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Memorandum

To: *Martin Trent, SCDHS*

From: *CDM*

Date: *January 25, 2008*

Subject: *Task 5.2 – Future Land Use Impacts*

1.0 Introduction

The original objective of Task 5.2 of the **Suffolk County Comprehensive Water Resources Management Plan** was to assess the cumulative impacts of development on groundwater quality and public water supplies. Suffolk County Department of Health Services (SCDHS) subsequently modified the originally proposed scope of work to replace evaluation of hypothetical wastewater management scenarios with the development of an approach to apply detailed groundwater flow and contaminant transport models of specific proposed land use scenarios to evaluate the impacts of alternative development schemes upon nitrate levels in groundwater. The results of this assessment will be used together with information presented in this memorandum and elsewhere, to help the County to assess the adequacy of present Suffolk County Sanitary Code restrictions in the protection of ground and surface water resources.

This task report will:

- Describe the development and application of an approach to evaluate a detailed development proposal in Suffolk County, as a template for future assessments of proposed development scenarios;
- Briefly describe existing wastewater management strategies in Suffolk County, and
- Summarize readily available information describing land use and wastewater management requirements associated with nitrogen impacts elsewhere in the country.

1.0 Montauk Highway Corridor Case Study

1.1 Modeling Approach

SCDHS identified the Montauk Highway Corridor in the Forge River watershed as the case study that will serve as the template for future modeling evaluations of land use development proposals. A modeling approach was developed and implemented to evaluate the impact of the Town of Brookhaven's proposed land use plan on groundwater nitrogen levels. The following steps were required:

1. Modification of existing groundwater model codes to allow simulation of nitrogen loading from various land use types on a parcel-specific basis;

2. Parcel-specific land use assignment for both existing conditions and for the future proposed development scenario;

3. Assignment of nitrogen loading associated with each of the land use types;

4. Simulation of nitrogen concentrations resulting from existing land use types and wastewater management;

5. Comparison of simulated nitrogen concentrations to measured groundwater concentrations and revision of loading rates as necessary;

6. Simulation of nitrogen concentrations resulting from proposed land uses and wastewater management techniques, and

7. Evaluation and documentation of results.

In order to assess the cumulative impacts of sanitary wastewater on water quality, a groundwater model was developed to simulate nitrogen concentrations resulting from existing land uses in the eastern portion of the Forge River watershed, and build-out conditions as defined in the Town of Brookhaven's 2004 Montauk Highway Corridor Study & Land Use Plan for Mastic & Shirley. Changes in nitrogen concentrations in area groundwater, which ultimately provides baseflow to the Forge River, were evaluated. The methodology used to assign nitrogen loading rates to each of the land use categories located within the study area is described in the following pages. Details of the modeling approach, along with the template for nitrogen load assignment are provided in Appendix A; an accompanying CD includes the required electronic files.

A summary of the existing and proposed land uses within the approximately 700 acre study area is tabulated in Table 1 and illustrated by Figures 1 and 2, respectively. Although the Forge River watershed extends well beyond the area described in Table 1 and shown in Figures 1 and 2, only the area that is within the Montauk Highway Corridor is described in the land use plan. On a parcel-specific basis, most of the proposed land use changes will result from conversion of vacant parcels to medium density residential use (Figure 3). The Town of Brookhaven has added three additional land use categories (***medium-high density residential, main street district, and transitional***) to the 13 categories utilized by the Suffolk County Planning Department (SCPD); each of these is discussed in further detail below.

Table 1
Existing and Proposed Land Use in the Montauk Highway Corridor

Land Use	Acres	
	Existing	Proposed
Low Density Residential	1.33	0.00
Medium Density Residential	211.83	300.64
High Density Residential	126.19	130.17
Commercial	97.94	36.83
Industrial	5.19	0.00
Institutional	8.88	8.88
Recreation and Open Space	51.85	61.25
Agricultural	0.00	0.00
Vacant	140.87	3.35
Transportation	23.30	21.41
Utilities	4.66	0.15
Waste Handling and Management	0.00	0.00
Water	21.11	21.11
Medium-High Density Residential	0.00	25.87
Main Street District	0.00	63.78
Transition Area	0.00	19.71
TOTAL	693.15	693.15

The Suffolk County Main Body groundwater model was used as the basis for evaluation of potential impacts to groundwater quality resulting from the proposed changes in land use. Using the regional model as the framework, a more detailed finite element grid that includes all parcels within the watershed and focuses specifically on the Montauk Highway Corridor has been developed. DYNTRACK, the companion contaminant transport model was also re-dimensioned, to allow simulation of the more than 10,000 individual sources of nitrogen represented by each parcel. Nitrogen levels in area groundwater resulting from the cumulative effect of all of the parcel-specific sources in the western portion of the Forge River watershed that has been defined as the study area were then estimated, using the models. Although the eastern portion of the watershed is included in the modeled area, it was not included in the nitrogen transport simulations since it is outside the Montauk Highway Corridor study area.

Figure 1

Figure 2

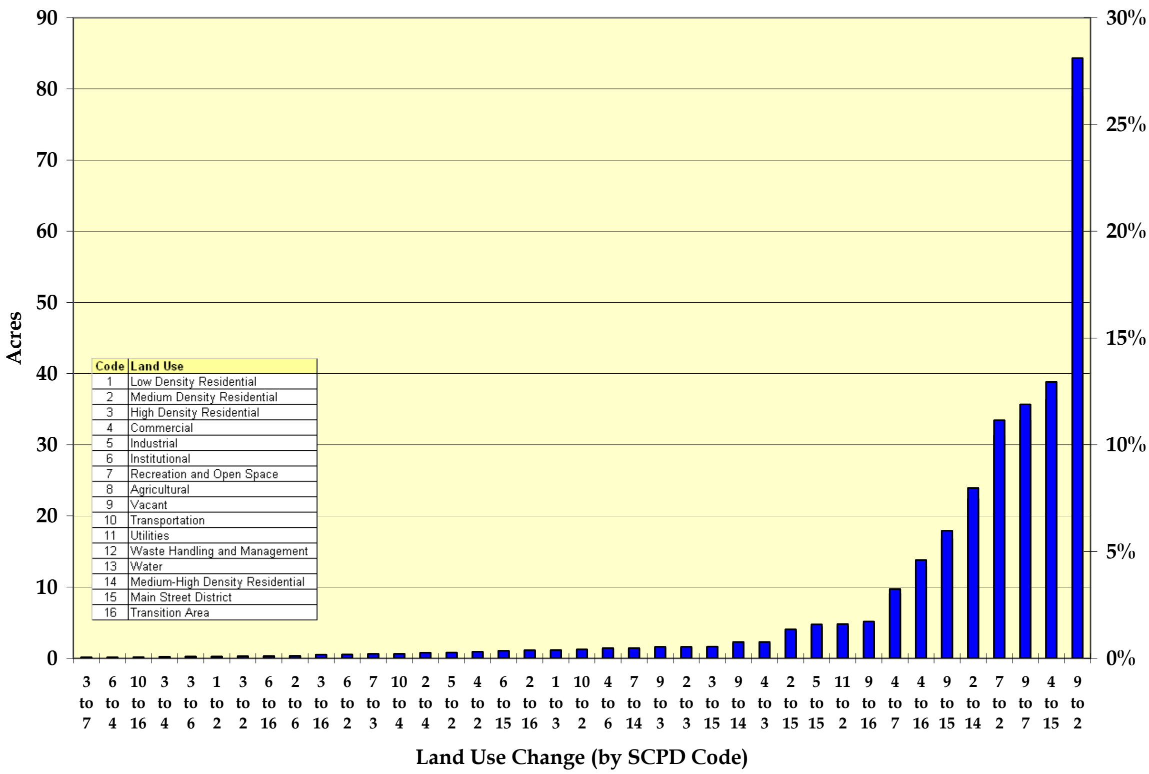

Figure 3 Land use changes within the Montauk Highway Corridor.

The model grid is shown on Figure 4. The northern boundary of the grid represents the Peconic River and the grid extends south to the Atlantic Ocean. The eastern boundary of the grid extends just east of Little Seatuck Creek and west to Carmans River. The grid contains 42,571 nodes comprising 84,978 elements and covers just over 115 square miles. Node spacing ranges from approximately 2,000 feet at the northern and southern boundaries down to less than 50 feet within the Montauk Highway Corridor. Since nitrogen loading and transport are simulated on a parcel-specific basis, very fine node discretization within the study area was required. Three monitoring wells installed by SCDHS are also shown on Figure 4; these monitoring wells were used to verify the nitrogen loading rates, as described below.

Stratigraphic data from the Suffolk County Main Body Groundwater Model was interpolated onto the refined model grid. Three additional model levels (total of 12 levels in the model) were added to the upper glacial aquifer to improve vertical discretization for simulation of shallow groundwater flow and around the monitoring well screens. The top level of the model represents topography and was intersected with the Digital Elevation Model (DEM) for Long Island. The model was run under steady-state conditions incorporating long-term average conditions of water supply pumping and recharge. As the northern boundary of the

INSERT FIGURE 4

grid coincided with the average position of a groundwater divide and the Peconic River, it was assigned as a no-flow boundary. The eastern and western boundaries were also assigned as no-flow boundaries. The southern boundary of the grid was assigned as a fixed head boundary condition representing sea level. Offshore nodes were set at a fixed head of 0.5 feet (msl) to account for recent sea level rise since 1929 (the vertical datum of the Suffolk County Main Body Groundwater Model). Heads at depth (at the southern perimeter of the grid) were fixed at the same elevations as assigned within the Suffolk County Main Body Groundwater Model and represent equivalent fresh water heads (CDM, 2003). More details of the modeling approach are included in Appendix A.

The simulated water table is shown on Figure 5. Figure 6, which illustrates the simulated water table and shallow groundwater flow direction shows that shallow groundwater flow in the western portion of the study area is towards the Carmans River, rather than the Forge River as previously assumed.

1.2 Nitrogen Loading Rate Assignment

In the literature, nitrogen loading estimates associated with various land use types are reported as both mass loading rates and as resulting groundwater nitrate concentrations. Examples of reported nitrogen loading rates and concentrations in septic tank effluent are shown in Table 2. Reported per-capita mass loading estimates range between 4.5 and 47.5 pounds of nitrogen per person per year, although most rates are between 5 and 10 pounds of nitrogen per person per year. Reported septic tank effluent concentrations range from 7.5 to 68 mg/L. Land use-specific nitrogen concentrations in groundwater from samples collected immediately downgradient of various land uses have been previously reported in the **1987 Suffolk County Comprehensive Water Resources Management Plan** (please see Table 3). Average nitrate concentrations at the water table beneath various types of overlying land uses in the Popponesset Bay watershed in Cape Cod, Massachusetts (Table 4) have recently been documented by Colman et al (2004).

1.2.1 Residential Land Use

Nitrogen loading is assigned as a mass rate (mg-N/day) in the model. For residential areas, the mass loading rate is based on the ranges of pounds of nitrogen per person per year (lbs-N/person/year) as reported in the literature and shown on Table 2. Although Table 2 indicates that mass loading rates range as high as 47.5 lbs-N/person/year, most reported rates range between 5 and 10 lbs-N/person/year; these were used to represent the range of concentrations used for the initial simulations.

The 2000 U.S. Census reported that there are an average of 3.1 people per household within the study area (from Mastic, Mastic Beach, and Shirley with a total population of 52,374, and total number of housing units equal to 16,881). The **1987 Suffolk County Comprehensive Water Resources Management Plan** defines low density residential as 1 housing unit per

Insert figure 5

Insert figure 6

INSERT TABLE 2

Table 3
Nitrate Concentrations in Groundwater Downgradient of Specified Land Uses
(from Dvirka and Bartilucci, 1987)

Land Use	Average Nitrate (mg/L)	Range (min-max; mg/L)
Low Density Residential	3.35	2.97 – 3.70
Medium Density Residential	5.82	4.40 – 7.94
Intermediate./High Density Residential	2.60	0.34 – 8.03
Commercial	1.74	0.08 – 4.05
Industrial	4.25	1.13 – 6.99
Institutional	8.20	7.87 – 8.53
Recreation/Open Space	3.91	2.40 – 6.07
Agricultural	7.83	5.62 – 10.0
Vacant	1.15	1.00 – 1.30
Transportation	2.39	0.59 – 4.54

Table 4
Nitrogen Concentrations at the Water Table beneath Specific Land Uses
(modified from Colman et al, 2004)

Land Use	Nitrate Concentration at the Water Table beneath Each Land Use (mg/L)	Notes
Wetland, water based recreation, salt wetland, water, and marina	0	Recharge to the aquifer does not occur
Pasture, forested, mining, and open space	0.07	Atmospheric deposition
Commercial, industrial, urban open space, and transportation	1.02	
Turf	3.75	Turf was added to residential loading at 500 sq. meters per housing unit
Participation recreation, spectator recreation, and golf	4.10	
Cropland	4.90	
Residential: multifamily, <0.25 acre, 0.25 to 0.5 acre, > 0.5 acre	43.4	
Solid waste disposal / landfill	99.40	

acre, medium density residential as 2 to 4 units per acre, and intermediate density as 5 to 6 housing units per acre. High density residential is not specified, but it was assumed to be 7 to 10 dwelling units per acre. For the purpose of estimating nitrogen loads, low density residential was represented as 1 housing unit per acre, medium density residential as 3 housing units per acre, medium-high density residential as 5.5 housing units per acre, and high density residential as 8.5 housing units per acre.

Nitrogen loading from residential land uses (septic only) was calculated as follows:

$$\left(\frac{lbs-N}{person-yr}\right)\left(\frac{1year}{365days}\right)\left(\frac{\#dwellingunits}{acre}\right)\left(\frac{3.1person}{dwellingunit}\right)(acres)=\frac{lbs-N}{day} \quad (1)$$

An example residential nitrogen load for a high density residential parcel is as follows:

$$\left(\frac{10lbs-N}{person-year}\right)\left(\frac{year}{365days}\right)\left(\frac{8.5units}{acre}\right)\left(\frac{3.1persons}{unit}\right)(0.156acres)=\frac{0.113lbs-N}{day}$$

Existing land use and associated nitrogen loading were used to develop the nitrogen loading rates (ranging between 5 to 10 lbs N/person/year) that were assigned for both existing and projected future residential land uses; loading rates in the simulations described here were developed after comparison of simulated nitrogen levels to nitrogen levels measured by SCDHS in downgradient shallow groundwater.

Incorporation of this information on a project-specific basis is further discussed in Appendix A.

1.2.2 Other Land Use Categories

Nitrogen load estimates for non-residential land uses were based upon literature estimates of nitrate concentrations reported in groundwater below and immediately downgradient of the various land use types (Tables 3 and 4). The mass rate can be calculated by multiplying the flow rate by the concentration:

Flow (L/day) x Concentration (mg/L) = Mass Rate (mg/day) (2)

Using SCDHS sewerage flow design standards (Table 5), flow rates were assigned for each specific land use. For commercial and industrial land uses, flow rate is assigned by floor area. It was assumed that building footprints occupy 20 percent of lot size. (This assumption was based on a brief desktop analysis using existing land use data and aerial photographs.) Commercial land use can be sub-divided into office space, “wet stores”, and “dry stores”. Dry stores are defined by SCDHS as those stores in which the only water use is for employee sanitary wastewater disposal (retail stores, etc.). Wet stores include restaurants and other establishments that use relatively large amounts of water. Wet stores (no food) are defined as stores in which water can be used for processes and/or additional customer sanitary wastewater disposal (hair salons, for example). Initial simulations assumed that commercial land use consists of 40 percent dry stores, 25 percent wet stores, and 35 percent non-medical office space. Representative flow rates are shown in Table 6.

Table 5
Sewerage Flow Design Standards (from SCDHS)

Structure Use	Design Flow Rate
Apartment, Condo, HOA – up to 600 sf	150 gpd/unit
Apartment, Condo, HOA – between 601-1,200 sf	225 gpd/unit
Apartment, Condo, HOA – greater than 1,200 sf	300 gpd/unit
General Industrial Space	0.04 gpd/sf (gross floor area)
Non-medical Office Space	0.06 gpd/sf (gross floor area)
Medical Arts Space	0.10 gpd/sf (gross floor area)
Theater	3 gpd/seat
Wet Store	0.15 gpd/sf (gross floor area)
Dry Store	0.03 gpd/sf (gross floor area)
Wet Store (no food)	0.10 gpd/sf (gross floor area)
Restaurant (with sewers)	30 gpd/seat
Multi-use Sports Complex	
Bowling	100 gal/lane
Ice Skating	15 gpd/skater + 5 gpd/spectator
Bar	10 gpd/seat
Mini-Golf	14 gpd/parking space
Food (single serve)	0.15 gpd/sf

For recreational and open space land use, the assigned recharge rate was 50 percent of the long-term average precipitation recorded at Brookhaven National Laboratory (BNL), corresponding to the average regional aquifer recharge rate on Long Island. As of February 2007, long-term average precipitation at BNL was 48.53 inches per year. Assuming 50 percent recharges the aquifer in open space, the average assigned recharge rate was derived as 0.04 gpd/sf. The same flow rate was applied to vacant parcels, using the same rationale.

Within the study area, the Brookhaven Airport and the Montauk Branch of the Long Island Railroad fall within the transportation category. For this study, the recharge rate from transportation land use was assigned as open space, since much of the airport is essentially open space, and railroad tracks are not impervious cover.

Within the study area, utilities comprise only a small portion of the Montauk Highway Corridor (0.67 percent; Table 1), represented by the Suffolk County Water Authority (SCWA) Lambert Avenue/Copaigue wellfield. Since the wellfield is primarily open space, the open space flow rate and nitrogen/nitrate concentrations were assigned. Throughout the Forge River watershed, only one parcel has a land use designation for waste handling and

Table 6
Sanitary Effluent Flow Rates and Nitrate/Nitrogen Concentrations
For Non-Residential Land Uses

Land Use	Assigned Flow Rate (gpd/sf)	Nitrate/Nitrogen Concentration (mg/L)	Notes
Commercial	0.07	0.08 – 4.05	Assume 40% dry stores (retail; 0.03 gpd/sf); 25% wet stores (0.15 gpd/sf); 35% office space (0.06 gpd/sf)
Industrial	0.04	1.02 – 6.99	SCDHS sewage flow design standards
Institutional	0.06	7.87 – 8.53[1]	Assume general office space
Recreation and Open Space	0.04	0.07 – 6.07	Based on 50% recharge of long-term average precipitation at BNL
Agricultural	N/A	N/A	Agricultural land is outside the study area (east of Forge River)
Vacant	0.04	1.00 – 1.30	Same as open space (see above)
Transportation	0.04		Essentially open space (see text)
Utilities	0.04		Primarily SCWA wellfields (essentially open space)
Waste Handling and Management	N/A	N/A	Outside study area.
Water	0.0		Water – does not recharge the aquifer in the study area.
Main Street District	varies		Mix between commercial (non-medical office space, dry stores) and apartments
Transition Area			Low-density residential mass rate for nitrogen.

1) 3.7 acre parcel on Mastic Road is represented as open space
3% of the 104 acre institutional property in the northwest portion of the watershed is simulated as institutional, the remaining 97% as open space.

management. This parcel is located east of the River outside the study area and was not specifically addressed during this analysis.

Nitrogen loading was also not applied to the "water" land use category, since the Forge River within the study area is a gaining stream and does not typically recharge the aquifer.The nitrogen concentration used for each specific land use type was based on the values listed in Tables 3 and 4. Initial simulations used average concentrations from the tables, but were varied within the ranges shown in Table 3 to better correspond to the SCDHS field data.

1.2.3 Future Development Land Use Categories

As mentioned above, three land use categories have been added to the 13 SCPD-established land use categories to account for the land use specified in the **2004 Montauk Highway**

Corridor Study: ***medium-high density residential, Main Street District,*** **and** ***transitional.*** Nitrogen loading for ***medium-high density residential*** land use was based on residential mass load estimates (equation 1), using 5.5 dwelling units per acre, based on the **1987 Suffolk County Comprehensive Water Resources Management Plan** designation of 5 to 6 housing units per acre for intermediate density.

Main Street Districts are defined in the **2004 Montauk Highway Corridor Study** as being composed of first floor commercial units with second (and/or third) story residential or office use. Currently, there is no indication as to how many parcels assigned as ***Main Street District*** will have a third story. For this analysis, it is assumed that parcels greater than or equal to ½ acre will have a third story. As a conservative approach, these third story parcels will be assigned a nitrogen mass loading rate equal to the mass loading of 2 residential units (6.1 people, 5-10 lbs-N/person/year), in addition to the mass loading from the underlying commercial use. For example, if a 0.50 acre parcel is designated as a ***Main Street District*** use, the following nitrogen load is applied:

$$\underbrace{(6.2\,people)\left(\frac{10lbs-N}{person-year}\right)\left(\frac{year}{365days}\right)}_{\text{Residential nitrogen load}}+\underbrace{\left(\frac{0.07gallons}{day-ft^2}\right)\left(\frac{43{,}560\,ft^2}{acre}\right)(0.5acres)}_{\text{Flow Rate (commercial)}}\underbrace{\left(1.74\frac{mg}{L}\right)\left(\frac{3.785L}{gallon}\right)\left(\frac{1lb}{453{,}592\text{ mg}}\right)}_{\text{avg nitrate conc. (commercial)}}=0.192\frac{lb-N}{day}$$

The lbs-N/person/year nitrogen loading rate assigned for future residential parcels is the same value assigned for residential land use during the existing land use evaluation (based upon SCDHS field data).

The third land use category, ***transitional***, is defined in the **2004 Montauk Highway Corridor Study** as areas that will separate ***Main Street Districts*** to provide a green space along Montauk Highway. Land uses that may be established in this category include single-family residential or low intensity commercial uses. For the purposes of this study, this land use is represented as "dry store" commercial, having a flow rate of 0.03 gpd/sf and a representative commercial nitrogen/nitrate concentration. For the commercial flow rate, it is assumed that 50 percent of the parcel size will be covered by the building footprint.

1.2.4 Nitrogen Losses

Nitrogen may be removed from wastewater disposal systems or groundwater by denitrification through various processes. Often, nitrogen losses are accounted for using an average loss method, but they have also been estimated using a method that incorporates the time of travel in the aquifer and Monod kinetics for denitrification (Colman et al, 2004). For denitrification in septic systems (limited carbon), nitrogen losses have been modeled by Colman et al (2004) as:

$$\frac{d[NO_3]}{dt} = -V_{\max} \frac{[NO_3]}{K_{NO_3} + [NO_3]} \frac{[DOC]}{K_{DOC} + [DOC]} \qquad (3)$$

where $[NO_3]$ is the nitrate concentration, K_{NO_3} is the half-saturation constant for nitrate, V_{max} is the asymptotic maximum reaction rate, [*DOC*] is the dissolved carbon concentration, and K_{DOC} is the half-saturation constant for carbon. The denitrification loss approach described above requires extensive water quality data and the use of numerical finite difference techniques.

If denitrification is not carbon-limited, the equation above reduces to:

$$K_{NO_3} \ln[NO_3] + [NO_3] = K_{NO_3} \ln[NO_3]_0 + [NO_3]_0 - tV_{\max} \qquad (4)$$

where *t* is the travel time (yrs) from the water table and $[NO_3]_0$ is the concentration of nitrate at time zero, which represents concentrations at the water table.

A more simplified approach to account for nitrogen loss is to use an average loss term in which a percentage of the nitrogen load is removed in the septic system. For most land uses, this loss term is approximately 35 percent (Colman et al, 2004). This approach is currently being used for the Massachusetts Estuaries Project, where 25 percent of nitrogen is assumed to be removed by the septic tank and soil adsorption field (Massachusetts DEP and SMAST, 2007).

For the purposes of this study, a constant nitrogen loss term of 35 percent has been applied to all residential land use categories. Nitrogen loads were multiplied by 0.65 to account for removal in the septic system and soil absorption field. Since all other land use categories utilize groundwater concentration data, the nitrogen loss term is inherently included in the mass loading calculation. However, note that more complex techniques can be applied to quantify nitrogen loading to surface waters should enough information become available.

1.2.5 Additional Nitrogen Load - Fertilizer

For residential land uses, additional nitrogen loading associated with fertilizer application has been incorporated to this approach. Various estimates of fertilization are found in the literature ranging from 3.0 pounds per year per 1,000 square feet (EPA, Table 2), 2.5 pounds per year per 1,000 square feet (Dvirka and Bartilucci, 1987) to 1.08 to 3.0 pounds per year per lawn (average lawn = 5,000 sq feet; Massachusetts DEP and SMAST, 2007).

The **1987 Suffolk County Comprehensive Water Resources Management Plan** reported a fertilizer application rate of 2.5 pounds per year per 1,000 square feet. In order to estimate a nitrogen contribution to groundwater, a leaching rate must also be assumed. The Massachusetts Estuaries Project utilized a groundwater leaching rate of 20 percent (Massachusetts DEP and SMAST, 2007).

For this study, to account for nitrogen load from fertilizer, a 20 percent leaching rate was assumed, using an application rate of 2.5 lbs/1,000 sq ft/year. Fertilization is applied to residential land uses (not to ***Main Street Districts*** or ***Transitional*** land use) and is applied to a percentage of each parcel, depending on housing density as listed below:

Percent of parcel fertilized: Low density residential: 80%
Medium-density residential: 65%
Medium-high density residential: 58%
High-density residential: 50%

These percentages are based on a brief desktop analysis of the lot percentage available for fertilization using land use data and aerial photographs.

Nitrogen loads, in units of mass/day, are applied to the centroid of each parcel. As there are no golf courses within the study area, fertilization from golf courses has not been included in these scenarios. However, when this nitrogen loading methodology is applied to other study areas that include golf courses, nitrogen loading from fertilization should be included.

1.3 Existing Land Use – Comparison of Model-Simulated and SCDHS Measured Nitrate Concentrations

The groundwater flow model was used as the basis for contaminant transport simulations using DYNTRACK. The DYNTRACK code was modified specifically for this study, so that thousands of individual point sources can be simulated simultaneously, permitting nitrogen fate and transport evaluation on a parcel-specific basis over the model domain (Figure 7).

As mentioned above, SCDHS installed three nested monitoring wells just west of the Forge River and immediately south – southeast of the study area (Figure 4). Groundwater samples were collected at various screen depths by SCDHS and were analyzed for water quality parameters, including total nitrogen. Results are summarized in Table 8. The results were used as target concentrations to refine nitrogen loading estimates. After nitrogen loading was assigned to each parcel, (Figure 7), the model was run under steady-state conditions for 50 years. Nitrogen was simulated as a conservative tracer, i.e., no retardation or decay was simulated.

As shown in Table 8, groundwater samples were collected to a depth of up to 90 feet. Samples from FR-03 were collected from up to 115 feet below the ground surface, but results indicate that the deeper screens are located within salt water (chloride concentration > 13,000 mg/l; SCDHS unpublished data, 2007). These nitrate values, therefore, were not considered in this analysis. Figure 8 shows model-simulated "back-tracks" from each well screen interval in Table 7. Back-track simulations were conducted by introducing a particle representing a conservative substance to the model at depths corresponding to the monitoring well screened

INSERT FIGURE 7 -Sources

INSERT FIGURE 8 Back-tracks

Table 7
Total Nitrogen Concentrations from Samples Collected from FR-01, 02, and 03

Well	Screen Depth (ft below surface)	Total Nitrogen (mg/L)
FR-01	15-10	12.72
	20-25	9.33
	30-35	12.05
	40-45	12.52
	60-65	12.60
	80-85	0.30
FR-02	5-10	16.30
	15-20	8.96
	25-30	10.19
	35-40	14.50
	45-50	5.90
	65-70	9.10
	85-90	0.50
FR-03	0-5	0.93
	10-15	17.87
	20-25	7.57
	30-35	2.80
	40-45	3.50

intervals, and running the model "backwards" in time. The model simulation continues until the particle reaches the water table, identifying a location where water reaching the well screen originated.

In this simulation, particles were released from the mid-point of each well screen. As shown by the back-tracks, only groundwater samples collected within 25 to 30 feet of the surface represented recharge originating within the study area. Water reaching the deeper well screens recharged the aquifer at areas located further upgradient than the study area. Also shown on Figure 8 are the simulated travel times from the water table to the well screen for each particle.

A comparison of measured and simulated total nitrogen concentrations of selected screen depths for FR-01, 02, and 03 is shown in Table 8. Three results from each well cluster are shown: one sample characterizing simulated results from within the study area (shallow), one sample characterizing recharge further upgradient (intermediate depth), and one sample from the deepest screen. As mentioned above, FR-03 screens deeper than 45 feet are located in salt water and the water quality results were not used.

In general, the model-simulated nitrogen concentrations are in agreement with measured concentrations. It is important to note that this model was developed as a tool to evaluate regional impacts associated with increased development. The intent of this project was not to specifically match observed concentration data, but to reproduce the general trend of nitrogen concentrations with depth. The model is based on a regional groundwater model and therefore does not contain site-specific stratigraphic information and may not be applicable for particular applications.

Table 8
Simulated vs. Observed Total Nitrogen in Forge River Monitoring Wells

Well	Screen Depth (ft below surface)	Total Nitrogen (mg/L)	
		Observed	Simulated
FR-01	20-25	9.33	7.80
	30-35	12.05	12.08
	80-85	0.30	1.26
FR-02	25-30	10.19	13.13
	45-50	5.90	6.39
	85-90	0.50	1.79
FR-03	20-25	7.57	7.08
	40-45	3.50	4.24

The model-simulated nitrogen loading factors assigned for non-residential land uses after refining the nitrogen loading estimates are summarized on Table 9. For residential land uses, a nitrogen mass loading rate of 10 lbs-N/person/year was applied and 25 percent was assumed to be removed by the septic systems. A population density of 3.1 people per household was used, based upon estimates by the 2000 U.S. Census. The fertilizer application rate in the study area is assumed to be very low and therefore, a nitrogen load from fertilizer at residential properties was not applied in the model. Since these loading factors resulted in model simulated concentrations that were in general agreement with observed data (Table 8), they were also applied for the proposed development model simulation, to evaluate the potential impacts upon nitrogen levels in groundwater resulting from the increased development.

Table 9
Sanitary Effluent Flow Rates and Nitrate/Nitrogen Concentrations For Non-Residential Land Uses used in Model Simulations

Land Use	Assigned Flow Rate (gpd/sf)	Nitrate/Nitrogen Concentration (mg/L)
Commercial	0.07	3.48
Industrial	0.04	4.25
Institutional	0.06	1.02
Recreation and Open Space	0.04	1.15
Agricultural	0.04	7.83
Vacant	0.04	1.15
Transportation	0.04	2.39
Utilities	0.04	1.02

1.4 Estimated Nitrogen Concentrations Resulting from Proposed Development

An additional model simulation was conducted using the nitrogen loading factors and methodology described above and the projected land use designation for the Montauk Highway Corridor study. As in the existing conditions simulation, parcel-specific nitrogen sources were simulated for a period of fifty years. It should be noted that only the land use designation was changed between the existing and proposed development scenarios. Parcel dimensions were held constant from the existing conditions simulation. The simulated total nitrogen concentrations at FR-01, 02 and 03 resulting from the proposed changes in land use are shown in Table 10.

Table 10
Simulated vs. Observed Total Nitrogen in Forge River Monitoring Wells

Well	Screen Depth (ft below surface)	Simulated Total Nitrogen (mg/L)		
		Existing Conditions	Projected	% Increase
FR-01	20-25	7.80	9.09	16.5
	30-35	12.08	14.81	22.6
	80-85	1.26	0.95	-15.9
FR-02	25-30	13.13	14.25	8.5
	45-50	6.39	8.28	29.6
	85-90	1.79	1.69	-5.6
FR-03	20-25	7.08	8.09	14.3
	40-45	4.24	5.00	17.9

In general, simulated concentrations of total nitrogen were projected to increase between nine and thirty percent at all but two of the monitoring well screens. Simulated increased nitrogen concentrations at the well screens reflecting aquifer recharge within the Montauk Highway Corridor area are attributed to the increased nitrogen loading within the study area.

Reductions in groundwater nitrate concentrations were observed at the deepest screened intervals in FR-01 and FR-02; these do not reflect nitrogen loading within the Montauk Highway Corridor area. The relatively small (0.31 and 0.10 mg/l) increases shown result from the assigned nitrogen loads further north of the study area. Estimated average time of travel from the water table to the well screens exceeds twenty years and the model simulation had not yet equilibrated by the end of the fifty year simulation time; the results shown here for the deeper well screens represent annual average values. There will be essentially no change in nitrogen concentration at the deeper well screens if the upgradient land use does not change.

Although the wells are useful to indicate changes in nitrogen concentrations in groundwater between the existing and proposed development scenarios, only the shallow water quality samples reflect nitrogen loads originating within the study area (Figure 8). Therefore, to quantify the average impact to groundwater within the study area itself, average simulated shallow groundwater (upper two model levels) concentrations were calculated for both existing and projected land use conditions.

Under existing conditions, the simulated average total nitrogen concentration in shallow groundwater near the water table within the study area is 12.5 mg/L. The simulated projected average nitrogen concentration in shallow groundwater within the study area resulting from the proposed development is simulated to increase by approximately 18 percent to 14.5 mg/L.

2.0 Existing Sanitary Wastewater Management

As described in some detail in the **Long Island Comprehensive Waste Treatment Management Plan** (Nassau Suffolk Regional Planning Board, 1978) and the **1987 Suffolk County Comprehensive Water Resources Management Plan** (Dvirka and Bartilucci, 1987) nitrate contamination of the County's groundwater has long been of concern. The Task 4.1 memorandum entitled **Groundwater Quality** includes a summary of nitrogen levels in public supply wells in 1987 and 2005. The data shows that overall, nitrogen levels remained below 6 mg/l in nearly ninety percent of the public supply wells, and that the drinking water quality standard of 10 mg/l was exceeded in samples obtained from less than two percent of the supply wells. Nevertheless, when comparing nitrogen levels from the same set of supply wells measured in 1987 and again in 2005, both the average nitrogen concentration and the number of supply wells with observed concentrations in excess of 6 mg/l have increased.

Nitrogen contamination resulting from disposal of sanitary wastewater and fertilization (associated with both residential and agricultural land uses) has been well documented (e.g., **Long Island Comprehensive Waste Treatment Management Plan, 1987 Suffolk County**

Comprehensive Water Resources Management Plan). Nitrogen contamination resulting from residential development is the primary focus of this memo.

The most recent review of sanitary wastewater management approaches in Suffolk County was documented in the draft **Report on the Sewage Treatment Plants of Suffolk County**, (SCDHS, Doroski and Olsen, November 2006.) SCDHS records indicate that wastewater disposal for 70 to 75 percent of the population is provided by individual on-site sanitary systems consisting either of septic tanks or septic tanks and/or leaching pools, while wastewater treatment/disposal is provided to the remaining twenty five to thirty percent of the population by sewage treatment plants.

2.1 Sewage Treatment Plants

As of 2006, 172 sewage treatment plants were located in Suffolk County, sixteen of which discharged to surface waters. All of the sewage treatment plants must operate in compliance with a State Pollutant Discharge Elimination System (SPDES) permit and Suffolk County Article 7 requirements. One hundred and forty three of the sewage treatment plants were designed to remove nitrogen from the wastewater, to comply with SPDES permit discharge limits of 10 mg/L. Monitoring wells are sited at the 156 plants discharging to groundwater to monitor the impacts of the treated effluent upon groundwater quality; samples are collected and analyzed on a quarterly basis from these wells. SCDHS records indicate that 139 of the sewage treatment plants are privately owned and inspected by SCDHS on a quarterly basis; the 33 municipal plants are inspected by NYSDEC. The SCDHS currently employs three full time inspectors, who review effluent quality and the condition of the plants' electrical and mechanical systems.

Nitrogen removal at the sewage treatment plants is accomplished via denitrification; two of the technologies most recently employed in the County are sequencing batch reactors (SBRs) and Cromaglass systems. As described elsewhere, the SBR technology was first proposed in Suffolk County in 1987, and the first Cromaglass system was proposed nearly ten years later in 1996. Cromaglass systems employ an SBR approach and were approved by NYSDEC as an acceptable technology in 1995.

Since 2003, SCDHS has collected 1430 samples from the community sewage treatment plants and analyzed them for nitrogen. The draft **Report on the Sewage Treatment Plants of Suffolk County** reports that the average total effluent nitrogen concentration in effluent samples was 10.2 mg/l, which is close to the 10 mg/l target.

However the SCDHS study statistics did not include nearly twenty five percent (34 out of 138) of the wastewater treatment plants in the calculated average nitrogen concentration, because the facilities were under consent order, or complying with a re-building directive that required taking part or all of the facility out of service for upgrade. Including data from all of the plants with nitrogen limits yields a different perspective on the effectiveness of the treatment systems. Considering effluent nitrogen levels from all 138 of the plants with reported data, the average effluent nitrogen concentration from 2003 through 2006 was 14.1 mg/l, well above the 10 mg/l limit. In fact, fewer than 50 percent of the plants (66 out of 138) had average effluent nitrogen concentrations less than or equal to the 10 mg/l limit.

It is not clear whether the poor performance of the community wastewater treatment systems should be attributed to inadequacies of the treatment systems themselves, or to operations. It is worth noting that operator experience/attention may have a significant impact upon treatment efficiency. While operators of these community wastewater treatment systems are required to be certified New York State operators, effluent quality varies widely. The small treatment systems are complicated to operate and treatment efficiency can be affected by diurnal flow variation and temperature. Nonetheless, all fifteen of the Suffolk County Sewer District plants discharging to groundwater successfully maintained average effluent nitrogen concentrations of less than 10 mg/l; the average effluent nitrogen level from these facilities was 5.2 mg/l.

Differences in technology performance were also evident. Out of sixty operating SBR facilities, fifty five percent (33 out of 60) had average effluent nitrogen levels less than or equal to the 10 mg/l limit. The average level of nitrogen in SBR effluent was 13 mg/l. Out of the sixteen Cromaglass facilities operating at the time that the document was prepared, only four, or 25 percent, had average effluent nitrogen levels below the 10 mg/l limit. The average level of nitrogen in Cromaglass effluent was 22.3 mg/l, more than twice the 10 mg/l limit. Considering all other types of treatment systems, less than fifty percent (28 out of 58) had average effluent nitrogen levels of less than or equal to 10 mg/l; the average effluent nitrogen concentration was 13.3 mg/l.

Due to a combination of process/mechanical and operational factors, the Cromaglass systems have come under increased scrutiny by SCDHS, as well as by other regulatory agencies. In fact, the Executive Director of the New Jersey Pinelands Commission has temporarily suspended installation of new Cromaglass systems until improvements increasing reliability are implemented (New Jersey Pinelands Commission, 2006)*. In 2005, SCDHS performed an evaluation of Cromaglass systems, which concluded that most systems were experiencing difficulty in meeting SPDES permit limits. SCDHS identified both mechanical and electrical problems, and maintenance challenges that caused the non-compliance.

Review of monthly discharge monitoring data and SCDHS sampling data characterizing Cromaglass performance at seventeen Cromaglass facilities operating in 2006 reveals the following:

- Only three of the seventeen facilities successfully achieved the 10 mg/L limit during all twelve months sampled.

- Monthly average nitrogen concentrations exceeded the 10 mg/L limit at eight of the seventeen facilities.

- SCDHS has inspected the Cromaglass facilities on a quarterly basis and has documented a variety of design and operational issues requiring correction. Twelve of the seventeen facilities have attended hearings and implemented repairs.

- Average nitrogen values in the effluent of facilities that have implemented the improvements required by SCDHS have been significantly reduced.

- SCDHS continues to work closely with Cromaglass, owners and operators to improve system performance and protect groundwater quality. Five year service contracts with Cromaglass will be required to improve operational reliability and immediate fines will be levied for violations.

Because the most recent data available indicated that less than fifty percent of the community sewage treatment plants do consistently comply with the 10 mg/L nitrogen discharge limit, further evaluation of the treatment systems' effectiveness and operational requirements are recommended.

2.2 On-Site Wastewater Disposal

Article 6 of the Suffolk County Sanitary Code allows on-site wastewater disposal for residential parcels greater than or equal to one acre in the deep recharge zone (Groundwater Management Zones III, V and VI), and on-site wastewater disposal for residential parcels greater than or equal to one half acre outside of the deep recharge zone (Groundwater Management Zones I, II, IV, VII or VIII; see Figure 9 for areal distribution of Groundwater Management Zones). Residential development on lot sizes smaller than one acre within the deep recharge zone and one half acre outside of the deep recharge zone require a use of a community sewage system for wastewater treatment and disposal. As nitrogen levels in groundwater (as characterized by measured concentrations in public supply wells) have continued to increase, the relationship between unsewered residential development density and nitrogen levels, and the adequacy of the density restrictions included in Article 6 in protecting groundwater quality have been questioned.

Article 6 was enacted in 1980, and a number of existing residences with on-site wastewater disposal systems had already been constructed on smaller parcels. Sufficient information to quantify the number of residential parcels that were developed with on-site sanitary wastewater disposal within and outside of the deep recharge zone prior to enactment of Article 6 was not available. However, using information provided by the Suffolk County

*Note: The Executive Director of the New Jersey Pinelands Commission had approved the Cromaglass technology for residential properties of at least one acre in late 2004, assuming that the technology would reduce an assumed influent total nitrogen level of 40 mg/L by 65 percent, to a final effluent level of 14 mg/L . It was further assumed that the 14 mg/L would be further reduced to 2 mg/L at the property line of a one acre parcel. As the median effluent from the approximately forty operating Cromaglass systems is 48.6 mg/L, the Executive Director temporarily suspended installation of new Cromaglass systems in November 2006 until the manufacturer implements modifications to the existing systems to improve performance, and data indicating satisfactory performance is collected.

Planning Department, the number of parcels less than or equal to one half acre and zoned for residential use was identified. The locations of these parcels are illustrated on Figure 10 and summarized by Town, on Table 11.

Table 11 shows that over half of the residential parcels in the five western towns of Babylon, Brookhaven, Huntington, Islip and Smithtown are less than or equal to one half acre, and approximately one third of the Towns of East Hampton, Riverhead, Southampton and Southold are less than or equal to one half acre. No information was readily available to identify whether or not a residence has been constructed on these properties, or what year any of the existing residences were constructed so the number of on-site sanitary wastewater disposal systems that may have been constructed prior to Article 6 cannot be reliably estimated at this time. Nevertheless, as the populations of Islip, Huntington and Smithtown have not increased significantly since 1970, it is evident that a large portion of the smaller parcels do rely upon on-site septic systems for wastewater disposal, and nitrate levels in groundwater reflect these conditions. Furthermore, the locations of residential parcels less than or equal to one quarter acre are depicted on Figure 11 and summarized by Town, on Table 12.

Table 11
Residential Parcels Smaller Than or Equal to One-Half Acre

Town	Number of Residential Parcels Less than or Equal to 1/2 Acre	Acres	Total Residential Parcels	Percent Parcels Less than or Equal to 1/2 Acre
Babylon	55,324	10633.91	65,925	83.92%
Brookhaven	107,646	27939.41	174,703	61.62%
East Hampton	8,496	2539.93	26,141	32.50%
Huntington	42,901	10882.06	70,687	60.69%
Islip	74,602	19569.27	94,852	78.65%
Riverhead	5,268	1420.83	13,772	38.25%
Shelter Island	440	153.16	3,567	12.34%
Smithtown	26,662	7442.28	41,316	64.53%
Southampton	16,071	4741.80	49,950	32.17%
Southold	6,693	1982.72	18,217	36.74%
Totals	344,103	87,305	559,130	61.54%

Insert figure 9

Insert figure 10

Table 12
Residential Parcels Smaller Than or Equal to One-Quarter Acre

Town	Number of Residential Parcels Less than or Equal to 1/4 Acre	Acres	Total Residential Parcels	Percent Parcels Less than or Equal to 1/4 Acre
Babylon	47,100	8010.13	65,925	71%
Brookhaven	55,977	9590.41	174,703	32%
East Hampton	3,262	492.83	26,141	12%
Huntington	25,431	4328.52	70,687	36%
Islip	34,943	6170.61	94,852	37%
Riverhead	2,604	416.65	13,772	19%
Shelter Island	120	20.29	3,567	3%
Smithtown	12,365	2445.52	41,316	30%
Southampton	5,873	928.82	49,950	12%
Southold	2,422	373.20	18,217	13%
Totals	190,097	32,777	559,130	34%

Table 12 shows that approximately one third of the residentially zoned properties in Brookhaven, Huntington, Islip and Smithtown are less than or equal to one quarter acre. Almost three quarters of the residential properties in Babylon are less than or equal to one quarter acre; groundwater contamination resulting from the on-site septic systems prompted the implementation of the Southwest Sewer District in the 1970s. Over ten percent of residential properties in the east end towns of East Hampton, Riverhead, Southampton and Southold are also less than or equal to one quarter acre.

This is further corroborated by census data provided by SCDHS (M. Trent, August 2007) documenting the presence of 340,519 on-site septic systems in Suffolk County in 1990. It is clear that a significant number of on-site sanitary wastewater disposal systems do serve properties that are less than the minimum sizes designated in Article 6; observed groundwater quality results from a combination of the Article 6-compliant and the older non-compliant parcels.

3.0 Septic System Density and Nitrogen

In order to provide some perspective on the residential density limits included in Article 6 of the Sanitary Code, housing density limits in similar unsewered areas relying upon groundwater for potable supply elsewhere throughout the country were reviewed. Housing

Insert figure 11

density is primarily regulated locally, comprehensive assessment of local regulations is beyond the scope of this evaluation.

A number of factors affect the impact of on-site wastewater systems upon nitrate levels in groundwater. In addition to the volume of wastewater discharged, site-specific characteristics such as precipitation and recharge rates, soil characteristics and groundwater flow patterns also affect density requirements. For example, groundwater quality in areas with low precipitation and groundwater recharge rates is generally more significantly impacted by discharges from on-site wastewater treatment disposal than groundwater quality in areas with greater precipitation and available recharge to dilute the wastewater.

An American Planning Association survey performed for the Illinois Department of Energy and Natural Resources (**Septic System Density and Groundwater Contamination in Illinois: A Survey of State and Local Regulation**, Thomas Smith and Martin Ince, principal investigators, 1989) reports that the most frequently utilized zoning control to reduce contamination from on-site wastewater disposal in Illinois communities was establishment of minimum lot sizes ranging from one half to two acres. The report quotes a previous National Academy of Sciences study which concluded that "*the only feasible means of controlling nitrate output from septic tank disposal is through proper land-use and zoning controls which … limit the density of housing*" and that small scale treatment plants would probably not be feasible due to cost and long term maintenance issues (**Nitrates – An Environmental Assessment**, National Academy of Sciences, 1978). The area is similar to Suffolk County in that approximately 90 percent of potable supply in Illinois was obtained from groundwater sources, and the area is underlain by highly transmissive glacial sediments.

Researchers compiled permitted lot sizes for unsewered counties that responded to their survey request. The minimum required lot sizes summarized in Table 13 were based on information that was current as of 1989. The basis for the lot sizes varied and was not documented in most cases. Communities within the counties sometimes reported greater restrictions – for example, in the Village of Roscoe, the Illinois Department of Energy and Natural Resources recommended that housing density should be limited to less than one home per acre to maintain compliance with the 10 mg/L nitrate-nitrogen standard (Winnebago County had not implemented the limitation at the time of document preparation).

Table 13
Residential Density Requirements in Unsewered Illinois Counties

County	Required Lot Size (sq. ft.)	Comments
Adams	20,000	
Christian	20,000	
DeWitt	87,120	
Ford	20,000	
Grundy	40,000	
Iroquois	20,000	
Kane	43,560	
Kankakee	30,000	
Lake	40,000 to 80,000	
Lee	21,780 to 43,560	Depends upon Percolation Rate
Macon	21,780	
Mason	20,000	
McHenry	21,780	May be larger, depending upon soil characteristics
McLean	22,500	
Monroe	108,900	
Ogle	15,000 to 43,560	Depends upon water source and percolation rates
Peoria	20,000	
Piatt	87,120	
Randolph	217,500	
Rock Island	20,000	
St. Clair	10,000 to 20,000	Depends on water source
Will	12,000 to 108,900	Depends upon water source and percolation rates
Winnebago	20,000 to 30,000	
Woodford	30,000	

Source: Septic System Density and Groundwater in Illinois: A Survey of State and Local Regulation; Prepared for Illinois Department of Energy and Natural Resources by the America Planning Association, 1989

Information collected from other sources throughout the country yielded the following:

- No communities that allow a development density greater than 2 dwelling units per acre, that are both unsewered and rely upon public water were identified.

- Unsewered areas that historically allowed greater than 2 dwelling units per acre report groundwater and/or surface water contamination that led to either code changes (e.g., Michigan) or subsequent construction of sanitary sewers. For example, as a result of groundwater nitrate levels in the residential area of Lake Havasu, Arizona exceeding 10 mg/L from septic tank input, a nearly $500 million dollar sanitary sewering program is now underway.

- Massachusetts has both Title 5 septic system regulations (enforcement authority is ceded to local municipalities) and legislation encouraging development of affordable housing ("Chapter 40B"). Over thirty percent of residences in Massachusetts rely upon on-site wastewater disposal systems. The Massachusetts Department of Environmental Protection has developed a nutrient loading approach that is described in their **Policy on Nutrient Loading Approach to Wastewater Permitting and Disposal** (1999). The nutrient loading approach establishes a 5 mg/L NO_3 limit at all sensitive receptors and at the downgradient property boundary, or a 10 mg/L NO_3 limit for all dischargers not located in nutrient sensitive areas. The Department was contacted directly with respect to allowable housing density (D. Noonan, personal communication, 2007). The MaDEP did not identify any unsewered Massachusetts communities currently allowing more than 2 dwelling units per acre.

- The New Jersey Department of Environmental Protection's Division of Science, Research and Technology published technical guidance (**A Recharge-Based Nitrate-Dilution Model for New Jersey**, 2001, Jeffrey L. Hoffman and Robert J. Canace, New Jersey Geological Survey) to be used as a planning tool to estimate regional concentrations of nitrate in groundwater resulting from residential developments with on-site wastewater disposal systems. Using assumptions similar to those applicable to Suffolk County (e.g., 3 persons per household and 10 pounds of nitrate per person per year), and a recharge rate of 19.4 inches per year, the minimum lot size required to meet their nitrate target of 5.2 mg/L (based upon New Jersey's anti-degradation approach) is approximately 2 acres. The minimum required area varied across the state, based upon recharge rates, from 1.7 acres/home in the northwest part of the state to 2.5 acres/home in the southeastern part of New Jersey.

Elsewhere across the country, other modeling studies have estimated even larger required lot sizes, based partly upon lower precipitation/recharge rates. For example, a modeling study in Minnesota concluded that sanitary wastewater recharge resulting from two acres/home in Anoka County would result in an average nitrate concentration of 7.9 mg/L, while the same two acres/home in Scott County would result in an average nitrate concentration of 13.2

mg/L (**Developing a Method to Evaluate Septic System Impacts on Nitrate Concentrations in Groundwater and Receiving Streams**, Mark McCluskey and Gordon McCurry, CDM, 2005). In Jefferson County, Colorado, researchers found that nitrate levels exceeded 10 mg/L in areas with housing densities higher than 1 dwelling unit/acre.

Readily available information characterizing allowable housing densities in unsewered areas of the country is summarized on Table 14, although it should be noted that some of these densities were specified based upon other factors (e.g., percolation rates, impact upon local surface waters, etc.). No communities with characteristics similar to Suffolk County were identified that permitted unsewered residential density greater than two dwelling units per acre.

5.0 Results and Conclusions

5.1 Montauk Highway Corridor Case Study

A modeling approach to simulate the impacts of changing development patterns upon nitrate groundwater levels was developed specifically for the Montauk Highway Corridor, to serve as the prototype for other future applications. The groundwater model focused upon the area of the Montauk Highway corridor that the Town of Brookhaven has proposed to redevelop. A spreadsheet model was developed to construct model input files for up to thousands of nitrogen point sources, which can be read into DYNTRACK for contaminant transport simulations. The spreadsheet is set up to read in the file structure corresponding to the SCPD land use dataset (as of 2006). This nitrogen loading spreadsheet can be readily applied to other areas of the County with only minor changes required (e.g., specific land use types not included in the Montauk Highway Corridor study area), as described in some detail in Appendix A.

Groundwater model simulations were conducted for both existing and proposed future development scenarios. The DYNTRACK code was re-dimensioned to account for several thousand individual point sources, thereby allowing for a parcel-specific contaminant transport simulation over a regional area. Water quality data collected from recently installed SCDHS monitoring wells were used as targets for nitrogen transport simulations under existing conditions, and loading parameters were varied until simulated and observed nitrogen concentrations were in general agreement.

Groundwater modeling evaluations of the Montauk Highway Corridor indicate the following:

- Simulated nitrogen concentrations at monitoring wells were in general agreement with observed concentrations;

- The average simulated concentration of total nitrogen in the shallow groundwater beneath the study area is 12.5 mg/L, which is consistent with water quality data collected from nearby monitoring wells;
- The total nitrogen concentration in shallow groundwater resulting from the proposed development is projected to increase to 14.5 mg/L, increase of 18 percent from existing conditions;
- Both existing development and the proposed development scenario result in nitrate levels that exceed 10 mg/L;
- As the Forge River already experiences severe water quality degradation (e.g., eutrophication), increased development of the Montauk Highway Corridor, without sewering, would be expected to exacerbate the problem;
- Model simulations suggest that groundwater in the western portion of the study area flows towards the Carmans River. It is anticipated that the proposed development would also result in increased nitrogen loading to the Carmans River; additional model simulations would be required to evaluate the magnitude of the impacts.

5.2 Sanitary Wastewater Disposal

Available data indicates that less than fifty percent of the 172 community sewage treatment plants in Suffolk County consistently complied with the 10 mg/L discharge limit for nitrogen. SCDHS has taken action to improve the effectiveness of the Cromaglass technology, one of the technologies currently approved for community sewage treatment plants in Suffolk County. Further evaluation of the community treatment systems' effectiveness and operational requirements are recommended.

Regulation of residential density in areas relying upon on-site wastewater disposal is widely implemented across the country to manage impacts on groundwater quality. A review of available residential density restrictions based upon nitrogen loadings across the country identified a minimum lot size of one half acre for unsewered areas, although minimum lot size requirements in some areas of the country were larger. The half acre minimum lot is consistent with Article 6 requirements.

Nitrogen levels measured in Suffolk County groundwater today result both from areas that have been developed in accordance with Article 6 density requirements, and areas with lot sizes smaller than one half acre – or even one quarter acre - that were developed prior to 1980. Additional modeling evaluation of the impact of the community sewage treatment plants on nitrate levels and of various unsewered residential densities would help to identify appropriate wastewater management alternatives associated with sewage treatment limits and/or unsewered residential density limitations.

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