Integrated Trends Analysis Team (ITAT)
Meeting

Wednesday, February 23, 2022
10:00 AM – 12:00 PM

Meeting Materials: Link

This meeting was recorded for internal use to assure the accuracy of meeting notes.

ACTION ITEMS

- **Rappahannock Tributary Summary Updates**
  - **Breck Sullivan and Vanessa Van Note will develop potential options for naming the models and explaining the options for adjusting the models. They will bring these terms to ITAT to review.**
  - **Mike Lane will ask Olivia Devereux about total acreages presented in Figure 2 that contradict the text in section 2.1 as the numbers are not consistent and the difference between them is uncertain.**
  - **Mike Lane will ask Angie Wei to revise Figure 4 so the legend matches the tidal segments in the map.**
  - **Rebecca Murphy sends the revised title for Section 3 to Mike Lane.**
  - **Breck Sullivan, Elgin Perry, and Roberto Llanso respond to the specific comments still requiring attention (2.1, 4.3.1, 4.3.2, 4.5, 4.6, 5.1.1, 5.1.2, 5.1.5, and 5.2) and send comments to Mike Lane.**
- **Create a multidisciplinary team for cluster analysis interpretation, which will report out to ITAT in the future.**
  - **The following individuals expressed interest in participating: Rebecca Murphy, Mike Lane, Elgin Perry, Roberto Llanso, Breck Sullivan, Dave Parrish, Carl Friedrichs.**
  - **Interested parties should reach out to Breck (bsullivan@chesapeakebay.net) and Elgin (eperry@chesapeake.net) if they are interested in joining.**

AGENDA

10:00 – 10:10 **Welcome – Vanessa Van Note** (EPA) and **Breck Sullivan** (USGS)

Announcements –

- Conferences of potential interest:
  - Joint Aquatic Sciences Meeting - May 14-22, 2022, Grand Rapids, MI.
  - Chesapeake Community Research Symposium - June 6-8, 2022, Annapolis, MD. (Hybrid: virtual and in-person)
- Jeni Keisman has taken a new opportunity as a branch chief within the water mission area at the Hydrologic Impacts branch in USGS.

10:10 – 10:30 **Review of Rappahannock Tributary Summary Edits and Responses – Mike Lane (ODU)**
Mike shared the status of the Rappahannock Tributary Summary and discussed any remaining edits.

Summary

Mike began by outlining the steps he has completed since the last meeting on the Rappahannock summary update. Some of these completed updates include adding the correct River Input Monitoring (RIM) loading stations estimates, added effects of physical setting, and added a first draft of the glossary.

Mike then brought up some issues he felt required group discussion and collective expertise to revise. The first issue was inconsistencies in terminology. Mike suggested agreeing upon specific terms for each of the two models being used. Some options for terminology included "nonlinear trend effects or nonlinear effects model" to describe the baseline non-linear trend effects model with seasonality included, and "flow effects model" to describe non-linear trend effects and flow effects. Breck Sullivan agreed consistent terminology would be helpful and said that based on previous documents, the term flow adjusted model has been used for the latter. Rebecca Murphy said they used the term flow adjusted because they wanted to communicate that flow has been removed from the model outputs and that they wanted to differentiate from the USGS flow normalized model, which is a different approach. Rebecca said she is fine tweaking the language but does not support the term flow effects because it might not truly represent the removal of flow. Breck said since a lot of different resources and webpages are already using the term flow adjusted, it might be best to stick with that and be consistent.

Breck said there has not been specific wording for the "nonlinear trend effects or nonlinear effects model" so asked how ITAT members felt about using that term. Rebecca said in the past they called it observed or true condition, but the terminology is not consistent in the reports, so she suggested choosing one of those options and sticking with it. Breck commented that it could be worthwhile to ask the communications team about which term might be best from an audience clarity perspective.

Elgin Perry cautioned against calling the "nonlinear trend effects or nonlinear effects model" observed or true condition as he felt it might be an oversimplification. Elgin noted in his cluster work he has seen artifacts in the data created from smoothing between periods of low and high flow. Elgin suggested using a model that addresses flow effects in two ways is a better way to do estimates: 1.) use with observed flow to produce estimates of the situation believed to be occurring in the estuary and 2.) standardize the flow effect through a flow adjusted curve. Elgin said there should be two sets of names, one for the model itself and one for how the model is used/model outputs. Elgin provided the examples of adjusting for seasonality and long-term trends as ways of describing the different outputs. Renee Karrh emphasized considering the impact from the intervention of GAMs5. Elgin agreed and said we adjust for methods changes, thus there are three classes of models used where one can either adjust or not adjust for those factors.

Mike then brought up a comment Elgin made about the acreage values in Figure 2. Rebecca and Qian commented Olivia Devereux created this graph and so they should reach out to her with Elgin's question.

Mike brought up a comment from Roberto Llanso about the legend in figure 4 not matching the river segments being mapped for the Rappahannock. Rebecca said Angie

Wei was the one who made these maps, so we should reach out to her to see if she can fix them.

For Section 3, Mike and Rebecca agreed that she can send the previously determined title to Mike for inclusion in the report.

Mike Lane shared the comment from Roberto Llano that disagrees with the use of salinity regimes as a descriptor for monitoring stations designations. Mike said he agrees with this comment since there are certain stations like the Tidal Fresh 3.3 that are actually Oligohaline. Mike said one way of addressing this could be to add explanations in the glossary. Roberto replied he was confused by inconsistent terminology between the plots (Figure 8) and text, so suggested using one set of names. Carl Friedrichs said this is a very interesting question because research from Jeremy Testa on secchi depth patterns found that stations naturally cluster, sometimes across salinity regimes or segments. Carl said that while this might be a bit of a circular argument, the best grouping might be what the data naturally fit to. Elgin commented that while most stations tend to be grouped in certain categories, it is important to acknowledge that minor inconsistencies will always exist and that it is not possible to come up with fixed station names based on the salinity regime. Elgin gave the example of the Tidal Fresh 3.3 station and said that its salinity regime will most likely vary based on whether the year is wet or dry. Elgin suggested acknowledging these consistencies and moving on. Breck asked if maybe Figure 8 can be moved to the appendix if it is replaced by Elgin's cluster analysis.

Due to a lack of time left in the meeting for this agenda item, Breck said she will respond to Mike with the outstanding discussion comments and encouraged others to respond as well if they wanted to address any points. Breck suggested if there is still need for more discussion, then maybe it would be best to save time for the next meeting or to have a small group meeting on this topic.

Mike concluded with the next steps he will undertake to complete the Rappahannock Tributary Summary update.

10:30 – 11:10 **Cluster Analysis – Elgin Perry**

Elgin reviewed the results of his amended cluster analysis and considered how they can be incorporated into the Rappahannock Tributary Summary.

Summary

Elgin began with a roadmap of the presentation, highlighting the types of clustering illustrated for chlorophyll-a and comparing and summarizing total nitrogen, total phosphorus, chlorophyll-a, secchi depth, and dissolved oxygen based on the clustering of longitudinal profiles. Elgin explained that he wants to relate these parameters to the overall narrative of health in the Chesapeake Bay.

Elgin then showed his standard cluster analysis output, walking through the components of the output. Dendrograms on the left show the grouping of stations by the similarity of the profiles over time. The graph on the right plots the groupings over time and the triangles indicate the flow conditions for that year. The final part of a standard output is the geographical component, which is a map designed by Jon Harcum and Erik Leppo that represents where the stations and groups are located in the tributary. For the long-term profiles, Elgin adjusted them to center on a mean of zero in order to focus on the

shape of the trend over time. Elgin then showcased group plots for surface chlorophyll-a with different clustering parameters where years were clustered based on relevant characteristics like flow and seasonality, which are identified.

Carl Friedrichs asked if Elgin has documentation written up on the clustering method. Elgin said it is a work in progress, but he can share a document with the different types of clustering for the five water quality parameters. In terms of the method, Elgin explained that he takes the Euclidian distance between any pair of stations (identified on slide 3 in the figure on the right), then squares and sums across all the stations to give a measure of distance between any two years. Elgin then groups the years that are closest to each other before using a centroid to represent that group in the dendrogram (identified on slide 3 in the figure on the left). Carl asked as a follow up question to confirm if there is no more information going into clustering on the left than is represented in the clustering on the right. Elgin confirmed that is correct.

Roberto Llanso asked if Elgin was using a particular criterion to delineate between each group of stations. Elgin replied he used an iterative, subjective process by trying out different numbers of groups and then reviewing the dendrogram and profile graph to see how it featured trends of interest.

For the second part of the presentation, Elgin compared and summarized group plots for water quality metrics like total nitrogen, total phosphorus, chlorophyll-a, secchi depth, and dissolved oxygen based on clustering of longitudinal profiles. Beneath the figure, the grouping of stations is defined as well as low flow years and high flow years. Carl asked about the units on the Y-axis. Elgin answered there are negative units because it is a log transform. Elgin suggested taking the long term mean adjusted trend clusters for the five water quality parameters to come up with a cohesive story.

Elgin then asked for conjectures as to why he is seeing these trends and why it does not seem to fit in with the bottom-up model. Elgin asked for assistance in interpreting these results to reveal a broad story of what is going on in the Rappahannock River.

Carl Friedrichs expressed how exciting and great this information is. Carl asked if these are annual summaries of the different stations and if there would be different groupings if the years were split into seasons because they were no longer averaged out. Elgin confirmed this is correct and that while he did not show it in the presentation, he has a table that breaks the results down by month. Elgin expressed interest in a Classification and Regression Tree (CART) analysis to improve understanding of which months have the most influential flow information compared to spring and summer algal blooms. Carl replied this is good because it seems like you would have identified a major trend this way if it had existed. Carl added that a major remaining question is if years are truly independent of each other. Peter Tango added that at some threshold a previous year lumps into impacts of next year. Elgin responded that is an interesting question because in looking at the profile clusters for all of the parameters, sequential years are often grouped together, suggesting a dependence among years. Elgin cautioned that this might not actually be this case, as he is working with the time model (flow not accounted for). Elgin thinks that this trend might have more to do with an artifact of GAMs trying to smooth between a low-flow year and a high-flow year. Elgin thinks an exercise to determine if this trend is real or not is to repeat this methodology but with the flow adjusted model. Elgin explained that in the exercise he ran, it was not flow adjusted but did experience flow effects. Carl asked if this is not just straight, long-term

averaged monitoring data. Elgin confirmed this is not the case, and part of it is run through GAMs where the profiles are the estimates for each stations, so this is the model fit to the data. The GAM is being used to smooth out the noise and the clustering is being done to make sense of the outputs. Elgin said he will make sure this is clearer in the methods section of the documentation.

Mark Nardi asked if GAMs removes the variability of water temperature. Elgin said at this point it does not address water temperature, but that is something they would like to add as it is an important parameter. Elgin hopes the Baytrends R Package can use GAMs to be comparable to the Weighted, Regression, Time, Discharge, and Seasonality (WRTDS) model used in the non-tidal areas. Elgin said it is fairly easy to add a new predictive variable to GAMs, so it seems feasible. This connects to Rebecca's work with temperature mixing. Mark responded asking if these trends correspond with physical characteristics like the bathymetry or flow of the channel. Elgin said this might be the case as 3.1 and 3.4 are fairly deep, while 3.3 and 3.7 are fairly shallow, but cautioned that bathymetry does not explain the differences between the 2003-2006 period and the 2018-2020 period.

Rebecca agreed temperature could be a factor in explaining dissolved oxygen. Rebecca added spring and summer chlorophyll-a maps have indicated a seasonal difference with increasing trends over time for the lower parts of Virginia tributaries and the main stem of the Chesapeake Bay. Rebecca said this might be worth investigating, and Elgin agreed. Roberto suggested exploring dissolved oxygen dynamics in the context of local versus basin wide influences. Roberto provided the examples of the lower parts of the York and Rappahannock reflecting trends in the mainstem, whereas upstream conditions are more connected to flow. Roberto considered integrating the data from the Rappahannock with other rivers like the Potomac and York to see if these trends are basin wide. Roberto suggested using a statistical criterion to differentiate between clustered groups, like a permutation test. Mike Lane suggested using Primer version 7 as it will do a permutation test using Euclidean distances. Elgin replied he thinks this is a fairly local phenomenon to the Rappahannock due to the extent of degradation at stations 3.3 and 3.4, but he agrees with Roberto that this is worth investigating. In response to the suggestion to identify an objective criterion, Elgin agreed there are some methods that could be used, and this would make it easier to automate to cluster analysis.

In the chat, Peter Tango commented hypoxia forecasting uses winter-spring chlorophyll-a to predict summer dissolved oxygen and asked if Elgin has tried something like that. Peter added if a year is large it might have a carryover effect over the next year. Peter mentioned that occasionally, low wind summers reduce mixing and enhance the persistent impact of oxygen demand due to lack of mixing.

In the chat, Roger Stewart asked if the input data are dissolved oxygen concentration mg/L and not dissolved oxygen % saturation. Rebecca confirmed the input is dissolved oxygen concentration in mg/L.

In the chat, Qian Zhang commented that putting the clusters for the different parameters on the same page would help with the interpretation, but a complicating factor is that clusters are not always consistent among different parameters. One easily implementable approach is combining different parameters first, e.g.,

Nitrogen:Phosphorus molar ratios. It would be interesting to learn how that may vary with time and space based on the clustering of these stations.

Breck thanked Elgin for his work on these efforts and commented how there seems to be strong interest in pursuing this cluster analysis further. Elgin expressed he would like to create a team with a broader knowledge base to help with interpreting these results. Breck asked to what degree Tetra Tech has been involved in this process. Elgin explained that Jon Harcum and Erik Leppo made the maps and Baytrends R Package that this cluster analysis work was built on.

Breck asked anyone interested in joining this cluster analysis team to email her (bsullivan@chesapeakebay.net) and Elgin (eperry@chesapeake.net).

11:10 – 11:40 **Results of Recent Publication and Using GAMs to Explain Trends – Rebecca Murphy (UMCES)**

Rebecca shared the recent publication (Nutrient Improvements in Chesapeake Bay: Direct Effect of Load Reductions and Implications for Coastal Management) she, Jeni Keisman, Jon Harcum, Renee Karrh, Mike Lane, Elgin Perry, and Qian Zhang worked on. She reviewed how GAMs were used to explain trends in estuarine nutrient concentrations by connecting them to watershed-based loads.

Summary

Rebecca began with the background and two primary goals of the study: 1.) Summarize the observed tidal nutrient changes over time for surface total nitrogen (TN) and total phosphorus (TP), and 2.) Evaluate and document the extent to which we can explain these estuary nutrient patterns with monitored nutrient loads from RIM stations, some nontidal network loads of TN and TP, and below-gage point loads. Rebecca then outlined the first part of the analysis, which was about bringing the data together and the methodology of the GAMs procedure. Part one was categorized by long-term decreases in TN and TP concentrations at 83% and 73% of the stations, shorter-term changes including more constant or increasing patterns, bottom patterns exhibiting similar behavior, and long-term patterns generally consistent with other findings showing some possible increases in oligohaline region for mainstem and strong decreases in the larger tributaries.

Carl Friedrichs asked a clarification question about the usage of GAMs, saying if it is being used to smooth the data and get rid of the noise, the purpose is not to explain the trends but instead make them easier to detect. Rebecca said that's a factual way of explaining the philosophy behind this approach. Tish Robertson said this is a helpful way of describing GAMs.

Part two was focused on using GAMs to test factors influencing trends and answering the question: Are variations in freshwater flow and nutrient loads causing the trends over time. Rebecca explained the methodology and results for this part as well. Rebecca concluded with the following points:

- Both riverine and point sources together are responsible for nutrient trends in the estuary.
- There is large spatial influence of loads from many parts of the watershed, indicating that reductions from only one source type or subbasin will not be sufficient to reduce nutrient concentrations bay wide.

- Flow impacts on trends are substantial.
    - The good news: After accounting for flow, TN and TP are improving at most stations.
    - However, reductions from nutrient sources may be masked in the estuary by impacts of large flows if flow variability increases in the future due to climate change.

Breck asked why on slide 15, the figure on the left had some observed trends represented, but the figure on the right did not. Rebecca mentioned that a lot of the ones not mapped in the GAM1 flow figure on the right were left out because the load gauges did not have a long enough data record. Rebecca added these were mostly smaller tributaries and they tried to substitute data where possible from the non-tidal network.

Claire Buchanan commented that based on this research, it looks like nutrient trading is not a good idea. Claire asked if the reason for lower confidence for Phosphorus (87%) compared to Nitrogen (95%) is due to greater retention of Phosphorus in the sediment and slower release over time. Rebecca said she is not sure, but the uncertainty comes down to the inability of the model to explain trends in the Potomac and Rappahannock. Rebecca said it could be caused by the method since they are comparing trends on a monthly basis and maybe a different period would be more accurate or maybe the real reasons for that difference, like the sedimentation conjecture Claire offered.

Carl Friedrichs commented on how great this research is and asked about the interaction term between flow and day of year and what the logic is behind that decision. Carl asked if it is consistent to sometimes use interaction terms and sometimes not, using it to explain variance. Rebecca replied they tried very hard to remove overlapping effects, so seasonal cycle was removed from flow and the loads so it could be its own term in the model. The same process was applied to removing flow from the loads. Rebecca said the biggest difficulty with putting variables like this into GAMs is that so many of the parameters in the Chesapeake Bay are co-varying, so it is important to try to get rid of those overlapping effects.

11:40 – 12:00 **Steps Needed to Develop and Update the Tributary Summaries – Vanessa Van Note**

There was not time to get to this agenda item during the meeting. This topic will be discussed at the next ITAT meeting.

12:00 **Adjourn**

Next Meeting: Wednesday, March 23, 2022

Participants: Alexander Gunnerson, Amy Goldfischer, Andrew Keppel, Blessing Edje, Carl Friedrichs, Carol Cain, Cindy Johnson, Claire Buchanan, Dave Parrish, Efeturi Oghenekaro, Elgin Perry, Erik Leppo, George Onyullo, Helen Golimowski, Jeremy Hanson, John Clune, Karl Blankenship, Mark Nardi, Mike Lane, Mukhtar Ibrahim, Peter Tango, Qian Zhang, Rebecca Murphy, Renee Karrh, Rikke Jepsen, Roberto Llanso, Roger Stewart, Tish Robertson, Tom Parham.