Chester River Deep-Channel Dissolved Oxygen Criterion Persistent Non-Attainment: Diagnostic Findings

U.S. EPA Chesapeake Bay Program Office
Annapolis, Maryland

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During the course of developing the Chesapeake Bay TMDL, numerous nutrient load reduction simulations were conducted to determine the effect of pollutant reductions on attainment of established Maryland, Virginia, Delaware and District of Columbia's Chesapeake Bay water quality standards (WQS) for dissolved oxygen (DO).

Chesapeake Bay water quality/sediment transport model-simulated nutrient load reductions resulted in higher simulated DO concentrations, allowing identification of load reductions sufficient for attaining the jurisdictions' WQS, in the majority of deep-water and deep-channel regions of the Chesapeake Bay and its tidal tributaries. The deep-channel of the lower tidal Chester River segment was a notable exception.

Historical monitoring data show a consistent pattern of summer severe hypoxic to anoxic (<0.2 mg/L dissolved oxygen concentrations) conditions in the deep-channel region of the lower Chester River, in the vicinity of monitoring station ET4.2 (Figure 1).

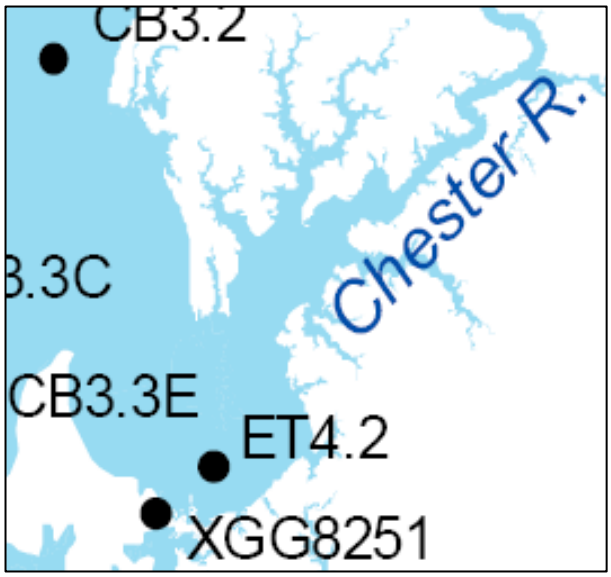

Figure 1. The Lower Chester River is characterized by Maryland's Chesapeake Bay water quality monitoring program station ET4.2.

In summer months, observed DO concentrations at monitoring station ET4.2 consistently fell below 1.0 mg/L, the instantaneous minimum criterion for the deep-channel designated use (Figure 2).

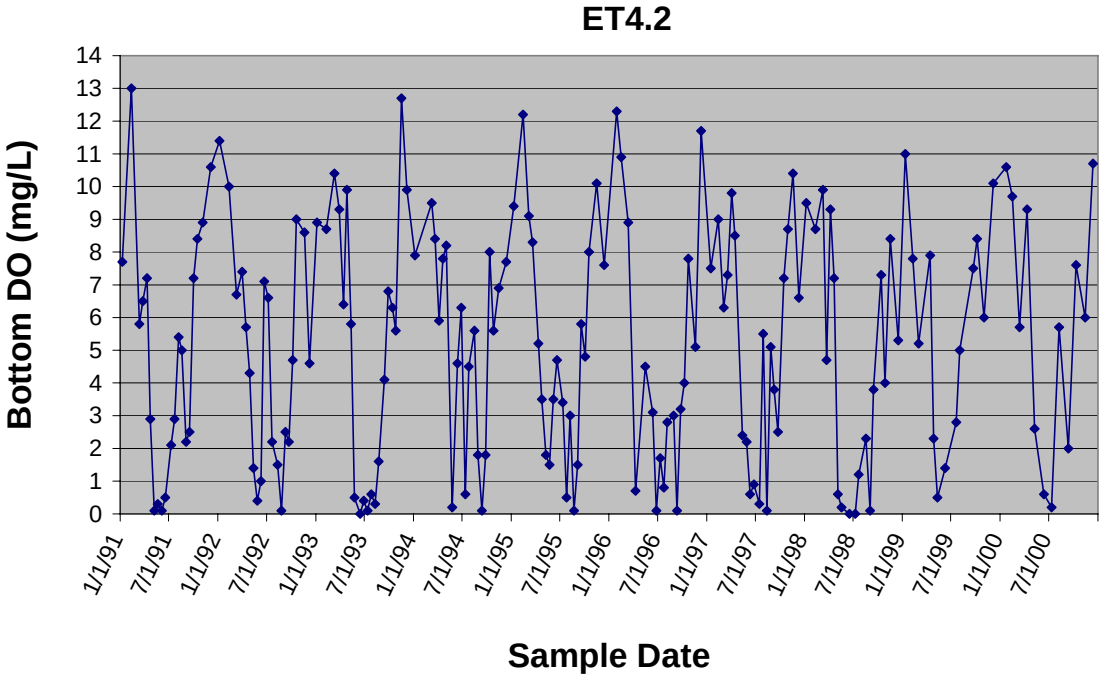

Figure 2. "Bottom" depth dissolved oxygen (DO) concentrations measured at monitoring station ET4.2 from January 1991 – December 2000. Source: http://www.chesapeakebay.net

At model-simulated nutrient load reductions that led to attainment of deep-channel dissolved oxygen criteria in all other deep-channel regions of the Chesapeake Bay and tidal tributaries (e.g. segments in the Chesapeake Bay mainstem, lower Potomac River, lower Rappahannock River, and Patapsco River), model simulated improvements in dissolved oxygen concentration in the lower Chester River's deep-channel did not yield full attainment of dissolved oxygen criteria. Whereas other deep-channel regions showed attainment of the deep channel dissolved oxygen criterion at or before the 190 TN, 12.7TP loading scenario, the lower Chester River's deep-channel non-attainment remained at a plateau of approximately 10-14% under loading scenarios ranging from 191 TN, 14.4 TP down to approximately 170 TN, 11.3 TP. Full attainment of the applicable dissolved oxygen criterion was not achieved for this deep-channel region until the highly theoretical and unattainable "All Forest" scenario, for which it is assumed that all land in the Chesapeake Bay watershed reverts to a forested condition (Figure 3).

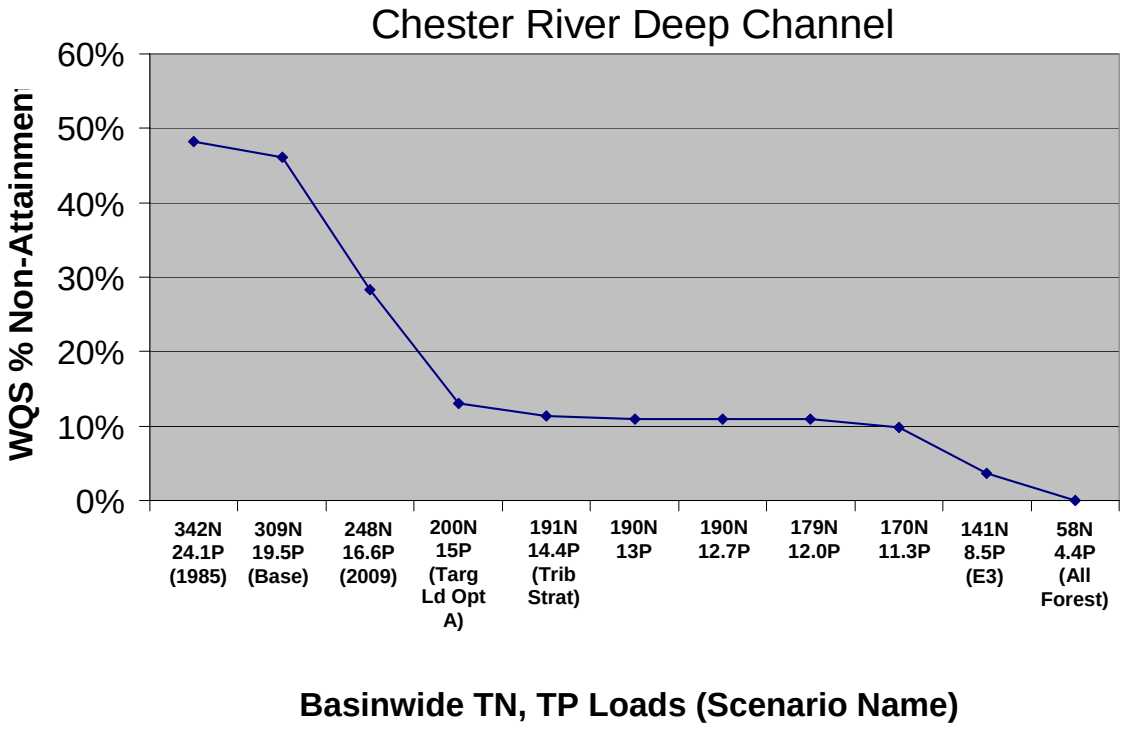

Figure 3. Percent non-attainment of lower Chester River deep-channel dissolved oxygen criterion with decreasing total nitrogen (TN) and total phosphorus (TP) loads.

In-depth examination of the Bay water quality model scenario outputs showed stepwise increases in DO concentrations with incremental nutrient load reductions in the lower Chester River (CHSMH) segment at surface and mid-depths, and consistent simulation of bottom water anoxia. However, the response of DO concentrations at lower-depths in the water column - and particularly at the bottom of the water column - appeared to be constrained to a degree that prevented full attainment of the 1.0 mg/L deep-channel dissolved oxygen criterion under model simulated nutrient load reductions that yield full attainment in all other deep-channel regions of the Chesapeake Bay and its tidal tributaries (Figure 4).

Cbseg	"91 -'00 Base Scenario 309TN, 19.5TP, 8950TSS '93-'95 DO Deep Channel	2009 Scenario 248TN, 16.6TP, 8110TSS '93-'95 DO Deep Channel	Target Load Option A 200TN, 15TP, 6390TSS '93-'95 DO Deep Channel	Trib Stategy 191TN 14.4TP, 6462 TSS '93-'95 DO Deep Channel	190 Loading Scenario 190TN 12.6TP, 6030TSS '93-'95 DO Deep Channel	179 Loading Scenario 179TN 12.0TP, 5510TSS '93-'95 DO Deep Channel	170 Loading Scenario 170TN 11.3TP, 5650TSS '93-'95 DO Deep Channel	E3 2010 Scenario 141TN 8.5TP, 5060TSS '93-'95 DO Deep Channel	All Forest Scenario '93-'95 DO Deep Channel
CB3MH	14%	6%	0%	0%	0%	0%	0%	0%	0%
CB4MH	46%	22%	4%	2%	2%	0%	0%	0%	0%
CB5MH	22%	2%	0%	0%	0%	0%	0%	0%	0%
CHSMH	38%	27%	14%	14%	14%	14%	9%	4%	0%
EASMH	26%	13%	4%	2%	1%	0%	0%	0%	0%
MD5MH	24%	4%	0%	0%	0%	0%	0%	0%	0%
PATMH	27%	21%	0%	0%	0%	0%	0%	0%	0%
POMMH	20%	0%	0%	0%	0%	0%	0%	0%	0%
POTMH	20%	0%	0%	0%	0%	0%	0%	0%	0%
POVMH	0%	0%	0%	0%	0%	0%	0%	0%	0%
RPPMH	31%	0%	0%	0%	0%	0%	0%	0%	0%
VA5MH	11%	0%	0%	0%	0%	0%	0%	0%	0%

Figure 4. Dissolved oxygen percent non-attainment for the deep-channel designated use segments in the Chesapeake Bay and its tidal tributaries.

It is postulated that the bathymetry of the lower Chester River provides a physical barrier to complete re-oxygenation of the deepest region of the lower Chester River even under extremely high nutrient reductions. A narrow deep channel transects the center of the lower Chester River, and exchange of oxygenated deep waters between the mainstem Chesapeake Bay and this deep hole may be restricted by the wider, shallower shoal region at the mouth of the river (Figures 5 and 6).

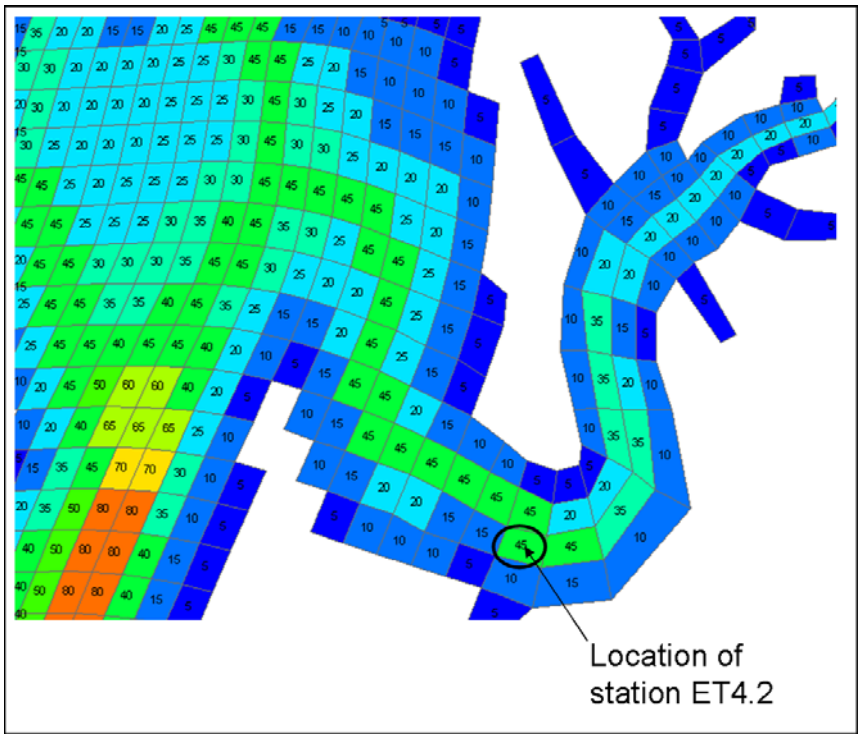

Figure 5. water quality model grid for the WQSTM in the lower Chester River, with total depth for each cell labeled (in feet). The cell corresponding to the location of monitoring station ET4.2 is outlined in black. Source: EPA Chesapeake Bay Program.

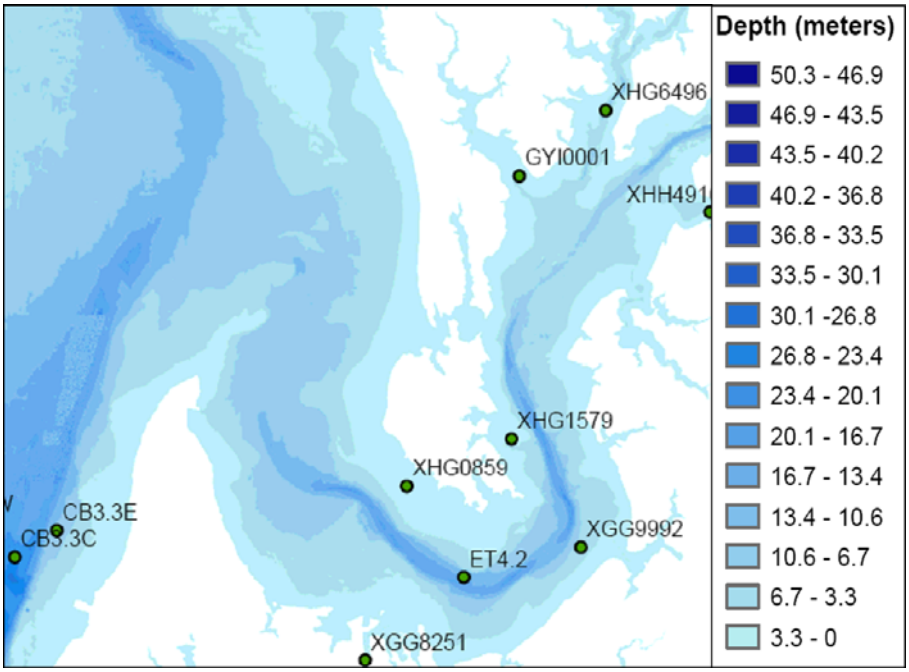

Figure 6. Bathymetry of the lower Chester River. Note that the mouth of the Chester River is shallower than the vicinity of fixed monitoring station ET4.2. Source: EPA Chesapeake Bay Program.

The limited response of DO concentrations to reduced nutrient loads (e.g., 30-140 million pounds basinwide) in the lower Chester River deep-channel, combined with the physical characteristics of the narrow, deep channel in this region, suggest a natural constraint on the re-oxygenation of the lower mixed layer by either deep riverine flows or deep estuarine flows from the adjacent mainstem Bay. Therefore, given the currently available information, EPA recommends a variance of 14% to account for persistent WQS non-attainment in the CHSMH Deep Channel designated use at the basinwide loads of 190TN, 12.7 TP. The selection of a 14% variance is based on the observation that dropping the basinwide loads by up to 20 million pounds per year yields relatively little change in the non-attainment percentage, which ranges only from 10-14% over this reduction level.