Application of the Deep-Water Designated Use to the Severn River: Technical Basis and Justification

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Background

In its May 2010 Criteria Addendum, EPA provided technical evidence that application of deep-water and deep-channel designated uses is appropriate under conditions of episodic stratification of the water column, as documented by presence of a pycnocline (U.S. EPA 2010). Within that document, EPA recommended the application of a summer (June-September) deep-water designated use in the South and Magothy rivers at times when a pycnocline is observed.

The following describes conditions under which the deep-water and deep-channel designated use habitats should apply in the lower regions of tidal rivers and the mainstem Chesapeake Bay (U.S. EPA 2003).

> The **Deep Water** designated use applies to regions where density-induced stratification prevents the physical exchange of oxygen between the surface and deeper layers of water, and the deeper layer is also not re-oxygenated by riverine or oceanic sub-surface flow.
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> The **Deep Channel** designated use applies to the very deep water-column and adjacent bottom surficial sediment habitats located principally in the river channel at the lower reaches of the major rivers and along the spine of the middle mainstem of the bay. This use is intended for depths below the Deep Water designated use (i.e. below the lower boundary of the pycnocline), at which seasonal anoxic to severe hypoxic conditions routinely set in and persist for extended periods of time under current conditions.

These designated use categories were originally applied to a small number of segments located in the mesohaline (>5-18 ppt salinity) and polyhaline (>18 ppt salinity) regions of the mainstem and the lower regions of some of the larger tidal tributaries.

In the Fall of 2009, a question arose regarding the applicability of the deep-water and deep-channel designated use habitat categories to additional regions of the Chesapeake Bay and its tidal tributaries (U.S. EPA 2010). While conducting simulations of various nutrient load reduction scenarios in order to identify target nutrient load reductions for the Chesapeake Bay TMDL, Chesapeake Bay Program Office modelers and analysts identified regions where simulated nutrient load reductions did not generate improved dissolved oxygen (DO) concentrations. In some of these regions, it was postulated that a

physical constraint – stratification of waters in the summer months – provides a physical barrier that prevents the lower water column from reaching sufficient DO concentrations to attain the open-water dissolved oxygen criteria, even when nutrient loads are reduced dramatically from existing levels.

In response, the EPA Chesapeake Bay Program Office's monitoring and analysis team was asked by the Bay Program's Water Quality Goal Implementation Team to conduct a review of summer stratification and persistent hypoxia in the tidally influenced portions of the Chesapeake Bay and its tributaries. Given that a thorough review of all tidal segments would require several months, the monitoring and analysis team proposed to conduct the review in two phases. Phase 1 would focus on only those "high priority" mesohaline and polyhaline segments (in keeping with the aforementioned "lower reaches") demonstrating *both* evidence of stratification using a preliminary automated, standardized screening method *and* persistent hypoxia under nutrient reduction scenarios (U.S. EPA 2010). Phase 2 would comprise a more thorough review of the presence of stratification-induced hypoxia in all tidally influenced segments of the Chesapeake Bay and its tributaries. The mesohaline and polyhaline segments listed in Table 1 showed preliminary evidence of episodic stratification and hypoxic conditions.

Table 1. Mesohaline and polyhaline segments which showed preliminary evidence of episodic stratification and hypoxic conditions.

River	**Segment**
Elizabeth River	EBEMH
Elizabeth River	WBEMH
Rappahannock River	CRRMH
Fishing Bay	FSBMH
Wicomico River	WICMH
Magothy River	MAGMH
Severn River	SEVMH
South River	SOUMH
West River	WSTMH
York River	YRKMH

Using the results from load reduction scenarios conducted in the Fall of 2009, it was determined that in 8 out of these 10 segments, DO concentrations were responding to nutrient load reductions, resulting in attainment of the dissolved oxygen water quality standards at or before draft "Target Load" nutrient reduction levels. These 8 segments were thus relegated to "Phase 2" review, to commence sometime after July 1, 2010. At the time, only two segments—Magothy (MAGMH) and South River (SOUMH)—showed persistent non-attainment with reduced loads and were thus considered for "Phase 1" (i.e. immediate) review (U.S. EPA 2010). Note that the mesohaline Severn River (SEVMH) showed attainment of the open-water designated use for the critical period being used at the time (1996-1998) at draft "Target Load" nutrient reduction levels of 198 million pounds per year (mpy) TN and 14.8 mpy TP (see Figure 1).

Figure 1: Plot showing attainment of all but the Magothy River (MAGMH) and South River (SOUMH) open water DO designated uses at the "Target Load" scenario given methods and allocations in use in Ocotober 2009.

Cbseg	1985 Scenario 420TN 28.4TP '96-'98 DO Open Water Summer Monthly	91 -'00 Base Scenario 340TN 24.1TP '96-'98 DO Open Water Summer Monthly	Intermediate B Scenario 279TN 17.2TP '96-'98 DO Open Water Summer Monthly	Loading Scenario 236TN 21.1TP '96-'98 DO Open Water Summer Monthly	Intermediate A-C Scenario 222TN 17.4TP '96-'98 DO Open Water Summer Monthly	Intermediate A Scenario 209TN 13.7TP '96-'98 DO Open Water Summer Monthly	Target Load Scenario Option 3 198TN 14.8TP '96-'98 DO Open Water Summer Monthly
EBEMH	32.5%	16.6%	0.0%	0.0%	0.0%	0.0%	0.0%
WBEMH	6.1%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%
CRRMH	10.8%	9.6%	1.5%	0.0%	0.0%	0.0%	0.0%
FSBMH	4.6%	4.6%	0.0%	0.0%	0.0%	0.0%	0.0%
WICMH	33.8%	32.3%	0.0%	0.0%	0.0%	0.0%	0.0%
MAGMH	10.0%	1.3%	5.1%	5.1%	5.1%	1.5%	2.6%
SEVMH	8.9%	0.5%	2.3%	0.0%	0.0%	0.0%	0.0%
SOUMH	15.9%	0.0%	13.5%	9.8%	9.8%	9.8%	8.4%
WSTMH	0.4%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%
YRKMH	34.9%	25.7%	1.6%	0.4%	0.0%	0.0%	0.0%

The Chesapeake Bay Program Office monitoring and assessment team therefore focused their analyses on MAGMH and SOUMH, the two segments showing persistent non-attainment at the draft "Target Load" level of load reductions. As described in the 2010 EPA Bay criteria addendum (U.S. EPA 2010), frequent episodic occurrence of stratification was found in these regions over the 10-year period investigated (1991-2000). Specifically, in the South River an upper pycnocline boundary was observed for 39 out of 43 sampling events (91%) between 1991-2000, and in the Magothy River an upper pycnocline boundary was observed for 16 out of 40 sampling events (40%).

After reviewing the combined findings of the monitoring and assessment team regarding episodic stratification coincident with hypoxic conditions, the Chesapeake Bay Program's Criteria Assessment Protocol (CAP) workgroup recommended to the Water Quality Goal Implementation Team that a "summer deep-water" designated use be added to the MAGMH and SOUMH segments for application in the presence of episodic pycnoclines.

Application of the Deep Water Designated Use To SEVMH

In the time between Fall 2009 and the publication of the 2010 EPA Bay criteria addendum in May, the EPA Chesapeake Bay Program's Water Quality Goal

Implementation Team started applying the recommended revised dissolved oxygen criteria assessment procedures described in the Bay criteria addendum. In addition, the Water Quality Goal Implementation Team changed the "critical period" for standards attainment from 1996-1998 to 1993-1995 based on new information and recommendations. A new set of nutrient load reduction scenarios and results were generated. When these modifications were implemented, the assessment results for the Severn River segment (SEVMH) changed, showing persistent non-attainment at the newly identified draft target load nutrient reduction level of 190 mpy TN and 12.7 mpy TP (see Figure 2).

Figure 2. Plot showing non-attainment of some open water segments with updated models and revision of the "critical period" from 1996-8 to 1993-5. SEVMH now shows persistent non-attainment at the new draft global target load of 190 TN, 12.7TP.

Cbseg	1985 Scenario 342TN, 24.1TP, 9790TSS '93-'95 DO Open Water Summer Monthly	"91 -'00 Base Scenario 309TN, 19.5TP, 8950TSS '93-'95 DO Open Water Summer Monthly	2007 Scenario 254TN, 17.1TP, 6498TSS '93-'95 DO Open Water Summer Monthly	Tributary Stategy 191TN 14.4TP, 6462 TSS '93-'95 DO Open Water Summer Monthly	190 Loading Scenario 190TN 12.6TP, 6030TSS '93-'95 DO Open Water Summer Monthly
EBEMH	23%	23%	21%	0%	0%
WBEMH	15%	11%	15%	8%	8%
CRRMH	40%	25%	0%	0%	0%
FSBMH	0%	0%	0%	0%	0%
WICMH	11%	11%	11%	5%	5%
MAGMH	1%	1%	1%	0%	0%
SEVMH	20%	16%	9%	6%	6%
SOUMH	0%	0%	0%	0%	0%
WSTMH	9%	0%	0%	0%	0%
YRKMH	18%	24%	7%	1%	1%

As a result of these changes, the Severn River (SEVMH) segment now met the criteria for the "Phase 1" group of segments – demonstrating both preliminary evidence of stratification and lack of sufficient response to nutrient load reductions – and was moved from the "Phase 2" review category to "Phase 1." A more thorough review of stratification in SEVMH showed persistent dissolved oxygen concentrations less than 5 mg/L coincident with episodes of stratification between the surface and deeper waters (i.e. presence of an upper pycnocline boundary). Specifically, stratification was observed

in 6 out of the 7 summer months from 1993-1995 during which dissolved oxygen concentrations failed to achieve the monthly average of 5 mg/L necessary for full attainment of the open-water dissolved oxygen criteria (Table 2). Note that insufficient DO concentrations persisted at dramatically reduced TN and TP loads, as far as 170 mpy TN and 11.3 mpy TP.

Table 2. Open-water dissolved oxygen criteria non-attainment for observed and model simulated (170 million pounds TN, 11.3 TP scenario) for 1993-1995 under episodic presence of a pycnocline.

Severn River		Observed Percent Non-attainment	170 TN/11.3 TP Scenario Percent Non-attainment	Pycnocline observed
Year	Month			
1993	6	25.9%	0.0%	yes
1993	7	25.4%	25.4%	yes
1993	8	14.0%	0.0%	yes
1993	9	0.0%	0.0%	no
1994	6	25.4%	25.4%	yes
1994	7	14.0%	1.8%	no
1994	8	14.0%	0.0%	yes
1994	9	24.6%	3.6%	yes
1995	6	40.0%	4.8%	yes
1995	7	14.0%	0.0%	yes
1995	8	57.5%	57.5%	yes
1995	9	40.0%	40.0%	yes

Further review revealed that over the course of 75 summer monitoring cruises during the 1991-2000 Bay TMDL hydrological period, an upper pycnocline boundary was observed 44 times, or for 58% of observations.

As a result of this review, EPA now recommends application of the deep-water designated use to the Severn River (SEVMH) segment when an upper pycnocline boundary is present (as determined by the standardized method for locating pycnocline boundaries described in U.S. EPA 2008).

Literature Cited

U.S. EPA (U.S. Environmental Protection Agency). 2003. *Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability*. October 2003. EPA 903-R-03-004. Region III Chesapeake Bay Program Office, Annapolis, Maryland.

U.S. EPA. 2008. *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries–2008 Technical Support for Criteria Assessment Protocols Addendum.* EPA 903-R-08-001. CBP/TRS 290-08. Region III Chesapeake Bay Program Office, Annapolis, Maryland.

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