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Release Alternatives on a 3-D Salinity Simulation

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Abstract

Hydraulic structures such as dams, locks or diversion gates, in the upstream or tributary of an estuary system can control necessary freshwater discharge to meet downstream water quality standards. One of the most significant purposes of these structures is maintaining target salinity to satisfy the environment concerns, such as fishery spawning in the high-flow season and drinking water criteria in the low-flow period. In order to evaluate possible alternative regulations for the reservoir operation, a reliable three-dimensional (3-D) hydrodynamic model is required as a management tool to simulate the impact of salinity variations due to release policy changes. This paper discusses the 3-D capability of presenting a complicated riverine- estuarine process for the release policy of Conowingo Reservoir, Susquehanna River, near the head of Chesapeake Bay, from an extremely dynamic system (Upper Chesapeake Bay-C&D Canal-Delaware Bay), as shown in Figure 1.

Introduction

Although the Conowingo release is a local issue of the Upper Chesapeake Bay system, all the literature shows that the C&D Canal and Delaware Bay must be considered as a whole system. Historically, the change in size of C&D Canal impacts to the flow and salt transport has been paid much attention by the regional researchers. Another mechanism that could also determine the circulation patterns in the Upper Chesapeake Bay system is the regulated riverflow discharge from the Conowingo Reservoir, Susquehanna River. The salinity intrusion in the head of Chesapeake Bay, especially in the Susquehanna Flats area, during the low-flow season has caused serious problems with drinking water quality. This study was to examine the possible modification of release regulation related to the

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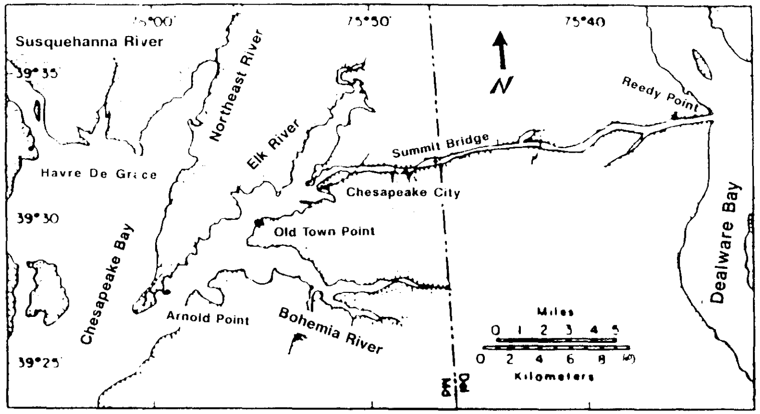

Figure 1. C&D Canal and Adjacent Estuaries.

salinity variations. Meanwhile, the net flow and salt transport through the C&D Canal due to regulation change were estimated by the model simulation process.

A three-dimensional (3-D) model extending from the Chesapeake Bay Bridge at Annapolis, MD, through the C&D Canal and connecting with a grid extending from Trenton, NJ, to the mouth of the Delaware Bay (Hsieh, Johnson and Richards, 1991) was used to test the release regulations in the Conowingo Reservoir during fall, 1984. The reservoir discharge during that period used to verify the model under the 1984 regulation was assumed as the base condition. Three other schemes, including 1988 regulation and two additional proposed regulations are used to examine the net salt transport through the C&D Canal and the salinity variations for selected locations of Upper Chesapeake Bay after the model has been verified by the field measurement. It is noted that these proposed regulations are not based on policies of any agencies. This simulation study deals only with testing.

<u>Summary of C&D Canal and Adjacent Estuaries 3-D Hydrodynamic Model</u>

The particular computer code used in this application is called CH3D (Curvlinear Hydrodynamics in Three Dimensions)-WES. The basic code was developed by Sheng (1986) for the US Army Engineer Waterways Experiment Station (WES) but was extensively modified during the Chesapeake Bay Model studied at WES. The theoretical basis of this code is contained in Sheng (1986) and Johnson et al. (1991). A variable-resolution 3-D grid of Upper Chesapeake Bay, the C&D Canal, and Delaware Bay based on important geometric features and local velocity gradient is presented in Figure 2. The complete grid contains 873 active horizontal cells, resulting in

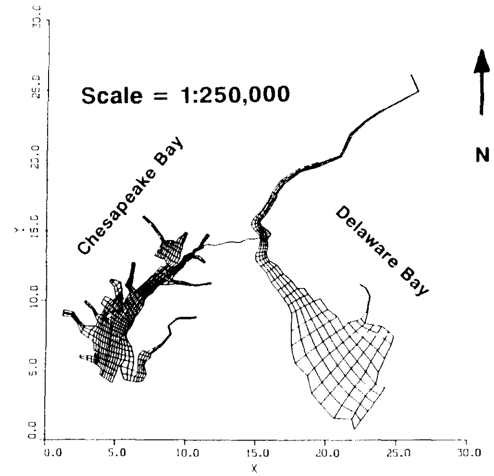

Figure 2. Computation Grid

3,325 computational cells. The main channel of Delaware Bay, the C&D Canal, and the navigable part of the Upper Chesapeake Bay are represented as a 40-ft (12.2-m)-deep waterway.

The model was verified using the field data of September 1984. Excellent agreement between model results and prototype data for currents and salinity was found in the C&D Canal. The change in of flow and salt transport through the canal due to channel deepening was computed. Details of the model verification can be found in Hsieh, Johnson,and Richards (1991). This verification process therefore has been extended to making computation over the 100 tidal cycles during the low-flow period of 1984 to examine the dynamic response of the transport through the C&D Canal during such low-flow periods. The most difficult part of the verification was to accurately generate the salinity boundary conditions. Biweekly discrete data collected near the surface and near the bottom were used to generate the required boundary profiles near the bay bridge at Annapolis, MD, for the Chesapeake Bay side. However, no Delaware source salinity data during this period were available. The boundary salinity at the Delaware Bay entrance was estimated by the trend analysis, harmonic method, and mass balance method.

<u>Release Policies and Riverflow Discharge at Conowingo Reservoir, Susquehanna River</u>

Riverflow from the Susquehanna River is discharged into the Chesapeake Bay after being regulated by a multiobjective reservoir, the Conowingo Reservoir. The operation schedules for this facility are based on the seasonal and weekly patterns. A specified minimum release is set during the seasonal change. At the same time, the pondage of the reservoir is held to approximately the same level between two successive Monday mornings. It results in very low discharge during the weekend, especially in the summer months. Before 1988, the release regulation was 5,000 cfs (141 cms) from 15 April to 15 September and no minimum release was required for the rest of year (release policy A). Since the beginning of 1988, a new policy with five minimum release values were seasonally distributed (release policy B). In this study, two additional proposed release schemes (policies C and D) were used to examine the salinity variations for several selected stations and their transport change through the C&D Canal. These release policies are listed in Table 1.

TABLE 1. Four Release Policies for Testing 3-D Salinity Variation

Release Policy (1)	Date (2)	Volume (m^3/s)	
		Minimum (3)	Maximum (4)
A	09/01-09/15 09/16-10/31	142 (5,000 cfs) Not required	Not required Not required
B	09/01-09/15 09/16-10/31	142 (5,000 cfs) 99 (3,500 cfs)	Not required Not required
C	09/01-09/15 09/16-10/31	71 (2,500 cfs) 71 (2,500 cfs)	Not required Not required
D	09/01-09/15 09/16-10/31	170 (6,000 cfs) 170 (6,000 cfs)	425 (15,000 cfs) 425 (15,000 cfs)

The simulated flow due to each release policy is obtained by using historical discharge from the Conowingo Dam at the same period of time. The mass balance consideration regarding the total volume of storage water in the reservoir was used to generate these new flow synthesis series. None of the other objectives for reservoir operation, such as optimal utility generation, are assumed for these test exercises.

Simulation Results

These new flow series were used as the input to generate the salinity outputs through a verified 3-D numerical model. The net flow and salt transport through C&D Canal from Summit Bridge cross section due to four different release regulations over 100 tidal cycles period are summarized in Table 2. The slight change for these values indicates that the most flow variations due to release regulations in the Conowingo Dam was not transported to the Delaware Bay. Because of the salinity variation due to the hydrograph condition being a very slow phenomenon, the particular geometry at the head of Chesapeake Bay estuary and greater amount of tidal flux relative to freshwater discharge volume, no significant net eastward transport would be expected, unless in the high-flow period of the year.

TABLE 2. Estimation of Net Volume and Salt Transport through the C&D canal at Summit Bridge Transect.

	Net Transport	
Release Policy (1)	Volume (m^3/s) (2)	Salt (kg/s) (3)
A	-73 cms	-612 kg/s
B	-73 cms	-607 kg/s
C	-71 cms	-603 kg/s
D	-69 cms	-590 kg/s

In order to identify the impact of salinity at a particular downstream location, four selected stations in the Upper Chesapeake Bay area were chosen to present the variation. The surface and bottom averaged salinity are obtained by taking 100 tidal cycle simulation results (Table 3). More change was found at the location near to the discharge point of the reservoir. Once again, the Reedy Point, the eastern end of the canal, does not show any significant variations. Havre De Grace, near the mouth of the Susquehanna River shows the strongest influence.

TABLE 3. Simulated Average Salinity (PPT.) (100 Tidal Cycles) due to Release Policy Change

Location (1)	Layer (2)	Policy			
		A (3)	B (4)	C (5)	D (6)
Reedy Pt.	Surface	6.83	6.81	6.80	6.80
	Bottom	6.91	6.90	6.90	6.89
Town Pt.	Surface	3.59	3.59	3.59	3.56
	Bottom	5.55	5.54	5.52	5.52
Howell Pt.	Surface	3.48	3.43	3.36	3.30
	Bottom	4.56	4.54	4.52	4.50
Havre De Grace	Surface	1.50	1.25	1.90	0.89
	Bottom	2.30	2.52	2.83	1.70

Conclusions

A three-dimensional hydrodynamic model was applied to evaluate the release regulations in the Upper Chesapeake Bay-C&D Canal-Delaware Bay system. The simulation shows that the regulations insignificantly impact the salinity regime except in the Susquehanna Flats area. Developing the contour graphics, collecting more field data including long-term boundary conditions, and extending the modeling process to the high-flow period can provide much deeper insight of flow patterns of this region.

Acknowledgements

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