



Chesapeake Bay Program
Science. Restoration. Partnership.

March 23, 2026

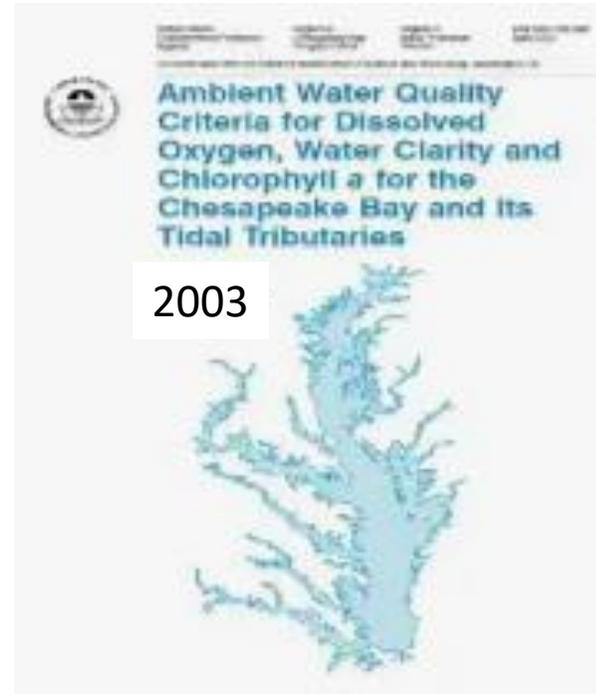
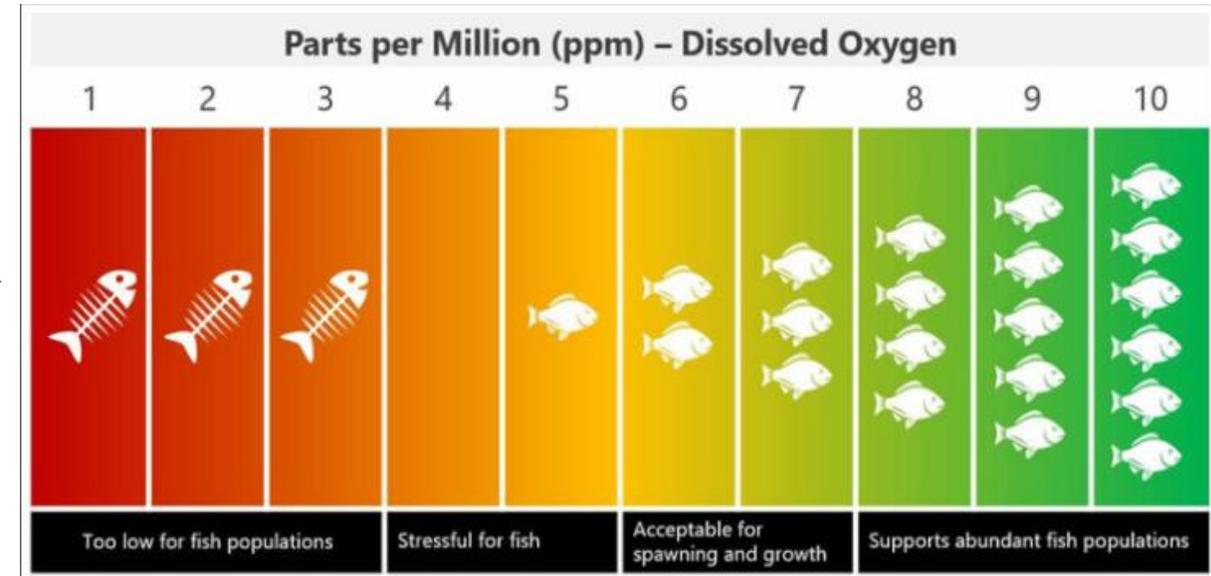
Chesapeake Bay Water Quality Criteria 101 Reference Curves & Bio-Reference Curve

Dr. Peter J. Tango (USGS, CBPO)

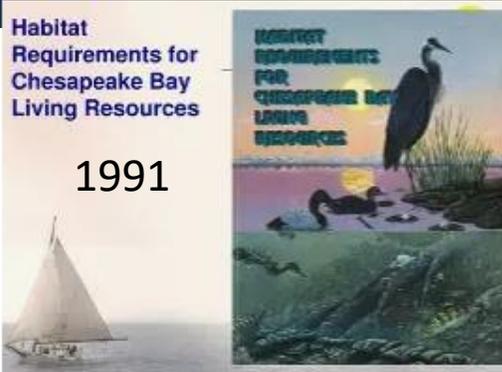


Chesapeake Bay Program
Science. Restoration. Partnership.

Informed understanding of habitat needs in setting criteria



2003



1991

II. PROCEDURES FOR ESTABLISHING A BAYWIDE DISSOLVED OXYGEN RESTORATION GOAL

1992 Chesapeake Bay DO Goal for Restoration of Living Resource Habitats

Figure 8-1. Effects of low dissolved oxygen on target species, summarized from Habitat Requirements for Chesapeake Bay Living Resources, 1991 Revised Edition (Funderburk et al. 1991). Note: does not account for temperature, salinity, dissolved oxygen interactions (Appendix A).

Species	Survivable	Tolerate Short Term	Tolerate	Lethal
BLUE CRAB	6.0	5.0	4.0	3.0
HARD CLAM	6.0	5.0	4.0	3.0
SOFTSHELL CLAM	6.0	5.0	4.0	3.0
CHSTER	6.0	5.0	4.0	3.0
BAY ANCHOVY	6.0	5.0	4.0	3.0
AMERICAN SHAD	6.0	5.0	4.0	3.0
YELLOW PERCH	6.0	5.0	4.0	3.0
WHITE PERCH	6.0	5.0	4.0	3.0
STRIPED BASS	6.0	5.0	4.0	3.0
ALEWIFE	6.0	5.0	4.0	3.0
BULLHEAD CATFISH	6.0	5.0	4.0	3.0
AMERICAN SHAD	6.0	5.0	4.0	3.0
HICKORY SHAD	6.0	5.0	4.0	3.0

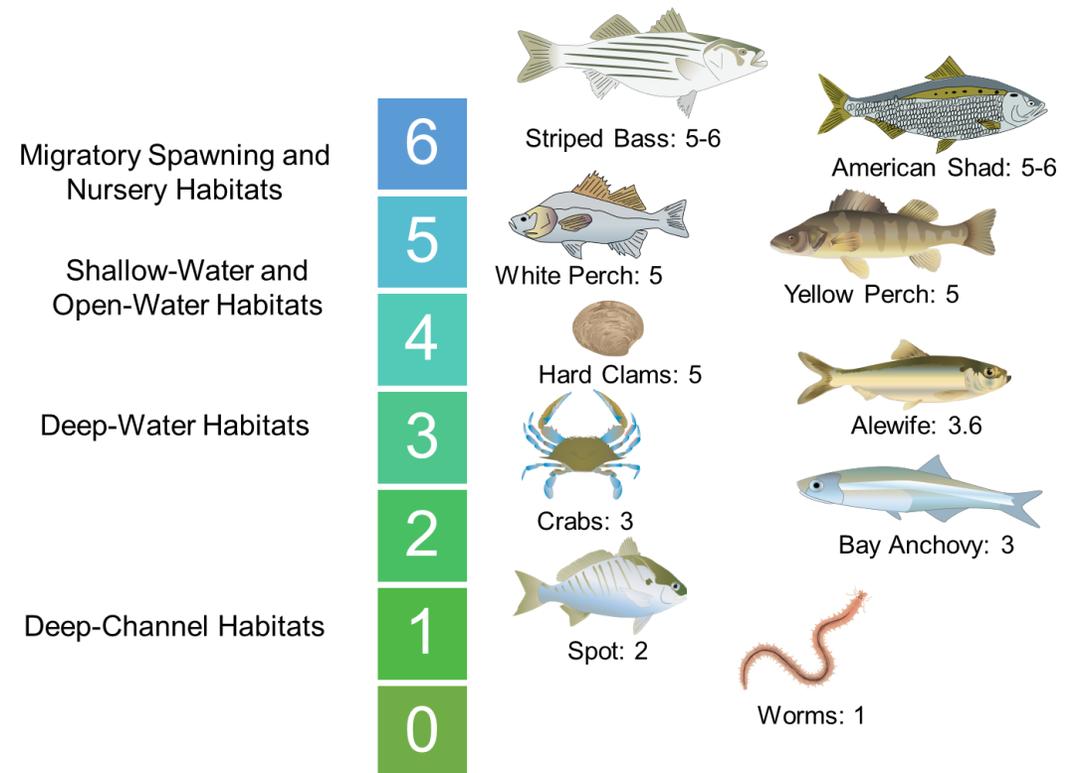
Water quality criteria were derived from decades of work, hundreds of studies, relating conditions that target species of fish, crabs, benthic organisms need to support their survival, growth and reproduction

Chesapeake Bay Water Quality Criteria

- Water quality criteria were derived to protect species *and* communities during specific time periods

Temporal resolution of Chesapeake Bay dissolved oxygen criteria:

- Instantaneous minimum
- 1-day mean
- 7-day mean
- 30-day mean

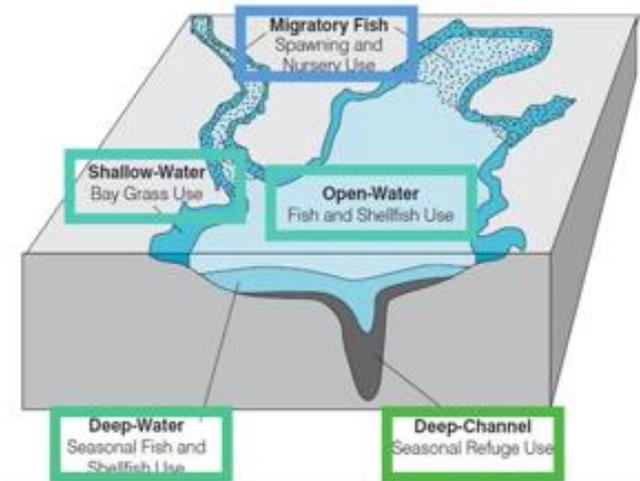


Dissolved oxygen (mg liter⁻¹) concentrations required by different species and communities.

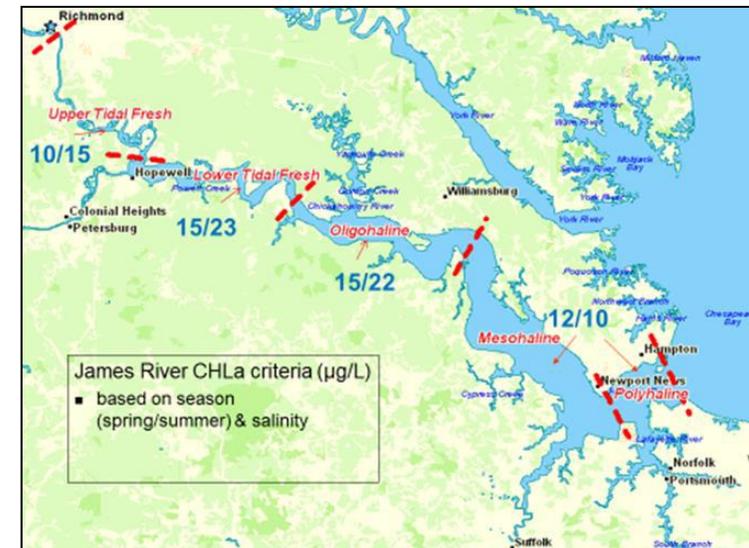
Chesapeake Bay Water Quality Criteria

Annual Assessment Breakdown

- DO designated uses
 - DC: Deep Channel (10 segments)
 - 1 criterion, 2 seasons
 - DW: Deep water (18 segments)
 - 3 criteria, 2 seasons
 - OW: Open water (92 segments)
 - 3 criteria, 2 seasons
 - MSN: Migratory fish spawning and nursery ground (71 segments)
 - 2 criteria, 2 seasons
- Chlorophyll:
 - Spring (5 segments)
 - Summer (7 segments)
- SAV and clarity: 98 segments



Five Chesapeake Bay tidal water designated use zones.

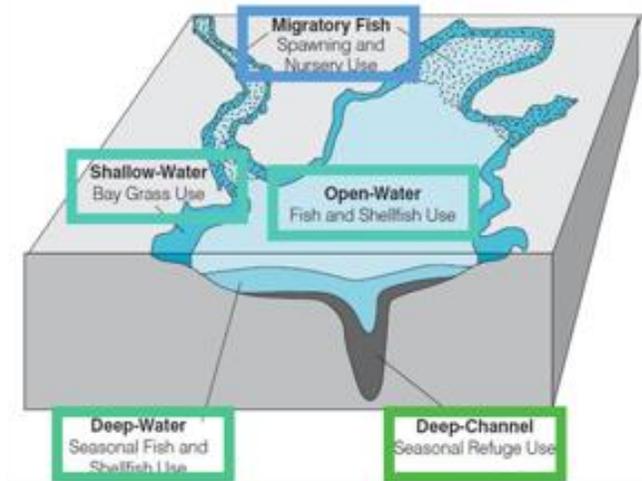


Chesapeake Bay Water Quality Criteria

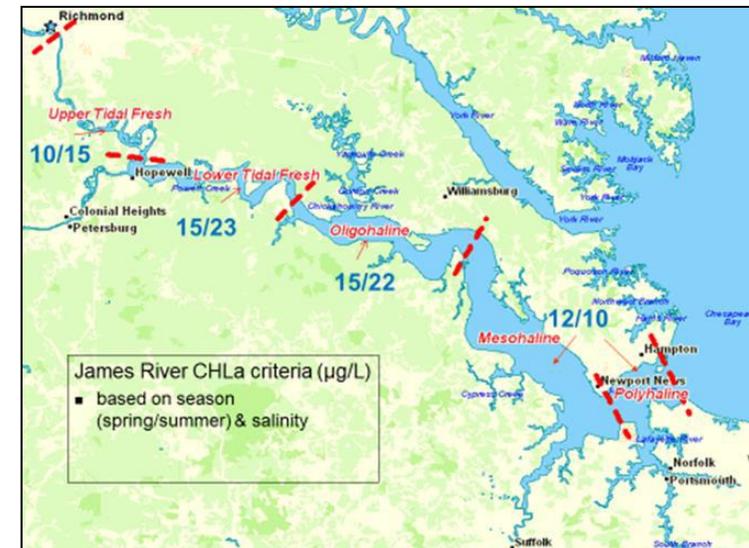
Annual Assessment Breakdown

- DO designated uses
 - DC: Deep Channel (11 segments)
 - 1 criterion, 2 seasons
 - DW: Deep water (25 segments)
 - 3 criteria, 2 seasons
 - OW: Open water (92 segments)
 - 3 criteria, 2 seasons
 - MSN: Migratory fish spawning and nursery ground (73 segments)
 - 2 criteria, 2 seasons
- Chlorophyll:
 - Spring (5 segments)
 - Summer (7 segments)
- SAV and clarity: 98 segments

Complete Bay attainment requires many hundreds of decisions to meet criteria simultaneously!



Five Chesapeake Bay tidal water designated use zones.



RESTORING THE CHESAPEAKE BAY

Clean Water Goal



Measurement of the Goal



Achieving the Goal

Protect Aquatic Living Resources

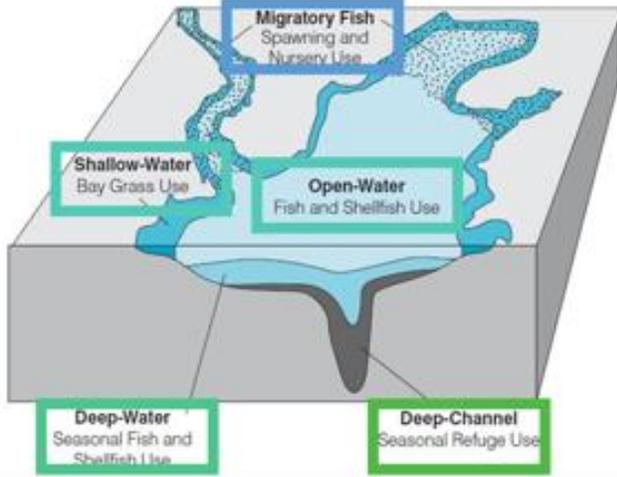
Migratory Spawning and Nursery Habitats	6	Striped Bass: 5-6	American Shad: 5-6
Shallow-Water and Open-Water Habitats	5	White Perch: 5	Yellow Perch: 5
Deep-Water Habitats	4	Hard Clams: 5	Alewife: 3.6
	3	Crabs: 3	Bay Anchovy: 3
Deep-Channel Habitats	2	Spot: 2	Worms: 1
	1		
	0		

Dissolved oxygen (mg liter⁻¹) concentrations required by different species and communities.

Numeric Criteria

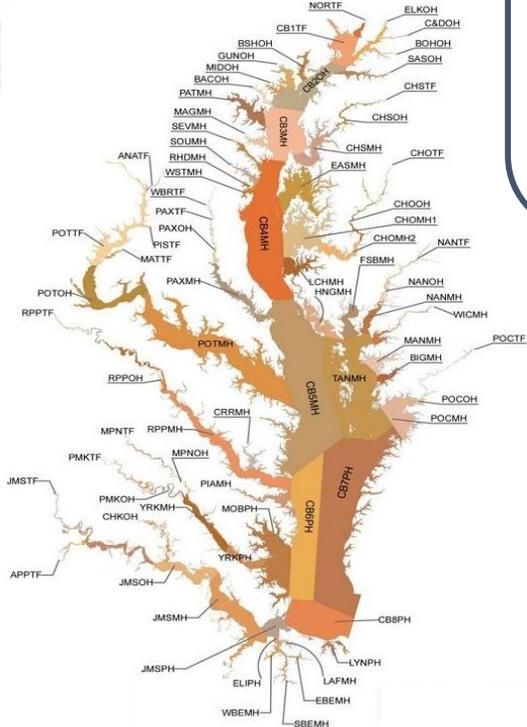
- Dissolved Oxygen
- Water Clarity/SAV
- Chlorophyll a

Across 5 habitats



Five Chesapeake Bay tidal water designated use zones.

in 92 Segments



TMDL

N, P, sediment targets to meet goal

↑

Pollutant Control Programs

↑

Accountability

The Process
 Assess with data,
 Plan with models,
 To achieve water quality
 and restore living
 resources!

RESTORING THE CHESAPEAKE BAY

Clean Water Goal



Measurement of the Goal



Achieving the Goal

Protect Aquatic Living Resources

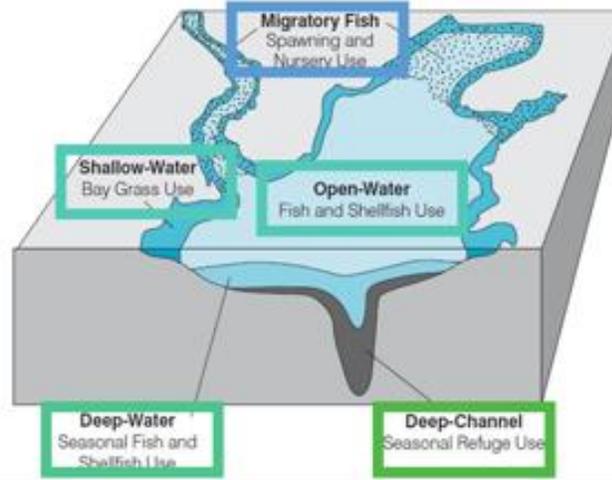
Migratory Spawning and Nursery Habitats	6	Striped Bass: 5-6	American Shad: 5-6
Shallow-Water and Open-Water Habitats	5	White Perch: 5	Yellow Perch: 5
Deep-Water Habitats	4	Hard Clams: 5	Alewife: 3.6
	3	Crabs: 3	Bay Anchovy: 3
Deep-Channel Habitats	2	Spot: 2	Worms: 1
	1		
	0		

Dissolved oxygen (mg liter⁻¹) concentrations required by different species and communities.

Numeric Criteria

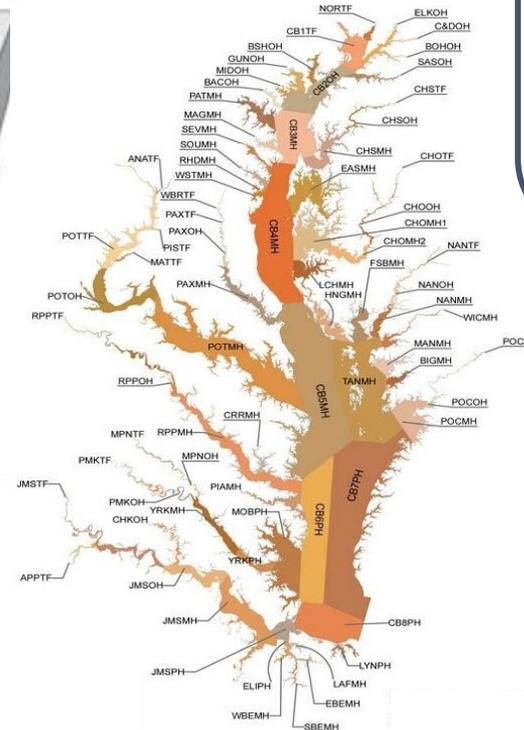
- Dissolved Oxygen
- Water Clarity/SAV
- Chlorophyll a

Across 5 habitats



Five Chesapeake Bay tidal water designated use zones.

in 92 Segments



TMDL

N, P, sediment targets to meet goal

↑

Pollutant Control Programs

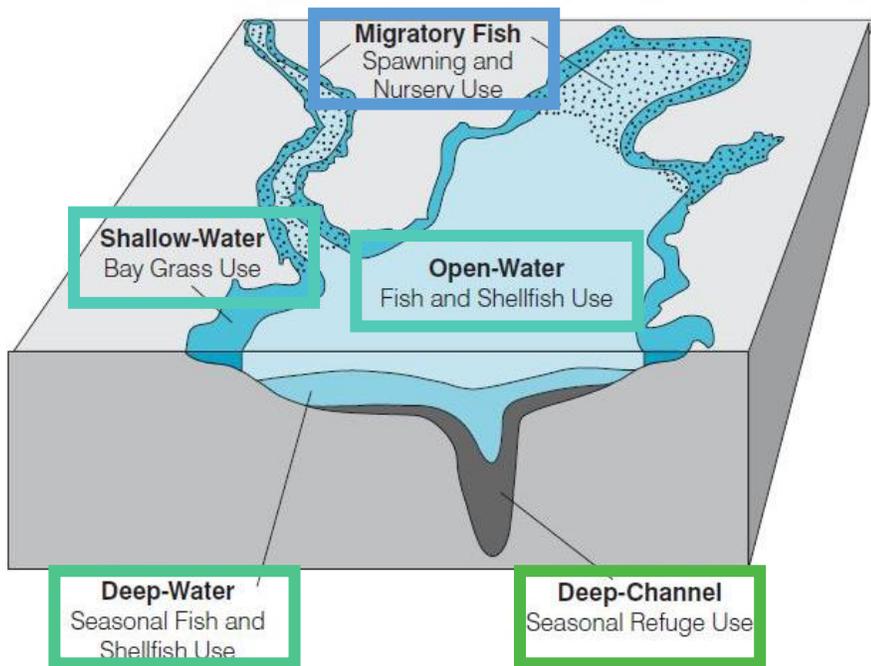
↑

Accountability

The Process
 Assess with data,
 Plan with models,
 To achieve water quality
 and restore living
 resources!

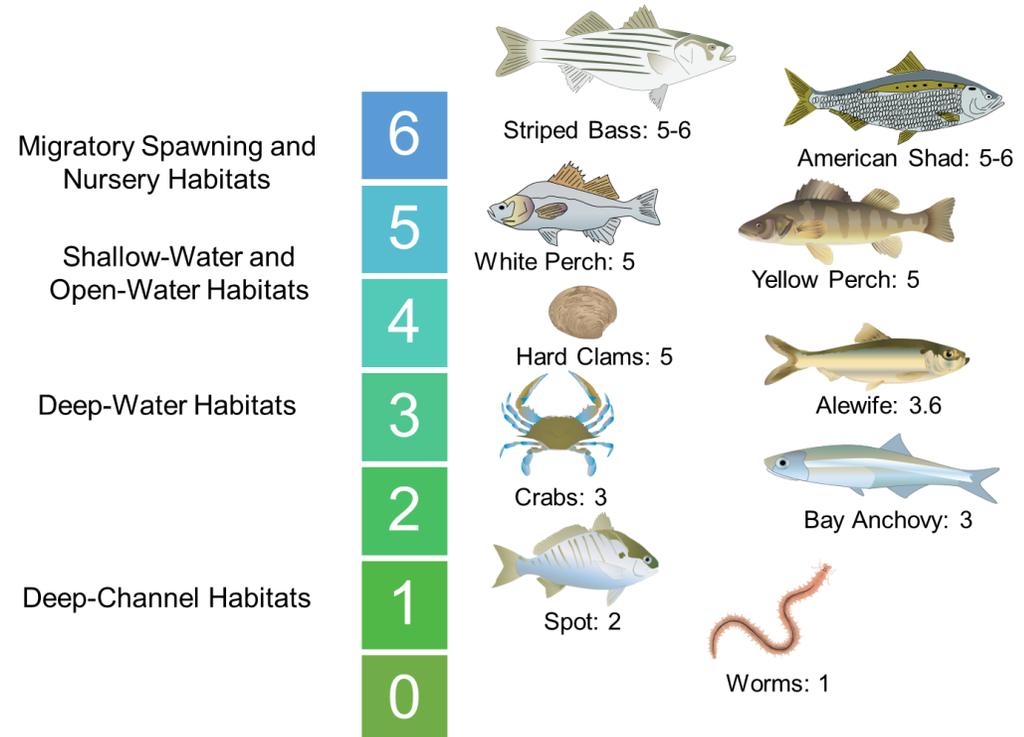
Chesapeake Bay Water Quality Criteria

- Water quality criteria were derived to protect species *and* communities during specific time periods
- These are the *minimum conditions necessary* to fully support target species of the Bay.



Five Chesapeake Bay tidal water designated use zones.

Graphics: IAN



Dissolved oxygen (mg liter^{-1}) concentrations required by different species and communities.

(US EPA, 2003)

Chesapeake Bay dissolved oxygen criteria protect survival, growth, and reproduction for living resources in space and across time.

These are *the minimum conditions* necessary to fully support target resources of the Bay.

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.

DO criteria that currently can be evaluated with existing approaches and data

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

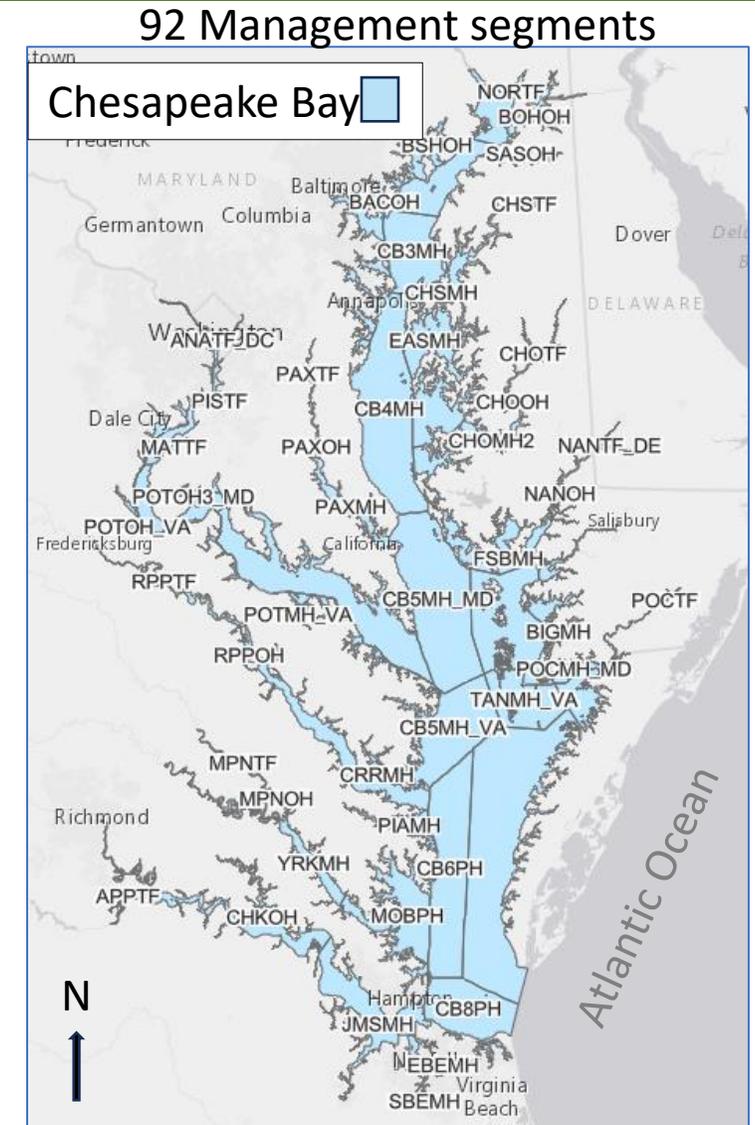
*Note a 30-day mean 6 mg/L MSN value is evaluated for purpose of the WQ indicator.

CAP Workgroup is charged with developing the protocols to assess these criteria for the Chesapeake Bay

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.

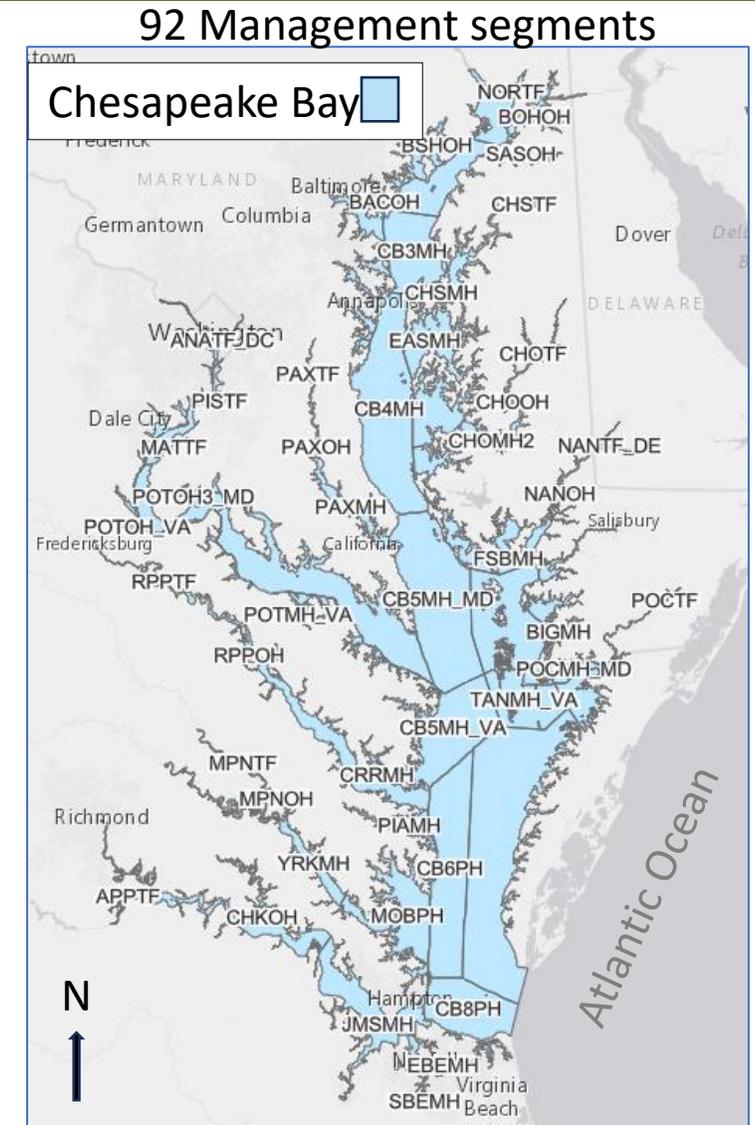
Chesapeake Bay Dissolved Oxygen Criteria

- Monitoring and Assessment Challenges for DO
 - Long term sampling 1-2x per month.
 - High temporal density nearshore sampling.
 - Insufficient high temporal density monitoring in challenging offshore habitats to support information needs

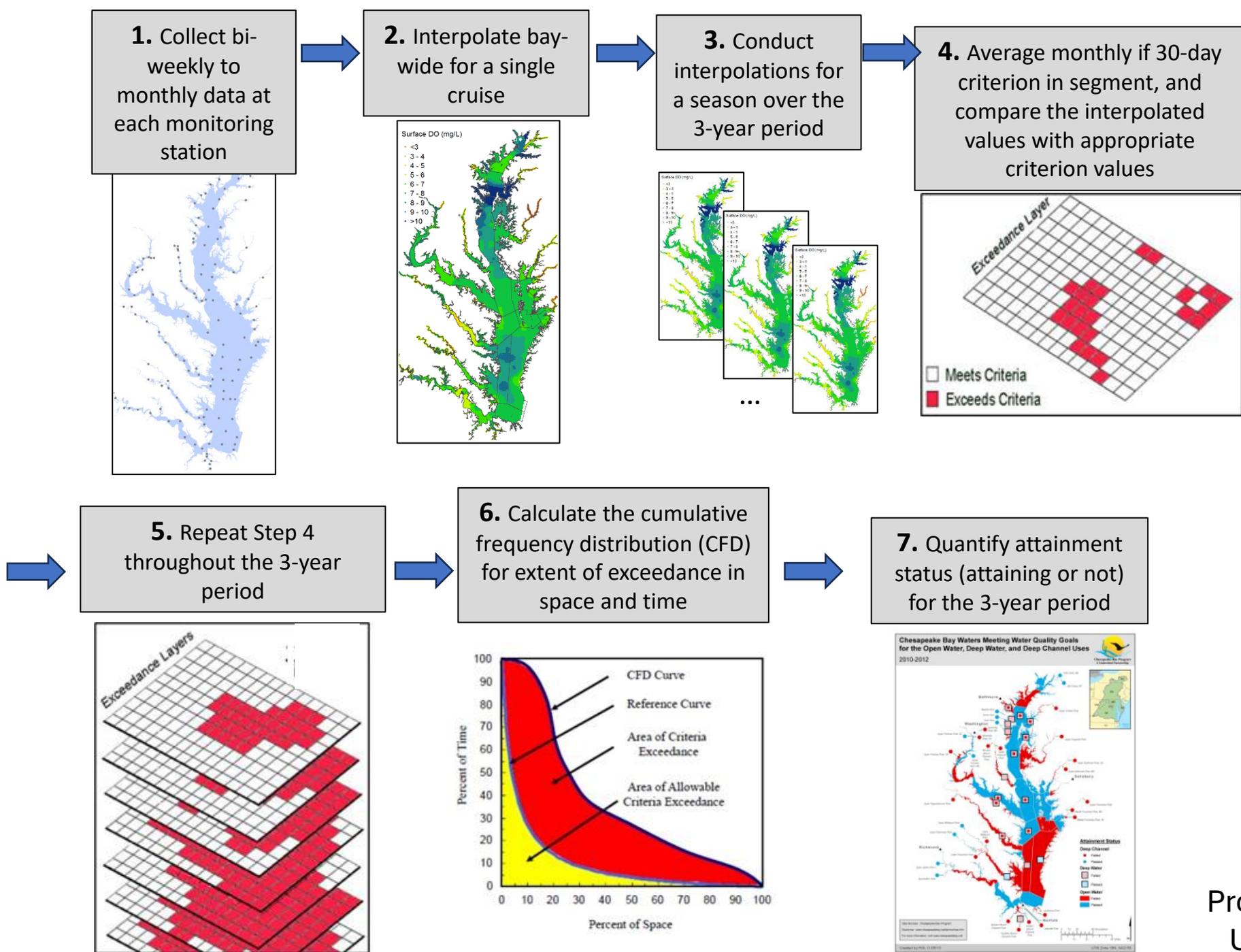


Chesapeake Bay Dissolved Oxygen Criteria

- Monitoring and Assessment Challenges for DO
 - Long term sampling 1-2x per month.
 - High temporal density nearshore sampling.
 - Insufficient high temporal density monitoring in challenging offshore habitats to support information needs
- Current Solution (20 years in the making...)
 - *New infrastructure investments*
 - *New monitoring network enhancements*
 - *New habitat assessment tool development*
 - *Partnership approach* for using new monitoring tools and managing new networks

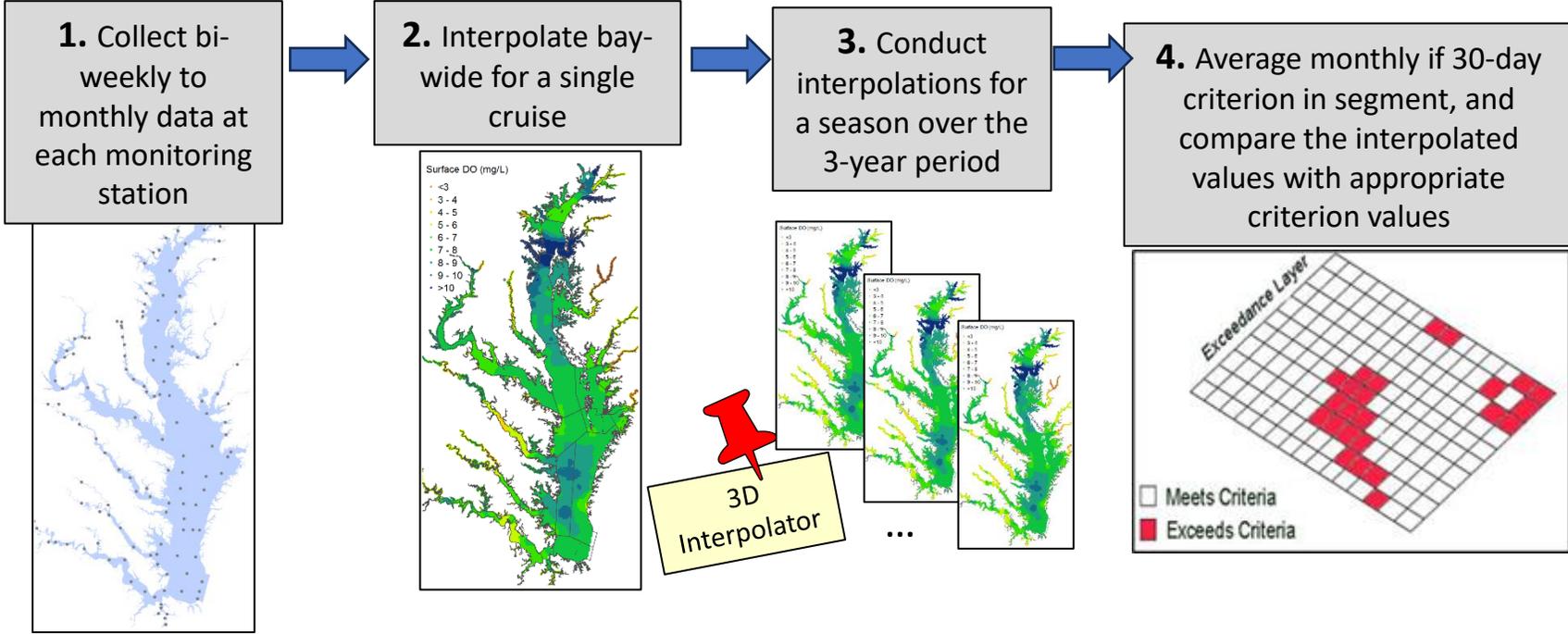


Chesapeake Bay WQ Criterion Assessment Process

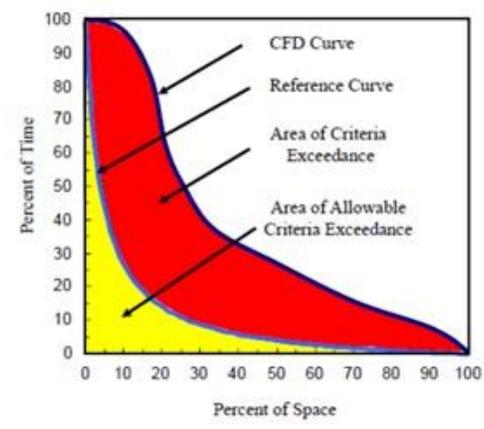
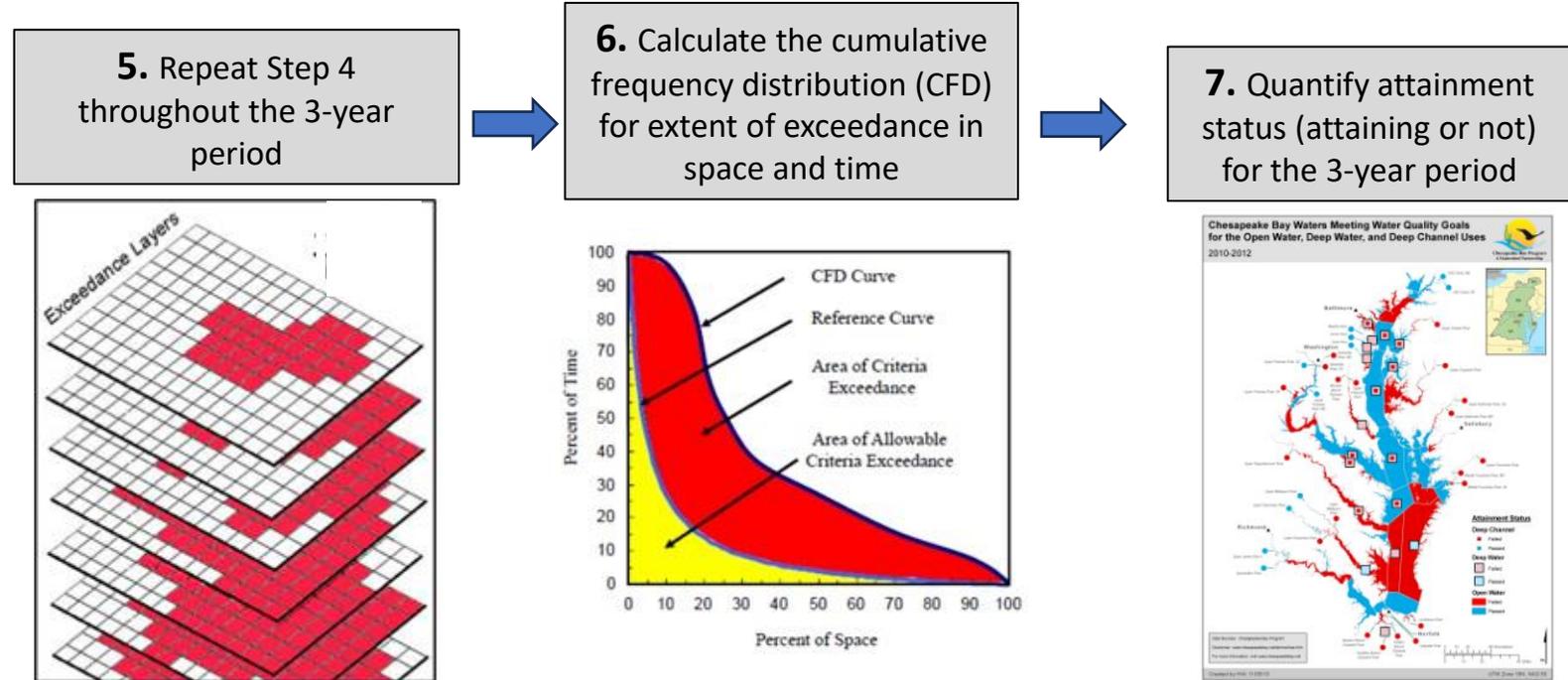


Process source
USEPA 2003

Chesapeake Bay WQ Criterion Assessment Process



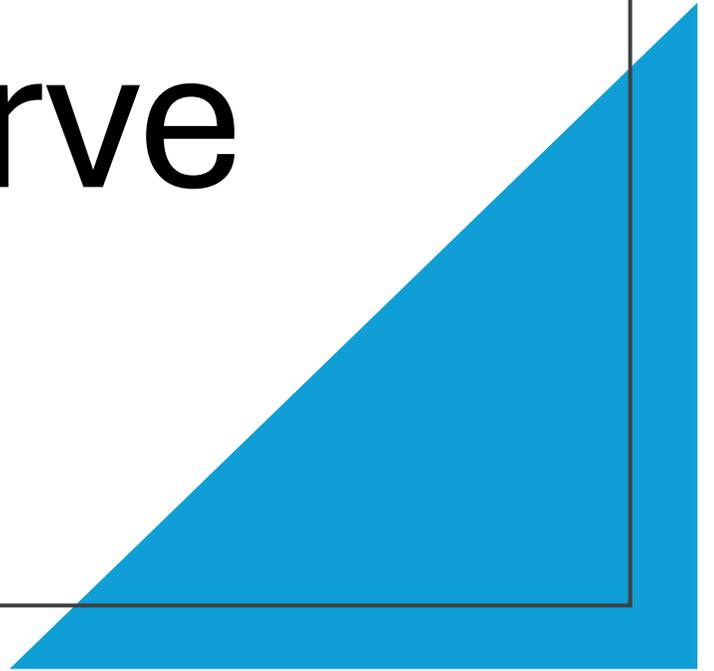
3D Interpolator



Monitoring data inform annual assessments AND this process is used in the Phase 6 suite of models

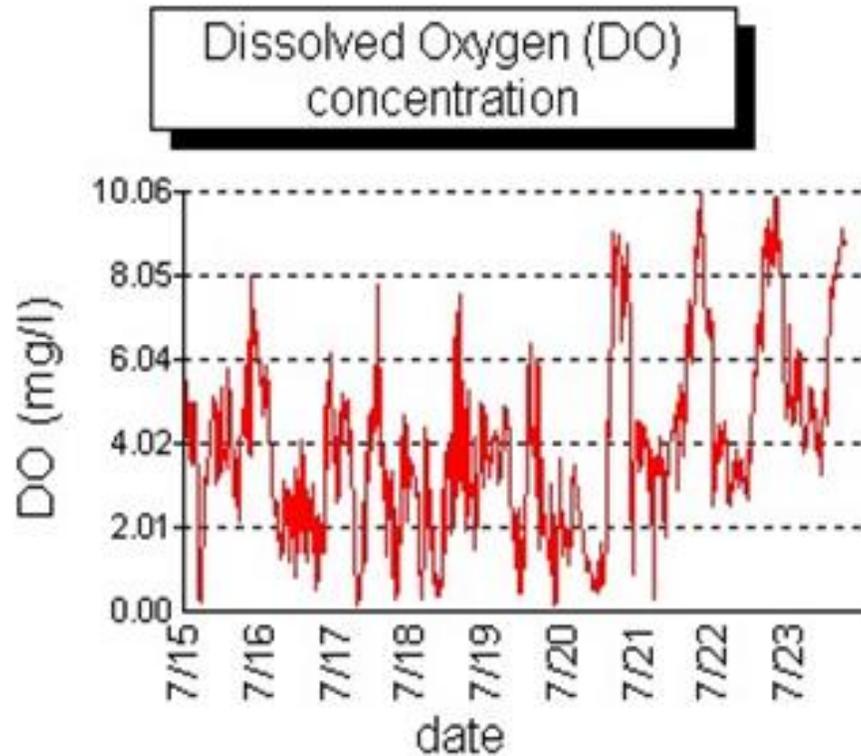
Process source
USEPA 2003

CBP Reference Curves and the Bio-reference Curve

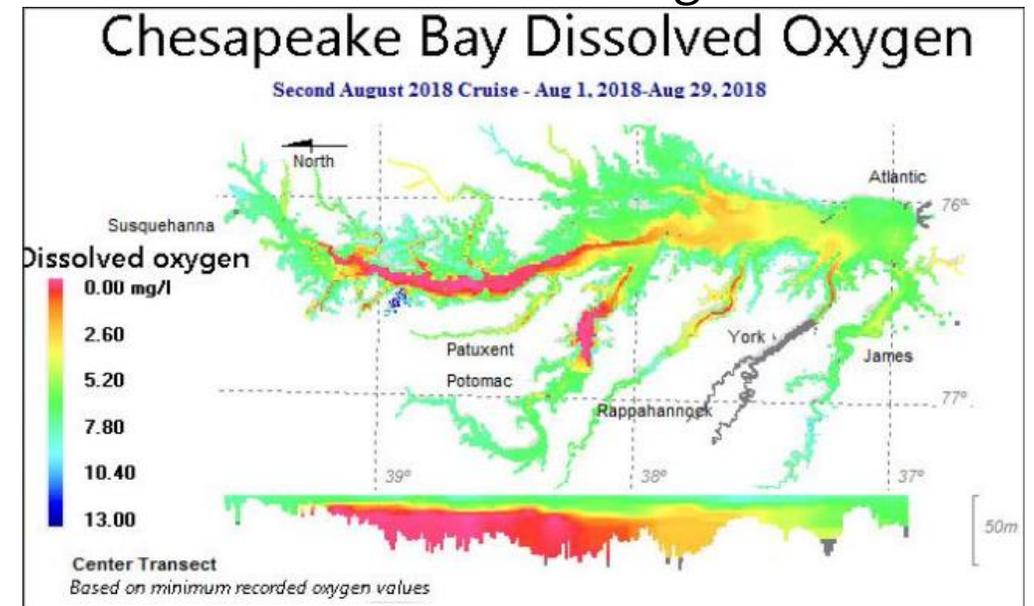




Chesapeake Bay Program
Science. Restoration. Partnership.



Spatial dissolved oxygen in the bay
of one summer monitoring cruise

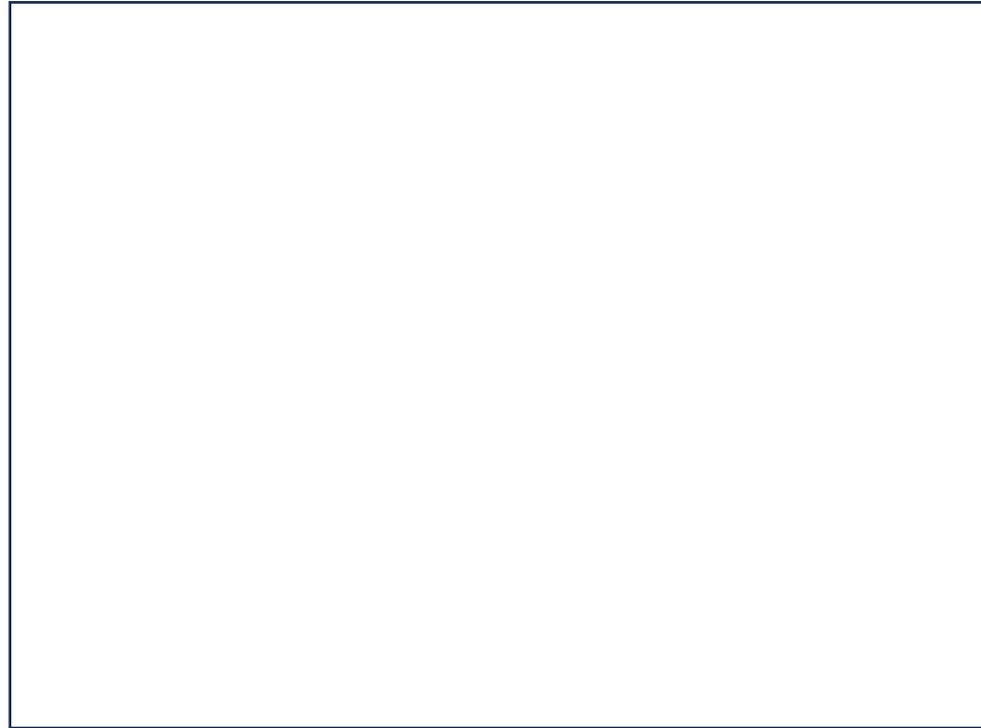


We evaluate habitat conditions over dimensions of **time** and across **space** (volume).



Chesapeake Bay Program
Science. Restoration. Partnership.

Criteria violations in **TIME**



Criteria violations in **SPACE** (volume)



We evaluate data and visualize habitat assessments using an **assessment graphic** showing any criteria violations in time and space.



Chesapeake Bay Program
Science. Restoration. Partnership.

Criteria violations in **TIME**

Anytime we detect a criterion violation, it will show up as a point in this graph space.

Criteria violations in **SPACE** (volume)



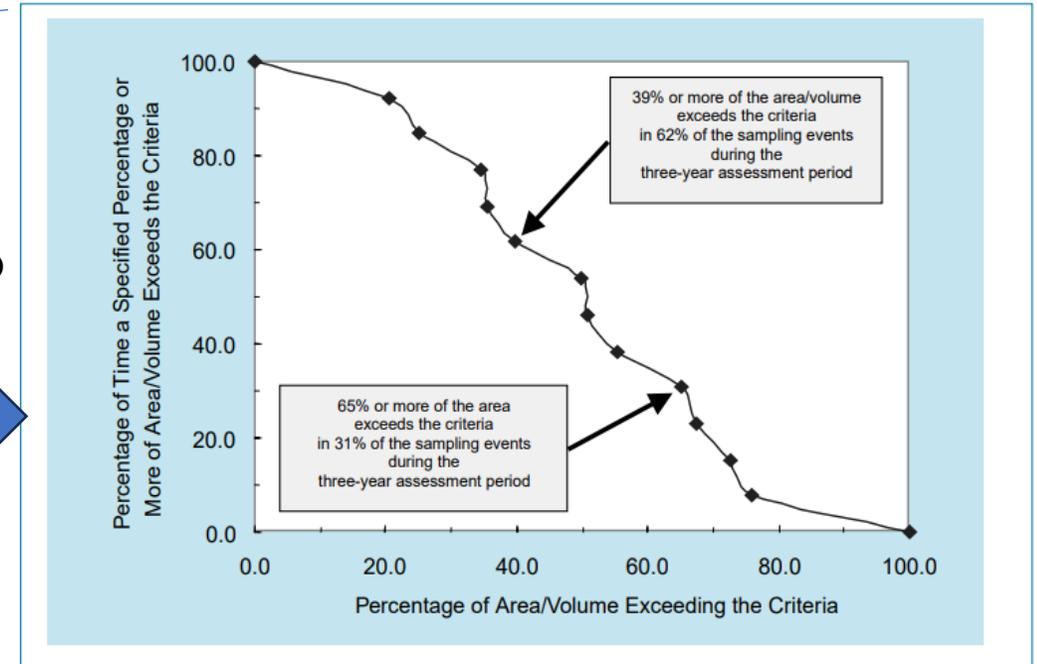
We evaluate data and visualize habitat assessments using an **assessment graphic** showing any criteria violations in time and space.



Chesapeake Bay Program
Science. Restoration. Partnership.

Month	Percent Area/ Volume	Rank	Cumulative Probability [Rank/(n+1)]
	100		0.00%
June 1998	75	1	7.69%
March 1998	72	2	15.38%
May 1999	67	3	23.08%
May 1998	65	4	30.77%
April 1998	55	5	38.46%
June 2000	50	6	46.15%
March 1999	49	7	53.85%
April 2000	39	8	61.54%
May 2000	35	9	69.23%
April 1999	34	10	76.92%
June 1999	25	11	84.62%
March 2000	20	12	92.31%
	0		100.00%

Data are translated into points in the plot



Violation plot

3 years of data.
Violation table

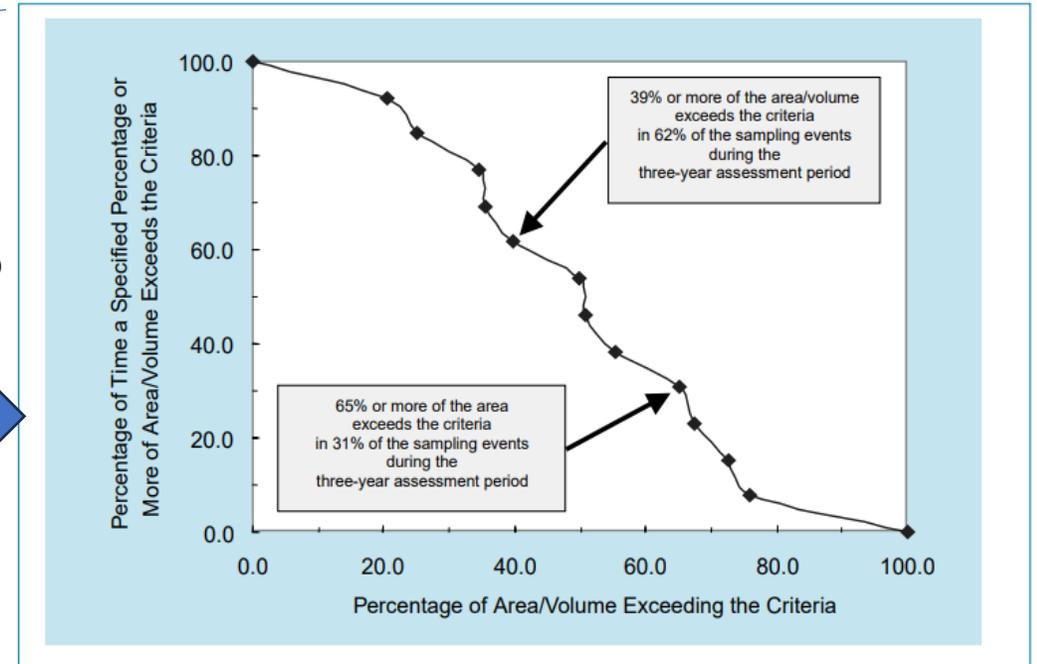
We translate our monitoring findings and create a **violation table** and then a **violation plot with cumulative frequency distribution (CFD)** from the table (USEPA 2003). This example clearly shows we have violations in space and time.



Chesapeake Bay Program
Science. Restoration. Partnership.

Month	Percent Area/ Volume	Rank	Cumulative Probability [Rank/(n+1)]
	100		0.00%
June 1998	75	1	7.69%
March 1998	72	2	15.38%
May 1999	67	3	23.08%
May 1998	65	4	30.77%
April 1998	55	5	38.46%
June 2000	50	6	46.15%
March 1999	49	7	53.85%
April 2000	39	8	61.54%
May 2000	35	9	69.23%
April 1999	34	10	76.92%
June 1999	25	11	84.62%
March 2000	20	12	92.31%
	0		100.00%

Data are translated into points in the plot



Violation plot

3 years of data.
Violation table

BUT WAIT! We are not done yet.

In the regulations, there is an **allowable level of criterion violation exceedance** in space and time.



Chesapeake Bay Program
Science. Restoration. Partnership.

How do we know if we are meeting the criterion given the additional allowable level of criterion exceedance ?

[What is the allowable exceedance?](#)



Chesapeake Bay Program
Science. Restoration. Partnership.

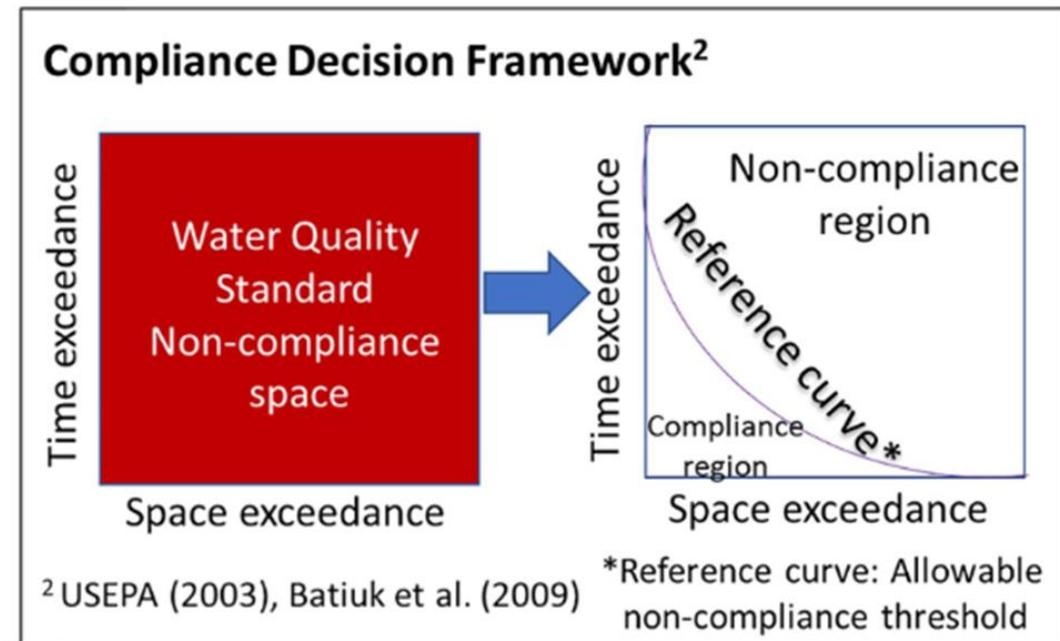
How do we know if we are meeting the criterion given the additional allowable level of criterion exceedance ?

What is the allowable exceedance?

Allowable exceedance in our analysis is defined by the area under a **reference curve** to compare to the line in the violation plot derived from our monitoring data.

What is a reference curve?

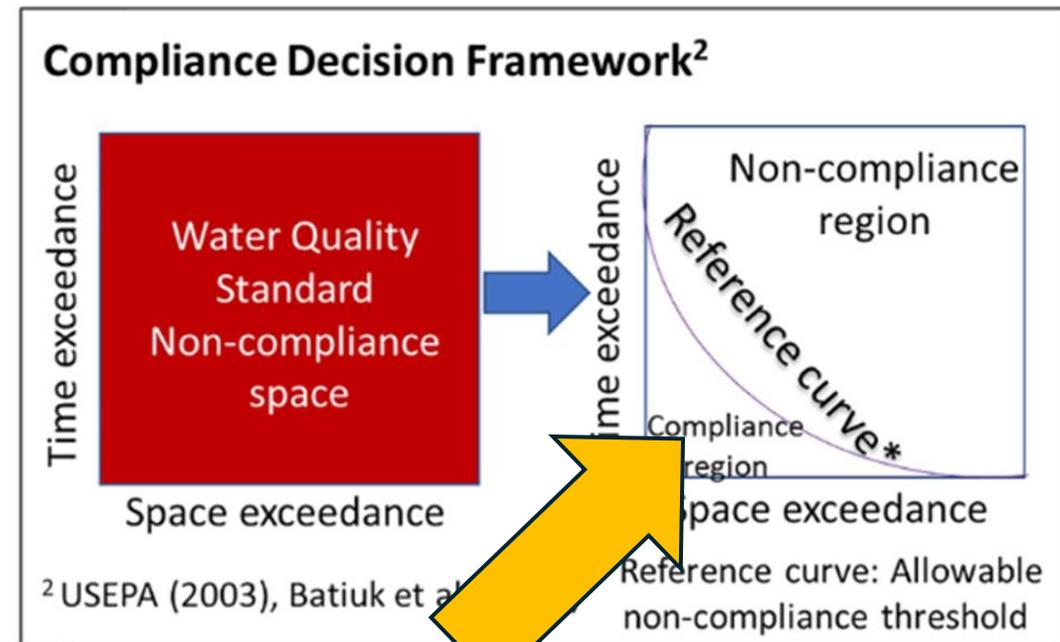
- Dissolved oxygen criteria for Chesapeake Bay are evaluated across space (volume of water) and time using a compliance decision framework.
- The framework utilizes a reference curve to assess compliance.
- Provides room for allowable exceedances
 - Some species can move, adapt, and/or tolerate low oxygen for a time



Source: Zhang and Tango

What is a reference curve?

- Dissolved oxygen criteria for Chesapeake Bay are evaluated across space (volume of water) and time using a compliance decision framework.
- The framework utilizes a reference curve to assess compliance.
- Provides room for allowable exceedances
 - Some species can move, adapt, and/or tolerate low oxygen for a time



Policy-based 10% allowable exceedance under the reference curve. Allowable exceedance accounts for measurement and sampling error.

What is a reference curve?

- **“Nonattainment”**: Any parcel of water in an assessment unit that has a measure beyond an accepted criterion value.
 - Exceedances count toward the total amount of space and time of noncompliance.
- **“Allowable exceedances”** – an accepted amount of nonattainment in a WQ criterion assessment.
 - A frequently used value is **10% allowable exceedance**.
- When considering space and time together, **a 10% default allowable exceedance curve (Cumulative Function Distribution or CFD curve in the diagram)** allows for habitat exceedances to be distributed equally in space and time totaling up to 10%.

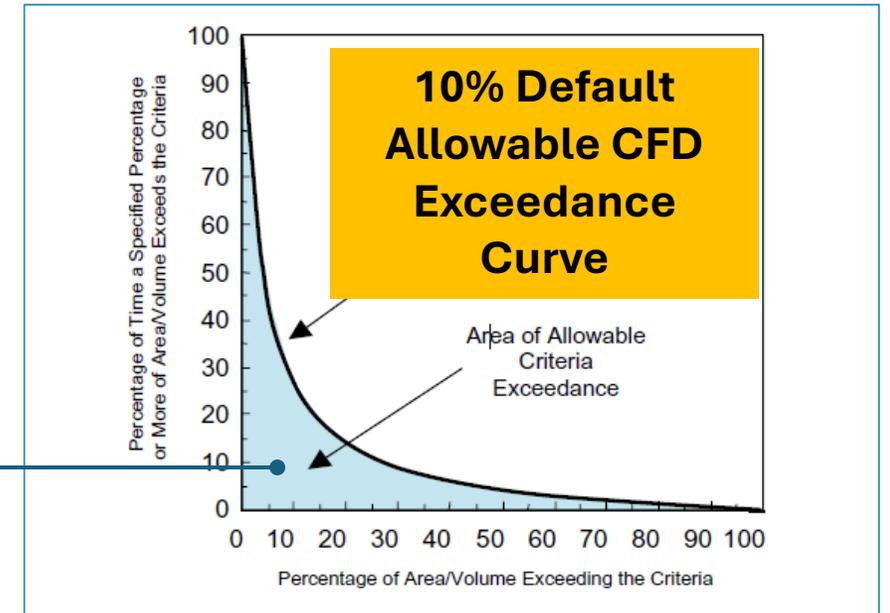


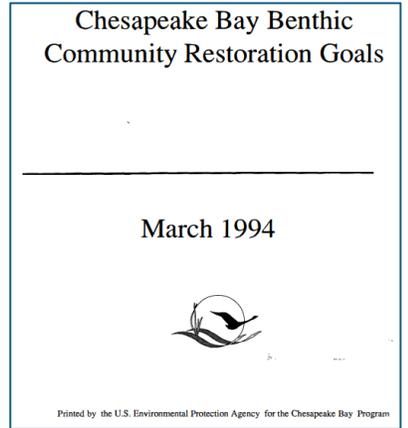
Figure VI-18. Cumulative frequency distribution curve in the shape of a hyperbolic curve that represents approximately 10 percent allowable exceedances equally distributed between time and space.

USEPA (2003)

What is a bio-reference curve?

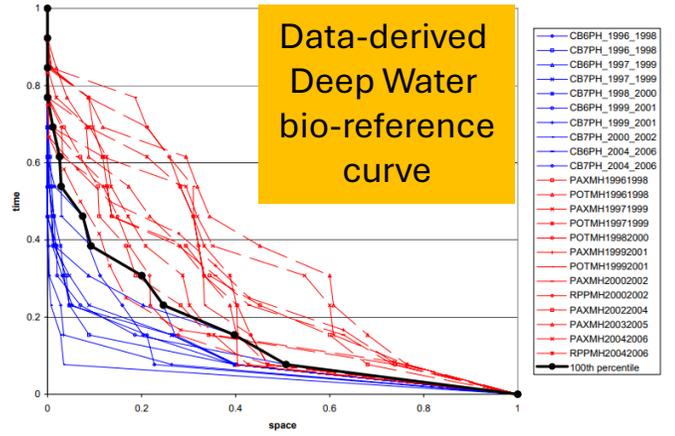
- A **bio-reference curve** is a scientifically-derived, biology-informed allowable exceedance curve, preferred over a 10% default curve when available.

USEPA 2003, 2010



WQ Mon Data

Figure 3: DO deep water criteria violation rates corresponding to healthy (blue) and degraded (red) benthic communities. Bioreference curve representing 100th percentile of healthy violations shown in black.



Healthy Habitats with some degradation
 Degraded Habitats

What is a bio-reference curve?

- A **bio-reference curve** is a scientifically-derived, biology-informed allowable exceedance curve, preferred over a 10% default curve when available.

USEPA 2003, 2010

- In 2009, STAC reviewed potential bio-reference curves the CBP might use. The Deep water bio-reference curve was the most robust curve.
- EPA published the curve and its derivation for State adoption and use in assessments (USEPA 2010).

Application of Reference Curves for Dissolved Oxygen Criteria Assessment:



**Chesapeake Bay Program Office
Review and Recommendations**

**Briefing Document for the
CBP Scientific and Technical Advisory Committee's
Peer Review Team**

July 2, 2009

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

May 2010
U.S. Environmental Protection Agency
Region III
Chesapeake Bay Program Office
Annapolis, Maryland

2010
and
Region III
Water Protection Division
Philadelphia, Pennsylvania

in coordination with
Office of Water
Office of Science and Technology
Washington, D.C.

and
The states of
Delaware, Maryland, New York
Pennsylvania, Virginia and
West Virginia and the District of Columbia

**Chesapeake Bay Benthic
Community Restoration Goals**

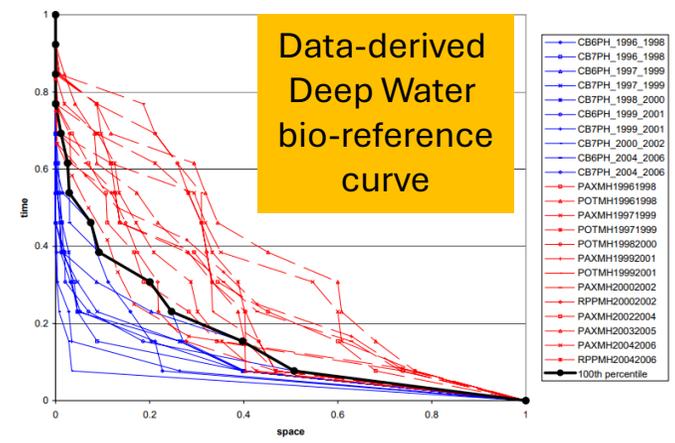
March 1994



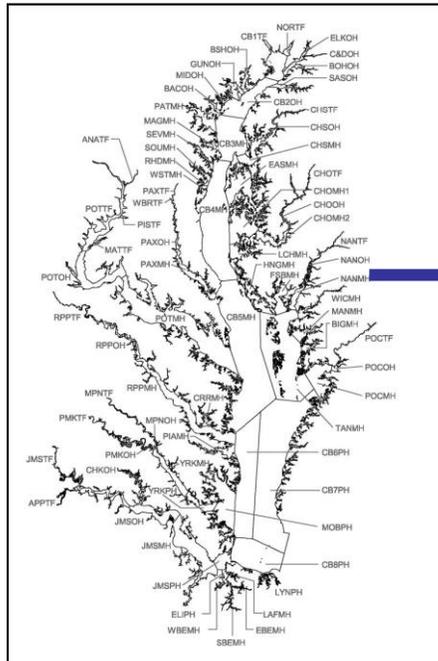
Printed by the U.S. Environmental Protection Agency for the Chesapeake Bay Program

WQ Mon Data

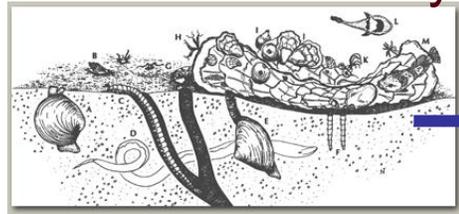
Figure 3: DO deep water criteria violation rates corresponding to healthy (blue) and degraded (red) benthic communities. Bioreference curve representing 100th percentile of healthy violations shown in black.



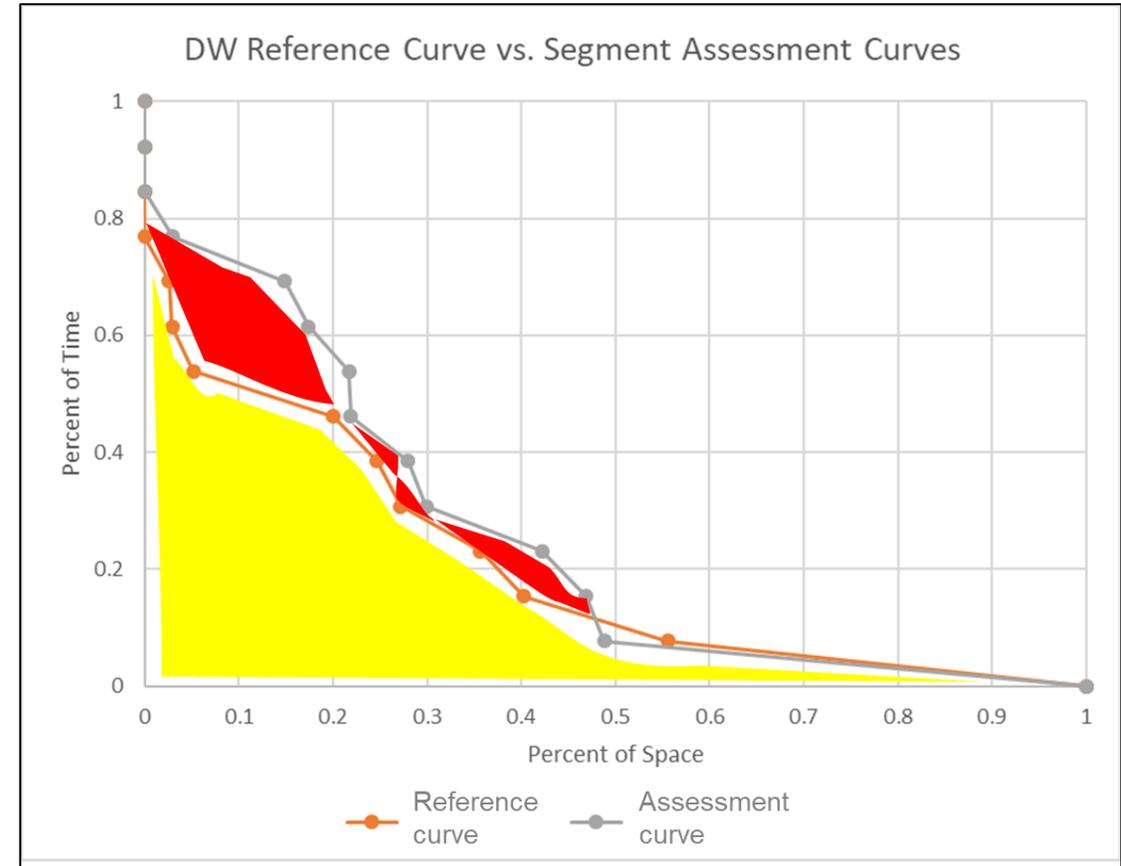
- A **bio-reference curve** is a cumulative frequency distribution (CFD) that is used to determine “unacceptable” exceedance of the criteria
 - Allows us to judge against a “healthy ecosystem”
- **Bio-reference curves** are derived from the Chesapeake Bay benthic index of biotic integrity (BIBI)



benthic community



CBP Segment	Year
APPTF	2004
BOHOH	2004
CB1TF	2004
CB2OH	2002
CB3MH	1995
CB6PH	1993
CB8PH	1996
FSBMH	2005
NANMH	1987
RPPMH	1988
RPPTF	1996
WICMH	1999
...	...

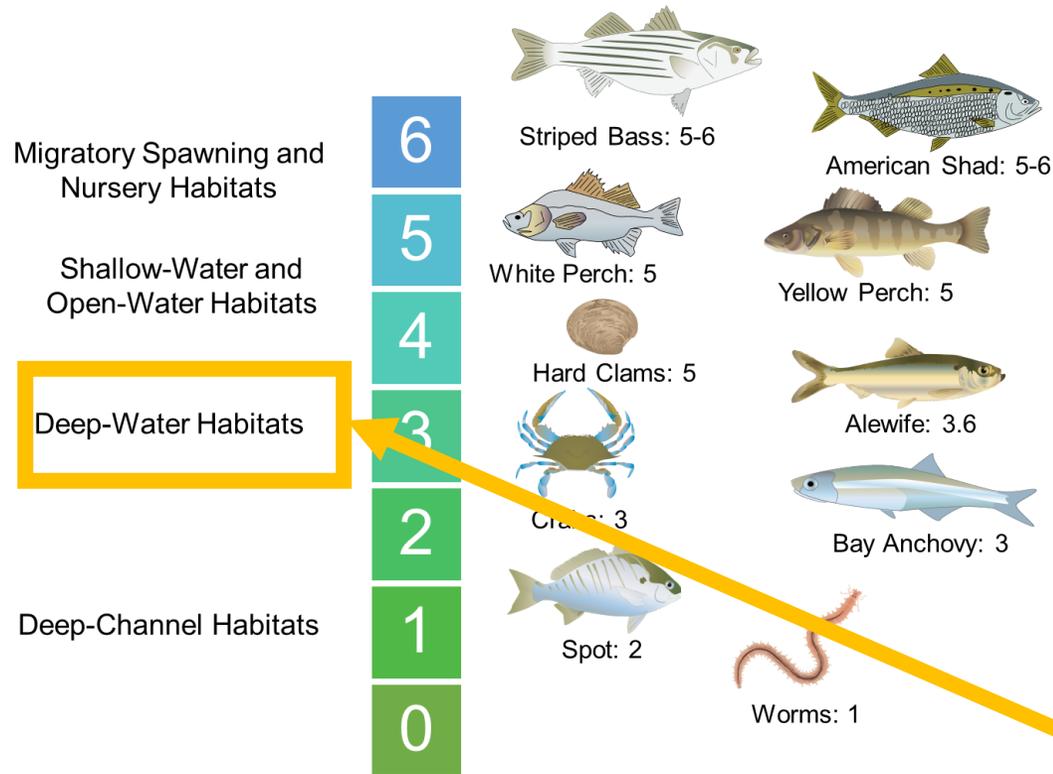


**Allowable
Criteria Exceedance**

**Criteria
Exceedance**

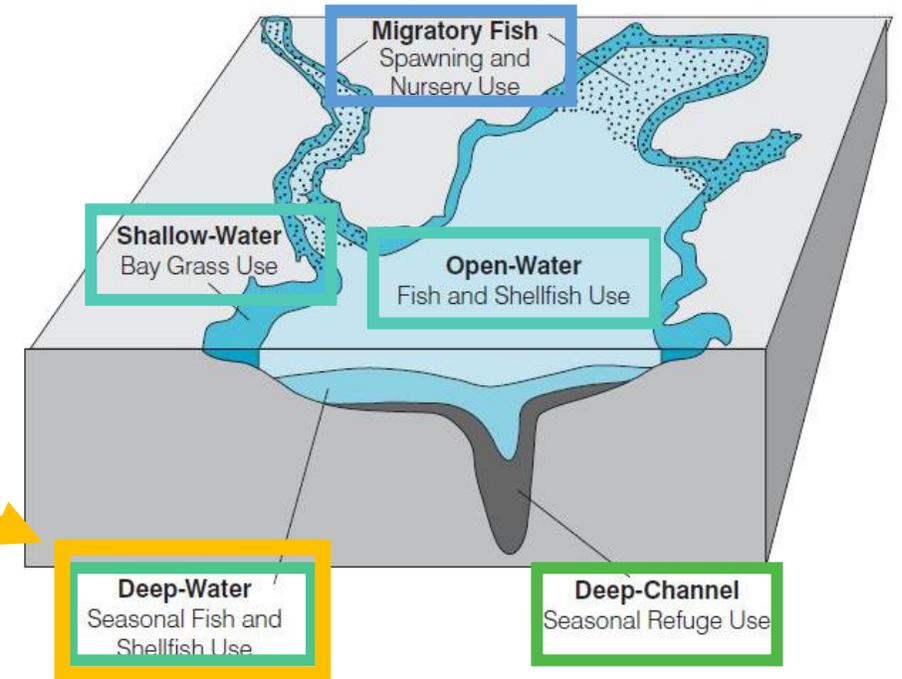
Attainment Deficit = the actual amount of space-time criterion exceedance

Which designated uses presently have a bio-reference curve available for criterion assessment?



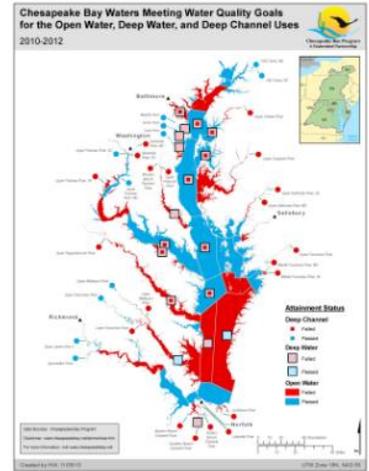
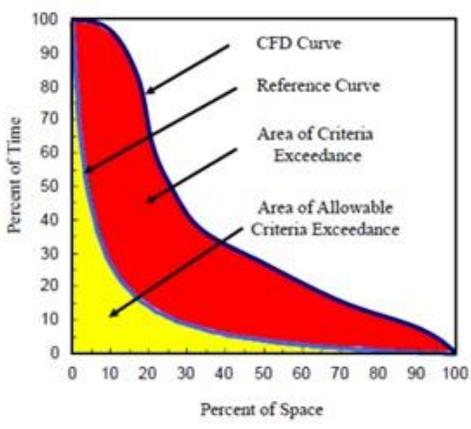
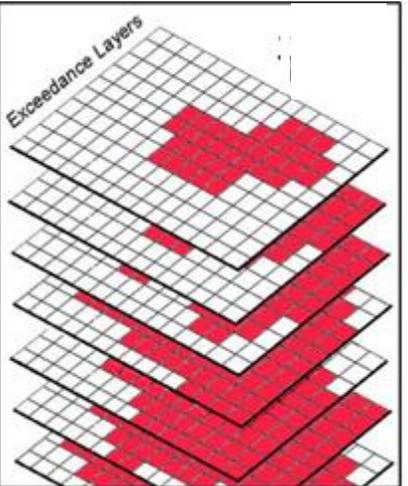
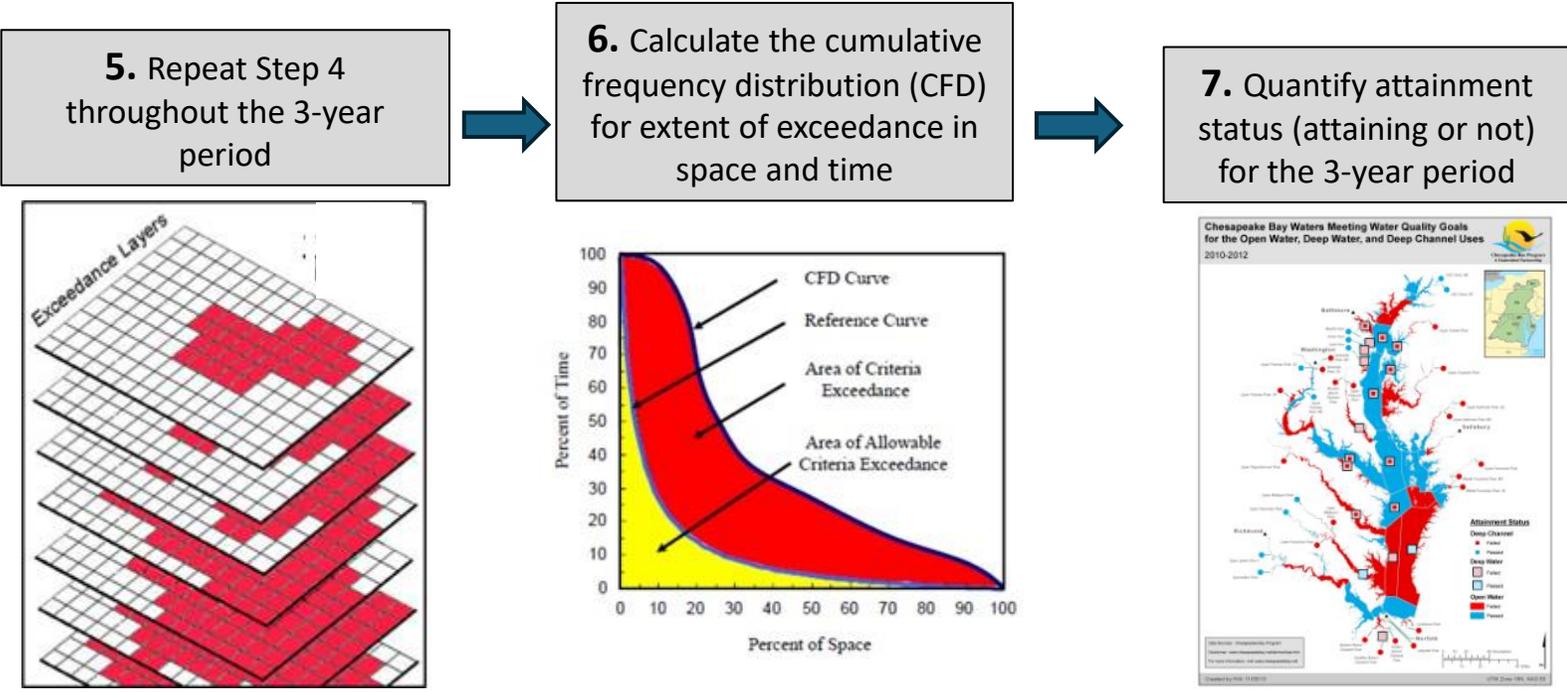
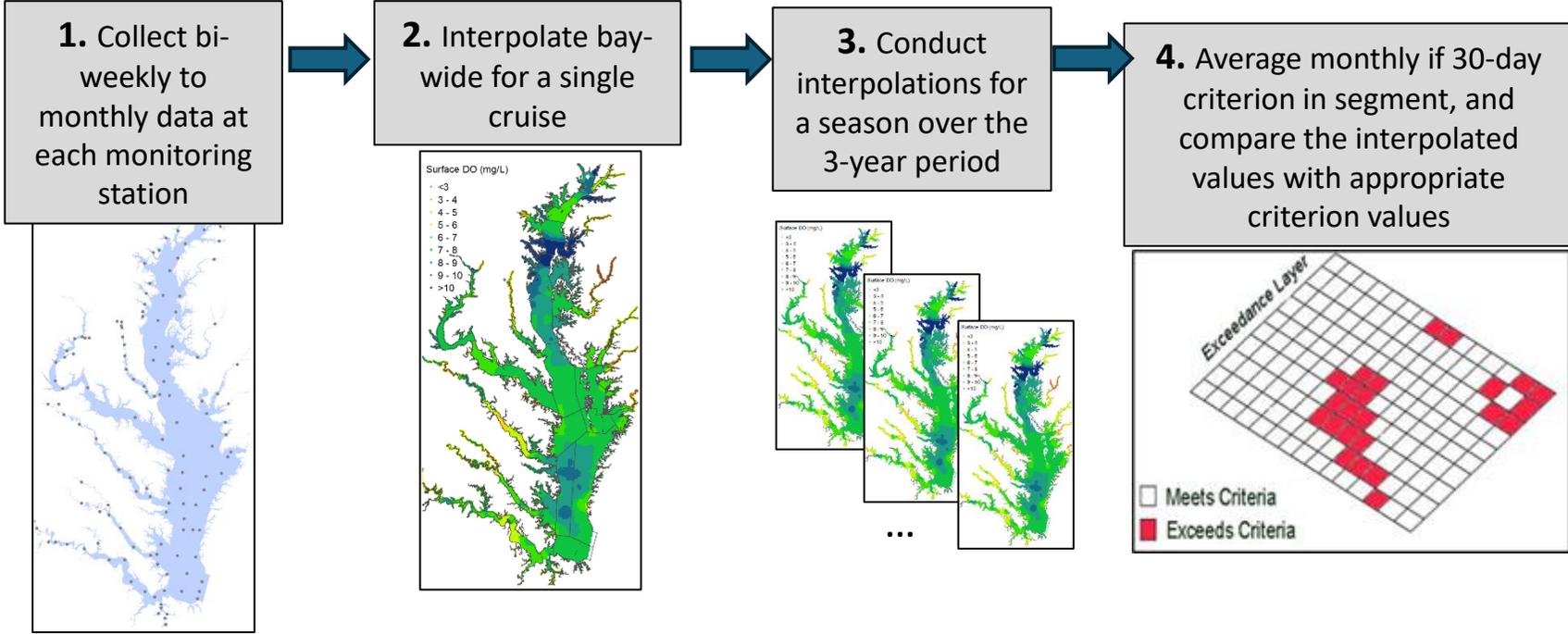
Dissolved oxygen (mg liter^{-1}) concentrations required by different species and communities.

Just one: Deep water (USEPA 2010)



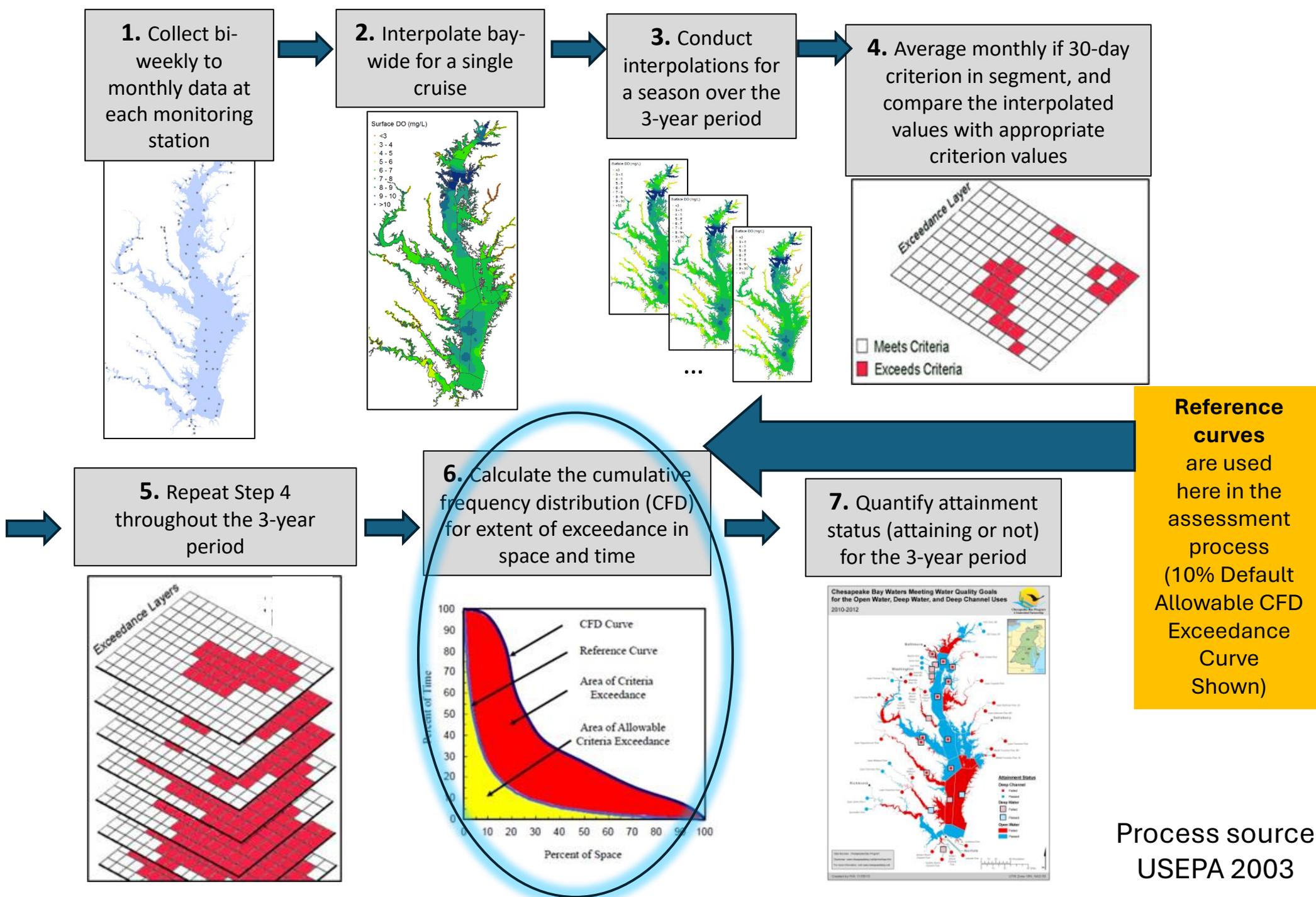
Five Chesapeake Bay tidal water designated use zones.

Chesapeake Bay WQ Criterion Assessment Process

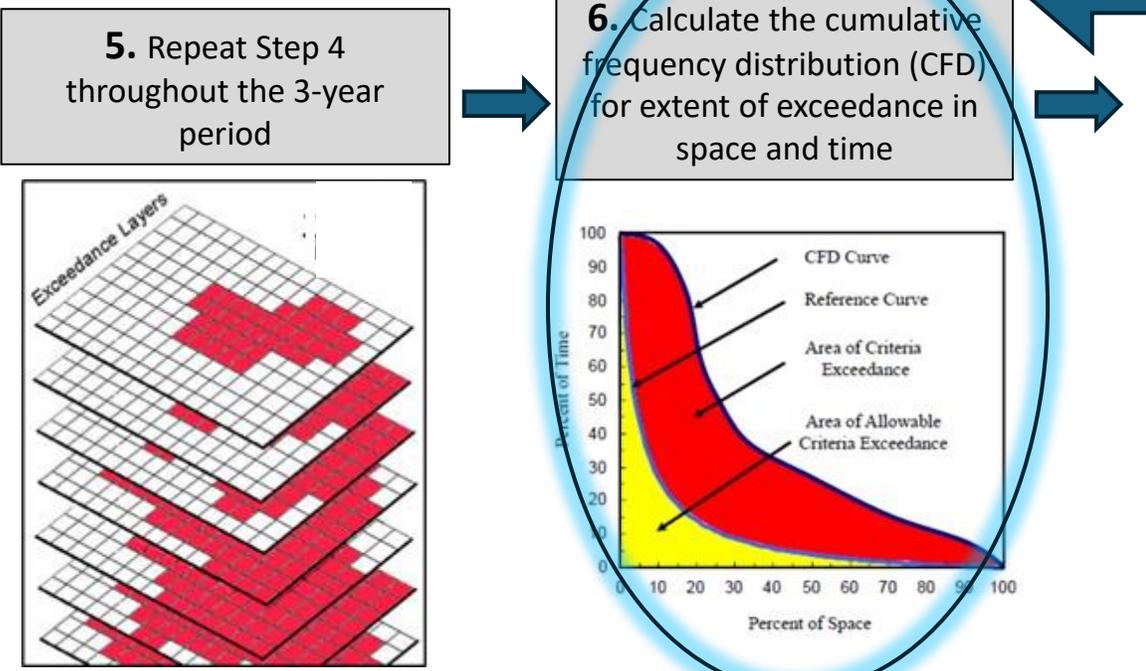
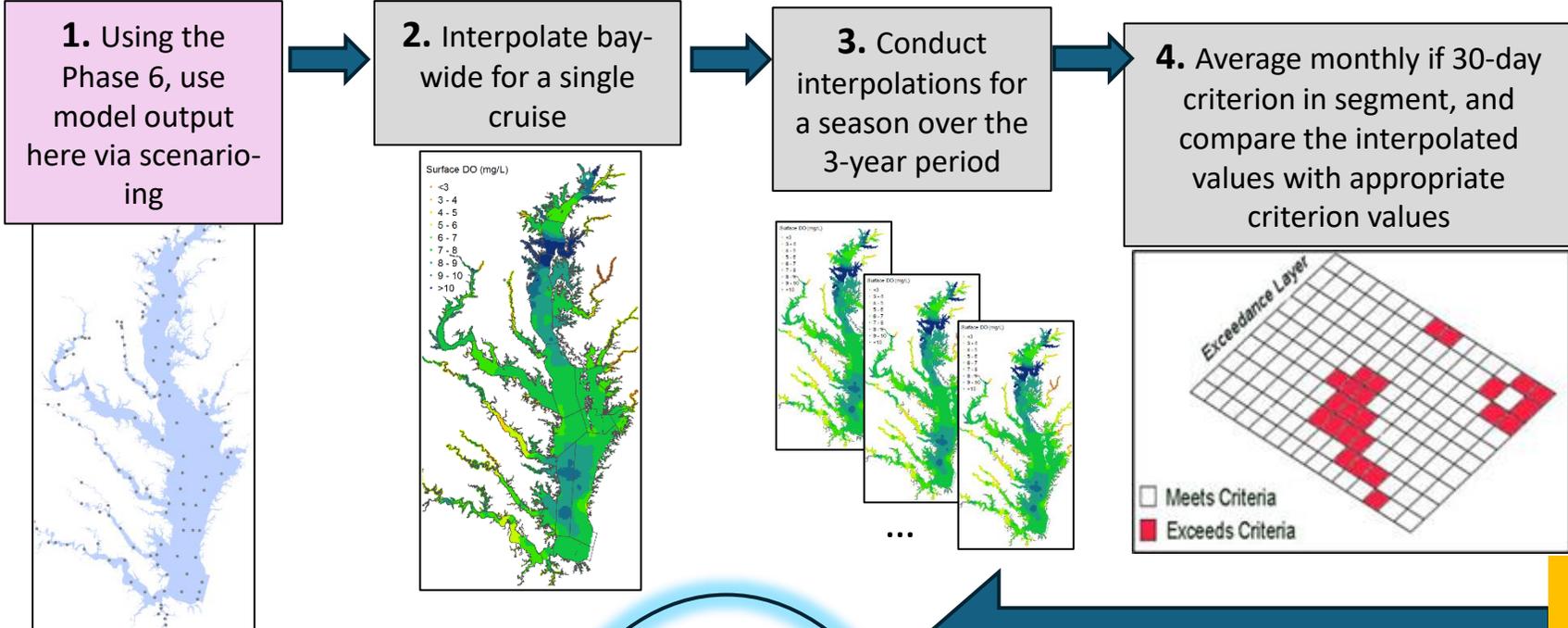


Process source
USEPA 2003

Chesapeake Bay WQ Criterion Assessment Process

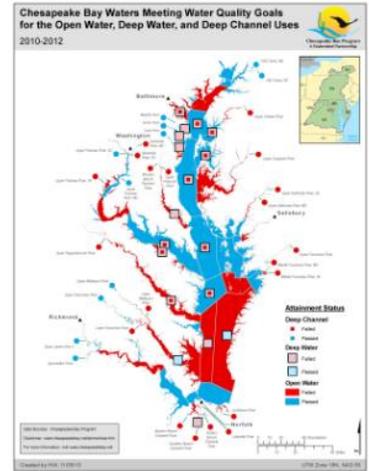


Chesapeake Bay WQ Criterion Assessment Process



7. Quantify attainment status (attaining or not) for the 3-year period

Reference curves are used here in the assessment process (10% Default Allowable CFD Exceedance Curve Shown)

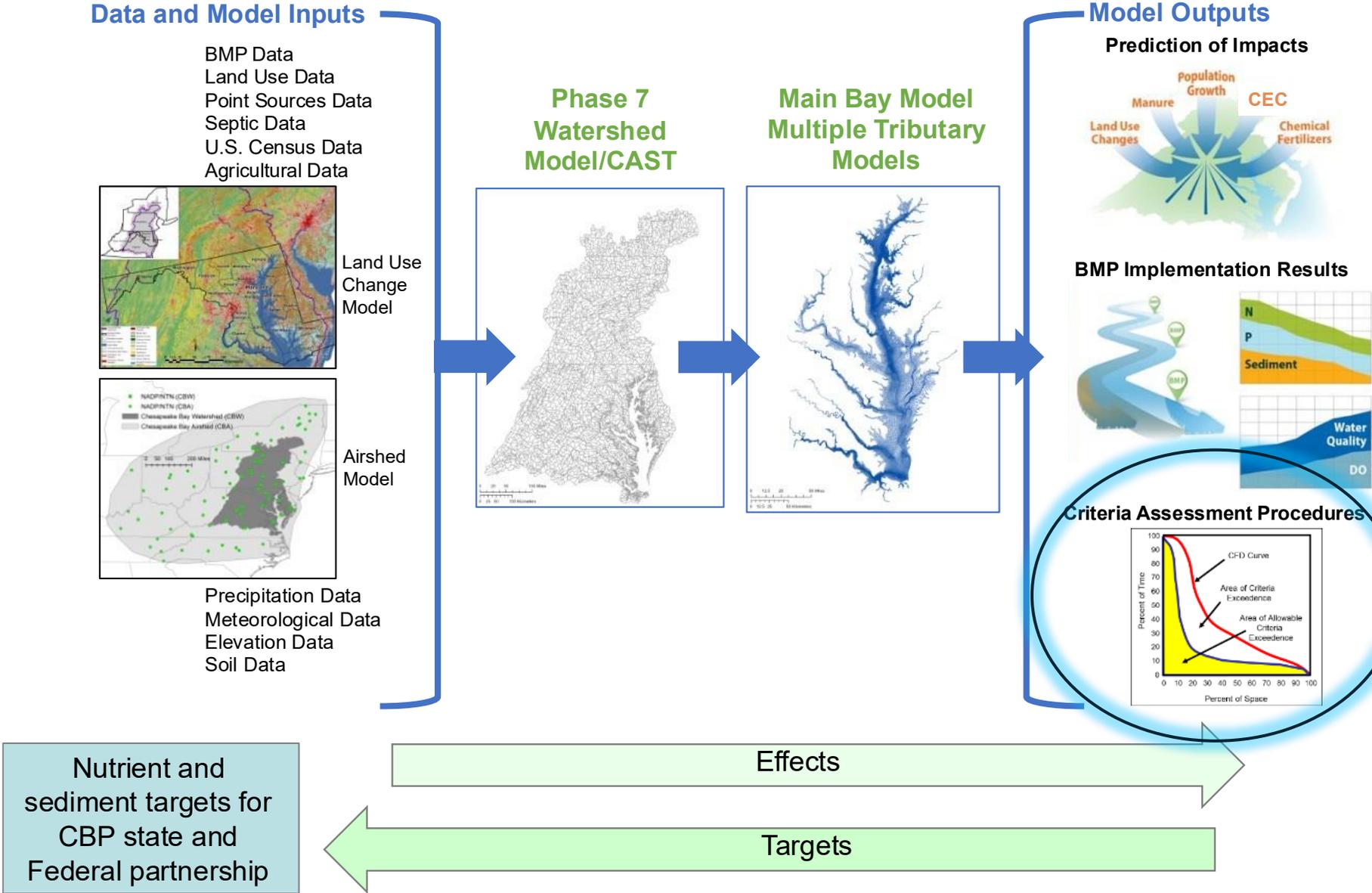


Process source
USEPA 2003

The CBP Model Suite – How the CBP Makes a Plan

Models are used to:

- Estimate levels of nutrients and sediment that reach the bay under different land management scenarios
- Set targets for nutrient and sediment reductions
- Plan for practices that will allow us to reach goals (Watershed Implementation Plans)
- Track progress towards restoration goals



Criterion Violation

In our water quality criterion assessments, any measure that exceeds a criterion represents a violation or a failure to protect the habitat.

Allowable Exceedance

Assessment protocols use "allowable exceedances" to give states flexibility in meeting strict criteria.

Habitat protection measures allow for some flexibility as long as 90% of expectations are met (10% exceedance).

Bio-reference curve

We evaluate
exceedance relative to
space (volume of
water) & time.

Biology-informed
allowable exceedance
developed when
information is
available (Deep Water,
aligns with 10%
default)

Criterion Violation

In our water quality criterion assessments, any measure that exceeds a criterion represents a violation or a failure to protect the habitat.

Allowable Exceedance

Assessment protocols use "allowable exceedances" to give states flexibility in meeting strict criteria.

Habitat protection measures allow for some flexibility as long as 90% of expectations are met (10% exceedance).

Bio-reference curve

We evaluate exceedance relative to space (volume of water) & time.

Biology-informed allowable exceedance developed when information is available (Deep Water, aligns with 10% default)

4-Dimensional (4-D) Interpolator 101

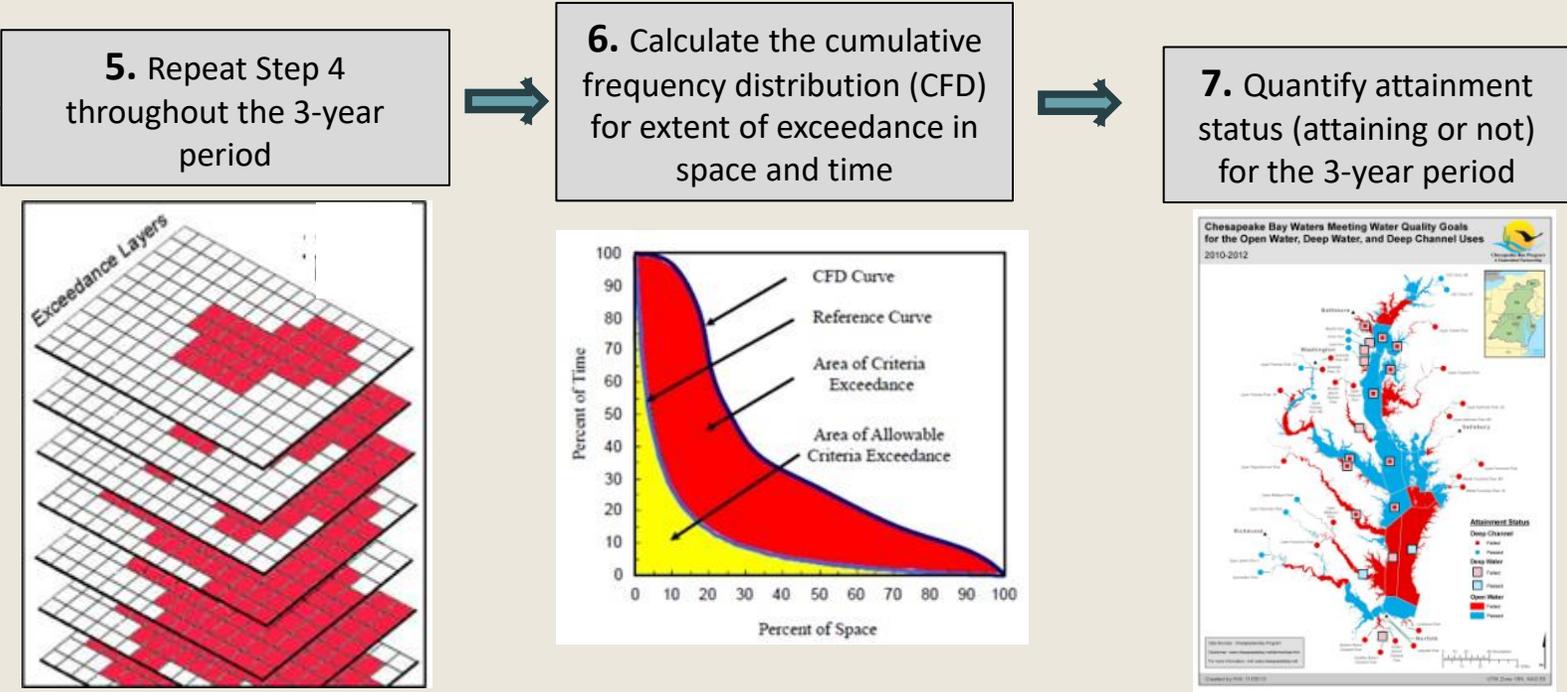
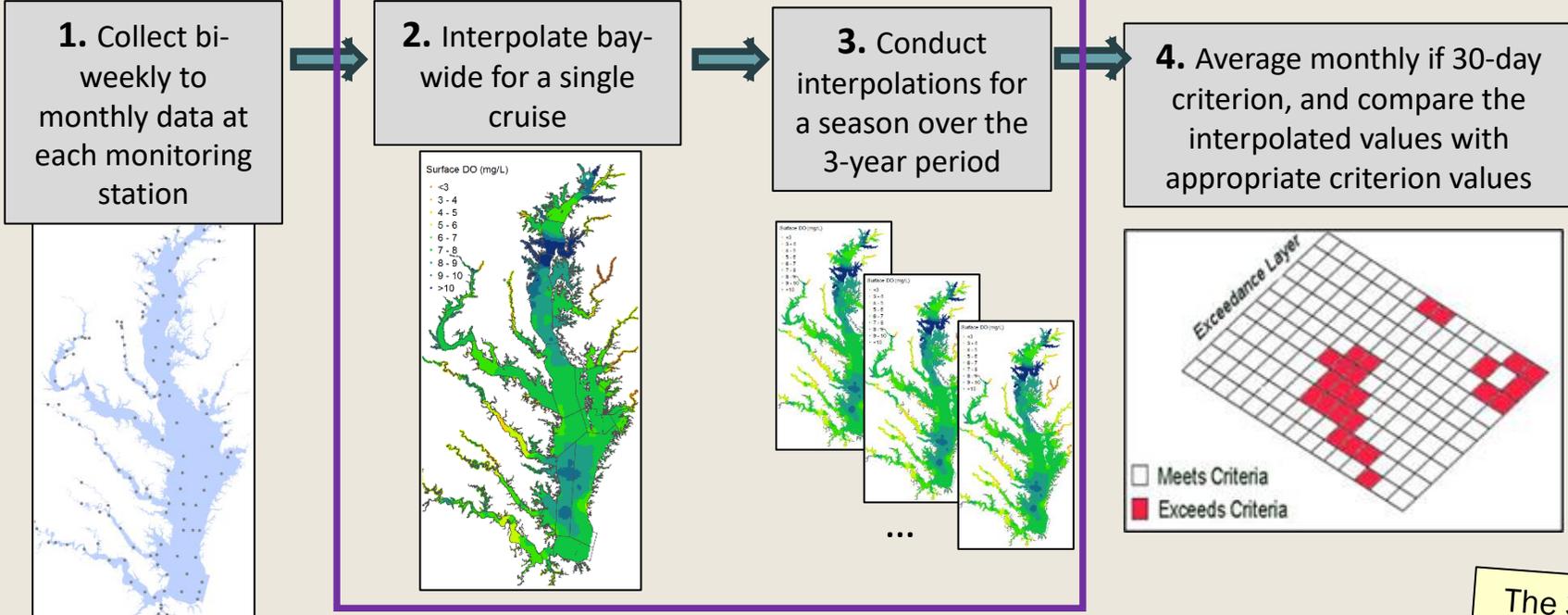
March 23, 2026

Kaylyn S. Gootman (EPA)

CBP team and developers:

Peter Tango (USGS), Rebecca Murphy (UMCES),
Breck Sullivan (USGS), Kaylyn Gootman (EPA), Allison Welch (CRC),
Elgin Perry (statistics consultant), Jon Harcum (Tetra Tech)

WQS Criterion Assessment



The 3D Interpolator is an important tool for this process for 1) annual assessments with monitoring data and 2) usage in the Phase 6 modeling suite.

Partnership Uses of the 3D Interpolator

- 1) Developing planning targets as part of the CBP partnership suite of modeling tools
 - *Develop Planning Targets to achieve Water Quality Criteria*
 - *Support effective Watershed Implementation Plans*
- 2) One Step In the Analysis for Annual Assessments
 - *Helps us answer how are we doing towards meeting our water quality goals*
 - *E.g., Water Quality Standards Attainment Indicator*
- 3) Support Jurisdictions' development of 303(d) lists
 - *Cycle is every two years*
- 4) Other Applications
 - *Research applications*
 - *Hypoxic volume and spatial habitat analyses by state partners*

Why Are We Developing a New Method?

- The current interpolator (developed 20+ years ago) was not designed to interpolate through time or work effectively with unstructured data that have mixed time scales and sampling patterns and are sourced from multiple monitoring programs.
 - 3D Interpolator was designed for discrete bi-monthly data
 - Cannot produce uncertainty estimates.
- 

- There is more high frequency data now to fill in temporal gaps.
- 

- A new interpolation will use all the data to fill in the gaps between data based on observed patterns to help accurately assess high frequency DO criteria.
 - Chesapeake Bay Program interest in 4D Interpolation started because there are water quality criteria that require assessments at finer space and time scales than current methods can support.
 - Needed for the Phase 7 suite of models.

What makes the
tool 4-D?

Volume

Time

Spatial &
Temporal

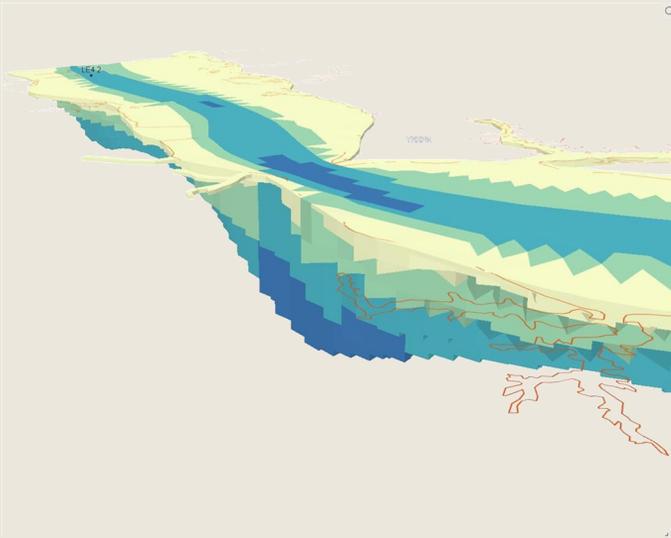
3-D



1-D



4-D



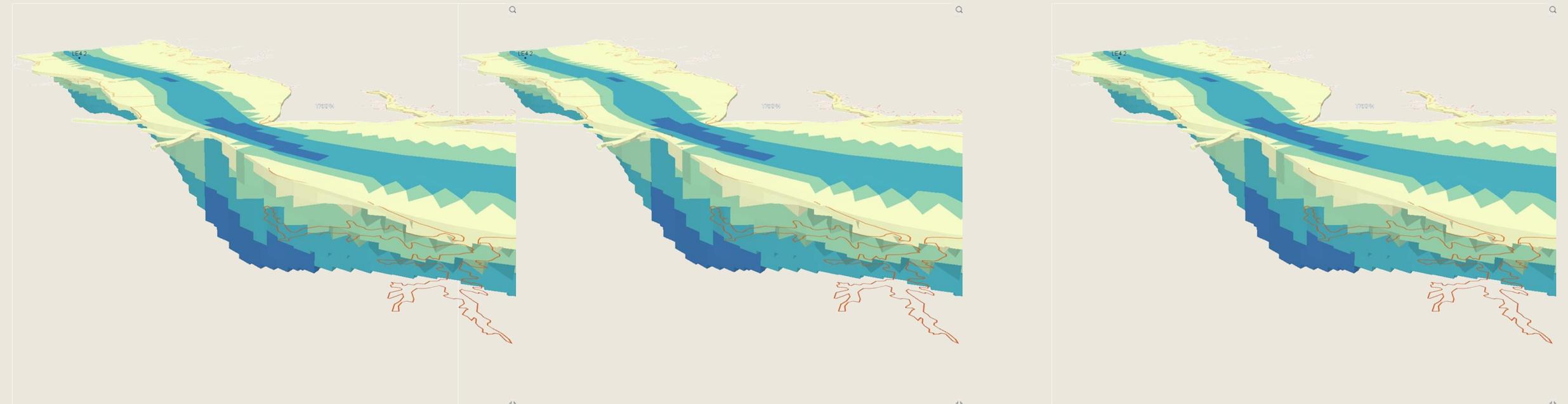
Create a 3D representation of DO through time (4D)

3/1/2024 Midnight

3/1/2024 1am

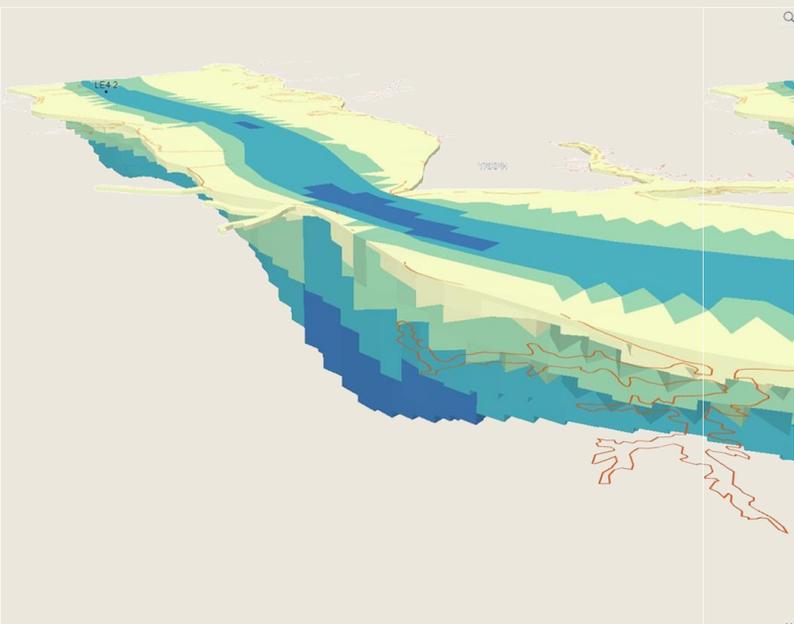
...

8/01/2025 11pm

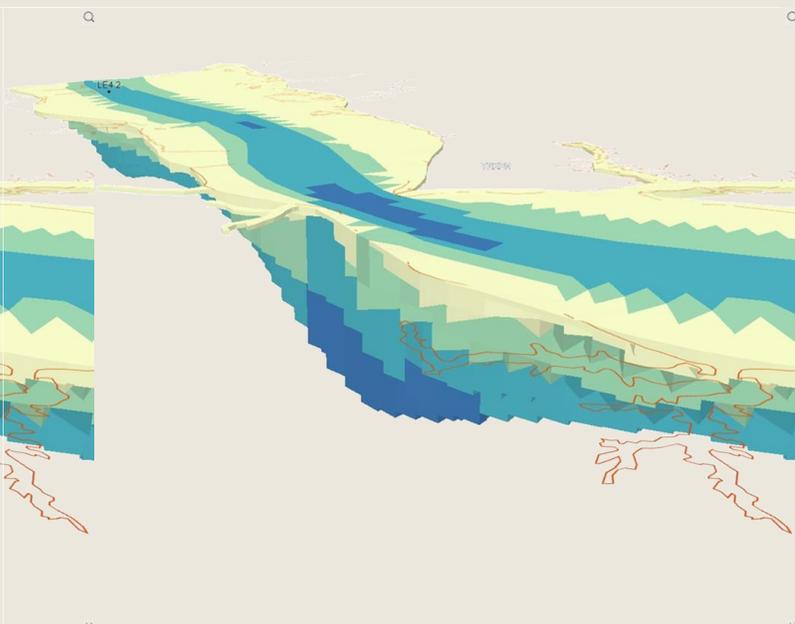


Interpolation makes a prediction inside your data to fill gaps

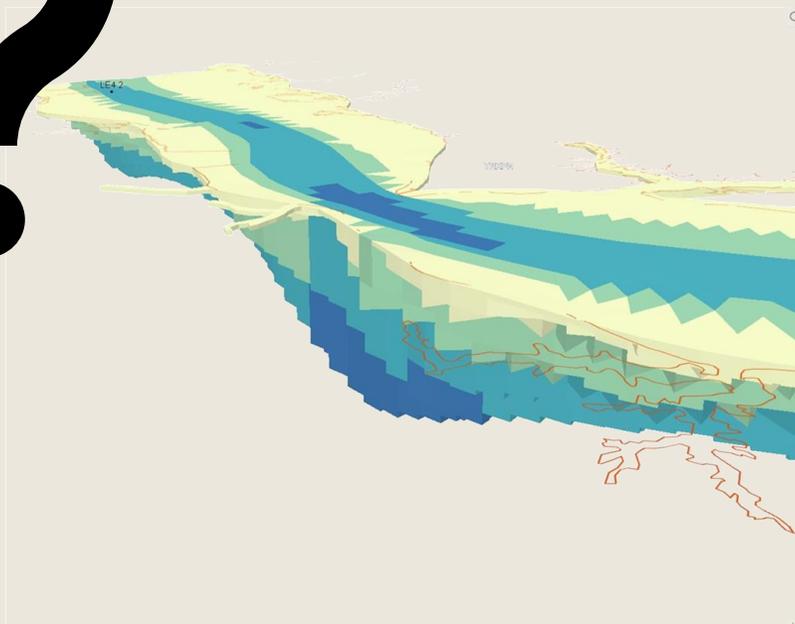
3/1/2024 Midnight



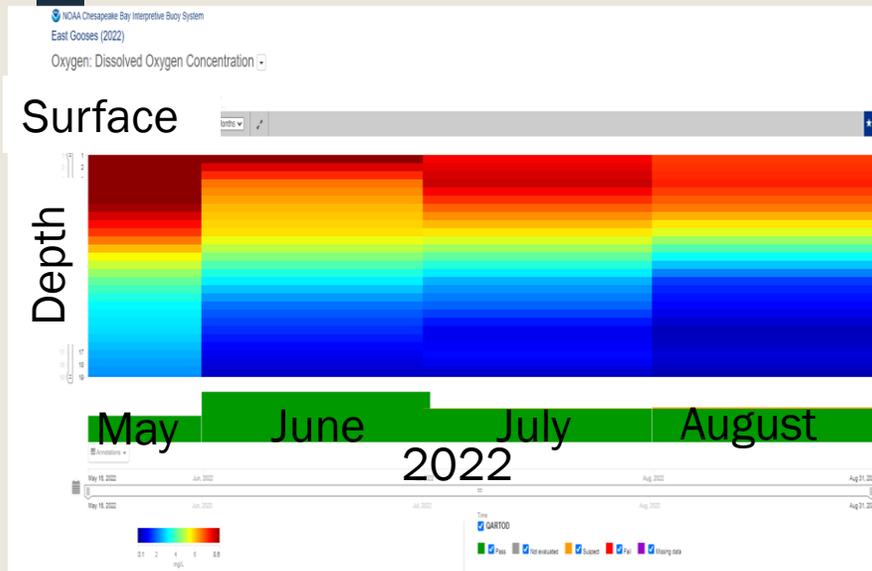
3/1/2024 1am



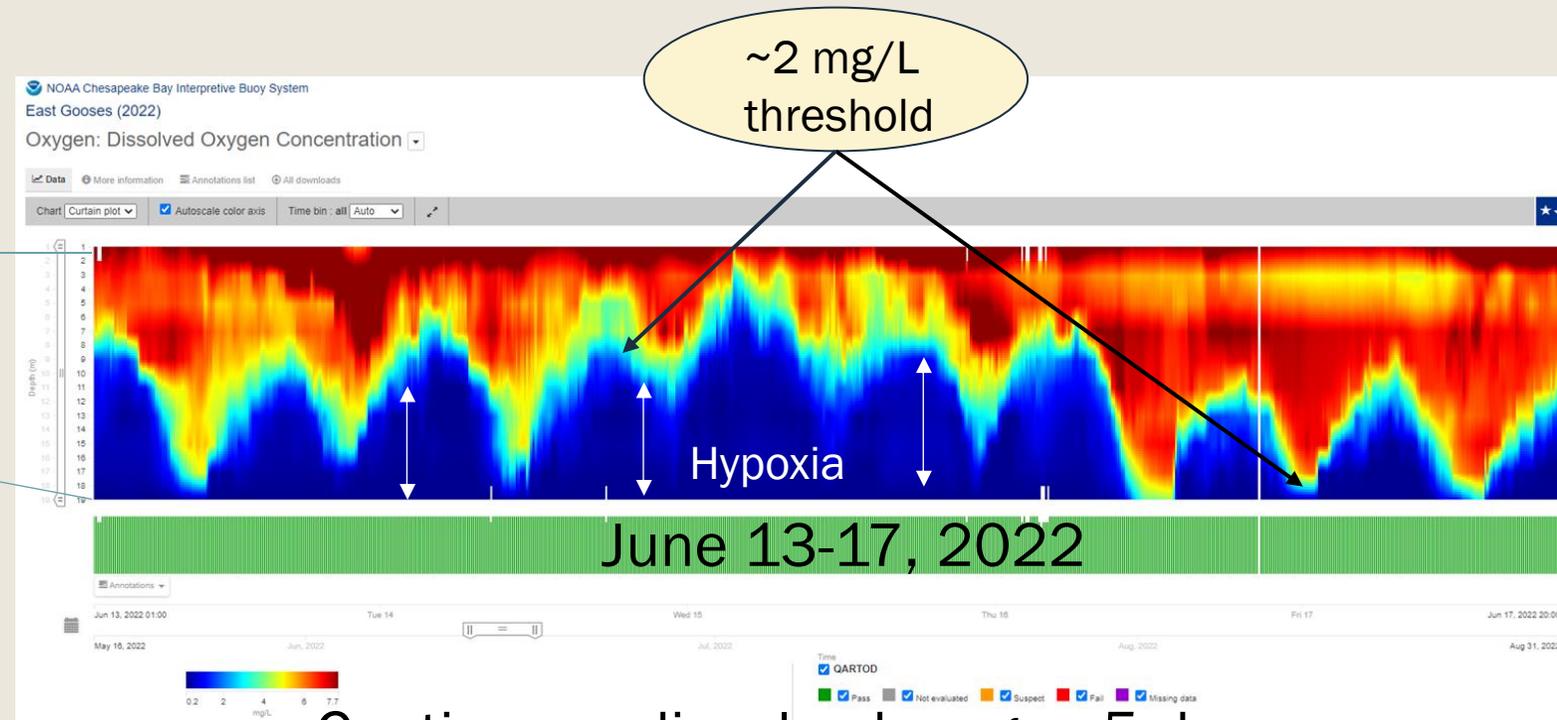
8/01/2025 11pm



What's the difference between the 3D and 4D Interpolators? *Data Inputs as an Analogy*



Traditional Bay monitoring
3.5 months
1x per month water
column
data collection



Continuous dissolved oxygen 5 days,
10-minute data collection intervals

What Improvements are Gained by Moving to a 4D Interpolator?

- We have more knowledge of the system from decades of monitoring investment, and it's currently not being used by the 3D Interpolator.
 - *We need updated analysis tools to maximize this monitoring investment.*
- Ingestion of continuous data.
- Using of all data results in more accurate condition estimates.
 - *This means more accurate determination of impairment and attainment.*
- Ability to assess all criteria.
- Ability to compute uncertainty.

Partnership History with the 3D and 4D Interpolators

2001

- 3D Interpolator published, built on methods from the 1980s

2003

- USEPA (2003a,b) sets up the basis for 3D Interpolator to be used for CBP assessment of WQ

2007-2008

- Further development of interpolation to measure WQ criteria attainment assessment
- STAC Workshop on 4D

2010

- Refinements/additions to the procedures for assessing the previously published criteria

2014

- 2014 Watershed Agreement Water Quality Goal includes the language “maintain and grow monitoring and assessment capacity”

2021-2022

- PSC Monitoring Report recommendation to invest in 4D Interpolator
- Bay Oxygen Research Group/4D Team start work on developing the 4D Interpolator

GOAL STATEMENT

To develop a spatial-and-temporal interpolation tool for water quality monitoring data collected in the tidal waters of the Chesapeake Bay, thus enabling the evaluation of both long- and short-duration water quality criteria.

Statement Developed by the Bay Oxygen Research Group

Purpose: Build a Tool for More Complete Criteria Assessment

DO criteria that currently can be evaluated with existing approaches and data

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

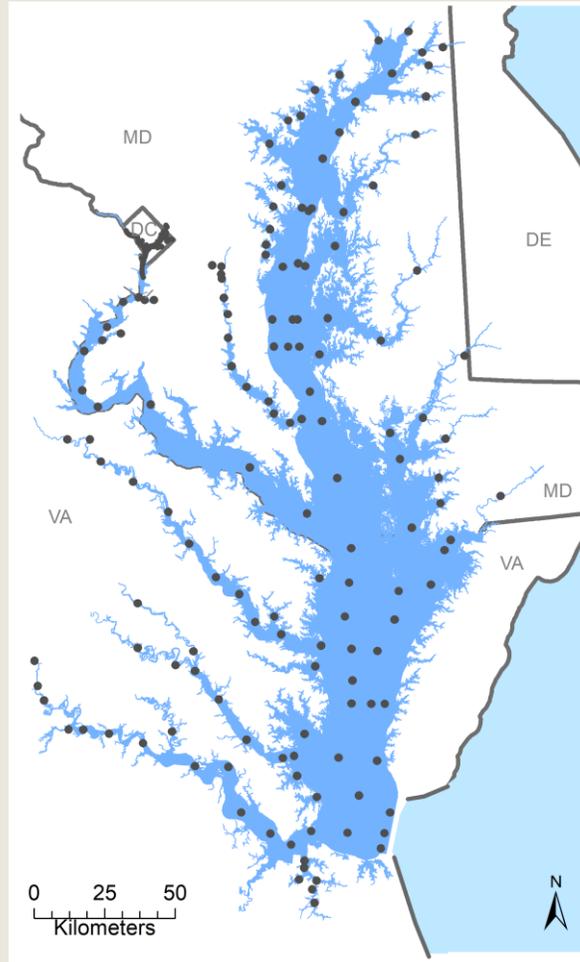
*Note a 30-day mean 6 mg/L MSN value is evaluated for purpose of the WQ indicator.

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.

Multiple Types of Data Being Used

Shallow water continuous monitoring (MDDNR and VECOS)

Bi-weekly long-term sampling (DOEE, MDDNR, VADEQ, ODU, CBP)

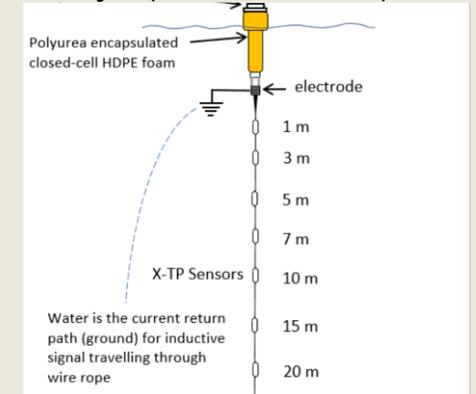


From <http://vecos.vims.edu/>



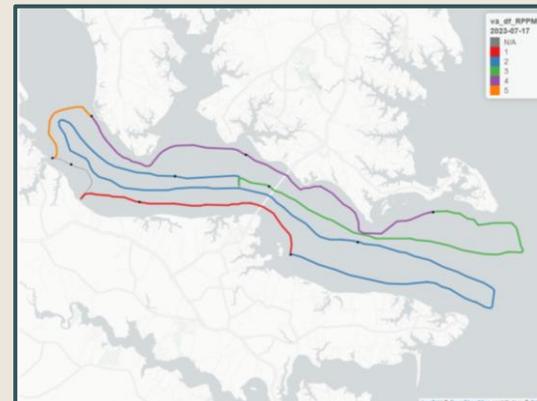
From <https://eyesonthebay.dnr.maryland.gov/>

New continuous vertical arrays (NOAA & CBP)



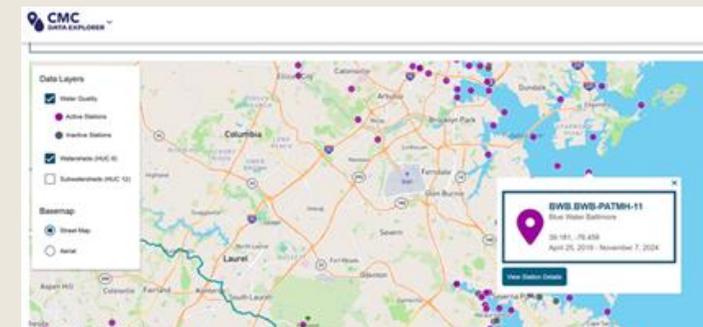
<https://www.chesapeakebay.net/who/gro/up/hypoxia-collaborative-team>

Dataflow (MDDNR and VECOS)



From <http://vecos.vims.edu/>

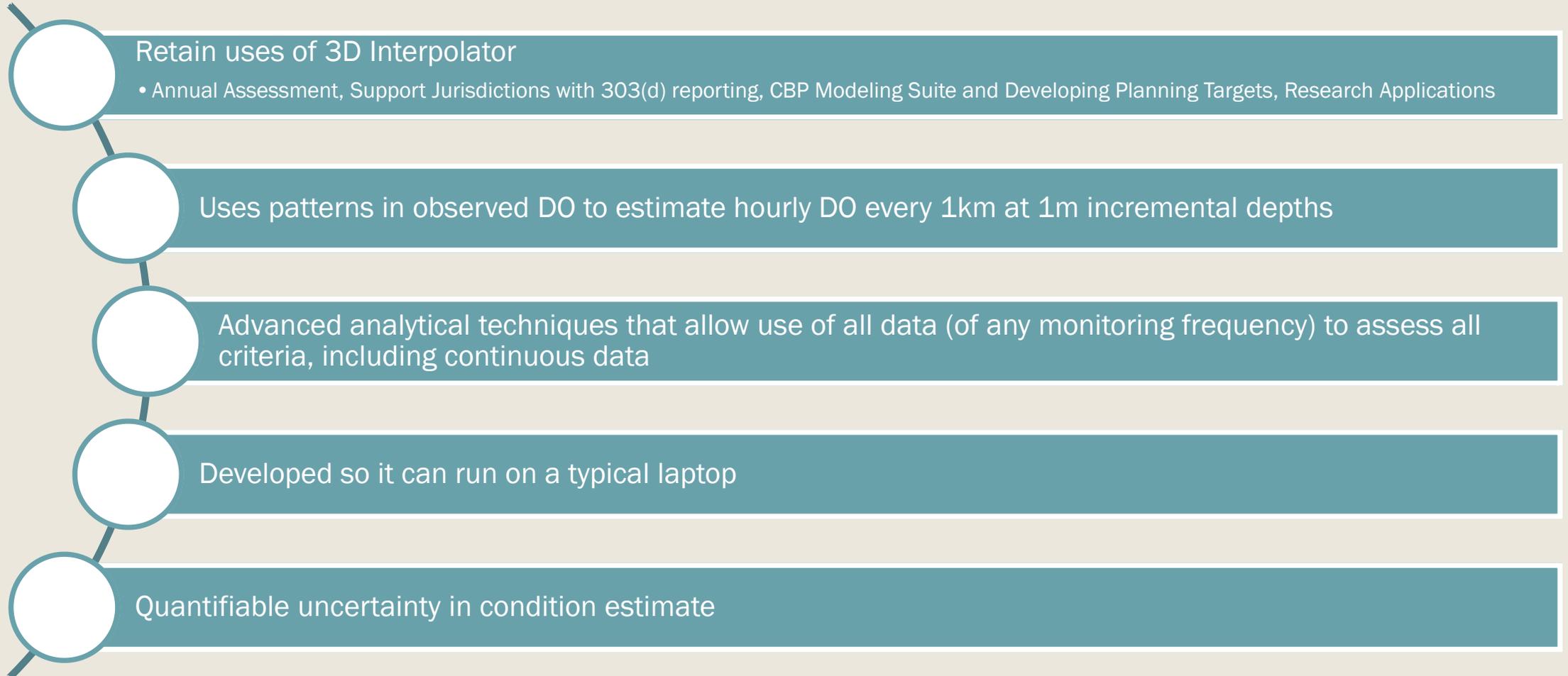
Citizen monitoring (CMC and multiple community groups)



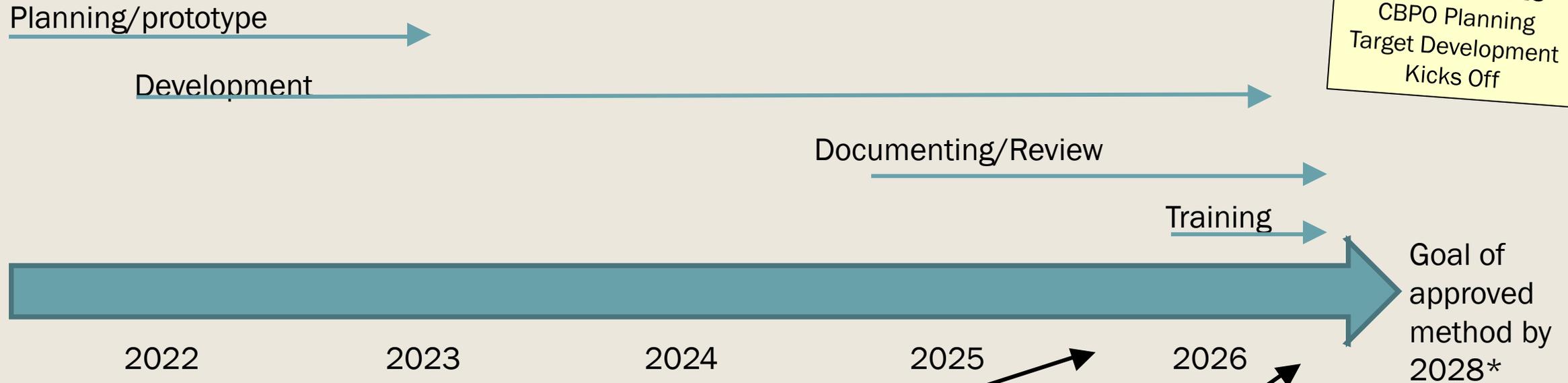
Chesapeake Monitoring Cooperative:
<https://www.chesapeakemonitoringcoop.org/>

+Additional State Agency Collected Data (MDE, VADEQ)

Key Features for the 4D Interpolator



4-D Interpolator Development Timeline



Through 2026:

- Working 4-D tool,
- Collaboration ongoing with CAP on criteria assessment methods.

In 2026-2027:

- Documenting,
- Additional functionality as needed for linking to criteria assessment,
- Preparing for training & review.

*with 2030 goal of reporting on all criteria