Orleans Wastewater System Expansion
25% Design Peer Review

TO: Orleans Board of Selectmen

FROM: Ian Catlow, P.E.
Tracy Adamski, AICP
David Popielarczyk, P.E.
Christopher Haker, P.E.

COPY: George Meservey, Director of Planning & Community Development

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Executive Summary

Tighe & Bond has reviewed the following preliminary design reports and collection system plans for the Town of Orleans, Massachusetts:

- Cultural Resources Evaluation, Dated March 29, 2017
- Geotechnical Evaluation, Dated April 14, 2017
- Collection System Preliminary Design Report – Downtown Area, Dated August 22, 2017
- Downtown Area Plans & Profiles – 25% Preliminary Design Report, Dated May 19, 2017
- Update WWTF Process Selection, Dated June 7, 2017
- Septage & Food Waste Market Study Technical Memorandum, Stantec, Dated December 23, 2014.

Our goal with this review was to confirm that these preliminary design documents conformed with industry standards such as *TR-16*, MADEP's *Guidelines for the Design, Construction, Operation & Maintenance of Small Wastewater Treatment Facilities with Land Disposal* and other applicable guidance documents. An additional goal of our review was to determine if the conclusions drawn by the above reports were reasonable, considering the supporting information provided and our experience with the planning, design and construction of similar systems. A brief summary of our findings related to the above preliminary design documents follows.

Cultural Resources Evaluation – AECOM's review of cultural resources was performed in accordance with standard industry practice and we found it to be a reasonable assessment of known conditions in the field. As design progresses we agree with AECOM's recommendations for further coordination with local native American tribes and the Massachusetts Historic Commission (MHC). We also agreed with the need for further evaluation of the Pump Station #2 site at Chatham Road and Academy Place so potential archeological impacts can be managed appropriately.

Geotechnical Evaluation – Our review of AECOM's Geotechnical Evaluation indicated that their report was preliminary in nature. It served mainly as a summary of their exploration program, as did the boring logs that were developed by the program. Geotechnical analysis related to trench support, the likelihood of soil liquefaction, construction dewatering or other design/construction geotechnical concerns was absent from this document. As such, we did not feel that this report served as an adequate guidance document for the incorporation of geotechnical concerns into the bid documents. We recommend that additional information be developed in this regard to address soil and groundwater issues. This is particularly true in areas where relatively deep, open cut, sewer installation is proposed.

Collection System Preliminary Design Report – AECOM's preliminary design report presents a discussion of pros and cons for low pressure sewers, gravity sewers, vacuum sewers, STEP systems, and STEG systems. Non-cost differentiators were considered in conjunction with a 20-year life cycle cost assessment (LCCA) for each of these systems, as well as two hybrid alternatives that include gravity/low pressure sewers and gravity/STEP sewers.

- Collection System Alternatives – Tighe & Bond believes that the collection system alternatives considered by this analysis are appropriate. AECOM's recommendation to utilize a hybrid system of low pressure sewers and gravity sewers relies on proven technology that is widely used across the region.
- Design Guidelines - Our review confirms that AECOM generally adhered to published design guidelines with respect to the estimation of flows and sewer system design criteria. Our review highlighted several areas where we thought additional detail regarding the design intent, or important design elements, would be beneficial.
- Operation & Maintenance Costs - Regarding collection system operation and maintenance (O&M) costs, Tighe & Bond found that AECOM's memorandum could benefit from a better accounting of labor costs associated with the maintenance of mechanical systems. This includes low pressure sewers, STEP systems and centralized pump stations. We also noted that AECOM has budgeted for the annual replacement of 5% of the low-pressure grinder pumps and STEP pumps, while our research and experience indicates that the design life of these pumps is typically only 10 years. Based on this design life, a replacement rate of 10% per annum is appropriate. These updates and several other minor clarifications regarding O&M costs should be made prior to updating the LCCA as described above. Once the LCCA has been updated for each of the alternatives, AECOM should restate the alternative rankings. While we do not anticipate a significant shift in the outcome of the LCCA, we believe that addressing the recommendations of our review will yield a more complete accounting of sewer ownership costs.
- Life Cycle Costs - The two lowest life cycle cost alternatives identified by this analysis were low pressure sewers with a net present value of $23.3M, followed by a hybrid system of gravity and low pressure sewers with a net present value of $28.0M. We are in general agreement with AECOM's technical approach to performing the LCCA. However, we noted several instances where we felt that unit costs were low and/or missing for collection system components. We also noted that in the instance of gravity sewers, the design life of pipes and manholes can exceed 50 years with relatively low maintenance costs, while other pumped systems will have significant ongoing costs across this period. To account for this we recommend that AECOM extend their LCCA out to 50 years. These discrepancies should be addressed, and the LCCA updated, to ensure that the least cost alternative has not changed.

Downtown Area Plans & Profiles – Our review of AECOM's plan and profile views for new sewers in the downtown area confirms that the collection system has generally been designed in accordance with industry standards. The work presented is typical for the 25% level of design development stated on the plans. Our review notes several concerns related to design flows/proposed pipe sizes, potential utility conflicts, trench support/dewatering, and traffic control during construction. We fully expect these issues to be resolved as the design advances.

Wastewater Process Selection – AECOM has reevaluated the previously recommended membrane bioreactor (MBR) technology against sequencing batch reactor (SBR) technology. We agree that either of these treatment technologies would provide adequate treatment for the Town's wastewater. Our detailed review, and the outline below, highlight several areas where the design of both systems could be refined and cost impacts evaluated prior to finalizing a decision.

- Flows & Loadings - AECOM's memorandum begins by attempting to define flows and loads for the new WWTF. The report states that anticipated flows are based on a septage flow rate of 6 million gallons per year, and an average annual commercial/residential flow rate of 163,200 gallons per day (GPD). Our review noted that influent septage pollutant concentrations were not explicitly stated, and this made it difficult to confirm design loading assumptions. Additionally, AECOM has distributed the 6 million gallons per year of septage across 365 days, while it will likely only be collected during the typical work week or for 250 days per year. This would increase the typical daily volumes to 24,000 GPD. While this was a small volumetric change, it could result in a significant loading change since septage can be almost 40 times stronger than typical municipal wastewater. We also found that AECOM utilized conservative peaking factors to determine the maximum day flow rates for the plant. In this instance, we recommend closely reviewing newer systems built with similar materials and techniques to determine peak day peaking factors. We suspect this will reduce the peak day peaking factor from 2.8 to something closer to 2.0 which will in turn reduce equipment and tank volumes throughout the facility.
- Discharge Limits - AECOM's memorandum cites anticipated permit limits of 30 mg/l for BOD and TSS and 10 mg/l for nitrogen. While these are typical limits issued by MADEP, Tighe & Bond noted that the Town's groundwater discharge permit will be subject to detailed MADEP review and a public comment period. It would be appropriate to finalize the groundwater discharge permit soon, or otherwise confirm with stakeholders that these limits are appropriate. Ongoing work by the Massachusetts Estuary Program (MEP) could recommend lower limits. If the Town's 2015 Consensus Plan adequately addressed this issue it should be stated in this memorandum.
- SBR vs. MBR Treatment Processes - The preliminary design memorandum uses the flow estimates and effluent limits described above to develop two competing design concepts for membrane bioreactor (MBR) treatment and sequencing batch reactor (SBR) treatment. We found that these designs have generally been developed in accordance with industry standards, such as TR-16 and MADEP's *Guidelines for the Design, Construction, Operation & Maintenance of Small Wastewater Treatment Facilities with Land Disposal*. One area where the memorandum deviated from these guidelines was in its lack of a process flow diagram annotated with the mass-balance of pollutants moving through the facility. These figures are required by MADEP and should be added for both alternatives to indicate key process design parameters such as aeration requirements and internal recycle flow rates, which were absent from the report. Without this data or manufacturer proposals, it was difficult to confirm several claims made in the text.
- Equipment and Processes - Tighe & Bond also reviewed design information regarding screening, flow equalization, odor control, sludge storage, sludge thickening and septage receiving facilities. In each of these processes, we identified additional data required to complete an accurate review and/or design alternatives that we felt could benefit the project. In many cases, issues we have highlighted would have an impact on capital or life cycle costs for one or both treatment alternatives. AECOM should address these concerns before advancing the design.

- Construction Costs - Our review of AECOM's life cycle cost analysis for the WWTF found that estimates provided a reasonable level of detail given the level of design development. Furthermore, construction contingencies and allowances for Contractor overhead and profit were in line with industry norms. We noted in our analysis that AECOM utilized concrete pricing of between $700 and $830 per cubic yard, and our review of recent bids and discussions with contractors suggest that this could be 20% or more below market rates. Average labor rates also appeared to be based on RS Means estimating manual and labor costs from a project in Pittsfield, MA. Since this project will be subject to Massachusetts Prevailing Wage rates, we believe that the estimate could be improved by utilizing prevailing wage data for Cape Cod which we expect to be higher. While addressing both issues will likely increase project costs, those below market rates were applied equally to SBR and MBR alternatives, and do not appear to have impacted LCCA outcomes. It was also noted in our review that equipment costs for influent screening, MBR systems, SBR systems, and UV disinfection equipment all originated from the same local manufacturer's representative. While we do not believe there is any impropriety here, we felt that this approach could be susceptible to inadvertent bias and we recommend obtaining competing quotations from other vendors. Following AECOM's response to the design issues identified in our report, as well as the above cost issues, we recommend that the capital costs for both alternatives be updated and presented to the Town.
- Operation & Maintenance Costs - Tighe & Bond's review of WWTF operation and maintenance (O&M) costs identified process modifications and data gaps that should be addressed before the O&M cost estimate is finalized. These deficiencies focused on the areas of: sludge storage odor control and mixing air; disc filter cleaning; disc filter backwashing; and bioreactor power costs. We also noted that the analysis did not account for disc filter media replacement, and recent quotations we've reviewed for similar products suggest that media should be replaced ever 7 to 10 years. Similar to the capital cost updates, we found that the above issues should be addressed before finalizing the O&M cost estimates.
- Life Cycle Costs - AECOM combined the capital and O&M cost estimates described above to develop an LCCA for the SBR and MBR alternatives. While we agree with their general approach to this analysis, we feel that the open issues highlighted by our report should be resolved and the LCCA updated before the results of the analysis are affirmed. It was also noted that the primary objective of AECOM's LCCA was to compare two treatment alternatives. Consequently, many costs related to staffing, sludge disposal, lab fees, energy and other parameters were omitted from the analysis. While we agree with this approach for an analysis of alternatives, the Town should also request a more detailed estimate of capital and O&M costs be developed so that rate payer impacts can be fully evaluated. It was also noted in our review that the LCCA did not consider the STEP alternative which had the third lowest present worth cost in the collection system analysis. This alternative has the potential to reduce influent loadings from the collection system at the WWTF, and we believe that it is appropriate for AECOM to at least address these impacts in their memorandum to show that process volumes are not altered significantly under this alternative. It is also worth noting that changes to the collection system LCCA recommended by our review could change the ranking of STEP systems in relation to other systems under consideration. We suspect that this could make STEP less favorable than it is currently.

Project Schedule - Tighe & Bond's review of AECOM's proposed project schedule suggests that the current proposed schedule should be expanded to include an additional 12 months. This extension is to account for a longer design period of up to 12 months, a bid period of roughly 4 months, and a construction duration of up to 24 months. It is also worth noting that these extensions would allow the Town to conduct a pre-procurement of the biological treatment system under MGL Ch 30b, and prequalify General Contractors and Subcontractors as required by MGL Ch 149.

Septage & Food Waste Study – Tighe & Bond's review of the Stantec Septage and Food Waste Study found that recommendations that the Town not construct an anaerobic digester for food waste and sludge were appropriate based on the availability of local food stocks to support the system. We also felt that Stantec's assessment of available septage quantities on the mid and outer-Cape was reasonable based on the research presented. Septage tipping fees of up to $0.14/gallon were also supported by Stantec's analysis of alternate disposal sites and the hauling cost to reach those sites.

Sewer User Rate Impact – While not a stated goal of the wastewater process selection memorandum, Tighe & Bond believes that it is an appropriate point in the Town's process to provide comprehensive project cost estimates which can be used to assess rate payer impacts. These estimates would clearly be preliminary, and subject to change over time. However they could also serve as a valuable tool to build public support and weigh project financing options.

Recommendations – After reviewing the documents outlined above, and in the report that follows, Tighe & Bond recommends that AECOM revise or clarify substantial portions of their preliminary design documents related to the Geotechnical Evaluation, the Collection System Preliminary Design Report, and the Updated Wastewater Process Selection memorandums. Performing these updates will result in changes to both capital and O&M cost estimates that must then be re-evaluated using the LCCA approach that AECOM has established. Following an update of the LCCA based on our comments, we recommend that the Town revisit its decision to proceed with a hybrid low pressure/gravity sewer system and an SBR based WWTF.

Scope of Review

Tighe & Bond has developed the following design review summary in response to the Town of Orleans' request for qualifications (RFQ) statements titled: "*Independent Engineering Review of 25% Design of Wastewater System for Downtown Orleans*", and our subsequent agreement with the Town dated January 9, 2018. Through the RFQ, the Town established the following objectives for the design review:

- Reasonableness of estimates of flows and quantities for wastewater, I/I, septage, wastewater treatment biosolids under current and future conditions;
- Conformance of collection and treatment facility design with applicable state and county standards. This includes TR-16 and the MassDEP Guidelines for the Design, Construction, Operation & Maintenance of Small Wastewater Treatment Facilities with Land Disposal;
- Suitability of wastewater treatment plant, septage and biosolids process design criteria and design details;
- Independent assessment of the wastewater collection and treatment options;
- Reasonableness of cost estimates for collection and treatment facilities. This includes unit construction costs, construction related costs, engineering costs, contingencies, lateral connection costs, and other cost factors;
- Reasonableness of estimated implementation phasing and construction durations;

- Reasonableness of estimated operation and maintenance costs for collection and treatment facilities;
- Adequacy of related planning and engineering studies.

The subsections that follow address the above review objectives as they relate to each of the preliminary design documents provided by the Town for review.

1 Cultural Resources Evaluation

The peer review of the Cultural Resources Evaluation included the review of the memorandum provided by the Town of Orleans. This consisted of a review for compliance with applicable local, state, and federal regulations, including: the Antiquities Act (M.G.L. c. 9 §§ 26 through 27c as amended by St. 1988, c. 254), Massachusetts Unmarked Burial Law (M.G.L. c. 38, § 6), Massachusetts Historical Commission (MHC) regulations (950 CMR 70), Protection of Properties Listed in the State Register of Historic Plans regulations (950 CMR 71), and Section 106 of the National Historic Preservation Act of 1966.

We offer the following comments for the Town's consideration:

1. The Cultural Resource Evaluation memorandum provided by AECOM and Public Archaeology Laboratory (PAL) assessed the sensitivity of the project area for the potential to contain previously unrecorded archaeological sites based on background research and a walk/drive-over field assessment of the project area. This is typical for projects of this size and complexity.
2. The project area sensitivity assessment assumed that the project does not have the potential to affect historic structures or landscapes. However, the proposed location of Pump Station #2 is an open, grassy park at the intersection of Chatham Road, Academy Place, and Main Street. It is also noted as the site of three war memorials listed in the State Register of Historic Places, and potentially the site of the former Rock Harbor Academy and Snow Library. The potential construction impacts of Pump Station #2 on historic structures should be investigated further as design advances.
3. The archaeological sensitivity assessment was based on key environmental attributes, the presence or absence of documented cultural resources in and adjacent to the project area, and the degree of disturbance. This is in accordance with established sensitivity assessment practices.
4. The archaeological sensitivity assessment resulted in an overall assessment for the project area of high to moderate for Native American Pre-Contact, Contact, and Early Post-Contact periods. This is consistent with the abundance of known archaeological resources and environmental characteristics near the project area.
5. Recommendations of the Cultural Resource Evaluation memorandum include development of formalized procedures guiding the discovery of any significant cultural resources and/or evidence of human remains during construction in areas not under archaeological monitoring. This would ensure implementation of protocols consistent with the Massachusetts Unmarked Burial Law.
6. The Cultural Resource Evaluation memorandum additionally recommended archaeological monitoring in all places where new sewer lines and pump stations will be impacting intact soils during construction. This is under an archaeological permit and in coordination with Mashpee Wampanoag and Wampanoag Tribe of Gay Head Tribal Historic Preservation Officers (THPOs). Tighe & Bond concurs with this recommendation, but also recommends that coordination with MHC and THPOs begin earlier in the design process, ideally before or during development of the final project design. Incorporating MHC and THPO input earlier in the design process will minimize

potential work stoppages during construction associated with the unanticipated discovery of archaeological features.

7. Tighe & Bond recommends a review of the permitting record (such as MEPA filings and associated comment letters) to determine what MHC and others have requested with respect to coordination and assessment of work areas. MHC may require close coordination during final project design to identify additional opportunities to avoid, minimize, and mitigate impacts to archaeological resources in the project area.

2 Geotechnical Evaluation Report

Tighe & Bond reviewed AECOM's Geotechnical Evaluation Memorandum dated April 14, 2017. The AECOM Geotechnical Evaluation is considered preliminary in nature. It is limited to boring logs and a description of the exploration program performed. Subsurface conditions, geotechnical findings, implications on the project, or design and construction recommendations were not provided. It is assumed a more comprehensive report will be forthcoming during the design phase.

The project is underlain by native sands common to Cape Cod, and will require relatively deep excavations below the water table. Based on our experience, potential liquefaction and excavation support/construction dewatering will likely be critical to geotechnical issues that should be addressed as the design advances. It appears that the borings included in this evaluation were performed with direct push methods, and no standard penetration tests or index laboratory tests were performed. It is recommended that these tests be performed to properly evaluate liquefaction potential, and for excavation support and dewatering design. It is understood that excavation support and dewatering design are normally the Contractor's responsibility as part of their means and methods of construction. However, sufficient data should be provided as part of the Construction Documents to properly design these systems and reduce the risk of claims during construction due to changed subsurface conditions.

3 Collection System Preliminary Design Report

3.1 Report Summary

Tighe & Bond reviewed the memorandum titled "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", prepared by AECOM and dated 8/22/17 (Collection System PDR).

The Collection System PDR evaluated the collection system technologies listed below in order to identify and compare the advantages and disadvantages of each type of wastewater collection system:

1. Gravity sewer system (GS)
2. Low pressure sewer system (LPS)
3. Septic tank effluent gravity sewer system (STEG)
4. Septic tank effluent pumping system (STEP)
5. Vacuum sewer system (VS)

In addition, the capital costs, annual operation and maintenance (O&M) costs, and life cycle costs to serve the Downtown Area, using each of the collection system technologies described above, were presented in the Collection System PDR. Costs were also estimated for two hybrid alternatives: one consisting of a combination of gravity sewers and low pressure sewers, and the other consisting of a combination of gravity sewers and STEP systems. A summary of the costs estimated for each alternative considered is presented in Table 1 below:

TABLE 1
Estimated Collection System Costs per Collection System PDR

Technology	Capital Cost	Annual O&M Cost	Present Value[1]
GS	$22,379,115	$656,910	$32,137,000
LPS	$17,074,450	$417,347	$23,283,000
STEG	$25,934,403	$715,043	$36,572,000
STEP	$21,832,658	$461,480	$28,699,000
VS	$28,785,038	$813,815	$40,893,000
Hybrid (GS & LPS)	$20,719,395	$489,536	$28,002,000
Hybrid (GS & STEP)	$21,466,985	$496,469	$28,853,000

[1]Life cycle cost over a 20-year period, considering both capital costs and annual O&M costs.

The LPS alternative was determined by AECOM to have the lowest capital cost, lowest annual O&M cost, and the lowest Present Value/life cycle cost over a 20-year period. The hybrid system using low pressure sewers and gravity sewers had the second lowest life cycle cost, and was ultimately recommended for implementation in Orleans.

Each technology was also rated in the Collection System PDR using the following criteria:

1. Site suitability
    a. Land ownership
    b. Constructability
2. Environmental considerations
    a. Permitability
    b. Extent of dewatering
    c. Sustainability
3. Financial considerations
    a. Construction costs
    b. O&M costs
    c. Life cycle costs
4. Maintenance concerns
    a. Level of maintenance-homeowner
    b. Level of maintenance-Town
    c. Impact to WWTF operations
5. Other considerations
    a. Reliability
    b. Ability to accommodate expansion
    c. Area of disturbance
    d. Use of property
    e. Duration/schedule

f. Aesthetics

Based on this rating analysis, the collection system technologies were ranked by AECOM as shown in Table 2:

TABLE 2
Technology Ranking per Collection System PDR

Ranking	Technology
1	LPS
2	STEP
3	GS
4	VS
5	STEG

As shown in Table 2, the LPS alternative was ranked highest overall, followed by the STEP alternative.

Following the development and comparison of costs and non-monetary criteria, the Collection System PDR indicates that the recommended collection system alternative is a hybrid system. This is one consisting of primarily gravity sewers with a small amount of low pressure sewers with grinder pumps to serve homes that cannot readily connect to a gravity system.

3.2 Tighe & Bond Review Comments

3.2.1 Current and Future Flow Estimates and Pipe Sizing

There is limited information within the Collection System PDR regarding the development of wastewater flows. However, the Collection System PDR does include a summary table of projected future average and peak wastewater flows to the three proposed pump stations in the Downtown Area (Table 10 on Page 42).

The technical memorandum titled "Water Quality and Wastewater Planning Facilities Engineering – Preliminary Design Report (25% Design) Downtown Area, Task 10.1.C.5 - Update WWTF Process Selection" (WWTF PDR), prepared by AECOM and dated 6/7/17, provides additional projected future wastewater flow data. The WWTF PDR indicates that wastewater flows were estimated as 95% of water use based on 2014 and 2015 water use data, which we believe is a reasonably conservative approach to estimating sanitary flows. In addition, the WWTF PDR indicates that infiltration was estimated as 300 gallons per day per inch of pipe diameter per mile of pipe length (gpd/im), assuming an average gravity pipe diameter of 10 inches. This projected infiltration rate is consistent with the document entitled *Technical Report No. 16, Guides for the Design of Wastewater Treatment Works*, 2011 edition, as revised in 2016, which is commonly referred to as TR-16. This document is often used as a guide for sewer design and construction in Massachusetts. TR-16 indicates that an allowance of 250–500 gpd/im is a normal range of infiltration for new gravity sewer piping. Note that the average gravity sewer pipe size within the proposed wastewater collection system is likely to be less than the value of 10 inches used for the estimation of infiltration.

The WWTF PDR provides a breakdown of future sanitary flows and infiltration by phase, as indicated below. This is in general agreement with the flow data for the proposed pump stations included in the Collection System PDR.

TABLE 3
Estimated Average Daily Wastewater Flows per WWTF PDR

Phase	Future Sanitary Flow (gpd)	Future Infiltration (gpd)[1]	Total Future Wastewater Flow (gpd)[2]
1	59,300	4,500	63,800
2	50,300	5,300	55,600
3	76,100	4,200	80,300
4	26,400	2,800	29,200
Total	**212,100**	**16,800**	**228,900**

[1]Calculated based on pipe length. Total shown matches total infiltration from Table 1 of WWTF PDR, but does not match the infiltration breakdown by phases.

[2]Sum of future sanitary flow and future infiltration.

Note that the total infiltration presented above in Table 3 was calculated based on the length of gravity sewer pipe proposed for each phase, included in the Collection System PDR, and an assumed average pipe diameter of 10 inches, as indicated in the WWTF PDR. The total calculated infiltration of 16,800 gpd matches the total infiltration value included in Table 10 of the Collection System PDR (at the Phase 3 Pump Station) and the total infiltration value included in Table 1 of the WWTF PDR. However, the calculated infiltration rates by phase do not match the phase breakdown provided in Table 1 of the WWTF PDR (e.g., the total infiltration for Phases 1 and 2 in the Downtown Area is reported as 8,400 gpd as compared to the calculated total infiltration of 9,800 gpd for these two phases). AECOM should correct this discrepancy.

The peaking factors shown in Table 10 of the Collection System PDR, which were used to calculate the peak sanitary flows to the three pump stations, are generally consistent with the peaking factors we estimate using TR-16. We assume that this same approach was used to determine peak sanitary and wastewater flows within individual pipe segments throughout the proposed piping system. However, we could not confirm proposed pipe sizing because a detailed breakdown of flows through the various proposed pipe segments was not included in the Collection System PDR.

The documents provided to Tighe & Bond do not include information on current wastewater flows which could be estimated through potable water records. This information would be useful in assessing AECOM's evaluation of alternatives since some of the collection system technologies (e.g., low pressure sewer systems and STEP systems) are less able to accommodate significant changes in wastewater flow.

Based on our review of the flow and pipe sizing data in the Collection System PDR, we suggest that a few clarifications be provided, as described below:

1. In Table 9, gravity sewer sizes are noted as 8-inch and 10-inch diameter. However, the drawings only show 8-inch diameter gravity sewers. We suggest that this be clarified in the Collection System PDR.

2. In Table 10, we suggest that the average daily flow labels be revised to clarify whether these are average sanitary flows or average wastewater flows (sanitary flow plus infiltration).
3. In Table 10, we believe that the "Peak Daily Flow (gpd)" values are peak sanitary flows and that the "Peak Daily Flow (gpm)" values are peak wastewater flows (peak sanitary flow plus infiltration). However, the difference between the two is not clear from the table. We suggest that these terms be clarified.
4. There is little information available in the Collection System PDR regarding how sewer mains have been sized, as noted above. However, we calculate the peak wastewater flow to the Phase 1 Pump Station as 753,848 gpd per Table 10 (average sanitary flow of 140,350 gpd x peaking factor of 5.28 + 12,800 gpd of infiltration). The force main from this pump station discharges into the Phase 3 service area on Old Colony Way. The gravity sewer that is downstream of the force main on Old Colony Way is 8-inch diameter set at the allowable minimum slope (0.4%). We calculate that this gravity sewer pipe has a hydraulic capacity of approximately 495,000 gpd, which is less than the predicted flow to this pipe from the Phase 1 Pump Station. As such, it appears that a larger pipe is needed at this location, or the proposed 8-inch sewer would need to be installed at a steeper slope, in order to provide sufficient hydraulic capacity to accommodate the estimated upstream wastewater flows. We recommend that AECOM re-evaluate the pipe sizes needed downstream of the Phase 1 Pump Station force main.
5. It is difficult to determine from the information provided whether AECOM's estimated pipe sizes are based on the proposed sewers flowing partially or completely full at the peak wastewater flow rates. We recommend that the sewers be designed to flow partially full to prevent surcharging the sewer mains and to provide some surplus capacity.

3.2.2 Conformance with Applicable Standards

As noted in Section 3.1, the proposed collection system in the Downtown Area is a hybrid system that consists primarily of gravity sewers with a small amount of low pressure sewers with grinder pumps. The Collection System PDR includes design criteria for these two types of collection systems, including:

Gravity Sewers

1. Minimum pipe sizes
2. Minimum pipe depths
3. Minimum pipe slopes
4. Locations of manholes
5. Infiltration estimates
6. Separation from water mains

Low Pressure Sewers

1. Minimum pipe sizes
2. Minimum pipe depths
3. Valve and cleanout locations
4. Separation from water mains

5. Pump and chamber requirements

The design criteria listed in the Collection System PDR is in general conformance with TR-16 recommendations. The preliminary design drawings for the recommended hybrid collection system also confirm that the gravity sewer design is in conformance with TR-16, as discussed in Section 4. However, because the drawings do not include low pressure sewer layouts, conformance with TR-16 design recommendations for low pressure sewers could not be confirmed.

3.2.3 Cost Estimates

As noted in Section 3.1, the Collection System PDR includes an estimate of capital costs, O&M costs and 20-year life cycle costs for each type of collection system considered. In addition, costs were developed for two hybrid systems: one consisting of a combination of gravity sewers and low pressure sewers and the other consisting of a combination of gravity sewers and STEP systems, assuming that 100% of the septic tanks will require replacement where STEP systems are proposed.

3.2.3.1 Capital Costs

The capital costs were estimated as the total of the construction costs, engineering costs, and Town administration costs related to each alternative. The construction costs were estimated using unit costs that were provided for the major components of the collection systems (e.g., pump stations and piping).

Based on our review of the capital costs and related unit costs in the Collection System PDR, we suggest that a few clarifications be provided and confirmations be performed, as described below:

1. We suggest that information on how the cost of the grinder pumps was considered be added to the PDR. There does not appear to be a separate item for them in the cost summary table.
2. We suggest that information be provided in the PDR on the assumptions that are the basis for the “custom pump stations” unit cost. That is, do the costs include a building, a generator, a wet pit and dry pit, etc.?
3. We suggest that information be provided in the PDR on the assumptions that are the basis for the “submersible pump stations” unit cost. That is, do the costs include a building and/or a generator?
4. We suggest that the force main unit prices be broken out by diameter.
5. We suggest that gravity sewer unit prices be presented based on installation depth and pipe diameter (if there are different pipe sizes), rather than using one unit price, which we assume is an average for the different sizes and installation depths.
6. We suggest that the gravity sewer/STEG sewer unit price of $125/linear foot be confirmed. We believe that this average unit price is low based on area bid prices, especially considering that deep sewer construction is required in some areas.
7. We suggest that additional geotechnical recommendations related to trench support, control of running sands, and construction dewatering be better accounted for in capital cost estimates, particularly for deep sewers.

8. We suggest that the low pressure sewer/STEP force main unit price of $100/linear foot be confirmed. We believe that this average unit price is low based on area bid prices.
9. We suggest that the Collection System PDR indicate the basis for the “Gravity Sewer – Private Property” unit cost of $7,800.
10. We suggest that the Collection System PDR indicate the basis for the “Low Pressure Sewer – Private Property” unit cost of $12,000.
11. We suggest that the Collection System PDR indicate the basis for the “STEP– Private Property” unit cost of $16,400.
12. Although it does not appear that the “Wet Pit/Dry Pit Pump Station” item was used, the unit cost in Table 6 of the memorandum of $470,000/each is slightly different than the unit cost in the cost comparison spreadsheet of $468,000/each. We suggest that this difference be clarified.
13. We recommend that generators be added to the cost of all pump stations or that an alternate means of complying with MADEP backup power requirements be specified.
14. Table 7 of the Collection System PDR indicates that a 15% contingency was applied. However, the cost spreadsheet indicates that a 25% contingency was used. We suggest that this difference in contingency values be clarified.
15. We suggest that the Collection System PDR indicate why a custom pump station has been included for the low pressure sewer and STEP system alternatives and where it is proposed.
16. We suggest that the Collection System PDR indicate whether traffic control costs and the impact of traffic on construction production were considered, which are likely to vary between the different alternatives.
17. We suggest that the Collection System PDR comment on the potential for contaminated soil and groundwater to be encountered in the project area. We assume that the potential is low since it does not appear that costs were included for the removal and disposal of contaminated material.

3.2.3.2 Operation and Maintenance Costs

Operation and maintenance (O&M) costs were estimated and compared in the Collection System PDR. O&M costs included the cost of cleaning and inspecting pipelines, the cost of electricity usage, chemical costs (for odor control), parts replacement, the labor costs associated with operating and maintaining the wastewater collection systems, septic tank pump-out costs, equipment replacement costs, and equipment monitoring costs. The Collection System PDR notes that it has not yet been determined who will maintain the system components that will be on private property (e.g., grinder pumps and STEP pumps).

Based on our review of the O&M cost descriptions in the Collection System PDR, we suggest that a few items be clarified, reviewed and/or adjusted, as described below:

1. The Collection System PDR indicates that labor costs are based on:
    a. One full time employee for administration and O&M for each type of technology, including O&M for collection system components on private property
    b. A minimum of 260 hours per year for the O&M of each pump station

We believe that if the pump stations are not considered (since they are accounted for separately), that there would be a need for greater maintenance/labor for the systems that have more mechanical components (i.e., those alternatives that have a greater number of grinder pumps or STEP pumps). We suggest that consideration be given to including higher labor costs for alternatives that include more mechanical equipment.

2. We suggest that the Collection System PDR indicate the basis for the pump station chemicals O&M costs. For example, we suggest that the Collection System PDR indicate whether it was assumed that odor control chemicals would be needed at each pump station (even if it is a smaller submersible pumping facility).
3. The Collection System PDR indicates that pump station electricity costs are based on 25 HP pumps running 15 minutes per day. If the same pump sizes and run times were used for every proposed pump station, we suggest that the analysis be adjusted to reflect the variation in electricity usage/costs between the different size pump stations. If a variation in electricity usage is already being considered, we suggest that the Collection System PDR text be revised to clarify this analysis. We also recommend AECOM evaluate force main residence times for potential septicity and where issues are expected add odor control measures at pump stations and discharge locations.
4. The O&M cost estimates in the Collection System PDR assume that 25% of the sewers will be cleaned and television inspected each year for the gravity sewer and STEG alternatives. We believe that this is a high projection and suggest that inspecting this percentage of pipe per year may not be necessary. Consider reducing the percent of pipe projected to be cleaned and inspected each year.
5. The technical memorandum indicates that the equipment on private property would be replaced at a rate of 5% of the total number of connections per year. Consider basing replacement frequency on expected service life. Based on discussions with communities who have low pressure sewers and grinder pumps, we believe that an appropriate service life for a grinder pump would be approximately 10 years. If 5% of the grinder pumps were to be replaced per year, all of the grinder pumps would not be replaced for 20 years.

3.2.3.3 Life Cycle Costs

Life cycle costs were developed for each alternative included in the collection system evaluation. The life cycle costs provide a comprehensive summary of the total costs anticipated over the life of the wastewater collection system, including capital costs, O&M costs, and replacement costs. The life cycle cost comparison is typically the most appropriate method of determining which alternative is most cost-effective. As part of the life cycle cost comparison, all future capital and O&M costs were converted to present worth costs so that all costs are on an equal time basis, for each alternative.

Based on our review of the life cycle cost descriptions in the Collection System PDR, we suggest that a few items be clarified, reviewed and/or adjusted, as described below:

1. We suggest that an adjustment to the life cycle cost analysis period from 20 years to 50 years be considered since some components of the technologies considered have service lives that are 50 years or greater (e.g., pipes and structures). We believe that this will better reflect the benefits of alternatives with fewer mechanical components. Correspondingly, we suggest that complete replacement of pump station pumps after 20 to 25 years be included in the evaluation. Similarly, we

suggest that the replacement of grinder pump cores after 10 years be included in the evaluation, as noted above.

2. We suggest that the Collection System PDR indicate the basis for the rate of return of 3%.

3.2.4 Estimated Implementation Phasing and Construction Durations

A preliminary schedule was included in the Collection System PDR for the following tasks:

Task	Estimated 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**

We have the following comments on the estimated project duration and proposed phasing:

1. It is common for the time period during which permits are being obtained to overlap with the time period during which the plans and specifications are being prepared. If this is feasible for this project, it would allow the total duration of the project tasks to be reduced.
2. We suggest that the Collection System PDR clarify whether portions of the construction activity were assumed to occur concurrently. For example, was it assumed that the pump station construction would occur concurrent with construction of the pipelines?
3. We suggest that information on the proposed schedule for each phase of work be included in the Collection System PDR. This schedule would provide the Town with a road map for the implementation of the program. This schedule would also confirm the order in which each phase would be performed. That is, would Phase 1 be implemented first? Based on the September 2017 map provided by AECOM entitled “Downtown Proposed Collection System Layout”, the most downstream area is the Phase 3 area. Typically, the most downstream area would be constructed first.

3.2.5 Ranking of Alternatives

As described above in Section 3.1, the alternatives included in the Collection System PDR were rated based on several categories and subsequently ranked. Based on the rating system used, the low pressure sewer technology/alternative was ranked highest, followed by the STEP system.

Based on our review of the rating evaluation in the Collection System PDR, we suggest that a few items be clarified, reviewed and/or adjusted, as described below:

1. A hybrid system is proposed in the Collection System PDR, which consists primarily of gravity sewers with a small amount of low pressure sewers. The hybrid system has a higher cost than the low pressure sewer alternative and, we assume, would rank lower than the low pressure sewer alternative since the vast majority of the hybrid system would consist of gravity sewers (the hybrid alternatives were not rated/ranked). We believe that this is an indication that the ranking analysis may not be correctly weighting the importance of certain items, or considering certain items that led to the decision to recommend the hybrid system. As such, we suggest

that the rating evaluation be reviewed to determine if adjustments should be made to better reflect the concerns related to the construction of a low pressure sewer system throughout the Downtown Area.

2. Some items included in the rating analysis appear related, such as Area of Disturbance and Duration/Schedule, which could be generally categorized as neighborhood impacts. Because these items are often related primarily to depth of construction (assuming the same length of pipe), the gravity sewer alternative is weighted negatively twice for impacts that may be a result of the same system characteristic (i.e., pipe depth). We suggest that combining related items be considered. In addition, we suggest that consideration be given to weighting these items lower under Table 3 since these are short-term impacts.

3. Under Sustainability, we infer from the scoring that it was determined that the electricity usage of 331 grinder pumps or STEP pumps would be less than the electricity usage of 5 municipal pump stations. If our assumption is correct, we suggest that this be confirmed.

4. Under Construction Costs, the Gravity Sewer alternative is given a score of "-1" while the STEP alternative is given a score of "1". The cost of these alternatives are similar (within 2.5% of each other). We suggest that consideration be given to reducing the difference in score between these two alternatives under this category.

5. Under Level of Maintenance-Town, the score is lower under the STEP system alternative than under the LPS alternative. Because the portions of these systems on Town property are expected to be similar, we expected the ratings under this category to be the same. We suggest that the ratings under this category be reviewed.

6. Under the Area of Disturbance, the score under the Gravity Sewer alternative is different than the score under the STEG alternative. We suggest that the Collection System PDR clarify why they are not rated the same.

7. Tighe & Bond noted AECOM's discussion of STEP system pros and cons and agrees with many of the stated points. We also thought it was worth emphasizing that there are very few STEP systems located in New England and at least one of the systems we are aware of has been plagued by problems with hydrogen sulfide attack of downstream infrastructure. The report could benefit from additional case study summaries of this technology.

4 Collection System Preliminary Design Drawings

4.1 Drawings Summary

Tighe & Bond reviewed the drawing set entitled "Downtown Area Plans and Profiles, 25% Preliminary Design Report" (the Preliminary Design Drawings), prepared by AECOM with a last saved date of 5/19/2017. The base mapping for the drawings was developed using information from a data accumulation survey, which included the following tasks:

- The performance of an aerial photography fly over and the preparation of photogrammetric mapping, supplemented by ground survey.

- The collection of utility information based on Dig-Safe markings.
- The collection of gravity pipe invert data based on existing records.
- The determination of building sill elevations along the streets where gravity sewers are proposed.

The Preliminary Design Drawings include proposed sewer layouts in plan and profile at a horizontal scale of 1 inch=40 feet and a vertical scale of 1 inch= 4 feet. The drawings illustrate that the design criteria described in the Collection System PDR were used to develop the proposed sewer layouts.

4.2 Tighe & Bond Review Comments

Based on our review of the Preliminary Design Drawings, we suggest that a few items be clarified, reviewed and/or adjusted, as described below:

1. We suggest that a key map be included in the drawing set.
2. We suggest that a legend be added to the drawing set and that the legend include an explanation for the sheet number coding. The drawings appear to be divided into three groups:
    a. Sheets 01 C-101 to 01 C-117
    b. Sheets 02 C-101 to 02 C-106
    c. Sheets 03 C-101 to 03 C-116
3. The “02” drawings do not show the future force main connection from the “01” area. Similarly, the “01” drawings do not show the future force main connection from the “03” area. We suggest that the future force main connections be added to the drawings to illustrate connectivity between phases.
4. All of the proposed sewers are shown on the plan/profile sheets as 8-inch diameter. As noted in the Collection System PDR comments, based on the flow data in Table 10 of the Collection System PDR, we believe that larger diameter sewers will be needed in some areas. We suggest that the sizes of the proposed sewers be reviewed.
5. The drawings do not show the layouts for the proposed low pressure sewers. We suggest that these be added to the layouts to provide a complete picture of the proposed sewers.
6. There are several locations where the building sill elevations are less than 8 feet above the invert of the proposed sewer. Consider building inspections to determine whether the buildings can be served by gravity, or whether a low pressure sewer service and grinder pump are necessary. Buildings with sill elevations less than 8 feet above the inverts of the proposed sewers, where a grinder pump has not already been proposed on the September 2017 Downtown Proposed Collection System Layout Map, are listed below:
    a. 4 Cranberry Highway
    b. 6 Cranberry Highway
    c. 10 Cranberry Highway

d. 16 Cranberry Highway

e. 158 Cranberry Highway

f. 21 Brewster Cross Road

g. 34 West Road (may be able to connect to proposed sewer at a point farther downstream with greater depth)

h. 73 Old Colony Way

i. 6 Old Tote Road (address per profile, may be incorrect; is correct address 22 Tote Road?)

j. 8 Old Tote Road (address per profile, may be incorrect; is correct address 24 Tote Road?)

7. There is the potential to impact existing utilities with the construction of the proposed sewers at the following locations:

    a. STA 26+00 on Cranberry Highway (Sheet 01 C-103); the proposed sewer is close to the existing drain horizontally (the depth of the existing drain, which is important in determining the potential impact, is not shown).

    b. STA 5+50 on Lots Hollow Road (Sheet 01 C-106); the proposed manhole appears to be at the same location horizontally as the existing gas main.

    c. STA 11+80 on Eldredge Parkway (Sheet 01 C-107); the proposed sewer is 6 inches below the existing drain.

    d. STA 4+50 on Brewster Crossroad (Sheet 01 C-108); the proposed sewer is at the same location horizontally as the existing gas main.

    e. STA 11+00 on Main Street (Sheet 01 C-111); the proposed sewer is at the same location horizontally as the existing drain.

    f. STA 11+12 on Old Colony Way (Sheet 02 C-104); there does not appear to be any vertical clearance between the proposed sewer and an existing drain that it will cross.

    g. STA 13+95 on Old Colony Way (Sheet 02 C-104); the proposed sewer is 8 inches below the existing 24” drain.

    h. STA 16+85 on Canal Road (Sheet 03 C-109); the proposed sewer is close to the existing water main horizontally (depth and material of water main, which are important in determining the potential impact, are not shown).

8. We recommend that traffic control impacts be considered when refining the layouts. Current layouts show the proposed sewer in the middle of the road on some streets, such as on Cranberry Highway. An adjusted layout may reduce traffic impacts, if an adjustment can be made, considering the location of existing utilities.

5 Septage & Food Waste Memorandum Review

Tighe & Bond reviewed the findings of Stantec’s memorandum titled: *Septage & Food Waste Market Study Technical Memorandum #2* to determine its adequacy for use as a basis of design document for the proposed Orleans wastewater treatment facility. The Stantec study was intended to address two separate issues: one involving the viability of an anaerobic digester for the treatment of septage and food waste, and a second related to the anticipated quantities and value of septage on Cape Cod that could ultimately be disposed of in Orleans. The memorandum quickly rejects the viability of a food waste oriented digester project on the basis of limited food sources to power the digester. We agree with this conclusion and believe it warrants no further discussion in this review. Regarding the issue of septage quantities generated across the Cape, and particularly from communities in the Tri-Town district or east of that point we found Stantec's findings to be reasonable estimates based on good research and sound engineering practice.

Several notable aspects of this study follow:

- Total septage quantities from the Cape summarized in the report total 9.2 million gallons per year in 2010 and decrease slightly to an expected 7.8 million gallons per year by 2040.
- The decrease in septage volumes is attributed largely to flat or negative population growth and increased sewering across the Cape which will reduce the total number of septic systems.
- Septage tipping fees across the Cape range from roughly $0.06 to $0.14 per gallon based on discharge site and the origin of the septage load. Values on the lower end of this range ($0.05 to $0.08 per gallon) are typical for off-Cape discharge locations.
- The relatively limited availability of alternate septage tipping sites from Brewster, east to Provincetown allows for a slightly higher tipping fee as evident from the seasonal rate of $0.14 per gallon at the former Tri-Town facility. Similar market based rates should be considered as the Town builds out the new treatment facility and restores septage acceptance service to the area.

Tighe & Bond did not agree with all of the findings of the Stantec memorandum and we felt the following aspects of the report were worth pointing out:

- The analysis of upgrading the existing septage treatment facility compared with converting the facility to a septage transfer station assumes that tipping fees entirely offset O&M costs for the treatment option but they do not make this same assumption for the transfer station option. Our analysis suggests that the transfer station could be neutral in terms of O&M costs if it charged a tipping fee of $0.14 to $0.15 per gallon. We believe that this rate could be supported by communities from Orleans east to Provincetown where trucking costs become more significant for septage haulers. While this discrepancy in how the two enterprise funded alternatives would be paid for is noteworthy, we do not believe that it should impact the Town's current course of action because providing a centralized collection and treatment system addresses other water quality and economic development objectives or the Town that a transfer station would not.
- Stantec presented an analysis of a $0.01 per gallon rate increase during the summer months that projected a revenue increase of roughly $45,000 but ultimately rejected the idea based on the opinion that it would push haulers to other facilities like the Yarmouth-Dennis plant or other off-Cape locations. While we agree with the idea that the added fuel needed to make this journey is less than the tipping cost increase for a 5,000 gallon truck, we feel that the lost productivity for haulers caused by three hours of travel and tipping time would still make the Tri-Town site a better tipping location. We acknowledge that this aspect of their study will not significantly impact septage volumes or the need to incorporate septage facilities in a new Orleans WWTF and the it will be very easy for Orleans to adjust rates based on market conditions after the new facility starts up.

6 Wastewater Process Selection

Tighe & Bond reviewed AECOM's memorandum titled: Facilities Engineering – Preliminary Design Report (25% Design) Downtown Area Task 10.1.C.5 – Update WWTF Process Selection for the following criteria:

- Reasonableness of estimates of flows and quantities for wastewater, I/I, septage, wastewater treatment biosolids under current and future conditions;
- Conformance of treatment facility design with applicable Sate & County standards including TR-16 and the MassDEP Guidelines for the Design, Construction, Operation & Maintenance of Small Wastewater Treatment Facilities with Land Disposal;
- Suitability of wastewater treatment plant, septage and biosolids process design criteria and design details;
- Reasonableness of cost estimates for treatment facilities, including unit construction costs, construction related costs, engineering costs, contingencies and other cost factors;
- Reasonableness of estimated implementation phasing and construction durations; and
- Reasonableness of estimated operation and maintenance costs for collection and treatment facilities

A summary of our findings dealing with each of these review objectives follows.

6.1 Flows & Loads

AECOM has followed standard engineering practice in their development of sewer system flow rates across the service area through their use of water use records, zoning and build-out analysis. We found their approach to estimating infiltration and inflow was in keeping with TR-16 recommendations for similar systems. However, our experience with newly constructed systems which utilize modern construction materials and quality control techniques suggests that the traditional TR-16 based approaches can be excessively conservative since they are based on older systems that utilize pipe materials more subject to cracks/leaking and have more frequent pipe joints throughout the system. To address this issue and avoid over sizing key infrastructure systems we recommend that AECOM survey newer systems, built within the last 10 to 15 years, utilizing PVC pipe gravity sewers and low pressure sewer networks similar to those proposed for Orleans to develop more reasonable I/I estimates and peaking factors.

AECOM's estimate of septage flows seems to somewhat arbitrarily decrease Stantec's septage estimate of 9.2 million gallons per year down to 6.0 million gallons per year (MGY). While it is not explicitly stated, we believe that the 6.0 MGY flow rate is based on 100% of the septage flow rate estimated for the year 2040 in the towns of Orleans, Brewster, Eastham, Provincetown, Wellfleet, and Truro. Their approach then divides this flow rate across 365 days per year when Stantec had assumed that septage would only be accepted during normal business hours, on Monday through Friday. Applying Stantec's approach to AECOM's 6.0 MGY estimate would yield a septage design flow of 24,000 gallons per day (GPD) rather than the 16,000 GPD that they have accounted for. Given that the Orleans facility has the potential to serve the entire outer Cape for septage treatment, we would favor increasing the septage volume to 24,000 GPD to better account for actual tipping practices. This approach would appropriately account for septage flows 20 years from now and due to a lag in collection system buildout following phase one plant construction, near term excess capacity at the plant could be used for additional septage acceptance.

In addition to septage quantities we also noted that AECOM utilized records from the Tri-Town facility to estimate septage strength. Unfortunately, there is no statement in the text of what values were used or where they were collected at the Tri-Town plant. Our experience, and EPA literature, suggests that septage loads for BOD and TSS can often be around 10,000 mg/l but also that they are highly variable. At these BOD and solids concentrations septage is roughly 40 times the strength of typical municipal influent for systems like this. AECOM should provide a more detailed accounting for the basis for these loads so they can be accurately factored into the design.

Once flows and loading rates are combined together for the purposes of treatment process design we would expect the report to present a discussion of peaking factors that includes a detailed discussion of variations in conditions and the basis for those variations. AECOM attempts to do this with respect to flow in Table 2 of their memorandum however we found that the lack of discussion regarding seasonal variation in flow could lead to oversized systems during the winter/non- tourist months of the year. Additionally, Table 4 of their report omits BOD, TSS and TKN values for the minimum month design condition. Not addressing these conditions explicitly in the design could lead to oversized process tanks and equipment and inefficient operation. We also noted that in deferring to "literature values" for peaking factors has resulted in a max day peaking factor of 2.8 while MADEP guidelines and Title 5 (310 CMR 15) only require a peaking factor of 2.0 for groundwater discharge facilities. Use of a lower peaking factor may be justified based on a review of more recently constructed systems as described above.

Regarding AECOM's summary of anticipated effluent limits provided in Table 5 of the report, we agree that the stated values are consistent with MADEP's RCGW-1 standards which are typically applied to groundwater discharge permits. However, we are also aware of specific concerns across the Cape related to nitrogen based contaminants and their impact on coastal embayments. While we acknowledge that our review has been limited to documents listed in the Town's RFP, and additional correspondence with MADEP may have occurred to confirm these limits, this information was not provided in the text. Our concern in this regard is that because the plant will be classified by MADEP as a major groundwater discharge requiring an individual facility permit it is subject to a public comment period and possible appeal. During this process it is likely that stakeholder groups will review the project for consistency with water quality goals developed through the Massachusetts Estuary Program (MEP). If this review suggest that plant effluent must be lower than the projected total nitrogen value of 10 mg/l this could significant impact design at a relatively late stage in the design process. This issue should be presented in more detail at this phase of the project to solicit stakeholder buy-in.

We recommend that AECOM revise the flow and load section of their basis of design report to address the deficiencies outlined above and better document the role of septage and collection system flows and loads on the WWTF design. We also felt that the flow and load section of their report could benefit from a discussion of what flow and load conditions are used for specific design elements and selection of the number of treatment trains used in the plant design.

6.2 Process Selection

AECOM's report references a prior study prepared for the Town which performed an initial screening of several technologies and ultimately recommended the implementation of a membrane bioreactor (MBR) system. This study also ranked conventional activated sludge and sequencing batch reactors (SBR) as the second and third most favorable alternatives respectively based on "qualitative factors". Citing the success of local SBR facilities in Provincetown and Falmouth as well as design improvements made after the conceptual design/technology screening phase, AECOM's report selects the MBR and SBR technologies for a more thorough quantitative analysis.

In general, we found AECOM's technical approach to be reasonable and in keeping with industry standards for similar analyses. Their report ultimately concludes that the MBR and SBR alternatives have 20-year life cycle costs of $15.1M and $14.7M, respectively. This represents a difference of less than 3% in terms of life cycle cost and we agree that based on the similarity of the costs that they have estimated it is reasonable to utilize non-cost differentiators as "tie-breaker" criteria as their report states. Through the consideration of non-cost differentiators AECOM ultimately recommends proceeding with the design and construction of an SBR system. However, our review identified several areas where specific equipment and material unit costs were low and replacement capital costs were omitted. We cannot say at this time if adjusting these costs will yield a different outcome, however we recommend that AECOM review these issues and report back to the Town before a decision is finalized. The paragraphs that follow detail additional observations made on the process selection portion of AECOM's memorandum.

Headworks Screening – Tighe & Bond agrees with AECOM's recommendation to utilize 2 mm and 6 mm screens for the MBR and SBR systems, respectively. The center flow screen that they are proposing is a proprietary design produced by the Hydrodyne Engineering company. While the screen is compact as stated in the report, it is worth considering other traveling rake or screw type screens for this application as the additional space required for such models is small and designing around a more traditional type of screen could help in the future if units required replacement.

Membrane Bioreactor (MBR) – AECOM's discussion of MBR systems seems to focus on hollow fiber products developed by Suez under the trade name Zenon. These products have been marketed for over twenty years in North America and they have a solid reputation in the marketplace. In addition to the benefits cited by AECOM for MBRs, we thought the following were also worth highlighting.

- MBR membranes have the ability to filter out fecal coliform and many other bacteria, reducing the reliance on UV disinfection systems for permit compliance;
- Superior solids retention provided by membrane filters protects soil absorption systems used for effluent disposal;
- Long solids retention times in MBR systems reduce sludge volumes over conventional activated sludge systems;

Regarding the drawbacks to MBR systems cited in the memorandum we found the following to be noteworthy.

- Membranes require some units to be offline for chemical cleaning operations but these events can be scheduled for off peak hours or the low flow season so we did not feel this was a significant drawback;
- While it is true that MBR effluent often has a lower effluent solids concentration than conventional activated sludge systems, it is probably only 1 to 3 mg/l lower than the proposed SBR and disc filter system. Additionally, the longer sludge age in the MBR likely produces a lower sludge yield than the SBR; and,
- Membranes must be stored wet so even during low flow seasons all membranes will need to be kept submerged and at least intermittently aerated even if not exposed to wastewater.

Overall, AECOM presented a reasonable discussion of system pros and cons. The discussion could have been improved by an additional description of the activated sludge process used in conjunction with the MBR system. Based on our experience with similar systems we would expect this MBR to be set up in a Modified Ludzac-Ettinger (MLE) configuration to achieve the anticipated total nitrogen limit of 10 mg/l. This configuration may require additional tank volume or partitioning to create anoxic and aerobic zones within the process that were not shown on the drawings or in the report. Aeration requirements and internal recycle flow rates were also absent from AECOM's discussion and should be included. Additionally, the discussion of the MBR process could benefit from a process flow diagram, similar to the one already included in the report, which also shows the mass-balance for BOD, TSS and total nitrogen across the plant.

Sequencing Batch Reactor (SBR) – AECOM's design memorandum seems to focus on an SBR design produced by Aqua-Aerobics, Inc. which is one of the leading SBR manufacturers in the North America. We agree with the author that SBRs have a long track record of reliable performance and the fact that similar systems are used nearby in Falmouth and Provincetown suggests that there is local expertise in their operation. Our review did not take exception to any of the stated benefits of SBR systems, however, we felt that similar claims related to; nitrification/denitrification without external carbon, multiple vendors providing equipment, and the ability to build above ground could all be made for the MBR as well. Also similar to AECOM's discussion of MBR systems, the SBR discussion did not include a process flow diagram with a mass-balance for pollutants across the plant. This information is typically included in preliminary design reports such as this and will be required by MADEP for their review of the Engineering Design Report that is required under the Groundwater Discharge Permit Program (314 CMR 5.0).

6.2.1 Technical Evaluation of Biological Process

AECOM's memorandum does a reasonable job defining major process design elements for both MBR and SBR systems and we have provided specific comments on many of these aspects of the design in the subsections that follow. As mentioned in previous sections, the memorandum could benefit from process flow diagrams that indicate the mass-balance of regulated pollutants across each unit operation. Additional information regarding process aeration requirements, mixing requirements and several other parameters that are specific to each alternative were also omitted from the memorandum and text should be added to better describe these aspects of the design. Including vendor pricing submittals for MBR and SBR systems as an appendix to the memorandum could also be beneficial.

AECOM's technical evaluation of biological processes relies on both a lifecycle cost assessment of the two alternatives and several non-cost differentiators. A summary of both aspects of the evaluation follows.

AECOM's cost analysis of the MBR and SBR alternatives appears to be based on vendor quotes from Suez and Aqua Aerobics for MBR and SBR systems respectively. Both of these manufacturers are represented locally by the same equipment sales company, Technology Sales, Inc of Bolton, MA. We also noted that costs for influent screens and UV equipment were provided by this same firm. While Tighe & Bond has found both of these manufacturers and the local representative to be reputable, we believe it is prudent to solicit pricing from other MBR and SBR manufacturers such as Ovivo and Evoqua respectively to ensure that the current system costs are not overly inflated. Comparing alternate manufacturers may also reveal a more cost effective process configuration that saves money on structures or energy as well.

The two main aspects of any life cycle cost assessment are initial capital and long term operating costs. AECOM has done a reasonable job trying to capture initial capital costs by obtaining vendor quotes and developing conceptual system layouts. We found that their opinion of probable construction cost for both options included a reasonable amount of detail given the level of design development. Similarly, values established for Contractor overhead and profit as well as project contingencies were in line with standard industry practice.

We reviewed specific cost data related to concrete and equipment to determine if these costs were in line with recent bid values and our experience with similar projects. Beginning with concrete, we tabulated the total required tank volumes for the SBR an MBR alternatives and determined that the two systems have process volumes of 958,000 gallons and 597,000 gallons respectively. In light of the nearly 460,000 gallon smaller tank volume associated with the MBR design we anticipated that concrete volumes and costs would be substantially lower for this alternative. However, after tabulating concrete quantities presented in the opinion of project cost we noted that SBR and MBR systems were projected to use roughly 2,522 and 2,349 cubic yards respectively. This 7% difference in concrete volume did not reconcile well with the projected 60% difference in tank volume and because of this we feel that these quantities should be revisited. Additionally, Tighe and Bond calculated gross unit costs for concrete used in AECOM's opinion of construction cost and noted that their values ranged from roughly $700/CY to $830/CY. These values are considerably lower than those observed in recent bids for off-Cape projects where we have seen unit costs of $1,100/CY and greater. We suspect that on-Cape costs would be 10 to 15% higher than this value. While higher concrete prices would effect both options equally, they account for over $2M in project costs and would have a significant impact on overall project cost that is worth quantifying at this time. We recommend that AECOM revisit these unit costs before finalizing the LCCA.

In addition to concrete costs we reviewed material costs for key components of the SBR and MBR systems as well as sludge blowers, septage receiving equipment, sludge thickening equipment and UV systems. For all of these systems and equipment items we found AECOM's stated costs to be in line with costs that we have recently obtained for similar scopes of supply. Similarly, many of the pumps listed in AECOM's estimate were in line with what we've experienced on similar projects. In spite of our general agreement with AECOM's approach to estimating capital costs we have outlined a number of design related issues in the following sections that we believe should be resolved before a decision is made regarding process selection. Some of these issues have potential cost impacts that should be addressed through a revised LCCA as well. Given that the two capital cost estimates are within the margin of error of each other we believe it is appropriate to withhold judgement on process selection until these issues are resolved.

In addition to the capital cost assessment provided in AECOM's memorandum their text cited six non-cost differentiators that they claim have changed since their prior process screening memorandum was submitted recommending MBR treatment. We felt it was worth addressing each of these items individually because it appears that the two treatment technologies are similar in cost and unless design changes modify the LCCA outcome it is appropriate to base the decision on these considerations. A brief discussion of each issue follows.

- Operational Complexity – AECOM cites the addition of an effluent filter to the SBR design as something that reduces the need for SBR solids control and makes the system similar to MBR in terms of process reliability. We agree with this general assertion however, our coordination with disc filter manufacturers Kruger and Aqua Aerobics suggests that both firms recommend chemical cleaning of their filter media at least annually.
- Expansion Capability – Tighe & Bond agrees that both systems are readily expandable and could accommodate projected Phase 2 expansion on the proposed site. It is worth mentioning that future phases of expansion will only include

additional tankage and support buildings should remain largely unchanged. This fact would seem to favor the MBR option because it's tank volumes are roughly 40% smaller than the SBR option.

- Ability to Achieve Lower Limits – We agree with AECOM's claim that both MBR and SBR systems are capable of achieving nitrogen levels less than the anticipated 10 mg/l. How much less they are capable of will likely vary seasonally and is difficult to fully project until actual influent data is collected. We also thought that it was worth noting that both MBR and disc filter systems have been used to produce effluent phosphorous values of less than 0.1 mg/l through chemical addition. We agree that phosphorous limits have not appeared on many groundwater discharge permits in the State and they seem unlikely here. We recommend that AECOM confirm regulatory coordination on this issue or present a schedule for that process.
- Compatibility With Wick Well Disposal – Wick wells are a shallow groundwater injection well sometimes used in effluent disposal for small treatment facilities. We agree with AECOM's conclusion that effluent filtration promotes longer life for groundwater discharge systems whether they are traditional infiltration beds or wick wells. Anecdotal evidence regarding problems with wick well failure in eastern Massachusetts seems to point towards effluent encouraging the growth of iron reducing bacteria that can then clog well screens and adjacent soils. This issue should be investigated separately before selecting wick well disposal.
- Footprint Requirements – AECOM suggests that the land area required for the MBR system is similar to that required for the SBR system. While we agree that the two plans are not dramatically different we would like to see how some modest design changes outlined below would impact system size. Additionally, on a site that is relatively unconstrained this issue of spatial requirements seems to be better accounted for by the capital cost estimate.
- Prevalence of Technology – AECOM cites the use of SBR systems in Provincetown and Falmouth as evidence of successful implementation and a skilled workforce that is familiar with the system. We agree with this conclusion but would also add that there are several smaller MBR systems across the region that are run by contract operators so there is a similar wealth of experience for that technology in the area too.

After reviewing AECOM's analysis of non-cost differentiators Tighe & Bond felt that there was not a compelling reason to fully commit to the SBR system at this time. While we agree with many of AECOM's technical analysis of both technologies we believe that several of the design related issues described in the following paragraphs should be resolved prior to finalizing a decision.

6.2.2 Comments Regarding Proposed Unit Operations

In addition to the technical evaluation of biological processes AECOM provided additional detail regarding many of the unit operations throughout the plant which included their design rationale and sizing data. Comments specific to these elements of the design follow.

Sludge Thickening – AECOM's analysis of sludge handling systems begins with the assumption septage solids and waste activated sludge will be thickened to 4 to 6% solids by weight and hauled to an offsite solids processing facility like the ones in Cranston or Warwick, RI that many other facilities in the region use. The memorandum pays little attention to onsite dewatering and sludge stabilization technologies and we feel this is appropriate given the likely capital and operational costs associated with these systems compared to hauling thickened liquid. There may be good reasons to avoid these operations at the site such as odor potential, added capital cost and labor requirements. However given the hauling costs associated with liquid sludge disposal an alternative that looks at reduced hauling of sludge cake instead should be examined.

We found AECOM's approach to sizing sludge thickening equipment, based on 6 hours/day and 5 days per week, to be reasonable given the likely staffing level of the facility. We also found the technologies that were considered, which included; disc thickeners, screw presses, rotary drum thickeners, and gravity belt thickeners, to be appropriate for the anticipated solids. Our experience and research suggests that each of these technologies could produce the desired solids concentration for thickened sludge. AECOM's analysis cites odor containment, a compact footprint and automation as reasons to focus future equipment selection efforts on disc thickeners and rotary drum thickeners. Tighe & Bond agrees with the use of these criteria in the selection process however, we also noted that there appears to only be one disc thickener manufacturer currently in the US market while there are multiple rotary drum thickener manufacturers. As design progresses we recommend that the space dedicated to sludge thickening be made large enough to accommodate either system and that bid documents allow for competitive bidding by multiple equipment manufacturers.

Odor Control – AECOM's analysis quickly excludes chemical odor control scrubbers and focuses on biofilters and activated carbon systems. Tighe & Bond agrees with this approach in general given the size of the facility, however we felt that several additional factors should be considered prior to finalizing odor control process selection. The first factor requiring additional consideration is the design air exchange rates listed in Table 7 of the memorandum. The rate of 18 air changes per hour (ACH) prescribed to the Septage Receiving Garage is in line with TR-16 and NFPA 820 requirements however the basis of design for the Headworks Building, sludge storage tanks and the flow equalization tank seemed to be on the high end of recommended ranges or above recommended air exchange rates. While we recognize that providing more fresh air and odor control capacity can reduce corrosion and improve worker safety we felt that several of the stated design points appeared excessive. By making excessively conservative design assumptions the Town is likely to experience higher construction costs in the form of oversized odor control and make-up air systems as well as higher heating and energy costs in the Septage and Headworks spaces due to excessive air turnover.

In addition to the proposed air flow rates, Tighe & Bond also questioned the need for odor control at the sludge storage tanks. While we agree that septage can be excessively odorous, secondary sludge is often a far lower source of odor at a treatment plant. We believe that if septage solids were sequestered in a gravity thickener, as primary solids and septage often are at large plants, this thickener could produce solids in the 5 to 10% range without additional processing. By keeping them separate from other waste activated sludge, the Town would also greatly reduce the odor potential of both secondary thickened and unthickened sludge. Our observations at other facilities indicate that some plants will even forgoe waste activated sludge aeration in exchange for mixing systems that can be used to agitate the tank immediately prior to truck load out. Our preliminary estimates on the size of a gravity thickener large enough to handle 24,000 gpd at a solids concentration of 8,000 mg/l indicate that the unit would only need to be 10 to 12 feet in diameter. A unit of this size could likely be constructed at a relatively low cost using precast concrete elements and it could decrease the size of sludge thickening, odor control and aeration systems. We recommend that AECOM consider the alternative design outlined above and revisit odor control flow rates in greater detail before finalizing equipment selection.

Regarding the memorandum's assessment of carbon and biofilter media we noted that AECOM's life cycle cost analysis of the two systems included carbon replacement every 550 days and biofilter media replacement every 10 years. These replacement timeframes can vary widely based on specific system designs and hydrogen sulfide loading rates and the latter issue can be difficult to estimate at new facilities. Regardless, our experience with similar systems at plants with similar design conditions suggests that activated carbon often lasts 2 to 3 years and biofilter media often requires replacement closer to 6 to 8 years. We also thought it was noteworthy that biofilters typically require irrigation to maintain the biological community that provides odor reduction and this can pose challenges in cold climates where water piping and filter media can freeze. Some facilities attempt to address this by putting the systems indoors which adds substantial cost to the system. Biofilters also occupy a much larger footprint than carbon systems and our estimates for a system treating the current design flow rate of 12,170 CFM indicate that roughly 4,000 square feet would be needed. In light of these observations and potential design changes we think it is appropriate or AECOM to revise the life cycle cost comparison based on updated air flow rates and media life cycles. More accurate sizing for the biofilter and a description of the structures and systems required to sustain it should also be provided.

Post Filtration – Tighe & Bond agrees with AECOM that filtration prior to discharge is a prudent step to protect groundwater discharge systems and ensure high quality effluent. MBR systems provide this through the membrane filtration step and the disc filter proposed under the SBR system also provides this. It is worth mentioning that both the MBR and disc filter have effective pore sizes that are lower than the filters used in total suspended solids testing (i.e. <15 micron), however MBR pore sizes are small enough to exclude fecal coliform bacteria while the 5 micron disc filter media cannot. Groundwater discharge regulations require effluent disinfection in both instances however numeric limit compliance is still possible in the event of a UV system failure with MBR while it is not with the disc filter.

Disinfection – AECOM has developed a design which utilizes UV disinfection technology which we believe to be appropriate for a facility like the Orleans WWTF. However, we noted that the proposed system utilizes an in-pipe pressurized UV technology as opposed to an open channel UV system design. We have found these systems to be more costly to operate than open channel systems and we believe that a more detailed life cycle cost assessment of UV systems is needed to account for construction cost, energy/cleaning chemical consumption, and bulb replacement. There are also more companies which manufacture open channel systems, allowing for a more competitive bid on the equipment.

Administration/Laboratory Building – While interior details for the treatment plant building are limited at this stage of design development we felt that AECOM's description of proposed spaces which included offices, a laboratory, messing facilities and a maintenance space all seemed appropriate given the likely use of the WWTF as a treatment facility and operations base for collection system staff. Given these projected uses we would also recommend creation of a small locker room with an employee shower and storage space for spare e-One grinder pumps.

In terms of the general layout of these facilities we thought that AECOM's design presented an efficient use of space. However, we noted that the common wall construction between the septage acceptance/sludge processing garage and the adjacent lab/administration building poses several challenges. The current level of design development does not allow a thorough evaluation of this issue but experience on similar projects suggests that the septage/sludge processing area will require Class 1, Division 1 (explosion proof) electronics under the NEC and NFPA 820 codes. This area may also require sprinklers and common walls with other spaces could require a 2 hour fire rating. These issues could increase costs for the entire facility and it may prove more cost effective to separate the septage and sludge operations from the administration building by a small distance. This separation would also prevent the possible migration of explosive or corrosive gas from the septage/sludge area into the administration building.

Septage Receiving – Tighe & Bond agrees that the use of a septage acceptance plant as proposed in the memorandum is appropriate for the Orleans WWTF. As stated earlier in our report, we believe that the 6 MGD annual flow rate is better distributed across the typical five-day work week, resulting in a septage acceptance flow rate of 24,000 gpd. We also believe that there are benefits to sequestering septage related solids in either their own storage tank with descant capabilities or in a small gravity thickener as previously outlined.

Headworks – Proposed headworks screens, their capacity, and the level of redundancy are reasonable for the MBR and SBR treatment alternatives. Given the size of the facility it could be argued that conveying both screens to a common washer/compactor adds excessive cost and complexity to the system and that aspect of the system could be omitted. Alternately, there are other types of screens that perform both functions with a single machine more economically and these should be considered as design advances.

Flow Equalization – The proposed design includes two, 150,000 gallon tanks for the purpose of equalizing influent flows over a peak day flow. Our calculations, based on the method outlined in the Metcalf & Eddy design manual and a typical municipal diurnal curve indicate that an equalization volume of 70,000 to 80,000 gallons is needed to support phase 1 peak day flows. MADEP guidelines require a capacity of 25% of the design flow which is roughly 130,000 gallons for phase 1. Based on this analysis it appears that the volume of the equalization tanks could be reduced slightly to save cost, however the proposed volume is a conservative approach to the design. Filter backwash volumes which could end up in the flow equalization tank were not quantified in the report and they may explain the apparent excess capacity.

Cloth Disc Filters – Little information is provided regarding the cloth disc filtration system in the memorandum however based on the fact that much of the report is written around the Aqua Aerobics SBR we have assumed that AECOM’s design is based on the same company’s disc filtration system. The report should clarify the capacity of proposed filters and how many filters are tow be provided. Filter backwash rates and frequency should also be estimated and summarized in both the text and a mass balance process flow diagram.

Post Equalization (SBR Only) – The memorandum states that post equalization is required only for the SBR alternative and it appears that the design intent for this structure is to provide a reservoir for filter backwash water, a means to mitigate peak flows prior to UV disinfection, and a wet well for soil absorption system dosing. Information provided in the report was inadequate to determine if the volume of this tank is sufficient for any of these functions. Additionally, the stated number of pumps proposed for use with this tank appears to meet redundancy requirements based solely on the number of pumps but without an understanding of backwash flow rates and effluent disposal system loading rates it is impossible to determine if these systems meet industry standards.

Effluent Pumping – Effluent pumping from the WWTF site to the soil absorption system site will be required for both the MBR and SBR alternatives. Tighe & Bond recognizes that the discharge site has not been finalized at this time, therefore, a detailed evaluation of pumping requirements was not performed. Proposed pumping rates are adequate to convey the peak day flow but they would need to operate nearly constantly over the course of 24 hours to convey this flow and soil absorption systems and wick wells typically operate on a more cyclical dosing system. It appears that additional information regarding the discharge site must be finalized before the design can be completed and reviewed.

Sludge Storage – AECOM proposes routing screened septage directly into the waste activated sludge storage tank prior to thickening and trucking offsite for disposal. Tighe & Bond is somewhat concerned with this approach because it combines waste activated sludge which is rich with denitrifying bacteria with a fresh source of carbon to fuel their growth and potentially release nitrogen gas or lead to sludge bulking in the storage tank. Aeration in the storage tanks could mitigate this risk but it simply applies energy to a problem that could be solved more efficiently by keeping these materials separated. We would prefer to keep these two materials separate until immediately prior to mechanical thickening, or in the case of the gravity thickener option that was summarized previously, we would keep both types of sludge separate until they are loaded onto a truck for disposal. It was noted that AECOM assumed MBR waste activated sludge (WAS) would be about twice the solids content of SBR sludge (1% vs. 0.5%) at the time of wasting and this should result in smaller storage tanks for the MBR system. While this difference was reflected in the design, the same amount of storage in terms of days was not provided for both alternatives. Our experience suggests that at least four days of WAS and thickened waste activated sludge (TWAS) storage be provided for a plant like this to account for a lack of sludge processing across holiday weekends such as Thanksgiving or extended storm periods that divert resources. AECOM's current approach provides a satisfactory amount of TWAS storage but the WAS storage volume varies between 2.2 and 3.1 days which is inadequate. Furthermore, the storage capacity in days could be further reduced by adjusting the septage receiving quantity to 24,000 gpd as previously discussed.

Aeration Systems – AECOM has proposed coarse bubble diffuser systems for the equalization, WAS and TWAS storage tanks. Aeration rates appear to be based on mixing requirements specified by TR-16 or other similar guidance documents. As previously discussed, sequestering septage from WAS could negate the need for mixing air and allow the design to use a pumped mixing system immediately prior to truck loading or thickening. This may produce a lower capital cost and lower energy design. Additional information comparing these design alternatives should be presented.

6.3 Project Schedule

Tighe & Bond has reviewed AECOM's proposed schedule presented in Table 23 of the report which claims a total project duration of 27 to 42 months from design phase through startup and testing. Tighe & Bond believes that this estimate may be overly optimistic in the following areas:

- **Preparation of Design Plans & Specification –** This had a stated duration of 6 to 9 months however obtaining Town buy-in and conducting value engineering or other design reviews could increase this process to 9 to 12 months.
- **Equipment Bidding –** Equipment bidding during the design phase was omitted from the schedule and should be included. Given the unique aspects of designing an MBR or SBR system Tighe & Bond recommends that the Town utilize a Goods and Services procurement process as allowed under MGL Ch. 30b to obtain firm equipment pricing and determine which vendor will be used. This will allow the designer to tailor spaces, tank volumes and equipment layouts to the specific items and configuration that the selected vendor proposes. This approach ensures competitive pricing and reduces the work associated with fitting off-spec equipment into the design during the construction phase of the project. This process should take roughly three months.
- **Construction Bidding –** Since the current project value exceeds $10M state regulations require the Town to prequalify general contractors and filed sub bid contractors. This process must occur before the bid for the actual construction work can occur. Our experience indicates that contractor prequalification takes roughly three months to complete and bidding the actual construction work for general contractors and sub bidders will take an additional three months from the time of

advertisement to contract award. Contractor prequalification may occur prior to design completion to minimize it's impact on the overall project schedule.

- **Construction –** Based on our experience with projects of similar cost and complexity we anticipate the Orleans WWTF taking 18 to 24 months to complete rather than the stated 12 to 18 months.

It would be appropriate for AECOM to revise their proposed schedule to account for the issues summarized above and depict the revised schedule on a Gant Chart. Such a chart might also benefit from indicating funding deadlines for State Revolving Fund Loan applications and awards as well as annual Town Meeting appropriations.

6.4 Operation & Maintenance Costs

AECOM's memorandum summarizes O&M Cost *Differences* for the SBR and MBR options for Phase 1 as indicated in the table below.

Description	**MBR Option**	**SBR Option**
Annual Costs		
Cleaning Chemical	$700	$0
Bioreactor Power Costs	$22,275	$17,300
EQ to Bioreactor Pumping Costs	$5,250	$10,500
Annual Cost Subtotal:	**$28,225**	**$27,800**
Non-Annual Costs		
Membrane Replacement (every 10 years)	$120,000	$0

Tighe & Bond understands that the intent of this analysis was to compare two competing options so costs that were believed to be similar between the two options were omitted from the analysis. Since vendor submittals were not included in the report and mass-balance PFDs were not provided it was impossible to check the validity of the costs summarized above. However, based on our experience with similar systems there were several other items that we felt should be explicitly called out in the O&M cost summary table before a treatment system choice is finalized. These items include the following:

- **Sludge Storage Odor Control & Mixing Air** – Both odor control flow rates and mixing air requirements are typically determined based on the volume of a storage tank and the volume of liquid being stored. Since the MBR system produces WAS at roughly twice the solids concentration of the SBR it should require roughly half the storage volume to maintain 4 days of storage. Odor control and mixing air flow rates for the WAS tanks in particular should be included in this analysis to accurately show the savings associated with the MBR alternative.
- **Disc Filter Cleaning –** Tighe & Bond has recently performed several evaluations of similar disc filter systems an in all cases we have found that manufacturers recommend some type of chemical cleaning for the units. The recommended frequency of these cleanings depend on a number of factors that can be site specific

but it is appropriate to carry some nominal cost in the analysis for SBR disc filter cleaning chemicals just as it is for MBR membranes.

- **Disc Filter Backwash –** Disc filters require some level of backwashing to prevent the loss of hydraulic capacity. This quantity varies between manufacturers and site conditions but it is often estimated as 1 to 4 % of design flow however, backwashing occurs at relatively high flow rates for short durations and requirements should be stated by the vendor. The energy associated with this backwashing activity should be accounted for in the analysis.
- **Bioreactor Power Costs –** More information should be provided on what is included in the Bioreactor Power Cost line items. For the MBR system we would expect this to include anoxic zone mixing, pre-aeration zone aeration, MBR cleaning air, and an internal recycle pump that could also double as the WAS pump. With the SBR system we would expect power costs to include aeration, mixing and descant pumps (if required). These costs may be accounted for in the analysis but it was not stated in the text.
- **Replacement Capital –** Several recent disc filter evaluations performed by Tighe & Bond indicate that filter manufacturers recommend filter cloth replacement every 7 to 10 years based on service conditions and the type of filter material used in the design. This cost should appear next to the membrane replacement cost in AECOM's Non-Annual Cost line item.

Once the above issues are addressed AECOM should repeat the life cycle cost assessment (LCCA) to confirm that the outcome still favors the SBR option.

In addition to the costs outlined above which AECOM has developed for comparative evaluation purposes, we felt it was appropriate as part of this memorandum for the design engineer to estimate the total operating costs for the facility so the Town could better evaluate ongoing operating costs and potential rate impacts. We would expect these additional costs to include heating/AC, lighting/administrative electrical costs, staffing based on MADEP requirements, a department vehicle, sludge disposal, replacement capital costs and other costs typically incurred through operation of a sewer department and WWTF.

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