The Oxygen Chronicles: Tales from the Watery Depths

Background and Approaches to Dissolved Oxygen Assessment Methodologies
Part II: Continuous Data Assessment

Leah Ettema

EPA Region 3

02/09/2026

The views expressed in this presentation are those of the authors and do not necessarily represent the views or the policies of the U.S. Environmental Protection Agency or the federal government.

Outline

- Review Part 1 Presentation
- Instantaneous min and CFD application
  - 2003 Criteria Document
  - 2007 TSD
  - 2010 TSD
- 2017 TSD: Alternative Assessment Methodologies (#1 & #2)
- Elements of a typical state continuous data assessment methodology
- 2017 TSD: Alternative Assessment Methodologies (#3)

Review Part I: First Conclusions

Assessment methodologies must be consistent with WQS

Yes, exceedances of CB instantaneous min is consistent with criteria implementation documentation

Space is an important component of Bay assessment

Recommended assessment method: reference curve and CFD evaluation (space - time assessment)

Review Part I

- 2017 Technical Addendum introduces alternate assessment methods
- Can sound rationale be further developed for allowable exceedances?
  - Different DO exceedance frequencies may be justified for different Bay designated uses
  - Different DO exceedance frequencies may be justified for different monitoring types (10% was intended for small datasets)
  - Are there circumstances where instantaneous minimum exceedance is acceptable (ie 30-day mean achieved, not high magnitude or long duration event?)
- Would more recent literature have additional insights?

Why we can't assess all criteria: 2003 CFD Required Monitoring

Assessment of some geographic regions for some short-term criteria elements must be waived for the time being

- Recommended monitoring: one continuous monitor (buoy) per assessment unit, combine with discrete data
- Adequate monitoring: place limited number of continuous monitors at representative locations. Extract and apply cyclic components of those monitors (spectral analysis) to similar locations, interpolate and develop CFD. Greater uncertainty.
- Marginal: Fixed-station data only. Fixed-station Monitoring reflects seasonal and interannual variation. Best suited for assessing 30-day mean, poorly suited for assessing shorter durations.

Criteria Assessed with 3D Interpolator

Table 1. Chesapeake Bay dissolved oxygen criteria.

Designated Use	Criteria Concentration/Duration	Protection Provided	Temporal Application
Migratory fish spawning and nursery use *	7-day mean ≥ 6 mg liter^{-1} (tidal habitats with 0-0.5 ppt salinity)	Survival/growth of larval/juvenile tidal-fresh resident fish; protective of threatened/endangered species.	February 1 - May 31
	Instantaneous minimum ≥ 5 mg liter^{-1}	Survival and growth of larval/juvenile migratory fish; protective of threatened/endangered species.	
	Open-water fish and shellfish designated use criteria apply		June 1 - January 31
Shallow-water bay grass use	Open-water fish and shellfish designated use criteria apply		Year-round
Open-water fish and shellfish use	30-day mean ≥ 5.5 mg liter^{-1} (tidal habitats with 0-0.5 ppt salinity)	Growth of tidal-fresh juvenile and adult fish; protective of threatened/endangered species.	Year-round
	30-day mean ≥ 5 mg liter^{-1} (tidal habitats with >0.5 ppt salinity)	Growth of larval, juvenile and adult fish and shellfish; protective of threatened/endangered species.	
	7-day mean ≥ 4 mg liter^{-1}	Survival of open-water fish larvae.	
	Instantaneous minimum ≥ 3.2 mg liter^{-1}	Survival of threatened/endangered sturgeon species.[1]	
Deep-water seasonal fish and shellfish use	30-day mean ≥ 3 mg liter^{-1}	Survival and recruitment of bay anchovy eggs and larvae.	June 1 - September 30
	1-day mean ≥ 2.3 mg liter^{-1}	Survival of open-water juvenile and adult fish.	
	Instantaneous minimum ≥ 1.7 mg liter^{-1}	Survival of bay anchovy eggs and larvae.	
	Open-water fish and shellfish designated-use criteria apply		October 1 - May 31
Deep-channel seasonal refuge use	Instantaneous minimum ≥ 1 mg liter^{-1}	Survival of bottom-dwelling worms and clams.	June 1 - September 30
	Open-water fish and shellfish designated use criteria apply		October 1 - May 31

[1] At temperatures considered stressful to shortnose sturgeon (>29°C), dissolved oxygen concentrations above an instantaneous minimum of 4.3 mg liter^{-1} will protect survival of this listed sturgeon species.

From EPA 2003 Ambient Water Quality Criteria

Why can Deep Channel Instantaneous Min be assessed using the CFD without continuous data?

Why assess Deep-Channel Instantaneous Min when it doesn't have enough data? 2007 Tech Addendum

- Low DO variability in the deep channel during the summer months because of the physical isolation from the atmosphere and the photic zone.
  - -> Continuous data not needed to capture range of variability
- Dissolved oxygen concentrations remain relatively constant; therefore, a 30-day mean should be similar to any instantaneous measure

2003 Criteria: Attainment procedures

- *4D interpolator beginnings:* “use long-term, low-frequency data from the monitoring program and shorter-term, high-frequency data from in situ semi-continuous monitors to synthesize a data set that incorporates both long- and short-term patterns of variability..... The synthetic data set is then analyzed at the appropriate temporal scale of the criteria.”
    - *Spectral analysis approach is now GAMS*

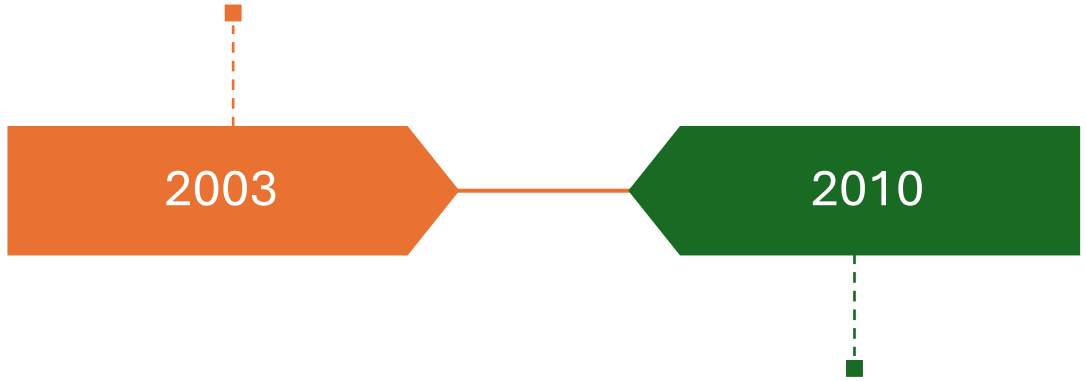
CB Criteria and Implementation Documents

Table 3-1. Chesapeake Bay water quality criteria and designated use related documentation and addenda

Document title	Month/year published	Document content and description
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. [USEPA 2003a]	April 2003	Original Chesapeake Bay water quality criteria document.
Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability. EPA 903-R-03-004. [USEPA 2003d]	October 2003	Original Chesapeake Bay tidal waters designated uses document.
Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries—2004 Addendum. EPA 903-R-03-002. [USEPA 2004a]	October 2004	Addresses endangered species protection, assessment of DO criteria, derivation of site-specific DO criteria, pycnocline boundary delineation methodology, and updated water clarity criteria/SAV restoration acreage assessment procedures.
Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability—2004 Addendum. EPA 903-R-04-006. [USEPA 2004e]	October 2004	Addresses refinements to Bay tidal waters designated use boundaries, segmentation boundaries, and Potomac River jurisdictional boundaries; documents SAV no-grow zones, restoration goal, and shallow-water acreages.
Chesapeake Bay Program Analytical Segmentation Scheme: Revisions, Decisions and Rationales 1983–2003. EPA 903-R-04-008. CBP/TRS 268-04. [USEPA 2004b]	October 2004	Details documentation on the history of the segmentation schemes and provides coordinates, georeferences, and narrative descriptions of the 2003 segmentation scheme.
Chesapeake Bay Program Analytical Segmentation Scheme: Revisions, Decisions and Rationales 1983–2003: 2005 Addendum. EPA 903-R-05-004. CBP/TRS 278-06. [USEPA 2005]	December 2005	Addresses methods used to subdivide the segments by jurisdiction and provides coordinates, georeferences, and narrative descriptions for those subdivided segments.
Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries—2007 Addendum. EPA 903-R-07-003. CBP/TRS 285-07. [USEPA 2007a]	July 2007	Addresses refinements to the Bay water quality DO, water clarity/SAV, and chlorophyll a criteria assessment methodologies and documents the framework for Bay tidal waters 303(d) list decision making.
Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries—2007 Chlorophyll Criteria Addendum. EPA 903-R-07-005. CBP/TRS 288/07. [USEPA 2007b]	November 2007	Publishes a set of numerical chlorophyll a criteria for Chesapeake Bay and the supporting criteria assessment procedures.
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. [USEPA 2008a]	September 2008	Addresses refinements to the Bay water quality DO, water clarity/SAV and chlorophyll a criteria assessment methodologies and documents the 2008 92-segment scheme for Bay tidal waters.
Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries—2010 Technical Support for Criteria Assessment Protocols Addendum. EPA 903-R-10-002. CBP/TRS 301-10. [USEPA 2010a]	May 2010	Addresses refinements to procedures for defining designated uses, procedures for deriving biologically based reference curves for DO criteria assessment and chlorophyll a criteria assessment procedures.
Technical Addendum Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity, and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries	Nov 2017	Provides previously undocumented features of the present procedures for assessing attainment of the Chesapeake Bay water quality criteria as well as refinements and clarifications to the previously published Chesapeake Bay water quality criteria assessment procedures

Why are exceedances allowed of the instantaneous min?

Criteria: Generally, exceedances of short enough time or small enough area have no adverse effects on designated use.



Expanded rationale for Deep Channel Instantaneous Min

2010 TSD: Rationale for Acceptable Exceedances of the Deep Channel Instantaneous Min DO Criterion

2003 Criteria:

“When dissolved oxygen drops significantly below 1 mg/l for even short periods of time **(on the order of hours)** mortality increases, even for tolerant species.”

2010 TSD Clarifies Deep Channel:

In light of both :

(1) the recognition that low dissolved oxygen conditions are a 'pre-historical’ feature of these deep channel habitats, and

(2) the observation that keystone benthic species of these deep channel habitats can tolerate small-scale occurrences of severe hypoxia (DO concentrations below 1 mg/L),

EPA believes that an allowance for a small, limited set of exceedances in time and space is acceptable in assessment of the deep-channel designated use dissolved oxygen criterion

Criteria and Implementation Documents

Table 3-1. Chesapeake Bay water quality criteria and designated use related documentation and addenda

Document title	Month/year published	Document content and description
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. [USEPA 2003a]	April 2003	Original Chesapeake Bay water quality criteria document.
Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability. EPA 903-R-03-004. [USEPA 2003d]	October 2003	Original Chesapeake Bay tidal waters designated uses document.
Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries—2004 Addendum. EPA 903-R-03-002. [USEPA 2004a]	October 2004	Addresses endangered species protection, assessment of DO criteria, derivation of site-specific DO criteria, pycnocline boundary delineation methodology, and updated water clarity criteria/SAV restoration acreage assessment procedures.
Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability—2004 Addendum. EPA 903-R-04-006. [USEPA 2004e]	October 2004	Addresses refinements to Bay tidal waters designated use boundaries, segmentation boundaries, and Potomac River jurisdictional boundaries; documents SAV no-grow zones, restoration goal, and shallow-water acreages.
Chesapeake Bay Program Analytical Segmentation Scheme: Revisions, Decisions and Rationales 1983–2003. EPA 903-R-04-008. CBP/TRS 268-04. [USEPA 2004b]	October 2004	Details documentation on the history of the segmentation schemes and provides coordinates, georeferences, and narrative descriptions of the 2003 segmentation scheme.
Chesapeake Bay Program Analytical Segmentation Scheme: Revisions, Decisions and Rationales 1983–2003: 2005 Addendum. EPA 903-R-05-004. CBP/TRS 278-06. [USEPA 2005]	December 2005	Addresses methods used to subdivide the segments by jurisdiction and provides coordinates, georeferences, and narrative descriptions for those subdivided segments.
Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries—2007 Addendum. EPA 903-R-07-003. CBP/TRS 285-07. [USEPA 2007a]	July 2007	Addresses refinements to the Bay water quality DO, water clarity/SAV, and chlorophyll a criteria assessment methodologies and documents the framework for Bay tidal waters 303(d) list decision making.
Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries—2007 Chlorophyll Criteria Addendum. EPA 903-R-07-005. CBP/TRS 288/07. [USEPA 2007b]	November 2007	Publishes a set of numerical chlorophyll a criteria for Chesapeake Bay and the supporting criteria assessment procedures.
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. [USEPA 2008a]	September 2008	Addresses refinements to the Bay water quality DO, water clarity/SAV and chlorophyll a criteria assessment methodologies and documents the 2008 92-segment scheme for Bay tidal waters.
Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries—2010 Technical Support for Criteria Assessment Protocols Addendum. EPA 903-R-10-002. [illegible]	May 2010	Addresses refinements to procedures for defining designated uses, procedures for deriving biologically based reference curves for DO criteria assessment and chlorophyll a criteria assessment procedures.
Technical Addendum Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity, and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries	Nov 2017	Provides previously undocumented features of the present procedures for assessing attainment of the Chesapeake Bay water quality criteria as well as refinements and clarifications to the previously published Chesapeake Bay water quality criteria assessment procedures

2017 Tech Addendum on continuous data assessment options

1.
2.
3.

1. Direct Assessment with Enhanced Monitoring

- Input high-frequency data into 3D-Interpolator for CFD assessment of reference curve
  - Why not implemented? Not discussed.
  - Perhaps?
    - Does high frequency data, when combined with discrete data, skew results?
    - Labor intensive analysis? 3D interpolator not designed to handle continuous data

2. Conditional Attainment

- Develop conditional relationships for 30-day mean to 7-day mean and instantaneous criteria
  - 30-day mean value that results in <10% risk of non-attainment of 7-day or instantaneous criteria
- Use 3D Interpolator to calculate 30-day mean, and then infer ultimate instantaneous or 7-day criteria attainment

2. Conditional Attainment

- Assessment depends on variability and temporal frequency of monitoring data (CBP STAC 2012, existing data)
  - High frequency data: 30-day mean of **5.3 mg/l** ensures 7-day mean DO >4 mg/l with less than 10% non-attainment
  - Discrete data: 30-day mean of **6.22 mg/l** ensures 7-day mean DO attains >4mg/l with less than 10% non-attainment

2. Conditional Attainment

Instantaneous Min:

- Attainment of instantaneous min could not be achieved with a 10% risk with 30-day mean even as high as 7.01 mg/l

Table II-2. Parametric simulation results for a gradient of dissolved oxygen mean data and their ability to mutually protect the summer, open-water instantaneous minimum dissolved oxygen criteria.

Summer Season, Open-water 30-day Mean Dissolved Oxygen (mg/L)				
Rate of instantaneous criterion > 10 percent	5.0058	5.6732	6.3407	7.0082
	47.6%	32.5%	25.3%	18.5%

Source: CBP STAC 2012

Common Elements of a Continuous Data Assessment Methodology (non-CB)

- Frequency of Exceedance
- Calculation details
- Temporal Representation: Target Sample Size
- Definition of Critical Periods
- Description of how different data types (discrete, continuous) are evaluated
- Overwhelming evidence clause
- Spatial considerations (general assessment method)

Exceedance Frequency: Approaches

1. Impairment based on percent exceedance

- # observations exceed/total # observations

2. Impairment based on number of exceedances (none allowed, 1 allowed, etc)

3. Impairment based on statistical probability testing (binomial, hypergeometric)

- For 26-32 days, 4-6 days of exceedances result in impairment
- M. Fernandez (Tt): Assumes data independence, results in artificially small confidence intervals with high frequency data
- Binomial test is really logistic regression without any predictors. Instead of assuming independence, assume autoregressive first order (AR1): GLM with AR1 term

Continuous Data Exceedance Frequency: R3 State Examples

PA (final 2024 IR): Determines impairment if more than 1% of year exceeds. (unmonitored times = no exceedances)

- Based on PA State Code Chapter 96.3:"The water quality criteria… shall be achieved in all surface waters at least 99% of the time."
- Minimum: impairment when 4 days exceed (4/365>1%)
- 7-day mean = impairment with one exceedance (7/365 > 1%)

WV (draft 2024 IR), DC (2022IR), MD (2024 IR): Impairment if 10% of observations exceed

VA (2024 IR):

- Minimum: day exceeds if 10.5% of daily observations exceeds, impaired if >10.5% of days exceed
- Daily mean: >10.5% of days exceed

DE (2024 IR):

- If 10th percentile of daily mean data exceed, DO mean is impaired
- Minimum impaired if >1% of observations exceed

Calculation Details

- If impairment is based on percent or number of samples that exceed, what is one “sample” or “exceedance”?
  - One observation?
  - Calculated statistics
    - Daily Min, 7-day average, etc.
  - For example, PA clarifies that denominator of 1% is not total observations, but number of days in a year
- What years of data are evaluated? (For Chesapeake Bay, most recent three years, state assessment windows often 5 years)
- Are years/seasons evaluated separately? How many years/seasons need to be impaired for impairment determination? How are critical conditions considered?
- Are exceedances calculated on a rolling or static basis?

Target Sample Size

- Hours for complete daily “sample”?
- Days to calculate longer duration (7-, 30- day) averages?
- Target number of monitored days to make an assessment?
- Target number of years/seasons of data to make an assessment?

Example: VA

“Every 24-hour period with at least 75% of its observations deemed as valid should be assessed and counted as a single sample.”

“A continuous monitoring dataset that is eligible for assessment must cover at least thirty 24-hour periods.”

Critical Periods of Monitoring

- **VA:** Monitoring dataset must cover thirty 24-hour periods… This allows for an informative characterization of a water during the critical period (May to September) when exceedances of conventional field parameters are most expected.
- **PA:** When multiple years of data are collected, assessment decisions will be based on years where the most critical or limiting conditions exist. … For this reason, it is also imperative to characterize conditions that drive critical or limiting conditions, and reference those conditions as part of the protected use assessment and subsequent reassessments.

Considerations for combining different Data Types (discrete, continuous)

- VA: (Min) Exceedances recorded during the continuous monitoring run should be combined with grab samples within the assessment data window. A 10.5% rule should then be applied to the combined data set. (Rule 4)
- PA: Grab samples combined with continuous with discrete to determine # of days out of the year exceeding.
- MassDEP: MassDEP's goal is to use the most recently validated data for making use attainment decisions. Long-term continuous data are considered more informative and reliable than discrete or short-term continuous data when multiple types of data are available for a given site.

Overwhelming evidence factor

Determine impairment even if exceedance frequency criteria not met

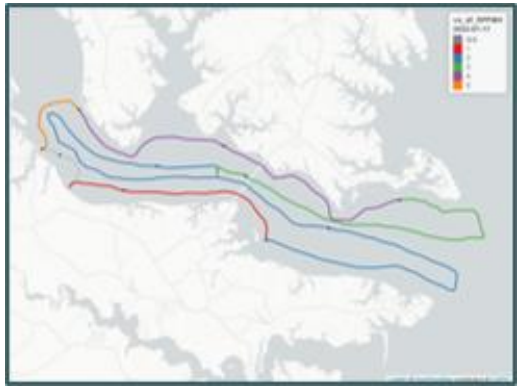
Consideration of magnitude or duration of exceedance (how badly did it exceed?)

Examples:

- OR: impairment if exceedance is >2x the acute magnitude
- WA: impairment when the above requirements are not met, but large deviations from the criterion magnitude are observed
- MI: It is conceivable, although likely infrequent, that in using BPJ, a water body may be assessed with a less rigorous set of data (e.g., than the preferred continuous monitoring over a two-week period), based on other environmental data concerns and/or multiple grab samples, showing degradation of water quality, collected over consecutive years or particularly egregious exceedance of WQS indicating obviously degraded conditions

Spatial Considerations

- Option 1: WV (draft 2024 IR): Impaired if any station in AU is impaired (don't change AU delineations)
- Option 2: VA (2024 WQA): If multiple monitoring stations differ in an AU, split AU to accurately reflect conditions (change AU delineation)
- Option 3: Bay – model condition spatially and temporally, determine impairment
- Option 4: Combine data from multiple stations, assume AU is homogenous. *Proceed with caution*
- Not described: PADEP, DCDOEE, DNREC, MDE



How would dataflow data be evaluated?

Common Elements of a Continuous Data Assessment Methodology (non-CB)

- Frequency of Exceedance
- Calculation details
- Temporal Representation: Target Sample Size
- Definition of Critical Periods
- Description of how different data types (discrete, continuous) are evaluated
- Overwhelming evidence clause
- Spatial considerations (general assessment method)

2017 Tech Addendum on continuous data assessment options

Recommended Assessment Methodology depends on Zone monitored

2017 TSD: Three Zone Delineation

- Zone 1 – Open, well-mixed Chesapeake Bay mainstem and tidal tributary waters
- Zone 2 – Shallow-water waters (generally <=2 m in depth)
- Zone 3 – Tributaries of tributaries off the mainstem Chesapeake Bay and tidal tributaries and embayments (weaker hydrodynamic links to open waters, poorly mixed)

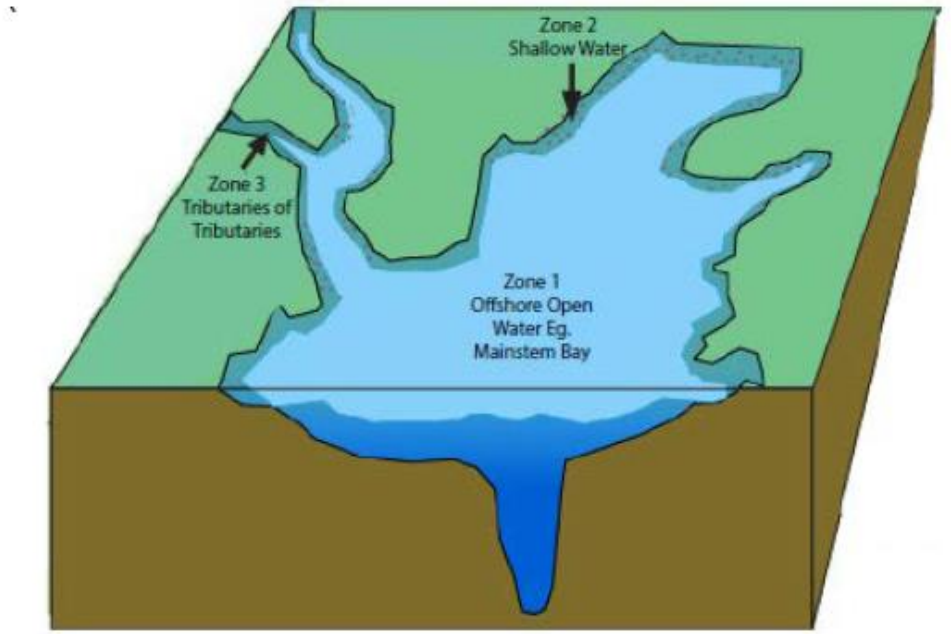


Figure II-4. Applying the concept of three zones to Chesapeake Bay open-water habitats.

Shallow Water Area in CB (Zone 2)

- Shallow: 2,833 km^2 are shallow (=<2m)
- Total bay: 11,601 km^2
- Shallow water ~ 24%

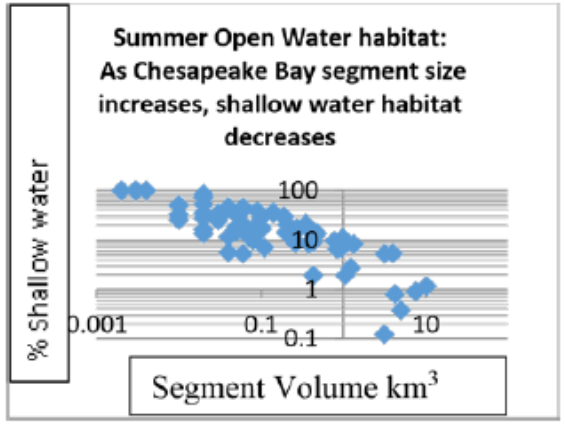


Figure B-1. The relationship of proportion of shallow-water habitat as it relates to the size of the Chesapeake Bay segments. Total segment volumes (km^3) were based on the U.S. EPA 2003b. Percent shallow water volumes were calculated from SAV Tier III acres (0-2m), converted to volume by assuming a rectangular volume 3 feet deep is roughly equivalent to a triangular volume with maximum depth of 2m, converted to gallons, then converted to km^3) and used to compare with the total segment volume for the proportion.

Why Zones?

- U.S. EPA (2007a):
  - Neither the need nor the requirement exists for a separate assessment of dissolved oxygen criteria attainment strictly within shallow waters (0-2 meters in depth)
  - Nearshore waters are considered to vary greatly from the mid-channel habitats of the open water, but there was no scientific basis for a dissolved oxygen-based delineation between the two habitats
  - Acknowledging that habitat differences do exist, a jurisdiction may, however, specifically delineate sub-segments within a Chesapeake Bay segment for purposes of criteria attainment assessment (U.S. EPA 2007a)
- Different patterns of variability in different zones - > AUs not homogenous

Rationale for Zone delineation – 2017 Appendix

Two Zone

- Based on high frequency data analysis, nearshore DO statistically similar to offshore DO at long-time scale (7-day and 30-day mean)
- But, statistically dissimilar at daily or shorter time steps (CBP STAC 2012)
  - Synthesized (spectral casting) data for offshore measurements
  - Confirmed with measured data in tidal York and Rappahannock
- Comparison of Patuxent River near- and off- shore, showed nearshore conditions were worse (22 and 39 days) than offshore in 2004 and 2005

Three Zone

- Nearshore monitoring sites with more mainstem tidal bay or mainstem tidal trib exposure had better DO.
- Tribs of Tribs have more violation rates than mainstem tribs

Analysis of Anoxic conditions in Shallow Water (2017 TSD)

Multiple time scales of hypoxia

- Diel scale: hypoxia occurs just after sunrise
- Sieching: Intrusion of anoxic deep water into shallow water
  - Examples: Piney Point (Potomac River) degraded DO for 48-72 hours
- Algal die off, bacteria decomposition reduces DO
  - Example: Corsica River, MD: week-long water quality and fish kill event (Sept 2005)
- 57 continuous summer DO records: nearshore locations experience hypoxia from minutes to weeks (Boynton et al 2014)

How do zones impact assessment?

Table II-4. Applicable criteria assessment procedures for each of the three zones within the open-water designated use.

Zone	Zone Description	Applicable Criteria Assessment Procedures
1	Open, well-mixed mainstem Bay and tidal tributary waters	• CFD-based assessment of the 30-day mean • CFD-based assessment of the 7-day mean with enhanced temporal frequency of monitoring • Conditional attainment assessment of the 7-day mean • Continuous monitoring-based assessment of the instantaneous minimum
2	Shallow-water waters	• Continuous monitoring-based assessment of the instantaneous minimum
3	Tributaries of tributaries off of the mainstem Chesapeake Bay and its tidal tributaries	• Discrete sampling-based assessment of the instantaneous minimum

2017 TSD on 10% exceedance

- “Further, EPA recommends making determinations of impairment for conventional pollutants “*when more than 10% of measurements exceed the water quality criterion*” (U.S. EPA 2005b).”
- “Though not stated explicitly, this recommendation assumes assessments are based on low-frequency discrete monitoring datasets, not continuous monitoring.”

What does continuous monitoring based assessment mean? (2017 TSD)

3 options examined, Rule 2-Alternate selected:

- “Rule 2-Alternate. No more than two consecutive days with 10 percent time (>2.5 hours) exceedance during a single season. This translates into 6 or more hours or about 0.2 percent of the summer season.”
- “Given it is the best option for addressing the need for separating out a random event from a more persistent event, Rule 2-Alternate is recommended for … instantaneous min

➢“based on the assumption that the instantaneous minimum criterion is interpreted as a discrete 1-hour average condition”, static averages

2017 TSD – Continuous Data Recommendation

- Continuous Monitoring Assessment only recommended for open water Use.
- Rule 2-Alt: "No more than two consecutive days with 10 percent time (>2.5 hours) exceedance during a single season. This translates into 6 or more hours or about 0.2 percent of the summer season."

DU	Instantaneous Criteria	Temporal Application	Days	Percent Exceedance of Days for impairment
MFSH	>= 3.2 mg/l (OW)	June 1 – Jan 31	244	1.2% (3/244 = 1.2% daily exceedance)
Open Water	>=3.2 mg/l	Year Round	365	0.8% of days
Deep Water	>=3.2 mg/l (OW)	Oct 1 – May 31	242	1.2%
Deep Channel	>=3.2 mg/l (OW)	Oct 1 – May 31	242	1.2%

2017 TSD – Continuous Data Recommendation

- Rule 2-Alt: “No more than two consecutive days with 10 percent time (>2.5 hours) exceedance during a single season. This translates into 6 or more hours or about 0.2 percent of the summer season.”
- Limitations:
  - Could allow 50% of days to exceed (if alternating)
  - Could allow 50 hours of consecutive exceedance (2 days + 2 hours)
- Not discussed: why these potential limitations are acceptable

Discrete Monitoring Assessment (Tribs of Tribs)

Impairment when >10% exceedance

$$\frac{\text{N samples exceeding}}{\text{n total observations}}$$ >10% - Impairment

Minimum of 10 samples per year over 3 years

50% of samples collected before 9AM

Table II-6. Recommended methods for assessing attainment of the short duration Chesapeake Bay dissolved oxygen criteria.

Designated Use	Assessment Scale	Assessment Method	Criteria	Supporting Documentation
All Designated Uses	Segment	**Direct Assessment with Enhanced Monitoring** Collecting data beyond the existing fixed station monitoring network using vertical water quality profilers, autonomous underwater vehicles, citizen science, etc.	All	U.S. EPA 2003a, U.S. EPA 2004a, this document
		Conditional Attainment with Monitoring Data Meet the longest duration mean dissolved oxygen threshold associated with a defined level of acceptable risk of nonattainment of the short duration dissolved oxygen criterion/criteria		

Remaining Questions

- Why only continuous and only discrete for zones 2 and 3?
- Why is Continuous Monitoring/discrete data assessment not recommended for other uses. Deep-water, Deep-channel, MFSN? (available data at the time?)

Open-water Designated Use	Full segment assessed with shoreline to shoreline Application	Segment	**Conditional Attainment with Bimonthly Monitoring Data** Meet the 30-day mean dissolved oxygen threshold associated with a defined level of acceptable risk of nonattainment of the 7-day mean dissolved oxygen criterion	7-day mean	U.S. EPA 2003a, U.S. EPA 2004a, CBP STAC 2012, this document
			Meet the 30-day mean dissolved oxygen threshold associated with a defined level of acceptable risk of nonattainment for the instantaneous minimum criterion	Instantaneous minimum	
	Sub-segment approach application	Zone 1: Open, well-mixed waters	**Zone 2 and Zone 3 Attainment Decision Rule** If sub-segments Zone 2 and Zone 3 pass, then the Zone 1 sub-segment is deemed passing and the entire segment is considered in attainment for the instantaneous minimum criterion	Instantaneous minimum	This document
			Conditional Attainment Meet the 30-day mean dissolved oxygen threshold associated with a a defined level of acceptable risk of nonattainment of the 7-day mean dissolved oxygen criterion	7-day mean, Instantaneous minimum	U.S. EPA 2003a, U.S. EPA 2004a, CBP STAC 2012, this document
		Zone 2: Shallow-water waters	**Continuous Monitoring** 15 minute interval data collected over the entire summer season with no more than two consecutive days with 10% time exceedance	Instantaneous minimum	This document
		Zone 3: Isolated Waters	**Discrete Sampling** 10 sample events per year collected over 3 years assessed based on 10% allowable exceedance	Instantaneous minimum	This document
Deep-water Designated Use	Segment		**Conditional Attainment with Bimonthly Data.** Meeting the deep water 30-day mean criterion ensures attainment of the short duration criteria	1-day mean, Instantaneous minimum	U.S. EPA 2004a

Recommendations/Considerations

- With 4D interpolator, will something be produced like the 2017 TSD?
- Should it clarify justification for allowing instantaneous min exceedances for specific uses?
- How will alternative assessment methods be addressed when 4D interpolator is developed?
  - Kept as options?
  - Expanded?
  - Address gaps in 2017 document?

Discussion

DO WQC (non-CB)

MD

- Warm Water Aquatic Life, Trout:
  - Dissolved Oxygen. The dissolved oxygen concentration may not be less than **5 milligrams/liter at any time**
- Nontidal Cold Water:
  - The dissolved oxygen concentration may not be less than **5 milligrams/liter at any time**, with a **minimum daily average of not less than 6 milligrams/liter**.

VA

9VAC25-260-50. Numerical criteria for dissolved oxygen, pH, and maximum temperature***.

CLASS	DESCRIPTION OF WATERS	DISSOLVED OXYGEN (mg/l)****		pH****	Max. Temp. (°C)
		Min.	Daily Avg.		
I	Open Ocean	5.0	--	6.0-9.0	--
II	Tidal Waters in the Chowan Basin and the Atlantic Ocean Basin	4.0	5.0	6.0-9.0	--
II	Tidal Waters in the Chesapeake Bay and its tidal tributaries	see 9VAC25-260-185		6.0-9.0	
III	Nontidal Waters (Coastal and Piedmont Zones)	4.0	5.0	6.0-9.0	32
IV	Mountainous Zones Waters	4.0	5.0	6.0-9.0	31
V	Stockable Trout Waters	5.0	6.0	6.0-9.0	21
VI	Natural Trout Waters	6.0	7.0	6.0-9.0	20
VII	Swamp Waters	*	*	3.7-8.0*	**

DO WQC (non-CB)

PA

- CWF: 7-day average 6.0 mg/l; minimum 5.0 mg/l
- WWF: 7-day average 5.5 mg/l; minimum 5.0 mg/l
- TSF:
  - February 15 to July 31" 7-day average 6.0 mg/l; minimum 5.0 mg/l.
  - For the remainder of the year, 7-day average 5.5 mg/l; minimum 5.0 mg/l.

DC: Non-tidal

Instantaneous Min: 5.0 mg/l

WV:

WWF: Not less than 5.0 mg/l at any time

TSF: Not less than 7.0 mg/l in spawning areas and in no case less than 6.0mg/l at any time

DE

4.5.2.1 Fresh Waters

- Daily average shall not be less than 5.5 mg/L
- Instantaneous minimum *shall not be less than* 4.0 mg/L

4.5.2.2 Marine Waters

- Daily average shall not be less than 5.0 mg/L
- Instantaneous Minimum *shall not be less than* 4.0 mg/L

4.5.2.3 Cold Water Fisheries (Put and Take)

- Daily average shall not be less than 6.5 mg/L during the applicable period.
- Instantaneous Minimum *shall not be less than* 5.0 mg/L during the applicable period

2003 Criteria Implementation: Assessment Methodology: How to count exceedances

- In defining what it means for the criteria to be attained, stressor magnitude, duration, return frequency, spatial extent and temporal assessment period must be accounted for.
  - The cumulative frequency distribution methodology for defining criteria attainment addresses the circumstances under which the criteria may be exceeded in a small percentage of instances, by integrating the five elements of criteria definition and attainment: magnitude, duration, return frequency, space and time.
- Using this approach to define criteria attainment, the EPA recommends a procedure to quantify the spatial extent (area or volume) to which the water quality criterion has been achieved or exceeded for each monitoring event.

CFD Method for Determining Water Quality Attainment

2006 STAC Report

- A novel statistical tool for attainment, termed the Cumulative Frequency Diagram (CFD) approach, was developed as a substantial revision of previous attainment procedures, which relied upon a simple statistical summary of observed samples. The approach was viewed as advantageous in its capacity to represent degrees of attainment in both time and space.