COMPARISON OF COSTS

FOR

WASTEWATER MANAGEMENT SYSTEMS

APPLICABLE TO CAPE COD

Guidance to Cape Cod Towns Undertaking Comprehensive Wastewater Management Planning

Prepared for:

Association to Preserve Cape Cod
Cape Cod Business Roundtable
Cape Cod Water Protection Collaborative

Prepared by:

Barnstable County Wastewater Cost Task Force

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EXECUTIVE SUMMARY

The Barnstable County Wastewater Cost Task Force was established to compile and analyze current local information on the costs to build and operate wastewater systems in use on Cape Cod. Based on that information, the Task Force has developed cost estimates for a wide range of wastewater system sizes and types to help Cape Cod towns fairly compare available options. The application of the results will allow towns to identify which options are best for their circumstances and thus streamline their comprehensive wastewater management planning.

Data were compiled and cost estimates prepared for four types of wastewater systems:

- **Individual on-lot systems** with and without nitrogen removal.
- **Cluster systems** serving up to approximately 30 homes with aggregate wastewater flows less than 10,000 gallons per day (gpd).
- **Satellite systems** serving from 30 to 1,000 homes (wastewater flows between 10,000 gpd and 300,000 gpd), intended to treat and dispose of wastewater from one area of a town.
- **Centralized systems** which can provide for most or all of a town's wastewater management needs, and that might be suitable for serving portions of neighboring towns.

Cost estimates were prepared to be inclusive of all aspects of wastewater management: collection, treatment, and disposal. Costs were also included for conveyance between the collection system and the treatment site, and between the treatment and disposal sites if they cannot be co-located. Four measures of cost were considered:

- Capital cost---the cost to design, permit and build the facilities, including land costs.
- Operation and Maintenance (O&M) costs---the ongoing expenses for labor, power, chemicals, monitoring, sludge disposal, etc.
- Equivalent annual costs---a mathematical combination of O&M expenses and amortized capital costs.
- Costs per pound of nitrogen removed---the equivalent annual cost divided by the annual nitrogen load removed from the watershed of a nitrogen-sensitive embayment.

Actual cost information was obtained from over 30 existing wastewater treatment facilities, located largely in southeastern Massachusetts. The data were carefully reviewed to be sure they included all pertinent cost items. "Unit costs" were computed by dividing construction costs and O&M costs by the associated wastewater flows. Graphs of these unit costs show clear trends and demonstrate significant economies of scale, which are summarized here:

Capacity	Unit Construction Cost	Unit O&M Cost
10,000 gpd	$70 per gpd of capacity	$13 per gpd of average flow
100,000 gpd	$35 per gpd of capacity	$ 5 per gpd of average flow
1,000,000 gpd	$17 per gpd of capacity	$ 2 per gpd of average flow

Compared to a satellite facility of 100,000-gpd capacity, a central facility of 1.0-mgd (million gallons per day) capacity costs about 50% less to build and 60% less to operate on a per-gallon basis.

Fourteen scenarios were developed to combine capital and O&M costs for wastewater collection, transport, treatment and disposal and to compare those costs with the nitrogen removal that can be expected. Costs and performance were estimated both for Base Cases (with a uniform set of assumptions for all scenarios) and as part of a sensitivity analysis to determine how costs might change with assumptions that are either more or less favorable for each system size. The results are as follows, expressed as equivalent annual cost per pound of nitrogen removed:

	Low	Base Case	High
Individual N-removing systems	$550	$770	$830
Cluster systems, 8,800 gpd	$500	$710	$790
Satellite systems, 50,000 gpd	$480	$680	$720
Satellite systems, 200,000 gpd	$380	$510	$550
Centralized systems, 1.5 mgd	$250	$305	$319
Centralized systems, 3.0 mgd	$230	$285	$295

The sensitivity analysis allows the identification of the most important cost factors, which are:

- Economies of scale--large systems may be significantly less expensive per gallon treated because many of the cost components do not increase directly with the flow.
- Density of development--wastewater collection costs are the largest component of a complete system and they increase in direct proportion to the lot size served.
- Location of disposal facilities--an effluent disposal site within a nitrogen-sensitive watershed returns some of the collected nitrogen to the watershed in the from of the residual nitrogen remaining in the effluent. Compared to a disposal site that is not in a sensitive watershed, the in-watershed disposal option must be larger to eliminate more septic systems and to remove enough additional nitrogen to offset that returned in the effluent.
- Land costs--land suitable for wastewater management functions is scarce and expensive. Using town-owned parcels is cost-advantageous for any scenario, but particularly if multiple small systems are to be built, each with its own need for set-backs and buffer zones.

From this sensitivity analysis, conclusions can be drawn about the circumstances that favor one size of system over another.

- **Individual systems**. The applicability of these systems is limited by their relatively poor performance and the administrative hurdles associated with using them as the sole means of meeting watershed-wide nitrogen control targets. However, since they are located on the parcel where the wastewater is generated, they eliminate collection costs and should be considered as adjuncts to other options for remote, sparsely developed neighborhoods within watersheds with relatively low nitrogen removal requirements.

- **Cluster systems**. These systems should be considered for existing neighborhood with small lots that are remote from sewered areas and have publically-owned land nearby. They also are good options for new cluster developments where infrastructure can be installed by the developer and later turned over to the town, or for shore-front areas that may not be connected to larger-scale systems until later phases of a project.
- **Satellite systems**. Satellite facilities make the most economic sense in remote watersheds (more than 5 miles from the existing sewer system or other areas or need), with vacant publically-owned land nearby. These systems are also applicable in the case of an existing or proposed private facility that can be taken over by the town and expanded to provide wastewater service to existing nearby properties currently on septic systems, particularly if the town-wide system may be not be available for many years and the developer is prepared to proceed in the near future.
- **Centralized Systems**. This option is likely to be the most viable when:
  - dense development exists in nitrogen-sensitive watersheds;
  - suitable treatment and disposal sites (outside sensitive watersheds and Zone IIs) are available at no or low cost;
  - a high degree of nitrogen control is required;
  - areas of dense development in sensitive watersheds are within 3 miles of desirable effluent treatment and disposal sites; and
  - opportunities are available for cost reductions through regionalization.

While the cost estimates presented in this report are conceptual and based on a uniform set of assumptions, they are supported by a review of actual data for nine example projects. Those examples indicate costs ranging from about \$300 per pound of nitrogen removed for centralized systems up to \$700 or more for smaller systems.

One of the goals of this study is to help Cape Cod towns streamline their Comprehensive Wastewater Management Plans by identifying the circumstances that are most favorable for each type of system. For example, if a town owns a site suitable for both treatment and disposal, which is not within a sensitive watershed, and is located near the most densely developed areas needing nitrogen control, then economies of scale will make a centralized system the least expensive by a considerable margin. Nonetheless, this report is intended as general guidance, and specific local conditions must be evaluated to be sure that the most cost-effective solution is determined. The sensitivity analysis conducted in this study should help towns target the most appropriate cost factors.

The estimated costs presented in this report are based on a common set of assumptions about the density of development served by the various systems. Towns with less dense development will be faced with higher collection costs than shown here. Costs for collection systems can be very expensive and towns should investigate alternatives to traditional gravity systems. Cost savings associated with the use of those alternative collection systems may apply to any of the scenarios reviewed in this study and should not be attributed to one option and not another.

COMPARISON OF COSTS
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PURPOSE

This report summarizes the methodology and results of an investigation of wastewater management costs that can be expected at public wastewater facilities on Cape Cod.

Wastewater management can be accomplished with relatively small-scale systems (serving single homes or neighborhoods of up to 30 homes), at moderate-sized facilities that might serve up to 1,000 properties, and/or in a central facility serving an entire town alone or with one or two neighboring towns.

This investigation addresses the costs to build and operate wastewater systems of various sizes and types. It identifies those circumstances where each type of system may be most applicable. The choice of wastewater management approach is an essential element of a town's Comprehensive Wastewater Management Plan (CWMP), and this report was prepared to provide general guidance to the towns who are preparing CWMPs.

DEFINITIONS

Wastewater systems have been considered in four categories as follows:

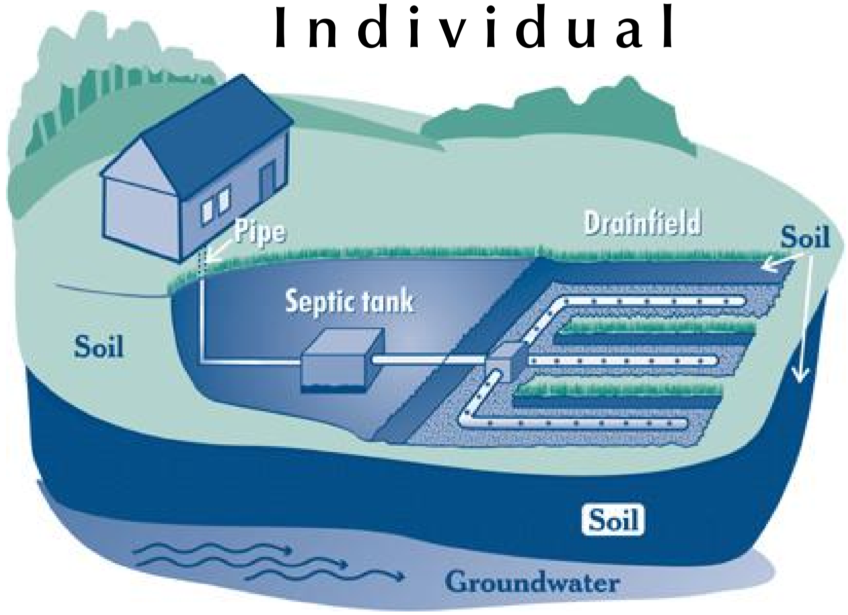
- **Individual system**--serving one property and located on the parcel where the wastewater is generated.
- **Cluster system**--serving nearby properties with an aggregate flow less than 10,000 gallons per day (gpd), roughly equivalent to 30 three-bedroom homes.
- **Satellite system**--serving an area of a town with an aggregate flow greater than 10,000 gpd (and thus requiring a DEP groundwater discharge permit), and as much as 300,000 gpd.
- **Centralized system**--a larger system that provides for most or all of a town's wastewater management needs, and could be regional.

Figure 1 illustrates these four types of wastewater systems.

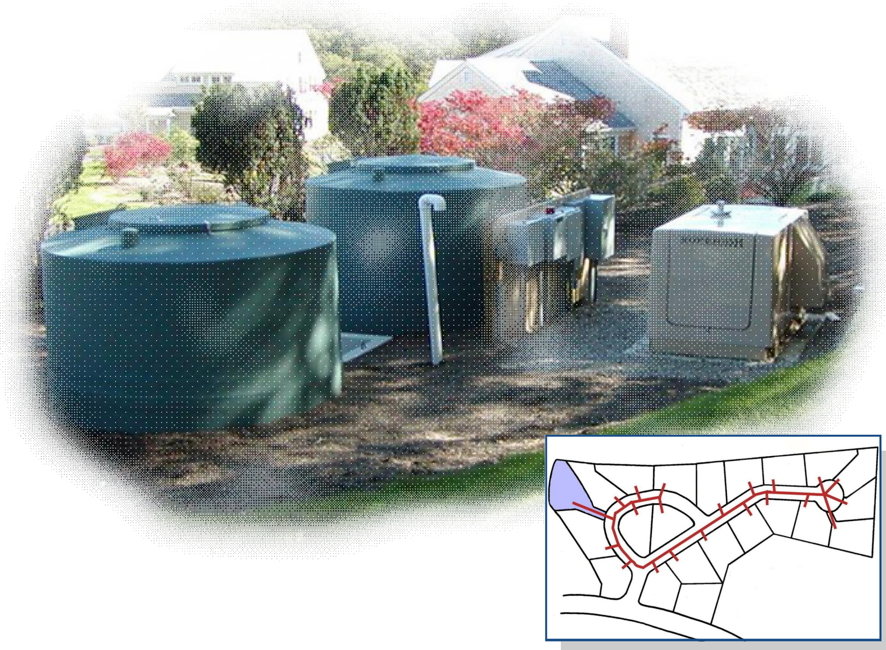
Estimates have been prepared for two types of costs:

- **capital costs** --the costs to plan, design, permit and build wastewater facilities, including the purchase of land; and
- **operations and maintenance (O&M) costs**--the annual expenses to run the facilities.

Individual



Cluster



Satellite

Centralized

FIGURE 1
TYPES OF WASTEWATER SYSTEMS

Wastewater management systems typically comprise the following elements, not all of which are needed in every instance:

- **Collection**, including sewers (of several types) and pumping stations needed to bring the collected wastewater to one point;
- **Transport from the collection area to the treatment site**, including pumping facilities and pipelines;
- **Treatment** to achieve effluent quality requirements as dictated by Title 5, by a DEP groundwater discharge permit, or by a nitrogen-based TMDL;
- **Transport from the treatment site to the effluent disposal site**, if the treatment and disposal functions cannot be co-located; and
- **Disposal**, which typically involves subsurface leaching or rapid infiltration, as well as monitoring wells, and may include effluent reuse.

These typical elements of a municipal wastewater system are shown conceptually in Figure 2. (While wastewater collection systems on Cape Cod are needed to eliminate Title 5 systems in the watersheds of nitrogen-sensitive embayments, it should be noted that the associated treatment and disposal facilities may be located either within or outside those watersheds.)

Wastewater facilities on Cape Cod are governed by three regulatory programs. The first is the state sanitary code, Title 5. A traditional on-site system consisting of a septic tank and leaching field is called a "Title 5 system". Title 5 systems may be appropriate for on-site wastewater management for many reasons, but their effluent contains significant amounts of nitrogen, the contaminant that is causing widespread water quality problems in Cape Cod's coastal waters. The second regulatory program is the DEP groundwater discharge permitting program that requires a permit (and significant nitrogen removal) for projects with wastewater flows exceeding 10,000 gpd. Most coastal embayments on Cape Cod are impacted by excess nitrogen loads resulting in ecological impairment. Under the Federal Clean Water Act, the third regulatory program has established Total Maximum Daily Loads (TMDLs) for these impaired embayments and has identified on-site wastewater disposal as the main contributor of nitrogen.

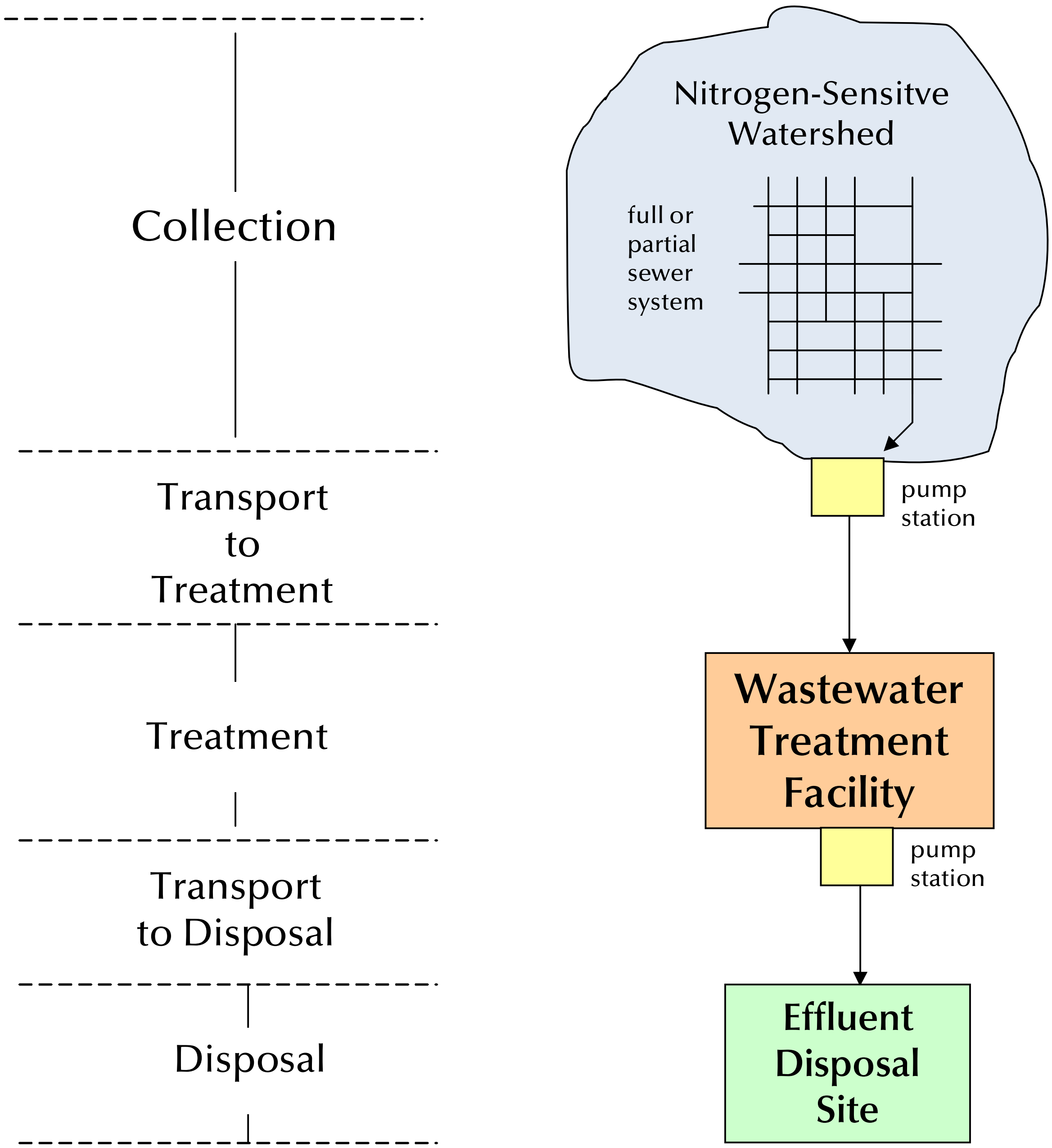
METHODOLOGY

Data Sources for Individual and Cluster Systems

Although many individual wastewater systems have been constructed on Cape Cod, both simple Title 5 systems and those with nitrogen-removal components, the purchasers of those systems are individual property owners and there is no readily accessible database on the costs to build and maintain these systems. Accordingly, data were obtained from the following sources for this study:

- Interviews with suppliers of treatment systems
- Discussions with construction contractors and developers
- Data available from the Massachusetts Alternative Septic System Test Center
- Reports from the New Jersey Pinelands Commission

The information from the Pinelands Commission is of interest because that organization has undertaken a formal program of tracking the cost and performance of nitrogen-removing systems



Notes: 1. Treatment and disposal may occur at a single site.
2. Treatment or disposal or both may occur within a nitrogen-sensitive watershed.

FIGURE 2

ELEMENTS OF TYPICAL WASTEWATER SYSTEM

installed within its jurisdiction, and data are available for four common technologies and approximately 180 individual systems. Although this database is not local to Cape Cod, there are many similarities in the soil types and groundwater regimes that allow its extrapolation to Cape Cod.

Data Sources for Satellite and Centralized Systems

There is considerable experience with satellite and centralized wastewater facilities on Cape Cod and in southeastern Massachusetts. Cost information from existing facilities was viewed as an important definitive database for this evaluation. Assembling an appropriate database was undertaken in the following steps:

1. Determine the actual costs to construct numerous wastewater facilities in southeastern Massachusetts in recent years.
2. Canvas existing wastewater facilities to determine actual O&M costs.
3. Adjust the capital and O&M costs to a common basis, both in time and in terms of included items.
4. Compute "unit costs" for construction (cost per daily gallon of capacity) and for O&M (cost per gallon treated) and develop graphical summaries to depict how those unit costs vary with facility size.

Cost Estimating Methodology

The costs to build and operate wastewater facilities were estimated for several wastewater management approaches, ranging from a single centralized facility down to multiple small facilities. For each approach, the cost estimates were prepared using a common set of assumptions to enable the results to be fairly compared.

The costs to design, permit and construct facilities (the capital costs) were estimated in the following steps:

1. Basic construction costs were estimated from data compiled from the surveys noted above. Costs were estimated for each of the elements shown in Figure 2.
2. An allowance was included for engineering planning and design costs, permitting costs, legal expenses and a contingency for unexpected construction items.
3. Land costs were estimated based on the nature and extent of the wastewater facilities.
4. Capital costs were computed as the sum of the three items above.

The costs to operate and maintain smaller wastewater facilities were prepared by estimating typical expenses for labor, power, chemicals, etc. For satellite and centralized facilities, the cost curves described above were applied based on the average flow treated.

As a final step, the assumptions for each scenario were systematically varied to estimate likely cost ranges for each management approach and to determine the circumstance where each type of system may be most favorable.

SURVEY RESULTS--INDIVIDUAL AND CLUSTER SYSTEMS

Construction Costs

From all of the sources available, it was determined that the costs to design, permit and build most conventional Title 5 septic systems fall in the range of $8,000 to $15,000. The low end of this range applies to new homes where the septic system is installed during home construction, sandy soils are available, and there is sufficient depth to groundwater. Higher costs pertain when the soils and groundwater conditions are less favorable, or when the system is built as a replacement and costs are incurred to restore site features that are disturbed. (There are documented cases of properties spending more than $30,000 for mounded systems that require influent pumping, significant site grading and restoration of landscaping.) For the purposes of this study, an average cost of $13,000 was used for a simple Title 5 system. Both lower and higher costs were considered as part of the sensitivity analysis.

Data from the Barnstable County Septic Loan Program were reviewed and found supportive of this estimate. For over 1,100 properties, owners borrowed an average of $11,000 (median of $8,500) to replace individual septic systems. These costs include some partial replacements (leaching field only) and some full replacements.

Nitrogen-removing systems typically add $9,000 to $15,000 to the cost of the basic septic tank and leaching field system, resulting in total costs of $17,000 to $30,000. The average cost for 180 homes in the Pinelands of New Jersey was $24,000, including $11,000 for the basic septic-tank-and-leaching-field components and $13,000 for the nitrogen-removing elements. This study has used $24,000 to $28,000 as the base case for new systems with nitrogen removal. The sensitivity analysis considered both lower and higher costs.

The $24,000 figure was used to characterize the current use of individual denitrifying systems on Cape Cod, where inexpensive construction and lack of oversight have resulted in less than optimum performance. (In the current DEP program under Title 5, systems are required to achieve effluent nitrogen of 19 mg/l and many do not perform that well.) It was assumed that a somewhat higher cost ($26,000) would best characterize a more rigorous design and better construction oversight as would be needed to achieve a lower effluent nitrogen concentration (13 mg/l), as demonstrated in the Pinelands program. If these systems are to be used for long-term, documented TMDL compliance, additional costs would be needed for a more robust and longer-lasting design and for more frequent testing of the effluent. A capital cost of $28,000 was assumed in this instance.

For cluster systems, data from several Cape Cod facilities were compiled and adjusted to a common basis. For the example 8,800-gpd systems, capital costs were estimated to be $250,000 for systems built under Title 5 (achieving 15 mg/l) and $360,000 for systems built under the DEP groundwater discharge permit program (achieving 8 mg/l). The higher figure reflects a separate denitrification process, chemical feed facilities, a small control building, monitoring wells and a smaller effluent disposal area. The $250,000 and $360,000 figures do not include effluent disposal, land or a collection system.

Operation and Maintenance Costs

Using data from all sources, a baseline O&M cost of $1,250 was computed for the typical individual denitrifying systems installed under current DEP program, and $2,000 for systems receiving more oversight and testing. (The average O&M cost for 180 systems in the Pinelands of New Jersey is $1,800, where somewhat lower labor costs prevail and where effluent testing is less rigorous than would be needed on Cape Cod. This figure was derived from discussions with participating vendors who charge approximately $9,000 for a 5-year contract for operation and maintenance.) Where TMDL compliance is to be documented, monitoring costs increase the annual total O&M expenses to $3,200.

By comparison, it is estimated that the typical Title 5 system would have an average O&M cost of $100, largely for once-in-four-year septage pumping.

SURVEY RESULTS--SATELLITE AND CENTRALIZED SYSTEMS

Construction Costs

To form a sound basis for predicting the construction costs of small-scale wastewater systems, contacts were established with the owners or builders of existing New England wastewater facilities to determine what was actually spent to construct them. To date, data have been obtained from 24 facilities, 14 of which are located in southeastern Massachusetts. Their design flows range from 15,000 gpd to 2.3 million gallons per day (mgd), and they were built over the last 13 years.

The surveyed facilities are largely satellite and centralized treatment plants that remove nitrogen and have groundwater discharge permits. About half are private facilities. A wide range of technologies is represented, including SBRs, RBCs, BioCleres, MBRs, and conventional activated sludge.

This segment of the survey has specifically focused on the costs of treatment, and not collection, transport or disposal. Many of the cost quotations required some analysis. Often the quoted construction cost includes both treatment and disposal; in those cases discussions were held with the developer or engineer to separately estimate the cost of the disposal system and subtract it from the quoted number. When the data received have included land, permitting or engineering costs, those items have been subtracted out to arrive at a pure construction cost. (The cost estimating procedure later adds a consistent allowance for non-construction aspects of the capital cost such as design, permitting, construction phase engineering services, legal expenses and land.)

The approximate bid date was obtained for all projects, and then the cost information was projected forward to late 2009 at an ENR cost index of 8600. (*Engineering News Record* is a construction industry publication that monthly reports a cost index that is a widely used to benchmark costs.)

For each facility, the date-adjusted construction cost was compared with the plant's design flow. For satellite and smaller facilities, the design flow is the Title 5 flow (which is typically viewed as a maximum-day or maximum-2-day flow.) For many of the larger plants, the quoted design flow is something other than the Title 5 flow, and a short-term peak flow was estimated so the data can be compared with facilities with Title 5 design flows. (For example, a facility with a maximum monthly design flow of 1.0 mgd might have a short-term peak flow of 1.3 mgd.) When the construction cost is divided by the design flow, the result is a metric expressed as "dollars per gpd of design flow". Those unit costs have been plotted using a logarithmic scale for the flow, and the results are shown in Figure 3.

Although there is significant scatter in the data, a trend line is evident. (Some scatter would be expected given the site-to-site variability among projects, the different treatment processes, varying degrees of conservatism in design, and the competitiveness of the bidding process.)

A mathematical curve-fitting approach was used to establish a line of central tendency. That line-of-best-fit yields the following points:

10,000 gpd	\$70 per gpd of design flow
100,000 gpd	\$35 per gpd of design flow
1,000,000 gpd	\$17 per gpd of design flow

Figure 3 is a good example of the concept of "economies-of-scale"; the larger the facility, the lower the cost to provide treatment for a daily gallon of capacity. These data indicate that, on a per-gallon basis, a 1.0-mgd plant can be built at 50% of the cost of a 100,000-gpd plant, and only 25% of the cost of a 10,000-gpd facility.

A tabulation of the assembled survey data is contained in Appendix A.

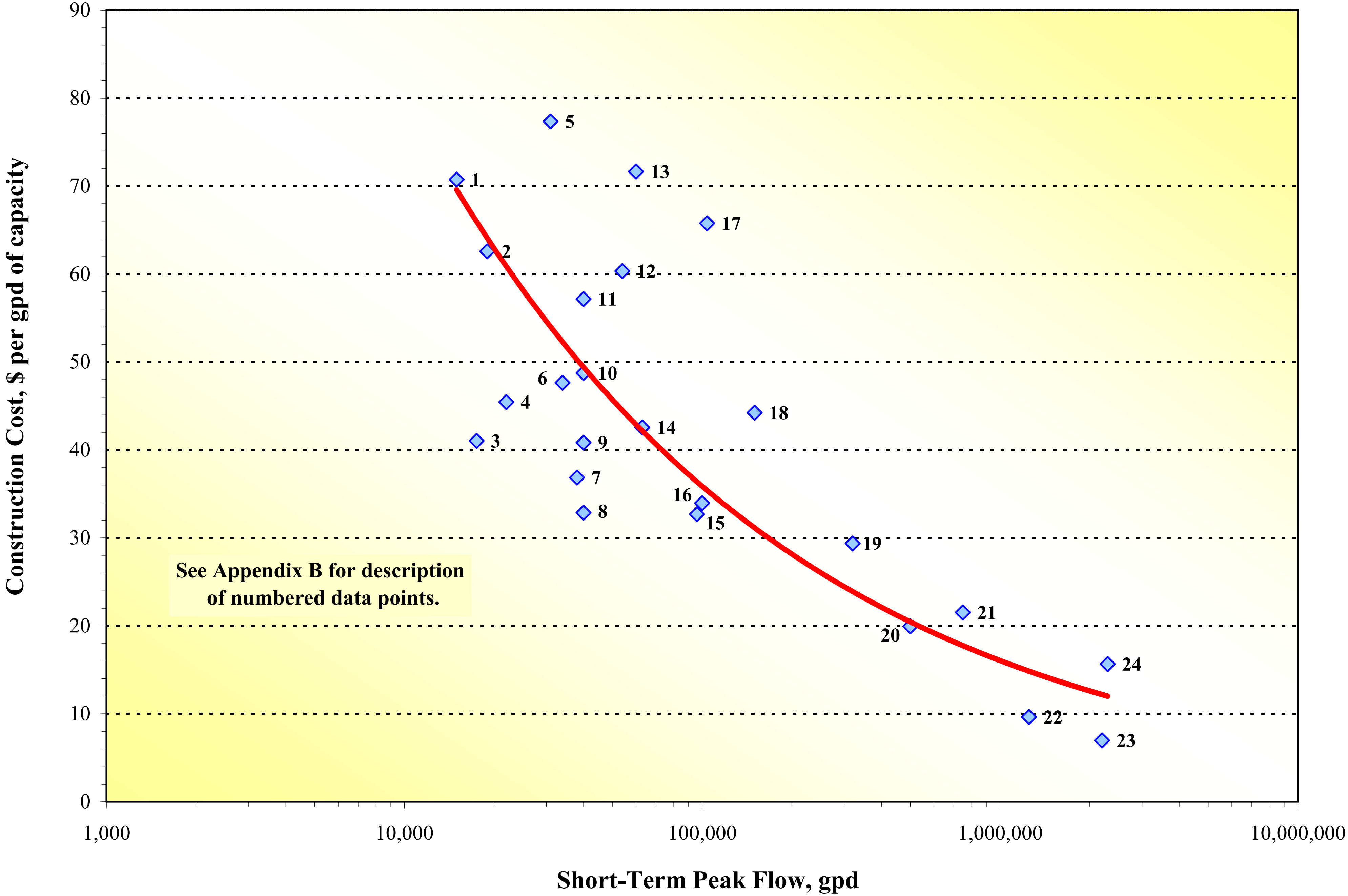
Operation and Maintenance Costs

A similar survey was conducted of existing New England wastewater facilities to determine actual O&M expenditures for collection, treatment and disposal. To date, 21 facilities have been contacted, 18 of which are in southeastern Massachusetts. Their design flows range from 17,000 gpd to 4.2 mgd. The surveyed facilities are largely satellite and centralized facilities that remove nitrogen and have groundwater discharge permits. A wide range of technologies is represented, including SBRs, RBCs, BioCleres, MBRs, and conventional activated sludge.

Care was taken to document what is included in the cost quotations that were received, to be sure that at least the following items are included:

- Labor
- Electricity
- Chemicals
- Laboratory analysis
- Repairs and equipment replacement
- Administrative costs including insurance
- Sludge disposal

FIGURE 3
RESULTS OF CONSTRUCTION COST SURVEY



When the data received did not include all of these cost items, discussions were undertaken with the owner, operator or DPW staff person to make the estimate more complete. In all cases, it was determined that no debt service costs or depreciation are included.

The private satellite system costs include only a small amount for operating and maintaining the collection system, because the facility is often located on the same property where the wastewater is generated. Public systems include significant collection system O&M costs. Therefore the private plant costs may understate what the O&M cost would be for a similarly-sized public satellite system. Partially offsetting that factor is the DEP annual compliance fee that is paid by private plants but waived for public plants. (That fee is $7,000 or $12,500 depending on whether the facility is smaller or larger than 40,000 gpd.)

For each facility, the annual O&M cost was compared with the estimated annual average flow. When the cost is divided by the flow, the result is a cost measure expressed as "dollars per year per gpd of actual flow". That unit cost was plotted on a graph with a logarithmic scale for the flow; see Figure 4. There is some scatter in the data, but less than with construction costs. A line of central tendency through all the data yields the following points:

10,000 gpd	$13 per year per gpd of actual flow
100,000 gpd	$ 5 per year per gpd of actual flow
1,000,000 gpd	$ 2 per year per gpd of actual flow

The apparent economies-of-scale are significant, perhaps stronger than with construction costs. These data indicate that a 1.0-mgd plant can treat one gallon of wastewater at 40% of the cost of a 100,000-gpd plant, and only 15% of the cost of a 10,000-gpd facility.

Appendix B contains a tabular summary of the data from this survey.

COSTS FOR COLLECTION SYSTEMS

Construction costs for wastewater collection systems were estimated by compiling typical unit costs for gravity pipe, pressure pipe, grinder pumps, and pumping stations of various sizes. It was assumed that 5% of the properties would require grinder pumps to access the sewer, and that one pumping station would be needed on average for every one hundred properties. Figure 5 illustrates the results of that analysis, and shows how construction costs for collection systems are significantly affected by the distance between individual connections. The construction costs vary directly with the average length of pipe needed to serve one connection.

BASIS FOR EVALUATION OF SCENARIOS

Description of Baseline Scenarios

Baseline scenarios were developed to portray typical circumstances on Cape Cod and to serve as the basis for a sensitivity analysis. Table 1 summarizes the assumptions included in the "base case" for each type of wastewater management system. A total of 14 scenarios were considered:

FIGURE 4
RESULTS OF O&M COST SURVEY

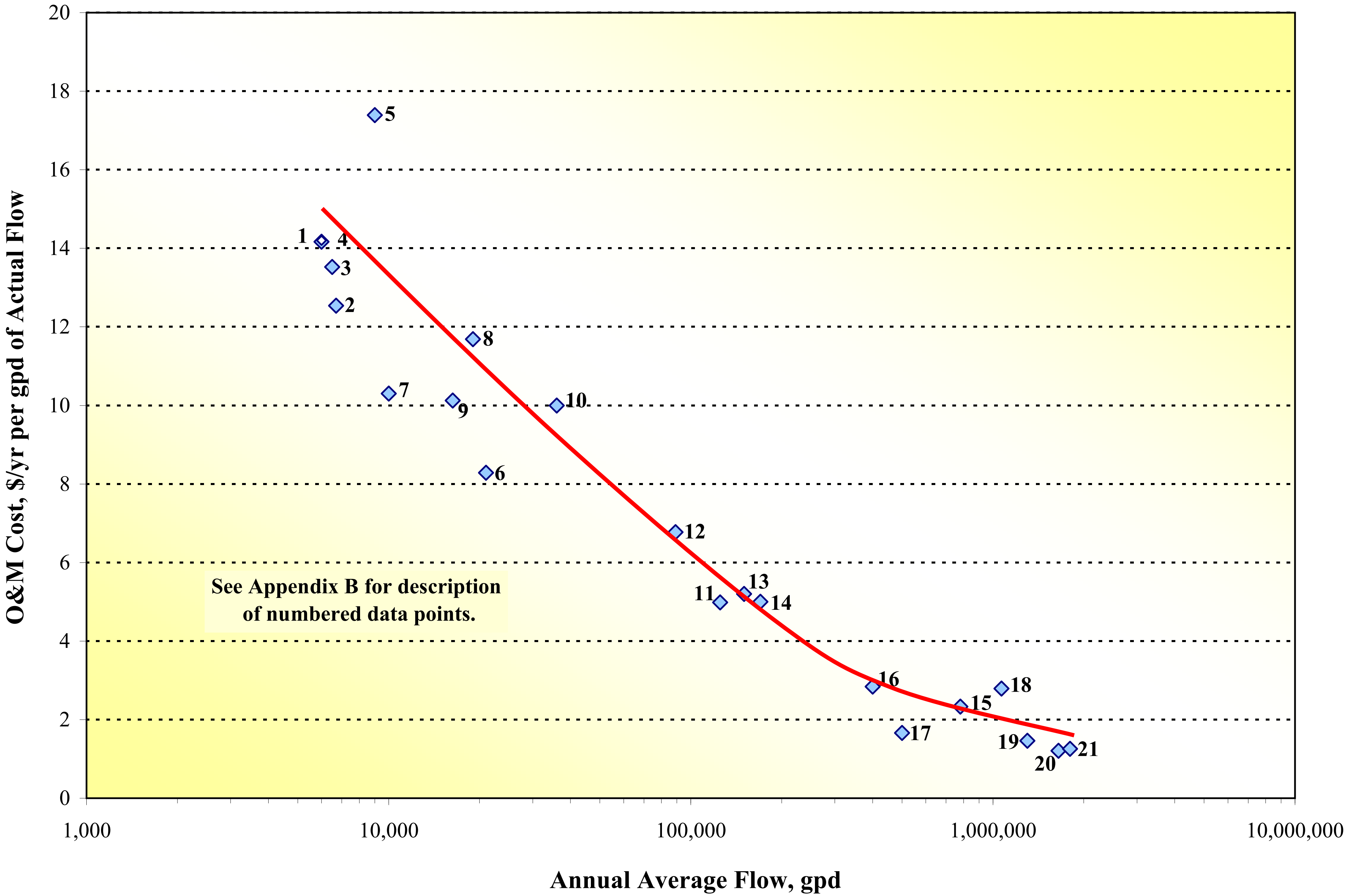


FIGURE 5
RELATIONSHIP BETWEEN COLLECTION COSTS AND DEVELOPMENT DENSITY

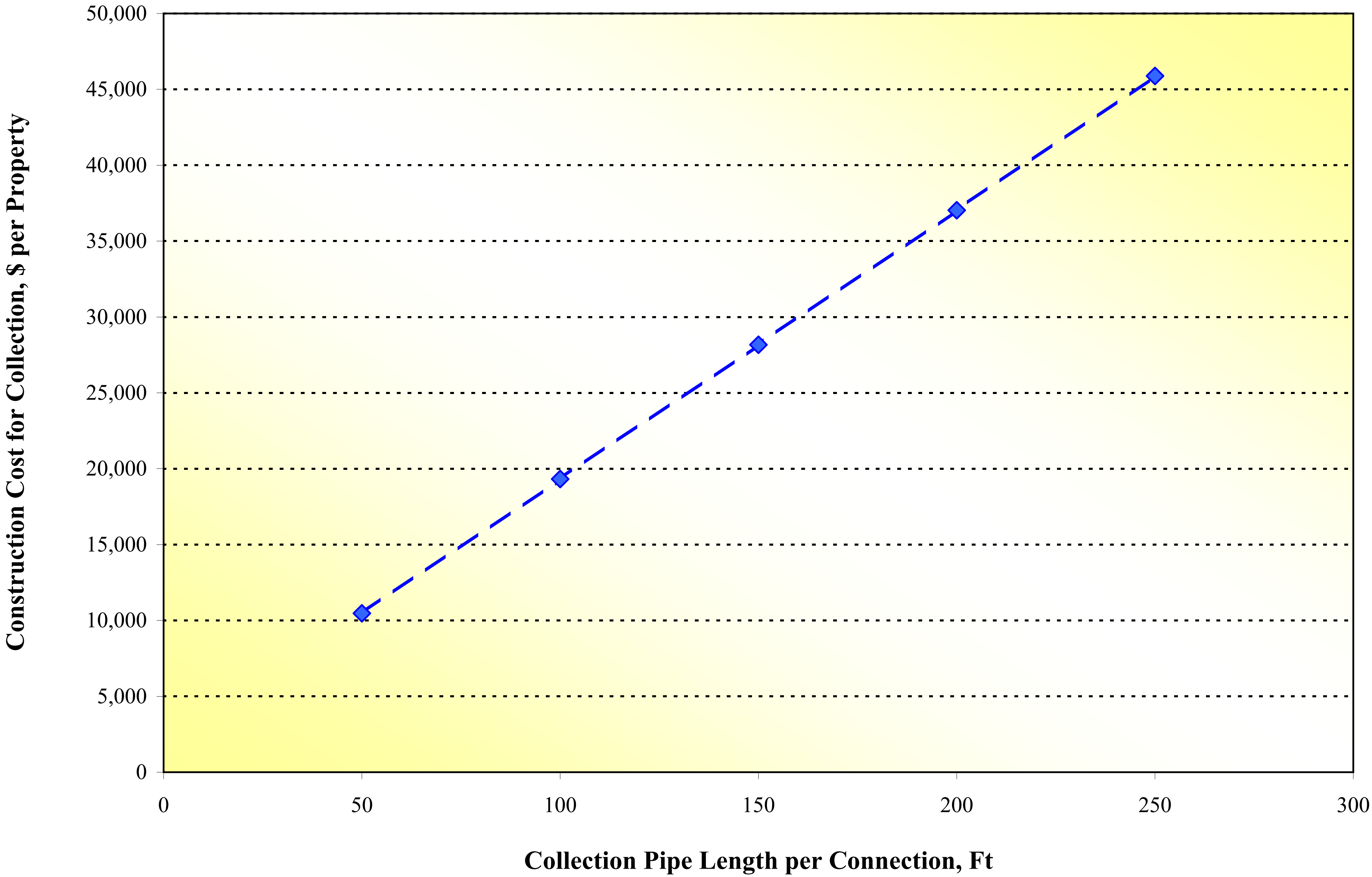


TABLE 1
DESCRIPTION OF "BASE CASE" CONDITIONS

		Individual N-Removing Systems		Cluster Systems			
	Title 5 System	**Enhanced Current Practice**	**For TMDL Compliance**	**Current Practice**	**For TMDL Compliance**	**Satellite Systems**	**Centralized Systems**
Groundwater Discharge Permit Needed?	No	No	No	No	Yes	Yes	Yes
Facilities Procured Publically?	No	No	No	Yes	Yes	Yes	Yes
Collection System Needed?	No	No	No	Yes	Yes	Yes	Yes
Collection System Elements							
Length of pipe per connection, ft	N/A	N/A	N/A	75	75	100	100
Grinder pumps per 100 properties served	N/A	N/A	N/A	5	5	5	5
Pump stations per 100 properties served	N/A	N/A	N/A	1	1	1	1
Overall construction cost per property	N/A	N/A	N/A	$17,000	$17,000	$20,000	$20,000
Wastewater Flows							
Design (see Note 1)	350 gpd	350 gpd	350 gpd	8,800 gpd	8,800 gpd	25,000 gpd to 300,000 gpd	1.5 mgd and 3.0 mgd
Annual average	175 gpd	175 gpd	175 gpd	4,400 gpd	4,400 gpd	45% of design	45% of design
Land costs, $/acre	none	none	none	$250,000	$250,000	$250,000	$200,000
Transport Distances, feet							
Collection to treatment	0	0	0	200	200	250 to 750	3,000 to 7,000
Treatment to disposal	0	0	0	100	100	200 to 500	2,000 to 4,000
Disposal in N-Sensitive Watershed?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Effluent Nitrogen Concentration, mg/l	26	13	13	15	8	6 to 8	5
Time Value of Money, interest rate, term	5%, 20 Yr	5%, 20 Yr	5%, 20 Yr	5%, 20 Yr	5%, 20 Yr	5%, 20 Yr	5%, 20 Yr

Note: For individual systems, estimates are based on a mix of 3-bedroom (80%) and 4-bedroom (20%) homes, consistent with an average of 3.2 bedrooms per home.

Individual systems (4 scenarios)

1. Conventional Title 5. These systems produce an average nitrogen concentration of 26 mg/l reaching the groundwater, as documented in the work of the Massachusetts Estuaries Project. This scenario is presented only as a benchmark and is not a viable alternative as the sole solution in nitrogen-sensitive watersheds.
2. Individual denitrifying systems as currently installed and operated, estimated to produce an effluent nitrogen concentration of 19 mg/l. Although these systems are capable of better performance, their success has been hindered by the driving forces of reducing initial cost and minimizing ongoing expense. Costs are reported here only to illustrate a full accounting of typical current practices, based on a $24,000 first cost and $1,250 in annual O&M costs. This scenario has been termed "current practice" in the exhibits that follow.
3. Individual denitrifying systems enhanced over current practice to achieve an average nitrogen concentration of 13 mg/l. This scenario assumes per-property capital costs of $26,000 and an annual O&M cost of $2,000. Costs and performance at this level have been demonstrated in the Pinelands of New Jersey. In the tables and figures that follow, this scenario has been termed "enhanced current practice".
4. Individual denitrifying systems, enhanced over current practice to achieve an average nitrogen concentration of 13 mg/l and monitored to document the level of nitrogen removal. When part of a comprehensive plan aimed at complying with a TMDL, the capital costs would be $28,000 and the O&M costs would be $3,200, reflecting a more robust long-term design and more oversight and monitoring. This scenario is been termed "for TMDL compliance" in the exhibits that follow. This nomenclature is used with the understanding that achieving only 13 mg/l effluent nitrogen precludes this approach as the sole means for TMDL compliance where more than 50% of the septic nitrogen load must be eliminated.

Cluster Systems (2 scenarios)

1. Cluster systems with single-stage treatment facilities producing an effluent nitrogen concentration of 15 mg/l. These systems are now in place serving commercial facilities and some residential developments, and are governed by Title 5. They generally rely on the recycle of effluent to the septic tank to provide partial denitrification. They perform somewhat better than individual denitrifying systems due to the benefits of more uniform flow and waste characteristics. In subsequent exhibits, this scenario is termed "current practice".
2. Cluster systems with two-stage treatment facilities producing an effluent nitrogen concentration of 8 mg/l. This scenario assumes that the treatment system will have separate processes for nitrification and denitrification, chemical feed facilities and a standby generator housed in a small control building, and groundwater monitor wells. Capital and O&M costs reflect the DEP position that these systems must be built and operated under the same conditions as the groundwater discharge permit program, including influent, effluent and groundwater monitoring. For simplicity, this scenario is called "for TMDL compliance" in the tables and figures that follow.

Satellite Systems (6 scenarios). Costs have been prepared for six design capacities (25,000 gpd, 50,000 gpd, 75,000 gpd, 100,000 gpd, 200,000 gpd and 300,000 gpd). In all cases, the standard provisions of the DEP groundwater discharge permit apply. Effluent quality is estimated to fall between 6 and 8 mg/l in the Base Case, with the larger facilities producing the better effluent. For simplicity, only 4 of these scenarios are reported in the some of the exhibits that follow.

Centralized Systems (2 scenarios). Costs have been prepared for two design capacities (1.5 mgd and 3.0 mgd). In all cases, the standard provisions of the DEP groundwater discharge permit program apply. Due to the quantities of wastewater to be treated and disposed of, much larger transport distances are included in this analysis compared with other scenarios, because of the presumed difficulty in finding sites of sufficient size near the collection area. The size of these facilities and the level of operational oversight justify the use of 5 mg/l as the baseline effluent quality for these scenarios.

Basis for Reporting of Costs and Performance

The fundamental elements of the cost analysis are capital cost and O&M cost. To be able to compare hypothetical Option #1 (that costs a lot to build but little to operate) with a low-capital-high-O&M alternative (hypothetical Option #2), the "equivalent annual cost" (EAC) of each scenario has been computed. The equivalent annual cost is the sum of the O&M cost and the amortized capital cost. For example, one could take a bank loan to offset a $31 million capital cost, and pay $2.5 million per year back to the bank over 20 years, assuming interest at 5%. If the operation and maintenance costs were $500,000 per year, the equivalent annual cost would be $3.0 million ($2.5 million in amortized capital plus $0.5 million in O&M). This one number reflects the combined impact of the capital and O&M costs, and it allows a consistent comparison with other alternatives.

Each of the treatment systems under consideration has a different ability to remove nitrogen, the driving force for wastewater management in most places on Cape Cod. To factor in the effectiveness of a given treatment system, the equivalent annual cost has been compared with the annual nitrogen removal effected by that option. The result can be converted to dollars per pound of nitrogen removed. In the example above, assume that the treatment system can remove 8,700 pounds of nitrogen per year. The unit cost for nitrogen removal would be $350 per pound ($3.0 million of equivalent annual cost divided by an annual removal of 8,700 pounds).

Figure 6 illustrates, in diagrammatic form, the computation of this measure of wastewater treatment cost effectiveness. Actual calculations are illustrated in Appendix C for two cases.

Each of the evaluated treatment systems was compared to the basic option of allowing individual properties to continue to use individual on-site septic systems. Based on the methodology of the Massachusetts Estuaries Project, individual septic systems are assumed to have 26 mg/l of nitrogen remaining in the system effluent. If a more sophisticated nitrogen-removing option can produce an effluent with, say, 6 mg/l of nitrogen, and provide for effluent disposal within the watershed, then that option "removes" 20 mg/l from the watershed. (If the untreated wastewater entering the treatment system is at 50 mg/l, the system actually removes about 44 mg/l from the

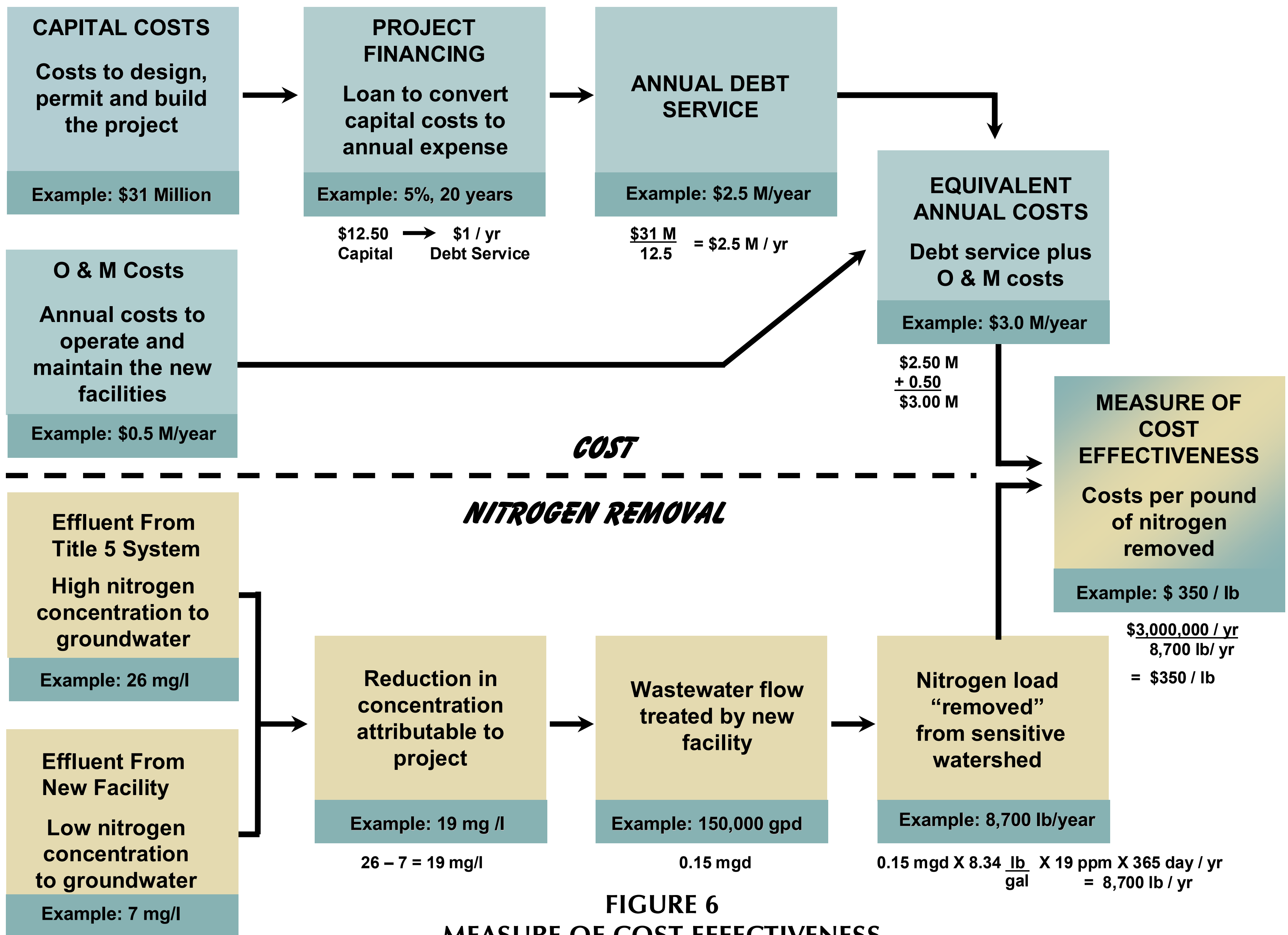


FIGURE 6
MEASURE OF COST EFFECTIVENESS

wastewater. However the removal quantity reported herein is "removed from the watershed", not "removed from the wastewater".) If the nitrogen removing system discharges outside the watershed, it removes all of the 26 mg/l that would otherwise be discharged on site through a Title 5 system.

EVALUATION RESULTS

Results of Base Cases

Table 2 summarizes the cost estimates prepared for the Base Cases. These estimates relate directly to the assumptions shown in Table 1. These costs cover all pertinent elements of a municipal wastewater system, including collection (all but individual systems), treatment, transport, and disposal.

The first column of Table 2 reports the estimated capital costs for each scenario and includes construction, engineering, permitting, legal, land, and contingencies. These costs are expressed on a per-property basis to allow comparison across scenarios that serve different numbers of properties. The estimated costs range from $24,000 to $55,000 per property, compared with the estimated $13,000 for a simple Title 5 system. These costs do not reflect actual betterment charges that a town may levy; towns may chose to spread some of these costs across the entire tax base.

Estimates of O&M costs are tabulated in the second column of Table 2. They range from $400 to $3,200, compared with $110 for a Title 5 system. The O&M costs are also expressed on a per-property basis to allow comparison among scenarios that serve different numbers of parcels.

In general, the individual systems have a lower capital cost and the centralized options have a smaller O&M cost. Combining capital costs and O&M expenses into an equivalent annual cost provides a methodical way to approximate total life-cycle costs, and this measure is reported in the third column of Table 2. Equivalent annual costs range from $3,200 to $6,900 per property, compared with $1,150 for the simple Title 5 system.

The data are further refined by incorporating an estimate of the nitrogen removed from the watershed. The fourth column of Table 2 presents the equivalent annual cost divided by the nitrogen removal, on a dollar-per-pound basis (see Figure 6 for a depiction of this computation approach.) These estimates range from about $300 for centralized systems to over $800 for some of the smaller-scale scenarios.

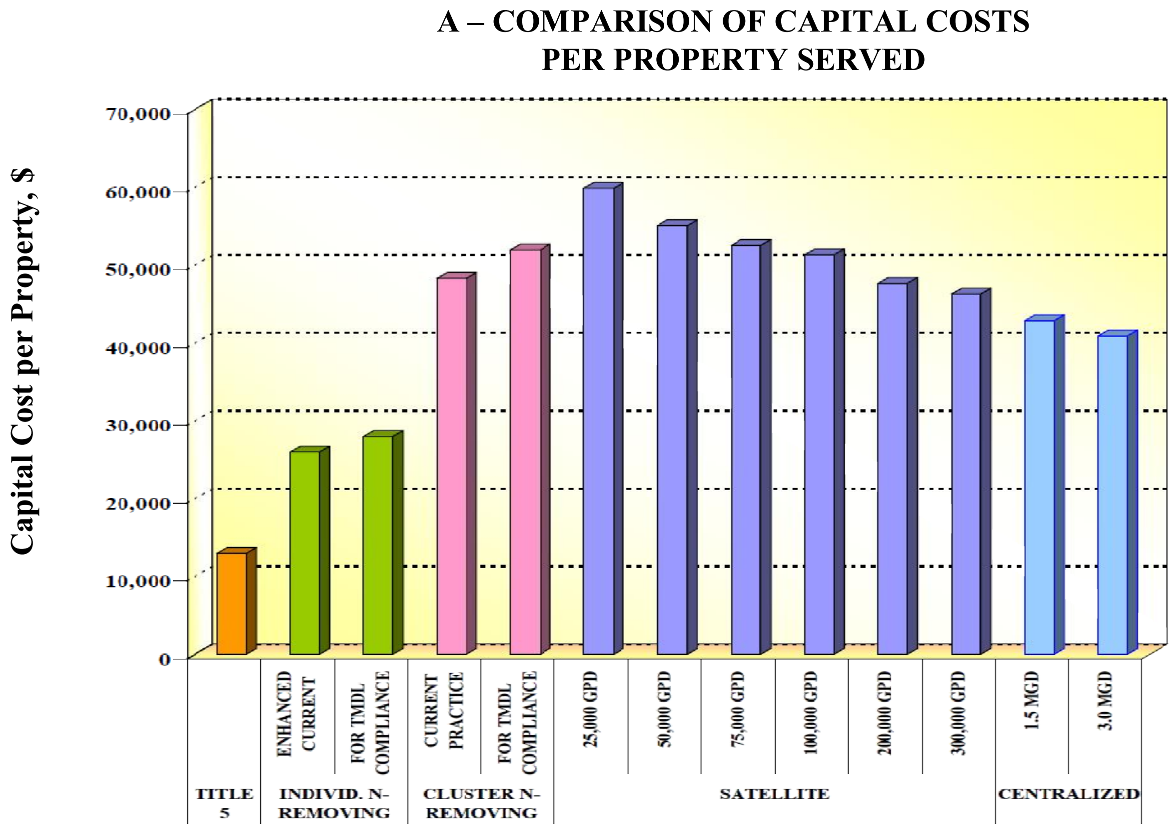
Figure 7 summarizes the costs for the Base Case scenarios, in the form of four sets of bar charts. The heights of the bars represent either the capital cost per property served (Fig. 7A), the O&M cost per property (Fig. 7B), the equivalent annual cost per property (Fig. 7C) or the cost per pound of nitrogen removed (Fig. 7D). The cost estimates are presented on a per-property-served basis to account for the fact that the various systems all serve a different number of properties. The reader should carefully review the discussion in a later section of this report related to the need to consider both the average per-property costs and the number of properties that must be served.

TABLE 2
SUMMARY OF COST ESTIMATES

	Estimated Cost per Property Served			**Equivalent Annual Cost per Pound of Nitrogen Removed**	
	Capital Cost	Annual O&M Cost	Equivalent Annual Cost	$/Lb N	Premium over 3.0-mgd Centralized System
Individual Systems					
Title 5	$13,000	$ 110	$1,150	N/A	Not Applicable
Nitrogen-removing --current practice	$24,000	$1,250	$3,180	$820	187%
Nitrogen-removing--enhanced current practice	$26,000	$2,000	$4,090	$580	102%
Nitrogen-removing --for TMDL compliance	$28,000	$3,200	$5,450	$770	169%
Cluster Systems					
Current practice	$48,300	$1,050	$4,920	$820	186%
For TMDL compliance	$52,000	$2,800	$6,940	$710	149%
Satellite Systems					
50,000 gpd	$55,100	$1,670	$6,080	$680	138%
100,000 gpd	$51,300	$1,360	$5,480	$590	109%
200,000 gpd	$47,700	$1,030	$4,860	$510	79%
300,000 gpd	$46,300	$860	$4,570	$470	64%
Centralized Systems					
1.5 mgd	$42,900	$ 500	$3,940	$305	7%
3.0 mgd	$40,900	$ 400	$3,680	$285	----

Notes: Equivalent annual costs are based on 5%, 20-year financing.
Watershed-wide costs must consider the number of properties served and the average cost per property; see Figure 9 and text.

FIGURE 7
SUMMARY OF COST ESTIMATES



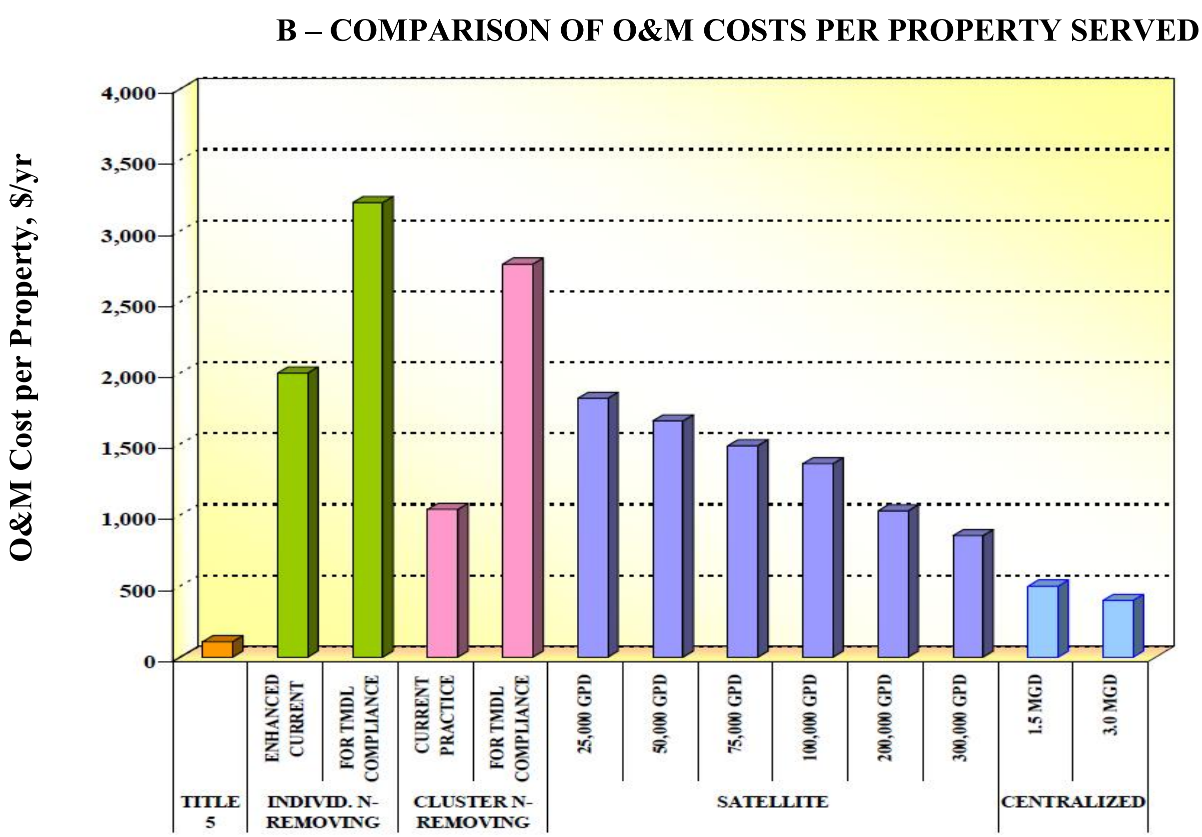
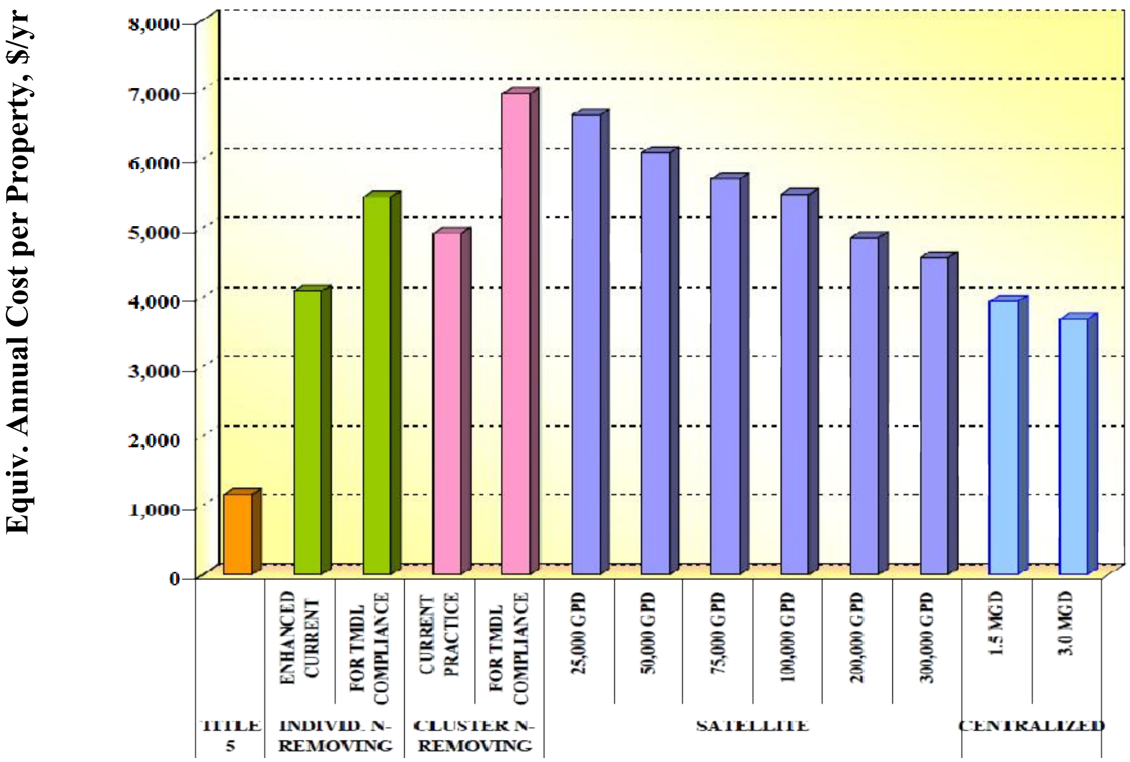
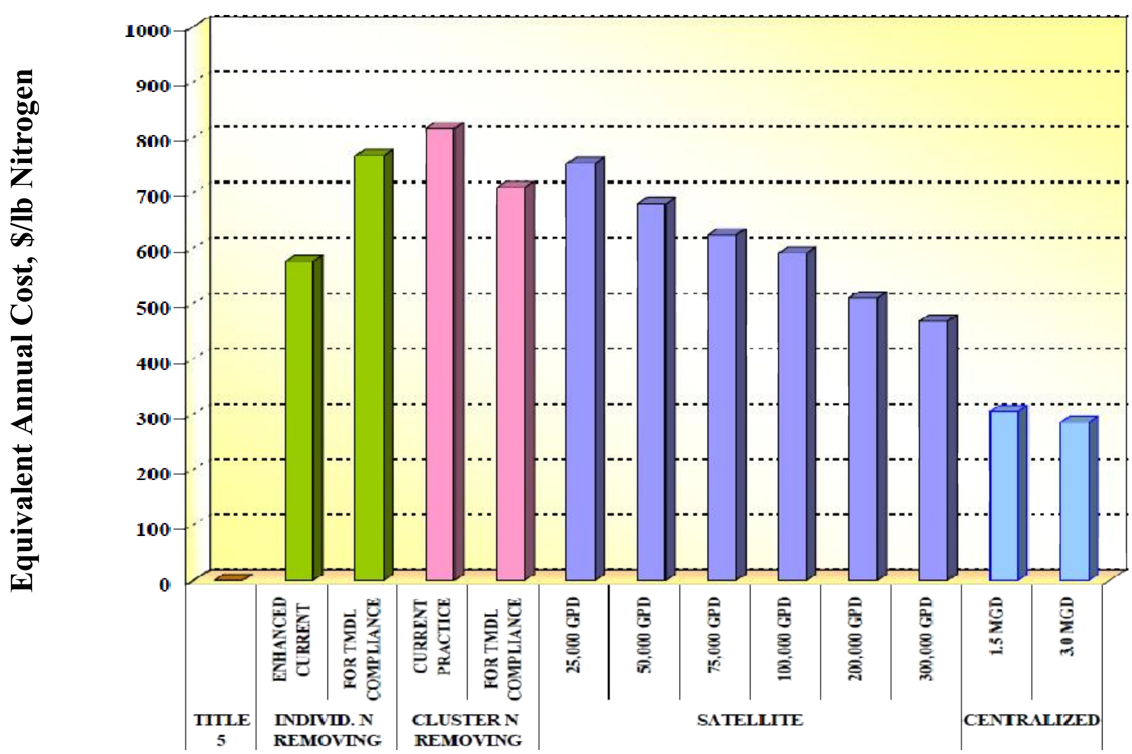


FIGURE 7 (CONT'D)
SUMMARY OF COST ESTIMATES

C – COMPARISON OF EQUIVALENT ANNUAL COST PER PROPERTY SEWERED



D – COMPARISON OF COSTS PER POUND OF NITROGEN REMOVED



Conclusions Related to the "Base Case"

Figure 7 allows some general conclusions to be drawn, specific to the assumptions of the Base Cases:

1. Individual denitrifying systems have the lowest capital cost, primarily because they avoid the need for a wastewater collection system. Cluster and small satellite systems have the highest capital cost per property served, in part because they benefit little from economies of scale.
2. With respect to O&M cost per property, centralized and large satellite systems are the least expensive, along with cluster systems designed for small amounts of nitrogen removal. Cluster systems designed for lower levels of effluent nitrogen have the highest per-property O&M costs, as do individual denitrifying systems.
3. When both capital cost and O&M expenses are combined into an equivalent annual cost per property, the centralized systems have a cost advantage.
4. When nitrogen removal capability is included in the analysis, centralized systems are clearly the lowest cost. The individual, cluster and small satellite systems are considerably more expensive in terms of equivalent annual cost per pound of nitrogen removed.

These conclusions are specific to the assumptions that form the basis for the Base Cases (see Table 1). To gauge how important the assumptions are to the conclusions, a sensitivity analysis was conducted. Appendix C contains illustrations of the computational procedure and descriptions of the assumptions used in the sensitivity analyses.

Sensitivity Analysis for Individual Denitrifying Systems

For the Base Case, individual nitrogen-removing systems were evaluated at 19 mg/l (approximating the current practice) and at 13 mg/l (assuming more rigorous design and operational oversight and, also with added monitoring to demonstrate TMDL compliance). The principal cost parameters were estimated as follows, with the lower capital and O&M costs typically pertaining to the 19 mg/l scenario:

Capital cost per property	$24,000 to $28,000
O&M cost per property	$1,250 to $3,200
Equiv. annual cost (EAC) per property	$3,200/yr to $5,400/yr
EAC per pound of N removed	$580 (13 mg/l) to $820 (19 mg/l)

The sensitivity analysis considered the impact of reusing existing Title 5 systems by adding new denitrifying equipment, a more conservative estimate of site restoration costs, possible reductions in monitoring requirements, added costs for municipal procurement and oversight, higher or lower effluent nitrogen concentrations, and the potential for future cost reductions related to advances in technology. The results are presented below, expressed as equivalent annual cost (EAC) per pound, and as a percentage reduction from the Base Case.

	Individual Nitrogen-Removing Systems	Enhanced Current Practice	For TMDL Compliance
	Base case	**$580**	**$770**
A	Adding $4,000 for site restoration	$620	$810
	(Change from base case)	(+8%)	(+6%)
B	Municipal procurement (+20%)	$630	$830
	(Change from base case)	(+10%)	(+8%)
C	Municipal oversight of operations	$600	$790
	(Change from base case)	(+4%)	(+3%)
D	Reusing 50% of existing systems	$520	$710
	(Change from base case)	(-10%)	(-7%)
E	Dropping BOD and TSS sampling	$550	$700
	(Change from base case)	(-4%)	(-8%)
F	Reducing the effluent N by 3 mg/l	$470	$630
	(Change from base case)	(-19%)	(-18%)
G	Reducing effluent to 5 mg/l	$430	$550
	(Change from base case)	(-26%)	(-28%)

This evaluation has considered a scenario where individual nitrogen-removing systems are designed, constructed and operated to be more effective than is the current situation on Cape Cod, on the premise that such steps would be necessary to enable these systems to be part of a town's plan for TMDL compliance. While there may be circumstances where individual systems are competitive with other options, there are two very important points to consider:

- DEP has stated that complete reliance on individual denitrifying systems may not be an acceptable means to achieve TMDL compliance, from an administrative and regulatory perspective; and
- If these systems can reliably achieve only 13 mg/l (the base case assumption here), then they would be applicable as the sole approach only in circumstances where less than 50% removal of the septic load in an embayment is needed.

Nonetheless, individual nitrogen-removing systems have been evaluated here because they may have some limited applicability moving forward, and there needs to be a better understanding of their relatively high cost among the planning boards, boards of health and conservation commissions that routinely require them.

A comparison of the first two scenarios for individual nitrogen-removing system (see Table 2) shows that by building a better treatment system and providing more oversight, the costs per pound of nitrogen decrease from $820 to $580. The improved performance (from 19 to 13 mg/l) more than offsets the added costs. However, the substantial increase in costs for monitoring to document that improved nitrogen removal causes the costs per pound to increase to $770.

Sensitivity Analysis for Cluster Systems

For the Base Case, cluster systems were evaluated for two scenarios. In the first approach, the systems would be developed under Title 5, as is standard for most or all cluster systems in operation today, with an estimated effluent quality of 15 mg/l nitrogen. In the second approach, the cluster system would be designed, permitted and operated under the groundwater discharge permitting program of DEP. The second approach would entail more costs for construction and operation, but would attain a lower effluent nitrogen concentration (8 mg/l assumed in the Base Case). With a groundwater discharge permit, the cluster system would cost more to build and to operate, but might be approvable by DEP as part of a TMDL compliance plan. One additional advantage of the second approach is a smaller effluent disposal system, because the groundwater permitting program allows higher loading rates than under Title 5. The principal cost parameters were estimated as follows, with the lower capital and O&M costs typically pertaining to the 15 mg/l (Title 5) scenario:

Capital cost per property	$48,000 to $52,000
O&M cost per property	$1,000 to $2,800
Equiv. annual cost per property	$4,900 to $6,900
EAC per pound of N removed	$710 (8 mg/l) to $820 (15 mg/l)

In this case, the added expense of construction, operation and monitoring are more than offset by the demonstrated reduction in nitrogen load, resulting in a substantial decline in cost per pound removed.

The sensitivity analysis considered the impact of using town-owned parcels to avoid land costs, serving only dense development of small lots to reduce collection costs, achieving lower effluent nitrogen concentrations, the potential for future cost reductions related to advances in technology, and possible reductions in labor costs assuming use of remote sensing capabilities. The results are presented below, expressed as EAC per pound, and as a percentage reduction from the Base Case.

	Cluster Systems	**Under Current Program**	**For TMDL Compliance**
	Base Case	**$820**	**$710**
A	Serving one-third seasonal homes	$910	$790
	(change from base case)	(+11%)	(+11%)
B	Eliminating land costs	$680	$660
	(change from base case)	(-16%)	(-7%)
C	Serving only denser developments	$750	$670
	(change from base case)	(-8%)	(-6%)
D	Reducing treatment costs by 20%	$790	$690
	(change from base case)	(-3%)	(-3%)
E	Reducing on-site operator time by 20%	$790	$670
	(change from base case)	(-3%)	(-6%)
F	Discharging outside sensitive watersheds	$350	$500
	(change from base case)	(-57%)	(-31%)
G	Reducing the effluent N by 2 mg/l	$690	$640
	(change from base case)	(-15%)	(-10%)
H	Reducing effluent to 5 mg/l	$440	$630
	(change from base case)	(-46%)	(-11%)

This sensitivity analysis establishes a wide range of costs for cluster systems. The equivalent annual costs per pound of nitrogen removed fall in the following broad ranges for the two scenarios:

Current Practice	$350 to $910
For TMDL Compliance	$500 to $790

The greatest reductions in cost per pound result from eliminating land costs, discharging outside sensitive watersheds, and reducing effluent nitrogen concentrations.

Sensitivity Analysis for Satellite Systems

For the Base Case, satellite systems were evaluated at 25,000 gpd, 50,000 gpd, 75,000 gpd, 100,000 gpd, 200,000 gpd, and 300,000 gpd. The principal cost parameters were estimated as follows, with the higher end of the range typically pertaining to the smaller facilities:

Capital cost per property	$46,000 to $60,000
O&M cost per property	$860 to $1,800
Equiv. annual cost per property	$4,600 to $6,600
EAC per pound of N removed	$470 to $750

The sensitivity analysis considered the impact of land costs, the transport distances to treatment and disposal sites, the location of the effluent disposal site inside or outside the watershed of a nitrogen-sensitive embayment, higher or lower effluent nitrogen concentrations, and the potential for future cost reductions related to advances in technology. The results are presented below, expressed as EAC per pound, and as a percentage reduction from the Base Case.

Satellite Systems		**50,000 gpd**	**100,000 gpd**	**200,000 gpd**
	Base case	**$680**	**$590**	**$510**
A	Tripling the transport distances	$700	$600	$520
	(change from base case)	(+3%)	(+2%)	(+2%)
B	Discharging in Zone II	$720	$630	$550
	(change from base case)	(+5%)	(+7%)	(+8%)
C	Reducing the land cost to zero	$650	$560	$480
	(change from base case)	(-5%)	(-5%)	(-5%)
D	Discharging outside sensitive watersheds	$480	$430	$380
	(change from base case)	(-29%)	(-27%)	(-25%)
E	Reducing the effluent N by 2 mg/l	$610	$540	$460
	(change from base case)	(-10%)	(-9%)	(-9%)
F	Reducing effluent N to 5 mg/l	$590	$540	$470
	(change from base case)	(-13%)	(-10%)	(-7%)
G	Reducing capital costs by 20%	$580	$500	$430
	(change from base case)	(-15%)	(-15%)	(-16%)

This sensitivity analysis establishes a range of costs for satellite systems. The equivalent annual costs per pound of nitrogen removed fall in the following ranges for these two sizes of satellite systems:

50,000 gpd	\$480 to \$720
200,000 gpd	\$380 to \$550

It is also possible to combine multiple variables in this analysis. For example, if land costs could be eliminated and effluent disposal could be outside sensitive watersheds, then the cost would be \$460 and \$360 for the 50,000 gpd and 200,000 gpd examples, a reduction of 28% to 33% from the Base Case. Discharge outside sensitive watersheds is the largest single factor reducing costs.

Sensitivity Analysis For Centralized Systems

For the Base Case, centralized systems were evaluated at 0.5 mgd, 1.5 mgd and 3.0 mgd. The principal cost parameters were estimated as follows, with the higher end of the range typically pertaining to the smaller facility:

Capital cost per property	\$41,000 to \$48,000
O&M cost per property	\$400 to \$800
Equiv. annual cost per property	\$3,700 to \$4,700
EAC per pound of N removed	\$285 to \$360

The sensitivity analysis considered the impact of land costs, the transport distances to treatment and disposal sites, the location of the effluent disposal site inside or outside the watershed of a sensitive embayment or a water supply Zone II, higher or lower effluent nitrogen concentrations, and the potential for cost reductions related to regionalization. The results are presented below, expressed as EAC per pound, and as a percentage reduction from the Base Case.

Centralized Systems		**1.5 mgd**	**3.0 mgd**
	Base case	**\$305**	**\$285**
A	Tripling the transport distances	\$315	\$292
	(change from base case)	(+3%)	(+2%)
B	Discharging in Zone II	\$319	\$295
	(change from base case)	(+5%)	(+4%)
C	Reducing the land cost to zero	\$293	\$274
	(change from base case)	(-4%)	(-4%)
D	Discharging outside sensitive watersheds	\$250	\$230
	(change from base case)	(-19%)	(-19%)
E	Reducing effluent to 3 mg/l	\$278	\$260
	(change from base case)	(-9%)	(-9%)
F	Reducing costs by 10% by regionalization	\$294	\$276
	(change from base case)	(-4%)	(-3%)

This sensitivity analysis establishes a range of costs for central systems. The equivalent annual costs per pound of nitrogen removed fall in the following ranges for two sizes of central systems:

1.5 mgd	\$250 to \$319
3.0 mgd	\$230 to \$292

It is also possible to combine multiple variables in this analysis. For example, if transport costs were tripled and effluent disposal could only occur in a Zone II, then the cost would be \$329 and \$302 for the 1.5 mgd and 3.0 mgd examples, an increase of 6% to 8% over the Base Case.

Figure 8 illustrates the results of this sensitivity analysis, in graphical form. The horizontal bar represents the range of costs developed from the sensitivity evaluation, and the vertical red bar denotes the Base Case for each type of system. The letters on each bar refer to the individual sensitivity analyses as noted above.

DISCUSSION OF RESULTS

There are two general purposes of this evaluation. The first is to make an "apples-to-apples" comparison of treatment systems in these categories. The second is to identify the circumstances under which each type of system is most cost-effective.

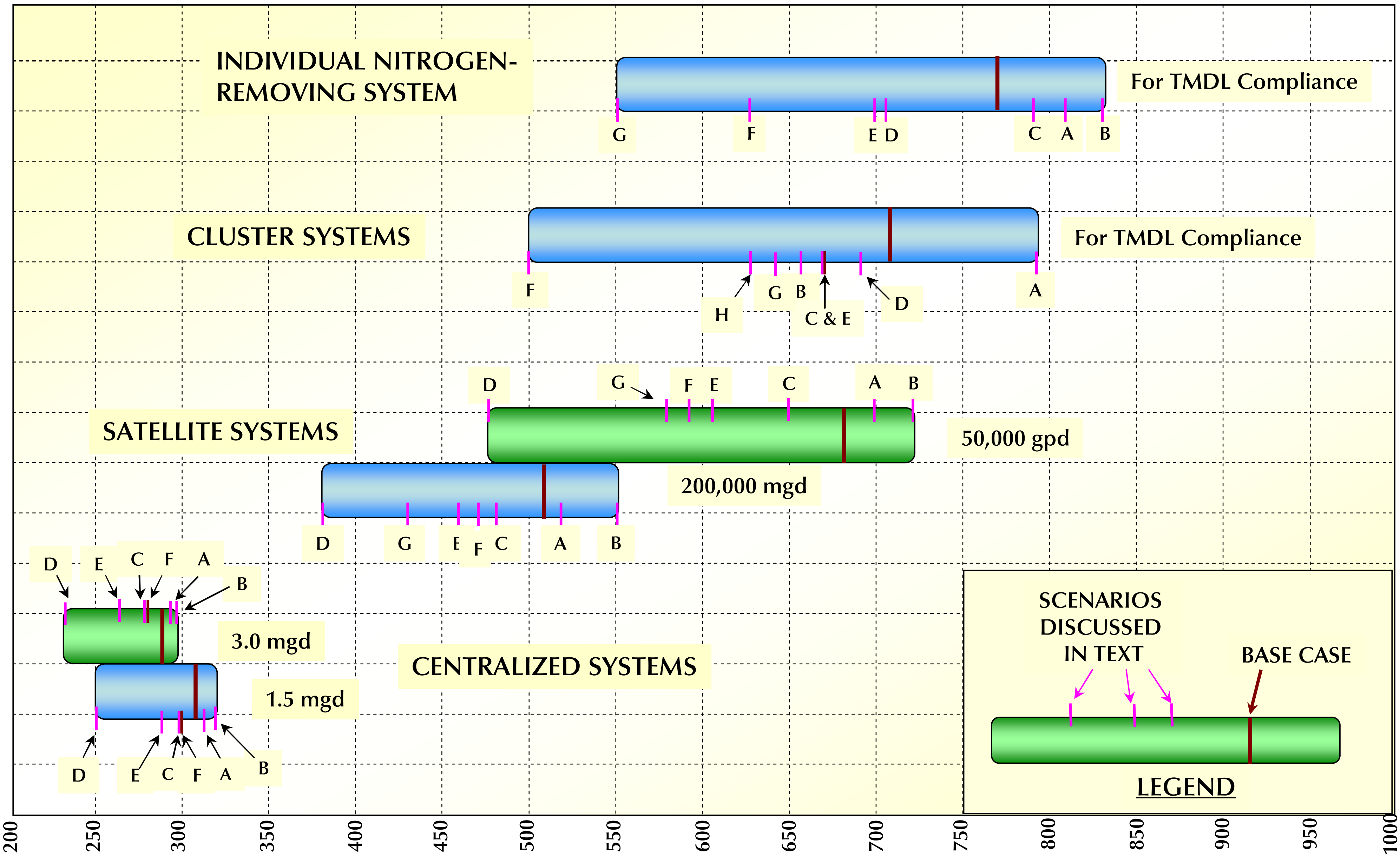
One striking feature of Figure 8 is the very broad range of costs for these systems, indicating the importance of many variables. Another important observation from Figure 8 is the fact that even the most favorable scenarios for TMDL-compliant individual, cluster and satellite systems all cost measurably more than the least favorable scenarios for the centralized systems. The most favorable case evaluated for satellite systems costs \$380 per pound, while the least favorable centralized scenario has a cost of \$330 per pound, a difference of about 15%.

For the assumptions of the Base Cases, the 3.0-mgd centralized system has the least cost when capital costs, O&M expenses and nitrogen removal capability are all considered. One way to view these data is to consider the "premium" associated with all other options compared to that low-cost alternative. The last column of Table 2 shows that premium as a percentage over the larger centralized option. Considering both cost and performance, the individual denitrifying systems are at least twice as expensive as the 3.0-mgd scenario, and the cluster systems are at least 150% more expensive. The satellite systems are 60% to 140% more expensive.

The first three columns of Table 2 list average per-property costs, without considering the fact that some scenarios require more properties to be served that other. The use of the dollar-per-pound-removed metric provides a more meaningful measure, because it accounts for the variable number of parcels that must be served among the scenarios.

The Base Cases were developed to provide a fair comparison of options under a uniform set of conditions as a tool to help guide more detailed analyses. If a town is faced with conditions similar to the Base Case, it is likely to find that centralized systems are the most cost-effective. However, a town should closely review these sensitivity analyses to see if conditions exist that warrant a detailed review of the other options. The ranges of costs depicted in

FIGURE 8
SUMMARY OF ESTIMATED COSTS PER POUND OF NITROGEN REMOVED



EQUIVALENT ANNUAL COST, $ PER LB OF N REMOVED

Figure 8 can be used to judge the importance of many factors that impact cost. If circumstances exist that reduce the cost of the smaller-scale options and increase the cost of the larger-scale alternatives, the cost premiums may be significantly less than show in Table 2.

Example Project Costs

The cost estimates presented above are the result of the application of a generic cost model to a prescribed set of circumstances, where every effort was made to use a common set of assumptions. To help illustrate that these hypothetical costs are realistic, several "real-life" projects were analyzed to compute their equivalent cost per pound of nitrogen removed. Table 3 is the result of that analysis. Nine projects, with design capacities ranging from 8,000 gpd to 2.3 mgd, were evaluated as to capital costs, O&M costs and actual annual nitrogen removal.

The computed costs per pound of nitrogen removed are shown at the bottom of Table 3, based on reported costs. The first set of unit costs (in bold print) represents direct calculations from the data in Table 3. The second set of unit costs reflects an adjustment to the collection costs to make them consistent with the density of sewered area (100 feet of collector pipe per connection) used in the hypothetical costs reported earlier. This adjustment was made to equalize a significant cost factor and aid in the understanding of the differences among the projects.

A third estimate of unit costs is included for the Brackett Landing project and the proposed Orleans project. The Brackett Landing project's current oversight and monitoring costs do not reflect the DEP requirements that would pertain if such a facility were to be used in a municipal setting with sufficient documentation to demonstrate TMDL compliance. The last adjusted unit cost for Brackett Landing ($723 per pound) is intended to approximate compliance with those DEP requirements. Table 3 also includes the costs for the proposed Orleans wastewater system, based on the CWMP. Those data are included in Table 3 to illustrate the results of the Town's evaluation of regionalization opportunities. A recent detailed study showed that Orleans could reduce the cost of its wastewater project by about 10% by expanding it to include capacity for wastewater from portions of Eastham and Brewster.

Appendix D is a summary of the sources of data and assumptions and adjustments used to compile Table 3.

These examples show that the costs for small systems can be over $700 per pound, versus larger systems at less than $300 per pound. These are the same conclusions that can be drawn from the hypothetical estimates presented above. The data in Table 3 also show the importance of reducing costs by focusing sewer systems on densely developed areas. The example projects that have only 50 to 70 feet of collection pipe per connection have costs that are over $100 per pound less than would be predicted for the 100-foot assumption in the conceptual analysis. The Brackett Landing example also illustrates that increased oversight and testing (as would be required by DEP to demonstrate TMDL compliance) increases costs by more than $100 per pound at this small scale, even with the very high level of treatment that has been demonstrated at that project.

TABLE 3
COSTS FOR EXAMPLE PROJECTS

Example Projects	Brackett Landing, Eastham	Camp Jewell, Colebrook Conn.	New Silver Beach, Falmouth	Mashpee Commons	West Island, Fairhaven	Tisbury	Province-town	Orleans CWMP	Chatham
Wastewater flows, gpd									
Design	8,230	19,000	60,000	80,000	100,000	104,000	575,000	1,440,000	2,300,000
Annual average	3,300	6,700	25,000	18,900	25,100	37,000	150,000	504,000	1,011,000
Groundwater Discharge Permit?	No	No	Yes	Yes	Yes	Yes	Yes	N/A	Yes
Public Procurement?	No	No	Yes	No	Yes	Yes	Yes	N/A	Yes
Treatment Technology	SeptiTech and Nitrex	BioClere	SBR	RBC	RBC	SBR	SBR	Bardenpho	Oxidation Ditch
Collector Length per Connection, ft	58	---	50	--	68	68	64	138	82
Capital Cost, $M	0.98	1.49	8.55	2.37	8.9	12.2	35	152	210
O&M Cost, $1000/yr	25.5	83.9	151	222	165	360	780	1,200	1,900
Equivalent Annual Cost (5%, 20 yr), $1000/yr	104	203	837	412	880	1,340	3,560	13,400	18,800
Nitrogen Load Removed, lb/yr	228	331	1,240	1,220	1,470	2,400	12,000	40,300	75,110
Unit Cost, $/lb N removed									
Based on data above	**455**	**613**	**677**	**337**	**596**	**560**	**297**	**333**	**250**
Adjusted for collection	551	953	852	754	704		328	296	265
Other computations	723							270	
(Basis)	(For TMDL Compliance)							(Regional-ization)	

Note: See Appendix D for sources, notes and assumptions.

Cost Impacts of Effluent Disposal within a Nitrogen-Sensitive Watershed

Caution is warranted in reviewing the estimated per-property capital costs presented above. Two alternative solutions with approximately the same per-property capital costs may have significantly different costs watershed-wide. This concept is illustrated in Figure 9, which contrasts a solution using a disposal site within a nitrogen-sensitive watershed (on the right) with one using out-of-watershed disposal (on the left) In this example, 44% more septic systems must be eliminated in the case of in-watershed-disposal to account for the nitrogen in the treatment plant effluent that remains in the watershed. Disposal of that residual nitrogen in a non-sensitive watershed allows fewer properties to be connected to the collection system. Figure 8 is based on an assumed 8 mg/l in the treatment plant effluent. The added burden of in-watershed disposal varies with the quality of the treatment plant effluent, as follows:

In-watershed effluent disposal at 13 mg/l	100% more parcels served
In-watershed effluent disposal at 10 mg/l	62% more parcels served
In-watershed effluent disposal at 8 mg/l	44% more parcels served
In-watershed effluent disposal at 5 mg/l	23% more parcels served

It is clear that the watershed-wide cost must consider both the average cost per property served and the total number of properties whose septic systems would be eliminated to meet a TMDL. That consideration is inherently incorporated in the dollar-per-pound measure of cost-effectiveness reported here, and therefore that cost measure should be the one given most consideration in CWMPs.

Applicability of Title 5 Systems

The inability of traditional septic-tank-and-leaching-field systems to control nitrogen and phosphorus is at the heart of the wastewater management problem on Cape Cod. Nonetheless, Title 5 systems are a very cost-effective way to deal with basic sanitary needs of wastewater disposal. This evaluation shows that the typical cost of a Title 5 system is only about a third that of centralized system and a much smaller percentage of other options that involve nitrogen removal. Therefore, towns should develop wastewater plans that allow maximum use of Title 5 systems. In a nitrogen-sensitive watershed, the lowest cost plan for nitrogen control will involve two parts:

- a sewer system to collect wastewater that will be treated and disposed of in the most economical way, and
- Title 5 systems for everyone else in the watershed.

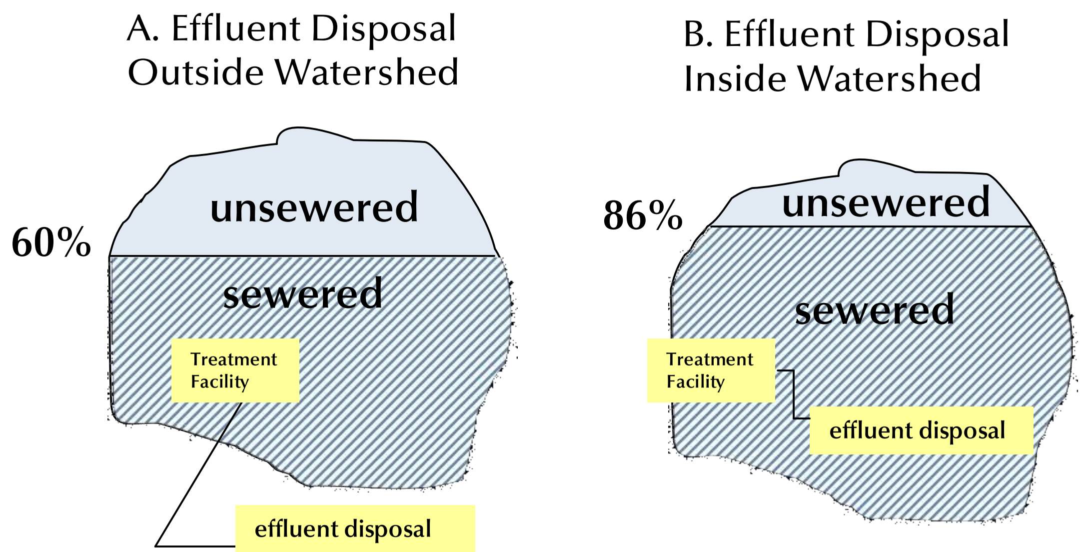
There are other reasons to eliminate or supplement Title 5 systems, such as to correct unsanitary conditions, avoid unsightly mounded systems, reduce the costs of frequent septage pumping, etc. Those reasons should be determined in a definitive needs assessment during the development of the CWMP. The most cost-effective wastewater plan will maximize the use of Title 5 systems (consistent with nitrogen control and all other needs) and efficiently deal with the wastewater collected to meet those overall needs.

FIGURE 9

IMPACT OF IN-WATERSHED DISPOSAL ON THE EXTENT OF SEWERS

Example Watershed

- 1,000 homes on septic systems
- Septic nitrogen load = 10,000 lb/yr
- TMDL = 4,000 lb/yr
- Required septic load removal = 60%



	A. Effluent Disposal Outside Watershed	B. Effluent Disposal Inside Watershed
Nitrogen from unsewered parcels (26 mg/l)	4,000 lb/yr	1,400 lb/yr
Nitrogen from effluent disposal in watershed (8mg/l)	0	2,600
Total wastewater-related load	4,000 lb/yr	4,000 lb/yr
Parcels sewered	**600**	**860** (44% more)

Applicability of Individual Nitrogen-Removing Systems

It is currently the opinion of DEP that these systems may not be suitable as the sole means of TMDL compliance, given the difficulty faced by a municipality to build them on large numbers of private parcels, monitor their nitrogen removal capabilities and provide for long-term operation and maintenance. Even in the absence of these concerns, the current capability of these systems to provide significant nitrogen removal restricts their applicability to watersheds where the necessary septic nitrogen removals are less than about 50%. However, there are circumstances where individual denitrifying systems can be a valuable adjunct to other options.

Conditions Most Favorable. The greatest benefit of individual denitrifying systems is the avoidance of a collection system, since they provide for treatment and disposal on the same parcel where the wastewater is generated. In neighborhoods where the average length of collection pipe per property served would exceed 200 feet, the substantial cost of wastewater collection may make other systems more expensive. In these circumstances, individual systems should be evaluated, considering all costs as well as the administrative issues related to property access and TMDL compliance.

Conditions Least Favorable. Where septic nitrogen control needs exceed 50%, these systems are not applicable. (This percentage may rise over time as technology improvements results in better routine nitrogen removal.) Even in those watersheds where relatively small percentages of nitrogen removal are needed, the very high cost per pound of nitrogen removed (greater than $550 per pound) should preclude their consideration if the collection system requires less than 150 feet per connection. Unless larger-scale systems must include very large transport distances to available treatment/disposal sites, and effluent disposal must occur in very sensitive watersheds or in water supply Zone IIs, these systems need not be evaluated in detail except for serving isolated areas.

Applicability of Cluster Systems

Wastewater treatment systems smaller than 10,000 gpd suffer significantly from "dis-economies of scale", but there are circumstances where they can be applicable. DEP is not inclined to allow a series of cluster systems as the primary means of TMDL compliance (for many reasons similar to the issues related to individual systems), but those DEP concerns may be addressed by developing cluster systems under the groundwater discharge permit program. It is for this reasons that two types of cluster systems were evaluated in this analysis.

Conditions Most Favorable. Cluster systems may be viable components of a CWMP in these circumstances:

- Existing neighborhoods of small lots (and therefore low collection costs) that are remote from proposed sewered areas, and that have publically-owned vacant land nearby;
- New cluster developments where the developer can install alternative collection systems at the time of construction and later turn the project's wastewater infrastructure over to the town; and

- Shore-front neighborhoods near small, poorly-flushed embayments where the cluster system can provide an early benefit of nitrogen control, and later be converted to a pumping station in later phases of a centralized system.

Non-cost factors should also be considered, such as the need to maintain water balance within watersheds.

Conditions Least Favorable. Given their high cost per pound of nitrogen removed (greater than $500 per pound), cluster systems do not warrant detailed consideration unless larger-scale systems must include very large transport distances to available treatment/disposal sites, and effluent disposal must occur in very sensitive watersheds or in water supply Zone IIs.

Applicability of Satellite Systems

Satellite systems, by definition, are designed to serve portions of a town or large individual developments. There are more than 50 such systems on Cape Cod, most privately developed. Most of the publically-owned satellite plants serve schools, but the New Silver Beach facility in Falmouth is a good example of a municipal system serving a specific portion of a town.

Conditions Most Favorable. Satellite systems may be viable components of a CWMP in these circumstances:

- A remote watershed in need of nitrogen control that is more than 5 miles from the existing sewer system or other areas or need, and that has publically-owned vacant land nearby;
- New large-scale residential or commercial developments where the developer can install collection, treatment and disposal facilities at the time of construction and later turn the project's wastewater infrastructure over to the town; and
- An existing or proposed private facility that can be taken over by the town and expanded to provide wastewater service to existing nearby properties currently on septic systems, particularly if the town-wide system may be available for many years and the developer is prepared to proceed in the near future.

Satellite systems of 150,000 gpd or larger have a distinct cost advantage over those 50,000 gpd and smaller.

Conditions Least Favorable. Given their high cost per pound of nitrogen removed (greater than $500 per pound), satellite systems smaller than 100,000 gpd have limited applicability unless they serve areas particularly remote from larger-scale wastewater infrastructure. If centralized facilities exist or can be developed within 5 miles, satellite facilities do not warrant detailed consideration. If regionalization is possible and desirable, satellite options have an added disadvantage.

Applicability of Centralized Systems

Wastewater infrastructure that relies on a single treatment plant and effluent disposal system has both advantages and disadvantages. From a cost perspective, the "best" and "worst" circumstances are as follows:

Conditions Most Favorable. Centralized systems are likely to be the most viable wastewater systems where:

- Dense development exists in nitrogen-sensitive watersheds;
- Suitable treatment and disposal sites (outside sensitive watersheds and Zone IIs) are available at no or low cost;
- A high degrees of nitrogen control is required, placing a cost premium on small-scale systems that discharge in sensitive watersheds;
- Areas of dense development in sensitive watersheds are within 3 miles of desirable effluent treatment and disposal sites;
- Opportunities are available for cost reductions through regionalization.

Conditions Least Favorable. Smaller-scale systems should be closely considered as alternatives to centralized systems where:

- Development in nitrogen-sensitive watersheds is relatively sparse; and
- Available effluent disposal site are remote, costly, and located in water supply Zone IIs or nitrogen-sensitive watersheds; and
- Only small amounts of nitrogen must be removed, allowing individual denitrifying systems to be applicable; and
- Water balance considerations favor local disposal.
- Otherwise favorable sites are poorly located with respect to nearby development or have unacceptable impacts on natural resources.

Figure 8 is a graphical comparison of the range of costs estimated herein for all of the technologies. It shows that centralized systems are generally much less expensive, although there are certain circumstances where smaller-scale systems are cost competitive.

Identification of Most Important Cost Factors

This evaluation of large and small wastewater systems, including this sensitivity analysis, reveals some important points with respect minimizing costs for wastewater infrastructure. The most important cost factors facing any town are as follows, in approximate order of importance (most important first):

1. **Economies of scale**. One 1.5-mgd centralized facility can cost less than half the aggregate cost of 10 facilities each 150,000 gpd in size, other things being equal.

2. **Density of development**. Wastewater collection costs are often more than 50% of the cost of the overall wastewater system. Collection costs for neighborhoods of lots with 75-foot frontage cost only about half as much as those with average 150-foot frontage.

Towns should make every effort to identify those portions of sensitive watersheds with the least amount of collection pipe required per pound of nitrogen collected.

3. **Location of effluent disposal.** Significant cost advantages accrue to towns that can locate their effluent discharges within watersheds leading to the open ocean or to coastal systems with adequate nitrogen-assimilative capacity. For a 1.5-mgd centralized system, the ideal effluent disposal site offers a 20% to 25% benefit, in terms of cost per pound of nitrogen removed. For discharges to nitrogen-sensitive watersheds or water supply Zone IIs, a premium must be paid for both a higher level of wastewater treatment and an expanded sewer system to account for the effluent nitrogen that remains in the watershed.

4. **Land costs**. While land costs may vary substantially across a town, use of town-owned land (or land that can be obtained at low cost) is, in general, a significant cost factor. In a decentralized plan with multiple treatment or disposal sites, more land is needed than in the comparable single-site alternative because of the buffer zones and set-backs needed at each site. Further, the chances for neighbor opposition increases, along with potential costs for delays, litigation and perhaps even eminent domain proceedings. (A countervailing factor is the potential for smaller sites, such as town parks, to be more readily available than larger sites.)

The sensitivity analysis reported herein indicates that projects that benefit from cost advantages in all four of these categories will be significantly less expensive than other options.

Readers should be cautioned to carefully consider the role of the efficiency of the wastewater treatment in overall system economics. While treatment System A that produces 5 mg/l effluent nitrogen may seem to be "twice as good" as System B treating to 10 mg/l, System A eliminates 21 of the 26 mg/l otherwise discharged from a septic system, while System B eliminates 16 mg/l. If Systems A and B cost the same to build and operate, System A will have a cost per pound of nitrogen removed that is 24% lower, not 50% lower. That cost advantage is largely eliminated if System A discharges within a sensitive watershed and System B discharges in a non-sensitive area.

OTHER ISSUES OF NOTE

Role of Collection System Costs in this Analysis

Except for individual denitrifying systems, which do not need a public collection system, collection system costs are a significant component of the overall cost of a public wastewater system. For this analysis, collection costs have been held constant among the satellite and centralized options, and clusters systems include a somewhat reduced collection cost. It was assumed that the density of development tributary to any of the satellite and centralized options would require 100 feet of collector pipe per property served (75 feet for cluster systems), and that 5% of the properties would require grinder pumps to access the sewer. On average, one pumping station was assumed for every one hundred properties. These assumptions lead to an estimated construction cost of $20,000 per property served for satellite and centralized systems ($17,000 for cluster options), and these fixed amounts were included in all of the cost estimates, except for the individual on-lot systems. The collection system for a 200,000 gpd satellite system accounts for $250 of the $510 per pound figure reported here for the Base Case.

There are alternative collection approaches, such as low-pressure systems and septic-tank-effluent-pump systems, which also can be used to reduce collection cost in certain circumstances. When those favorable circumstances present themselves, it is assumed that these alternative collection systems would be implemented, regardless of the size of the treatment facility receiving the collected wastewater. Any cost reductions associated with these alternative collection systems should not be attributed to one scenario and not another.

Many communities may be faced with higher costs than presented herein due to the density of the sewered area. Whereas 75 to 100 feet of collector pipe per connection was assumed for this analysis, there may be areas of Cape Cod where 150 feet or more are needed, increasing the capital costs of any option requiring public sewers. The collection costs for neighborhoods requiring 150 feet of collector pipe per connection would translate to an extra $100 per pound of nitrogen compared to the base case of 100 feet per connection.

Including collection costs in this analysis provides a more appropriate comparison among alternatives, and allows these figures to be compared with actual costs that have been incurred in some communities. However, the inclusion of a constant cost factor tends to mask the differences in treatment costs among the options. If the costs in Table 2 did not include collection costs, the percentage premiums for the small-scale options would be larger than those shown.

Optimizing Town Expenditures for Comprehensive Wastewater Management Planning

The Base Cases evaluated in this report represent one set of typical circumstances, but those circumstances may not reflect the situation that exists in any one town on Cape Cod. Towns embarking on comprehensive wastewater management planning should review this evaluation of the both the Base Cases and the sensitivity analysis to determine how its circumstances compare. Then that town can focus on the types of wastewater management systems that are likely be best for its circumstances, and avoid expensive analyses of systems that can be determined from this evaluation to have limited applicability. For example, a town with large lots, moderate nitrogen control needs and available public lands for local systems should plan to conduct an intensive evaluation of small-scale systems. Conversely, a town with publically-owned sites near collection areas and outside sensitive watersheds or Zone IIs can plan to focus its planning budget on centralized systems and minimize time and expense in evaluation smaller-scale systems.

Use of Individual Denitrifying Systems for Other Purposes

In most Cape Cod towns, individual nitrogen-removing systems are routinely required by Town boards and commissions to address real or perceived environmental or public health impacts unrelated to nitrogen. This analysis shows how such systems can be expensive and ineffective for nitrogen control. Boards and commissions should focus on the particular environmental issue of concern and be cautious in requiring individual denitrifying systems.

Water Balance Considerations

Smaller-scale systems provide a benefit with respect to maintaining the water balance between watersheds. In some circumstances, this relocation of water that otherwise would be recharged locally is a significant factor; in other areas it is not. Each town should closely consider water balances to be sure that this factor is appropriately addressed.

Applying These Costs to Specific Properties

In translating these cost estimates to specific amounts that might be paid by specific properties in sewered areas, the following factors should be considered:

- Towns must decide how to apportion capital costs between betterments (paid only by property owners served by the public infrastructure) and property taxes (paid by property owners town-wide). Amounts allocated to property taxes reduce the costs to properties that are served by the system.
- Betterments may be separately applied to collection costs and treatment costs, and collection system betterments may rely on one or more property features (such a total lot area or parcel frontage).
- The County Septic Loan Program may reduce costs for some property owners, although funding for this program is unlikely to be sufficient for widespread application.
- No consideration has been given here to possible increases in property values for parcels connected to public sewers.

Need for Treatment Capability for Septage and Other Trucked Wastes

For the smaller-scale systems considered in this evaluation, it was assumed that sludge would be removed periodically and transported by truck to a regional septage facility, such as the Yarmouth-Dennis plant in Yarmouth, or the Tri-Town facility in Orleans. Separate sludge dewatering equipment is not warranted at these small-scale systems. Costs for centralized systems include facilities for handling septage from unsewered areas of the town. The ability of a town to reduce its wastewater-related expenses by providing septage or liquid sludge handling services to nearby towns has not been accounted for in this cost analysis.

Importance of Low-Interest Loans

This analysis of costs has been based on the traditional debt service assumptions of 5% interest over a 20-year loan period. Alternative assumptions were also evaluated to reflect the current favorable municipal bond market, and the availability of low interest loans under the State Revolving Fund (SRF). Using the Base Case for a 200,000-gpd satellite system as an example, costs were computed (expressed as equivalent annual costs per pound of nitrogen removal) for several interest rates over 20 years, with the following results:

5% (basis for costs reported in this report)	$510 per lb
4% (current municipal rate)	$477 per lb (6% less than 5% loan)
2% (SRF rate for most projects)	$414 per lb (19% less than 5% loan)
0% (SRF rate under some circumstances)	$359 per lb (30% less than 5% loan)

The equivalent annual cost is reduced with a lower interest rate because the annual debt service costs are lower; O&M costs are unaffected. By availing themselves of the SRF loans, towns can save 18% to 28% of the cost reported in this document for the traditional 5%, 20-year loan. For this example, the savings in debt service expenses with a zero-percent loan are slightly greater than the total O&M cost; that is, the savings in debt service are enough to pay for all of the O&M costs for 20 years.

BARNSTABLE COUNTY WASTEWATER COST TASK FORCE

This report was prepared by a task force that was established to compile and evaluate information on the costs of various wastewater management options that are applicable to Cape Cod. Members of the Wastewater Cost Task Force were selected based on their experience and expertise with a wide variety of technologies and system sizes. They are:

- **Thomas Cambareri.** A hydrogeologist and planner, Mr. Cambareri is the Water Resources Program Manager for the Cape Cod Commission. He and his staff review all Comprehensive Wastewater Management Plans prepared on Cape Cod, as well as the wastewater facilities implemented in Developments of Regional Impact. He was one of the principal authors of the 2003 Cape Cod Comprehensive Regional Wastewater Management Strategy report and the 2010 Cape Cod Regional Wastewater Management Plan.
- **Brian Dudley.** Mr. Dudley is an environmental engineer and the senior staff member at the Hyannis Office of the Massachusetts Department of Environmental. He is also DEP's manager of the Massachusetts Estuaries Project. Mr. Dudley overseas the issuance of groundwater discharge permits on Cape Cod, and has reviewed the design and operation of over one hundred projects involving most applicable wastewater technologies. Prior to joining DEP, he worked in the private sector designing small wastewater treatment plants and developing innovative treatment systems.
- **Michael Giggey**. Mr. Giggey is a registered professional engineer and Senior Vice President of Wright-Pierce. He was the principal author of the 2004 report "Enhancing Wastewater Management on Cape Cod: Planning, Administrative and Legal Tools", and continues to advise the Cape Cod Commission on wastewater planning issues. He has designed or provided peer review for several dozen small-scale wastewater systems in the region, and is a well-known advocate for new and appropriate technology.
- **George Heufelder.** As director of the Barnstable County Department of Health and Environment, Mr. Heufelder oversees the County's water quality laboratory, the community septic loan program and other public health initiatives. He is also the director of the Massachusetts Alternative Septic System Test Center, and in that capacity has installed and operated many new wastewater treatment technologies. Mr. Heufelder is a registered sanitarian and member of the Falmouth Board of Health. He is the author of several publications related to the performance of small-scale wastewater treatment systems.
- **Susan Rask**. Ms. Rask is a registered sanitarian and former member of the Barnstable Board of Health. As Environmental Health Specialist for the Barnstable County Department of Health and Environment, she manages the County's internet-based

reporting system that compiles operating data for over 1,400 small wastewater systems in 14 towns. She was the principal author of the 2007 report "Projected Use of Innovative/Alternative On-site Sewage Treatment Systems in Eastham" and served as project manager for the "Sewers and Smart Growth" project completed in 2009.

Funding for the Task Force's work was provided by Barnstable County and by grants to the Association to Preserve Cape Cod from the Cape Cod Five Charitable Trust Foundation and the Horizon Foundation. This report was developed with the assistance of the GIS and technical staff of the Cape Cod Commission.

APPENDIX A
Survey of Construction Costs for Wastewater Treatment Facilities

APPENDIX A

SURVEY OF CONSTRUCTION COSTS FOR WASTEWATER TREATMENT FACILITIES

FACILITY	#	TOWN	DESIGN FLOW, gpd	CONSTRUCTION COST PRIOR YEAR	CONSTRUCTION COST 2009	UNIT COST, $/gpd	SOURCES AND NOTES
				Variable ENR	*ENR, 2009*		
Anonymous	1	E. Bridgewater	15,000	970,000	1,061,000	70.7	Wright-Pierce
(residential)				*7,864*	*8,600*		preconstr. estimate
Camp Jewell	2	Western Conn.	19,000	1,010,000	1,189,000	62.6	Wright-Pierce
				7,308	*8,600*		includes upgrade
Anonymous	3	So. New England	17,500	648,000	718,000	41.0	Aquapoint
(school)				*7,763*	*8,600*		
Cotuit Stop n Shop	4	Barnstable	22,000	760,000	1,000,000	45.5	VHB
				6,538	*8,600*		
Mass. Correct. Fac.	5	Plymouth	31,000	*2,300,000*	2,398,000	77.4	Horsley-Witten
				8,250	*8,600*		
Harvard Ridge	6	Boxborough	34,000	1,250,000	1,620,000	47.6	EarthTech
				6,635	*8,600*		
Anonymous	7	Cohasset	38,000	1,280,000	1,401,000	36.9	RH White
(residential)				*7,856*	*8,600*		
Berkshire School	8	W. Mass.	40,000	1,000,000	1,315,000	32.9	Zenon
				6,538	*8,600*		
Camp Beckett	9	W. Mass.	40,000	1,500,000	1,633,000	40.8	CDM
				7,900	*8,600*		
Bolton Municipal	10	Bolton	40,000	1,800,000	1,950,000	48.8	Tata & Howard
				7,940	*8,600*		
Anonymous	11	Weston	40,000	2,100,000	2,286,000	57.2	RH White
(residential)				*7,900*	*8,600*		
Shops at Derby Street	12	Hingham	54,000	2,500,000	3,258,000	60.3	Martinage Eng. Assoc.
				6,600	*8,600*		
New Silver Beach	13	Falmouth	60,000	4,000,000	4,300,000	71.7	Town of Falmouth
				8,000	*8,600*		
Anonymous	14	No. Reading	63,000	2,400,000	2,681,000	42.6	RH White
(residential)				*7,700*	*8,600*		
Anonymous	15	Acton	96,000	2,879,000	3,139,000	32.7	Developer
(residential)				*7,888*	*8,600*		
West Island	16	Fairhaven	100,000	2,300,000	3,396,000	34.0	Town of Fairhaven
				5,825	*8,600*		

FACILITY	#	TOWN	DESIGN FLOW, gpd	CONSTRUCTION COST PRIOR YEAR	CONSTRUCTION COST 2009	UNIT COST, $/gpd	SOURCES AND NOTES
Tisbury Municip.	17	Tisbury	104,000	5,170,000 *6,500*	6,840,000 *8,600*	65.8	Town of Tisbury
Pine Hills	18	Plymouth	150,000	4,800,000 *6,222*	6,635,000 *8,600*	44.2	Wright-Pierce Phase 1 only
Oak Bluffs Municip.	19	Oak Bluffs	320,000	6,800,000 *6,222*	9,399,000 *8,600*	29.4	Wright-Pierce
Provincetown Mun.	20	Provincetown	500,000	7,420,000 *6,400*	9,971,000 *8,600*	19.9	Town of Provincetown Phase 1 only
Edgartown Mun.	21	Edgartown	750,000	12,200,000 *6,500*	16,142,000 *8,600*	21.5	Town of Edgartown
Jaffrey Municip.	22	Jaffrey, NH	1,250,000	11,000,000 *7,850*	12,051,000 *8,600*	9.6	Wright-Pierce
Falmouth Municip.	23	Falmouth	2,200,000	12,500,000 *7,000*	15,357,000 *8,600*	7.0	Town of Falmouth
Chatham Municip.	24	Chatham	2,300,000	36,000,000 *8,600*	36,000,000 *8,600*	15.7	Town of Chatham some existing facil.

April 16, 2010

APPENDIX B
Survey of O&M Costs for Wastewater Treatment Facilities

APPENDIX B
SURVEY OF O&M COSTS FOR WASTEWATER TREATMENT FACILITIES

FACILITY	#	TOWN	FLOWS, gpd DESIGN	FLOWS, gpd ANNUAL AVG	O&M COST, $/yr	UNIT COST, $/yr/gpd	SOURCES AND NOTES
Patriot Square	1	Dennis	17,000	6,000	85,000	14.2	Coastal Engineering
Camp Jewell	2	Western Conn.	19,000	6,700	84,000	12.5	Owner
Comm. of Jesus	3	Orleans	21,700	6,500	87,900	13.5	Owner
Skaket Corner	4	Orleans	22,000	6,000	85,200	14.2	Coastal Engineering
Martha's Vineyard Airport	5	Edgartown	37,000	9,000	156,500	17.4	Dukes County
Anonymous (residential)	6	Cohasset	38,000	21,000	174,000	8.3	Weston & Sampson projected future
Horace Mann School	7	Barnstable	42,000	10,000	103,000	10.3	Town of Barnstable
Mashpee Commons	8	Mashpee	80,000	19,000	222,000	11.7	Owner
West Island	9	Fairhaven	100,000	16,300	165,000	10.1	Town of Fairhaven
Tisbury Municipal	10	Tisbury	104,000	36,000	360,000	10.0	Town of Tisbury
Pine Hills	11	Plymouth	300,000	125,000	623,000	5.0	Veolia
Oak Bluffs Municipal	12	Oak Bluffs	320,000	89,000	603,000	6.8	Town of Oak Bluffs
Provincetown Mun.	13	Provincetown	575,000	150,000	780,000	5.2	Town of Provincetown
Edgartown Municipal	14	Edgartown	750,000	170,000	850,000	5.0	Town of Edgartown
Spencer Municipal	15	Spencer	1,080,000	780,000	1,820,000	2.3	Town of Spencer
Falmouth Municipal	16	Falmouth	1,200,000	400,000	1,137,000	2.8	Town of Falmouth
Jaffrey Municipal	17	Jaffrey, NH	1,250,000	500,000	832,000	1.7	Town of Jaffrey
Wareham Municipal	18	Wareham	1,560,000	1,067,000	2,980,600	2.8	Town of Wareham
Chatham Municipal	19	Chatham	2,300,000	1,300,000	1,900,000	1.5	Town fo Chatham projected future
Plymouth Municipal	20	Plymouth	3,000,000	1,650,000	1,996,000	1.2	Veolia
Hyannis Municipal	21	Barnstable	4,200,000	1,800,000	2,265,000	1.3	Town of Barnstable

<u>APPENDIX C</u>
Example Calculations and Assumptions for Sensitivity Analyses

BARNSTABLE COUNTY WASTEWATER COST TASK FORCE

Sample Calculations

Base Case for 100,000-gpd Satellite and 1.5-mgd Centralized Systems

	Satellite: 100,000 gpd	Centralized: 1.5 mgd
Wastewater Flow		
Number of homes/properties	284	3,375
Number of bedrooms/home	3.2	
Number of bedrooms	909	
Title 5 flow, gpd	99,990	
Short-term peak flow, gpd		1,500,000
Annual average flow		
Percent of Title 5	45	45
Actual, gpd	45,000	675,000
Capital Costs		
Collection		
Sewer length per connection	100	100
Cost per property	20,000	20,000
Number of properties	284	3,375
Construction cost	5,681,000	67,500,000
Transport to treatment		
Distance, 1000 ft	0.40	5.00
Cost per foot	200	250
Construction cost	80,000	1,250,000
Treatment		
Cost per unit flow	34	16
Flow, gpd	100,000	1,500,000
Construction cost	3,400,000	24,000,000
Transport to disposal		
Distance, 1000 ft	0.35	3.00
Cost per foot	200	250
Construction cost	70,000	750,000
Disposal		
Construction cost	520,000	5,250,000
Total construction cost		
Cost	9,751,000	98,750,000

		Satellite: 100,000 gpd	Centralized: 1.5 mgd
Construction contingencies, legal, engineering, permitting, etc.			
Percentage of construction		40	40
Cost		3,900,000	39,500,000
Land			
Treatment area, acres		1.10	8
Disposal area, acres		2.65	24
Total area		3.75	32
Cost per acre		250,000	200,000
Cost		935,000	6,400,000
Total capital cost		14,586,000	144,650,000
Capital costs summary		14,586,000	144,650,000
O&M Costs			
Annual average flow, gpd		45,000	675,000
Unit cost, $/yr per gpd		8.6	2.5
O&M cost, $/yr		387,000	1,687,500
O&M Cost summary		387,000	1,687,500
Present Worth			
Period, yr	20		
Interest rate, '	5		
PW Factor	12.46		
Capital cost		14,586,000	144,650,000
O&M cost		387,000	1,687,500
PW of O&M		5,047,000	21,030,000
Total present worth		19,633,000	165,680,000
Equivalent Annual Cost, $/yr			
Amortized capital cost		1,170,000	11,607,000
O&M cost		387,000	1,688,000
Total EAC		1,557,000	13,295,000

	Satellite: 100,000 gpd	Centralized: 1.5 mgd
Nitrogen removal (compared with Title 5)		
Title 5 effluent N conc., mg/l	26.25	26.25
Satellite effluent N conc., mg/l	7	5
Conc removed, mg/l	19.25	21.25
Load removed, lb/yr		
In-watershed disposal	2,637	43,600
Out-of-watershed disposal	3,596	53,900
Cost of N removal--in-watershed disposal		
EAC, $/lb	**590**	**305**
Cost of N removal--out-of--watershed disposal		
EAC, $/lb	433	247
Costs per property		
Capital	51,300	42,900
O&M	1,360	500
EAC	5,480	3,940

April 16, 2010

ASSUMPTIONS INCLUDED IN SENSITIVITY ANALYSES

Individual Denitrifying Systems

Base Case--see Table 1

A. Additional site restoration--capital costs increased by $4,000 to reflect possible greater disruption of decks, patios and landscaping at currently developed properties, and/or for pumping.
B. Municipal procurement--capital costs increased by 20% to reflect public bidding requirements and prevailing wages.
C. Municipal oversight of operation--O&M costs increased by $150 per year to account for possible town staff overseeing the contract operations of these systems.
D. Reuse of existing on-site system components--one half of properties would incur reduced capital cost by reusing septic tank and leaching field. New construction would be limited to denitrifying system for one half of properties.
E. Reduced effluent sampling--BOD and TSS tests eliminated from suite of effluent testing.
F. Improved effluent quality--effluent nitrogen concentration reduced by 3 mg/l (to 16 mg/l for "current practice", and to 10 mg/l for "enhanced current practice" and "TMDL compliance").
G. Further improved effluent quality--effluent nitrogen concentration reduced to 5 mg/l for all scenarios.

Cluster Systems

Base Case--see Table 1

A. Seasonal nature of service area--annual average flow (and therefore annual nitrogen load reduction) decreased by 10% to approximate a neighborhood with one-third seasonal homes.
B. Reduced land costs--land for treatment and disposal assumed to be available at no cost to project.
C. More densely-developed service area--construction costs for collection reduced by 20% to reflect serving a neighborhood with smaller lots.
D. Reduced treatment costs--construction costs for treatment system reduced by 20% to anticipate possible future technology breakthroughs.
E. Reduced operator oversight--use of remote sensing of treatment system performance to reduce operator time by 20%.
F. Discharge outside sensitive watersheds--effluent disposal site located in watershed with adequate assimilative capacity.
G. Improved effluent quality--effluent nitrogen concentration reduced by 2 mg/l (to 13 mg/l for "current practice", and to 6 mg/l for "TMDL compliance").
H. Further improved effluent quality-- effluent nitrogen concentration reduced to 5 mg/l for all scenarios.

Satellite Systems

Base Case--see Table 1

A. Increasing the transport distances--both the distance from the collection area to the treatment plant site and the distance between the treatment and disposal sites are increased by a factor of 3.0.
B. Discharging within a water supply zone II--construction costs for treatment are increased by 35% to address the requirements of the groundwater discharge permitting program, and O&M costs are increased by 40%. The effluent nitrogen concentration is reduced to 5 mg/l.
C. Reduced land costs--land for treatment and disposal assumed to be available at no cost to project.
D. Discharge outside sensitive watersheds--effluent disposal site is located in watershed with adequate assimilative capacity.
E. Improved effluent quality--effluent nitrogen concentration reduced by 2 mg/l.
F. Further improved effluent quality-- effluent nitrogen concentration reduced to 5 mg/l for all scenarios.
G. Reduced treatment costs--construction costs for treatment system reduced by 20% to anticipate possible future technology breakthroughs.

Centralized Systems

Base Case--see Table 1

A. Increasing the transport distances--both the distance from the collection area to the treatment plant site and the distance between the treatment and disposal sites are increased by a factor of 3.0.
B. Discharging within a water supply zone II--construction costs for treatment are increased by 35% to address the requirements of the groundwater discharge permitting program, and O&M costs are increased by 40%. The effluent nitrogen concentration is reduced to 5 mg/l.
C. Reduced land costs--land for treatment and disposal assumed to be available at no cost to project.
D. Discharge outside sensitive watersheds--effluent disposal site is located in watershed with adequate assimilative capacity.
E. Improved effluent quality--effluent nitrogen concentration reduced to 3 mg/l for all scenarios.
F. Regionalization--construction and O&M costs for treatment system reduced by 10% to account for economies of scale in a regional system.

APPENDIX D
Sources of Data and Summary of Adjustments and Assumptions for Example Projects

APPENDIX D

SOURCES OF DATA
AND
SUMMARY OF ADJUSTMENTS AND ASSUMPTIONS
FOR
EXAMPLE PROJECTS

BRACKETT LANDING, EASTHAM
Sources

McShane Construction and SeptiTech

Adjustments and Assumptions--"Current Practice" Scenario

Capital cost. McShane Construction quoted a cost of $530,000 for the wastewater facilities that were completed in early 2006. To this figure was added 10% for engineering, legal and permitting, and $300,000 for land (estimated 1.2 acres at $250,000 per acre). This project was not subject to public procurement requirements.

Operation and Maintenance Costs. McShane quoted $12,000 for the operator and for testing. Added to this figure were: $2,600 for electricity, $5,400 for sludge disposal, $3,500 for administrative costs including engineering and insurance, and $2,000 for equipment repair and replacement.

Flow. Current annual average flows are approximately 1,600 gpd, reflecting less than full development of the project. This analysis is based on an estimated flow at project completion of 3,300 gpd, approximately 40% of the design flow, consistent with other example projects.

Nitrogen Load. Load is based on 3.5 mg/l average effluent quality (as reported by Barnstable County) and in-watershed disposal.

Adjustments and Assumptions--"For TMDL Compliance" Scenario

Operation and Maintenance Costs. Based on DEP input on the level of oversight and testing associated with this scenario (see text), upward adjustments were made to the "current practice" costs to a revised total of $64,500. Labor costs were increased to $41,600 to reflect 10-hour-per-week oversight at $80 per hour. Testing costs were increased to $6,900 for monthly testing of influent and effluent and quarterly testing of monitoring wells. An allowance of $1,000 was added for chemicals (alkalinity). Also added were $1,000 for additional engineering, and $500 for additional equipment repair and replacement.

CAMP JEWELL, COLEBROOK CONNECTICUT
Sources

Greater Hartford YMCA and Wright-Pierce

Adjustments and Assumptions

Capital cost. Costs are based on amounts paid to the construction contractor for Phase 1 and on the engineer's estimates for a proposed upgrading. To these figures was added

25% for engineering, legal and permitting expenses. No land costs or collection costs are included. This project was not subject to municipal procurement requirements.

Operation and Maintenance Costs. The YMCA's quoted costs were increased by $3,000 for power and $500 for engineering. Recent repair costs were assumed to represent once-in-three-year expenditures.

Nitrogen Load. Load is based on the expected 10 mg/l average effluent quality (after upgrading) and in-watershed disposal.

NEW SILVER BEACH, FALMOUTH

Sources

Falmouth Department of Public Works

Adjustments and Assumptions

Capital cost. Costs are based on amounts paid to contractors for construction of collection, treatment and disposal facilities. To these figure was added 25% for engineering, legal and permitting expenses. No land costs are included.

Flow. Connections are still being made to this system. This analysis is based on the expected flow of 25,000 gpd, approximately 40% of the design flow, consistent with other example projects.

Nitrogen Load. Since the plant is in the start-up phase, the load is based on an expected 10 mg/l average effluent quality and in-watershed disposal.

MASHPEE COMMONS, MASHPEE

Sources

Cornish LP

Adjustments and Assumptions

Capital cost. Costs include construction, engineering, permitting and legal expenses, and land. No collection costs are included. Municipal procurement requirements did not apply.

Nitrogen Load. Load is based on 5 mg/l average effluent quality and in-watershed disposal.

WEST ISLAND, FAIRHAVEN

Sources

Fairhaven Department of Public Works

Adjustments and Assumptions

Capital cost. Costs are based on amounts paid to contractors for the original construction plus 25% for engineering, legal, permitting and land acquisition expenses.

Operation and Maintenance Costs. The DPW's quoted costs were increased by $30,000 for labor, $15,000 for sludge handling and $4,000 for administrative and engineering cost.

Nitrogen Load. Load is based on 7 mg/l average effluent quality and in-watershed disposal.

TISBURY MUNICIPAL FACILITIES

Sources

Tisbury Department of Public Works

Adjustments and Assumptions

Capital cost. Costs are based on actual amounts paid to contractors and engineers for the original construction. No land costs are included; treatment and disposal sites were Town-owned.

Nitrogen Load. Load is based on 5 mg/l average effluent quality and in-watershed disposal.

PROVINCETOWN MUNICIPAL FACILITIES

Sources

Provincetown Department of Public Works

Adjustments and Assumptions

Capital cost. Costs are based on amounts paid to contractors for the Phases 1 and 2 of construction plus 20% for engineering, legal, permitting, land acquisition and DBO procurement expenses.

Nitrogen Load. Load is based on out-of-watershed disposal.

PROPOSED ORLEANS MUNICIPAL FACILITIES

Sources

Orleans Comprehensive Wastewater Management Plan, April 2009

Adjustments and Assumptions

Capital cost. Costs are based on CWMP estimates and include construction, land, engineering, legal and contingencies. Costs for proposed supplemental cluster systems are not included. The proposed treatment and disposal sites are town-owned.

Operation and Maintenance Costs. Costs are based on CWMP estimates for all standard expenses, and exclude costs for treatment of out-of-town septage.

Nitrogen Load. Load is based on out-of-watershed disposal.

Regionalization. Cost advantages of regionalization are based on 2009 Wastewater Regionalization Study, assuming participation by Orleans, Eastham and Brewster.

CHATHAM MUNICIPAL FACILITIES

Sources

Chatham Department of Health and Environment and Stearns & Wheler

Adjustments and Assumptions

Capital cost. Costs are based on CWMP estimates for Phase 1 facilities updated for construction bids received in early 2010. Costs for proposed Phase 2 facilities are not included. Treatment and disposal site is town-owned.

Operation and Maintenance Costs. Costs are based on CWMP estimates for all standard expenses and exclude Phase 2 O&M costs.

Nitrogen Load. Load is based on out-of-watershed disposal.