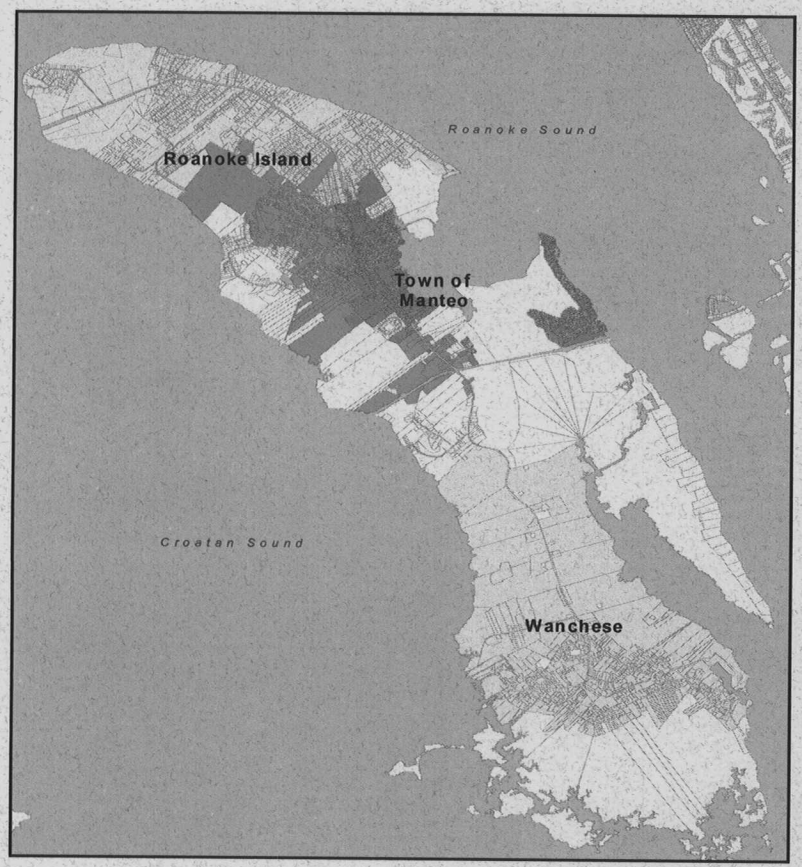
CDM

## Dare County Water Department, North Carolina

# Roanoke Island/Manteo/Wanchese Water System Study

April 2006




# *Final Report*

# Dare County Water Department
# North Carolina

# Roanoke Island/Manteo/Wanchese Water System Study

**Final Report**
**April 2006**


CDM

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## E.1 Introduction

The Dare County Water Department has been providing potable water to the Town of Manteo and some unincorporated areas in the central section of Roanoke Island since 1980. The remaining unincorporated areas of Roanoke Island and Wanchese rely on private wells for potable water.

The *2003 Dare County Land Use Plan* indicates that the area outside Manteo consists primarily of year-round population, with the oldest and most traditional setting for year-round residency in Dare County. Wanchese also consists of year-round population. A large portion of Wanchese has been incorporated into the Wanchese Seafood Industrial Park as well as commercial fishing and boating industries.

It is a goal of the Dare County Water Department to work in a professional manner with engineers, private contractors, and State agencies to expand the distribution system and meet the water needs of areas within Dare County. Local fire departments have expressed an interest to the County in continued expansion of public water service to unserved areas of Roanoke Island and Wanchese to improve fire protection.

This study evaluates system improvements necessary to extend water service throughout Roanoke Island and Wanchese based on 2025 projected water demands. The evaluation was conducted using a computer model of the water distribution system.

## E.2 Water Demands

Water demand projections for the 2025 planning period were developed based on a review of water billing data, available population projections, parcel data, and land use data. A summary of the recommended water demand projections is presented in Table E-1.

**Table E-1: 2025 Projected Water Demands for Existing and New Customers**

| Customer | Average Day Demand (gpd) | Maximum Day Demand (gpd) |
|---|---|---|
| Existing 2005 Roanoke Island/Manteo Customers | 448,000 | 1,120,000 |
| New Roanoke Island Customers | 359,000 | 898,000 |
| Wanchese Customers | 326,000 | 815,000 |
| Total | 1,133,000 | 2,833,000 |

Note: Maximum Day Demand = 2.5 x Average Day Demand; gpd = gallons per day (rounded to nearest thousand)

## E.3 Existing Water System

Water is supplied to unincorporated areas of central Roanoke Island and Manteo by the Skyco Water Treatment Plant (WTP), which is located at the US 64/NC 345

intersection. A 200,000-gallon elevated storage tank located at the WTP site also supplies water to the area. Skyco finished water pumps no. 5 and 6 alternately feed the service area and are controlled by the water levels of the elevated storage tank. Water is transported to Manteo through a 12-inch diameter main along US 64/NC 264 that feeds into the Town of Manteo's bulk meter located east of the Fernando Street/Simon Street intersection. The Town of Manteo also has a second tie-in to the Dare County water system at Manteo High School.

## E.4 Hydraulic Model Development

To conduct the hydraulic evaluation, a model of the existing water distribution system of Dare County on Roanoke Island and the Town of Manteo was developed using WaterGEMS™, a software developed by Haestad Methods that directly interfaces with ArcGIS™. WaterGEMS™ was previously selected by Dare County for the hydraulic model of the northern beaches due to its direct integration with the GIS database of their water system.

The pipe network of the existing system was developed using GIS files provided by the County. Nodes were assigned to pipe endpoints and at intersections. Water demands were allocated by assigning the billing data of each account to the nearest node. The Skyco ground storage tank and elevated storage tank were modeled based on their diameter, capacity, operating range, and high water level elevation. Skyco finished water pumps no. 5 and 6 were modeled using their pump curves.

The scope of work of this project included model validation based on available SCADA data. Hourly SCADA data for the existing Roanoke Island/Manteo water distribution system is limited to hourly water levels of the Skyco ground storage tank and elevated storage tank. Model calibration based on hydrant flow tests was not included in the scope of work due to funding limitations. In the future, the County may want to consider conducting field tests and calibrating the model to enhance model accuracy.

## E.5 Evaluation Approach and Criteria

To evaluate the ability of the water system to meet the projected 2025 water demands, the Roanoke Island/Manteo WaterGEMS™ model was extended to potential service areas in northern Roanoke Island and Wanchese. It was assumed that the water main extensions required would be located along major roads within existing rights-of-way. Water mains were added to the model using GIS road centerline data provided by the County. Junctions were provided at road intersections and at the end of the pipes. Each parcel was assigned to the closest model junction. Water demands were distributed in the model based on the developable acreage of each parcel. Ground elevations were based on topographical information provided by the North Carolina Department of Transportation.

Hypothetical conditions were simulated on the computer model and their effects on the system observed. Hypothetical conditions included average day, maximum day,

maximum day plus fire flow, and peak hour demand conditions. Computer simulations were also conducted to determine if the system is capable of filling existing and proposed storage facilities during minimum nighttime demand conditions on the maximum day.

The evaluation was based on the following criteria:

- Maintaining the County's desirable minimum system pressure of 60 pounds per square inch (psi) during average day, maximum day, and peak hour demand conditions and 20 psi during maximum day plus fire flow demand conditions. A minimum system pressure of 30 psi is required by the North Carolina Department of Environment and Natural Resources (NCDENR) during peak demand conditions.

- Limiting velocity to 10 feet per second (fps), with velocities less than 5 fps as the desirable range

- Limiting headloss to 5 feet/1,000 feet.

- Providing a minimum fire flow of 750 gallons per minute (gpm) based on the Insurance Services Office (ISO) fire flow requirement for one- and two-family dwellings not exceeding two stories in height, spaced 31 to 100 feet apart.

For the purposes of this evaluation, it was assumed that adequate water supply would be available at the Skyco WTP to meet the projected demands of Roanoke Island, Manteo, and Wanchese. The projected 2025 maximum day demand of the Roanoke Island/Manteo/Wanchese service area constitutes approximately 65 percent of the Skyco WTP capacity of 4.3 million gallons per day (mgd). Hence, the available supply to the northern beach areas is projected to be approximately 1.5 mgd. Implementation of water supply alternatives identified in the *Dare Countywide Hydrogeological Study and Groundwater Resource Evaluation Update Final Report,* prepared by CDM, dated April 2006, including expansion of the North Reverse Osmosis (NRO) WTP and application of aquifer storage recovery (ASR) technology, is recommended to meet the projected demands of the Dare County northern beaches.

## E.6 Evaluation Results

Evaluation results indicate that additional pumping capacity is required at the Skyco WTP to meet projected demands of the area. The capacity of the 8-inch diameter pump suction and discharge lines is also inadequate for the projected demands. Parallel installation of 16-inch diameter pump suction and discharge piping or dual 12-inch diameter mains is recommended. A discussion of improvements specific to the Roanoke Island/Manteo service area and the Wanchese service area follows.

### E.6.1 Roanoke Island/Manteo

The capacity of the 12-inch diameter main from the Skyco elevated storage tank to Manteo is inadequate to meet the projected demands. Parallel installation of a 16-inch

diameter main on US 64/NC 264 from the Skyco elevated storage tank northward to Viccars Lane is recommended. At Viccars Lane, the 16-inch diameter main feeds north into an existing 12-inch diameter main and west into a proposed 12-inch diameter main of the Town of Manteo. Installation of a 12-inch diameter main on US 64/NC 264 from the 12-inch diameter main on Ananias Dare Street and the 12-inch diameter main on Devon Street, north to Swain Drive, and on Swain Drive to Wingina Avenue is recommended.

The capacity of the 200,000-gallon Skyco elevated storage tank is inadequate for the projected demands. Additional storage is required in the northern Roanoke Island area. Two potential storage tank sites were considered:

- Site A - Former Highway Rest Area
- Site B - Manteo High School

It should be noted that both sites are hypothetical and that the County would need to secure property prior to design. Both sites are also located in close proximity to the Dare County Regional Airport. The Federal Aviation Administration (FAA) requires approval for construction of facilities located within 5 miles of an airport or extending 200 feet or greater above ground. Any structure which exceeds a height from a nearest airport runway at a slope of 100-foot horizontal for each 1-foot vertical to a distance of 20,000 feet requires approval from FAA. Hence, construction of an elevated storage tank on either site requires approval from FAA. FAA permitting is not included in the scope of work of this project. The County indicated that one of the runways at the airport has been abandoned and that the sites may not be in the flight path.

The County indicated that the Skyco elevated storage tank is in good condition and that they would like to continue its operation. Implementation of a 300,000-gallon elevated storage tank on either Site A or Site B with associated transmission improvements is recommended to provide additional storage. Tank Site A requires installation of a 16-inch diameter main on US 64/NC 264 from the Wingina Avenue/Swain Drive intersection to the tank site. With Tank Site B, the 16-inch diameter main reduces to a 12-inch diameter main. It is recommended that the Skyco WTP finished water pumps serving the Roanoke Island/Manteo/Wanchese area be controlled by the water elevation of the proposed remote elevated storage tank. It is also recommended that an altitude valve be installed at the Skyco elevated storage tank to prevent overflow since it will fill quicker than the remote tank.

In general, fire protection governed the sizing of water distribution main extensions. Fire protection is limited in cul-de-sacs and dead end mains. Wetlands appear to be a limiting factor in looping dead-end mains to improve flow and circulation. For cul-de-sacs and dead-end mains, a fire flow requirement of 500 gpm (ISO's minimum residential fire flow requirement) was considered, particularly if the cul-de-sac was within 500 feet of a junction where at least 750 gpm was available, assuming a fire

hydrant is located at the intersection. Potential water quality problems may occur on long dead-end mains with low demands due to low velocities if the pipes are increased in size to improve fire protection. Specific fire flow requirements should be re-evaluated based on the proposed development.

### E.6.2 Wanchese

Prior to extension of service to Wanchese, it is assumed that additional storage is provided in Roanoke Island/Manteo to supplement the Skyco elevated storage tank. To serve Wanchese, installation of a 16-inch diameter main on NC 345 from the Skyco WTP to the Old Wharf Road/Mill Landing Road intersection is recommended. Installation of 12-inch diameter mains on Old Wharf Road from NC 345 to Old Schoolhouse Road and on Mill Landing Road from NC 345 to Harbor Road is recommended. Fire protection governed the sizing of the distribution main extensions in Wanchese.

The Wanchese Seafood Industrial Park is located off of Harbor Road. The County indicated that the Wanchese Seafood Industrial Park is equipped with a 250,000-gallon elevated storage tank. The hydraulic design of the tank is unknown. If the Wanchese Seafood Industrial Park becomes a Dare County water customer, it is recommended that the feasibility of using the existing elevated storage tank for the Wanchese service area be investigated. The hydraulic effectiveness of the tank must be considered in relation to its operation in conjunction with the Skyco and proposed Roanoke Island/Manteo elevated storage tank. As an alternative, continued use of the Wanchese Seafood Industrial Park elevated storage tank for onsite fire protection may be considered.

## E.7 Cost Estimates

Preliminary planning-level cost estimates were developed for the recommended system improvements. The intended use of this type of estimate is long-range planning. The final cost of any project will depend on the project complexity, actual labor and material costs, competitive market conditions, actual site conditions, final scope of work, implementation schedule, continuity of personnel, and engineering.

Preliminary planning level cost estimates for Roanoke Island/Manteo and Wanchese are presented in Tables E-2 and E-3, respectively. A cost estimate summary is presented in Table E-4. The preliminary planning level cost estimates do not include costs for property acquisition.

## Table E-2: Roanoke Island/Manteo Water Distribution System Improvements Planning-Level Cost Estimates[1]

| | Potential Elevated Storage Tank Site A | | Potential Elevated Storage Tank Site B | |
|---|---|---|---|---|
| | Length (feet) | Cost Estimate ($) | Length (feet) | Cost Estimate ($) |
| 0.3 MG Elevated Tank | --- | 1,100,000 | --- | 1,100,000 |
| 16" PVC | 25,800 | 1,680,000 | 9,800 | 640,000 |
| 12" PVC | 4,100 | 230,000 | 18,400 | 1,010,000 |
| 8" PVC | 26,500 | 1,190,000 | 26,500 | 1,190,000 |
| 6" PVC | 117,700 | 4,120,000 | 119,400 | 4,180,000 |
| Subtotal | 174,100 | 8,320,000 | 174,100 | 8,120,000 |
| 25% Construction Contingencies | | 2,080,000 | | 2,030,000 |
| 15% Design, Legal, and Financial | | 1,250,000 | | 1,220,000 |
| Total | | 11,650,000 | | 11,370,000 |
| Annualized Cost[2] | | 980,000 | | 950,000 |

Notes:
1. Costs are presented in 2006 dollars with an ENR construction cost index of 7695.10 (April 2006). Costs do not include property acquisition. Assumes additional finished water pumps are included in a separate water supply and treatment project.
2. Based on capital cost recovery factor of 0.0837 (20 years @ 5.5%).

## Table E-3: Wanchese Water Distribution System Improvements Planning-Level Cost Estimates[1]

| | Length (feet) | Cost Estimate ($) |
|---|---|---|
| 16" PVC | 12,200 | 790,000 |
| 12" PVC | 6,300 | 350,000 |
| 8" PVC | 12,600 | 570,000 |
| 6" PVC | 57,600 | 2,020,000 |
| Subtotal | | 3,730,000 |
| 25% Construction Contingencies | | 930,000 |
| 15% Design, Legal, and Financial | | 560,000 |
| Total | | 5,220,000 |
| Annualized Cost[2] | | 440,000 |

Notes:
1. Costs are presented in 2006 dollars with an ENR construction cost index of 7695.10 (April 2006). Costs do not include property acquisition. Assumes additional storage is provided in northern Roanoke Island (refer to Table E-2). Costs assume additional Skyco WTP finished water pumps are included in a separate water supply and treatment project.
2. Based on capital cost recovery factor of 0.0837 (20 years @ 5.5%).

**Table E-4: Roanoke Island/Manteo/Wanchese Water Distribution System Improvements Planning-Level Cost Estimate Summary**

| | Potential Elevated Storage Tank Site A | Potential Elevated Storage Tank Site B |
|---|---|---|
| Roanoke Island/Manteo[1] | $11,650,000 | $11,370,000 |
| Wanchese[2] | $ 5,220,000 | $ 5,220,000 |
| Total | $16,870,000 | $16,590,000 |

Notes:
1. Refer to Table E-2.
2. Refer to Table E-3.

## E.8 Summary and Recommendations

This study was intended to identify system improvements necessary to extend water service to unserved areas of Roanoke Island and Wanchese. The analysis was based on projected 2025 water demands. Prior to implementing the recommended system improvements, CDM recommends that the County proceed with the following tasks:

- Conduct hydrant flow tests and calibrate the model of the existing system based on the field test results.
- Contact FAA to determine if Sites A and/or B are feasible for an elevated storage tank.
- Re-evaluate the recommended improvements presented in this report using the calibrated model and based on near-term (2010) and long-term (2025) projected demands.

In addition, the following general recommendations are recommended to improve/enhance system operation:

- Provide additional finished water ground storage at the Skyco WTP and replace transmission and finished water pumps including associated motor controls to meet the demands of the northern beaches and Roanoke Island/Manteo service area, particularly during the summer months.
- Monitor flow of Skyco finished water pumps no. 5 and 6 to improve accountability of water usage.
- Retain SCADA data for longer than 65 days, preferably several years, to maximize use of historical data in conducting system evaluations.
- To reduce water main installation costs, create an in-house water line construction division and install 6-inch diameter water mains and service connections.

Transmission and storage improvements directly affect water quality in distribution systems. Pipes sized to meet projected demands of the system may be oversized for the current demands of the system and, as a result, experience problems in maintaining a disinfectant residual. Prior to implementing the system improvements, potential water quality impacts should be evaluated, particularly with near-term demands (e.g., 2010). Alternative sources for fire protection in low density areas, such as the reliance on pumper trucks, should be evaluated if the demand in the area is insufficient to promote turnover in a pipe sized to provide fire protection. If fire protection is not required, a smaller diameter main could be installed in the near-term with a parallel main installed in the future when demands in the area increase.

# Section 1
# Introduction

The Dare County Water Department is the primary water purveyor for the Outer Banks of North Carolina. The existing service area is shown on Figure 1-1. Public water supply availability to the Outer Banks began in 1964 with the operation of the Fresh Pond Water Treatment Plant (WTP). The Fresh Pond WTP draws surface water from Fresh Pond and is owned by the Town of Nags Head. The Fresh Pond WTP is currently only in operation to supplement peak summer demands.

In 1979, the Skyco WTP was constructed on the southern end of Roanoke Island as a second public water supply. The Skyco WTP draws water from wells that tap into the upper Yorktown and Principal aquifers.

In response to increasing demands, the North Reverse Osmosis (NRO) WTP was constructed in Kill Devil Hills in 1989 as a third public water supply. The NRO WTP treats water from wells that tap into the Yorktown aquifer.

The Skyco WTP began supplying water to the Town of Manteo in 1980. The Skyco WTP also provides water to customers in the unincorporated areas of Roanoke Island and outer Manteo between the WTP and the Town of Manteo. The extent of the existing Roanoke Island/Manteo service area is shown on Figure 1-2. The remaining unincorporated areas of Roanoke Island and Wanchese rely on private wells for potable water.

It is a goal of the Dare County Water Department to work in a professional manner with engineers, private contractors, and State agencies to expand the distribution system and meet the water needs of areas within Dare County. Local fire departments have expressed an interest to the County in continued expansion of public water service to unserved areas of Roanoke Island and Wanchese to improve fire protection.

The Dare County Water Department contracted Camp Dresser and McKee (CDM) to conduct a water system study to evaluate improvements necessary to extend water service to unserved areas of Roanoke Island and Wanchese. This report presents the results of the evaluation which included the following tasks:

- Development of 2025 water demand projections
- Development of a computer model of the existing and proposed water distribution system using WaterGems™
- Model validation based on available data
- Hydraulic evaluation
- Planning-level cost estimates for recommended system improvements

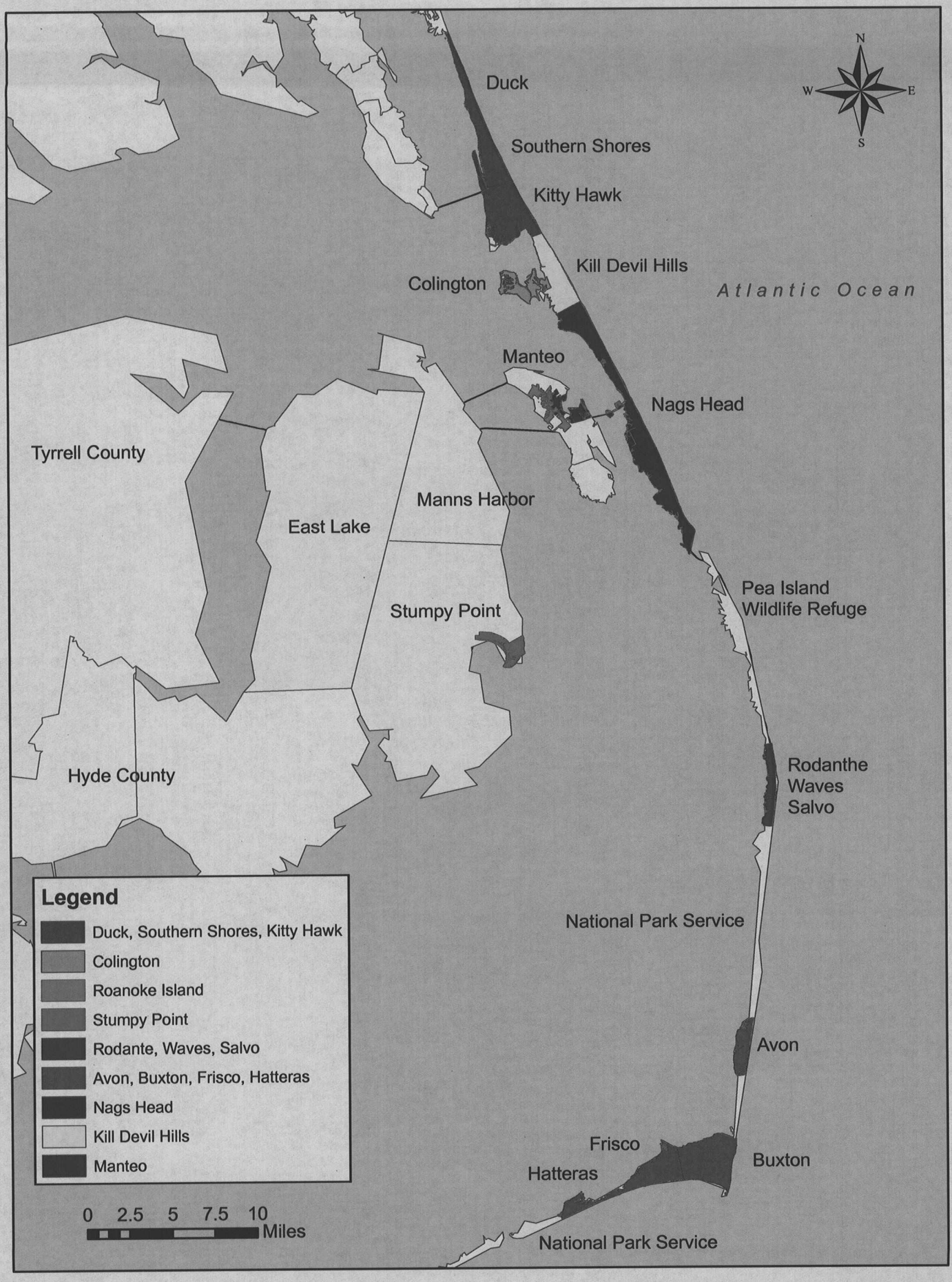



Figure 1-1
DARE COUNTY WATER DEPARTMENT SERVICE AREA

CDM

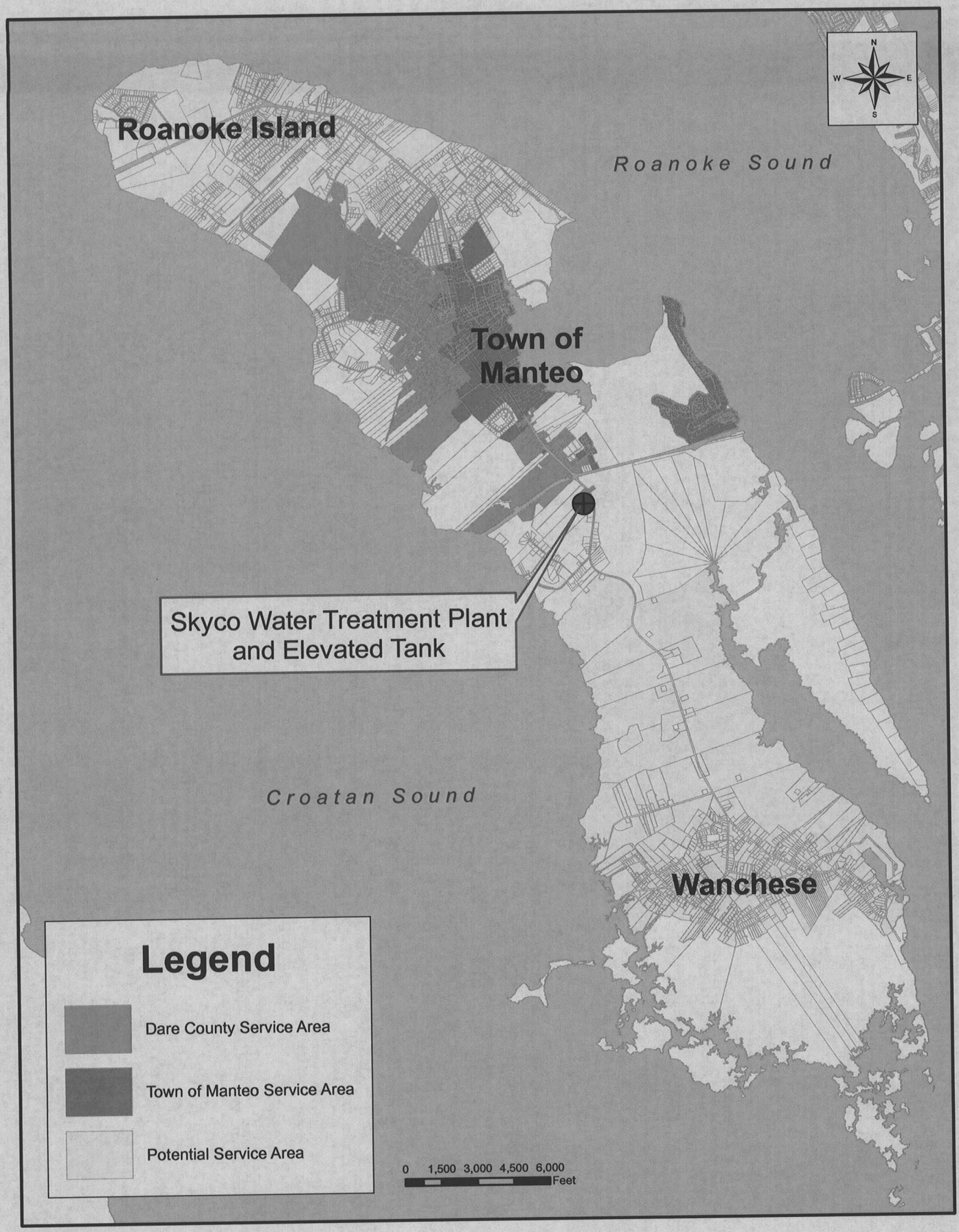



Figure 1-2
ROANOKE ISLAND/MANTEO
EXISTING AND POTENTIAL SERVICE AREA

CDM

The scope of work of the contractual agreement for this project also included a water system study to provide public water service to Manns Harbor. The *Manns Harbor Water System Study* is presented in a separate report. CDM also completed the *Dare Countywide Hydrogeological Study and Groundwater Resource Evaluation Update Final Report,* dated April 2006, which discusses water supply availability of the Skyco WTP as well as potential water supply sources for the County.

# Section 2
# Water Demands

## 2.1 General

Water demands were developed for Roanoke Island, Manteo, and Wanchese based on a review of the following data:

- Dare County water billing data
- Town of Manteo water billing data
- Population projections from the North Carolina State Data Center
- Population data from the U.S. Census Bureau
- *2003 Dare County Land Use Plan*

A discussion of the methodology used to develop the demand projections follows.

## 2.2 Population

Historical population data for Dare County was obtained from the *2003 Dare County Land Use Plan*. The *2003 Dare County Land Use Plan* population data is based on the 2000 U.S. Census Bureau population data. The 2000 year-round population for Dare County was estimated to be 29,967 with a seasonal population of 200,000. U. S. Census Bureau population data for Dare County is shown on Figure 2-1.

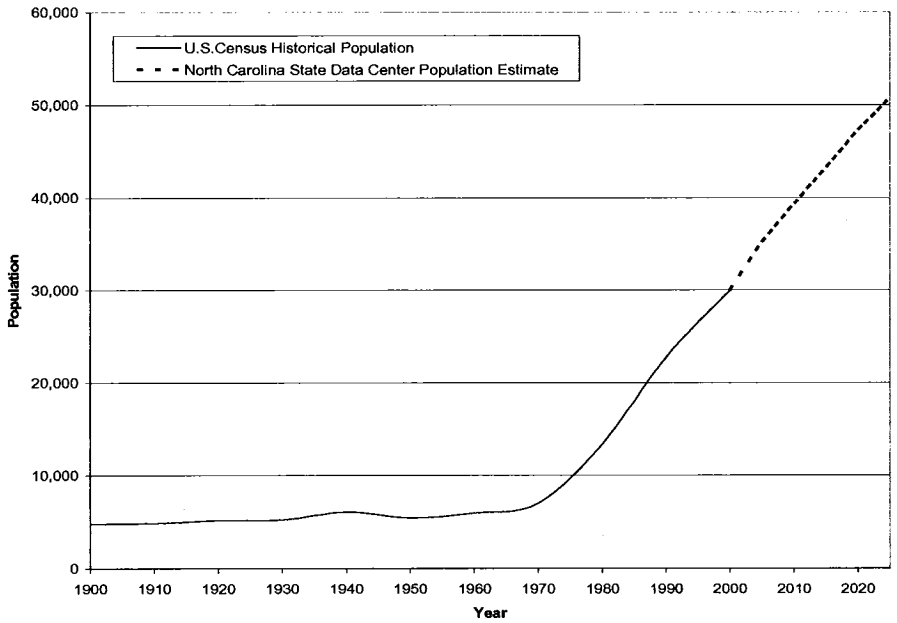



**Figure 2-1: Dare County Population**

The *2003 Dare County Land Use Plan* generally indicates that the area of Roanoke Island outside Manteo consists primarily of year-round population, with the oldest and most traditional setting for year-round residency in Dare County. Wanchese also consists of year-round population. A large portion of Wanchese has been incorporated into the Wanchese Seafood Industrial Park as well as commercial fishing and boating industries. Dare County indicated that the Wanchese Seafood Industrial Park currently consists of boat repair/boat building establishments. There are no major fishing industries in the area due to loading problems for fishing vessels.

The 2000 U.S. Census Bureau population estimates for the study area, which are defined by the Manteo and Wanchese zip code areas, are listed in Table 2-1.

**Table 2-1: Dare County Population Estimates**

| Year | Dare County[1,2] | Manteo[1,3,4] (zip code 27954) | Wanchese[1,4] (zip code 27981) |
|---|---|---|---|
| 2000 | 29,967 | 5,168 | 1,556 |
| 2004 | 34,248 | 5,906 | 1,778 |
| 2005 | 35,145 | 6,061 | 1,825 |
| 2006 | 36,027 | 6,213 | 1,871 |
| 2007 | 36,866 | 6,358 | 1,914 |
| 2008 | 37,699 | 6,501 | 1,957 |
| 2009 | 38,551 | 6,648 | 2,002 |
| 2010 | 39,370 | 6,790 | 2,044 |
| 2011 | 40,107 | 6,917 | 2,083 |
| 2012 | 40,878 | 7,050 | 2,123 |
| 2013 | 41,634 | 7,180 | 2,162 |
| 2014 | 42,438 | 7,319 | 2,204 |
| 2015 | 43,235 | 7,456 | 2,245 |
| 2016 | 44,018 | 7,591 | 2,286 |
| 2017 | 44,830 | 7,731 | 2,328 |
| 2018 | 45,633 | 7,870 | 2,369 |
| 2019 | 46,478 | 8,015 | 2,413 |
| 2020 | 47,278 | 8,153 | 2,455 |
| 2021 | 47,950 | 8,269 | 2,490 |
| 2022 | 48,655 | 8,391 | 2,526 |
| 2023 | 49,338 | 8,509 | 2,562 |
| 2024 | 50,075 | 8,636 | 2,600 |
| 2025 | 50,798 | 8,760 | 2,638 |

Notes:
1. 2000 population estimates based on U.S. Census Bureau statistics (American FactFinder).
2. 2004 through 2025 Dare County population projections provided by North Carolina State Data Center.
3. Manteo includes incorporated and unincorporated surrounding area.
4. Manteo and Wanchese 2004 through 2025 population projections based on North Carolina State Data Center growth rate for Dare County.

Available population projections for the study area are limited to the population projections for Dare County provided by the North Carolina State Data Center presented in Table 2-1. Population projections for the entire County are provided for each year from 2004 through 2029. The population projections are not geographically distributed within the County. For the purposes of this study, the population projection for each entity (as defined by the U.S. Census Bureau zip code area) was estimated based on the same rate of growth as the Dare County population. Population projections for the study area are included in Table 2-1.

The estimated number of people per household for 2000 provided by the U.S. Census Bureau is presented in Table 2-2. Manns Harbor is included in Table 2-2 since the development of Manns Harbor demand projections was done concurrent with the Manteo and Wanchese projections in accordance with the scope of work for this project.

**Table 2-2: Estimated Number of People per Household Based on 2000 U.S. Census Bureau Data**

| Entity | Estimated Number of People per Household[1] |
|---|---|
| Dare County | 2.34 |
| Manteo (Zip Code 27954)[2] | 2.44 |
| Wanchese (Zip Code 27981) | 2.49 |
| Manns Harbor (Zip Code 27953)[3] | 2.57 |
| Average (Dare County + zip code areas) | 2.46 |
| Town of Manteo | 2.03 |

Notes:
1. Source: U.S. Census Bureau (American FactFinder)
2. Manteo zip code area includes incorporated and unincorporated surrounding area.
3. Manns Harbor zip code area includes East Lake.

# 2.3 Historical Water Consumption

## 2.3.1. Dare County

Quarterly water billing data from December 1, 2004 through September 1, 2005 was provided by Dare County. It should be noted that October and November consumption is reflected in the December billing data since the data reflects quarterly usage. Each account was identified with a street address. In order to assimilate the consumption data into GIS, the account addresses were geocoded (matched and placed according to street coordinates) using the GIS road centerline data files provided by Dare County. Initial geocoding efforts resulted in a 66 percent match of accounts to street coordinates. CDM improved geocoding efforts of accounts to 89 percent by rewording and/or correcting street names in the billing data to match the street names in the GIS files (e.g., renaming Highway 12, correcting suffixes such as

Street versus Drive). It was determined that the remaining 11 percent of accounts that were not geocoded were generally located outside the study area.

Based on a review of the quarterly billing data, it was determined that the billing data for the period ending in September 1, 2005 would be reasonable for use in the demand allocation distribution. The accounts were matched to parcels in the following files provided by the County:

- coling3.shp
- kdhills7.shp
- kdh12.shp
- mnteoi10.shp
- mnteoo11.shp

Geocoding of the September 2005 accounts resulted in 2,091 individual account records, with 1,994 accounts matched to parcel data. Averages for account usage and acreage were calculated for these parcels using a 95 percent standard deviation, with the relatively high outliers removed. The estimated unit water demands were 150 gallons per day (gpd)/account and 443 gpd/acre. The estimated per capita consumption was 61 gallons per capita per day (gpcd), assuming each account consists of a single-family household with an average of 2.46 people per household as presented in Table 2-2. A representative acreage for an average parcel in Dare County was estimated to be 0.34 acres.

GIS zoning data was also provided by the County for the existing outer Manteo service area. The parcel data for the existing outer Manteo district was disaggregated based on zoning to develop a unit water demand factor for each zoning category. Only the areas zoned R-1, R-2, and RS-8 contained sufficient amount of parcels with water billing data to establish historical unit demand estimates. A summary of the unit water demand estimates for each zoning category with sufficient available data is presented in Table 2-3.

A per capita consumption rate was also estimated for the R-1 zoning category assuming a single-family household per residential account. The per capita consumption rate was estimated to be 70 gpcd based on an average of 2.46 people per household (account) as presented in Table 2-2. It should be noted that the zoning definition of R-2 and RS-8 allows for development of multi-family housing. However, the water billing data does not clearly indicate whether the existing account is a single-family or multi-family residence. For the purposes of this study, it is assumed that the existing R-2 and RS-8 accounts are single-family residences. A summary of the unit demand factors estimated for each zoning category is presented in Table 2-3. The per capita consumption rate for the R-2 and RS-8 categories will be lower than indicated if the account involves a multi-family unit.

**Table 2-3: Dare County Unit Water Demand Estimates**

| Service Area | Zone Code[1] | Number of Accounts Basis[2] | Average Acreage per Account[4] | gpd/acre[3,4] | gpd/account[2,3] | gpcd[5] |
|---|---|---|---|---|---|---|
| Dare County | All | 1,994 | 0.34 | 443 | 150 | 61 |
| Outer Manteo | R-1 | 10 | 0.48 | 356 | 171 | 70 |
| | R-2 | 123 | 0.36 | 465 | 171 | 70 |
| | RS-8 | 46 | 0.27 | 611 | 162 | 66 |

Notes:
1. Includes only zone codes with sufficient amount of data for calculation.
2. Includes accounts geocoded to parcels.
3. Based on Dare County quarterly billing data from December 1, 2004 through September 1, 2005; gpd = gallons per day
4. Based on parcel acreage for accounts
5. gpcd = gallons per capita per day assuming 2.46 people per household (account) [U.S. Census Bureau average for study area, refer to Table 2-2]

### 2.3.2 Town of Manteo

Historical water billing data from July 15, 2004 through June 30, 2005 was provided by the Town of Manteo. Zoning data was not available for the Town of Manteo. Geocoding efforts resulted in a match of over 80 percent of the accounts to parcels. The accounts were also manually identified as residential or commercial accounts based on whether the customer name identified appeared to be an individual or a business. Water billing data which contained 1 to 12 entries were averaged for each account. Unit water demand estimates for each customer category are presented in Table 2-4. Unit water demand estimates per capita and per acre were generally lower for the Town of Manteo in comparison to the Dare County and outer Manteo area estimates presented in Table 2-3.

**Table 2-4: Town of Manteo Unit Water Demand Estimates**

| Customer Category | Number of Accounts[1,2] | gpd/account[1] | gpcd[3] | gpd/acre[4] |
|---|---|---|---|---|
| Residential | 1,128 | 102 | 50 | 187 |
| Commercial | 123 | 162 | 80 | 162 |

Notes:
1. Based on available Town of Manteo, July 15, 2004 through June 30, 2005, billing data.
2. Excludes 45 accounts related to public facilities, e.g. government buildings, hospitals, etc.
3. Based on U.S. Census Bureau estimate for Manteo of 2.03 people per household (account) for 2000.
4. Based on acreage from geocoded parcel data.

## 2.4 NCDENR Criteria

The North Carolina Department of Environment and Natural Resources (NCDENR) (NCAC T15A:18C.0409) indicates that units of local government which are operating

under a local water supply plan (e.g., Dare County) shall not be limited in the number of service connections. For public water systems that do not have a water supply plan, NCDENR limits the number of service connections based on the following alternatives for calculating design flows:

- Design flow of 400 gpd per residential connection. Design flows for other types of connections (e.g., commercial establishments, schools, hospitals, etc.) are also specified and are determined based on criteria such as the number of employees, students, etc.

- For public water systems serving different types of connections, design flow of a maximum day demand equivalent to 2.5 times the average day demand for communities serving 10,000 or less people or 2.0 times the average day demand for communities serving more than 10,000 people. Average day demand is defined as the total amount of water consumed in a given year divided by the number of days in the year. Maximum day demand is defined as the largest demand to occur during a single day in a given year.

Although Dare County has a water supply plan, these NCDENR unit water demands were considered for comparison purposes. The NCDENR residential design flow of 400 gpd per connection results in an average day demand per capita consumption of 65 gpcd, based on the maximum day to average day factor of 2.5, assuming 2.46 people per household. Hence, the range of 50 to 70 gpcd based on the historical Dare County and Town of Manteo billing data is in range of the NCDENR criteria.

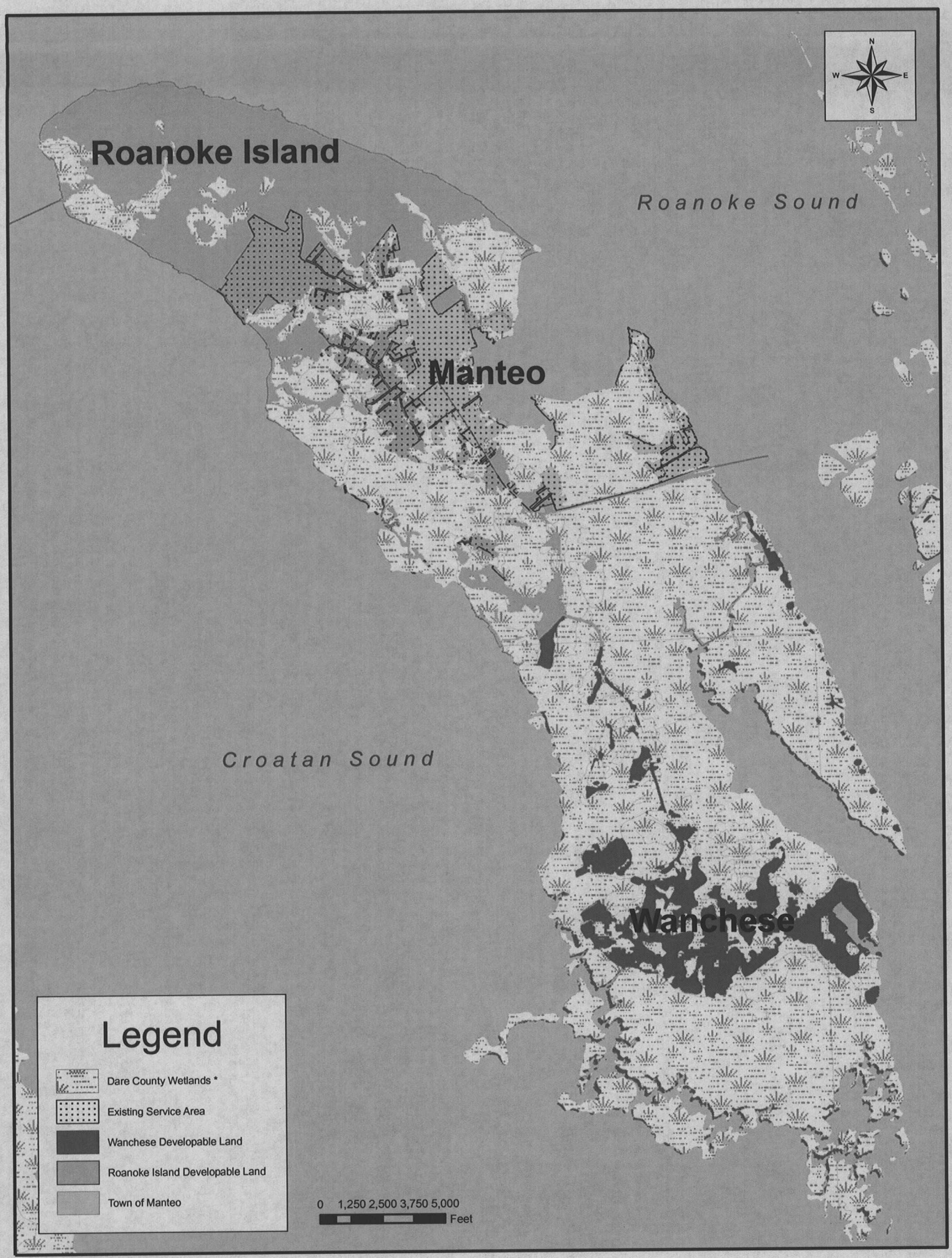
## 2.5 Water Demand Projections

Preliminary average day demand projections were developed using two methods:

- Population-based, assuming a per capita consumption rate of 70 gpcd, based on the upper range of the prior year's records for Dare County and the Town of Manteo and the NCDENR per capita estimate.

- Developable land area-based, assuming a unit demand per acre and that wetlands are considered undevelopable land. Wetland areas were identified based on information provided by the North Carolina Coastal Management. Wetland areas are shown on Figure 2-2. Wetland acreage was eliminated from the parcel acreage to estimate the developable acreage for the service area. It was assumed that the developable acreage includes both residential and non-residential zoning and that build-out occurred by 2025. Water demand projections were based on 200 to 500 gpd/acre based on the Dare County and Town of Manteo historical billing data.

Preliminary projected average day demands developed based on these methods are presented in Table 2-5.




*Wetland Data Source: North Carolina Coastal Management

Figure 2-2

CDM

ROANOKE ISLAND/MANTEO/WANCHESE DEVELOPABLE LAND AREA

## Table 2-5: Preliminary Projected Average Day Demands

| U.S. Census Bureau Zip Code Area | 2005 | | 2025 Population-Based Projected Demand | | 2025 Developable Acreage-Based Projected Demand | | |
|---|---|---|---|---|---|---|---|
| | 2005 Population Estimate[2] | Estimated 2005 Water Demand (gpd) | 2025 Population Estimate[2] | 2025 Projected Water Demand Based on Population (gpd)[4] | Developable Area (acres)[5] | 200 gpd/acre Basis (gpd) | 500 gpd/acre Basis (gpd) |
| Manteo[1] | 6,061 | 448,000[3] | 8,760 | 613,000 | 2,307 | 461,000 | 1,153,000 |
| Wanchese | 1,825 | 128,000[4] | 2,638 | 185,000 | 929 | 186,000 | 465,000 |

Notes:
1. Manteo includes incorporated and unincorporated surrounding areas.
2. Refer to Table 2-1.
3. Based on calendar year 2005 reported demand.
4. Based on 70 gpcd, rounded to nearest 1,000 gpd.
5. Excludes wetland areas; assumes build-out by 2025.

Commercial unit water demand estimates are limited to the available data for the Town of Manteo presented in Table 2-4 which appears to be in range of the residential unit demand estimates.

In general, the 2025 water demand projections developed based on population were in range of the projections based on developable acreage, with Wanchese close to the lower end of the range.

Appendix C of the *2003 Dare County Land Use Plan* lists the number of properties in Wanchese and outer Manteo for various land use categories. A summary of the number of properties is presented in Table 2-6. For comparison, it was assumed that build-out for outer Manteo and Wanchese was based on development of the total number of properties listed. An average day unit water demand of 171 gpd per account was assumed based on the upper end of the range of values listed in Tables 2-3 and 2-4. A summary of the water demand projections based on the number of properties is presented in Table 2-6.

The estimated average day demand based on the number of properties presented in Table 2-6 is within 4 percent of the estimated average day demand based on 200 gpd/acre for Wanchese presented in Table 2-5. The estimated average day demand based on the number of properties for outer Manteo presented in Table 2-6 is within range of the estimated demand based on acreage in Table 2-5 which includes both inner and outer Manteo.

For the purposes of this study, it is recommended that this evaluation be based on an average of the unit demand acreage-based projections since they are more conservative than the population-based estimates. A summary of the recommended average day demand projections is presented in Table 2-7.

## Table 2-6: Projected Build-Out Average Day Demand Based on Number of Properties in *2003 Dare County Land Use Plan*

| 2003 Land Use Plan Description | Outer Manteo | Wanchese |
|---|---|---|
| Vacant Land – Private Ownership | 964 | 313 |
| Vacant Land - Public Ownership | 67 | 16 |
| Developed Properties | | |
| Residential Use | 1,597 | 608 |
| Commercial Use | 55 | 54 |
| Other Uses[1] | 61 | 44 |
| Government Uses[2] | 16 | 6 |
| Total Number of Properties | 2,760 | 1,041 |
| Average Day Demand (gpd) based on 171 gpd per account, rounded to nearest thousand | 472,000 | 178,000 |

Notes:
1. Other Uses include cemeteries, churches/religious buildings, secondary improvements.
2. Government Uses include federal, state, and Dare County uses.

## Table 2-7: Recommended Water Demand Projections

| U.S. Census Bureau Zip Code Area | 2025 Average Day Demand (gpd)[1] | 2025 Population Projection[2] | Per Capita Consumption (gpcd)[3] | 2025 Maximum Day Demand (gpd)[4] |
|---|---|---|---|---|
| Manteo (inner and outer) | 807,000 | 8,760 | 92 | 2,018,000 |
| Wanchese | 326,000 | 2,638 | 124 | 815,000 |
| Total | 1,133,000 | | | 2,833,000 |

Notes:
1. Based on average of 200 gpd/acre and 500 gpd/acre projections in Table 2-5.
2. Refer to Table 2-1.
3. 2025 Average Day Demand divided by 2025 population projection.
4. 2025 Average Day Demand x 2.5

As a "reasonableness" check, a per capita consumption rate was also estimated based on the acreage-based average day demand and population projections presented in Table 2-7. The estimated per capita consumption rate for Manteo was 92 gpcd which is in range of typical values for residential communities. This per capita consumption rate is more conservative than the per capita consumption rate of 70 gpcd initially assumed in Table 2-5. The estimated per capita consumption rate for Wanchese was 124 gpcd. The higher value for Wanchese in comparison to Manteo appears reasonable since it provides an allowance for the Wanchese Seafood Industrial Park as well as commercial fishing and boating industries in addition to the residential demand.

Historical maximum day and average day demand data for the Roanoke Island/Manteo service area is presented in Table 2-8. The historical maximum day demand from 2001 through 2005 was 0.95 million gallons per day (mgd).

**Table 2-8: Historical Average Day and Maximum Day Demands for Roanoke Island/Manteo Service Area**

| Year | Average Day Demand (mgd) | Maximum Day Demand | | Maximum Day Demand / Average Day Demand |
|---|---|---|---|---|
| | | mgd | Date | |
| 2001 | 0.443 | 0.936 | July 28, 2001 | 2.11 |
| 2002 | 0.436 | 0.826 | August 13, 2002 | 1.89 |
| 2003 | 0.419 | 0.832 | May 2, 2003 | 1.99 |
| 2004 | 0.439 | 0.952 | June 2, 2004 | 2.17 |
| 2005 | 0.448 | 0.861 | May 24, 2005 | 1.96 |
| Average | | | | 2.02 |

Note: Based on Skyco WTP data; excludes maximum days associated with unusual events such as flushing.

The historical maximum day demand to average day demand ratio for the Roanoke Island/Manteo service area from 2001 through 2005 (excluding maximum day demands associated with flushing or other unusual events) ranged from approximately 1.9 to 2.2 with an average of 2.0. NCDENR recommends a maximum day to average day demand factor of 2.5 for systems serving 10,000 people or less. For conservative purposes, projected 2025 maximum day demands were based on a maximum day to average day demand ratio of 2.5 and are presented in Table 2-7. A summary of the recommended projected demands for existing and new customers is presented in Table 2-9.

**Table 2-9: 2025 Projected Water Demands for Existing and New Customers**

| Customer | Average Day Demand (gpd) | Maximum Day Demand (gpd)[4] |
|---|---|---|
| Existing 2005 Roanoke Island/Manteo Customers[1] | 448,000 | 1,120,000 |
| New Roanoke Island Customers[2] | 359,000 | 898,000 |
| Wanchese Customers[3] | 326,000 | 815,000 |
| Total | 1,133,000 | 2,833,000 |

Notes:
1. Average day demand based on 2005 average day demand.
2. Average day demand = Table 2-7 Manteo zip code area average day demand - 2005 average day demand
3. Refer to Table 2-7, Wanchese zip code area demands
4. Maximum day demand = 2.5 x average day demand

# Section 3
# Existing Water System

## 3.1 Water Supply and Treatment

Water is supplied by the Dare County Water Department to unincorporated areas of Roanoke Island and Manteo by the Skyco WTP, which is located in the vicinity of the US 64/NC 345 intersection. The Skyco WTP also supplies water to the northern Dare County beaches. The Skyco WTP utilizes ion exchange for treatment and has a capacity of approximately 4.3 mgd. The plant is supplied by 10 production wells tapping the Upper Yorktown Aquifer.

A graph representing the historical monthly average day and maximum day demands of the areas served by the Skyco WTP is shown on Figures 3-1 and 3-2. During the peak summer months from 2001 through 2005, approximately 2.5 to 3.5 mgd of the average Skyco WTP production and approximately 3 to 4 mgd of the maximum Skyco WTP production was used to supply water to the Dare County northern beaches. The Roanoke Island/Manteo demand consumed less than 20 percent of the Skyco WTP production during the peak summer months. The projected 2025 maximum day demand of the Roanoke Island/Manteo/Wanchese service area of 2.8 mgd constitutes approximately 65 percent of the Skyco WTP capacity of 4.3 mgd. Hence, with the expansion of the Roanoke Island/Manteo service area to northern Roanoke Island and Wanchese, the available supply at the Skyco WTP for the Dare County northern beaches would be limited to 1.5 mgd in 2025 without a plant expansion.

Water supply options for the Dare County water system, including the feasibility of expanding the Skyco WTP, are discussed in the *Dare Countywide Hydrogeological Study and Groundwater Resource Evaluation Update Final Report*. Expansion of the Skyco WTP is not recommended at this time due to issues related to water quality, wellhead protection, and long-term sustainability of the resource which have not been fully addressed. To meet long-term water supply needs of the Dare County service areas, improvements recommended in the report included:

- Expand the NRO WTP capacity from 5.35 to 8.5 mgd
- Implement Skyco wellfield improvements and wellhead protection ordinances
- Construct a new production well at Rodanthe-Wave-Salvo (RWS) and pilot test nanofiltration membranes at RWS and Hatteras
- Utilize aquifer storage recovery (ASR) technology to meet peak demands

For the purposes of this study, it is assumed that adequate water supply is available at the Skyco WTP to meet the projected 2025 maximum day demands of the Roanoke Island, Manteo, and Wanchese service area and that the recommendations presented in the *Dare Countywide Hydrogeological Study and Groundwater Resource Evaluation Update Final Report* will be implemented.

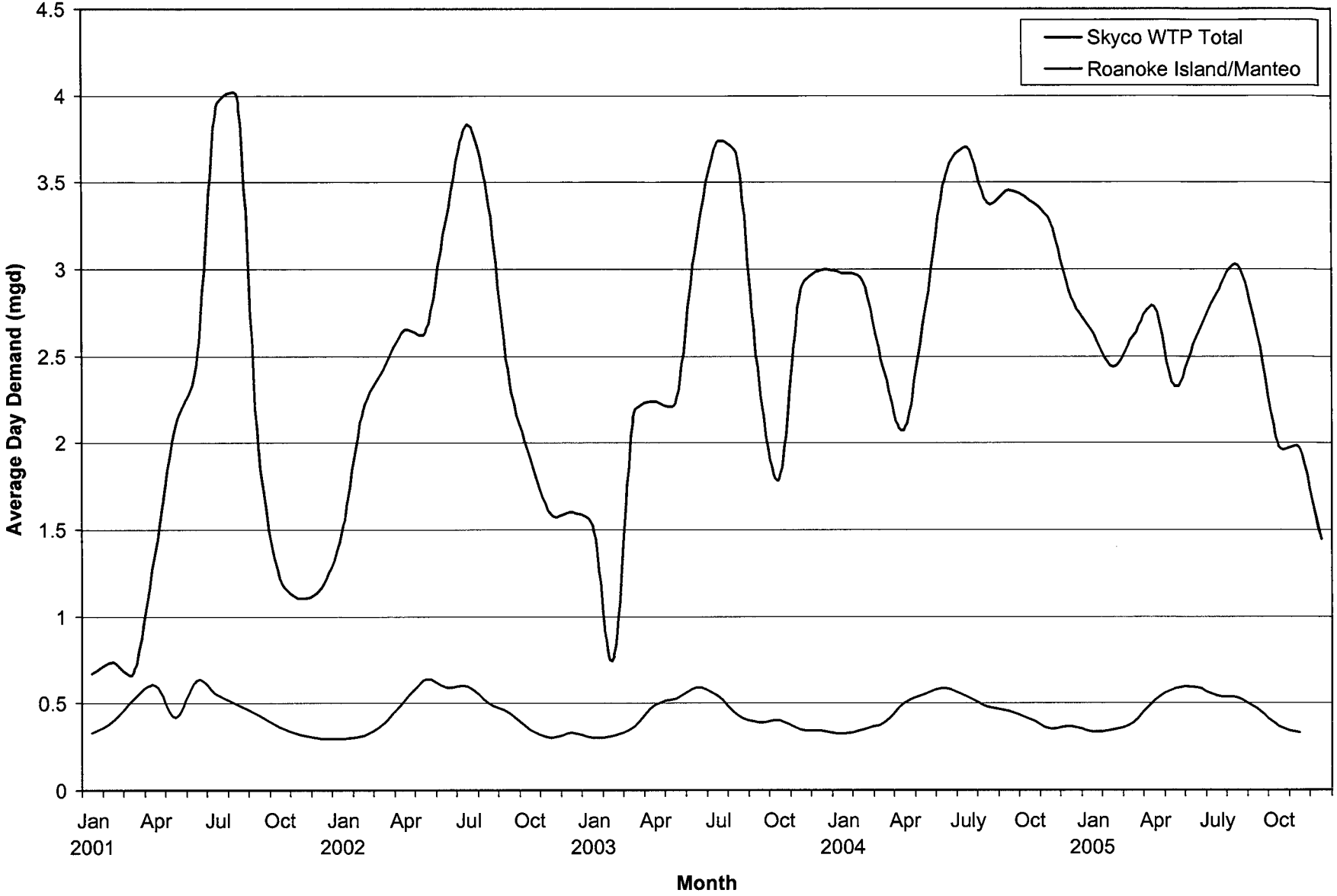



**Figure 3-1**
**SKYCO WTP SERVICE AREA**
**MONTHLY AVERAGE DAY DEMAND (2001 - 2005)**

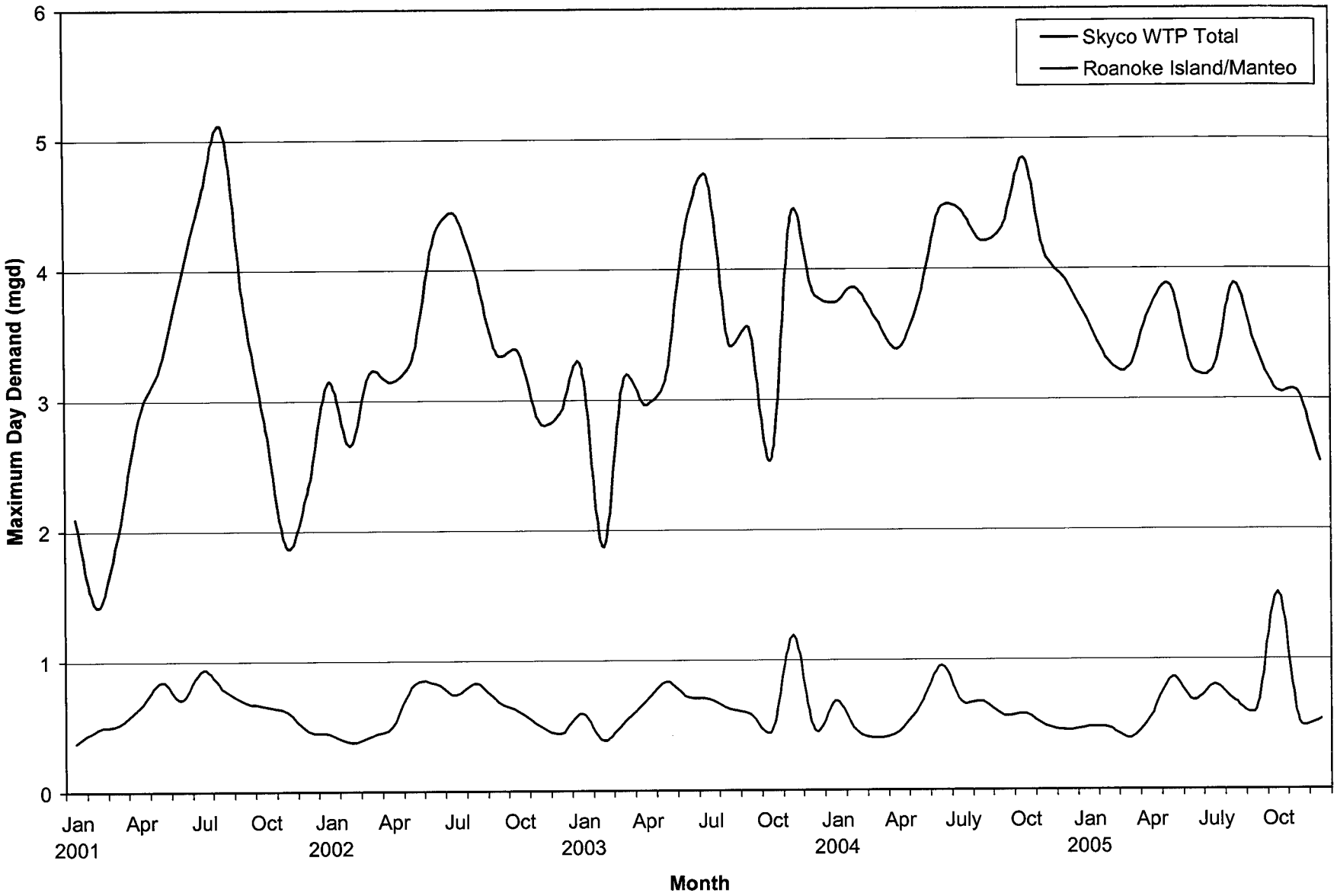



**Figure 3-2**
**SKYCO WTP SERVICE AREA**
**MONTHLY MAXIMUM DAY DEMAND (2001 - 2005)**

## 3.2 Finished Water Pumping and Storage

Finished water from the Skyco WTP is stored in a 2-million-gallon ground storage tank. Skyco finished water pumps no. 1 through 4 serve the Dare County northern beach areas. The County indicated that pumps no. 3 and 4 (each rated at 700 gallons per minute (gpm)) are obsolete since they are of no benefit to the operation. Finished water pumps no. 5 and 6 alternately feed the Roanoke Island/Manteo service area. Each pump has a design capacity of 850 gpm at a total dynamic head (TDH) of 170 feet and is driven by a 50 horsepower (hp) motor.

The County indicated that the capacity of the Skyco ground storage tank is inadequate to keep pace with the distribution pumping during the summer months, requiring operators to discontinue pumping to the northern beaches. The County has plans to construct a new 3-million-gallon ground storage tank and to replace Skyco finished water pumps and associated motor controls in their capital improvements plan.

A 200,000-gallon elevated storage tank located at the Skyco WTP site also supplies water to the Roanoke Island/Manteo service area. The tank has an operating range of 26 feet and a high water level elevation of 158.7 feet. Operation of Skyco finished water pumps no. 5 and 6 is controlled by the water level in the elevated storage tank. A pump is set to turn on when the water level is below 19 feet and set to turn off when the water level reaches 24 feet.

## 3.3 Transmission and Distribution

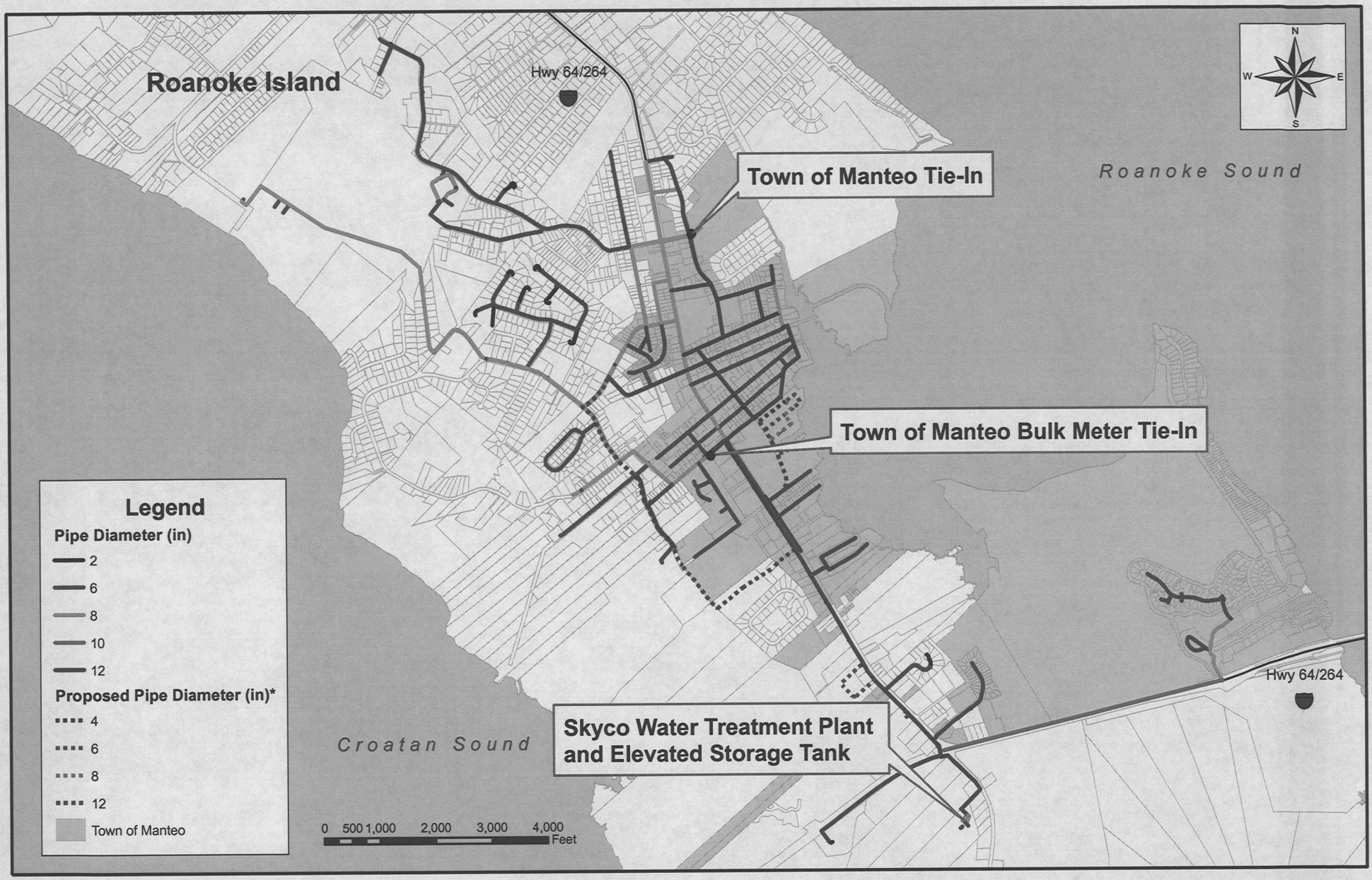
### 3.3.1 Dare County

The Dare County water distribution system on Roanoke Island consists of pipes with diameters ranging from 2 to 12 inches. The pipes are primarily constructed of polyvinyl chloride (PVC). A schematic of the existing distribution system is shown on Figure 3-3.

Skyco finished water pumps no. 5 and 6 discharge into an 8-inch diameter main which feeds into the Skyco elevated storage tank. The elevated storage tank discharges into a 12-inch diameter main. From the WTP site, the 12-inch diameter main continues north along US 64/NC 264 to the Town of Manteo's distribution system.

### 3.3.2 Town of Manteo

The Town of Manteo purchases water from Dare County through a bulk meter located east of the Fernando Street/Simon Street intersection. The Town of Manteo also has a second tie-in to the Dare County water system at Manteo High School. The location and size of existing pipes in the Manteo water distribution system were provided in a GIS file. Pipe sizes ranged from 2 to 12 inches. The GIS file also included pipes identified as "proposed" pipes by the Town of Manteo. For the purposes of this analysis, all pipes identified as proposed in the Town of Manteo GIS




*Town of Manteo Proposed Pipe assumed to be constructed prior to 2025

CDM

Figure 3-3
EXISTING WATER DISTRIBUTION SYSTEM PIPE SCHEMATIC

file were assumed to be existing pipes prior to 2025. The Manteo water distribution system is shown on Figure 3-3.

# Section 4
# Hydraulic Model Development

## 4.1 General Description

To conduct the hydraulic evaluation, a model of the existing water distribution system of Dare County on Roanoke Island and the Town of Manteo was created using WaterGEMS™, a software developed by Haestad Methods that directly interfaces with ArcGIS™. WaterGEMS™ was previously selected by Dare County for the hydraulic model of the northern beaches (Duck, Southern Shores, and Kitty Hawk) developed by CDM in 2004 due to its direct integration with the GIS database of their water system.

## 4.2 Pipe Network

The pipe network of the existing system was developed using GIS files provided by the County. It was assumed that the GIS database was constructed in a manner that accurately depicts the finished water distribution system and that the pipes are connected to one another properly. The following GIS shapefiles were used to develop the pipe network of Roanoke Island and the Town of Manteo:

- **Lines10.shp:** Contains water distribution mains of the Town of Manteo.
- **Lines11.shp:** Contains Dare County's water distribution mains on Roanoke Island.
- **Transmission main.shp**: Contains Dare County's major transmission mains connecting the treatment facilities to the storage facilities.
- **Plant_sky.shp**: Contains yard piping at the Skyco WTP
- **Manteo tie-ins.shp**: Identifies tie-ins of the Manteo water distribution system to the Dare County water distribution system.

A shapefile is a GIS file which contains information on locations as well as attributes of a given feature. The shapefiles listed above were merged into a single shapefile defining the Roanoke Island service area. Since the shapefiles did not have nodes (also referred to as junctions) to define the end point of pipes and pipe connectivity, nodes with "to" and "from" assignments were created in the pipe data file.

The shapefiles were then imported into WaterGEMS™ and the connectivity of the system was checked. The "data check" identified nodes associated with pipes in the model that were disconnected from the system. A possible cause of these disconnects is that the "snap" function which automatically connects the ends of lines (pipes) together may not have been used in these areas during the development of the GIS database.

Pipes were added to the model to connect the disconnected pipes to the system. The pipes that were added are differentiated in the model from the pipes that were in the GIS database by a letter designation after the pipe number in the pipe label, e.g., 186A. Nodes were added to connect a disconnected pipe to a perpendicular pipe in the model. A pipe that was split by the addition of a node was also designated by a letter after the pipe number.

A list of the pipes that were added to the model is included in Appendix A. In order to have a "one-to-one" correlation between the model and the GIS database, it is recommended that the GIS database be re-evaluated and updated to eliminate the disconnects in the GIS database of the water system.

The GIS database included pipe length and diameter, but did not include pipe age. Pipe material was specified for a few of the pipes. The County indicated that the majority of the pipes in the system are constructed of PVC and that most of the pipes are relatively new and in sound condition. Hence, a Hazen-Williams roughness coefficient (C value) of 120 was initially assigned to the pipes.

The GIS database did not include elevations for the end points of pipes (i.e., nodes). Node elevations included in the model were obtained from topographic data of the North Carolina Department of Transportation (NCDOT). It is recommended that elevations in the model be updated as GIS elevation data becomes available.

A schematic of the water distribution system model color-coded by pipe diameter is shown on Figure 3-1 (refer to Section 3).

## 4.3 Water Demand Allocation

### 4.3.1 Dare County

Water demand allocation was based on the quarterly water billing data provided by the County. The customer billing database included the meter account number, the recorded water use at each meter, and the meter location (site address). The meters were located on a GIS base map as discussed in Section 2. Meters were associated to the nearest node using a GIS spatial join command.

Based on a review of the billing data, it was determined that the quarterly billing data from July through September 2005 would be reasonable for use in the allocation of peak season demands.

### 4.3.2 Town of Manteo

Monthly water billing data for the Town of Manteo was provided from July 2004 through June 2005. The billing data for some accounts were incomplete, particularly for the May and June 2005 billing period. Based on a review of the billing data, it was determined that the April 2005 billing period had the most records for each account and was used for the demand allocation. A review of accounts that had monthly

billing data indicated that July 2004 had the highest monthly water usage. The monthly water usage for accounts that had both a July 2004 and April 2005 consumption record was totaled to develop a peaking factor for adjusting the April 2005 demands to reflect July peak season demands. For accounts that did not have an April 2005 record, the maximum monthly usage reported was assumed for the peak season demand.

## 4.4 Water Supply, Treatment, Pumping, and Storage Facilities

For the purposes of this evaluation, it was assumed that adequate supply of finished water is available at the Skyco WTP to meet the projected 2025 maximum day demands. The Skyco ground storage tank, which stores the finished water, was modeled as a reservoir.

The Skyco elevated storage tank was modeled based on its diameter, capacity, operating range, and high water level elevation. The model assumes a constant diameter for the Skyco elevated storage tank. The model volume is slightly higher than the design capacity since it does not take into account the lower volume in the bottom cone section of the tank which gradually decreases in diameter.

Skyco finished water pumps no. 5 and 6 were modeled using their pump curves. Pump operational control was established based on the water level of the Skyco elevated storage tank.

## 4.5 Model Validation

Based on discussions with the County, it was assumed that model validation would be based on the ability of the model to reproduce system hydraulics for a maximum day demand. The County indicated that hourly supervisory controlled and data acquisition (SCADA) data is only maintained for 65 days. Hourly SCADA data for the existing Roanoke Island/Manteo water distribution system is limited to hourly water levels of the Skyco ground storage tank and elevated storage tank. The status and flow of Skyco finished water pumps no. 5 and 6 are not monitored by SCADA.

CDM reviewed hourly SCADA Skyco ground storage tank and elevated storage tank data provided from September 28, 2005 through December 7, 2005 to determine the maximum day demands during that time period. The County indicated that the on/off status of Skyco finished water pumps no. 5 and 6 can be estimated based on the water level in the Skyco elevated storage tank. Only one pump is on at a time. A pump was determined to be "on" when the Skyco elevated storage tank water level is below 19 feet and "off" when the water level reaches 24 feet.

Since the flow of finished water pumps no. 5 and 6 is not monitored, various assumed pump flow rates were considered to estimate hourly demands. The County identified June 20 through 22 as a peak demand period for 2005. The County estimated an

average pump flow rate of 728 gpm for June 20; 1,050 gpm for June 21; and 1,156 gpm for June 22. Hence, the average daily demands from September 28, 2005 through December 7, 2005 were estimated based on assumed pump flows ranging from 730 to 1,200 gpm.

The top three maximum day demands for the SCADA time period occurred on September 29, October 7, and October 8, 2005, regardless of the assumed pump flow rate. Hourly demands were estimated for each day based on an assumed pump flow rate and the change in the Skyco elevated storage tank water levels. A considerable amount of fluctuation in peak demands seems to occur in the diurnal hydrograph for each day. The County did not have an explanation for the fluctuation. It is uncertain if the sporadic fluctuations may be attributed to short run time of the pump to fill the elevated storage tank which is not accurately represented since the demands were based on hourly data rather than data from a continuous shorter time period (e.g., minutes, seconds).

To validate the model, the hourly demands and system operation for September 29, October 7, and October 8, 2005 were simulated and the water levels of the Skyco elevated storage tank generated by the model were compared with the SCADA data. The County indicated that the pump flow rate seldom exceeds 850 to 950 gpm. Model validation considered hourly demands based on this assumed pump flow range. The estimated hourly total system demand in the model was adjusted using a global factor. The hourly water level of the Skyco ground storage tank was simulated in the model. The on/off status of Skyco finished water pumps no. 5 and 6 was determined based on the water level of the Skyco elevated storage tank. The model turned one pump "on" when the elevated storage tank water level was at or below 19 feet and turned the pump "off" when the water level reached 24 feet.

A comparison between the Skyco elevated storage tank levels in the SCADA field data and the model is presented in Figures 4-1 through 4-3. For the top three maximum day demands of the time period in which SCADA data was provided, hourly Skyco elevated storage tank levels generated by the model appear to follow a similar pattern as the SCADA data for assumed pump flow rates ranging from 850 to 900 gpm. SCADA data is not available to test the "reasonableness" of the model remote from the Skyco WTP site.

The accuracy of a computer model is highly dependent on its degree of calibration. To determine if a model is calibrated, actual field conditions based on hydrant flow tests are simulated using the model. Model calibration was not included in the scope of work of this project due to funding limitations. In the future, the County may want to consider conducting field tests and calibrating the model to enhance model accuracy.

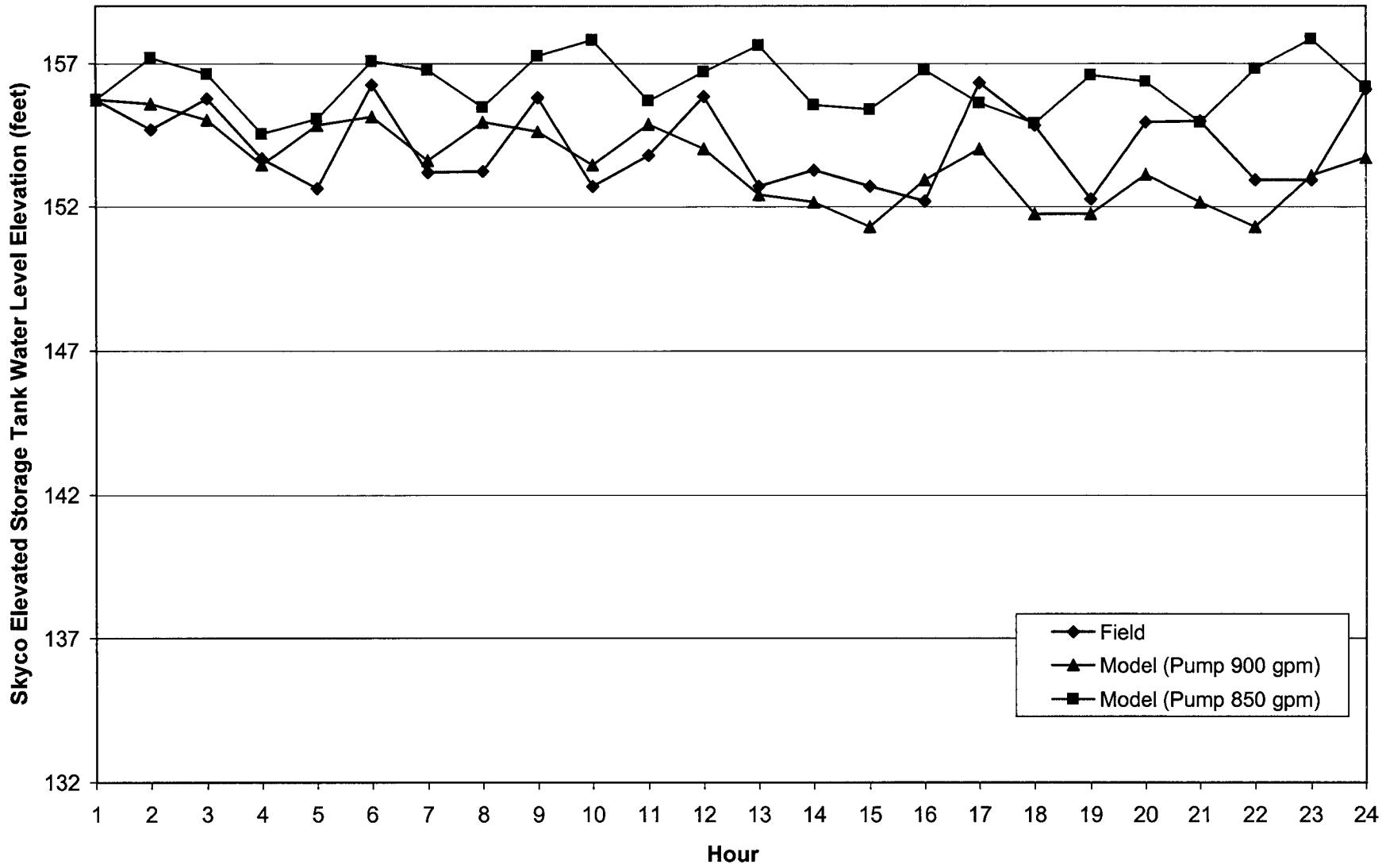



**Figure 4-1**
**MODEL VALIDATION RESULTS**
**SKYCO ELEVATED STORAGE TANK WATER LEVELS**
**SEPTEMBER 29, 2005**

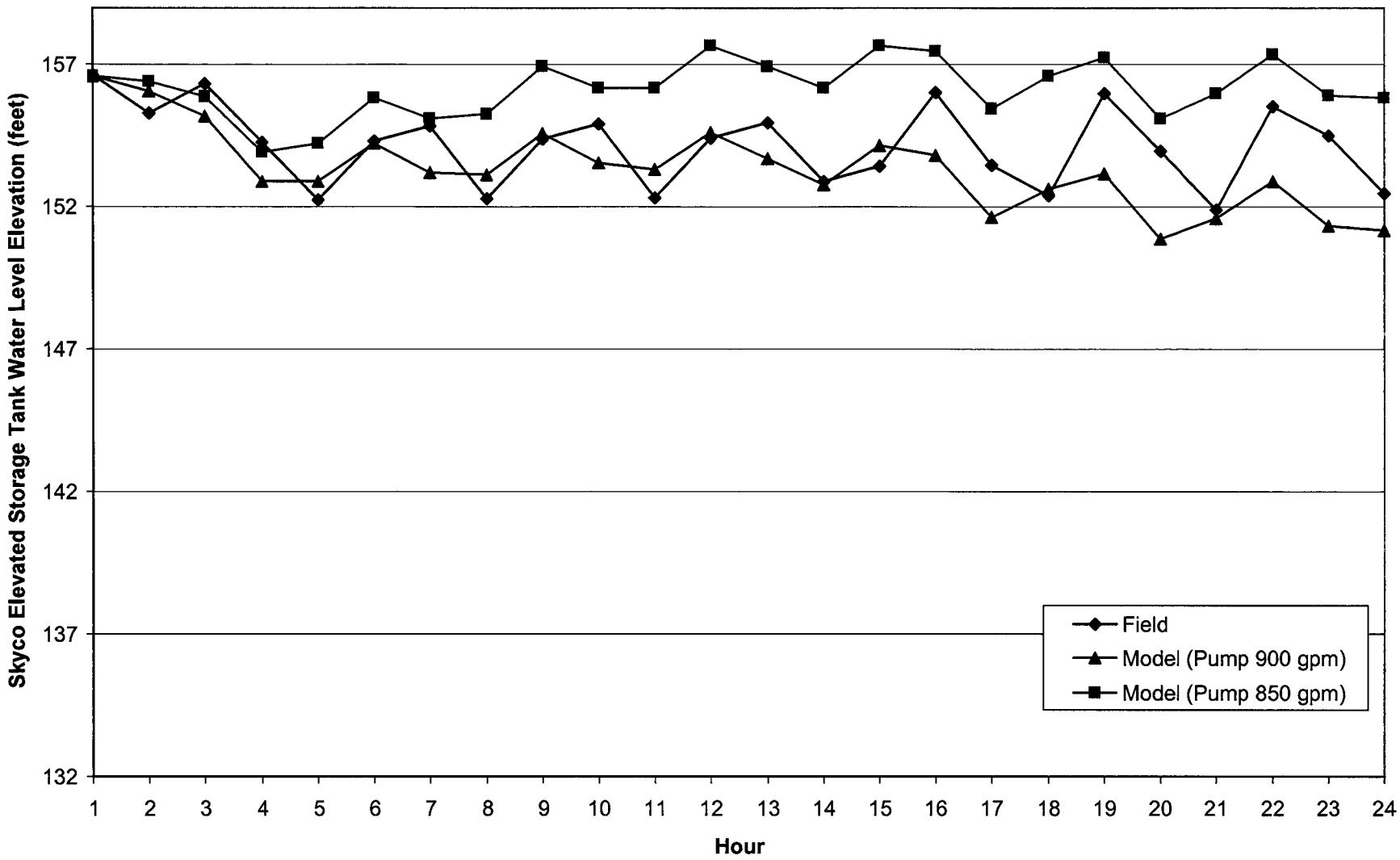



**Figure 4-2**
**MODEL VALIDATION RESULTS**
**SKYCO ELEVATED STORAGE TANK WATER LEVELS**
**OCTOBER 7, 2005**

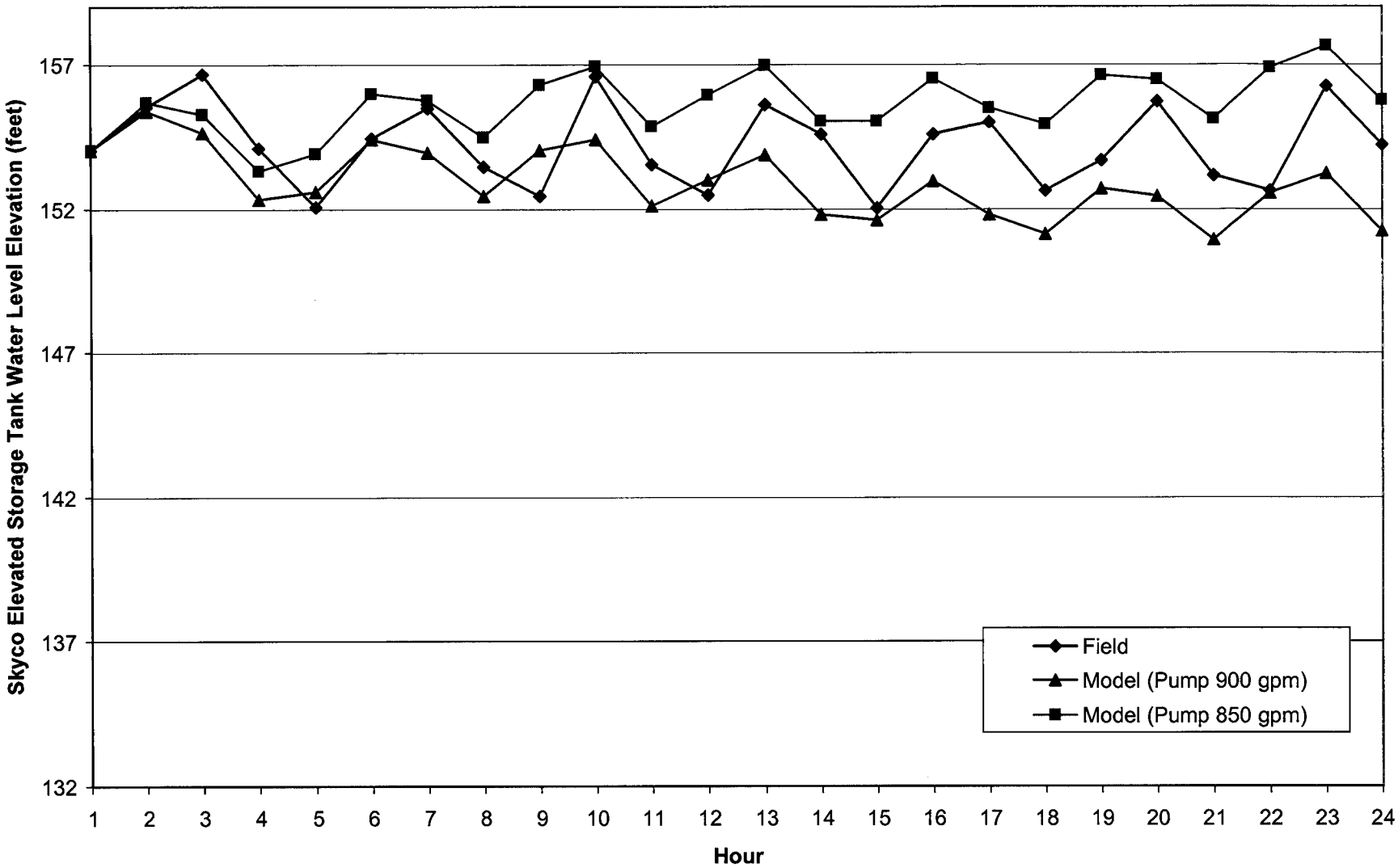



**Figure 4-3**
**MODEL VALIDATION RESULTS**
**SKYCO ELEVATED STORAGE TANK WATER LEVELS**
**OCTOBER 8, 2005**

# Section 5
# Evaluation Approach and Criteria

## 5.1 Evaluation Approach

To evaluate the ability of the existing water system to meet the projected 2025 water demands, the Roanoke Island WaterGEMS™ model discussed in Section 4 was extended to potential service areas in northern Roanoke Island and Wanchese. It was assumed that the water main extensions required would be located along major roads within existing rights-of-way. Water mains were added to the model using GIS road centerline data provided by the County. Nodes were provided at road intersections and at the end of the pipes. Each parcel was assigned to the closest model node. Water demands were distributed in the model based on the developable acreage of each parcel.

Hypothetical conditions were simulated on the computer model and their effects on the system observed. Hypothetical conditions included maximum day, maximum day plus fire flow, and peak hour demand conditions. Computer simulations were also conducted to determine if the existing system is capable of filling existing and proposed storage facilities during minimum nighttime demand conditions on the maximum day.

For the purposes of this evaluation, it was assumed that adequate water supply would be available at the Skyco WTP to meet the projected demands of the Roanoke Island, Manteo, and Wanchese service areas. Water supply availability at the Skyco WTP is discussed in the *Dare Countywide Hydrogeological Study and Groundwater Resource Evaluation Update Final Report.*

## 5.2 Evaluation Criteria

### 5.2.1 System Pressures

The adequacy of a water system is evaluated based on its ability to provide the volume of water required to satisfy the demands of the customers at adequate system pressures. The American Water Works Association (AWWA) indicates that most municipal water systems operate with system pressures in the 30 to 90 pounds per square inch (psi) range, with desirable pressures in the 40 to 50 psi range during average day demand conditions. High pressures in excess of 100 psi are generally avoided due to the potential for higher water losses and water main breaks. In addition, the North Carolina Plumbing Code requires the installation of pressure reducing valves at service connections where pressures exceed 80 psi.

Water systems are designed to satisfy maximum day demand conditions from the WTP. Under maximum day demand conditions, system pressures greater than 30 psi are desirable and storage facilities should remain full, i.e., not draining or filling. Storage facilities are intended to provide equalization, fire protection, and

emergency storage. Hence, under maximum day demand conditions, the adequacy of the transmission, distribution, and pumping systems are of significant importance.

Under peak hour and maximum day plus fire flow demand conditions, the adequacy of storage facilities is evaluated in addition to the transmission, distribution, and pumping systems. System pressures greater than 30 psi are required by NCDENR for peak hour demand conditions. Under maximum day plus fire flow demand conditions, a minimum system pressure of 20 psi is required. The residual pressure is necessary to overcome frictional losses through the hydrant and hoses, and maintain positive pressure on the suction side of the fire department pumper truck. NCDENR further indicates that the elevation of a storage facility must be sufficient to provide a designed minimum distribution system pressure of 20 psi during fire flow conditions and 30 psi during peak flow conditions (NCAC T15A:18c.0405b).

Dare County prefers to maintain system pressures in the 60 psi range to provide allowance for delivery to multi-story structures, particularly hotels and apartment buildings. Houses in waterfront areas also tend to have multiple stories to avoid potential flooding impacts to living spaces at ground level. The evaluation was based on the ability of the water system to provide the County's desirable minimum system pressure of 60 psi during maximum day demand conditions with the storage tanks in a full condition. System pressures in the 40 to 60 psi range were considered for peak hour demand conditions when storage tank water levels fluctuate. Under maximum day demand plus fire flow demand conditions , a minimum system pressure of 20 psi must be maintained throughout the system to provide adequate fire flow.

### 5.2.2 Velocity and Headloss

For transmission mains, AWWA recommends a maximum design velocity of 10 feet per second (fps), with velocities less than 5 fps as the desirable range. AWWA recommends limiting headloss in transmission mains to 10 feet/1,000 feet with headlosses limited to 3 feet/1,000 feet for pipe sizes greater than 16 inches in diameter. Cesario (1995) recommends limiting headloss to 2 to 5 feet/1,000 feet for pipe sizes less than 24 inches in diameter and 1 to 2 feet/1,000 feet for pipe sizes greater than 24 inches in diameter. These criteria were considered in the evaluation based on the role of the transmission main (e.g., major transmission mains from the WTP versus transmission mains for flow distribution) and its effectiveness in improving the hydraulics of the system. For this evaluation, velocity was limited to 10 fps, with velocities less than 5 fps as the desirable range. Headloss was generally limited to 5 feet/1,000 feet.

## 5.3 Fire Flow Requirements

The fire flow requirements used for the hydraulic evaluations were based on the Insurance Services Office (ISO) fire flow requirements. ISO is a rating service that is utilized by insurance companies for establishing fire flow requirements for communities. ISO determines required fire flows on the basis of a field survey and

evaluation of data relative to the floor area of the structures, availability of sprinkler systems, type of construction, as well as other factors. Flows required for fire protection are based on maintaining a residual pressure of 20 psi. As discussed in the previous section, this residual pressure is necessary to overcome frictional losses through the hydrant and hoses, and maintain positive pressure on the suction side of the fire department pumper truck.

For residential areas, ISO estimates the following fire flow requirements for one- and two-family dwellings not exceeding two stories in height:

| Distance Between Buildings (feet) | Needed Fire Flow (gpm) |
|---|---|
| Over 100 | 500 |
| 31-100 | 750 |
| 11-30 | 1,000 |
| Less than 11 | 1,500 |

The County indicated that ISO's fire flow requirement of 750 gpm for residential buildings spaced 31 to 100 feet apart is representative of the majority of the type of development in the service area. This evaluation was based on providing a minimum fire flow of 750 gpm throughout the area, with the exception of cul-de-sacs/dead end roads. A minimum fire flow requirement of 500 gpm was considered for the cul-de-sac/dead end roads, particularly if the road was less than 500 feet long and 750 gpm was available at a hydrant on the upstream road intersection based on model results.

Fire flow requirements for commercial/industrial areas are generally higher than residential areas. It is recommended that the County evaluate specific fire flow requirements for commercial/industrial developments as well as public facilities such as schools, hospitals, nursing homes, etc. The County indicated that the Wanchese Seafood Industrial Park is equipped with a 250,000-gallon elevated storage tank for its own fire protection.

## 5.4 Storage Requirements

### 5.4.1 Storage Components

Storage in a water distribution system has three functions:

- Equalization Storage
- Fire Protection Storage
- Emergency Storage

A discussion of each function follows.

### Equalization Storage

Equalization storage is needed to meet hourly fluctuations in demand that occur on a daily basis. The equalization storage needed to supply demand variations is determined from a diurnal water demand hydrograph. The diurnal water demand hydrograph is a graphical representation of hourly water demand variations over a 24-hour period.

The diurnal hydrographs generated based on the Skyco WTP ground storage and elevated storage tank SCADA water levels and assumed pump flows discussed in Section 3 appeared to have frequent fluctuations in peak demands that do not appear realistic for a predominantly residential area. The accuracy of the diurnal hydrographs is questionable since the actual flow and status of Skyco finished water pumps no. 5 and 6 were not monitored by SCADA. For the purposes of this evaluation, the diurnal hydrograph developed as part of the northern Dare County water system evaluation (Duck, Southern Shores, Kitty Hawk) was used for this evaluation. The model diurnal hydrogaph was based on the average of the hydrographs for July 4, 2004 through July 7, 2004. A copy of the diurnal hydrograph is included in Appendix B. The diurnal hydrograph was input into the hydraulic model to analyze the ability of the system to meet peak hour demands as well as the system's ability to refill the storage tanks during the low demand periods.

### Fire Protection Storage

Fire protection storage must be sufficient to supply, at a minimum, the fire flow requirement for the service area for the expected duration of the fire. To supply 750 gpm (ISO's fire flow requirement for one- to two-family dwellings not exceeding two stories in height spaced 30 to 100 feet apart) for a duration of 2 hours, an estimated fire protection storage of 90,000 gallons is required. The fire protection storage must be delivered to the system at a minimum residual pressure of 20 psi to be considered adequate. From a system-wide perspective, it is assumed that only one fire is occurring in the system at a single time.

### Emergency Storage

Emergency storage is storage reserved for emergency situations such as power outages or water main breaks. An emergency storage capacity equal to one average day demand is desirable. However, some utilities consider emergency storage equal to one average day demand unrealistic for financial reasons. The County does not have specific emergency storage requirements for the system.

## 5.4.2 NCDENR Requirements

As required by NCDENR (NCAC T15A:18C.0805), "elevated storage for a municipality shall be sufficient to minimize the effect of fluctuating demand plus provide a reserve for fire protection, but not be less than 75,000 gallons in capacity. The combined elevated and ground storage of the finished water for community and non-transient, non-community water systems shall be a minimum of one-half day's

supply of the average annual daily demand." NCDENR further states in NCAC T15A:18c.0405b that the elevation of the storage facility must be sufficient to provide a designed minimum distribution system pressure of 20 psi during fire flow conditions and 30 psi during peak flow conditions.

### 5.4.3 Storage Evaluation Approach

The adequacy of storage facilities to meet the needs of a water system is dependent on several factors:

- volume
- geographic location with respect to demand distribution
- hydraulic effectiveness

The storage volume required is based on the volume required for equalization, fire protection, and emergency storage. The storage volume must be located in an appropriate location with respect to the demand distribution. The effectiveness and reliability of storage facilities are also highly affected by the hydraulics of the system. A storage facility with the required volume and at an appropriate location in relation to the demand distribution may not be hydraulically effective because its overflow elevation is below the hydraulic grade line elevation of the service area. Storage requirements were evaluated based on these factors and are discussed in Section 6.

# Section 6
# Evaluation Results

## 6.1 Water Supply and Pumping Capacity

The projected 2025 maximum day demand of the Roanoke Island/Manteo/Wanchese service area of 2.8 mgd constitutes approximately 65 percent of the Skyco WTP capacity of 4.3 mgd. Hence, with the expansion of the Roanoke Island/Manteo service area to northern Roanoke Island and Wanchese, the available supply at the Skyco WTP for the Dare County northern beaches would be limited to 1.5 mgd in 2025 without a plant expansion. As discussed in Section 3.1, implementation of water supply alternatives identified in the *Dare Countywide Hydrogeological Study and Groundwater Resource Evaluation Update Final Report,* including expansion of the NRO WTP and application of ASR technology, is recommended to meet the projected demands of the Dare County northern beaches.

The capacity of Skyco finished water pumps no. 5 and 6 is inadequate to meet the projected 2025 maximum day demand of the Roanoke Island/Manteo/Wanchese service area. Additional pumping capacity is required. The capacity of the 8-inch diameter pump suction and discharge lines is also inadequate for the projected demands. The pumps discharge into an 8-inch diameter main that feeds directly into the Skyco elevated storage tank. Velocities exceeding 10 fps were observed during the maximum day demand model simulations.

A schematic of the Skyco WTP yard piping is shown on Figure 6-1. Parallel installation of 16-inch diameter suction piping is recommended from the existing ground storage tank to the pumps. It is recommended that the pump piping manifold be re-evaluated based on the intended operation of the pumps in serving the needs of the northern beaches and the Roanoke Island/Manteo/Wanchese area.

Parallel installation of a 16-inch diameter main or dual 12-inch diameter mains is also recommended from the pump discharge to the Skyco elevated storage tank. With a 16-inch diameter main, the plant would only have the 8-inch diameter main as a discharge if the 16-inch diameter main is out-of-service for maintenance or repairs. The use of dual 12-inch diameter mains increases system reliability in the event that one 12-inch diameter main is out-of-service.

## 6.2 Roanoke Island/Manteo Service Area

### 6.2.1 Transmission

The capacity of the 12-inch diameter main from the Skyco elevated storage tank to Manteo is inadequate to meet the projected demands. Parallel installation of a 16-inch diameter main on US 64/NC 264 from the Skyco elevated storage tank northward to Viccars Lane is recommended. At Viccars Lane, the 16-inch diameter main feeds into two 12-inch diameter mains of the Town of Manteo. Installation of a 12-inch diameter

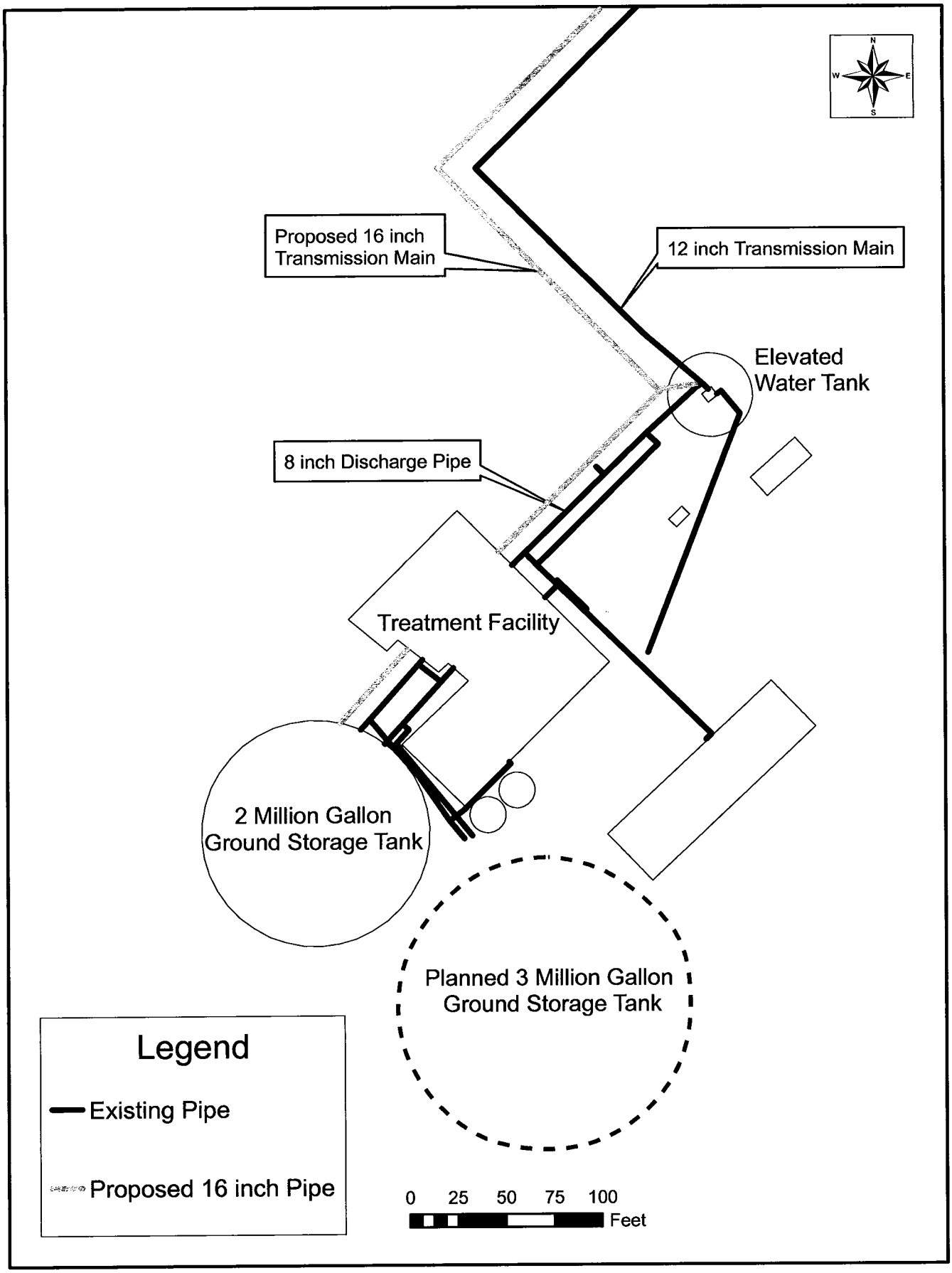



Figure 6-1
SCHEMATIC OF SKYCO WTP YARD PIPING

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main on US 64/NC 264 from the 12-inch diameter main on Ananias Dare Street and the 12-inch diameter main on Devon Street, north to Swain Drive, and on Swain Drive to Wingina Avenue is recommended. The location of the proposed transmission improvements is shown on Figure 6-2. Other transmission improvements recommended for the Roanoke Island/Manteo service area are dependent on the proposed storage tank site location. A discussion of proposed storage tank site alternatives follows.

## 6.2.2 Storage

The capacity of the 200,000-gallon Skyco elevated storage tank is inadequate for the projected peak hour demands and fire protection. Additional storage is required in the northern Roanoke Island area. Two potential storage tank sites were considered based on input from the County:

- Site A - Former Highway Rest Area
- Site B - Manteo High School

The potential storage tank sites are shown on Figure 6-3.

It should be noted that both sites are hypothetical and that the County would need to secure property prior to design. Both sites are located in close proximity to the Dare County Regional Airport. The Federal Aviation Administration (FAA) requires approval for construction of facilities located within 5 miles of an airport or extending 200 feet or greater above ground. Any structure which exceeds a height from a nearest airport runway at a slope of 100-foot horizontal for each 1-foot vertical to a distance of 20,000 feet requires approval from FAA. Hence, construction of an elevated storage tank on either site requires approval from FAA. FAA permitting is not included in the scope of work of this project. The County indicated that one of the runways at the airport has been abandoned and that the sites may not be in the flight path. A discussion of each storage tank site follows.

### 6.2.2.1 Site A - North Roanoke Island (Former Highway Rest Area)

Site A is located on the northwestern extremity of the service area. To provide additional storage with continued operation of the Skyco elevated storage tank, implementation of a 300,000-gallon elevated storage tank is recommended. Installation of a 16-inch diameter main on US 64/NC 264 from the Wingina Avenue/Swain Drive intersection to the tank site is recommended to provide transmission to and from the Site A elevated storage tank. To maximize use of the Skyco elevated storage tank, the same overflow elevation of 158.7 feet was assumed for the proposed tank.

The range in ground elevations of the Roanoke Island/Manteo/Wanchese service area is shown on Figure 6-4. Ground elevations generally range from 2 to 22 feet. Higher ground elevations were observed in the area between Morrison Grove Road

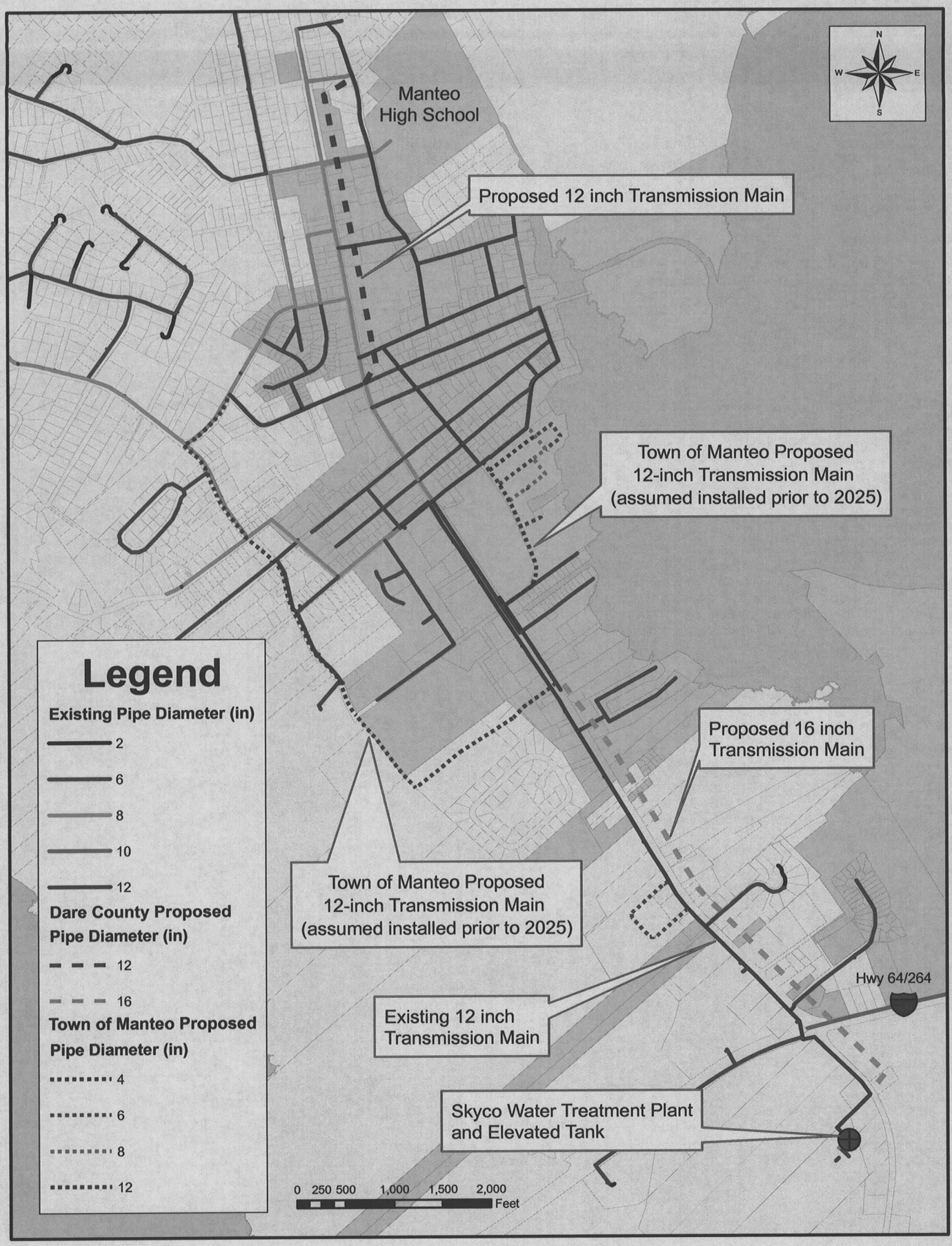


Figure 6-2
ROANOKE ISLAND/MANTEO
TRANSMISSION MAIN

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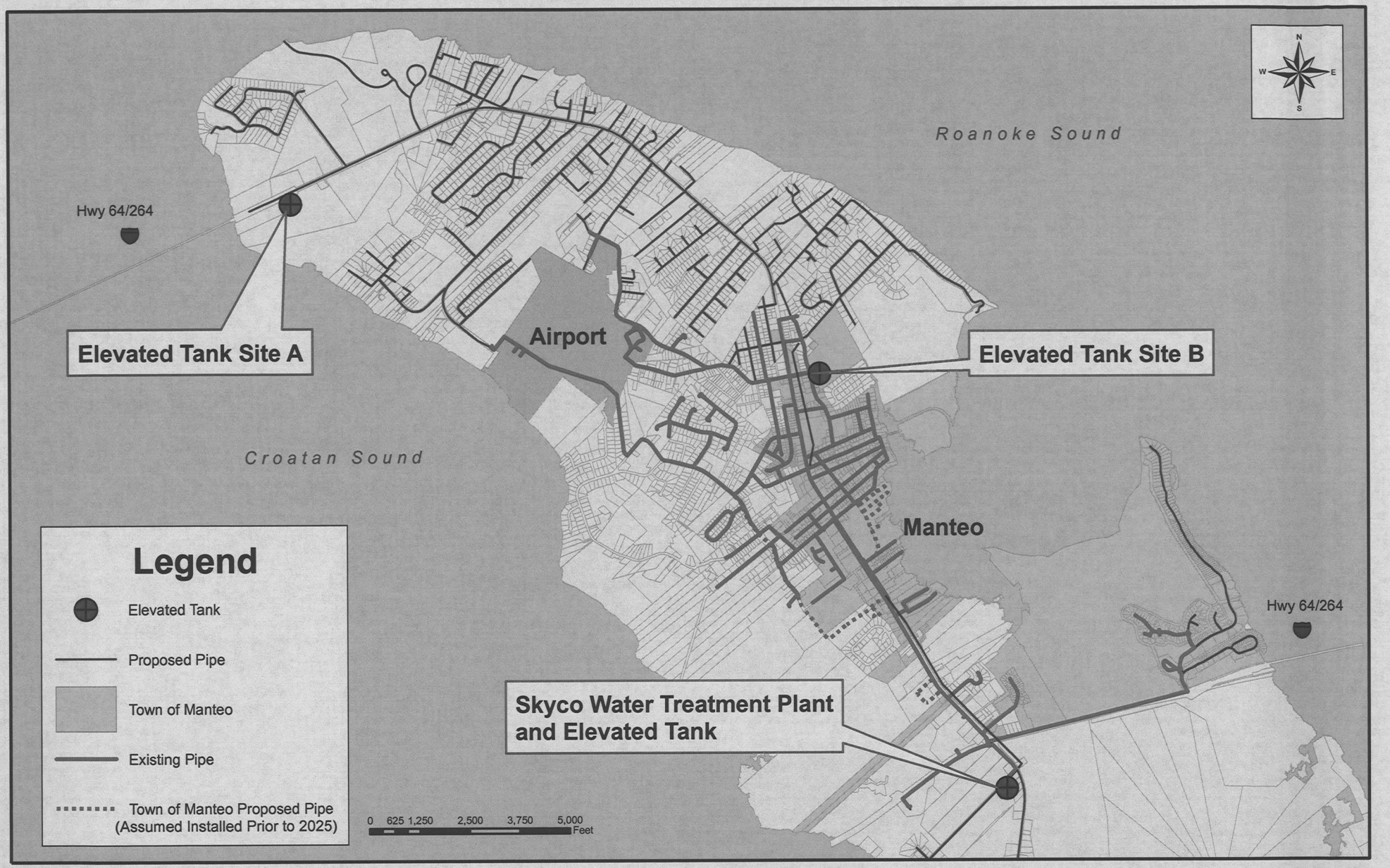


Figure 6-3
ROANOKE ISLAND/MANTEO
POTENTIAL ELEVATED STORAGE TANK SITES

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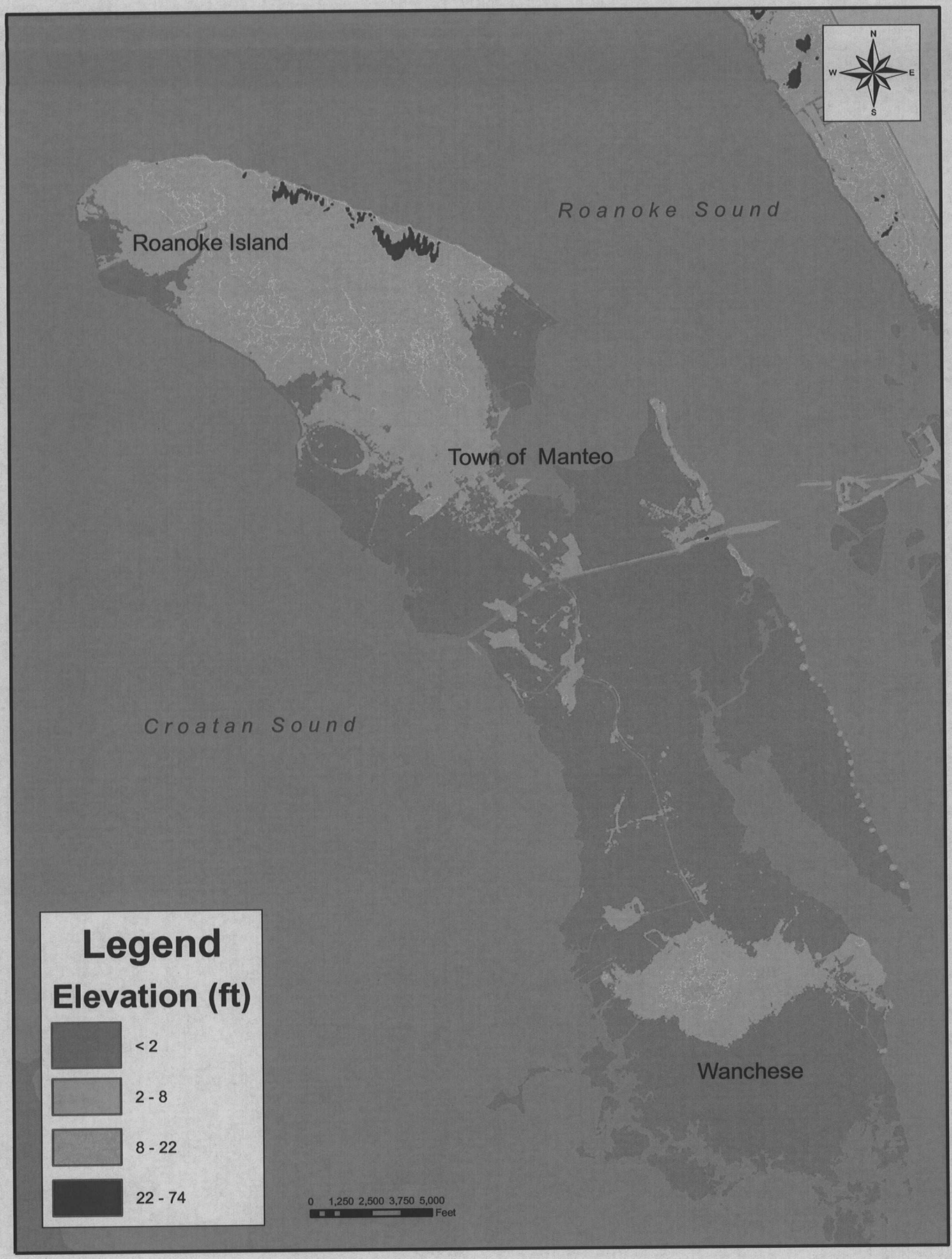


Figure 6-4
ROANOKE ISLAND/MANTEO/WANCHESE
GROUND ELEVATIONS

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and Holly Hills Lane, north of US 64/NC 264. Ground elevations in Wanchese are generally lower than the majority of the Roanoke Island/Manteo area. The Skyco elevated storage tank high water level elevation of 158.7 feet provides the County's minimum desirable pressure of 60 psi to ground elevations less than or equal to 20 feet.

System pressures generated by the model for the projected 2025 maximum day demand, with the proposed storage tank full, are shown on Figure 6-5. The County's minimum desirable system pressure of 60 psi was observed throughout most of the service area. System pressures at the higher ground elevations between Morrison Grove Road and Holly Hills Lane ranged from 50 to 60 psi, with the exception of the end of Holly Hill Lane where pressures ranged from 40 to 50 psi.

Hourly variations in the projected 2025 maximum day demand were simulated on the model. Model simulation results of the elevated storage tank hourly water levels are shown on Figure 6-6. The Skyco elevated storage tank water level generally fluctuated 5 to 6 feet while the proposed storage tank at Site A fluctuated 11 to 12 feet. The Site A storage tank is more hydraulically effective in supplementing the peak hour demands than the Skyco elevated storage tank. Peak hour demands depleted approximately 20 percent of the Skyco elevated storage tank volume, with approximately 80 percent (160,000 gallons) remaining as available fire protection and emergency storage. Peak hour demands depleted approximately 45 percent of the proposed Site A storage tank volume, with approximately 55 percent (165,000 gallons) remaining as available fire protection and emergency storage. A north-south hydraulic grade line profile reflecting the impact of the maximum day and a peak hour demand on the Skyco and the proposed storage tank at Site A is shown on Figure 6-7.

Since the effectiveness of the Skyco elevated storage tank decreases with the remote elevated storage tank at Site A, removing the Skyco elevated storage tank from service may be considered as an alternative. Without the Skyco elevated storage tank, an increase in the proposed elevated storage tank capacity from 300,000 to 500,000 gallons is required to meet the projected demands. Model simulation results of the proposed 500,000-gallon elevated storage tank water levels, without the Skyco elevated storage tank, are shown on Figure 6-8. The location of the tank at Site A, however, is not as reliable as the Skyco elevated storage tank, due to its remoteness from Wanchese.

#### 6.2.2.2 Site B – Manteo High School

Site B is located adjacent to Manteo High School. To provide additional storage with continued operation of the Skyco elevated storage tank, implementation of a 300,000-gallon elevated storage tank is recommended. Transmission is provided through the proposed 12-inch diameter main on Wingina Avenue. With the storage tank at Site B, the 16-inch diameter main proposed for the storage tank on US 64/NC 264

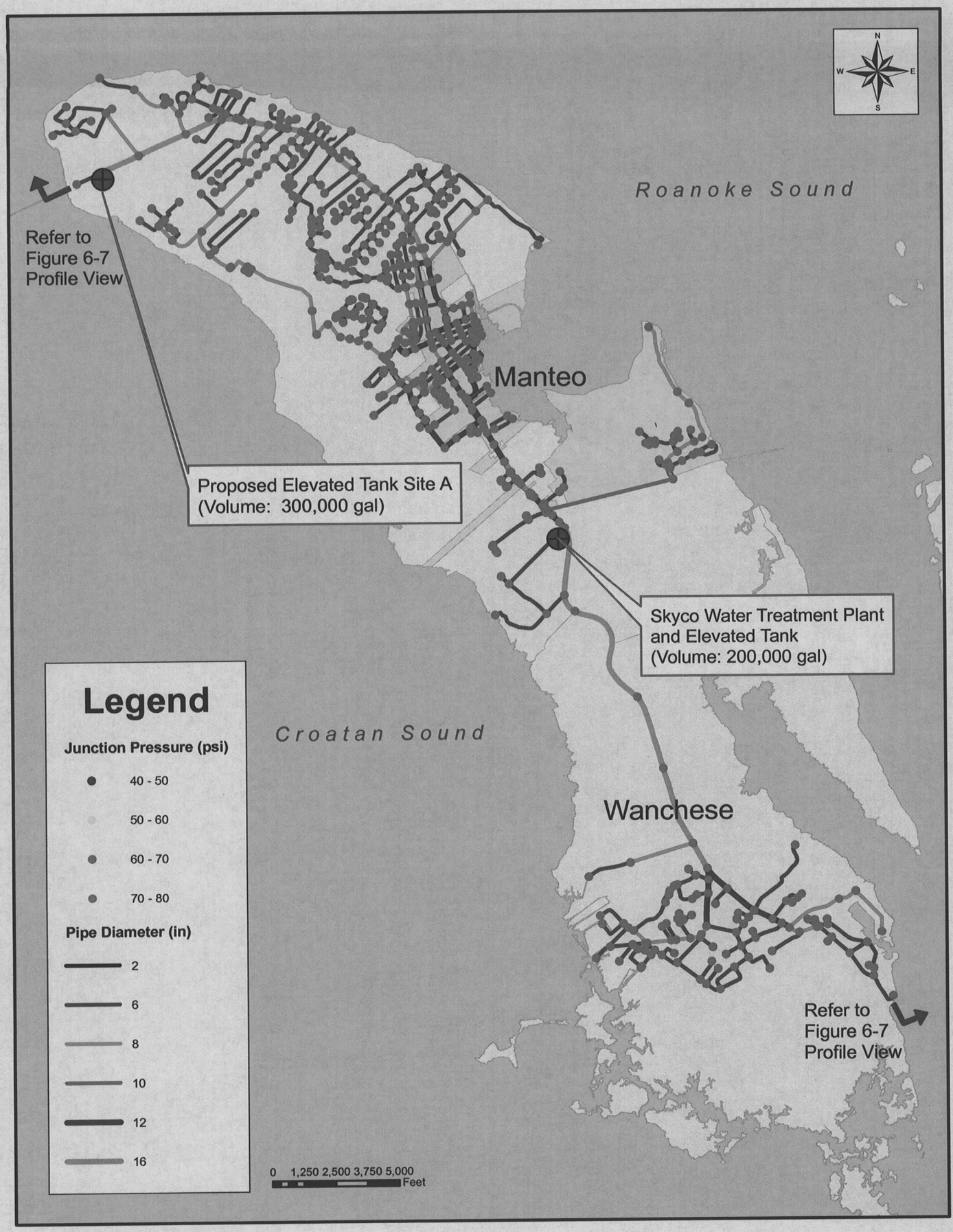


Figure 6-5
2025 MAXIMUM DAY DEMAND - TANK SITE A
MODEL SIMULATION SYSTEM PRESSURES

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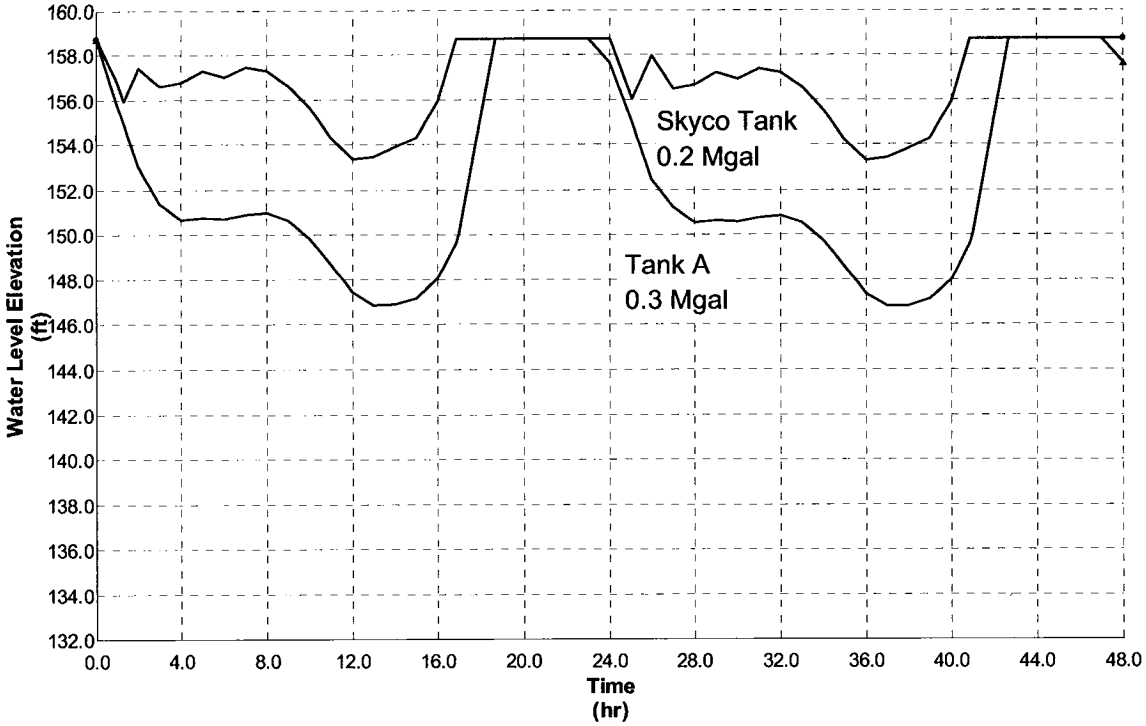
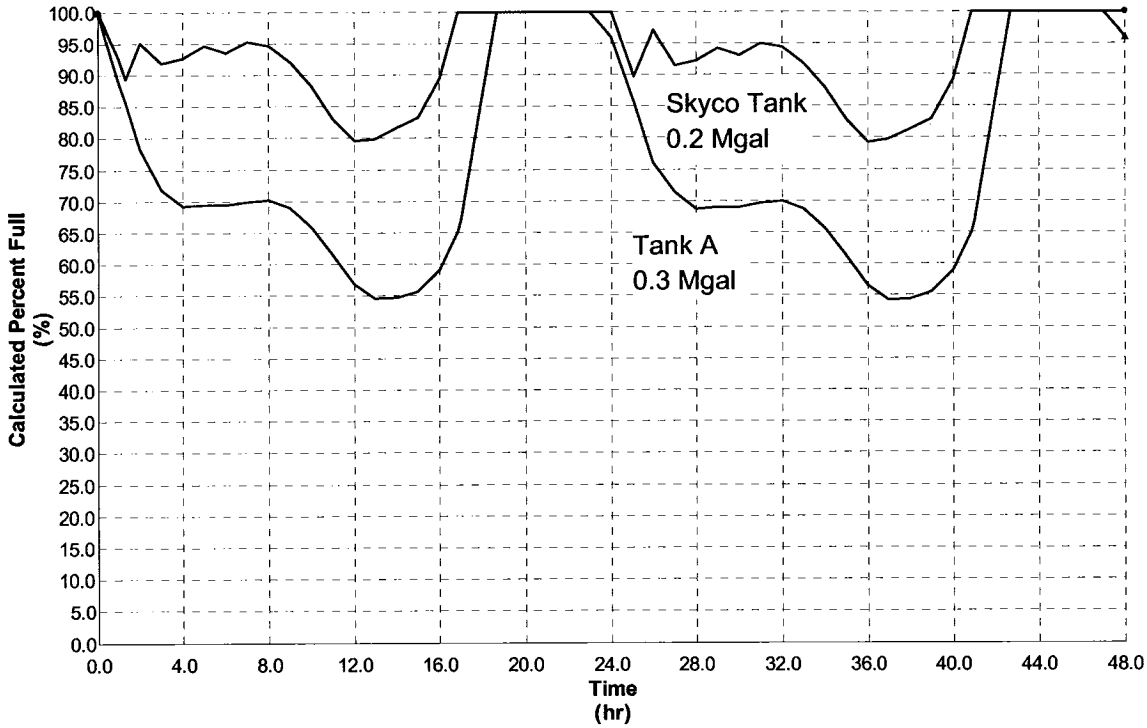



Elevated Storage Tank Water Level Elevation vs Time




Elevated Storage Tank Water Calculated Percent Full vs Time

Figure 6-6
2025 MAXIMUM DAY DEMAND - TANK SITE A WITH SKYCO TANK
MODEL SIMULATION ELEVATED STORAGE TANK GRAPHS

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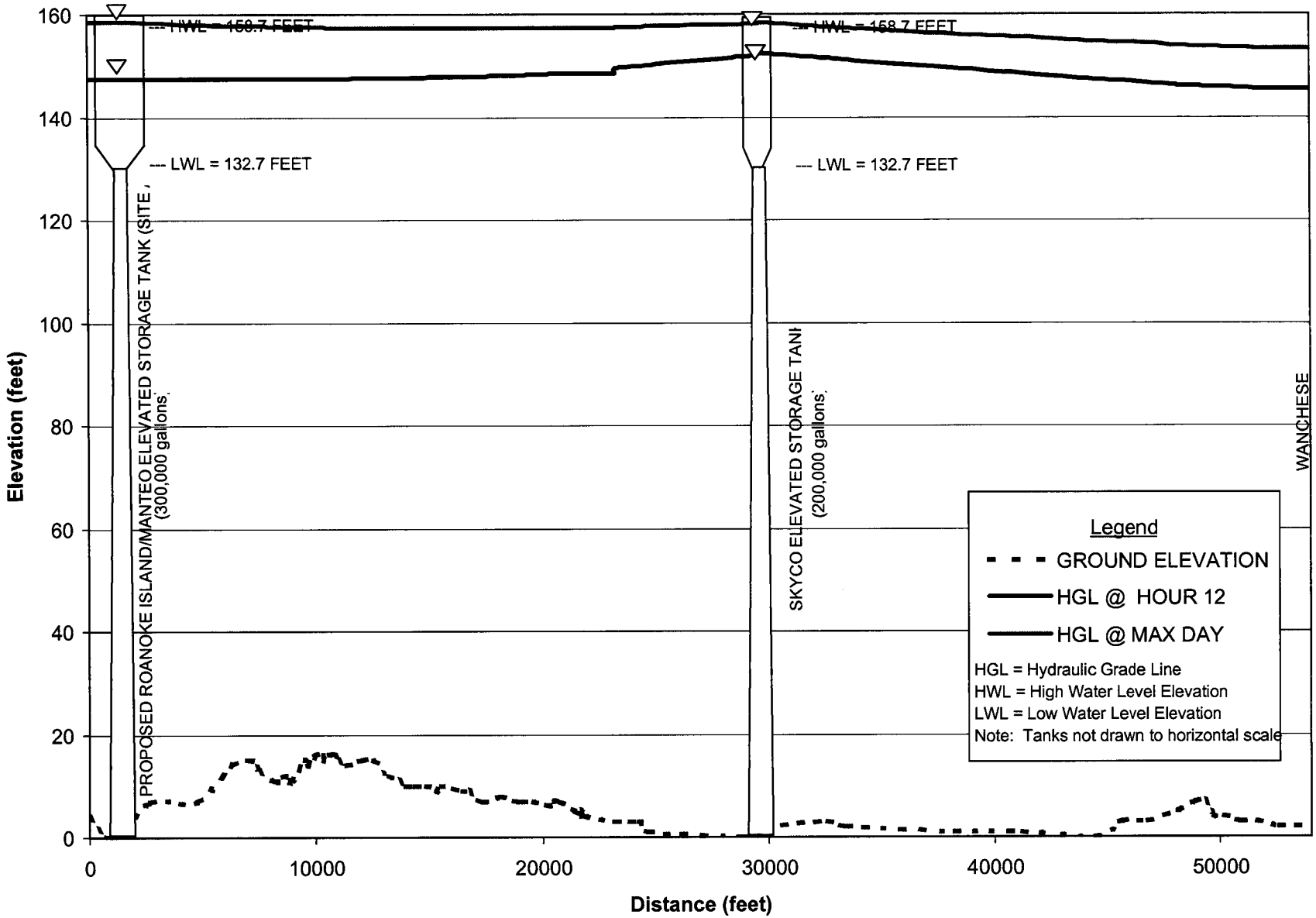


**Figure 6-7**
**ROANOKE ISLAND/MANTEO/WANCHESE - TANK SITE A**
**NORTH-SOUTH HYDRAULIC GRADE LINE PROFILE**

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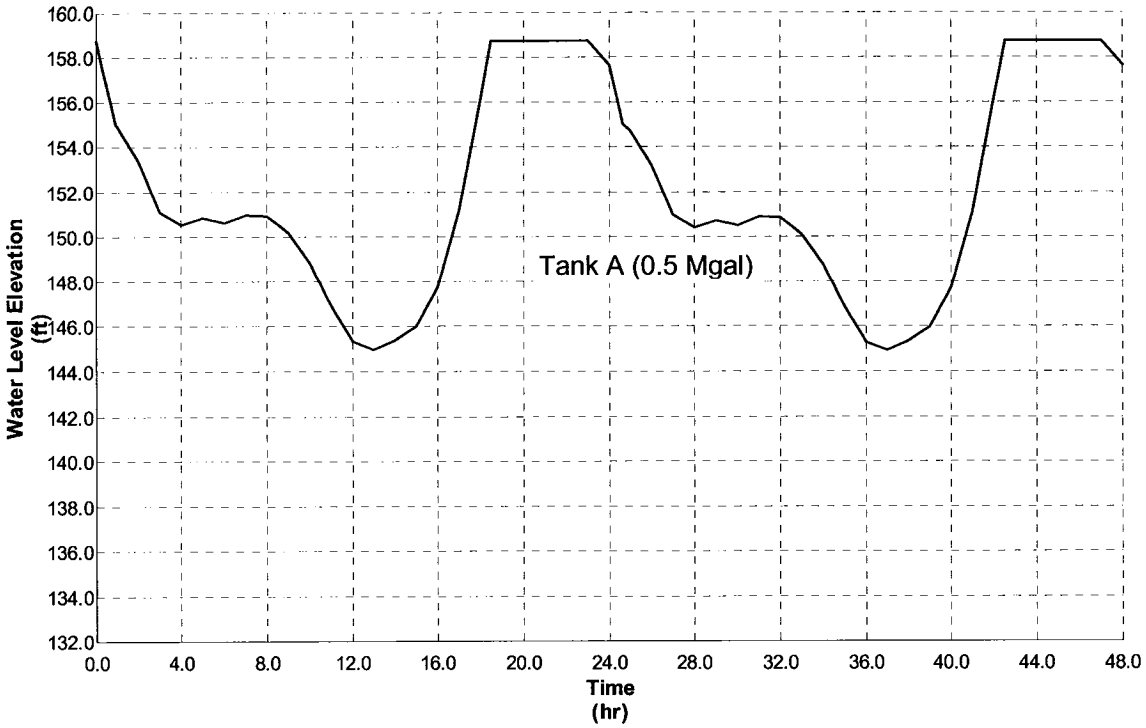
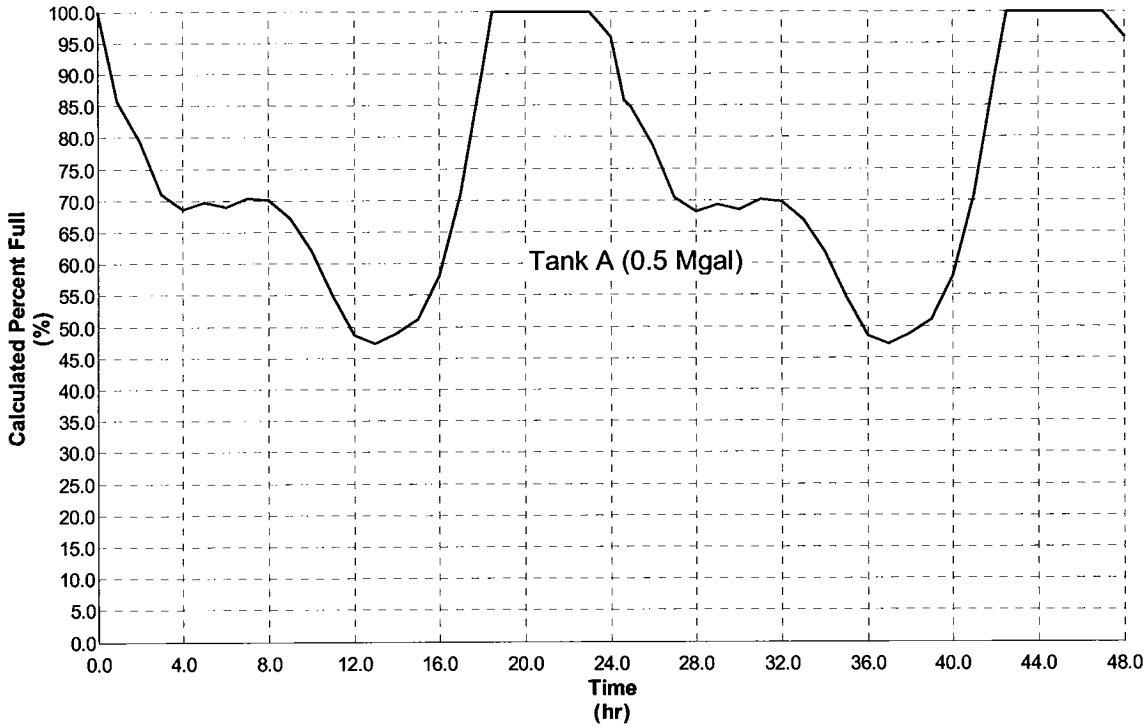



Elevated Storage Tank Water Level Elevation vs Time




Elevated Storage Tank Water Calculated Percent Full vs Time

Figure 6-8
2025 MAXIMUM DAY DEMAND - TANK SITE A WITHOUT SKYCO TANK
MODEL SIMULATION ELEVATED STORAGE TANK GRAPHS

CDM

from the Wingina Avenue/Swain Drive intersection to the tank site is reduced to 12-inch diameter.

System pressures generated by the model for the projected 2025 maximum day demand with the Site B proposed storage tank full are shown on Figure 6-9. The system pressures with the tank at Site B are similar to the system pressures shown on Figure 6-5 for the tank at Site A.

Model simulation results of the Site B elevated storage tank hourly water levels are shown on Figure 6-10. The Skyco elevated storage tank level generally fluctuated approximately 5 feet while the proposed storage tank at Site B fluctuated approximately 10 to 11 feet. The Site B storage tank is more hydraulically effective in supplementing the peak hour demands than the Skyco elevated storage tank. Peak hour demands depleted approximately 20 percent of the Skyco elevated storage tank volume, with approximately 80 percent (160,000 gallons) remaining as available fire protection and emergency storage. Peak hour demands depleted approximately 43 percent of the proposed Site B storage tank volume, with approximately 57 percent (171,000 gallons) remaining as available fire protection and emergency storage. A north-south hydraulic grade line profile reflecting the impact of the maximum day and a peak hourly demand on the Skyco and the proposed storage tank at Site B is shown on Figure 6-11.

Since the effectiveness of the Skyco elevated storage tank decreases with the remote elevated storage tank at Site B, removing the Skyco elevated storage tank from service may be considered as an alternative. Without the Skyco elevated storage tank, an increase in the proposed elevated storage tank capacity from 300,000 to 500,000 gallons is required to meet the projected demands. Model simulation results of the proposed 500,000-gallon elevated storage tank water levels, without the Skyco elevated storage tank, are shown on Figure 6-12.

#### 6.2.2.3 Summary

The County indicated that the Skyco elevated storage tank is in good condition and that they would like to continue its operation. Implementation of a 300,000-gallon elevated storage tank with associated transmission improvements is recommended to provide additional storage. It is recommended that the Skyco WTP finished water pumps serving the Roanoke Island/Manteo/Wanchese area be controlled by the water elevation of the proposed remote elevated storage tank. It is also recommended that an altitude valve be installed at the Skyco elevated storage tank to prevent overflow since it will fill quicker than the remote tank.

To meet NCDENR's minimum storage volume requirement of one-half the average day demand, a total finished water storage volume of approximately 0.6 million gallons is required for the projected 2025 average day demand of 1.1 mgd. The Skyco ground storage tank provides finished water to both the Roanoke Island/Manteo/Wanchese service area and the Dare County northern beaches.

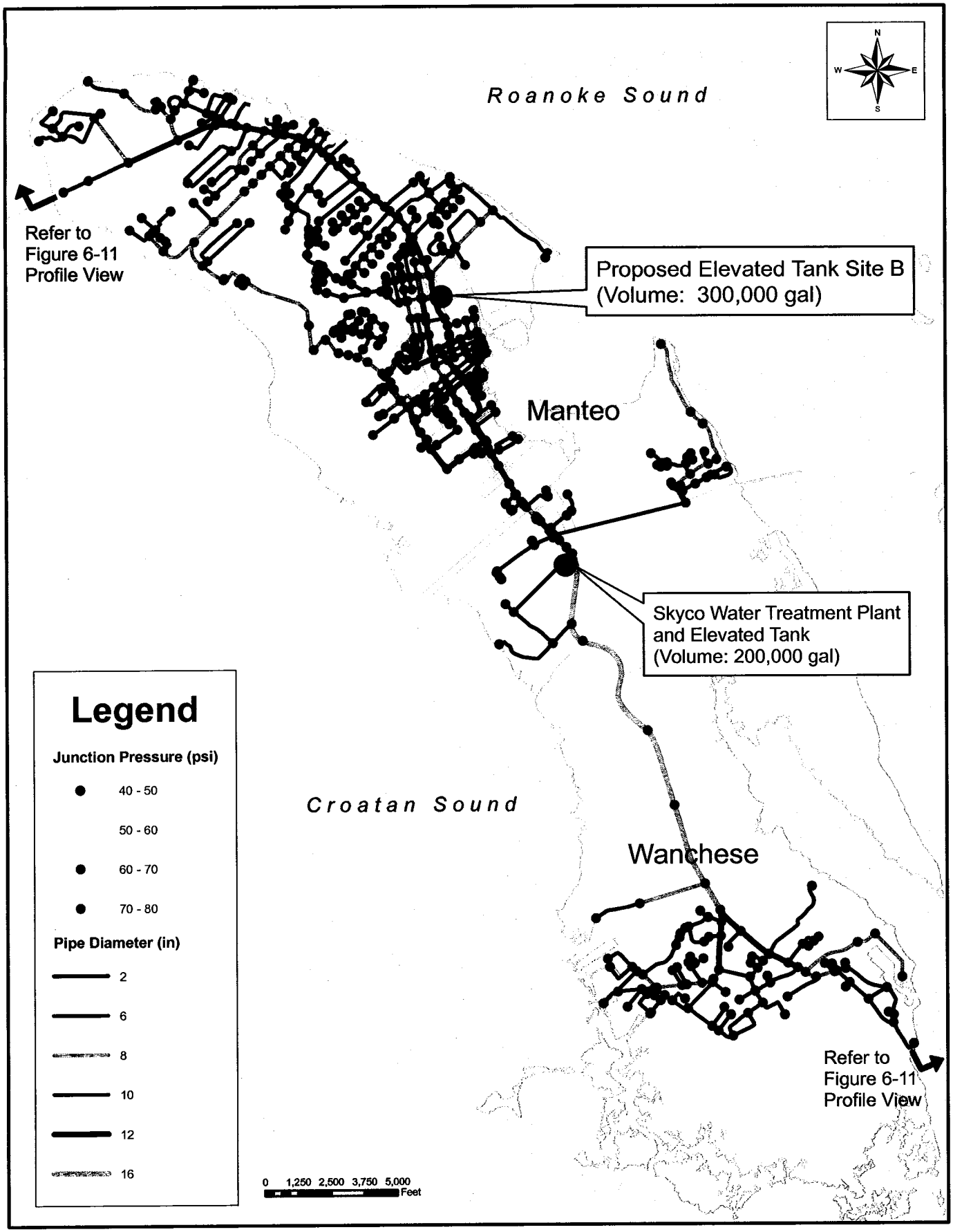



Figure 6-9
2025 MAXIMUM DAY DEMAND
TANK SITE B MODEL SIMULATION SYSTEM PRESSURES

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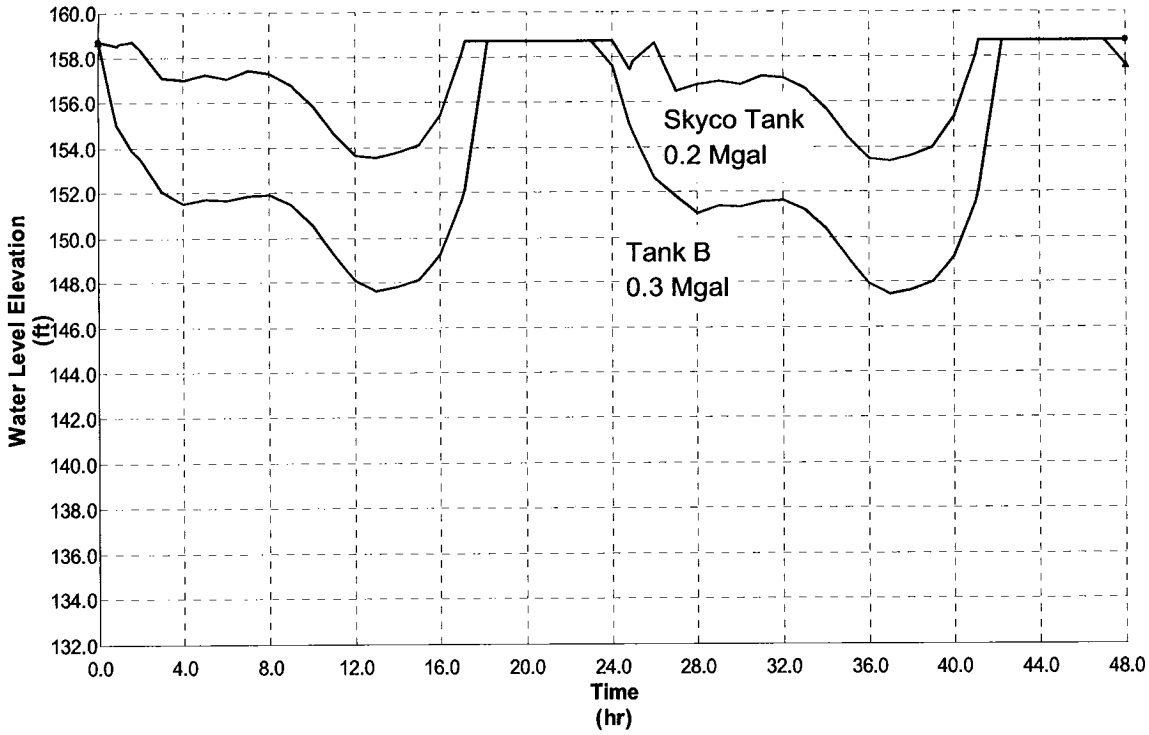
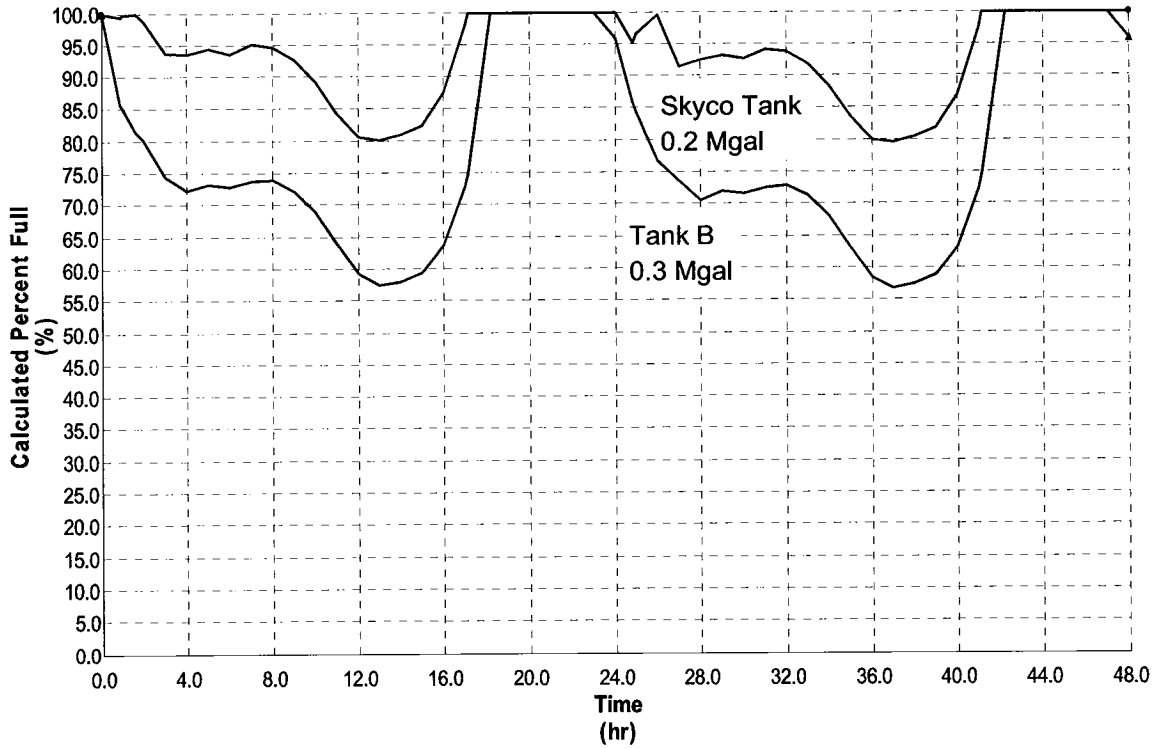



Elevated Storage Tank Water Level Elevation vs Time




Elevated Storage Tank Water Calculated Percent Full vs Time

Figure 6-10
2025 MAXIMUM DAY DEMAND - TANK SITE B WITH SKYCO TANK
MODEL SIMULATION ELEVATED STORAGE TANK GRAPHS

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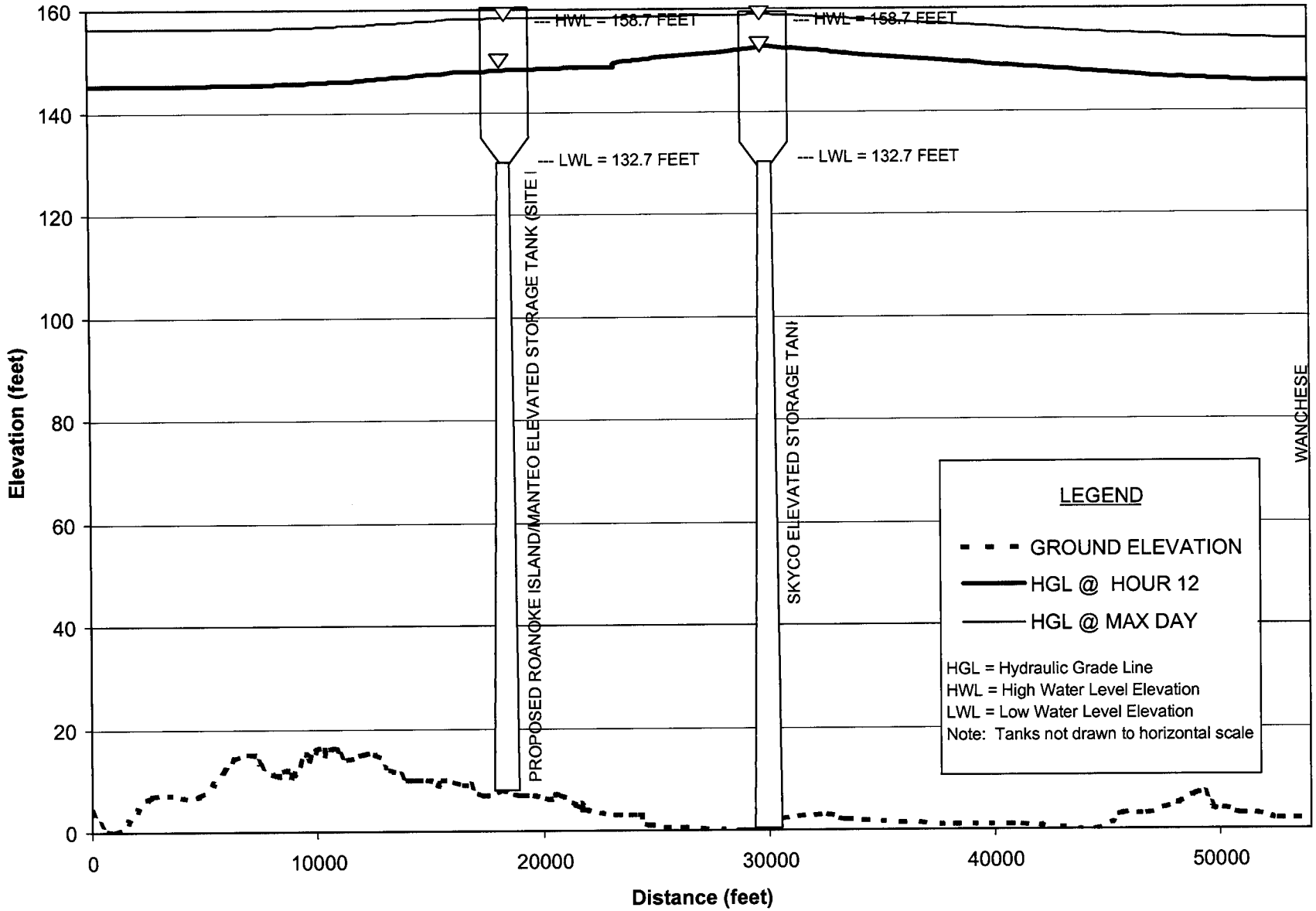
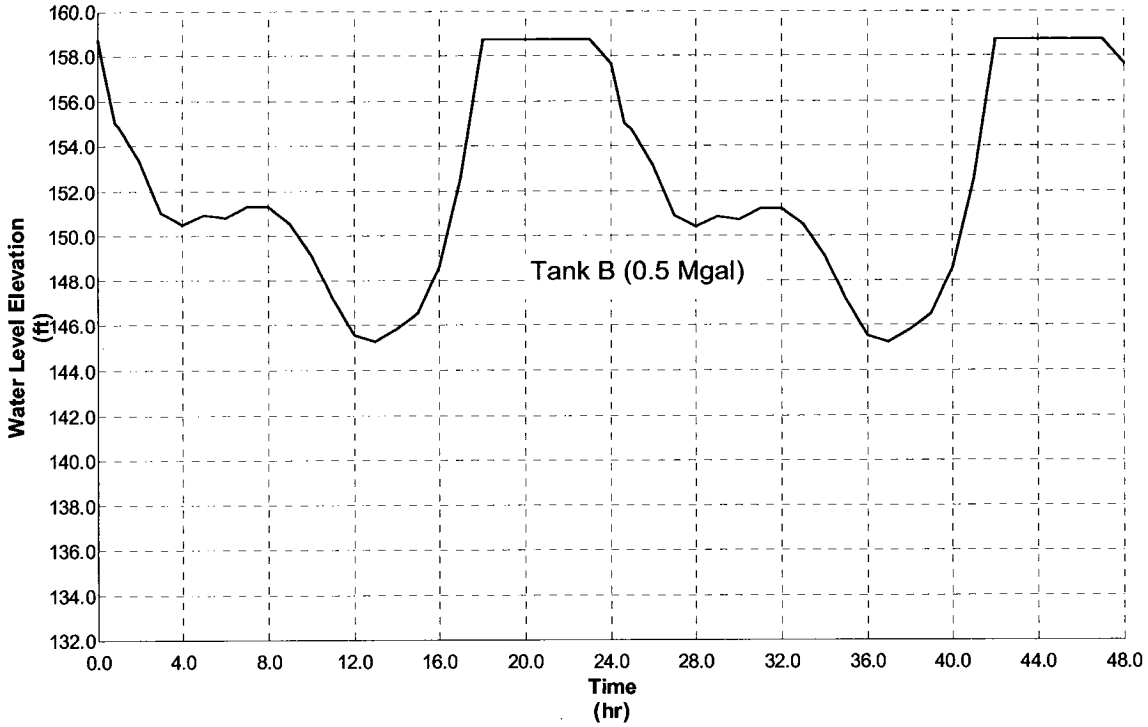
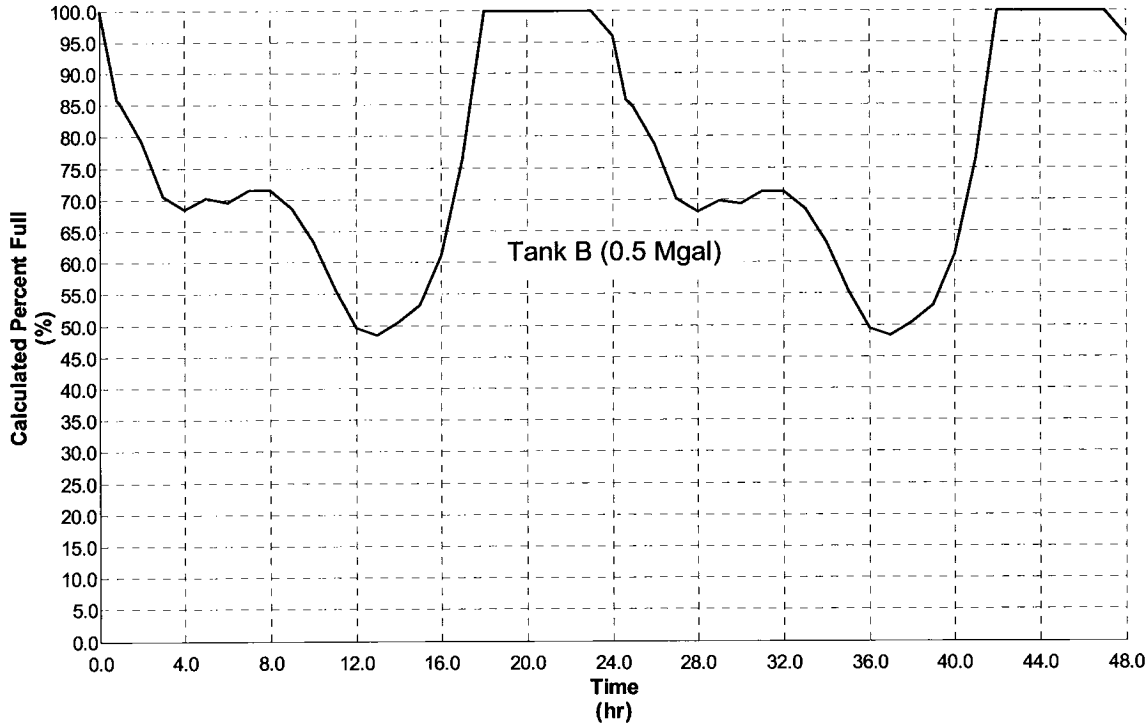



**Figure 6-11**
**ROANOKE ISLAND/MANTEO/WANCHESE - TANK SITE B**
**NORTH-SOUTH HYDRAULIC GRADE LINE PROFILE**




Elevated Storage Tank Water Calculated Level vs Time




Elevated Storage Tank Water Calculated Percent Full vs Time

Figure 6-12
2025 MAXIMUM DAY DEMAND - TANK SITE B WITHOUT SKYCO TANK
MODEL SIMULATION ELEVATED STORAGE TANK GRAPHS

The County is planning to construct a new 3-million-gallon ground storage tank to supplement the Skyco ground storage tank. For conservative purposes, only the existing storage tank was considered at this time. It was assumed that the volume of the Skyco ground storage tank available for the Roanoke Island/Manteo/Wanchese service area was in proportion to the percentage of the WTP capacity necessary to meet the projected 2025 maximum day demand of the service area. Approximately 65 percent of the WTP capacity of 4.3 mgd is needed to meet the projected maximum day demand of 2.8 mgd. A summary of the total finished water storage volume for the service area with the proposed elevated storage tank is presented in Table 6-1. The combined volume of the Skyco elevated storage tank, proposed elevated storage tank, and allocated portion of the Skyco ground storage tank to the service area exceeds NCDENR's minimum finished water storage volume requirement.

**Table 6-1: Roanoke Island/Manteo/Wanchese Storage Volume**

| Storage Facility | Available Storage Volume (million gallons) |
|---|---|
| Skyco Ground Storage Tank* | 1.3 |
| Skyco Elevated Storage Tank | 0.2 |
| Proposed Roanoke Island/Manteo Elevated Storage Tank | 0.3 |
| Total Finished Water Storage Volume | 1.8 |
| NCDENR Total Finished Water Storage Requirement = ½ Average Day Demand | 0.6 |

*Based on 65 percent of total volume of 2 million gallons (i.e., percentage of 2025 maximum day demand of 2.8 mgd to Skyco WTP capacity of 4.3 mgd)

## 6.2.3 Distribution

In general, fire protection governed the sizing of water distribution main extensions. A schematic of the water distribution system and available fire flow for storage tank sites A and B is shown on Figures 6-13 and 6-14, respectively. Fire protection is limited in cul-de-sacs and dead end mains. Wetlands appear to be a limiting factor in looping dead-end mains to improve flow and circulation. For cul-de-sacs and dead-end mains, a fire flow requirement of 500 gpm (ISO's minimum residential fire flow requirement) was considered, particularly if the cul-de-sac was within 500 feet of a junction where at least 750 gpm was available, assuming a fire hydrant is located at the intersection. Junctions identified in Figures 6-13 and 6-14 with available fire flow less than 500 gpm were at the end of 2-inch diameter mains.

Potential water quality problems may occur on long dead-end mains with low demands due to low velocities if the pipes are increased in size to improve fire protection. It is recommended that potential looping options be investigated to improve flow and circulation. Specific fire flow requirements should be re-evaluated based on the proposed development.

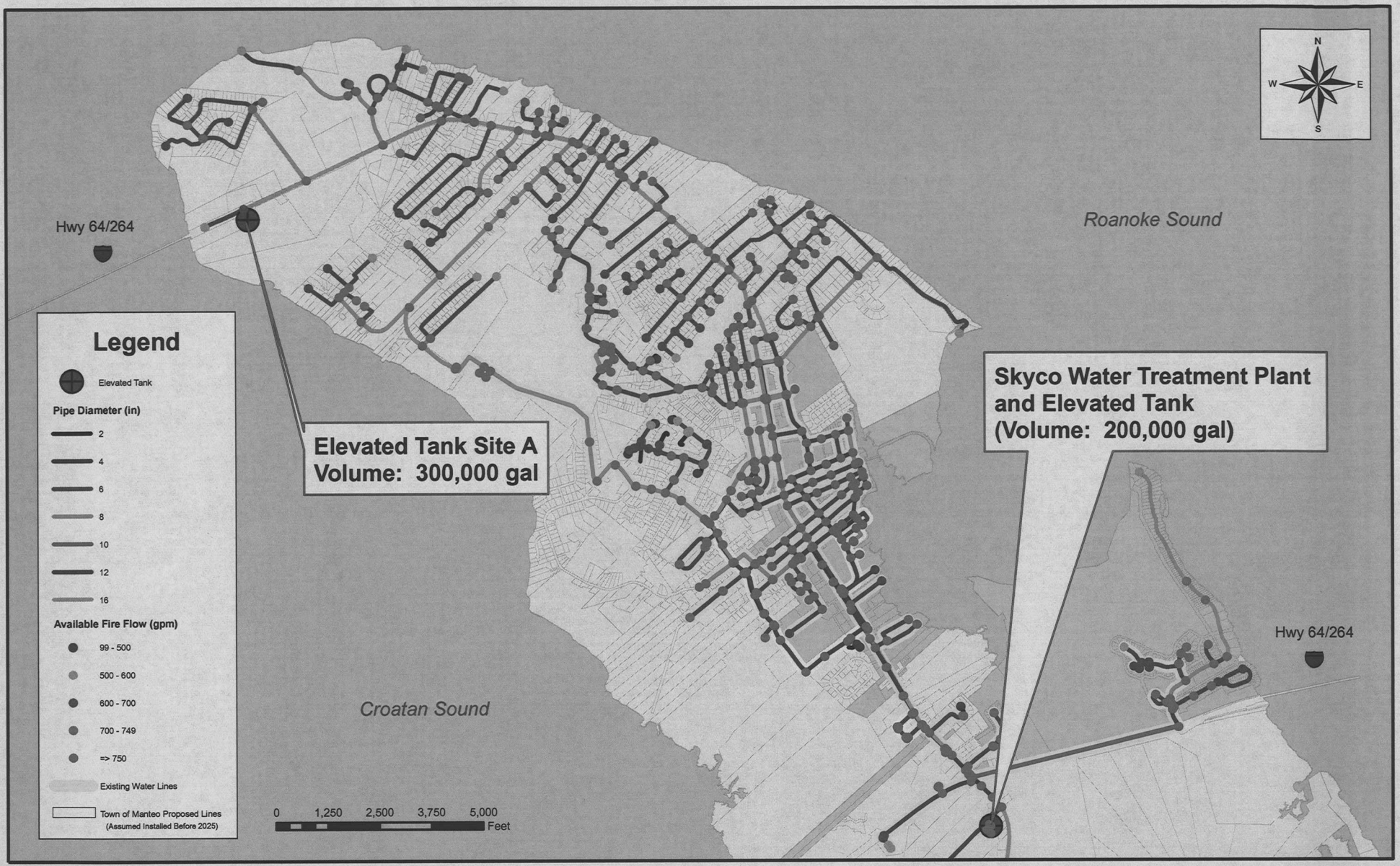



Figure 6-13
ROANOKE ISLAND/MANTEO
2025 MAXIMUM DAY DEMAND - TANK SITE A
MODEL SIMULATION AVAILABLE FIRE FLOW

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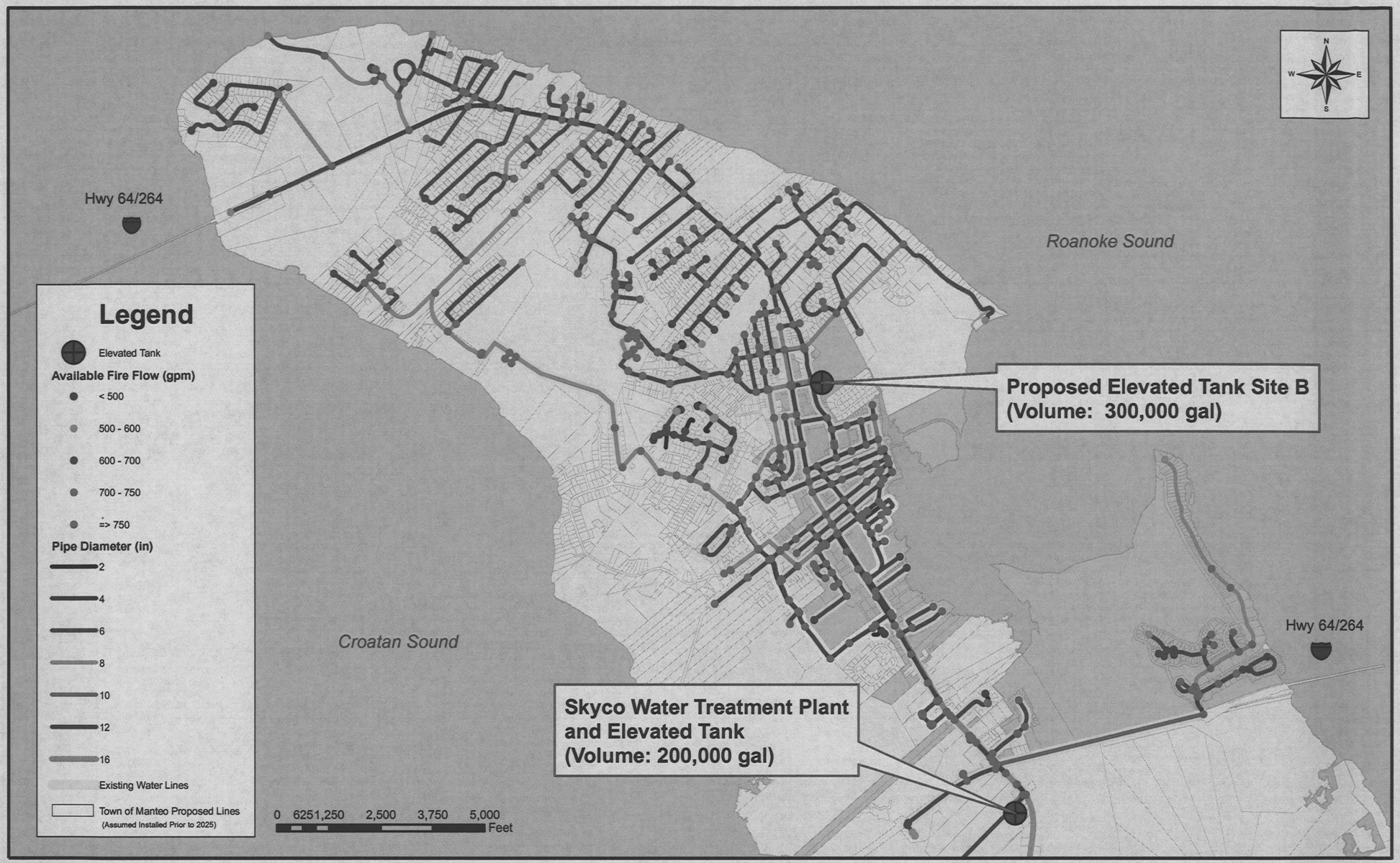


Figure 6-14
ROANOKE ISLAND/MANTEO WITH SKYCO TANK
2025 MAXIMUM DAY DEMAND - TANK SITE B
MODEL SIMULATION AVAILABLE FIRE FLOW

CDM

## 6.3 Wanchese Service Area

### 6.3.1 Transmission

To serve Wanchese, installation of a 16-inch diameter main on NC 345 from the Skyco WTP to the Old Wharf Road/Mill Landing Road intersection is recommended. Installation of 12-inch diameter mains on Old Wharf Road from NC 345 to Old Schoolhouse Road and on Mill Landing Road from NC 345 to Harbor Road is recommended. The Wanchese Seafood Industrial Park is located off of Harbor Road.

### 6.3.2 Storage

Prior to extension of service to Wanchese, it is assumed that construction of an elevated storage tank in northern Roanoke Island will be implemented. The Skyco elevated storage tank and the proposed northern Roanoke Island elevated storage tank is adequate for the Wanchese service area, based on a fire protection requirement of 750 gpm. Re-evaluation of storage requirements is recommended if additional fire protection is required.

The County indicated that the Wanchese Seafood Industrial Park is equipped with a 250,000-gallon elevated storage tank. The hydraulic design of the tank is unknown. If the Wanchese Seafood Industrial Park becomes a Dare County water customer, it is recommended that the feasibility of using the existing elevated storage tank for the Wanchese service area be investigated. The hydraulic effectiveness of the tank must be considered in relation to its operation in conjunction with the Skyco and proposed Roanoke Island/Manteo elevated storage tank. As an alternative, continued use of the Wanchese Seafood Industrial Park elevated storage tank for onsite fire protection may be considered.

### 6.3.3 Distribution

Pipe diameters recommended to serve Wanchese are shown on Figures 6-15 and 6-16. Fire protection governed the sizing of the distribution main extensions in the area. The evaluation was based on providing a fire flow of at least 750 gpm. For cul-de-sacs and dead-end mains, a fire flow requirement of 500 gpm was considered, particularly if the cul-de-sac was within 500 feet of a junction where at least 750 gpm was available, assuming a fire hydrant is located at the intersection. Potential water quality problems may occur on long dead-end mains with low demands due to low velocities if the pipes are increased in size to improve fire protection. Specific fire flow requirements should be re-evaluated based on the proposed development.

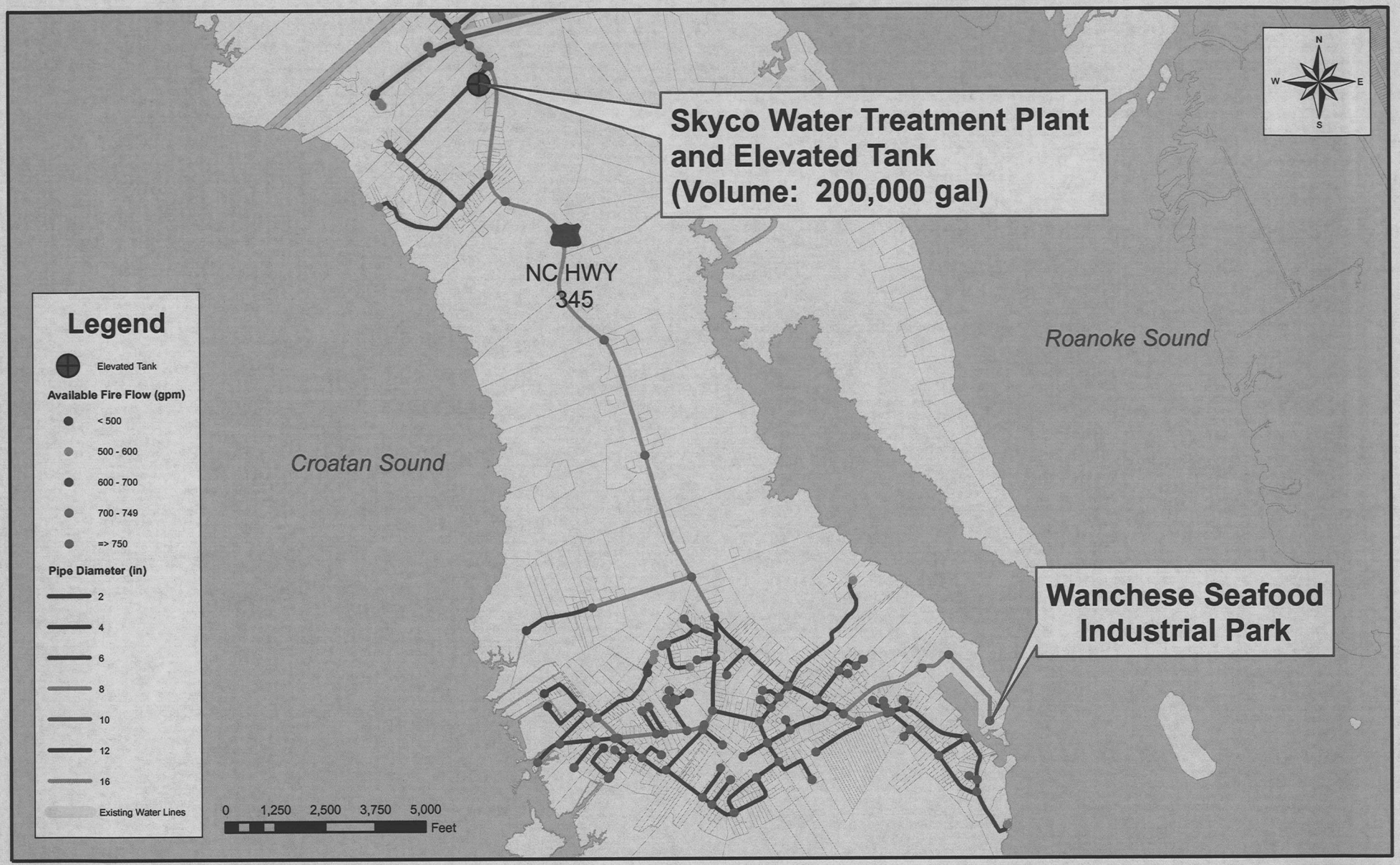


Figure 6-15
WANCHESE TANK SITE A
2025 MAXIMUM DAY DEMAND
MODEL SIMULATION AVAILABLE FIRE FLOW

CDM

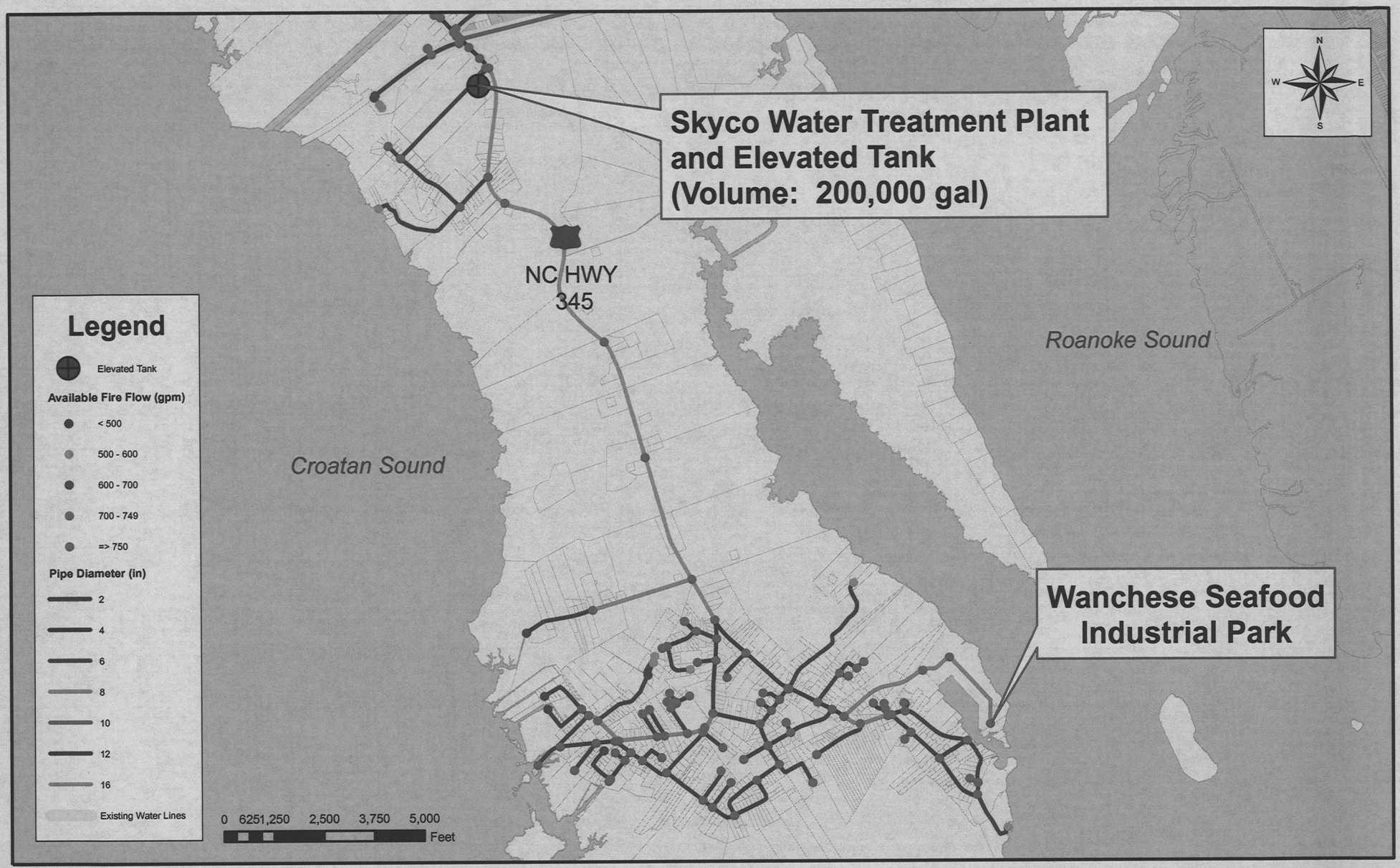


Figure 6-16
WANCHESE TANK SITE B
2025 MAXIMUM DAY DEMAND
MODEL SIMULATION AVAILABLE FIRE FLOW

CDM

# Section 7
# Cost Estimates and Recommendations

## 7.1 Planning-Level Cost Estimates

The American Association of Cost Engineers (AACE) defines three levels of cost estimates, each of which is applicable at a different stage of project completion. The three levels of estimates are: (1) order-of-magnitude, (2) budgetary, and (3) definitive. The comparative construction cost estimates presented in this report are intended to represent "order-of-magnitude" estimates as defined by AACE. An order-of-magnitude estimate is made without detailed engineering data, and relies on the use of previous estimates and historical data from comparable work, estimating guides, handbooks, and costing curves.

The intended use of this type of estimate is long-range planning and for comparing alternatives, not for project control. The final cost of any project described in this report will depend on the project complexity, actual labor and material costs, competitive market conditions, actual site conditions, final scope of work, implementation schedule, continuity of personnel, and engineering. In order to estimate total capital costs, the estimated construction costs have been increased using the following percentages:

- Construction contingency: 25 percent
- Design engineering, construction administration, legal, and financial: 15 percent

The following criteria was used to develop planning-level cost estimates for the recommended system improvements:

- Preliminary estimated construction costs were based on bid tabulations provided by the County, budget costs provided by equipment suppliers, and recent bid tabulations from similar projects.
- It is assumed that piping will be installed within existing easements and right-of-ways to the extent feasible.
- Pipe installation costs assume a consistent depth of burial of 3 - 4 feet.
- New water pipes will generally be PVC.
- Elevated storage tanks will be spheroid-type with pile foundation.
- Costs do not include property acquisition.

Unit costs for pipeline construction based on these assumptions are presented in Table 7-1.

**Table 7-1: Unit Costs for Water Mains**

| PVC Pipe Diameter (inches) | Unit Cost ($/Linear Foot) |
|---|---|
| 6 | 35 |
| 8 | 45 |
| 12 | 55 |
| 16 | 65 |

For the purposes of this evaluation, it was assumed that the costs for additional finished water pumps are included as part of a separate water supply and treatment project. Water supply and treatment alternatives for the Dare County water system are discussed in the *Dare Countywide Hydrogeological Study and Groundwater Resource Evaluation Update Final Report.*

The proposed Roanoke Island/Manteo/Wanchese water main extensions and system improvements are shown on Figure 7-1. Preliminary planning-level cost estimates for Roanoke Island/Manteo and Wanchese are presented in Tables 7-2 and 7-3, respectively. A cost estimate summary is presented in Table 7-4. The preliminary planning-level cost estimates do not include costs for property acquisition. Costs presented are in 2006 dollars with an Engineer News Record (ENR) Construction Cost Index of 7695.10 (April 2006).

**Table 7-2: Roanoke Island/Manteo Water Distribution System Improvements Planning-Level Cost Estimates[1]**

| | Potential Elevated Storage Tank Site A | | Potential Elevated Storage Tank Site B | |
|---|---|---|---|---|
| | Length (feet) | Cost Estimate ($) | Length (feet) | Cost Estimate ($) |
| 0.3 MG Elevated Tank | --- | 1,100,000 | --- | 1,100,000 |
| 16" PVC | 25,800 | 1,680,000 | 9,800 | 640,000 |
| 12" PVC | 4,100 | 230,000 | 18,400 | 1,010,000 |
| 8" PVC | 26,500 | 1,190,000 | 26,500 | 1,190,000 |
| 6" PVC | 117,700 | 4,120,000 | 119,400 | 4,180,000 |
| Subtotal | 174,100 | 8,320,000 | 174,100 | 8,120,000 |
| 25% Construction Contingencies | | 2,080,000 | | 2,030,000 |
| 15% Design, Legal, and Financial | | 1,250,000 | | 1,220,000 |
| Total | | 11,650,000 | | 11,370,000 |
| Annualized Cost[2] | | 980,000 | | 950,000 |

Notes:
1. Costs are presented in 2006 dollars with an ENR construction cost index of 7695.10 (April 2006). Costs do not include property acquisition. Assumes additional finished water pumps are included in a separate water supply and treatment project.
2. Based on capital cost recovery factor of 0.0837 (20 years @ 5.5%).

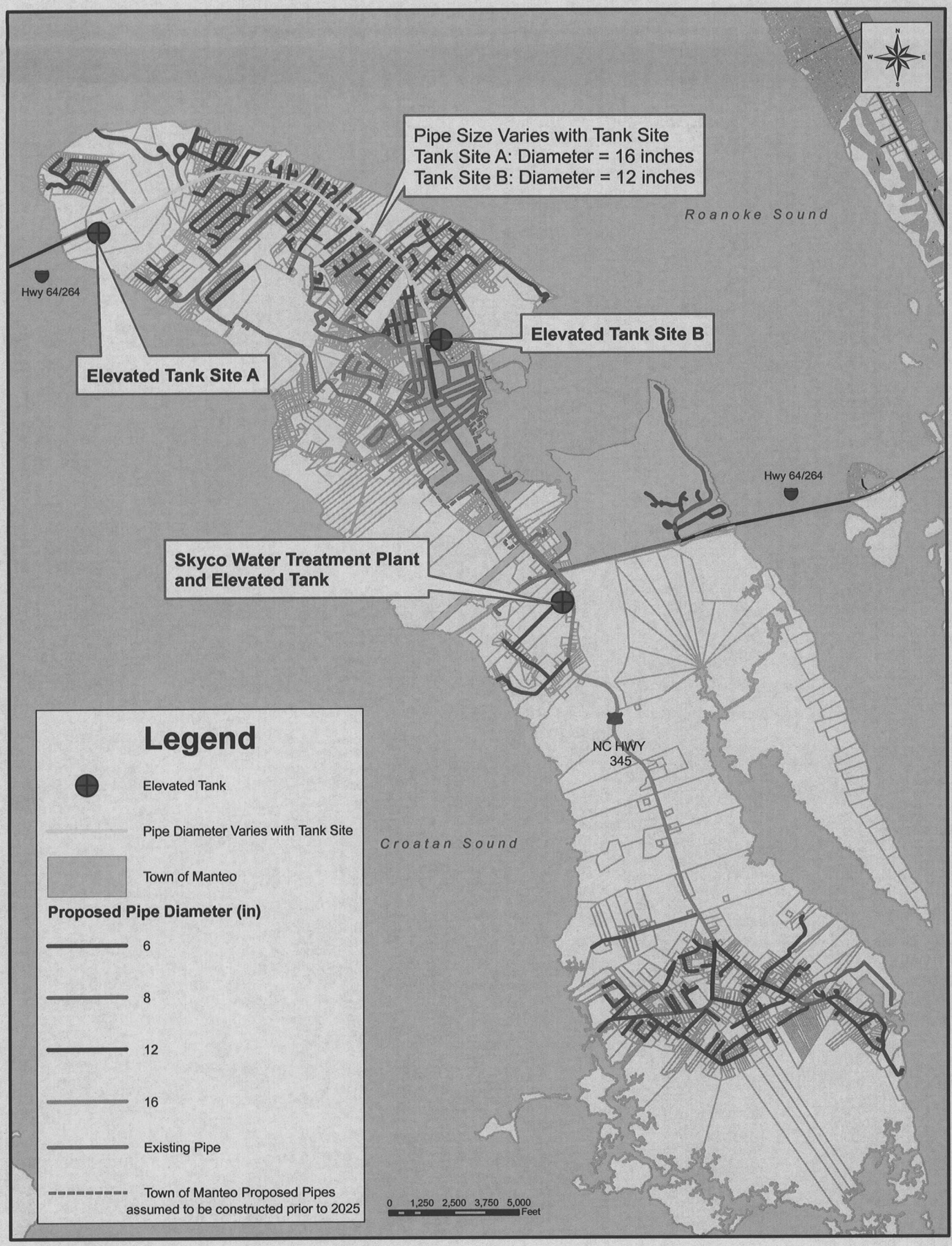


Figure 7-1
ROANOKE ISLAND/MANTEO/WANCHESE
PROPOSED IMPROVEMENTS AND SYSTEM EXTENSIONS

CDM

**Table 7-3: Wanchese Water Distribution System Improvements Planning-Level Cost Estimates[1]**

| | Length (feet) | Cost Estimate ($) |
|---|---|---|
| 16" PVC | 12,200 | 790,000 |
| 12" PVC | 6,300 | 350,000 |
| 8" PVC | 12,600 | 570,000 |
| 6" PVC | 57,600 | 2,020,000 |
| Subtotal | | 3,730,000 |
| 25% Construction Contingencies | | 930,000 |
| 15% Design, Legal, and Financial | | 560,000 |
| Total | | 5,220,000 |
| Annualized Total[2] | | 440,000 |

Notes:
1. Costs are presented in 2006 dollars with an ENR construction cost index of 7695.10 (April 2006). Costs do not include property acquisition. Assumes additional storage is provided in northern Roanoke Island (refer to Table 7-2). Costs assume additional Skyco WTP finished water pumps are included in a separate water supply and treatment project.
2. Based on capital cost recovery factor of 0.0837 (20 years @ 5.5%).

**Table 7-4: Roanoke Island/Manteo/Wanchese Water Distribution System Improvements Planning-Level Cost Estimate Summary**

| | Potential Elevated Storage Tank Site A | Potential Elevated Storage Tank Site B |
|---|---|---|
| Roanoke Island/Manteo[1] | $11,650,000 | $11,370,000 |
| Wanchese[2] | $ 5,220,000 | $ 5,220,000 |
| Total | $16,870,000 | $16,590,000 |

Notes:
1. Refer to Table 7-3.
2. Refer to Table 7-4.

## 7.2 Summary and Recommendations

This study was intended to identify system improvements necessary to extend water service to unserved areas of Roanoke Island and Wanchese. The analysis was based on projected 2025 water demands. Prior to implementing the recommended system improvements, CDM recommends that the County proceed with the following tasks:

- Conduct hydrant flow tests and calibrate the model of the existing system based on the field test results.
- Contact FAA to determine if Sites A and/or B are feasible for an elevated storage tank.

- Re-evaluate the recommended improvements presented in this report using the calibrated model and based on near-term (2010) and long-term (2025) projected demands.

In addition, the following general recommendations are recommended to improve/enhance system operation:

- Provide additional finished water ground storage at the Skyco WTP and replace transmission and finished water pumps including associated motor controls to meet the demands of the northern beaches and Roanoke Island/Manteo service area, particularly during the summer months.
- Monitor flow of Skyco finished water pumps no. 5 and 6 to improve accountability of water usage.
- Retain SCADA data for longer than 65 days, preferably several years, to maximize use of historical data in conducting system evaluations.
- To reduce water main installation costs, create an in-house water line construction division and install 6-inch diameter water mains and service connections.

Transmission and storage improvements directly affect water quality in distribution systems. Pipes sized to meet projected demands of the system may be oversized for the current demands of the system and, as a result, experience problems in maintaining a disinfectant residual. Prior to implementing the system improvements, potential water quality impacts should be evaluated, particularly with near-term demands (e.g., 2010). Alternative sources for fire protection in low density areas, such as the reliance on pumper trucks, should be evaluated if the demand in the area is insufficient to promote turnover in a pipe sized to provide fire protection. If fire protection is not required, a smaller diameter main could be installed in the near-term with a parallel main installed in the future when demands in the area increase.

# References

American Water Works Association. *Distribution Network Analysis for Water Utilities, AWWA Manual M32.* 1989.

Camp Dresser & McKee. *Dare Countywide Hydrogeologic Update Draft Report,* March 2006.

Cesario, Lee. *Modeling, Analysis, and Design of Water Distribution Systems.* 1995.

Missimer International, Inc. *Dare County-Wide Hydrogeological Study and Groundwater Resource Evaluation,* May 1998.

North Carolina Department of Environment and Natural Resources. *Rules Governing Public Water Systems, North Carolina Administrative Code, Title 15A, Subchapter 18C – Water Supplies – Sections .0100 through .2100, Division of Environmental Health, Public Water Supply Section,* September 2004.

North Carolina Office of State Planning. North Carolina State Data Center 2004 through 2029 Dare County Population Projections.

Quible & Associates, P.C. *Wanchese Water Study,* October 1989.

U. S. Bureau of Census (American FactFinder). 2000 census data for Dare County, Manteo zip code area, Wanchese zip code area, and Manns Harbor zip code area.

# Appendix A
# Pipes/Nodes added to the Model

APPENDIX A
DARE COUNTY WATER SYSTEM - MANTEO EXISTING SERVICE AREA
PIPES AND NODES ADDED TO THE MODEL CURRENTLY NOT INCLUDED IN GIS DATABASE

Table 1. Pipes Split to Establish Connectivity in Existing Manteo Model

| (1) | (2) | (3) | (4) |
|---|---|---|---|
| **At junction** | **Pipe Split** | **New Pipes** | **Description** |
| J3070 | 3104 | 3104A, 3104B | Pipe 3104 split into 3104A and 3104B at junction J3070 |
| J3001 | 3060 | 3060A, 3060B | (format repeats only exceptions listed below) |
| J3003 | 3001 | 3001A, 3001B | |
| J3007 | 3007 | 3007A, 3007B | |
| J3009 | 3006 | 3006A, 3006B | |
| J3015 | 3292 | 3292A, 3292B | |
| J3019 | 3003 | 3003A, 3003B | |
| J3021 | 3013 | 3013A, 3013B | |
| J3025 | 3044 | 3044A, 3044B | |
| J3027 | 3013 | 3013A,3013B | |
| J3028,J3030,J3032,J3033 | 3018 | 3018 A,B,C,D,E | Pipe 3018 split into 5 pipes |
| J3035 | 3057 | 3057A, 3057B | |
| J3037 | 3044 | 3044A, 3044B | |
| J3039 | 3016 | 3016A, 3106B | |
| J3041 | 3011 | 3011A, 3011B | |
| J3044 | 3030 | 3030A, 3030B | |
| J3069 | 3110 | 3110A, 3110B | |
| J3076 | 3055 | 3055A, 3055B | |
| J3093 | 3140 | 3140A, 3140B | |
| J3094 | 3051 | 3051A, 3051B | |
| J3304 | 3250 | 3250A, 3250B | |
| J3306 | 3184 | 3184A, 3184B | |
| J3311 | 3225 | 3225A, 3225B | |
| J3330 | 3278 | 3278A, 3278B | |
| J3364 | 3205 | 3205A, 3205B | |
| J3316 | 3299 | 3299A, 3299B | |
| J3324 | 3220 | 3220A, 3220B | |
| J3392 | 3199 | 3199A, 3199B | |
| J3633, J3636 | 3201 | 3201A,B,C | Pipe 3201 split into 3 pipes |
| J3320 | 3193 | 3193A, 3193B | |
| J3500 | 3255 | 3255A, 3255B | |
| J3518 | 3269 | 3269A, 3269B | |
| J3368 | 3186 | 3186A, 3186B | |
| J3450 | 3233 | 3233A, 3233B | |
| J3490 | 3221 | 3221A, 3221A | |
| J3528, J3554 | 3266 | 3266A,B,C | Pipe 3266 split into 3 pipes |
| J3532 | 3272 | 3272A, 3272B | |
| J3513 | 3315 | 3315A, 3315B | |
| J3639 | 3319 | 3319A, 3319B | |
| J3642, J3627 | 3323 | 3323A,B,C | Pipe 3323 split into 3 pipes |
| J3043 | 3280 | 3280A, 3280B | |
| J3036 | 3033 | 3033A, 3033B | |
| J3055, 3058 | 3028 | 3028A, 3028B | |
| J10, J6003, J6004 | 3324 | 3324, 3324A, B, C | Pipe 3324 split into 4 pipes |
| 3213 | 3213 | P-69, 3213 | |
| J3023 | 3023 | 3023A, 3023B | |
| J-2 | 3288 | 3288A, 3288B | |
| J-4 | 3143 | 3143A,3143B | |
| J-6 | 3047 | 3047A,3047B | |
| J-4 | 3157 | 3157A,3157B | |
| J-7 | 3157A | 3157A,3157C | |
| J-11 | 3030A | 3030A,3030C | |
| J-11 | 3280A | 3280A,3280C | |

NOTES:
(1) Disconnection in GIS database
(2) Pipes in the GIS data that were modified in the model to eliminate the disconnection.
(3) New pipes have a letter designation at the end of the number, e.g., 3021A.
(4) New pipes are designated with a letter designation at the end of the number. New pipe has same diameter and "C" value as pipe extended.

Table 2. Nodes and Pipes Deleted from Existing Manteo Model

| Deleted Nodes and Pipes | Remaining | Reason | Notes |
|---|---|---|---|
| J3071 | J3071 | Duplicate | |
| J3084 | J3086 | Duplicate | |
| J3089 | J3092 | Duplicate | 1 ft removed from pipe 3045, was overlapping |
| J3145, J3062 | J3051 | Duplicate | |
| J3359 | 3355 | Duplicate | |
| J3055 | 3088 | Duplicate | |
| J3401 | 3629 | Duplicate | |
| J3511 | 3636 | Duplicate | |
| J3302 | | Orphan | |
| J3793 | | Orphan | |
| J3495, P-104 | | Overlapping Pipe | 1.2 ft long, appears to be an error |

Table 3. Pipes and Nodes Added to Existing Manteo Model

| Added | To Connect |
|---|---|
| P-3024A | P-3024 |
| P-3108A | J3215 and J3087 |
| P-3057C | J3113 and J3087 |
| P-3023C | P-3023 |

In the process added: J3023 and J-2

NOTES:
(A) J designates a node in the model.
(B) 3000 series pipes and junctions designate existing pipes.
(C) W designates Wanchese and M designates Manteo for proposed pipes.

# Appendix B
# Dare County Northern Service Area Diurnal Hydrograph

## DARE COUNTY - KITTY HAWK, SOUTHERN SHORES & DUCK SERVICE AREA