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Development, Calibration, and Analysis of a Hydrologic and Water-Quality Model of the Delaware Inland Bays Watershed

Progress Report June 30–December 31, 2001

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Project Description

Problem

The Delaware Inland Bays (Figure 1) have experienced significant environmental degradation due to human activities over the past several decades. Excessive nutrients and sediment are among the most severe environmental stressors in the Inland Bays. The sources of nutrients, sediment, and other contaminants include point-source discharges from industries and wastewater-treatment plants, runoff and infiltration to ground water from agricultural fields and poultry operations, septic-system effluent, and atmospheric deposition.

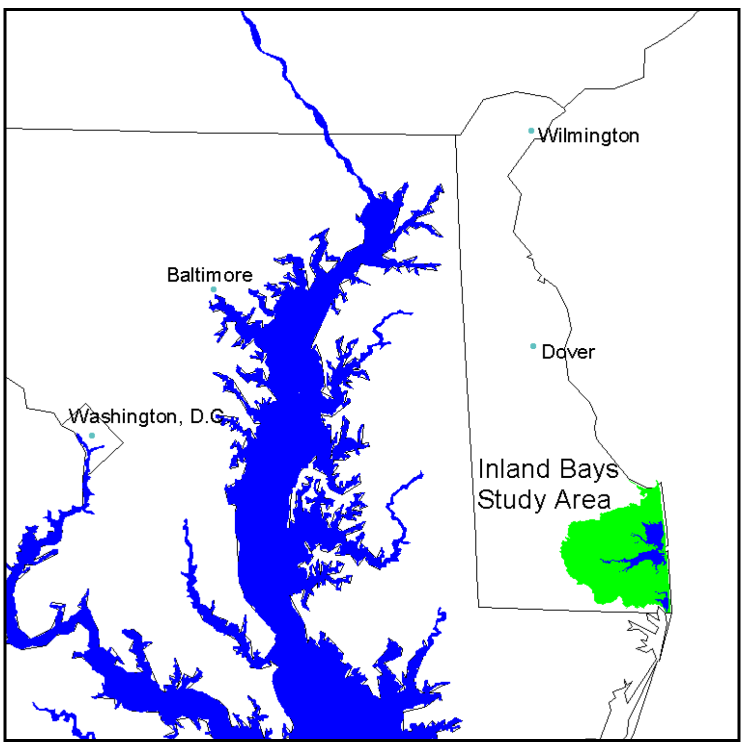

Figure 1. Location of the Delaware Inland Bays Watershed.

In order to determine how best to approach restoration of the Inland Bays, it is necessary to understand the relative distribution and contribution of each of the potential sources of nutrients, sediment, and other contaminants. It is also important to understand the hydrology of the Inland Bays Watershed in order to effectively restore them. Understanding the complex interrelations and interactions between hydrology and the various water-quality inputs is a prerequisite to restoration.

Objective

This project is a cooperative effort involving the Delaware Department of Natural Resources and Environmental Control (DNREC), the Delaware Geological Survey (DGS), and the U.S. Geological Survey (USGS). The objective of this project is to develop a hydrologic and water-quality model of the Delaware Inland Bays Watershed that can be used as a water-resources planning and management tool. The water-quality constituents of concern will be suspended sediment and nutrients (nitrogen and phosphorus). A well-documented model, Hydrologic Simulation Program—FORTRAN (HSPF), will be applied by the USGS to meet the objective.

The USGS role in this cooperative project is to construct, calibrate, and demonstrate the use of the hydrologic and water-quality model for the portion of the Inland Bays Watershed discharging to the Bays themselves. The following tasks are included in this role: (1) Compilation of existing hydrologic, climatological, water-quality, and ancillary data into model data sets; (2) construction and calibration of a hydrologic model; (3) construction and calibration of a water-quality model for suspended sediment, nitrogen, and phosphorus; (4) use of the model to simulate selected scenarios of the allocation of point and nonpoint sources; and (5) presentation of the model results to DNREC and DGS in the form of electronic model files, a written USGS report, and training in use of the model.

Background

The hydrologic and water-quality data needed to calibrate the model were collected during water year 1999 and the beginning of water year 2000. The USGS collected streamflow data at six stations in the Delaware Inland Bays Watershed, and the University of Delaware and DGS collected water-quality data at the same six stations for the same time period. All the streams for which data were collected (except Munchy Branch, 01484668) are on Delaware's 303(d) list, and all six streams also were monitored as part of Delaware's water-quality monitoring program in water years 1999 and 2000.

Responsibilities

USGS is responsible for developing the HSPF model framework and for model calibration. The framework of the model is based on Geographic-Information-System (GIS) data in ARC/INFO format previously prepared by USGS for DGS, and supplemented by DNREC and other agencies as appropriate. GIS data include land use, geology, soils, digital-elevation-model (DEM) data, drainage basins, stream network, data-collection points, and point-source discharges. The data sets will be properly attributed and include critical information such as fertilizer application rates and timing for agricultural areas and lawns. USGS will use the GIS data to build the framework of the model and produce appropriate model segmentation. USGS will provide streamflow data and assemble climatological data for model operation.

DNREC is responsible for providing existing water-quality data including suspended-sediment, nitrogen, and phosphorus concentrations for calibration points and other model nodes of interest. These data will include all the water-quality data collected by the University of Delaware and DGS during 1999 and 2000 at the six established stream stations mentioned above, as well as any other pertinent water-quality data for the Inland Bays Watershed. DNREC will also provide quantity and quality data for point-source discharges to streams in the study area, and supply or facilitate the obtaining of other data needed for the model application, including stream hydraulic characteristics and fertilizer-application data.

DGS is responsible for supplying selected data that may enhance the model application, including analysis and interpretation of results. DGS provides coordination between USGS and DNREC as appropriate.

Progress

During the reporting period (June 30-December 31, 2001), the following tasks were completed by the USGS:

1. Allocation of agricultural land acreages into the five simulated crop categories using the 1997 Agricultural Census data.

2. Development of nutrient application rates; this information was processed and incorporated into the simulation.

3. Development of water-quality database for HSPF model calibration.

4. Meteorological data was updated to include hourly observations from the station located in Georgetown.

5. Development of binary files containing the atmospheric deposition inputs, septic information, and point source data.

1. Allocation of Agricultural Acreages to Crop Acreages

The 1997 Delaware Office of Planning (DOP) land use/land cover data was allocated to the model segments (Table 1). Taking into consideration the lack of specific information for model parameter values, the given categories were aggregated into four broader classifications as follows: (1) forest, wetland, barren and brush categories were aggregated into a "forest" land use; (2) crops and orchards categories were aggregated into "crops"; (3) the pasture category stayed as "pasture"; and (4) low, medium, and high residential as well as institutional, industrial, and commercial categories were aggregated into an "urban" classification. This urban class was then divided into pervious and impervious using information provided by DNREC on the percent of imperviousness within the county. For simulation purposes, and using the 1997 Agricultural Census Data and information provided by the Division of Soil and Water Conservation of the District Operations from the State of Delaware, the crops category was divided into five classifications which are: corn, full-season beans, double crops, vegetables, and hay.

2. Development of Nutrient Application Rates

Mineral and animal waste fertilizer calculations were based on methodologies developed for the Chesapeake Bay Model, and found in Appendix H of the Watershed Model documentation (1998, Chesapeake Bay Watershed Model Applications and Calculations of Nutrient and Sediment Loads, Appendix H: Tracking Best Management Practice Nutrient Reductions in the Chesapeake Bay Program: U.S. Environmental Protection Agency, Chesapeake Bay Program). The University of Maryland (Wye Research and Education Center) guided modifications to these methodologies. Nutrient application rates were based on a mass balance between the animal wastes produced within each model segment and the expected average yield in the corresponding county, reported in the 1998 Delaware Statistics. These nutrient application rates were developed taking into consideration the high degree of uncertainty in the development of nutrient balances for each cropland category and to define information representative of field and farm practices.

Table 1.Land use in acres by model segment.

SEG	Corn	Full-season beans	Double crops	Vegetables	Hay	Forest	Pasture	Pervious Urban	Impervious Urban
10	28.0	35.2	16.8	7.4	0.6	26.0	0.0	117.4	97.5
20	251.0	315.6	150.6	66.0	5.0	1364.6	0.0	1391.3	1003.3
30	612.8	770.3	367.7	161.0	12.1	1751.2	16.8	201.8	106.3
40	861.4	1082.9	516.8	226.4	17.0	2152.8	80.9	563.3	314.0
50	630.9	793.2	378.5	165.8	12.5	2864.5	0.0	449.5	218.6
60	364.2	457.9	218.5	95.7	7.2	2765.1	18.8	672.8	475.3
70	574.3	722.0	344.6	150.9	11.4	1271.7	13.2	129.0	106.1
80	286.0	359.5	171.6	75.2	5.7	782.7	0.0	82.0	66.9
90	87.0	109.4	52.2	22.9	1.7	400.5	0.0	219.1	112.3
100	463.2	582.3	277.9	121.7	9.2	2360.8	35.1	508.1	440.7
110	52.1	65.5	31.3	13.7	1.0	705.5	23.1	129.7	221.0
120	724.9	911.3	434.9	190.5	14.3	3062.5	41.6	1235.2	1256.1
130	201.7	253.6	121.0	53.0	4.0	2021.0	0.0	137.1	110.9
140	450.2	566.0	270.1	118.3	8.9	3201.7	13.7	347.0	193.2
150	170.5	214.3	102.3	44.8	3.4	1314.4	0.0	366.1	468.4
160	229.6	288.7	137.8	60.3	4.5	1096.1	27.3	373.7	252.3
170	490.2	616.2	294.1	128.8	9.7	1021.7	0.0	287.8	229.6
180	424.3	533.4	254.6	111.5	8.4	1130.9	7.0	237.5	168.1
190	394.6	496.1	236.8	103.7	7.8	386.3	0.0	302.6	198.9
200	762.6	958.7	457.6	200.4	15.1	2341.7	12.8	152.8	120.8
210	466.9	586.9	280.1	122.7	9.2	2596.5	0.0	164.3	126.1
220	429.1	539.5	257.5	112.8	8.5	1776.2	1.8	180.0	133.8
230	333.4	419.1	200.0	87.6	6.6	690.2	0.0	81.5	73.2
240	163.8	206.0	98.3	43.1	3.2	285.8	0.0	190.6	146.3
250	706.2	887.8	423.7	185.6	14.0	1167.8	0.0	126.7	180.1
260	830.4	1044.0	498.3	218.2	16.4	1864.0	8.1	229.0	175.8
270	625.9	786.8	375.5	164.5	12.4	1415.6	0.0	95.0	116.5
280	387.0	486.5	232.2	101.7	7.7	2887.9	18.1	669.5	784.3
290	832.0	1046.0	499.2	218.7	16.5	1969.0	38.6	246.3	288.4
300	1608.3	2021.9	965.0	422.7	31.8	6737.0	13.6	626.4	580.9
310	469.7	590.4	281.8	123.4	9.3	525.3	6.0	120.1	93.4
320	468.3	588.7	281.0	123.1	9.3	2080.8	72.1	697.5	469.8
330	351.0	441.3	210.6	92.2	6.9	240.1	7.4	135.2	93.3
340	574.9	722.7	344.9	151.1	11.4	2135.1	28.2	1172.2	707.3
350	197.8	248.6	118.7	52.0	3.9	1006.7	0.0	318.1	231.2
360	839.2	1055.0	503.5	220.5	16.6	1215.4	41.9	250.5	213.4
370	907.4	1140.7	544.4	238.5	17.9	2769.9	66.7	541.6	446.1
380	6.6	8.2	3.9	1.7	0.1	407.1	0.0	170.5	153.1
390	111.5	140.2	66.9	29.3	2.2	1220.3	0.0	812.6	574.1
400	0.0	0.0	0.0	0.0	0.0	1675.7	0.0	127.0	138.0
410	204.5	257.1	122.7	53.8	4.0	1455.4	26.4	215.2	217.5
420	545.2	685.4	327.1	143.3	10.8	5514.0	52.6	1980.6	1356.7
440	0.4	0.4	0.2	0.1	0.0	262.4	16.2	600.2	374.4
450	548.5	689.5	329.1	144.1	10.8	2037.8	0.0	362.0	315.1
470	430.6	541.3	258.3	113.2	8.5	842.6	25.2	383.5	365.1

2.1. Animal counts

The Sussex Conservation District of the State of Delaware provided animal count information for 1999. The information was provided in a GIS format, which was overlaid with the model segmentation to allocate the animal numbers to the model segments (Table 2). This data was used to calculate the amount of animal waste available for application to cropland, and to calculate "manure acres," a derived land use to represent what was susceptible to runoff from feedlot operations.

2.2. Animal units and manure acres

"Manure acre" is a derived land use to represent what is susceptible to runoff from feedlot operations. Although in the Inland Bays Watershed these loads represent less than 1% of the total loads, manure acres were incorporated in the simulation and were calculated through the following procedure: the number of animals in each model segment was divided by the conversion factors found in Table 3 to obtain animal units. These animal unit values were then multiplied by the fraction of time confined and divided by a "compromise animal density" of 145 animal units per acre to yield the final number of manure acres (CBP, 1994). The animal categories used to calculate manure acres were beef and dairy cattle, swine, horses, and sheep. The associated manure acres were subtracted from the pastureland use category. The assumption for this allocation was that manure is stored and treated through the implementation of control programs, and that a portion of these acres would revert back to pasture acres. Because control actions such as guttering, diversions, and manure containment are not totally effective, some proportion of each manure acre remains in the manure land use to account for control efficiencies of less than 100% (CBP, 1994).

Table 2. Animal count by animal type and model segment.

SEG	BEEF	SWINE	HORSES	SHEEP	POULTRY[1]
30	50	0	0	0	273800
40	100	0	24	0	185600
50	0	0	0	0	56000
80	41	0	0	0	0
90	39	0	0	0	0
100	0	0	0	0	32000
120	0	0	0	20	80000
140	20	0	0	0	305000
150	0	0	0	0	36000
160	0	0	0	0	186200
170	0	0	0	0	379000
180	0	0	0	0	366900
190	0	0	0	0	230000
200	0	0	0	0	289667
210	0	0	0	0	248200
220	0	0	0	0	278900
230	0	0	0	0	228500
240	0	0	0	0	318000
250	0	0	0	0	131000
260	0	0	0	0	403800
270	0	200	0	0	294000
280	0	1050	0	0	478000
290	0	0	0	0	475100
300	0	1536	0	0	1464500
310	0	0	0	0	402000
320	0	100	0	0	1207600
330	0	0	0	0	441000
340	0	0	50	0	318000
350	0	0	0	0	32000
360	0	200	0	0	1129200
370	0	0	0	0	809800
390	0	0	0	0	54000
410	0	0	0	0	282000
420	0	0	0	0	0
450	0	0	0	0	431800
470	130	0	0	0	1004000

[1] For this study, the poultry count was assumed to be a "layers" type.

Table 3. Conversion factors used to calculate manure acres based on confinement by animal type.

Animal Type	Animals/Animal Unit	Fraction of Time Confined	Fraction of Time Unconfined
Beef	1	0.2	0.8
Dairy	0.71	0.8	0.2
Hogs	5	1.0	0.0
Sheep	5	0.5	0.5
Horses	0.855	0.5	0.5
Poultry	250	1.0	0.0

2.3. Manure calculations

Animal waste applied to cropland was calculated on the assumption that manure was stored throughout the year for spring and fall applications; in the case of pastureland, it was assumed that animal waste is applied throughout the year except in the winter months of December, January, and February. The allocation of animal waste to crops was based on the assumption that animal waste generated in a segment was applied to the crops in the same segment; however, there were cases in which land use records indicated that crops were cultivated in a particular segment and animal waste was not available for application within the segment. For these particular cases, animal count from nearby segments were added, and reallocated according to the agricultural acreage per segment to the same group of segments but including the segment with no animal population. Table 4 contains information on the selected group of segments where relocation of animal waste was performed.

Table 4. Group of segments where animal waste relocation was assumed.

From Segments	To Segments
	Group 1
30, 40, 50, 420	10, 20, 30, 40, 50, 60, 70, 420
	Group 2
80, 90, 100, 120	80, 90, 100, 110, 120
	Group 3
250	130, 250
	Group 4
310, 320, 330, 340, 350, 360, 370, 390, 410	310, 320, 330, 340, 350, 360, 370, 390, 410

Within the Inland Bays Watershed, ninety-nine percent of the organic fertilizer comes from poultry waste and less than one percent is derived from other animal types, according to the animal population data reported by the Sussex Conservation District. In the modeling effort, poultry count was assumed to be a layers type, as recommended by the Sussex Conservation District; the count was defined in terms of animal units using values from Table 3, and the amount of animal waste available for application to pasture and cropland was based on the assumed amount of time that the animals spent in confinement.

The amounts of organic fertilizer were then expressed in terms of total nitrogen (TN) and total phosphorus (TP) per animal unit, and calculated using data from Table 5. Poultry values presented in Table 5 are capacity-based assuming 5.5 flocks per year. (For the calculation of per flock values in parentheses in the table, the manure constants were divided by 5.5 flocks per year, representing the amount of nitrogen and phosphorus contained in a pound of poultry waste per animal unit per flock, and with approximately 20% moisture content.) Once TN and TP were calculated, runoff and volatilization losses from

Table 6 were applied to obtain the final amounts of TN and TP in lb/yr to be applied to pasture and cropland. Values of TN and TP are then multiplied by the mass fraction values from

Table 7 to derive the forms of nutrients simulated by the HSPF AGCHEM module; these forms include: (1) nitrate (NO3); (2) ammonia (NH4) (adsorbed and dissolved); (3) organic nitrogen (ORN); (4) orthophosphate (PO4) (adsorbed and dissolved); and (5) organic phosphorus (ORP). Mass fraction values for animal waste were obtained from the Chesapeake Bay Program Office.

Table 5. Manure constants. Poultry values are based on capacity, assuming 5.5 flocks per year. Values in parentheses indicate per animal values, assuming 5.5 flocks per year.

Animal	N per animal unit (lb/yr)	P per animal unit (lb/yr)
Beef	113.15	40.15
Dairy	164.25	25.55
Swine	153.30	58.40
Poultry	207.52 (37.73)	84.98 (15.45)
Sheep	113.15	40.15
Horses	113.15	40.15

Table 6. Runoff losses and volatilization factors.

Animal Type	Fraction Not Volatilized or Lost to Runoff	
	N	P
Beef	0.30	0.85
Dairy	0.40	0.85
Swine	0.25	0.85
Poultry	0.69	1.0

Table 7. Mass fractions per animal type.

Animal Type	NH3	ORN	PO4	ORP
Beef, Dairy, Swine, Sheep, Horses	0.48	0.52	0.17	0.82
Poultry	0.22	0.78	0.38	0.62

2.4. Nutrient applications

For the simulation of pasture, it was assumed that manure is the only source of fertilizer and 15% volatilization losses are applied during the model simulation. The ordering procedure for nutrient applications was as follows:

- Manure is applied to 75% of the corn acres; the other 25% receive mineral fertilizer. If there is not enough manure, mineral fertilizer will supplement as needed.
- If manure remains after application to corn acres, it will be applied to 10% of the double crop acres. Otherwise, 100 % of the double crop acres receive mineral fertilizer.
- If manure remains after application to double crops, it is applied to full-season beans for up to 50% of the expected plant uptake.
- If additional manure remains, it is applied to pasture land.
- The ratio of nitrogen to phosphorus in mineral fertilizer applied to agricultural land is assumed to be 5:1, except for applications to double crops, which is assumed to be 2.5:1.

2.5. Recommended fertilizer applications

The recommended applications refer to the amount of fertilizer that a farmer applies and expects to be used by the crops during their growing cycle. The yield of the crop, however, will increase or decrease from year to year based on meteorological conditions in the area. Crop goal yields for corn, full-season beans, double-crops, hay-alfalfa, and hay-grass are shown in Table 8; the goal yield was used to determine the nutrient application rates for nitrogen and phosphorus. Nutrient application rates were increased by 15% as an uncertainty factor for cases where nutrient applications exceed the recommended.

Table 8. Crop goal yields.

CROP	GOAL YIELD	UNITS
Corn	130	Bushels/acre
Full-Season Beans	50	Bushels/acre
Double crops	40	Bushels/acre
Hay-alfalfa	5.0	Tons/acre
Hay-grass	3.0	Tons/acre

The goal yield was used to compute the total plant uptake under average conditions. Multiplication factors representing TN and TP content in the grain, fodder, and roots were provided by the Wye Research Institute to determine the target uptake by crop type as shown in Table 9. The calculated values (goal yield multiplied by the multiplication factor) were input to the model through the NIT-YIELD and PHOS-YIELD tables, which represent the total annual target for plant uptake of nitrogen and phosphorus for all soil layers during the simulated year (Table 10).

Table 9.Multiplication factors used to determine TN and TP for the NIT-YIELD and PHOS-YIELD tables.

	Corn (lb/bushel)		Full-season beans (lb/bushel)		Double crops (lb/bushel)	
	TN	TP	TN	TP	TN	TP
Grain	0.8	0.15	3.6	0.35	1.0	0.21
Fodder	0.5	0.05	1.1	0.1	0.5	0.08
Roots	0.2	0.04	0.7	0.09	0.3	0.05
Total	1.5	0.24	5.4	0.54	1.8	0.34

Table 10.Values of TN and TP for the NIT-YIELD and PHOS-YIELD tables.

Crop Type	TN	TP
Corn	195	31
Double Crops	110	20
Full-Season Beans	270	27
Hay	62	16
Vegetables	150	18

2.6. Schedule of modeled manure applications

Manure was applied according to the schedule shown in Table 11. For pasture, manure was applied throughout the year except for the months of December, January, and February. Manure was applied to specific soil layers for different crop types as follows:

Corn → Applied to the soil surface (10%) and to the upper zone (90%)

Full-season beans → Applied to the surface (50%) and upper zone (50%)

Double crops → Applied to the surface (10%) and the upper zone (90%)

Table 11. Manure applications to crops.

Crop Type	APPLICATIONS						
	March	April	May	September	October	November	December
Corn	25%	25%		10%	20%	10%	10%
Double Crops	10%	10%			80%		
Full-Season Beans	40%	30%	30%				
Hay	40%	30%	30%				
Vegetables	40%	30%	30%				

2.7. Schedule of modeled mineral fertilizer applications

Mineral fertilizer was applied according to the following schedule:

Corn → 20% of application at planting

80% of application 30 to 40 days after planting

Double crops → 10% of N application daily throughout the month of October

20% of N application daily throughout the month of February

70% of N application daily throughout the month of March

100% of P application daily throughout the month of October

Full-season beans → 100% of P application daily throughout the month of May

3. Development of Water-Quality Database for HSPF Model Calibration

All water-quality data to be used for model calibration (including field parameters and laboratory analyses of nitrogen and phosphorus species concentrations and total suspended solids concentrations) were provided by DNREC. These data are taken from the Inland Bays TMDL database, version 6.23 (Andres, Savidge, and others, 2001), that is described in a report by Ullman, Scudlark, and Andres (2001), and that is available at the Delaware Geological Survey's World Wide Web site (http://www.udel.edu/dgs/ftp/cisnet/CHEMDATA/). All methods used for sample collection, processing, preservation, and analysis are described in Ullman, Scudlark, and Andres (2001).

The water-quality data provided by DNREC are in the form of a Microsoft Access database, for a number of analyzed constituents and in specified concentration units (Table 12). Two additional steps were performed in order to make the data directly comparable with HSPF-simulated constituents. The first step was to convert concentrations in μM (micromoles/L) to concentrations in mg/L (as C, N, or P), by multiplying the reported values by the atomic weights of carbon (12.011 g/mol), nitrogen (14.0067 g/mol), or phosphorus (30.97376 g/mol), and then dividing by 1000. The second step was to derive a number of other quantities, such as total nitrogen and total phosphorus, that are necessary for model calibration and that were not reported by DNREC. The derivations of these quantities are shown in Table 12.

Table 12. Carbon, nitrogen, and phosphorus constituents reported by DNREC with reported units and units required for HSPF calibration, as well as constituent values derived from reported values (derived constituents are in bold).

Reported or Derived Parameter	Symbol	Reported Concentration Unit	Required Concentration Unit	Derivation
Dissolved Organic Carbon	DOC	μM	mg/L as C	
Particulate Organic Carbon	POC	μM	mg/L as C	
Total Organic Carbon	**TOC**		**mg/L as C**	**TOC = POC + DOC**
Nitrate + Nitrite	NO23	μM	mg/L as N	
Ammonium	NH4	μM	mg/L as N	
Total Dissolved Nitrogen	TDN	μM	mg/L as N	
Particulate Organic Nitrogen	PON	μM	mg/L as N	
Dissolved Inorganic Nitrogen	**DIN**		**mg/L as N**	**DIN = NO23 + NH4**
Dissolved Organic Nitrogen	**DON**		**mg/L as N**	**DON = TDN - DIN**
Total Organic Nitrogen	**TON**		**mg/L as N**	**TON = PON + DON**
Total Nitrogen	**TN**		**mg/L as N**	**TN = PON + TDN**
Phosphate	PO4	μM	mg/L as P	
Total Dissolved Phosphorus	TDP	μM	mg/L as P	
Particulate Organic Phosphorus	POP	μM	mg/L as P	
Dissolved Organic Phosphorus	**DOP**		**mg/L as P**	**DOP = TDP - PO4**
Total Organic Phosphorus	**TOP**		**mg/L as P**	**TOP = POP + DOP**
Total Phosphorus	**TP**		**mg/L as P**	**TP = TDP + POP**

4. Update of Meteorological Data

HSPF simulations are mostly driven by the precipitation data and it is expected that the quality of the simulation be in great part a function of the quality of the precipitation data. For the Inland Bays Watershed model, simulations are run on an hourly basis and the period in which the stream discharged was recorded at the gage established the period of the calibration and therefore the period of the simulation. For the majority of the streams in the Inland Bays Watershed, this period started in the fall of 1998 and ended during the spring of 2000, with the exception of the basins draining to Millsboro Pond (01484525) and Beaverdam Ditch (01484695) in which discharge records are still collected. Precipitation data was obtained from the National Climatic Data Center (NCDC). The closest NCDC gage recording hourly precipitation (073570 at Georgetown) provided information between 1998 and present time; two additional stations recording daily values of precipitation were also analyzed as potential information for the simulation: (1) station 075320 located in Lewes, DE, provided inputs between January, 1998, and December, 2000; (2) station 180335 located on Assateague Island, MD, and approximately 40 km south of the Inland Bays was also analyzed but the data was not used because of the distance from the Watershed. The period of record used for the simulation is shown in Table 13 while Figure 2 shows the location of the precipitation stations evaluated for use in the simulations. To allocate daily into hourly precipitation, proportions of hourly rainfall from station 075320 (Georgetown, DE) were used. To guarantee the complete allocation of the daily precipitation, a default allocation of 1/24 was used for days in which precipitation did not occur at the auxiliary station.

The second meteorological dataset used in the simulation was pan evaporation obtained from records developed by the Chesapeake Bay Program Office for the region.

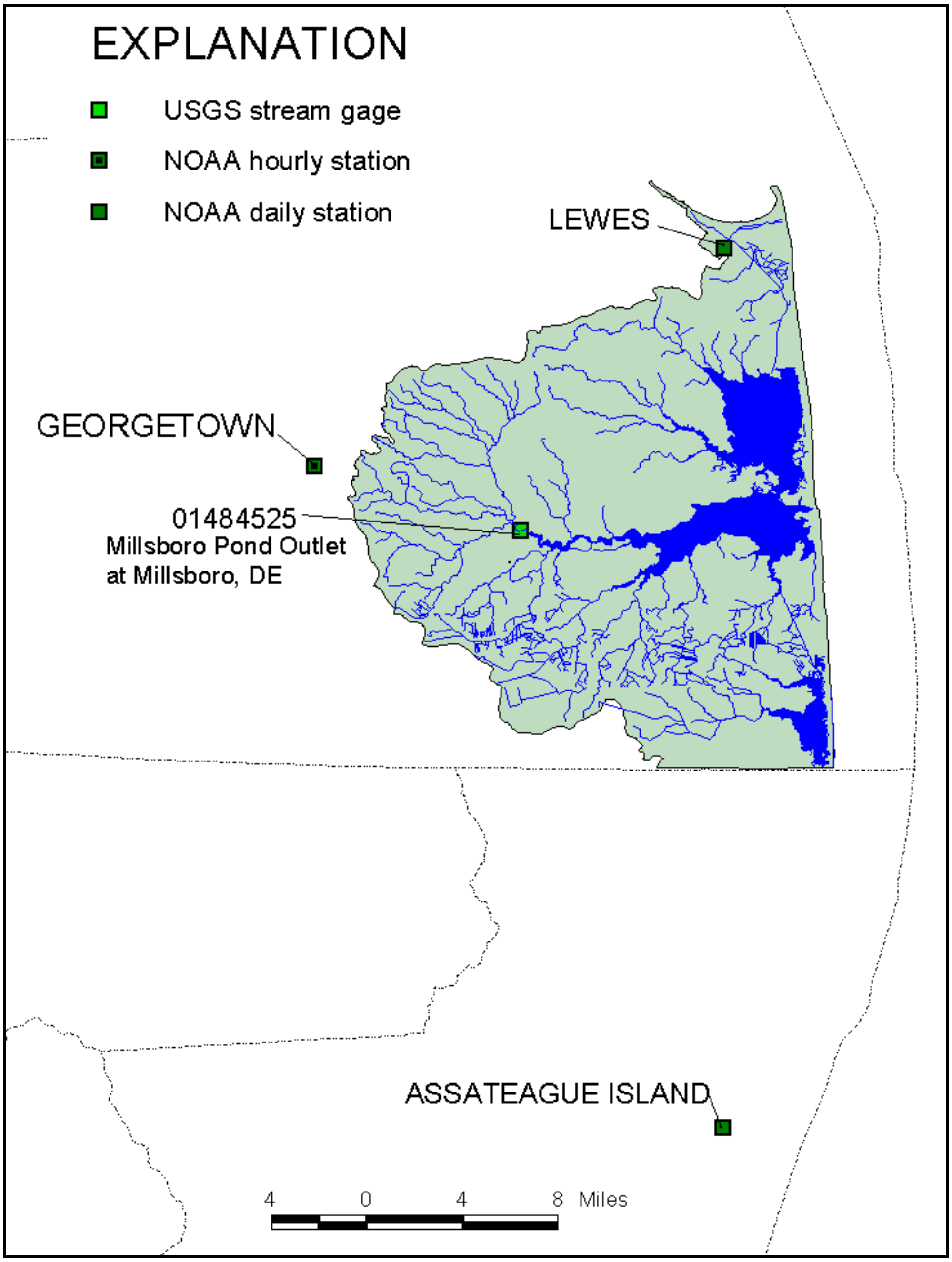

Figure 2.Inland Bays Watershed and location of gages recording precipitation data.

5. Development of Binary Data Files

5.1. Atmospheric deposition

As part of the nutrient balance, atmospheric deposition was input as NO3 (wet and dry) and NH4. This information was produced through the application of a regression model, and was obtained from the time series for the Chesapeake Bay Watershed Model, developed by the EPA-Chesapeake Bay

Program Office. The average annual deposition values are 7.05 (lbs/acre) for NO3, and 2.08 (lbs/acre) for NH4.

Table 13. Stations used in the analysis of precipitation data.

Agency	Data Type	Station ID	Available period of record	Location	Period of record used	Segments calibrated	Comments
NCDC	HR	073570	1984 - 1997	Georgetown, DE	01/98 - 07/01	130 - 450	Used to allocate daily into hourly precipitation and for the simulation of the Millsboro watershed
NCDC	DY	075320	1984 - 2000	Lewes, DE	01/98 - 05/00	10 - 30	Data allocated into hourly using METCMP
NCDC	DY	180335	1984 - 2000	Assateague I., MD	01/98 - 05/00	310 - 330	Data allocated into hourly using METCMP

5.2. Septic information

GIS methodologies were used to determine the septic information by model segment. The Inland Bays Watershed segmentation was overlaid with the GIS layer provided by DNREC with the septic information to determine the frequency of septic by segment. The number of individuals using each septic unit was calculated at the county level using U.S. census data compiled by EPA (1998, Chesapeake Bay Watershed Model Applications and Calculations of Nutrient and Sediment Loads, Appendix H: Tracking Best Management Practice Nutrient Reductions in the Chesapeake Bay Program: U.S. Environmental Protection Agency, Chesapeake Bay Program). The mean EPA Bay Program NO3-N loading coefficient (0.0256 lb per person per day) was used to generate estimated loads per model segment, which were incorporated in the simulation as an edge of stream load. Phosphorus was assumed to be 100% retained.

5.3. Point sources

Point source information was obtained from DNREC, who provided data from the Permit Compliance System (PCS). The PCS is a database management system that supports the National Pollutant Discharge Elimination System (NPDES) regulations. Loadings from the municipal facility located at Georgetown (Figure 3) were incorporated to the simulation because of the location of the facility in the non-tidal area. Flow and concentrations are reported as monthly average values in units of million of gallons per day (MGD) for flow, and milligrams per liter (mg/L) for concentrations. This information was input into the model as a load in pounds per day (lb/day) in a time series format for the following constituents: BOD5, TSS, DO, NH3, NO3, PO4, and FLOW.

Plans for Next Six Months

1. Modify assumptions in the development of nutrient application rates as needed. This progress report describes all of the assumptions made and methods used to develop source (N and P manure and mineral fertilizer) and observation (water-quality data) databases. Evaluation by DNREC is necessary to corroborate these methods and assumptions.

2. Complete calibration of sediment and nutrients. An initial calibration is complete; however, this is subject to corroboration of the methods and assumptions (see above). Final calibration can be performed once the methods and assumptions have been validated.

3. Present calibration to DNREC for approval. A meeting will be scheduled for early March to present initial calibration with the methods and assumptions described in this progress report. Any necessary adjustment will be accomplished soon after this meeting. Another meeting will be scheduled for early April to present final calibration.

4. Transfer HSPF model files to DNREC. Once final calibration is complete in April, all files required for HSPF model simulation will be delivered to DNREC.

5. Begin working with DNREC staff on scenario generation using GENSCN.

6. Draft final report. A report outline and purpose and scope, along with a report-planning package, were completed earlier in the study period, and were included with the previous semi-annual progress report. Portions of the final report relating to methods and database development, as well as the methods and assumptions, have been drafted. A complete final draft ready for colleague review will be completed during the first half of 2002.

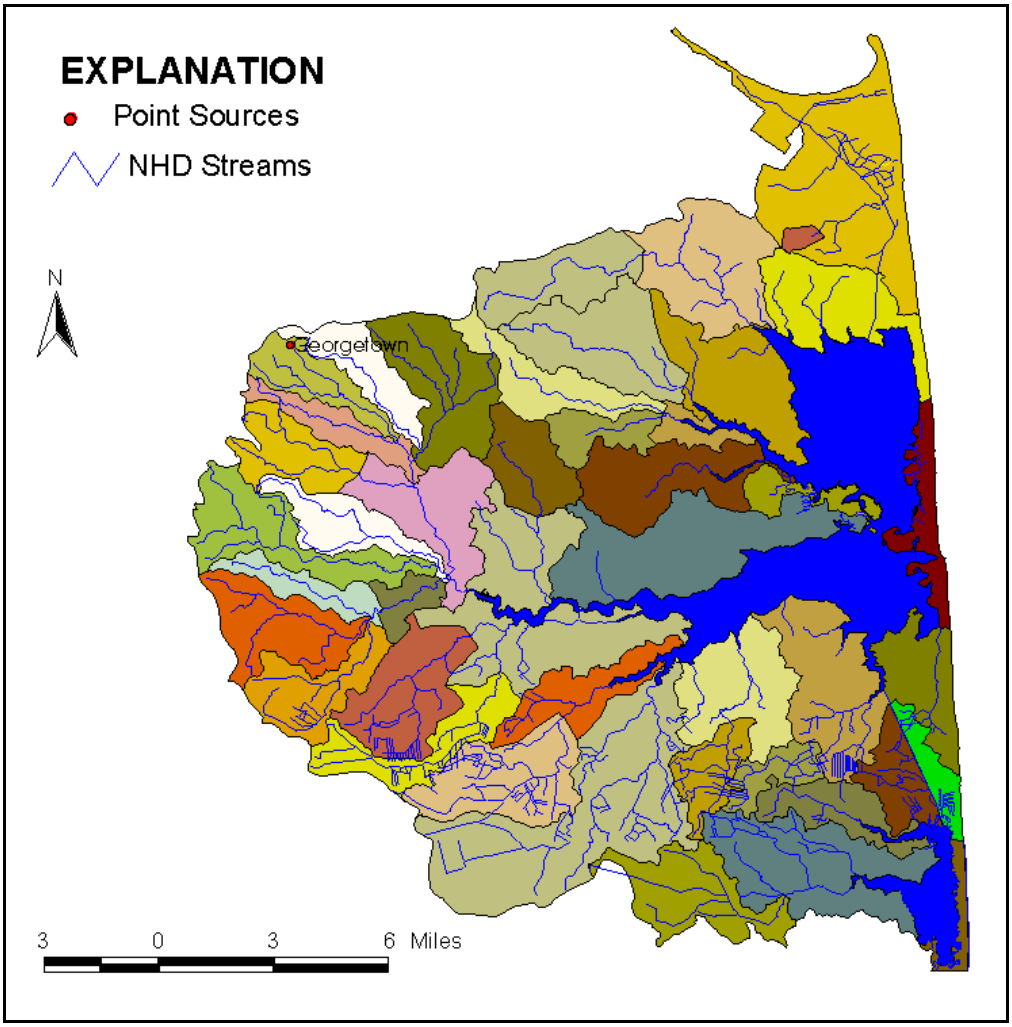

Figure 3. Location of the point source incorporated into the Inland Bays Watershed model simulation.

References

Andres, A.S., Savidge, K.S., Scudlark, J., and Ullman, W.J., 2001, IBTMDL612 database: Delaware Geological Survey Digital data product No.02-001.

Ullman, W.J., Scudlark, J., and Andres, A.S., 2001, Storm-water sampling and analysis in the Inland Bays: final report to the Delaware Department of Natural Resources and Environmental Control under Contract No. 939519: Delaware Geological Survey Final Report of Research.