment technologies for different portions of the service area. Once again, we investigated Sequencing Batch Reactor (SBR) and Membrane BioReactor (MBR) technologies, each of which are biological processes that will provide treated effluent of a quality consistent with groundwater discharge requirements, including a target nitrogen effluent limit of 3mg/l. As with the centralized system we concluded that, while both technologies provide the level of treatment required to achieve project goals, the SBR technology is more attractive because it has a lower life cycle cost and provides greater operational flexibility.

We are also recommending the same technology for each of the three proposed decentralized treatment sites because of operational efficiencies. Three similar plants will have similar operating requirements, and use the same mechanical equipment. This makes managing spare parts and maintenance less difficult, and training for operations much simpler. All of these factors should result in lower operating costs to the community.

Please not that for this option, septic tanks will still be in use. While septic tank effluent will be collected, treated and disposed of at designated sites, solids will still collect in each septic tank, at each residence. Orleans will still need to maintain some form of septage collection and treatment system. For this option, we have assumed that septage will still be collected as it has been, and will still be treated at the Tri-Town Septage Treatment Facility. Because the same number of homes in the community will still have septic tanks, we anticipate that the septage treatment facilty will have the same operational requirements, as well as related operational costs. A second treatment facility, for septic tank effluent only, is proposed for the same site as one of the three decentralized treatment plants. This treatment facility will treat septic tank effluent, collected from the northwestern segment of the overall service area.

For this conceptual design we propose the following sequence of treatment processes at each decentralized facility to achieve the target effluent quality:

1. SBR (biological treatment)
2. Methanol addition (at the SBR) as a carbon source for biological nitrogen removal
3. Effluent equalization
4. Pressurized UV disinfection

As noted above, the existing septage treatment facility will need to be maintained to handle the current septage load. Costs to upgrade this facility and extend it's useful life were provided in the CWMP and have been included in our cost analysis. We have assumed that the operation and maintenance budget for the existing septage treatment facility will remain valid.

The conceptual flow diagrams and site plans are shown on Figures 4-5 thru 4-14 as follows:

- Figure 4-5 Flow Diagram for Decentralized WWTF Option
- Figure 4-6 Site 241 Conceptual Design – Decentralized STE Treatment Facility
- Figure 4-7 Site 163 Conceptual Design – Decentralized STE Treatment Facility
- Figure 4-8 Site 172 – Conceptual Discharge Configuration
- Figure 4-9 Site 173 – Conceptual Discharge Configuration
- Figure 4-10 Site 181 – Conceptual Discharge Configuration
- Figure 4-11 Site 111 Conceptual Design – Decentralized STE Treatment Facility
- Figure 4-12 Site 112 – Conceptual Discharge Configuration
- Figure 4-13 Site 321 – Conceptual Discharge Configuration
- Figure 4-14 Site 322 – Conceptual Discharge Configuration

Final effluent discharge at Site 241 will be to rapid infiltration basins, as with the centralized hybrid option. All other discharge sites identified above are proposed to involve subsurface leaching due to the residential location of the discharge sites.

4.3 STE System Experience (Pending)

5.0 TASK 4

Under Task 4, a public presentation was conducted at the February 15, 2012 Board of Selectmen's meeting. The purpose of this presentation was to summarize the two preliminary engineering design options and demonstrate they had progressed sufficiently in detail to proceed to the cost estimating phase.

This was the first opportunity to present design bases for the centralized plan and STE technology to the Town. This presentation emphasized the equivalence between the two main options, including refinement of the centralized option to reflect a hybrid sewer system layout and determination to employ a decentralized approach to the STE option.

A complete copy of the PowerPoint presentation from the February 15th meeting is included in Appendix A.

6.0 TASK 5

Upon completion of the preliminary layouts of the two alternatives (centralized hybrid and decentralized STE), Task 5 involved developing comprehensive cost estimates for each of the two design options considered.

As with Tasks 2 and 3, in preparing the cost estimates, we separated our analysis into the two basic elements of wastewater management: 1) collection; and 2) treatment and disposal.

6.1 Collection System

Table 6-1 below presents a summary of the main components of the two proposed collection systems examined in this report.

Table 6-1
Comparison of Proposed Collection System Alternatives

	CENTRALIZED HYBRID COLLECTION	DECENTRALIZED STE COLLECTION
Properties Served –	2,830	3,080
Linear Feet of Pipe –	341,000 lf	338,000 lf
Total Number of Pump Stations and Types –	19	6
Large Stations:	1	1
Medium Stations:	5	3
Small Stations:	13	2
On-Lot Pump System:	1,100 grinder pumps	2,300 STEP pumps

Cost Drivers

As previously discussed, the linear nature of a collection system leads to significant cost implications in the overall wastewater management process. Factors that affect the costs of such projects include:

- Size and Depth of Pipe
    - Number of manholes/structures
    - Number of pump stations
    - Number of individual on-lot pumps/STE systems
- Subsurface Conditions
- Method of Installation
- Surface Restoration
- Public Safety
- Land Acquisition and Legal Assistance

In addition to pipe size, depth, and appurtenances, which have been previously calculated for both alternatives, one of the most important cost drivers impacting the construction of any wastewater collection system is the existing subsurface conditions. Because this project is in the preliminary design stage, geotechnical investigations (i.e. – soil borings/probes/rock cores) were not performed. Such investigations would, however, be necessary during final design. In order to evaluate the existing subsurface conditions at this time, we relied on soil conservation maps and, most importantly, local knowledge of the town. We met with town representatives from the health department, water department and highway department to gain their knowledge and understanding of areas in town where ledge, unsuitable soils, high groundwater, etc. were present. We also discussed existing underground utilities and where open corridors in streets may be available for new sewers.

The method of construction is also a contributing factor to the overall cost of a project. For both of the alternatives, we investigated the possibility of utilizing trenchless technologies (i.e. - horizontal direction drilling) for the installation of the low-pressure and STEP sewers instead of conventional open-cut methods. Horizontal directional drilling is most effective for the installation of long lengths of pressure pipe in non-congested areas where there are limited existing underground utilities and limited service connections required. Under each of the alternatives discussed herein, while the mainline can be installed by trenchless construction methods, it would still be necessary to excavate by standard open-cut methods to connect the service connections to the mainline. Due to the number of houses on each street, we determined that in the majority of streets, it would not be cost-effective to install the mainline by trenchless methods since multiple excavations would still be required to cut in the service connections.

We also explored the option of using the shoulders of the roads instead of the centerlines, thereby minimizing or eliminating pavement replacement requirements. Based on our discussions with the town, most of the road shoulders are already occupied by another utility (i.e. – water, gas, drain, telephone, etc.). According to the water department, most water mains in town are "right along the curb line or just under the edge of the road." Therefore, for the purposes of our preliminary design, we have assumed that all sewers (under both options) will be installed with open cut methods beneath the paved surface of the roads.

Another major factor that impacts costs is the final surface restoration of the streets (i.e. – pavement replacement within the town roads, including private ways, and state highway) within the project area. As part of our windshield survey for the project, we identified all of the existing paved roads and the existing gravel/dirt roads in town. Also, there are two state highways within the project area – Route 28 (South Orleans Road) and Route 6A. These streets are under the jurisdiction of the MA Department of Transportation (MADOT) and subject to their requirements for trench and surface restoration. In our meeting with the Orleans highway department, we determined the town's surface restoration requirements. The following is a summary of these discussions and the state highway requirements:

- Due to the need to meet line and grade and the subsequent depth and trench width, gravity sewers (including STEG systems) in town roads (including private ways) would be installed in the center of the road and would require temporary trench pavement, 2-inch trench-width binder pavement and 1 ½-inch full width curb-to-curb top course pavement.

- Due to the ability to maintain narrow trench widths, it was assumed that low-pressure sewers (including STEP systems) and force mains in town roads (including private ways) would be trench patched in lieu of full width resurfacing. This would entail temporary trench pavement, 2-inch trench-width binder pavement and 1 ½-inch trench-width top course pavement.

- Any sewer in a gravel/dirt road would be restored to its previously existing condition (i.e. – pavement not required).

- Any sewer in the state highway would require:

    - Control density fill (CDF) as trench backfill to within seven inches of the existing ground surface. It should be noted that if during the final design, the MADOT granted a waiver of this requirement, the town could save significant money.
    - 4-inch trench-width black base pavement course
    - 1 ½-inch trench-width binder course
    - 1 ½-inch trench-width top course

One of the largest expenses in any construction project is related to public safety (i.e. – police details). Therefore, as part of our investigations, we met with Scott W. McDonald, Deputy Chief of Police, to determine the town's requirements for police details on construction jobs. Based on these discussions, the following requirements were used in determining the cost for police details:

- State Highway – assume 3 police officers per day
- Town Roads – assume 2 police officers per day

The total opinion of probable cost for each option was calculated based on the following format:

- Construction Costs for Public Way Infrastructure
- Construction Costs for Private (On-Lot) Infrastructure
- Design, Permitting, and Construction Services Costs
- Contingency Costs
- Police Detail Costs
- Land Acquisition and Legal Assistance Costs

Tables 6-2 and 6-3 present the overall opinion of probable cost for each of the preliminary sewer layouts. Hand calculation sheets of specific quantity take-offs are included in Appendix F. In addition to the information presented above, a detailed breakdown of the steps taken and data compiled during the cost estimating process, including critical criteria and/or assumptions used in developing the estimates, is as follows:

<u>Public Way Costs</u>

- In determining the unit prices for all of the items presented in Tables 6-2 and 6-3, we relied on similar construction projects in the Massachusetts communities of Chatham, Scituate, Chelmsford, and Essex. Copies of bid tabulations from these projects are included in this report as Appendix G.

- All quantities for gravity sewers, low-pressure sewers, STEG sewers, STEP sewers, force mains, pump stations, and respective appurtenances (wye/tee branches, manholes, cleanout structures, etc.) within the public way were calculated and previously presented in the tables in Sections 3 and 4 of this report.

- In order to determine an estimated amount of rock excavation and disposal, the following parameters were used:

- For gravity sewers less than 12-feet deep, approximately 50 cubic yards (cy) of rock for every 1,000 linear feet (lf) of gravity sewer.

- For gravity sewers greater than 12-feet deep, approximately 100 cy of rock for every 1,000 lf of gravity sewer.

- For low-pressure sewers, STEG sewers and STEP sewers, approximately 25 cy of rock for every 1,000 lf of sewer.

- Based on our discussions with town representatives, the Finlay Road area of Orleans was identified as an area where there was known high amounts of ledge/rock. Streets in this area included Finlay Road, Kettle Pond Way, Daley Terrace, Nickerson Road, Commerce Drive and Lots Hollow Road. For both the hybrid collection system alternative and the STE alternative, we calculated the total footage of sewer along these streets and calculated the total volume of trench work. For gravity sewers, we estimated the trench dimensions to be 5-feet wide by 10-feet deep; for low-pressure sewers, STEG sewers, and STEP sewers, we estimated the trench dimensions to be 4-feet wide by 6-feet deep. Based on the total volume of trench calculated, we then estimated that a total of 25% of all trench volume in these areas would be ledge/rock. This additional quantity of rock was added to the respective rock excavation and disposal items in Tables 6-2 and 6-3 (also see Appendix F).

- In order to estimate the amount of unsuitable material within the trench limits for the two alternatives, we again relied on the knowledge and information gathered from our meeting with town representatives. Based on our discussions, the following areas of Orleans were identified with potentially unsuitable subsurface material (i.e. – clay, peat, etc.):

  - <u>Tributary Area to Pump Station #12/STEG #8</u> (Route 6A, South Orleans Road (Route 28), Old County Road) – According to the town, there are high amounts of peat in this area. Therefore, for both alternatives, we estimated that 100% of the soils (in cy) in this area would be unsuitable and need to be replaced within the trench limits.

  - <u>Tributary Areas to Pump Station #13/STEP #7/STEG #3</u>; <u>Tributary to Pump Station #14/STEP #9/STEG #4</u>; <u>Tributary to Pump Station #18/STEP #8</u> – According to the town, there are high amounts of clay in this area. Therefore, for both alternatives, we estimated that 50% of the soils (in cy) in these areas would be unsuitable and need to be replaced within the trench limits.

- Similar to our estimates for rock excavation and disposal, the trench limits for gravity sewers were estimated to be 5-feet wide by 10-feet deep and the trench limits for low-pressure sewers, STEG sewers and STEP sewers were estimated to be 4-feet wide by 6-feet deep.

- Quantities for pavement replacement (local streets and state highway) were based on the linear footage of sewers, force mains, and effluent disposal lines in each street. A street listing that identified all town roads, private roads, scenic roads, and state highways, was provided by the town. The breakdown of paving requirements that were used to generate our pavement quantities was previously presented herein in accordance with our discussions with the Orleans highway department.

- Lengths of building service connections (gravity and low-pressure) within the existing town right-of-ways were estimated based on the number of properties being served in each of the two alternatives multiplied by an average of 25-feet per building connection.

- As shown on Figure 3-1 and Figure 4-1, there are two crossings of Route 6 in each alternative. For each crossing, we will be installing force main(s)/low-pressure sewer under Route 6 – one from the Rock Harbor Road area to Pump Station #11 and one for the force mains from Pump Station #8 and Pump Station #10 to the new wastewater treatment facility at the existing septage treatment facility site. It is assumed that trenchless technologies (i.e. horizontal directional drilling) will be utilized for these crossings. Estimates for this special construction have been included in the opinions of probable costs (Tables 6-2 and 6-3).

<u>On-Lot Costs</u>

- Opinions of probable costs for work on private (on-lot) infrastructure included quantities and unit prices for:

    - 1 ½-inch pressure building connections for grinder pumps and STEP systems
    - 4-inch building connections for STEG systems
    - 6-inch building connections for gravity sewers
    - Estimated number of grinder pump units
    - Estimated number of STEP tanks
    - Estimated number of STEG tanks
    - Allowances for electrical upgrades to accommodate new grinder pumps and STEP pumps were also included.

- The following assumptions were used to determine the quantities within the private (on-lot) infrastructure:

  - Assumed 85% of the total number of properties in each alternative (hybrid collection system and STE system) will be setback from the road between 100- and 200-feet. For these properties, we assumed 150-feet per building connection.

  - Assumed the remaining 15% of the total number of properties in each alternative (hybrid collection system and STE system) will be setback from the road between 300 and 700-feet (based on observations from our windshield survey). For these properties, we assumed 500-feet per building connection.

    - For example, in the hybrid collection system – 15% of 2,830 total properties is approximately 425 properties.

  - In general, we further assumed that 5% of the gravity connections for both the conventional gravity service connections (i.e. – 6-inch pipe) and STEG service connections (i.e. -4-inch pipe) would require long gravity service connections.
    - For example, in the hybrid collection system – 5% of 1,780 gravity-served properties is approximately 89 properties which was rounded up to 100 properties. Therefore, approximately 100 of the gravity-served properties would be setback from the road between 300- and 700-feet. Of these 100 properties, we assumed that at least 50% would require a grinder pump based on the length of the service connection. Therefore, under the hybrid collection system option, the estimated length of the gravity building connections was calculated as follows:

      - Approximately 1,730 properties will require 150-feet of service connection per property
      - Approximately 50 properties will require 500-feet of service connection per property

    - Based on the above paragraphs for the hybrid collection system, of the total 425 properties with setbacks between 300- and 700-feet, the 325 remaining properties (425 total properties–100 long gravity-served properties=325 long pressure building connections) will require long pressure building connections. An additional 50 gravity-served properties will require a grinder pump and pressure building connection. Therefore, there will be a total of 375 properties with long pressure building connections. Therefore, under the hybrid collection system option, the estimated length of the pressure building connection was calculated as follows:

- Approximately 725 properties will require 150-feet of service connection per property
- Approximately 375 properties will require 500-feet of service connection per property

- The same procedure as described herein for estimating the private on-lot building connections under the hybrid collection system alternative was used for estimating the on-lot building connection quantities for the STE collection system alternative. The following is a summary of the private on-lot building connections under the STE collection system alternative:

  - Approximately 710 STEG-served properties will require 150-feet of service connection per property
  - Approximately 25 STEG-served properties will require 500-feet of service connection per property
  - Approximately 1,860 STEP-served properties will require 150-feet of service connection per property
  - Approximately 430 STEP-served properties will require 500-feet of service connection per property

- As presented in Table 6-1, there will be 1,100 grinder pump units under the hybrid collection system alternative and 2,300 STEP pump tanks under the decentralized STE collection system alternative. For electrical system upgrades, we assumed the following:

  - Approximately 25% of the properties receiving a grinder pump unit will require upgrades to their existing electrical system.
  - Approximately 10% of the properties receiving a STEP pump will require upgrades to their existing electrical system.
  - A higher percentage of electrical upgrades was used for the grinder pump units since larger pumps with higher horsepower are required under this alternative.

- The interceptor tanks themselves pose many issues/considerations for the Town:

  - Precast concrete tanks seem to be the most common used in these systems, primarily because they are generally cheaper. Polyethylene and fiberglass tanks are lighter in weight and, therefore, tend to be easier to install but proper bedding and antiflotation measures are required. For this report, we have assumed the use of 1,500 gallon concrete tanks.

- The tanks must be water-tight so as not to be a source of I/I.

- A major cost issue is the consideration to reuse some or all of the existing septic tanks with installation of STEP and STEG systems.

    - According to *Alternative Sewer Systems – WEF Manual of Practice No. FD-12, 2nd edition*, "The use of existing septic tanks has seldom been successful. Because of age, poor construction, poor installation, or homeowner abuse, existing septic tanks have proven to be one of the most significant sources of infiltration and inflow in effluent sewer systems. Unless a particular tank is known to be well-designed and manufactured, installed by a reputable installer, and effectively tested for water-tightness, it is better to replace the tank than risk it becoming a significant source of infiltration and inflow. In turn, replacement tanks should be prequalified for their structural strength and water-tightness and be tested during installation."

    - Replacement of all tanks results in costs as follows:

        - STEP - 2,300 X $8,000 = $18,400,000
        - STEG – 780 X $6,000 = $4,680,000
        - Total cost of replacement = $23,080,000

    - Understanding the significant cost implications of replacing all of the tanks, additional analysis was performed to determine a recommended course of action:

        - We worked with Board of Health staff to compile data from a representative sample of files.

            - 338 files were reviewed
            - 49 Cesspools were identified (14.5%)
            - 157 tanks were installed prior to 1995, under the 1978 Title 5 code (44%)
            - 125 systems installed under the 1995 code with minimum 1,500 gallon tank (37%)
            - 74 of the 1,500 gallon tanks installed under the 1995 code were installed between 1995 and 2005 (59%)

        - Assuming that all cesspools and 1,000 gallon tanks installed under the 1975 code will need to be replaced, 37% of the files reviewed could be considered for re-use in the new system.

- Extrapolating this over the entire project area, we could assume that 1,140 tanks could be considered for re-use (3,080 X .37).

- As part of the consideration, each tank would need to be inspected to confirm watertightness. This cost is estimated at $500 per tank, including a pump out and visual on-site inspection by Town staff, for a total cost of $570,000 (1,140 X 500).

- Assuming 75% of the tanks pass the inspection, that would leave 855 tanks that could be re-used.

- Considering that 75% of the tanks would need to be converted to STEP tanks (2,300 STEP tanks/3,080 total tanks), 641 tanks (855 X .75) would need to be retrofitted with pumps and effluent screens at an estimated cost of $3,000 per tank (including system pump out, construct baffle wall, install and hook up pump, install effluent filter) for a total cost of $1,923,000.

- The remaining 214 STEG tanks would need to be retrofitted with effluent screens at an estimated cost of $700 (including pump out and effluent filter installation) per tank for a total cost of $149,800.

- Based on the above assumptions, the total cost savings of re-using some of the tanks is estimated as follows:

    - 1,659 new STEP tanks @ $8,000 each = $13,272,000
    - 566 new STEG tanks @ $6,000 each = $3,396,000
    - Inspections = $570,000
    - 641 retrofitted STEP tanks = $1,923,000
    - 214 retrofitted STEG tanks = $149,800
    - Total cost = $19,310,800
    - Total savings = $23,080,000 - $19,310,800 = $3,769,200

- Considering that the cost of replacing the re-used tanks at some later date would need to be included in the life cycle cost analysis, we recommend that the Town consider replacement of all tanks as part of the construction project.

- As previously discussed, the recommended pump out interval varies widely within the industry but the *Water Environment Federation Manual of Practice FD-12, Alternative Sewer Systems* states that for residential systems, the septage is typically removed at an interval of approximately five to ten years, depending on system usage. This interval is more frequent for certain commercial establishments. For this analysis, we have assumed a pump out interval of seven (7) years.

Police Details

- As previously discussed, the following requirements were used in determining the cost for police details:

    - State Highway – assume 3 police officers per day
    - Town Roads – assume 2 police officers per day

- Based on the current hourly rates for the Orleans police (plus a 10% administrative fee), the cost for one police officer is approximately $400 per day.

- For each alternative, we estimated the approximate number of days of construction (both in the state highway and in town roads) based on assumed construction rates. Tables 6-4 and 6-5 present the estimated daily production rates and estimated time of construction for each alternative.

- Depending on the location of work, the number of days was multiplied by the number of officers per day and multiplied by $400 per officer. An additional 10% contingency was also added to the estimate. The following is a summary of the estimated police costs for both alternatives.

    - **Hybrid Collection System** –
        - State Highway – 527 days x 3 officers/day x $400/officer = $632,400
        - Town Roads – 3,845 days x 2 officers/day x $400/officer = $3,076,00
        - Total = $3,708,400 x 1.10 = $4,079,240
        - Assume $4.1 million

    - **Decentralized STE Collection System** –
        - State Highway – 334 days x 3 officers/day x $400/officer = $400,800
        - Town Roads – 2,970 days x 2 officers/day x $400/officer = $2,376,000
        - Total = $2,776,800 x 1.10 = $3,054,480
        - Assume $3.1 million

Easements/Land Takings

- During the preliminary design of both options, we identified the proposed pump station locations. Under the centralized hybrid collection system, we identified 19 proposed pump station locations while under the decentralized STE collection system we reduced the pump stations down to 6 locations. Whenever possible, we chose town-owned land to minimize the cost of land acquisition. If a pump station was located on private property, we estimated a cost for the land acquisition based on current land values obtained from the Orleans Assessors office, the total value of the land per square foot, and square footage required for the pump station.

- Table 6-6 presents the estimated land acquisition costs for the proposed pump stations in the centralized hybrid collection system. Additional costs associated with the land takings include land surveyor fees, easement plan preparation, recording fees at the registry of deeds, pump station site stakeout, and legal fees. For the purposes of our preliminary design, we estimated a cost of $5,000 per pump station and included an additional 25% contingency for additional fees.

- In addition to the pump station land takings, there are perpetual easement and public access requirements for town appurtenances on private property (i.e. grinder pumps and interceptor tanks) assuming the Town chooses to own, operate, and maintain these units. The cost of acquiring these easements can be accomplished several ways with varying cost implications. For example, the Town could do a blanket easement town-wide at very low cost, depending upon advice of legal counsel. For this report, we have assumed a nominal cost of approximately $200 per property, which translates to total cost of $220,000 for the homes on grinder pumps (1,100 X $200).

- Therefore, the total land and legal costs associated with the pump stations and grinder pumps under the centralized hybrid collection system, as presented in Table 6-2, is:

    - Pump Station Land Acquisition = approximately $160,000
    - Additional land and legal costs – 19 pump stations x $5,000/pump station = $95,000
    - Contingency = 25% of $255,000 = approximately $64,000
    - Grinder Pump Easements = $220,000
    - Total = approximately $540,000

- Table 6-7 presents the estimated land acquisition costs for the proposed pump stations in the decentralized STE system. Additional costs associated with the land takings again, include land surveyor fees, easement plan preparation, recording fees at the registry of deeds, pump station site stakeout, and legal fees. Utilizing the same cost parameters as above, the total land and legal costs associated with the pump stations and interceptor tanks under the decentralized STE collection system, as presented in Table 6-3, is:

    - Land Acquisition = approximately $41,000
    - Additional land and legal costs – 6 pump stations x $5,000/pump station = $30,000
    - Contingency = 25% of $71,000 = approximately $18,000
    - Interceptor Tank Easements = $616,000
    - Total = approximately $700,000

- Appendix F includes copies of the current land values, obtained on-line from the Orleans Assessors Office website, for each of the proposed pump station locations.

- Table 6-7 also presents the estimated land acquisition costs for the proposed wastewater treatment facilities (Site #163 and Site #111) as well as the associated effluent disposal sites, which are discussed further in Section 6.2 below.

<u>Other Cost Considerations</u>

- Once the total opinion of probable construction cost was determined for each alternative, it was necessary to estimate a cost for the design, permitting, and construction services. Based on our experience, the cost for these services are typically approximately 25% of the total construction costs. Therefore, as presented in Tables 6-2 and 6-3, we included 25% of the total construction cost for engineering services.

- We also carried an additional 25% construction contingency for each alternative to account for additional costs that may arise during construction due to differing subsurface conditions, expanded scope, and other factors that could arise during the final design, permitting, and construction of the project.

Collection System Cost Summaries

Tables 6-8 through 6-12 below provide summaries of the collection system costs. The complete breakdown is provided in Tables 6-2 and 6-3 at the end of this Chapter.

Table 6-8
Collection System Capital Costs

	CENTRALIZED HYBRID	DECENTRALIZED STE
Public Way Infrastructure	$58,145,000	$36,070,000
Private On-Lot Infrastructure	$18,125,000	$33,078,000
Construction Contingency (25%)	$19,067,000	$17,287,000
Engineering Costs (25%)	$19,067,000	$17,287,000
Public Safety (Police Details)	$4,100,000	$3,100,000
Land and Legal Costs	$540,000	$700,000
TOTAL	**$119,044,000**	**$107,522,000**

Table 6-9
Public Way Infrastructure Costs

	CENTRALIZED HYBRID	DECENTRALIZED STE
Pipe and Appurtenances	$24,545,000	$16,096,000
Pump Stations and Force Mains	$12,605,000	$5,366,000
Subsurface Conditions	$3,861,000	$2,757,000
Surface Restoration	$14,365,000	$10,134,000
Mobilization	$2,769,000	$1,718,000
TOTAL	**$58,145,000**	**$36,070,000**

Table 6-10
Average Cost per Property Served (Public Way Infrastructure)

	CENTRALIZED HYBRID	DECENTRALIZED STE
Total Infrastructure Cost	$58,145,000	$36,070,000
Number of Properties	2,830	3,080
TOTAL	**$20,546**	**$11,711**

Table 6-11
Private On-Lot Infrastructure Costs

	CENTRALIZED HYBRID	DECENTRALIZED STE
Pipe and Appurtenances	$10,200,000	$9,825,000
Pumps/Tanks	$7,925,000	$23,253,000
TOTAL	**$18,125,000**	**$33,078,000**

Table 6-12
Average Cost per Property Served (Private On-Lot Infrastructure)

	CENTRALIZED HYBRID	DECENTRALIZED STE
Total Infrastructure Cost	$18,125,000	$33,078,000
Number of Properties	2,830	3,080
TOTAL	**$6,404**	**$10,740**

6.2 Treatment & Disposal Systems

Detailed information with regard to the costing of the WWTFs, including anticipated O&M costs, Equivalent Uniform Annual Costs (EUAC), and basis of design, are included in Appendix I – Tables 1 thru 17.

Tables 6-13 & 6-14 below provide summaries of the WWTF costs.

Table 6-13
Wastewater Treatment Cost Summary

	CENTRALIZED	DECENTRALIZED			
		Site #163	Site #111	Site #241	Total
Construction Subtotal	$16,155,000	$5,673,000	$6,321,000	$8,824,000	$20,818,000
Engineering, Permitting, Project Development	$4,039,000	$1,418,000	$1,580,000	$2,206,000	$5,204,000
Construction Contingencies	$4,039,000	$1,418,000	$1,580,000	$2,206,000	$5,204,000
Land and Legal	N/A	$800,000	$2,500,000	N/A	$3,300,000
TOTAL	**$24,240,000**	**$9,310,000**	**$11,990,000**	**$13,240,000**	**$34,540,000**

Table 6-14
Wastewater Treatment Construction Cost Breakdown

	CENTRALIZED	**DECENTRALIZED**		
		Site #163	Site #111	Site #241
Primary Treatment	$1.283,000	N/A	N/A	N/A
Septage Receiving	$693,000	N/A	N/A	N/A
Biological Treatment	$2,777,000	$1,548,000	$1,688,000	$1,548,000
Chemical Addition	$65,000	$35,000	$35,000	$35,000
Solids Handling	$424,000	$25,000	$25,000	$25,000
Disinfection	$260,000	$131,000	$131,000	$131,000
Pumping	$235,000	$321,000	$321,000	$321,000
Odor Control	$340,000	$50,000	$50,000	$50,000
Wastewater Effluent Disposal	$767,000	$1,013,000	$1,400,000	$270,000
Site Work	$2,588,000	$163,000	$163,000	$968,000
Miscellaneous Work	$3,702,000	$1,326,000	$1,326,000	$1,326,000
Update Septage Treatment Plant	N/A	N/A	N/A	$2,500,000
General	$3,021,000	$1,061,000	$1,182,000	$1,650,000

6.3 Total Costs & Life Cycle Analysis

Total estimated system costs are presented below in Table 6-15.

Table 6-15
Total Estimated System Capital Costs

	CENTRALIZED HYBRID	**DECENTRALIZED STE**
Collection System	$119,044,000	$107,522,000
Treatment Plant(s)	$24,240,000	$34,540,000
Total	**$143,284,000**	**$142,062,000**
Number of Properties	2,830	3,080
Capital Cost per Property	$51,000	$46,000

Operation and Maintenance

Anticipated annual O&M costs for the proposed collection systems can be found in Tables 6-17 & 6-18 at the end of this section. For the WWTFs, this information is included in Appendix I as Tables 2, 5, 8, and 11.

Table 6-18
Annual Operation & Maintenance Costs

	CENTRALIZED HYBRID	**DECENTRALIZED STE**
Collection System	$736,000	$654,000
Treatment Plant(s)		
Site #241	$1,216,000	$1,447,700
Site #163	N/A	$548,700
Site #111	N/A	$556,500
Total	**$1,960,000**	**$3,210,000**

Equivalent Uniform Annual Costs (EUAC)
Anticipated EUAC for the proposed collection systems can be found in Tables 6-19 & 6-20 at the end of this section. For the WWTFs, this information is included in Appendix I as Tables 3, 6, 9, and 12.

Table 6-21
Equivalent Uniform Annual Cost (EUAC)

	CENTRALIZED HYBRID	**DECENTRALIZED STE**
Collection System	$8,762,000	$7,914,000
Treatment Plant(s)	$1,790,000	$2,560,000
Operation & Maintenance	$1,960,000	$3,210,000
Total	**$12,512,000**	**$13,684,000**

7.0 TASK 6

Under Task 6, a public presentation was conducted at the April 18, 2012 Board of Selectmen's meeting to review the current status of the cost estimates developed under Task 5. This was the first opportunity to present the cost basis for the two plans to the Town.

A complete copy of the PowerPoint presentation from the April 18^{th} meeting is included in Appendix A.

8.0 TASK 7 (Pending)

Conduct a public presentation at a Board of Selectmen's meeting that details the draft final report and the Designer's recommended option.

9.0 TASK 8 (Pending)

Conduct a public presentation of the final report at a Board of Selectmen's meeting.

10.0 Conclusions & Recommendations (Pending)

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