VI. WATER QUALITY MODELING

VI.1 DATA SOURCES FOR THE MODEL

Several different data types and calculations are required to support the water quality modeling effort for the Nantucket Harbor system. These include the output from the hydrodynamics model, calculations of external nitrogen loads from the watersheds, measurements of internal nitrogen loads from the sediment (benthic flux), and measurements of nitrogen in the water column.

VI.1.1 Hydrodynamics and Tidal Flushing in the Embayments

Extensive field measurements and hydrodynamic modeling of the embayments were an essential preparatory step to the development of the water quality model. The result of this work, among other things, was a calibrated hydrodynamic model representing the transport of water within the Nantucket Harbor system. Files of node locations and node connectivity for the RMA-2V model grids were transferred to the RMA-4 water quality model; therefore, the computational grid for the hydrodynamic model also was the computational grid for the water quality model. The period of hydrodynamic model output used for the water quality model calibration was the 5 day period beginning August 30, 2004 0000 EST. This period corresponds to that used in the flushing analysis presented in Chapter V. Each modeled scenario (e.g., present conditions, build-out) required the model be run for a 28-day spin-up period, to allow the model to reach a dynamic "steady state", and ensure that model spin-up would not affect the final model output.

VI.1.2 Nitrogen Loading to the Embayments

Three primary nitrogen loads to sub-embayments are recognized in this modeling study: external loads from the watersheds, nitrogen load from direct rainfall on the embayment surface, and internal loads from the sediments. Additionally, there is a fourth load to the Nantucket Harbor system's sub-embayments, consisting of the background concentrations of total nitrogen in the waters entering from Nantucket Sound. This load is represented as a constant concentration along the seaward boundary of the model grid.

VI.1.3 Measured Nitrogen Concentrations in the Embayments

In order to create a model that realistically simulates the total nitrogen concentrations in a system in response to the existing flushing conditions and loadings, it is necessary to calibrate the model to actual measurements of water column nitrogen concentrations. The refined and approved data for each monitoring station used in the water quality modeling effort are presented in Table VI-1. Station locations are indicated in the area map presented in Figure VI-1. The multi-year averages present the "best" comparison to the water quality model output, since factors of tide, temperature and rainfall may exert short-term influences on the individual sampling dates and even cause inter-annual differences. Three years of baseline field data are the minimum required to provide a baseline for MEP analysis. Typically, six years of data (collected between 1988 and 2005) were available for stations monitored by the Woods Hole Oceanographic Institute (WHOI) between 1988 and 1994, and the Town of Nantucket Marine Department between 1992 and 1994.

Table VI-1. Measured data and modeled Nitrogen concentrations for the Nantucket Harbor estuarine system used in the model calibration plots of Figures VI-2 and VI-3. All concentrations are given in mg/L N. “Data mean” values are calculated as the average of the separate yearly means. Data represented in this table were collected in the summers of 1988 through 1990 and 1992 though 1994 by the Woods Hole Oceanographic Institute (WHOI), and between 1992 and 2005 by the Town of Nantucket Marine Department.

Sub-Embayment	monitoring station	MEP ID	data mean	s.d. all data	N	model min	model max	model average
Head of the Harbor - Upper	2	2	0.408	0.188	81	0.388	0.405	0.397
Head of the Harbor - Mid	Town 3	2.2	0.401	0.115	45	0.377	0.399	0.390
Head of the Harbor - Lower	2A	2.1	0.339	0.070	46	0.329	0.377	0.353
Pocomo Head	3	3	0.335	0.081	74	0.324	0.361	0.340
Quaise Basin	3A+Town 2	3.1	0.336	0.112	98	0.303	0.339	0.325
East Polpis Harbor	4+Town 6	4	0.362	0.105	107	0.354	0.371	0.361
West Polpis Harbor	4A+Town 5	4.1	0.388	0.119	100	0.358	0.385	0.371
Abrams Point	5	5	0.335	0.060	39	0.271	0.322	0.296
Monomoy	6	6	0.297	0.086	76	0.282	0.300	0.291
Mooring Area	7+Town 1,1A	7	0.326	0.106	123	0.276	0.291	0.285
Nantucket Sound	OS+Town 4	7.1	0.239	0.041	41	-	-	-

VI.2 MODEL DESCRIPTION AND APPLICATION

A two-dimensional finite element water quality model, RMA-4 (King, 1990), was employed to study the effects of nitrogen loading in the Nantucket Harbor estuarine system. The RMA-4 model has the capability for the simulation of advection-diffusion processes in aquatic environments. It is the constituent transport model counterpart of the RMA-2 hydrodynamic model used to simulate the fluid dynamics of Nantucket Harbor. Like RMA-2 numerical code, RMA-4 is a two-dimensional, depth averaged finite element model capable of simulating time-dependent constituent transport. The RMA-4 model was developed with support from the US Army Corps of Engineers (USACE) Waterways Experiment Station (WES), and is widely accepted and tested. The MEP Technical Team has utilized this model in water quality studies of other Cape Cod embayments, including systems other Massachusetts estuarine systems such as Falmouth (Howes *et al*., 2005); Mashpee, MA (Howes *et al*., 2004) and Chatham, MA (Howes *et al*., 2003).

The overall approach involves modeling total nitrogen as a non-conservative constituent, where bottom sediments act as a source or sink of nitrogen, based on local biochemical characteristics. This modeling represents summertime conditions, when algal growth is at its maximum. Total nitrogen modeling is based upon various data collection efforts and analyses presented in previous sections of this report. Nitrogen loading information was derived from the Cape Cod Commission watershed loading analysis (using watersheds delineated originally by the USGS and modified by WHOI), as well as the measured bottom sediment nitrogen fluxes. Water column nitrogen measurements were utilized as model boundaries and as calibration data. Hydrodynamic model output (discussed in Section V) provided the remaining information (tides, currents, and bathymetry) needed to parameterize the water quality model of the Nantucket Harbor system.

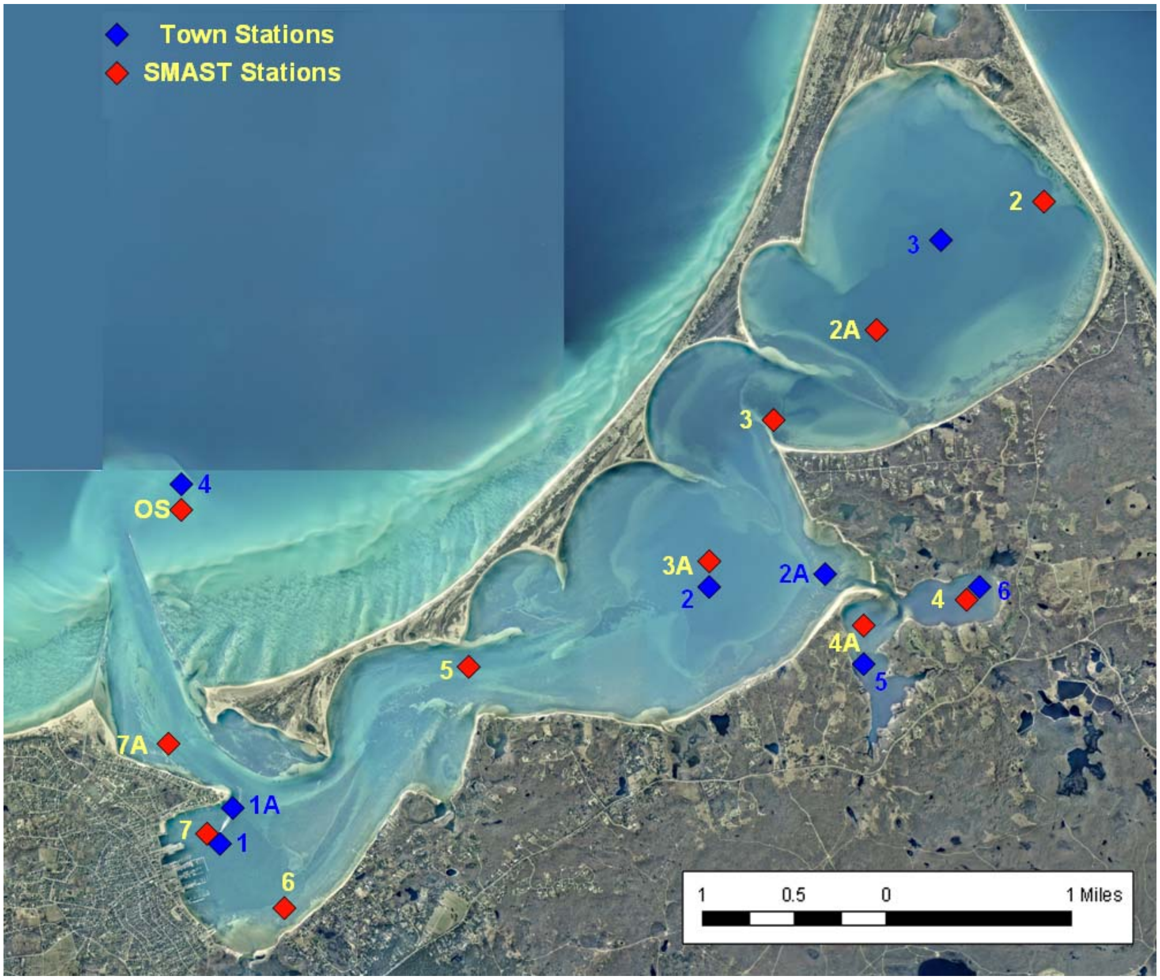

Figure VI-1. Estuarine water quality monitoring station locations in the Nantucket Harbor estuary system. Station labels correspond to those provided in Table VI-1.

VI.2.1 Model Formulation

The formulation of the model is for two-dimensional depth-averaged systems in which concentration in the vertical direction is assumed uniform. The depth-averaged assumption is justified since vertical mixing by wind and tidal processes prevent significant stratification in the modeled sub-embayments. The governing equation of the RMA-4 constituent model can be most simply expressed as a form of the transport equation, in two dimensions:

$$\left(\frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} + v\frac{\partial c}{\partial y}\right) = \left(\frac{\partial}{\partial x}D_x\frac{\partial c}{\partial x} + \frac{\partial}{\partial y}D_y\frac{\partial c}{\partial y} + \sigma\right)$$

where *c* in the water quality constituent concentration; *t* is time; *u* and *v* are the velocities in the *x* and *y* directions, respectively; D_x and D_y are the model dispersion coefficients in the *x* and *y* directions; and σ is the constituent source/sink term. Since the model utilizes input from the RMA-2 model, a similar implicit solution technique is employed for the RMA-4 model.

The model is therefore used to compute spatially and temporally varying concentrations *c* of the modeled constituent (i.e., total nitrogen), based on model inputs of 1) water depth and velocity computed using the RMA-2 hydrodynamic model; 2) mass loading input of the modeled constituent; and 3) user selected values of the model dispersion coefficients. Dispersion coefficients used for each system sub-embayment were developed during the calibration process. During the calibration procedure, the dispersion coefficients were incrementally changed until model concentration outputs matched measured data.

The RMA-4 model can be utilized to predict both spatial and temporal variations in total for a given embayment system. At each time step, the model computes constituent concentrations over the entire finite element grid and utilizes a continuity of mass equation to check these results. Similar to the hydrodynamic model, the water quality model evaluates model parameters at every element at 10-minute time intervals throughout the grid system. For this application, the RMA-4 model was used to predict tidally averaged total nitrogen concentrations throughout the sub-embayments of the Nantucket Harbor system.

VI.2.2 Water Quality Model Setup

Required inputs to the RMA-4 model include a computational mesh, computed water elevations and velocities at all nodes of the mesh, constituent mass loading, and spatially varying values of the dispersion coefficient. Because the RMA-4 model is part of a suite of integrated computer models, the finite-element meshes and the resulting hydrodynamic simulations previously developed for Nantucket Harbor also were used for the water quality constituent modeling portion of this study.

For each model, an initial total N concentration equal to the concentration at the open boundary was applied to the entire model domain. The model was then run for a simulated month-long (28 day) spin-up period. At the end of the spin-up period, the model was run for an additional 7 tidal-day (174 hour) period. Model results were recorded only after the initial spin-up period. The time step used for the water quality computations was 10 minutes, which corresponds to the time step of the hydrodynamics input for the Nantucket Harbor model.

VI.2.3 Boundary Condition Specification

Mass loading of nitrogen into each model included 1) sources developed from the results of the watershed analysis, 2) estimates of direct atmospheric deposition, and 3) summer benthic regeneration. Nitrogen loads from each separate sub-embayment watershed were distributed across the sub-embayment. For example, the combined watershed and direct atmospheric deposition loads for Head of the Harbor were evenly distributed at grid cells that formed the perimeter of the sub-embayment. Benthic regeneration loads were distributed among another sub-set of grid cells which are in the interior portion of each basin.

The loadings used to model present conditions in the Nantucket Harbor system are given in Table VI-2. Watershed and depositional loads were taken from the results of the analysis of Section IV. Summertime benthic flux loads were computed based on the analysis of sediment cores in Section IV. The area rate ($g/sec/m^2$) of nitrogen flux from that analysis was applied to the surface area coverage computed for each sub-embayment (excluding marsh coverages, when present), resulting in a total flux for each embayment (as listed in Table VI-2). Due to the highly variable nature of bottom sediments and other estuarine characteristics of coastal embayments in general, the measured benthic flux for existing conditions also is variable. For some areas of Nantucket Harbor (i.e., Head of the Harbor and the Town Basin), the net benthic flux is negative which indicates a net uptake of nitrogen in the bottom sediments.

In addition to mass loading boundary conditions set within the model domain, concentrations along the model open boundary were specified. The model uses concentrations at the open boundary during the flooding tide periods of the model simulations. TN concentrations of the incoming water are set at the value designated for the open boundary. The boundary concentration in the Nantucket Sound region offshore the Harbor was set at 0.267 mg/L, based on SMAST data collected during nine summers between 1988 and 2000.

Table VI-2. Sub-embayment and surface water loads used for total nitrogen modeling of the Nantucket Harbor system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **present loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)
Head of the Harbor	1.858	22.239	-17.211
Polpis Harbor	3.529	2.190	27.441
Quaise Basin	2.123	20.126	43.896
Town Basin	15.901	13.888	-2.793
System Total	23.411	58.443	51.333

VI.2.4 Model Calibration

Calibration of the total nitrogen model of Nantucket Harbor proceeded by changing model dispersion coefficients so that model output of nitrogen concentrations matched measured data. Generally, several model runs of each system were required to match the water column measurements. Dispersion coefficient (*E*) values were varied through the modeled system by setting different values of *E* for each grid material type, as designated in Section V. Observed values of *E* (Fischer, *et al.*, 1979) vary between order 10 and order 1000 m^2/sec for riverine estuary systems characterized by relatively wide channels (compared to channel depth) with moderate currents (from tides or atmospheric forcing). Generally, the relatively quiescent estuarine embayments encircling Nantucket Sound require values of *E* that are lower compared to the riverine estuary systems evaluated by Fischer, *et al.*, (1979). Observed values of *E* in these calmer areas typically range between order 10 and order 0.001 m^2/sec (USACE, 2001). The final values of *E* used in each sub-embayment of the modeled system are presented in Table VI-3. These values were used to develop the "best-fit" total nitrogen model calibration. For the case of TN modeling, "best fit" can be defined as minimizing the error between the model and data at all sampling locations, utilizing reasonable ranges of dispersion coefficients within each sub-embayment.

Comparisons between calibrated model output and measured nitrogen concentrations are shown in plots presented in Figures VI-2 and VI-3. In these plots, means of the water column data and a range of two standard deviations of the annual means at each individual station are plotted against the modeled maximum, mean, and minimum concentrations output from the model at locations which corresponds to the SMAST monitoring stations.

For model calibration, the mid-point between maximum modeled TN and average modeled TN was compared to mean measured TN data values, at each water-quality monitoring station. The calibration target would fall between the modeled mean and maximum TN because the monitoring data are collected, as a rule, during mid ebb tide.

Table VI-3. Values of longitudinal dispersion coefficient, E, used in calibrated RMA4 model runs of salinity and nitrogen concentration for the Nantucket Harbor estuary system.

Embayment Division	E m^2/sec
Nantucket Sound	5.0
Harbor Jetties	5.0
Jetty Channel	5.0
Inlet Channel	5.0
Town Basin	1.0
The Creeks	5.0
Quaise Basin	10.0
Head of the Harbor	2.0
Polpis Harbor	15.0
Pocomo Meadow	5.0

Also presented in this figure are unity plot comparisons of measured data verses modeled target values for each system. Computed root mean squared (rms) error is less than 0.02 mg/L, which demonstrates the exceptional fit between modeled and measured data for this system.

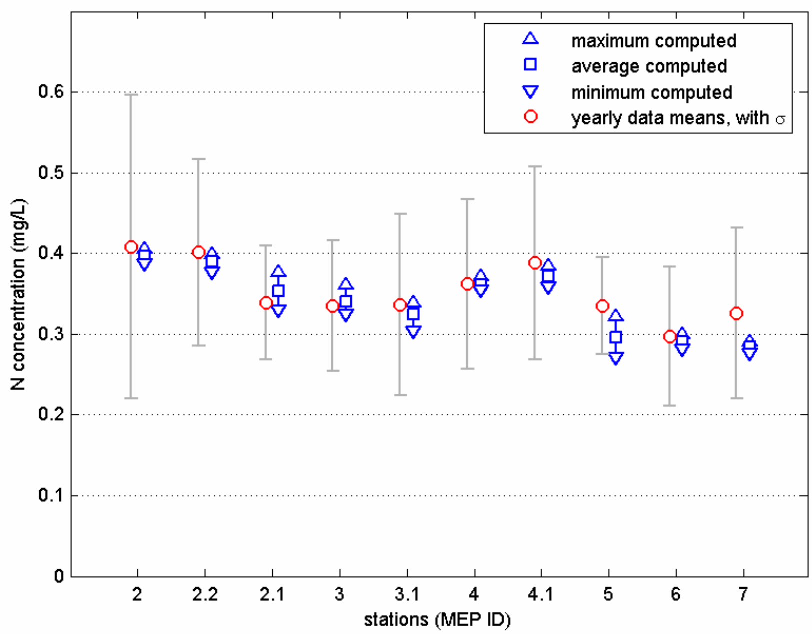

Figure VI-2. Comparison of measured total nitrogen concentrations and calibrated model output at stations in the Nantucket Harbor system. Station labels correspond with the MEP IDs provided in Table VI-1. Model output is presented as a range of values from minimum to maximum values computed during the simulation period (triangle markers), along with the average computed concentration for the same period (square markers). Measured data are presented as the total yearly mean at each station (circle markers), together with ranges that indicate ± one standard deviation of the entire dataset

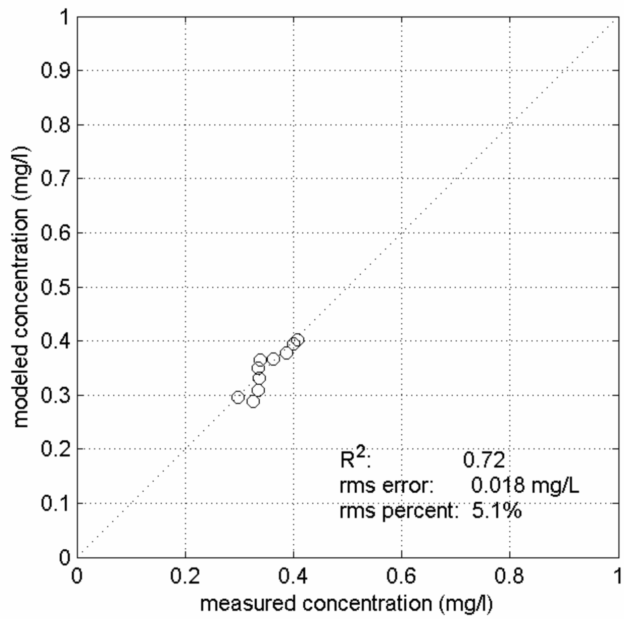

Figure VI-3. Model total nitrogen calibration target values are plotted against measured concentrations, together with the unity line. Computed correlation (R^2) and error (rms) for the model are also presented.

A contour plot of calibrated model output is shown in Figures VI-4. In this figure, color contours indicate nitrogen concentrations throughout the model domain. The output in these figures show average total nitrogen concentrations, computed using the full 7-tidal-day model simulation output period.

VI.2.5 Model Salinity Verification

In addition to the model calibration based on nitrogen loading and water column measurements, numerical water quality model performance is typically verified by modeling salinity. This step was performed for the Nantucket Harbor system using salinity data collected at the same stations as the nitrogen data. The only required inputs into the RMA4 salinity model of the system, in addition to the RMA2 hydrodynamic model output, were salinities at the model open boundary, and groundwater inputs. The open boundary salinity was set at 31.9 ppt. Groundwater input salinities were set at 0 ppt. Groundwater inputs used for each model were 3.04 ft^3/sec (7,430 m^3/day) for the Head of the Harbor watershed, 8.33 ft^3/sec (20,390 m^3/day) for Polpis Harbor, 4.39 ft^3/sec (10,750 m^3/day) for the Quaise basin and 9.23 ft^3/sec (61,150 m^3/day) for the town harbor basin. Groundwater flows were distributed evenly in the model through the use of several 1-D element input points positioned along the model's land boundary.

Comparisons of modeled and measured salinities are presented in Figures VI-5 and VI-6, with contour plots of model output shown in Figure VI-7. The rms error of the model is less than 0.7 ppt. The model output shows the same trend of the measured data, where there is only a slight salinity gradient between the Head of the Harbor and the inlet to the system. This is because tidal exchange rate (39,353,000 m^3/day) is two orders of magnitude larger than the groundwater recharge rate (100,000 m^3/day) of the entire Harbor system.

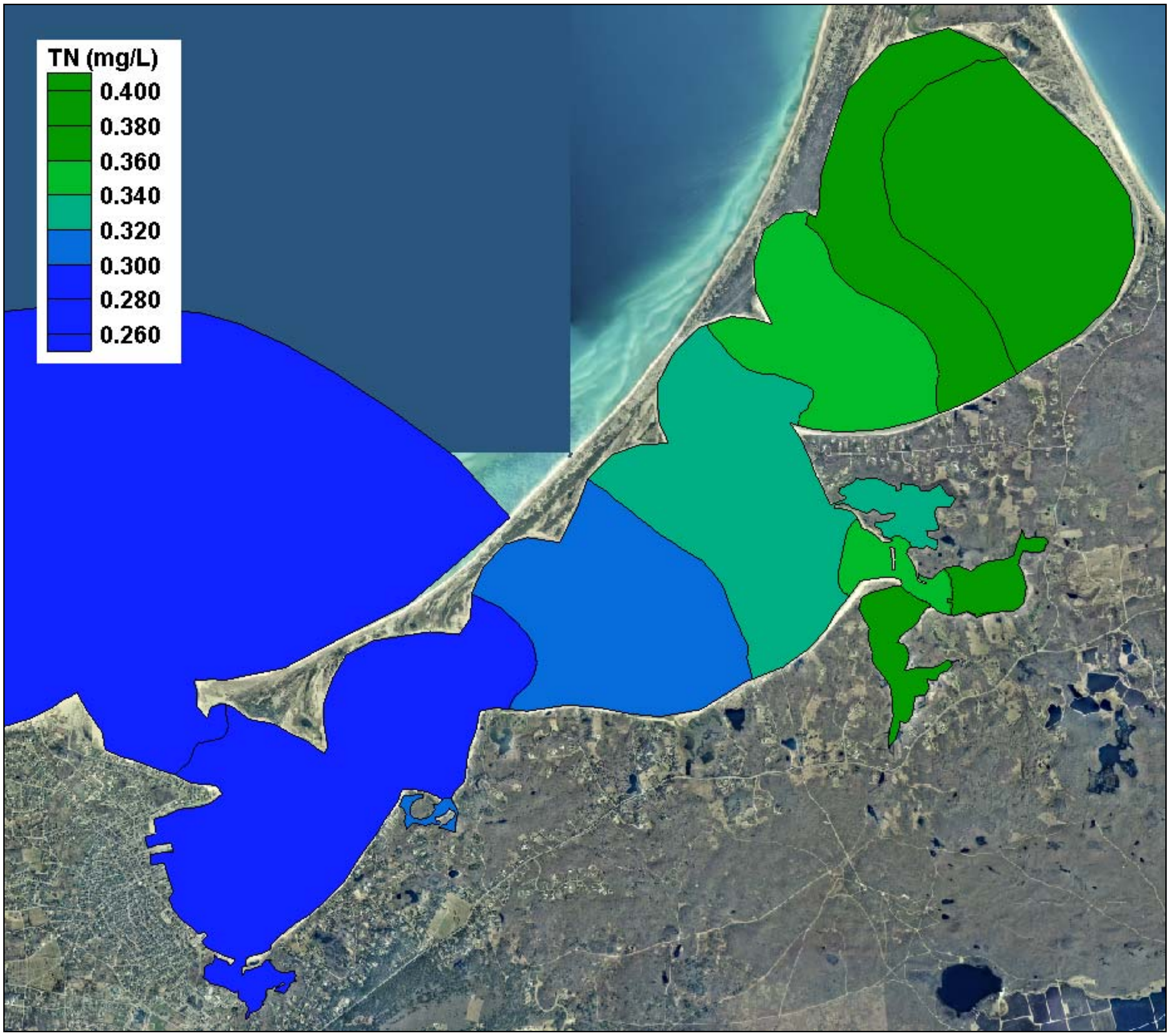

Figure VI-4. Contour plot of average total nitrogen concentrations from results of the present conditions loading scenario, for the Nantucket Harbor system.

VI.2.6 Build-Out and No Anthropogenic Load Scenarios

To assess the influence of nitrogen loading on total nitrogen concentrations within the Nantucket Harbor, the standard "build-out" and "no-load" water quality modeling scenarios were run. These runs included two "build-out" scenarios, based on potential development (described in more detail in Section IV), and a "no anthropogenic load" or "no load" scenario assuming only atmospheric deposition on the watershed and sub-embayment, as well as a natural forest within each watershed. Comparisons of the alternate watershed loading analyses are shown in Table VI-4. Loads are presented in kilograms per day (kg/day) in this Section, since it is inappropriate to show benthic flux loads in kilograms per year due to seasonal variability.

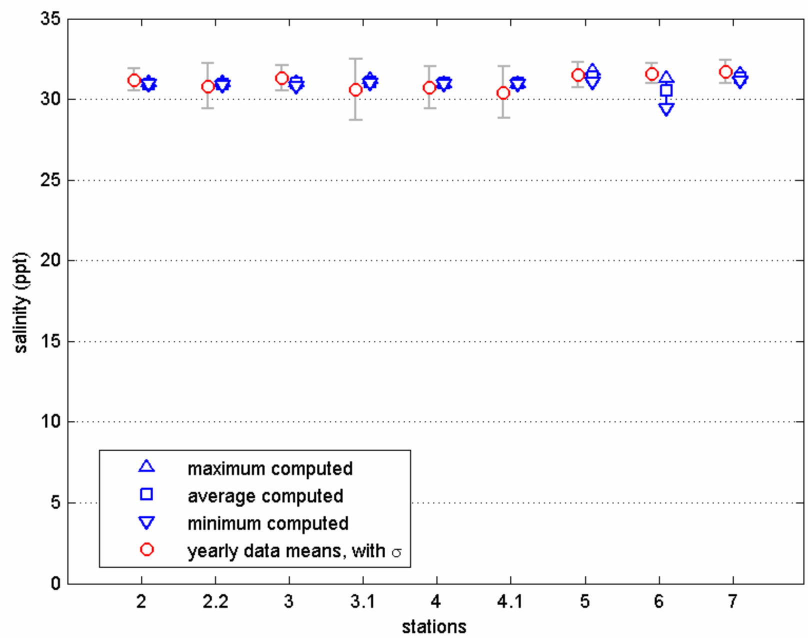

Figure VI-5. Comparison of measured and calibrated model output at stations in Nantucket Harbor. Stations labels correspond with those provided in Table VI-1. Model output is presented as a range of values from minimum to maximum values computed during the simulation period (triangle markers), along with the average computed salinity for the same period (square markers). Measured data are presented as the total yearly mean at each station (circle markers), together with ranges that indicate ± one standard deviation of the entire dataset.

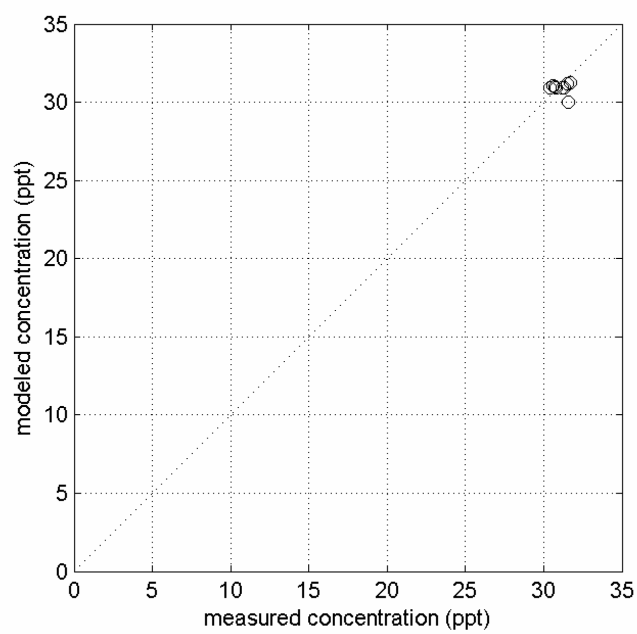

Figure VI-6. Model salinity target values are plotted against measured concentrations, together with the unity line. RMS error for this model verification run is 0.65 ppt or 2.03% of measurements.

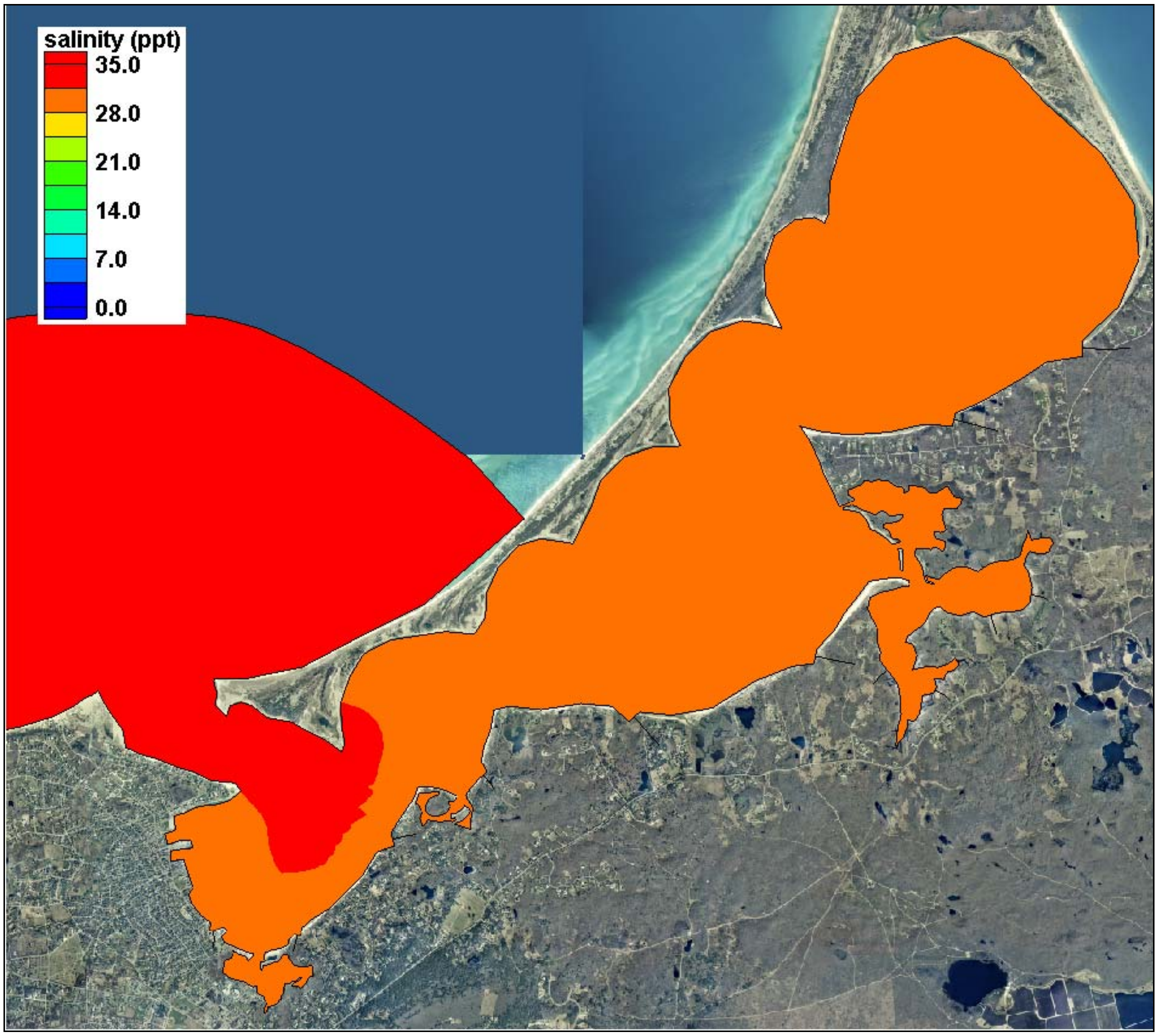

Figure VI-7. Contour Plot of modeled salinity (ppt) in the Nantucket Harbor system.

Table VI-4. Comparison of sub-embayment watershed loads used for modeling of present, build-out (scenarios "A" and "B"), and no-anthropogenic ("no-load") loading scenarios of the Nantucket Harbor system. These loads do not include direct atmospheric deposition (onto the sub-embayment surface) or benthic flux loading terms.

sub-embayment	present load (kg/day)	build out "A" (kg/day)	build-out "A" % change	build out "B" (kg/day)	build-out "B" % change	no load (kg/day)	no load % change
Head of the Harbor	1.858	2.375	+27.9%	2.375	+27.9%	0.526	-71.7%
Polpis Harbor	3.529	3.868	+9.6%	3.868	+9.6%	1.836	-48.0%
Quaise Basin	2.123	2.422	+14.1%	2.422	+14.1%	0.896	-57.8%
Town Basin	15.901	20.118	+26.5%	16.438	+3.4%	1.321	-91.7%
System Total	23.411	28.784	+22.9%	25.104	+7.2%	4.578	-80.4%

VI.2.6.1 Build-Out

Two build-out scenarios were modeled for the Nantucket Harbor system. For build-out scenario "A", wastewater loads from all developable properties with the Town sewer district were treated as septic groundwater inputs to the Town basin. For scenario "B", all remaining developable properties were assumed to be connected to the town sewer system and therefore not contribute to the groundwater load to the Harbor.

A breakdown of the total nitrogen load entering each sub-embayment is shown in Tables VI-5 and VI-6 for the two modeled build-out scenarios. The benthic flux for the build-out scenarios is assumed to vary proportional to the watershed load, where an increase in watershed load will result in an increase in benthic flux (i.e., a positive change in the absolute value of the flux), and *vise versa*.

Projected benthic fluxes (for both the build-out and no load scenarios) are based upon projected PON concentrations and watershed loads, determined as:

$$(Projected\ N\ flux) = (Present\ N\ flux) * [PON_{projected}]/[PON_{present}]$$

where the projected PON concentration is calculated by,

$$[PON_{projected}] = R_{load} * \Delta PON + [PON_{(present\ offshore)}],$$

using the watershed load ratio,

$$R_{load} = (Projected\ N\ load) / (Present\ N\ load),$$

and the present PON concentration above background,

$$\Delta PON = [PON_{(present\ flux\ core)}] - [PON_{(present\ offshore)}].$$

Table VI-5. **Build-out scenario "A"** sub-embayment and surface water loads used for total nitrogen modeling of the Nantucket Harbor system, with total watershed N loads, atmospheric N loads, and benthic flux.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)
Head of the Harbor	2.375	22.239	-17.677
Polpis Harbor	4.093	2.190	28.120
Quaise Basin	2.405	20.126	44.654
Town Basin	20.090	13.888	-2.659
System Total	28.964	58.443	52.439

Table VI-6. **Build-out scenario "B"** sub-embayment and surface water loads used for total nitrogen modeling of the Nantucket Harbor system, with total watershed N loads, atmospheric N loads, and benthic flux.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)
Head of the Harbor	2.375	22.239	-17.598
Polpis Harbor	4.093	2.190	27.709
Quaise Basin	2.405	20.126	44.274
Town Basin	16.411	13.888	-2.642
System Total	25.285	58.443	51.744

Following development of the nitrogen loading estimates for the build-out scenarios, the water quality models of each system were run to determine nitrogen concentrations within each sub-embayment (Table VI-7 and VI-8). Total nitrogen concentrations in the receiving waters (i.e., Nantucket Sound) remained identical to the existing conditions modeling scenarios. Results from both build-out scenarios are presented in Tables VI-7 and VI-8. For both cases the increase in modeled TN concentrations is less than 1% at all monitoring stations, with the largest increases occurring at the monitoring stations in Polpis Harbor Contour plots showing TN concentrations throughout the Harbor are presented in Figures VI-8 and VI-9, for both build-out scenarios.

Table VI-7. Comparison of model average total N concentrations from present loading and the **build-out scenario "A"**, with percent change, for the Nantucket Harbor system. The sentinel threshold station is in bold print.

Sub-Embayment	monitoring station (MEP ID)	present (mg/L)	build-out "A" (mg/L)	% change
Head of the Harbor - Upper	2	0.397	0.400	+0.7%
Head of the Harbor - Mid	2.2	0.390	0.392	+0.7%
Head of the Harbor - Lower	**2.1**	**0.353**	**0.355**	**+0.6%**
Pocomo Head	3	0.340	0.342	+0.6%
Quaise Basin	3.1	0.325	0.327	+0.5%
East Polpis Harbor	**4**	**0.361**	**0.364**	**+0.9%**
West Polpis Harbor	4.1	0.371	0.374	+0.9%
Abrams Point	5	0.296	0.297	+0.3%
Monomoy	6	0.291	0.292	+0.5%
Mooring Area	7	0.285	0.286	+0.3%

Table VI-8. Comparison of model average total N concentrations from present loading and the **build-out scenario "B"**, with percent change, for the Nantucket Harbor system. The sentinel threshold station is in bold print.

Sub-Embayment	monitoring station (MEP ID)	present (mg/L)	build-out "B" (mg/L)	% change
Head of the Harbor - Upper	2	0.397	0.398	+0.3%
Head of the Harbor - Mid	2.2	0.390	0.391	+0.3%
Head of the Harbor - Lower	**2.1**	**0.353**	**0.354**	**+0.3%**
Pocomo Head	3	0.340	0.340	+0.2%
Quaise Basin	3.1	0.325	0.326	+0.2%
East Polpis Harbor	**4**	**0.361**	**0.363**	**+0.5%**
West Polpis Harbor	4.1	0.371	0.373	+0.5%
Abrams Point	5	0.296	0.296	+0.1%
Monomoy	6	0.291	0.291	+0.1%
Mooring Area	7	0.285	0.285	+0.1%

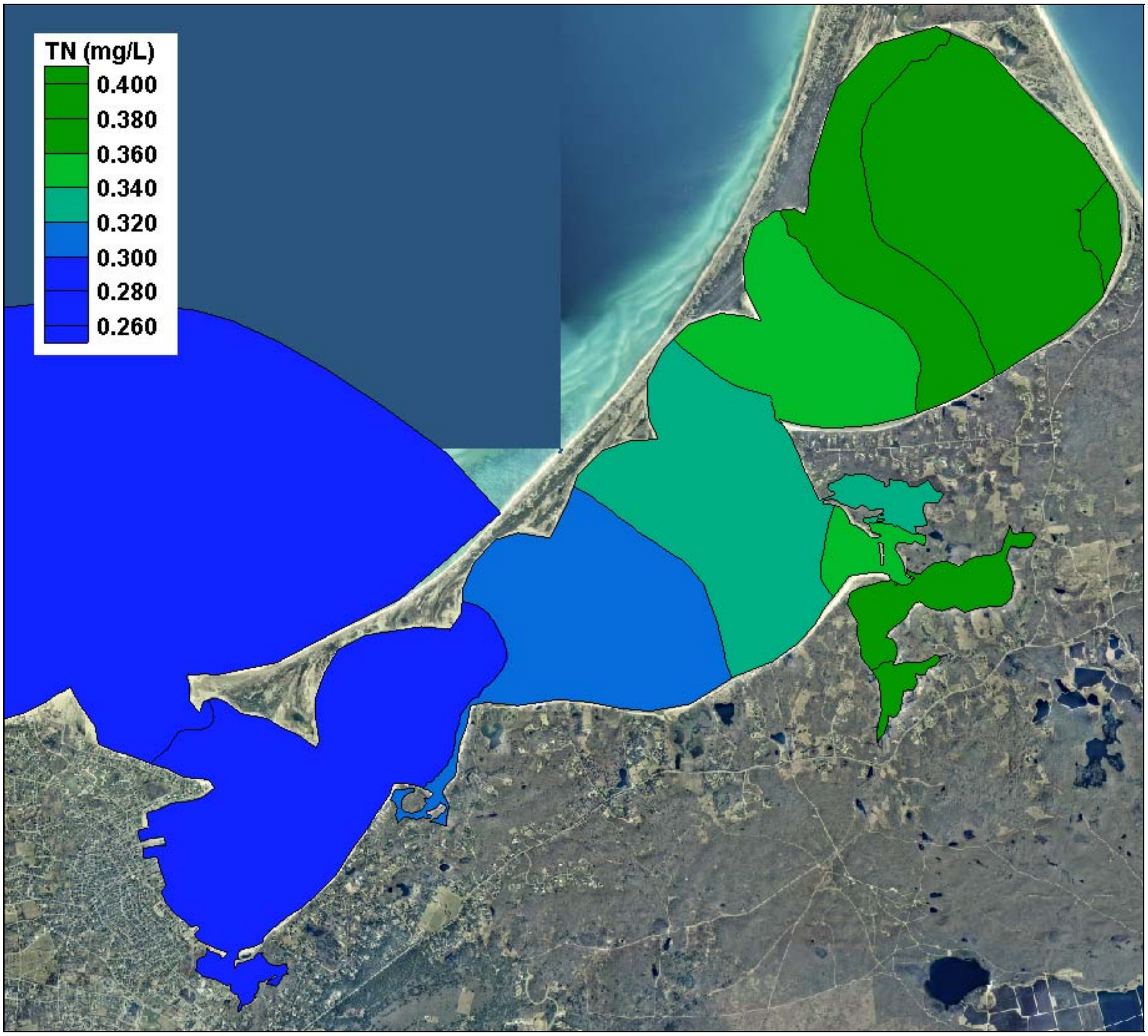

Figure VI-8. Contour plot of modeled total nitrogen concentrations (mg/L) in the Nantucket Harbor system, for projected build-out scenario "A" loading conditions.

VI.2.6.2 No Anthropogenic Load

A breakdown of the total nitrogen load entering each sub-embayment for the no anthropogenic load ("no load") scenarios is shown in Table VI-9. The benthic flux input to each embayment was reduced (toward zero) based on the reduction in the watershed load (as discussed in §VI.2.6.1). Compared to the modeled present conditions and build-out scenario, atmospheric deposition directly to each sub-embayment becomes a greater percentage of the total nitrogen load as the watershed load and related benthic flux decrease.

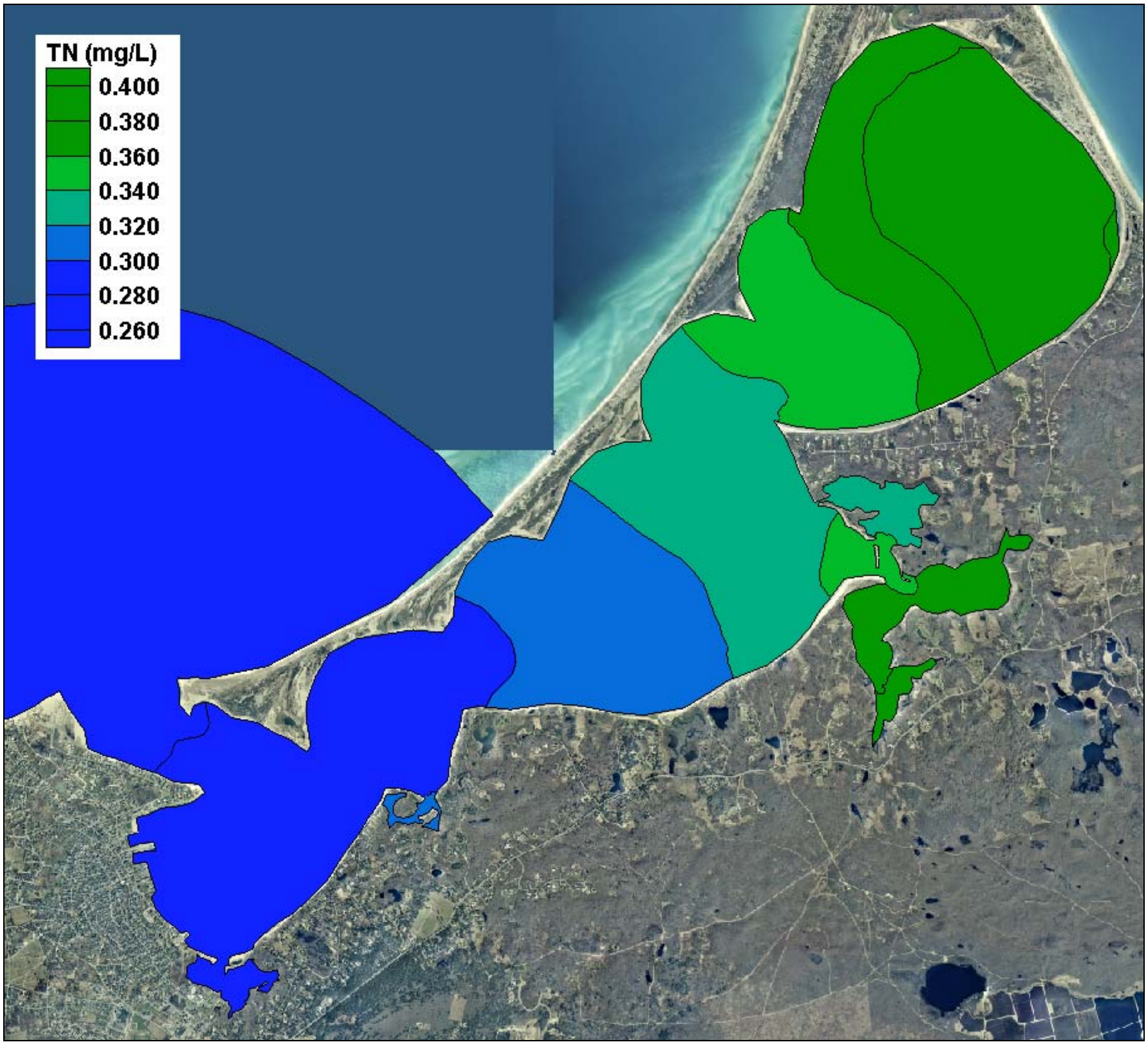

Figure VI-9. Contour plot of modeled total nitrogen concentrations (mg/L) in the Nantucket Harbor system, for projected build-out scenario "B" loading conditions.

Table VI-9. "**No anthropogenic loading**" ("no load") sub-embayment and surface water loads used for total nitrogen modeling of the Nantucket Harbor system, with total watershed N loads, atmospheric N loads, and benthic flux

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)
Head of the Harbor	0.526	22.239	-16.405
Polpis Harbor	1.836	2.190	25.226
Quaise Basin	0.896	20.126	41.619
Town Basin	1.321	13.888	-2.975
System Total	4.578	58.443	47.466

Following development of the nitrogen loading estimates for the no load scenario, the water quality model was run to determine nitrogen concentrations at each monitoring station. Again, total nitrogen concentrations in the receiving waters (i.e., Nantucket Sound) remained identical to the existing conditions modeling scenarios. The relative change in total nitrogen concentrations resulting from "no load" was small as shown in Table VI-10, with reductions less than 3% occurring at all stations in the Harbor system. A contour plot showing TN concentrations throughout the system is shown pictorially in Figure VI-10.

Table VI-10. Comparison of model average total N concentrations from present loading and the no anthropogenic ("no load") scenario, with percent change, for the Nantucket Harbor system. Loads are based on atmospheric deposition and a scaled N benthic flux (scaled from present conditions). The sentinel threshold station is in bold print.

Sub-Embayment	monitoring station (MEP ID)	present (mg/L)	no load (mg/L)	% change
Head of the Harbor - Upper	2	0.397	0.387	-2.5%
Head of the Harbor - Mid	2.2	0.390	0.380	-2.5%
Head of the Harbor - Lower	**2.1**	**0.353**	**0.345**	**-2.1%**
Pocomo Head	3	0.340	0.333	-2.0%
Quaise Basin	3.1	0.325	0.319	-1.8%
East Polpis Harbor	**4**	**0.361**	**0.351**	**-2.8%**
West Polpis Harbor	4.1	0.371	0.360	-2.9%
Abrams Point	5	0.296	0.293	-1.1%
Monomoy	6	0.291	0.286	-1.8%
Mooring Area	7	0.285	0.282	-1.0%

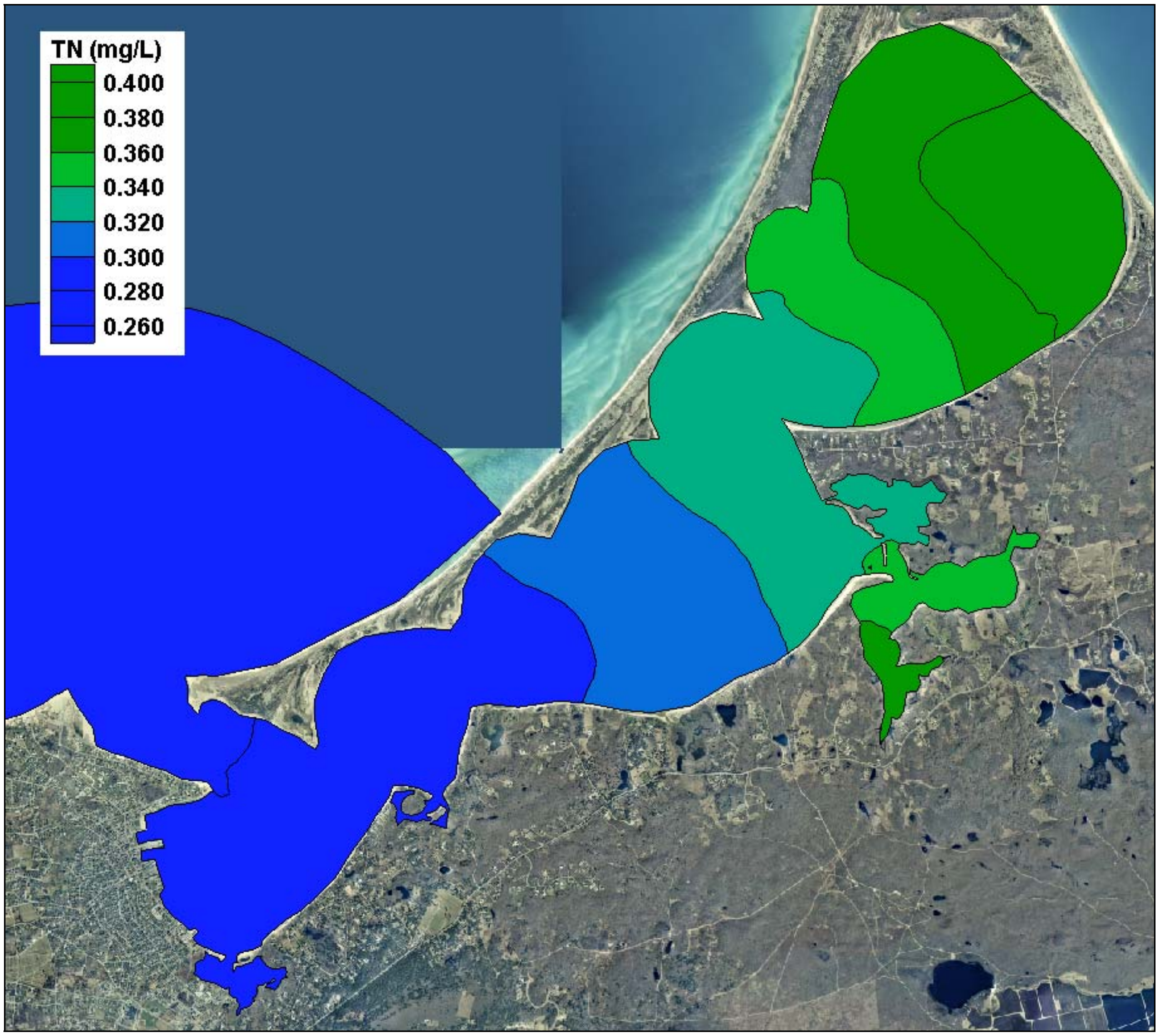

Figure VI-10. Contour plot of modeled total nitrogen concentrations (mg/L) in Nantucket Harbor, for no anthropogenic loading conditions.