Developing a New Chesapeake Bay Water Quality Indicator for Tracking Progress toward Bay Water Quality Standards Achievement

Chesapeake Bay Program Partnership's
Water Quality Goal Team Review Draft Version

November 5, 2012 Draft
[SUBJECT TO REVIEW AND FURTHER REVISION]

The Chesapeake Bay Program Partnership needs to develop a combined indicator to measure progress towards the Chesapeake Bay Executive Order's water quality outcome to "meet water quality standards for dissolved oxygen, water clarity/underwater grasses and chlorophyll *a* in the Bay and tidal tributaries by implementing 100 percent of the pollution reduction actions for nitrogen, phosphorus and sediment no later than 2025." The 2009 baseline condition, as documented in the Chesapeake Bay TMDL, was 89 of 92 segments of the Chesapeake Bay and its tidal tributaries and embayments were impaired (USEPA 2010). This new indicator could supplement or replace the individual dissolved oxygen, water clarity and chlorophyll *a* indicators currently reported by the Chesapeake Bay Program (CBP) Partnership.

There are a variety of unique combinations of Chesapeake Bay water quality criteria applied to each of the five tidal water designated uses within each of the 92 segments. The four tidal water jurisdictional partners –Delaware, District of Columbia, Maryland, and Virginia—and EPA work collaboratively to assess water quality standards attainment based on the criteria applicable to the designated uses (Figure 1). Each segment can have between one (i.e., Eastern Branch of the Elizabeth River which only has open water) and all five designated uses (i.e., Lower Rappahannock River which has migratory fish and spawning nursery, open-water, deep-water, deep-channel, and shallow-water bay grass designated uses) (Table 1).

This indicator would be based on annually reported criteria assessment results, which are based on a three-year assessment period. It would combine the dissolved oxygen, water clarity and chlorophyll *a* assessment results and be reported annually as a baywide percentage of water quality standards in attainment.

There are two sets of decisions to be made by the CBP Partnership in creating this new water quality indicator:

1) how to address the fact that the CBP Partnership has not fully developed, reached agreement on, published nor adopted into the tidal water jurisdictions' water quality standards regulations a full set of criteria assessment procedures for all the applicable dissolved oxygen criteria; and

2) whether to take an area-based (or volume-based) approach versus the count of number of designated use segments approach as the basis to reporting the water quality indicator.

The Chesapeake Bay Program Office, working with EPA Region 3's Water Protection Division and Office of Regional Counsel, explored a series of options for analysis. Working through the CBP Partnership's Scientific, Technical Assessment and Reporting Team's (STAR) and the Criteria Assessment Protocols (CAP) Workgroup, we explored a series of options for analysis and narrowed it down to two options and a recommendation. We conducted these analyses considering attainment for each segment by each of its unique tidal water designated uses (i.e., middle James River open-water) and applicable water quality criteria (i.e., chlorophyll *a*).

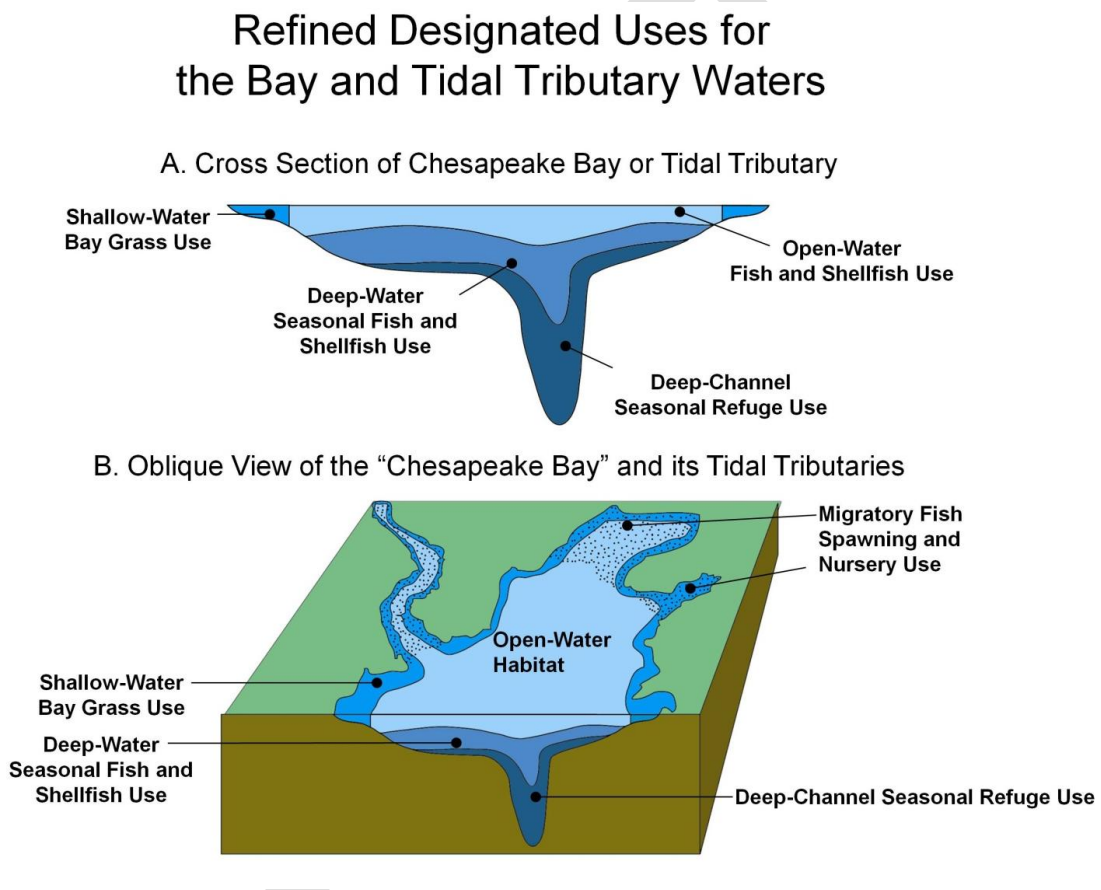

Figure 1. Conceptual illustration of the five Chesapeake Bay tidal water designated use zones.

Source: USEPA 2003

Table 1. Tidal water designated uses by Chesapeake Bay segment

Waterbody	CBP Segments & Split Segments	Jurisdiction	Migratory Spawning & Nursery	Open Water	Deep Water	Deep Channel	Shallow Water Bay grasses	Chlorophyll-a (applies to open water)
Anacostia River	ANATF_DC	DC	X	X			X	X

Anacostia River	ANATF_MD	MD	X	X			X	
Appomattox River	APPTF	VA	X	X			X	
Back River	BACOH	MD	X	X			X	
Big Annemessex River, Lower	BIGMH1	MD	X	X			X	
Big Annemessex River, Upper	BIGMH2	MD					X	
Bohemia River	BOHOH	MD	X	X			X	
Bush River	BSHOH	MD	X	X			X	
C&D Canal	C&DOH_DE	DE	X	X				
C&D Canal	C&DOH_MD	MD	X	X			X	
Northern Chesapeake Bay, Turkey Pt. South	CB1TF1	MD	X	X			X	
Northern Chesapeake Bay, Susquehanna River and Flats	CB1TF2	MD					X	
Upper Chesapeake Bay	CB2OH	MD	X	X			X	
Upper Central Chesapeake Bay	CB3MH	MD	X	X	X	X	X	
Middle Central Chesapeake Bay	CB4MH	MD	X	X	X	X	X	
Lower Central Chesapeake Bay	CB5MH_MD	MD		X	X	X	X	
Lower Central Chesapeake Bay	CB5MH_VA	VA		X	X	X	X	
Western Lower Chesapeake Bay	CB6PH	VA		X	X		X	
Eastern Lower Chesapeake Bay	CB7PH	VA		X	X		X	
Mouth of the Chesapeake Bay	CB8PH	VA		X			X	
Chickahominy River	CHKOH	VA	X	X			X	
Mouth of the Choptank River	CHOMH1	MD	X	X			X	
Lower Choptank River	CHOMH2	MD	X	X			X	
Middle Choptank River	CHOOH	MD	X	X			X	
Upper Choptank River	CHOTF	MD	X	X				
Lower Chester River	CHSMH	MD	X	X	X	X	X	
Middle Chester River	CHSOH	MD	X	X			X	
Upper Chester River	CHSTF	MD	X	X			X	
Corrotoman River	CRRMH	VA	X	X			X	
Eastern Bay	EASMH	MD		X	X	X	X	
Eastern Branch Elizabeth River	EBEMH	VA		X				
Mouth of the Elizabeth River	ELIPH	VA		X				
Elk River, Upper	ELKOH1	MD	X	X			X	
Elk River, Lower	ELKOH2	MD					X	
Fishing Bay	FSBMH	MD	X	X			X	
Gunpowder River, Upper	GUNOH1	MD	X	X			X	
Gunpowder River, Lower	GUNOH2	MD					X	
Honga River	HNGMH	MD		X			X	

Lower James River	JMSMH	VA	X	X			X	X
Middle James River	JMSOH	VA	X	X			X	X
Mouth of the James River	JMSPH	VA		X			X	X
Upper James River	JMSTF1	VA	X	X			X	X
Upper James River	JMSTF2	VA	X	X			X	X
Lafayette River	LAFMH	VA		X				
Little Choptank River	LCHMH	MD		X			X	
Lynnhaven River	LYNPH	VA		X			X	
Magothy River	MAGMH	MD	X	X	X		X	
Manokin River, Lower	MANMH1	MD	X	X			X	
Manokin River, Upper	MANMH2	MD					X	
Mattawoman Creek	MATTF	MD	X	X			X	
Middle River	MIDOH	MD	X	X			X	
Mobjack Bay	MOBPH	VA		X			X	
Lower Mattaponi River	MPNOH	VA	X	X				
Upper Mattaponi River	MPNTF	VA	X	X			X	
Lower Nanticoke River	NANMH	MD	X	X			X	
Middle Nanticoke River	NANOH	MD	X	X			X	
Upper Nanticoke River	NANTF_DE	DE	X	X				
Upper Nanticoke River	NANTF_MD	MD	X	X				
Northeast River	NORTF	MD	X	X			X	
Patapsco River	PATMH	MD	X	X	X	X	X	
Lower Patuxent River, Lower	PAXMH1	MD	X	X	X		X	
Lower Patuxent River, Upper	PAXMH2	MD					X	
Lower Patuxent River, Mill Creek	PAXMH3	MD					X	
Lower Patuxent River, Cuckold Creek	PAXMH4	MD					X	
Lower Patuxent River, St. Leonard Creek	PAXMH5	MD					X	
Lower Patuxent River, Island Creek	PAXMH6	MD					X	
Middle Patuxent River	PAXOH	MD	X	X			X	
Upper Patuxent River	PAXTF	MD	X	X			X	
Piankatank River	PIAMH	VA		X			X	
Piscataway Creek	PISTF	MD	X	X			X	
Lower Pamunkey River	PMKOH	VA	X	X				
Upper Pamunkey River	PMKTF	VA	X	X			X	
Lower Pocomoke River	POCMH_MD	MD	X	X			X	
Lower Pocomoke River	POCMH_VA	VA	X	X			X	
Middle Pocomoke River	POCOH_MD	MD	X	X				
Middle Pocomoke River	POCOH_VA	VA	X	X				
Upper Pocomoke River	POCTF	MD	X	X				

Lower Potomac River	POTMH_MD	MD	X	X	X	X	X	
Lower Potomac River	POTMH_VA	VA	X	X	X	X	X	
Middle Potomac River, MD Mainstem	POTOH_VA	VA	X	X			X	
Middle Potomac River, MD Port Tobacco River	POTOH1_MD	MD	X	X			X	
Middle Potomac River, MD Nanjemoy Creek	POTOH2_MD	MD	X	X			X	
Middle Potomac River	POTOH3_MD	MD	X	X			X	
Upper Potomac River	POTTF_DC	DC	X	X			X	X
Upper Potomac River	POTTF_MD	MD	X	X			X	
Upper Potomac River	POTTF_VA	VA	X	X			X	
Rhode River	RHDMH	MD	X	X			X	
Lower Rappahannock River	RPPMH	VA	X	X	X	X	X	
Middle Rappahannock River	RPPOH	VA	X	X			X	
Upper Rappahannock River	RPPTF	VA	X	X			X	
Sassafras River, Lower	SASOH1	MD	X	X			X	
Sassafras River, Upper	SASOH2	MD					X	
Southern Branch Elizabeth River	SBEMH	VA		X	X			
Severn River	SEVMH	MD	X	X	X		X	
South River	SOUMH	MD	X	X	X		X	
Tangier Sound	TAHMH_VA	VA		X			X	
Tangier Sound, MD Main Body	TANMH1_MD	MD					X	
Tangier Sound, MD Deal Island to Mouth of Nanticoke River	TANMH2_MD	MD		X			X	
Western Branch Elizabeth River	WBEMH	VA		X				
Western Branch Patuxent River	WBRTF	MD	X	X			X	
Wicomico River	WICMH	MD	X	X			X	
West River	WSTMH	MD	X	X			X	
Middle York River	YRKMH	VA	X	X			X	
Lower York River	YRKPH	VA		X	X		X	
TOTAL Number of Segments by Designated Use & Applicable Criteria			**72**	**92**	**18**	**10**	**90**	**7**

Note: This table contains additional split segments (in grey) beyond the 92 Chesapeake Bay segments strictly for purposes of applying separate water clarity criteria application depths (0.5, 1, or 2 meters) within the same Bay segment for assessing water clarity/SAV criteria attainment only (USEPA 2004).

Sources: USEPA 2004, 2010; Code of Maryland Title 26 Subtitle 08, Chapter 2, Section 3; Code of Virginia 9 62.1-44.13 3a; Delaware Administrative Code 7401; District of Columbia Municipal Regulations Title 21, Chapter 11.

Criteria Assessment Options and Recommended Resolution

The two criteria assessment options are directly related to the question posed earlier: how to address the fact that the CBP Partnership has not fully developed, reached agreement on, published, nor adopted into the tidal water jurisdictions' water quality standards regulations a full set of criteria assessment procedures for all the applicable dissolved oxygen criteria. One option would be only assess attainment for those dissolved oxygen criteria for which criteria assessment procedures have been published and adopted into the jurisdictions' water quality standards regulations. Taking this option, however, would be completely inconsistent with the approach the four tidal water jurisdictions have taken in establishing their lists of impaired Bay tidal waters and provide the public with contradictory information.

We are recommending to the Partnership's Water Quality Goal Implementation Team that for those designated use criteria where a full suite of dissolved oxygen criteria assessment procedures have not yet been agreed to by the CBP Partnership, the segment is considered to be in non-attainment for that specific tidal water designated use. For example, for the open-water, deep-water, and migratory fish spawning and nursery designated uses, there are no published procedures in place for the assessment of the 7-day mean, 1-day mean, and instantaneous minimum dissolved oxygen criteria. Therefore, these three designated uses will continue to be considered not in attainment because the jurisdictions cannot assess attainment for all the dissolved oxygen criteria applicable to these three designated uses. This approach is fully consistent with the three states and the District's current tidal impaired waters listing approach for Chesapeake Bay segments as published individually in their 2010 and 2012 lists and, collectively, within the 2010 Chesapeake Bay TMDL.

Work is currently underway, under the leadership and oversight of the CBP Partnership's CAP Workgroup, to develop, submit to independent scientific peer review, seek the review and agreement of the partnership, and publish (by EPA on behalf of the larger partnership) a complete set of dissolved oxygen criteria assessment procedures. The expectation is, upon publication of these criteria assessment procedures, Delaware, District of Columbia, Maryland, and Virginia will amend, as necessary, their water quality standards regulations to adopt these criteria assessment procedures.

Attainment Accounting Options and Recommended Resolution

We considered the choice between a count (e.g., number of attaining segments) or weighted (e.g., by area or volume) approach in computing and reporting the water quality indicator. We determined that strictly using a count of the number of segments, be they the original 92 segments or all the 289 designated-use segments, would not be representative of the true amount of Bay tidal waters achieving water quality standards (Table 2). The shear size difference, whether measured as surface area or total volume, between the Magothy River segment and the middle central Chesapeake Bay segment is a several hundred fold. Weighting them equally by taking the count approach does not provide the public with an honest measure of how much of the Bay tidal waters are achieving water quality standards.

Table 2. Criteria attainment accounting using the count approach.

COUNT APPROACH			
289 Designated Use Segments (making up the 92 CBP Segmentation Scheme)			
Designated Use	Total# DU Segments	# DU Segments IN ATTAINMENT	% in Attainment
Migratory Fish Spawning and Nursery	72	0	0
Open Water - DO	92	0	0
Open Water CHLA (spring + summer)	7	0	0
Deep Water - DO	10	1	10
Deep Channel - DO	18	0	0
Shallow-Water Bay Grasses - SAV/Water Clarity	90	27	30
Baywide Percentage of WQS Attainment	**289**	**28**	**10**

Note: As the CBP Partnership works through and reaches agreement on the remaining dissolved oxygen criteria assessment procedures, the percentage of designated-use segments attaining will increase.

Then we considered taking a volumetric approach. This approach works well for dissolved oxygen criteria whose attainment is assessed on a volume-basis. However, in the case of the water clarity/SAV and chlorophyll *a* criteria, both are assessed on a surface area-basis. We were unable to determine a method for accounting for both volume and surface area within the same metric which would have accounted for the how much of the Bay tidal waters were achieving water quality standards.

Therefore, having narrowed down the choice for the accounting approach to area, we still had to:

1) account for the area for those segments with two or more designated uses with depth (e.g., open-water, deep-water, and deep-channel); and

2) determine how to factor in the shallow-water Bay grasses designated uses which will have very small areas compared with open-water uses but are equally critical and important habitats.

The proposed solution was using the surface area of each of the 92 segments times the number of applicable designated uses for that segment. This approach factors in the relative size of each segment, ensuring we report the best available measure of how much of the Bay tidal waters were achieving water quality standards. At the same time, this approach gives equal weight to achievement of the criteria protective of each designated use and segment, preventing any need to weigh differently the importance of restoring dissolved oxygen versus bringing back underwater bay grasses. Restoration of fully functioning Chesapeake Bay ecosystem requires attainment of all five designated uses. The indicator consolidates the baywide results in the final calculations and reports percent of Bay water quality standards meeting attainment (Table 3).

Table 3. Criteria attainment accounting using the area-based approach.

AREA-BASED APPROACH			
289 Designated-Use Segments (contained within the 92 Chesapeake Bay segments)			
Chesapeake Bay Tidal Water Designated Use	Total Surface Area (km^2)	Total Surface Area in Attainment (km^2)	Percentage in Attainment
Migratory Fish Spawning and Nursery	5565101169.36	0.00	0
Open Water – DO	11660174083.95	0.00	0
Open Water CHLA (spring + summer)	620327627.29	0.00	0
Deep Water – DO	6932558324.18	0.00	0
Deep Channel – DO	4404190644.45	83660695.00	2
Shallow-Water Bay Grasses - SAV/Water Clarity	11558645485.84	2616220341.04	23
Baywide Percentage of WQS Attainment	**40740997335.07**	**2699881036.04**	**7**

Note: As the CBP Partnership works through and reaches agreement on the remaining dissolved oxygen criteria assessment procedures, the percentage of designated-use segments attaining will increase.

Please note, however, that there can be slight variations in the total number of designated uses reported each year depending on annual climatic conditions. Since designated use boundaries between the open-water, deep-water, and deep-channel designated uses are based on the presence a stratified water column measured by upper and lower bounds of a pycnocline. The absence of a pycnocline in a specific segment due to a fully mixed water column in a specific year due to seasonal weather conditions means one (or two) less designated uses for that year. In these cases, the total number of designated use segments would be a number less than 289 for that year within the three-year assessment window.

Finally, this area-based criteria attainment accounting approach also directly lends itself to a visual illustration of the indicator status in a single graphic—the relative shading or different color of each individual segment would reflect the percent of all applicable designated uses in attainment with all the applicable criteria—as well as a single percentage for all Bay tidal waters. Figure 2 serves as a hypothetical example displaying the indicator results. Further refinements are being considered by the Chesapeake Bay Program Office's Monitoring and GIS teams on how to illustrate the designated uses within an individual segment that are in and out of attainment and better illustrations of more incremental progress in criteria attainment.

Recommended Water Quality Indicator

The recommended water quality indicator for reporting on progress towards the Executive Order's water quality outcome as well as future CBP Partnership reporting of water quality restoration progress is as follows:

- The indicator will be based on an accounting of attainment of all Bay water quality criteria—dissolved oxygen, clarity/underwater grasses, and chlorophyll *a*—applicable to the 289 number of designated-use segments contained within the 92 Bay segments.

- The indicator will be reported annually as a baywide percentage based on the summation of the surface area of each of the designated-use segments determined to be in full attainment of all applicable criteria divided by the summation of the surface areas of the total number of designated use segments.

- For those designated-use criteria where a full suite of dissolved oxygen assessment procedures have not been agreed to by the CBP Partnership and published by EPA, those respective designated use segments where these dissolved oxygen criteria apply will be considered to be in non-attainment.[1]

- The indicator will be graphically illustrated by shading or coloring each of the 92 Bay segments according to the percent of all applicable designated uses for that individual segment which are in attainment with all the applicable criteria.

[1] By 2015, EPA and its seven jurisdictional partners are committed to working collaboratively on developing, subjecting to independent scientific peer review, agreeing to, and then publishing criteria assessment procedures for the remaining dissolved oxygen criteria currently without Partnership approved assessment procedures.

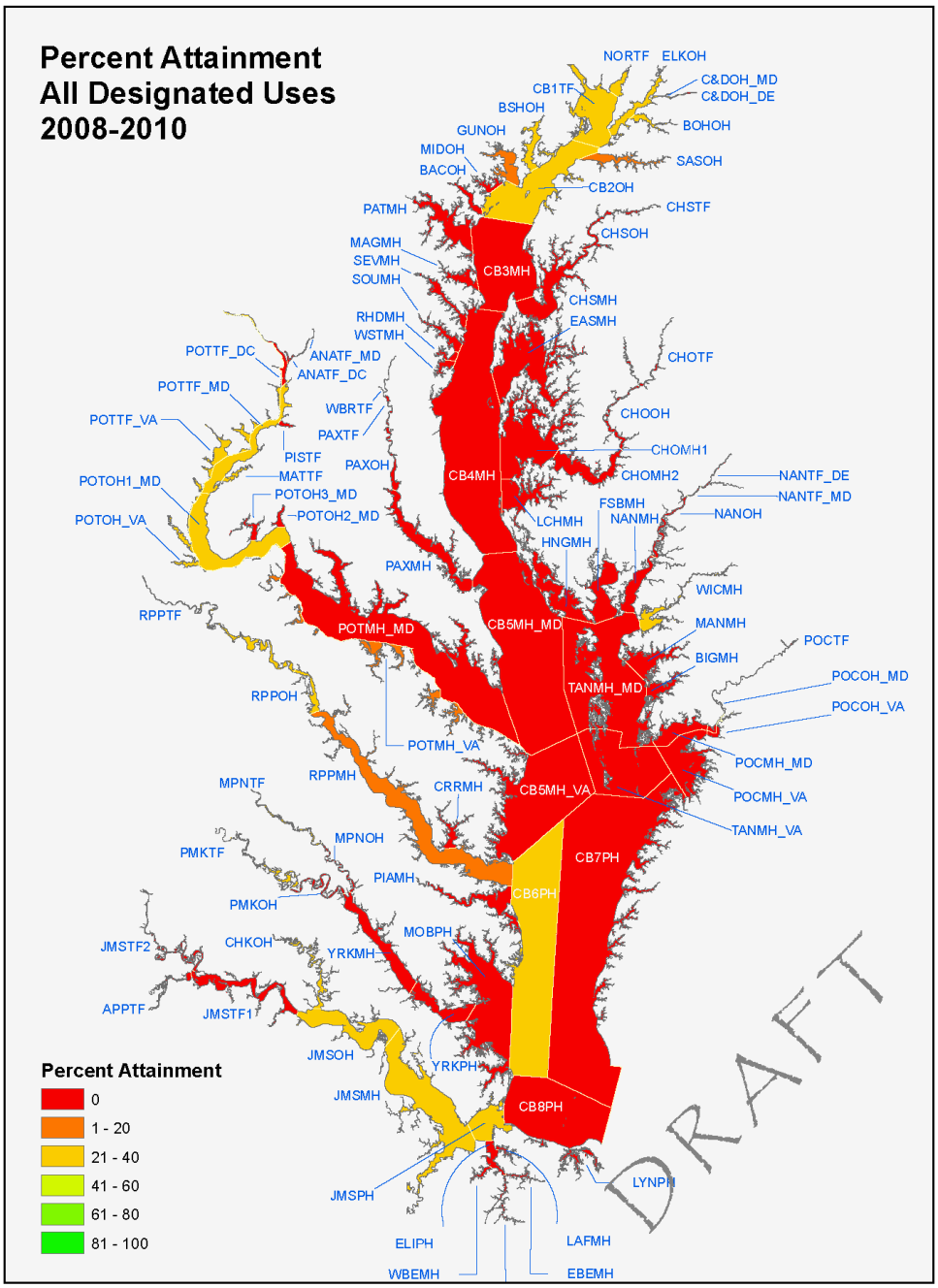

Figure 2. Visual illustration of the indicator status as a single percentage of attainment for all Bay tidal waters.

Recommended Next Steps

- CBPO Monitoring and GIS teams work up a refined set of visual illustrations of the indicator and work to address any comments/concerns raised by WQGIT members.
- Work through the CAP Workgroup and bring forward a recommend suite of approaches to illustrating the results of this water quality indicator, seek final WQGIT review at the January 14, 2013 WQGIT conference call, and ask for approval to bring the new indicator forward to the Management Board for final Partnership adoption.

References:

U.S. Environmental Protection Agency. 2003. *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries.* EPA 903-R-03-002. Region 3 Chesapeake Bay Program Office, Annapolis, MD.

U.S. Environmental Protection Agency. 2004. *Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability.* EPA 903-R-03-004. Region 3 Chesapeake Bay Program Office, Annapolis, MD.

U.S. Environmental Protection Agency. 2010. *Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorus and Sediment*. Region 3, Philadelphia, PA.