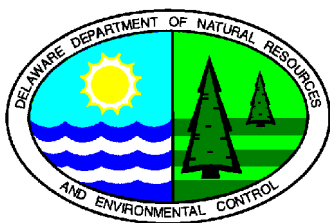


**TOTAL MAXIMUM DAILY LOAD (TMDL) ANALYSIS**  
**FOR**  
**INDIAN RIVER, INDIAN RIVER BAY, AND REHOBOTH BAY,**  
**DELAWARE**

**Prepared by:**

**Watershed Assessment Section**  
**Division of Water Resources**  
**Delaware Department of Natural Resources and Environmental Control**  
**29 State Street**  
**Dover, DE 19901**



**December 1998**



**TABLE OF CONTENTS**

	<u>Page</u>
Executive Summary . . . . .	vi
Section 1. Introduction and Background . . . . .	1-1
Designated Uses . . . . .	1-1
Applicable Water Quality Standards . . . . .	1-3
Land Uses . . . . .	1-4
Water Quality Conditions of the Inland Bays . . . . .	1-6
Pollutants of Concern . . . . .	1-13
Development of the Inland Bays Hydrodynamic and Water Quality Model for the Inland Bays . . . . .	1-13
Scope and Objectives of the Proposed TMDL Analysis . . . . .	1-14
Section 2. The Hydrodynamic and Water Quality Model of the Indian River, Indian River Bay, and Rehoboth Bay . . . . .	2-1
The Inland Bays Hydrodynamic Model (CH3D) . . . . .	2-2
The Inland Bays Water Quality Model (CE-QUAL-ICM) . . . . .	2-6
Point Source Discharges . . . . .	2-9
Nonpoint Sources of Pollution . . . . .	2-12
Atmospheric Deposition Loads . . . . .	2-16
Water Quality Model Outputs . . . . .	2-17
Use of the Inland Bays Hydrodynamic and Water Quality Model to Develop TMDLs for Nitrogen and Phosphorous . . . . .	2-25
Section 3. Development of Total Maximum Daily Loads for Nitrogen and Phosphorous for the Indian River, Indian River Bay, and Rehoboth Bay . . . . .	3-1
A. Scenario 34 . . . . .	3-1
B. Scenario 69 . . . . .	3-6
Selection of the TMDL Loading Condition . . . . .	3-10
Waste Load Allocation for Point Source Discharges . . . . .	3-10
Load Allocation for Nonpoint Sources . . . . .	3-10
Load Allocation for Atmospheric Nitrogen Deposition . . . . .	3-13
Total Maximum Daily Load for Total Suspended Solids . . . . .	3-13
Consideration of a Margin of Safety . . . . .	3-17
Authority and Responsibility for TMDL Development . . . . .	3-18
Pollution Control Strategy . . . . .	3-18

**TABLE OF CONTENTS, Cont.**

---

References	.....	3-19
Appendix A	The master input file for the Inland Bays Water Quality Model .....	A-A
Appendix B	Various Scenarios Considered for the Inland Bays Model .....	B-A

**LIST OF FIGURES**

<u>Page</u>		
Figure 1.1	Delaware Inland Bays Sub-basin . . . . .	1-2
Figure 1.2	1992 Land Use . . . . .	1-5
Figure 1.3	Summary of Land Use Activities in the Inland Bays Sub-basin . . . . .	1-6
Figure 1.4	Dissolved Oxygen Concentrations in the Inland Bays (1995 - 1997 Period) .	1-8
Figure 1.5	Chlorophyll a Concentrations in the Inland Bays (1995 - 1997 Period) . . . .	1-8
Figure 1.6	Total Nitrogen Concentrations in the Inland Bays (1995 - 1997 Period) . . .	1-9
Figure 1.7	Nitrite + Nitrate Concentrations in the Inland Bays (1995 - 1997 Period) . .	1-9
Figure 1.8	Total Phosphorous Concentrations in the Inland Bays (1995 - 1997 Period)	1-10
Figure 1.9	Dissolved Inorganic P Concentrations in the Inland Bays (1995 - 1997 Period) . . . . .	1-10
Figure 1.10	Designated Use Support for the Indian River Bay, Delaware (1996) . . . . .	1-11
Figure 1.11	Designated Use Support for the Indian River Bay, Delaware (1998) . . . . .	1-12
Figure 1.12	The Four Water Body Segments included in the TMDL Analysis . . . . .	1-15
Figure 2.1	Components of the Inland Bays Model . . . . .	2-1
Figure 2.2	The Inland Bays Hydrodynamic Model Segmentation . . . . .	2-4
Figure 2.3	A Snapshot of Tidal Velocity and Direction in the Inland Bays . . . . .	2-5
Figure 2.4	Water Quality Model Segmentation . . . . .	2-7
Figure 2.5	Point Source Discharges in the Inland Bays Sub-basin . . . . .	2-10
Figure 2.6	Tributary Flows to the Inland Bays . . . . .	2-13
Figure 2.7	Phosphorous and Nitrogen Loads From Tributaries in the Inland Bays Sub-basin (during base-line period, 1988 - 1990) . . . . .	2-15
Figure 2.8	Stream Flow at Stockley Branch Gaging Station, Stockley, USGS-01484500 (during base-line period, 1988 - 1990) . . . . .	2-16
Figure 2.9	Chlorophyll a Distribution in the Inland Bays (August, 1988) . . . . .	2-18
Figure 2.10	Total Nitrogen Concentration Distribution in the Inland Bays (August, 1988) . . . . .	2-19
Figure 2.11	Total Phosphorous Concentration Distribution in the Inland Bays (August 1988) . . . . .	2-20
Figure 2.12	Segments of the Indian River, Indian River Bay, and Rehoboth Bay . . . . .	2-21
Figure 2.13	Chlorophyll a and Dissolved Oxygen Concentrations in Various Regions of the Inland Bays . . . . .	2-22
Figure 2.14	Total Nitrogen and Total Phosphorous Concentrations in Various Regions of the Inland Bays . . . . .	2-23
Figure 2.15	Dissolved Inorganic Nitrogen and Dissolved Inorganic Phosphorous Concentrations in various Regions of the Inland Bays . . . . .	2-24
Figure 3.1	Dissolved Oxygen and Chlorophyll a Concentrations in various Regions of the Inland Bays Under Scenario 34 . . . . .	3-3

**LIST OF FIGURES, cont.**

<u>Page</u>		
Figure 3.2	Dissolved Inorganic Nitrogen and Dissolved Inorganic Phosphorous Concentrations in various Regions of the Inland Bays Under Scenario 34	3-4
Figure 3.3	Total Nitrogen and Total Phosphorous Concentrations in various Regions of the Inland Bays Under Scenario 34	3-5
Figure 3.4	Dissolved Oxygen and Chlorophyll a Concentrations in various Regions of the Inland Bays Under Scenario 69	3-7
Figure 3.5	Dissolved Inorganic Nitrogen and Dissolved Inorganic Phosphorous Concentrations in various Regions of the Inland Bays Under Scenario 69	3-8
Figure 3.6	Total Nitrogen and Total Phosphorous Concentrations in various Regions of the Inland Bays Under Scenario 69	3-9
Figure 3.7	Scatter plot of total suspended solids vs. chlorophyll a during growing season in Upper Indian River (1989 through 1997)	3-15
Figure 3.8	Fitted model for TSS vs. Chlorophyll a in upper Indian River during growing season	3-16

**LIST OF TABLES**

	<u>Page</u>
Table 2.1	Point Source Discharges in the Inland Bays Sub-basin (during base-line period 1988 - 1990) . . . . . 2-11
Table 2.2	Major Tributaries of the Inland Bays Sub-basin . . . . . 2-14
Table 3.1	Proposed Nitrogen and Phosphorous Load Reductions . . . . . 3-11
Table 3.2	Preliminary Load Allocation Among Major Categories of Nonpoint Source Load . . . . . 3-12
Table 3.3	Summary Statistics for TSS and Chl_a in Upper Indian River During Growing Season (1989 through 1997) . . . . . 3-15

## **EXECUTIVE SUMMARY**

Section 303(d) of the Clean Water Act (CWA), as amended by the Water Quality Act of 1987, requires States to identify and list those waters within their boundaries that are water quality limited (303(d) List), to prioritize them, and to develop Total Maximum Daily Loads (TMDLs) for pollutants of concern. A water quality limited water is a waterbody in which water quality does not meet applicable water quality standards, or is not expected to meet applicable standards, even after application of technology-based effluent limitations for Publicly Owned Treatment Works (POTW) and other point sources. A TMDL sets a limit on the amount of a specific pollutant that can be discharged into a waterbody and still protect water quality. TMDLs have three elements: Waste Load Allocations (WLAs) for point sources, Load Allocations (LAs) for nonpoint sources, and a Margin of Safety (MOS).

Intensive water quality monitoring performed by the State of Delaware, the federal government, various university and private researchers, and citizen monitoring groups has shown that the Indian River, Indian River Bay, and Rehoboth Bay are highly enriched with the nutrients nitrogen and phosphorous. As the result, Department of Natural Resources and Environmental Control (DNREC) has included these waters on the State's 1996 and 1998 303(d) Lists and has established Total Maximum Daily Loads for nitrogen and phosphorous. These TMDLs are based on analyzing the effects of various pollution reduction scenarios while using a comprehensive and state-of-the-art hydrodynamic and water quality model (the Inland Bays Model). The Inland Bays Model was developed through a cooperative agreement between DNREC and the US Army Corps of Engineers - Waterway Experiment Station, Vicksburg, Mississippi with significant financial support from the U.S. Environmental Protection Agency.

The Total Maximum Daily Loads for the Indian River (segment DE140-004), Indian River Bay (segments DE140-E01 and DE140-E02) and Rehoboth Bay(segment DE280-E01) requires that:

1. All point source discharges to the Indian River, Indian River Bay, Rehoboth Bay, and their tributaries should be eliminated systematically.
2. The nonpoint source nitrogen loads from five tributaries in the upper Indian River should be reduced by 85 percent (from the base-line period of 1988 through 1990). These tributaries include Swan Creek, Iron Branch, Pepper Creek, Vines Creek, and Millsboro Pond. This will result in reducing nitrogen loads from these tributaries during a normal rainfall year from 1285 kilograms per day (2833 pounds per day) to 193 kilograms per day (425 pounds per day).
3. The nonpoint source phosphorous loads from these five tributaries in the upper Indian River should be reduced by 65 percent (from the base-line period of 1988 through 1990). This will result in reducing phosphorous loads from these tributaries during a normal rainfall year from 38 kilograms per day ( 84 pounds per day) to 13 kilograms per day (29 pounds per day).
4. The nonpoint source nitrogen loads from all remaining tributaries to the Indian River, Indian River Bay, and Rehoboth Bay should be reduced by 40 percent (from the base-line period of 1988 through 1990). This will result in reducing nitrogen loads from these tributaries during a normal rainfall year from 732 kilograms per day (1614 pounds per day) to 439 kilograms per day (968 pounds per day).
5. The nonpoint source phosphorous loads from all remaining tributaries to the Indian River, Indian River Bay, and Rehoboth Bay should be reduced by 40 percent (from the base-line period of 1988 through 1990). This will result in reducing phosphorous loads from these tributaries during a normal rainfall year from 36 kilograms per day ( 79 pounds per day) to 22 kilograms per day (49 pounds per day).

6. The atmospheric nitrogen deposition rate should be reduced by 20 percent (from the base-line period of 1988 through 1990). This will result in reducing the atmospheric nitrogen deposition rate from 765 kilograms per day (1687 pounds per day) to 612 kilograms per day (1349 pounds per day).

The result of hydrodynamic and water quality model runs has shown that through implementation of the above requirements, all water quality standards and targets in the Indian River, Indian River Bay, and Rehoboth Bay will be achieved with an adequate margin of safety.

Implementation of this proposed TMDL will be achieved through development and implementation of a Pollution Control Strategy (PCS). The PCS will be developed by DNREC in concert with the Department's ongoing Whole Basin Management Program and the affected public.