

Proposed Path Forward for James River Chlorophyll Assessment Methodology

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Fall 2015 SAP Meeting
November 6, 2015



Outline

- Background
- Current procedure
- Limitations of current procedure
- Alternative method
- Discussion

Background

Water quality criteria are defined in terms of magnitude, duration, and frequency.



Excerpt from 9 VAC 25-260 Virginia Water Quality Standards

bb. The following site specific numerical chlorophyll a criteria apply March 1 through May 31 and July 1 through September 30 as seasonal means to the tidal James River (excludes tributaries) segments JMSTF2, JMSTF1, JMSOH, JMSMH, JMSPH and are implemented in accordance with subsection D of 9VAC25-260-185.

Designated Use	Chlorophyll a μ /l	Chesapeake Bay Program Segment	Temporal Application
Open Water	10	JMSTF2	March 1 - May 31
	15	JMSTF1	
	15	JMSOH	
	12	JMSMH	
	12	JMSPH	
	15	JMSTF2	July 1 - September 30
	23	JMSTF1	
	22	JMSOH	
	10	JMSMH	
	10	JMSPH	

 Magnitude  Duration

Excerpt from 9 VAC 25-260 Virginia Water Quality Standards

9VAC25-260-185 D

3. Attainment of these criteria shall be assessed through comparison of the generated cumulative frequency distribution of the monitoring data to the applicable criteria reference curve for each designated use. If the monitoring data cumulative frequency curve is completely contained inside the reference curve, then the segment is in attainment of the designated use. The reference curves and procedures to be followed are published in the USEPA, 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, April 2003 and the 2004 (EPA 903-R-03-002 October 2004) and 2007 (CBP/TRS 285-07, EPA 903-R-07-003), 2007 (CBP/TRS 288/07, EPA 903-R-07-005), 2008 (CBP/TRS 290-08, EPA 903-R-08-001, and 2010 (CBP/TRS 301-10, EPA 903-R-10-002) addenda. An exception to this requirement is in measuring attainment of the SAV and water clarity acres, which are compared directly to the criteria.

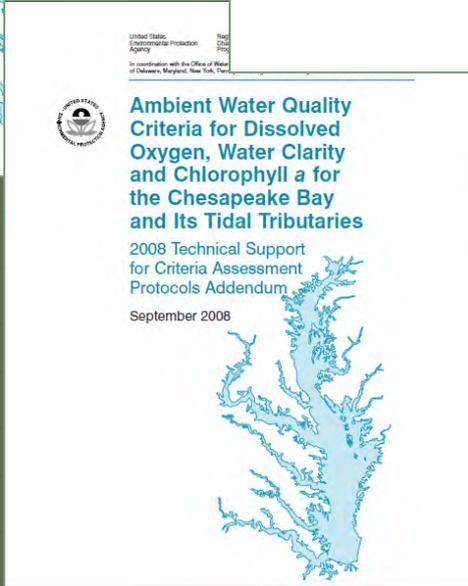
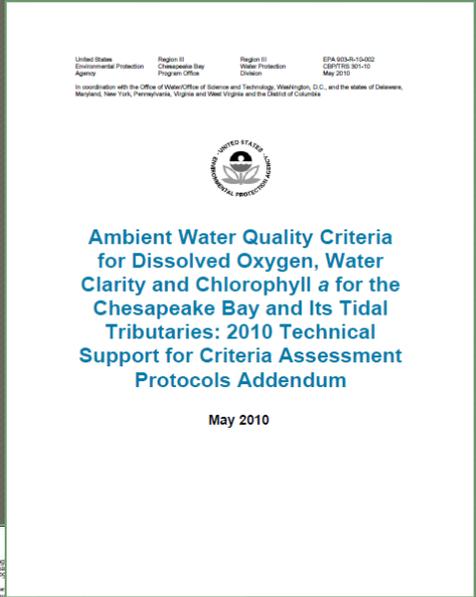
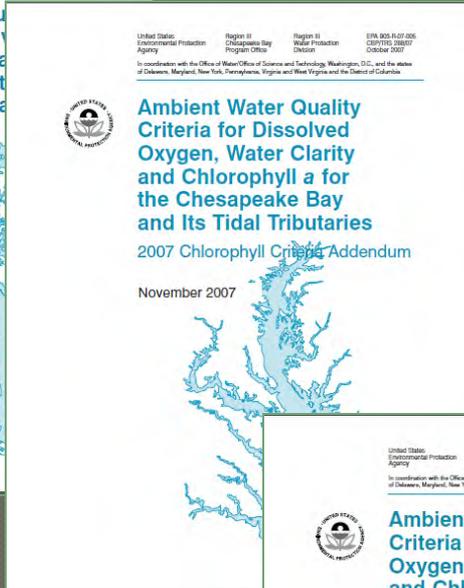
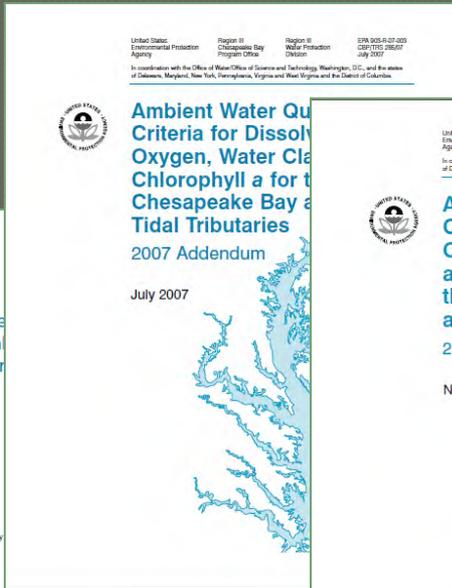
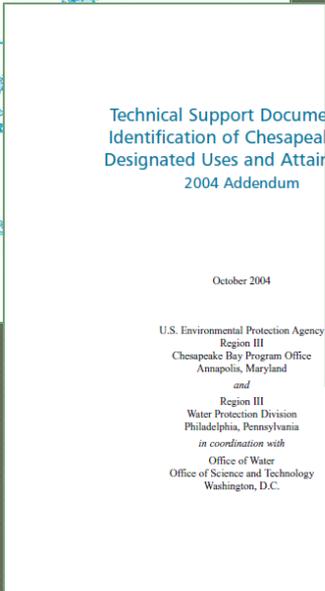
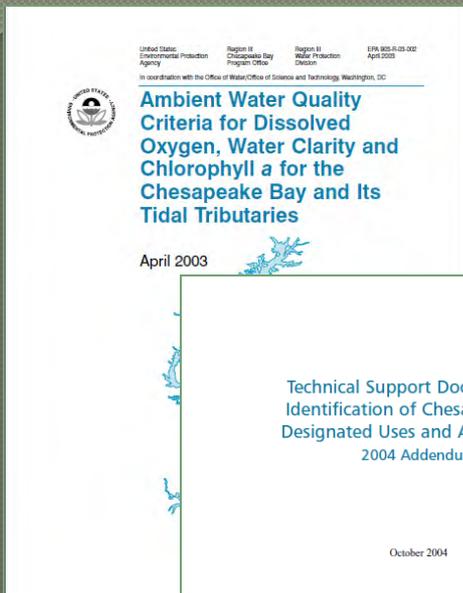
 Frequency

WATER QUALITY STANDARDS



ASSESSMENT METHODOLOGY





Years of work have gone into the current Bay assessment protocols, as detailed in EPA technical documents spanning more than ten years.

Current Assessment Procedure for JR Chlorophyll

Three basic ingredients of JR chlorophyll assessment:

- Spatial Interpolation of Monitoring Data
- Spatial Exceedance Rate
- Cumulative Frequency Diagram (CFD)

1. Spatial Interpolation of Monitoring Data

Station 1



10

Station 2



15

Station 3



30



Station 1



10

Station 2



15

Station 3



30

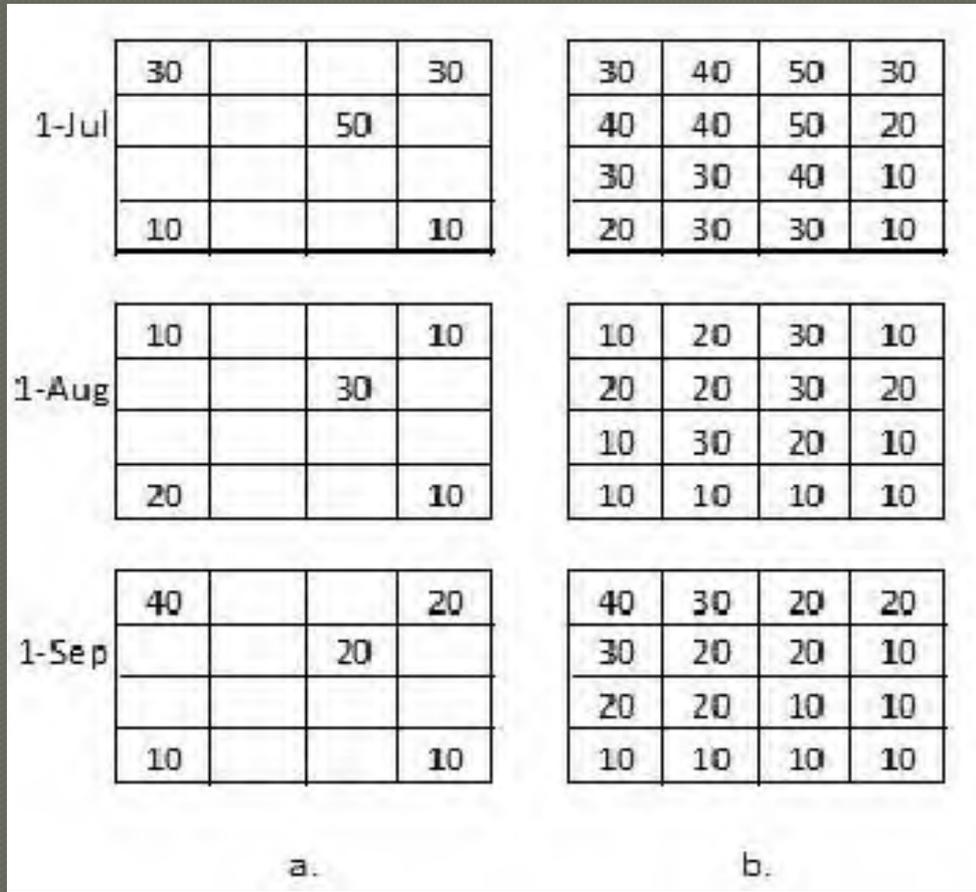
12.5

20

22.5

25

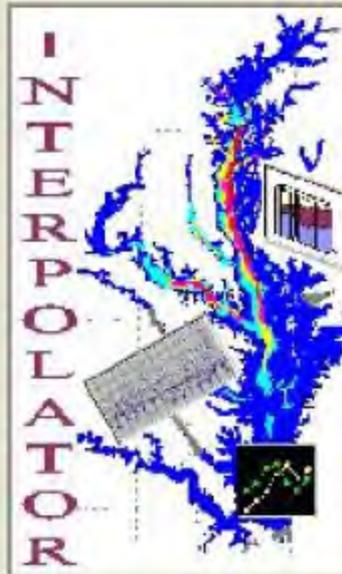
30



Monthly Chlorophyll
Observations

Monthly
Interpolations

Shareware - No license is required to use this software



Chesapeake Bay Program

Interpolator

Windows XP Pro

Version 4.61 August 2006

Lowell Bahner

NOAA Chesapeake Bay Office

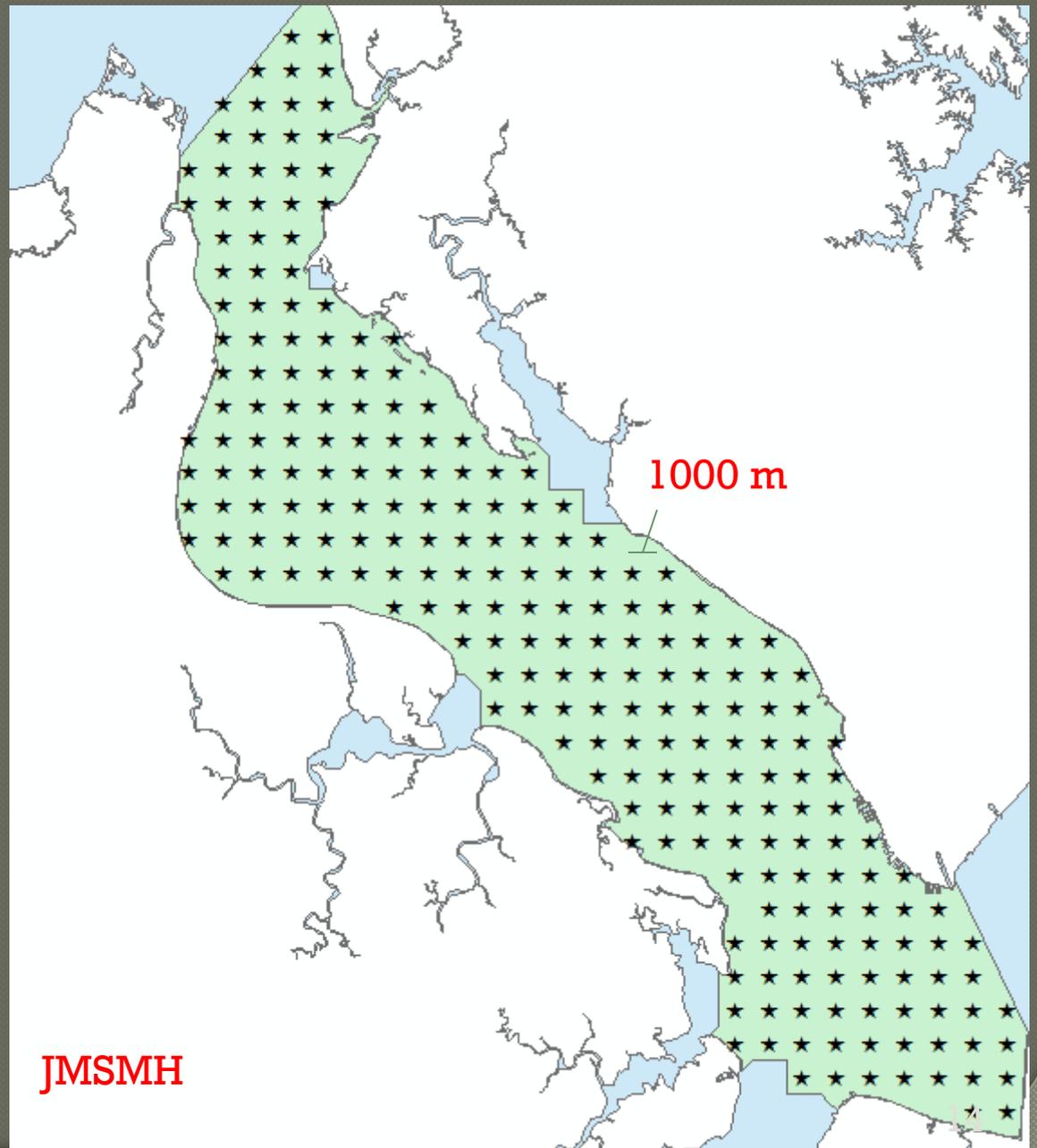
410 Severn Ave, Suite 107

Annapolis, MD 21403

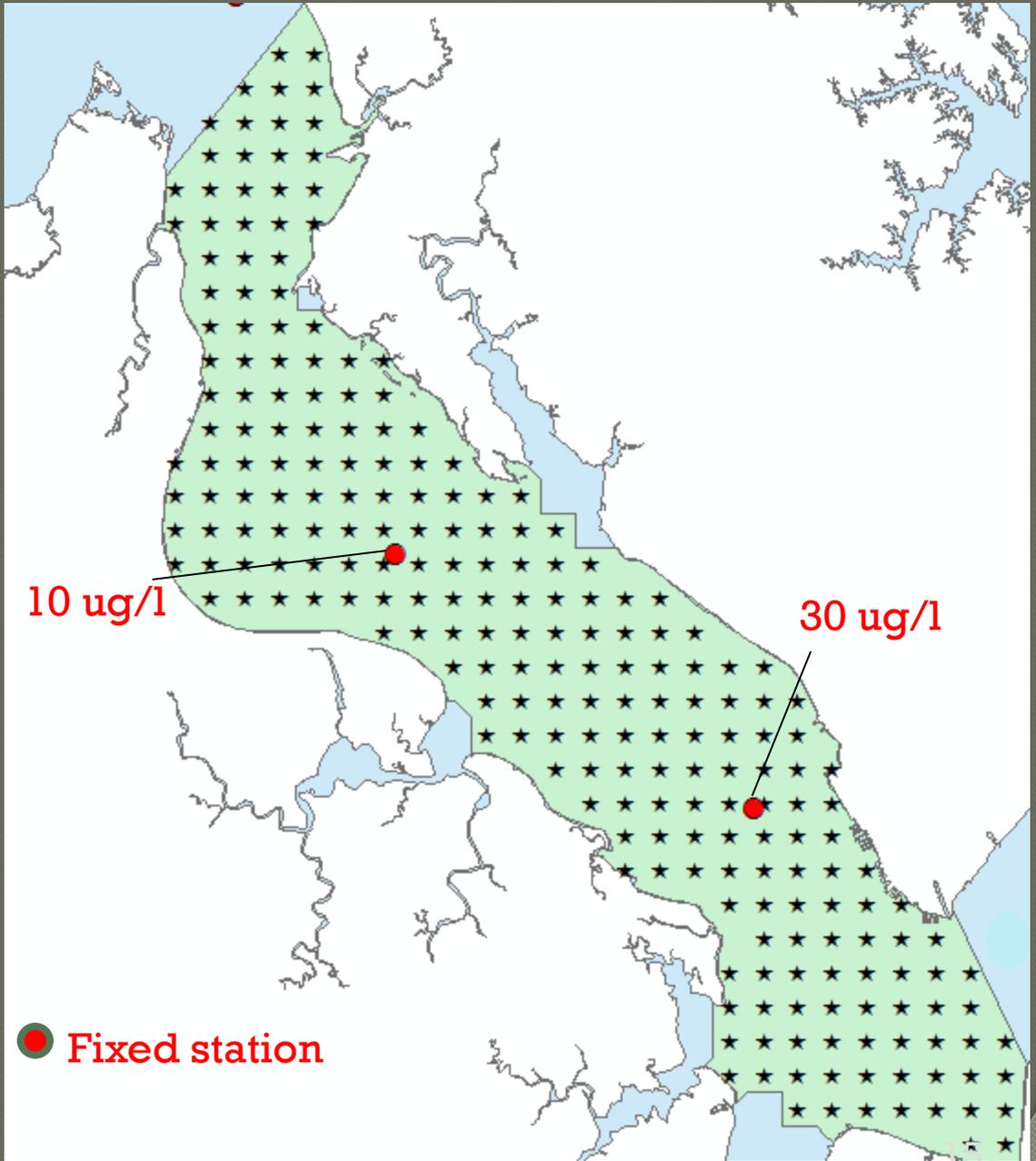
Email: lowell.bahner@noaa.gov

We use the Bay Program Interpolator

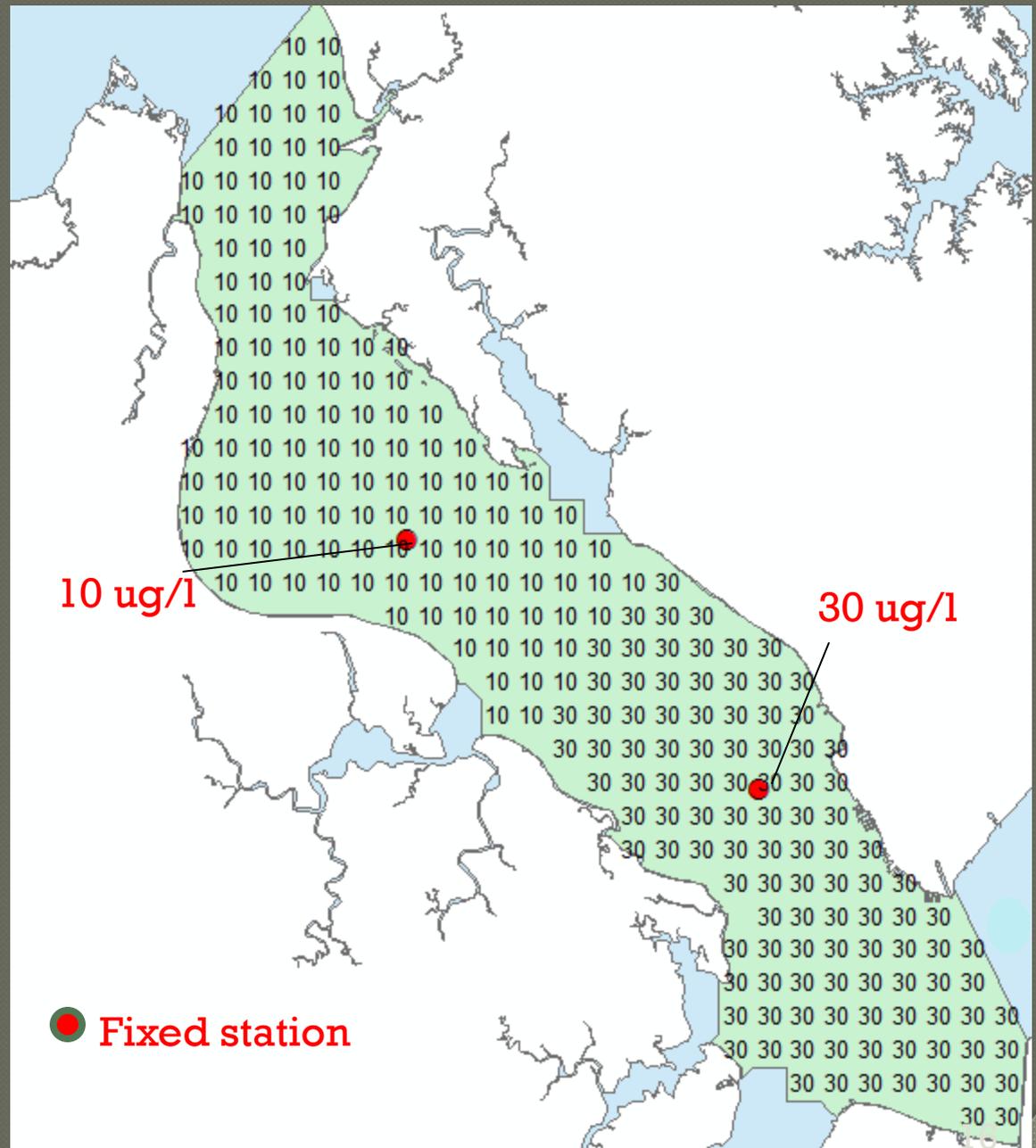
Each JR segment is represented in the Interpolator by an array of point locations.

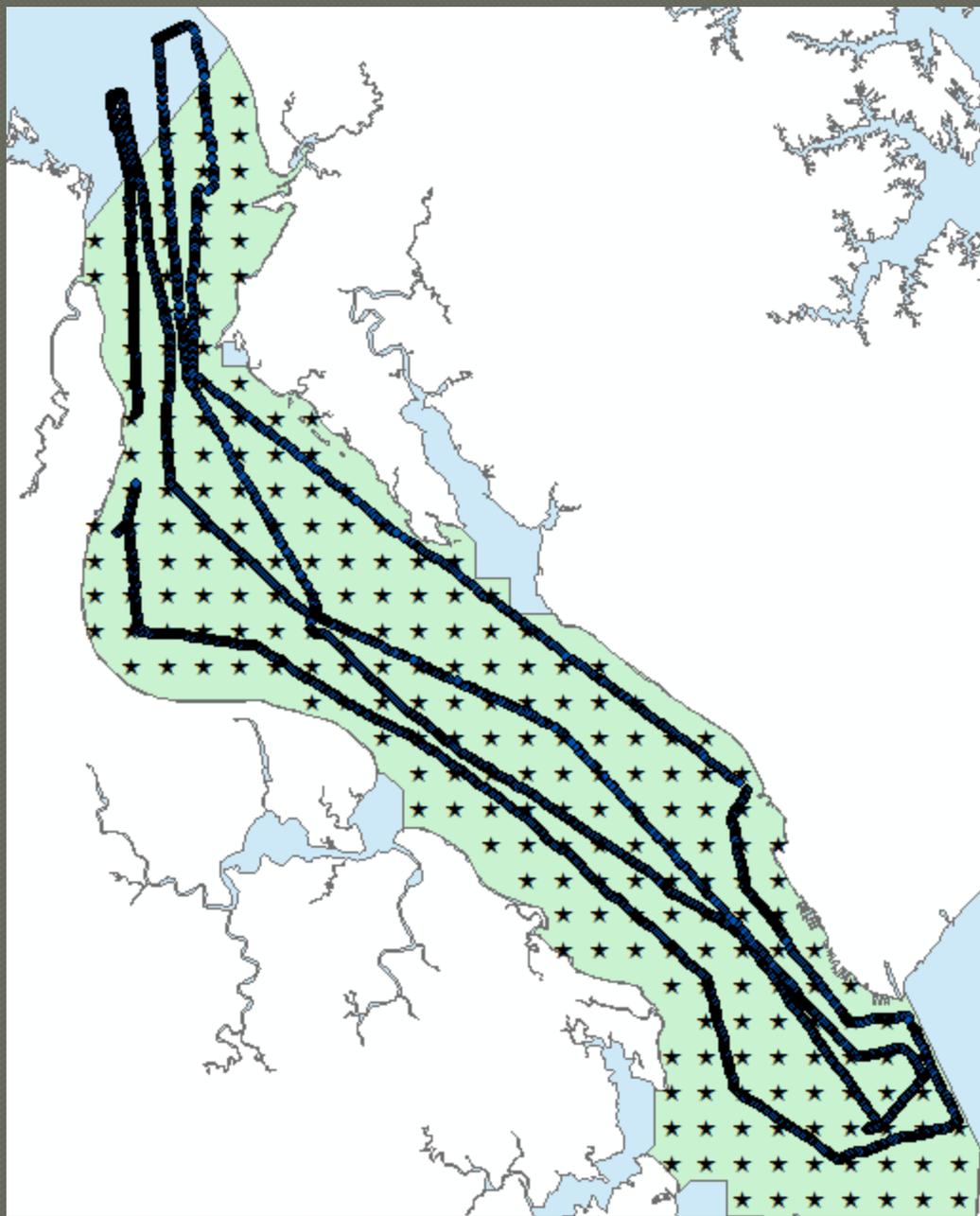


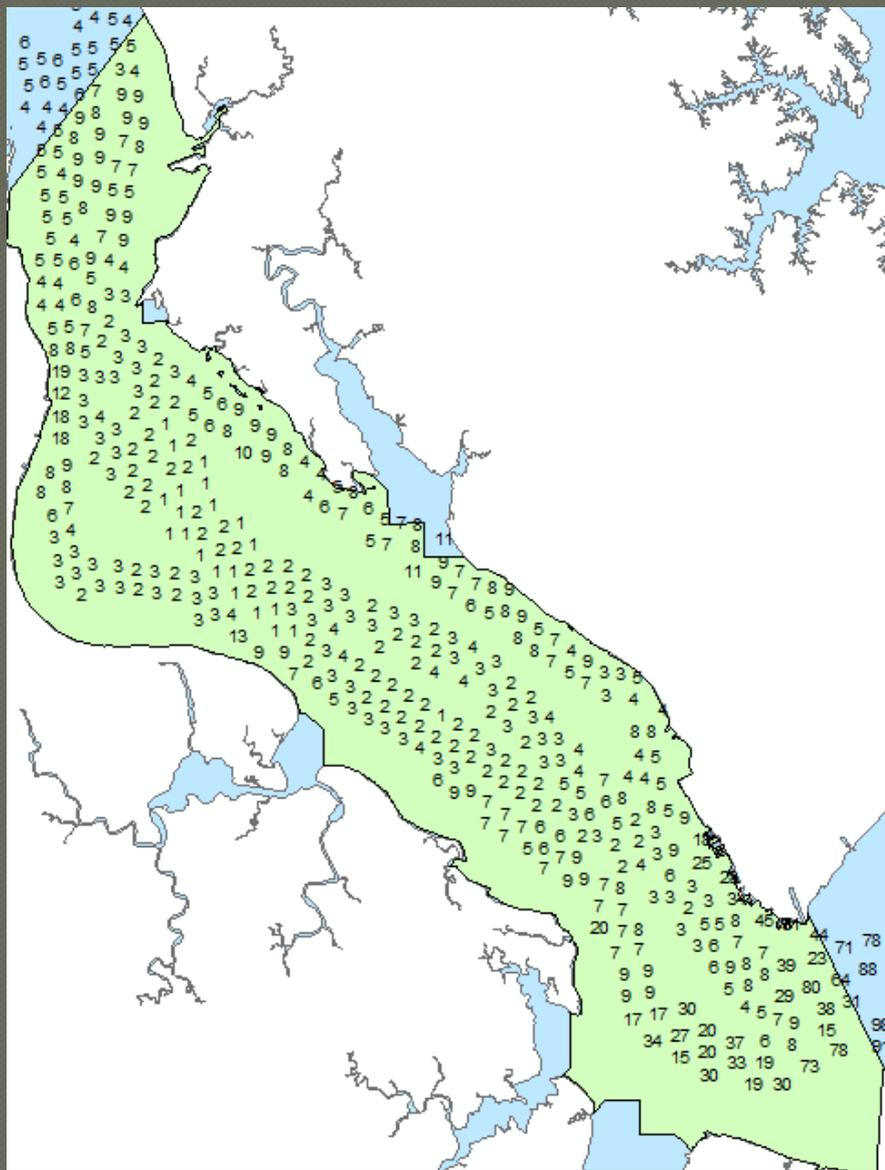
Let's say we measure chlorophyll at two locations.



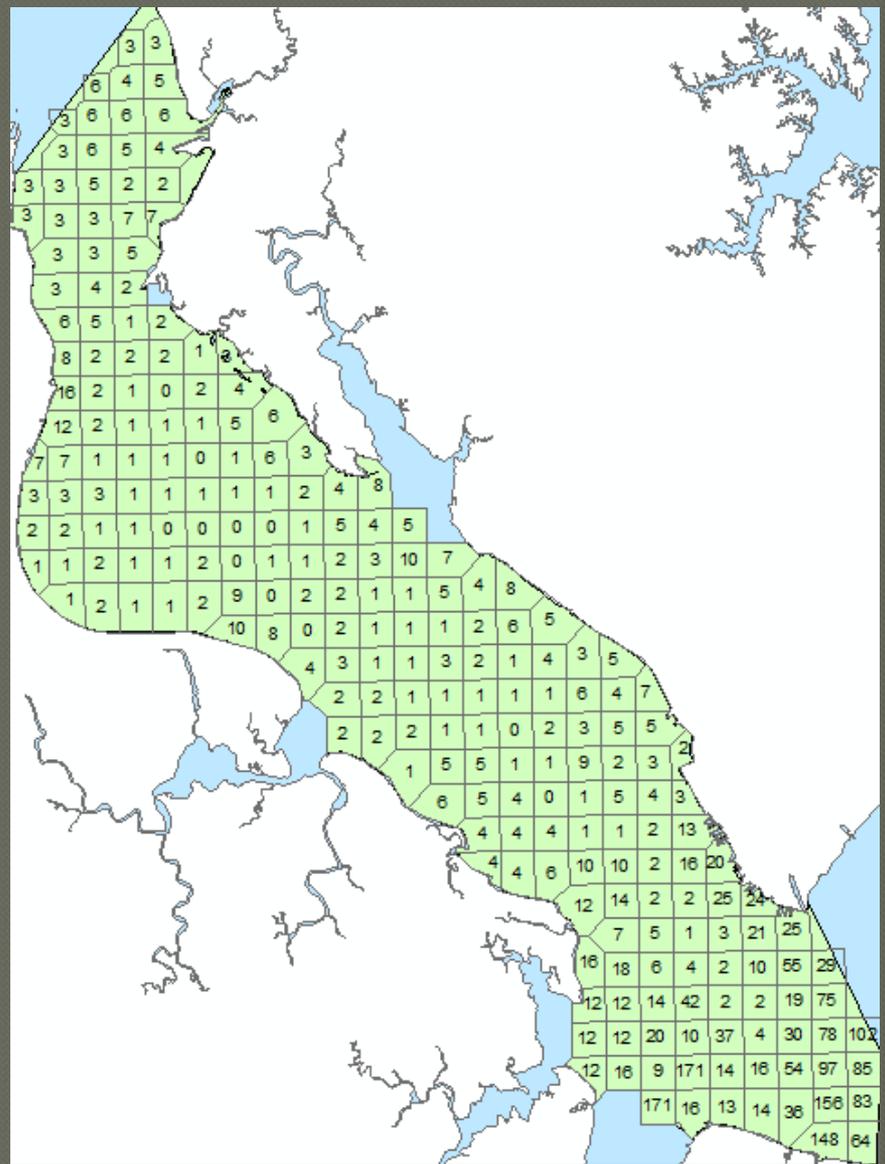
The Interpolator generates a estimate at each point location (centroid).





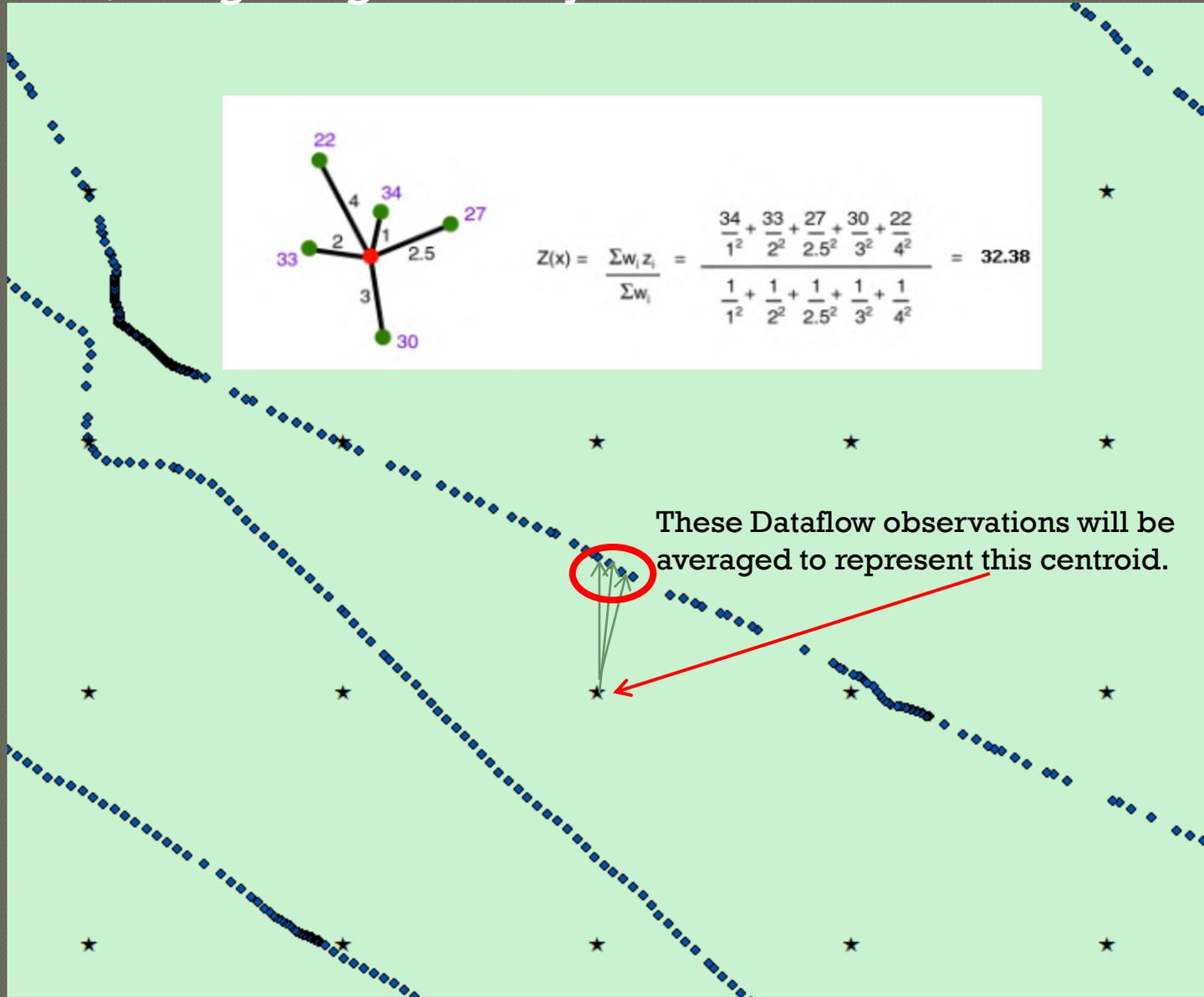
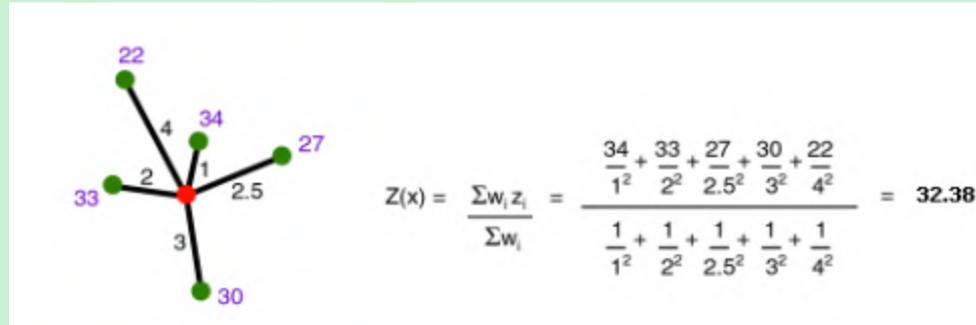


“Raw” Dataflow



Interpolated Dataflow

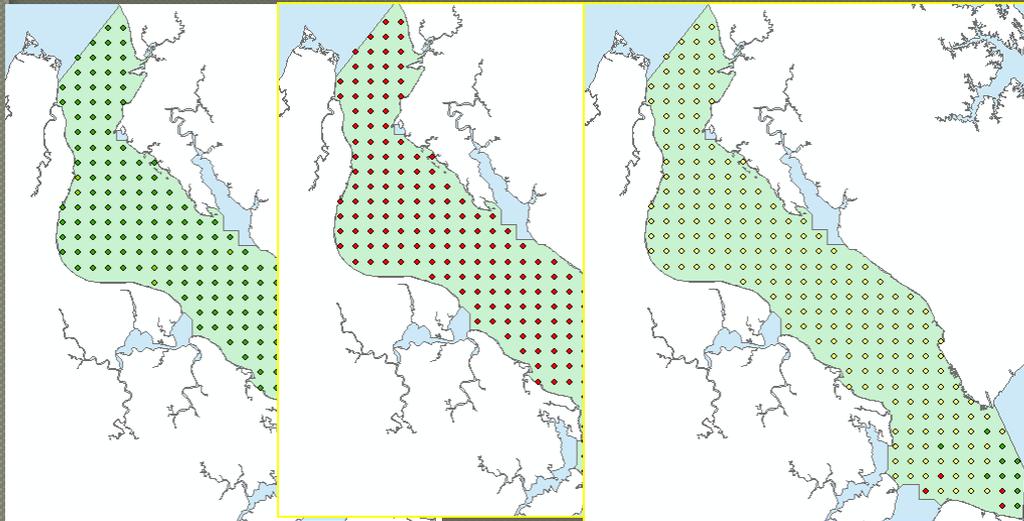
The Interpolator averages the closest observations to each centroid, weighting them by distance.



These Dataflow observations will be averaged to represent this centroid.

2. Calculation of Spatial exceedance

Based on Monthly Fixed Station Cruises



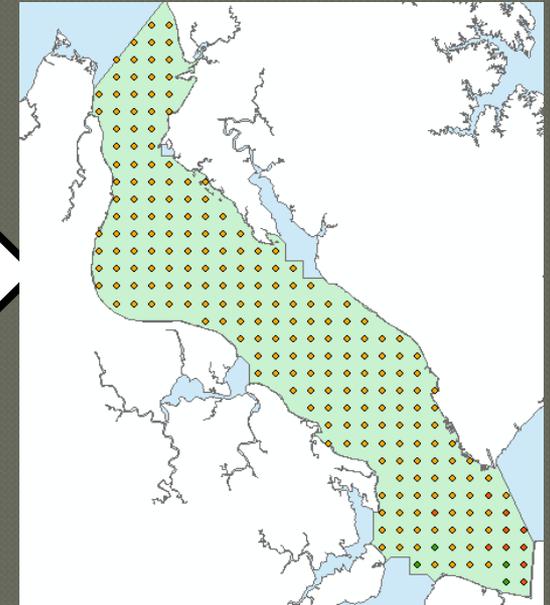
July

August

September

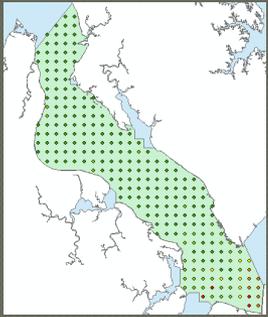
averaging

Season Geometric Mean



Create a seasonal “snapshot” by averaging all the interpolations.

Based on Weekly Dataflow Cruises



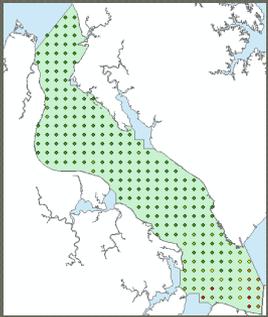
July 2



July 9



July 16



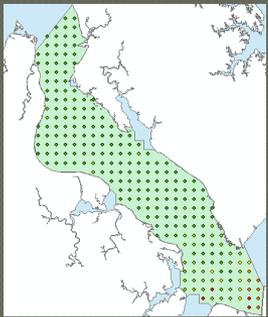
August 1



August 8



August 15



September 6



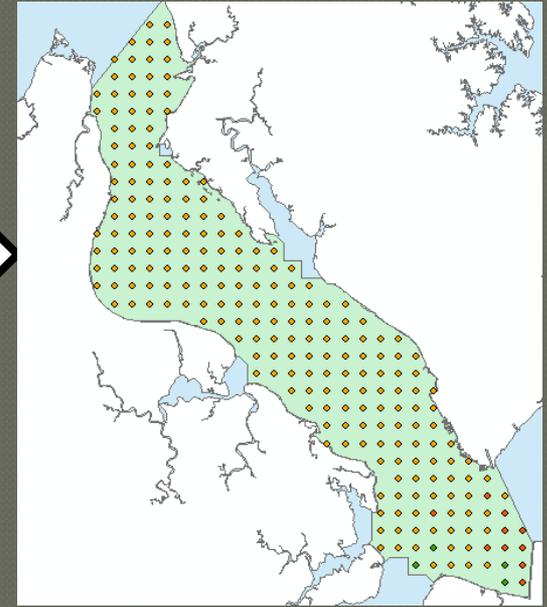
September 15



September 30

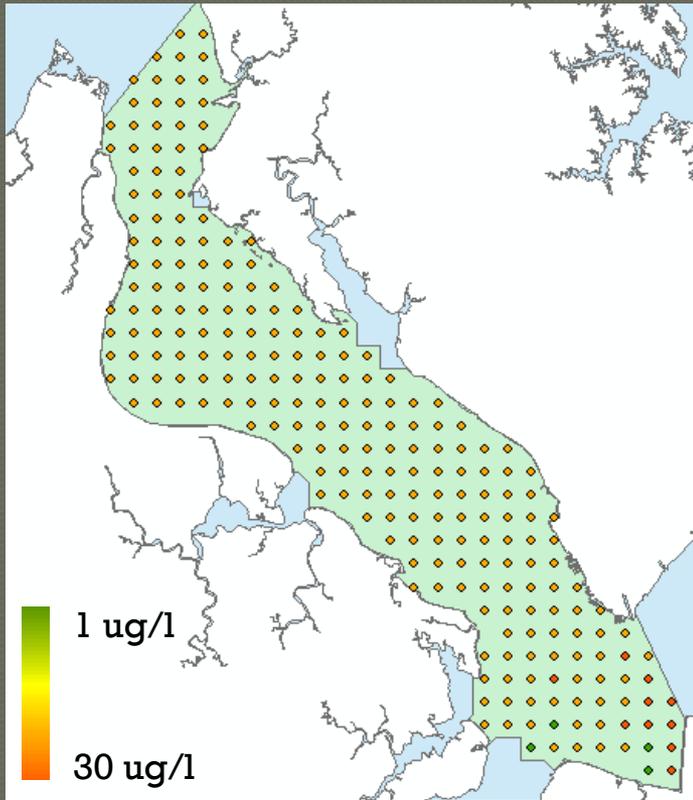
averaging →

Season Geometric Mean



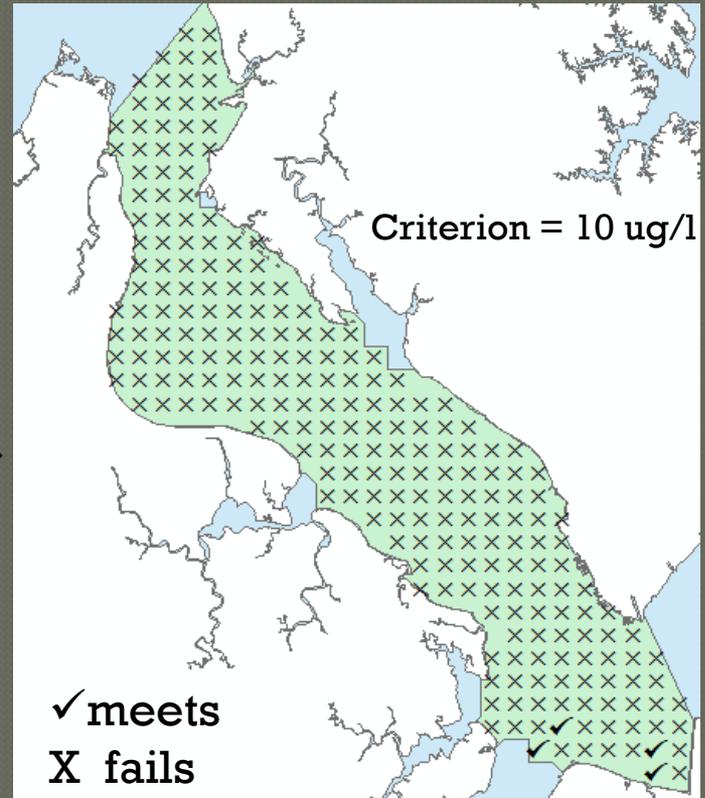
Create a seasonal “snapshot” by averaging all the interpolations.

Season Mean



Assessment →

Season Assessment



1-Jul

30			30
		50	
10			10

30	40	50	30
40	40	50	20
30	30	40	10
20	30	30	10

23	29	31	18
29	25	31	16
18	26	20	10
13	14	14	10

1-Aug

10			10
		30	
20			10

10	20	30	10
20	20	30	20
10	30	20	10
10	10	10	10

c.

X	X	X	X
X	X	X	X
X	X	X	✓
✓	✓	✓	✓

d.

1-Sep

40			20
		20	
10			10

40	30	20	20
30	20	20	10
20	20	10	10
10	10	10	10

a.

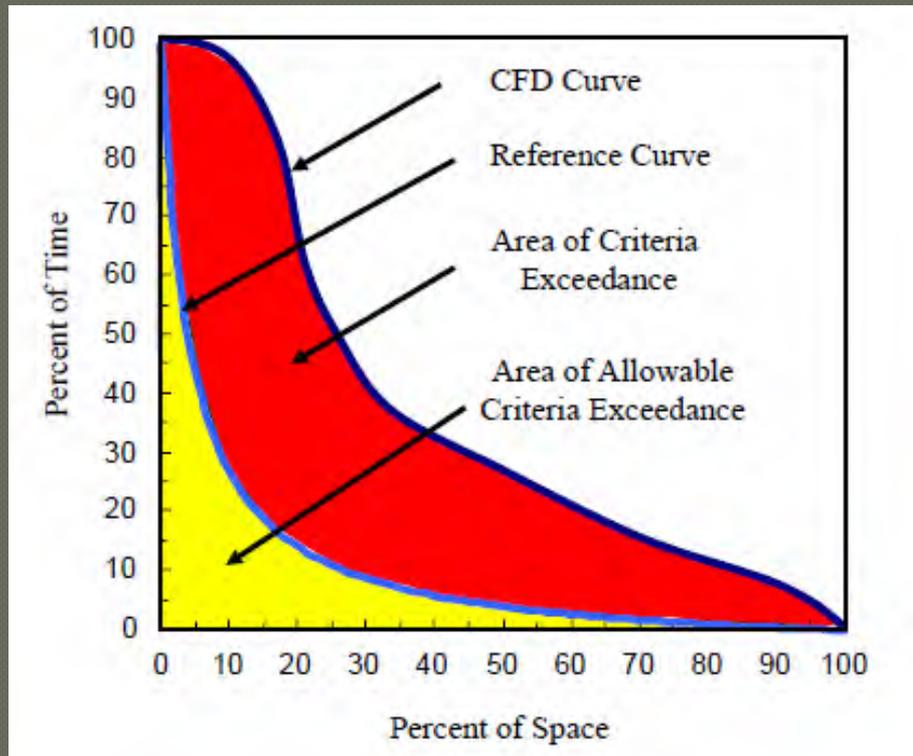
b.

- a. Observed chlorophyll
- b. Interpolated chlorophyll
- c. Seasonally averaged chlorophyll
- d. Assessment layer

X 3

3. Cumulative Frequency Diagram (CFD)

- Used to determine if spatial exceedances are “excessive”

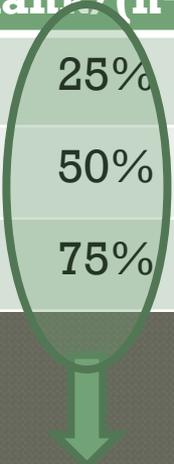


[Tango, Peter J. and Richard A. Batiuk, 2013. Deriving Chesapeake Bay Water Quality Standards. Journal of the American Water Resources Association \(JAWRA\) 1-18.](#)

First...

We organize our seasonal exceedance rates in a table like this one.

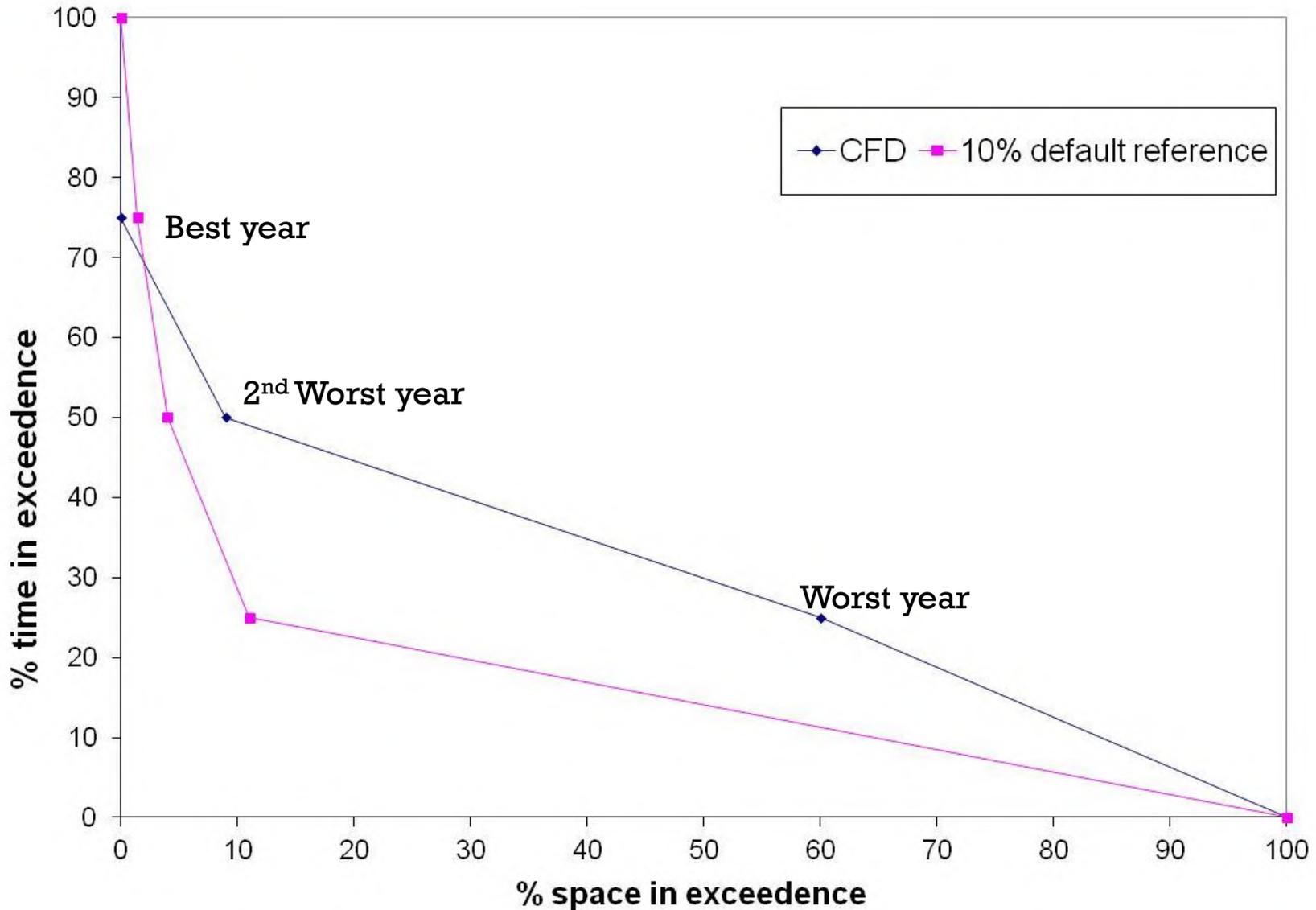
Rank	Season-Year	Space exceedance Rate (hypothetical)	Cumulative Probability = Rank/(n+1)
1	Worst Year	60%	25%
2	2 nd Worst Year	9%	50%
3	Best Year	0%	75%

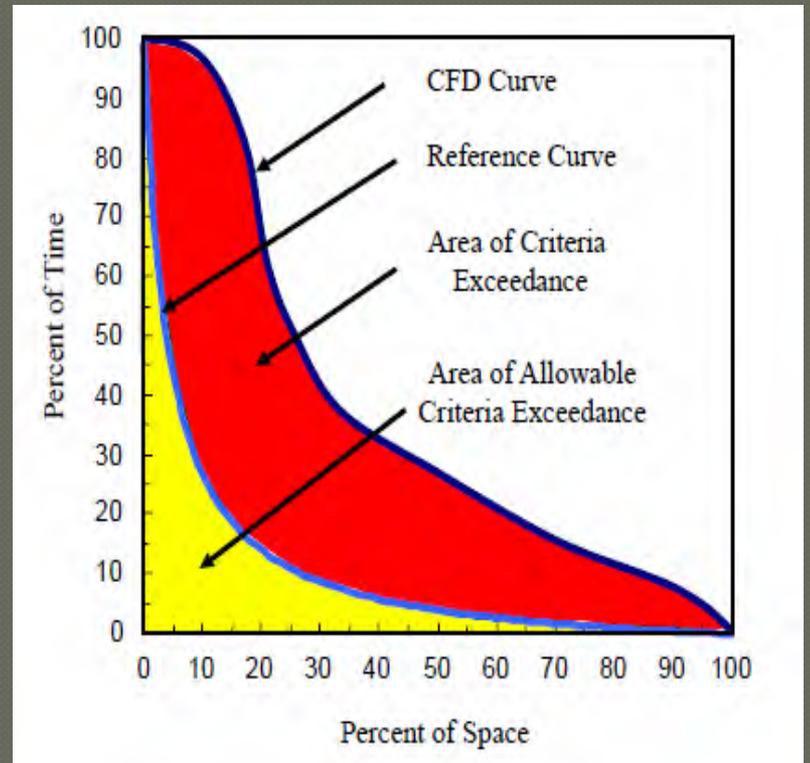
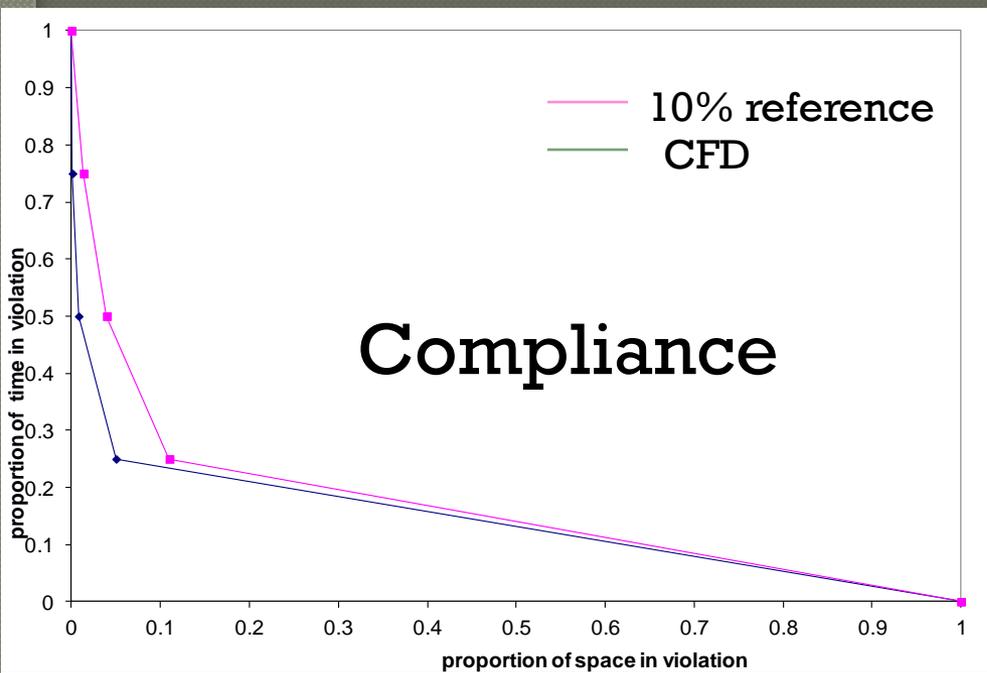
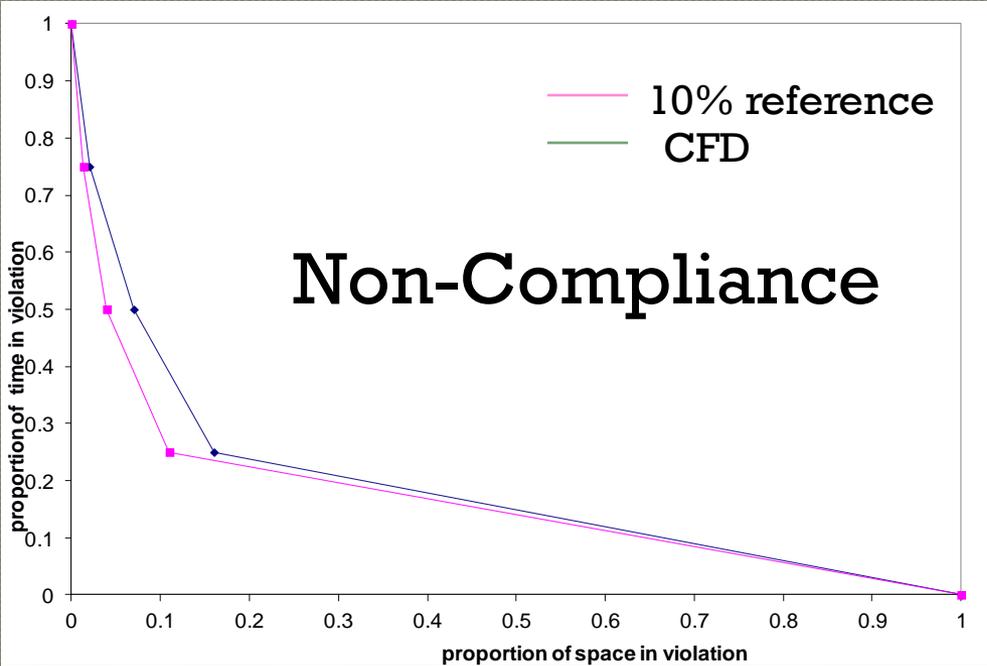


% time in exceedance

Rank	Season-Year	Space exceedance Rate (hypothetical)	Cumulative Probability = Rank/(n+1)
		100%	0%
1	Worst Year	60%	25%
2	2nd Worst Year	9%	50%
3	Best Year	0%	75%
		0%	100%

Then we create a plot like this one.





Default
10%
Reference

Rank	Season-Year	Seasonal Spatial exceedance Rate	Allowable Spatial exceedance Rate%
1	Worst Year	60.0%	11.0%
2	2 nd Worst Year	9.0%	4.0%
3	Best Year	0.0%	1.4%

Generated from
the 10%
hyperbolic
function

All of these segments fail too...

Rank	Season -Year	Hypothetical Space exceedance Rate	Allowable Space exceedance Rate%
1	Worst Year	11.5 %	11.0%
2	2 nd Worst Year	4.1%	4.0%
3	Best Year	1.5%	1.4%

Scenario 1

Rank	Season -Year	Hypothetical Space exceedance Rate	Allowable Space exceedance Rate%
1	Worst Year	13.0%	11.0%
2	2 nd Worst Year	4.0%	4.0%
3	Best Year	1.4%	1.4%

Scenario 2

Rank	Season -Year	Hypothetical Space exceedance Rate	Allowable Space exceedance Rate%
1	Worst Year	10.0%	11.0%
2	2 nd Worst Year	3.0%	4.0%
3	Best Year	2.0%	1.4%

Scenario 3

Rank	Season -Year	Hypothetical Space exceedance Rate	Allowable Space exceedance Rate%
1	Worst Year	2.0%	11.0%
2	2 nd Worst Year	2.0%	4.0%
3	Best Year	2.0%	1.4%

Scenario 4

Why?!

The assumption is....

For a reference waterbody, you'd expect there to be a...

1 in 3 chance of having a season with a spatial exceedance up to 11.0%

2 in 3 chance of having a season with a spatial exceedance up to 4.0%

3 in 3 chance of having a season with a spatial exceedance up to 1.4%

		3 : 3
		1.4% or less
	2 : 3	1.4% or less
		4.0% or less
1 : 3		1.4% or less
		4.0% or less
		11.0% or less

If a particular segment doesn't conform to these expectations, it is likely impaired.

Critical Evaluation

Two Big Questions

- Is the CFD framework compatible with fixed station datasets?
- Does the 10% CFD adequately represent exceedance frequencies under reference conditions?

Two Big Questions

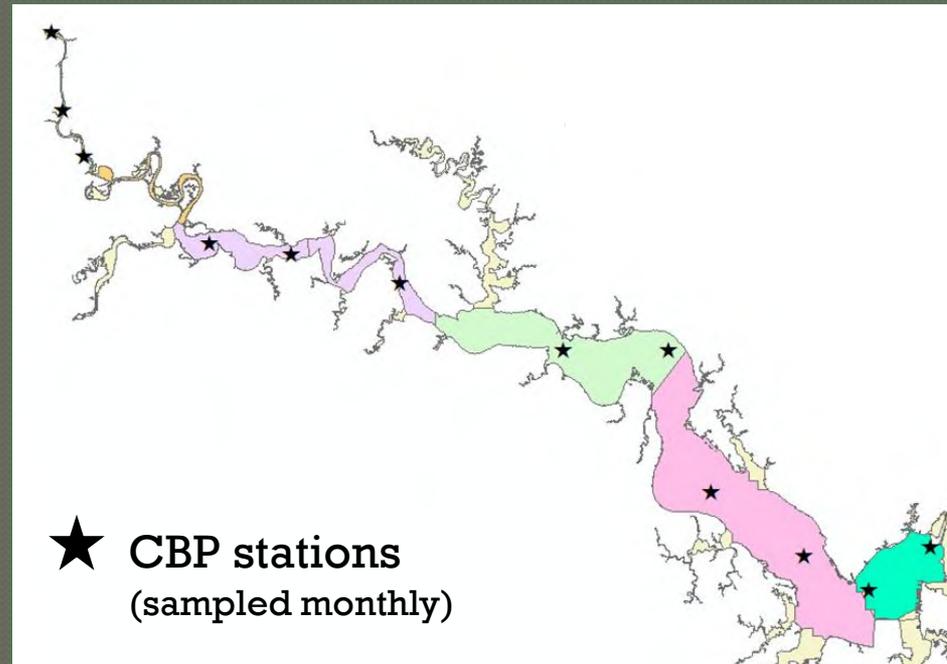
- Is the CFD framework compatible with fixed station datasets?
- Does the 10% CFD adequately represent exceedance frequencies under reference conditions?

Do fixed station datasets generate accurate estimates of:

- spatial exceedance?
- spatial-temporal exceedance?

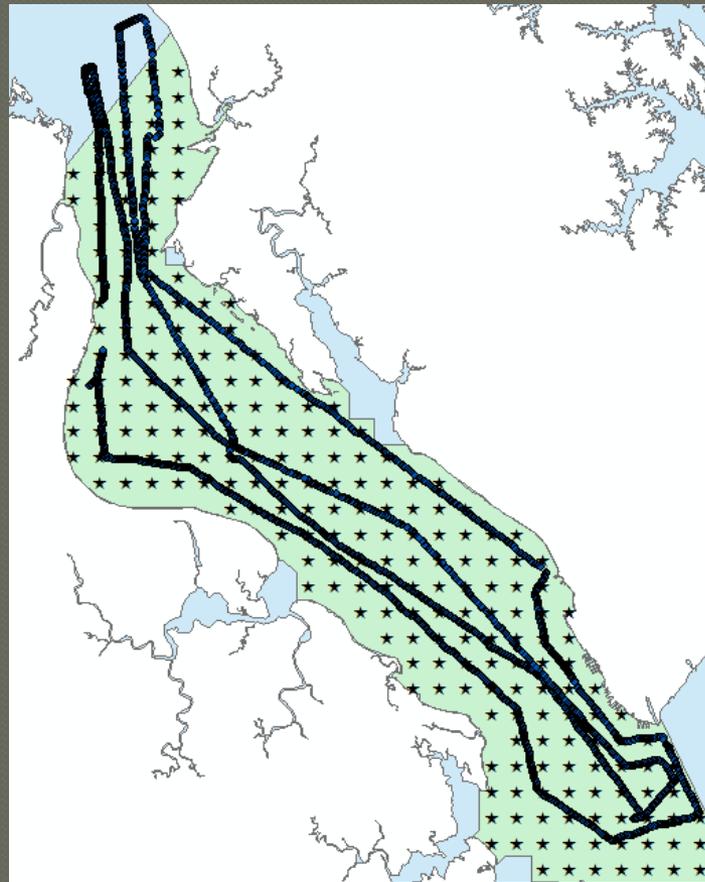
Spatial exceedance

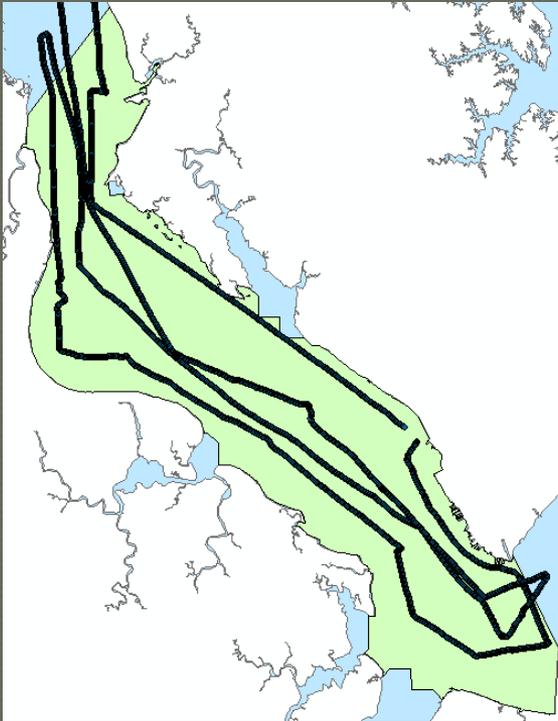
Are 2-3 sampling locations per segment sufficient to generate accurate estimates of spatial exceedance?



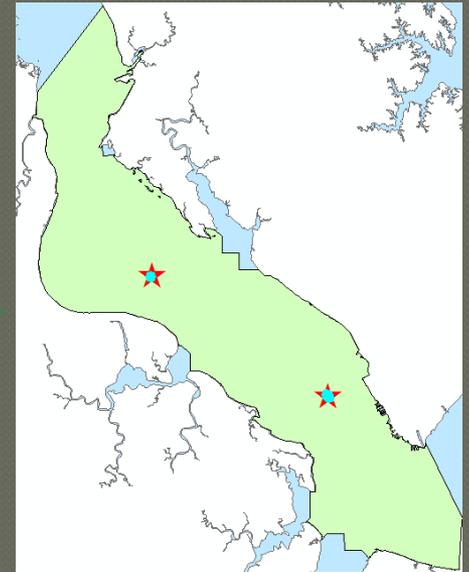
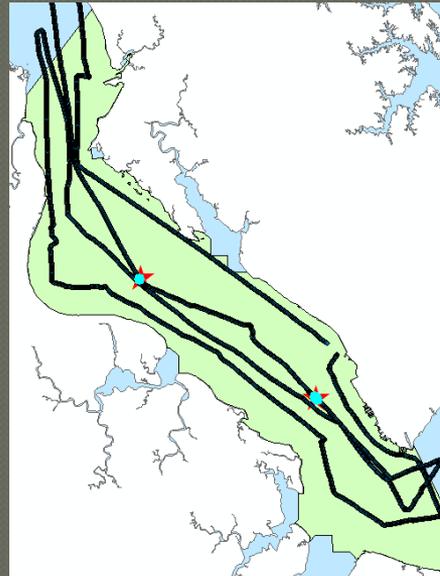
To answer this question...

I performed a validation study using Dataflow

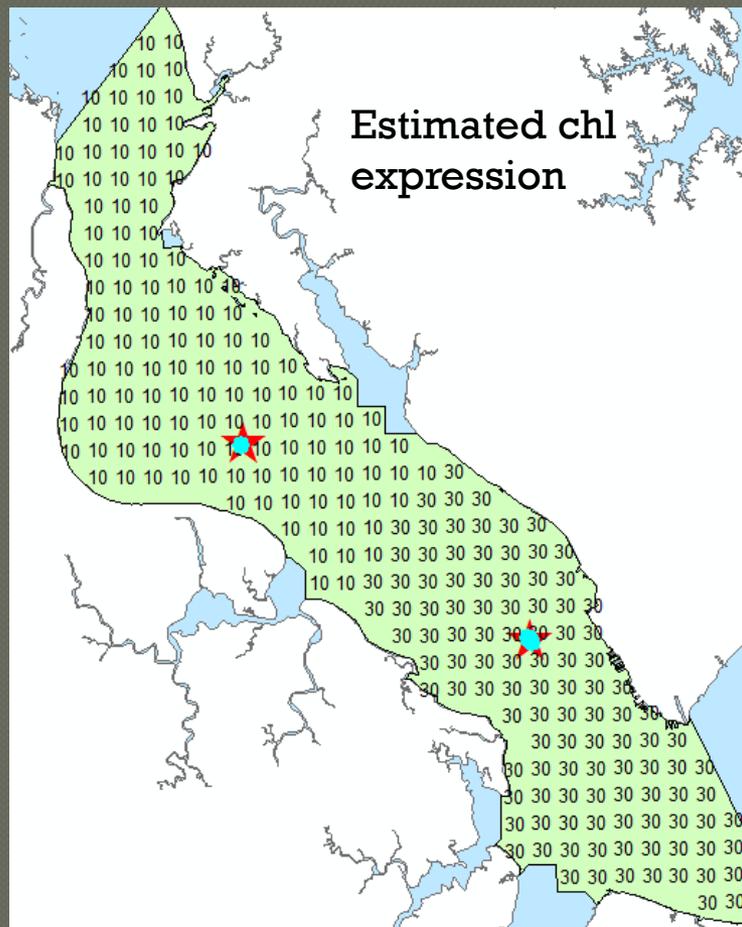




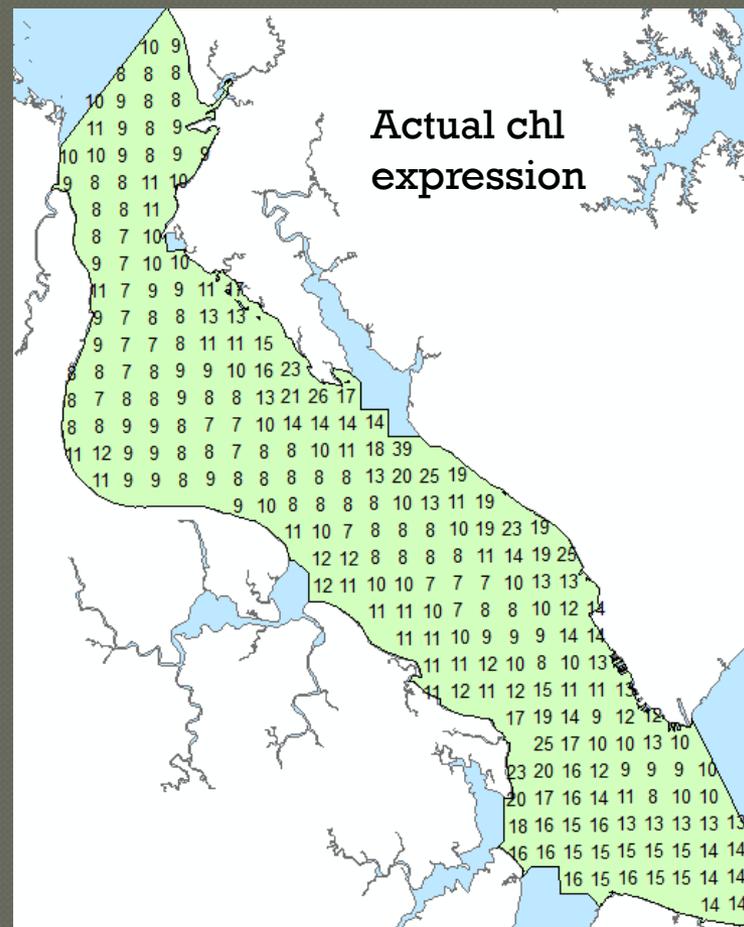
I selected Dataflow cruises with a low/moderate number of “exceedances”



From each cruise, I extracted the Dataflow observations corresponding to the CBP stations. These will be our “fixed stations” samples.



The fixed station samples were interpolated.



The entire Dataflow cruise track was also interpolated.

The spatial exceedance rates derived from each interpolation were compared.

JMSTFU cruise date	Dataflow Spatial Exceedence Rate	CBP Stations Spatial Exceedence Rate	Percent Error
4/26/2006	2	0	100
4/26/2007	21	0	100
9/11/2008	9	100	1011
median percent error →			100%

JMSTFL cruise date	Dataflow Spatial Exceedence Rate	CBP Stations Spatial Exceedence Rate	Percent Error
4/26/2006	11	0	100
9/19/2007	18	22	22
7/1/2008	26	41	58
median percent error →			58%

JMSOH cruise date	Dataflow Spatial Exceedence Rate	CBP Stations Spatial Exceedence Rate	Percent Error
3/28/2006	57	28	52
8/20/2007	6	0	100
8/11/2008	2	0	100
5/21/2012	5	0	100
8/20/2012	1	0	100
3/5/2013	4	0	100
7/11/2013	17	0	100
median percent error →			100%

JMSMH cruise date	Dataflow Spatial Exceedence Rate	CBP Stations Spatial Exceedence Rate	Percent Error
5/27/2010	5	0	100
4/9/2012	5	0	100
3/12/2007	20	50	150
3/17/2010	12	53	342
3/8/2006	36	0	100
9/1/2011	14	0	100
8/26/2010	13	0	100
median percent error →			100%

JMSPH cruise date	Dataflow Spatial Exceedence Rate	CBP Stations Spatial Exceedence Rate	Percent Error
4/18/2006	5	0	100
5/24/2006	14	54	286
9/12/2006	2	0	100
3/8/2007	17	0	100
5/22/2007	17	0	100
9/15/2009	9	45	400
8/31/2011	2	0	100
3/4/2013	5	0	100
median percent error →			100%

Spatial exceedance

Are 2-3 sampling locations per segment sufficient for generating accurate estimates of spatial exceedance?

No. Highly erroneous estimates of spatial exceedance are generated when fixed station datasets are the basis of assessment.

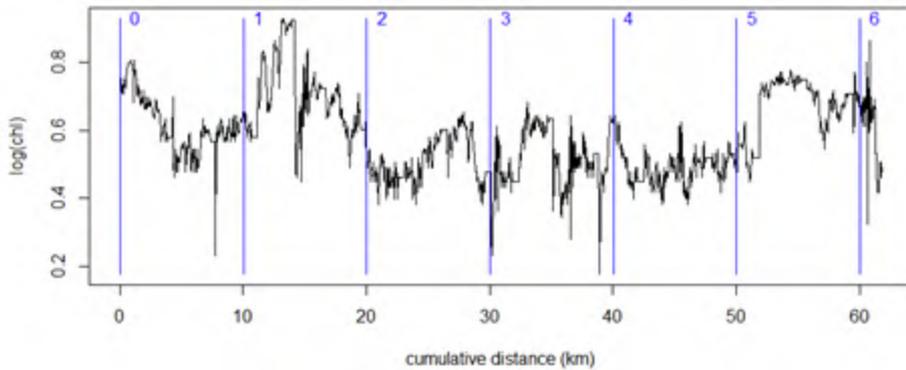
Spatial-temporal exceedance

How well do monthly site visits predict spatial-temporal exceedance rates?



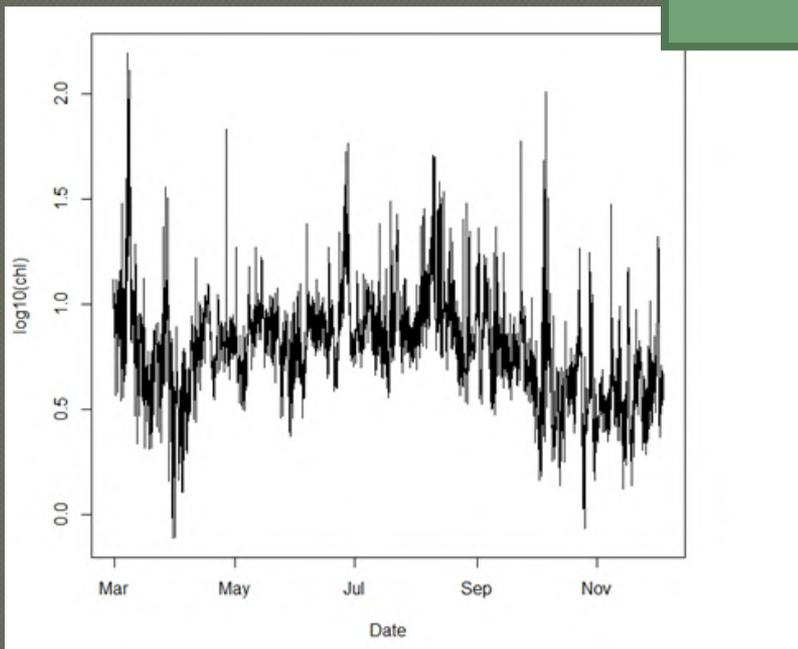
To answer this question...

Independent statistician Elgin Perry used Dataflow and ConMon to simulate the “true” chlorophyll during the spring and summer seasons 2005-2007 in JMSPH.

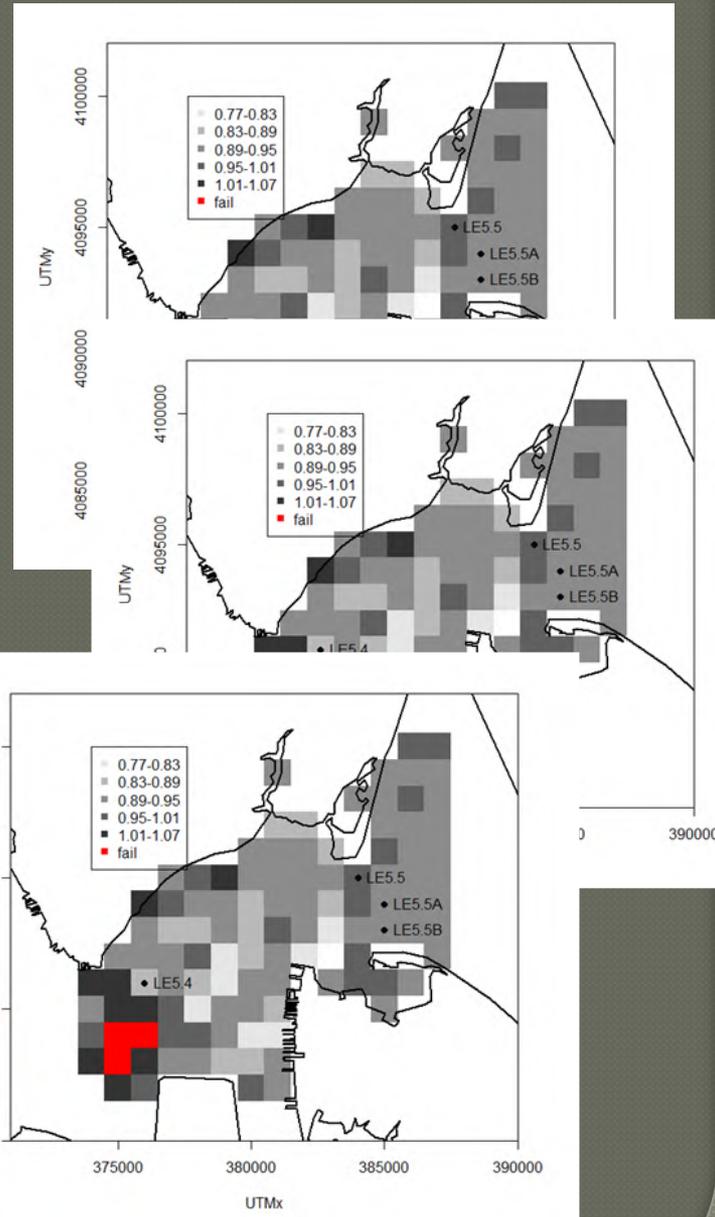


Spatial variability (Dataflow)

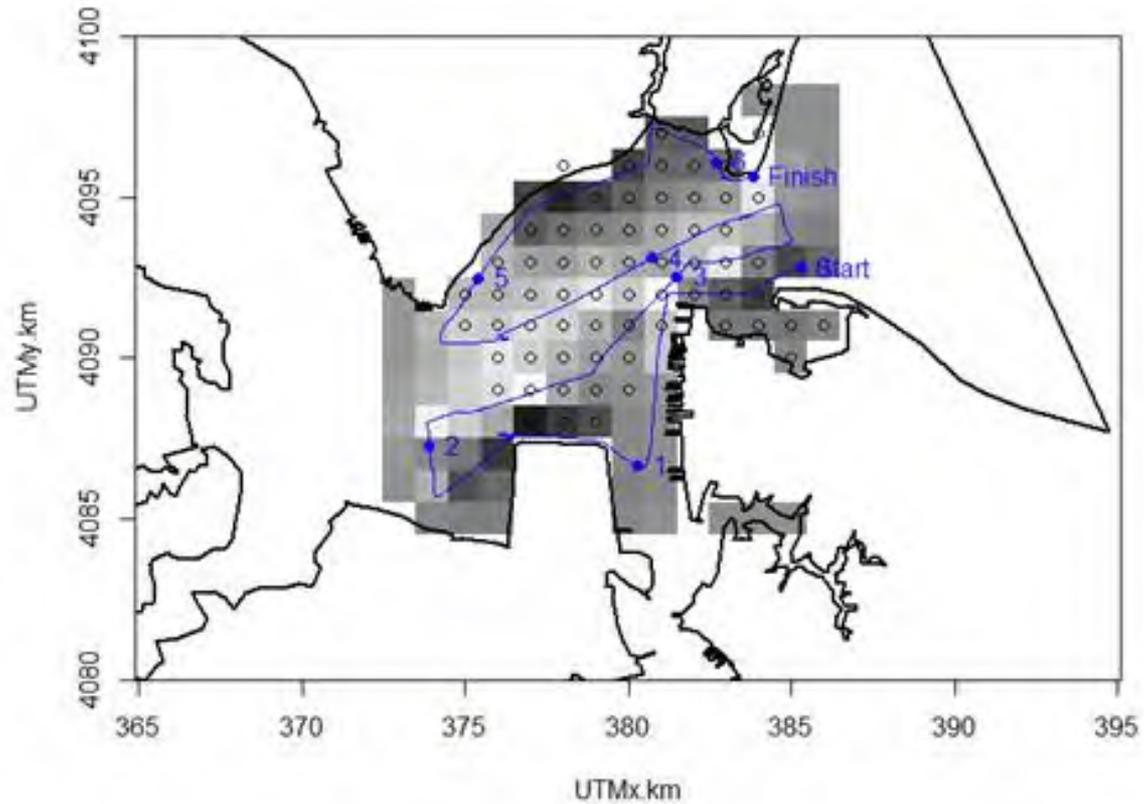
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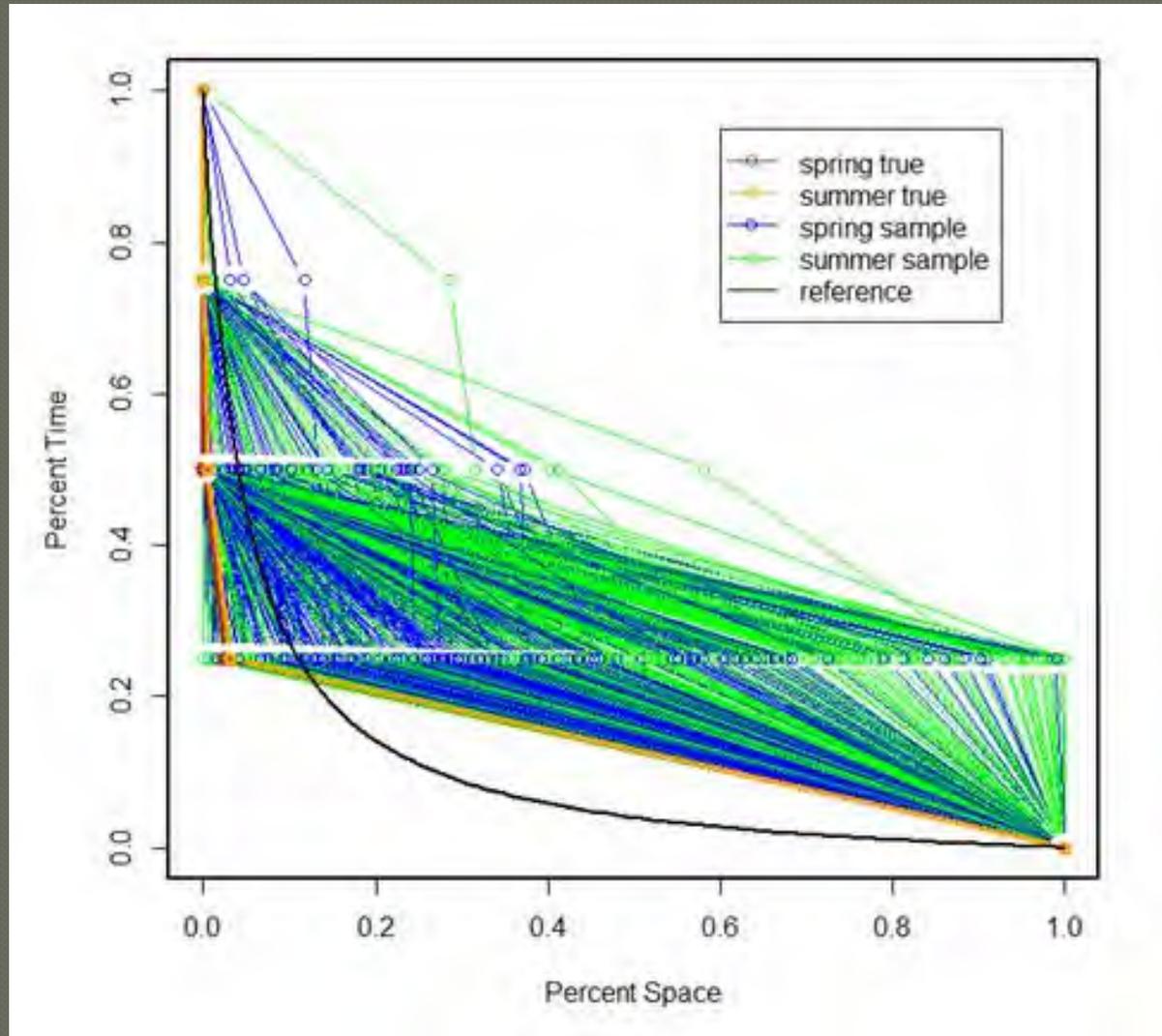
Temporal variability (ConMon)



“true” season means



From Elgin's synthetic dataset, "samples" were taken from six "stations" and interpolated via IDW. CFDs were then created. Repeat 1000 times.



Fixed station datasets generate CFD curves that differ dramatically from the “true” distribution. Moreover, fixed station-based CFDs differ amongst each other and are biased towards noncompliance.

Spatial-temporal exceedance

How well do monthly site visits predict spatial-temporal exceedance rates?

Very poorly.

Two Big Questions

- Is the CFD framework compatible with fixed station datasets?
- Does the 10% CFD adequately represent exceedance frequencies under reference conditions?

Does this really describe the distribution of exceedances for reference water quality?

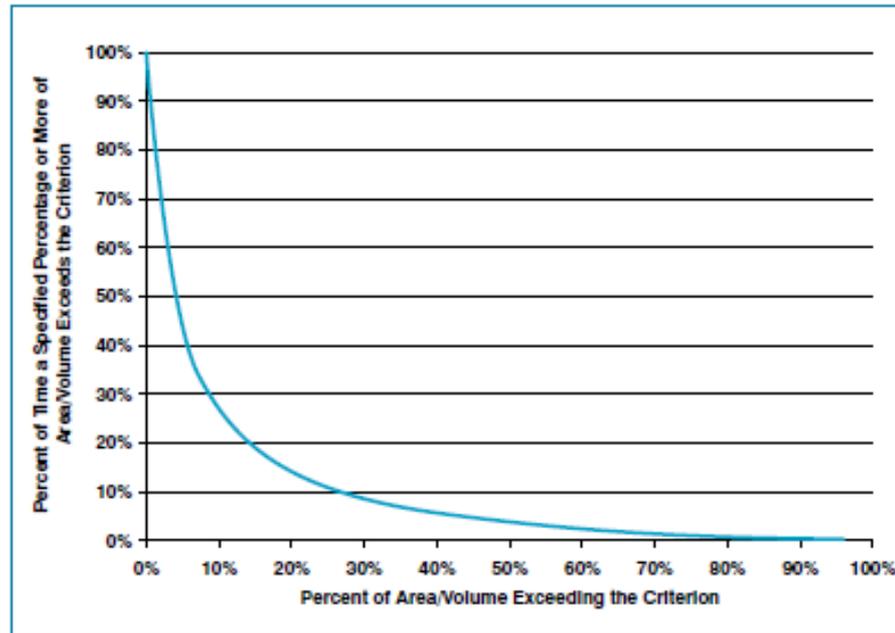


Figure II-4. Default reference curve for application in the attainment assessment of Chesapeake Bay water quality criteria for which biologically based reference curves cannot be derived.

From [July 2007 Technical Addendum](#)

Reference conditions are....

	Spring	June	Summer	Autumn	Winter
Secchi depth (m)					
TF	>0.9	>0.8	>0.8	>0.9	>0.6
OH	>0.7	>0.6	>0.6	>0.5	>0.6
MH	>1.8	>1.45	>1.45	>2.0	>1.8
PH	>2.15	>1.85	>1.85	>2.5	>2.3
DIN (mg/liter)	≤0.07 (all seasons and salinity zones)				
PO ₄ (mg/liter)	≤0.007 (all seasons and salinity zones)				

Reference thresholds

Table 2. Water quality categories. See Table 1 for classification thresholds.

Category name	Description
Better/Best	meets all thresholds for Secchi, DIN, & PO ₄
Mixed Better Light (MBL)	meets Secchi threshold, fails DIN and/or PO ₄ threshold
Mixed Poor Light (MPL)	fails Secchi threshold, meets DIN and/or PO ₄ threshold
Poor/Worst	fails all thresholds for Secchi, DIN, & PO ₄

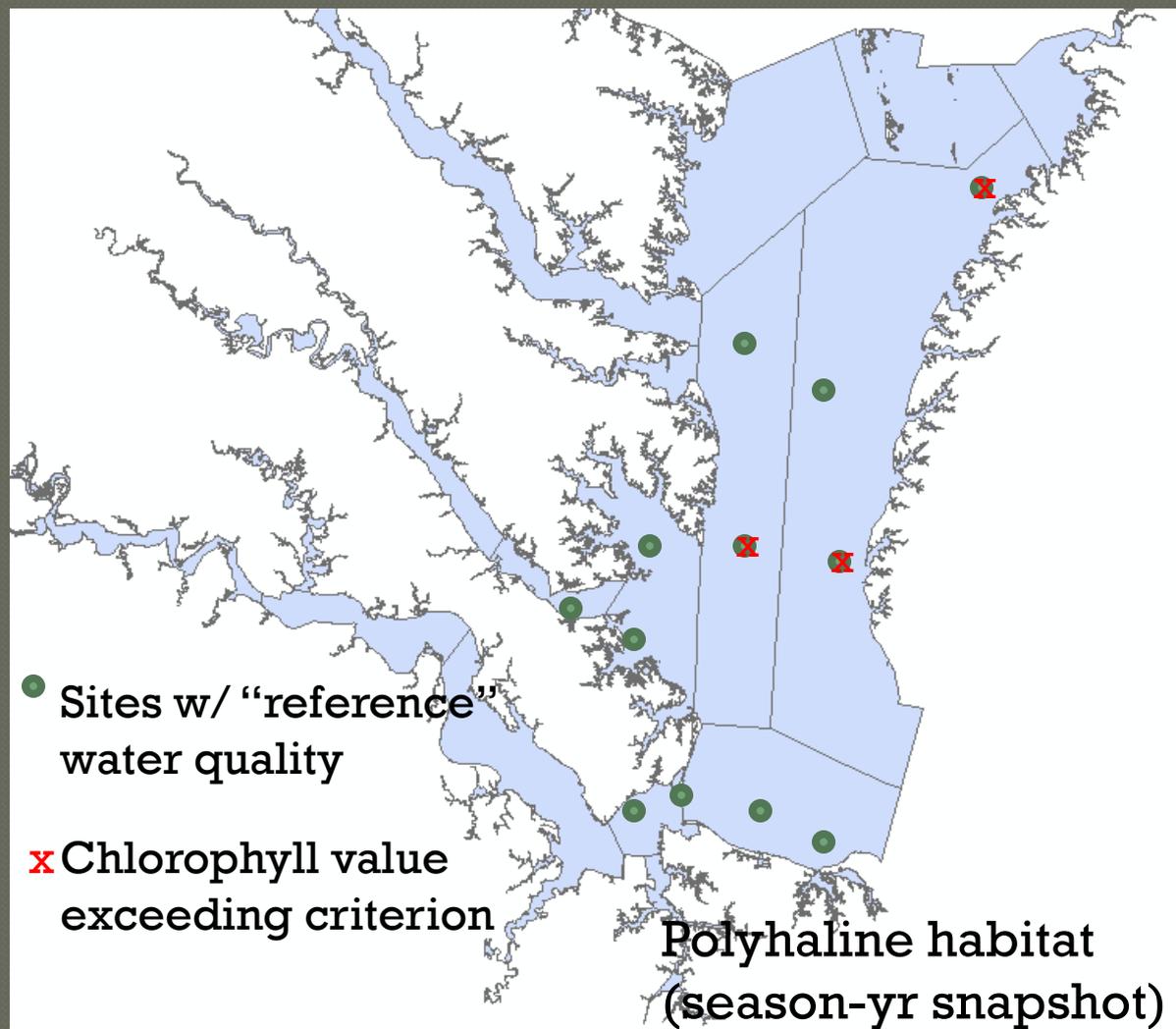
Reference conditions

From Claire Buchanan's "Biological Reference Curves for Assessing the James River Chlorophyll a Criteria"

Using the Chesapeake Bay water quality database, Claire selected all the chlorophyll values collected during “reference water quality” conditions and sorted them by habitat (salinity) and season-year.

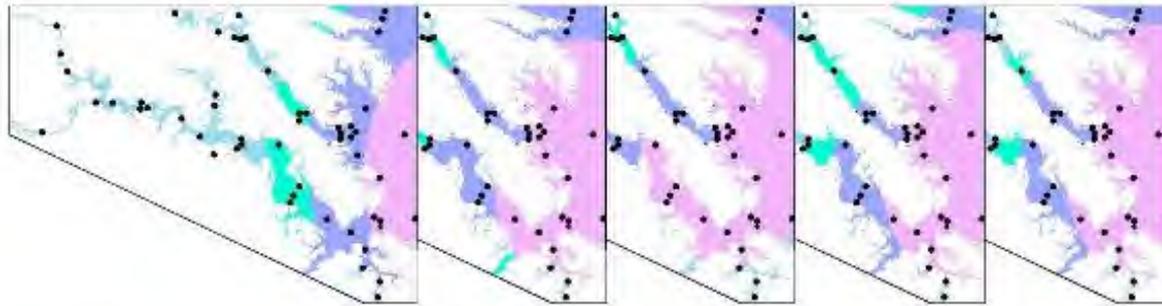
These values were compared to JR segment-season criteria.

The reference samples were assumed to be adequately spatially representative of the habitat's area.

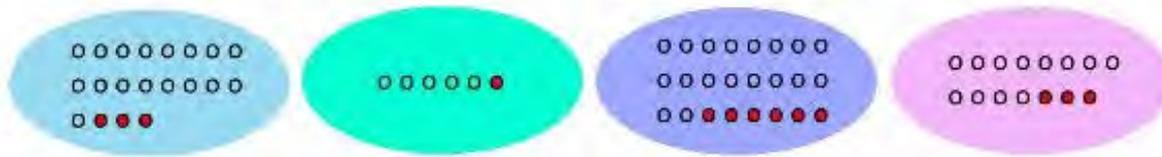


In this example, 25% of the fixed stations have chl values above the criterion. Thus, we assume 25% of the area of under "reference water quality" exceeded the criterion for this season-year.

A) Individual cruise periods in one season-year, bay wide (all samples)



B) One season-year (all samples from reference quality conditions regardless of cruise periods)



Salzone: TF

OH

MH

PH

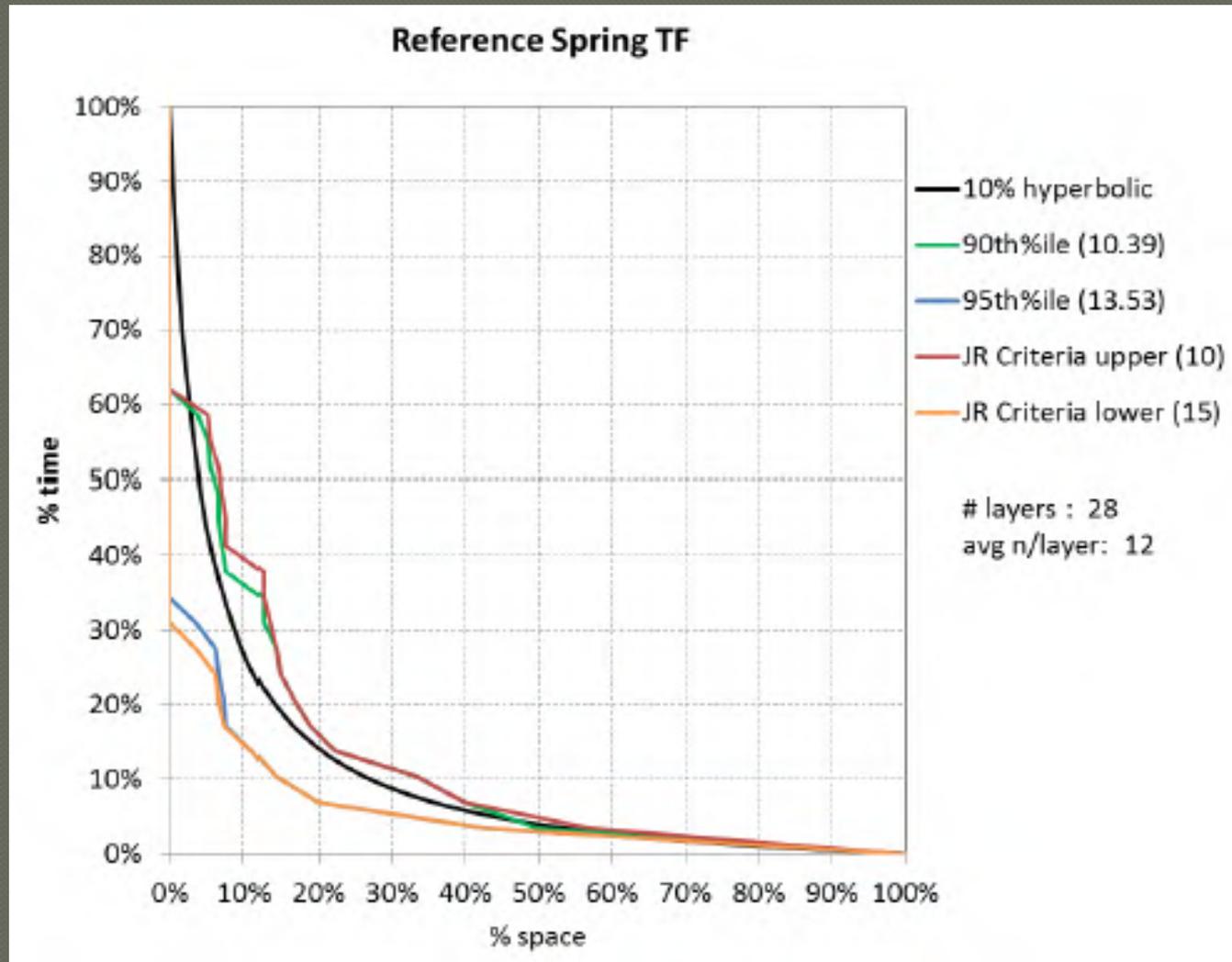
C) Multiple season-years

Year T	2%	0%	1%	0.5%
Year U	0%	1%	0%	4%
Year V	1.2%	1.5%	9%	1%
Year W	0%	0%	2.1%	0%
Year X	4%	5%	3%	0%
Year Y	2.6%	10%	0%	1.3%
Year Z	0%	0%	0.5%	2%
⋮				
Salzone :	TF	OH	MH	PH

Claire's bioreference curves are based on instantaneous exceedances of the criteria, rather than seasonal mean exceedances.

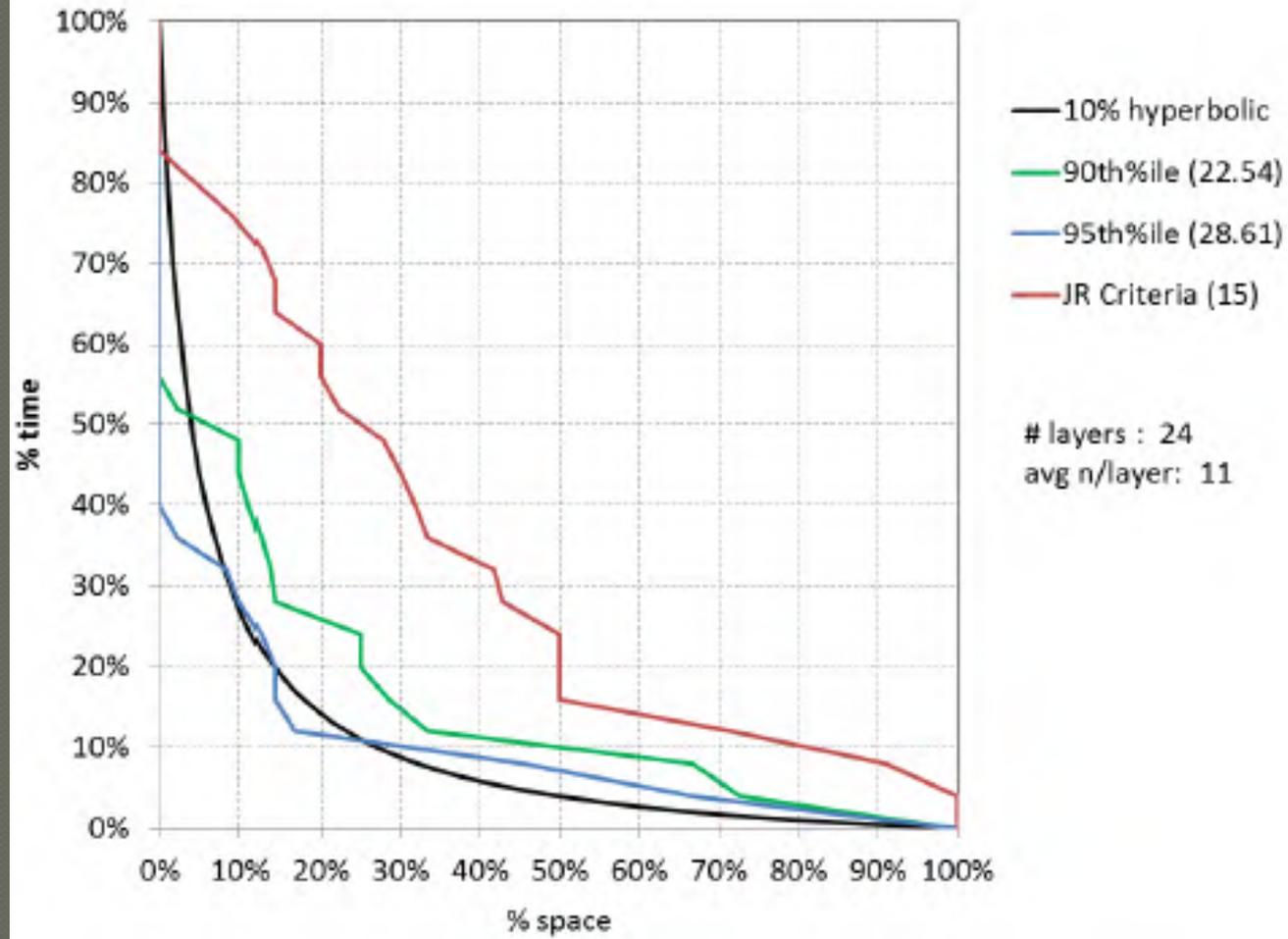
Thus, we can't assume that Claire's bioreference curves are representative of seasonal mean exceedances under reference conditions.

HOWEVER, if her bioreference curves depart considerably from 10% CFD, then it is reasonable for us to assume that seasonal mean-based bioreference curves would likely also depart from the 10% CFD.



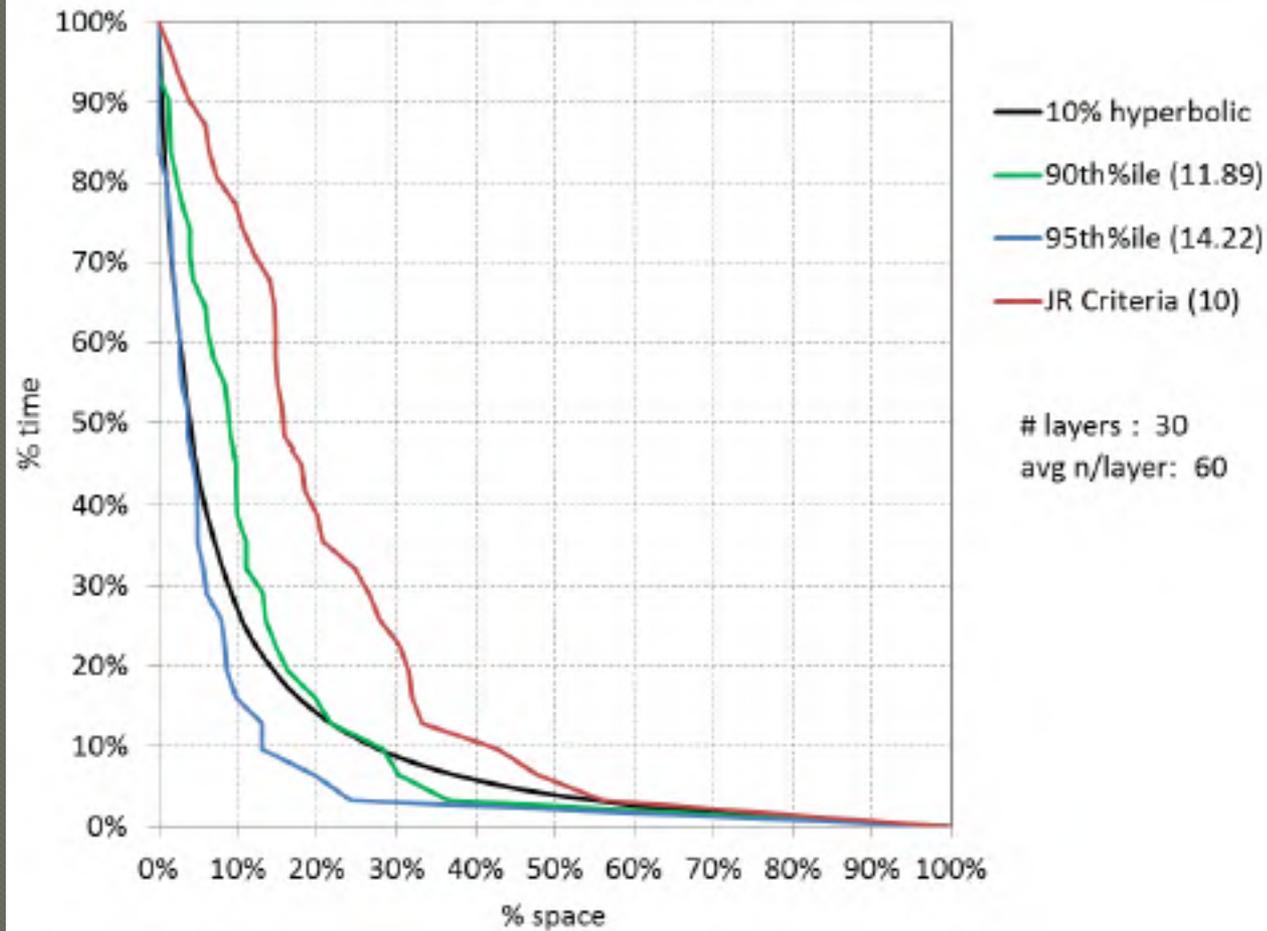
Bioreference exceedances of spring JMSTFU criterion (red) is similar to 10%.
 Bioreference exceedances of spring JMSTFL criterion (orange) is more stringent than 10%.

Reference Spring OH



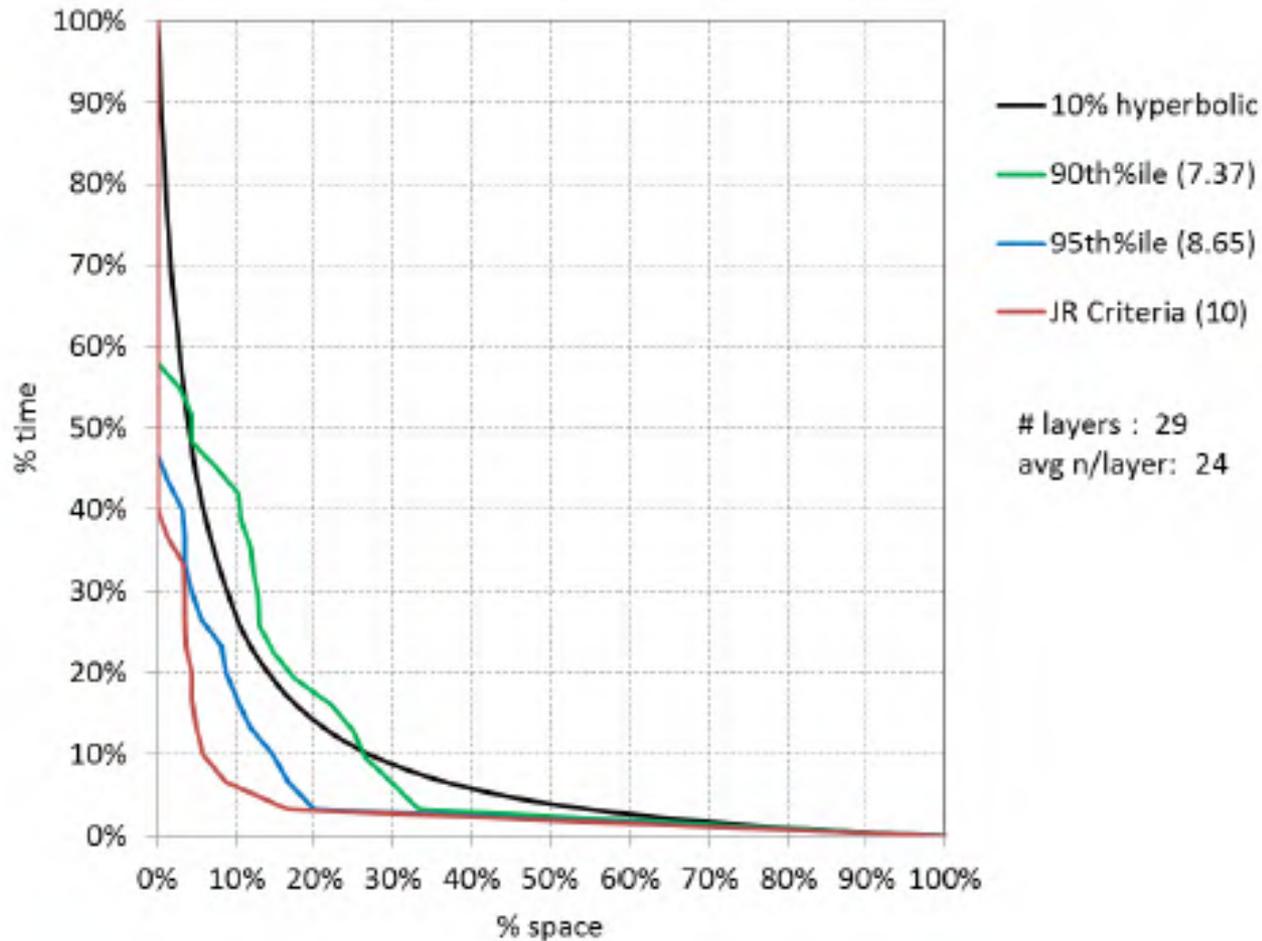
Bioreference exceedances of spring JMSOH criterion (red) is more lenient than 10%

Reference Summer MH



Bioreference exceedances of summer JMSMH criterion (red) is more lenient than 10%.

Reference Summer PH



Bioreference exceedances of summer JMSPH criterion (red) is more stringent than 10%.

Does this really describe the distribution of exceedances for reference water quality?

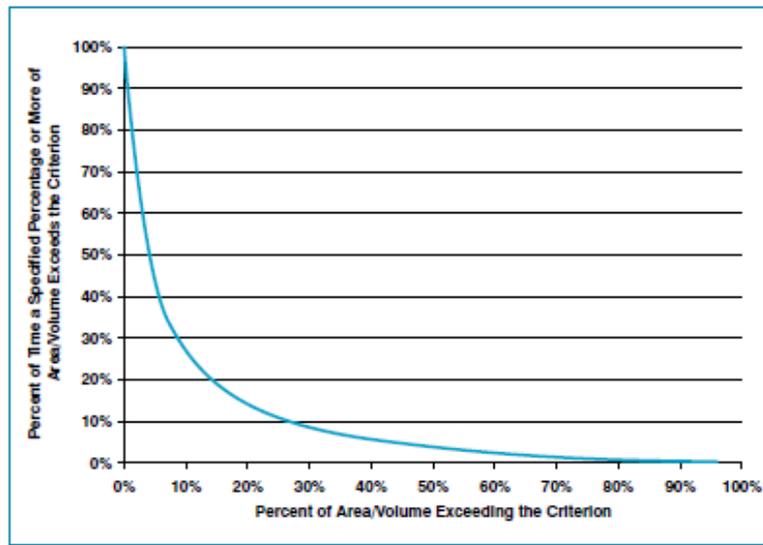


Figure II-4. Default reference curve for application in the attainment assessment of Chesapeake Bay water quality criteria for which biologically based reference curves cannot be derived.

Probably not, at least when “reference” is defined as the current JR chlorophyll criteria.

In summary...

**Our current assessment framework is ahead
of its time...**

The current assessment approach assumes our monitoring program is like this.



When really we're driving this...



Solid and dependable, but limited.

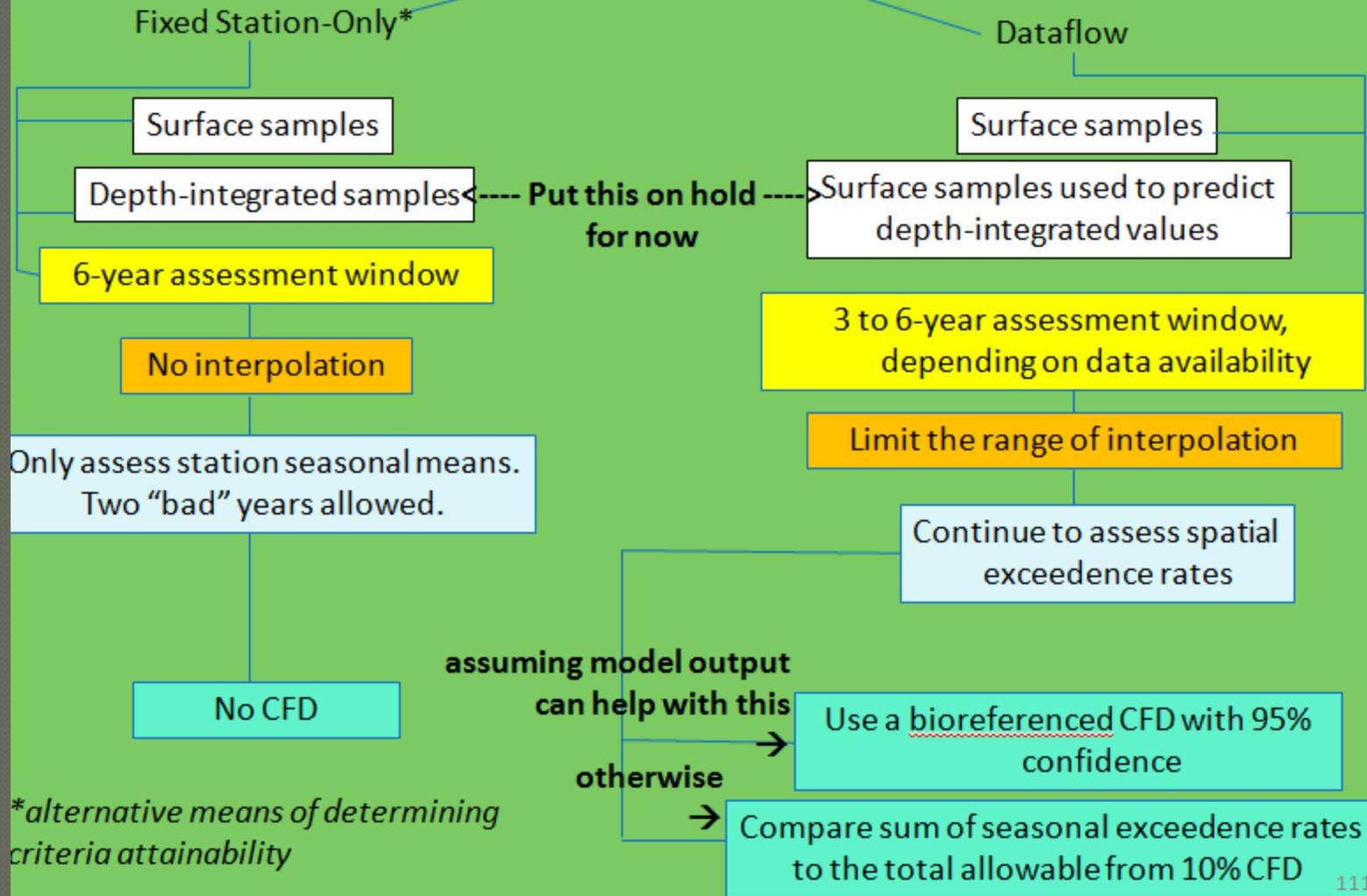
It also assumes that we have enough understanding to confidently set target chlorophyll exceedance frequencies. But there is still a lot we don't know about what reference chlorophyll looks like spatially and temporally.



Alternative Assessment Approach

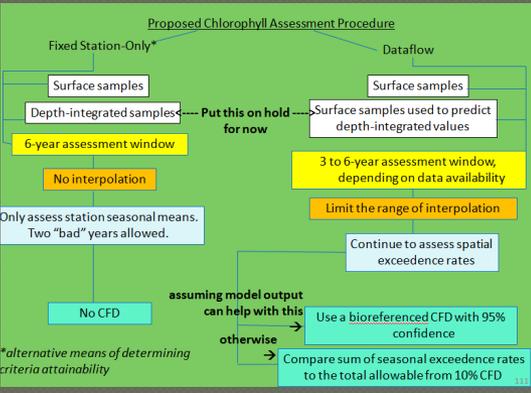
A “strawman” was presented at the July webinar to get ideas flowing.

Proposed Chlorophyll Assessment Procedure



Six people sent in comments addressing the strawman...

- Four commenters expressed agreement with the idea to expand the assessment period from 3 to 6 years.
- Four commenters recommended discontinuing the use of the CFD all together. One commenter believes the CFD still had utility for assessing Dataflow, however.
- Five commenters questioned the wisdom of predicating attainment on *station* seasonal means, expressing concern that this would discourage DEQ from adding more stations.



- Two commenters recommended basing attainment on *segment* seasonal means (i.e., average all data collected within a segment during each season of the assessment period.)
- Two commenters had some reservation about this idea, though.



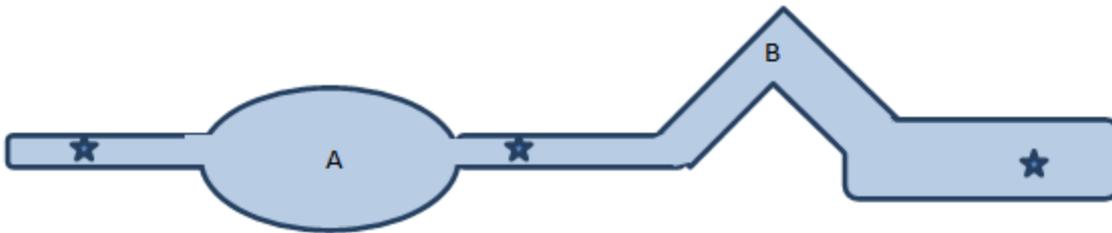
You want to average *all* the data?!

While it is true that DEQ pools samples together in other waterbodies, we don't do this lightly. Data are supposed to be aggregated *only* when you can safely assume that an assessment unit (segment) is uniform in terms of physical, biological, and chemical conditions (EPA, 2005).

U.S. Environmental Protection Agency. 2005. Guidance for 2006 Assessment, Listing and Reporting Requirements Pursuant to Sections 303(d), 305(b) and 314 of the Clean Water Act. U.S. Environmental Protection Agency, Office of Water, Office of Watershed, Oceans, and Wetlands, Assessment and Watershed Protection Division, Washington, DC.



Uniform segment



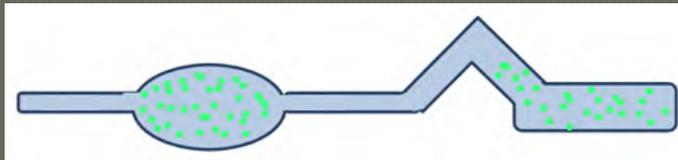
Non-Uniform segment

The non-uniform segment has different habitats with different physical regimes. The dynamics and distribution of pollutants will likely vary with location.

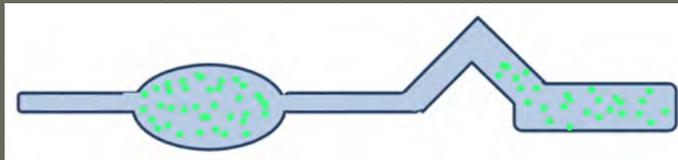
If pollutant concentrations are always elevated in areas A and B, how would we know?

One way we can verify that a segment is uniform is to determine if there are any strong spatial patterns in our chlorophyll datasets.

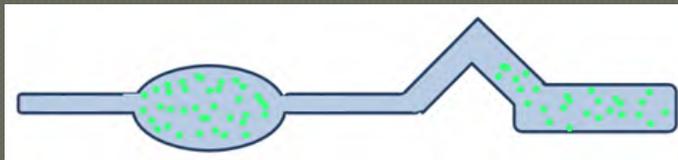
Chlorophyll is always going to be patchy. But consistent patchiness is concerning.



July 1

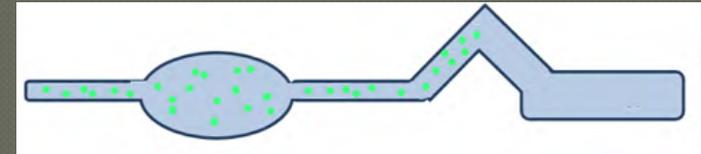


August 1

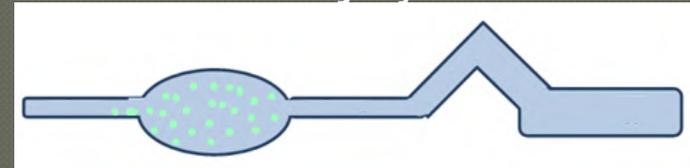


September 1

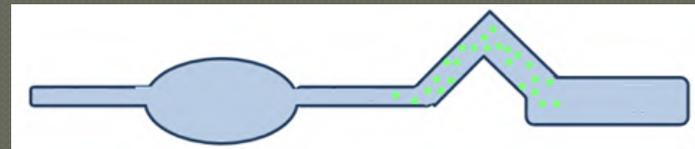
Consistent patchiness



July 1



August 1



September 1

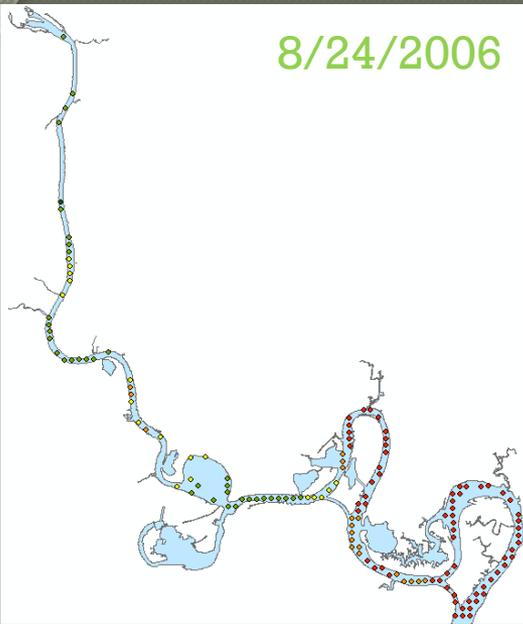
Inconsistent patchiness

For each segment, I examined Dataflow cruise data indicating the presence of a bloom (chlorophyll ≥ 25 ug/l).

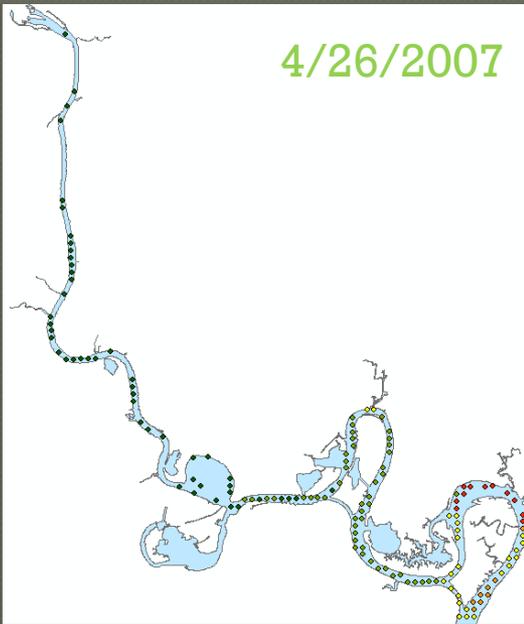
The cruise data were interpolated at the Bay Interpolator centroids.

For each cruise, I analyzed the centroid values using the Grouping Analysis tool of ArcGIS (v 10.1). This tool identifies groups based on the variance structure of multiple variables. In this case, each interpolated cruise was treated as a separate variable.

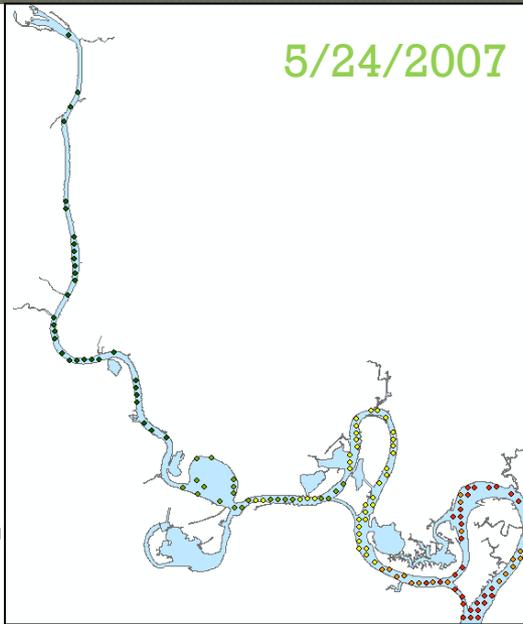
8/24/2006



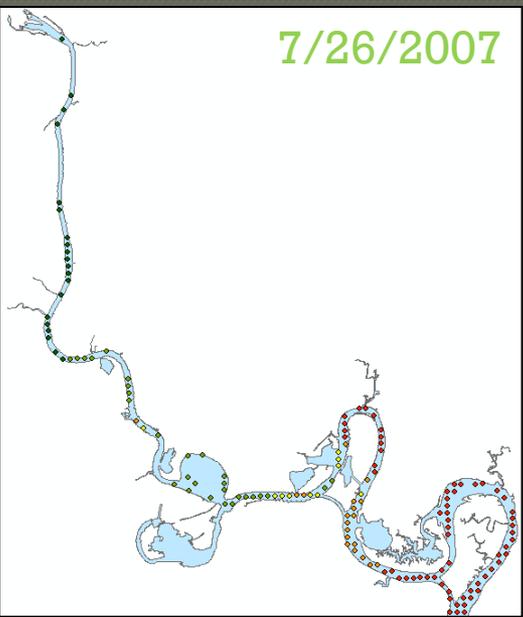
4/26/2007



5/24/2007



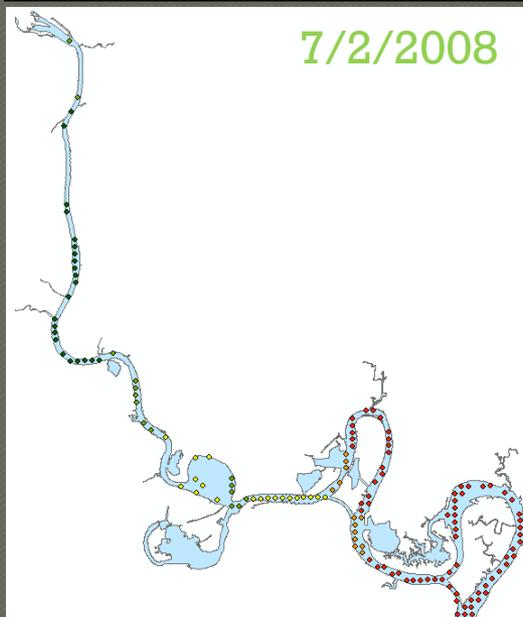
7/26/2007



9/22/2007



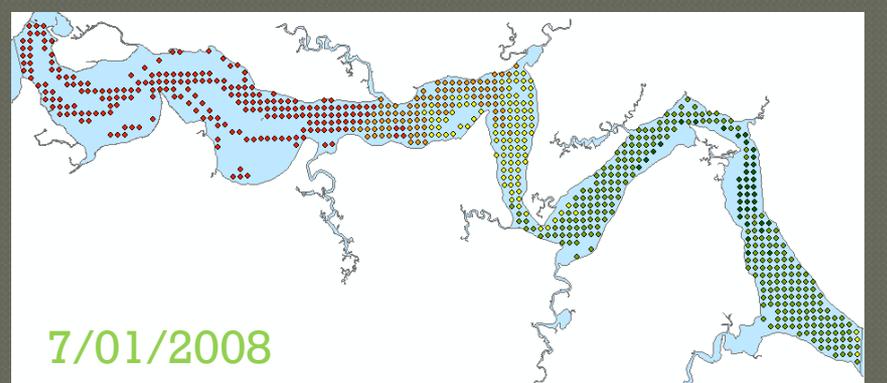
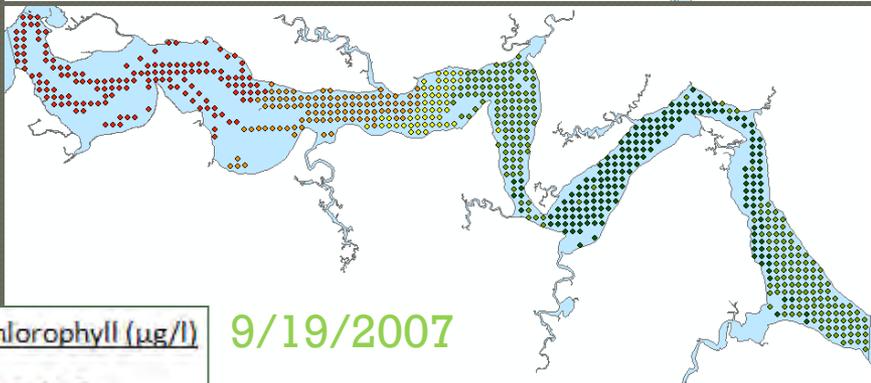
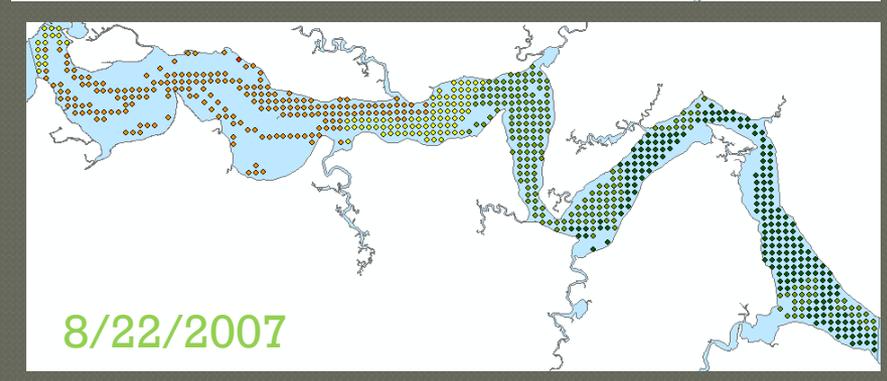
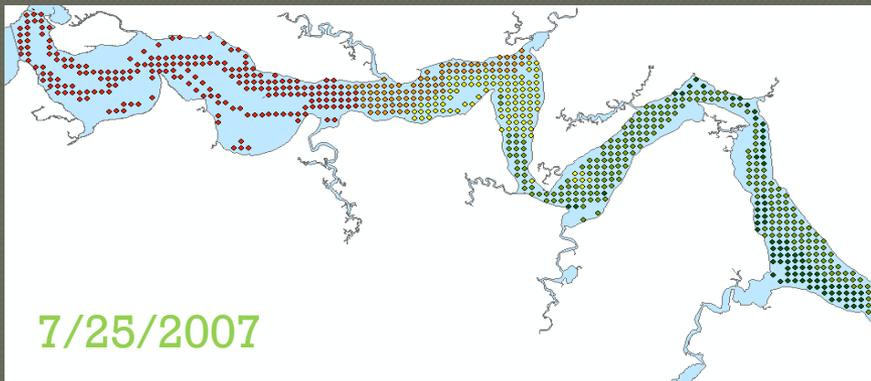
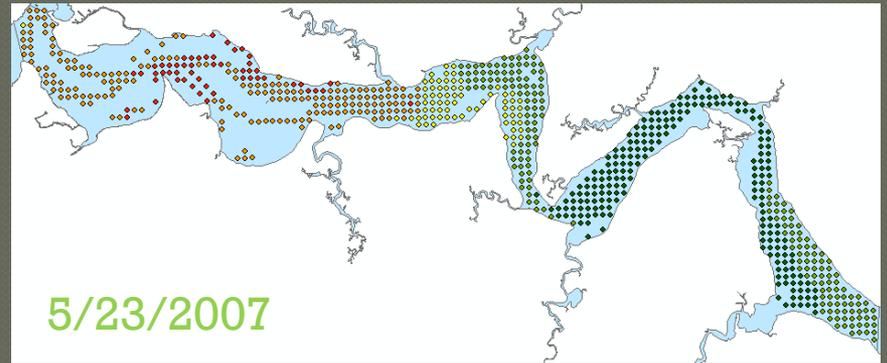
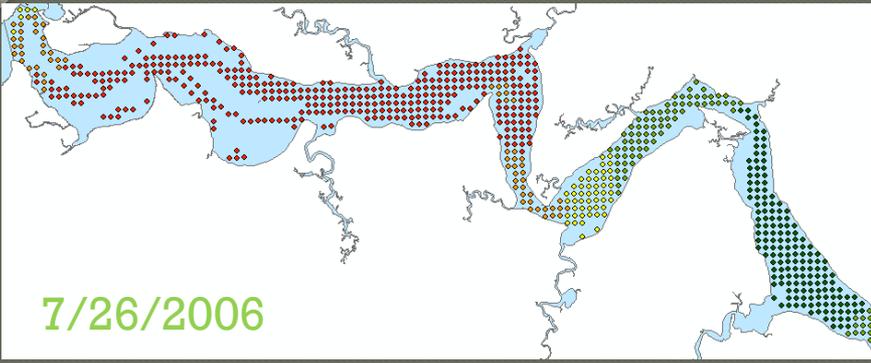
7/2/2008



JMSTFU

chlorophyll ($\mu\text{g/l}$)

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- > 20

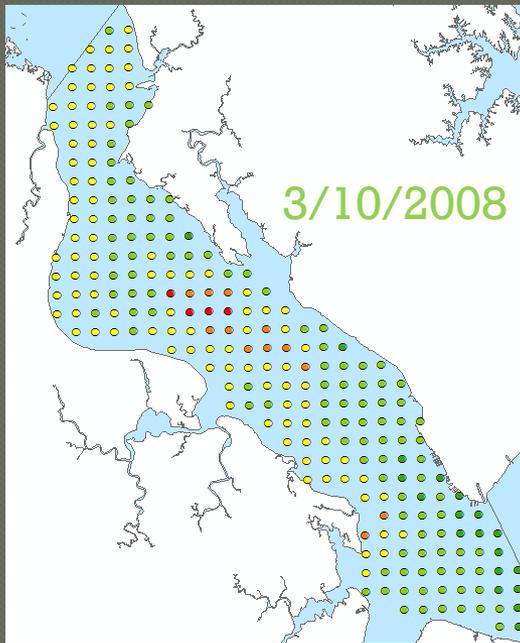


chlorophyll ($\mu\text{g/l}$)

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- > 20

9/19/2007

JMSTFL

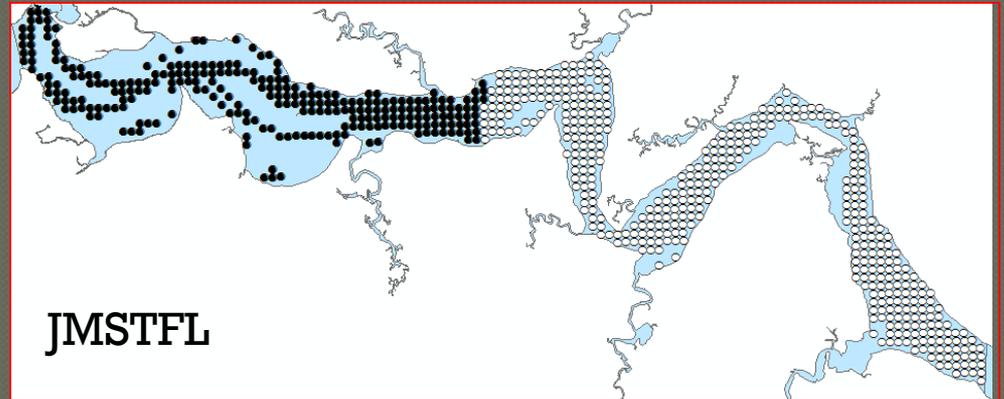
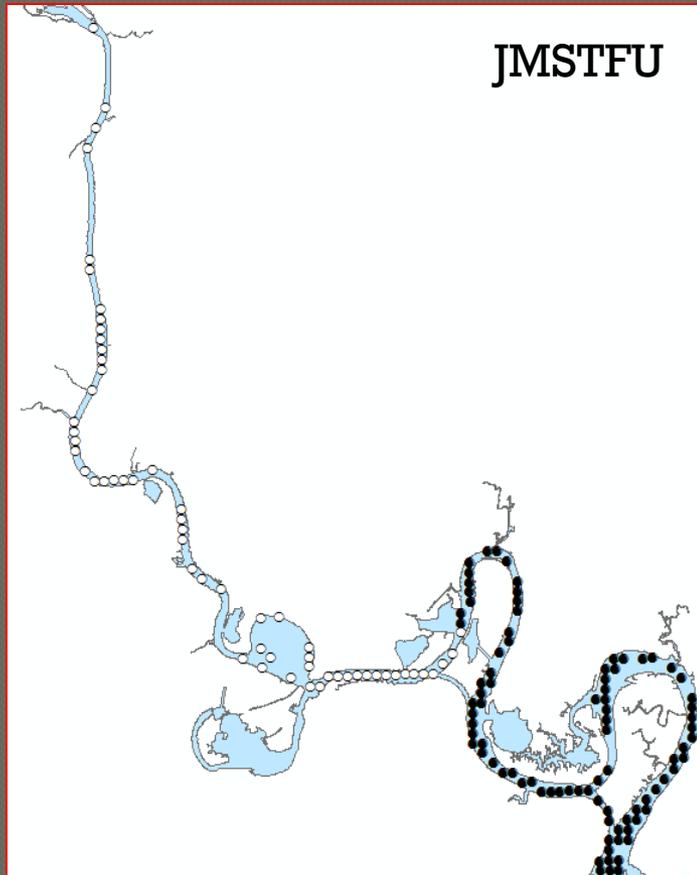


JMSMH

chlorophyll ($\mu\text{g/l}$)

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- > 20

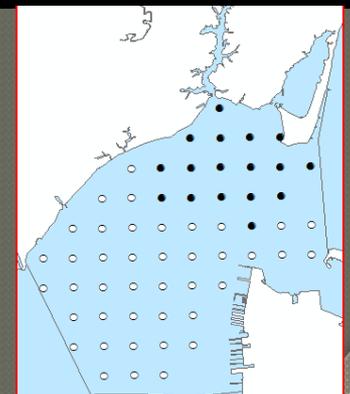
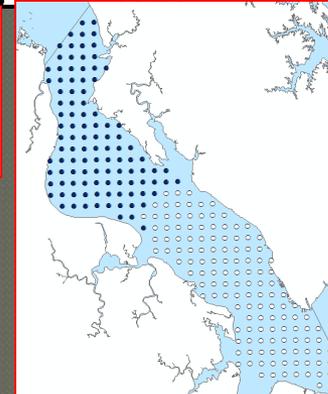
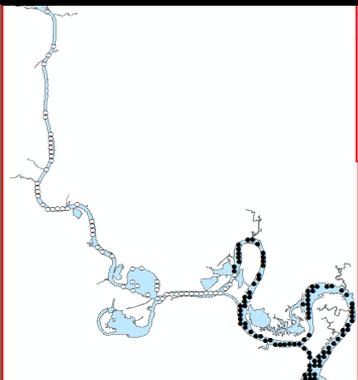
But only two segments had groupings that were considered meaningful.



Criteria used to define “meaningful” groupings

- Large proportion of cruises with a clustering pattern similar to model ($R^2 \geq 0.60$).
- Large proportion of cruises with high percent difference between group medians ($\geq 100\%$).

JMSTFU			JMSTFL			JMSOH			JMSMH			JMSPH		
cruise date	R^2	percent difference between group medians	cruise date	R^2	percent difference between group medians	cruise date	R^2	median percent difference between group medians	cruise date	R^2	percent difference between group medians	cruise date	R^2	percent difference between group medians
7/27/2006	0.60	120	7/26/2006	0.57	103	3/28/2006	0.42	142	3/6/2006	0.02	11	8/6/2009	0.14	72
8/24/2006	0.77	97	5/23/2007	0.82	108	8/20/2007	0.29	63	3/8/2006	0.20	131	3/18/2010	0.19	29
4/26/2007	0.56	172	7/25/2007	0.77	126	8/11/2008	0.01	8	8/14/2007	0.01	12	4/22/2010	0.51	29
5/24/2007	0.70	179	8/22/2007	0.89	108	8/20/2012	0.56	66	8/22/2007	0.09	42	8/4/2010	0.01	6
7/26/2007	0.71	102	9/19/2007	0.70	121	3/5/2013	0.42	95	3/10/2008	0.08	11	8/24/2011	0.05	27
9/22/2007	0.77	79	7/1/2008	0.75	106	7/11/2013	0.49	22	7/7/2009	0.17	52	3/15/2012	0.42	27
7/2/2008	0.72	92	8/13/2008	0.89	89				7/12/2010	0.09	40	3/19/2012	0.14	17
8/14/2008	0.78	94							4/25/2011	0.13	45	7/18/2012	0.16	81
									4/6/2011	0.29	86	7/25/2012	0.02	19
									3/7/2012	0.16	92	7/31/2012	0.01	20
									7/17/2012	0.17	95	8/17/2012	0.05	25
									7/23/2012	0.11	51	3/13/2013	0.12	37
									8/1/2012	0.34	152	4/3/2013	0.12	35
									8/12/2013	0.18	97	8/28/2013	0.31	81
									8/19/2013	0.00	12	9/4/2013	0.24	71
median	0.72	100	0.77	108	0.42	65	0.09	40	0.14	27				



chlorophyll ($\mu\text{g/l}$)

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- > 20

7/27/2006

Group median chl = 5
Max chl = 11

$R^2 = 0.60$
% diff = 120

Group median chl = 19
Max chl = 39

5/24/2007

Group median chl = 1
Max chl = 12

$R^2 = 0.70$
% diff = 179

Group median chl = 18
Max chl = 27

7/26/2007

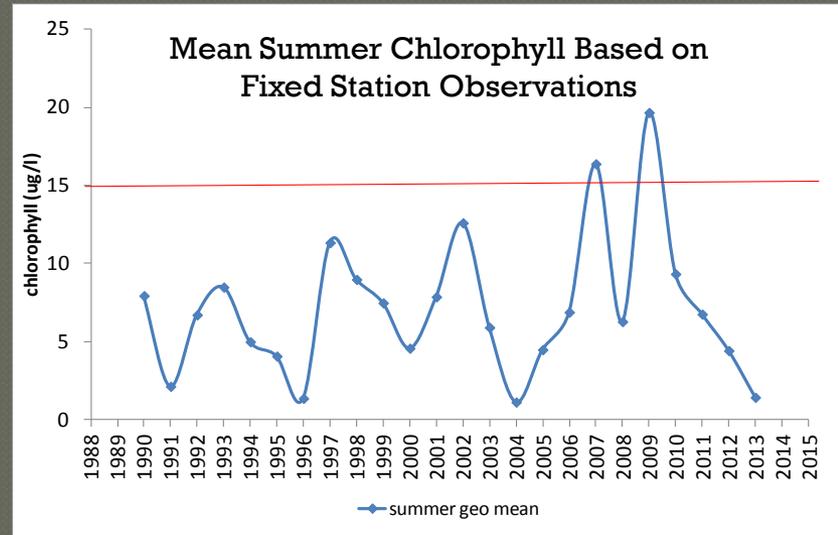
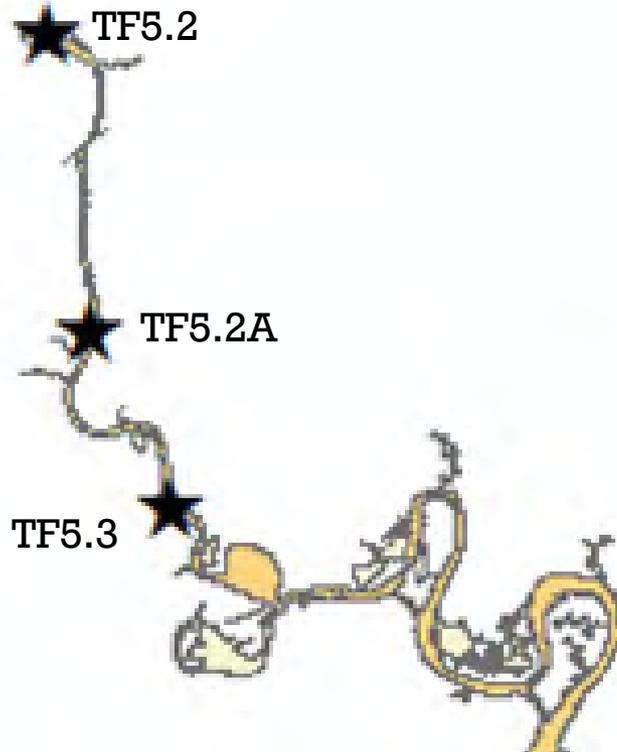
Group median chl = 8
Max chl = 16

$R^2 = 0.71$
% diff = 102

Group median chl = 24
Max chl = 38

% diff = $100 * \frac{|\text{group 1 median} - \text{group 2 median}|}{\text{average of group medians}}$

The current chlorophyll monitoring stations in JMSTFU

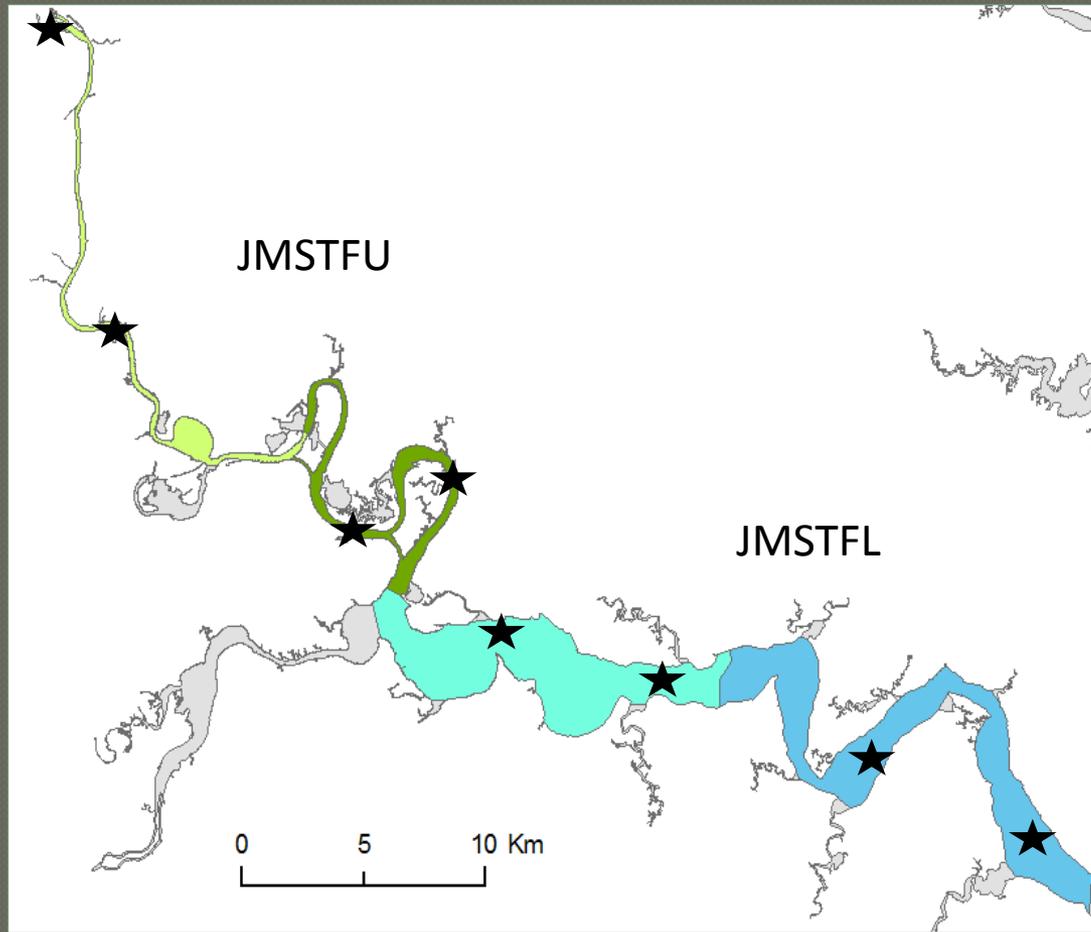


We have probably been underestimating chlorophyll concentrations in JMSTFU!

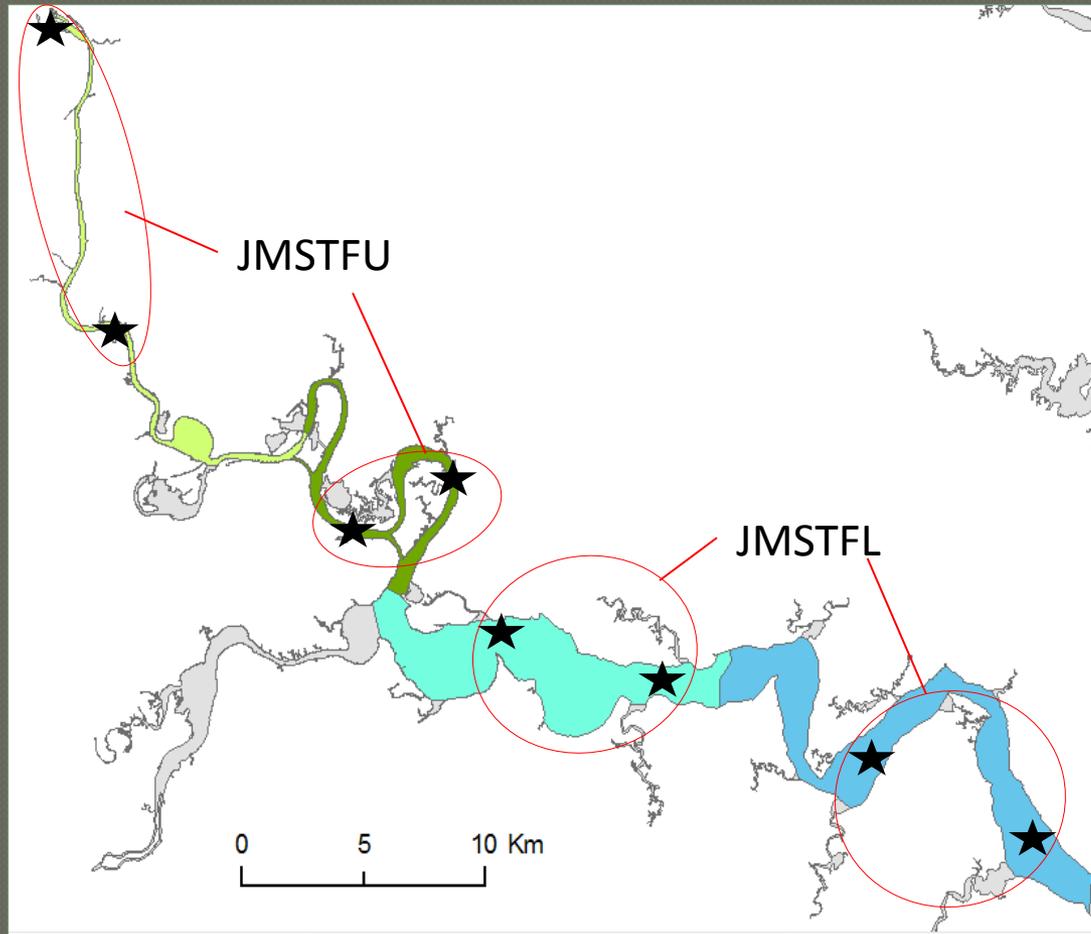


How can we analyze monitoring data given all the non-uniformity in the tidal fresh?

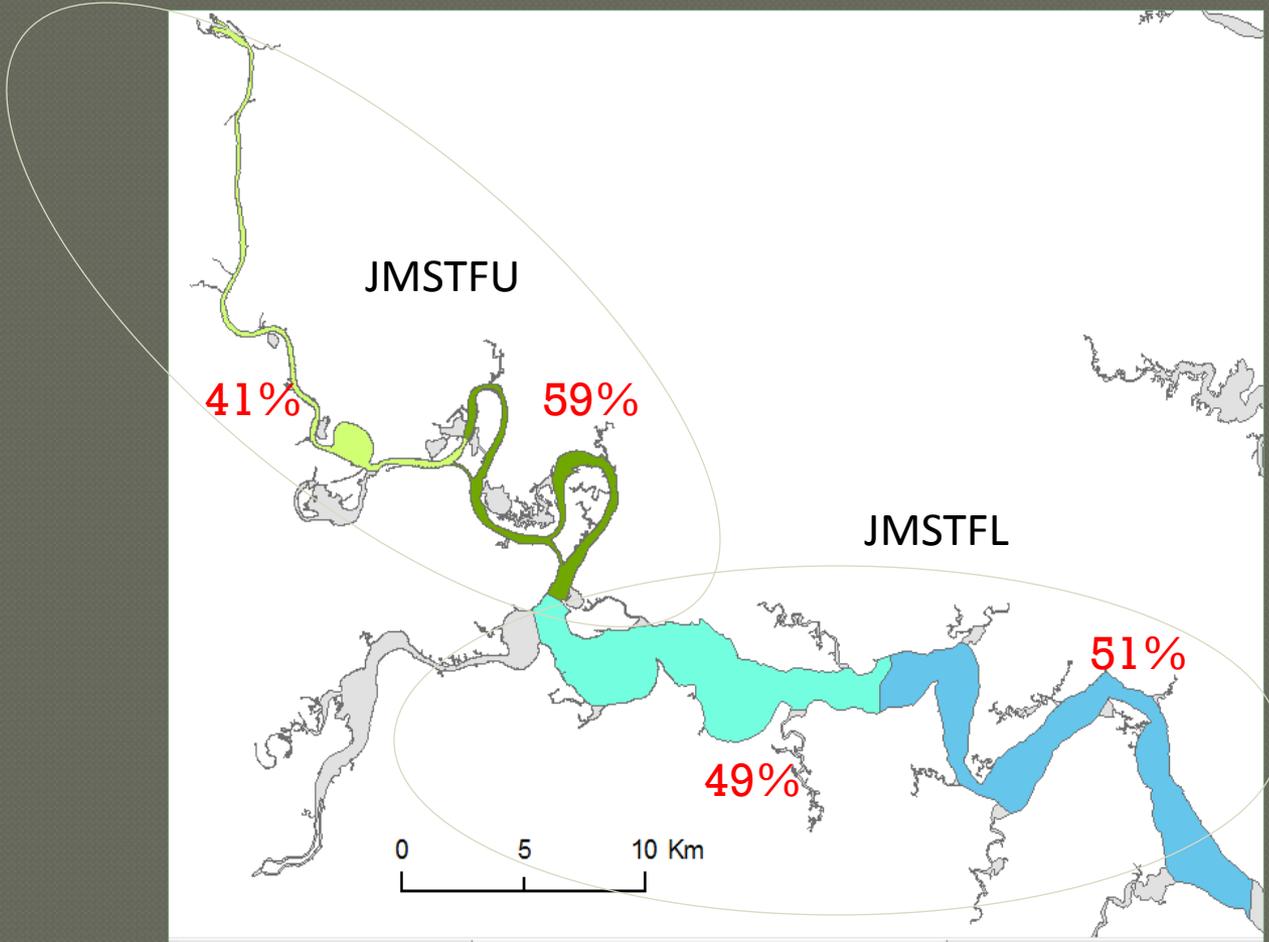
For each monitoring event, samples would be pooled together based on the “zone” they were collected in.



For each monitoring event, samples would be pooled together based on the “zone” they were collected in.



- A seasonal mean would be calculated for each zone.
- A segment seasonal mean would then be calculated by averaging the zone-specific seasonal means, *weighted by their areal proportions*.



Non-Uniform Segment

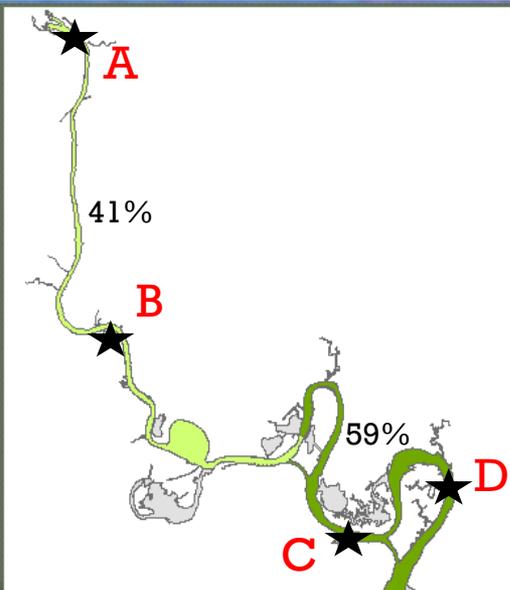
Zone 1			
FIXED STATION SAMPLES			
Sampling Date	Station A	Station B	Spatial Median
1-Jul	10	12	11
1-Aug	10	8	9
1-Sep	9	5	7

Zone seasonal geometric mean = 9

Zone 2			
FIXED STATION SAMPLES			
Sampling	Station C	Station D	Spatial Median
1-Jul	43		43
30-Jul		30	30
1-Aug	30		30
1-Sep	56		56
30-Sep		50	50

Zone seasonal geometric mean = 40

Segment seasonal geometric mean (value to be compared to the criterion) = (Zone 1 Seasonal Mean) * 0.41 + (Zone 2 Seasonal Mean) * 0.59 = 28



proportion of segment area

For the other segments, all same-day samples would be pooled together. These composite values would then be used to calculate the segment seasonal mean.

Uniform Segment					
	FIXED STATION SAMPLES				
<u>Sampling Date</u>	<u>Station A</u>	<u>Station B</u>	<u>Station C</u>	<u>Station D</u>	<u>Spatial Median</u>
1-Jul	10	12	43		12
30-Jul				30	30
1-Aug	10	8	30		10
1-Sep	9	5	56		9
30-Sep				50	50
Segment seasonal geometric mean (value to be compared to the criterion)					= 17

Contrast this result with the one shown on the previous slide

Allowable Frequency of Exceedance

- Six year assessment period
- Two exceedances per criterion are allowed
- Three or more exceedances = segment is impaired

Year	Spring Means	Summer Means
2011	9	10
2012	11	10
2013	8	14
2014	13	9
2015	10	8
2016	7	15

Supporting

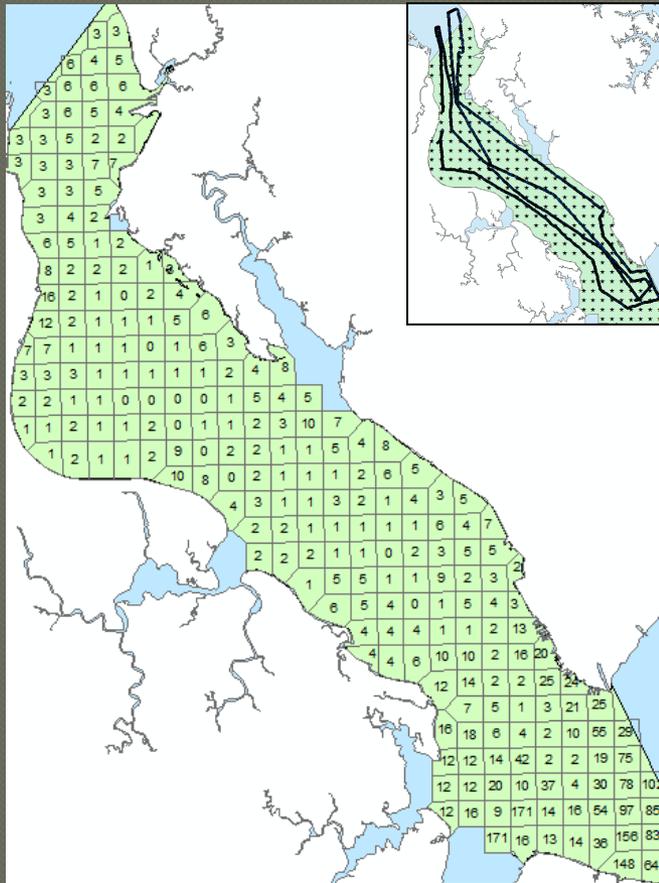
Year	Spring Means	Summer Means
2011	9	10
2012	11	10
2013	8	14
2014	13	15
2015	10	8
2016	7	15

Impaired

Advantages of this approach

- A more literal interpretation of the water quality standards.
- Easier to implement and explain.
- More consistent with EPA/DEQ guidance.
- Fewer assumptions.
- Compatible with Dataflow and ConMon

Dataflow processing

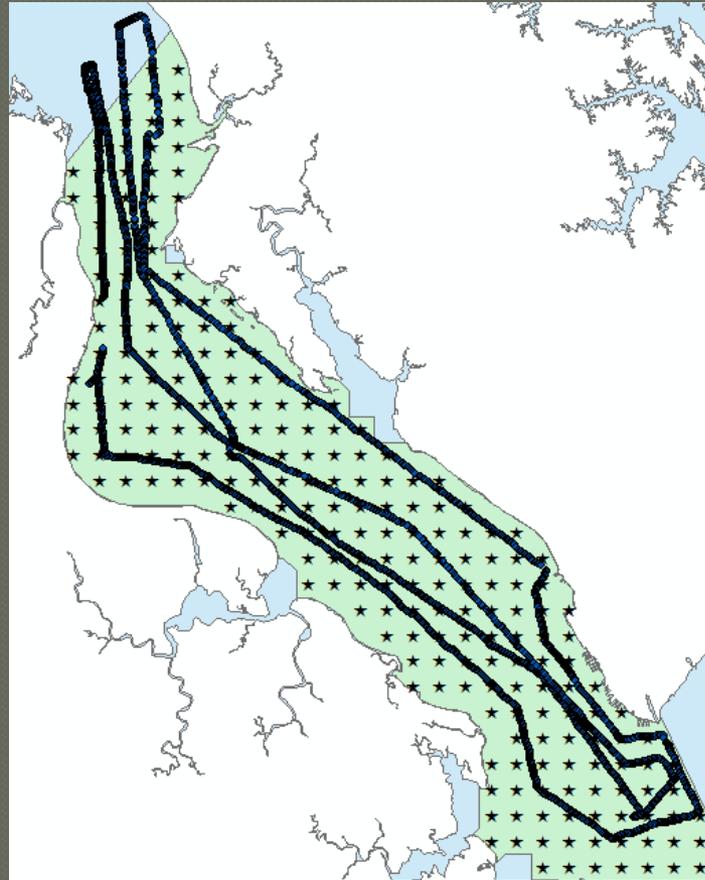


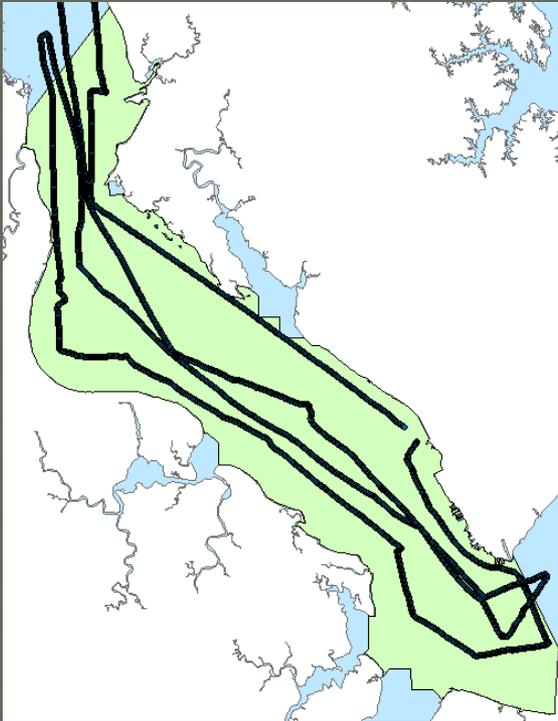
Instead of interpolating at all points in the segment (left), we'd limit estimates to points within 500 m of the cruisetrack (right). The median of these estimates would be used to represent the segment's chlorophyll expression on the cruise date.

Does this alternative approach perform better than the current one?

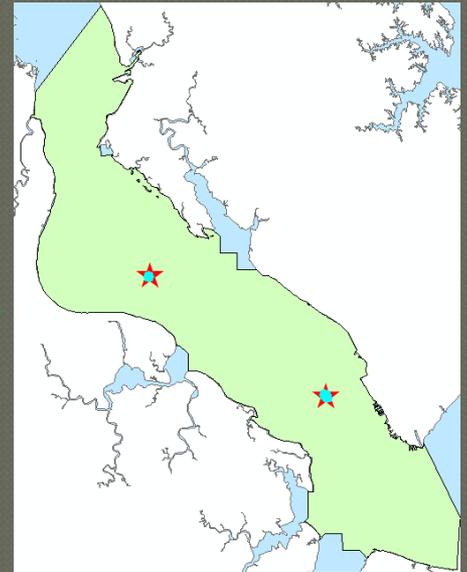
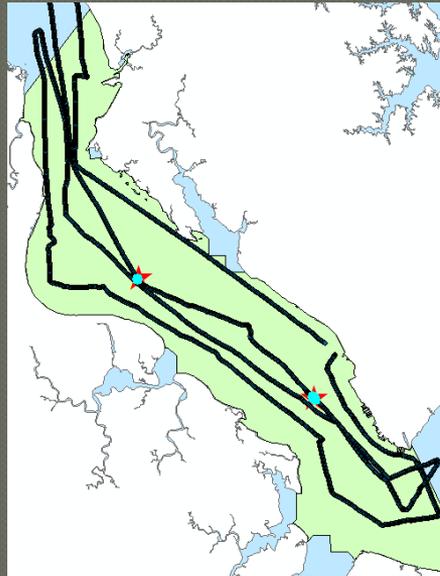
To answer this question...

I performed another validation study using Dataflow!

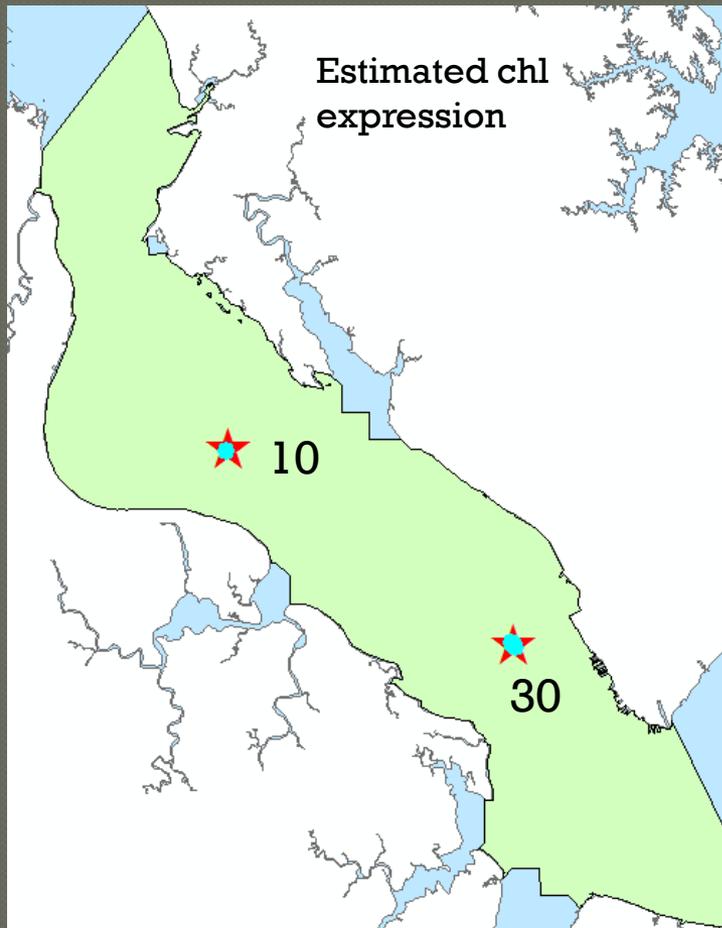




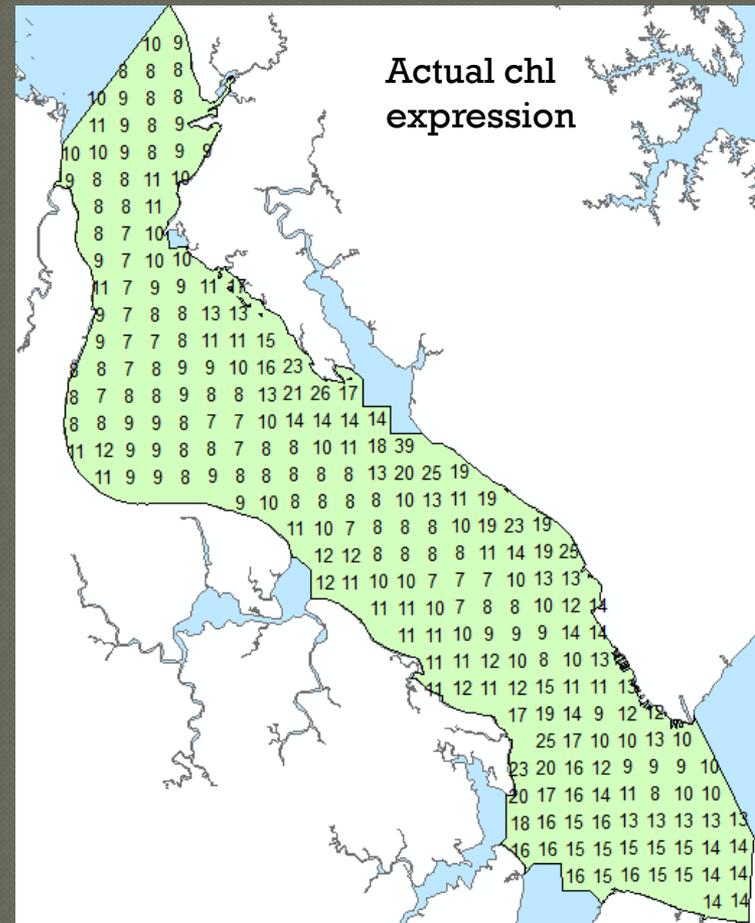
I selected Dataflow cruises with a high proportion (>50%) of “exceedances”



From each cruise, I extracted the Dataflow observations corresponding to the CBP stations. These will be our fixed stations samples.



The spatial central tendency indicated by fixed station samples was calculated in accordance with the proposed procedure.



The spatial central tendency indicated by the interpolated Dataflow was calculated in accordance with the proposed procedure.

The two averages were compared to the appropriate criterion.

JMSTFL cruise date	Criteria	Dataflow Spatial Median	CBP Stations Spatial Median	"erroneous" assessment
4/26/2006	15	9	10	
5/24/2006	15	11	10	
5/23/2007	15	11	12	
7/25/2007	23	17	15	
8/22/2007	23	15	14	
9/19/2007	23	14	14	
7/1/2008	23	18	16	
error rate →				0%

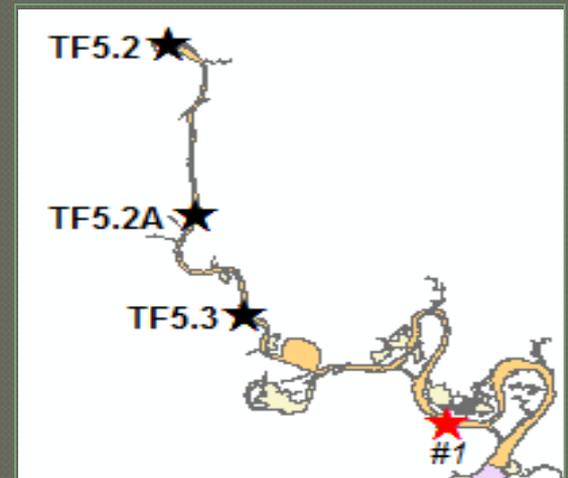
JMSOH cruise date	Criteria	Dataflow Spatial Median	CBP Stations Spatial Median	"erroneous" assessment
3/28/2006	15	<u>24</u>	<u>52</u>	
8/20/2007	22	8	15	
8/11/2008	22	10	16	
8/20/2012	22	5	6	
3/5/2013	15	4	5	
7/11/2013	22	16	15	
error rate →				0%

— "exceedance"

JMSPH cruise date	Criteria	Dataflow Spatial Median	CBP Stations Spatial Median	"erroneous" assessment
3/7/2006	12	7	8	
7/19/2006	10	<u>11</u>	<u>11</u>	
7/2/2007	12	11	11	
7/16/2007	10	11	11	
9/5/2007	10	6	<u>11</u>	x
3/19/2008	12	7	6	
9/3/2008	10	8	8	
7/8/2009	10	<u>12</u>	<u>13</u>	
3/1/2010	12	<u>14</u>	12	x
4/22/2010	12	<u>18</u>	<u>16</u>	
5/14/2012	12	<u>14</u>	<u>15</u>	
7/18/2012	10	<u>33</u>	<u>16</u>	
4/29/2013	12	<u>16</u>	<u>17</u>	
7/8/2013	10	<u>11</u>	<u>11</u>	
7/17/2013	10	<u>11</u>	<u>11</u>	
error rate →				13%

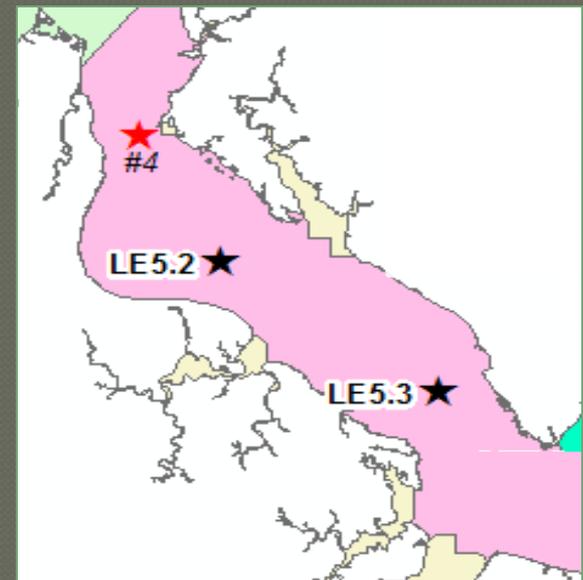
JMSTFU cruise date	Criteria	Dataflow Spatial Median	CBP Stations Spatial Median	"erroneous" assessment	CBP Stations + Station #1 Spatial Median	"erroneous" assessment	
4/27/2006	10	5	2		6		
5/25/2006	10	<u>12</u>	2	x	<u>13</u>		
7/27/2006	15	15	4		9		
8/24/2006	15	<u>17</u>	8	x	<u>16</u>		
4/26/2007	10	5	1		5		
5/24/2007	10	10	1		<u>12</u>	x	
7/26/2007	15	13	3		14		
8/23/2007	15	12	3		13		
9/20/2007	15	<u>18</u>	6	x	<u>17</u>		
7/2/2008	15	<u>16</u>	9	x	<u>17</u>		
8/14/2008	15	<u>16</u>	6	x	12	x	
error rate →				45%	error rate →		19%

The current CBP stations in JMSTFU produce assessments that are biased towards compliance. But adding a station to the downstream "zone" eliminates this bias.



JMSMH cruise date	Criteria	Dataflow Spatial Median	CBP Stations Spatial Median	"erroneous" assessment	CBP Stations + Station #4 Spatial Median	"erroneous" assessment	
3/16/2006	12	<u>27</u>	<u>45</u>		<u>80</u>		
8/24/2006	10	<u>12</u>	<u>11</u>		<u>11</u>		
3/13/2007	12	6	6		6		
8/8/2007	10	<u>11</u>	8	x	8	x	
8/14/2007	10	<u>11</u>	9	x	9	x	
9/10/2007	10	9	8		5		
8/18/2008	10	<u>16</u>	<u>87</u>		<u>53</u>		
8/17/2009	10	<u>15</u>	<u>60</u>		<u>14</u>		
7/27/2010	10	8	<u>13</u>	x	3		
4/13/2011	12	8	9		9		
3/14/2012	12	10	6		7		
8/1/2012	10	10	7		4		
8/8/2012	10	8	<u>23</u>	x	<u>28</u>	x	
8/19/2013	10	<u>12</u>	8	x	10	x	
9/3/2013	10	8	11	x	7		
error rate →				40%	error rate →		30%

We're going to need more than 3 stations for JMSMH. Thankfully, HRSD has no plans to stop Dataflowing.



Does the alternative approach perform better than the current one?

Yes.

Next steps

- Apply alternative method to model output.
- STAC review

The datasets featured in this presentation are available for download from
www.vecos.org

Questions?