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Town of Nags Head Decentralized Wastewater Management Plan

Final Technical Report

Stone Project No.04-1477

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EXECUTIVE SUMMARY

The Town of Nags Head is located in a classic barrier beach environment on the Atlantic Ocean in Dare County, North Carolina. With its attractive beaches, diverse natural environments, and small community atmosphere, the Town has built an economy based primarily on family vacation tourism. In order to sustainably manage their onsite wastewater treatment systems (OWTS or onsite systems) to protect public health, the environment, and their future economic stability, the Town is actively managing their OWTS through developing and implementing a Septic Health Initiative. This initiative was implemented in 2000 and includes four key areas:

- Education and outreach
- OWTS system inspections and pumpouts
- Surface and groundwater water quality monitoring (including data collected from 2000 through April 2005)
- Development of a Decentralized Wastewater Management Plan (DWMP, Management Plan)

This final technical report prepared by Stone Environmental, Inc. (Stone) of Montpelier, Vermont brings together the results of the inspection program, the findings from the water quality monitoring program, and information from a wealth of other local, county, and state sources in order to provide a technical background for the DWMP. Stone wishes to acknowledge Dr. David Lindbo with North Carolina State University for providing assistance in the development of this study. The DWMP provides the Town with a sustainable plan for implementing additional management components, while continuing to review water quality testing and system inspection results and policy decisions regarding the environmental and public health impacts of failing or substandard systems.

Nags Head represents a classic barrier island environment: a highly dynamic area with several distinct zones of soil types, dunes, vegetation, and animal life. The Town is approximately 11 miles long along the oceanfront, and 0.25 to 1.5 miles wide, with the Roanoke Sound on the westerly boundary. The Town of Kill Devil Hills is to the north, the Island of Manteo is to the west off Route 64 in an area called the Whalebone, and the National Seashore is to the south. There are approximately 3,500 residences, both seasonal and year-round, and 200 non-residential properties made up of commercial businesses and public facilities. Ground elevations range from at and near sea level to nearly 80 feet at the top of the Jockey's Ridge sand dunes. There are two large natural areas, Nags Head Woods and Jockey's Ridge State Park, plus numerous beach and sound accesses that the Town manages.

The Town contains a municipal water supply and 85% of the properties rely on individual OWTS for wastewater treatment. The area around Nags Head Village is served by a small sewage collection and treatment plant that discharges into a series of ponds in the golf course area.

While most of the soils in Nags Head are sandy and well-drained, there are some areas, especially closer to Roanoke Sound, that have finer-grained soils and shallow water tables. These areas may pose some limitations for the siting or operation of OWTS. Nags Head has several types of important water resources in addition to the Atlantic Ocean and Roanoke Sound. There is a freshwater groundwater aquifer under Nags Head, various small ponds and wetlands, and one larger freshwater lake (Fresh Pond) at the northern end of town. Fresh Pond is a part of the Town's municipal water supply, particularly during the summer months when demand is high. While the groundwater beneath Nags Head is not used as a drinking water source, its quality is important because the water in the groundwater aquifer eventually reaches the Sound and the Ocean.

All OWTS in Nags Head, including standard systems with a septic tank and drainfield (leachfield), alternative and experimental systems, and large (more than 3,000 gallons per day) systems, are regulated by North Carolina's Sewage Treatment and Disposal Systems (Rules). These Rules contain soils and site requirements, design and construction requirements, and administrative procedures. The Dare County Health Department administers the program for most systems in the Nags Head area, while permitting for large systems is administered by the North Carolina Department of Environment and Natural Resources.

Most properties utilize conventional OWTS consisting of septic tanks and drainfields. New construction and renovations are increasingly using alternative pre-treatment technologies to reduce the soils and site requirements and maximize on-lot development potential. The drainfield is designed to maintain unsaturated soils conditions below the field and to perform physical and biological treatment. However, some nutrients (such as nitrate and, under some conditions, phosphorus) are capable of moving through the soil into the groundwater and eventually into surface water ditches, the Sound, or Ocean. Older and substandard systems may exist on earlier developed properties, and these may not treat wastewater effluent completely before it reaches the groundwater. Some of the older systems in Nags Head include consist of sand bottom septic tanks, which may not even contain a drainfield. The tank, instead of being a watertight container, acts like a cesspool, providing limited treatment and a greater chance of discharging poorly treated effluent into the groundwater. Inadequate separation to groundwater also increases the risk of wastewater not being adequately treated in the drainfield and unsaturated soils.

Data from numerous sources was compiled, formatted, and imported into a relational database for analysis. This relational database structure was optimized for use in managing and querying onsite system and related data. Once built, this database is easily linked with a Geographic Information System to enable mapping and analysis, and serves as the foundation for all onsite system and water quality based data analysis. Data collected in the database for use during the analysis phase of this preliminary report included:

- Parcel and structure information
- Onsite system permits
- Onsite system inspection results and maintenance records

- Water use records
- Water quality sampling program results

An extensive base of spatial information was also collected for use in the analysis phase of the report. These datasets enabled a GIS (Geographic Information System) assessment of the data and provided a method for displaying the results of the data collection and analysis effort. Spatial data collected for this report included:

- Parcels
- Subdivisions
- Zoning
- Elevations and topography
- Water quality sampling locations
- Onsite system leachfields monitored during the water quality testing program
- Soils
- Groundwater levels and elevations

Conditions related to onsite systems throughout Nags Head were evaluated to identify town-wide trends, and identify any possible areas for concern. The primary observations pertaining to development of a Decentralized Wastewater Management Plan are as follows:

- Over 85% of Nags Head properties treat their wastewater with onsite systems. The remaining developed properties are connected to a package wastewater treatment plant that discharges to ponds in the golf course.

- The vast majority of onsite systems are conventional systems that serve residential properties.

- Current systems in operation are of widely varying ages, the older of which will require special management considerations.

- Approximately 29% of the onsite systems in Nags Head have been inspected as part of the voluntary inspection program. Increasing the number of systems getting inspected may require additional incentives as part of the Management Plan.

- System failure rates, based upon the inspection program data, suggest that approximately 16% of systems have failed in the last 4 years. Repair permit data indicates that the failure rates may be slightly higher, as some systems were repaired without having had an inspection.

- Septic tank pumpouts have occurred largely as part of the voluntary inspection program, although pumpouts may have occurred elsewhere that were not reported. Regular tank pumpouts, independent of inspections, could be considered as a component of the Management Plan.

- Excess water use for periods of up to 2-months a year occurs on a significant number of properties in Nags Head. The most common time for this to occur is in late summer.
- Excess water use is most common for non-residential and seasonal use properties.

These conclusions suggest that while onsite systems are largely performing well and receiving appropriate maintenance, there are a significant number of properties that are not performing properly and need more active management. Managing water use is clearly an important component to consider in the management plan.

The Water Quality Sampling Program results form part of the basis for the overall assessment of impacts of current wastewater management practices on water quality, and are a major factor in building the Decentralized Wastewater Management Plan. Thirty groundwater monitoring wells and 14 surface water points were sampled approximately weekly by contractors for the Town of Nags Head starting in February of 2001. Five parameters currently monitored by the Town were considered most indicative of possible impacts from onsite systems on local groundwater and surface water quality: fecal coliform bacteria, total phosphorus, ammonia, nitrate, and dissolved oxygen. Water quality characteristics near onsite systems were compared to concentrations in background wells, and to water quality standards and guidelines where applicable.

Major conclusions from the water quality sampling program included the following:

- Except for during the landfalls of major tropical storms or hurricanes, there was not a strong relationship between weather patterns and water quality parameters.
- Groundwater elevations in many parts of Town change by a foot or more over the course of a year. On the sound side of Nags Head north of the Whalebone, significant rainfall events are the primary influence on water table elevations. On the ocean side of Nags Head, tidal fluctuations a pronounced influence on water table elevations and often mask the influence of rainfall events.
- Groundwater quality in Nags Head Woods, in developing areas away from individual onsite systems, and in the area served by the package wastewater treatment plant was generally good.
- Groundwater quality near individual onsite systems in Nags Head is variable. Overall trends in water quality near onsite systems tend to be more readily apparent in the northern part of town, particularly north of the Huron Access monitoring well series.
  - Fecal coliform bacterial levels near onsite systems were higher during the summer months, but near background levels during the rest of the year. A relationship was

observed between extreme rainfall events and increased fecal coliform concentrations near OWTS.

  - Total phosphorus concentrations in groundwater near onsite systems are often above expected background levels and are increasing over time, particularly north of the Huron Access monitoring well series.
  - Ammonia concentrations in the groundwater near onsite systems are generally within background levels except in a few locations.
  - Nitrate concentrations in the groundwater near onsite systems are at or above background levels, and tend to be highest in wells close to individual systems.

- Surface water quality in Nags Head is also variable; however, this variability appears to be more influenced by the degree of circulation of the individual water body than by the presence or nearness of onsite systems.
  - Other sources of fecal coliform bacteria, including wildlife and storm runoff, significantly influence fecal coliform bacteria concentrations during colder months. Fecal coliform levels in the surface water ditches tended to be higher overall than levels in the finger canals. There was a fairly strong relationship between warmer water temperatures in the summer and early fall months and higher fecal coliform concentrations in the surface water ditches; this relationship was weaker but still apparent in the finger canals.
  - Natural soil processes appear to be removing phosphorus from OWTS effluent before the effluent reaches the finger canals. The phosphorus removal capacity of sandy soils is finite, however, so it is possible that phosphorus from OWTS could impact the finger canals in the future. Total phosphorus concentrations in the surface water ditches tended to be markedly higher and more variable than those in the finger canals.
  - Ammonia concentrations in the finger canals were near the detection limit and did not increase or decrease over time. Ammonia levels in the ditches are generally higher and increasing over the four years of the monitoring program (particularly in the northern ditches).
  - Nitrate levels in the finger canals are generally stable or decreasing and are usually near or below historic background levels for the sound and water quality guideline levels. Nitrate levels in surface water ditches are higher and sometimes exceed the water quality guideline value.

Once the water quality sampling program results were evaluated, these results were combined with the permit information, water use data, and other characteristics of the onsite systems influencing individual monitoring points (14 systems and groups of monitoring points in total) to establish what particular characteristics of these individual systems were causing impacts on local water quality. Throughout the Town, impacts from individual onsite systems on the nearby groundwater were generally confined to a narrow region located directly downgradient from the individual leachfield. Impacts in the groundwater monitoring wells from other onsite systems within 150 feet of the wells were generally not observed.

The results of the system-by-system analysis fell into three major groups:

- Individual systems where high ammonia concentrations were observed in the groundwater near the leachfield. These three systems (Lost Colony 1, Lost Colony 2, and Juncos St. Access) each had a local or regional depth to groundwater of less than 3.0 feet. Excessive water use, particularly during the spring and summer months, may also be contributing to the observed impacts of these three systems on local groundwater quality. Systems in this grouping were generally more than 20 years old.

- Individual systems where high total phosphorus concentrations, seasonally high fecal coliform bacteria concentrations, and some level of nitrate impact were observed in the groundwater downgradient from the leachfield. Systems in this grouping (Old Cove, Cobia Way, Amberjack, S. Blue Marlin, and Huron Access) have an adequate separation distance between the bottom of the leachfield and the local water table, but still have the potential to transmit pollutants to nearby surface waters. These five systems were at least 20 years old. Excessive water use may also be contributing to the observed impacts of these systems on local groundwater quality.

- Individual systems where impacts from individual systems on local groundwater quality were generally low or were not observed in the nearby monitoring wells, primarily because groundwater monitoring wells were not located where impacts could be observed.

A town-wide environmental impact potential analysis was performed using GIS to provide a basis for developing wastewater management options and to help differentiate between high management need and low management-need areas. The analysis was composed of four components:

1. Impact potential due to onsite system characteristics

2. Impact potential due to proximity to water resources

3. Development of an combined impact potential ranking

4. Environmental impact potential clustering analysis

The primary observations from the environmental impact potential analysis pertaining to development of a Decentralized Wastewater Management Plan are as follows:

- Properties with the highest environmental impact potential due to onsite system conditions have shallow depth to groundwater and excessive water use. Properties with either shallow depth to groundwater or excessive water use have a significant, but lower environmental impact potential. Of all other properties, those with older onsite systems (pre-1986) have a more significant impact potential than those with newer systems.

  - Properties with the high environmental impact potential due only to onsite system conditions are scattered throughout town.
  - The majority of properties in Nags Head have a moderate environmental impact potential due to onsite system.

- Properties with a high environmental impact potential due to proximity to water resources are located along the immediate shore. A small group of properties (5%) located near the beach have a moderate impact potential due to proximity to water resources. While this small group of properties is located far enough from the ocean that most bacteria from their OWTS would be treated in the soil before reaching surface waters, persistent pathogens such as some viruses can persist for longer periods and may be able to travel from these systems' OWTS to the ocean.
- A combined environmental impact potential ranking was calculated by adding the onsite system and water resource proximity rankings. The breakdown of the number of properties in each class is as follows:
  - High potential impact: 227 properties
  - Moderate potential impact: 2,076 properties
  - Low impact potential impact: 1,447 properties
- A clustering analysis showed that clustering of high environmental impact potential properties were located in several contiguous regions throughout Nags Head. Similarly, the analysis showed that clustering of low environmental impact potential properties also occurred in several areas.

The environmental impact potential analysis provides a basis to begin formulating management options by identifying the factors contributing to potential environmental impact, differentiating the impact potential of properties with onsite systems, and identifying neighborhoods with common impact potential characteristics. The analysis provides a bridge between the water quality monitoring program data, the onsite system inspection program, and the formulation of appropriate management options to support the most efficient and effective strategies to minimize the impact of onsite systems on the important environmental resources in Nags Head.

1. INTRODUCTION

The Town of Nags Head is actively managing their onsite wastewater treatment systems (OWTS) through developing and implementing their Septic Health Initiative. The development of the Septic Health Initiative and thus this Onsite Wastewater Treatment Systems Preliminary Report fit well with the Town's Mission and Vision Statements. "The mission of the Town of Nags Head is to provide for the health, safety and welfare of the citizens, property owners and visitors of the town, to fulfill the requirements placed on it by the State of North Carolina and to facilitate the achievement of community goals by providing municipal services in a flexible, cost effective, customer friendly manner and to achieve this thorough an open, consensus driven process that treats all with respect." The vision statement further recognizes the need to build a community that respects its natural resources.

Starting in 1999, this initiative includes four key areas:

- Education and outreach
- OWTS system inspections and pumpouts
- Surface and groundwater water quality monitoring
- Development of a Decentralized Wastewater Management Plan (DWMP)

Education and outreach efforts provided residents with some basic information on how OWTS work and about some important operation and maintenance issues that are the responsibility of the owner. A voluntary septic tank and leachfield inspection program was developed for septic tank pumpers. The pumper reviews and fills out the inspection form, and if the tank needs pumping, the system is pumped out. The homeowner receives a $60 refund on their water bill once they submit the required paperwork from the inspection. The inspection information is then entered into a spreadsheet. Additionally, a comprehensive groundwater and surface water quality monitoring program was developed and implemented. A total of 30 groundwater monitoring wells and 14 surface water points were sampled on a weekly basis beginning in February of 2001. A certified laboratory analyzed the water quality parameters, and town staff entered the data into spreadsheets.

The next step towards improving water quality in Nags Head was to compile and analyze data, and assist with implementing the DWMP. Stone Environmental, Inc. of Montpelier, Vermont was hired to provide these services.

This Preliminary Report, produced in January 2005, focused on the data analysis phase of the work. This Final Technical Report provides updates the Preliminary Report, including new data through the end of April 2005 and responding to comments received regarding the previous report. A draft and final DWMP detailing the management plan recommendations were produced separately and are scheduled for implementation by July of 2005.

This Final Technical Report is organized into major sections as follows:

- Background
- Database Development
- Onsite Wastewater Treatment System Review
- Water Quality in Nags Head
- Evaluating the Impact of Onsite Systems on Water Quality
- Town-wide Environmental Impact Potential Analysis
- Results and Conclusions

Tables and figures are located behind tabs at the end of the report text.

2. BACKGROUND

The Town of Nags Head, located in the northern portion of the Outer Banks of North Carolina, is developing a Decentralized Wastewater Management Plan as part of its wider Septic Health Initiative. This approach, the culmination of years of data collection and hard work, provides an opportunity to clarify environmental and public health impacts related to OWTS, to gauge the success of the Septic Health Initiative to date, and to choose an appropriate level of wastewater management for the future.

Nags Head is a unique and attractive coastal resort community. It has significant natural resources, including the ocean and its beaches, Roanoke Sound, complex natural areas, and unique geological features like Jockey's Ridge. Figure 3.1 shows the town area highlighted with an orthophotogaph, showing the long narrow nature of the town, with approximately 11 miles of ocean beach and sound boundaries, including Bodie Island at the south end of town, and Horse Island and Pond Island off the Route 64 Causeway heading west towards Manteo. Nags Head has experienced tremendous growth and development pressures-especially during the mid- to late-1980s. Town officials have expressed concerns that the cumulative impacts from failing or substandard OWTS may harm water quality in the groundwater, estuaries, and ocean, particularly in sensitive and densely developed coastal areas. The Town's drinking water sources include the upper and middle Yorktown groundwater aquifers and Fresh Pond at the north end of town. Nags Head currently has no centralized sewers, with the exception of Nags Head Village, which has a collection, treatment and discharge system.

While central sewers generally have established management programs, decentralized wastewater management is a relatively new concept in the United States. There are state, county and local regulations in place that establish minimum requirements for designing and installing OWTS. However, OWTS owners often do not know what the components of a system are, how systems function, or how they can negatively impact groundwater and surface waters if not properly used and maintained. Nags Head has a good start on developing a comprehensive management program, including an established education and outreach effort. A Decentralized Wastewater Management Plan strengthens this effort by targeting education and awareness to system owners and by providing the community with a sustainable plan for implementing additional management components, while continuing to review analytical results and policy decisions regarding environmental and public health impacts of failing or substandard systems.

A Decentralized Wastewater Management Plan also gives the Town options on the legal authority to require routine inspections or to implement other management tasks. If systems require repair or replacement, the plan can provide low-interest funding options like the Town's existing loan program. The plan must include approaches that can be easily accepted and implemented, and must be acceptable to regulatory authorities. In addition, in order to be truly effective, the plan must reflect the input of and have support from the community's citizens.

2.1. Land Use and Demographics

Because of Nags Head's proximity to water and beaches, its abundance of open spaces, its relatively low-density development, and its natural environment, it is primarily a recreational oriented community (Town of Nags Head, 2000). During its early years (the 1800s) Nags Head consisted predominantly of single-family cottages, small family businesses, and a few hotels. It was not until the 1980s that the Town began to experience tremendous growth and development pressures brought on, in part, by a significant increase in the Town's permanent population, and by an explosion of seasonal resort development.

Today in Nags Head, zoning is the basic means of land use control. Zoning imposes different controls and regulations on each district. The Town of Nags Head has ten zoning districts and several areas of extraterritorial property. Figures 3.2a and 3.2b show the parcel boundaries, zoning districts, beach and sound accesses, and property uses.

2.2. Physiography, Soils and Geology

Nags Head's physiography, soils and geology relate to the town being a barrier island, where the contours and soil types relate to the beach and dune features, and where bedrock is observed only at great depths.

2.2.1. Physiography

Nags Head represents a classic barrier island physiographic environment: a highly dynamic geologic environment with several distinct zones of soil types, vegetation, and animal life. The barrier island also protects the mainland from the direct impact of the ocean, and bears the brunt of its erosional power. Barrier islands are constantly moving and shifting, primarily toward the mainland, due to constant and complex erosional and depositional processes.

The distinct physiographic regions on the barrier island, from east to west, include beach and foredune, active dunes, washover flats, stabilized dunes, backbarrier flats, marsh, and islands (Daniels *et al*., 1999). The beach and foredune environment is adjacent to the ocean and is subject to constant wave and tide related erosion. Vegetation in the beach zone consists of salt resistant species, including American beachgrass, sea oats, bitter panicgrass, and seashore elder. Animals include small mammals and migratory birds (USDA, 1977). As you move inland from the beach/foredune environment to the dunes and washover flats you transition from the salt resistant species to the shrub zone. The shrub zone includes such species as live oak, eastern red cedar, wax myrtle, sea oats, broomsedge, American beachgrass, and yaupon holly. Animal life in the shrub zone includes small mammals and songbirds. Further inland are the beach ridges and backbarrier flats, where the shrub zone transitions to the forest zone. The forest zone contains species including loblolly pine, live oak, water oak, dogwood, sweetgum, hickory, and blueberry. Animal life in the forest zone includes small and large mammals and songbirds. Closest to the Sound is the marsh zone, which contains species including smooth cordgrass, black needlerush, cattails, saltmeadow cordgrass, and giant cordgrass. Animal life in the marsh zone depends primarily on salinity and flooding. Wildlife commonly includes shorebirds such as herons, egrets, geese, ducks, and gulls. Also present are turtles, snakes, and small mammals.

2.2.2. Soils

Sandy beach deposits underlain by sandy and silty estuarine deposits dominate the soils of Nags Head. The sands and interbedded sands and silts comprise the surficial aquifer. Based on several soil borings in the northern part of the study area, the sand deposits were determined to have a thickness ranging from 16 to 30 feet (5 to 9 meters) (Whittecar and Salyer, 1986). Ground penetrating radar data by Mallinson *et al*. (2003) confirmed Whittecar and Salyer's observations and estimated the average thickness of the beach sands to be 20-23 feet (6-7 meters). The underlying sands and silts, interpreted to be estuarine sediments by both Whittecar and Salyer and Mallinson *et al*., were determined to have a thickness ranging from approximately 10 to 59 feet (3 to 18 meters). Based on the soil boring logs of Whittecar and Salyer, the total thickness of the surficial aquifer in the northern portion of the study area was estimated to be between approximately 49 and 89 feet (15 and 27 meters). The elevation of the bottom of the surficial aquifer is estimated to be between approximately 26 and 66 feet (8 and 20 meters) below sea level. Underneath the sands and silty sands lies a compact clay layer that represents the bottom of the surficial aquifer. The clay layer was likely deposited in an offshore environment or estuarine mud flat. In general, the predominant surface soil textures are sand and fine sand, with minor muck (Figures 3.3a and 3.3b). As a result, average permeabilities are very rapid ranging from 12 to greater than 20 inches per hour (Figures 3.4a and 3.4b). The permeabilities in the muck are typically less than 3 inches per hour, but this represents a small portion of the study area, west of Nags Head Woods (Figure 3.4a).

The surficial soils are almost exclusively sands with some organic soils in the marshes on the sound side (Daniels *et al*., 1999). The beach-foredune unit is comprised of sands and follows the eastern coast of Bodie Island and the Nags Head study area. Toward the western side of the island and Roanoke Sound, Newhan fine sand, Newhan-Corolla complex, Duneland-Newhan complex, and Newhan-Urban Land complex soils become prevalent. All these soil types are well-drained sands with the exception of the urban complex, which typically represents impermeable surfaces. Other soil types include the Duckson fine sand and the Corolla-Duckson complex, which are also well-drained sands. The marsh soils adjacent to Roanoke Sound are comprised of Carteret sands and Hobonny organic marsh soils. The Nags Head Woods are comprised primarily of Fripp fine sands. South of Nags Head Woods and north of the Whalebone, Duneland sands are also prominent (USDA, 1977).

2.2.3. Geology

Bedrock is typically several hundred feet below land surface under the Outer Banks region of North Carolina. Based on a log from a drilled well on Roanoke Island (Brown *et al*., 1972), the first consolidated rock, a limestone, was encountered at approximately 260 feet below sea level in the Yorktown Formation. The limestone strata appear to be approximately 10-20 feet thick. Underneath the limestone, however, is another 300 feet of unconsolidated sands, silts, and clays. The next substantial bedrock occurs at approximately 600 feet below sea level, and caps the Pungo River Formation.

2.3. Water Resources

Freshwater and saltwater resources both exist in Nags Head. There is a freshwater groundwater aquifer under Nags Head, various small ponds and wetlands, particularly in the Nags Head Woods area, and one larger freshwater lake (Fresh Pond) at the northern end of town.

2.3.1. Groundwater

There is a surficial fresh water aquifer underlying the Town of Nags Head. It remains largely untapped, except for a small number of wells used for irrigation. A prolonged lowering of the water table, however, could significantly alter the ecology of the wetlands in Nags Head. The top of the aquifer, which is unconfined, is near the land surface. Its elevation is expressed in the numerous ponds in Nags Head Woods (Whittecar and Salyer, 1986) and in surface water ditches throughout the study area (Figures 3.5a and 3.5b). Since the ditches may in some cases lower the local water table, the quality of the groundwater may in turn impact the quality of the surface water.

The thickness of the surficial aquifer varies (Whittecar and Salyer, 1986), although it is commonly believed to be lens shaped in cross-section, mirroring the general shape of the barrier island. This hypothesis is supported by two data sets, Whittecar and Salyer (1986) and the Nags Head water quality testing program results. Whittecar and Salyer monitored 38 wells in the vicinity of Fresh Pond and Nags Head Woods. Water levels were taken bi-weekly for a period of one year. They concluded that the shape of the surficial aquifer was an elongated dome, with a high near the longitudinal center of the island and lows where the island met the ocean and the sound. This conclusion is supported by the water levels collected by the Town of Nags Head as part of their water quality monitoring program. The Town began measuring water levels from a network of 25 monitoring wells throughout the study area in June 2004, including wells in the north that allow comparison with the Whittecar and Salyer (1986) data. Figures 3.5a and 3.5b show groundwater elevations over the entire town of Nags Head based upon interpolated monitoring well data and information from the Whittecar and Slayer study. The elevations shown represent approximate annual average water table elevations. Figures 3.6a and 3.6b show depths to water table that are calculated from the groundwater elevation dataset and a surface elevation dataset derived from LIDAR. These figures show that in many locations within Nags Head, the water table is shallow, with a depth of less than 4 feet below ground surface.

The sands comprising the surficial aquifer are highly conductive, and this property can result in the rapid movement of groundwater. Numerous studies have determined that hydraulic conductivities in the upper surficial aquifer range from 10-4 to 10-5 m/s (Whittecar and Emry, 1992). If porosity is assumed to be 25% (Freeze and Cherry, 1979), and the hydraulic gradient is 0.2% (measured in northern Nags Head, from Fresh Pond to Atlantic Ocean), groundwater velocity in the surficial aquifer may be calculated using the range of hydraulic conductivities referenced above. Groundwater velocities in the surficial aquifer are between 7-63 cm/day. These velocities will lessen as the hydraulic gradient decreases towards the south end of the study area (Figures 3.6a and 3.6b). These velocities compare well with Whittecar and Embry (1992), who conclude lateral groundwater flow velocities were 50 cm/day or less.

There are currently no data that delineate the fresh water/salt water interface below Nags Head. However, the interface between the fresh water aquifer and the salt water most likely occurs at the beach/ocean interface and projects below the island at an angle of less than 90º (Freeze and Cherry, 1979). The angle of the interface changes as the elevation of the surficial aquifer's water table changes. As the water table rises, the interface angle gets steeper, and as the water table drops, the interface becomes less steep.

2.3.2. Fresh Pond and Drinking Water

Fresh Pond is a fresh water lake located on the eastern edge of Nags Head Woods, halfway between the Atlantic Ocean and the Roanoke Sound. The northern half of Fresh Pond is in Kill Devil Hills and the southern half is located in the town of Nags Head. Fresh Pond, a 30-60 acre lake, has historically been pumped to supply drinking water the towns of Kill Devil Hills and Nags Head. Water was pumped from Fresh Pond at rates from 0.13-1 million gallons per day (mgd) during periods of the 1960's, 1970's, and 1980's, that resulted in water level drawdown of 6-10 feet (Whittecar and Emry, 1992). The Pond is currently only being pumped for drinking water in the summer when demand is highest.

2.3.3. Atlantic Ocean

Nags Head has over 11 miles of frontage along the Atlantic Ocean. There are over 30 public accesses to the beach that the town maintains, plus many properties have direct access to the beach. The beach gently slopes to the ocean. There are no embayments to separate the beaches from the direct ocean.

There are five surface water drainage outlets along the Atlantic Ocean, four in the northern one-third of town, and one at the southern end of town. The drainage outlets are usually located at beaches and are primarily for draining stormwater.

2.3.4. Roanoke Sound

Nags Head is bound to the west by the Roanoke Sound, with over 10 miles of frontage. The Sound is a fresh to brackish estuarine water body. The low salinities are due to the large influx of fresh water from several major rivers. The most significant resource provided by the sound is estuarine fisheries. These fisheries have an annual economic value of one billion dollars, a significant contribution to the coastal economy. Fish include resident shellfish, such as oysters and clams, in addition to anadromous and migratory species such as striped bass, herring, weakfish, crab and shrimp (NCDWQ, 1997). There are also several threatened or endangered species in the Sound. These include seven species of reptiles (mostly turtles), one mammal species (Manatee), and two fish species (Lyre Goby and Waccamaw Killifish).

2.3.5. Swimming Advisories for the Ocean and Sound

The North Carolina Department of Environment and Natural Resources began monitoring beaches along the coast in 1997, using fecal coliform bacteria as the primary organism indicating contamination of the water by potentially disease-causing agents. From 1997-2002, swimming advisories were posted based on exceedances of the US EPA's recommended geometric mean standard of 200 MPN/100 mL.

In 2003, North Carolina adopted BEACH Act (Beaches Environmental Assessment and Coastal Health Act of 2000) standards and began an ambitious beach monitoring program using *Enterococcus* as the indicator organism. Under this new program, Tier 1 beaches (those that are the most popular or are at the greatest risk for pollution) are monitored at least once per week; all ocean beaches are considered to be Tier 1, including those in Nags Head. Swimming advisories are posted for Tier 1 beaches upon single-sample exceedances of US EPA's recommended standard for *Enterococcus* (104 MPN/100 mL), or for exceedances of the recommended geometric mean standard of 35 MPN/100 mL out of five samples taken within 30 days. Tier 2 and 3 beaches (those with lower use or more difficult access) are tested once a month. Advisories are only issued for Tier 2 beaches if single-sample *Enterococcus* concentrations exceed 276 MPN/100 mL, and for Tier 3 beaches if single-sample concentrations exceed 500 MPN/100 mL.

A summary of swimming advisories by year for Nags Head is shown in Table 2.1.Due to the changes in the monitoring programs, indicator organisms, standards used for determining the posting of advisories, and testing locations, the advisory data for 2003 and 2004 are not directly comparable to the pre-2003 data. Prior to 2002, no ocean beach advisories were reported in Nags Head, while one location on the sound had advisories reported in 1998 and 1999. In 2003, the monitored ocean beaches had advisories posted for a total of 63 days; all but one of these posted days occurred at the ocean outfall at the southern border of Nags Head. Many of these postings were likely due primarily to increased storm runoff associated with the landfall of Hurricane Isabel in September 2003. In 2004, the monitored ocean beaches had advisories posted for a total of 23 days; again, most of these posted days occurred at the south ocean outfall. In 2005, no ocean or soundside beach advisories were posted before the end of April.

2.4. Onsite (Decentralized) Wastewater Treatment Systems

Onsite or decentralized wastewater treatment systems refer to the use of wastewater treatment and dispersal solutions that are at or near the point of wastewater generation. This includes the use of individual onsite wastewater treatment systems (OWTS or onsite systems), alternative treatment systems, shared OWTS (for example, two or more buildings on the same property using a common system or systems), and cluster systems (for example, buildings on multiple properties utilizing a common system).

The United States Environmental Protection Agency (US EPA) estimates that approximately 23% of existing housing in the United States relies on 26 million onsite systems for wastewater treatment (US EPA, 2002). Decentralized wastewater treatment and dispersal technology choices can serve development density goals and land use patterns. These onsite and clustered systems can be protective of public health, drinking water supplies, and the quality of water resources if they are properly designed, installed, operated, and maintained.

All onsite systems in North Carolina are regulated through the state Title 15A – Department of Environmental Health, and Natural Resources, Chapter 18 – Environmental Health, Subchapter 18A – Sanitation, Section .1900 – Sewage Treatment and Disposal Systems (Rules). These rules were originally effective July 1, 1977, and certain sections have been most recently amended with an effective date of May 1, 2004.

The following sections will discuss the site and soils requirements, design considerations and system components, system performance, system operation and maintenance, and current permit and local voluntary programs related to onsite systems. The discussion will be framed around the current state regulations.

2.4.1. Site, Soils and Design Requirements

The site and soils characteristics govern the location and design of OWTS. Following is a discussion of the key characteristics.

2.4.1.1. Site Characteristics

Site requirements including slope and horizontal setbacks to various features help determine the system location and layout. Setbacks include distances between the OWTS and property lines (10 feet), water supply wells and sources (100 feet), coastal water classified as SA (100 feet from mean high water mark); and other coastal waters (50 feet from mean high water mark). For systems with design flows over 3,000 gpd, greater setbacks are required. For systems using alternative treatment units (such as peat filters) with reduced wastewater strengths and suspended solids, reduced horizontal setbacks can be used (i.e. coastal waters classified as SA would be 70 feet instead of 100 feet for conventional systems).

2.4.1.2. Soils Characteristics Related to OWTS Design

Soils are grouped based on soil particle size and distribution. Textural classes range from sands (Soil Group I), which is the predominant soil group for Nags Head, to loams and clays (Soil Groups II-IV). This grouping determines the range of long-term acceptance rates of the soil used in sizing the dispersal field. In the case of Nags Head, the rate is on the range of the fastest permeability, where the system can be sized smaller due to the very permeable soil.

The depths to rock, saprolite (a type of permeable bedrock), and wetness (seasonal high groundwater table) determine the system type and maximum depth to the bottom of the leach field. Soil depths to saprolite, rock, or wetness greater than 48 inches are considered suitable for conventional systems. Soil depths between 36 and 48 inches to rock, saprolite, or wetness are considered provisionally suitable, and soil depths less than 36 inches are considered unsuitable unless additional investigation shows that a modified or alternative system can be installed in accordance with the Rules.

In North Carolina, the required separation from the bottom of a conventional leachfield to wetness or seasonal groundwater table is 18 inches for group I soils, the predominant soil group in the Nags Head area. The required separation depth is 12 inches for soil groups II, III, and IV. For low-pressure pipe systems (LPP systems), which are considered alternative systems, the separation from the bottom of the dispersal field and rock and wetness is 18 inches. For systems using pretreatment technologies such as peat filters, the vertical separation to rock and wetness is 12 inches for existing systems and 18 inches for new systems.

2.4.1.3. Design Considerations- Flows and Wastewater Strength

Design considerations for onsite systems include determining the estimated design flows and anticipated wastewater strength. The Rules designate wastewater design flows based on the building's use. For residences, the flow is based on 120 gallons per day (gpd) per bedroom, with a minimum volume of 240 gpd per dwelling unit. This assumes a maximum occupancy rate of two persons per bedroom. If additional persons are expected, the volume would be based on 60 gallons per day per person per day. This is in the middle of the range for residences prescribed by the 2002 EPA Onsite Wastewater Treatment Systems Manual (EPA Design Manual). These estimated flows may not take into consideration the seasonal rental use of many properties in Nags Head. The design flows are meant to represent a maximum daily flow for the building. The Rules are currently being redrafted, and one of the changes being considered is to increase design flows for properties that are considered "rental".

The design flows for commercial buildings are variable based on use. For example, a retail store might be based on the maximum number of employees times 25 gpd/employee, which for a 10-employee retail store would be 250 gpd. A restaurant is calculated at 40 gallons per seat, or for a 24-hour restaurant it is increased to 75 gallons per seat, so a 100-seat restaurant would be in the range of 4,000 to 7,500 gpd.

Wastewater strength is another consideration when designing an OWTS. Wastewater strength is determined using two methods, the Biological Oxygen Demand (BOD) concentration, and the amount of Total Suspended Solids (TSS). Using in-sink garbage disposals can significantly increase the wastewater strength from a household. The EPA Design Manual estimates that garbage disposals can account for 28% of the total BOD, 37% of the TSS, and 4-5% Total nitrogen and Total Phosphorus. Toilet wastewater accounts for 26% of the BOD, 38% of the TSS, and 78% of the Total Nitrogen and 59% of the Total Phosphorus, with the rest of the plumbing accounting for the remainder. Eliminating garbage disposals and improving user habits to eliminate disposal of chemicals, pharmaceuticals, fats oils and grease from entering the wastewater stream can greatly reduce wastewater strength and constituents. Modifying product selection on cleaning products low in phosphorus can also reduce wastewater loads.

The number and type (low-flow) of plumbing fixtures can also have an impact on the actual flows from a building. In 1992, the U.S. Congress passed the U.S. Energy Policy Act (EPACT), which established national standards for plumbing flow capacities. Effective January 1994, fixtures such as faucets were reduced from 3 gallons per minute (gpd) to 2.5 gpm (16%); showerheads were reduced from 3.5 gpm to 2.5 gpm (28%), and toilets from 3.5 gallons per flush to 1.6 gallons per flush (54%). These fixtures have now become standard and are considered a part of the reasoning for the current wastewater design flows. The state Rules do allow for a decrease in design flows for the use of "extreme water conserving fixtures such as 1.6 gallons per flush or less, spring-loaded faucets with flow rates of 1 gpm or less, and showerheads with flow rates of 2 gpm or less." The reductions are made by the county Health Department on a case-by-case basis and only pertain to pressured dosed or nitrification fields. A consideration must be made as to whether the reduction in flows will have an effect on wastewater strength, potentially concentrating the pollutants. Buildings with plumbing fixtures installed prior to 1994 can be targeted for outreach to upgrade fixtures and thus reduce overall water usage.

2.4.2. Types of Systems and Components

2.4.2.1. Conventional Septic Tank/Leachfield

The septic tank is the first component of an OWTS. The septic tank is a watertight structure that allows solids to settle to the bottom. Scum and oils rise to the top of the tank and are held in by baffles. In North Carolina, the current tank configuration is to have two compartments, with the first compartment comprising about two-thirds of the total tank volume. Relatively clear effluent leaves the septic tank. Newer tanks include access risers to the ground surface for easier locating and maintenance, and an effluent filter at the outlet that keeps solids from leaving the tank and plugging the disposal field. The septic tank provides primary treatment of the sewage and its maintenance is important to the health of the entire system.

The next component in a conventional system is a distribution box to split the flows between trenches, or drop boxes at the ends of the trenches. These boxes are usually made of watertight concrete or other materials, and are designed to distribute wastewater flows evenly to the various trenches or pipe laterals. Where there is not adequate slope for a gravity-based system, a pump station or dosing tank may be needed. This tank stores the wastewater from the septic tank, and when it reaches a certain level, the pump is triggered to dose the system.

The final component in a conventional OWTS is the leachfield. The soils and site characteristics govern the location, depth and design of the leachfield. In North Carolina, the required separation from the bottom of a conventional leachfield to wetness or seasonal groundwater table is 12-18 inches as discussed above. The nitrification trenches are placed relatively level along the slope of the ground and consist of hard washed stone (typically 6 inches of stone below the distribution pipe and 2 inches above the pipe) covered with filter fabric to keep finer soils from entering the stone and 4 inches of sandy topsoil. The pipe usually a perforated PVC pipe laid nearly level. On flat sites, seepage beds can be used instead of trenches, when the site conditions favor this type of disposal system. Gravelless trenches can also be substituted for stone.

For systems using pretreatment technologies such aerobic sewage treatment units (ATUs), sand filters, or peat filters, the vertical separation between the bottom of the drainfield and wetness is 12 inches for existing systems and 18 inches for new systems. For leachfields connected to these systems, reductions are given for separation to wetness and horizontal setbacks. The maximum LTAR can also be increased by 25%, reducing the size of the leachfield. A settling tank is needed if the flows from these systems are greater than 7,500 gpd.

2.4.3. Other Dispersal Fields

2.4.3.1. LPP Systems

Low-pressure pipe systems (LPP systems) use a pump or dosing tank to provide a small amount of pressure (2-5 psi) when dosing the leachfield. They use small diameter pipe (1-2" diameter) with holes drilled in the pipe. The pump tank pushes a volume of water into the LPP system, where it is equally distributed along the trenches. The leachfield trenches are usually 12-18 inches below ground and a minimum of 8 inches wide, with a minimum distance of 5 feet between trenches. The LTAR is reduced by one-half, which doubles the size of the leachfield. The separation from the bottom of the dispersal field and rock and wetness is 18 inches. If used in conjunction with an ATU, the separation distance is reduced to between 12 to 18 inches.

2.4.3.2. Fill Systems

Fill systems are simply leachfield trenches installed in fill material. They are made with sand or loamy sand (Group I) soils. Fill systems must maintain a 24-inch separation to wetness unless an LPP system is used. They are used where there is a minimum of 18 inches of soil that is suitable or provisionally suitable. If an ATU and LPP system is incorporated, the minimum separation to wetness is further reduced to 12 inches.

2.4.3.3. *Innovative Systems*

Innovative systems, technologies, components or devices may apply to the state for review and approval. Once an innovative system is approved, the local health department can issue permits for installation and use if the conditions of approval can be met.

2.4.3.4. *Experimental and Controlled Demonstration Systems*

A third party testing program can be performed for systems wanting experimental or controlled demonstration approval.

2.4.4. *Commercial and Larger Systems*

The design flows for commercial buildings are variable based on use. For example, a retail store might be based on the maximum number of employees times 25 gpd/employee, which for a 10-employee retail store would be 250 gpd. A restaurant is calculated at 40 gallons per seat, or for a 24-hour restaurant it is increased to 75 gallons per seat, so a 100-seat restaurant would be in the range of 4,000 to 7,500 gpd. A restaurant or other building with higher strength wastewater including grease and oils may require a grease interceptor tank as the first component of an OWTS. Otherwise the system is designed basically the same as a conventional system. The State Department of Natural Resources (NCDENR) Systems regulates systems with greater than 3,000 gpd design flows.

2.4.5. *Alternative Systems*

Alternative wastewater treatment systems are used in many areas of the United States where site conditions, such as shallow water tables, small lot sizes, or nearby sensitive natural resources, preclude the use of conventional OWTS. Town of Nags Head staff requested additional information about alternative wastewater treatment technologies and specific information about permitting requirements and the application of these technologies in North Carolina and in Nags Head.
While a variety of technologies are approved for use in North Carolina, this report focused on technologies currently installed in Nags Head, including:

- Puraflo® and Ecoflo® peat biofilters
- Bioclere® and AdvanTex® trickling filters
- Low-pressure pipe (LPP) distribution systems

The findings of the alternative systems report are included as Appendix A of this report.

2.4.6. System Performance

2.4.6.1. Conventional Systems

The disposal field is designed to maintain unsaturated soil conditions below the disposal field, and is designed to perform physical and biochemical treatment. The physical processes include filtering and slowing of the wastewater movement in the soil. As the effluent moves through the soil, solids and microbes are physically filtered out of the wastewater. The unsaturated soils between the leach field and groundwater, impervious soils, and bedrock significantly reduces total pathogens, but can have a varying impact on nitrogen and phosphorous.

Much of the treatment in the disposal field occurs at the interface between the media (i.e., stone) and the undisturbed soil, where a chemical and biological layer known as a biomat forms. This biomat can be less permeable than the surrounding soils. System design standards take into effect the long-term acceptance rate of this mat. Highly permeable soils with deeply placed disposal systems may not develop biomats, and may contribute more phosphorus, organic nitrogen or ammonia, and bacteria into waters than shallow-placed systems on finer textured soils.

Soil can provide treatment of effluent through the physical, chemical, and biological processes described above. However, some of the nutrients (such as nitrate) are capable of moving through the soil. Nitrate is a negatively charged compound, and therefore tends to move through the negatively charged soil. In some cases, the site conditions allow the nitrate to be transformed into nitrogen gas through the nitrification-denitrification process described above. The depth of unsaturated soil beneath the leachfield can have an impact on additional reductions in contamination amounts. The 2002 US EPA Design Manual, shows improvements in soil water quality at 2 feet and 4 feet beneath the leachfield. This separation allows for a dramatic reduction in pathogen levels and other pollutants. For instance, systems with a 3-5 foot separation to groundwater had over 90% removal of BOD and TSS, a 10-20% reduction in total nitrogen, between 0 and 100% reductions in total phosphorus, and greater than 99.99% removal of fecal coliform (US EPA, 2002).

Nutrient loading assessments and modeling can help determine regional contributions of nitrogen and phosphorus. This contribution is a combination of system sizes, development density, and other factors. This overall water budget/nutrient budget approach is another way to consider contributions from a variety of sources that are typically categorized under stormwater impacts. The University of Rhode Island's computer MANAGE assessment method, one example of this type of approach, uses GIS and other inputs to identify environmental hotspots, develop nutrient loading estimates, and develop treatment performance standards along Rhode Island's coastal communities.

Onsite and cluster OWTS can have public health and ecological impacts on groundwater, surface waters, and people. The traditional onsite OWTS can treat many of the constituents present in residential wastewater. Domestic sewage contains high concentrations of Total Suspended Solids (TSS), 5-Day Biochemical Oxygen Demand (BOD_5), pathogens, ammonium nitrogen, total nitrogen, and total phosphorus, as well as varying amounts of heavy metals, organic compounds, pharmaceuticals, and other potentially hazardous materials.

Other wastewater constituents that can cause problems in drinking water and surface waters include the following:

- Toxic organic compounds in household chemicals can be persistent in groundwater and cause damage to surface water ecosystems and human health
- Heavy metals like lead and mercury in drinking water can cause human health problems, and when in aquatic environments they can accumulate in fish and shellfish
- Dissolved inorganics like chloride and sulfide can cause taste and odor problems in drinking water; and
- Pharmaceuticals can be persistent in groundwater and recent studies are evaluating their potential impact on drinking water and surface waters.

Plumes of contamination in groundwater have been identified from OWTS. These plumes generally migrate along the surface of the groundwater and spread slowly. A Florida study (US EPA, 2002) showed nitrate plumes from OWTS after 5 years of use that were 60 feet long, 15 feet wide, and 1.2 feet deep. Another study in an unconfined aquifer (similar to Nags Head) found that after 12 years, the contaminant plume from the OWTS had distinct boundaries with a length of 426 feet and a uniform width of about 33 feet.

The Massachusetts Septic System Test Center has been testing conventional and pretreatment technologies since 1999. A conventional leachfield in Massachusetts requires a minimum separation to groundwater of 4 to 5 feet, depending on the soil type. The results of their testing program can be found at http://www.buzzardsbay.org. For conventional systems, their testing results indicated significant reductions in BOD, TSS, and fecal coliform bacteria, and approximately 23% reduction in nitrogen.

2.4.6.2. Failing Systems

The Rules describe a system as failing if one of the following conditions exist:

1. Effluent is discharging to the surface of the ground, the surface waters, or directly into the groundwater,
2. Effluent is backing up into the building or portions of the tank above normal levels,
3. Effluent in the leachfield is within three inches of finished grade along the trench for 2 or more observations taken at least 24 hours apart,
4. The tank needs to be pumped out more frequently than once per month in order to meet other conditions.

Conditions that can cause the soil to provide poor treatment include organic overloading of the leaching system, primarily due to failure to maintain the septic tank, or hydraulic overloading. If the leaching system receives effluent at a higher rate than the soil can assimilate, contaminants can be carried through the soil without receiving adequate treatment.

2.4.6.3. Substandard Systems

Many older systems were installed before people reached a scientific understanding of how OWTS function and what soil and site requirements are needed for best system performance. These systems may “function” in the sense that they are not backing up into the plumbing or surfacing in the yard, but they do not always function properly in terms of treating the wastewater before it reaches the groundwater or surface water. Sand bottom septic tanks are one type of substandard system installed on many older properties in town. A septic tank is supposed to be a watertight container to settle out the solids and provide some treatment before discharging a relatively clear effluent. A sand bottom tank, being open at the bottom, provides questionable treatment before the effluent reaches the groundwater table, particularly in areas of town with shallow depths to groundwater. The system may never fail hydraulically, but provides little to no treatment of the wastewater.

Many existing properties may not have adequate soils and site conditions to upgrade older systems so that they treat wastewater properly. When Nags Head was first developed in the 18th and 19th centuries, sewage treatment as we understand it today was not considered.

Older tanks can leak and eventually collapse. Baffles in the septic tank can also deteriorate, allowing solids to escape into the leachfield. Older plumbing fixtures can also impact systems, since they use significantly more water than the current low flow fixtures. Older systems also tend to be undersized for today’s water use.

2.4.6.4. Impacts on Groundwater and Surface Waters

An overabundance of nutrients from human sources in surface waters can lead to the excessive growth of algae and other nuisance aquatic plans—a process known as cultural eutrophication. Freshwater lakes and ponds can be impacted by phosphorous from OWTS effluent. Coastal embayments with shellfisheries can also be negatively impacted by high nutrient loads, and can be closed to production because of high pathogen counts in the waters. While the critical thresholds for eutrophication vary with individual water bodies, guideline values that are potentially applicable to Nags Head are discussed in Section 5.1.

Impacts on surface waters used for bathing and recreation are typically monitored, and swimming areas can be closed if pathogens, such as E. coli, are reported in high numbers. New methods for monitoring recreation areas have been developed in recent years, including microbial source typing to determine what type of animal was the source for a certain bacteria and monitoring for surfactants and optical brighteners that commonly occur in laundry wastewater.

2.4.7. System Operation

System operation is completely dependent on the habits of the occupants of a building. What is dumped down the drain—cleaners, disinfectants, grease and oil, and vegetable matter—all can impact the ability of the OWTS to function. The wastewater constituents and flow times varies across the day, and across the week (particularly in resort communities).

The amount of water used in the building is also dependent on the number and habits of the occupants. Older plumbing fixtures and new fixtures designed for high flows can make a significant impact on the actual flows received by the OWTS.

2.4.8. System Maintenance

Individual onsite system maintenance is left up to the property owner to arrange.

2.4.8.1. Septic Tank Pumping

Septic tanks should be checked on a regular basis and pumped when the volume of the clear zone of the tank is less than one-third of the total volume. Effluent screens on tank outlets should be checked at least annually, and hosed down into the tank. The condition of the tank should be checked to make sure it remains watertight and the baffles are in place.

2.4.8.2. Component/Leachfield Inspections

Distribution boxes should be opened and checked to make sure the outlet pipes are level and the box is watertight. Leachfield inspections can be performed by a surface inspection looking for signs of wetness, wet plant growth, or odors. If observation ports are installed in the trenches, the presence and depth of ponded wastewater can be seen. Leachfield inspections can also identify new changes on the property, such as a new deck, which might impact the access to tanks or otherwise interfere with the system.

2.4.8.3. Alternative Treatment System Maintenance

When an alternative system is given an Operation Permit, there are requirements for obtaining and maintaining an operation and maintenance contract with an operator for the life of the system. A licensed operator inspects the system components and leachfield on a semi-annual basis. Effluent samples are taken at the treatment unit outlet, and are evaluated against the relevant performance standards (discussed further in Appendix A). The results of inspections and sampling are reported to the County Health Department and the state on a regular basis. Remedial actions are set in place if the performance standards are not met.

Innovative, experimental and controlled demonstration systems also typically include operation and maintenance contracts, inspections, and monitoring.

2.4.9. Current Permit Programs

All onsite wastewater treatment systems (OWTS) are regulated under the North Carolina Title 15A – Department of Environment, Health, and Natural Resources, Chapter 18 – Environmental Health, Subchapter 18A – Sanitation, Section .1900 – Sewage Treatment and Disposal Systems (Rules). These Rules contain the soils and site requirements, design and construction requirements, and administrative procedures.

2.4.9.1. County Administered

The Dare County Health Department administers the program in the Nags Head area. This office conducts a preliminary review of an application, conducts a soil and site evaluation, issues a denial letter when the site is denied from use, or a site approval letter stating the conditions under which the site is approved, and specifies the system type. The design is then submitted to the Health Department, and an Improvement Permit (Site Approval) is issued. Concurrently or just following, the Health Department issues an Authorization for Construction based on the system design. Once the system is installed and inspected by the Health Department, an Operation Permit is issued. The operation permit may identify the maximum number occupants in a building.

2.4.9.2. State Administered

NCDENR administers the program in Nags Head related to all systems with design flows greater than 3,000 gpd.

2.4.9.3. Town Administered

The Town Zoning Regulations require building permits once the County issues an Authorization for Construction. Once the system is constructed and an Operation Permit is issued, the town issues a Certificate of Occupancy. The zoning regulations also include information related to the density of parcels and limit the number of bedrooms in a single family residence to 8 bedrooms.

3. DATABASE DEVELOPMENT

Data from numerous sources was compiled, formatted, and imported into a relational database. This relational database structure, herein referred to as *IWIMS* (Integrated Wastewater Information Management System), has been optimized for use in managing and querying OWTS and related data. Once built, this database is easily linked with a Geographic Information System to enable mapping and analysis, and serves as the foundation for all OWTS and water quality based data analysis. The following sections discuss the incorporation of the multiple raw data sources into the IWIMS database.

3.1. Parcels and Structures

Parcel records were obtained from the Dare County Information Technology Department Web site, http://www.co.dare.nc.us/, in April of 2004. The database includes parcel address, ownership, land use, and structure information for all the parcels in Nags Head. This dataset formed the foundation of the IWIMS database developed for the Nags Head water quality and OWTS data analysis. The information contained in the Dare County parcel database was separated into information about the parcels themselves, contact information for the parcel owners, and information about the structures (buildings) on the parcel.

For the parcel information, a new data field was created to link the parcel records to a Geographic Information System (GIS) parcel layer. This new field, the "PIN_GIS" was created from the "PIN" field in parcel database, which is an identification number for the property. The "PIN_GIS" field represents the first 12 characters of the "PIN" field. The "PIN" field can be anywhere from 12 to 14 characters, with the last 2 characters utilized mostly for condominium type developments. In the original Dare County database, there were some parcels that had multiple records, the vast majority of which were government owned parcels. One record per parcel and PIN combination was created from the raw data for use in the relational database.

Two other datasets were obtained to supplement the parcel information from Dare County. The first was a data table containing the PINs for properties that use "package plants" for wastewater treatment. The second was a data table containing the PINs for rental properties, which are commonly seasonal residences. Both of these tables were obtained from the Town of Nags Head Planning Department. The following information from the Dare County database were imported to the IWIMS database Parcel table:

- Parcel ID
- PIN
- PIN_GIS
- Subdivision
- Street Address

- Owner
- Package Treatment
- Seasonal Use
- Parcel Use

Contact information for the owners from the parcel database was extracted for each parcel. In some cases, multiple records existed in the parcel database for each parcel. In these cases, the first contact encountered was assigned to the parcel. The following information from the Dare County database was imported to the IWIMS database Contact table:

- Parcel ID
- Owner
- Address

Structure information for buildings on each parcel were extracted and formatted into a table. If multiple structures were recorded on the same parcel, each structure received its own records in the database. Each structure was related to its source parcel. The following information from the Dare County database was imported to the IWIMS database Structure table:

- Parcel ID
- Baths
- Bedrooms
- Year Built
- Building Use

3.2. Onsite System Data

Data related to the conditions of OWTS were collected from several sources, including the *Septic Health Database* developed by the Town of Nags Head Planning Department, a *Permits Database* maintained by the Dare County Health Department, and an *I/A (Innovative/Alternative) Systems Inventory* developed by the Town of Nags Head Planning Department. These data were evaluated to extract information on system type and location, components of systems, system inspections, permits on systems, and system maintenance. The following describes the procedures followed in extracting data from these raw sources into a format suitable for the IWIMS database.

3.2.1. Systems

A system record in the database was created for every PIN that contained either a record in the *Septic Health Database*, in the *Permit Database*, or the *I/A Systems Inventory*. It is known that OWTS exist on other properties, however only records for systems with at least some additional information found in the raw data sources were created in the IWIMS database. The following pieces of data were extracted from the raw data sources and formatted for import into IWIMS (the raw source is listed):

- Parcel ID, from *Septic Health Database*, *Permit Database*, or the *I/A systems Inventory*
- System Type, from *I/A systems Inventory*. Assumed conventional if not found in the *I/A systems Inventory*.
- Design Flow, from *Permit Database*. If multiple permits were found, the maximum design flow was recorded for a system to account for possible system upgrades. (For about a dozen parcels, the most recent design flow permitted is less than the maximum.)
- Design Bedrooms, from *Permit Database*. If multiple permits were found, the maximum design flow was recorded for a system. As with Design Flow, this accounts for possible system upgrades.

3.2.2. Components

Onsite systems are composed of multiple components. Types of components include septic tanks, distribution boxes, leach fields, effluent filters, and many others. The IWIMS database is designed to track each system component separately. Some component information was extracted from the raw data sources. The principal types of components extracted were septic tanks and I/A components. While there was some information concerning leach trenches in the *Permit Database*, it was not complete enough to include for this study. In situations where information on a component for a system was found in both the *Permit Database* and the *Septic Health Database*, the data from *Permit Database* took precedence. The following pieces of data were extracted from the raw data sources and formatted for import into the IWIMS Component table (the raw source is listed):

- SystemID, from IWIMS System table.
- ParcelID, from IWIMS Parcel table.
- Component Type, from *Septic Health Database*, *Permit Database*, or the *I/A Systems Inventory*. The types of components extracted were:
  - Septic Tank
  - Advanced Treatment
    - Bioclere/Advantex
    - LPP
    - Peat Filter/Ecoflo
    - Peat Filter/Puraflo
    - Unspecified
- Tank Type
  - Block
  - Block-Sand Floor

    - Precast
    - Precast-Traffic
    - Unknown
- Tank Capacity

3.2.3. Permits

A permit record in the database was created for every PIN for every permit record in the *Permit Database* that contained a matching, valid PIN and was an OWTS related permit. Each permit was then linked directly to the system it is related to. The following pieces of data were extracted from the raw data sources and formatted for import into the IWIMS Permit table (the raw source is listed):

- PermitID, from *Permit Database*.
- SystemID, from IWIMS System table.
- Permit Date, from *Permit Database*.
- Permit Type, from *Permit Database*. The following types of permits were recognized:
    - New
    - Repair
    - Rewrite (addition to OWTS for increased sleeping capacity or moving OWTS to install pool or deck)
    - S-21 (addition that does not require additional sewage)
    - Unknown
- Permitee, from *Permit Database.*
- Permit Fee, from *Permit Database*.

3.2.4. Inspections

System inspections have been recorded in the *Septic Health Database* since July of 2000, during which a wealth of information was collected. The standard IWIMS Inspection table was modified to accommodate the information collected in the Nags Head inspection program. In addition, based upon the information collected during each inspection, a judgment was made as to whether the inspection constituted a "fail" or a "pass." An inspection was classified as a "fail" if one or more of the conditions were noted in the inspection:

- The tank was leaking or had a sand bottom
- The septic field was noted in poor condition
- Ponding of effluent was noted
- Soils were saturated
- General system failure

The following pieces of data were extracted from the raw data sources and formatted for import into the IWIMS Inspection table (the raw source is listed):

- SystemID, from IWIMS System table.
- Inspector, from *Septic Health Database*.
- Date Inspected, from *Septic Health Database*.
- Inspection Result (pass/fail), calculated from *Septic Health Database*.
- Evidence of Parking on Field, from *Septic Health Database*.
- Tank Leaking, from *Septic Health Database*.
- Septic Field Condition, from *Septic Health Database*.
- Ponding, from *Septic Health Database*.
- Saturated Soils, from *Septic Health Database*.
- Failed System, from *Septic Health Database*.
- Grasses on Field, from *Septic Health Database*.
- Bushes on Field, from *Septic Health Database*.
- Trees on Field, from *Septic Health Database*.
- System Maintained, from *Septic Health Database*.
- Comments, from *Septic Health Database*.
- Discussion with Owner, from *Septic Health Database*.

3.2.5. System Maintenance

System maintenance information, including repair or replacement, filter cleaning, pumpouts, and others are recorded for each system in the IWIMS database. Septic tank pumpouts were noted in some of the inspections that were recorded in the *Septic Health Database*, and these records were identified for inclusion in the System Maintenance table. The following pieces of data were extracted from the raw data sources and formatted for import into the IWIMS System Maintenance table (the raw source is listed):

- SystemID, from IWIMS System table.
- System Maintenance Type, (only pumpouts were recorded)
- Date Completed, from *Septic Health Database*.
- Gallons Pumped, from *Septic Health Database*.

3.3. Water Use Records

Municipal water use records were extracted from the Town of Nags Head databases by the Planning Department staff and provided by the Town as an ASCII text file. The raw data, collected approximately every two months basis, contained the water meter reading date and amount of water consumed for all the water accounts in the Town database from August 1999 through May 2005. For each water consumption record, the appropriate land use PIN value was determined for all matching records in the Town of Nags Head *AddressPoints* data table. This table serves as a lookup table to relate parcel IDs to PINs and water accounts. Of the 4,674 water accounts in the raw data table provided by the Town, 290 did not have a corresponding value in the *AddressPoints* data table. Since it was impossible to relate these 290 records to a location, their records were not included in the remainder of the analysis. The reason for the 290 unmatched records was explored in collaboration with Town staff. It was determined that many account numbers simply did not exist at the time the *AddressPoints* layer was created, and in other cases the account numbers had been discontinued. The water records from the remaining accounts underwent several additional steps before incorporation into the IWIMS database.

Several of the valid water accounts were associated with multiple PINs. These cases were commonly town homes or condominiums where multiple buildings (each with a different PIN) were located on adjacent properties. In order to assign water use to each individual PIN, the consumption associated with the water account number was split equally across the associated PINs. In addition, in order to calculate water use rates, the number of days between meter readings was required. A Visual Basic procedure was written to calculate this and write the results to a field in the data table. The water consumption information that was imported to IWIMS database format included the following data fields:

- Water Account
- PIN
- Reading Date
- Days since the last reading

In total, 146,492 water use records were incorporated into the database for analysis.

3.4. Water Quality Data

Analytical data from groundwater and surface water samples collected between February 23, 2001 and April 26, 2005 were gathered for this analysis. The data included 49 monitoring locations, most of which were sampled weekly. A few sample locations were discontinued or moved during the three and a half year period. The data were provided by the Town in the form of individual Excel worksheets for each sampling event. These data were converted into IWIMS format to enable efficient data extraction and analysis. The data imported for this analysis can be summarized as follows:

- 49 sample locations
- 217 sample events
- 5,586samples
- 55,531 analytical measurements

These data were broken down into three primary tables, one containing the monitoring point data, one containing the sample data, and one containing the analytical results. The data fields imported into these tables are summarized as follows:

- Monitoring Point Table
  - Well Name
  - Well Description
- Sample Table
  - Sample ID
  - Sample Date
  - Water Level (after June 2004 only)
- Analytical Table
  - Analyte
    - Ammonia
    - Fecal Coliform
    - DO
    - Field Temp
    - Nitrate
    - pH
    - Salinity
    - Specific Conductance
    - Total Phosphorus
    - Turbidity
  - Units
  - Qualifier

3.5. Geographic Information System Data

Spatial datasets covering the town of Nags Head comprised an important piece of the database developed for this analysis. These datasets enabled a GIS (Geographic Information System) assessment of the data and provided a method for displaying the results of the data collection and analysis effort. The following sections discuss the key datasets that were collected for this analysis. Some datasets that were derived for specialized purposes are discussed in other sections. Additional spatial datasets, such as roads and political boundaries, were collected and used for background and display purposes only. All datasets were obtained from the Nags Head Planning Department in shapefile format, unless otherwise specified.

3.5.1. Parcels

The parcel shapefile contained both a "PIN" and a "Parcel" attribute. Based on discussions with the Nags Head GIS specialist, it was determined that the PIN attribute represented the unique identifier for each property in the spatial dataset. Thus, the PIN attribute was chosen as the identifier used to relate information in the IWIMS database back to spatial locations throughout the study.

The raw parcel shapefile was modified to create one spatial feature per PIN value. This affected cases where a single property was split by a road or right of way. Creating a single feature for each property is important to prevent errors when calculating the numbers of properties associated with specific characteristics.

3.5.2. Subdivisions

The subdivisions shapefile contained neighborhood boundaries that were used as reference in discussions throughout the report.

3.5.3. Zoning

Zoning boundaries were to help distinguish properties in the development of the management plan options.

3.5.4. Elevation

A shapefile of LIDAR-based elevation points from was used to create a DEM (digital elevation model) of Nags Head. The LIDAR data represents surface elevations at points 10 to 15 feet apart. Elevations were not collected below buildings. A DEM was created to produce a continuous surface of elevation to assist in the determination of surface water drainage and in the estimation of depth to groundwater.

The DEM was generated using the “Topo to Raster” tool in ArcGIS 9.0. The cell size chosen for the output DEM was 10 feet. Drainage enforcement was not turned off, allowing natural and man-made depressions to be represented. The resulting DEM was clipped to the boundaries of the Nags Head parcel dataset.

3.5.5. Water Quality Monitoring Locations

A shapefile containing the locations of water quality monitoring points was created by the Nags Head Planning Department. The dataset was created by reviewing othophotography of the sites and estimating the location of the well or surface water sampling location based on local knowledge of the sites. Surveyed X-Y coordinates for the monitoring points were not available at the time of this study.

3.5.6. Onsite System Fields

Many water quality monitoring sites were located adjacent OWTS leach fields. The Nags Head Planning department digitized the approximate locations and areas of these fields using orthophotos and local knowledge of the sites.

3.5.7. Soils

A GIS dataset of soils was obtained from the NRCS (Natural Resources Conservation Service) SSURGO (Soil Survey Geographic) database. This dataset, which covers all of Dare County, contains information on soil texture, percolation rate, and groundwater depth, and many other soil characteristics for soils in Nags Head.

3.5.8. Groundwater

Spatial datasets of water table elevation and depth to groundwater were created for the town of Nags Head in order to assess effluent flow directions and general groundwater vulnerability. The primary data set used in calculating ground water elevations was from a network of 25 groundwater monitoring wells currently being sampled by the Town of Nags Head (Figure 3.2a and 3.2b). The Nags Head Woods well was omitted from this analysis because its precise location was unknown.

Water level data for most wells included weekly water levels for the entire month of June 2004; however, not all wells were measured every week. To account for natural rise and fall in the groundwater levels due to tides and precipitation, we used the average water level for each well for the entire month of June. Once the average depth to water below the measuring point on the well riser was determined for each well, the riser stick-up was subtracted (or added if the measuring point was below ground surface) to get the depth to water below the ground surface (bgs). Since the wells have not been surveyed, we assumed the measuring point for each flush-mount well was 2 inches below grade (personal communication, 2004). The depth to water bgs was then subtracted from the ground elevation at the well point, as determined by DEM described in Section 3.4.4. The result was groundwater elevation values for the 24 currently monitored points in the study area.

Due to large spatial gaps in the data set, water elevation contours were most accurately estimated by using manual triangulation methods (SOP SEI-4.15.2, 2003). The shape and elevation of the water table is well constrained in the northern part of the study area by previous data contained in a hydrogeologic analysis near Fresh Pond and Nags Head Woods (Whittecar and Salyer, 1986). The hydrogeologic analysis also provided a common measuring point, Fresh Pond, allowing us to correlate our data set with that of Whittecar (1986). Also guiding our water table estimation was the assumption that the shape of the water table under barrier islands is generally convex, with its high point near the longitudinal middle and sloping toward zero where the land meets the ocean or sound. This assumption is supported by the Whittecar (1986) data and by the June 2004 water level data.

Once the water table elevation contours were estimated, they were digitized to create a GIS shapefile of elevation contours. These contours were then interpolated to generate a continuous raster dataset using the "Topo to Raster" tool in ArcGIS

9.0. The cell size chosen for the output groundwater elevation raster was 10 feet. The resulting raster was clipped to the boundaries of the Nags Head DEM dataset. Finally, subtracting the water table elevation raster from the surface elevation raster (DEM) created a raster dataset of the depth to groundwater. The results of this calculation were evaluated by comparing the depth to groundwater values with known ponds and wetlands. Many areas where the depth to groundwater calculation showed water to be at or near the surface corresponded with ponds or wet areas identified from the orthophoto.

Additional water level data was collected from July 2004 through April 2005. Furthermore, surveys were conducted to determine the top of casing elevations for each of the wells (horizontal coordinates for the well locations were not collected). These data provided new information with which to compare the estimates of groundwater elevation based upon the June 2004 data. Average water level elevations for each monitoring point were calculated using the surveyed well elevations and the measured water level depths. These elevations were plotted on a map of Nags Head and new contours were drawn. The shape of the water table indicated by the additional water level data closely followed the shape derived from the original evaluation. However, the calculated water table elevations ranged from nearly the same as the June data to nearly 2 feet higher.

A town-wide depth to water table dataset was constructed based on an approximation of this updated water table elevation dataset. At this point, we identified an inconsistency between the updated water table elevations (based upon the survey data) and the water table depths calculated from the LIDAR-based surface elevations. The updated, survey-based water table elevation data indicated that the water table was above the ground surface over several residential regions of Nags Head. It was thus determined that the updated groundwater elevations, while representative of the specific well locations, would not be appropriate for constructing a town-wide groundwater map. There are several possible explanations for this inconsistency. The most likely explanations are uncertainty in the horizontal positions of the wells, error in the LIDAR elevations, and inconsistencies in the vertical datum between the surveyed well elevations and the LIDAR-based elevations. Ultimately, it was decided that the groundwater elevation and associated depth to groundwater map derived from the original set of June 2004 data was the most representative town-wide dataset of groundwater. This dataset was fine-tuned to be consistent with the LIDAR-based surface elevations and will serve as the most appropriate groundwater reference for assessing property-scale vulnerability to onsite system failure as a result of shallow groundwater.

Future enhancement to the groundwater dataset constructed for Nags Head would benefit most from a collection of water levels from a larger number of wells in regions of town where current monitoring locations area limited. The number and spatial distribution of the wells would be more important than the number of samples taken from each well.

4. ONSITE SYSTEM INFORMATION REVIEW

The current conditions of OWTS across Nags Head were evaluated based upon the information developed in the IWIMS database described in the previous section. The objectives of this assessment included:

- Understand the extent to which OWTS are used as a wastewater treatment option in Nags Head
- Describe the types of OWTS being used in Nags Head
- Evaluate the type of information available from Dare County permits
- Assess the results of the OWTS inspection program
- Evaluate OWTS maintenance
- Estimate OWTS performance
- Understand water use trends in comparison to system design flows

Each of these objectives is addressed in the following sections.

4.1. Wastewater Treatment Status

Understanding the extent of OWTS, the types of systems found, and the spatial distribution of systems across Nags Head will form the foundation of the development of a wastewater management plan.

4.1.1. Method of Treatment

The wastewater treatment method was estimated for every land use parcel (identified by the PIN value) found in the GIS parcel dataset for Nags Head. The goal was to classify every PIN as either being served by an OWTS, a package treatment plant, or to classify the parcel as undeveloped. Parcels were estimated to be served by an OWTS if the following information was present in the IWIMS database:

- A permit for a new system or repair was present for the parcel
- A structure with greater than zero bedrooms or bathrooms was present for the parcel
- An inspection was recorded for a system on the parcel
- The parcel had not been identified by the Town Planning Department as being served by a package treatment plant

Parcels were identified as being served by a package treatment plant if they had been identified as such by the Planning Department. All other parcels were classified as undeveloped.

Figures 4.1a and 4.1b show the distribution of OWTS and package plants across Nags Head. For this assessment, the wastewater treatment plant that serves the Villas Condominiums and discharges to the subsurface has been classified as a package plant, since it is a community system and is very different from most onsite wastewater treatment systems. The distribution of treatment methods is as follows:

- 5,358 Total properties (PINs)
- 3,753 (70%) served by OWTS
- 586 (11%) served by package plants
- 1,019 (19%) undeveloped

In addition, the figures show that the vast majority of the properties served by package plants are concentrated in Nags Head Village, with only a few additional clusters of parcels served by smaller package plants. Onsite systems represent the most frequently used wastewater treatment method, with 86% of the developed properties.

4.1.2. Types of Systems

The type of OWTS, in conjunction with the type of use it serves, reveals a great deal concerning how that system may impact the environment. Systems with innovative or alternative (I/A) technologies will, in many cases, leave less of an impact of environmental quality than conventional systems. Furthermore, OWTS serving commercial properties will often receive heavier use than systems serving residential properties.

The Town of Nags Head Planning Department identified parcels served by I/A systems. Parcels with uses other than residential were identified based on the parcel use code from the parcel database. The distribution of these systems is shown in figures 4.2a and 4.2b. The types of OWTS in Nags Head break down as follows:

- Residential (conventional): 3,435 systems (92%)
- Residential (I/A): 118 systems (3%)
  - Bioclere/Advantex: 3 systems
  - Peat Filter/Ecoflo: 13 systems
  - Peat Filter/Puraflo: 44 systems
  - LPP: 35 systems
  - Unspecified: 23
- Non-residential (conventional): 168 systems (4%)
- Non-residential (I/A): 32 systems (1%)
  - Bioclere/Advantex: 2 systems
  - LPP: 22 systems
  - Unspecified: 8

The overwhelming majority of systems in Nags Head serve residential properties and are conventional systems. Only 5% of the total systems are for non-residential use. In total, 4% of the parcels are served by I/A type systems. This suggests that while the main focus of the wastewater management plan may be on conventional, residential type systems, attention should also be given to I/A systems (since use of these systems is increasing over time and they are often utilized in areas with site limitations or to increase allowed design flows) and to non-residential systems.

4.2. Onsite System Age

The age of onsite systems is an important indicator of its potential performance. Several aspects of age contribute to how well a system performs. First, different regulations were in effect during different time periods. Systems built more recently, i.e., under newer regulations, incorporate advances in understanding of design and construction of OWTS. Second, as any set of systems ages, the systems will tend to fail—at higher rates if they are not properly maintained. The ages of systems were estimated based on several different sets of information. These methods are described in the following sections.

Permit information was available for permits recorded after 1998. This information was used to identify when new systems were installed or repairs made, the design flow of systems, and the types of systems. For the purposes of estimating system age, the date of the most recent repair or new construction permit was assigned to the age of that system. The reason for including dates of repair permits is that after the repair has been made, the system should be operating according to current regulations of the time period. Ages for systems on 1,200 PINs were identified directly from permit data. System age information from permit information was not available for systems on 2,553 PINs. For these PINs, system age was assumed to be the same as the "actual year built" of the most recent structure with bedrooms or bathrooms on the property. The ages of 5 systems identified from the inspection program were unknown.

The distribution of systems age is shown in Figure 4.3a and 4.3b. The ages of the systems have broken into the five eras. The dividing points for the eras are based on significant milestones for OWTS management in Nags Head. The years corresponding with these milestones are as follows:

- 1975: Approximate time when sand-bottom tanks were phased out
- 1979: North Carolina State Regulations came into effect
- 1994: Maintenance requirements begin for all non-conventional systems (LPP systems and those > 3000 gpd)
- 1999: Effluent filters required

The number of systems within each age group is as follows:

- ≤ 1975: 616
- 1976 – 1978: 271
- 1979-1993: 1,285
- 1994-1998: 332
- 1999-present: 1,241

The vast majority of systems (76%) were built after the establishment of state-level regulations. A significant number of systems (33%) were built since effluent filters were mandated in 1999.

4.3. Onsite System Inspections

An onsite system inspection program was initiated as part of the Septic Health Initiative by the Nags Head Planning Department in the summer of 2000. This inspection program has both heightened awareness of proper onsite system maintenance among town residents and helped to initiate improvements to poorly performing systems. The results of the inspection program and the actions taken as a result of the program will be discussed in this section.

4.3.1. Inspection Program Results

Over 1,000 systems (nearly a third of all systems) have been inspected. Figures 4.1a and 4.1b show the locations and results of OWTS inspections as part of the Nags Head Septic Health initiative between July 2000 and early May 2005. The figures show that inspections have been well distributed across all neighborhoods of Nags Head that rely upon OWTS. For each property, only the most recent inspection is reported. Each inspection was classified as either a pass or fail. Of the 1,009 systems (inspected on 1,082 properties) having been inspected, 16% were classified as "failing." Each system was judged to have failed for one or more reasons. Sand bottom septic tanks and leaky septic tanks were included as failed systems, since these components are not properly functioning. A non-watertight septic tank may never fail to the surface or back up into the building, but may be providing inadequate treatment and potentially be hydraulically connected to the groundwater table.

The number of occasions a particular reason for system failure was noted is summarized as follows:

- Sand Bottom Tank: 59 systems
- Leaky Tank: 95 systems
- Saturated Soils: 40 systems
- Effluent Ponding: 30 systems
- Septic Field Failing: 167 systems
- General System Failure: 132 systems

The trend in the inspection results over time is shown in Table 4.1.

The percentage of inspected systems classified as failed varies from 10% to 26%. As would be expected for an inspection of a sample of systems ranging from very recently built to over 30 years old, there is no apparent trend in the percentage of systems that failed inspection over the time of the program. The total number of inspections peaked in 2002, though the data for 2005 are not complete.
Part of the objective of the Septic Health Inspection program is to identify failing systems and take action to improve their performance. By reviewing the permits filed with the Dare County Health Department, we can identify which properties with failing systems were repaired or replaced. Inspections identified 182 systems on 177 properties as failing; some systems failed inspection more than once, which is why the total number of failures in Table 4.1 is 204. Of these, 58 systems received repairs or upgrades after a failed inspection was reported. This represents 31% of the systems that had been identified as failing. The status of the remaining 124 systems is unknown. Additional investigation and/or follow-up should be performed to determine what has happened to these systems.

4.3.2. Estimation of System Performance

The performance of OWTS can be estimated by combining the information from the inspection program and the permit database. A system is assumed to be performing poorly if an inspection indicated a failure and no repair or upgrade work was performed. A system is assumed to be performing acceptably if it meets one of several criteria:

- A failed inspection occurred and was followed by a new or repair permit,
- The system's most recent inspection passed, or
- A new or repair permit was filed between 1998 and 2004 (The permit database has data from 1998 forward). System performance was not estimated for systems without inspection data or without permit data since 1998.

Figures 4.4a and 4.4b show the estimated system performance based upon the assessment from the permits and the inspections. In total, 119 properties are estimated to have poorly performing systems. Another 1,907 properties are estimated to have acceptably performing systems. The performance of the systems on the remaining 1,724 properties served is unknown. The ranking of a system's performance is based upon the inspection results, whether or not a repair was performed, as well as the system age. It is likely that the percentage of poorly performing systems out of the 1,724 "unknown" properties would be similar to the percentage of inspections that resulted in failures. If this is the case, we can estimate that on the order of 6% (or 103 of the 1,724 unknown properties) are likely to be performing poorly. Evaluation of other aspects of these systems, such as depth to groundwater and water use, may help in the estimation of their performance. This type of approach will be addressed in later sections.

4.4. Onsite System Maintenance

Proper maintenance of onsite systems is critical to their proper performance. Systems that operate for extended periods without pumpouts or without necessary repairs will have a negative impact of the environment. As part of the Septic Health Inspection program, basic system maintenance was performed on some systems. This information is discussed in the following sections.

4.4.1. Septic Tank Pumpouts

Septic tank pumpouts have been recorded as part of the Septic Health Inspection program, when the pumpouts have been performed at the time of the inspection or as a result of the inspection. These records indicate that 932 systems on 925 different properties have been pumped at least once since the inspection program began in the summer of 2000. Some of the systems have been pumped more than once in that time period. The breakdown of the number of pumpouts per system is as follows:

- 6 pumpouts: 1 system
- 3 pumpouts: 7 systems
- 2 pumpouts: 69 systems
- 1 pumpout: 848 systems

Systems that were pumped out during the 2000 – 2004 period but not as part of the Septic Health Inspection program were not recorded. Furthermore, information on pumpouts before 2000 was not collected. Figure 4.5a and 4.5b show the locations of system pumpouts and the number of times the system has been pumped during the past 5 years. This data indicates that 25% of properties with OWTS are known to have had pumpouts in the past 5 years. A management plan that incorporates regular system pumpouts based upon system characteristics should be considered.

4.4.2. System Repairs

The Dare County Health Department's permit database contains information on permits issued for OWTS repairs. Some of these permits for repairs were initiated based on results of the Septic Health inspection program, while some were initiated independently. Repair permits were classified as follows:

- Repair permit issued after a failed inspection: 55 systems
- Repair permit issued after a passed inspection: 57 systems

- Repair permit issued before an inspection or without an inspection: 405

Most repairs were unconnected with an inspection. However, the repairs data go back to 1998, and the inspections began in 2000. Only 22% of repairs occurred after an inspection occurred, and only 11% after a failed inspection. It is possible that repairs were made after a passed inspection, because the repair occurred significantly after the inspection, or that while the system passed, a repair was suggested to reduce the possibility of future failure. It is also possible that some of the repair permits were for system upgrades or increases in design flows, and were unrelated to inspections or system failures.

4.5. Water Use and Onsite Systems

Water usage is an important indicator of the stress put on an onsite system. Onsite systems are built to be able to accommodate a specific "design flow". If inputs to the onsite system regularly exceed the design flow, then the system performance is reduced and failures become more likely. The following sections will evaluate parcel level water usage and how it compares with system design flows.

4.5.1. Water Use Trends

4.5.1.1. Multi-year Trends

Total water use in Nags Head for the years of 2000 through 2005 is shown in Figure 4.6. The water use shown represents the totaled yearly water use for all properties that could be matched with water account numbers. Approximately 2% of the water accounts could not be matched with property Ids, and are not included in this analysis. Water use in Nags Head has experienced an increase of approximately 12% between 2000 and 2004. This increase in water use may be related to an increase in population, however recent population data was unavailable for comparison. The change in water use associated with properties using OWTS shows a slightly smaller 9% increase over the same period. In total, water use on properties with OWTS accounts for 80% of the total water use in the town. This is slightly less than the 86% of developed properties that are served by OWTS, suggesting some of the heaviest water users are served by package treatment plants.

4.5.1.2. Seasonal Trends

The average water use rate for each month was estimated from the water use records. The water use in each month for each property was made based on the following assumptions:

- Water use rate was calculated as the total gallons used during a billing period divided by the number of days in that billing period.

- The month represented by each billing cycle was determined by identifying the month corresponding to the midpoint of the billing cycle.

In order to identify the monthly patterns in water use, the average use rate for all properties reported in a given month were calculated. The average monthly use rates were then normalized by the highest use rate found in any one month. This results in the month with the highest average use rate receiving a value of 100% and all other months receiving a value from 0 to 100% of that "peak" monthly use rate. If use rates were consistent throughout the year, all months would have a value equal to 100%. The results of this analysis are shown in Figure 4.7. The monthly average use rates were calculated for each month data was available (late 1999 – mid 2005). This figure shows a clear peak in water use in the summer and early fall, followed by a sharp decline during the mid fall through late spring. The water use rate during February is only 25% of the peak months.

A similar analysis was done on a seasonal basis to smooth out some of the variability seen in individual months. This analysis, shown in Figure 4.8, indicated that the January through March and October through December periods experience water use that is less than 50% of the use rates experienced during the summer early fall peak of July through September.

The high use rates in the summer and early fall are a result of several factors:

- Greater population due to seasonal population increase
- Higher use for irrigation and pools/ spas

The period of higher water use corresponds with the months when OWTS are at most risk of being overstressed, if most or all of the water is going through the OWTS. Water used for irrigation is unlikely to affect system performance, unless it is applied excessively on the leach field itself. An assessment of how these periods of increased water use correspond with OWTS performance will be discussed in Section 7.

4.5.1.3. Variability By Property Use

Water use rates can vary significantly by property use type. Commonly, water use will be higher for non-residential properties such as restaurants and hotels than for single family residential properties. OWTS for these properties are designed to accommodate these higher use rates. However, the variability in use rates, both monthly and seasonally, between residential non-residential properties might indicate if different strategies are required for these different uses. Figure 4.7 shows the monthly trends in average water use rates for residential and non-residential properties. The pattern in monthly use rates is similar, with non-residential properties showing a little more variability from month to month (such as increases in September and November). In addition, July use for non-residential properties is 18% greater than the next highest month (September), while for residential properties, June, July, and August use rates are nearly the same.

The higher variability in non-residential water use as well the more dramatic spike in mid-summer is likely due to the large influx of visitors that stay at hotels and motels and those that come out to Nags Head for day trips to eat at local restaurants. This data suggests that special management of non-residential OWTS may need to focus on the high use issues during the peak visitor periods. As shown in Figure 4.8, when aggregating to a seasonal level, water use patterns for both residential and non-residential properties are nearly identical. This suggests that while non-residential use rates are more variable intra-seasonally than residential properties, they are all similar inter-seasonally.

4.5.2. Water Use Compared to Design Flow

Water use above OWTS design flows can lead to poor effluent treatment and ultimately system failure. The analysis of water use trends showed that water use in Nags Head varies considerably over the year. If there are periods when OWTS are being stressed as a result of excess water use, these are most likely to occur for a limited period of time during the summer and early fall. The following sections will evaluate the water use and design flows in more detail.

4.5.2.1. Timing of Peak Water Use Periods

The previous discussion on seasonality of water use rates showed that water use varies considerably over the year. That analysis showed clearly that the highest amount of total water use occurs during the summer. In order to assess the timing of peak water use on a property-level basis, the month during which the highest water use occurred for each property was identified. The month representative of a property's highest use period was determined by determining the month corresponding to the midpoint of the billing cycle. The distribution of which months coincide with the maximum water use period is shown in Figure 4.9. The figure separates residential and non-residential properties, similar to previous figures. This figure shows an even more pronounced seasonality than the seasonality in the total average water use shown in Figure 4.7. For residential properties, 64% percent of the properties have had their highest water use period occur during the months of June through August. For non-residential properties, 51% of properties had their highest use period during that same period, however 38% of all non-residential properties saw their highest water use occur during July. This data corresponds well with conclusions from Figure 7 that July is an especially high water use periods for non-residential properties.

4.5.2.2. *Frequency of Water Use at or Above Design Flow*

Many properties experience periods where their water use is greater than what is sustainable by the system or systems on that property. When a system has an average loading of greater than 75% of the design flow in readings made monthly or less frequently, it is a good sign that the daily loading has exceeded design flow for at least part of that period. Since meters are read approximately every two months in Nags Head, for the purposes of this discussion, a measured flow at 75% of design flow will be referred to as "sustainable flow". In order to evaluate the frequency at which this occurs, the number of billing cycles during which the average daily water use rate was higher than the sustainable flow of the OWTS was determined. The data used for this analysis was from August 1999 through May 2005.

Figure 4.10 shows a graph of the frequency of water use billing cycles during which water use is above sustainable flow of the OWTS. The figure indicates that 31% of the properties never exceed this level. Nearly 27% of the properties have exceeded the sustainable flow but only do so during less than 10% of the billing cycles. Approximately 20% of properties exceed design flow more than 25% of the time. Table 4.2 shows how the frequency of sustainable flow exceedance varies for residential, non-residential, seasonal, and year-round properties. The data shows that non-residential and seasonal properties more often exceed design flows than residential and year-round properties.

4.5.2.3. *Magnitude of Water Use At Or Above Design Flows*

The magnitude of water use relative to design flows was assessed to identify the degree to which specific properties are exceeding the design flows of their onsite systems. Rather than take the water use from the single worst 2-month period during the last 5 years, the water use rate during the highest period in each of the past 5 years was averaged. This was done to smooth out any anomalies in the use patterns that may have only occurred for a single year. This average annual maximum use rate was then represented as a percentage of the property's onsite system design flow. A map showing the distribution of water use as a percentage of design flow is shown in Figures 4.12a and 4.12b.

Although approximately 50% of properties using OWTS exceeded design flows at least one billing cycle during the five years analyzed, only 19% exceeded design flows when the highest flow billing cycles were averaged over five years (Figure 4.12a and 4.12b). Almost half of those properties, 9% of all systems, exceed their design flow by more than 50%. Another significant number of properties (579) operates in the range of 75% - 100% of their design flows for a 2-month period every year. These properties likely exceed their design flows for some period of time during their peak 2-month period, suggesting that there are occasions when they are not performing at desired levels.

The variability in peak water use rates by property use type is shown in Table 4.3. These data show that non-residential and seasonal properties are more likely to have peak water use rates that exceed their OWTS design flows. For example, 21% of seasonal residential properties have peak use rates above 100% of design flows, while 11% of non-seasonal properties have peak use rates above 100% of design flow. Furthermore, 72% of all non-residential properties have peak water use rates above 100% of design flows, while 16% of all residential properties have peak water use rates above 100% of design flows. This data is also presented in Figure 4.11. The magnitude of the water use above design flows for the non-residential properties particularly stands out in this figure.

The water use characteristics described in this section are important in understanding the impact that excessive water use has on OWTS performance and the impact on water quality. This analysis also serves as a component for developing a management strategy that accounts for different patterns of water use.

4.6. Summary and Conclusions

Conditions related to OWTS throughout Nags Head were evaluated to identify town-wide trends, and identify any possible areas for concern. Onsite systems are by far the predominant method for wastewater treatment in Nags Head, with 86% of the developed properties relying upon them. The vast majority of these systems (95%) serve residential properties. Furthermore, conventional OWTS are much more common than innovative/alternative systems in Nags Head, which make up only 4% of all systems. This distribution of system types suggests that the Decentralized Wastewater Management Plan should focus heavily on addressing the needs of residential properties with conventional OWTS.

The age of systems in Nags Head varies widely. The approximately 24% of properties built before 1979, when modern state regulations came were phased in, warrant the most immediate management attention. These properties may be candidates for replacements, repairs, or a more intensive management program. The 33% built after 1999 have been based on the most current guidelines for OWTS construction, and while unlikely candidates for replacement, may still require active management. The conditions of the systems on the remaining 43% of properties will vary considerable based upon maintenance history, and local hydrogeological conditions. These other factors will play important roles if defining management strategies for systems in the middle age categories.

The voluntary OWTS inspection program in Nags Head has resulted in approximately 29% of OWTS being inspected over the past 4 years. Of the systems inspected, approximately

16% were classified as failing. A significant proportion of these failing systems were found to have sand-bottom tanks. The permit data suggested that nearly 70% of the properties classified as failing did not have repair or upgrade permits filed. This should be investigated further. Requirement for obtaining repairs for failing systems in a timely manner should be considered as part of the Decentralized Wastewater Management Plan. In addition, the condition of nearly 70% of system is uncertain. Adoption of inspection requirements is an option to consider as part of the Decentralized Wastewater Management Plan.

A significant number of OWTS had their tanks pumped as part of the OWTS inspection program. Since pumpout records are unavailable for properties not participating in the voluntary inspection program, it is difficult to characterize the town-wide system maintenance patterns. However, given that nearly 85% of the systems that were inspected had their tanks pumped, it is likely that many other system's tanks are in need of pumping. Regular tank pumpouts should be considered as a component of the Management Plan. Repair permits suggest that some systems received repairs directly as a result of the voluntary OWTS inspection program. However, a significant number of repairs occurred unrelated to the inspection program. These are likely due to obvious failures, such as effluent surfacing or unpleasant odors that lead homeowners to take immediate action. The frequency of such catastrophic system failures would be significantly reduced under a management plan that requires regular inspections and maintenance.

Water use is closely tied to the performance and effectiveness of OWTS. Systems are designed to handle a specific amount water input. When this level of water input is exceeded, performance declines. Water use in Nags Head is highly seasonal, with peak use rates occurring during the summer and early fall months. The timing of the absolute highest use rate is commonly July. For non-residential properties, nearly 40% of the properties have their highest water use in July. In a typical year, the peak 2-month use rate will exceed a critical threshold of 75% of design flow for 35% of all the systems in Nags Head. It is much more common for both non-residential and seasonal use properties to exceed their design flows. Non-residential and seasonal use properties also spend a greater percent of the year using water at rates above the design flows for their OWTS. These data all suggest that excessive water use must be monitored as part of a comprehensive Decentralized Wastewater Management Plan. The seasonal use properties, where designated occupancy rates are often exceeded, as well as non-residential properties such as hotels and restaurants, may require more targeted water use reduction strategies.

5. WATER QUALITY IN NAGS HEAD

The Town of Nags Head is fortunate to have a variety of highly valued water resources, including groundwater, Fresh Pond, Roanoke Sound, and the Atlantic Ocean. Protecting these water resources is a key element of the wastewater management program. As part of its Septic Health Initiative, the Town instituted a detailed Water Quality Testing Program in 2001 that continues to this day and has collected tens of thousands of results throughout the study area. The first part of this section describes the water quality characteristics evaluated during this program that are most likely to indicate an impact from OWTS on groundwater or surface water quality, and describes applicable standards and guidelines for each of these characteristics. The results of the sampling program, along with a description of historical water quality near Nags Head and current water quality testing conducted by the Town of Nags Head Water Department at Fresh Pond, are described in the sections that follow. The relationship between weather patterns, particularly precipitation, and water quality in Nags Head is also discussed generally in Section 5.6.2. The Water Quality Monitoring Program results are an important part of the basis for the overall assessment of impacts of current wastewater management practices on water quality that is performed in Section 6 of this report.

5.1. Water Quality Characteristics, Standards, and Guidelines

A first step in assessing and managing water quality as part of a wastewater management program is understanding what parameters are most indicative of wastewater impacts, what concentrations are associated with "healthy" water quality conditions, and what concentrations indicate "compromised" conditions. This process can be complicated due to factors such as varied or uncertain background conditions, and other non-wastewater sources of these parameters (e.g. stormwater). For the purposes of this study, the following parameters are considered potentially indicative of wastewater impacts: bacteria, phosphorus, nitrogen, nitrate, ammonia, and dissolved oxygen (DO) (Section 2.4.6). The subsections below present a general overview of these five parameters, develop the rationale for using each parameter as an indicator of impacts from OWTS on water quality, and identify applicable standards and guidelines for each of the Town's waters.

5.1.1. Bacteria

Pathogenic microorganisms found in domestic wastewater include a number of different bacteria, viruses, protozoa, and parasites that can cause a wide range of gastrointestinal, respiratory, and other diseases (US EPA, 2002). The normal operation of OWTS results in the retention and die-off of most pathogenic indicator bacteria within 2-3 feet of the bottom of the disposal field (US EPA, 2002). Onsite systems that are not properly sited, designed, installed, and/or maintained can result in the introduction of potentially pathogenic bacteria into groundwater or surface waters, particularly where disposal fields are sited too close to the water table or to seasonal high groundwater levels. Once bacteria reach the groundwater, they have been observed to survive for considerable lengths of time (7 hours to 63 days) and to travel 100 feet or more from the disposal field (US EPA, 2002). Besides OWTS, bacteria can also enter groundwater and surface water from stormwater and agricultural runoff, natural sources such as wildlife or pets, and (in surface waters) boats that dump sewage.

Total coliform is a widely used indicator bacterium for characterizing the presence and magnitude of a contamination condition, especially with respect to water supply impacts. In a drinking water supply, the presence of total coliform is an indicator that some type of foreign material is present in the water. Fecal coliform bacteria, a subset of total coliform bacteria, are a group of bacteria found in the intestinal tract of mammals and enter the environment from the feces of mammals. This group of bacteria is a commonly used indicator of bacterial pathogens in water.

Fecal coliform bacteria levels are used as a water quality standard in many places, including in North Carolina. The standards applicable to Nags Head and associated background conditions include the following:

- Groundwater: The federal drinking water standard for total coliform bacteria (including fecal coliform and E. coli) is 0 MPN/100 mL (US EPA, 2004). Although groundwater is currently not a drinking water source for the Town, this is a potentially applicable standard. Fecal coliform concentrations in groundwater near OWTS can be compared to concentrations in undeveloped areas to help determine whether the OWTS is impacting groundwater quality. Based on the Town's water quality sampling program results, background coliform concentrations for groundwater are between <1 and 4 MPN/100 mL (5.6.3).
- Roanoke Sound: Since there are shellfishing areas in the sound, a potentially applicable standard is the Class SA (shellfishing) of 14 MPN/100 mL (MPN = Most Probable Number), based on median value. No more than 10% of fecal coliform samples may exceed 43 in areas most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions (NC DENR, 2003). There are currently no data available indicating background concentrations of fecal coliform in the Sound against which the Town's water quality sampling program results could be compared to help determine impacts or changes over time.
- Open ocean and fresh surface waters: These water resources fall into Class B/SB (primary recreation, fresh and tidal salt water), where the standard is not to exceed a geometric mean of 200 MPN/100 mL based on at least five consecutive samples examined during any 30 day period, and also may not

> exceed 400 MPN/100 mL in more than 20% of the samples examined during such period (NC DENR, 2003). There are currently no data available indicating background concentrations of fecal coliform in the open ocean, against which the Town's water quality sampling program results could be compared to help determine impacts or changes over time.

Table 5.1 presents a summary of the potentially applicable water quality standards and guidelines for each of the selected parameters and each of the Town's water resources.

The standards listed above will be used in the discussion of the water quality sampling program results later in this report (Section 5.6), as this sampling program collected an extensive dataset of fecal coliform results. We recommend that the Town begin sampling for Enterococcus in addition to fecal coliform bacteria. In 2003, North Carolina began using enterococcus as the indicator bacterium for water quality testing at all beaches, including those in Nags Head. Fecal coliform is still used as an indicator organism for shellfish-growing waters; the Food and Drug Administration regulates this standard, while the US EPA regulates recreational water quality. Beaches in North Carolina are classified as Tier 1 (high usage), Tier 2 (less frequent use, low accessibility), and Tier 3 (low usage). North Carolina Department of Environment and Natural Resources (NC DENR) staff test Tier 1 sites weekly from April to October. All ocean beaches, including those in Nags Head, are Tier 1 sites, while the soundside accesses and beaches are generally Tier 1 or 2. Swimming advisories are posted for Tier 1 sites upon single-sample exceedances of EPA's recommended standard (104/100 ml of water) or for exceedances of EPA's recommended geometric mean standard of 35/100 ml out of 5 samples taken within 30 days. Tier 2 sites are tested twice monthly, and advisories are only issued for Tier 2 sites when enterococcus concentrations exceed 276/200 ml of water.

5.1.2. Phosphorus

Phosphorus is a component of wastewater effluent from OWTS. Concentrations of total phosphorus in septic tank effluent usually range from 5 to 15 mg/L (US EPA, 2002). Monitoring below the disposal fields of OWTS has shown that the amount of phosphorus that reaches groundwater depends primarily on soil characteristics, the thickness of the unsaturated zone through which the wastewater percolates, the loading rate, and system age (US EPA, 2002 and references therein). Fine-textured soils with significant iron, aluminum, or calcium concentrations, well-separated from surface waters, generally have the greatest capacity for treating phosphorus from OWTS. Conversely, the risk of phosphorus contamination from OWTS is greatest in areas with coarse soils close to surface waters without significant iron, aluminum, or calcium concentrations.

Phosphorus is an essential nutrient for aquatic plants and algae. It occurs naturally in water and is often the limiting nutrient in freshwater aquatic systems. Excessive phosphorus inputs can stimulate the growth of algae and diatoms, causing periodic algal blooms. Sources of phosphorus besides OWTS include soil, disturbed land, wastewater treatment plants, and runoff from fertilized lawns or impermeable areas. Phosphorus is often sorbed to soil particles; thus, phosphorus concentrations can increase greatly during rains where surface runoff is a problem.

Total phosphorus is the measure of all the chemical forms of phosphorus in a system. Total phosphorus includes dissolved orthophosphate, phosphorus bound to particulate materials, and phosphorus locked up biologically in algae and bacteria. Most particulate-bound phosphorus is not readily available to plants, algae and bacteria. However, between 15% and 40% of this particulate-bound phosphorus will eventually become chemically available to organisms as orthophosphate.

There is no legal water quality standard, but it is generally accepted that total phosphorus levels must be below about 0.10 mg/L to prevent eutrophication in freshwater systems (US EPA, 1986). The monitoring program for the only phosphorus-related Total Maximum Daily Load (TMDL) in North Carolina observed median total phosphorus concentrations between 0.09 and 0.15 mg/L (NC DENR, 2003); these data generally support the 0.10 mg/L guideline. Therefore we will use this guideline for comparison to surface water phosphorus concentrations in Nags Head. There are no data available that show background concentrations of total phosphorus in the ocean or the Sound near Nags Head.

There are no standards for total phosphorus in groundwater or drinking water, and this nutrient is not known to have adverse health effects for animals or humans. Total phosphorus concentrations in groundwater near OWTS can be compared to concentrations in undeveloped areas to help determine whether the OWTS is impacting groundwater quality. Based on the Town's water quality sampling program results, background total phosphorus concentrations for groundwater are between <0.01 and 0.3 mg/L (Section 5.6.3). Table 5.1 summarizes the total phosphorus ranges and guidelines used for comparative purposes later in this report.

5.1.3. Nitrogen

Nitrogen species in groundwater are a result of percolating water containing residual nitrogen typically derived from a variety of sources, including atmospheric deposition, decomposition of organic matter, fertilizer, stormwater, leaking sanitary sewers, animal wastes, and sewage discharges to land, including those from OWTS.

Total nitrogen is the sum of all nitrogen species present, including ammonia-nitrogen and organic nitrogen (reported as Total Kjeldahl Nitrogen or TKN), nitrate-nitrogen and nitrite-nitrogen. Water quality samples collected for the Town's water quality monitoring program were analyzed only for nitrate-nitrogen and ammonia-nitrogen. The water quality standard for nitrate-nitrogen is 10 mg/L as nitrogen (US EPA, 2004). This standard is established for the protection of drinking water uses and does not necessarily protect recreational waters or aquatic habitat quality.

Nitrogen is present in high concentrations in raw sewage and in septic tank effluent. In septic tanks, nitrogen occurs primarily as ammonium nitrogen (75-80%), with organic nitrogen making up the remainder. Nitrogen does not occur or remain in the nitrate form in septic tanks due to the anaerobic environment that readily consumes the oxygen associated with nitrate molecules. Total nitrogen concentrations in septic tank effluent vary typically from about 20 mg/L to more than 100 mg/L (US EPA, 2002 onsite manual). The mass loading of nitrogen is determined by the type of facility and degree of use (e.g., population). The resulting concentration of nitrogen in wastewater effluent can also be influenced by the amount of water used.

5.1.3.1. Nitrate

Like phosphorus, nitrate is a nutrient that can contribute to excessive algal growth. In addition, nitrate is highly toxic to infants and the unborn causing inhibition of oxygen transfer in the blood stream at high doses. This condition is known as "blue-baby" disease and is the basis for the 10 mg/L national drinking water standard. Sources of nitrate include wastewater treatment plants, OWTS effluent, and runoff from fertilized lawns and impermeable areas.

Nitrate is not found in septic tanks, but it is commonly found in high concentrations in the oxidized effluent from OWTS, as well as in fertilizer. In properly operating OWTS, virtually all of the organic nitrogen and ammonia in septic tank effluent is converted to nitrate during percolation through the unsaturated soil zone. Conversion to nitrate is also achieved where the system includes an aerobic treatment process prior to dispersal to the receiving environment. Nitrate is a stable anionic species and moves readily through the vadose (unsaturated) zone, ultimately reaching the groundwater below. Within the groundwater and, to some extent, during percolation through the vadose zone, nitrate can be reduced to nitrogen gas and released to the atmosphere by a microbial process called denitrification. The process of denitrification requires anaerobic (low oxygen) conditions and a source of carbon in the saturated soil or groundwater environment.

As stated before, the national nitrate-nitrogen water quality standard for drinking water (usually groundwater) protection is 10 mg/L as nitrogen. Nitrate concentrations in groundwater that are consistently greater than 50% of this standard (5 mg/L) may be considered an "action level" (US EPA, 2004). At this level, if a groundwater resource is to be protected as a water supply source, some action should be taken to ensure that nitrate levels do not continue to increase. Nitrate concentrations in groundwater near OWTS can be compared to concentrations in undeveloped areas to help determine whether the OWTS is impacting groundwater quality. Based on the Town's water quality sampling program results, background nitrate concentrations for groundwater are between <0.01 and 0.3 mg/L (Section 5.6.3).

The drinking water standard for nitrate does not necessarily protect surface water aquatic habitats or recreational uses. Based on a review of historical data (Section 1.2) and on monitoring data from recent nutrient TMDL development efforts in North Carolina (NC DENR, 2001; NC DENR, 2004), a nitrogen guideline value of 0.4 mg/L or less for surface water is potentially applicable. This guideline will be used for comparative purposes for both nitrate and ammonia in surface waters in the following sections of this report. Table 5.1 summarizes the nitrate concentration ranges, standards, and guidelines used for comparative purposes.

5.1.3.2. Ammonia

In a developed area such as Nags Head, likely sources of ammonia in groundwater include fertilizer applications, stormwater infiltration, sediments, or discharges from OWTS where there is insufficient exposure to aerobic soil conditions to allow the ammonia to be nitrified, i.e., oxidized to nitrate. The normal ambient level in fresh water is approximately 0.10 mg/L or less (US EPA, 1986). Elevated levels of ammonia can be toxic to fish. Although the actual toxicity depends on the pH of the water and on water temperature, ammonia levels lower than 1.0 mg/l in summer and 2.0 mg/l in winter are considered adequate to protect sensitive fish. Waters with low oxygen concentrations that are polluted with nitrogen-rich organic matter may show high ammonia levels and low nitrate levels. Where waters are more oxygen-rich, ammonia will more quickly oxidize to nitrite and nitrate.

There are no standards for ammonia in groundwater or drinking water. Ammonia concentrations in groundwater near OWTS can be compared to concentrations in undeveloped areas to help determine whether the OWTS is impacting groundwater quality. Based on the Town's water quality sampling program results, background ammonia concentrations for groundwater are between <0.1 and 0.3 mg/L (Section 5.6.3). Although there is historical information available about ammonia concentrations in Roanoke Sound (Section 5.2, Table 5.2), the analysis method used was able to detect much lower ammonia concentrations than the method used during the Town's water quality sampling program. Thus, ammonia concentrations measured in the surface waters near Nags Head under the current monitoring program are not necessarily directly comparable to historical background levels in the sound. Table 5.1 summarizes the ammonia ranges and guidelines used for comparative purposes later in this report.

5.1.4. Dissolved Oxygen

Dissolved oxygen (DO) is a measure of the amount of oxygen contained in water. A specific range of DO values define the living conditions for aquatic organisms that require oxygen. Oxygen has limited solubility in water, usually ranging from 6 to 14 mg/L for surface waters (Connell and Miller, 1984). Dissolved oxygen concentrations reflect an equilibrium between oxygen-producing processes (like photosynthesis) and oxygen-consuming processes (like aerobic respiration or nitrification), and the rates at which DO is added to and removed from the system by atmospheric exchange and hydrodynamic processes (Connell and Miller, 1984). Groundwater generally has low DO concentrations because it has very limited contact with the atmosphere.

Most aquatic organisms require oxygen in specified concentration ranges for respiration and efficient metabolism, and DO concentration fluctuations above or below this range can be harmful. Even short-lived anoxic or hypoxic events can cause major "kills" of aquatic organisms. The death of immobile organisms and avoidance of low-oxygen conditions by mobile organisms can also cause changes in the structure and diversity of aquatic communities. In addition, if DO becomes depleted in bottom waters (or sediment), nitrification, and therefore denitrification, may be terminated, and phosphorus and ammonium may be released from the sediment to the water column. These recycled nutrients can give rise to or reinforce algal blooms. Ammonia and hydrogen sulfide gas, also the result of anaerobic respiration, can be toxic to benthic organisms and fish assemblages in high concentrations (Connell and Miller, 1984).

There are no standards for DO in groundwater or drinking water. DO concentrations in groundwater near OWTS can be compared to concentrations in undeveloped areas to help determine whether the OWTS is impacting groundwater quality. Based on the Town's water quality sampling program results, background DO concentrations in groundwater are between 0 and 3.0 mg/L (Section 5.6.3).

The US EPA recommends a DO criterion of 4.8 mg/L for coastal waters in the Virginian Province, which is defined as Cape Cod, MA to Cape Hatteras, NC (US EPA, 2000). If DO conditions are always above 4.8 mg/L, the aquatic life at that location should not be harmed. If DO conditions are below 2.3 mg/L, there is not enough DO to protect aquatic life. Therefore, we will use 4.8 mg/L as a standard for DO in surface waters. DO concentrations in surface waters in Nags Head can also be compared to historical DO concentrations in Roanoke Sound, which averaged between 7.4 and 10.8 mg/L (Section 5.2). Table 5.1 summarizes the DO ranges and standards used for comparative purposes later in this report.

5.2. Historic Water Quality Conditions

Knowledge of past water quality conditions around Nags Head provides a baseline against which potential impacts from OWTS and other sources can be measured. Historic water quality data are generally not available for groundwater or surface water resources in Nags Head. However, water quality was monitored in Roanoke Sound in the 1970s and 1980s. This data is available from the U.S. Environmental Protection Agency (US EPA), and is described below.

The U.S. Environmental Protection Agency (EPA) maintains two data management systems containing water quality information for the nation's waters: the Legacy Data Center (LDC), and STORET. The LDC is a static, archived database; while STORET is an operational system actively being populated with water quality data. STORET contains data collected beginning in 1999, along with older data that has been properly documented and migrated from the LDC. Both systems contain raw biological, chemical, and physical data on surface and ground water collected by federal, state and local agencies, Indian Tribes, volunteer groups, academics, and others. All 50 States, territories, and jurisdictions of the U.S. are represented in these systems. These data systems are available online at http://www.epa.gov/storet/.

Historical water quality data are available from STORET for two sampling stations in Nags Head between 1973 and 1986. One station (Roanoke Sound at Manteo) is located on the causeway midway between Manteo and Nags Head. The other station (Roanoke Sound at Herring Shoal Island) is located just south of the study area. Water quality results for these stations are summarized in Table 5.2, including ammonia-N, nitrate + nitrite-N, and DO. Generally, ammonia-N values were low, averaging between not detected and 0.005 mg/L at both stations. Nitrate + nitrite-N values were also low, averaging between not detected and 0.25 mg/L at both stations. Dissolved oxygen values averaged between 7.4 and 10.8 mg/L at both stations, well above the levels that are required to sustain aquatic life in saline waters (Table 5.1).

5.3. Water Quality at Fresh Pond

Fresh Pond is a 27-acre reservoir on the northern edge of the study area, straddling the political boundary between Nags Head and Kill Devil Hills. Fresh Pond is an important natural resource to the town of Nags Head, as they treat and sell a significant amount of water during the summer months to the Dare County Regional Water System. This water supplies a portion of the drinking water for the residents of Nags Head. Fresh Pond is bordered on the south and west by Nags Head Woods where there is little to no development. The pond is bordered on the east by sparse commercial developments, including the water treatment plant, and on the north by sparse residential development. The lack of significant development, coupled with the fact that the Fresh Pond is near the top of the groundwater divide (Figure 3.5a), make it unlikely that there would be a negative impact on the pond water quality from nearby OWTS.

Water quality samples were collected at Fresh Pond by the Town of Nags Head Water Department as part of their normal monitoring program between July 6, 2001 and April 20, 2005, with a data gap between June 16, 2003 and January 17, 2004. Samples were collected from the Soundside Road beach access, and were analyzed for *Enterococcus* and *E. coli*. Water temperature was reported along with the bacteria data. Although this data set is not directly comparable to the data collected during the Town's water quality monitoring program, there are some trends in the data that are worth mentioning.

The available monitoring results for Fresh Pond are summarized in Table 5.3 and on Figure 5.1. The data show a distinct seasonal trend as well as a strong correlation with water temperatures. Temperature levels begin to rise from yearly lows (~5 ºC) in February and plateau around June or July between 25 and 30 degrees Celsius (ºC). The exception to this is in 2003 where the temperatures plateau near 20 ºC, although there is a 6-month data gap starting in July 2003. The rise in bacteria levels, particularly in *Enterococcus*, corresponds well with the rise in water temperatures; however, bacteria levels do not begin increasing until the water temperature reaches approximately 20 ºC. For 2002 and 2004, the rise in bacteria levels starts in late April and early May, while the data sets for 2001 and 2003 are incomplete. In 2003, bacteria levels drop dramatically with an associated drop in water temperature in late November. Based on the limited data, it appears that *E. coli* levels were similar to *Enterococcus* levels in 2002, but were lower than *Enterococcus in* 2001 and 2004. The maximum *Enterococcus* level over the monitoring period was 2419.2 MPN/100 mL (upper detection limit) and this occurred on several occasions. The maximum *E. coli* level was 2071.2 MPN/100 mL. Although levels of indicator bacteria are high during the late summer months, levels of both indicators are reduced to non-detectable levels via the drinking water treatment process. Interestingly, high levels of indicator bacteria are observed during the summer months, even though there is little possibility of impact from nearby OWTS. Another source of bacteria, such as wildlife or stormwater runoff, is likely responsible for the seasonal impact observed at Fresh Pond.

5.4. Water Quality Monitoring Program in Nags Head

Thirty groundwater monitoring wells and 14 surface water points were sampled approximately weekly by contractors for the Town of Nags Head starting in February of 2001. Samples were collected by a firm called Environmental Professionals.

Several water quality parameters were collected during the sampling process, including DO, pH, temperature, salinity, turbidity, and specific conductance. The main goal of collecting parameters such as temperature, pH, turbidity, and specific conductance during sampling is to ensure that the well has been thoroughly purged prior to collecting a sample. Once these parameters have stabilized (± 10%), it is assumed the well has been purged and the water is representative of the surrounding aquifer and not the well casing.

This report focuses on five major constituents that are considered to be potentially indicative of impacts on water quality from OWTS: fecal coliform, total phosphorus, ammonia, nitrate, and DO. Samples were analyzed by Envirochem of Nags Head according to the following methods: fecal coliform, EPA 9222d; nitrate and nitrite, EPA 353.3; total phosphorus, EPA 365.2; and ammonia-N, SM 4500 h3f. Although DO was collected under field conditions, it is an important parameter to consider when evaluating OWTS impacts on water quality. The water quality sampling program continues to date; however, this report includes results from February 2001 through April 2005. Figures 5.2a and 5.2b show the locations and names of the sampling points, along with their associated leachfields (if applicable).

5.5. Sampling Program Results: Field-Collected Parameters

Several water quality parameters are collected as part of the sampling protocol; pH, temperature, salinity, specific conductance, and turbidity. While these parameters are not necessarily indicative of the impact of OWTS on water quality, they do ensure that the sample collected is representative of the aquifer surrounding the well, and not the well casing itself. The parameters used are typically descriptive in nature, and are monitored continuously throughout the well purging process. The water quality parameters collected as part of the Nags Head sampling protocol, as well as overall results for each parameter, are described below.

5.5.1. pH

The pH of water is a descriptive property that identifies the acidity, or concentration of free hydrogen ions, in the water. pH values range from 0 to 14, with 0 being the most acidic and 14 being the most basic. While the US EPA does not mandate pH monitoring for drinking water supplies, it recommends voluntary monitoring and sets a secondary standard range at 6.5-8.5 (US EPA, 1992). A normal range for groundwater pH values is between 6 and 8. The presence of household cleaning agents, such as ammonia, in an OWTS can increase the pH of the effluent.

Median field pH measurements for the groundwater wells in Nags Head ranged from 6.7 at Curlew-G to 8.0 at Jeanette's Pier-G and Ida Access #1-G (Table 5.4), well within normal values for groundwater pH. Median pH values were slightly higher in the southern part of the study area (Old Cove and south). Median field pH measurements for surface water sampling points ranged from 6.9 at Cobia Way #3-S to 8.0 at N. Side of Ditch S.O.O.I.R.-S, also within the normal expected range. The median pH values for surface water points that are associated with monitoring well clusters near OWTS do not differ significantly from the median pH values at the associated groundwater monitoring wells.

5.5.2. Temperature

The temperature of water is a descriptive parameter, and is the fundamental property of water measured in most sampling protocols. Median field temperature measurements for the groundwater monitoring wells in Nags Head ranged from 17.0 ºC at Nags Head Woods-G to 22.1 ºC at Baltic-G and Jeannette's Pier-G (Table 5.5). These are fairly typical groundwater temperatures. As expected, the deepest groundwater monitoring well (Nags Head Woods-G) has the coldest average water temperatures.

Median field temperature measurements for the surface water sampling points in Nags Head ranged from 18.1 ºC at Cobia Way #3-S to 22.8 ºC at Cobia Way#3a-S. It is interesting to note that the median surface water temperatures do not differ significantly from the median groundwater temperatures. The median temperature values for surface water points that are associated with monitoring well clusters near OWTS do not differ significantly from the average temperature values at those wells. Typically, the difference between groundwater and surface monitoring points in each series is less than 1 ºC.

5.5.3. Salinity

Salinity describes the amount of dissolved salts present in water. The typical salinity for seawater is 35 g/L and for fresh water is <0.5 g/L (Marine Resources Council, 2003). Median salinity measurements for the groundwater monitoring points in Nags Head ranged from 0.0 g/L at 6 monitoring wells to 0.5 g/L at Jeannette's Pier-G and Juncos St. Access #2-G (Table 5.6). The average salinity values are fairly typical of freshwater salinities; however, the Jeannette's Pier and Juncos Street Access #2 monitoring wells are likely at least slightly influenced by seawater or by another source of dissolved salts (such as stormwater runoff).

Average salinity measurements for the surface water sampling points in Nags Head ranged from 0.1 g/L at Nags Head Village Area #2-S to 26 g/L at Ocean outfall @ S.N.H.- S. Generally speaking, inland monitoring points had the lowest salinities, while monitoring points closest to the ocean had the highest salinity values. The median salinity values for surface water points that are associated with monitoring well clusters near OWTS were all an order of magnitude higher the average salinity values at those wells, but this result is primarily indicative of the brackish nature of water in the finger canals and does not indicate impact from OWTS in the area.

5.5.4. *Specific Conductance*

Specific conductance is a water quality parameter that estimates total dissolved solids present in water. Electrical conductivity is a measure of water's ability to conduct electricity, and therefore a measure of the water's ionic activity and content. The higher the concentration of ionic (or dissolved) constituents, the higher the conductivity. Conductivity of the same water changes substantially as its temperature changes. This property can make it difficult to compare conductivities across different waters, or to compare seasonal changes in this parameter for a particular body of water. The use of specific conductance (with units of micromhos per centimeter, or mmhos/cm), which is the conductivity normalized to a standard temperature (typically 25 ºC), eliminates this complication and allows comparisons to be made.

Median specific conductance values for the groundwater wells in Nags Head ranged from 74 mmhos/cm at Lost Colony #3-G to 1165 mmhos/cm at Amberjack #2-G (Table 5.7). Median specific conductance values for the surface water sampling points in Nags Head ranged from 12 mmhos/cm at ONHC Canal Inlet Area-S to 36,000 mmhos/cm at Ocean Outfall @ S.N.H.- S. Not surprisingly, the median surface water specific conductance values are usually significantly higher than the average groundwater specific conductance values.

5.5.5. *Turbidity*

Turbidity is a water quality parameter that describes the clarity of the water. The greater the amount of suspended solids in the water, the murkier it appears and the higher the measured turbidity. In groundwater, high turbidity values often reflect insufficient well development at the time of well construction. The suspended solids are typically fine-grained sediments, such as clays and silts. In surface water, suspended solids include algae and phytoplankton, in addition to clays and silts. Algal turbidity in surface water typically varies seasonally and with depth in response to physical, chemical, and biological changes in the water body. Nutrient loads from surface water runoff can contribute significantly to high turbidity values.

Turbidity is measured in nepholometric turbidity units (NTUs), and is basically a measure of scattered light as a result of suspended solids in the sample. Median turbidity measurements for the groundwater monitoring wells in Nags Head ranged from 4 NTUs at Old Cove #1-G and #2-G to 41 NTUs at Nags Head Woods-G (Table 5.8). Most of the median groundwater turbidity values lie between 4 and 14 NTUs.

Median turbidity measurements for the surface water sampling points in Nags Head ranged from 3 NTUs at Cobia Way #3-S and at Blue Fin Canal Drain-S to 75 NTUs at Wrightsville #1-S. The median turbidity values for surface water points that are associated with monitoring well clusters near OWTS do not differ significantly from the median turbidity values at those wells. The exception was Jeanette's Pier, where the surface water values were higher on average than groundwater values. This result is not surprising, however, since Jeanette's Pier-S is in the surf zone of the ocean where sand and other particles are constantly being resuspended by breaking waves.

5.6. Sampling Program Results: Water Quality Conditions in Nags Head

This section presents in detail the results of the Town's Water Quality Testing Program throughout Nags Head. The rationale for locating and testing each of the monitoring points, as described to the consultant team by Dr. David Lindbo, is presented in Section 5.6.1. Groundwater quality in "background" areas (generally those groundwater points not near OWTS) is described in Section 5.6.3. This section defines the ranges of background concentrations of fecal coliform bacteria, total phosphorus, ammonia, nitrate, and DO in the groundwater in Nags Head for comparative purposes. Next, these background ranges, along with any applicable water quality standards and guidelines, are compared to groundwater and surface water quality near individual OWTS (Section 5.6.4). Finally, surface water quality throughout the Town is described: the water quality in surface water ditches in the northern (Section 5.6.5.1) and southern (Section 5.6.5.2) areas of town, in the finger canals (Section 5.6.6), and in the Sound and the ocean where data are available (Section 5.6.7). The relationship between weather patterns, particularly precipitation, and water quality in Nags Head is discussed generally in Section 5.6.2. This section of the report only describes the results of the monitoring program; it does not attempt to associate individual or collective OWTS characteristics with impacts on water quality (see Section 6 of this report).

On each of the figures describing the water quality sampling program results (Figures 5.3 through 5.20), monitoring points are grouped together either according to their series identification or because they share a common characteristic. For example, monitoring points in the Old Cove well series (Old Cove #1-G, Old Cove #2-G, and Old Cove #3-S) are grouped together in one figure because the three points were intended to form a transect between a single OWTS and the nearest surface water.

On each figure, hydrologic data, including the 30-day running total precipitation and measured groundwater elevations (where applicable) are shown at the top of the page. Monthly geometric means are shown for fecal coliform bacteria with error bars showing one standard deviation from that mean. Monthly medians with error bars showing one standard deviation are plotted for all other water quality characteristics (total phosphorus, ammonia, nitrate, and DO). Linear trends over the entire sampling period are shown as straight lines in colors corresponding to the datasets the trendlines describe.

5.6.1. Rationale For Location of Monitoring Points

Sampling sites throughout the Town of Nags Head were chosen to represent a cross-section of the types of land uses present in the Town (Figures 5.2a and 5.2b). Five general areas where selected representing an established subdivision, a developing area, an established subdivision with finger canals, an area served by a package plant, and a narrow residential area. Wherever possible, multiple wells where installed in a transect leading away (downgradient) from the drainfield to the property line, finger canal, or surface water ditch. In addition to these clusters, sampling was also conducted at a well in Nags Head Woods representing background groundwater conditions. Additional surface water sampling at the south end of the Town was included to provide insight on potential stormwater impacts.

The two Lost Colony well series were placed in an established subdivision. The exact location was chosen based on homeowner cooperation and past history of the sites. Contrasting with this area are the wells located across Hwy 158 in a developing area of the Town (including the Blackman and Curlew groundwater points and the two Wrightsville surface water points). These wells and surface sampling sites were chosen to establish some background conditions as well as to track changes due to development of the area.

The Old Cove area wells were located to identify three types of impacts: effluent plume(s) down gradient from drainfields, direct surface water quality impacts from OWTS, and potential stagnation of surface water in the finger canals. In order to achieve these goals, a transect of 2-3 points were chosen down gradient from the drainfield and a surface water sampling point was located at the end of this transect. The overall selection of specific parcels was done to have one parcel at the distal end of the finger canals (Cobia Way, Cobia Way A, and South Blue Marlin), locations approximately in the middle of the subdivision (Amberjack and Old

Cove), and one location at the outlet (ONHC Canal Inlet Area). Blue Fin Canal Drain represents drainage into the finger canal system.

Several wells and surface sampling points are located in and around the Nags Head Village area (Fire Station and Seachase-G, and the Nags Head Village Area surface water points). Although a package plant serves this area, data from these points represent the impact of surface runoff and human activity in an area not served by OWTS. The sampling points at Jeanette's Pier represent runoff and groundwater inputs from a more commercial rather than residential area.

The final area encompasses much of South Nags Head from Huron Street to Juncos Street. These sites are located in a narrow development bordered on one side by the Atlantic Ocean and on the other by marshland. The general drainage of the area is towards the west (sound or marsh side) and is transected by a surface drainage ditch parallel to S. Old Oregon Inlet Rd. that has an outlet to the ocean at the southern end of the development. This area is served by conventional as well as LPP and advanced treatment systems. Groundwater monitoring well locations in this area were selected adjacent to beach access locations.

5.6.2. Weather Patterns and Water Quality

In coastal environments such as Nags Head, weather patterns can be quite variable. The Atlantic Ocean, which is slow to warm and cool and heats to a maximum of about 80 degrees in the summer, affects air, groundwater, and surface water temperatures. Summer air temperatures are, on average, about 10 degrees cooler than those of mainland North Carolina; while in the winter, temperatures are generally more moderate due to the influence of the Gulf Stream.

The wind blows most of the time at an average of 8 to 10 mph. Occasional gale force winds range from 30 to 35 mph. In summer the wind blows predominantly out of the southwest, often increasing in the late afternoon. Southwest winds are warm and usually create a generally flat ocean but stir up the sound. The wind also frequently comes out of the northeast; these winds create a rough ocean on east-facing beaches and are more predominant in fall and winter.

General water temperature and precipitation information for Nags Head is summarized on Figure 5.3. Average water temperature was calculated by taking the mean of all field temperature data collected for each sampling event during the water quality monitoring program to date. Daily precipitation data were collected from the National Climatic Data Center for the closest weather station to Nags Head (the co-op weather station in Manteo, station ID 315303). In order to smooth the precipitation data and to better observe precipitation trends, a 30-day running total was calculated and is shown in black. The 30-day running total precipitation data is also shown on the water quality results figures discussed in the following sections of this report.

Water temperatures in Nags Head between February 2001 and April 2005 ranged between an annual low of 10 to11°C occurring in January or February and an annual high of about 23 to 25°C occurring in late August or early September. The single spike in water temperature to 32°C in early September 2002 may have been a result of Hurricane Gustav, which affected North Carolina between September 8 and 10, 2002 (see below).

Rainfall patterns and amounts varied markedly from year to year during the water quality monitoring program. 2001 appeared to be a very dry year, with a total of only 28 inches of rainfall recorded at the Manteo weather station. In contrast, there were 53 inches of total rainfall in 2002, 66 inches in 2003, and 52 inches in 2004. January was generally the driest month of each year, and in most years precipitation levels were often higher in spring and in late summer.

Often, spikes in precipitation during the spring and summer months are associated with tropical storms or hurricanes. At least one major tropical storm made landfall in the Outer Banks during each year of the water quality monitoring program. The tropical storms affecting Nags Head during the water quality monitoring program were:

- June 15-17, 2001: Tropical Storm Allison
- September 8-10, 2002: Hurricane Gustav
- September 18-19, 2003: Hurricane Isabel
- August 2-3, 2004: Hurricane Alex
- August 13-14, 2004: Hurricane Charley

Severe storms, including hurricanes, other tropical storms, and nor'easters have the potential to cause beach erosion, structural damage, and both ocean and soundside flooding. These and less severe storm events also have the potential to affect water quality. Heavy rains may flush contaminants from OWTS, including nutrients and pathogens, into the groundwater or surface waters before they can be properly treated in the soil. These rains may also cause runoff from impermeable areas such as rooftops, roads, and parking lots. This stormwater can contain pathogens, nutrients, and metals or other contaminants that can impact surface water resources.

Several preliminary analyses were conducted using data collected during the water quality monitoring program to determine whether there was a relationship between rainfall and water quality impacts. Regression analyses were performed using several different sets of assumptions and subsets of water quality data, as summarized in Table 5.9. Relationships between both daily and 30-day total precipitation and water quality results were quite weak overall. Between 0% and 4% of the variations in fecal coliform or turbidity concentrations were explained by the linear relationship between those two variables and the amount of precipitation falling either on that day or within the previous 30 days. Occasional relationships were observed between increased precipitation and water quality results at individual monitoring points. These relationships will be discussed in the appropriate sections below.

5.6.3. Background Groundwater Quality

Several monitoring points in the northern part of Nags Head were sited in undeveloped areas (Nags Head Woods-G), and in developed areas 100 feet or more from OWTS (Blackman-G, Curlew-G, Fire Station-G, and Seachase-G). The water quality results for these five monitoring points are shown together on Figure 5.4, and background water quality ranges derived from these monitoring points are summarized in Table 5.1. The Nags Head Woods monitoring well has data as far back as March 2001 (n = 52 months), while the other four monitoring wells were not installed and sampled until April 2003 (n = 28 months). Water levels were measured at all five background locations starting in June 2004, and measurements continue to date. These results and trends will define background conditions for the discussion of groundwater quality near OWTS (Section 5.6.4).

Water table elevations ranged from 3.87 to 10.89 feet AMSL (above mean sea level) at the background monitoring wells (Figure 5.4). Water table elevations were generally lowest at Nags Head Woods-G and highest at Fire Station-G. Water table elevations at all five monitoring points show a clear and rapid response to Hurricanes Alex and Charley in August 2004. During August, water table elevations increased by at least 1.0 feet at all five locations and then re-equilibrated over then following one to two months. Although precipitation data were not available for April 2005, water table elevations indicate that another significant rainfall event occurred. Otherwise, water table elevations at all background points usually varied by less than a foot during the last year.

Fecal coliform levels were low overall at all monitoring points in this series, ranging from not detected at all monitoring points to a maximum of 1680 MPN/100 mL at Fire Station-G (Table 5.10). Monthly geometric mean values at Nags Head Woods-G, Blackman-G, and Curlew-G generally remained at or near detection limits (1-2 MPN/100 mL) and did not increase or decrease significantly over time (Figure 5.4). Monthly geometric mean values at Blackman-G and Fire Station-G also generally remained near detection limits, but exhibited occasional spikes during summer months. Overall, the linear trends for the background sites in developed areas were higher than the trend at the undeveloped background site, Nags Head Woods-G. During the summer and early fall of 2003, there was a cluster of small increases in monthly geometric mean fecal coliform concentrations, particularly at the developed background sites. The landfall of Hurricane Isabel on September 18, 2003 resulted in over 3.5 inches of rainfall in the Nags Head area over a 24-hour period (NOAA, 2003). Increased runoff and stormwater infiltration associated with this storm may be responsible for the concurrent and temporary increase in fecal coliform concentrations observed at the developed monitoring points. A similar cluster of small increases in August 2004, and a significant increase in monthly geometric mean fecal coliform levels at Seachase-G, is associated with increased precipitation and higher groundwater elevations. Based on these data, the background range of fecal coliform concentrations in Nags Head groundwater is from <1 to 4 MPN/100 mL.

Total phosphorus levels ranged from not detected (less than 0.01 mg/L) to 3.5 mg/L (Table 5.11). Interestingly, both the minimum and maximum total phosphorus concentrations occurred at Nags Head Woods-G, the monitoring point farthest from any development. For Nags Head Woods-G and most of the developed monitoring points, median total phosphorus concentrations are below 0.3 mg/L and were stable or slightly decreasing over time (Figure 5.4). The upper end of this range is higher than the expected range of background phosphorus concentrations for North Carolina of 0.005 mg/l to 0.1 mg/l (NC DENR, 2004). The sandy soils of Nags Head may have limited phosphorus sorption capacity, and the slightly higher range of background total phosphorus concentrations in both developed and undeveloped areas may be a reflection of this limited capacity. There was no clear relationship between water table elevation/precipitation data and total phosphorus concentrations. Monitoring point Fire Station-G was the exception to the observed total phosphorus trends in both developed and undeveloped areas of Nags Head. At this point, the median total phosphorus concentration was 0.85 mg/L and appeared to be increasing over time. This monitoring point is located near the golf course at Nags Head Village, and it is possible that excess fertilizer from the golf course is migrating through the groundwater to this well. However, much of the groundwater beneath the golf course probably drains towards the sound, and correspondingly higher total phosphorus concentrations are not observed at Seachase-G, which is located roughly halfway between Fire Station-G and the sound. Fire Station-G is also located within approximately 100 feet of, and is downgradient from, the package wastewater treatment plant that serves Nags Head

Village. Based on these data, the background range of total phosphorus concentrations in Nags Head groundwater is from <0.01 to 0.3 mg/L.

Ammonia levels ranged from not detected (less than 0.1 mg/L) to 5.5 mg/L (Table 5.12). For all monitoring points except Curlew-G, median ammonia concentrations were 0.3 mg/L or less and were stable over time (Figure 5.3). Nags Head Woods-G (the undeveloped background point), Fire Station-G, and Seachase-G had overall medians at the detection limit, while Blackman-G had a slightly higher median of 0.4 mg/L. At Curlew-G, the median ammonia concentration was 2.8 mg/L (the highest median of any sampling point in the program), and concentrations appeared to be increasing over time. Dissolved oxygen concentrations at this point were very low (median of 0.23 mg/L), so any nitrogen present would likely be converted to ammonia. There was no clear relationship between water table elevation/precipitation data and ammonia concentrations. Based on these data, the background range of ammonia concentrations in Nags Head groundwater is from <0.1 to 0.3 mg/L.

Nitrate levels ranged from the limit of detection (less than 0.01 mg/L) to 19.9 mg/L at the monitoring points in this series (Table 5.13). For all undeveloped and developed monitoring points except Seachase-G and Fire Station-G, median nitrate concentrations were less than 0.1 mg/L and were stable over time (Figure 5.3). At Fire Station-G, the median nitration concentration was 2.22 mg/L, and was lower (0.36 mg/L) at Seachase-G. While the trend at these two monitoring points was stable overall, there was a definite seasonal variation in nitrate concentrations, with the highest monthly median concentrations occurring in April-June of 2003 and 2004 at both stations, and in Decebmer 2004-January 2005 at Fire Station-G. During July of 2003, the median nitrate concentration at Fire Station-G was 10.3 mg/L, exceeding the drinking water standard of 10 mg/L. There was no clear relationship between water table elevation/precipitation data and nitrate concentrations. Based on these data, the background range of nitrate concentrations in Nags Head groundwater is from <0.01 to 0.3 mg/L.

Dissolved oxygen concentrations ranged from 0.01 to 16.0 mg/L at the five monitoring points in this series (Table 5.14). Higher DO concentrations (3-8 mg/L) were observed at Nags Head Woods-G from the start of the sampling program in February 2001 through about April of 2002 (Figure 5.3). After April 2002, DO concentrations of less than 3 mg/L were generally observed at all monitoring points in this series. These DO values would be considered low for surface waters, but they are not unexpected or unreasonable for groundwater that has limited contact with the atmosphere. While DO concentrations at Nags Head Woods-G decreased over time, levels at the other four monitoring points did not change significantly during the monitoring period. Dissolved oxygen levels appear to be increasing slightly during the spring of 2005. There was no clear relationship between water table elevation/precipitation data and DO concentrations. Based on these data, the background range of DO concentrations in Nags Head groundwater is from <0.01 to 3 mg/L.

5.6.4. Water Quality Near Onsite Systems

Fourteen sets of monitoring points were installed throughout Nags Head to evaluate the potential impact of individual OWTS on water quality in the nearby groundwater and surface waters. The water quality results for these sets of monitoring points are shown on Figures 5.5 through 5.18; the figures are numbered and described from north to south, as the monitoring point locations appear on Figures 5.2a and 5.2b. Generally, the black data series on the figures represents the groundwater monitoring point closest to a leachfield, the green data series (if any) represents a groundwater monitoring point farther away from the same leachfield, and the blue data series (if any) represents a surface water monitoring point that completes a transect between the leachfield and the nearest surface water body.

5.6.4.1. Baltic

The Baltic series includes the monitoring point Baltic-G. This monitoring point was sampled between June 2004 and April 2005 (n = 10 months). Baltic-G is located approximately 5 feet north of a set of eight peat filter pods serving a single-family residence. There is no surface water monitoring point associated with this monitoring well. Groundwater flow in this area is generally east towards the ocean; thus, the Baltic-G monitoring well appears to be cross-gradient from the peat filter pods.

Between June 2004 and April 2005, water table elevations at Baltic-G ranged from 2.88 to 6.26 feet AMSL, or 3.3 to 6.7 feet bgs (below ground surface) (Figure 5.5). Water table elevations varied significantly at Baltic-G during the sampling period. This variation was best explained by comparing the measured water level elevations to the maximum tide height that occurred during the sampling day as measured at Jeannette's Pier, in feet referenced to Mean Lower Low Water (MLLW). Maximum tide height for each day between June 1, 2004 and April 30, 2005 is shown in violet on this figure. Water level readings taken close to a neap tide (for example, during late June 2004) tended to be the lowest observations recorded, while those taken close to a spring tide (for example, during early February 2005) were the highest observations recorded. Water table elevations at Baltic-G may respond to severe rainfall events, such as the one that occurred with the landfalls of Hurricanes Alex and Charley in August 2004, but this response is difficult to distinguish from the response of groundwater to tidal fluctuations. Water table elevations often varied by a foot or more between sampling events. Despite the magnitude of fluctuation in groundwater elevations at this point, at least 4 feet of separation between the ground surface and groundwater was usually maintained.

Fecal coliform levels were sometimes above background levels (<1-4 MPN/100 mL; Table 5.1) at Baltic-G, ranging from not detected to a maximum of 129 MPN/100 mL (Table 5.10). Monthly geometric mean values were slightly above background levels during June and July 2004, and then generally remained at or below background levels (4 MPN/100 mL or less) (Figure 5.5). There were no exceedances (of 10 months) of the 200 MPN/100 mL recreational water quality standard during the monitoring period. The linear trend at Baltic-G decreased over time. There was no apparent relationship between water table elevations, precipitation data, or tidal fluctuations and fecal coliform concentrations. These data indicate that fecal coliform levels in groundwater near the Baltic well are generally at or below background levels, and are within the range of concentrations expected near an OWTS.

Total phosphorus levels were generally above background levels (0.3 mg/L or less; Table 5.1) at Baltic-G, ranging from 0.05 to 4.18 mg/L (Table 5.11). The monthly median total phosphorus values at Baltic-G were generally above expected background levels (0.3 mg/L or less), and increased fairly steadily by about 3 mg/L over the sampling period (Figure 5.5). There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and total phosphorus concentrations. These data indicate that total phosphorus levels in groundwater near the Baltic well are above background levels, and are at the within the range of concentrations expected near an OWTS.

Ammonia concentrations were generally above background levels (0.3 mg/L or less; Table 5.1) at Baltic-G, ranging from not detected (less than 0.1 mg/L) to a maximum of 8.5 mg/L (Table 5.12). Median monthly ammonia concentrations were within background levels only during the first two months of the monitoring period (Figure 5.5). After August 2004, median monthly ammonia concentrations increased to approximately 6 mg/L in October 2004, then declined to near-background levels. Another smaller peak in median monthly ammonia concentrations occurred during January 2005, after which ammonia levels again declined to near-background levels by the end of April 205. There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and ammonia concentrations. These data indicate that ammonia levels in groundwater near Baltic-G are above background levels, but are within the range of concentrations expected near an OWTS.

Nitrate levels in groundwater were generally above background levels (0.3 mg/L or less; Table 5.1) at Baltic-G, ranging from 0.10 to 25.6 mg/L (Table 5.13). From July through October of 2004, median monthly nitrate values at Baltic-G were above background levels, but were below the action level of 5.0 mg/L (Figure 5.5). During October 2004-April 2005, median monthly nitrate concentrations abruptly increased to greater than 5 mg/L. The nitrate drinking water standard was exceeded at Baltic-G during December 2004 and January 2005. The linear trend for nitrate increased over the sampling period. There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and nitrate concentrations; however, periods of high nitrate concentrations did tend to correspond with periods of relatively low ammonia concentrations. These data indicate that nitrate levels in groundwater near the Baltic well are above background levels, and are within the range of concentrations expected near an OWTS.

Dissolved oxygen levels in groundwater were within background levels (0.01-3.00 mg/L; Table 5.1) at Baltic-G, ranging from 0.10 to 4.12 mg/L (Table 5.14). Dissolved oxygen concentrations at Baltic-G were low throughout the monitoring period, but increased slightly during April 2005 (Figure 5.5). There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and dissolved oxygen concentrations. These data indicate that DO levels in groundwater near the Baltic well are at background levels, and are within or above the range of concentrations expected near an OWTS.

5.6.4.2. Lost Colony 1

The Lost Colony 1 series includes the monitoring points Lost Colony #1-G and Lost Colony #2-G. These monitoring points were sampled between February 2001 and April 2005 (n = 52 months). Lost Colony #1-G is located approximately 10 feet east-northeast of a leachfield serving a single-family house, and Lost Colony #2-G is located approximately 50 feet south of the same leachfield. Lost Colony #1-G appears to be hydraulically downgradient of the leachfield, while Lost Colony #2-G appears to be cross-gradient and slightly upgradient. There is no surface water monitoring point associated with this group of monitoring points.

Between June 2004 and April 2005, water table elevations at Lost Colony #1-G ranged from 9.22 to 11.42 feet AMSL, or 0.97 to 3.17 feet bgs (below ground surface) (Figure 5.6). At Lost Colony #2-G, water table elevations ranged from 9.04 to 11.09 feet AMSL, or 0.22 to 2.27 feet bgs. Water table elevations at both monitoring points show a clear and rapid response to rainfall events, particularly to Hurricanes Alex and Charley in August 2004. During August, water table elevations increased by 1.2 to 1.3 feet at both locations and then re-equilibrated over then following one to two months. Otherwise, water table elevations usually varied by less than a foot during the last year. During normal rainfall conditions, approximately 3.5 feet of separation between the ground surface and groundwater was maintained at Lost Colony #1-G, and a separation distance of approximately 2.5 feet was maintained at Lost Colony #2-G.

Fecal coliform levels were sometimes above background levels (<1-4 MPN/100 mL; Table 5.1) at both monitoring points in this series, ranging from not detected at both monitoring points to a maximum of 21,000 MPN/100 mL at Lost Colony #1-G (Table 5.10). Monthly geometric mean values for each of these monitoring points generally remained at or near the detection limit (1-2 MPN/100 mL) between November and June of each year, and were higher between July and October, with the highest levels generally occurring in August. The only exceedance of the 200 MPN/100 mL recreational water quality standard out of 52 monthly datapoints occurred at Lost Colony #1-G in September 2002 (654 MPN/100 mL) (Figure 5.6). Increased runoff and stormwater infiltration associated with the landfall of Hurricane Gustav in early September 2002 may be somewhat responsible for the temporary increase in fecal coliform concentrations observed at both monitoring points. This pattern, however, was not repeated during the landfall of Hurricanes Alex and Charley in August 2004 even though the separation distance between the ground surface and groundwater was greatly reduced. The linear trends for both monitoring points did not increase or decrease significantly over time. The linear trend at Lost Colony #2-G is slightly lower overall than the trend for Lost Colony #1-G. These data indicate that fecal coliform levels in groundwater near the Lost Colony 1 well series are above background levels, but are within the range of concentrations expected near an OWTS.

Total phosphorus levels were sometimes above background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at both monitoring points to a maximum of 27.4 mg/L at Lost Colony #1-G (Table 5.11). From the beginning of the sampling program through February 2002, median monthly total phosphorus concentrations remained at or near background levels at both monitoring locations (Figure 5.6). From March 2002 through July 2002, median monthly total phosphorus concentrations at Lost Colony #2-G were significantly higher (0.85-1.7 mg/L) than those at Lost Colony #1-G (0.21-0.41 mg/L). After July 2002, median monthly total phosphorus concentrations remained near background levels at Lost Colony #2, while at Lost Colony #1 total median phosphorus levels increased significantly, and remained between 2.3 and 12 mg/L for the duration of the sampling period. There was no apparent relationship between water table elevation/precipitation data and total phosphorus concentrations. The linear trend for Lost Colony #1-G increased significantly over time, while the trend at Lost Colony #2-G remained stable near background levels for the duration of the sampling period. These data indicate that total phosphorus levels in groundwater near the Lost Colony 1 well series (particularly at Lost Colony #1-G) are above background levels, but are within the range of concentrations expected near an OWTS.

Ammonia levels were sometimes above background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.1 mg/L) at both monitoring points to a maximum of 44.2 mg/L at Lost Colony #1-G (Table 5.12). From the beginning of the sampling program through July 2001, median monthly ammonia concentrations remained at or near background levels at both monitoring locations (Figure 5.4). From August 2001 through January 2002, median monthly ammonia concentrations at Lost Colony #1-G were slightly above background (0.34-1.1 mg/L), while those at Lost Colony #2-G remained near the detection limit. Between February 2002 and November 2002, median monthly ammonia concentrations remained near background levels at both monitoring points. From December 2002 through the end of the monitoring period, median ammonia concentrations increased significantly at Lost Colony #1, from near-background levels to a high of 36 mg/L in May-July of 2003. There appears to be a relationship between increased precipitation, high water table elevations, and increased ammonia concentrations at Lost Colony #1-G, particularly between August and October of 2004; during this time, the separation distance between the ground surface and groundwater was two feet or less. The linear trends at both monitoring points in this series increased over time, although the magnitude of the increase was greater at Lost Colony #1 than at Lost Colony #2. These data indicate that ammonia levels in groundwater near Lost Colony #1-G are above background levels, and are also above the concentrations expected near an OWTS. Ammonia concentrations at Lost Colony #2 are near background levels and within the range of concentrations expected near an OWTS.

Nitrate levels were sometimes above background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at both monitoring points to a maximum of 53.1 mg/L at Lost Colony #1-G (Table 5.13). From the beginning of the sampling program through December 2001, median monthly nitrate concentrations remained at or near background levels at both monitoring locations (Figure 5.6). From January 2002 through July 2002, median monthly nitrate concentrations at both locations were slightly above background levels (0.70-1.5 mg/L). In August 2002, monthly median nitrate concentrations at Lost Colony #1-G increased sharply (to 36 mg/L), then decreased gradually through May 2003. This gradual decrease in nitrate concentrations was also observed at Lost Colony #2-G. From May through

October of 2003, median monthly nitrate concentrations were near or below background levels at both monitoring points, although nitrate concentrations varied considerably at Lost Colony #1-G during this period. After October 2003, median monthly nitrate concentrations gradually increased at Lost Colony #1-G from near-background levels to 22 mg/L in June 2004, while nitrate levels remained at background levels at Lost Colony #2-G. Nitrate levels remained high at Lost Colony #1-G and relatively low at Lost Colony #2-G through the end of the monitoring period. There was no clear relationship between water table elevation/precipitation data and nitrate concentrations. However, at Lost Colony #1-G, there appears to be a relationship between higher ammonia concentrations and somewhat lower nitrate concentrations, suggesting that nitrification may be inhibited at this location when groundwater elevations are high. Overall, the linear trend at Lost Colony #1-G increased over time, while the linear trend at Lost Colony #2 decreased. These data indicate that nitrate levels in groundwater near Lost Colony #1-G are generally above background levels, and are within the range of concentrations expected near an OWTS. Except for January-September of 2002, nitrate concentrations at Lost Colony #2-G are near background levels and below the range of concentrations expected near an OWTS.

Dissolved oxygen levels were at or above background levels (0.01-3.00 mg/L; Table 5.1) at both monitoring points in this series, ranging from 0.0 mg/L at Lost Colony #2-G to a maximum of 13.0 mg/L also at Lost Colony #2-G (Table 5.14). Higher median DO concentrations (2.8-8.1 mg/L) were observed at both monitoring points from the start of the sampling program in February 2001 through about July of 2002. After July 2002, DO concentrations of less than 1.0 mg/L were generally observed at both monitoring points in this series, although they appear to be recovering slightly during the spring of 2005 (Figure 5.6). Dissolved oxygen concentrations at both monitoring points decreased over time. The linear trends for both points were similar, with Lost Colony #2-G slightly higher than Lost Colony #1-G overall. These data indicate that DO levels in groundwater near the Lost Colony 1 series are generally at or above background levels, and are within the range of concentrations expected near an OWTS.

5.6.4.3. Lost Colony 2

The Lost Colony 2 series includes the monitoring points Lost Colony #3-G and Lost Colony #4-G. These monitoring points were sampled between February 2001 and April 2005 (n = 52 months). Lost Colony #3-G is located approximately 50 feet northeast of a leachfield serving a single-family house, and Lost Colony #4-G is located approximately 50 feet due east of the same leachfield. Lost Colony #3-G appears to be hydraulically downgradient and slightly cross-gradient from the leachfield, while Lost Colony #4 appears to be downgradient. There is no surface water monitoring point associated with this group of monitoring points.

Between June 2004 and April 2005, water table elevations at Lost Colony #3-G ranged from 8.10 to 11.51 feet AMSL, or 0.6 to 4.0 feet bgs (below ground surface) (Figure 5.7). At Lost Colony #4-G, water table elevations ranged from 8.90 to 11.80 feet AMSL, or 0.3 to 3.2 feet bgs. Water table elevations at both monitoring points show a clear and rapid response to rainfall events, particularly to Hurricanes Alex and Charley in August 2004. During August, water table elevations increased by 1.3 to 1.5 feet at both locations and then re-equilibrated over then following one to two months. Otherwise, water table elevations usually varied by less than a foot during the last year. During normal rainfall conditions, approximately 3.2 feet of separation between the ground surface and groundwater was maintained at both monitoring points.

Fecal coliform levels were sometimes above background levels (<1-4 MPN/100 mL; Table 5.1) at both monitoring points in this series, ranging from not detected at both monitoring points to a maximum of 60,000 MPN/100 mL at Lost Colony #4-G (Table 5.10). Monthly geometric mean values for each of these monitoring points generally remained at or near detection limits (1-2 MPN/100 mL) between November and June of each year, and were higher between July and September or October, with the highest levels generally occurring in August or September (Figure 5.7). The only exceedance of the 200 MPN/100 mL recreational water quality standard occurred at both monitoring points in September 2002 (850 MPN/100 mL at Lost Colony #3-G and 1043 MPN/100 mL at Lost Colony #4-G). Increased runoff and stormwater infiltration associated with the landfall of Hurricane Gustav in early September 2002 may be somewhat responsible for the temporary increase in fecal coliform concentrations observed at both monitoring points. This pattern, however, was not repeated during the landfall of Hurricanes Alex and Charley in August 2004 even though the separation distance between the ground surface and groundwater was greatly reduced. The linear trends for both monitoring points decreased slightly over time. These data indicate that fecal coliform levels in groundwater near the Lost Colony 2 well series are above background levels in the summer months, but are within the range of concentrations expected near an OWTS.

Total phosphorus levels were generally near background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at both monitoring points to a maximum of 2.23 mg/L at Lost Colony #4-G (Table 5.11). From the beginning of the sampling program through September 2002, median monthly total phosphorus concentrations remained at or near background levels at both monitoring locations (Figure 5.7). After September 2002, median monthly total phosphorus concentrations at Lost Colony #4-G were at or above background levels (0.3-1.2 mg/L), while those at Lost Colony #3-G remained generally less than 0.1 mg/L. There was no apparent relationship between water table elevation/precipitation data and total phosphorus concentrations. The linear trend for Lost Colony #3-G remained stable over time, while the trend at Lost Colony #4-G increased slightly during the sampling period. These data indicate that total phosphorus levels in groundwater near the Lost Colony 2 well series are at or slightly above background levels, and are at the low end of the range of concentrations expected near an OWTS.

Ammonia levels were generally near background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.1 mg/L) at both monitoring points to a maximum of 13.7 mg/L at Lost Colony #4-G (Table 5.12). From the beginning of the sampling program through October 2003, median monthly ammonia concentrations remained at or near background levels at both monitoring locations (Figure 5.7). Ammonia concentrations at Lost Colony #3-G remained near the detection limit through the end of the sampling period. From November 2003 through May 2004, median monthly ammonia concentrations at Lost Colony #4-G increased sharply from 0.9 mg/L in November 2003 to a high of 12.3 mg/L in May 2004. After this peak, monthly median ammonia concentrations declined to about 3.5 mg/L in September 2004 and fluctuated around that value through the end of the sampling period. In contrast to the findings at the Lost Colony 1 well series (Section 5.6.4.2 above), increased precipitation and higher groundwater levels did not appear to significantly affect the peak in ammonia concentrations observed at Lost Colony #4-G. The linear trend at Lost Colony #3-G did not change over time, while the linear trend at Lost Colony #4-G increased significantly over the monitoring period. These data indicate that ammonia levels in groundwater near Lost Colony #3-G are at background levels and within the range of concentrations expected near an OWTS. Ammonia levels at Lost Colony #4-G after October 2003 are above background levels, and at times also exceed the concentrations expected near an OWTS.

Nitrate levels were generally near background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at both monitoring points to a maximum of 32.4 mg/L at Lost Colony #3-G (Table 5.13). This maximum is not representative of the data in this series; the next highest result at this monitoring point was only 1.12 mg/L. Throughout the sampling period, median monthly nitrate concentrations remained at or near background levels at both monitoring locations (Figure 5.7). There was no clear relationship between water table elevation/precipitation data and nitrate concentrations. The linear trends at both monitoring points were stable to slightly decreasing throughout the sampling period. These data indicate that nitrate levels in groundwater near the Lost Colony 2 well series are at or slightly above background levels, and are below the range of concentrations expected near an OWTS.

Dissolved oxygen levels were at or above background levels (0.01-3.00 mg/L; Table 5.1) at both monitoring points in this series, ranging from 0.0 mg/L to a maximum of 13.1 mg/L (both at Lost Colony #4-G) (Table 5.14). There are two different trends apparent in this data series. First, there is a general seasonal trend at both monitoring points of higher monthly median DO concentrations during the fall, winter, and spring of each year, and lower concentrations during the summer (particularly during July and August) (Figure 5.7). This seasonal trend is overprinted by a gradual decrease in median monthly DO concentrations at both monitoring points from the start of the sampling program in February 2001 through about July of 2003. After July 2003, DO concentrations of less than 1.0 mg/L were generally observed at both monitoring points in this series. It appears that DO concentrations may be recovering slightly during the spring of 2005. There was no clear relationship between water table elevation/precipitation data and DO concentrations. These data indicate that DO levels in groundwater near the Lost Colony 2 series are generally at or above background levels, and are within the range of concentrations expected near an OWTS.

5.6.4.4. Pamlico

The Pamlico series includes the monitoring points Pamlico #1-G and Pamlico #2-G. These monitoring points were sampled only between February 2001 and May 2002 (n = 15 months). Pamlico #1-G is located approximately 15 feet southwest of a leachfield serving a single-family house, and Pamlico #2-G is located approximately 45 feet south-southwest of the same leachfield. Both wells appear to be upgradient of the leachfield. There is no surface water monitoring point associated with this group of monitoring points.

No water level readings were taken during the time period that the Pamlico monitoring wells were active.

Fecal coliform levels were generally below background levels (<1-4 MPN/100 mL; Table 5.1) at both monitoring points in this series, ranging from not detected at both monitoring points to a maximum of 2,300 MPN/100 mL at Pamlico #2-G (Table 5.10). Monthly geometric mean values for each of these monitoring points generally remained below detection limits (1-2 MPN/100 mL) between November and June, and were higher in August and September. There was no clear relationship between precipitation data and fecal coliform concentrations. The linear trends for both monitoring points decreased slightly over time (Figure 5.8). These data indicate that fecal coliform levels in groundwater near the Pamlico well series are above background levels in the summer months, but are within the range of concentrations expected near an OWTS.

Total phosphorus levels were generally near background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at both monitoring points to a maximum of 1.10 mg/L at Pamlico #1-G (Table 5.11). Throughout the sampling period, median monthly total phosphorus concentrations remained at or near background levels at both monitoring locations (Figure 5.8). During April of 2001, the median monthly total phosphorus concentration was slightly higher (0.38 mg/L). There was no clear relationship between precipitation data and total phosphorus concentrations. The linear trends for both monitoring points showed a slight decrease over time. These data indicate that total phosphorus levels in groundwater near the Pamlico well series within the background range, and are at the low end of the range of concentrations expected near an OWTS.

Ammonia levels were generally near background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.1 mg/L) at both monitoring points to a maximum of 0.8 mg/L at Pamlico #2-G (Table 5.12). Median monthly ammonia concentrations remained at or near background levels at both monitoring locations throughout the sampling period, and the overall trends were level over time (Figure 5.8). There was no clear relationship between precipitation data and ammonia concentrations. These data indicate that ammonia levels in groundwater near the Pamlico well series are at background levels and within the range of concentrations expected near an OWTS.

Nitrate levels were generally near background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at both monitoring points to a maximum of 3.5 mg/L at Pamlico #2-G (Table 5.13). Throughout the sampling period, median monthly nitrate concentrations (0.06-0.53 mg/L) remained at or slightly above background levels at both monitoring locations (Figure 5.8). There was no clear relationship between precipitation data and nitrate concentrations. The linear trend at Pamlico #1-G increased slightly over the monitoring period, while the trend at Pamlico #2-G decreased over the same time period. These data indicate that nitrate levels in groundwater near the Pamlico well series are at or slightly above background levels, and are below the range of concentrations expected near an OWTS.

Dissolved oxygen levels were at or above background levels (0.01-3.00 mg/L; Table 5.1) at both monitoring points in this series, ranging from 0.05 mg/L at Pamlico #1-G to a maximum of 12.2 mg/L at both points (Table 5.14). Dissolved oxygen concentrations at both monitoring points are higher than is normally expected in groundwater, with monthly median concentrations generally between 3.5 and 8.5 mg/L (Figure 5.6). There is also a general seasonal trend at both monitoring points of higher monthly median DO concentrations during the fall, winter, and spring of the year, and lower concentrations during the summer (particularly during July and August). There was no clear relationship between precipitation data and DO concentrations. The linear trends for both monitoring points are stable to slightly increasing over the monitoring period. These data indicate that DO levels in groundwater near the Pamlico series are generally above background levels, and are higher than the concentrations expected near an OWTS.

5.6.4.5. Old Cove

The Old Cove series includes the monitoring points Old Cove #1-G, Old Cove #2-G, and Old Cove #3-S. These monitoring points were sampled between February 2001 and April 2005 (n = 52 months). Old Cove #1-G is located approximately 15 feet south of a leachfield serving a single-family house, and Old Cove #2-G is located approximately 60 feet south of the same leachfield. The surface water monitoring point associated with this group of monitoring points (Old Cove #3-S) is located in the finger canal approximately 100 feet south of the leachfield. Both monitoring wells and the surface water sampling point appear to be downgradient of the leachfield.

Between June 2004 and April 2005, water table elevations at Old Cove #1-G ranged from 0.17 to 2.42 feet AMSL, or 5.8 to 8.0 feet bgs (below ground surface) (Figure 5.9). At Old Cove #2-G, water table elevations ranged from 0.02 to 2.14 feet AMSL, or 3.7 to 5.8 feet bgs. Water table elevations at Old Cove #1-G were usually slightly higher than those at Old Cove #2-G. Water table elevations at both monitoring points show little response to rainfall events. Even during Hurricanes Alex and Charley in August 2004, water table elevations increased by only 0.5 to 0.6 feet at both locations and then re-equilibrated within a month. Water table elevations usually varied by less than a foot during the sampling period. During normal rainfall conditions, at least 7.0 feet of separation between the ground surface and groundwater was maintained at Old Cove #1-G, and 4.7 feet of separation was maintained at Old Cove #2-G.

Fecal coliform levels were sometimes above background levels (<1-4 MPN/100 mL; Table 5.1) at all monitoring points in this series, ranging from not detected at all monitoring points to a maximum of 53,000 MPN/100 mL at Old Cove #2-G

(Table 5.10). Monthly geometric mean values for each of the two groundwater monitoring points generally remained at or near detection limits (1-2 MPN/100 mL) between November and June of each year, and were higher between July and October, with the highest levels generally occurring in August (2001, 2004) or September (2002-2003) (Figure 5.9). Contrastingly, at Old Cove #3-S, fecal coliform monthly geometric mean values were generally higher than expected groundwater background values (4 MPN/100 mL or less) and had less seasonal variation than either of the two groundwater monitoring points. With the exceptions of August-September of 2002 and July 2004, fecal coliform monthly geometric mean concentrations were higher at Old Cove #3-S than at either of the groundwater monitoring points. There were two exceedances of the 200 MPN/100 mL recreational water quality standard during the 52 months of the monitoring period: at Old Cove #2-G in September 2002 (578 MPN/100 mL), and at Old Cove #3-S in September 2003 (502 MPN/100 mL). Increased runoff and stormwater infiltration associated with the landfall of Hurricane Gustav in early September 2002 may be somewhat responsible for the temporary increase in fecal coliform concentrations observed at both monitoring points. This pattern, however, was not repeated during the landfall of Hurricanes Alex and Charley in August 2004; in this case, the seasonal peak in fecal coliform concentrations in the groundwater was observed prior to the storm events. The linear trends for the three monitoring points did not increase or decrease significantly over time. The linear trend at Old Cove #2-G is higher overall than the trend for Old Cove #1-G, while the linear trend for Old Cove #3-S was higher than either of the groundwater points. These data indicate that fecal coliform levels in groundwater near the Old Cove well series are above groundwater background levels only during the summer months, and are within the range of concentrations expected near an OWTS. Fecal coliform levels in surface water near the Old Cove well series are generally above groundwater background levels, and are within the range of concentrations expected near an OWTS.

Total phosphorus levels were generally above background levels (0.3 mg/L or less; Table 5.1) at both groundwater monitoring points in this series, ranging from not detected (less than 0.01 mg/L) to a maximum of 9.67 mg/L (both at Old Cove #1-G (Table 5.11). The monthly median total phosphorus values at Old Cove #1-G were generally above expected background levels, and gradually increased by approximately 2 mg/L over the sampling period (Figure 5.9). At Old Cove #2-G, however, monthly median total phosphorus concentrations were higher (medians around 1.5-1.6 mg/L) in early 2001, then slowly declined over the sampling period to near-background levels. Monthly median values for total phosphorus at Old Cove #3-S were generally at or below the guideline value for surface waters (0.1 mg/L or less), and increased slightly over the sampling period (Figure 5.7). There was no clear relationship between water table elevation/precipitation data and total phosphorus concentrations. These data indicate that total phosphorus levels in groundwater near the Old Cove well series are above background levels, and are within the range of concentrations expected near an OWTS. Total phosphorus levels in surface water near the Old Cove well series are generally at or below water quality guideline levels, and are at the low end of the range of concentrations expected near an OWTS.

Ammonia levels were generally within background levels (0.3 mg/L or less; Table 5.1) at all monitoring points in this series, ranging from not detected (less than 0.1 mg/L) at all monitoring points to a maximum of 5.0 mg/L at Old Cove #1-G (Table 5.12). With the exception of two data points at Old Cove #1 (November 2002 and May 2003) and one datapoint at Old Cove #3 (March 2005), median monthly ammonia concentrations remained at or near background levels at all three monitoring locations (Figure 5.9). There was no clear relationship between water table elevation/precipitation data and ammonia concentrations. Median monthly ammonia concentrations at Old Cove #3-S were also below the recommended surface water quality guideline of 0.4 mg/L. These data indicate that ammonia levels for the Old Cove series are within expected background levels and water quality guidelines. These values are also within the range of concentrations expected near an OWTS.

Nitrate levels in groundwater were generally above background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at all monitoring points to a maximum of 70.8 mg/L at Old Cove #1-G (Table 5.13). The monthly median nitrate values at Old Cove #1-G were above expected background levels. From the beginning of the monitoring period through July 2002, median monthly nitrate values at Old Cove #1-G were above background levels, but were below the action level of 5.0 mg/L (Figure 5.9). From August 2002 through August 2004, nitrate levels at this point were generally high and variable. The nitrate drinking water standard was exceeded at Old Cove #1-G during all months of 2003 except March, April, and December, and was exceeded during 2004 for every month except March (a total of 16 exceedances of 52 months). From August 2004 through the end of the monitoring period, nitrate levels at Old Cove #1-G declined to near-background levels. At Old Cove #2-G, monthly median nitrate concentrations were lower overall, fluctuating between background levels and about 4.5 mg/L with no discernable trend over time. Monthly median values for nitrate at Old Cove #3-S were generally at or below the guideline value for surface waters (0.4 mg/L or less), and decreased slightly over the sampling period. There was no clear relationship between water table elevation/precipitation data and nitrate concentrations. These data indicate that nitrate levels in groundwater near the Old Cove well series are well above background levels, and are within or above the range of concentrations expected near an OWTS. Nitrate levels in surface water near the Old Cove well series are generally at or below water quality guideline levels, and are at the low end of the range of concentrations expected near an OWTS.

Dissolved oxygen levels in groundwater were generally within or above background levels (0.01-3.00 mg/L; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at all monitoring points to a maximum of 15.8 mg/L at Old Cove #3-S (Table 5.14). Dissolved oxygen concentrations at both groundwater monitoring points were initially higher than is normally expected in groundwater, with monthly median concentrations generally between 3.0 and 8.3 mg/L from the beginning of the sampling program through July 2002 (Figure 5.7). There was also a general seasonal trend at both groundwater monitoring points of higher monthly median DO concentrations during the fall, winter, and spring of the year, and lower concentrations during the summer (particularly during July and August). After July 2002, DO concentrations at both groundwater monitoring points were within the expected range for groundwater (less than 3 mg/L), and the previously described seasonal trends were less apparent. DO concentrations at both groundwater monitoring points appear to be increasing again during the winter and spring of 2005. There was no clear relationship between water table elevation/precipitation data and DO concentrations. The linear trends for both groundwater monitoring points decreased over the monitoring period. Monthly median values for DO at Old Cove #3-S were above the guideline value for surface waters (4.8 mg/L or more) for much of the sampling period. In 2001 and 2002, the seasonal trend observed was similar to that of the groundwater monitoring points: higher concentrations in the fall, winter, and spring; and lower concentrations in the summer. During July and August 2001, and August and September 2002, median monthly DO concentrations dropped below the surface water guideline. This seasonality was not observed during the fall and winter of 2003-04; only a slight increase in DO levels occurred in the winter and spring of 2003, and then gradually declined to a low of approximately 3 mg/L in June 2004. Dissolved oxygen levels recovered during the fall of 2004. Between September 2003 and September 2004, median monthly DO levels in the surface water were near or below the 4.8 mg/L water quality guideline; however, they did not fall below the 2.3 mg/L threshold below which aquatic life is not supported. Between late fall and spring (November 2001-April 2002, November 2002-June 2003, and October 2004-April 2005), median monthly dissolved concentrations were within or slightly above historical background levels in Roanoke Sound (Table 5.1). At all other times, monthly median DO levels were below historical background levels. Dissolved oxygen concentrations at both groundwater monitoring points in this series decreased over the sampling period, while DO concentrations at Old Cove #3-S did not change significantly over time. These data indicate that DO levels in groundwater near the Old Cove well series are at or above background levels, and are within or above the range of concentrations expected near an OWTS. Dissolved oxygen levels in surface water near the Old Cove well series are generally at or above water quality guideline levels, except during the summer months and between September 2003-September 2004.

5.6.4.6. Cobia Way

The Cobia Way series includes the monitoring points Cobia Way #1-G, Cobia Way #2-G, and Cobia Way #3-S. These monitoring points were sampled between February 2001 and March 2003 (n = 25 months). Cobia Way #1-G is located approximately 15 feet west-southwest of a leachfield serving a single-family house, and Cobia Way #2-G is located approximately 55 feet west-southwest of the same leachfield. The surface water monitoring point associated with this group of monitoring points (Cobia Way #3-S) is located in the finger canal approximately 90 feet west-southwest of the leachfield. Both monitoring wells and the surface water sampling point appear to be downgradient of the leachfield.

No water level readings were taken during the time period that the Cobia Way monitoring wells were active.

Fecal coliform levels were sometimes above background levels (<1-4 MPN/100 mL; Table 5.1) at all monitoring points in this series, ranging from not detected at all monitoring points to a maximum of 89,000 MPN/100 mL at Cobia Way #2-G (Table 5.10). Monthly geometric mean values for each of the two groundwater monitoring points generally remained at or near detection limits (1-2 MPN/100 mL) between November and June of each year, and were higher between July and October, with the highest levels generally occurring in July (2002) or August (2001 and 2002) (Figure 5.10). This seasonal variation was more pronounced in 2002 than in 2001 for both groundwater monitoring locations. It is unlikely that increased runoff and stormwater infiltration associated with the landfall of Hurricane Gustav in early September 2002 was responsible for the increase in fecal coliform concentrations observed at both monitoring points, since the peaks occurred well before the landfall of this storm. Contrastingly, at Cobia Way #3-S, fecal coliform monthly geometric mean values were always above expected groundwater background values (4 MPN/100 mL or less) and had less seasonal variation than either of the two groundwater monitoring points. With the exception of August-November of 2002, fecal coliform monthly geometric mean concentrations were higher at Cobia Way #3-S than at either of the groundwater monitoring points. There were five exceedances (of 25 months) of the 200

MPN/100 mL recreational water quality standard during the monitoring period: at Cobia Way #3-S in May 2001; and at both Cobia Way #1-G and #2-G in July and August 2002. The linear trend at Cobia Way #2-G is higher overall than the trend for Cobia Way #1-G, and both trends increased over the monitoring period. However, the overall linear trend for Cobia Way #3-S decreased slightly over the monitoring period. These data indicate that fecal coliform levels in groundwater near the Cobia Way well series are above background levels only during the summer months, and are within the range of concentrations expected near an OWTS. Fecal coliform levels in surface water near the Cobia Way well series are generally above groundwater background levels, and are within the range of concentrations expected near an OWTS.

Total phosphorus levels were generally above background levels (0.3 mg/L or less; Table 5.1) at both groundwater monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at Cobia Way #3-S to a maximum of 11.0 mg/L at Cobia Way #1-G (Table 5.11). The monthly median total phosphorus values at Cobia Way #1-G were generally above expected background levels, and gradually increased by approximately 2 mg/L over the sampling period (Figure 5.10). At Cobia Way #2-G, monthly median total phosphorus concentrations were still above background levels, but were generally lower (medians around 1.3-2.0 mg/L) gradually increasing by about 1 mg/L over the sampling period. Monthly median values for total phosphorus at Cobia Way #3-S were generally below the guideline value for surface waters (0.1 mg/L or less) before August 2002. Between August 2002 and March 2003, total phosphorus values at this point were at or slightly above the guideline value. There was no clear relationship between precipitation data and total phosphorus concentrations. These data indicate that total phosphorus levels in groundwater near the Cobia Way well series are above background levels, and are within the range of concentrations expected near an OWTS. Total phosphorus levels in surface water near the Cobia Way well series are generally at or slightly above water quality guideline levels, and are at the low end of the range of concentrations expected near an OWTS.

Ammonia levels were generally within background levels (0.3 mg/L or less; Table 5.1) at all monitoring points in this series, ranging from not detected (less than 0.1 mg/L) at all monitoring points to a maximum of 1.1 mg/L at Cobia Way #2-G (Table 5.12). Median monthly ammonia concentrations remained below groundwater background levels at all three monitoring locations (Figure 5.10). Median monthly ammonia concentrations at Cobia Way #3-S were also below the recommended surface water quality guideline of 0.4 mg/L. There was no clear relationship between precipitation data and ammonia concentrations. These data indicate that ammonia levels for the Cobia Way series are within expected background levels and water quality guidelines. These values are also within the range of concentrations expected near an OWTS.

Nitrate levels in groundwater were generally above background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at all monitoring points to a maximum of 16.5 mg/L at Cobia Way #1-G (Table 5.13). The monthly median nitrate values at Cobia Way #1-G were above expected background levels (Figure 5.10). From the beginning of the monitoring period through July 2002, median monthly nitrate values at Cobia Way #1-G were above background levels, but were generally below the action level of 5.0 mg/L. From August 2002 through the end of the monitoring period, nitrate levels at this point were generally higher and variable, but were below the 10 mg/L drinking water standard for nitrate. At Cobia Way #2-G, monthly median nitrate concentrations were lower overall, fluctuating between background levels and about 7 mg/L in a pattern similar to that observed at Cobia Way #1-G. Monthly median values for nitrate at Cobia Way #3-S were generally at or below the guideline value for surface waters (0.4 mg/L or less), and did not increase or decrease over the sampling period. There was no clear relationship between precipitation data and nitrate concentrations. These data indicate that nitrate levels in groundwater near the Cobia Way well series are well above background levels, and are within the range of concentrations expected near an OWTS. Nitrate levels in surface water near the Cobia Way well series are generally at or below water quality guideline levels, and are at the low end of the range of concentrations expected near an OWTS.

Dissolved oxygen levels in groundwater were generally within or above background levels (0.01-3.00 mg/L; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at Cobia Way #1-G and #3-S to a maximum of 15.75 mg/L at Cobia Way #3-S (Table 5.14). Dissolved oxygen concentrations at both groundwater monitoring points were initially higher than is normally expected in groundwater, with monthly median concentrations generally between 3.0 and 7.7 mg/L from the beginning of the sampling program through July 2002 (Figure 5.10). There was also a general seasonal trend at both groundwater monitoring points of higher monthly median DO concentrations during the fall, winter, and spring of the year, and lower concentrations during the summer (particularly during July and August). Between August 2002 and January 2003, DO concentrations at both groundwater monitoring points were within the expected range for groundwater (less than 3 mg/L), after which levels at both points were again above the expected range. The linear trends for both groundwater monitoring points decreased over the monitoring period. Monthly median values for DO at Cobia Way #3-S were above the guideline value for surface waters (4.8

mg/L or more) for much of the sampling period. The seasonal trend observed was similar to that of the groundwater monitoring points: higher concentrations in the fall, winter, and spring; and lower concentrations in the summer. During July and August 2001, and August, September, and November 2002, median monthly DO concentrations dropped below the surface water guideline. In September and November 2002, median monthly DO concentrations were below the 2.3 mg/L threshold for supporting aquatic life. Between late fall and spring (November 2001-May 2002 and December 2002-March 2003), median monthly dissolved concentrations were within or slightly above historical background levels in Roanoke Sound (Table 5.1). At all other times, monthly median DO levels at Cobia Way #3-S were below historical background levels. Dissolved oxygen concentrations at both groundwater monitoring points in this series decreased over the sampling period, while levels in surface water did not increase or decrease overall. There was no clear relationship between precipitation data and DO concentrations. These data indicate that DO levels in groundwater near the Cobia Way well series are at or above background levels, and are within or above the range of concentrations expected near an OWTS. Dissolved oxygen levels in surface water near the Cobia Way well series are generally at or above water quality guideline levels, except during the summer months and during November 2002.

5.6.4.7. Cobia Way A

The Cobia Way A series includes the monitoring points Cobia Way #1a-G, Cobia Way #2a-G, and Cobia Way #3a-S. These monitoring points were sampled between May 2003 and April 2005 (n = 23 months). Cobia Way #1a-G is located approximately 15 feet west-southwest of a leachfield serving a single-family house, and Cobia Way #2a-G is located approximately 70 feet west-southwest of the same leachfield. The surface water monitoring point associated with this group of monitoring points (Cobia Way #3a-S) is located in the finger canal approximately 95 feet west-southwest of the leachfield. Both monitoring wells and the surface water sampling point appear to be downgradient of the monitoring well.

Between June 2004 and April 2005, water table elevations at Cobia Way #1a-G ranged from 1.12 to 2.5 feet AMSL, or 7.8 to 9.2 feet bgs (below ground surface) (Figure 5.11). At Cobia Way #2a-G, water table elevations ranged from 0.38 to 2.28 feet AMSL, or 3.7 to 5.7 feet bgs. Water table elevations at Cobia Way #1a-G were usually slightly equal to or slightly higher than those at Cobia Way #2a-G. Water table elevations at both monitoring points show little response to rainfall events. Even during Hurricanes Alex and Charley in August 2004, water table elevations increased by only 0.4 to 0.8 feet at both locations and then re-equilibrated within a month. Water table elevations usually varied by less than a foot during the sampling period. During normal rainfall conditions, at least 9.2 feet of separation between the ground surface and groundwater was maintained at Cobia Way #1a-G, and 4.8 feet of separation was maintained at Cobia Way #2a-G.

Fecal coliform levels were sometimes above background levels (<1-4 MPN/100 mL; Table 5.1) at all monitoring points in this series, ranging from not detected at all monitoring points to a maximum of 1,200 MPN/100 mL at Cobia Way #1a-G and #2a-G (Table 5.10). Monthly geometric mean values for each of the two groundwater monitoring points generally remained at or below background levels (4 MPN/100 mL or less), except for in October 2003 and August-September 2004 at Cobia Way #1a-G and in July-October 2003 and May, August, September, and October 2004 at Cobia Way #2a-G. Contrastingly, at Cobia Way #3a-S, fecal coliform monthly geometric mean values were generally higher than expected groundwater background values and had seasonal variation similar to the two groundwater monitoring points (Figure 5.11). Fecal coliform monthly geometric mean concentrations were higher at Cobia Way #3a-S than at either of the groundwater monitoring points. There were no exceedances of the 200 MPN/100 mL recreational water quality standard during the monitoring period. Increased runoff and stormwater infiltration associated with the landfall of Hurricanes Alex and Charley in August 2004 may be somewhat responsible for the temporary peak in fecal coliform concentrations observed concurrently at the groundwater monitoring points. It is interesting, however, that a concurrent peak was not also observed at Cobia Way #3a-S. The linear trend at Cobia Way #1a-G increased slightly over time, while the trend at Cobia Way #2a-G remained stable and the trend at Cobia Way #3a-S decreased. The linear trend at Cobia Way #1a-G is higher overall than the trend for Cobia Way #2a-G, while the linear trend for Cobia Way #3a-S was higher than either of the groundwater points. These data indicate that fecal coliform levels in groundwater near the Cobia Way A well series are above groundwater background levels only during the summer months, and are within the range of concentrations expected near an OWTS. Fecal coliform levels in surface water near the Cobia Way A well series are generally above groundwater background levels, and are within the range of concentrations expected near an OWTS.

Total phosphorus levels were generally at or below background levels (0.3 mg/L or less; Table 5.1) at both groundwater monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at Cobia Way #1a-G and #2a-G to a maximum of 3.08 mg/L at Cobia Way #1a-S (Table 5.11). The monthly median total phosphorus values at Cobia Way #1a-G and #2a-G were generally at or below expected groundwater background levels, and did not increase or decrease significantly over the sampling period (Figure 5.11). Monthly median values for total phosphorus at Cobia Way #3a-S were generally at or below the guideline value for surface waters (0.1 mg/L or less), except for during December 2003-February 2004, when monthly medians were slightly above the guideline value. The total phosphorus trend at Cobia Way #3a-S increased slightly over the sampling period. There was no clear relationship between water table elevation/precipitation data and total phosphorus concentrations. These data indicate that total phosphorus levels in groundwater near the Cobia Way A well series are within background levels, and are at the low end of the range of concentrations expected near an OWTS. Total phosphorus levels in surface water near the Cobia Way A well series are generally within or slightly above water quality guideline levels, and are at the low end of the range of concentrations expected near an OWTS.

Ammonia levels were generally within background levels (0.3 mg/L or less; Table 5.1) at all monitoring points in this series, ranging from not detected (less than 0.1 mg/L) at all monitoring points to a maximum of 0.8 mg/L at Cobia Way #3a-S (Table 5.12). With the exception of one data point at Cobia Way #3a-S (March 2004), median monthly ammonia concentrations remained within background levels at all three monitoring locations (Figure 5.11). Median monthly ammonia concentrations at Cobia Way #3a-S were also below the recommended surface water quality guideline of 0.4 mg/L. There was no clear relationship between water table elevation/precipitation data and ammonia concentrations. These data indicate that ammonia levels for the Cobia Way A series are within expected background levels and water quality guidelines. These values are also within the range of concentrations expected near an OWTS.

Nitrate levels in groundwater were generally above background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from 0.01 mg/L at Cobia Way #3a-S to a maximum of 9.93 mg/L at Cobia Way #2a-G (Table 5.13). Throughout the monitoring period, median monthly nitrate values at both groundwater points were above background levels, but were generally below the action level of 5.0 mg/L. The only exceptions were during April 2004, when median monthly nitrate concentrations at both groundwater monitoring points were above the action level, and during August and October 2004, when nitrate concentrations at Cobia Way #1a-G were above the action level (Figure 5.11). The linear trend at both monitoring points increased slightly over the monitoring period. Monthly median values for nitrate at Cobia Way #3a-S were generally near or below the guideline value for surface waters (0.4 mg/L or less) until December 2003. In early 2004, and again in early 2005, median monthly nitrate concentrations fluctuated between near-background levels and concentrations as high as 5.5 mg/L. These increases do not appear to correspond to periods of increased rainfall. Nitrate at Cobia Way #3a-S increased by about 1 mg/L over the sampling period. These data indicate that nitrate levels in groundwater near the Cobia Way A well series are above background levels, and are within or above the range of concentrations expected near an OWTS. Nitrate levels in surface water near the Cobia Way A well series are generally at or above water quality guideline levels, and are within the range of concentrations expected near an OWTS.

Dissolved oxygen levels in groundwater were generally within or above background levels (0.01-3.00 mg/L; Table 5.1) at both monitoring points in this series, ranging from 0.23 mg/L to a maximum of 13.3 mg/L (both at Cobia Way #3a-S) (Table 5.14). Dissolved oxygen concentrations at both groundwater monitoring points were initially higher than is normally expected in groundwater, with monthly median concentrations generally between 3.5 and 7.1 mg/L from May through October 2003 (Figure 5.11). Between October 2003 and October 2004, DO concentrations at both groundwater monitoring points were within the expected range for groundwater (less than 3 mg/L). Between October 2004 and the end of the monitoring period, DO levels at Cobia Way #1a-G were above the expected background range for groundwater, while levels at Cobia Way #2a-G increased slightly but generally remained within the expected background range. The linear trends for Cobia Way #1a-G decreased slightly over the monitoring period, while the trend at Cobia Way #2a-G did not change. Monthly median values for DO at Cobia Way #3a-S were above the guideline value for surface waters (4.8 mg/L or more) between May and August of 2003. After August 2003, DO levels gradually declined to a low of approximately 2.5 mg/L in June 2004. This value is near but not below the 2.3 mg/L threshold below which aquatic life is not supported. Dissolved oxygen levels remained low until October2004, when they increased to over 7 mg/L and remained high through the end of the monitoring period. Surface water median monthly DO concentrations were generally below historical background levels in Roanoke Sound (Table 5.1). Dissolved oxygen concentrations at Cobia Way #3a-S generally increased over the sampling period. These data indicate that DO levels in groundwater near the Cobia Way A well series are at or above background levels, and are within or above the range of concentrations expected near an OWTS. Dissolved oxygen levels in surface water near the Cobia Way A well series are only at or above water quality guideline levels during the summer of 2003 and after September 2004.

5.6.4.8. Amberjack

The Amberjack series includes the monitoring points Amberjack #1-G, Amberjack #2-G, and Amberjack #3-S. These monitoring points were sampled between March 2001 and April 2005 (n = 52 months). Amberjack #1-G is located approximately 5 feet south-southeast of a leachfield serving a single-family house, and Amberjack #2-G is located approximately 45 feet south-southeast of the same leachfield. The surface water monitoring point associated with this group of monitoring points (Amberjack #3-S) is located in the finger canal approximately 70 feet south-southeast of the leachfield. The hydraulic position of the sampling points relative to the leachfield is ambiguous; however, they appear to be hydraulically crossgradient.

Between June 2004 and April 2005, water table elevations at Amberjack #1-G ranged from 0.74 to 2.34 feet AMSL, or 6.6 to 8.2 feet bgs (below ground surface) (Figure 5.12). At Amberjack #2-G, water table elevations ranged from 0.62 to 2.12 feet AMSL, or4.5 to 6.0 feet bgs. Water table elevations at Amberjack #1-G were usually slightly equal to or slightly higher than those at Amberjack #2-G, although there were several sampling events where water table elevations at Amberjack #2-G were higher than those at Amberjack #1-G. Water table elevations at both monitoring points show little response to rainfall events. Even during Hurricanes Alex and Charley in August 2004, water table elevations increased by only 0.4 to 0.8 feet at both locations and then re-equilibrated within a month. Water table elevations usually varied by less than a foot during the sampling period. During normal rainfall conditions, at least 7.8 feet of separation between the ground surface and groundwater was maintained at Amberjack #1-G, and 5.5 feet of separation was maintained at Amberjack #2-G.

Fecal coliform levels were sometimes above groundwater background levels (<1-4 MPN/100 mL; Table 5.1) at all monitoring points in this series, ranging from not detected at all monitoring points to a maximum of 80,000 MPN/100 mL at Amberjack #2-G (Table 5.10). Monthly geometric mean values for each of the two groundwater monitoring points generally remained at or near detection limits (1-2 MPN/100 mL) from February 2001 through July 2002 (Figure 5.12). After 2001, monthly geometric mean fecal coliform levels were higher between July and October, with the highest levels generally occurring in August or September. Contrastingly, at Amberjack #3-S, fecal coliform monthly geometric mean values were generally higher than expected groundwater background values (4 MPN/100 mL or less) and had less seasonal variation than either of the two groundwater monitoring points. There were three exceedances (of 52 months) of the 200 MPN/100 mL recreational water quality standard during the monitoring period: at Amberjack #1-G in August 2002 and June 2004, and at Amberjack #2-G in August 2003. Increased runoff and stormwater infiltration associated with the landfall of Hurricane Gustav in early September 2002 may be somewhat responsible for the temporary increase in fecal coliform concentrations observed at all three monitoring points. This pattern, however, was not repeated during the landfall of Hurricanes Alex and Charley in August 2004; in this case, the seasonal peak in fecal coliform concentrations in the groundwater was observed prior to the storm events. The linear trends Amberjack #1-G increased over time, while Amberjack #2-G remained stable and the surface water trend decreased slightly. These data indicate that fecal coliform levels in groundwater near the Amberjack well series are above background levels only during the summer months, and are within the range of concentrations expected near an OWTS. Fecal coliform levels in surface water near the Amberjack well series are generally above background levels, and are within the range of concentrations expected near an OWTS.

Total phosphorus levels were generally above background levels (0.3 mg/L or less; Table 5.1) at both groundwater monitoring points in this series, ranging from not detected (less than 0.01 mg/L)at Amberjack #3-S to a maximum of 8.74 mg/L at Amberjack #2-G (Table 5.11). The monthly median total phosphorus values at both groundwater monitoring points were steady between 0.5 and 1.5 mg/L until May 2003 (Figure 5.12). After this, total phosphorus concentrations increased gradually at both monitoring points, to highs of 3.1 mg/L at Amberjack #1-G in November 2003 and 4.4 mg/L at Amberjack #2-G in March 2004. From these peaks through April 2005, median total phosphorus concentrations declined to about 0.5 mg/L at Amberjack #1-G and about 1.5 mg/L at Amberjack #2-G. During the last year of the sampling period, there appears to be a slight correlation between water table elevations and total phosphorus concentrations. When the water table elevation at Amberjack #2-G was higher than the water table elevation at Amberjack #1-G, total phosphorus concentrations at Amberjack #2-G declined slightly. However, there was no apparent relationship between precipitation data and total phosphorus concentrations. Overall, total phosphorus concentrations increased at both groundwater monitoring points during the sampling period. Monthly median values for total phosphorus at Amberjack #3-S were generally at or below the guideline value for surface waters (0.1 mg/L or less), and did not change over the sampling period. These data indicate that total phosphorus levels in groundwater near the Amberjack well series are above background levels, and are within the range of concentrations expected near an OWTS. Total phosphorus levels in surface water near the Amberjack well series are generally at or below water quality guideline levels, and are at the low end of the range of concentrations expected near an OWTS.

Ammonia levels were within background levels (0.3 mg/L or less; Table 5.1) at all monitoring points in this series, ranging from not detected (less than 0.1 mg/L) at all monitoring points to a maximum of 1.7 mg/L at Amberjack #2-G (Table 5.12). Median monthly ammonia concentrations remained at or near background levels at all three monitoring locations (Figure 5.12). Median monthly ammonia concentrations at Amberjack #3-S were also below the recommended surface water quality guideline of 0.4 mg/L. There was no apparent relationship between water table elevation/precipitation data and ammonia concentrations. These data indicate that ammonia levels for the Amberjack series are within expected background levels and water quality guidelines. These values are also within the range of concentrations expected near an OWTS.

Nitrate levels in groundwater were generally above background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at all monitoring points to a maximum of 8.92 mg/L at Amberjack #2-G (Table 5.13). The monthly median nitrate values at Amberjack #1-G were above expected background levels (Figure 5.12). From the beginning of the monitoring period through July 2002, median monthly nitrate values at both Amberjack #1-G and Amberjack #2-G were above background levels, but were steady between 0.5 and 1.5 mg/L. From August 2002 through the end of the monitoring period, nitrate levels at this point were generally higher and more variable, but did not exceed the action level of 5.0 mg/L until the summer of 2004. During August-October 2004, nitrate levels at Amberjack #2-G were between 5.3 and 6.8 mg/L, after which they declined below the action level for the remainder of the monitoring period. Throughout the monitoring period, monthly median nitrate concentrations at Amberjack #2-G were higher than those at Amberjack #1-G, and this trend was more pronounced after July 2002. Monthly median values for nitrate at Amberjack #3-S were generally at or below the guideline value for surface waters (0.4 mg/L or less), and decreased slightly over the sampling period. There was no apparent relationship between water table elevations or precipitation data and nitrate concentrations. These data indicate that nitrate levels in groundwater near the Amberjack well series are above background levels, and are within or above the range of concentrations expected near an OWTS. Nitrate levels in surface water near the Amberjack well series are generally within water quality guideline levels, and are at the low end of the range of concentrations expected near an OWTS.

Dissolved oxygen levels in groundwater were generally within or above background levels (0.01-3.00 mg/L; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.01 mg/L) to a maximum of 31.36 mg/L at Amberjack #3-S (Table 5.14). This maximum is not representative of the data in this series; the next highest result at this monitoring point was 16.08 mg/L. Dissolved oxygen concentrations at both groundwater monitoring points were initially higher than is normally expected in groundwater, with monthly median concentrations generally between 3.0 and 7.2 mg/L from the beginning of the sampling program through July 2002 (Figure 5.12). There was also a general seasonal trend at both groundwater monitoring points of higher monthly median DO concentrations during the fall, winter, and spring of the year, and lower concentrations during the summer (particularly during July and August). Between July 2002 and October 2004, DO concentrations at both groundwater monitoring points were within the expected range for groundwater (less than 3 mg/L), and the seasonal trends were less apparent. Between October 2004 and the end of the monitoring period, DO levels at both monitoring points increased slightly, but remained within the expected background range for groundwater. Monthly median values for DO at Amberjack #3-S were above the guideline value for surface waters (4.8 mg/L or more) for much of the sampling period. In 2001 and 2002, the seasonal trend observed was similar to that of the groundwater monitoring points: higher concentrations in the fall, winter, and spring; and lower concentrations in the summer. During July and August 2001, and September and October 2002, median monthly DO concentrations dropped below the surface water guideline. This seasonal variation was not observed during the 2003-2004 season, but in October2004, DO concentrations increased to over 7 mg/L and remained high through the end of the monitoring period. After September 2003, median monthly DO levels in the surface water were near or below the 4.8 mg/L water quality guideline, and were below the 2.3 mg/L threshold below which aquatic life is not supported in September 2002 and February 2004. Between late fall and spring (November 2001-May 2002, December 2002-June 2003, and October 2004-April 2005), median monthly dissolved concentrations were within or slightly above historical background levels in Roanoke Sound (Table 5.1). At all other times, monthly median DO levels were below historical background levels. Dissolved oxygen concentrations at both groundwater monitoring points in this series decreased over the sampling period, while the overall trend in surface water remained stable. There was no apparent relationship between water table elevation/precipitation data and dissolved oxygen concentrations. These data indicate that DO levels in groundwater near the Amberjack well series are at or above background levels, and are within or above the range of concentrations expected near an OWTS. Dissolved oxygen levels in surface water near the Amberjack well series are generally at or above water quality guideline levels, except during the summer months and between July 2003-September 2004.

5.6.4.9. South Blue Marlin

The South Blue Marlin series includes the monitoring points S. Blue Marlin #1-G, S. Blue Marlin #2-G, and S. Blue Marlin #3-S. These monitoring points were sampled between March 2001 and June 2003 (n = 27 months). S. Blue Marlin #1-G is located approximately 10 feet west-southwest of a leachfield serving a single-family house, and S. Blue Marlin #2-G is located approximately 55 feet west-southwest of the same leachfield. The surface water monitoring point associated with this group of monitoring points (S. Blue Marlin #3-S) is located in the finger canal approximately 70 feet west-southwest of the leachfield. Both monitoring wells

and the surface water sampling point appear to be hydraulically downgradient of the leachfield.
No water level readings were taken during the time period that the S. Blue Marlin monitoring wells were active.

Fecal coliform levels were sometimes above groundwater background levels (<1-4 MPN/100 mL; Table 5.1) at all monitoring points in this series, ranging from not detected at all monitoring points to a maximum of 240,000 MPN/100 mL at S. Blue Marlin #2-G (Table 5.10). Monthly geometric mean values for each of the two groundwater monitoring points generally remained within background levels (4 MPN/100 mL or less) between November and June of each year, and were higher between July and October, with the highest levels occurring in August and September 2002 (Figure 5.13). Contrastingly, at S. Blue Marlin #3-S, fecal coliform monthly geometric mean values were always above expected groundwater background values (4 MPN/100 mL or less) and had less seasonal variation than either of the two groundwater monitoring points. Increased runoff and stormwater infiltration associated with the landfall of Hurricane Gustav in early September 2002 may be somewhat responsible for the temporary increase in fecal coliform concentrations observed at S. Blue Marlin #2-G and #3-S. With the exception of August-October of 2002, fecal coliform monthly geometric mean concentrations were higher at S. Blue Marlin #3-S than at either of the groundwater monitoring points. There were four exceedances of the 200 MPN/100 mL recreational water quality standard during the monitoring period: at S. Blue Marlin #1-G in August 2002; and at all three monitoring points in September 2002. The linear trend at S. Blue Marlin #2-G is lower overall than the trend for S. Blue Marlin #1-G or #3-S, but all three trends increased over the monitoring period. These data indicate that fecal coliform levels in groundwater near the S. Blue Marlin well series are above background levels only during the summer months, and are within the range of concentrations expected near an OWTS. Fecal coliform levels in surface water near the S. Blue Marlin well series are generally above background levels, and are within the range of concentrations expected near an OWTS.

Total phosphorus levels were generally above background levels (0.3 mg/L or less; Table 5.1) at both groundwater monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at S. Blue Marlin #1-G and #3-S to a maximum of 16.0 mg/L at S. Blue Marlin #2-G (Table 5.11). This maximum is not representative of the data in this series; the next highest result at this monitoring point was 4.25 mg/L. The monthly median total phosphorus values at S. Blue Marlin #1-G were generally above expected background levels, and gradually increased by approximately 1.2 mg/L over the sampling period (Figure 5.13). At S. Blue Marlin #2-G, monthly median total phosphorus concentrations were above background levels, but were slightly lower overall and gradually increased by about 1.6 mg/L over the sampling period. Monthly median values for total phosphorus at S. Blue Marlin #3-S were generally below the guideline value for surface waters (0.1 mg/L or less) before May 2002 and after December 2002. Between May and December 2002, total phosphorus values at this point were at or slightly above the guideline value. There was no apparent relationship between precipitation data and total phosphorus concentrations. These data indicate that total phosphorus levels in groundwater near the S. Blue Marlin well series are above background levels, and are within the range of concentrations expected near an OWTS. Total phosphorus levels in surface water near the S. Blue Marlin well series are generally at or above water quality guideline levels, and are at the low end of the range of concentrations expected near an OWTS.

Ammonia levels were generally within background levels (0.3 mg/L or less; Table 5.1) at all monitoring points in this series, ranging from not detected (less than 0.1 mg/L) at all monitoring points to a maximum of 0.8 mg/L at S. Blue Marlin #2-G and #3-S (Table 5.12). Median monthly ammonia concentrations remained at or near background levels at all three monitoring locations (Figure 5.13). Median monthly ammonia concentrations at S. Blue Marlin #3-S were also below the recommended surface water quality guideline of 0.4 mg/L. There was no apparent relationship between precipitation data and ammonia concentrations. These data indicate that ammonia levels for the S. Blue Marlin series are within expected background levels and water quality guidelines. These values are also within the range of concentrations expected near an OWTS.

Nitrate levels in groundwater were generally above background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at all monitoring points to a maximum of 21.3 mg/L at S. Blue Marlin #2-G (Table 5.13). The monthly median nitrate values at S. Blue Marlin #1-G were above expected background levels (Figure 5.13). From the beginning of the monitoring period through July 2002, median monthly nitrate values at both groundwater monitoring points were above background levels, but were generally below the action level of 5.0 mg/L. The only exception was in October 2001 at S. Blue Marlin #1-G, where the median nitrate concentration was 8.1 mg/L. From August 2002 through the end of the monitoring period, nitrate levels at both groundwater monitoring points were generally higher and variable, but were usually below the 10 mg/L drinking water standard for nitrate. The nitrate drinking water standard was exceeded at S. Blue Marlin #1-G during October 2002 and at S. Blue Marlin #2-G during February 2003. Monthly median values for nitrate at S. Blue Marlin #3-S were generally at or below the guideline value for surface waters (0.4 mg/L or less), and did not increase or decrease over the sampling period. There was no apparent relationship between precipitation data and nitrate concentrations. These data indicate that nitrate levels in groundwater near the S. Blue Marlin well series are well above background levels, and are within the range of concentrations expected near an OWTS. Nitrate levels in surface water near the S. Blue Marlin well series are generally at or below water quality guideline levels, and are at the low end of the range of concentrations expected near an OWTS.

Dissolved oxygen levels in groundwater were generally within or above background levels (0.01-3.00 mg/L; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at S. Blue Marlin #2-G and #3-S to a maximum of 241 mg/L at S. Blue Marlin #1-G (Table 5.14). Dissolved oxygen concentrations at both groundwater monitoring points were initially higher than is normally expected in groundwater, with monthly median concentrations generally between 3.1 and 7.5 mg/L from the beginning of the sampling program through July 2002 (Figure 5.13). There was also a general seasonal trend at both groundwater monitoring points of higher monthly median DO concentrations during the fall, winter, and spring of the year, and lower concentrations during the summer (particularly during July and August). Between August 2002 and June 2003, DO concentrations at both groundwater monitoring points were within the expected range for groundwater (less than 3 mg/L). The linear trends for both groundwater monitoring points decreased over the monitoring period. Monthly median values for DO at S. Blue Marlin #3-S were above the guideline value for surface waters (4.8 mg/L or more) for much of the sampling period. The seasonal trend observed was similar to that of the groundwater monitoring points: higher concentrations in the fall, winter, and spring; and lower concentrations in the summer. During July and August 2001, and August through November 2002, median monthly DO concentrations dropped below the surface water guideline. In August and September 2002, median monthly DO concentrations were below the 2.3 mg/L threshold for supporting aquatic life. Between late fall and spring (September 2001-May 2002, December 2002-January 2003, and April 2003), median monthly dissolved concentrations were within or slightly above historical background levels in Roanoke Sound (Table 5.1). At all other times, monthly median DO levels at S. Blue Marlin #3-S were below historical background levels. Dissolved oxygen concentrations at all monitoring points in this series decreased over the sampling period. There was no apparent relationship between precipitation data and DO concentrations. These data indicate that DO levels in groundwater near the S. Blue Marlin well series are at or above background levels, and are within or above the range of concentrations expected near an OWTS. Dissolved oxygen levels in surface water near the S. Blue Marlin well series are generally at or above water quality guideline levels, except during the summer months.

5.6.4.10. Jeannette's Pier

The Jeannette's Pier series includes the monitoring points Jeannette's Pier-G and Jeannette's Pier #-S. These monitoring points were sampled between May 2003 and April 2005 (n = 23 months). Jeannette's Pier-G is located approximately 5 feet west of a set of two leachfields serving the businesses on the pier. The surface water monitoring point associated with this group of monitoring points (Jeannette's Pier-S) is located in the surf zone of the Atlantic Ocean approximately 215 feet east-northeast of the leachfields. The Jeannette's Pier-G monitoring well appears to be immediately upgradient of the leach fields while the Jeannette's Pier-S surface water sampling point is downgradient of the leachfields.

Between June 2004 and April 2005, water table elevations at Jeannette's Pier-G ranged from 0.79 to 5.49 feet AMSL, or 2.6 to 7.4 feet bgs (below ground surface) (Figure 5.14). Water table elevations varied significantly at Jeannette's Pier-G during the sampling period. This variation was best explained by comparing the measured water level elevations to the maximum tide height that occurred during the sampling day, in feet referenced to Mean Lower Low Water (MLLW). Maximum tide height for each day between June 1, 2004 and April 30, 2005 is shown in green on this and subsequent figures. Water level readings taken close to a neap tide (for example, during early December 2004) tended to be the lowest observations recorded, while those taken close to a spring tide (for example, during early February 2005) were the highest observations recorded. Any response of local water table elevations at Jeannette's Pier-G to rainfall events was swamped by the response of groundwater to tidal fluctuations. Water table elevations often varied by a foot or more between sampling events. Despite the magnitude of fluctuation in groundwater elevations at this point, at least 4 feet of separation between the ground surface and groundwater was usually maintained.

Fecal coliform levels were sometimes above background levels (<1-4 MPN/100 mL; Table 5.1) at all monitoring points in this series, ranging from not detected at both monitoring points to a maximum of 3,120 MPN/100 mL at Jeannette's Pier -S (Table 5.10). Monthly geometric mean values at Jeannette's Pier-G generally remained at or below background levels (4 MPN/100 mL or less), except for in August-September 2003 and July-September and October 2004. Contrastingly, at Jeannette's Pier-S, fecal coliform monthly geometric mean values were only within groundwater background values during January-February 2004 and December 2004-February 2005 and were higher during the rest of the sampling period (Figure 5.14). There were two exceedances (of 23 months) of the 200 MPN/100 mL recreational water quality standard during the monitoring period, at Jeannette's Pier-S in May and July 2002. The linear trend at the groundwater point remained stable over time, while the surface water trend decreased. There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and fecal coliform concentrations. These data indicate that fecal coliform levels in groundwater near the Jeannette's Pier well series are above groundwater background levels only during the summer months, and are within the range of concentrations expected near an OWTS. Fecal coliform levels in surface water near the Jeannette's Pier well series are generally above groundwater background levels, and are within the range of concentrations expected near an OWTS.

Total phosphorus levels were generally above background levels (0.3 mg/L or less; Table 5.1) at both groundwater monitoring points in this series, ranging from not detected (less than 0.01 mg/L) mg/L at both monitoring points to a maximum of 7.97 mg/L at Jeannette's Pier-G (Table 5.11). The monthly median total phosphorus values at Jeannette's Pier-G were generally above expected background levels (0.3 mg/L or less), and increased fairly steadily by about 2 mg/L over the sampling period (Figure 5.14). Monthly median values for total phosphorus at Jeannette's Pier -S were generally at or above the guideline value for surface waters (0.1 mg/L or less). During August 2003, the monthly median was high for surface waters (2.04 mg/L), but the medians for subsequent months returned to more reasonable levels. The total phosphorus trend at Jeannette's Pier -S decreased slightly over the sampling period. There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and total phosphorus concentrations. These data indicate that total phosphorus levels in groundwater near the Jeannette's Pier well series are above background levels, and are at the within the range of concentrations expected near an OWTS. Total phosphorus levels in surface water near the Jeannette's Pier well series are generally slightly above water quality guideline levels, and are at the low end of the range of concentrations expected near an OWTS.

Ammonia levels were within background levels 0.3 mg/L or less; Table 5.1) at all monitoring points in this series, ranging from not detected (less than 0.1 mg/L) to a maximum of 0.1 mg/L at both monitoring points (Table 5.12). Median monthly ammonia concentrations remained within background levels at both monitoring locations. Median monthly ammonia concentrations at Jeannette's Pier-S were also below the recommended surface water quality guideline of 0.4 mg/L (Figure 5.14). There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and ammonia concentrations. These data indicate that ammonia levels for the Jeannette's Pier series are within expected background levels and water quality guidelines. These values are also within the range of concentrations expected near an OWTS.

Nitrate levels in groundwater were generally above background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from 0.03 mg/L at both monitoring points to a maximum of 13.9 mg/L at Jeannette's Pier-G (Table 5.13). Throughout the monitoring period, median monthly nitrate values at Jeannette's Pier-G were above background levels, but were well below the action level of 5.0 mg/L through March 2004 (Figure 5.14). During April-June 2004, median monthly nitrate concentrations abruptly increased to greater than 10 mg/L. After June 2004, nitrate levels fluctuated between 4 and 8 mg/L until March 2005, when nitrate concentrations abruptly decreased to less than 2 mg/L. The nitrate drinking water standard was exceeded at Jeannette's Pier-G during May and June 2004. Monthly median values for nitrate at Jeannette's Pier-S were generally near or below the guideline value for surface waters (0.4 mg/L or less), except during June 2003 (0.62 mg/L), September 2003 (0.49 mg/L), and January-February 2005 (0.6-2.8 mg/L). The linear trend for nitrate at Jeannette's Pier-S remained stable over the sampling period. There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and nitrate concentrations. These data indicate that nitrate levels in groundwater near the Jeannette's Pier well series are above background levels, and are within the range of concentrations expected near an OWTS. Nitrate levels in surface water near the Jeannette's Pier well series are generally within water quality guideline levels, and are within the range of concentrations expected near an OWTS.

Dissolved oxygen levels in groundwater were generally within or above background levels (0.01-3.00 mg/L; Table 5.1) at both monitoring points in this series, ranging from 0.22 mg/L at Jeannette's Pier-G to a maximum of 14.5 mg/L at Jeannette's Pier-S (Table 5.14). Dissolved oxygen concentrations at Jeannette's Pier-G were initially higher (about 4.5 mg/L) than is normally expected in groundwater, but steadily declined to about 1 mg/L by June 2004 (Figure 5.14). Monthly median values for DO at Jeannette's Pier-S were above the guideline value for surface waters (4.8 mg/L or more) except during February and July-August of 2004, when they were slightly lower. Surface water median monthly DO concentrations were generally within historical background levels in Roanoke Sound during about half of the sampling events. Dissolved oxygen concentrations at Jeannette's Pier-S remained stable over the sampling period. There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and dissolved oxygen concentrations. These data indicate that DO levels in groundwater near the Jeannette's Pier well series are at or above background levels, and are within or above the range of concentrations expected near an OWTS. Dissolved oxygen levels in surface water near the Jeannette's Pier well series are generally at or above water quality guideline levels.

5.6.4.11. *Huron Access*

The Huron Access series includes the monitoring points Huron Access #1-G and Huron Access #2-G. These monitoring points were sampled between March 2001 and April 2005 (n = 52 months). Huron Access #1-G is located approximately 10 feet south of a leachfield serving the Bodie Island Beach CLub, and Huron Access #2-G is located approximately 65 feet east of the same leachfield. There is no surface water monitoring point associated with this group of monitoring points. Both monitoring wells appear to be hydraulically downgradient and slightly cross-gradient of the corresponding leachfield.

Between June 2004 and April 2005, water table elevations at Huron Access #1-G ranged from 2.46 to 4.87 feet AMSL, or 6.7 to 9.1 feet bgs (below ground surface) (Figure 5.15). Water table elevations at Huron Access #2-G ranged from 2.08 to 4.58 feet AMSL, or 4.2 to 6.6 feet bgs. Water table elevations varied significantly at both monitoring points during the sampling period. This variation was best explained by comparing the measured water level elevations to the maximum tide height that occurred during the sampling day, in feet referenced to Mean Lower Low Water (MLLW). Water level readings taken close to a spring tide (for example, during late October 2004) tended to be the highest observations recorded, while those taken close to a neap tide (for example, during early November 2004) were the lowest observations recorded. Water table elevations often varied by a foot or more between sampling events. Furthermore, it appears that the hydraulic gradient (the direction of groundwater flow) in this area is influenced by the tides. During spring tides, water table elevations at Huron Access #1-G are generally higher that those at Huron Access #2-G, indicating that groundwater is moving towards the sound side of the island. During neap tides, water table elevations at Huron Access #2-G are generally higher than those at Huron Access #1-G, indicating that groundwater is moving towards the Atlantic Ocean. While the local water table elevation may increase following the landfall of Hurricanes Alex and Charley in August 2004, the increase observed is within the range of tidally-induced water table fluctuation that normally occurs at these monitoring points. Despite the magnitude of fluctuation in groundwater elevations, at least 4 feet of separation between the ground surface and groundwater was always maintained.

Fecal coliform levels were sometimes above background levels (<1-4 MPN/100 mL; Table 5.1) at both monitoring points in this series, ranging from not detected at both monitoring points to a maximum of 90,000 MPN/100 mL at Huron Access #1-G (Table 5.10). Monthly geometric mean values for each of these monitoring points generally remained within background levels (4 MPN/100 mL or less) between November and June of each year, and were higher between July and October, with the highest levels generally occurring in August and September

(Figure 5.15). The seasonal trend is overprinted by a few isolated increases above background levels, particularly at Huron Access #2-G during the winter of 2003. There were two exceedances of the 200 MPN/100 mL recreational water quality standard at Huron Access #2-G in September and October 2002. Increased runoff and stormwater infiltration associated with the landfall of Hurricane Gustav in early September 2002 may be somewhat responsible for the temporary increase in fecal coliform concentrations observed at this monitoring point. This pattern, however, was not repeated at either point during the landfall of Hurricanes Alex and Charley in August 2004; in this case, the seasonal peak in fecal coliform concentrations in the groundwater was observed prior to the storm events. There did not appear to be a strong relationship between water table elevations or hydraulic gradient and fecal coliform concentrations. Fecal coliform levels at Huron Access #1-G increased over the sampling period, while remaining stable at Huron Access #2-G. The linear trend at Huron Access #2-G is higher overall than the trend for Huron Access #1-G. These data indicate that fecal coliform levels in groundwater near the Huron Access well series are generally above background levels only during the summer months with a few isolated occurrences during cooler seasons. These levels are within the range of concentrations expected near an OWTS.

Total phosphorus levels were sometimes above background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at both monitoring points to a maximum of 7.32 mg/L at Huron Access #1-G (Table 5.11). From the beginning of the sampling program through May 2001, median monthly total phosphorus concentrations declined rapidly from highs of 3.5-4.5 mg/L to near background levels (0.3 mg/L or less) at both monitoring locations (Figure 5.15). From May 2001 through October 2002, median monthly total phosphorus concentrations at both monitoring points increased steadily to highs of 2.5-3.5 mg/L. After October 2002, median monthly total phosphorus concentrations declined steadily to around 1.0 mg/L by the end of the sampling period. The linear trends at both monitoring points decreased by about 0.8 mg/L over the sampling period. There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and total phosphorus concentrations. These data indicate that total phosphorus levels in groundwater near the Huron Access well series are above background levels, but are within the range of concentrations expected near an OWTS.

Ammonia levels were generally within background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.1 mg/L) at both monitoring points to a maximum of 20.0 mg/L at Huron Access #2-G (Table 5.12). Median monthly ammonia concentrations remained within background levels at Huron Access #1-G for the duration of the monitoring period. At Huron Access #2-G, median monthly ammonia concentrations generally remained within background levels, except a few isolated instances where concentrations were slightly higher (May 2001, August 2001, and July 2002) (Figure 5.15). The linear trends at both monitoring points in this series remained stable over time. There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and ammonia concentrations. These data indicate that ammonia levels in groundwater near the Huron Access well series are within background levels and within the range of concentrations expected near an OWTS.

Nitrate levels were above background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at Huron Access #2-G to a maximum of 71.0 mg/L at Huron Access #1-G (Table 5.13). From the beginning of the sampling program through January 2001, median monthly nitrate concentrations fluctuated between 1.0 and 6.0 mg/L at both monitoring locations (Figure 5.13). From January 2002 through July 2002, median monthly nitrate concentrations at both locations were steady and slightly above background levels (0.80-1.7 mg/L). In August 2002, monthly median nitrate concentrations at both monitoring points increased sharply (to 20 mg/L), then decreased gradually through November 2002. A similar sharp increase in median nitrate concentrations was observed only at Huron Access #1-G during July-October 2003. After October 2003, median monthly nitrate concentrations fluctuated between 0.37 and 3.9 mg/L at both monitoring points. Overall, the linear trend at both monitoring points decreased slightly. There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and nitrate concentrations. These data indicate that nitrate levels in groundwater near the Huron Access well series are generally above background levels, and are within the range of concentrations expected near an OWTS.

Dissolved oxygen levels were at or above background levels (0.01-3.00 mg/L; Table 5.1) at both monitoring points in this series, ranging from 0.04 mg/L at Huron Access #2-G to a maximum of 15.7 mg/L at Huron Access #1-G (Table 5.14). Dissolved oxygen concentrations at both groundwater monitoring points were initially higher than is normally expected in groundwater, with monthly median concentrations generally between 3.1 and 7.8 mg/L from the beginning of the sampling program through July 2002 (Figure 5.15). There was also a general seasonal trend at both groundwater monitoring points of higher monthly median DO concentrations during the fall, winter, and spring of the year, and lower concentrations during the summer (particularly during July and August). Between August 2002 and April 2005, DO concentrations at both groundwater monitoring points were within or slightly above the expected range for groundwater (less than 3 mg/L). Between November 2004 and April 2005, DO concentrations increased slightly at both monitoring points. There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and dissolved oxygen concentrations. The linear trends for both groundwater monitoring points decreased over the monitoring period. These data indicate that DO levels in groundwater near the Huron Access well series are at or above background levels, and are within or above the range of concentrations expected near an OWTS.

5.6.4.12. Ida Access

The Ida Access series includes the monitoring points Ida Access #1-G and Ida Access #2-G. These monitoring points were sampled between February 2001 and April 2005 (n = 52 months). Ida Access #1-G is located approximately 15 feet north of a leachfield serving a single-family house, and Ida Access #2-G is located approximately 145 feet west-southwest of the same leachfield. There is no surface water monitoring point associated with this group of monitoring points. Monitoring well Ida Access #1-G appears to be hydraulically upgradient, while Ida Access #2-G appears to be hydraulically downgradient of the associated leachfield. Both monitoring points also appear to be slightly cross-gradient from the leachfield.

Between June 2004 and April 2005, water table elevations at Ida Access #1-G ranged from 2.24 to 4.97 feet AMSL, or 3.4 to 6.2 feet bgs (below ground surface) (Figure 5.16). Water table elevations at Ida Access #2-G ranged from 1.49 to 3.84 feet AMSL, or 2.4 to 4.7 feet bgs. Water table elevations varied significantly at both monitoring points during the sampling period. This variation was best explained by comparing the measured water level elevations to the maximum tide height that occurred during the sampling day, in feet referenced to Mean Lower Low Water (MLLW). Water level readings taken close to a spring tide (for example, during late October 2004) tended to be the highest observations recorded, while those taken close to a neap tide (for example, during early November 2004) were the lowest observations recorded. Water table elevations often varied by a foot or more between sampling events. Water table elevations at Ida Access #1-G are generally higher that those at Ida Access #2-G, indicating that groundwater is moving towards the sound side of the island. During spring tides, water table elevations at Ida Access #1-G are as much as 1 foot higher than those at Ida Access #2-G, while during neap tides the difference between the two points is only about 0.3 feet. While the local water table elevation may increase following the landfall of Hurricanes Alex and Charley in August 2004, the increase observed is within the range of tidally-induced water table fluctuation that normally occurs at these monitoring points. At least 2.5 feet of separation between the ground surface and groundwater was always maintained at both monitoring points.

Fecal coliform levels were sometimes above background levels (<1-4 MPN/100 mL; Table 5.1) at both monitoring points in this series, ranging from not detected at both monitoring points to a maximum of 8,200 MPN/100 mL at Ida Access #1-G (Table 5.10). Monthly geometric mean values for each of these monitoring points remained within background levels (4 MPN/100 mL or less) except during July (2004), August (2001), and September (2002-2003), when fecal coliform levels were higher (Figure 5.16). Increased runoff and stormwater infiltration associated with the landfall of Hurricane Gustav in early September 2002 may be somewhat responsible for the temporary increase in fecal coliform concentrations observed at both monitoring points. This pattern, however, was not repeated during the landfall of Hurricanes Alex and Charley in August 2004; in this case, the seasonal peak in fecal coliform concentrations in the groundwater was observed prior to the storm events. There were no exceedances of the 200 MPN/100 mL recreational water quality standard during the sampling period. The linear trend at Ida Access #1-G was slightly higher than the trend at Ida Access #2-G, but both trends remained stable over time. There was no apparent relationship between water table elevation or tidal fluctuations and fecal coliform concentrations. These data indicate that fecal coliform levels in groundwater near the Ida Access well series are generally above background levels only during the summer months. These levels are within the range of concentrations expected near an OWTS.

Total phosphorus levels were generally within background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at both monitoring points to a maximum of 5.30 mg/L at Ida Access #1-G (Table 5.11). Except for a few isolated instances at Ida Access #1-G (in April, August, and October 2001), median monthly total phosphorus concentrations were within background levels for groundwater at both monitoring locations (Figure 5.16). The linear trends at both monitoring points decreased slightly over the sampling period. There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and total phosphorus concentrations. These data indicate that total phosphorus levels in groundwater near the Ida Access well series are within background levels, and are at the low end of the range of concentrations expected near an OWTS.

Ammonia levels were generally within background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.1 mg/L) at both monitoring points to a maximum of 1.9 mg/L at Ida Access #2-G (Table 5.12). Except for a few isolated instances at Ida Access #1-G (in May 2001) and Ida Access #2-G (in May and August 2001), median monthly total phosphorus concentrations were within background levels for groundwater at both monitoring locations (Figure 5.16). The linear trends at both monitoring points in this series decreased slightly over the monitoring period. There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and ammonia concentrations. These data indicate that ammonia levels in groundwater near the Ida Access well series are within background levels and within the range of concentrations expected near an OWTS.

Nitrate levels were generally above background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from 0.01 mg/L to a maximum of 5.30 mg/L (both at Ida Access #2-G) (Table 5.13). Throughout the sampling period, median monthly nitrate concentrations fluctuated between 0.30 and 1.4 mg/L at both monitoring locations (Figure 5.16). Slight increases to 2-3 mg/L were observed in October 2001, October-November 2002, and January-February 2005. Overall, the linear trend at Ida Access #1-G remained stable over time, while the linear trend at Ida Access #2 increased slightly. There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and parameter concentrations. These data indicate that nitrate levels in groundwater near the Ida Access well series are generally above background levels, and are within the range of concentrations expected near an OWTS.

Dissolved oxygen levels were at or above background levels (0.01-3.00 mg/L; Table 5.1) at both monitoring points in this series, ranging from 0.01 mg/L to a maximum of 15.8 mg/L (both at Ida Access #2-G) (Table 5.14). Dissolved oxygen concentrations at both groundwater monitoring points were initially higher than is normally expected in groundwater, with monthly median concentrations generally between 3.5 and 8.6 mg/L from the beginning of the sampling program through July 2002 (Figure 5.16). There was also a general seasonal trend at both monitoring points of higher monthly median DO concentrations during the fall, winter, and spring of the year, and lower concentrations during the summer (particularly during August). The only exception to this trend was an increase to 11 mg/L that observed at both monitoring points only in September 2001. After the summer of 2003, DO concentrations at both monitoring points remained within the expected range for groundwater (less than 3 mg/L). Dissolved oxygen concentrations appear to be increasing during the winter and spring of 2004-2005, particularly at Ida Access #2-G. The linear trends for both monitoring points decreased over the monitoring period. There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and DO concentrations. These data indicate that DO levels in groundwater near the Ida Access well series are at or above background levels, and are within or above the range of concentrations expected near an OWTS.

5.6.4.13. Jay Street Access

The Jay Street Access series includes the monitoring points Jay Street Access #1-G and Jay Street Access #2-G. These monitoring points were sampled between February 2001 and April 2005 (n = 52 months). Jay Street Access #1-G is located approximately 20 feet north of a leachfield serving a single-family house, and Jay Street Access #2-G is located approximately 20 feet north-northeast of the same leachfield. There is no surface water monitoring point associated with this group of monitoring points. Monitoring well Jay Street Access #1-G appears to be upgradient of the associated leachfield, while monitoring well Jay Street Access #2-G appears to crossgradient to the associated leachfield.

Between June 2004 and April 2005, water table elevations at Jay St. Access #1-G ranged from 2.48 to 4.31 feet AMSL, or 4.1 to 5.9 feet bgs (below ground surface) (Figure 5.17). Water table elevations at Jay St. Access #2-G ranged from 1.48 to 4.29 feet AMSL, or3.0 to 5.8 feet bgs. Water table elevations varied significantly at both monitoring points during the sampling period. This variation was best explained by comparing the measured water level elevations to the maximum tide height that occurred during the sampling day, in feet referenced to Mean Lower Low Water (MLLW). Water level readings taken close to a spring tide (for example, during late October 2004) tended to be the highest observations recorded, while those taken close to a neap tide (for example, during early November 2004) were the lowest observations recorded. Water table elevations often varied by a foot or more between sampling events. Water table elevations at Jay St. Access #1-G are generally slightly higher that those at Jay St. Access #2-G, indicating that groundwater in this area is moving towards the sound side of the island. Water table elevations at Jay St. Access #1-G were only slightly higher (0.6 feet or less) than those at Jay St. Access #2-G during spring tides, and the difference was less than 0.2 feet during neap tides. While the local water table elevations increase following the landfall of Hurricanes Alex and Charley in August 2004, the increase observed is within the range of tidally-induced water table fluctuation that normally occurs at these monitoring points. At least 3.0 feet of separation between the ground surface and groundwater was always maintained at both monitoring points.

Fecal coliform levels were sometimes above background levels (<1-4 MPN/100 mL; Table 5.1) at both monitoring points in this series, ranging from not detected at both monitoring points to a maximum of 17,000 MPN/100 mL at Jay Street Access #2-G (Table 5.10). Monthly geometric mean values for each of these monitoring points remained within background levels (4 MPN/100 mL or less) except during August and September 2002, when fecal coliform levels were higher (Figure 5.17). Increased runoff and stormwater infiltration associated with the landfall of Hurricane Gustav in early September 2002 may be somewhat responsible for the temporary increase in fecal coliform concentrations observed at both monitoring points. This pattern, however, was not repeated during the landfall of Hurricanes Alex and Charley in August 2004; in this case, the seasonal peak in fecal coliform concentrations in the groundwater was observed well after the storm events. There were no exceedances of the 200 MPN/100 mL recreational water quality standard during the sampling period. The linear trend at Jay Street Access #2-G was slightly higher than the trend at Jay Street Access #1-G, but both trends remained stable over time. There was no apparent relationship between water table elevations or tidal fluctuations and fecal coliform concentrations. These data indicate that fecal coliform levels in groundwater near the Jay Street Access well series are generally above background levels only during the summer months. These levels are within the range of concentrations expected near an OWTS.

Total phosphorus levels were within background levels for groundwater (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at both monitoring points to a maximum of 1.70 mg/L at Jay Street Access #1-G (Table 5.11). The linear trends at both monitoring points decreased slightly over the sampling period (Figure 5.17). There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and total phosphorus concentrations. These data indicate that total phosphorus levels in groundwater near the Jay Street Access well series are within background levels, and are at the low end of the range of concentrations expected near an OWTS.

Ammonia levels were generally within background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.1 mg/L) at both monitoring points to a maximum of 30.0 mg/L at Jay Street Access #2-G (Table 5.12). Median monthly ammonia concentrations were within background levels for groundwater at both monitoring locations (Figure 5.17). The only exception was during May 2001, when the median monthly ammonia level at Jay Street Access #1-G was slightly elevated (1.2 mg/L) and the level at Jay Street Access #2-G was high (18.7 mg/L). The linear trends at both monitoring points in this series decreased slightly over the monitoring period. There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and ammonia concentrations. These data indicate that ammonia levels in groundwater near the Jay Street Access well series are within background levels and within the range of concentrations expected near an OWTS.

Nitrate levels were generally above background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from 0.01 mg/L to a maximum of 19.4 mg/L (both at Jay Street Access #2-G) (Table 5.13). Throughout the sampling period, median monthly nitrate concentrations fluctuated between 0.20 and 1.5 mg/L at both monitoring locations (Figure 5.17). Slight increases to 2-3 mg/L were observed at both monitoring locations early in the monitoring period (February-November 2001) and again late in the monitoring period (April-June 2004). Overall, the linear trends for both monitoring decreased slightly over time. There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and nitrate concentrations. These data indicate that nitrate levels in groundwater near the Jay Street Access well series are generally above background levels, and are within the range of concentrations expected near an OWTS.

Dissolved oxygen levels were at or above background levels (0.01-3.00 mg/L; Table 5.1) at both monitoring points in this series, ranging from 0.37 mg/L at Jay Street Access #2-G to a maximum of 11.3 mg/L at Jay Street Access #1-G (Table 5.14). Dissolved oxygen concentrations at both groundwater monitoring points were initially higher than is normally expected in groundwater, with monthly median concentrations generally between 3.1 and 7.5 mg/L from the beginning of the sampling program through July 2002 (Figure 5.15). There was also a general seasonal trend at both monitoring points of higher monthly median DO concentrations during the fall, winter, and spring of the year, and lower concentrations during the summer (particularly during August). The only exception to this trend was an increase to 10-11 mg/L that observed at both monitoring points only in September 2001. Between the summer of 2003 and September 2004, DO concentrations at both monitoring points remained within the expected range for groundwater (less than 3 mg/L). After September 2004, DO concentrations increased slightly at both monitoring wells, but remained within the range of expected background concentrations. The linear trends for both monitoring points decreased over the monitoring period. There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and DO concentrations. These data indicate that DO levels in groundwater near the at Jay Street Access well series are at or above background levels, and are within or above the range of concentrations expected near an OWTS.

5.6.4.14. Juncos Street Access

The Juncos Street Access series includes the monitoring points Juncos Street Access #1-G and Juncos Street Access #2-G. These monitoring points were sampled between February 2001 and April 2005 (n = 52 months). Juncos Street Access #1-G is located approximately 40 feet east of a leachfield serving a single-family house, and Juncos Street Access #2-G is located approximately 10 feet south of the same leachfield. There is no surface water monitoring point associated with this group of monitoring points. Monitoring well Juncos Street Access #1-G appears to be upgradient of its associated leachfield, while monitoring well Juncos Street Access #2-G appears to be downgradient and slightly cross-gradient from the leachfield.

Between June 2004 and April 2005, water table elevations at Juncos St. Access #1-G ranged from 1.72 to 4.31 feet AMSL, or 1.2 to 3.8 feet bgs (below ground surface) (Figure 5.18). Water table elevations at Juncos St. Access #2-G ranged from 1.87 to 3.92 feet AMSL, or 0.8 to 2.9 feet bgs. Water table elevations varied significantly at both monitoring points during the sampling period. This variation was best explained by comparing the measured water level elevations to the maximum tide height that occurred during the sampling day. Water level readings taken close to a spring tide tended to be higher, while those taken close to a neap tide were lower although the variation at the Juncos St. wells was less noticeable than at the other well series to the north. Water table elevations usually varied by half a foot or less between sampling events. Water table elevations at Juncos St. Access #1-G are generally slightly higher that those at Juncos St. Access #2-G, indicating that groundwater in this area is moving towards the sound side of the island. Water table elevations at Juncos St. Access #1-G were only slightly higher (0.4 feet or less) than those at Juncos St. Access #2-G during spring tides, and the difference was less than 0.2 feet during neap tides. The local water table elevations increased following the landfall of Hurricanes Alex and Charley in August 2004, and then re-equilibrated within about a month after the storms. Under normal rainfall conditions, at least 2.4 feet of separation between the ground surface and groundwater was always maintained at both monitoring points.

Fecal coliform levels were sometimes above background levels (<1-4 MPN/100 mL; Table 5.1) at both monitoring points in this series, ranging from not detected at both monitoring points to a maximum of 25,000 MPN/100 mL at Juncos Street Access #2-G (Table 5.10). Monthly geometric mean values for each of these monitoring points remained within background levels (4 MPN/100 mL or less) except during August-September 2002, August and October 2003, and August-September 2004, when fecal coliform levels were higher (Figure 5.18). Increased runoff and stormwater infiltration associated with the landfall of Hurricane Gustav in early September 2002 may be somewhat responsible for the temporary increase in fecal coliform concentrations observed at both monitoring points. This pattern was repeated but was muted during the landfall of Hurricanes Alex and Charley in August 2004. There were no exceedances of the 200 MPN/100 mL recreational water quality standard during the sampling period. The linear trend at Juncos Street Access #2-G was slightly higher than the trend at Juncos St. Access #1-G. The trend at Juncos St. #1-G increased slightly over time, while the trend at Juncos St. Access #2-G remained stable. There was no apparent relationship between water table elevations or tidal fluctuations and fecal coliform concentrations. These data indicate that fecal coliform levels in groundwater near the Juncos Street Access well series are generally above background levels only during the summer months. These levels are within the range of concentrations expected near an OWTS.

Total phosphorus levels were generally within background levels for groundwater (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at both monitoring points to a maximum of 2.78 mg/L at Juncos Street Access #1-G (Table 5.11). The only exception to this was in January 2002, when median total phosphorus concentrations at both monitoring points were elevated (between 1.0 and 1.6 mg/L). The linear trends at both monitoring points were stable over the sampling period (Figure 5.18). There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and total phosphorus concentrations. These data indicate that total phosphorus levels in groundwater near the Juncos Street Access well series are within background levels, and are at the low end of the range of concentrations expected near an OWTS.

Ammonia levels were sometimes above background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.1 mg/L) at both monitoring points to a maximum of 398 mg/L at Juncos St. Access #2-G (Table 5.12). Median monthly ammonia concentrations were within background levels for groundwater at Juncos St. Access #1-G, with the exception of one month (May 2001) where the median ammonia concentration was 1.4 mg/L (Figure 5.18). At Juncos Street Access #2-G, however, monthly median ammonia concentrations were high during the spring of 2001, peaking in May 2001. Between June 2001 and July 2002, monthly median ammonia concentrations at Juncos St. Access #2-G fluctuated between 0.2 and 2.8 mg/L. After July 2002, monthly median ammonia concentrations at Juncos St. Access #2-G were generally within background levels for groundwater. The linear trend for Juncos St. Access #1-G remained stable over the monitoring period, while the trend for Juncos St. Access #2-G decreased over the monitoring period. There was no apparent relationship between water table elevation/precipitation data or tidal fluctuations and ammonia concentrations. These data indicate that ammonia levels in groundwater near Juncos St. Access #1-G are within background levels and within the range of concentrations expected near an OWTS. Ammonia levels near Juncos St. Access #2-G were initially very high but decreased over time to levels within the range of concentrations expected near an OWTS and eventually reached background levels.

Nitrate levels were generally above background levels (0.3 mg/L or less; Table 5.1) at both monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at both monitoring points to a maximum of 32.8 mg/L at Juncos St. Access

#2-G (Table 5.13). From February 2001 through September 2002, median monthly nitrate concentrations fluctuated between 0.20 and 2.0 mg/L at both monitoring locations, and median nitrate concentrations at Juncos St. Access #1-G were slightly higher than those at Juncos St. Access #2-G (Figure 5.18). After September 2002, median monthly nitrate concentrations at Juncos St. Access #1-G continued to fluctuate, but median nitrate concentrations were slightly lower overall (0.1-1.4 mg/L). At Juncos St. Access #2-G, however, median monthly nitrate concentrations were higher overall, increasing in a series of peaks to a high median of 27.2 mg/L in March 2005. The nitrate drinking water standard of 10 mg/L was exceeded at Juncos St. Access #2-G during July 2003, June –July and December 2004, and January-March 2005.The linear trend at Juncos St. Access #1-G remained stable over time, while the trend at Juncos St. Access #2-G increased. There was no apparent relationship between water table elevations, precipitation data, or tidal fluctuations and nitrate concentrations. These data indicate that nitrate levels in groundwater near the Juncos Street Access well series are generally above background levels, and are within the range of concentrations expected near an OWTS.

Dissolved oxygen levels were at or above background levels (0.01-3.00 mg/L; Table 5.1) at both monitoring points in this series, ranging from 0.00 mg/L at Juncos St. Access #1-G to a maximum of 12.0 mg/L at Juncos St. Access #2-G (Table 5.14). Dissolved oxygen concentrations at both groundwater monitoring points were initially higher than is normally expected in groundwater, with monthly median concentrations generally between 3.0 and 8.0 mg/L from the beginning of the sampling program through July 2002 (Figure 5.18). There was also a general seasonal trend at both monitoring points of higher monthly median DO concentrations during the fall, winter, and spring of the year, and lower concentrations during the summer (particularly during August). The only exception to this trend was an increase to 11 mg/L that observed at both monitoring points only in September 2001. After the summer of 2002, DO concentrations at both monitoring points remained within the expected range for groundwater (less than 3 mg/L), although DO concentrations appear to be increasing slightly in the spring of 2005. The linear trends for both monitoring points decreased over the monitoring period. There was no apparent relationship between water table elevations, precipitation data, or tidal fluctuations and dissolved oxygen concentrations. These data indicate that DO levels in groundwater near the at Juncos Street Access well series are at or above background levels, and are within or above the range of concentrations expected near an OWTS.

5.6.5. *Water Quality in Surface Water Ditches*

The primary function of the surface water ditches in Nags Head is to lower local groundwater tables, although the ditches may also provide some drainage during rainfall events. Effluent from upgradient OWTS near a drainage ditch may influence surface water quality in the ditch, particularly in areas where water tables are very close to the ground surface. Understanding water quality characteristics and trends in the ditches is important because these water bodies may discharge to the ocean and affect recreational water quality there.

Initially, rainfall patterns, water temperatures, and tidal fluctuations were all evaluated relative to relationships between these natural conditions and water quality parameters in surface water ditches. However, only water temperatures and rainfall patterns were found to have any relationship with water quality parameters in the ditches, so tidal fluctuations are not illustrated in the figures that accompany the discussions in the following sections.

5.6.5.1. *Northern Ditches*

Three monitoring points are included in this series: Wrightsville #2-S, Wrightsville #1-S, and Nags Head Village Area #2-S. Wrightsville #2-S is located near the northern border of Nags Head, in the eastern end of a drainage ditch that appears to run east-northeast towards the Atlantic Ocean. Wrightsville #1-S is located near the south end of Wrightsville Avenue near Curlew-G, at an outfall to a drainage ditch that appears to run east-northeast towards the Atlantic Ocean. Nags Head Village Area #2-S is located at the midpoint (corner) of a drainage ditch that runs north-northwest and east-northeast from the monitoring point. These three monitoring points are not hydraulically connected. All three monitoring points were sampled between August 2002 and April 2005 (n = 32 months).

Fecal coliform levels at these surface water points ranged from not detected (<2 MPN/100 mL) at Wrightsville #1-S and Nags Head Village Area #2-S to a maximum of 12,000 MPN/100 mL at Wrightsville #1-S (Table 5.10). Monthly geometric mean values for each of these monitoring points were generally lower during winter months (January-April) of each year, and higher during the spring, summer and fall, with the highest values occurring during August and September (Figure 5.19). During the monitoring period, the 200 MPN/100 mL recreational water quality standard was exceeded eight times (25% of monthly data points) at Wrightsville #1-S, and 11 times (34% of monthly data points) at Wrightsville #2-S and Nags Head Village Area #2-S. The linear trend at Wrightsville #1-S increased over time, while the trend at the other two points decreased slightly. Fecal coliform levels at all three monitoring points appear to be closely related to water temperatures, where the seasonal peaks in fecal coliform levels tend to occur during the months of warmest water temperatures. There was no clear relationship between rainfall patterns and fecal coliform concentrations at these monitoring points. These data indicate that fecal coliform levels in surface water ditches in northern Nags Head are generally above groundwater background levels particularly during the summer months, and sometimes exceed water quality standards for contact recreation.

Total phosphorus levels were generally above the guideline value for surface water (0.1 mg/L or less) at all three monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at Wrightsville #1-S and Nags Head Village Area #2-S to a maximum of 12.0 mg/L at Wrightsville #2-S (Table 5.11). At least two-thirds of the monthly median total phosphorus concentrations at all three sites were above the guideline (Figure 5.19). Monthly median total phosphorus concentrations at all three points fluctuated between 0.1 and 2.0 mg/L without any clear seasonal variation. The linear trends at Wrightsville #1-S and Nags Head Village Area #2-S decreased slightly over the sampling period, while the trend at Wrightsville #2-S did not change over time. There was no clear relationship between rainfall patterns or water temperatures and total phosphorus concentrations at any of the monitoring points. These data indicate that total phosphorus levels in surface water ditches in northern Nags Head are above water quality guideline levels.

Ammonia levels were above historic background levels for surface water (0.005 mg/L or less) at all monitoring points in this series, ranging from not detected (less than 0.1 mg/L) at all three monitoring points to a maximum of 3.8 mg/L at Wrightsville #2-S (Table 5.12). Monthly median ammonia concentrations at Wrightsville #2-S fluctuated between 0.2 and 2.8 mg/L without any clear seasonal variation (Figure 5.19). Median monthly ammonia concentrations were generally lower at Wrightsville #1-S (0.1-2.0 mg/L) and Nags Head Village Area #2-S (0.1-0.6 mg/L). The monthly median ammonia concentrations at Nags Head Village Area #2-S were generally below the water quality guideline for ammonia (1 month of 32 total months, or 3% of the monthly data points, were above the guideline). Concentrations at Wrightsville #1-S and #2-S were generally above the water quality guideline (25-26 months of 32 total months, or 78-81% of the monthly data points, were above the guideline). The linear trends for Wrightsville #2-S and Nags Head Village Area #2-S remained stable over the monitoring period, while the trend for Wrightsville #1-S increased dramatically over the monitoring period. There was no clear relationship between rainfall patterns or water temperatures and ammonia concentrations at any of the monitoring points. These data indicate that ammonia levels in surface water ditches in northern Nags Head are above historic background levels. At two of the monitoring points, ammonia levels are often above the water quality guideline value (0.4 mg/L or less).

Nitrate levels were sometimes above historic background levels for surface water (0.25 mg/L or less) at all three monitoring points in this series, ranging from 0.01 mg/L at all three monitoring points to a maximum of 2.23 mg/L at Nags Head Village Area #2-S (Table 5.13). In 2003 and 2004, median monthly nitrate concentrations were somewhat higher in the spring and early summer (March or April through June), and lower from late summer through the winter months (Figure 5.19). Median monthly nitrate concentrations at Nags Head Village Area #2-S were generally below historical background levels (0.25 mg/L or less). Median monthly nitrate concentrations at Wrightsville #1 and #2-S were below historical background levels only between July 2003 and March 2004. Otherwise, median nitrate levels at these two points were above historic background levels. Median nitrate levels were also sometimes above the water quality guideline value for surface water (0.4 mg/L or less), particularly at Wrightsville #2-S. Median nitrate levels were above the water quality for 3-5 months (9-16%) at Wrightsville #1-S and Nags Head Village Area #2-S, but were above the guideline for 13 months (41%) at Wrightsville #2. There was no clear relationship between rainfall patterns or water temperatures and nitrate concentrations at any of the monitoring points. The linear trend for Nags Head Village Area #2-S remained stable over the monitoring period, while the trend for Wrightsville #1-S decreased and the trend for Wrightsville #2-S increased. These data indicate that nitrate levels in surface water ditches in northern Nags Head are at or below background levels except during the spring and early summer months. At two of the monitoring points, nitrate levels are often above the water quality guideline value (0.4 mg/L or less), particularly during the spring and early summer months.

Dissolved oxygen levels were lower than historic background levels for surface water (7.4-10.8 mg/L) at all monitoring points in this series, ranging from 0.00 mg/L at Wrightsville #1-S and Nags Head Village Area #2-S to a maximum of 8.19 mg/L at Nags Head Village Area #2-S (Table 5.14). Monthly median DO concentrations at all three monitoring points fluctuated between 0 and 4 mg/L (Figure 5.19). Monthly median DO values at all three monitoring points were lower than the water quality standard for DO of 4.8 mg/L or greater, and 22-24 of the months at all three points (69-75%) were below the limit at which aquatic life is generally not supported (2.3 mg/L or less). Dissolved oxygen concentrations appeared to be slightly, but not significantly, higher during winter and early spring with water temperatures were colder; and there was no clear relationship between rainfall patterns and DO concentrations. The linear trends for Wrightsville #1-S and #2-S were stable over time, while the linear trend for Nags Head Village Area

#2-S increased slightly over the monitoring period. These data indicate that DO levels in surface water ditches in northern Nags Head are lower than historic background levels, and are often lower than the threshold for the survival of aquatic life.

5.6.5.2. Southern Ditches

Three monitoring points are included in this series: N. Side of Ditch S.O.O.I.R.-S, S. Side of Ditch S.O.O.I.R.-S, and Ocean Outfall at S. Nags Head-S. N. Side of Ditch S.O.O.I.R.-S is located at the north end of the surface water ditch that parallels South Old Oregon Inlet Road, just southwest of the Ida Access monitoring well series. S. Side of Ditch S.O.O.I.R.-S is located at the southern end of the same surface water ditch. Ocean Outfall at S. Nags Head-S is located in the surf zone of the Atlantic Ocean at the southern border of the town, about 200 feet from the edge of the sand dunes. These three monitoring points are hydraulically connected. All three monitoring points were sampled between February 2001 and April 2005, except that no chemical data was collected between December 2002 and February 2003. Also, between August 2003 and April 2005, there were several instances where not enough samples were taken at Ocean Outfall at S. Nags Head-S to allow calculation of median values for the chemical data (n = 50 for N. Side of Ditch S.O.O.I.R.-S and S. Side of Ditch S.O.O.I.R.-S, and 35 for Ocean Outfall at S. Nags Head-S).

Fecal coliform levels at these surface water points ranged from not detected (<2 MPN/100 mL) at all three monitoring points to a maximum of 10,800 MPN/100 mL at S. Side of Ditch S.O.O.I.R.-S (Table 5.10). Monthly geometric mean values for each of these monitoring points were generally lower during winter months (January-April) of each year, and higher during the spring, summer and fall, with the highest values occurring during August and September (Figure 5.20). This seasonal trend was apparent for all years except during the fall and winter of 2002-2003, when geometric mean fecal coliform levels remained near spring-summer levels. During the monitoring period, the 200 MPN/100 mL recreational water quality standard (Table 5.1) was exceeded during 9 months (18%) at N. Side of Ditch S.O.O.I.R.-S, during 21 months (42%) at S. Side of Ditch S.O.O.I.R.-S, and during 7 months (20%) at Ocean Outfall at S. Nags Head-S. Fecal coliform levels at all three monitoring points appear to be somewhat related to water temperatures, where the seasonal peaks in fecal coliform levels tend to occur during the months of warmest water temperatures; however, the relationship was not as clear as the one that occurred in the northern ditches. Increased runoff and stormwater infiltration associated with the landfall of Hurricane Gustav in early September 2002 may be somewhat responsible for the concurrent, temporary increase in fecal coliform concentrations observed at N. Side of Ditch S.O.O.I.R.-S and at the ocean outfall.

This pattern, however, was not repeated at any of the monitoring points during the landfall of Hurricanes Alex and Charley in August 2004. The linear trend at N. Side of Ditch S.O.O.I.R.-S decreased slightly over time, while the linear trend at the other two monitoring points increased slightly. These data indicate that fecal coliform levels in surface water ditches in southern Nags Head are generally high, and sometimes exceed water quality standards for contact recreation.

Total phosphorus levels were sometimes above the guideline value for surface water (0.1 mg/L or less; Table 5.1) at all monitoring points in this series, ranging from not detected (less than 0.01 mg/L) at all three monitoring points to a maximum of 2.00 mg/L at S. Side of Ditch S.O.O.I.R.-S and Ocean Outfall at S. Nags Head-S (Table 5.11). Monthly median total phosphorus concentrations at all three monitoring points tended to be higher during the spring and summer, and lower during the rest of the year (Figure 5.20). This trend did not appear to be clearly related to either water temperatures or rainfall patterns. Total phosphorus levels were above the water quality guideline during about 80% of the monitoring period (39-40 of 50 months) at both N. and S. Side of Ditch S.O.O.I.R.-S, and during 31% of the monitoring period (11 of 35 months) at the ocean outfall. The linear trend for S. Side of Ditch S.O.O.I.R.-S remained stable over the monitoring period, while the trend for N. Side of Ditch S.O.O.I.R.-S decreased and the trend for Ocean Outfall at S. Nags Head-S increased. These data indicate that total phosphorus levels in surface water ditches in southern Nags Head are generally above water quality guideline levels.

Ammonia levels were above historic background levels for surface water (0.005 mg/L or less; Table 5.1) at all monitoring points in this series, ranging from not detected (less than 0.1 mg/L) at all three monitoring points to a maximum of 5.9 mg/L at Ocean Outfall at S. Nags Head-S (Table 5.12). Monthly median ammonia concentrations at N. Side of Ditch S.O.O.I.R.-S fluctuated between 0.1 and 1.1 mg/L without any clear seasonal variation (Figure 5.20). Ammonia concentrations did not appear to be clearly related to either water temperatures or rainfall patterns. Median monthly ammonia concentrations were slightly higher at S. Side of Ditch S.O.O.I.R.-S (0.1-1.3 mg/L), and then were lowest of all at the ocean outfall (0.1-1.0 mg/L). The monthly median ammonia concentrations at Ocean Outfall at S. Nags Head-S and Ocean Outfall at S. Nags Head-S were generally at or below the water quality guideline for ammonia (0.4 mg/L or less). Ammonia concentrations were only above the guideline during 9-10% of the monitoring period at these two locations, while concentrations at S. Side of Ditch S.O.O.I.R.-S were above the water quality guideline during 34% of the monitoring period (17 of 50 months). The linear trend for N. Side of Ditch S.O.O.I.R.-S decreased over the monitoring period, while the trends for S. Side of Ditch S.O.O.I.R.-S and Ocean Outfall at S.

Nags Head-S increased. These data indicate that ammonia levels in surface water ditches in southern Nags Head are generally above historic background levels. In the ditches, ammonia levels are sometimes above the water quality guideline value (0.4 mg/L or less), while at the ocean outfall ammonia levels are at or below the guideline value.

Nitrate levels at the monitoring points in this series ranged from not detected (<0.01 mg/L) at all three monitoring points to a maximum of 4.10 mg/L at N. Side of Ditch S.O.O.I.R.-S (Table 5.13). There were no discernable seasonal trends in the median monthly nitrate concentrations in the southern ditches (Figure 5.20). Median monthly nitrate concentrations were generally highest at N. Side of Ditch S.O.O.I.R.-S, and were lowest at Ocean Outfall at S. Nags Head-S. Median monthly nitrate concentrations at Ocean Outfall at S. Nags Head-S were generally below historical background levels (0.25 mg/L or less; Table 5.1), while median monthly nitrate concentrations at the two ditch sites tended to be slightly higher, particularly at N. Side of Ditch S.O.O.I.R.-S and towards the end of the sampling period. Median monthly nitrate concentrations at N. Side of Ditch S.O.O.I.R.-S were above the water quality guideline value for surface water (0.4 mg/L or less) during 42% of the sampling period (21 of 50 months) while levels at S. Side of Ditch S.O.O.I.R.-S only exceeded the guideline during 14% of the sampling period (7 of 50 months). Median monthly nitrate concentrations at Ocean Outfall at S. Nags Head-S did not exceed the water quality guideline value. The linear trend at all three points increased over the monitoring period. These data indicate that while nitrate levels in surface water ditches in southern Nags Head are generally at or above background levels and sometimes exceed the water quality guideline value, nitrate levels at the ocean outfall remain near historic background levels.

Dissolved oxygen levels at the monitoring points in this series ranged from 0.00 mg/L at N. Side of Ditch S.O.O.I.R.-S to a maximum of 32.4 mg/L at S. Side of Ditch S.O.O.I.R.-S (Table 5.14). From the beginning of the monitoring period through the summer of 2002, monthly median DO concentrations at all three monitoring points tended to be higher during the fall, winter, and spring, and to be lowest during July and August (Figure 5.20). Monthly median DO values tended to be lower at N. Side of Ditch S.O.O.I.R.-S and higher at the other two monitoring points. During late 2003 and through the summer of 2004, monthly median DO concentrations at all three monitoring points showed little seasonality, and were often lower than the water quality standard for DO of 4.8 mg/L or greater, and sometimes exceeded the limit below which aquatic life is generally not supported (2.3 mg/L or less; Table 5.1). Dissolved oxygen concentrations generally increased again after September-October 2004. Monthly median DO values at N. Side of Ditch S.O.O.I.R.-S were below the limit at which aquatic life is generally not supported (2.3 mg/L or less) during 54% of the monitoring period (27 of 50 months), while values at S. Side of Ditch S.O.O.I.R.-S were below the limit 30% of the time (15 of 50 events) and values at the ocean outfall were below the limit during 15% of the monitoring period (5 of 35 months). Dissolved oxygen concentrations were generally higher during winter and early spring when water temperatures were colder; however, there was no clear relationship between rainfall patterns and DO concentrations. The linear trends for all three points decreased over the monitoring period. These data indicate that DO levels in surface water ditches in southern Nags Head and at the ocean outfall are now lower than historic background levels, and are sometimes lower than the threshold for the survival of aquatic life.

5.6.6. Water Quality in the Finger Canals

The surface water monitoring points in the finger canals were chosen to investigate local surface water quality impacts from OWTS and the potential stagnation of surface water in the finger canals. The overall selection of specific sites included the distal end of the finger canals (Cobia Way #3-S and Cobia Way #3a-S), locations approximately in the middle of the subdivision (Amber Jack #3-S, S. Blue Marlin #3-S, and Old Cove#3-S), and outlet (ONHC Canal Inlet Area-S). Blue Fin Canal Drain-S represents drainage into the canal system. All of these monitoring points are hydraulically connected. Many of the monitoring points, with the exceptions of Blue Fin Canal Drain-S and ONHC Canal Inlet Area-S, are associated with individual OWTS and were described in detail in Section 5.6.4. Blue Fin Canal Drain-S was sampled between February 2001-October 2003 and March-April 2005, while the canal inlet was sampled between August 2002 and April 2005. As with the surface water ditches, understanding water quality characteristics and trends in the finger canals is important because these canals discharge to the sound and may affect shellfisheries or recreational water quality there.

Initially, rainfall patterns, water temperatures, and tidal fluctuations were all evaluated relative to relationships between these natural conditions and water quality parameters in the finger canals. However, only water temperatures and rainfall patterns were found to have any relationship with water quality parameters, so tidal fluctuations are not illustrated in the figure that accompanies the following discussion.

Fecal coliform levels in the finger canals ranged from not detected (<2 MPN/100 mL) at all monitoring points to a maximum of 14,000 MPN/100 mL at S. Blue Marlin #3-S (Table 5.10). Overall, there was a weak seasonal trend towards higher monthly geometric mean fecal coliform concentrations in the summer and early fall when water temperatures were warmer, and lower fecal coliform concentrations in the winter when water temperatures were cooler. Overall, however, these trends were less pronounced than similar trends in area groundwater monitoring points. Monthly geometric mean values were almost always higher than background groundwater values, even during the fall and winter months when any groundwater impacts appear to be quite low. Exceedances of the recreational water quality standard (200 MPN/100 mL; Table 5.1) in groundwater and in surface water were rare near the finger canals. Exceedances at groundwater monitoring points usually do not correspond with surface water exceedances; the only exception was at the S. Blue Marlin series in September of 2002. Interestingly, monthly geometric mean values for all monitoring points in the finger canals generally track together; standard deviations are often greater than the differences between mean values for any given month. If the waters in the finger canals were stagnant, one might expect higher fecal coliform levels at distal points (such as Cobia Way #3a-S and S. Blue Marlin #3-S) and lower fecal coliform levels near the canal inlet, but this is generally not the case. These data suggest that while OWTS in the area may contribute some fecal coliform bacteria to the finger canals, particularly during the summer months, other sources (such as wildlife and storm runoff) may significantly influence fecal coliform bacteria concentrations during colder months.

Total phosphorus levels in the finger canals ranged from not detected (less than 0.01 mg/L) at all monitoring points to a maximum of 7.30 mg/L at Cobia Way #3-S (Table 5.11). With only a few exceptions during spring and summer months, monthly median total phosphorus concentrations in the finger canals fluctuated between the detection limit and about 0.2 mg/L at most sites (Figure 5.21). There was no clear relationship between total phosphorus levels and water temperatures or rainfall patterns. Monthly median total phosphorus concentrations in the finger canals were lower than those in groundwater near OWTS. Interestingly, while total phosphorus concentrations in groundwater near the finger canals generally increased over the sampling period, similar increases at corresponding surface water points were not observed. Groundwater monitoring points that are 60 feet or more from older OWTS, or that are near newer OWTS, generally do not display increased total phosphorus concentrations. It is possible natural soil processes (described in Section 5.1.2 of this report) are removing phosphorus from OWTS effluent before the effluent reaches the finger canals. The phosphorus removal capacity of sandy soils is finite, however, so it is possible that phosphorus from OWTS could impact the finger canals in the future. Other possible reasons for the apparent disconnect between groundwater and surface water trends include the aggregate nature of the surface water samples, and removal of phosphorus in the water column via sedimentation or uptake by aquatic organisms. There was a slight tendency for total phosphorus concentrations to be lower near the canal inlet and higher in distal areas (particularly at S. Blue Marlin and Cobia Way); distal sites (Cobia Way and Cobia Way A, Amberjack, and S. Blue Marlin) had median concentrations at or above the water quality guideline, while sites closer to the canal inlet were at or below the guideline. Also, while trends within the finger canals tended to be stable to slightly increasing, the trend at the canal inlet decreased over time.

Ammonia levels in the finger canals ranged from not detected (less than 0.1 mg/L) at all monitoring points to a maximum of 1.5 mg/L at Blue Fin Canal Drain-S (Table 5.12). Overall, monthly median ammonia levels in the finger canals were near the detection limit and did not increase or decrease over time (Figure 5.21). There was no clear relationship between ammonia levels and water temperatures or rainfall patterns. Elevated median monthly ammonia concentrations in groundwater sometimes corresponded to elevated concentrations in surface waters, particularly in distal areas (the Cobia Way, Amberjack, and S. Blue Marlin series). Although the ammonia levels are above the historical background levels observed in Roanoke Sound (0.005 mg/L or less), the analytical method used to collect historical data was much more sensitive, so results are directly comparable.

Nitrate levels were sometimes above historic background levels for surface water (0.25 mg/L or less) at all three monitoring points in this series, ranging from 0.01 mg/L at all three monitoring points to a maximum of 2.23 mg/L at Nags Head Village Area #2-S (Table 5.13). Monthly median nitrate concentrations at groundwater monitoring points near the finger canals are generally above background levels, and concentrations are increasing slightly over time. However, monthly median nitrate concentrations at corresponding surface water points in the finger canals are generally stable or decreasing (Figure 5.21) and are usually near or below historic background levels for the sound (0.25 mg/L or less; Table 5.1) and water quality guideline levels (0.4 mg/L or less). There was no clear relationship betweennitrate levels and water temperatures or rainfall patterns. The few small "spikes" above the water quality guideline at surface water monitoring points do not correspond with increased nitrate concentrations at nearby groundwater points. The only exception to the above description is the Cobia Way A series surface water monitoring point, the most distal point from the canal inlet. Here, nitrate concentrations in the surface water were more variable and were often above historic background levels for the sound.

Dissolved oxygen levels in the finger canals ranged from 0.00 mg/L at five of the monitoring points to a maximum of 31.4 mg/L at Amberjack #3-S (Table 5.14). Monthly median values for DO in the finger canals were above the guideline value for surface waters (4.8 mg/L or more; Table 5.1) for much of the sampling period.

The seasonal trend of higher concentrations in the fall, winter, and spring; and lower concentrations in the summer was generally consistent at all monitoring points, particularly during 2001-2003 and 2005 (Figure 5.21). During the summers of 2001 and 2002, when water temperatures were warmer, median monthly DO concentrations dropped below the surface water quality guideline at most monitoring points, but then recovered to background levels (7.4-10.8 mg/L) in the fall. During the summer of 2003, DO concentrations again dropped below the surface water quality standard, but only recovered slightly in the fall/winter of 2003 and remained low through the end of summer 2004. During the fall of 2004, DO levels recovered once again to background levels. Dissolved oxygen levels were stable or declining at all groundwater and surface water monitoring points in the area of the finger canals over the monitoring period. The DO levels in the finger canals are generally not indicative of stagnant waters. Before July 2002, there is little difference between inlet and distal points; monthly medians have similar values and trends track closely at different monitoring points. Between August 2002 and September 2003, overall trends are less clear and it appears that distal points (particularly S. Blue Marlin) have somewhat lower DO concentrations than are observed near the canal inlet. Between September 2003 and October 2004, concentrations are lower overall but the individual points are once again very close together and trends are similar at all monitoring locations in the canals.

5.6.7. Water Quality in Receiving Waters

The surface water monitoring points nearest to the sound and to the ocean were plotted on one figure (Figure 5.22) to investigate the potential impacts of a variety of pollutant sources on the water quality in the ocean and the sound. The monitoring points on this figure encompass the outlet of the finger canals into the sound (ONHC Canal Inlet Area-S), the outlet of a drainage channel from a package plant into the sound (NH Village Area #1-S), a stormwater outfall whose drainage area includes a significant number of OWTS (Ocean Outfall at S. Nags Head-S), and a point near a commercial OWTS (Jeannette's Pier-S). Many of the monitoring points, with the exception of NH Village Area #1-S, were described in detail in earlier sections of this report. NH Village Area #1-S was sampled between August 2002 and April 2005. Each of these four surface water monitoring points was located to capture some form of environmental impact. Thus, there is no "no impact" monitoring point on either the surf side or the sound side of Nags Head with which to compare these "impacted" points. However, some useful general observations may still be made from these monitoring data.

Initially, rainfall patterns, water temperatures, and tidal fluctuations were all evaluated relative to relationships between these natural conditions and water quality parameters in the receiving waters. However, only water temperatures and rainfall patterns were found to have any relationship with water quality parameters, so tidal fluctuations are not illustrated in the figures that accompany the discussions in the following sections.

Fecal coliform levels at the receiving water points ranged from not detected (<2 MPN/100 mL) at three monitoring points to a maximum of 9,000 MPN/100 mL at NH Village Area #1-S (Table 5.10). Seasonal trends towards higher monthly geometric mean fecal coliform concentrations in the summer and early fall concurrent with warmer water temperatures, and lower fecal coliform concentrations in the winter were generally less apparent at this group of monitoring points than they were in the finger canals (Figure 5.22). On the sound side, monthly geometric mean values were almost always higher at NH Village Area #1-S than they were at the canal inlet. Monthly geometric mean fecal coliform concentrations were greater than the recreational water quality standard (200 MPN/100 mL; Table 5.1) during 45% of the monitoring period (15 of 33 months) at NH Village Area #1-S, while only one exceedance occurred at the finger canals outlet (1 of 33 months, or 3% of the monitoring period). On the ocean side, monthly geometric mean fecal coliform values were similar at Jeannette's Pier-S and the ocean outfall point. While more exceedances of the recreational water quality standard occurred at the ocean outfall (7 of 35 months, or 20%) than at Jeannette's Pier (2 of 23 months, or 9%), the ocean outfall dataset is also more extensive.

Total phosphorus levels at the receiving water points ranged from not detected (less than 0.01 mg/L) at three monitoring points to a maximum of 4.15 mg/L at NH Village Area #1-S (Table 5.11). Monthly median total phosphorus concentrations at all points except NH Village Area #1-S fluctuated between the detection limit and about 0.2 mg/L at most sites (Figure 5.20). There was no clear relationship between rainfall patterns or water temperatures and total phosphorus concentrations. At NH Village Area #1-S, monthly median total phosphorus levels were strikingly higher overall (0.2-2.5 mg/L), and appear to be higher in the spring and summer than during the rest of the year. Whether this increase is due to excessive water use during the summer months or to application practices at the adjacent golf course is unclear.

Ammonia levels at the receiving water points ranged from not detected (less than 0.1 mg/L) at all monitoring points to a maximum of 5.9 mg/L at the ocean outfall site (Table 5.12). Overall, monthly median ammonia levels in the receiving waters were near the detection limit and did not increase or decrease over time (Figure 5.20). There was no clear relationship between rainfall patterns or water temperatures and ammonia concentrations. As with total phosphorus, higher ammonia levels were observed at NH Village Area #1-S than at the other three monitoring points, particularly during the summers of 2003 and 2004. Whether this increase is due to excessive water use during the summer months or to application practices at the adjacent golf course is unclear.

Nitrate levels at the receiving water points ranged from not detected (less than 0.01 mg/L) at the ocean outfall site to a maximum of 2.78 mg/L at the canal inlet (Table 5.13). Monthly median nitrate concentrations at most of the monitoring points are generally stable (Figure 5.22) and are usually near or below water quality guideline levels (0.4 mg/L or less; Table 5.1); however, the medina nitrate concentrations at Nags Head Village Area #1-S appear to be increasing slightly over time. There was no clear relationship between rainfall patterns or water temperatures and nitrate concentrations. The few small "spikes" above the water quality guideline generally occur at Jeannette's Pier-S and NH Village Area #1-S.

Dissolved oxygen levels in the finger canals ranged from 0.02 mg/L at NH Village Area #1-S to a maximum of 18.7 mg/L at ONHC Canal Inlet Area-S (Table 5.14). Monthly median values for DO in the receiving waters were above the guideline value for surface waters (4.8 mg/L or more; Table 5.1) for much of the sampling period, with the exception of NH Village Area #1-S, where DO values were generally below the guideline (Figure 5.22). The seasonal trends in DO concentrations that were observed in the finger canals are also generally observed in the receiving waters, with higher DO concentrations generally relating to lower water temperatures in the fall and winter of 2001, 2002, and 2004. Dissolved oxygen linear trends were stable at the canal inlet and Jeannette's Pier, but declined at the ocean outfall and NH Village Area #1-S over the monitoring period.

5.7. Summary and Conclusions

The Water Quality Sampling Program currently being conducted by the Town of Nags Head is an important component of the Town's continued efforts to protect valuable water resources, including Roanoke Sound and the Atlantic Ocean. The sampling program results are an important part of the basis for the overall assessment of impacts of current wastewater management practices on water quality, and are a major factor in building the Decentralized Wastewater Management Plan.

Little historical water quality information is available for water quality in Nags Head, Roanoke Sound, or the nearby Atlantic Ocean. Historical records were available in Roanoke Sound for ammonia, nitrate, and DO; however, no contemporary records are available in undisturbed areas of the sound. The Town is sampling two locations on the shore of the sound, but both sampling locations are near pollutant sources and are not characteristic of the sound's open waters. Thus, it is difficult to assess whether the Town's current OWTS management practices are having an impact on the ocean or the sound over time.

Rainfall patterns and amounts varied markedly from year to year during the water quality monitoring program. Spikes in precipitation during the spring and summer months were generally associated with tropical storms or hurricanes. At least one major tropical storm made landfall in the Outer Banks during each year of the water quality monitoring program, the most significant of which were Hurricane Gustav (September 2002) and Hurricanes Alex and Charley (August 2004). With the exception of these storms, there was not a strong relationship between weather patterns and water quality parameters.

Water depth measurements taken between June 2004 and April 2005 revealed that groundwater elevations in many parts of the Town change by a foot or more over the course of a year. On the sound side of Nags Head north of the Whalebone (including the locations of the background wells, the Lost Colony wells, and groundwater wells in the finger canals area), rapid increases in water table elevations occur in response to significant rainfall events such as the landfalls of Hurricanes Alex and Charley in August 2004. Following such a rise in groundwater elevations, the local water table on the sound side of Nags Head takes at least a month to re-equilibrate. On the ocean side of Nags Head (from Baltic-G in the north to the Juncos St. Access well series in the south), tidal fluctuations have a pronounced influence on water table elevations. Groundwater elevations during spring tides were as much as 1.5 feet higher than groundwater elevations at the same point during neap tides. This tidal fluctuation often obscures any relationship between rainfall patterns and increased water table elevations that may occur on the ocean side of Nags Head.

Five parameters currently monitored by the Town were considered most indicative of possible impacts from OWTS on local groundwater and surface water quality: fecal coliform bacteria, total phosphorus, ammonia, nitrate, and DO. These five characteristics, their expected ranges near OWTS, and any applicable standards or guidelines were described and were summarized in Table 5.1.

Groundwater quality in Nags Head Woods, in developing areas away from individual OWTS, and in the area served by the package wastewater treatment plant was generally good (Table 5.15). Fecal coliform levels in the groundwater in all of these areas were low year-round. Nutrient concentrations were more variable, but were generally lowest in Nags Head Woods, in part of a developed area (Blackman-G), and in the area served by the package plant (Seachase-G). Higher ammonia concentrations were observed at one monitoring well in a developing area (Curlew-G). Higher total phosphorus and nitrate concentrations were observed at Fire Station-G, which is close to and hydraulically downgradient from the package wastewater treatment plant. Dissolved oxygen concentrations in the groundwater in the background and developing areas were generally low, but this is not unexpected for groundwater, which naturally has little contact with the atmosphere. At all five of the background wells, there was little relationship between water table elevations, weather patterns, or tidal fluctuations and water quality trends.

Groundwater quality near individual OWTS in Nags Head is variable. Overall trends in water quality near OWTS tend to be clearer in the northern part of town, particularly north of the Huron Access monitoring well series (Table 5.15). Fecal coliform bacterial levels near OWTS are above background levels at almost all monitoring points during the summer months, but are generally near background levels during the rest of the year. Monthly geometric mean fecal coliform levels rarely exceed the recreational water quality standard of 200 MPN/100 mL (Table 5.1). A relationship was observed between extreme rainfall events (such as the landfall of Hurricane Gustav in September 2002) and increased fecal coliform concentrations near OWTS. Total phosphorus concentrations in groundwater near OWTS are often above expected background levels and are increasing over time, particularly north of the Huron Access monitoring well series. At the monitoring well series in the finger canals area, total phosphorus concentrations are often lower at the #2-G monitoring wells than they are at the #1-G wells. Thus, it appears that the phosphorus sorption capacity of the local soils is finite and may be exceeded as systems age. Ammonia concentrations in the groundwater near OWTS are generally within background levels except near the Baltic, Lost Colony 1, Lost Colony 2, and Juncos Street Access monitoring well series, where ammonia levels are relatively high. High ammonia concentrations in groundwater may indicate that the thickness of unsaturated soil between the bottom of the leachfield and the groundwater is not adequate. Nitrate concentrations in the groundwater near OWTS are at or above background levels. Groundwater monitoring points closest to individual OWTS tend to have the highest nitrate concentrations and the most exceedances of the 10 mg/L drinking water standard, while the more distant monitoring points have lower nitrate concentrations overall. In some cases (particularly at the Lost Colony 1, Old Cove, and Cobia Way series), the decrease in nitrate concentrations between the #1-G and #2-G wells is dramatic and may indicate that denitrification, as well as dilution, is taking place in the groundwater. Dissolved oxygen concentrations in groundwater near OWTS were above expected background levels at many monitoring points towards the beginning of the monitoring program. However, DO levels also decreased over time at almost all of the groundwater monitoring points associated with OWTS. Other than the relationship between extreme rainfall events and increased fecal coliform concentrations, and despite the dynamic nature of groundwater flow on the ocean side of Nags Head, no other consistent relationships between weather patterns, water table elevations, or tidal fluctuations and water quality parameters were observed near OWTS.

Surface water quality in Nags Head is also variable; however, this variability appears to be more influenced by the degree of circulation of the individual water body than by the presence or nearness of OWTS. Fecal coliform bacteria concentrations in the finger canals were generally stable or slightly decreasing over time, with few (if any) exceedances of the recreational water quality standard (Table 5.15). However, bacteria levels in the finger canals were almost always higher than background groundwater values and were usually higher than the levels observed in nearby groundwater monitoring wells, even during the fall and winter months when concentrations in the local groundwater were low. Thus, while OWTS in the area may contribute some fecal coliform bacteria to the finger canals, particularly during the summer months, other sources (such as wildlife or storm runoff) may significantly influence fecal coliform bacteria concentrations during colder months. Contrastingly, fecal coliform levels in the ditches tended to decrease slightly over time but were higher overall, with little seasonality and more exceedances of the recreational water quality standard. There was a fairly strong relationship between warmer water temperatures in the summer and early fall months and higher fecal coliform concentrations in the surface water ditches; this relationship was weaker but still apparent in the finger canals and receiving waters. There was also a relationship between the landfall of Hurricane Gustav in September 2002 and increased fecal coliform concentrations at Nags Head Village Area #1-S and in the southern surface water ditches.

Monthly median total phosphorus concentrations in the finger canals were lower than those in groundwater near OWTS. While total phosphorus concentrations in groundwater near the finger canals generally increased over the sampling period, similar increases at corresponding surface water points were not observed (Table 5.15). It is possible that natural soil processes are removing phosphorus from OWTS effluent before the effluent reaches the finger canals. The phosphorus removal capacity of sandy soils is finite, however, so it is possible that phosphorus from OWTS could impact the finger canals in the future. There was a slight tendency for total phosphorus concentrations to be lower near the canal inlet and higher in distal areas. Total phosphorus concentrations in the surface water ditches tended to be markedly higher and more variable than those in the finger canals, although levels in the ditches appear to be decreasing slightly over time. There was no clear relationship between rainfall patterns or water temperatures and total phosphorus concentrations.

Ammonia concentrations in the finger canals are near the detection limit, below the water quality guideline, did not increase or decrease over time (Table 5.15). Ammonia levels in the ditches are generally higher and increasing over time (particularly in the northern ditches). Ammonia concentrations in the ditches are also more likely to be above the water quality guideline of 0.4 mg/L. Nitrate concentrations at groundwater monitoring points near the finger canals are generally above background levels, and concentrations are increasing over time. Monthly median nitrate concentrations at corresponding surface water points in the finger canals are generally stable or decreasing and are usually near or below historic background levels for the sound and water quality guideline levels. Nitrate levels in surface water ditches, however, are generally at or above background levels, and sometimes exceed the water quality guideline value.

Dissolved oxygen concentrations in the surface waters remained stable or decreased across the board during the sampling program (Table 5.15). However, DO levels in the surface water ditches were far more likely to drop below the water quality standard (4.8 mg/L; Table 5.1) than were the DO levels in the finger canals or in the receiving waters. There was a fairly strong relationship between cooler water temperatures and higher DO concentrations during the fall and winter months in the finger canals and the receiving waters. This relationship was weaker in the surface water ditches, and was practically nonexistent in the northern ditches.

6. EVALUATING THE IMPACT OF ONSITE SYSTEMS ON WATER QUALITY

Onsite systems have a direct connection to groundwater through percolation of effluent from the leach field through unsaturated soils to the water table. In Nags Head, sandy soils allow for relatively rapid percolation, 6-20 inches/hour (SSURGO, 1999), and short travel times to groundwater. For example, if we assume the minimum saturated hydraulic conductivity of 6 in/hr, and a water table 3 feet below the bottom of the leach field, it would take 6 hours for the effluent to reach the water table. At the maximum rate of 20 in/hr, it would take less than two hours for the effluent to reach the water table.

The water quality monitoring program results described in Section 5 suggest that some OWTS may be having an impact, particularly on nearby groundwater quality. Evaluating the water quality monitoring data in conjunction with the characteristics of the OWTS influencing individual monitoring points will help to establish what particular characteristics of these individual systems are causing impacts on local water quality.

The objective of this section is to determine whether certain characteristics of a system, such as the age, construction, water use history, or separation distance to groundwater, influence water quality near the system. If relationships can be established between system characteristics and trends in groundwater quality parameters, then criteria for ranking a system's environmental vulnerability can be confidently established. The ranking of a how likely a system is to have an impact on nearby water resources will be an important component to establishing management options.

Some of the monitoring well clusters may be impacted by more than one OWTS. A region upgradient of a groundwater monitoring point will have direct impact on the water quality at that point. In areas of very low hydraulic gradients in the groundwater table, regions surrounding a monitoring point in multiple directions may have some impact on the water quality in that location. In the following sections, this region is referred to as the "zone-of-influence". The following sections will first investigate the characteristics of the single OWTS closest to a monitoring point cluster, and then evaluate a group of systems within a "zone-of-influence" of the monitoring points.

6.1. Process for System-by-System Analysis

The analysis process involves seven major steps:

1. **Associate the appropriate water quality monitoring points with individual property and OWTS information**. The locations of OWTS leach fields associated with each monitoring well group were identified by the Nags Head Planning Department. The properties where these leach fields were located were then identified.

2. **Determine local hydrogeologic conditions;** including depth to groundwater beneath the leachfield and groundwater flow direction. Determine whether

monitoring points are upgradient, cross-gradient, or downgradient compared to the leachfield.

3. **Gather data about the individual property and OWTS**. The following information was extracted from the IWIMS database and GIS data sources for each of those systems:

- Associated well
- Property Use
- Structure info
    - Number of structures
    - Total bedrooms
    - Total baths
- System type
    - Conventional
    - I/A
- Design flow
    - Source for design flow
- Water Use
    - Average peak water use rate as percent of design flow
    - All water use records from 1999 - 2004
- System age
    - Source for system age
- System performance
- All permits
    - Permit type
    - Permit Date
- All components
    - Component type
    - Tank type
    - Tank capacity
    - I/A technology
- Number of pumpouts
- Most recent inspection info
    - Date
    - Result
    - Sand bottom tank
    - Tank leaking
    - Field failing
    - Field ponding
    - Saturated soils

- System failing

4. **Create the "zone-of-influence" buffer for each well cluster and evaluate systems within the buffer zone.** An approximation of the "zone-of-influence" for each monitoring well cluster was made by creating a 150-ft buffer around each well cluster. A more precise zone-of-influence could be calculated using a hydrogeologic model; however, the approximation is suitable for the purposes of this analysis. All properties that intersected the zone-of-influence were identified and the characteristics of the associated OWTS were extracted from the IWIMS database. The information regarding each system was the same as was extracted for the nearest system analysis described in the previous section.
5. **Evaluate water quality characteristics over time at each monitoring point in the series** (including fecal coliform, total phosphorus, ammonia, nitrate, and DO).
6. **Consider other possible sources of contaminants**, and other potential factors that may affect the observed water quality results and trends.
7. **Assess the impact of the individual OWTS on water quality**, clearly identifying the characteristics of each OWTS (if any) that are correlated with the water quality results and trends.

6.2. System-by-System Analysis and Results

Each monitoring cluster and its associated OWTS will be discussed in order from north to south in the following sections, as they were in Section 5. At the end of each system's analysis, the results for that individual system are summarized. Overall trends and system characteristics that appear to impact groundwater quality are summarized in Section 6.3.

6.2.1. Baltic

The Baltic series includes the monitoring point Baltic-G, which is located approximately 5 feet north of a set of eight peat filter pods serving a single-family residence. The average separation distance between the ground surface and the groundwater near the system, based on water table elevations from June 2004-April 2005, is 4.5 feet (Figure 3.6a and Figure 5.5). Groundwater flow in this area is generally east towards the ocean (Figure 3.5a); thus, the Baltic-G monitoring well appears to be cross-gradient from the peat filter pods.

The property associated with the Baltic well contains a single-family seasonal residence with eight bedrooms. The OWTS serving this structure is a Puraflo® peat filter system with a design flow of 960 gpd (Figure 4.2a). The system consists of a precast septic tank and a pump tank connected to eight peat filter units. This system was permitted in June 2004, and thus there has been no inspection by either the Septic Health program or by the Dare County Health Department, nor has there been any there been any compliance sampling of this system. There are no pumpouts on record for this system (Figure 4.5a). Average water use for this property between June 2004 and April 2005 was generally between 5% and 64% of design flow (Figure 4.12a). Water use was highest in July 2004 and lowest in January-March 2005.

There are 8 developed properties within the "zone-of-influence" associated with the Baltic well. Seven of the properties contain single-family residences, and one contains a commercial building. Two of the residences are year-round homes; one has one bedroom, while the other has 10 bedrooms and seven bathrooms. The rest of the residences and the commercial property are seasonal use properties with 4-8 bedrooms. The estimated separation distance between the ground surface and the groundwater beneath the entire "zone-of-influence" is 4.8 feet (Figure 3.6a). The OWTS serving the year-round residences and three of the seasonal properties in the "zone-of-influence" are conventional systems with design flows of 240-1200 gpd (Figure 4.2a), which were constructed between 1960 and 2001. These systems consist of precast 1,000-gallon or 1,250-gallon septic tanks and a standard leachfield. The OWTS serving the other three seasonal residences are Puraflo® peat filter systems with design flows of 960 gpd (Figure 4.2a), which were constructed in 2004. These systems consist of precast septic tanks and a pump tanks, each connected to eight peat filter units. Four permits are on record for this area between 1999 and 2005 (all for new construction). One inspection was conducted on a seasonal residence in this area in December 2004, and this inspection had a "poor" result due to a failing leachfield. There are no pumpouts on record for all systems in this area. Water use records were available for all of the developed properties within the "zone-of-influence" for the Baltic well. Average water use for all of these properties between 1999 and April 2005 was between 43% and 172% of design flow (Figure 4.12a). There was a strong seasonal component to water use at all properties in this area, with water use much higher in the summer (July-September) than during the rest of the year. Five of the properties had an overall average water use greater than 75% of the design flow.

The water quality sampling program results for the Baltic well show a variety of impacts that may be due to the nearby OWTS (Figure 5.5). Fecal coliform levels were slightly elevated during the first two months of the monitoring period but then decline to background levels, indicating that the peat system is adequately removing bacteria. Total phosphorus, ammonia, and nitrate are often significantly elevated above background levels. Elevated total phosphorus concentrations indicate that, at least near the dispersal field, the phosphorus sorption capacity of the soil may have been exceeded. The presence of elevated ammonia concentrations indicates that there is not an adequate separation distance between the leachfield and the local water table. The presence of high nitrate concentrations in December 2004, coupled with low ammonia concentrations during the same month, suggests that the separation distance is adequate during at least part of the year. It does not seem likely that the measured separation distance of more than 4 feet between the ground surface and the water table is not adequate for proper nitrification following a peat filter system that is not being hydraulically overloaded. It may be that the residence associated with this system is not consistently occupied, and thus the system is erratically loaded and has been unable to mature properly.

In summary, the OWTS associated with the Baltic monitoring well is impacting local groundwater quality. Impacts observed were total phosphorus, ammonia, and nitrate (Table 6.1). The impacts observed are consistent with an insufficient separation distance between the bottom of the leachfield and the local water table; however, inconsistent occupancy and thus uneven system loading are likely contributing to the observed impacts of the OWTS on local groundwater quality.

6.2.2. Lost Colony 1

The Lost Colony 1 series includes the monitoring points Lost Colony 1-G and Lost Colony #2-G. Lost Colony #1-G is located approximately 10 feet east-northeast of the leachfield, and Lost Colony #2-G is located approximately 50 feet south of the same leachfield. The average separation distance between the ground surface and the groundwater beneath the leachfield, based on water table elevations from June 2004-April 2005, is 2.5 feet at Lost Colony #1-G and 1.5 feet at Lost Colony #2-G (Figure 3.6a and Figure 5.6). The general groundwater flow direction in this area is east-northeast, towards the Atlantic Ocean (Figure 3.5a). Lost Colony #1-G appears to be hydraulically downgradient of the leachfield, while Lost Colony #2-G appears to be cross-gradient and slightly upgradient.

The property associated with the Lost Colony 1 well series contains a single-family, year-round residence with three bedrooms and two bathrooms. The OWTS serving this structure is a conventional system with a design flow of 360 gpd (Figure 4.2a). The system consists of a precast 1,000-gallon septic tank and a standard leachfield. This system was inspected in November 2001 with an “acceptable” result, and a repair permit was obtained for this system in December 2001. There are no pumpouts on record for this system (Figure 4.5a). Average water use for this property between 1999 and April 2005 was generally between 54% and 82% of design flow (Figure 4.12a). The only exceptions to this were in August-October of 2003, when water use was 100-120% of design flow, and in May-September of 2004, when water use was 106-141% of design flow. Water use was generally higher in the late spring and summer (May-August).

There are 16 developed properties within the "zone-of-influence" associated with the Lost Colony 1 well series. Each of these properties contains a single-family residence with 2-4 bedrooms and 1-3 bathrooms. Two of the homes are seasonal residences, and the rest are occupied year-round. The estimated separation distance between the ground surface and the groundwater beneath the entire "zone-of-influence" is 2.3 feet (Figure 3.6a). The OWTS serving the structures in the "zone-of-influence" are conventional systems with design flows of 240-600 gpd (Figure 4.2a), which were constructed between 1979 and 2004. The systems consist of precast 1,000-gallon or 1,250-gallon septic tanks and a standard leachfield. Seven permits are on record for this area between 1999 and 2004 (three permits for new construction, three repairs, and one permit rewrite). Six inspections were conducted in this area between April 2001 and April 2003, and all inspections had an "acceptable" result. There are four pumpouts on record for all systems in this area. Water use records were available for 13 of the 16 developed properties within the "zone-of-influence" for the Lost Colony 1 well series. Average water use for all of these properties between 1999 and April 2005 was between 24% and 175% of design flow (Figure 4.12a). Water use was generally higher in the late spring and summer (May-August) than during the rest of the year. Eight of the properties had an overall average water use greater than 75% of the design flow.

The water quality sampling program results for groundwater points in this series show a variety of impacts that may be due to the nearby OWTS, particularly at Lost Colony #1-G directly downgradient of the leachfield (Figure 5.6). Fecal coliform levels are elevated during warmer months, although levels at this series rarely exceed the 200 MPN/100 mL recreational water quality criteria. Total phosphorus, ammonia, and nitrate are often significantly elevated above background levels. Elevated total phosphorus concentrations indicate that, at least near the leachfield, the phosphorus sorption capacity of the soil may have been exceeded. The presence of particularly high ammonia concentrations indicates that there is not an adequate separation distance between the leachfield and the local water table. Low levels of DO may be enabling a certain amount of denitrification during the warmer summer months, as evidenced by very low nitrate concentrations at Lost Colony #1-G during the summer of 2003. However, it is also possible that the local water table was very shallow during these months, and thus there was simply very little transformation of ammonia and organic nitrogen to nitrate (nitrification) in the unsaturated soils beneath the leachfield. The repair of the system that occurred in December 2001 did not improve groundwater quality downgradient of the system. If anything, it appears that groundwater quality at Lost Colony #1-G has become progressively poorer since the system was repaired.

In summary, the OWTS associated with the Lost Colony 1 monitoring well series is impacting local groundwater quality. Impacts observed were fecal coliform (summers only), total phosphorus, ammonia, and nitrate (Table 6.1). The system characteristic most responsible for this impact appears to be an insufficient separation distance between the bottom of the leachfield and the local water table. Excessive water use, particularly during the spring and summer months, may also be contributing to the observed impacts of the OWTS on local groundwater quality.

6.2.3. Lost Colony 2

The Lost Colony 2 series includes the monitoring points Lost Colony #3-G and Lost Colony #4-G. Lost Colony #3-G is located approximately 50 feet northeast of a leachfield serving a single-family house, and Lost Colony #4-G is located approximately 50 feet due east of the same leachfield. The average separation distance between the ground surface and the groundwater beneath the leachfield, based on water table elevations from June 2004-April 2005, is 2.2 feet at Lost Colony #3-G and 2.1 feet at Lost Colony #4-G (Figure 3.6a and Figure 5.7). The general groundwater flow direction in this area is east-northeast towards the Atlantic Ocean (Figure 3.5a). Lost Colony #3-G appears to be hydraulically downgradient and slightly cross-gradient from the leachfield, while Lost Colony #4-G appears to be downgradient.

The property associated with the Lost Colony 2 well series contains a single-family, year-round residence with three bedrooms and two bathrooms. The OWTS serving this structure is a conventional system with a design flow of 360 gpd (Figure 4.2a), which was constructed in 1978. The system consists of a concrete-block/sand-floor 700-gallon septic tank and a standard leachfield. This system was inspected in April 2001 with a "poor" result. The septic tank was leaking, but no other evidence of failure was observed. No permits were obtained for this system. There is one pumpout on record for this system (Figure 4.5a). Average water use for this property between 1999 and April 2005 was generally between 2% and 69% of design flow (Figure 4.12a). The only exceptions to this were in June-August of 2002-2004, when water use was 108-260% of design flow. Water use was generally higher in the late spring and summer (May-August), and summer water use increased sharply between 2002 and 2004.

There are 12 developed properties within the "zone-of-influence" associated with the Lost Colony 2 well series. Each of these properties contains a single-family residence with 2-4 bedrooms and 1-3 bathrooms. One of the homes is a seasonal residence, and the rest are occupied year-round. The estimated separation distance between the ground surface and the groundwater beneath the entire "zone-of-influence" is 2.6 feet (Figure 3.6a). The OWTS serving the structures in the "zone-of-influence" are conventional systems with design flows of 240-480 gpd (Figure 4.2a), which were constructed between 1978 and 2004. The systems, where components are known, consist of precast or concrete block 1,000-gallon septic tanks and a standard leachfield. Five permits are on record for this area between 1999 and 2004 (two permits for new construction and three repairs). Four inspections were conducted in this area between April 2001 and May 2002; all inspections except the one described above had an "acceptable" result. There are three pumpouts on record for all systems in this area (Figure 4.5a). Water use records were available for 11 of the 12 developed properties within the "zone-of-influence" for the Lost Colony 2 well series. Average water use for all of these properties between 1999 and April 2005 was between 24% and 110% of design flow (Figure 4.12a). Water use was generally higher in the late spring and summer (May-August) than during the rest of the year. Five of the properties had an overall average water use greater than 75% of the design flow.

The water quality sampling program results for groundwater points in this series show a variety of impacts that may be due to the nearby OWTS, particularly at Lost Colony #4-G directly downgradient of the leachfield (Figure 5.7). Fecal coliform levels are elevated during warmer months, although levels at this series rarely exceed the 200 MPN/100 mL recreational water quality criteria. Total phosphorus is at or above background levels at Lost Colony #4-G, but is not significantly elevated as it was near the Lost Colony 1 series leachfield. The presence of elevated ammonia concentrations from early 2004 through the end of the monitoring period indicates that there may not be an adequate separation distance between the leachfield and the local water table; however, for this monitoring well series increased ammonia concentrations do not appear to correlate with either increased water use or increased precipitation/elevated water table elevations. In contrast to the trends observed at the Lost Colony 1 series, nitrate levels near the Lost Colony 2 system remained low throughout the monitoring period.

In summary, the OWTS associated with the Lost Colony 2 monitoring well series is impacting local groundwater quality. Impacts observed were fecal coliform (summers only), total phosphorus, and ammonia (Table 6.1). The system characteristic most responsible for this impact appears to be an insufficient separation distance between the bottom of the leachfield and the local water table. Excessive water use, particularly during the spring and summer months, may also be contributing to the observed impacts of the OWTS on local groundwater quality.

6.2.4. Pamlico

The Pamlico series includes the monitoring points Pamlico #1-G and Pamlico #2-G. Pamlico #1-G is located approximately 15 feet southwest of a leachfield serving a single-family house, and Pamlico #2-G is located approximately 45 feet south-southwest of the same leachfield. The estimated separation distance between the ground surface and the groundwater beneath the leachfield is 7.1 feet (Figure 3.6a). The general groundwater flow direction in this area is east-northeast towards the Atlantic Ocean (Figure 3.5a). Both monitoring points appear to be hydraulically upgradient from the leachfield.

The property associated with the Pamlico well series contains a single-family, year-round residence with two bedrooms and two bathrooms. The OWTS serving this structure is a conventional system with a design flow of 360 gpd (Figure 4.2a), which was upgraded in 2002. The system currently consists of a precast concrete 1000-gallon septic tank and a standard leachfield. This system was inspected in February 2001. Both a leaking septic tank and a failed disposal field were observed during the inspection, so the inspection concluded with a "poor" result. A repair permit was obtained for this system shortly after the inspection, April 2002. There are no pumpouts on record for this system (Figure 4.5a). Average water use for this property between 1999 and April 2005 was generally between 2% and 28% of design flow (Figure 4.12a). The only exception to this was in August of 2002, when water use was 98% of design flow. Water use was generally slightly higher in the late spring and summer (May-August).

There are 11 developed properties within the "zone-of-influence" associated with the Pamlico well series. Each of these properties contains a single-family residence with 2-4 bedrooms and 1.5-3 bathrooms. Three of the homes are seasonal residences, and the rest are occupied year-round. The estimated separation distance between the ground surface and the groundwater beneath the entire "zone-of-influence" is 6.1 feet (Figure 3.6a). The OWTS serving the structures in the "zone-of-influence" are conventional systems with design flows of 360-480 gpd (Figure 4.2a), which were constructed between 1975 and 2003. The systems, where components are known, consist of precast or concrete block/sand floor 750-gallon to 1,000-gallon septic tanks and a standard leachfield. Seven permits are on record for this area between 2000 and 2004 (five permits for new construction and two repairs). Five inspections were conducted in this area between February 2001 and February 2004; four of these inspections, including the one described above, had a "poor" result. Two of the systems had concrete block/sand floor tanks, and one had a failed, saturated leachfield. There are three pumpouts on record for all systems in this area (Figure 4.5a). Water use records were available for 10 of the 11 developed properties within the "zone-of-influence" for the Pamlico well series. Average water use for all of these properties between 1999 and April 2005 was between 17% and 83% of design flow (Figure 4.12a). Water use was generally higher in the late spring and summer (May-August) than during the rest of the year. Only one of the properties had an overall average water use greater than 75% of the design flow.

The water quality sampling program results for groundwater points in this series generally do not show impacts that may be due to the nearby OWTS (Figure 5.8). Despite the documented evidence of failing and substandard systems at and near this series, fecal coliform levels are only slightly elevated above background during warmer months, and nutrient and DO values are generally within expected background ranges. It is clear from these results that both monitoring wells associated with the leachfield were hydraulically upgradient, and thus did not capture the contaminant plume associated with the leachfield.

In summary, although it is likely that the OWTS associated with the Pamlico monitoring well series impacted local groundwater quality, evidence of specific water quality impacts was not observed during the monitoring period because the monitoring wells were upgradient from the OWTS effluent plume (Table 6.1).

6.2.5. Old Cove

The Old Cove series includes the monitoring points Old Cove #1-G, Old Cove #2-G, and Old Cove #3-S. Old Cove #1-G is located approximately 15 feet south of a leachfield serving a single-family house, and Old Cove #2-G is located approximately 60 feet south of the same leachfield. The surface water monitoring point associated with this group of monitoring points (Old Cove #3-S) is located in the finger canal approximately 100 feet south of the leachfield. The average separation distance between the ground surface and the groundwater beneath the leachfield, based on water table elevations from June 2004-April 2005, is 6.7 feet at Old Cove #1-G and 4.4 feet at Old Cove #2-G (Figure 3.6a and Figure 5.9). The general groundwater flow direction in this area is southwest towards the nearest finger canal (Figure 3.5a). Both monitoring wells and the surface water sampling point appear to be downgradient of the leachfield.

The property associated with the Old Cove well series contains a single-family, seasonal residence with four bedrooms and two bathrooms. The OWTS serving this structure is a conventional system with a design flow of 480 gpd (Figure 4.2a), which was constructed in 1985. The system consists of a precast 1,000-gallon septic tank and a standard leachfield. This system was inspected in March 2001 with an "acceptable" result. No permits were obtained for this system. There is one pumpout on record for this system. Average water use for this property between 1999 and June 2004 was generally between 2% and 78% of design flow (Figure 4.12a). The only exceptions to this were in December 2003-April 2004 and January-

March 2005, when water use was 142-175% of design flow. Water use was generally higher in the winter and early spring (particularly in December) at this property.

There are 11 developed properties within the "zone-of-influence" associated with the Old Cove well series. Each of these properties contains a single-family residence with 2-4 bedrooms and 1.5-2.5 bathrooms. Two of the homes are seasonal residences, and the rest are occupied year-round. The estimated separation distance between the ground surface and the groundwater beneath the entire "zone-of-influence" is 4.5 feet (Figure 3.6a). The OWTS serving the structures in the "zone-of-influence" are conventional systems with design flows of 240-480 gpd (Figure 4.2a), which were constructed between 1972 and 2003. The systems, where components are known, consist of precast concrete or concrete block 1,000-gallon septic tanks and standard leachfields. One permit for new construction, granted in August 2003, is on record for this area. Seven inspections were conducted in this area between March 2001 and January 2003, and all inspections had an "acceptable" result. There are five pumpouts on record for all systems in this area (Figure 4.5a). Water use records were available for all of the 11 developed properties within the "zone-of-influence" for the Old Cove well series. Average water use for all of these properties between 1999 and April 2005 was between 12% and 139% of design flow (Figure 4.12a). There were no trends in water use that were common across all properties in this area. Six properties had low water use year-round, four properties had generally higher water usage in the summer and fall (June-October), and one property had higher water usage in the winter. Two of the properties had an overall average water use greater than 75% of the design flow.

The water quality sampling program results for groundwater points in this series show a variety of impacts that may be due to the nearby OWTS, particularly at Old Cove #1-G directly downgradient of the leachfield (Figure 5.9). Fecal coliform levels are elevated during warmer months, although levels at this series rarely exceed the 200 MPN/100 mL recreational water quality criteria. Total phosphorus and nitrate are often significantly elevated above background levels. Elevated total phosphorus concentrations indicate that, at least near the leachfield, the phosphorus sorption capacity of the soil may have been exceeded. The presence of low ammonia concentrations indicates that the separation distance between the leachfield and the local water table is generally adequate. The marked difference between high nitrate levels at Old Cove #1-G and elevated but much lower nitrate levels at Old Cove #2-G, particularly after July 2002, suggests that denitrification may be taking place in the saturate soils between the two monitoring wells. However, it is also possible that the local hydraulic gradient shifted over time so that Old Cove #1-G was in the center of the effluent plume, but Old Cove #2-G did not capture the plume. There did not appear to be a strong relationship between elevated water table elevations/precipitation patterns and water quality impacts at this site, with the possible exception of a relationship between intense storm events and slightly elevated fecal coliform levels. There was also no discernable relationship between periods of excessive water use and water quality impacts.

In summary, the OWTS associated with the Old Cove monitoring well series is impacting local groundwater quality. Impacts observed were fecal coliform (summers only), total phosphorus, and nitrate (Table 6.1). However, the system appears to be functioning properly and has an adequate separation distance between the bottom of the leachfield and the local water table. Excessive water use, in this case, does not contribute significantly to the observed impacts of the OWTS on local groundwater quality.

6.2.6. Cobia Way

The Cobia Way series includes the monitoring points Cobia Way #1-G, Cobia Way #2-G, and Cobia Way #3-S. Cobia Way #1-G is located approximately 15 feet west-southwest of a leachfield serving a single-family house, and Cobia Way #2-G is located approximately 55 feet west-southwest of the same leachfield. The surface water monitoring point associated with this group of monitoring points (Cobia Way #3-S) is located in the finger canal approximately 90 feet west-southwest of the leachfield. The estimated separation distance between the ground surface and the groundwater beneath the leachfield is 11 feet (Figure 3.6a). The general groundwater flow direction in this area is west-southwest towards the nearest finger canal (Figure 3.5a). Both monitoring wells and the surface water sampling point appear to be downgradient of the leachfield.

The property associated with the Cobia Way well series contains a single-family, year-round residence with four bedrooms and three bathrooms. The OWTS serving this structure is a conventional system with a design flow of 480 gpd (Figure 4.2a), which was constructed in 1970. The system consists of a precast 1,000-gallon septic tank and a standard leachfield. This system was inspected in May 2002 with an "acceptable" result. No permits were obtained for this system. There is one pumpout on record for this system (Figure 4.5a). Average water use for this property between 1999 and April 2005 was generally between 27% and 95% of design flow (Figure 4.12a). Water use was generally slightly higher in December and in the summer (June-August) at this property.

There are 13 developed properties within the "zone-of-influence" associated with the Cobia Way well series. Each of these properties contains a single-family residence with 2-4 bedrooms and 1.5-3 bathrooms. Five of the homes are seasonal residences, and the rest are occupied year-round. The estimated separation distance between the ground surface and the groundwater beneath the entire "zone-of-influence" is 7.2 feet (Figure 3.6a). The OWTS serving the structures in the "zone-of-influence" are conventional systems with design flows of 240-480 gpd (Figure 4.2a), which were constructed between 1973 and 1989. The systems, where components are known, consist of precast concrete or concrete block 750-gallon to 1,000-gallon septic tanks and standard leachfields. No permits have been obtained for systems in this area. Seven inspections were conducted in this area between March 2001 and March 2004. Six of the inspections had an "acceptable" result, and one had a "poor" result due to a leaking concrete block septic tank. There are seven pumpouts on record for all systems in this area (Figure 4.5a). Water use records were available for all of the 13 developed properties within the "zone-of-influence" for the Cobia Way well series. Average water use for all of these properties between 1999 and April 2005 was between 24% and 117% of design flow (Figure 4.12a). There were no trends in water use that were common across all properties in this area. Eight properties had low water use year-round, three properties had generally higher water usage in the summer and fall (especially in August), two properties had generally higher water usage in the winter (November-December), and one property had higher water usage in both summer and winter. Two of the properties had an overall average water use greater than 75% of the design flow.

The water quality sampling program results for groundwater points in this series show a variety of impacts that may be due to the nearby OWTS, particularly at Cobia Way #1-G directly downgradient of the leachfield (Figure 5.10). Fecal coliform levels are elevated during warmer months, although levels at this series rarely exceed the 200 MPN/100 mL recreational water quality criteria. Total phosphorus and nitrate are often significantly elevated above background levels at both groundwater monitoring wells in this series. Elevated total phosphorus concentrations indicate that, near the leachfield and as far away as Cobia Way #2-G, the phosphorus sorption capacity of the soil may have been exceeded. The presence of low ammonia concentrations indicates that the separation distance between the leachfield and the local water table is adequate. Nitrate levels are elevated at both monitoring wells in this series, although the concentrations observed are not as high as those near the Old Cove series. As with the Old Cove series, nitrate concentrations were generally lower at Cobia Way #2-G as compared to the #1 monitoring well, although the magnitude of the decrease is less than observed at Old Cove. This decrease is likely due to dilution, as DO levels are often not low enough to allow denitrification in the saturated soils between the two monitoring wells. There did not appear to be a strong relationship between precipitation patterns and water quality impacts at this site. There was also no discernable relationship between periods of excessive water use and water quality impacts.

In summary, the OWTS associated with the Cobia Way monitoring well series is impacting local groundwater quality. Impacts observed were fecal coliform (summers only), total phosphorus, and nitrate (Table 6.1). However, the system appears to be functioning properly and has an adequate separation distance between the bottom of the leachfield and the local water table.

6.2.7. Cobia Way A

The Cobia Way A series includes the monitoring points Cobia Way #1a-G, Cobia Way #2a-G, and Cobia Way #3a-S. Cobia Way #1a-G is located approximately 15 feet west-southwest of a leachfield serving a single-family house, and Cobia Way #2a-G is located approximately 70 feet west-southwest of the same leachfield. The surface water monitoring point associated with this group of monitoring points (Cobia Way #3a-S) is located in the finger canal approximately 95 feet west-southwest of the leachfield. The average separation distance between the ground surface and the groundwater beneath the leachfield, based on water table elevations from June 2004-April 2005, is 8.7 feet at Cobia Way #1a-G and 4.5 feet at Cobia Way #2a-G (Figure 3.6a and Figure 5.11). The general groundwater flow direction in this area is west-southwest towards the nearest finger canal (Figure 3.5a). Both monitoring wells and the surface water sampling point appear to be downgradient of the leachfield.

The property associated with the Cobia Way A well series contains a single-family, seasonal residence with three bedrooms and two bathrooms. The OWTS serving this structure is a conventional system with a design flow of 480 gpd (Figure 4.2a), which was constructed in 2000. The system consists of a precast 1,000-gallon septic tank and a standard leachfield. This system was inspected in February 2003 with an "acceptable" result. No permits were obtained for this system. There are three pumpouts on record for this system (Figure 4.5a). Average water use for this property between 2000 and April 2005 was generally between 1% and 29% of design flow between September and June, and was between 45% and 84% of design flow during July-August (Figure 4.12a).

There are 12 developed properties within the "zone-of-influence" associated with the Cobia Way A well series. Each of these properties contains a single-family residence with 2-4 bedrooms and 1.5-2.5 bathrooms. Seven of the homes are seasonal residences, and the rest are occupied year-round. The estimated separation distance between the ground surface and the groundwater beneath the entire "zone-of-influence" is 7.7 feet (Figure 3.6a). The OWTS serving the structures in the "zone-of-influence" are conventional systems with design flows of 240-480 gpd (Figure 4.2a), which were constructed between 1972 and 2002. The systems, where components are known, consist of precast concrete 1,000-gallon septic tanks and standard leachfields. Five permits were obtained between January 2000 and July 2002 for systems in this area (four permits for new construction and one repair). Four inspections were conducted in this area between March 2002 and February 2003, and all had an "acceptable" result. There are seven pumpouts on record for all systems in this area (Figure 4.5a). Water use records were available for all of the 12 developed properties within the "zone-of-influence" for the Cobia Way A well series. Average water use for all of these properties between 1999 and April 2005 was between 16% and 139% of design flow (Figure 4.12a). There were no trends in water use that were common across all properties in this area. Four properties had low water use year-round, five properties had generally higher water usage in the late spring and summer, two properties had generally higher water usage in the winter (October-December), and one property had higher water usage in both spring and fall. Six of the properties had an overall average water use greater than 75% of the design flow (five of these were seasonal properties).

The water quality sampling program results for groundwater points in this series show a few impacts that may be due to the nearby OWTS (Figure 5.11). Fecal coliform levels are elevated during warmer months, although levels at this series do not exceed the 200 MPN/100 mL recreational water quality criteria. Nitrate is usually significantly elevated above background levels at both groundwater monitoring wells in this series. Low total phosphorus concentrations at both monitoring wells indicate that the phosphorus sorption capacity of the soil near the system has not yet been exceeded. The presence of low ammonia concentrations indicates that the separation distance between the leachfield and the local water table is adequate. Nitrate levels are elevated at both monitoring wells in this series, although the concentrations observed are slightly lower than those near the Cobia Way series. Nitrate concentrations are generally lower at Cobia Way #2a-G as compared to the #1a monitoring well, although the differences are often small. There did not appear to be a strong relationship between elevated water table elevations/precipitation patterns and water quality impacts at this site, with the possible exception of a relationship between intense storm events and slightly elevated fecal coliform levels. There was also no discernable relationship between periods of excessive water use and water quality impacts.

In summary, the OWTS associated with the Cobia Way A monitoring well series is impacting local groundwater quality. Impacts observed were fecal coliform (summers only) and nitrate (Table 6.1). However, the system appears to be functioning properly and has an adequate separation distance between the bottom of the leachfield and the local water table.

6.2.8. Amberjack

The Amberjack series includes the monitoring points Amberjack #1-G, Amberjack #2-G, and Amberjack #3-S. Amberjack #1-G is located approximately 5 feet south-southeast of a leachfield serving a single-family house, and Amberjack #2-G is located approximately 45 feet south-southeast of the same leachfield. The surface water monitoring point associated with this group of monitoring points (Amberjack #3-S) is located in the finger canal approximately 70 feet south-southeast of the leachfield. The average separation distance between the ground surface and the groundwater beneath the leachfield, based on water table elevations from June 2004-April 2005, is 7.6 feet at Amberjack #1-G and 5.3 feet at Amberjack #2-G (Figure 3.6a and Figure 5.12). The general groundwater flow direction in this area is ambiguous. Depending on the local conditions, the direction of groundwater flow may be either south-southeast towards a finger canal (where the monitoring wells are installed), or northwest towards the main canal (Figure 3.5a). Thus, both monitoring wells and the surface water sampling point may be located either downgradient or cross-gradient from the leachfield.

The property associated with the Amberjack well series contains a single-family, year-round residence with three bedrooms and two and a half bathrooms. The OWTS serving this structure is a conventional system with a design flow of 360 gpd (Figure 4.2a), which was constructed in 1984. The system consists of a precast septic tank and a standard leachfield. This system was inspected in February 2001 with an "acceptable" result. No permits were obtained for this system. There is one pumpout on record for this system (Figure 4.5a). Average water use for this property between 1999 and April 2005 was generally between 22% and 37% of design flow (Figure 4.12a). The only exception to this was in December 2000, when water use was 74% of design flow. Water use was otherwise slightly lower in the winter and early spring (particularly in December) at this property than it was during the rest of the year.

There are 12 developed properties within the "zone-of-influence" associated with the Amberjack well series. Each of these properties contains a single-family residence with 3-6 bedrooms and 2-4 bathrooms. Five of the homes are seasonal residences, and the rest are occupied year-round. The estimated separation distance between the ground surface and the groundwater beneath the entire "zone-of-influence" is 5.2 feet (Figure 3.6a). The OWTS serving the structures in the "zone-of-influence" are both conventional (10 systems) and I/A (two systems) OWTS with design flows of 360-720 gpd (Figure 4.2a), which were constructed between

1976 and 2003. The conventional systems, where components are known, consist of precast concrete or concrete block/sand floor 750-gallon to 1,000-gallon septic tanks and standard leachfields. One of the I/A systems is identified as a Puraflo® peat filter, while the other type of alternative system was not identified. Four permits are on record for this area between April and July 2003 (two for new construction and two repairs). Both repair permits were for the installation of alternative systems. Five inspections were conducted in this area between February 2001 and March 2003; three inspections had an "acceptable" result, and two inspections had a "poor" result because of the presence of concrete block/sand bottom septic tanks. There are four pumpouts on record for all systems in this area (Figure 4.5a). Water use records were available for all of the 12 developed properties within the "zone-of-influence" for the Amberjack well series. Average water use for all of these properties between 1999 and April 2005 was between 6% and 58% of design flow (Figure 4.12). There were no trends in water use that were common across all properties in this area. Six properties had low water use year-round, and six properties had generally higher water usage in the summer and fall (August-October). None of the properties had an overall average water use greater than 75% of the design flow.

The water quality sampling program results for groundwater points in this series show a variety of impacts that may be due to the nearby OWTS (Figure 5.12). Fecal coliform levels are elevated during warmer months, although levels at this series rarely exceed the 200 MPN/100 mL recreational water quality criteria. Total phosphorus and nitrate are often significantly elevated above background levels at both monitoring wells in this series. Elevated total phosphorus concentrations indicate that, both near and farther away from the leachfield, the phosphorus sorption capacity of the soil may have been exceeded. In contrast to trends observed at other nearby monitoring well series, total phosphorus concentrations at Amberjack #2-G were often higher than those at Amberjack #1-G. The presence of low ammonia concentrations indicates that the separation distance between the leachfield and the local water table is adequate. Nitrate levels at both groundwater monitoring points are elevated, but nitrate at Amberjack #2-G is often higher than nitrate at Amberjack #1-G, particularly after July 2002. Generally higher concentrations of total phosphorus and nitrate farther away from the leachfield may indicate that there is another nutrient source, such as fertilizer, to the local groundwater in addition to the OWTS.

In summary, the OWTS associated with the Amberjack monitoring well series is likely impacting local groundwater quality. Impacts observed were fecal coliform (summers only), total phosphorus, and nitrate (Table 6.1); however, the nutrient impacts observed at these monitoring wells may not be caused only by the OWTS.

The system appears to be functioning properly and has an adequate separation distance between the bottom of the leachfield and the local water table.

6.2.9. South Blue Marlin

The South Blue Marlin series includes the monitoring points S. Blue Marlin #1-G, S. Blue Marlin #2-G, and S. Blue Marlin #3-S. S. Blue Marlin #1-G is located approximately 10 feet west-southwest of a leachfield serving a single-family house, and S. Blue Marlin #2-G is located approximately 55 feet west-southwest of the same leachfield. The surface water monitoring point associated with this group of monitoring points (S. Blue Marlin #3-S) is located in the finger canal approximately 70 feet west-southwest of the leachfield. The estimated separation distance between the ground surface and the groundwater beneath the leachfield is 6.5 feet (Figure 3.6a). The general groundwater flow direction in this area is southwest towards the nearest finger canal (Figure 3.5a). Both monitoring wells and the surface water sampling point appear to be hydraulically downgradient of the leachfield.

The property associated with the S. Blue Marlin well series contains a single-family, year-round residence with three bedrooms and two bathrooms. The OWTS serving this structure is a conventional system with a design flow of 360 gpd (Figure 4.2a), which was constructed in 1981. The system consists of a precast 1,000-gallon septic tank and a standard leachfield. This system was inspected in November 2000 with an “acceptable” result. No permits were obtained for this system. There are no pumpouts on record for this system (Figure 4.5a). Average water use for this property between 1999 and April 2005 was generally between 26% and 109% of design flow (Figure 4.12a). Water use was higher in summer and during October-December of 2000.

There are 11 developed properties within the “zone-of-influence” associated with the S. Blue Marlin well series. Each of these properties contains a single-family residence with 3-4 bedrooms and 1.5-3 bathrooms. Three of the homes are seasonal residences, and the rest are occupied year-round. The estimated separation distance between the ground surface and the groundwater beneath the entire “zone-of-influence” is 6.1 feet (Figure 3.6a). The OWTS serving the structures in the “zone-of-influence” are conventional systems with design flows of 360-480 gpd (Figure 4.2a), which were constructed between 1976 and 2004. The systems, where components are known, consist of precast concrete 1,000-gallon septic tanks and standard leachfields. Two permits for new construction, granted in December 1998 and June 2004, are on record for this area. Two inspections were conducted in this area in November 2000 and March 2003, and both inspections had an “acceptable” result. There is one pumpout on record for all systems in this area (Figure 4.5a).

Water use records were available for 10 of the 11 developed properties within the "zone-of-influence" for the S. Blue Marlin well series. Average water use for all of these properties between 1999 and April 2005 was between 26% and 171% of design flow (Figure 4.12a). There were no trends in water use that were common across all properties in this area. Four properties had low water use year-round, four properties had generally higher water usage in the summer (June-August), one property had higher water usage in the fall (October-December), and one property had higher water usage in April. Three of the properties had an overall average water use greater than 75% of the design flow.

The water quality sampling program results for groundwater points in this series show a variety of impacts that may be due to the nearby OWTS at both downgradient monitoring points (Figure 5.13). Fecal coliform levels are elevated during warmer months, although levels at this series rarely exceed the 200 MPN/100 mL recreational water quality criteria. Total phosphorus and nitrate are often significantly elevated above background levels. Elevated total phosphorus concentrations at both monitoring wells indicate that the phosphorus sorption capacity of the soil may have been exceeded. The presence of low ammonia concentrations indicates that the separation distance between the leachfield and the local water table is generally adequate. Nitrate levels are elevated at both monitoring wells in this series. Nitrate concentrations are generally lower at S. Blue Marlin #2-G as compared to the #1 monitoring well, although the differences are often small.

In summary, the OWTS associated with the S. Blue Marlin monitoring well series is impacting local groundwater quality. Impacts observed were fecal coliform (summers only), total phosphorus, and nitrate (Table 6.1). However, the system appears to be functioning properly and has an adequate separation distance between the bottom of the leachfield and the local water table. With the possible exception of fecal coliform, there does not appear to be a relationship between excessive water use and impacts on local groundwater quality.

*6.2.10. **Jeannette's Pier***

The Jeannette's Pier series includes the monitoring point Jeannette's Pier-G. Jeannette's Pier-G is located approximately 5 feet west of a set of two leachfields serving the pier. The average separation distance between the ground surface and the groundwater beneath the leachfield, based on water table elevations from June 2004-April 2005, is 5.0 feet at Jeannette's Pier-G (Figure 3.6b and Figure 5.14). The general groundwater flow direction in this area is northeast towards the Atlantic Ocean (Figure 3.5b). The Jeannette's Pier-G monitoring well appears to be hydraulically upgradient of the leachfields.

The property associated with the Jeannette's Pier well series contains a year-round commercial building with two public bathrooms. The OWTS serving this structure is an I/A system with two septic tanks (one 3,800 gallon tank and one 2,000 gallon tank), a 4,000-gallon pump tank, and a 1,680 total linear foot low-pressure pipe (LPP) dispersal field. The system also has a 1,500-gallon grease trap. The design flow is 4,207 gpd, and there is no electronic permit information available for this system. The structure was constructed in 1962. There is no electronic inspection or pumpout information available for this system (Figure 4.5b). Information collected from paper files at the Dare County Health Department office indicated that operator inspections were conducted in 2003 and 2004, and that the septic tanks were pumped in 2002 and 2003. Average water use for this property between 1999 and April 2005 was between 1% and 50% of design flow (Figure 4.12b). Water use was generally higher during the summer months, with the exception of November 2002, when average water use was 114% of design flow.

There are four developed properties within the "zone-of-influence" associated with the Jeannette's Pier well series. One of these properties contains a restaurant and a trailer park with an unknown total design flow. The other two developed properties appear to be a hotel and a group of small commercial buildings. The estimated separation distance between the ground surface and the groundwater beneath the entire "zone-of-influence" is 5.5 feet (Figure 3.6b). The OWTS serving the hotel and restaurant/trailer park properties in the "zone-of-influence" are conventional systems (Figure 4.2b), which were constructed between 1947 and 1960. The OWTS serving the group of commercial buildings is a conventional system with estimated design flows of 2,880 gpd, which was constructed in 1970. Aside from the LPP system serving the Jeannette's Pier property, the components of these systems are unknown. No permit, inspection, or pumpout information was available for these properties. Water use records were available for all of the developed properties within the "zone-of-influence" for the Jeannette's Pier well series. Average water use for all of these properties between 1999 and April 2005 was between 47% and over 200% of design flow (Figure 4.12b). There were no trends in water use that were common across all properties in this area. Three of the properties had an overall average water use greater than 75% of the design flow.

The water quality sampling program results for groundwater points in this series show a few impacts that may be due to the nearby OWTS (Figure 5.12). Fecal coliform levels are elevated during warmer months, although levels do not exceed the 200 MPN/100 mL recreational water quality criteria. Total phosphorus and nitrate are elevated above background levels. Elevated total phosphorus concentrations indicate that the phosphorus sorption capacity of the soil may have been exceeded. The presence of low ammonia concentrations indicates that the separation distance between the leachfield and the local water table is generally adequate. Nitrate levels are elevated during about half of the monitoring period at this location. It is likely, given the upgradient location of the Jeannette's Pier monitoring well, that this monitoring well is not capturing the entire effluent plume associated with the leachfield.

In summary, the OWTS associated with the Jeannette's Pier monitoring well series is likely impacting local groundwater quality. Impacts observed were fecal coliform (summers only), total phosphorus, and nitrate (Table 6.1). Although it is likely that greater impact from this system occurs downgradient from the leachfield, the monitoring well is located upgradient from the OWTS effluent plume, and thus captures only an occasional impact.

6.2.11. ***Huron Access***

The Huron Access series includes the monitoring points Huron Access #1-G and Huron Access #2-G. Huron Access #1-G is located approximately 10 feet south of a leachfield serving a group of 10 structures, and Huron Access #2-G is located approximately 65 feet east of the same leachfield. The average separation distance between the ground surface and the groundwater beneath the leachfield, based on water table elevations from June 2004-April 2005, is 8.0 feet at Huron Access #1-G and 5.3 feet at Huron Access #2-G (Figure 3.6b and Figure 5.15). The monitoring locations and the leachfield are close to the apparent groundwater divide, the location of which is influenced by tidal patterns. During spring tides, the groundwater in this area likely flows west-southwest toward the sound, while during neap tides groundwater likely flows east-northeast toward the ocean (Figure 3.5b). Both monitoring wells appear to be hydraulically downgradient and slightly cross-gradient of the corresponding leachfield.

The property associated with the Huron Access well series is the Bodie Island Beach Club, a group of seasonally occupied buildings with a total of 30 two-bedroom condominium units. The OWTS serving this structure is an I/A system with two 5,000-gallon septic tanks, a pump tank with two effluent pumps, and three LPP dispersal fields (total of 4,000 linear feet), with a design flow of 7,200 gpd (Figure 4.2b). The structures were constructed in 1962, while the earliest permit on file for the system was issued in 1983. There is no electronic permit, inspection, or pumpout information available for this system. Paper files for this system were reviewed at the Dare County Health Department office. The system has a past history of relatively poor maintenance (needed repairs not completed, tanks not pumped), but currently appears to be compliant, with operator inspections occurring in 2003 and 2004 and a new operating permit in June of 2004. As of

December 2004, the building was not occupied due to hurricane damage, but was under repair. Average water use for this property between 1999 and December 2003 was between 13% and 155% of design flow (Figure 4.12b). There was a strong seasonal component to the water use at this property: water use for July-September of each year was 120%-155% of design flow, while during the rest of each year water use was 100% of design flow or less, with the lowest water use occurring in January-March of each year. Between January 2004 and April 2005, water use was generally less than 40% of design flow, and was very low after August of 2004 (3% or less of design flow).

There are four developed properties within the "zone-of-influence" associated with the Huron Access well series. All of the properties contain seasonal residences. Two properties contain one residential building; one property contains four residential buildings; and one property contains the beach club structures as described above. The estimated separation distance between the ground surface and the groundwater beneath the entire zone of influence is 7.2 feet (Figure 3.6b). The two properties with a single structure included 4-8 bedrooms and 4-6 bathrooms. The systems serving these properties are conventional systems with design flows from 480-960 gpd (Figure 4.2b), which were constructed in 1998 and 2000. Both properties were inspected with acceptable results, and their septic tanks were pumped. The remaining property contains four residential buildings with a total of 32 bedrooms and 24 bathrooms. The conventional system(s) serving these structures was constructed in 1998, and has a total design flow of 3,840 gpd. There were no permits, inspections, or pumpouts on record for this system. Average water use for all of these properties between 1999 and April 2005 was between 28% and 122% of design flow (Figure 4.12b). There were no trends in water use that were common across all properties in this area. Three properties had excessive water use during the summer months (June-August), and one property had low water use year-round. One of the properties had an overall average water use greater than 75% of the design flow.

The water quality sampling program results for groundwater points in this series show several impacts that may be due to the nearby OWTS (Figure 5.13). Fecal coliform levels are generally elevated during warmer months, although levels rarely exceed the 200 MPN/100 mL recreational water quality criteria. The relationship between summer months / elevated water use and elevated fecal coliform levels is not as clear at Huron Access as it is at other monitoring series in the northern part of Nags Head. Total phosphorus and nitrate are elevated above background levels at both monitoring wells. Elevated total phosphorus concentrations indicate that the phosphorus sorption capacity of the soil may have been exceeded at both monitoring locations in this series. The presence of low ammonia concentrations indicates that the separation distance between the leachfield and the local water table is generally adequate. Elevated nitrate levels at both monitoring points in 2002, and at Huron Access #1-G in 2003, appear to correspond with periods of excessive water use. However, this relationship does not appear during the first year of the monitoring program. Groundwater flow directions in this area vary considerably, and this may explain why the relationship between excessive water use and elevated nitrate concentrations is not observed consistently at both monitoring wells in this series.

In summary, the OWTS associated with the Huron Access monitoring well series is impacting local groundwater quality. Impacts observed were fecal coliform (summers only), total phosphorus, and nitrate (Table 6.1). However, the system appears to be functioning properly and has an adequate separation distance between the bottom of the leachfield and the local water table. There appears to be a relationship between excessive water use and fecal coliform and nitrate impacts on local groundwater quality at this location.

*6.2.12. **Ida Access***

The Ida Access series includes the monitoring points Ida Access #1-G and Ida Access #2-G. Ida Access #1-G is located approximately 15 feet north of a leachfield serving a single-family house, and Ida Access #2-G is located approximately 145 feet west-southwest of the same leachfield. The average separation distance between the ground surface and the groundwater beneath the leachfield, based on water table elevations from June 2004-April 2005, is 5.3 feet at Ida Access #1-G and 3.5 feet at Ida Access #2-G (Figure 3.6b and Figure 5.16). The general groundwater flow direction in this area is west-southwest towards the sound (Figure 3.5b). Monitoring well Ida Access #1-G appears to be hydraulically upgradient, while Ida Access #2-G appears to be hydraulically downgradient of the associated leachfield. Both monitoring points also appear to be slightly cross-gradient from the leachfield.

The property associated with the Ida Access series contains a single-family seasonal residence with 4 bedrooms and 2 bathrooms. The OWTS serving this structure is a conventional system with a design flow of 480 gpd (Figure 4.2b). The structure associated with this system was built in 1976. There is no information available regarding system components, inspections, permits, or pumpouts for this system. There is currently no water use information available for this property.

There are 10 developed properties within the “zone-of-influence” associated with the Ida Access well series. Nine of the properties contain single family residences (four seasonal and five year-round residences), and one property contains a commercial building. The estimated separation distance between the ground surface and the groundwater beneath the entire zone of influence is 7.4 feet (Figure 3.6b). The single-family residences include 3-5 bedrooms and 2-4.5 bathrooms. The OWTS serving the structures in the "zone-of-influence" are conventional systems with design flows of 360-600 gpd (Figure 4.2b), which were constructed between 1968 and 1999. The systems, where components are known, consist of precast concrete or concrete block/sand floor 1,000-gallon to 1,250-gallon septic tanks and standard leachfields. One permit for new construction, granted in June 1999, is on record for this area. The commercial property also has an operating permit that was renewed in 2005. Four inspections were conducted in this area between February 2001 and April 2002. Two of these inspections had an "acceptable" result, and two had a "poor" result due to leaking septic tanks. There are three pumpouts on record for all systems in this area. Water use records were available for eight of the 10 developed properties within the "zone-of-influence" for the Ida Access well series. Average water use for all of these properties between 1999 and April 2005 was between 2% and 94% of design flow (Figure 4.12b). There were no trends in water use that were common across all properties in this area. Four properties had low water use year-round, and four properties had generally higher water usage in the summer (June-August). Two of the properties had an overall average water use greater than 75% of the design flow.

The water quality sampling program results for groundwater points in this series show limited impacts that may be due to the nearby OWTS (Figure 5.16). Fecal coliform levels are elevated during warmer months, although levels do not exceed the 200 MPN/100 mL recreational water quality criteria. The relationship between summer months and elevated fecal coliform levels is clear at Ida Access, but it is subdued when compared to other monitoring well series to the north. Total phosphorus concentrations are within background levels, and nitrate levels are only slightly elevated above background levels at both monitoring wells in this series. Low phosphorus concentrations, particularly at the downgradient well Ida Access #2-G, may indicate that the phosphorus sorption capacity of the soil has not yet been exceeded. The presence of low ammonia concentrations may indicate that the separation distance between the leachfield and the local water table is generally adequate. While it appears that there are few impacts from this older OWTS on local groundwater quality, this conclusion is confounded somewhat by the upgradient location of the nearby well (Ida Access #1-G) and the long distance between the leachfield and the downgradient well (Ida Access #2-G). It is possible that neither monitoring well is capturing the effluent plume associated with the leachfield.

In summary, the OWTS associated with the Ida Access monitoring well series may be impacting local groundwater quality, but the evidence is inconclusive. Possible impacts observed were fecal coliform (summers only) and nitrate (Table 6.1). The system appears to be functioning properly and to have an adequate separation distance between the bottom of the leachfield and the local water table. However, it is likely that neither monitoring well in this series is capturing the effluent plume associated with the leachfield.

6.2.13. Jay Street Access

The Jay Street Access series includes the monitoring points Jay Street Access #1-G and Jay Street Access #2-G. Jay Street Access #1-G is located approximately 20 feet north of a leachfield serving a single-family house, and Jay Street Access #2-G is located approximately 20 feet north-northeast of the same leachfield. The average separation distance between the ground surface and the groundwater beneath the leachfield, based on water table elevations from June 2004-April 2005, is 5.1 feet at Jay St. Access #1-G and 4.3 feet at Jay St. Access #2-G (Figure 3.6b and Figure 5.17). The general groundwater flow direction in this area is west-southwest towards the sound (Figure 3.5b). Monitoring well Jay Street Access #1-G appears to be upgradient of the associated leachfield, while monitoring well Jay Street Access #2-G appears to be crossgradient to the associated leachfield.

The property associated with the Jay Street well series contains a single-family year-round residence with 3 bedrooms and 1.5 bathrooms. The OWTS serving this structure is a conventional system with a design flow of 360 gpd (Figure 4.2a), which was constructed in 1960. There is no information available regarding system components, inspections, permits, or pumpouts for this system. Average water use for this property between 1999 and April 2005 was between 1% and 61% of design flow (Figure 4.12b). Water use was higher during July-August of each year (47%-61% of design flow) than during the rest of the year (1-32% of design flow). The only exception to this was during 2004, when water use did not exceed 7% of design flow.

There are five developed properties within the zone of influence associated with the Jay Street well series. Each of the properties contains a single family residence with 3-5 bedrooms and 1-2.5 bathrooms. Two of the properties are seasonal, while the rest are occupied year-round. The estimated separation distance between the ground surface and the groundwater beneath the entire zone of influence is 4.8 feet (Figure 3.6b). The OWTS serving the structures in the zone of influence are all conventional systems with design flows of 360-600 gpd (Figure 4.2b). The systems were constructed over a range of years from 1960 through 2001. The systems, where components are known, consist of precast concrete 1,000-gallon septic tanks and standard leachfields. Two permits (one for a repair and one rewrite) granted in September 1998 and May 2001 are on record for this area. Three inspections were conducted in this area between September 2000 and May 2004, and all inspections had an “acceptable” result. There are three pumpouts on record for all systems in this area (Figure 4.5b). Water use records were available for all of the five developed properties within the “zone-of-influence” for the Jay St. Access well series. Average water use for all of these properties between 1999 and April 2005 was between 41% and 267% of design flow (Figure 4.12b). There were no trends in water use that were common across all properties in this area. One property had low water use year-round and four properties had higher water usage in the summer (June-August). One of the four properties had average water use of over 250% of design flow during June-August; this was the same property with a permit for repair in 1998. Three of the properties had an overall average water use greater than 75% of the design flow.

The water quality sampling program results for groundwater points in this series show limited impacts that may be due to the nearby OWTS (Figure 5.17). Fecal coliform levels are elevated during warmer months, although levels do not exceed the 200 MPN/100 mL recreational water quality criteria. The relationship between summer months and elevated fecal coliform levels is clear at Jay St. Access, but it is subdued when compared to other monitoring well series to the north. Total phosphorus concentrations and ammonia concentrations are generally within background levels, and nitrate levels are only slightly elevated above background levels at both monitoring wells in this series. Although it appears that there are few impacts from this older OWTS on local groundwater quality, this conclusion is confounded by the upgradient and cross-gradient locations of the nearby monitoring wells. It clear from these results that neither monitoring well is fully capturing the effluent plume associated with the leachfield.

In summary, the OWTS associated with the Jay St. Access monitoring well series may be impacting local groundwater quality, but the evidence is inconclusive. Possible impacts observed were fecal coliform (summers only) and nitrate (Table 6.1). The system appears to be functioning properly and to have an adequate separation distance between the bottom of the leachfield and the local water table. However, it is likely that neither monitoring well in this series is fully capturing the effluent plume associated with the leachfield.

6.2.14. Juncos Street Access

The Juncos Street Access series includes the monitoring points Juncos Street Access #1-G and Juncos Street Access #2-G. Juncos Street Access #1-G is located approximately 40 feet east of a leachfield serving a single-family house, and Juncos

Street Access #2-G is located approximately 10 feet south of the same leachfield. The average separation distance between the ground surface and the groundwater beneath the leachfield, based on water table elevations from June 2004-April 2005, is 2.5 feet at Juncos St. Access #1-G and 1.8 feet at Juncos St. Access #2-G (Figure 3.6b and Figure 5.18). The general groundwater flow direction in this area is west-southwest towards the sound (Figure 3.5b). Monitoring well Juncos Street Access #1-G appears to be upgradient of the associated leachfield, while monitoring well Juncos Street Access #2-G appears to be downgradient and slightly cross-gradient from the leachfield.

The property associated with the Juncos Street well series contains a seasonal single family residence with 10 bedrooms and 7.5 bathrooms. The OWTS serving this structure is an I/A system with a design flow of 1200 gpd (Figure 4.2b), which was permitted in 1999. The system consists of a septic tank, a pump tank, and an LPP dispersal field. The system has not been inspected, and there are no pumpouts on record. Average water use for this property between 2000 and April 2005 was between 6% and 106% of design flow (Figure 4.12b). There was a strong seasonal component to the water use at this property: water use was higher during June-August of each year (81%-106% of design flow) than during the rest of the year (6-63% of design flow).

There are eight developed properties within the "zone of influence" associated with the Juncos Street well series. Six of these properties contain residential structures with 4-6 bedrooms and 2-6 bathrooms while the other two properties contain residential structures with 10-15 bedrooms and 7.5-10 bathrooms. Eight of the properties are seasonal, while the rest are occupied year-round. The estimated separation distance between the ground surface and the groundwater beneath the entire zone of influence is 2.6 feet (Figure 3.6b). The OWTS serving the six properties with smaller structures in the zone of influence are all conventional systems with design flows of 480-720 gpd (Figure 4.2b). The systems were constructed over a range of years from 1988 through 2002. Two repair permits, granted between January 2001 and September 2002, are on record for these smaller systems. Two inspections were conducted on the smaller systems between October 2001 and August 2002. One inspection had a "poor" result due to a failing leachfield (this system was repaired), and one inspection had an "acceptable" result. Both inspected systems were pumped out (Figure 4.5b). The OWTS serving the two properties with larger structures in the zone of influence are I/A systems with design flows of 1200-1800 gpd (Figure 4.2b). The systems were constructed in 1986 and 1999. One permit for new construction, granted in December 1999, is on record for these larger systems. No inspections or pumpouts are on record for the larger systems. Water use records were available for all of the eight developed properties within the "zone-of-influence" for the Juncos St. Access well series. Average water use for all of these properties between 1999 and April 2005 was between 31% and 255% of design flow (Figure 4.12b). All of the properties had higher water usage in the summer (June-August). Four of the properties had an overall average water use greater than 75% of the design flow.

The water quality sampling program results for groundwater points in this series show limited and sporadic impacts that may be due to the nearby OWTS (Figure 5.18). Impacts are generally only observed at Juncos St. Access #2-G, which is downgradient and cross-gradient from the leachfield. Fecal coliform levels are elevated only during the summer of 2002, and levels do not exceed the 200 MPN/100 mL recreational water quality criteria. Total phosphorus concentrations are generally within background levels. Ammonia and nitrate levels are both significantly but sporadically elevated above background levels at Juncos St. Access #2-G. The presence of elevated ammonia concentrations during portions of the monitoring period indicates that there may not be an adequate separation distance between the leachfield and the local water table; however, during the last year of the sampling period elevated ammonia concentrations were not observed even when there was less than a foot of separation between the ground surface and the water table. As with the Huron St. Access series, there may be a relationship between excessive water use and elevated nitrate concentrations; this relationship appears during the summers of 2003 and 2004. Although the impacts from this larger LPP system on local groundwater quality appear to be sporadic, this conclusion is confounded by the upgradient and cross-gradient locations of the nearby monitoring wells. It clear from these results that neither monitoring well is fully capturing the effluent plume associated with the leachfield.

In summary, the OWTS associated with the Juncos St. Access monitoring well series may be impacting local groundwater quality, but the evidence is not always conclusive. Impacts observed were fecal coliform (two summers only), ammonia, and nitrate (Table 6.1). The system may not have an adequate separation distance between the bottom of the leachfield and the local water table. However, neither monitoring well in this series is fully capturing the effluent plume associated with the leachfield.

6.3. Summary and Conclusions

The characteristics of OWTS influencing individual monitoring points were evaluated together with the water quality monitoring data to establish what particular characteristics of these individual systems are causing impacts on local water quality. The process for the system-by-system analysis included the following steps:

1. Associate the appropriate water quality monitoring points with individual property and OWTS information.
2. Determine local hydrogeologic conditions.
3. Gather data about the individual property and OWTS.
4. Create the "zone-of-influence" buffer for each well cluster and evaluate systems within the buffer zone.
5. Evaluate water quality characteristics over time at each monitoring point in the series (including fecal coliform, total phosphorus, ammonia, nitrate, and DO).
6. Consider other possible sources of contaminants, and other potential factors that may affect the observed water quality results and trends.
7. Assess the impact of the individual OWTS on water quality, clearly identifying the characteristics of each OWTS (if any) that are correlated with the water quality results and trends.

Throughout the Town, impacts from individual OWTS on the nearby groundwater were generally confined to a narrow region located directly downgradient from the individual leachfield. Groundwater monitoring wells that were located as little as 10-15 feet cross-gradient or upgradient from individual leachfields tended to show sporadic impacts from OWTS or, in the case of Pamlico-G, no impact at all. Impacts in the groundwater monitoring wells from OWTS in the "zone-of-influence" surrounding each well cluster were generally not observed. The discrete nature of the impacts from individual systems on the local groundwater, coupled with the cross-gradient and upgradient locations of several monitoring wells intended to capture these impacts, makes it nearly impossible in some cases to determine specific impacts from OWTS. This observation is particularly true for the monitoring wells in the Pamlico well cluster, and for many of the wells near OWTS south of the Jeannette's Pier well cluster.

The results of the system-by-system analysis fall into three major groups (Table 6.1). The first group includes individual systems where high ammonia concentrations were observed in the groundwater near the leachfield (Lost Colony 1, Lost Colony 2, and Juncos Street Access). These three systems each had a local or regional depth to groundwater of less than 3.0 feet. For this group of systems, there is clearly an insufficient separation distance between the bottom of the leachfield and the local water table. Excessive water use, particularly during the spring and summer months, may also be contributing to the observed impacts of these three systems on local groundwater quality.

The second group includes individual systems where high total phosphorus concentrations, seasonally high fecal coliform bacteria concentrations, and some level of nitrate impact were observed in the groundwater downgradient from the leachfield (Old Cove, Cobia Way, Amberjack, S. Blue Marlin, and Huron Access). Systems in this grouping have an adequate separation distance between the bottom of the leachfield and the local water table (4.5 feet or more), but still have the potential to transmit pollutants, including bacteria and nutrients, to nearby surface waters. These five systems were constructed between 1970 and 1985, so they are at least 20 years old. Excessive water use may also be contributing to the observed impacts of these systems on local groundwater quality. Peak average water uses greater than 75% of design flows were observed at three of the five systems in this grouping.

The third group includes individual systems where impacts from individual systems on local groundwater quality were generally low or were not observed in the nearby monitoring wells (Pamlico, Cobia Way A, Jeannette's Pier, Ida Access, and Jay St. Access). At most of these monitoring locations, the groundwater monitoring wells were located cross-gradient or upgradient from the leachfield, and so the impact of the individual system on the local groundwater was not observed. The only exception is the Cobia Way A series, where both monitoring wells are located downgradient from the leachfield, yet low to no impact was observed. This system is relatively new (constructed in 2000), and water use during the period that water quality sampling was conducted (May 2003-June 2004) was very low—generally less than 25% of design flow.

The characteristics of OWTS that are correlated with water resource impact potential will be identified as a result of the analysis presented. This will be discussed in Section 7 of this report.

7. TOWN-WIDE ENVIRONMENTAL IMPACT POTENTIAL ANALYSIS

Previous sections of this report focused on assessing groundwater and surface water quality trends throughout Nags Head, and how individual onsite systems may be contributing to those trends. This section presents a methodology for predicting an onsite system's potential environmental impact based upon the conclusions from the water quality and onsite system discussions (Sections 5 and 6). The results of this impact potential analysis will provide the basis from which management plan options will be designed.

7.1. Impact Potential Due to Onsite System Conditions

Water quality trends at each of the monitoring locations were described in Section 5. From this assessment, we identified locations where water quality conditions were above or below levels of concern, and where quality was improving or declining over time. In Section 6, the characteristics of the onsite systems being monitored were evaluated to identify the characteristics of those systems that may influence the trends in water quality at each monitoring location. The summarized data in Section 6 were used to determine which characteristics of onsite systems lead to the greatest potential environmental impart.

7.1.1. Methodology

Table 6.1 summarizes the results of the onsite system characteristics and water quality analysis. It shows the characteristics associated with each system and well cluster being monitored and the water quality impact observed at each location. Several methods were considered for drawing correlations between onsite system characteristics and impacts on water quality using data from this table. The first was a quantitative statistical methodology and the second was a more qualitative evaluation of the data.

The quantitative statistical approach was explored by applying several methods. The objective was to perform an exploratory analysis employing some basic statistical measures to see if some system characteristics were more strongly correlated with high water quality impact than others, and to justify whether a more rigorous statistical analysis had potential to produce useful results. In order to apply these methods, the onsite system characteristics and the observed water quality impact had to ranked and classified. The following onsite system characteristic were ranked from 1 to 3:

- System Age/Type:
  - 3: System built before 1979
  - 2: System built 1979-1992
  - 1: System built after 1992 or an I/A system
- Water Use:

  - 3: Local excess water use = “Yes” and regional excess use ≥ 30%
  - 2: Local excess water use = “Yes” and regional excess use < 30% or local excess water use = “No” and regional excess use ≥ 30%
  - 1: Local excess water use = “No” and regional excess use < 30%
- Failed Inspections:
  - 3: Percent failed ≥ 50% and number failed ≥ 2
  - 2: Number failed = 1
  - 1: Number failed = 0
- Groundwater Depth:
  - 3: local groundwater depth ≤ 3 ft
  - 2: local or regional groundwater depth 3 – 6 ft
  - 3: local or regional groundwater depth > 6 ft

The water quality impact was ranked by summing of the impact scores of the individual water quality parameters shown in Table 6.1.

Correlations between ranks of individual characteristics and the overall water quality impact rank were evaluated by computing standard correlation coefficients as well as the non-parametric Spearman’s Rank Correlation Coefficient, which is more appropriate for non-continuous or non-normally distributed data. In addition, multiple variable linear regression was applied using the four onsite system characteristic ranks as independent variables and the water quality impact rank as the dependent variable. The results of these statistical calculations were then evaluated to determine the correlations were supported by the data and if additional statistical tests were warranted.

The second, more qualitative method sought to examine the information in Table 6.1 and identify typical characteristics regarding onsite systems that occurred when water quality impact was high at the monitoring locations. This method also required ranking the onsite system characteristics as previously discussed and used the same water quality impacts pertaining to the individual groundwater pollutants.

7.1.2. Results and Discussion

The exploratory statistical analysis showed poor correlation between the individual onsite system characteristics and the water quality impact ranking. Values for the standard correlation coefficient were all between –0.15 and +0.15, where a value of 1 or –1 would suggest perfect correlation and 0 would suggest no correlation. For the Spearman Rank Correlation Coefficient, values were similarly low, all falling within 0.20 of zero. Furthermore, the multiple variable linear regression analysis did not provide any insight as to which characteristics best explained the variability in the observed water quality impacts.

There are several possible reasons for the weak correlations found in this exploratory analysis. First, our sample size is very small. Data were available for well clusters monitoring 13 systems, some of which did not appear to be fully capturing the downgradient treated wastewater plume. If a larger sample size were available, then a broader range of conditions could have been evaluated, possibly leading to the realization of some stronger trends. Second, it is difficult to equitably quantify how much a system is impacting water quality at monitoring wells that are not an equal distance to the onsite septic system. It was common in the monitoring data to see changes in water quality parameters as one moved further away from the system, suggesting that a truly fair comparison of how well systems are treating wastewater would require that monitoring wells be sited at equal down-gradient distances from systems. Third, it is possible that if a correlation exists between onsite system characteristics and water quality impact, it is either not dependent upon just one factor, or it is not statistically significant. This possibility will be revisited in the discussion of the qualitative assessment. Finally, it may be that a more rigorous statistical assessment of this data would reveal some relationships not readily apparent using tests described. Rather than explore this final possibility, a qualitative assessment was performed to determine if in fact there were some commonalities amongst the more heavily impacted well clusters.

The qualitative analysis was performed by ranking the onsite system characteristics and water quality impacts, as performed for the statistical analysis, then sorting the table of data by the impact ranking. After reviewing the table in this format, it was observed that in order for high water quality impact to be observed (a value of "3" for at least one of the 4 water quality criteria in Table 6.1), one or more of the following conditions had to occur:

- Local depth to groundwater less than or equal to 3 feet
- Have a local peak annual water use greater than 75% of design flow
- Have a system built before 1986

Although having failed systems in the region often occurs for well clusters showing high impact, it is not required. In addition, a failed system is often a result of another condition, such as shallow groundwater or an older system.

Further review of Table 6.1 revealed that shallow groundwater is the most consistent characteristic associated with high water quality impact. All three of the systems with shallow groundwater evaluated had at least 2 of the 4 water quality criteria impacts ranked as high. Therefore, this characteristic should be given greater weight when determining the overall vulnerability of a system. The data did not clearly reveal whether excessive water use of system age had a more significant impact on water quality. None of the systems with one or fewer high water quality impacts had excessive water use, suggesting that high water use has a significant influence on water quality impacts. However, there are several systems, S. Blue Marlin and Amberjack , that had 2 or more high water quality impacts, whose only limiting characteristic was having an older system (no shallow groundwater or water use problems). Based on this data, equal weight was given to both excessive water use and system age when calculating an overall system vulnerability.

Based upon the qualitative assessment of conditions corresponding to high water quality impact, the following ranking scheme was derived:

- High: Both groundwater ≤ 3 ft and average peak water use ≥ 75% of design flow, or both groundwater ≤ 3 ft and a system age >= 20 years old
- Moderate: Either groundwater ≤ 3 ft, or water use ≥75% along with a system age ≥ 20 years old
- Low-Moderate: No groundwater problems, but either high water use or an older system
- Low: No groundwater or water use problems, with a system built after 1985

Although the quantitative statistical approach did not identify strong correlations, the qualitative approach did reveal commonalities between systems that showed a high impact to water quality, suggesting that perhaps a statistical approach with a larger sample size or application of different statistical techniques might support stronger correlations. The criteria that compose this ranking scheme are supported by data from the limited number of onsite systems monitored. The criteria also agree with recommendations that we would make based on our best professional judgment.

The ranking scheme outlined above was applied to all of the properties where onsite systems are thought to exit in Nags Head. The results of this assessment are shown in Figures 7.1a and 7.1b. The breakdown of properties falling into the four classes of impact potential due to onsite system characteristics is as follows:

- High potential impact: 363 properties
- Moderate potential impact: 1,125 properties
- Low-Moderate potential impact: 1,280
- Low potential impact: 982 properties

Approximately 10% of the properties fall into the high impact classification, approximately 26% in the low impact class, and the remaining 64% in the middle two classes. More than half of the properties are estimated to have a moderate to high potential environmental impact.

Figures 7.1a and 7.1b show that clustering of properties with high impact potential is not very strong. There is somewhat of an area of low impact properties near the Pamlico neighborhood, and in and around the Deering and Cobb Streets neighborhood. In addition, the section of North Nags Head between Wrightsville and Virginia Dare streets tends have systems with higher impact potential, as does the area south of Nags Head Village and north of the Whalebone. In South Nags Head, pockets of low impact and high impact potential properties are scattered throughout the area.

7.2. Impact Potential Due to Water Resource Proximity

The proximity of an onsite system to a water body of concern will have an effect of the environmental impact potential of that system. Systems that are hydrologically closer to a water body will be greater potential pollutant sources. This is particularly true for pathogens and nitrate. Nitrate travels rapidly in groundwater and pathogens can survive for several months in groundwater. In Nags Head, the primary water bodies of concern are the Atlantic Ocean and Roanoke Sound. A technique for ranking the proximity of onsite systems to these two water bodies was developed in order to further refine the impact potential based upon the onsite system conditions.

7.2.1. Methodology

The primary method by which pollutants from onsite systems reach the Atlantic Ocean and Roanoke Sound is through direct groundwater flow. Therefore, estimated groundwater flow velocity was used to determine the distance from water bodies within which potential impacts from onsite systems would be most significant.

Groundwater flow velocities are a function of subsurface geological material and the gradient of the groundwater table elevation. While subsurface geological materials are similar across Nags Head, the groundwater table gradient varies somewhat from the northern part of the town to the southern part of the town. For this assessment, a single representative groundwater flow velocity was assumed to apply to the entire town. The velocity chosen was based upon previously published work and corroborated with calculations made from groundwater contours and hydraulic properties developed in this study. In the 1992 Whittecar and Emry report, groundwater flow velocities for northern Nags Head were estimated to be approximately 50 cm/day. This value was compared with groundwater flow velocities calculated from the hydraulic characteristics and water table gradients developed in this study. The water table gradient is generally steeper in the northern portion of Nags Head (leading to higher velocities) and is flatter in the central and southern portion of the town. Based upon this variety of conditions, groundwater flow velocities were estimated to range from approximately 10 cm/day to 60 cm/day. The 50 cm/day reported by Whittecar and Emry falls on the higher end of this calculated range. While 50 cm/day may over-estimate groundwater flow velocities in some sections of Nags Head, it is an appropriate value to use for assessing impact potential, as it will provide results that more conservatively predict impact. A more accurate estimate of groundwater flow velocities and their variability could be obtained by applying a physically-based hydrogeological model to the region.

As discussed in Section 5.1.1, bacteria in groundwater can survive for over 2 months, and possibly longer in the right conditions. Other types of pathogens, such as viruses, can survive as long as 6 months (US EPA, 2002). Based upon expected survival times of pathogens from onsite systems in groundwater and the representative groundwater flow velocity of 50 cm/day, travel distances were calculated that were associated with 3-month and 6-month travel times. These travel distances are:

- 3-month travel distance: 148 ft
- 6-month travel distance: 295 ft

Onsite systems within 148 feet of the Ocean or Sound would have a high potential of contributing pathogens to these water resources, while systems between 148 and 295 ft would have moderate potential for contributing pathogens. Systems beyond the 6-month travel time of 295 ft would be much less likely to contribute pathogens to the Ocean or Sound.

GIS was used to buffer the shoreline of both the Atlantic Ocean and Roanoke Sound by the 3-month travel distance of 148 ft and the 6-month travel distance of 295 ft. Properties that intersected the 3-month travel distance were given a water resource proximity impact potential of "3", with properties intersecting the 3 to 6 month travel distance receiving a rating of "2", and properties outside the 6-month travel time receiving a ranking of "1".

The effect of surface drainage ditches on reducing travel times from more interior onsite systems to the ocean or sound was not considered in this analysis. In order to accurately account for the effect of these ditches on transferring groundwater more quickly to the ocean or sound, a clear understanding of the drainage paths and flow direction would be required. This dataset was not available at the time of this study.

7.2.2. Results and Discussion

The results of the impact potential due to water body proximity analysis are shown in Figures 7.2a and 7.2b. The breakdown of properties falling into the three classes of impact potential due to water body proximity is as follows:

- High potential impact: 966 properties
- Moderate potential impact: 183 properties
- Low potential impact: 2,601 properties

Fully 25% of properties fall into the high impact class, only 5% in the moderate class, and a significant 70% in the low potential class.

All the properties immediately adjacent to the shoreline, and some just inland, received a ranking indicating a high impact potential. Properties in the moderate impact potential zone are commonly the properties that are one row of properties beyond the shore front properties. There are a much smaller number of properties in the moderate impact class than in the high impact class. This is because the 248-foot 6-month travel distance rarely extends beyond the closest property to the shore. This assessment suggests that effluent from shorefront properties can have very different impact potential than their neighbors just a few houses back from the beach.

7.3. Combined Environmental Impact Potential

A ranking of combined environmental impact potential due to onsite system characteristics and proximity to water resources was calculated for each property with an onsite system in Nags Head. This ranking of environmental impact potential will serve as a method for prioritizing properties for management

7.3.1. Methodology

The ranking of impact potential due to onsite system characteristics varied from a value of "4" representing the highest level of impact to a value of "1" representing the lowest level of impact. The ranking of impact potential due to proximity to water resources ranged from a value of "3" representing the highest level of impact to a value of "1" representing the lowest level of potential impact. A combined impact potential ranking was obtained by summing the onsite system characteristics ranking with the water resources proximity ranking. This resulted in a combined ranking range from "2" to "7". Each ranking represents the following conditions:

- Rank 2: Onsite impact "Low" and proximity impact "Low"

- Rank 3: Onsite impact “Low-Moderate” and proximity impact “Low”, or onsite Impact “Low” and proximity impact “Moderate”
- Rank 4: Onsite impact “Moderate” and proximity impact “Low”, or onsite Impact “Low-Moderate” and proximity impact “Moderate” or Onsite impact “Low” and proximity impact “High”
- Rank 5: Onsite impact “High” and proximity impact “Low”, or onsite Impact “Moderate” and proximity impact “Moderate”, or onsite impact “Low-Moderate” and proximity impact “High”
- Rank 6: Onsite impact “High” and proximity impact “Moderate”, or onsite impact “Moderate” and proximity impact “High”
- Rank 7: Onsite impact “High” and proximity impact “High”

As a final step the six possible ranking values were aggregated into three groups representing “Low”, “Moderate”, and “High” impact potential for display and reporting purposes. The aggregation applied was as follows:

- High potential impact: Combined rank of 6 or 7
- Moderate potential impact: Combined rank of 4 or 5
- Low potential impact: Combined rank of 2 or 3

The methodology chosen assumes approximately equal weighting in the relative importance of onsite system characteristics and proximity to water resources in determining environmental impact potential. The data analysis presented in this report does not support more heavily weighting one factor of the other. The method of approximately equal weighting chosen was based on best professional judgment.

7.3.2. Results and Discussion

The results of the combined environmental impact potential ranking are shown in Figures 7.3a and 7.3b. This figure displays the aggregated ranking described in the previous section. The breakdown of properties by aggregated ranking is as follows:

- High potential impact: 227 properties
- Moderate potential impact: 2,076 properties
- Low impact potential impact: 1,447 properties

There are several areas of Nags Head where high environmental impact potential properties are moderately clustered. These are:

- Old Cove (finger canals area)
- The Whalebone
- Ocean side waterfront properties

The areas of Nags Head where low environmental impact potential properties are moderately clustered include:

- The Pamlico and Woodhill neighborhoods
- The Deering and Cobb street neighborhoods
- Blackman Street north to the Baltic neighborhood

A significant number of the neighborhoods in Nags Head contain a mix of higher, moderate, and lower impact potential properties. This a direct result of the spatial variability of the criteria used to calculate the impact rankings. Some factors, such as water use, have little if any spatial correlation (see Figures 4.12a and 4.12b). System age (Figures 4.3a and 4.3b) can have somewhat greater spatial correlation, but still can be variable in cases where systems have been upgraded or repaired in an older neighborhood, and lots have been redeveloped. Aside from proximity to water resources, groundwater depth (Figures 3.6a and 3.6b) may have the greatest spatial correlation, but even this variable can be variable over short distances, particularly in hilly areas. Finally, even within an area of general concern, there will be variability in impact potential from property to property.

7.4. Environmental Impact Potential Clustering Analysis

The results of the combined environmental impact potential assessment presented in Figures 7.3a and 7.3b and discussed in the previous section suggested that there might be some clustering of properties with similar impact potential. If clustering is found to occur, then the door opens to the possibility of using neighborhoods in the design of management options. The presence or absence of clustering of "hot spots' and "cold spots" was examined to determine if a neighborhood-based approach is feasible.

7.4.1. Methodology

There are several spatial statistics measures that can be used to assess the relative clustering of features that vary in space. Some of these include average nearest neighbor analysis, the Moran's I spatial autocorrelation, and the Getis-Ord GI* statistic. The Getis-Ord GI* statistic (G-statistic) is particularly well suited for use in analyzing "hot" and "cold" spots. It describes whether high values or low values (but not both) tend to cluster in a particular area. Thus, it is often used to identify whether hot spots or cold spots exist. A high value for the G-statistic indicates that high values—that is, values higher than the mean for the study area—tend to be found near each other. A low value for the G-statistic indicates that values lower than the mean tend to be found together.

The G-statistic was applied to the combined environmental impact potential rank for all properties in the Nags Head study area to help determine if low rank properties tend to cluster together and whether high rank properties tend to cluster together. The G-statistic was run from the ArcGIS Spatial Statistics toolbox with the following input parameters:

- Conceptualization of Spatial Relationship: Zone of Indifference
- Distance Method: Euclidean Distance
- Distance Band Threshold: 1,760 ft (1/3 mile)

Properties with a G-statistic score of less than –1.96 are statistically significant at the 5% level and represent a cluster of low combined impact scores, while properties with a G-statistic score of greater than 1.96 are statistically significant at the 5% level and represent a cluster of high combined impact scores. The following classes were created from G-statistic results and mapped for the town:

- High Impact Clustering: G-statistic ≥ 1.96
- Low Impact Clustering: G-statistic ≤ -1.96
- No Clustering: G-statistic > -1.96 and < 1.96

7.4.2. Results and Discussions

The results of the clustering analysis are shown in Figures 7.4a and 7.4b. This assessment of high and low impact clustering shows some well defined neighborhoods that have a predominance of high or low impact potential properties. Significant clustering of high environmental impact potential properties is found in the following areas:

- The northern and central portion of South Nags Head
- The Whalebone north to Nags Head Village
- The Old Cove area
- The Northeast corner
- Virginia Dare from Soundside north to Balden

Significant clustering of low environmental impact potential properties is found in the following areas:

- Villa Dunes and Windjammer north through Pamlico and Lost Colony, and east along Bonnett and Baltic
- Danube north to Soundside
- The southern end of South Nags Head

Only a small percentage of the properties fall in an area classified as un-clustered with either high or low impact potential properties.

This clustering analysis suggests that developing management options based upon geographically contiguous neighborhoods may be a feasible approach. There will certainly be some variability of impact potential within a “high impact cluster” and “low impact cluster”. Nevertheless, the use of cluster neighborhoods may serve as an excellent starting point for delineating wastewater management districts.

7.5. Summary and Conclusions

A town-wide environmental impact potential analysis was performed to provide a basis for developing wastewater management options and to help differentiate between high management-need and low management-need areas. The analysis was composed of four components:

- Impact potential due to onsite system characteristics
- Impact potential due to proximity to water resources
- Development of an combined impact potential ranking
- Environmental impact potential clustering analysis

The criteria for ranking the environmental impact potential due to onsite systems was based on the onsite systems and water quality data. The onsite system characteristics that were identified as influencing an onsite system’s environmental impact potential were:

- Depth to groundwater
- Water use
- System age

This analysis resulted in the majority of properties falling into the “moderate” and “low-moderate” impact potential classifications. Only 10% fell into the “high” impact potential class. Properties with different impact levels were found all throughout Nags Head.

The assessment of the environmental impact potential due to proximity to water resources required that groundwater travel times form onsite systems to important water resources be determined. Properties within a 3-month travel time were ranked as having “high” impact potential; properties within the 3 to 6-month travel time were ranked as having “moderate” impact potential, while properties beyond the 6-month travel time were ranked as having “low” impact potential. The results of this analysis showed that the “high” impact potential properties were limited to the immediate shorefront properties. The “moderate” impact properties were much fewer in number, and fell just beyond some of the shorefront properties. The majority of properties, 70%, fell into the low impact potential classification.

A combined environmental impact potential ranking was calculated by adding the onsite system and water resource proximity rankings. The rankings were then grouped into three classes representing “high”, “moderate”, and “low” impact potential. The breakdown of the number of properties in each class is as follows:

- High potential impact: 227 properties
- Moderate potential impact: 2,076 properties
- Low impact potential impact: 1,447 properties

A clustering analysis was performed to determine if properties with low impact potential were clustered together and properties with high impact potential clustered together. The analysis showed that clustering of high environmental impact potential properties were located in the following areas:

- The northern and central portion of South Nags Head
- The Whalebone north to Nags Head Village
- The Old Cove area
- The Northeast corner
- Virginia Dare from Soundside north to Balden

Significant clustering of low environmental impact potential properties are found in the following areas:

- Villa Dunes and Windjammer north through Pamlico and Lost Colony, east along Bonnett and Baltic
- Danube north to Soundside
- The southern end of South Nags Head

The results of the clustering analysis suggest that developing management options based upon geographically contiguous neighborhoods may be a valid approach.

The environmental impact potential assessment combined conclusions supported by the analysis of the water quality and onsite system data, past publications, and best professional judgment. The analysis provides a basis to begin formulating management options by identifying the factors contributing to potential environmental impact, differentiating the impact potential of properties with onsite systems, and identifying neighborhoods with common impact potential characteristics. The analysis provides a bridge between the water quality monitoring program, the onsite system inspection program, and the formulation of appropriate management options to support the most efficient and effective strategy to minimize the impact of onsite systems on the important environmental resources in Nags Head.

8. CONCLUSIONS AND RECOMMENDATIONS

This report focused on an analysis of the available onsite system conditions and water quality monitoring data to help define a management framework as part of the Decentralized Wastewater Management Plan. This section summarizes the key findings and provides recommendations for additional data collection and analysis that would help to refine the conclusions and better formulate the Management Plan.

8.1. Conclusions

The data analysis was composed of four sections: evaluating onsite system conditions, assessing water quality, identifying the impact of onsite systems on water quality, and estimating town-wide environmental impact potential. The following sections will summarize the conclusions from each of these analyses and provide an overall summary of the assessment.

8.1.1. Onsite System Conditions

Conditions related to onsite systems throughout Nags Head were evaluated to identify town-wide trends, and identify any possible areas for concern. The primary observations pertaining to development of a Decentralized Wastewater Management Plan are as follows:

- Over 85% of Nags Head properties treat their wastewater with onsite systems.
- The vast majority of onsite systems are conventional systems that serve residential properties. The owners are responsible for operation and maintenance, and there is no regulatory oversight of residential systems.
- Innovative/alternative (I/A) systems, which include more complicated technologies, require additional operation, maintenance and monitoring. The current system maintenance reports indicate some problems, mainly due to high water use. Monitoring reports are less consistently submitted to the county Health Department, and many pretreatment systems have not met effluent performance standards.
- Current systems in operation are of widely varying ages, the older of which will require special management considerations. Older systems may not be functioning properly due to lack of separation to seasonal high groundwater table, overloading the system for its size, materials needing repair and replacement.
- Approximately 29% of the onsite systems in Nags Head have been inspected as part of the voluntary inspection program. Increasing the number of systems getting inspected may require additional incentives as

part of the Management Plan. Regular inspections should be encouraged after the first inspection for ongoing maintenance.

- System failure rates, based upon the inspection program data, suggest that approximately 16% of systems have failed in the last 4 years. Repair permit data indicates that the failure rates may be slightly high, as some systems were repaired without having had an inspection. Additionally, the failure rates included sand bottom or leaky septic tanks, which are not officially considered a failure condition. A review of County repair permits indicates only 30% of the systems identified as failed during an inspection were repaired or upgraded.
- Septic tank pumpouts have occurred largely as part of the voluntary inspection program, although pumpouts may have occurred elsewhere but were not reported. Septic tank pumpers who might benefit from the pumpout, and may be limited in training in onsite system treatment and disposal components and techniques conduct the current inspection. Regular tank pumpouts, independent of inspections, should be considered as a component of the Management Plan.
- Excess water use for periods of up to 2-months a year occurs on a significant number of properties in Nags Head. The most common time for this to occur is in late summer.
- Excess water use is most common for non-residential and seasonal use properties.

These conclusions suggest that while onsite systems are largely performing well and receiving appropriate maintenance, there are a significant number of properties that are not performing properly and need more active management. Inspecting and upgrading older and substandard systems will help with overall system performance. Managing water use is also an important component to consider in the management plan, particularly for seasonal and non-residential properties.

8.1.2. Water Quality in Nags Head

The Water Quality Sampling Program is an important component of the Town's continued efforts to protect valuable water resources, including Roanoke Sound and the Atlantic Ocean. The sampling program results form part of the basis for the overall assessment of impacts of current wastewater management practices on water quality, and are a major factor in building the Decentralized Wastewater Management Plan.

Little historical water quality information is available for water quality in Nags Head, Roanoke Sound, or the nearby Atlantic Ocean. Thus, it is difficult to assess whether the Town's current onsite system management practices are having an impact on the ocean or the sound over the long term.

Rainfall patterns and amounts varied markedly from year to year during the water quality monitoring program. Spikes in precipitation during the spring and summer months were generally associated with tropical storms or hurricanes. At least one major tropical storm made landfall in the Outer Banks during each year of the water quality monitoring program, the most significant of which were Hurricane Gustav (September 2002) and Hurricanes Alex and Charley (August 2004). With the exception of these storms, there was not a strong relationship between weather patterns and water quality parameters.

Groundwater elevations in many parts of the Town change by a foot or more over the course of a year. On the sound side of Nags Head north of the Whalebone, rapid increases in water table elevations occur in response to significant rainfall events such as the landfalls of Hurricanes Alex and Charley in August 2004. Following such a rise in groundwater elevations, the local water table on the sound side of Nags Head takes at least a month to re-equilibrate. On the ocean side of Nags Head, tidal fluctuations have a pronounced influence on water table elevations. Groundwater elevations during spring tides were as much as 1.5 feet higher than groundwater elevations at the same point during neap tides. This tidal fluctuation often obscures any relationship between rainfall patterns and increased water table elevations that may occur on the ocean side of Nags Head.

Five parameters currently monitored by the Town were considered most indicative of possible impacts from OWTS on local groundwater and surface water quality: fecal coliform bacteria, total phosphorus, ammonia, nitrate, and dissolved oxygen (DO).

Groundwater quality in Nags Head Woods, in developing areas away from individual onsite systems, and in the area served by the package wastewater treatment plant was generally good. Fecal coliform levels in the groundwater in all of these areas were low year-round. Nutrient concentrations were more variable, but were generally lowest in Nags Head Woods, in part of a developed area (Blackman-G), and in the area served by the package plant (Seachase-G). Higher nutrient concentrations were observed at Curlew-G and at Fire Station-G. Dissolved oxygen concentrations in the groundwater in the background and developing areas were generally low, but this is not unexpected for groundwater, which naturally has little contact with the atmosphere. At all five of the background wells, there was little relationship between water table elevations, weather patterns, or tidal fluctuations and water quality trends.

Groundwater quality near individual OWTS in Nags Head is variable. Overall trends in water quality near OWTS tend to be clearer in the northern part of town, particularly north of the Huron Access monitoring well series. Fecal coliform bacterial levels near OWTS are above background levels at almost all monitoring points during the summer months, but are generally near background levels during the rest of the year. Monthly geometric mean fecal coliform levels rarely exceed the recreational water quality standard of 200 MPN/100 mL (Table 5.1). A relationship was observed between extreme rainfall events (such as the landfall of Hurricane Gustav in September 2002) and increased fecal coliform concentrations near OWTS. Total phosphorus concentrations in groundwater near OWTS are often above expected background levels and are increasing over time, particularly north of the Huron Access monitoring well series. At the monitoring well series in the finger canals area, total phosphorus concentrations are often lower at the #2-G monitoring wells than they are at the #1-G wells. Thus, it appears that the phosphorus sorption capacity of the local soils is finite and may be exceeded as systems age. Ammonia concentrations in the groundwater near OWTS are generally within background levels except near the Baltic, Lost Colony 1, Lost Colony 2, and Juncos Street Access monitoring well series, where ammonia levels are relatively high. High ammonia concentrations in groundwater may indicate that the thickness of unsaturated soil between the bottom of the leachfield and the groundwater is not adequate. Nitrate concentrations in the groundwater near OWTS are at or above background levels. Groundwater monitoring points closest to individual OWTS tend to have the highest nitrate concentrations and the most exceedances of the 10 mg/L drinking water standard, while the more distant monitoring points have lower nitrate concentrations overall. In some cases (particularly at the Lost Colony 1, Old Cove, and Cobia Way series), the decrease in nitrate concentrations between the #1-G and #2-G wells is dramatic and may indicate that denitrification, as well as dilution, is taking place in the groundwater. Dissolved oxygen concentrations in groundwater near OWTS were above expected background levels at many monitoring points towards the beginning of the monitoring program. However, DO levels also decreased over time at almost all of the groundwater monitoring points associated with OWTS. Other than the relationship between extreme rainfall events and increased fecal coliform concentrations, and despite the dynamic nature of groundwater flow on the ocean side of Nags Head, no other consistent relationships between weather patterns, water table elevations, or tidal fluctuations and water quality parameters were observed near OWTS.

Surface water quality in Nags Head is also variable; however, this variability appears to be more influenced by the degree of circulation of the individual water body than by the presence or nearness of OWTS. Fecal coliform bacteria levels in the finger canals were usually higher than background groundwater values and were usually higher than the levels observed in nearby groundwater monitoring wells, even during the fall and winter months when concentrations in the local groundwater were low. Thus, while OWTS in the area may contribute some fecal coliform bacteria to the finger canals, particularly during the summer months, other sources (such as wildlife or storm runoff) may significantly influence fecal coliform bacteria concentrations during colder months. In contrast with the finger canals, fecal coliform levels in the surface water ditches tended to be higher overall, with little seasonality and more exceedances of the recreational water quality standard. There was a fairly strong relationship between warmer water temperatures in the summer and early fall months and higher fecal coliform concentrations in the surface water ditches; this relationship was weaker but still apparent in the finger canals and receiving waters. There was also a relationship between the landfall of Hurricane Gustav in September 2002 and increased fecal coliform concentrations at Nags Head Village Area #1-S and in the southern surface water ditches.

Monthly median total phosphorus concentrations in the finger canals were lower than those in groundwater near OWTS. While total phosphorus concentrations in groundwater near the finger canals generally increased over the sampling period, similar increases at corresponding surface water points were not observed. It is possible that natural soil processes are removing phosphorus from OWTS effluent before the effluent reaches the finger canals. The phosphorus removal capacity of sandy soils is finite, however, so it is possible that phosphorus from OWTS could impact the finger canals in the future. There was a slight tendency for total phosphorus concentrations to be lower near the canal inlet and higher in distal areas. Total phosphorus concentrations in the surface water ditches tended to be markedly higher and more variable than those in the finger canals, although levels in the ditches appear to be decreasing slightly over time. There was no clear relationship between rainfall patterns or water temperatures and total phosphorus concentrations.

Ammonia concentrations in the finger canals are near the detection limit and did not increase or decrease over time. Ammonia levels in the ditches are generally higher and increasing over time (particularly in the northern ditches). Nitrate concentrations at groundwater monitoring points near the finger canals are generally above background levels, and concentrations are increasing over time. Monthly median nitrate concentrations at corresponding surface water points in the finger canals are generally stable or decreasing and are usually near or below historic background levels for the sound and water quality guideline levels. Nitrate levels in surface water ditches, however, are generally at or above background levels, and sometimes exceed the water quality guideline value. As with total phosphorus, there was no clear relationship between rainfall patterns or water temperatures and ammonia or nitrate concentrations.

Dissolved oxygen concentrations in the surface waters remained stable or decreased across the board during the sampling program. However, DO levels in the surface water ditches were far more likely to drop below the water quality standard than were the DO levels in the finger canals or in the receiving waters. There was a fairly strong relationship between cooler water temperatures and higher DO concentrations during the fall and winter months in the finger canals and the receiving waters. This relationship was weaker in the surface water ditches, and was practically nonexistent in the northern ditches.

8.1.3. Impact of Onsite Systems On Water Quality

The characteristics of onsite systems influencing individual monitoring points were evaluated together with the water quality monitoring data to establish what particular characteristics of these individual systems are causing impacts on local water quality. A total of fourteen series of groundwater monitoring wells and surface water points were analyzed for potential water quality impacts.

Throughout the Town, impacts from individual onsite systems on the nearby groundwater were generally confined to a narrow region located directly downgradient from the individual leachfield. Groundwater monitoring wells that were located as little as 10-15 feet cross-gradient or upgradient from individual leachfields tended to show sporadic or no impact from onsite systems. Impacts in the groundwater monitoring wells from other onsite systems within 150 feet of the wells were generally not observed. The discrete nature of the impacts from individual systems on the local groundwater, coupled with the cross-gradient and upgradient locations of several monitoring wells intended to capture these impacts, makes it nearly impossible in some cases to determine specific impacts from onsite systems.

The results of the system-by-system analysis fall into three major groups. The first group includes individual systems where high ammonia concentrations were observed in the groundwater near the leachfield (Lost Colony 1, Lost Colony 2, and Juncos Street Access). These three systems each had a local or regional depth to groundwater of less than 3.0 feet. For this group of systems, there is clearly an insufficient separation distance between the bottom of the leachfield and the local water table. Excessive water use, particularly during the spring and summer months, may also be contributing to the observed impacts of these three systems on local groundwater quality.

The second group includes individual systems where high total phosphorus concentrations, seasonally high fecal coliform bacteria concentrations, and some level of nitrate impact were observed in the groundwater downgradient from the leachfield (Old Cove, Cobia Way, Amberjack, S. Blue Marlin, and Huron Access). Systems in this grouping have an adequate separation distance between the bottom of the leachfield and the local water table (4.5 feet or more), but still have the potential to transmit pollutants, including bacteria and nutrients, to nearby surface waters. These five systems were constructed between 1970 and 1985, so they are at least 20 years old. Excessive water use may also be contributing to the observed impacts of these systems on local groundwater quality.

The third group includes individual systems where impacts from individual systems on local groundwater quality were generally low or were not observed in the nearby monitoring wells (Pamlico, Cobia Way A, Jeannette's Pier, Ida Access, and Jay St. Access). At most of these monitoring locations, the groundwater monitoring wells were located cross-gradient or upgradient from the leachfield, and so the impact of the individual system on the local groundwater was not observed.

8.1.4. Environmental Impact Potential

A town-wide environmental impact potential analysis was performed to provide a basis for developing wastewater management options and to help differentiate between high management need and low management-need areas. The analysis was composed of four components:

1. Impact potential due to onsite system characteristics
2. Impact potential due to proximity to water resources
3. Development of an combined impact potential ranking
4. Environmental impact potential clustering analysis

The primary observations from the environmental impact potential analysis pertaining to development of a Decentralized Wastewater Management Plan are as follows:

- Properties with the highest environmental impact potential due to onsite system conditions have both shallow depth to groundwater and either excessive water use or an older (pre-1986) system. Properties with either shallow depth to groundwater or excessive water use along with older system age have a significant, but lower environmental impact potential. Of all other properties, those with older onsite systems (pre-1986) have a more significant impact potential than those with newer systems.
- Properties with the high environmental impact potential due to onsite system conditions only are scattered throughout town.

- The majority of properties in Nags Head have a moderate environmental impact potential due to onsite system.
- Properties with a high environmental impact potential due to proximity to water resources are located along the immediate shore. A small group of properties (5%) located just off the beach have a moderate impact potential due to proximity to water resources.
- A combined environmental impact potential ranking was calculated by adding the onsite system and water resource proximity rankings. The breakdown of the number of properties in each class is as follows:
    - High potential impact: 227 properties
    - Moderate potential impact: 2,076 properties
    - Low impact potential impact: 1,447 properties
- A clustering analysis showed that clustering of high environmental impact potential properties were located in several contiguous regions throughout Nags Head. The analysis showed that clustering of low environmental impact potential properties occurred in several areas as well.

The environmental impact potential analysis provides a basis to begin formulating management options by identifying the factors contributing to potential environmental impact, differentiating the impact potential of properties with onsite systems, and identifying neighborhoods with common impact potential characteristics. The analysis has also provides a bridge between the water quality monitoring program data, the onsite system inspection program, and the formulation of appropriate management options to support the most efficient and effective strategy to minimize the impact of onsite systems on the important environmental resources in Nags Head.

8.2. Recommendations

The strategy suggested for developing a decentralized wastewater management plan for Nags Head included a preliminary data analysis, followed by the development of management options. A data analysis update was completed and included in the final technical report, and the technical report helped to inform the final Decentralized Wastewater Management Plan.

The Technical Report is a living document that captures a particular moment in time. Many aspects of the Initiative, including outreach initiatives, the inspection program, and the water quality monitoring program, continue as of this writing. The following section outlines recommendations for refining and continuing the collection and use of the technical information that informs the Management Plan.

8.2.1. Technical Report Update

The current report primarily includes data from the beginning of the Septic Health Initiative in 2000 through April of 2005. Data collection efforts will continue, especially on the inspection program and water quality monitoring. The data analysis performed in this Technical Report should be updated every two to four years. Annual summary reports can be performed by Town staff on key pieces of information, such as numbers of inspections performed. Qualified consultants can provide scientific and/or GIS-based analyses.

8.2.2. Water Quality Monitoring Program Recommendations

Major recommendations include realigning water quality sampling locations based on the results of the Technical Report, adding sampling for additional indicator bacteria, and the addition of a "no impact" surface water sampling location.

8.2.2.1. Realign Sampling Locations

Realign water quality sampling locations based on the results of the Preliminary Report and the Final Technical Report. Several groundwater monitoring locations that are currently being sampled for the purpose of determining OWTS impacts on groundwater are located either upgradient or cross-gradient from the systems' drainfields and thus are not actually capturing impacts. Some of these monitoring wells are also damaged and in need of either repair or abandonment.

8.2.2.2. Monitoring for Enterococcus Concentrations

Add testing for Enterococcus to the list of water quality characteristics monitored by the sampling program. In 2003, North Carolina adopted BEACH Act (Beaches Environmental Assessment and Coastal Health Act of 2000) standards and began a beach monitoring program using Enterococcus as the indicator organism. Previously, beach advisories were posted based on exceedances of a fecal coliform-based standard. The North Carolina DENR now monitors ocean (Tier 1) beaches in Nags Head weekly from April through October for Enterococcus, salinity, and water temperature. In order for the Town's sampling program results to be directly comparable with the results from DENR's new beach monitoring program results, both programs must monitor the same indicator bacterium. Sampling for Enterococcus would also enable comparisons between the Town's surface water monitoring results and data collected by the water department at Fresh Pond. Shellfishing area closures are still determined by exceedance of a fecal coliform-based standard, so we do not yet recommend discontinuing the monitoring of fecal coliform bacteria levels.

8.2.2.3. *Background Surface Water Monitoring*

Add a "background" surface water sampling point in Roanoke Sound and (secondarily) in the Atlantic Ocean to the points already monitored in the sampling program. Each of the surface water monitoring points already being sampled is near some form of "outlet" situation (either near clusters of onsite systems, near the outlet from a package wastewater treatment plant, or near a stormwater outfall). The addition of background monitoring points for surface water quality in the ocean and the sound would enable comparisons with historical water quality information (for the Sound), understanding of whether water quality in the wider water bodies is changing over time, and understanding over the long term of whether the Town's management activities are positively impacting water quality. The Sound side point might be the historical sampling point along the Causeway. The Ocean point(s) could be spaced along the beach, as far from outfalls as possible.

8.2.2.4. *Water Use Information During Sampling Events*

Collect extra water meter readings during regular water quality sampling events where applicable. Collecting specific water use data from the building's water meter along with water levels and water quality characteristics during each sampling event would allow a vastly clearer understanding of the relationship(s) between excessive water use and system performance/impacts on local groundwater quality. This recommendation only applies to monitoring wells located downgradient of leachfields serving buildings where water meters can be easily read.

8.2.2.5. *Quality Assurance Project Plan (QAPP)*

A QAPP for the Water Quality Sampling Program would describe field and laboratory sampling activities, along with detailed Standard Operating Procedures (SOPs) for tasks such as field water level measurements, collection of samples, and Chain of Custody procedures. All staff covered under the QAPP would need to have documented training in implementing the sampling procedures.

8.2.3. *Intensive Individual System Monitoring Study*

Perform an intensive monitoring study on one conventional and one I/A (peat filter) system over a one month period in the summer. The study would include obtaining detailed permit, design, soils and construction information, collecting daily water use readings and daily water level measurements. Also, collect weekly water quality samples of septic tank effluent, peat filter treated effluent, and a nearby downgradient monitoring well. This study would greatly improve understanding of peak flow impacts on system performance and water quality, particularly where systems may be exceeding design flows.

8.2.4. County Permit Data Collection

Most of the available electronic datasets pertinent to water quality and onsite were collected and used for the analysis presented. However, some data sources available in only hard copy format, such as Dare County permits before 1999, were not collected. This resulted in some systems' characteristics being estimated from other data sources. The two most important examples of this are system design flow being estimated from structure bedrooms and bathrooms, and system age being estimated from structure age. While this method provided reasonable estimates for most residential properties, the estimates are likely not as accurate for non-residential properties. We encourage the Town to continue conversations with Dare County Health Department staff regarding the conversion of older permit information to a database or other electronic format.

8.2.5. Integrated Stormwater/Onsite System Analysis

The scientific analysis completed in this Technical Report indicated a need for additional review and consideration of the impacts of stormwater on water quality, particularly in the surface water ditches. Developing an integrated approach to looking at the impacts of both of these can lead to a defensible management strategy. Much of the data collected and analyzed in this report can also be useful in stormwater management decisions. Several of the recommendations (such as adding background ocean sampling points) in the water quality sampling subsection would also be useful for stormwater management purposes. Following are some recommendations for additional information related to stormwater and wastewater impacts.

8.2.5.1. Surface Drainage Analysis

A comprehensive dataset of the surface drainage network was not available at the time of this study. A dataset detailing the surface drainage system in Nags Head would enable a better understanding of the impacts onsite systems have on surface waters. Development of this dataset may represent a significant effort, depending on the availability of existing data from departments such as Public Works.

8.2.5.2. Dry Weather and Storm Event-Based Sampling

Dry weather water inputs and sampling can help identify illicit discharges into ditches, such as straight pipes. Storm event sampling can be completed just following a storm event. Both of these methods have merit in identifying wastewater and stormwater contributions to pollutant loading.

8.2.5.3. Additional Constituent Sampling

One means of analyzing nutrient loading includes developing a nitrogen mass balance. This analysis uses total nitrogen and organic nitrogen in addition to the nitrogen species currently sampled. Collecting these two additional constituents in the surface water samples would provide additional information needed to conduct the mass balance equation.

8.2.6. State Regulation Considerations

The Town could consider making informal recommendations for system design changes and providing additional information to State and County regulators. Recommended changes could include: how the depth to wetness is determined; increasing the separation from the bottom of the dispersal field to wetness for all system types; and increasing design flows or long term acceptance rates for rental properties, which would increase the drainfield size.

The state Rules for design and construction of onsite systems allow drainfields to be located near the groundwater for a period each year. There are over a thousand undeveloped lots in Nags Head, which may be built upon and will most likely use an onsite system. Encouraging revisions to the state's design and construction rules for onsite systems can protect water quality when these lots are developed.

Some areas in Nags Head may contain soils with shallower seasonal groundwater tables than those indicated by traditional soil evaluations, as observed by NCSU staff in Nags Head Woods. The Town could informally assist the County Health Department staff in determining depth to seasonal groundwater (or wetness) by making available information on actual depths to groundwater collected in groundwater monitoring wells throughout Nags Head.

There also may be some areas (such as in the Old Cove area and near the ocean) where the groundwater may fluctuate based on tidal influences as well as from infiltration or rainfall. The Town could consider installing automatic dataloggers in the wells to track water levels every 15 minutes or less. The dataloggers could be downloaded into a database for analysis purposes.

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