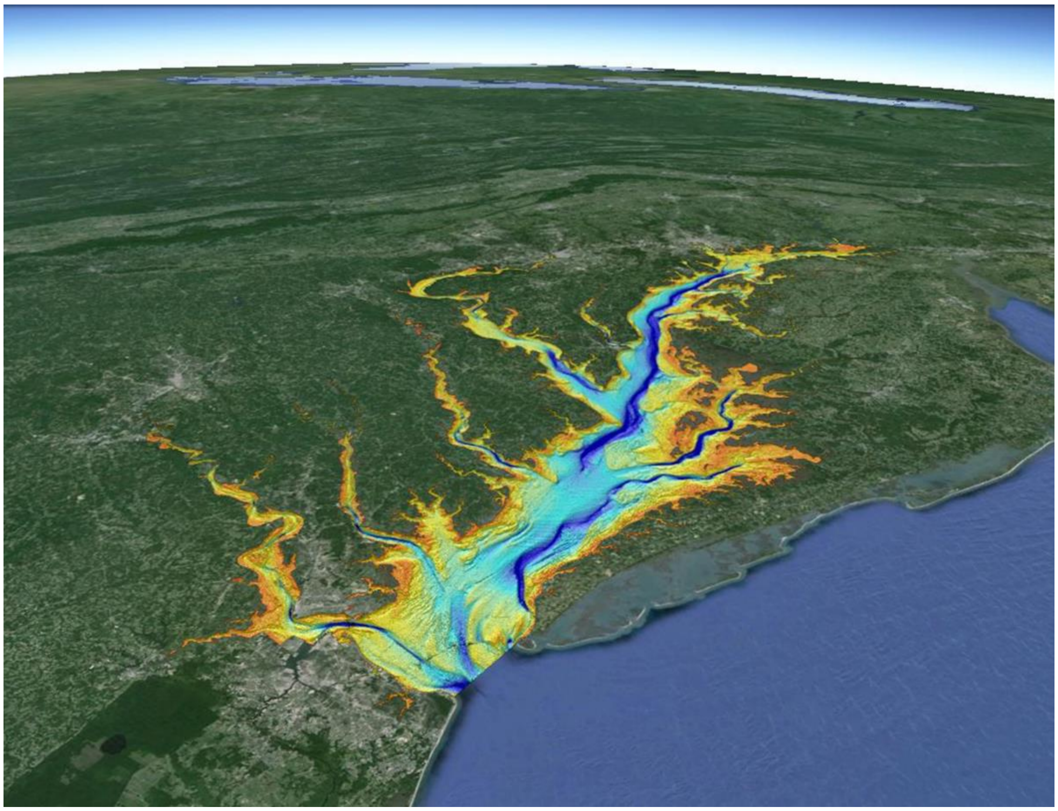
Integrating Recent Findings to Explain Water-Quality Change: Support for the Mid-Point Assessment and Beyond



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About the Scientific and Technical Advisory Committee

The Scientific and Technical Advisory Committee (STAC) provides scientific and technical guidance to the Chesapeake Bay Program (CBP) on measures to restore and protect the Chesapeake Bay. Since its creation in December 1984, STAC has worked to enhance scientific communication and outreach throughout the Chesapeake Bay Watershed and beyond. STAC provides scientific and technical advice in various ways, including (1) technical reports and papers, (2) discussion groups, (3) assistance in organizing merit reviews of CBP programs and projects, (4) technical workshops, and (5) interaction between STAC members and the CBP. Through professional and academic contacts and organizational networks of its members, STAC ensures close cooperation among and between the various research institutions and management agencies represented in the Watershed. For additional information about STAC, please visit the STAC website at http://www.chesapeake.org/stac.

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- James Davis-Martin, VA DEQ
- James Webber, USGS
- Scott Ator, USGS
- Greg Noe, USGS
- Carl Friedrichs, VIMS
- JJ Orth, VIMS
- Jonathon Lefcheck, Bigelow
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Executive Summary

This workshop, hosted by the Chesapeake Bay Program's (CBP) Scientific and Technical Advisory Committee (STAC), brought together water-quality managers and several groups of scientists working to synthesize management-relevant insights in their respective fields, in order to identify elements of research findings that could inform the development of Watershed Implementation Plans (WIPs) and future adaptive management. Session topics included:

- Insights from monitoring and analysis of the Chesapeake Bay watershed
- Insights from monitoring and analysis of watershed sediment transport, estuarine water clarity, and SAV abundance
- A history of major tributary nutrient and sediment loads and conceptual models of estuarine response
- Integrating research and science communication from watershed to estuary to inform management strategies

After each session, breakout groups discussed and developed ideas for (1) scientific messages for further communication; (2) potential implications for management; and (3) research recommendations.

Some recommended next steps include:

- Throughout 2018, provide in-person technical expertise to assist local WIP planners in applying scientific insights and existing CBP decision-support tools to WIP development. Incorporate insights from this report on implications for management into technical assistance and WIP development tools. Consider leveraging the expertise of the CBP's Local Government Advisory Committee (LGAC), Citizen's Advisory Committee (CAC), local extension agents, and watershed groups, and provide additional support to counties that have fewer resources for planning.
- Provide resources to build science communication priorities identified in this report (i.e., "Scientific messages for further communication" in each Breakout Discussion section) into science communication products, and disseminate to CBP partners at all levels.
- Evaluate research recommendations from each breakout session for management relevance and feasibility, and provide support for the most relevant and feasible analyses.
- Integrate analyses of watershed and estuary trends and their explanations.

Workshop Purpose

Over the past two years, several groups of researchers have been working to synthesize key insights from the body of research in their areas of expertise, in both estuarine and watershed systems, in order to inform adaptive management in the Chesapeake Bay watershed.

The purpose of this STAC workshop was two-fold:

1. To convene these research synthesis groups in one venue, so that they could share their findings and identify complementary and contradictory insights across disciplinary and geographical boundaries;
2. To foster a dialogue between these scientists and a group of managers representing each jurisdiction of the Chesapeake Bay Program (CBP) Water Quality Goal Implementation Team (WQGIT).

The format of the workshop was designed to foster discussion among scientists regarding insights from different areas of research and how they inform each other, as well as create a dialogue between researchers and managers on the value of these insights for informing decision-making. To set the stage for these discussions, the two-day workshop began with a presentation on the common challenges faced by natural resource managers in making evidence-based decisions. Research synthesis presentations were grouped by topic, with two or three 20-minute presentations followed by breakout and full-group discussion sessions of approximately 80-90 minutes each. Participants were not formally assigned to breakout groups, but were encouraged to distribute themselves so that each group contained a mix of experts from watershed and estuary, as well as at least one jurisdiction representative.

Research topics included:

1. Insights from decades of USGS water-quality monitoring and analysis of the Chesapeake Bay watershed.
2. Insights from decades of monitoring, analysis, and research on watershed sediment dynamics, estuarine water clarity patterns, and factors affecting submersed aquatic vegetation (SAV) distribution and abundance.
3. Perspectives on patterns of monitored nutrient and sediment fluxes to Chesapeake Bay and conceptual models of estuarine response.
4. Integrating research and analysis from watershed to estuary to inform natural resource management.

This report is organized into sections corresponding to each workshop session. Each section contains abstracts for the session’s presentations, followed by a summary of the session’s breakout discussion. Breakout discussion insights are presented in three categories: (1) scientific messages for further communication; (2) potential implications for management; and (3) research recommendations. The workshop culminated in a jurisdiction panel in which representatives provided feedback to researchers on workshop content; this feedback is summarized in the final section of the report. Finally, messages and findings from the workshop are condensed into recommendations regarding jurisdiction support for WIP development and future adaptive management, jurisdiction priorities for science communication, and priorities for further research and synthesis.

Workshop Introduction: Decision Support and Challenges Faced

Challenges faced by stakeholders in developing evidence-based management decisions (James Davis-Martin, VADEQ)

James Davis-Martin (VADEQ) kicked off the workshop with a primer for scientists on obstacles to incorporating science for decision-making. Key among these is the required timetable of managers' decisions, which tends to intensify remaining challenges. If relevant scientific insights are not available within the necessary timeframe, then opportunities to inform evidence-based decisions may be lost. Remaining challenges include: a lack of awareness that relevant and adequate scientific data exist; the difficulty of understanding findings that are often couched in scientific jargon; and the difficulty of translating scientific findings into appropriate actions. Finally, these challenges must be tackled in the context of the social, economic, and political pressures that can constrain managers' decision framework.

Timing

The CBP's "accountability schedule" drives decision-making for the jurisdictions. As a result, information must be available in an accessible format, with insights for application, within that timeframe. In the near-term, currently available information may be used to inform development of the jurisdictions' Phase 3 Watershed Implementation Plans (WIPs), which will be developed between May 2018 and January 2019. Further opportunities exist if the scientific community can provide information to help jurisdictions assess and improve progress towards meeting implementation goals through the 2-year milestone evaluation process.

Technical Challenges

The over-arching decision that managers face is to select the most effective Best Management Practices (BMPs) for any given environmental setting, in order to maximize ecological, economic, and societal benefits. Decision-making is complicated by the watershed's highly variable landscape and the local scale at which several of these decisions must be made. Extrapolating scientific insights to scales and locations outside of their original scope adds uncertainty with regard to source attribution and BMP effectiveness.

Social and Political Challenges

The degree to which science-based information can guide decision-making is mediated by an array of factors over which managers may have little to no control. Decisions are constrained by the availability of limited public resources, with multiple public needs competing for attention and prioritization. The desire to place BMPs in those locations where they will be most effective is complicated by the need to consider fair and equitable distribution of resources across communities. Finally, private property rights and lack of a regulatory mandate for most non-point sources limit the options open to managers when it comes to optimal BMP placement.

Session I: Insights from USGS Monitoring and Analysis of the Chesapeake Bay Watershed

Presentations

Dissecting Drivers of Nutrient Trends in Chesapeake Bay Streams (Jimmy Webber, USGS)

Jimmy Webber (USGS) presented a review of on-going research summarizing how and why nitrogen and phosphorus loads have changed in Chesapeake Bay streams. The objective of this research topic was to describe the relations between water-quality conditions and hypothesized drivers of change to better inform management decisions related to the selection and placement of conservation practices. The presentation demonstrated that nutrient loads are unevenly distributed throughout the watershed and that the highest loading areas are typically found in locations with the greatest intensity of human activities. Over the past ten years, nutrient fluxes have shown a mixture of improving, degrading, or static conditions that are the result of changing nutrient applications in the watershed or dynamic processes that enhance or retard the movement of nutrients to streams. The effects of conservation practices were presented as one potential driver of observed changes. Current research suggests that the estimated effects of conservation practices have not been linked to water-quality improvements in most streams. Nutrient load reductions have been associated with point source improvements in some streams, but the link between changes in nonpoint inputs and stream response is less clear. Expected water-quality improvements can be delayed or offset by large stores of nitrogen in the groundwater and phosphorus in soils. These conditions tend to occur in agricultural areas where inputs of fertilizer and manure exceed crop needs.

Factors Affecting Nutrient Trends in Chesapeake Bay Tributaries (Scott Ator, USGS)

Scott Ator (USGS) presented a synthesis of results from integrative tools that have been recently applied to disentangle the effects of multiple factors on recent nutrient trends in Chesapeake Bay tributaries. Nitrogen flux to the Bay declined between 1992 and 2012, but not at a pace that would be sufficient to reach TMDL (Total Maximum Daily Load) goals by 2025. The decline in flux is due primarily to point source reductions, and to a lesser extent by declines in atmospheric deposition and inputs from urban non-point sources. Agricultural inputs provide the majority of nitrogen flux to the Bay, but changed little between 1992 and 2012. Changes in average nitrogen yields from certain urban and agricultural settings may reflect changes in land management or climate. Phosphorus flux to streams have also declined since 1992, primarily due to point source reductions. Reduced retention in Conowingo Reservoir, however, caused flux to the Bay to increase. Changes in average phosphorus yields from certain landscape settings have been marginal, although the increasing proportion of dissolved phosphorus in total phosphorus yields from agricultural areas may reflect soil saturation.

Highlights from Session I Breakout Discussion

Scientific messages for further communication:

- Historically, croplands have been identified as primary sources of excess nutrients and sediment.
- Increasing evidence suggests that urbanization also imposes significant detrimental effects upon regional water resources, including increased supply of fine sediments often contaminated with heavy metals, flashier, more erosive river flow dynamics, and elevated surface water temperatures.
- The relative strengths and weakness of statistical models versus process models, and estimates of flow-normalized versus observed loads to the estuary, provide a complementary suite of tools for informing management decisions.
- Existing spatial information on geology, loading hotspots, land use, and other relevant factors can be applied locally to inform BMP implementation decisions.
- Local management efforts have resulted in changes to local water quality in some areas.

Possible implications for management:

- Managers may want to consider targeting newly urban and urbanizing areas for urban BMPs rather than well-established urban areas, especially given the expense of retrofitting older development with modern storm water infrastructure. Direct hydrologic connectivity between development and regional waterways, however, continue to present a challenge to mitigating human impacts upon regional water resources.

Suggestions for future research:

- Incorporate intensive spatial surveys of stream concentrations and loads to identify high-priority BMP target areas.
- Identify and map primary flow paths for each pollutant in various places, in order to inform how BMPs can be targeted to better interrupt those flow paths.
- Quantify and illustrate age distributions of groundwater discharge for smaller areas than currently available, and conduct analysis on expected lag times for detecting BMP effects.
- Develop a better understanding of P transport pathways and the implications of P speciation, in a manner that can inform BMP placement.
- Apply regional insights to smaller areas that are consistent with information needs for BMP implementation.
- Apply monitoring and assessment strategies that account for varying turnover times of N, P, and sediment pools in watersheds.

- Compare conclusions from water quality trends analysis and tools like SPARROW and structural equation modeling with CBP model results, and clarify the strengths and weaknesses of each approach.
- Combine model output and "boots-on-the-ground" consultation to maximize incorporation of local hydrogeologic variables.
- In the absence of short-term water quality trends, consider how long-term trends in water quality can inform 2-year milestones and provide science-based insights into what current actions should be.
- Consider conducting a water sustainability study, incorporating climate change into expectations for growing season length and agricultural practices such as crop selection and rotation.
- Evaluate whether nutrient retention in the watershed has increased through time, and the potential nitrogen surpluses to be removed through denitrification and changes in crop yields per unit fertilizer input (i.e., fertilizer use efficiency).

Session II: Insights from monitoring and analysis of watershed sediment transport, estuarine water clarity, and SAV abundance

Presentations

Reviewing sediment sources, transport, delivery, and impacts in the Chesapeake Bay watershed to guide management actions (Greg Noe, USGS)

Greg Noe (USGS) summarized the current state of knowledge of sediment in the Chesapeake Bay watershed to guide management actions on the landscape for the restoration of the watershed and estuary. Sediment is notable for its direct impacts on aquatic habitats and wildlife, and also as a vector for the delivery of other contaminants. Insights were placed in the context of three geomorphic principles that can be used to guide the understanding and management of sediment transport from watershed to estuary: scale, time, and land use. Geology and historical land use have generated a physical template that current land use, climate, and management are acting upon to control sediment delivery to Chesapeake Bay. Spatial scale-dependent factors include both stream size and location; sediment processes differ in uplands and headwater streams versus lowlands and larger rivers. Temporal factors include the current impact of historical land use as well as variable transport times, as sediment "hops and rests" in and out of different storage zones as it moves downstream. Active sediment storage can delay detection of effects of BMPs on sediment loads. Land-use factors include historical and current patterns. Agricultural, developed land, and stream banks are all important sources of sediment, but locally and temporally variable. Variations in the temporal and spatial scale of these factors and landscape processes interact in complex ways and require further study in order to improve predictability of sediment sources, transport, fate, and BMP effectiveness. Scientific expertise and technical tools for addressing questions relevant to management are available and continue to expand. Approaches can identify and target hot spots of erosion, erosion sources, and trapping zones, although different techniques can yield different results in space and time. Least certain elements of current conceptual models include time spent in different storage zones and how this varies across watersheds, interactions of sediment transport and storage with phosphorus, and how individual BMPs affect downstream sediment processes. Improving knowledge of sources and lags can help target BMP type and locations.

Understanding patterns in Chesapeake Bay water clarity: the importance of measurement, location, and physical versus biological controls (Carl Friedrichs, VIMS)
Carl Friedrichs (VIMS) described Bay-wide patterns in water clarity from the mid-1980s through 2015, both as defined by transparency (secchi disk) and by light attenuation (k_d). Improvement in both measures indicates unambiguously improving clarity. However, in the early part of this period, transparency continued to decline while light attenuation improved in many locations. Since approximately 2005, both measures are showing consistent improvements in many areas of the Bay. He presented the current state of knowledge on the spatial variability of water clarity trends, as well as on drivers of contrasting patterns in water transparency and light attenuation. Patterns of water clarity are distinctly different in the upper tidal tributaries relative to the open waters of the mainstem bay, and these differences are related to overall inorganic TSS (total suspended solids) concentration and fraction of organics vs. inorganics. Riverine sediment loads affect clarity in the upper tidal portions and the turbidity maximum of Chesapeake Bay tributaries, but not in the central and lower portions of the mainstem bay. Inter-annual variations in precipitation and associated nutrient loads correlate with transparency trends in the mainstem. Optical modeling suggests that a combination of reduced inorganic fine sediment and increased organic fine sediment may inform contrasting patterns of transparency and light attenuation, however the drivers of these changes are still poorly understood.

SAV Status and Trends (JJ Orth, VIMS, and Jonathan Lefcheck, Bigelow)
JJ Orth (VIMS) and Jonathan Lefcheck (Bigelow) presented insights on factors affecting the distribution and abundance of submerged aquatic vegetation (SAV) across Chesapeake Bay, and on how these patterns have changed over time. SAV is an important and highly responsive indicator of water quality conditions, and provides critical habitat for aquatic living resources. SAV species are also indicators of environmental change due to their sensitivity to water quality and shoreline development. Increases in human and livestock populations, associated changes in land use, increases in nutrient loadings, and shoreline armoring have altered SAV habitats. Orth provided an overview of a two-year synthesis effort by a team of 14 scientists from a diversity of backgrounds and affiliations to assess the status and trends of SAV in Chesapeake Bay. In addition to producing three peer-reviewed journal articles, the team was also in the process of developing SAV fact sheets for over fifty distinct regions, with management recommendations to ensure healthy SAV populations in the future. A fourth journal article was planned for 2018. Jonathan Lefcheck provided a summary of research that he led to predict the cascading effects of

anthropogenic impacts on SAV. He applied structure equation modeling (SEM) to 30 consecutive years of data provided by co-authors on watershed land use, nutrient inputs, nutrient and sediment loads, within-estuary water quality parameters, and comprehensive aerial SAV surveys, which allowed him to quantify relationships between hypothesized drivers and SAV populations. Lefcheck was able to quantify causal links between land use change and higher nutrient loads, which in turn reduced SAV cover through multiple, independent pathways. These models also showed that high biodiversity of SAV consistently promotes cover, an unexpected finding that corroborates emerging evidence from other terrestrial and marine systems. The study empirically demonstrated that nutrient reductions and biodiversity conservation are effective strategies to aid the successful recovery of degraded systems at regional scales.

Highlights from Session II Breakout Discussion

Scientific messages for further communication:

- Species diversity in SAV populations and the presence of invasive species both play a role in SAV abundance.
- SAV beds are an important resource for local fish species and for improving local stream health.
- In places where nutrient loads and concentrations have been reduced, SAV has shown recovery within about 3-4 years.
- Controlling sediment erosion is important for local stream health, and local sediment management benefits local fish populations and farm productivity.

Potential implications for management:

- To manage for SAV abundance and improved water clarity, continue to implement current strategies for nutrient load reductions and keep monitoring their effects. If progress plateaus, reevaluation can occur.
- Target fine sediment transport and suspension rather than coarse sediment.
- Implement strategies to improve sediment monitoring of small, flashy systems.
- Implement strategies to improve quantification of sediment transport during large storms.

Research recommendations:

- Conduct more research on sediment effects on insects, algae, and nutrient concentrations in small stream areas.
- Conduct more targeted monitoring of sediment-loading hot spots for more immediate condition and response information.
- Conduct research and analysis to quantify how population growth is affecting sediment transport.
- Better characterize sediment-associated P availability as it moves into the estuary.

- Produce a sediment budget for the Bay, incorporating local variability in mass and dynamics. This would include models of sediment transport that consider the input, transport, and fate of sediments of various sizes.
- Collect and analyze data to better characterize causes of change in suspended particle size and composition in tidal waters. This likely should be in the form of detailed new research projects.
- Assess the resilience of the "recovered" SAV beds in various salinity zones.

Session III: The history of major tributary loads and conceptual models of estuarine response

Presentations

A History of Nutrient and Sediment Inputs to Chesapeake Bay, 1985-2016: Three decades of monitoring and coordinated restoration in the Chesapeake Watershed (Joel Blomquist, USGS)

Joel Blomquist (USGS) presented a summary of nutrient and sediment inputs to Chesapeake Bay from 1985-2016, distinguishing between flow-normalized loads (an indicator of the effects of changes in sources over time) and true condition loads (actual loads received by the estuary, which may be more relevant to understanding estuarine response). Monitoring data and analysis show that flow-normalized nitrogen loads have declined in 8 out of 9 monitored watersheds, while flow-normalized P loads have increased since 1985 from 6 out of 8 monitored watersheds. Wastewater treatment improvements and declining atmospheric deposition are responsible for declines in flow-normalized N loads, while effects of nonpoint source controls were small. Both wastewater treatment plant upgrades and the P detergent ban also improved P loads. Flow-normalized P load reductions for the Patuxent, Potomac, and James rivers are strongly linked to point-source reductions. Nonpoint source N inputs to the Bay are disproportionately contributed from the southern Susquehanna basin and eastern shore regions. Observed changes do not currently match expected effects of current BMP implementation levels. Average annual P loads from the Susquehanna watershed have begun to increase due to decreased trapping efficiency of the Conowingo reservoir. In contrast to flow-normalized load patterns, true condition loads of both N and P showed no significant change for 7 out of 9 watersheds. Exceptions include decreasing N loads to the Patuxent River, decreasing P loads to the James River, and increasing N and P loads to the Choptank River.

Progress toward the Restoration of Chesapeake Bay in Time and Space: A Synthesis of Biogeochemical Changes in Chesapeake Bay (Jeremy Testa, UMCES)

Jeremy Testa (UMCES) presented a synthesis of findings from a workshop and white paper on the current state of knowledge on progress towards restoration of Chesapeake Bay in time and space. The goals of the group who collaborated on this effort were: to review the current conceptual model of eutrophication; to examine changes in N and P loading for all 92 water quality segments and the associated change in N and P concentration, chlorophyll-*a*, and other variables; to review case studies of both restoration success and resistance to change; and to identify consistent themes where restoration actions have (or have not) led to improved water quality. The group reviewed evidence of declines in loads from the 9 major tributaries between 1985 and 2014. These declines were due in large part to wastewater treatment plant load reductions, although decreasing atmospheric N deposition also played a role. Load declines generally correspond to estuarine nutrient concentration declines. TN and TP concentration declines are widespread, however only a subset of regions have shown evidence of clear recovery in response to nutrient reductions. Water column nutrient concentrations are increasing in some areas. In a few cases, changes in estuarine TN and TP concentrations do not correspond to changes in TN and TP loads. In evaluating long-term change, seasonal and regional differences must be considered. For example, responses may be observed as seasonal shifts that are not evident in annually aggregated data. Key results from the synthesis include the message that wastewater treatment upgrades work; that there is evidence of declines in both N and P concentrations in the estuary but that shifts in response vary seasonally and regionally; and that the response of an estuarine region to restoration depends on its location along the estuarine salinity gradient.

Highlights from Session III Breakout Discussion

Scientific messages for further communication:

- Flow-normalized loads and concentrations are useful for detecting effects of management actions and other changes in the watershed, and for comparing to TMDL models. Observed loads and concentrations are important for understanding what the estuary is experiencing and how it is responding.
- Communicate watershed and estuary science together more frequently.
- Communicate how far point source reductions can take us towards load reduction goals.
- Communicate our current understanding of how lag times vary across the watershed, at the RIM stations, and across the estuary.
- Summarize the current science regarding the impacts on water quality of conservation tillage versus continuous no-till practices.

Potential implications for management:

- Information on geographic distribution of nutrient sources can be used to target areas that provide most of the loads to the bay for BMP implementation.
- It may be useful to incentivize geographic targeting of BMP implementation with changes in policy. For example, assigning a single permit for total load could provide more flexibility to target reductions.
- The value of local tradeoffs in N, P, and sediment reductions varies depending on local conditions and BMP choices.

Research recommendations:

- Improve estimates of loads from un-monitored areas in the watershed, especially below the USGS RIM stations.
- Improve understanding of the effect of storms on the dynamics of estuarine response over short- and long-term time scales.
- Update conceptual models to consider the effects of location on estuarine response, for example in shallow versus deep water, in the mainstem estuary versus the tributaries, and in low-salinity versus high-salinity areas.
- Apply the conceptual model approach to explaining why N, P, and S concentrations and fluxes show different patterns, and why N trends tend to agree across load estimation methods while P and S trends do not.
- Improve our understanding of how lag times vary across the watershed, at the RIM stations, and across the estuary.
- Re-instate the phytoplankton monitoring program in order to better evaluate changes in plankton community composition and productivity under reduced nutrient loads.
- Pursue a more comprehensive understanding of the effect of the mainstem bay on water quality on the seaward regions of tidal tributaries that exchange water with the mainstem.
- Re-assess how the extent and spatial pattern of phytoplankton productivity limitation relates to N and P concentrations and light availability (i.e. water clarity).

Session IV: Integrating research and science communication from watershed to estuary to inform management strategies

Presentations

Documenting Impacts of Climate, Clams, and a Changing Watershed on the Potomac Estuary (Lora Harris, UMCES)

Lora Harris (UMCES) presented a collaborative analysis linking watershed and estuarine environmental and management factors to riverine water quality, as well as to chlorophyll-*a* and dissolved oxygen concentrations in the tidal Potomac River. Potomac River fall line flow-weighted concentrations were examined statistically, and results suggest only modest, mostly non-significant, decreases in TN and TP yields and concentrations. A source analysis study was conducted as well that involved summing TN and TP watershed inputs from fertilizer application, livestock consumption, and human consumption (and total deposition and fixation for N), minus removals from crop and livestock production. Increased poultry production and human population growth increased nutrient inputs into the watershed, but these increased inputs were offset by reductions in fertilizer use, point source loads, and atmospheric deposition inputs along with increased nutrient use efficiency in cropland. The flow-weighted concentrations of TN and TP from the watershed were then transferred down to the estuary, where conceptual models were created to investigate the causes of long-term water quality response. Chlorophyll-*a* concentrations were associated with watershed nutrients, point source inputs, climate, and biological factors in a generalized additive model (GAM) approach. Findings suggest that water quality is responding to nutrient reductions, but that other factors can mediate these responses and need to be considered. For example, a drop in bivalve abundance in the later part of the record, as well as a changing climate, may have played a role in observed chlorophyll-*a* increases over time. A technique was presented demonstrating how a GAM can be used to generate scenarios for the presence or absence of different hypothesized factors. For instance, if the bivalve drop and temperature increases had not occurred, chlorophyll-*a* concentrations would have continued to respond to the nutrient load reductions. These analyses demonstrated that changing agricultural practices, such as increased poultry production, mask some declines in other nutrient sources, and that climatic and ecological factors are helpful in understanding lack of expected response.

Tributary Summary Reports and Syntheses: Example concept for the Choptank River (Rebecca Murphy, UMCES and Emily Trentacoste, EPA)

Rebecca Murphy (UMCES) and Emily Trentacoste (EPA) performed an integrated analysis that synthesized water-quality trends research with monitoring, modeling, and management data. They provided insights into potential drivers of water-quality trends by linking local tidal water responses to non-tidal water quality, watershed influences, and current and past restoration efforts. Their work demonstrated that the middle and lower portions of the Choptank River are showing signs of recovery. However, low oxygen concentrations in the uppermost tidal segment have continued to decline in the last two decades, and nutrient loads measured from the watershed into this segment are increasing. In these three regions of the tidal Choptank, proximate nutrient trends are consistent with progress on DO concentrations, confirming that further reductions will improve water quality. This case study demonstrates the scientific tools that are currently available to help focus and target restoration efforts in the watershed, both geographically and by sector. Future efforts will create decision-support tools that allow managers to integrate scientific and management information in local areas and construct their own local water quality stories. Integrated analyses like this will empower Bay jurisdictions and their local partners to determine drivers and sources behind water quality and focus restoration efforts, resulting in better-informed water-quality management decisions.

Highlights from Session IV Breakout Discussion

Science messages for further communication:

- Translate research insights from watershed to county scale for communication.
- Provide information provided for the Choptank for all sub-basins in the watershed.
- Show how the problems on land relate to the problems in the water using the fact sheet approach to communicate key messages accessible to both politicians and practitioners.

- Direct interaction between scientists and managers within jurisdictions fosters trust and improves information sharing between the management and research communities. "Honest broker" intermediaries can effectively connect the two groups. This is an area worthy of investment.
- Continue to communicate that nutrient reductions have an effect. Do not exclude the roles of uncertainty and complexity in how streams, rivers, and the estuary respond.
- If science is telling us that manure is the problem, be forthright about that.
- Explain the importance and complementary nature of data, conceptual models, statistical models, and process models. There is a general misconception that data are right and models (especially the CBP models) are wrong.
- Incorporate insights on SAV and fish into tributary summaries

Potential implications for management:

- Consider mechanisms to allow county-scale planning to reach across county boundaries, to better match scale of research findings.
- For the TMDL, focus resources on the smallest area that can give us the greatest reduction.
- Management decisions may need to incorporate targeting particular species of pollutants, as well as N:P ratios.

Research recommendations:

- Translate knowledge of BMPs into "management zones of effectiveness" that articulate a BMP's zone of influence and expectations of what a management action will do. Include additivity through time and the cumulative effect of expectations.
- Improve understanding of location-dependence (i.e., upper vs lower tributaries and low versus high salinity regions) of water quality-trend drivers and responses.
- Continue synthesis of both broader regional stories and local-level stories.
- Connect nutrients and water-quality trends to living resources in both directions, i.e. effects of living resources on water quality and effects of water quality on living resources.
- Expand research on BMP performance.
- Expand research into the role of different nutrient forms (dissolved versus particulate) on estuarine responses to loads.
- Establish an ongoing mechanism for supporting synthesis activities, with requirements for the management-relevance of topics and for the composition of groups.

Jurisdiction Panel

What was useful?

- Examples showing that point source reductions have worked; the fact that local improvements to an action have been observed gives us more confidence to write our WIP.
- To see that there actually is a lot of scientific information that you can apply locally.
- Information that there is a scientifically established lag effect.
- That there are ways that science can inform prioritizing resources. This makes resource decisions easier, and is a good direction for future synthesis projects.
- Direct communication between managers and scientists, without ulterior motives or agendas.
- The opportunity to give feedback directly to scientists on what we need, such as more information at local scales.

What was missing?

- The full atmospheric deposition story. Communicate the importance of change in atmospheric deposition at the local level, even if its importance is relatively small over larger areas.
- Sufficient actionable information relating diffuse (i.e., nonpoint source) loads to water quality.
- Sufficient actionable information tying water quality to fishable and swimmable goals.
- The incorporation of economic cost into science that informs BMP effectiveness. This will help us prioritize resources with regard to BMP decisions.
- A holistic discussion of uncertainty, confidence levels, and variability in a management context. Distinguish between variability (which in some cases is well understood) and uncertainty (which is less well understood). Managers can handle uncertainty. They want to hear what the best currently available science is, what the gaps are, and that the research community is working towards filling those gaps.
- Analysis of whether the Bay TMDL is more or less restrictive than local TMDLs. This will drive restoration action.
- A clear statement about what on the land is causing the problem, and whether there is solid science and technology to manage it.
- A scientific analysis of what works and what doesn't, what doesn't work if you mess it up, and whether practices implemented in the past are still working. Examples include prioritizing the number of septic replacements over installation of more efficient septic systems, and street sweeping that mobilizes fine sediment.
- An analysis of whether it would be more cost-effective to fully fund agricultural non-point source BMPs than to spend money on nutrient trading.
- More local basin storylines for all synthesis topics, that can be taken to both the Secretary level and the local conservation group level.

Recommendations and Next Steps

Recommendations to the Chesapeake Bay Program to support jurisdiction implementation

- Throughout 2018, provide in-person technical expertise to assist local WIP planners in applying scientific insights and existing CBP decision-support tools to WIP development. Incorporate insights from this report on implications for management into technical assistance and WIP development tools. Consider leveraging the expertise of LGAC, CAC, and local extension agents, and watershed groups, and provide additional support to counties with fewer resources for planning.
- Use insights from synthesis storylines and the CBP Phase 6 model's effectiveness assumptions to recommend narrowing counties' efforts to specific BMPs.

Recommendations to the Chesapeake Bay Program for science communication

- Provide resources to build science communication priorities identified in this report (i.e., "Scientific messages for further communication" in each Breakout Discussion section) into science communication products, and disseminate to CBP partners at all levels.
- Establish an easily accessible mechanism for environmental planners to contact interested scientists for input to support decision-making.

Recommendations to the Chesapeake Bay Program to promote research for BMP implementation decision support

- Evaluate research recommendations from each breakout session for management relevance and feasibility, and provide support for the most relevant and feasible analyses.
- Establish a mechanism for managers and scientists to coordinate BMP monitoring and research efforts so that researchers can establish pre- and post-implementation monitoring for analysis of system response.
- Conduct additional science integration workshops to generate place- or system-based products. For example, hold a workshop focusing on the Shenandoah Valley or other areas of high yield.
- Expand monitoring to better support analysis of the role of nutrient processing and biological feedbacks on ecosystem response to change. Potential examples include better monitoring of event response, expanded continuous monitoring, monitoring alkalinity at RIM stations, improved characterization of suspended organic and inorganic particulate matter, reinstating the phytoplankton monitoring program, and incorporation of alternative stream data sources into model calibration and BMP targeting.

Recommendations to Chesapeake Bay Watershed jurisdictions

- Coordinate with researchers to establish pre- and post-implementation monitoring of BMP implementation in order to advance scientific understanding of BMP effectiveness.
- Prioritize monitoring and research of BMP implementation effectiveness in "hot spot" areas. See the Fairfax County partnership with the USGS and the MDE urban sector program for incentivizing research as examples.
- Coordinate with the Chesapeake Bay Program to facilitate information exchange between state and local environmental planners and interested scientists to support decision-making. Consider leveraging the expertise of groups like LGAC and CAC, as well as local extension agents and watershed groups.
- Provide additional technical and financial support to counties with fewer resources for planning.

Recommendations to the Chesapeake Bay Watershed research community

- Expand and prioritize research and synthesis on local co-benefits of BMPs.
- Incorporate social science and economics into environmental research for driving BMP recommendations.
- Incorporate living resources into water quality conceptual models and research syntheses.
- Conduct more integrated analysis of watershed and estuary trends and their explanations.
- Use conceptual models of ecosystem functioning that incorporate local differences in drivers and responses to identify unknowns and priorities for future research and analysis.
- Pursue more integration of research findings from statistical, place-based, and process-based models. Expand use of sophisticated analytical techniques on available data, in order to maximize and demonstrate the value of existing monitoring programs.

Next Steps

The workshop steering committee will engage the Chesapeake Bay Program Office (CBPO) to communicate workshop findings to the CBP Partnership and discuss resources for acting on workshop recommendations.

Appendix A – Workshop Agenda

Integrating Recent Findings to Explain Water Quality Change: Support for the Mid-Point Assessment and Beyond

A Scientific and Technical Advisory Committee (STAC) Workshop

Dates: December 12-13, 2017
Location: Westin Annapolis Hotel, 100 Westgate Circle, Annapolis MD 21401
Workshop Webpage: http://www.chesapeake.org/stac/workshop.php?activity_id=286

This STAC workshop will provide the mechanism for a focused exchange among the scientists leading the efforts below to explain water-quality change and the managers working to incorporate those explanations into management of the Chesapeake Bay restoration effort. Workshop findings will guide future science communication and applied research priorities.

Tuesday, December 12

8:30 – 9:00 am **Continental Breakfast (provided)**

Session I

9:00 – 9:30 am **Introductions, Goals and Format of workshop –** ***Jeni Keisman (USGS)***

9:30 – 9:50 am **Decision Support: Stakeholder challenges –** ***James Davis-Martin (VADEQ)***

9:50 – 10:10 am **Synthesis Topic: "NTN1" - Key findings from USGS nontidal network analysis of water quality, land use change, and best management practices.**

Leaders: James Webber, Scott Ator, and Jeff Chanat (USGS)

Brings together findings from 1) watershed change characterization, 2) hydrologic process studies, and 3) integration building blocks to tell a summary story that describes drivers of water-quality changes across the watershed. Discusses factors driving yields and associated trends.

10:10 – 10:30 am **Synthesis Topic: "NTN2" - Explaining yields and trends at sites throughout the Chesapeake Bay watershed to support management decisions as part of the mid-point assessment**

Same general goals as NTN1, but with a focus on insights from new modeling approaches.

10:30 – 10:50 am **Break**

10:50 – 11:40 am **Breakout #1**

11:40 – 12:15 pm **Integration discussion**

12:15 – 1:00 pm **Lunch (provided)**

Session II

1:00 – 1:20 pm **Synthesis Topic: Reviewing sediment sources, transport, delivery, and impacts in the Chesapeake Bay watershed to guide management actions**

Leaders: Greg Noe, Katie Skalak, Matthew Cashman, and Allen Gellis (USGS)

The USGS is summarizing the state of knowledge of sediment in the Chesapeake Bay watershed to guide management actions on the landscape for the restoration of the watershed and estuary.

1:20 – 1:40 pm **Synthesis Topic: Understanding patterns in Chesapeake Bay water clarity: the importance of measurement, location, and physical versus biological controls.**

Leaders: Carl Friedrichs (VIMS) and Jeni Keisman

This effort documents historical water clarity patterns in Chesapeake Bay, and how our perception of those patterns is affected by the tools that we use to measure them. It further describes our current understanding of the interaction of different physical, chemical, and biological forces that affect water clarity, and how this knowledge relates to the information needs of the region's natural resource managers. Case studies demonstrate how physical and biological drivers of water clarity vary with environmental setting. Some cases also illustrate improvements in water clarity following known interventions that reduced nutrient inputs or increased filtering capacity. Gaps between our scientific understanding of water clarity and the needs of managers can inform research priorities for supporting future decision-making.

1:40 – 2:00 pm **Synthesis Topic: Explaining temporal and spatial patterns in SAV abundance**

Leaders: JJ Orth (VIMS) and Bill Dennison (UMCES)

This effort has used data from the long-term SAV monitoring and water quality monitoring programs, as well as data on watershed nutrient sources and inputs, to better understand the factors affecting SAV abundance across Chesapeake Bay. The effort has produced a journal article synthesizing existing knowledge, a handful of new research articles, and a set of fact sheets describing SAV trends and take-home messages for several locations around Chesapeake Bay. A total of 50-some fact sheets are planned.

2:00 – 3:00 pm **Breakout #2**

3:00 – 3:20 pm **Integration discussion**

3:20 – 3:30 pm **Break (refreshments provided)**

Session III

3:30 – 3:50 pm **Synthesis Topic**: ***Explaining loads and trends in loads to Chesapeake Bay***

Leaders: Joel Blomquist and Doug Moyer (USGS)

This synthesis reflects on the body of research describing patterns of inputs to Chesapeake Bay over the period of coordinated restoration. The results will incorporate results as measured at long-term monitoring stations, modeled data for unmonitored regions of the Eastern and Western Shore, as well as direct wastewater and atmospheric inputs to the estuary. The results are summarized with an eye towards the implications of these patterns for estuarine response.

3:50 – 4:10 pm **Synthesis Topic: Conceptual models and case studies of eutrophication and restoration in Chesapeake Bay**

Leader: Jeremy Testa, UMCES

Three decades of monitoring in Chesapeake Bay and its tributaries has allowed for the mapping of water quality change in response to watershed restoration activities, climatic variation, and, biological change. Comprehensive analysis and review of past monitoring data has revealed clear signs of successful water quality remediation in some Chesapeake regions, while less-than-clear changes have occurred in other regions. This combination of new and old has allowed for a refinement of our existing conceptual models of the eutrophication process in Chesapeake Bay.

4:10 – 5:00 pm **Breakout #3**

5:00 – 5:30 pm **Integration Discussion, Plans for Day 2**

5:30 pm **Recess**

Wednesday, December 13

8:30 – 9:00 am **Continental breakfast (provided)**

9:00 – 9:30 am **Re-Cap of Day 1**

Session IV

9:30 – 9:50 am **Synthesis Topic: Factors affecting changes in tidal Potomac River water quality**

Leader: Lora Harris (UMCES)

An updated analysis of the Potomac is timely because a number of management actions have taken place since the early 2000s. Here we present our approach of applying General Additive Models to unravel the complex impacts of nutrient and freshwater inputs from the watershed, as well as within-estuary processes driven by climatic conditions, as they relate to two key water quality criteria. The results of this analysis permit us to present a narrative that connects dynamics in the watershed to ecological processes within the tidal Potomac in an effort to assess how management actions related to nutrient loadings impact chlorophyll-a and dissolved oxygen concentrations.

9:50 – 10:20 am **Synthesis Topic: Tributary Summary Reports**

Leaders: Rebecca Murphy (UMCES), Emily Trentacoste (EPA) and Jeni Keisman (USGS)

We will provide an overview of a basin-specific approach for summarizing both watershed and tidal trends and existing research in a format to share with management audiences. We will discuss distilling watershed-wide data to a local basin scale, as well as using estuarine research and station-based water quality trends to help understand progress towards meeting water quality criteria. Timed as the last presentation of the workshop, we hope these examples will help continue our discussion on ways to synthesize the existing research into information for local jurisdictions.

10:20 – 10:30 am **Break**

10:30 – 11:30 am **Breakout #1**

11:30 – 12:00 pm **Integration discussion**

12:00 – 1:00 pm **Lunch (provided)**

1:00 – 2:00 pm **Group Discussion: Major workshop findings**

2:00 – 3:00 pm **Jurisdiction Panel: Relevance to stakeholder challenges**

3:00 – 3:30 pm **Group Discussion: Major findings and research gaps for communication and future research**

3:30 pm **Adjourn**

Appendix B – Workshop Participants

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