Enhancing the Chesapeake Bay Program Monitoring Networks
A Report to the Principals' Staff Committee

Chesapeake Bay Program
Science. Restoration. Partnership.

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Appendix A:

A1: Chesapeake Bay Program Land Use Workgroup and Leads of Land Use Methods and Metrics Development Outcome

A2: Chesapeake Bay Program Toxic Contaminants Workgroup

A3: Chesapeake Bay Program Sustainable Fisheries Goal Implementation Team

Appendix B: Breck Sullivan (U.S. Geological Survey)

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Denice Wardrop (CRC) provided technical guidance on report organization and findings

Amy Goldfischer (CRC) contributed to production and editing of all sections.

We appreciate the contributions of the Chesapeake Bay Program Goal Implementation Teams to the report.

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Executive Summary

In March 2021, the Principals' Staff Committee (PSC) requested a study and recommendations on how to improve Chesapeake Bay Program (CBP) monitoring networks. The monitoring networks include (1) CBP core networks supported primarily by EPA Chesapeake Bay Program funding, and (2) partnership networks supported by multiple federal and state agencies. The monitoring review was guided by leadership from the CBP Scientific, Technical Assessment and Reporting (STAR) team, the CBPO Monitoring Team, with input from the CBP Scientific and Technical Advisory Committee (STAC) leadership.

The report is organized into 4 major sections:

- Section 1: Chesapeake Bay Program Network Portfolios. Provides a summary of the existing CBP core networks (most with a focus on water quality) with recommendations and potential investments to address development, maintenance and improvement of these networks.
- Section 2: Chesapeake Bay Agreement Goals and Outcomes Monitoring Needs. Summarizes the partner-led monitoring and broader needs of the 10 goals and associated outcomes in the 2014 Watershed Agreement.
- Section 3: Partnership Opportunities to Enhance Chesapeake Bay Program Monitoring. Provides potential approaches for partners to collaborate on addressing the vast number of monitoring data needs to support decision-making requirements of the Chesapeake Bay Program partnership.
- Section 4: Principals' Staff Committee Charge to the Monitoring Review Team and Foundational Assessment Results. Provides an overview of methodology used to conduct the monitoring program assessment for the Principal's Staff Committee request and details of input from the collective monitoring representatives to inform the information in the previous sections of the report.

Key Findings

1) *Monitoring is critical to assess progress towards meeting goals and outcomes of the 2014 Watershed Agreement.* Monitoring is critical for evaluating progress and identifying challenges towards meeting the goals and outcomes of the 2014 *Chesapeake Bay Watershed Agreement*, many of which need to be met by 2025. Sustained and improved monitoring will allow the CBP partners to assess and evaluate progress from restoration and conservation efforts, while identifying gaps where more attention is needed in the future.

2) *Monitoring is insufficient for many CBP outcomes.* There is significant support for Bay and watershed resource monitoring, conducted by multiple CBP partners, which provides consistent information over time for tracking the status of, and progress towards about half of the thirty-one CBP *Watershed Agreement* outcomes. However, the review highlights a need for new investments to address significant gaps in providing decision-support for existing applications. This includes CBP's inability to meet all the monitoring requirements to fully assess the attainment of tidal water-quality standards which tracks progress in bay health in response to management actions implemented with the Bay TMDL. Further, monitoring for the remaining CBP outcomes is insufficient and needs to be improved. This urgently needs to be improved by 2025 to achieve stated outcomes.

3) *Opportunities for enhancing the networks exist but funding is a challenge.*
Funding is needed to maintain the integrity of existing monitoring networks, expand and enhance these networks, and invest in new monitoring opportunities that address critical gaps to assess progress toward the meeting targets of all CBP Watershed Agreement outcomes. Currently, the EPA and partners invest $13M in the CBP core monitoring networks (Figure ES1). The estimate to enhance the CBP core networks is $5.4M in the first year ($1.8M in capital costs and $3.6M for operation and maintenance). Cost estimates of the recommendations were developed and provided as guidance and do not reflect endorsement of, or distribution to, any specific agency, institution, or depend on one type of equipment or supplier. Therefore, final costs for implementing any option could rise or fall subject to details within the final scope of work, sampling designs, awardee requirements, annual inflationary pressures, and more.

The CBP partners are exploring using funding from the 2021 Bipartisan Infrastructure Law (BIL), and about $1.5M of BIL funds has been identified for monitoring. However, the BIL funding is only available for 5 years. Therefore, the CBP partners have a challenge to increase monitoring capacity and associated resources to fill the funding gap over the next 5 years, and longer-term sources of funding that sustain the existing and new capacity. Pursuing funds for monitoring investments will require a long-term, strategic effort of increased collaboration between federal, state, academic and local monitoring partners to successfully maintain and enhance existing networks, and develop, establish, and sustain new networks.

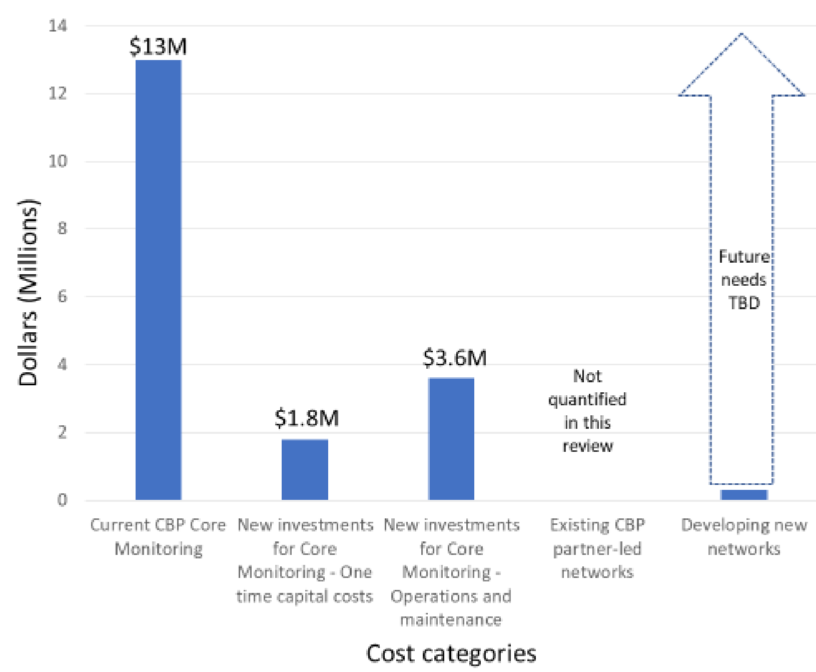

Figure ES1. Current CBP funding and funding gaps identified to support development, maintenance and enhanced monitoring programming to address assessment needs for outcome tracking under the 2014 Watershed Agreement.

Section 1 Summary: Chesapeake Bay Program Network Portfolios

From March 2021 through December 2021, the Monitoring Review Team interacted extensively with the CBP partnership's Goal Implementation Teams (GITs), their workgroups, and partners currently responsible for operating and maintaining CBP monitoring networks. Agenda topics sought to 1) understand of status of monitoring network support to sustain existing operations, 2) evaluate their financing needs in line with providing existing information needs, 3) determine their priorities for sustaining existing operations and growing to meet decision-support expectations of the CBP, 4) discuss and record options for potential enhancements to the monitoring efforts that address the priorities and needs, and 5) request guidance on potential costs for sustaining existing networks and process-identified network growth options. Section 1 provides an overview of the initial funding guidance developed through community support focused on four goals and selected CBP outcomes:

- Water quality: A priority investment is to assess water-quality criteria in tidal waters to support living resources habitat assessments and water quality standards. An additional investment is to enhance monitoring to assess the watershed response to implementation of nutrient and sediment reduction practices.
- Vital Habitat: Investments are proposed for enhancing SAV monitoring in the estuary, an important living resource indicator in the estuary.
- Land Conservation and Habitat: Investments are proposed for enhancing land-change monitoring to better track progress toward riparian forest buffers, tree canopy, and land change metrics.
- Toxic Contaminants: A monitoring network coordinated from existing state efforts is proposed to assess changes to PCBs, which cause fish health impairments in the watershed and estuary.

Recommendations and cost estimates were developed through shared insights from managers, technicians and program administrators based on best available information and experience as guidance to address development, maintenance and improvement of CBP core networks. The recommendations, found in Section 1 of this document, are presented as a menu of investment opportunities. Line-item cost projections for 5 years are further provided as guidance in Section 1, Table 1.2. The menu was designed to help CBP partners choose where they can support individual items that will collectively improve monitoring toward addressing the information needs of multiple outcomes.

Section 2 Summary: Chesapeake Bay Agreement Goals and Outcomes Monitoring Needs

Section 2 of the report describes the monitoring needs, based on input from the GITs, for outcomes of the 2014 *Chesapeake Bay Watershed Agreement*. The GITs identified 2 completed outcomes, 13 outcomes requiring maintenance of their monitoring programs, 9 outcomes which lack coordinated monitoring, and 7 outcomes where new monitoring needs to be established. Throughout the text, outcomes lacking coordinated monitoring or not having monitoring programs in place are termed "developing new networks for outcomes lacking sufficient monitoring".

Funding estimates were not developed for monitoring needed to enhance existing, fully supported partner-led monitoring networks, or for new networks of CBP outcomes currently lacking monitoring. Section 2 provides an overview of the priority monitoring needs. Detailed monitoring plans will be needed in order to translate plans for cost estimates on capital costs and coincident guidance for funding guidance on support for operations and maintenance (similar to what is provided in the Section 1 network portfolios).

Table ES1. 2014 Chesapeake Bay Watershed Agreement 31 outcomes expressing monitoring needs categorized for network maintenance, enhancement, and/or new network establishment. (See Section 2 for more details.)

Goal	Outcome	Maintain	Enhance	Establish
Sustainable Fisheries	Forage Fish		x	x
	Fish Habitat		x	x
	Oysters	x	x	
	Blue Crab Abundance	x	x	
	Blue Crab Management	Outcome is complete		
Vital Habitats	Wetland		x	
	Black Duck		x	
	Stream Health		x	
	Brook Trout		x	
	Fish Passage	x		
	Forest Buffers	x	x	
	Tree Canopy	x	x	
	Submerged Aquatic Vegetation		x	
Water Quality	Watershed Implementation Plan (WIP) 2017	Outcome is complete		
	Watershed Implementation Plan (WIP) 2025		x	
	Water Quality Standards Attainment and Monitoring (WQSAM)	x	x	x
Toxic Contaminants	Toxic Contaminants Research			x
	Toxic Contaminants Policy & Prevention			x
Healthy Watersheds	Healthy Watersheds	x		
Climate Resiliency	Climate Monitoring and Assessment	x	x	x
	Climate Adaptation			x
Land Conservation	Protected Lands	x	x	x
	Land Use Methods and Metrics	x	x	
	Land Use Options Evaluation	x		
Stewardship	Citizen Stewardship	x		
	Local Leadership			x
	Diversity		x	x

Public Access	Public Access Site Development	x		
Environmental Literacy	Student	x		
	Sustainable	x		
	Environmental Literacy Planning	x		

Section 3 Summary: Partnership Opportunities to Enhance CBP Monitoring

A partnership approach is needed to address the vast scope of monitoring needs described in Sections 1 and 2 of this report. Partners include federal and state agencies, local governments, academic institutions, and nongovernmental agencies. The partners need to sustain CBP core networks and partner-led networks by increasing resources to adjust for inflation and replace outdated equipment. New resources will be needed to (1) enhance existing CBP networks, and to (2) establish new networks for Watershed Agreement outcomes that currently lack sufficient monitoring.

There is no single funding source available to enhance the existing CBP core networks or establish new networks. Funds from the Bipartisan Infrastructure Law (BIL), passed in 2021, offered a potential new source of funding but the opportunities for monitoring appear limited. The CBP received over $200M for five years from the BIL, and approximately $1.5M a year has been slated for monitoring. However, the BIL funding is only for five years so other longer-term funding sources will need to be explored. Therefore, monitoring partners will need to consider how to increase their respective monitoring programs to enhance existing CBP monitoring, sustain partner-led networks, and develop, establish and sustain new monitoring networks.

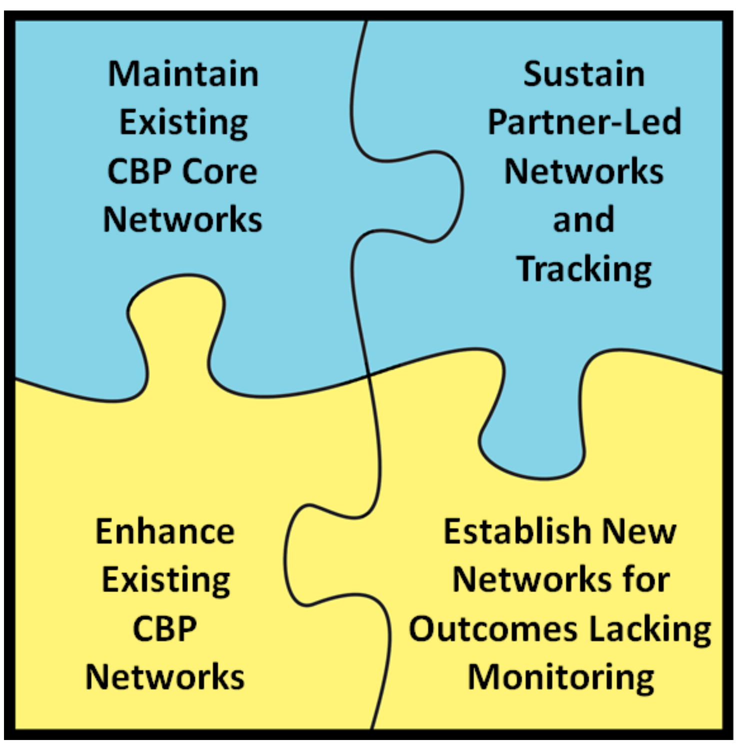

Figure ES2. Existing Chesapeake Bay Program (CBP) water quality monitoring networks and new monitoring needed to address the CBP Watershed Agreement Outcomes (CBP. 2014. Watershed Agreement). The top row illustrates existing monitoring efforts including the CBP core networks and partner-led monitoring to address CBP Watershed Agreement outcomes. The bottom row represents new monitoring needs that can be addressed by enhancing the CBP core networks or developing new networks for CBP Watershed Agreement outcomes without sufficient monitoring.

Section 4 Summary: Principals' Staff Committee Charge to the Monitoring Review Team and Foundational Assessment Results

The 9-month review process was used to gather the information for the foundational assessment provided in this report from the collective wisdom and experience of CBP monitoring representatives. The information has been synthesized and organized in this report as guidance to help the PSC strategically plan monitoring program support necessary to sustain and improve networks that address decision-support requirements of the CBP partnership. For each of the core CBP monitoring networks, the following information was collected, and foundational assessment findings summarized for 8 questions:

1. What is the status of the network?
2. What are the monitoring network's vulnerabilities?
3. What is the program's management strategy?
4. What gaps need to be filled to improve the CBP monitoring networks?
5. How can existing monitoring data and analysis be used to address these gaps?
6. What innovations are available?
7. Who are the partners in operationalizing the innovations?
8. What are potential financial needs associated with sustaining, growing and innovating the networks?

The Monitoring Review Team used the findings from the 8 questions to inform the structure and content expressed as monitoring needs. Guidance was further provided from CBP monitoring program managers, technicians and administrators for estimated costs of options for financial and technical gap-filling solutions identified during the review process. The options provided here fulfilled the PSC request for understanding the anticipated levels of funding needed to improve monitoring program capacities to address decision-support needs across the CBP partnership for core monitoring networks.

Moving Forward: Implementation Steps

Pursuing funds for monitoring investments that sustain and grow the decision-support capacity of the CBP partnership will require a long-term effort of increased collaboration between federal, state, academic and local monitoring programs (Figure ES3). The CBP plans to have an initial meeting of monitoring program managers so they can identify their interest in different investments to enhance existing CBP core networks. More detailed discussions would be conducted through the STAR Integrated Monitoring Networks (IMN) Workgroup. Establishing new monitoring networks would probably require a different approach, with collaboration between the CBP workgroup responsible for the outcome and the STAR IMN workgroup.

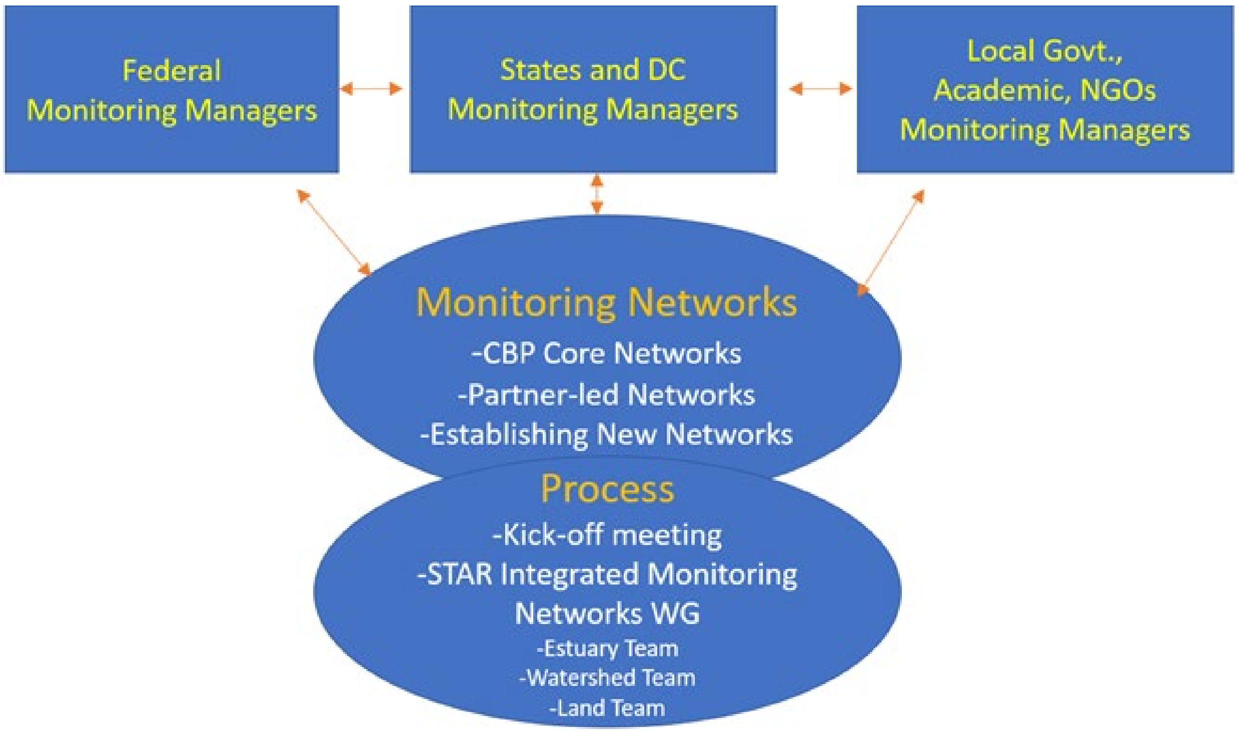

Figure ES3: Monitoring managers from different levels of government and academic partners that support Chesapeake Bay Program monitoring (boxes at top) would come together to address sustaining integrity and supporting growth of the Chesapeake Bay monitoring networks to meet decision-support needs (middle) through a kick-off meeting and subsequent discussions through the Scientific, Technical Assessment and Reporting (STAR) Integrated Monitoring Networks Workgroup (bottom). Subsequent meetings following the kick-off meeting could be organized for estuary, watershed, and land monitoring.

Glossary

- **Network:** Refers to an interconnected system of monitoring stations, equipment and personnel involved in monitoring a suite of criteria in order to track changes.
- **Management:** Refers to any management personnel at federal, state and local levels of leadership. Refers to the people in management positions, not their actions.
- **Watershed Management:** Refers to the activities of management (actions), including implementation actions.
- **Improve Monitoring**: Refers to increasing the number of network sites, and implementing improved protocols at network sites. If only one of these two improvement activities is meant, it will be specified.
- **Short-term:** Refers to a 0-to-5-year time frame.
- **Long-term:** Refers to a 5-to-10-year time frame.

Section 1: Chesapeake Bay Program Monitoring Network Portfolios

Significant detail on network characterization was provided during the monitoring review process. Characterization covered core monitoring network's history, operation status, funding and management vulnerabilities affecting CBP partners ability to maintain their capacity and integrity, as well as details about innovations and their potential applications to address decision-support data gaps (see Section 4). Network portfolios were developed as quick reference guides that deliver network characterization summaries with funding option menus and funding level summaries as requested by the PSC to inform network improvement investments. These portfolios are 1) Tidal Bay Long-term Monitoring, 2) Nontidal Monitoring, 3) Submerged Aquatic Vegetation (SAV), 4) Tidal Benthic, 5) Community Science, 6) Land Cover and Land Use (LCLU), and 7) Toxic Contaminant Monitoring programs and are structured with the following sections:

- **Recommendations:** Funding needs were summarized from the best understanding of funding needed to sustain long-term existing monitoring programs providing decision-support to the CBP partnerships, and options for monitoring improvements were identified that could fill reported data gaps affecting decision-support requirements. Decision support requirements include measurements needed to assess statutes, regulations and track CBP outcome commitments of the 2014 Chesapeake Bay Watershed Agreement. The needs assessment and understanding of cost estimates were developed by working with the CBP monitoring community during the review process.
- **Current Investment:** Investment information identifies the financial resources provided through grants and other agreements to support current monitoring program operation and maintenance as of the date of this report.
- **Status:** Highlights when the program was established or initiated and how it is implemented (stations in operation, sampling effort, etc.) as of the date of this report.
- **Innovations:** The items included as bullets describe how the program could advance based on implementing the recommendations offered.
- **Vulnerabilities:** The bullets identify the vulnerabilities that have been identified through this review.
- **Monitoring gaps:** Highlights decision-support data gaps the recommendations were developed to address.

The key findings of the monitoring assessment are based on engaging the CBP partnership on the status and needs of existing networks and addressing information gaps for 2014 Chesapeake Bay Watershed Agreement outcomes. The overview of recommendations and cost estimates for the initial priorities to improve CBP networks is provided in Table 1.1. Specific line-item recommendations are presented as a menu of investment opportunities in Table 1.2 with estimated costs for capital costs, and operations and maintenance support of monitoring program investments during the first 5 years.

Some of the overarching monitoring gaps and recommendations from the monitoring portfolios for both the estuary and watershed are listed below. In the process of making investments to sustain and grow network integrity and capacity, CBP partners may choose items that align with their priorities and will collectively improve monitoring toward multiple outcomes.

Table 1.1. Initial funding options and their applications for CBP networks providing support for assessing status and progress towards achieving 2014 Chesapeake Bay Watershed Agreement goals and outcomes.

2014 Chesapeake Bay Watershed Agreement Goal	Outcomes	Application of monitoring results	Enhanced data needed	Initial Cost Estimates	
				One-Time Capital Costs[1]	O&M (yearly)[2]
Water Quality	Water Quality Standards Attainment and Monitoring	Assess progress toward tidal water-quality standards	Dissolved oxygen/ salinity/temperature	$825K	$901K
			Annual SAV cover	$380K	$200K
			Summer benthic macrofauna	N/A	$3K
			Nutrient limitation	N/A	$275K
	WIP 2025	Assess watershed response to WIP2025 practices	Nontidal water quality	$551K	$674K
Vital Habitats	SAV	Assess progress towards 185K acre goal	Field verification and calibration data	$40K	$250K
Land Conservation and Habitat	Land Use methods and metrics development outcome; Riparian Forest Buffers, Tree Canopy	Assess changes in land data for listed outcomes.	Higher resolution land-change data for listed outcomes	N/A	$1.0M
Toxic Contaminants	Toxics Prevention and Policy	PCB assessment	Lab analyses of field samples	N/A	$276K
Totals				$1.8M	$3.6M
				Total costs[3] = $5.4M	

1. **Capital costs** are 1) continuous tidal and nontidal water quality monitoring sensor packages, 2) software supporting submerged aquatic vegetation monitoring, and 3) field equipment for community scientists.
2. **Operations and Maintenance (O&M)** costs are for 1) sustaining integrity of existing water quality and SAV annual programs and 2) costs to support the first year of new water quality, SAV, community science and toxics programs.

3. **Total costs** are the sum of Total infrastructure + the initial year of support needed to operate and maintain the investments.
    a. Network specific costs are provided below in Section 1 Chesapeake Bay Program Network Portfolios.
    b. Line-item cost projections for 5 years are further provided in Table 1.2 below.

Some of the priority data gap for monitoring in the estuary are:

- Short-temporal duration dissolved oxygen measurements: No tidal segment in the Chesapeake Bay has been assessed for its full suite of dissolved oxygen, water clarity/SAV and chlorophyll *a* criteria across all seasons and designated uses, largely as a function of the lack of data to support short-duration dissolved oxygen criteria assessment
- Cost effective intra-annual detail of SAV cover
- SAV calibration and verification data from sentinel sites
- Tidal water nutrient limitation assays

Without this information, the CBP can't fully assess progress for the following (1) attainment of water-quality standards, (2) implementation of nutrient- and sediment-reduction efforts, and (3) water-quality improvements to support healthy habitat for crabs, oysters, and other fisheries.

Recommended investments for existing CBP tidal estuary monitoring networks include:

<u>One-time capital investments:</u>

- Address short-duration dissolved oxygen criteria by establishing a high-frequency, water-column sensor system.
- Develop new SAV protocols for satellite image collection, data management, and Artificial Intelligence (AI) interpretation and alignment with historical data.
- Implement Chesapeake Bay SAV Sentinel Site Monitoring Program to inform AI development of satellite imagery and monitor changes in SAV habitat.
- Incorporate volunteer SAV Watchers data into Chesapeake Monitoring Cooperative database

<u>Long-term operations and maintenance costs include:</u>

- Continue to evaluate cost of living and inflation increases for personnel who support monitoring, best cost opportunities to sustain tidal water quality, tidal benthic macroinvertebrate, SAV, and hypoxia monitoring programs.
- Develop and implement 4D interpolator to ingest available data and output assessments for all frequencies provided for dissolved oxygen criteria.
- Enhancing network efficiency and capacity to maintain high frequency open water hypoxia monitoring program, both in terms of the monitoring equipment and the personnel.
- Management personnel for Sentinel Site Monitoring program
- Coordination for Community Science SAV Watchers Monitoring program to allow for broad-scale condition assessments and identifying and quantifying driver/response relationships.
- Conduct nutrient limitation survey to verify management progress predictions

Some of the priority data gaps that were identified for watershed monitoring include:

- Collection of more frequent data on nutrient and sediment loads to improve understanding of tidal water quality changes.
- Collection of more data specific to how water-quality practices provide benefits and improved understanding for other outcomes.

This information is critical to further explain the factors, such as changing land use and climate, that may affect the response of water-quality to assess the system response of nutrient and sediment-reduction efforts. Better targeting the placement of nutrients and sediment reduction practices in agricultural and other watersheds and assessing water-quality response in local waters.

Recommended investments for existing CBP Watershed Networks include:

<u>One-time capital investments include:</u>

- Add continuous monitoring equipment at River-Input monitoring (RIM) stations and strategic Lower Susquehanna Reservoir stations to better detect changes in nutrient and sediment concentrations and understand watershed and tidal water quality response to management actions. In calendar year 2022, 5 of the 9 RIM stations now have continuous monitoring
- Increase continuous monitoring infrastructure in selected small watersheds to: assess water-quality response; better understand management effectiveness; and inform targeting of nutrient and sediment practices.
- Land cover and land change monitoring to improve tracking of CBP outcomes for evaluating land matrices, tree canopy cover, forest buffers distribution and extent, and tracking of Best Management Practice, to explain patterns, trends and response to management practices, and potential benefits to other outcomes.

<u>Longer-term operational costs include:</u>

- Increase grant funding to sustain existing Nontidal Network (NTN) sites and improve monitoring in the Susquehanna basin.
- Maintain new continuous monitoring stations of major river RIM stations and strategic Lower Susquehanna monitoring sites to enhance network efficiency and capacity.
- Support a coordinator position for community science nitrate monitoring program to address gaps in understanding water quality improvements from restoration practices.

Table 1.2. Recommendations to improve Chesapeake Bay Program monitoring with line-item cost projections for a 5-year planning horizon.

CBP Network	Recommendation	Category	Funding				
			Year 1	Year 2	Year 3	Year 4	Year 5
Tidal	Equipment and Supplies for 8 advanced vertical sensor array stations.	Capital Cost	$500,000				
Tidal	Support operation and maintenance of vertical sensor arrays	Operation & Maintenance	$300,000	$315,000	$330,750	$347,288	$364,652
Funder							
Tidal	Sustain Existing Tidal Water Quality Program	Operation & Maintenance	$304,000	$394,000	$484,000	$584,000	$684,000
Funder							
Tidal	4D Interpolator Development	Operation & Maintenance	$60,000	$60,000	$60,000	$60,000	$60,000
Funder							
Tidal	Calibrate and Verify Models for Nutrient Limitation Survey	Operation & Maintenance	$275,000	$275,000			
Funder							
Tidal	VADEQ 3% COLA (WQ and Benthic)	Operation & Maintenance	$30,000	$30,900	$31,827	$32,782	$33,765
Funder							
SAV	Gathering Satellite Imagery	Capital Cost				TBD	TBD
Funder							
SAV	Develop SAV protocols for AI interpretation of diverse satellite imagery	Capital Cost	$240,000 (cumulative for 3 Yrs)				
Funder			NASA, ODU	NASA, ODU	NASA, ODU		
SAV	Develop SAV protocols to convert AI produced maps to layers like those manually created	Capital Cost	$140,000 (cumulative for 2 Yrs)				
Funder							
SAV	Calibrate and align the use of aerial images and satellite images	Operation & Maintenance	50,000	50,000	$50,000		
Funder							

SAV	Proof of Concept: Test AI satellite-derived assessment on spring *Zannachelia* survey	Operation & Maintenance	$150,000	$150,000			
Funder							
SAV	Management of Sentinel Site Monitoring Program	Operation & Maintenance	$120,000	$123,600	$127,308	$131,127	$135,061
Funder							
SAV	SAV Monitoring Program 5% COLA	Operation & Maintenance	$17,500	$18,375	$19,294	$20,258	$21,271
Funder							
Benthic	VA Benthic Monitoring Program*	Operation & Maintenance	*included in TIDAL VADEQ program COLA	*included in TIDAL VADEQ program COLA	*included in TIDAL VADEQ program COLA	*included in TIDAL VADEQ program COLA	*included in TIDAL VADEQ program COLA
Funder							
Land Use & Land Change	High resolution image acquisition and processing	Operation & Maintenance	$1,000,000	$1,000,000		$1,000,000	$1,000,000
Funder							
Nontidal	Adding 7 RIM Continuous Monitoring sensor packages	Capital Cost	$325,000				
Funder							
Nontidal	Adding 3 Lower Susquehanna Reservoir Input Continuous Monitoring sensor packages	Capital Cost	$126,300				
Funder							
Nontidal	Sustain new RIM Continuous Monitoring Network	Operation & Maintenance	$210,000	$214,200	$218,484	$222,854	$227,311
Funder							
Nontidal	Sustain new Lower Susquehanna Reservoir Continuous Monitoring Network	Operation & Maintenance	$125,570	$146,380	$148,576	$150,804	$153,066
Funder							
Nontidal	10 more discrete samples at Marietta annually	Operation & Maintenance	$17,460	$17,460	$17,722	$17,988	$18,258
Funder							
Nontidal	Sustain existing Nontidal Network with PADEP	Operation & Maintenance	$233,000	$233,000	$233,000	$233,000	$233,000
Funder							
Nontidal	Annual Risks Coverage: Station loss backfill	Operation & Maintenance	$45,000	$45,000	$45,000	$45,000	$45,000

Funder							
Nontidal	Adding 5 Small Watershed Continuous Monitoring stations	Capital Cost	$375,000				
Funder							
Nontidal	Sustain 5 new Small Watershed Continuous Monitoring stations	Operation & Maintenance	$150,000	$157,500	$165,375	$173,644	$182,326
Funder							
Community Science	Build out an Application Programming Interface (API) to streamline way to access and use the data in Data Explorer	Capital Cost	$50,000				
Funder							
Community Science	SAV Watchers Database Development	Capital Cost	$30,000				
Funder							
Community Science	SAV Watchers Database Management	Operation & Maintenance	$10,000	$10,300	$10,609	$10,927	$11,255
Funder							
Community Science	Volunteer SAV Watchers Program & Nitrate Monitoring Program	Operation & Maintenance	$205,000	$211,150	$217,485	$224,010	$230,730
Funder							
Community Science	Equipment and supplies for 5 under-represented community monitoring groups	Capital Cost	$10,000				
Funder							
Toxics	Adding 3 sites in 1 geographic-focus area to monitor PCB response to management efforts	Operation & Maintenance	$276,000	$289,800	$304,290	$319,505	$335,480
Funder							
Total		Capital Cost + Operation & Maintenance	Year 1 = $5,374,830	Year 2 = To Be Determined (TBD)	Year 3 = TBD	Year 4 = TBD	Year 5 = TBD

Tidal Long Term Water Quality Network

RECOMMENDATIONS

- $304,000 Yr1, increasing by $90,000 per year for Yr2 & Yr3 and $100,000 per year for Yr4 & Yr5. Operations. Support network sustainability and integrity. Annual cost to tidal network funding addressing existing cost of living impacts in MD.
- $500,000. Capital Cost. Enhance hypoxia network efficiency and capacity with one time purchase of equipment and supplies for 8 advanced vertical profile water quality monitoring stations.
- $300,000 Yr1, Plan annual increase of 5% COLA. Operations. Deploy and maintain the expanded hypoxia monitoring network arrays to address short duration water quality criteria and fish habitat health assessment.
- $275,000 Yr1 – Yr2. Operations. Nutrient limitation annual survey. Verify predictions on management progress, calibrate bay models.
- $30,000 Yr1, Plan 3% annual COLA. Operations. Accounting for VADEP COLA.
- $60,000 Yr1 – Yr5. Operations. Design & implement the 4-D interpolator. Support water quality criteria attainment assessments.
- **Total Capital cost investment need**: $500,000
- **Total Operations and maintenance annual investment need**: $969,000 Yr1, requiring increases to accommodate COLA needed each year in Yrs 2-5 depending on recommendation.
- ***Funding for data analysis and reporting are not included the estimates.**

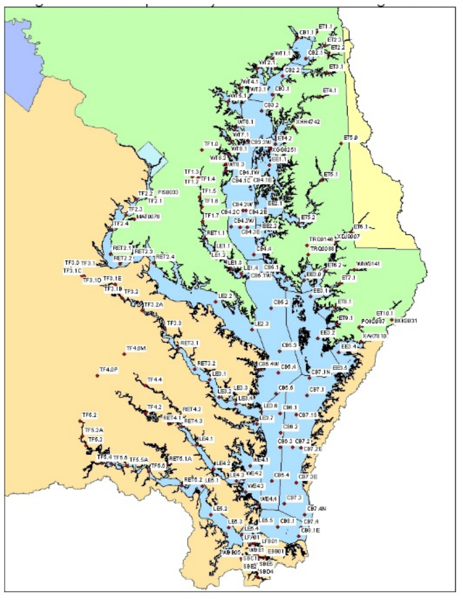

Figure 1. Tidal Bay Monitoring Program locations

CURRENT INVESTMENT: Approximately $2.7M. Federal Clean Water Act 117e program funds which includes 1:1 matching support from grant partners.

STATUS: The current tidal monitoring network was established in 1984, its first full year was 1985. There are 154 active stations sampled for physical, chemical, and biological measures throughout the water column with Bay-wide consistent collection and analysis protocols. One or more monitoring sites are located in each of the 92 Bay segments. Stations are sampled 1 or 2 times per month depending on location and season. Targeted sampling occurs in shallow water in a limited number of Bay segments each year including mapping surface water quality and/or providing continuous (i.e., every 15 minutes) water quality measures at one depth for a fixed location in a season. Statistical analyses are used to report annual and seasonal trends. Some water quality criteria are evaluated. An indicator is used to estimate water quality standards attainment.

INNOVATIONS:

- Robust, cost-effective continuous monitoring sensor units (vertical arrays) for open water, shallow and deep water, water column water quality monitoring (dissolved oxygen, salinity and temperature)
- “Big data” management.
- Advanced statistical analyses

VULNERABILITIES:

- Annual cost of living increases have not been built into funding support and fixed annual funding has been a normal practice. Fixed annual funding leads to less buying power through time. Capacity has declined with fixed financing of the network.
- States applying matching funds in the Clean Water Act 117e monitoring grant may apply significant levels of non-monitoring program dollars to meet the monitoring match obligations. Reductions in monitoring capacity have occurred. Meeting match obligations has and will be a challenge based on current conditions.
- Higher cost options to replace aging Infrastructure factors into costs for sustaining program operations.

MONITORING GAPS:

- Short duration water quality (dissolved oxygen, salinity and temperature) supporting criteria attainment assessment with water quality standards.
- Shallow-water monitoring representation.
- Annual full bay water clarity and chlorophyll measures and assessment

NONTIDAL NETWORK – WATERSHED MONITORING

RECOMMENDATIONS

- $325,000. Capital Cost. Enhance network efficiency and capacity. One time purchase of equipment and supplies for 5 advanced RIM continuous water quality monitoring stations equipped with 6-parameter continuous water quality monitoring sensor arrays.
- $126,300. Capital Cost. Adding 3 Lower Susquehanna Reservoir continuous monitoring sensor packages in Pennsylvania (Marietta).
- $375,000. Capital Cost. Adding 5 Small Watershed Continuous Monitoring stations (locations TBD).
- $150,000, Plan 5% COLA. Operations. 5 new small watershed continuous monitoring sites.
- $233,000. Operations. Annual network sustainability and integrity. PADEP.
- $210,000 Yr1, Plan 2% COLA. Operation. Sustain 5 new RIM continuous monitoring network sites + 2 (Potomac & Susquehanna) funding ends FY22.
- $125,570 Yr1, Plan for COLA increase. Operation. Sustain new Lower Susquehanna continuous monitoring stations.
- $17,460 Yr1, Plan 1.5% COLA after Yr2. Operation. Adding 10 more discrete samples at Marietta annually. Costs align with Conowingo protocols.
- $45,000 Yr1 – 5. Operation. Annual Risks Coverage: Station loss backfill.
- **Total Capital cost investment need**: $826,300
- **Total Operations and maintenance annual investment need**: $781,030 Yr1, estimated growth for Yrs 2-5.
- ***Funding for data analysis and reporting are not included.**

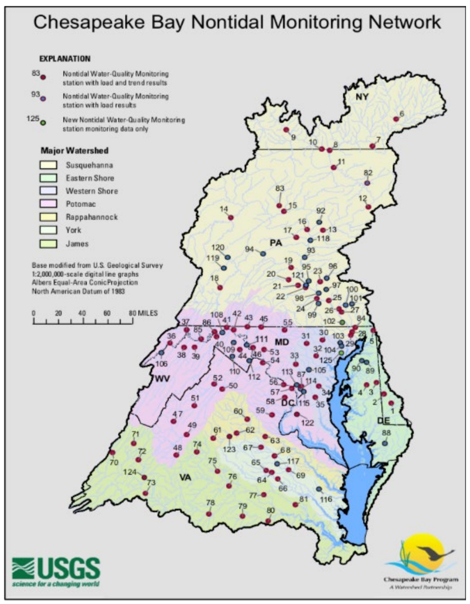

Figure 1. Chesapeake Bay Nontidal Monitoring Network.

CURRENT INVESTMENT: EPA 117e grants and USGS-EPA IAG. Approximately $2.3M. Includes State match 1:1 on 117e grant funding.

STATUS: The current nontidal water quality monitoring network has 123 monitoring stations. The network was established with 85 stations in September 2004 with the signing of a Nontidal Network (NTN) Memorandum of Understanding (MOU). The MOU aligned the seven jurisdictions, the Susquehanna River Basin Commission, and USGS under an agreement to use the same set of standardized sample and analysis protocols for NTN operations. Protocols were based on USGS field sampling methods and EPA-approved analytical lab methods. Approximately $2M was invested from EPA between 2009-2012 to expand the network into small watersheds, coastal plain geography, and under-represented land uses. Advanced statistical analyses are used to report streamflow statistics, monthly and annual nitrogen, phosphorus and suspended sediment loads, as well as 10-year and long-term trends in loads. https://cbrim.er.usgs.gov/

INNOVATIONS:

- Robust, cost-effective continuous monitoring sensor units including nutrient (nitrate) sensors for concentration and load measurement support
- "Big data" management
- Advanced statistical analyses

VULNERABILITIES:

- The cost of living is increasing, but the level of funding towards the program is staying fixed.
- Meeting the Clean Water Act 117e match obligations has and will be a challenge based on current conditions, reducing the amount of funding towards monitoring.
- Unpredictable changes in partner support threatens network integrity on an annual basis, lessening the ability to assess the water-quality response to nutrient reduction efforts being implemented.

MONITORING GAPS:

- Need for high temporal frequency monitoring which supports detection of water quality change through time more quickly due to the power of enhanced data density.
- Spatial representation of our network has diverse watershed sizes. Small watersheds are underrepresented. Targeted monitoring in small watersheds where significant BMP actions are planned and underway are important.
- Under-representation of coastal plain geography and single-land use monitoring station positions remain important to network growth considerations.

Submerged Aquatic Vegetation (SAV) Network

RECOMMENDATIONS

- $240,000. Capital cost. Support additional field data to develop algorithms to advance use of Artificial Intelligence (AI) for interpretation of diverse satellite imagery. ***Funding secured at the start through NASA partnering with ODU and CBP SAV Workgroup.
- $140,000 Cumulative for 2 Yrs. Capital cost. Invest in work on converting AI produced maps to layers like those manually created.
- $120,000 Yr1, Plan 3% COLA. Operations. Invest in Sentinel Site Program which is necessary to obtain and process the samples needed to determine biomass, productivity, and consequently carbon sequestration of the Bay's SAV. Additional growth required each year for five years, totaling $552,564.
- $150,000 each year for Yr1 - 2. Operations. Proof of Concept: Test AI satellite-derived assessment on spring *Zannachelia* survey
- $50,000 First year is Yrs3. Operations. An investment for additional staff time needed to collect, calibrate/align aerial and satellite images.
- $17,500 Yr1, Plan 5% COLA. Operation. Accounting for SAV Monitoring Program maintenance and cost of living adjustment.
- TBD Yr4 - 5. Infrastructure. Confirm continuous partnership to gather satellite imagery. Cost will depend on negotiations and policies between Govt and companies.
- **Total Capital Cost investment need:** $380,000 ***$240,000 already secured, Uncertain funding estimate for gathering satellite imagery due to future negotiations.
- **Total Operations annual investment need: Yr1** $337,500
- *** Funding for data analysis and reporting are not included.**

Current Investment:

Salary + Fringe: $163,000
Flights contract: $150,000
Meetings * Supplies: $2,500
Indirect Costs: $78,188
Total EPA cost: $393,806

Additional Sources (VIMS Match, VA Legislature, CZM, MDE, MDDNR):
Salary + Fringe: $308,000
Indirect Costs: $33,000
Flights contract: $18,000

Total cost:
Salary + Fringe: $471K
Flights: $168K
Meetings/Supplies: $2.5K
Indirect Costs: $111K
Total: $752K

Status:

Annual Bay-wide SAV monitoring is required by statute and is essential to reaching the Chesapeake Bay tidal water 185,000-acre SAV restoration goal. Currently, SAV monitoring towards goal achievement in the Chesapeake Bay is dependent on the Baywide annual aerial survey conducted by the Virginia Institute of Marine Science (VIMS) for the assessment. This survey consisting of 188 flight lines is a broad-scale assessment that characterizes SAV acreage and density. A volunteer-based ground survey program, the Chesapeake Bay SAV Watchers supplements the aerial survey by providing data on more specific species and habitat. A higher-level monitoring action, SAV Sentinel Site Program, is in development, but it is not presently funded.

Vulnerabilities:

- Aerial survey imaging is subject to weather with climate change effects; contractor availability/costs.
- SAV Watchers, volunteer-based monitoring support was hindered by COVID and potential future health crises.
- The cost of living is increasing, but the level of funding towards the program is staying fixed.
- Meeting the Clean Water Act 117e match obligations has and will be a challenge based on current conditions, reducing the amount of funding towards monitoring.

Innovations:

The NextView License allows federal agencies to request satellite imagery from contracted commercial sources and obtain the imagery at no cost. Based on the results and recommendations from a STAC Workshop, satellite imagery can be used for SAV assessment if it is available. However, pilot studies thus far indicated mapping SAV throughout the Bay will require a coordinated targeting and tasking of operations, and these issues may be alleviated with targeted acquisition of imagery, new satellite image sources (e.g., PlanetScope), and additional funding for staff time. AI image assessment shows increased promise for use in the Chesapeake Bay.

Monitoring Gaps:

- Additional field data are necessary to fully train algorithms in the use of AI to accurately detect and quantify SAV from satellite imagery.
- Understanding how climate change impacts will directly affect SAV and determine if it will limit ability to reach Bay-wide SAV restoration targets.
- Quantifying the ability of freshwater, mesohaline, and polyhaline SAV to sequester carbon.
- Determine if microplastics are affecting the health of the Bay's SAV beds and if those beds are serving as sources/sinks.

TIDAL BENTHIC MONITORING

RECOMMENDATIONS

- Sustain summer season benthic monitoring. MD sustaining funds are set for the next 5 years of the program.
- Operation. Plan 3% COLA for VADEQ programming. Dollars here are a subset of total VA DEQ need identified in Tidal WQ monitoring.
- ***Funding for data analysis and reporting not included.**

Virginia	Year 1	Year 2	Year 3	Year 4	Year 5
COLA Increase included in VA DEQ Tidal WQ	$3,000	3% COLA	3% COLA	3% COLA	3% COLA

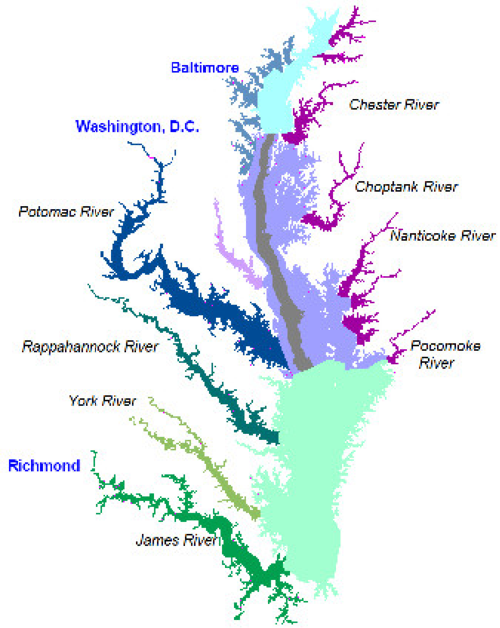

Figure 1. Tidal Benthic Monitoring Region.

STATUS: The current Chesapeake Bay Long-term Benthic Monitoring Program initiated in Maryland in 1984 and in Virginia in 1985. The program consists of two elements: a fixed-site monitoring sampling effort (53 sites) directed at identifying trends in benthic condition, and a probability-based sampling effort (≈200 random sites) intended to create an index which estimates the area in MD and VA with benthic communities meeting or failing to meet the Chesapeake Bay Program's Benthic Community Restoration Goals. The program historically consisted of separate spring and summer season monitoring, but the spring season monitoring was eliminated in 2009 due to funding constraints. The summer season monitoring program is conducted between July 15th and September 30th.

VULNERABILITIES:

- The cost of living is increasing, but the level of funding towards the program is staying fixed. If current funds are reallocated to account for COLA, there would be monitoring cuts. Without investments towards cost of living, partners will not be able to maintain data collections and sample processing support, and the program will not be able to attract or may lose valuable employees.
- Meeting the Clean Water Act 177e match obligations has and will be a challenge based on current conditions, reducing the amount of funding towards monitoring.

CURRENT INVESTMENT:

The Tidal Benthic Monitoring Program is supported by a partnership between the Maryland Department of Natural Resources, Virginia Department of Environmental Protection, and EPA Chesapeake Bay Program. Based on the 117e grant, estimated funding from MD is $212k, and the estimated funding from VA is $233K. MD DNR recently went through a process with the Board of Public Works to set up a 5-year benthic contract to look at the tidal waters that requires no additional support.

MONITORING GAPS:

- Presently there are no monitoring gaps associated with this program. During this monitoring program review, CBP partners did not see a need to reinstate the spring season benthic monitoring due to various reasons – lack of use of benthic data for tidal waters, no interest from management, and extensive time needed to build a base dataset suitable to assess trends.
- The Academic Community remains interested in a spring season benthic monitoring program element for understanding the state of the Bay, diagnostic differences between seasons, and tracking status while seasons transition. This may be a topic for reconsidering future support. There is spring data from the 1980's to 2009 if researchers want to use it to investigate changes in response to ecosystem changes through time.

Community Science Monitoring

RECOMMENDATIONS

- $50,000. Capital Cost. Build Application Programming Interface to streamline access and use of Data Explorer.
- $30,000. Capital Cost. SAV Watchers Database phase of development.
- $10,000. Capital Cost. Equipment and supplies for 5 underrepresented community monitoring groups.
- $10,000 Yr1, Plan 3% COLA. Operation. SAV Watchers Database Management.
- $205,000 Yr1, Plan 3% COLA. Operation. Volunteer SAV Watchers & Nitrate Monitoring Program.
- **Total Capital Costs investment need:** $90,000
- **Total Operations annual investment need: Yr1** $215,000, Plan 3% COLA
- ***Funding for data analysis and reporting not included.**

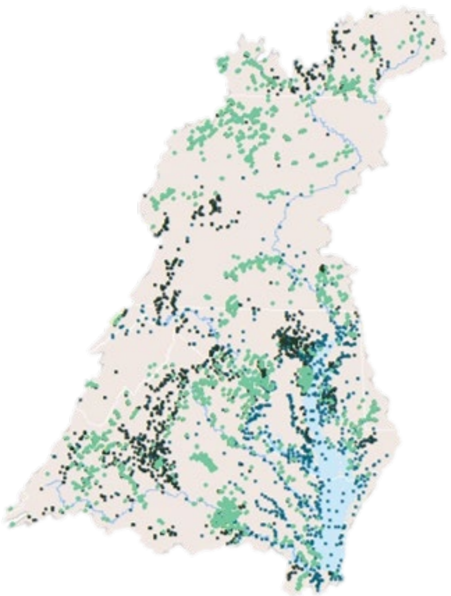

Figure 1. Community Science Monitoring Program. Blue represents Chesapeake Bay Program samples, black represents volunteer monitors, and green represents CMC integrated volunteer monitoring data locations

Current Investment:

EPA 6-year award approximately $470K per year. The first year of the grant was 2021.

Status: The Chesapeake Monitoring Cooperative (CMC) is a partnership that aims to provide technical, logistics, and outreach support for the integration of volunteer-based and nontraditional water quality and benthic macroinvertebrate monitoring data into the CBP partnership. The CMC is supported by the following partner organizations that act as service providers – The Alliance for the Chesapeake Bay, The Izaak Walton League of American, Dickinson College's Alliance for Aquatic Resource Monitoring, University of Maryland Center for Environmental Science, Chesapeake Bay National Estuarine Research Reserve in Virginia. They work with over 100 community and volunteer-based monitoring groups and integrate data into the Data Explorer which has over 365,000 volunteer-based water quality and macroinvertebrate monitoring data points in it. These data are publicly available and used to enhance the understanding of the health of the Chesapeake Bay watershed.

Innovations: In 2018, all CBP partner jurisdictions signed the Citizen Science data use MOU. Going forward, per the policy underpinning the MOU, the jurisdictions and EPA need to include approved citizen science (now "Community Science") data available into water quality standards attainment assessments, thus enhancing CBP capacity and filling data gaps in space and time left by shortfalls of the long-term tidal water quality monitoring program. Similar support by CMC is occurring the Stream Health outcome data needs in the watershed.

Vulnerabilities:

- Volunteer retention is about 1 to 5 years that can cause temporal and spatial gaps in the data when there is turnover.
- A volunteer group may earn a grant for 2 – 3 years, but there are no sustainable funding sources to guarantee funding for future years.
- Improve capacity of underrepresented communities. These communities do not have the capacity and resources to apply to grants to start or support local monitoring programs.
- Rising lab costs hindering promotion of groups to Tier 3 and supporting Chesapeake Bay Watershed trends and assessments.

Monitoring Gaps:

- Developing QA guidelines for non-traditional partners to use as alternatives for conventional sample analysis methods.
- More engagement between jurisdictions and CMC to integrate community science and nontraditional partner data into state assessment programs.
- Expand nontidal benthic sampling to fill gaps in space over time to support the CBP Stream Health Indicator which currently requires modeling for 50% of the watershed.

Land Use and Land Cover Monitoring Network

RECOMMENDATIONS

- $1,000,000 Yr1, Yr2, Y4, Yr5. Operation. High resolution image acquisition and processing.

- **Total Operations and maintenance annual investment need**: $4,000,000
- ***Funding for data analysis and reporting are not included in the estimate.**

Recommendation	Year 1	Year 2	Year 3	Year 4	Year 5	Total
High rez LULC	$1,000,000	$1,000,000	---	$1,000,000	$1,000,000	$4,000,000

Current Investment: In the summer of 2018, a six-year, $7.5 million Cooperative Agreement was awarded to the Chesapeake Conservancy (CC). The Cooperative Agreement allows the CBP Partners to actively participate in the development of products and enables adjustments to the scope to address evolving technology and partnership needs.

There is currently no funding or plan in place to continue this 1-m² resolution land use/land cover (LULC) change monitoring effort. The current Cooperative Agreement includes additional funding to award CC and University of Vermont for support. If the next agreement doesn't include additional support, all the work will go to the CBP GIS team which will limit the capacity of the team to support GIS needs for the rest of the CBP efforts to address all 31 Agreement outcomes.

Status: The temporal baselines are the years 2013 (New York, Pennsylvania, District of Columbia, Delaware, and Maryland) and 2014 (Virginia, and West Virginia) for which 1-m² resolution LULC data exist for all counties located within the Bay watershed. "Hot spots" of land change will be monitored every two years while completing watershed-wide remapping of these counties every four years (2017/18, 2021/22). In March 2022, the U.S. Geological Survey, CC and University of Vermont released the 1-m² spatial resolution LULC data products based on 2013/14 and 2017/2018 National Agriculture Imagery Program (NAIP) data along with change products from the data. The datasets will inform multiple outcomes in the 2014 Chesapeake Bay Watershed Agreement, reinforcing the need to re-solicit a Cooperative Agreement to monitor LULC change every 4-5 years through 2030 and institutionalizing high-res LULC monitoring in the Bay watershed. The current six-year Agreement with the CC expires in June 2024. To ensure the timely production of data for the year 2025, a new RFP will need to be issued by summer 2025 to establish a new Cooperative Agreement by winter 2025.

Innovations:

- Increased affordability of high-resolution satellite spectral data
- Increased affordability and precision of LiDAR imagery
- Advancements in artificial intelligence for mapping and predicting land use/cover conditions and change.

Vulnerabilities:

- If high-resolution monitoring of land cover and land use discontinues, the CBP Partners will only have data spanning an eight-year period which happens to correspond to a period with slow economic growth. A better understanding of how the land changes through time is critical to assess progress towards the TMDL and other goals in addition to serving as the foundation for future watershed and land change model calibration and parameterization. A longer monitoring period is needed to better capture the breadth of phenomena that impacts water quality, watersheds, and communities. Continued technological advancements hold promise to reduce the costs and improve the quality of land change monitoring.

Monitoring Gaps:

- Land Use monitoring metrics cannot monitor wetland change effectively across time. If CBP partners want to track wetland change, a study is needed on available approaches.
- Gap of temporal record prior to 2013 with classification that can be used now. There is currently no way to understand land change prior to 2013, but if land use/land cover monitoring is continually supported, by 2030, there will be 16 years of data. There will be no uncertainty of land change during that period.

Toxic Contaminant Monitoring

RECOMMENDATIONS

- Focus monitoring in geographic focus-areas to help the jurisdictions assess PCB response where mitigation actions are being implemented or planned.
  - Initiate 3 monitoring sites in a single geographic-focus area as a proof-of-concept.

Recommendation	Year 1	Year 2	Year 3	Year 4	Year 5	Total
PCB Monitoring	$276,000	$289,800	$304,290	$319,505	$335,480	$1,525,075

Figure 1. Impaired waters based on PCBs as of 2017.

Current Investment:

There are no CBP investments towards PCB monitoring.

In general, there is limited monitoring for PCB concentration and distribution response to mitigation efforts by jurisdictions, particularly at a scale of interest to the CBP (i.e., broader than a single contaminated site).

Status: The Toxic Contaminant Workgroup (TCW) reviewed the two toxic contaminant outcomes in the 2014 Chesapeake Bay Agreement to identify items related to monitoring. TCW decided to focus efforts on their highest priority need, "*Enhance PCB monitoring to (1) assess current conditions and identify impairments, (2) better define sources to focus mitigation efforts, **(3) characterize PCB response to mitigation efforts** and (4) evaluate fish conditions in relation to consumption thresholds.*" The proposed monitoring recommendation and information provided is focused on part 3.

Fish tissue monitoring is done by all the jurisictions to assess current conditions and to track progress for fish consumption advisories. Sampling is usually done on a rotational basis to cover an entire jurisdction every several years. These results are used to establish baseline conditions and identify impaired waters in each state, that is updated every two years, and development of local TMDLs to address the impairments. In selected places with impairments, additional sampling is often conducted to help develop and implement a local TMDL. If a PCB TMDL is developed to address an impairment, "track-back studies" are often employed to better define the sources of PCBs to better focus mitigation efforts. The number of current track-back studies vary by jurisdiction. While there is no Bay-wide PCB TMDL today, assessments show 83.7% of the 92 Bay TMDL segments are partially or fully impaired from PCBs.

Vulnerabilities:

- There are limited management actions being implemented for PCBs reductions at this time across the watershed
- The PCB data for fish are more robust than surface water in terms of frequency and consistency of collection. A focus on fish data and sampling would provide more opportunities for leveraging existing monitoring efforts and in some cases a comparison to historical data but may take longer to detect the reduction in PCB concentrations.
- Lab methods for both fish analysis and surface water samples are different across the jurisdictions.

Monitoring Gaps:

- Highest: Assessing changes in PCB concentrations due to management actions.
- Middle: Assessing contaminants of emerging concern (focus on PFAS and microplastics).
- Middle: Assessing contaminants of widespread concern (specifically, pesticides).
- Lowest: Changes in mercury from management actions.

Section 2: Chesapeake Bay Watershed Agreement Goals and Outcomes' Monitoring Needs

There are a vast set of monitoring needs for assessing progress towards meeting the Goals and Outcomes in the 2014 *Chesapeake Bay Watershed Agreement (CBP 2014) (hereafter, 2014 Watershed Agreement)*. The monitoring needs of the ten goals and related outcomes are summarized in this section. A recent effort (https://www.chesapeakebay.net/documents/2021_Outcome_Attainability.pdf) charged by the Management Board evaluated progress toward achieving management targets for each of the 31 outcomes associated with the 10 goals. Challenges were identified in meeting some outcomes including some not having identified quantifiable targets, a lack of information to track progress, or needing a significant change in course of action to attain the outcome. While some outcomes have work supporting progress toward management targets and can maintain their present course of actions, alternatives, and solutions to guide other outcomes towards success will require enhancing a monitoring network. Enhanced monitoring networks may require a more coordinated and efficient effort or developing new monitoring networks for outcomes lacking sufficient monitoring.

The existing Chesapeake Bay Program (CBP) networks have primarily focused on assessing water-quality standards in the estuary, and changes in nutrient and sediment conditions in the watershed (Wardrop and Haywood 2009). The water-quality monitoring programming remains a partnership priority due to regulatory mandates of the Clean Water Act (1972). However, CBP partners further have a commitment outlined in the 2014 Watershed Agreement to sustain and grow monitoring so they can better assess progress toward achieving the Agreement outcomes.

The monitoring needs for all the outcomes in the *2014 Watershed Agreement* were gathered and updated using the Strategic Science and Research Framework (SSRF) and meetings between the Scientific, Technical Assessment and Reporting Team (STAR) and Goal Implementation Teams (GITs) and their associated workgroups. The SSRF is used to consistently identify and assess both short- and long-term science needs of the CBP partnership. These science needs are captured and tracked in the CBP Science Needs Database, which is continually updated throughout the year. Through the SSRF, the CBP can better look at science needs across the program, assess whether those needs are being met, and recommend approaches to address them.

As of March 2022, The CBP Science Needs Database (https://star.chesapeakebay.net/) contains approximately 111 monitoring related needs (e.g., data gathering, analysis) collected through SSRF, so Goal Implementation Teams and workgroups were asked to provide input on their priorities for each outcome. Multiple outcomes have a successful monitoring network, but it is pertinent they are maintained so outcomes may continue tracking their progress. Also, while these networks exist, all of them do not have dedicated funding.

For most of the outcomes, monitoring is insufficient and requires an enhanced framework for incorporating monitoring and collaborating with partners or a new monitoring network established because they lack the necessary data to support production of tracking metrics. The details for each monitoring need vary from a topic of interest throughout the partnership to providing monitoring design considerations. There are no cost estimates to address the monitoring needs in this section of the report because more effort would be needed on network design and costs. To support the partners' commitment to achieving all the outcomes, unmet monitoring needs will continue to be presented to the PSC (Principals' Staff Committee) as they become more well defined and structured. Upcoming efforts to outline scientific and monitoring needs for some outcomes are included in Appendix B. The short-term efforts to sustain and enhance monitoring programming identified in this report include a range of activities:

- Continued support of core CBP monitoring networks and partner monitoring programs
- Develop monitoring objectives and network design criteria
- Establish tracking methods
- Refine and expand current tracking methods
- Inventory existing monitoring programs that may meet these criteria
- Work with partners conducting existing monitoring to consider potential modifications
- Identify gaps where additional resources are needed
- Identify and incorporate newly advanced monitoring technology
- Pursue funding opportunities to fill the gaps

All these activities would require additional partnership capacity to help Goal Implementation Teams, workgroups, and the CBP Monitoring Team to design and implement activities and opportunities. A balance needs to be reached in the effort of improving water quality networks and the effort allocated to the unmet monitoring needs for all the outcomes in the *2014 Watershed Agreement*.

Monitoring needs for Goals and Outcomes

The Outcome leads were given the choice to present their monitoring needs solely through the information available in the Science Needs Database or provide a statement detailing their need and its use in management decisions. Outcomes' monitoring needs are categorized in Table 2.1 by those needed to be maintained, enhanced, or established. Table 2.1 provides a Spring 2022 accounting of the priority monitoring needs by each outcome in the 2014 Watershed Agreement. Below the table are outcome-specific details that define the status of data collections, data needs and indicator developments to be used to establish status of progress toward an outcome target and track change over time toward achieving the outcomes.

Table 2.1 2014 Chesapeake Bay Watershed Agreement 31 outcomes expressing monitoring needs categorized for network maintenance, enhancement, and/or new network establishment. (Last updated May 2022)

		Maintain	Enhance	Establish
Goal	**Outcome**			
Sustainable Fisheries	Forage Fish		x	x
	Fish Habitat		x	x
	Oysters	x	x	
	Blue Crab Abundance	x	x	
	Blue Crab Management	Outcome is complete		
Vital Habitats	Wetland		x	
	Black Duck		x	
	Stream Health		x	
	Brook Trout		x	
	Fish Passage	x		
	Forest Buffers	x	x	
	Tree Canopy	x	x	
	Submerged Aquatic Vegetation		x	
Water Quality	Watershed Implementation Plan (WIP) 2017	Outcome is complete		
	Watershed Implementation Plan (WIP) 2025		x	
	Water Quality Standards Attainment and Monitoring (WQSAM)	x	x	x
Toxic Contaminants	Toxic Contaminants Research			x
	Toxic Contaminants Policy & Prevention			x
Healthy Watersheds	Healthy Watersheds	x		
Climate Resiliency	Climate Monitoring and Assessment	x	x	x
	Climate Adaptation			x
Land Conservation	Protected Lands	x	x	x
	Land Use Methods and Metrics	x	x	
	Land Use Options Evaluation	x		
Stewardship	Citizen Stewardship	x		
	Local Leadership			x
	Diversity		x	x

Public Access	Public Access Site Development	x		
Environmental Literacy	Student	x		
	Sustainable	x		
	Environmental Literacy Planning	x		

Sustainable Fisheries Goal

Protect, restore, and enhance finfish, shellfish and other living resources, their habitats, and ecological relationships to sustain all fisheries and provide for a balanced ecosystem in the watershed and Bay.

Forage Fish and Fish Habitat

Determining abundances and trends in forage fishes and benthic invertebrates that serve as forage for managed predator species are important to understand their dynamics and dependence on habitats in Chesapeake Bay. Forage and forage habitat outcomes have related monitoring needs that fall under shallow-water surveys, plankton surveys, and fish habitat assessments. Addressing these monitoring needs would support ecosystem-based fishery management and contemporary assessments of ecological responses to water quality actions. The monitoring data generated would be used to update and develop new habitat suitability models and forecasts of forage trends under changing bay conditions.

Fishery and benthic invertebrate survey gaps (shallow water and smaller fish sampling)

The Sustainable Fisheries GIT (Goal Implementation Team), including the Forage and Fish Habitat Action Teams, has identified the need for shallow water fishery independent monitoring that would support both stock assessments and ecosystem-based approaches to fishery management. The need for mainstem Chesapeake Bay smaller size fish monitoring has also been raised to aid forage base assessment. With respect to fishery survey interests, shallow water monitoring is broken into two categories 1) Shallow (~2.4m to ~6m) mainstem and tributaries and 2) Littoral zone (<2.4m). These surveys should target both managed and unmanaged species and both adult and juvenile life stages. They would also include collection of supplementary environmental data to aid analysis of how habitat conditions may be influencing fish and invertebrate abundance, distribution, and other key parameters of interest.

Trawl and seine surveys are the best probable candidates for baywide application of these surveys. Such surveys provide data on multiple species from multiple habitats; however, additional approaches (e.g., underwater video) may be included in sampling designs. Shallow water surveys would also require standardization and coordination across jurisdictions to be most effective in leveraging existing resources. Specific sampling designs, opportunities to link habitat and fish surveys (such as Submerged Aquatic Vegetation (SAV) and sampling at restoration sites), and cost estimates would need to be developed. Some recommendations are available in the CBP Fishery Ecosystem Advisory Panel Report (2006) .

Specific examples of needs include 1) sampling specific structural shoreline habitat such as SAV beds, restored oyster reefs, natural and developed shorelines to expand species utilization and species assemblages across this full range of shoreline habitats, and 2) shallow water overwinter blue crab surveys. New data gathering opportunities include 1) coordinating fish sampling at SAV sentinel sites, 2) using shallow water telemetry arrays, 3) exploring underwater camera and acoustic methods of evaluating fish utilization, and 4) engaging community science in survey sampling efforts.

In addition to fish sampling, benthic infauna in shallow waters are also under-sampled due to the vessel limitations of the CBP monitoring effort, as well as the difficulty in monitoring benthos in any structured habitats (e.g., SAV, oyster reefs). Studies have previously shown comparable results for habitat health between offshore and nearshore benthic macroinvertebrate assessment results in Virginia suggesting insights can be extended on benthic infauna from the long-term Chesapeake Bay tidal macrobenthic invertebrate monitoring program, however, these are highly productive areas for benthos and should be further included.

Plankton monitoring

Phytoplankton and zooplankton are key living resource components of the food web and ecosystem. Plankton respond to changes in temperature, precipitation and other environmental factors, and serve as prey for key fishery species such as oysters, menhaden, striped bass and bay anchovy. The timing, species composition, abundance, temporal and spatial variability in distribution of plankton are all important as well as evaluating how water quality and climate factors may be affecting plankton populations. Monitoring programs for CBP supported baywide zooplankton and phytoplankton monitoring programs were discontinued in 2004 and 2009 respectively (Wardrop and Haywood, 2009). Previous workshops have outlined and recommended plankton monitoring approaches for Chesapeake Bay (e.g., Olson, M. and K. Sellner, 2005), however, implementation of the recommendations was deemed too costly and therefore has not been supported. One option is to develop a reduced-scale zooplankton survey over a series of years that duplicates some of the stations monitored in the past which showed declines in key zooplankton species and a shift in dominant phytoplankton to cyanobacteria before bay-wide programing was discontinued. Another approach is to explore new in situ and remote (satellite) technologies that are available today (e.g., National Oceanic and Atmospheric Administration (NOAA) Coast watch program) and could allow for faster cheaper sampling along a bay transect and/or in targeted locations (as striped bass spawning areas and mysid sampling). Further, new research is being supported by Maryland Sea Grant on methods to improve mysid assessment (https://www.mdsg.umd.edu/onthebay-blog/mysterious-mysids-maryland-sea-grant-funded-scientists-are-using-innovative-methods). The array of options requires further discussion to ensure they are coupled to fishery and other management objectives. A draft zooplankton monitoring program proposal is included in Appendix B.

Fish Habitat Assessment

The National Fish Habitat Partnership and the CBP's Fish Habitat Action Team have identified fish habitat assessments as a critical need for mapping and analyzing the quality of fish habitat. These assessments can be used to identify degraded and high value habitat areas which may be used to inform restoration, water quality, land use practices, conservation, and fishery management decisions. NOAA and USGS are currently piloting a coupled nontidal and tidal fish habitat assessment in the Patuxent watershed, informed by fish habitat studies on the Choptank River and in nontidal waters of the watershed. This pilot assessment will provide a spatial analysis of integrated water and fish habitat quality at the finest resolution possible based on the best available data. The outcomes of the Patuxent pilot program will guide decisions about the utility and approach for future assessments in other targeted watersheds or bay-wide.

USGS and NOAA gathered and evaluated existing monitoring data to conduct the estuary and watershed assessments and undertake the joint assessment in the Patuxent River system. The data evaluation revealed that finer-resolution monitoring and spatial data are needed for future watershed-estuary assessments in additional locations. The enhanced monitoring data needed at finer spatial scales includes fish species, fish habitat, and stressor data (such as water quality and land use). Monitoring of these conditions would also be needed over time to evaluate the effects of management approaches and effects from changing land use and climate.

Oysters

Oyster Restoration

Monitoring to evaluate the performance of restored oyster reefs is critical to guiding continued restoration design and communicating successes. All restored reefs are monitored per the success metrics at 3 and 6 years post restoration. As more reefs across the 10 restoration tributaries have been restored, the monitoring needs and costs have increased significantly. Divers and patent tong are the primary methods for monitoring reefs with high sampling density. This monitoring has been supported by Maryland (MD), Virginia (VA), NOAA and U.S. Army Corps of Engineers (USACE). As a result of the increased level of effort and costs, the oyster workgroups commissioned a study to evaluate what changes could be made for faster, cheaper approaches that still meet the success metric requirements. The study resulted in a reduction in the number of sampling sites required and some cost savings. In addition, the oyster workgroups are pursuing innovative approaches utilizing underwater video called a rapid assessment protocol. The new approach is still being developed and its application to restoration monitoring will need to be reviewed. Additional funding to support testing and implementation of the rapid assessment protocol or potentially other sampling methods is needed to enhance oyster monitoring.

Blue Crab Abundance

The annual winter dredge survey (WDS) is the primary monitoring program that generates measures of blue crab abundance (juvenile and adult) on a bay-wide scale. The WDS samples 1,500 sites throughout the bay and is run during the winter each year. The resulting data are analyzed by the Chesapeake Bay Stock Assessment Committee (CBSAC) and provided to managers and the public via the Blue Crab Advisory Report (e.g., Bromilow 2022). The Blue Crab Advisory Report is used by the management jurisdictions to develop and coordinate their harvest regulations for each season. The summer trawl survey has also been used to track the blue crab population over the summer as juveniles recruit into the fishery.

Gaps in these surveys include shallow water sampling, and includes temperature, salinity and dissolved oxygen monitoring to evaluate impacts on overwintering mortality. The former would focus on juveniles to get better recruitment estimates since the WDS is not very effective at sampling smaller crabs. The latter parameters could also help assess climate change effects and guide refinements to the existing winter dredge survey.

Vital Habitats Goal

Restore, enhance, and protect a network of land and water habitats to support fish and wildlife and to afford other public benefits, including water quality, recreational uses and scenic value across the watershed.

Wetlands and Black Duck

The priority monitoring need for both the Wetlands and Black Duck Outcomes is the need for improvements to the data tracking system in order to more accurately and efficiently measure progress towards the goals. This need is being met through contractor support (Devereux Consulting) over the next two years (2022-2023), who will work with the Wetland and Black Duck outcome leads and Habitat GIT leads to develop an improved data tracking system. This effort is funded by the Environmental Protection Agency (EPA). In addition, there are a series of workshops and current GIT-funded projects scheduled over the next several months that will help to outline scientific and monitoring needs associated with tidal wetland marsh loss and the potential for marsh migration. These efforts will also help with the need to evaluate monitoring around non-tidal wetland creation, restoration, and enhancement. Conversations about the intersection of SAV, aquaculture, living shorelines, and other shallow water habitat management opportunities and conflicts are also occurring across GITs and workgroups and will likely lead to monitoring needs in the future.

Stream Health

The priority monitoring need for the Stream Health workgroup is the collection of freshwater macroinvertebrate data from under-represented catchment types. The Chesapeake basin-wide index of biotic integrity for stream macroinvertebrates (Chessie BIBI), is a multi-metric index of stream health applicable to freshwater streams and small rivers across the Chesapeake Bay watershed. It is composed of family-level macroinvertebrate metrics, or indicators, that are especially responsive to differences between high quality and degraded stream conditions. The index is calculated from stream macroinvertebrate data collected by state, federal, and local agencies and other groups. Only about 7% of stream catchments (< 200 km^2 drainage area) in the Chesapeake watershed are sampled and some catchment types such as high-quality streams are under-represented. A model was developed that uses landscape features to predict a Chessie BIBI rating for unsampled catchments (Maloney et al. 2018). When monitoring and modeling results are merged, a Chessie BIBI rating can be assigned to 99% of catchments. To estimate the overall percentage of healthy streams in the Chesapeake watershed, the ratings are weighted either by their catchment's area or stream miles and summed. Freshwater macroinvertebrate data from under-represented catchment types are critically needed to fill in monitoring gaps and improve model predictions.

Brook Trout

The Brook Trout Outcome requires a more accurate and comprehensive monitoring program for quantifying gains and losses in brook trout habitat across the Chesapeake Bay Watershed. Multiple agencies, nongovernmental agencies, and other practitioners implement restoration projects with the objective of creating or expanding brook trout habitat. However, there is often little monitoring to determine pre-project baselines or the actual presence of brook trout post-project to document project success and efficacy. More effort and resources are required to develop monitoring protocols (e.g., sampling design, methodologies like eDNA, etc.) that can document results of on-the-ground restoration projects. This will also provide information to help identify the most cost-effective actions to increase brook trout occupancy.

Fish Passage

The outcome does not have any monitoring needs during this monitoring assessment period.

Forest Buffers

The monitoring needs are:

- Monitor forest buffer cover change using high resolution (approximately 1m-squared) satellite-based image data
- Monitor forest and tree cover change in developed areas using hi-resolution satellite-based image data
- Develop low-cost methods for verifying buffer acres

More details are available on the Chesapeake Bay Program Science Needs Database (https://star.chesapeakebay.net/).

Tree Canopy

Monitor forest and tree cover change in developed areas using high resolution (approximately 1m-squared) satellite-based image data. More details are available on the Chesapeake Bay Program Science Needs Database (https://star.chesapeakebay.net/).

Submerged Aquatic Vegetation

Please refer to Section 2 and Appendix A of the report which details the monitoring needs for this outcome along with funding estimates to sustain and grow the required program to address stakeholder information needs.

Water Quality Goal

Reduce pollutants to achieve the water quality necessary to support the aquatic living resources of the Bay and its tributaries and protect human health.

Watershed Implementation Plans (WIPs) - 2025

Incorporation of monitoring and trends data into assessment of jurisdictions' progress in achieving the Bay TMDL planning targets. More details are available on the Chesapeake Bay Program Science Needs Database (https://star.chesapeakebay.net/).

Water Quality Standards Attainment and Monitoring

Please refer to Section 2 and 4 of the report which details the monitoring needs for this outcome along with funding estimates to sustain and grow the required program to address stakeholder information needs.

Toxic Contaminants Goal

Ensure that the Bay and its rivers are free of effects of toxic contaminants on living resources and human health.

Toxic Contaminants Research

Please refer to Section 2 and Appendix A of the report which details the monitoring needs for this outcome along with funding estimates to sustain and grow the required program to address stakeholder information needs.

Toxic Contaminants Policy and Prevention

Please refer to Section 2 and Appendix A of the report which details the monitoring needs for this outcome along with funding estimates to sustain and grow the required program to address stakeholder information needs.

Healthy Watersheds Goal

Sustain state-identified healthy waters and watersheds, recognized for their high quality and/or high ecological value.

Healthy Watersheds

The CBP, through its Maintain Healthy Watersheds Goal Implementation Team (HWGIT), has a goal of maintaining the long-term health of watersheds identified as healthy by its partner jurisdictions. **Therefore, the primary monitoring need of HWGIT is the continued support, maintenance, and timely update of monitoring data that is used to inform the Chesapeake Healthy Watershed Assessment (CHWA).** The CHWA supports the CBP and its jurisdictional partners in detecting signals of change in the state-identified healthy watersheds by assessing current watershed conditions and tracking future conditions. It also provides information useful to support management applications to protect and maintain watershed health from future degradation. The list of monitoring metrics and programs States rely on to identify healthy watersheds through the CHWA includes:

- Maryland Biological Stream Survey (MBSS)
- Pennsylvania Department of Environmental Protection (PA DEP) Statewide Surface Water Monitoring and Assessment Program
- Chesapeake Basin-wide Index of Biotic Integrity (Chessie BIBI)
- 6 candidate geomorphic metrics (combination of remote sensing data and modeling analysis):
    - Streambank lateral erosion
    - Streambank change (meter-squared)

    - Streambank sediment flux – incorporates bank height, lateral erosion, and bulk density
    - Streambed D50 median particle size
    - Streambed fine sediment cover
    - Streambed fine sediment + sand cover
- MBSS Stronghold Watersheds (developed from MBSS monitoring data)
- Conductivity (developed from field data and modeling)
- Recent Forest loss (Hansen data, from remote sensing imagery)

Climate Resiliency Goal

Increase the resiliency of the Chesapeake Bay watershed, including its living resources, habitats, public infrastructure and communities, to withstand adverse impacts from changing environmental and climate conditions.

Climate Monitoring and Assessment

The Climate Monitoring and Assessment Outcome has the need for development of climate change indicators for monitoring and assessing ecological and community effects and resilience related to tidal bay water temperature change, stream temperature change, sea level rise, flooding, and extreme heat. The CBP's STAR Climate Resiliency Workgroup, in coordination with the Management Board and respective workgroups, agreed that there is a need to better connect changes in temperature, precipitation, and sea level rise with ecological and community impacts related to the outcomes in the 2014 Watershed Agreement. They prioritized the following natural resource-related climate change indicators: stream and Bay water temperature change related to fish (e.g., brook trout, striped bass) and SAV habitat and relative sea level rise effects on tidal marsh extent and relevant marsh migration corridors. They also prioritized the following community-related climate change indicators: 1) change in high temperature extremes in connection with tree canopy needs for underserved urban areas and 2) river and coastal flooding effects on communities. To have effective climate change indicators to inform resilience and adaptation decisions there is a need for engagement efforts with stakeholder groups doing the restoration, conservation, and land-use planning to define the purpose of the indicator. Indicator development includes the need to identify the data and methodology, including the temporal and spatial scales needed for the defined purpose, and the determination of whether there are existing monitoring and assessment programs that have the means to provide the data and analyses consistently into the future. Monitoring and assessment considerations for the longevity of the indicator (e.g., cooperative agreements with data providers, indicator maintenance plans) will be important to ensure the continued reliability of the indicator for use in resilience and adaptation decision-making.

A primary monitoring need is the establishment of an Ocean Acidification Monitoring Network. The quickly rising levels of carbon dioxide (CO_2) in the atmosphere (see https://gml.noaa.gov/ccgg/trends/) in conjunction with increasing land-based pollution is leading to acidification in coastal waters. The resulting acidification effects on water quality may be sufficient to impact the survival of living resources in Chesapeake Bay. Characterizing the carbonate system in the Bay is important for understanding calcification stress on bay organisms such as clams and oysters, assessing habitat suitability for these living resources, and understanding carbon storage. There is no long-standing monitoring network for ocean acidification (OA) in the Bay, but there are current assets where additional monitoring could be implemented to make OA a feature captured and reported. Recommended steps for establishing bay-wide baseline conditions includes coordination between state agencies (MD, VA, DE, DC) and scientists to determine a suitable monitoring design and sampling strategy, and if there are discrepancies among methods between the states then working to align methods and outputs to support a regionally consistent story about OA measures and effects. Monitoring results can then be used to inform management-relevant data gaps for guidance on addressing OA impacts. This monitoring network will be used to identify shifts in the carbonate system allowing managers to make strategic restoration decisions to protect habitats and living resources both ecologically and economically important to the region.

There has been interest expressed by the CBP and its partners to better understand the quantification of carbon sequestration from tidal wetlands and SAV and potential application of conservation and restoration efforts of these resources in the carbon market. A review of existing blue carbon crediting protocols demonstrated the need for improved understanding of carbon fluxes and long-term storage in coastal ecosystems, including both the aboveground biomass and soil carbon pools. Additional needs include improved knowledge of carbon stock changes from sea level rise pertaining to marsh drowning and erosion and landscape conversions (e.g., mature forest to new marshland). Specific to SAV, gaps in knowledge include the leakage of carbon from degraded seagrasses and the difference in the carbon sink capacity among different seagrass species. There is also a need to better understand how human drivers that lead to ecosystem degradation and loss, such as drainage, harvesting, burning, and clearing of vegetation, affect carbon fluxes and emission rates over time. The monitoring and assessment of blue carbon projects need to allow for the quantification of aboveground and belowground carbon stocks and the assessment of risk associated with potential loss in carbon stocks in the project area over a period of 100 years. The establishment of baseline emissions include the consideration of carbon stock change from sea level rise and change in biomass pool and net greenhouse gas (GHG) emissions from soil. Additionally, assessments are needed on whether the project will lead to increased GHG emissions outside the project area from both an ecological (e.g., hydrological connectivity with adjacent areas) and economical (e.g., displacement of economic activities) perspective. Monitoring and assessment to verify blue carbon projects needs to be maintained for at least 30 years and the baseline reevaluated every ten years. Models used in the blue carbon assessments need to be validated with direct measurements from a system with the same or similar water table depth, salinity, hydrology, sediment allocation, and plant community. Overall, the monitoring and assessment of blue carbon projects for application in carbon markets needs to support the quantification of GHG emissions and removals, establish the permanence of carbon stocks, and evaluate sea level rise effects on the carbon stocks in the project area. Activities that could result in leakage leading to an increase in emissions or a decrease in removals of GHG outside the project area also need evaluation for blue carbon projects.

Climate Adaptation

The outcome does not have any monitoring needs during this monitoring assessment period.

Land Conservation Goal

Conserve landscapes treasured by citizens in order to maintain water quality and habitat; sustain working forests, farms and maritime communities; and conserve lands of cultural, indigenous and community value.

Protected Lands – Tracking the amount of protected lands within the Chesapeake Bay Watershed has been a long-term initiative of the Chesapeake Bay Program over the past decade. This effort builds on comprehensive work completed by USGS, National Park Service (NPS), CBP, state-level partners, the Chesapeake Conservancy and land trusts throughout the watershed.

The Protected Lands Outcome relies on the continued support for monitoring the landscape at 1-meter resolution. Currently, the USGS in partnership with the Chesapeake Conservancy is finalizing two, 1-meter resolution raster datasets. One dataset represents land use/cover (LULC) conditions in 2017/18 and the other represents LULC change from 2013/14 to 2017/18. These datasets help inform the habitat value, level of impervious surface and other key information that aids in understanding the value and vulnerability of protected lands through time. There is a need for continued support to fund the data collection efforts for continued land use land change monitoring beyond 2017/18. There is currently no funding or plan in place to continue this 1-m LULC monitoring effort.

There are specific monitoring needs that have emerged within the data attributes collected for tracking progress toward the CBP Protected Lands indicator. These have been outlined in the analysis and methods documentation of the Protected Lands indicator on Chesapeake Progress (https://www.chesapeakeprogress.com/). Specifically, State and other protected lands databases have not consistently included the date of protection (aka "date established") for each parcel, which makes understanding the rate of land conservation difficult. In addition, attributes related to public access and the GAP Status Code (which is a measure of management intent to permanently protect biodiversity) are not well attributed in the data. This lack of knowledge on the year established, public access or presence of biodiverse habitat makes additional detailed analysis for cross outcome, co-benefits, and other important questions for managing protected lands difficult if not impossible on a watershed-wide scale.

In addition to monitoring needs related to the protected lands data and outcome, additional monitoring is needed in the face of climate change. The CBP would benefit from the following actions aimed at increasing understanding on climate, carbon, and best management practices (BMPs) on protected lands:

- Increase understanding for how projected climate change impacts and other pressures, like development, will influence the land in the watershed of highest value for maintaining water quality.
- Collect data related to the potential for forest and agriculture lands to sequester carbon and the related co-benefits.
- Focus monitoring efforts on the impacts of climate change on certain types of conserved lands (e.g., agricultural and forest lands in low-lying coastal areas) increasingly impacted by saltwater intrusion due to sea-level rise and land subsidence.

- Monitor the effectiveness of land conservation as a strategy to provide areas for the managed retreat and migration of wetlands inland as sea levels continue to rise.
- Support the monitoring of BMPs of protected lands to determine whether they are being maintained. New IT applications have been designed to use GIS high resolution mapping to screen these lands to reduce the need for in-the-field staff to achieve more routine monitoring of all lands. Limited staff can be deployed to visit lands that have been flagged on the GIS applications as 'problematic.'

Additional information about the science needed to support the Protected Lands Outcome is available on the CBP Science Needs Database (https://star.chesapeakebay.net/).

Land Use Options Evaluation

Preventing the loss of forests and wetlands by minimizing the amount of natural lands lost to development is the best method for retaining the natural hydrology and pollution control that these lands provide to sustain and improve the health of the Chesapeake Bay and its watershed. Land use change is a local issue with regional consequences. It can impact restoration and protection efforts if not understood, mitigated, or otherwise planned for. The Land Use Options and Evaluations Outcome depends on the support of the monitoring needs reflected in Section 2. for the Land Use and Land Change Monitoring. This outcome needs land use metrics to understand, communicate, and provide resources that guide reduction of the rate of harmful land conversion. Specifically, continued support is needed for monitoring the landscape with remote sensing at 1-meter resolution. Currently, the USGS in partnership with the Chesapeake Conservancy is finalizing two, 1-meter resolution raster datasets. One dataset represents land use/cover (LULC) conditions in 2017/18 and the other represents LULC change from 2013/14 to 2017/18. There is a need for continued support to fund the data collection efforts for continued land use land change monitoring beyond 2017/18. There is currently no funding or plan in place to continue this remote sensing based 1-m resolution LULC monitoring effort.

Stewardship Goal

Increase the number and diversity of local citizen stewards and local governments that actively support and carry out the conservation and restoration activities that achieve healthy local streams, rivers and a vibrant Chesapeake Bay.

Citizen Stewardship; Local Leadership; Diversity

The CBP is committed to tracking its progress for the Stewardship goal of the 2014 Watershed Agreement which includes the following three outcomes: Citizen Stewardship, Local Leadership, and Diversity. To do this, the CBP plans to implement three surveys: the Stewardship Survey, the Local Leadership Survey, and the Diversity Profile Survey. The CBP determined the best approach for continued implementation of these surveys would be to submit a joint Information Collection Request (ICR) that they are waiting for the Office of Management and Budget (OMB) to approve in accordance with the Paperwork Reduction Act (1995) (PRA)[*]. It is pertinent that the surveys and methodologies are approved because there is currently no other entity collecting appropriate data that can be used. It also allows the CBP to collect data to tell the story of progress and set new directions for the future. Below is further information specific to each survey:

- The Stewardship Survey is the first comprehensive survey of stewardship actions and attitudes in the Chesapeake Bay watershed. Data collected through this survey was used to establish a baseline indicator for the Stewardship Outcome. Additional data collection is needed approximately every five years to assess progress toward attaining the Outcome. There are three components to the index score: The Personal Action score, the Volunteering score, and the Advocating score. Funding for the survey is through the contract that supports the CBP Partnerships and Accountability Branch. The future application of the survey will be conducted by the contractor which is currently Eastern Research Group (ERG).
- The Local Leadership Survey will evaluate the knowledge and capacity of local leaders and monitor both over time. Once approval is given, funding is available to pay a contractor to conduct the survey, establish a baseline and re-conduct the survey on a regular basis (between 2021 and 2027).
- The Diversity Survey previously conducted in 2016 and 2019, is distributed to approximately 750 people who work for or with the CBP partnership and asks for individuals to self-identify certain demographic information such as race, ethnicity, sexual orientation, and age. In addition to demographic information, respondents indicate whether they are a member of CBP leadership. The survey provides the data required to measure progress on the diversity indicator and was originally planned to be distributed in 2021, 2023, and 2025.

*****As of March 2022, the joint ICR was approved.

Diversity

Diversity Indicator Target/Goal for 2025 using American Community Survey Data (Overlaying state Demographic and Economic census block data over Chesapeake Bay Watershed). More details are available on the CBP Science Needs Database (https://star.chesapeakebay.net/).

Public Access Goal

Expand public access to the Bay and its tributaries through existing and new local, state and federal parks, refuges, reserves, trails and partner sites.

Public Access Site Development

The priority monitoring need is to identify public access sites and potential effects from climate change (sea-level rise and flooding). More details are available on the CBP Science Needs Database (https://star.chesapeakebay.net/).

Environmental Literacy Goal

Enable students in the region to graduate with the knowledge and skills to act responsibly to protect and restore their local watershed.

Student; Sustainable Schools; Environmental Literacy Planning

The primary monitoring need for the Environmental Literacy Planning, Sustainable Schools, and Student Outcomes is the continued collection of data through the Environmental Literacy Indicator Tool (ELIT). The ELIT survey is a voluntary data collection tool administered electronically to all local education agencies that fall within the Chesapeake Bay watershed (and every local education agency in MD, VA, and PA). In addition to ELIT, CPB works with programs that provide green school certifications to maintain a list of all sustainable schools in the watershed. To ensure every student in the region graduates with the knowledge and skills necessary to act responsibly to protect and restore their local watershed, as called for in the 2014 Watershed Agreement, environmental education should be embedded into the local curriculum, school buildings and grounds should be maintained using sustainable practices, and Meaningful Watershed Education Experiences (MWEEs) should occur at least once during each level of instruction (elementary, middle, and high school). The ELIT survey and the sustainable schools certificate data collection are structured to collect data to help us better understand how school districts are supporting this work.

The data is collected biennially, and the ELIT survey has Paperwork Reduction Act clearance through NOAA as the lead agency for this work. ELIT provides data to better understand:

- School district preparedness to implement a comprehensive and systemic approach to environmental literacy education
- Student participation in MWEEs during the school year
- School district practices and support for sustainable schools
- School district needs to support further improvements in environmental literacy education

Teams Influencing CBP Work

Within the CBP, there are workgroups and action teams charged with a specific mission and generating explicit products that do not reside within the work context of a particular GITs. However, such workgroup and team contributions influence and support the progress of the GITs towards achieving goals and outcomes. Their priority monitoring needs were requested through multiple STAR meetings. The needs of workgroups or teams that submitted monitoring needs were compiled or with the support of related GITs, integrated into the monitoring needs of CBP outcomes.

The CBP Modeling Workgroup has a responsibility to the Partnership to provide state-of-the-art decision-support modeling tools to assess effects of current and proposed watershed management on changes in nutrient and sediment loads delivered to the Bay, and the effect those changing loads have on water quality and living resources. The integration of monitoring and modeling activities is an active and ongoing process. Together they support management decisions in the restoration of Chesapeake's watershed and Bay and also provide necessary support for coastal watershed restoration science. One new area that can be greatly improved by a short-term two-year monitoring effort would be the measurement of dissolved organic carbon (DOC) and particulate organic carbon (POC) concentrations and their degree reactivity at all River Input Monitoring (RIM) stations. This work would provide direct support of the CBP's management decisions in the milestone year of 2025 by the CBP monitoring program by augmenting the few measurements of DOC and POC currently available from the Conowingo. Other monitoring enhancements would be continuous measurements of nitrate and turbidity at all RIM as well as a program of widely expanded continuous temperature measurements throughout the watershed.

River Input Monitoring (RIM) Monitoring of Particulate Organic Carbon (POC) and Dissolved Organic Carbon Reactivity

The DOC and POC RIM station monitoring would be done with flow weighted measurements on a timeframe consistent with the schedule for the measurement of nutrients at the RIM stations. The flow weighted measurements would collect enough DOC and POC sample for standard measurements of Biological Oxygen demand (BOD) as 5-day BOD (BOD5), 20-day BOD (BOD20), and BOD ultimate (BODU)) of both DOC and POC. Understanding the reactivity of DOC and POC has a direct influence on hypoxia in the Bay, and examining its seasonal and spatial differences could be applied to the 2025 Bay Model and its application to CBP's 2035 assessment of climate change risk to the Chesapeake Bay TMDL. The DOC/POC measurements at RIM stations would be a two-year special monitoring study.

River Input Monitoring (RIM) Monitoring of Continuous Nitrate, Turbidity, and Temperature

A secondary priority is the continuous measurement of oxidized nitrogen, turbidity, and temperature using probes at all RIM stations. The continuous monitoring would be useful if conducted for a period of at least two years in all months of the year, but continuing beyond a two-year period under varying hydrologic and conditions would be beneficial.

Expansion of Continuous Temperature Monitoring

The expansion of continuous temperature monitoring in as many monitoring stations as is practical could be of immediate assistance to the Phase 7 Watershed simulation as well as for future watershed simulations beyond 2025. The utility of the widespread continuous temperature data would be in the direct calibration of the dynamic Phase 7 Model, and it could be used for improved elucidation and confirmation of simulated co-benefits for cold water fish habitat. In addition, the measurements could be utilized in analyses which would have the potential to better separate ground and surface waters at a finer scale than previously available.

The Plastic Pollution Action Team (PPAT) seeks to reduce the presence and impacts of plastic pollution on the Chesapeake Bay and its watershed. The PPAT was formed at the directive of the CBP Management Board and was charged to develop a preliminary ecological risk assessment model, in addition to a plastic pollution size classification document and a monitoring and science strategy. In 2021, the Plastic Pollution Action Team finalized a monitoring and science strategy for Chesapeake Bay (Murphy et al. 2021). The strategy contains several recommendations concerning monitoring of plastic pollution in the bay and watershed, including:

- Design and implement a microplastic monitoring program, integrated into the existing Chesapeake Bay watershed monitoring framework;
- Support research to understand microplastic pathways in the Bay, including trophic pathways that may affect living resources such as striped bass, blue crabs, oysters, and other species critical to the Bay ecosystem; and
- Ensure adequate infrastructure resources are available to process microplastic samples, including analytical equipment.

A monitoring program for identifying source, fate, and transport of plastic pollution in the Chesapeake Bay and watershed so that well-informed policy and management decisions can be made.

In 2022, the PPAT will begin work on fleshing out a monitoring program with the assistance of STAR and other CBP goal implementation teams and workgroups. However, the PPAT feels at this time that it's important to highlight the need for bay and watershed wide monitoring program with STAR. This is an essential component to understanding the source and fate of plastic pollution in the bay. In Fall of 2021, the Principals' Staff Committee tasked the PPAT with also developing a plastic pollution source reduction strategy. Members of the Chesapeake Bay Commission have expressed concerns to the PPAT that before controls are implemented, CBP partners need to have a better understanding of the sources.

Monitoring data showing the presence and concentrations of plastic contamination in living resources in the Chesapeake Bay; and experimental study looking at biological impacts of plastic contamination on living resources.

While understanding source, fate, and transport of plastic pollution is important, additional research needs to be completed focusing on impacts of plastic pollution on bay living resources. The PPAT is currently working on the second iteration of an ecological risk assessment looking at the impact of plastic pollution on striped bass in the Potomac River. However, this exercise will continue to be limited by the lack of empirical data collected in the region showing presence of microplastics and nanoplastics in living resources. Laboratory research on the impacts of plastic pollution to different species is also essential to understanding the impacts to the wider Chesapeake Bay ecosystem and drawing a more complete picture of ecological risk.

Funding to establish research capacity at the region's institutions for conducting plastic pollution research. This includes purchasing analytical equipment that can effectively and efficiently analyze microplastic plastic samples.

Finally, the PPAT believes that the region's research institutions lack capacity for conducting research on plastic pollution. Very few research programs and laboratories have been established to focus on this issue. One major deficiency is the lack of the necessary analytical equipment to examine samples of microplastics and nanoplastics. In order to implement recommendations number 1 and 2 above, the PPAT believes the need for laboratory resources are essential and should be made apparent to decision makers.

(Note – During the final production of the report, funding support to the PPAT was announced by EPA Region 3: The EPA Region 3 Water Division (WD) is continuing to support monitoring and research on the impacts of plastic pollution in partnership with the PPAT. In FY23, the WD is committing ~$150k to support research and activities into monitoring surrounding plastic pollution. The EPA Trash Free Waters team in partnership with the PPAT leadership is in the early stages of determining what the details of the project will be but some actions being considered in response to feedback from the last PPAT meeting include developing an SOP reference guide and/or a monitoring framework with the plan to pilot a few strategies. More details will come in early FY23 when a contract has been awarded with the final task details. K. Somers EPA, Oral Comm., 5/26/2022)

Section 3: Partnership opportunities to enhance Chesapeake Bay Program monitoring

Overview

A partnership approach is needed to address the vast scope of monitoring needs described in sections 1 and 2 of the report. Partners include federal and state agencies, local governments, academic institutions, and nongovernmental agencies. The partners need to sustain Chesapeake Bay Program (CBP) core networks and partner-led networks (top half of Fig. 3.1) by increasing resources to adjust for inflation and replace outdated equipment. New resources will be needed to (1) enhance existing CBP networks, and to (2) establish new networks for 2014 Watershed Agreement outcomes that currently lack sufficient monitoring (bottom of figure 3.1).

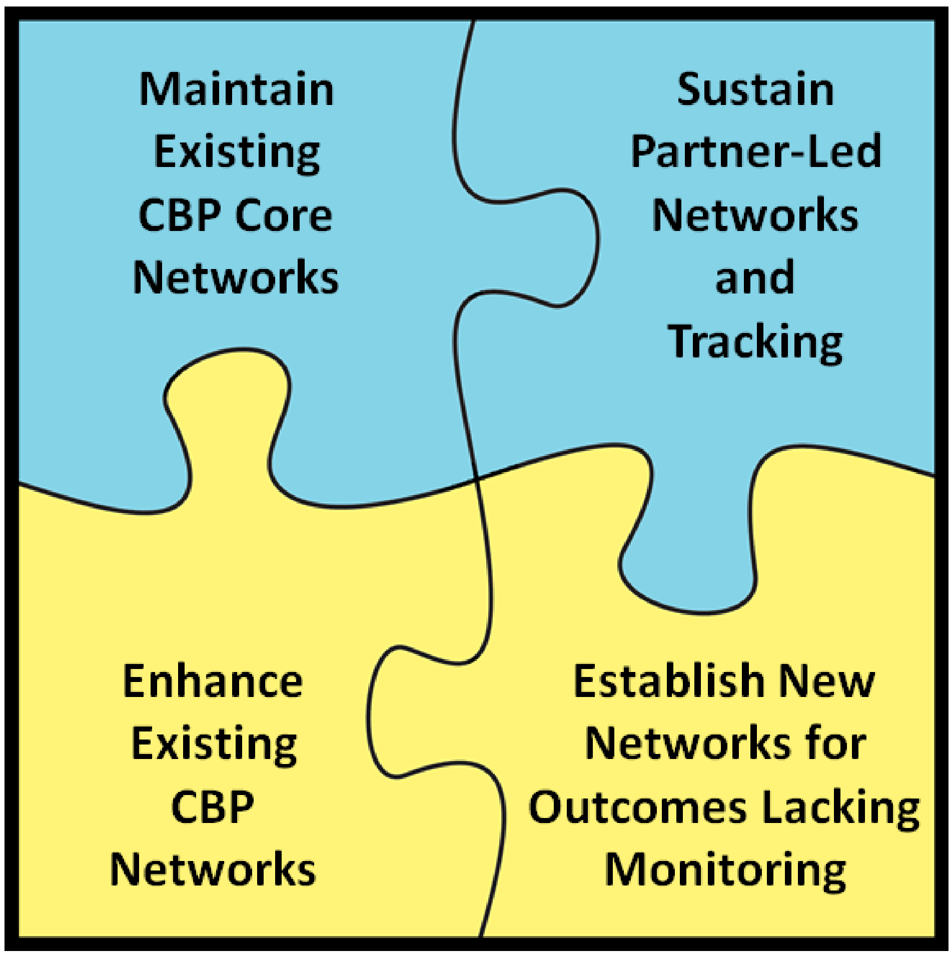

Figure 3.1: Existing Chesapeake Bay Program (CBP) water quality monitoring networks and new monitoring needed to address the CBP 2014 Watershed Agreement outcomes. The top row illustrates existing monitoring efforts including the CBP core networks and partner-led monitoring to address CBP 2014 Watershed Agreement outcomes. The bottom row represents new monitoring needs that can be addressed by enhancing the CBP core

networks or developing new networks for CBP 2014 Watershed Agreement outcomes without sufficient monitoring to address information needs of the Partnership.

Section 2 of the report describes the monitoring needs, based on input from the GITs, for outcomes of the 2014 *Chesapeake Bay Watershed Agreement*. The GITs identified 2 outcomes completed, 13 outcomes requiring maintenance of their monitoring programs, 9 outcomes which lack coordinated monitoring, and 7 outcomes where new monitoring needs to be established. For this section, outcomes lacking coordinated monitoring or not having monitoring are considered "developing new networks for outcomes lacking sufficient monitoring."

There is no single funding source available to enhance the existing CBP core networks or establish new networks. Funds from the 2021 Bipartisan Infrastructure Law (BIL) offered a potential new source of funding but the opportunities for monitoring appear limited. The EPA CBP received over $200M for five years under from the BIL, but only about $1.5M a year has been slated for monitoring. Other federal agencies did not receive any BIL funding that can be used to meet the Chesapeake monitoring needs. Therefore, monitoring partners will need to consider how to increase their respective monitoring programs to enhance existing CBP monitoring, sustain partner-led networks, and establish new monitoring networks.

Pursuing funds for monitoring investments will require long-term effort of increased collaboration between federal, state, academic and local monitoring programs (Fig. 3.2). The CBP plans to have an initial meeting of monitoring program managers so they can identify their interest in different investments to enhance existing CBP networks (discussed in section 1 of the report). More detailed discussions would be conducted through the Scientific, Technical Assessment and Reporting (STAR) Integrated Monitoring Networks Workgroup. Establishing new monitoring networks (discussed in section 2 of the report) would probably require a different approach for collaboration. The potential approaches for each are provided next.

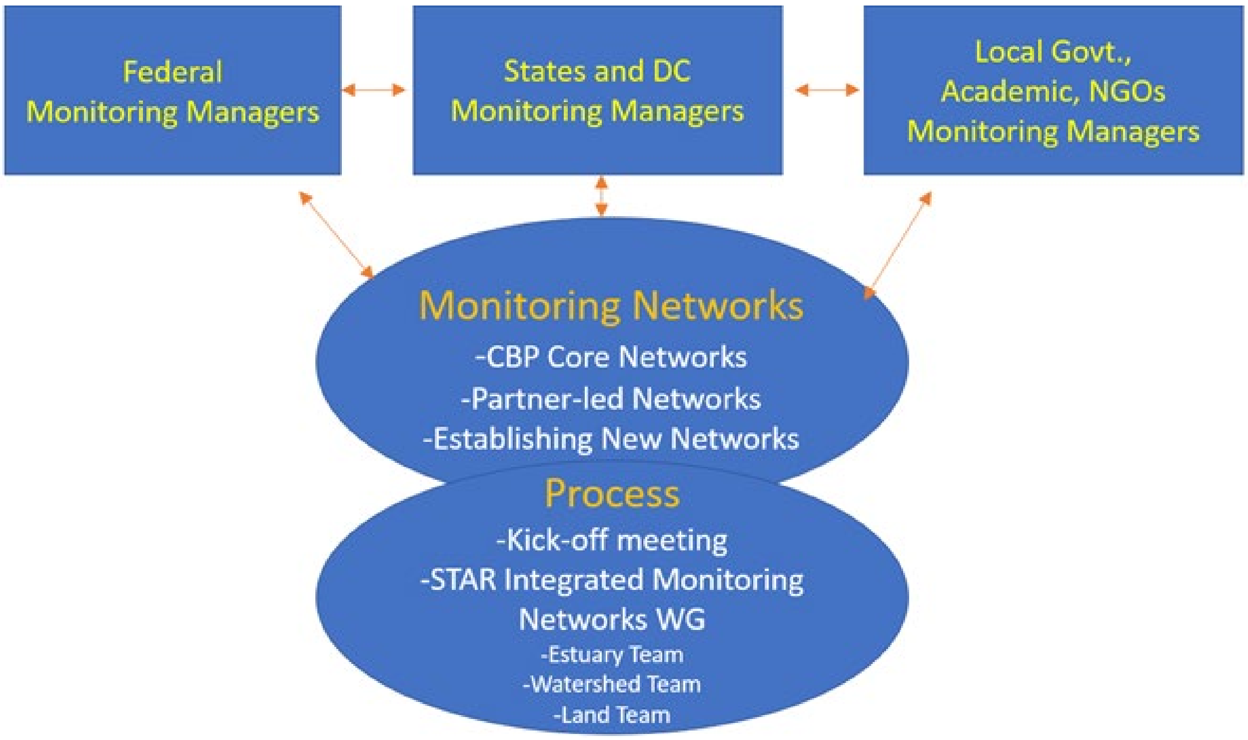

Figure 3.2: Conceptual framework as guidance for monitoring program managers to address monitoring report recommendations. Program managers from different government entities and academic partners that support Chesapeake Bay Program monitoring (boxes at top) would come together to address sustaining integrity and supporting growth of the Chesapeake Bay monitoring networks to meet decision-support needs (middle) through a kick-off meeting and subsequent discussions through the Scientific, Technical Assessment and Reporting (STAR) Integrated Monitoring Networks Workgroup (bottom). Subsequent meetings following the kick-off meeting could be organized for estuary, watershed, and land monitoring.

3. 1 Approaches for sustaining and enhancing existing CBP monitoring networks

The approach to enhance existing CBP monitoring networks could be organized into estuary, watershed, and land monitoring teams (Table 3.1). The core estuary networks are tidal water quality, tidal Submerged Aquatic Vegetation (SAV) assessment, and benthic macroinvertebrates. Community science networks include monitoring in both the estuary and watershed. The nontidal water-quality monitoring network is the primary CBP watershed network. The toxic contaminant monitoring network for Polychlorinated Biphenyls (PCBs) has been proposed. The land use/land cover monitoring program has a separate group of partners. An initial meeting of the existing program managers could use the monitoring portfolios (section 1) as a starting point for identifying their interest for potential investments. Subsequent discussions could be carried out through the STAR Integrated Monitoring Networks Workgroup.

Table 3.1: Potential Teams, Existing Partners, and New Collaborators to Enhance Chesapeake Bay Program (CBP) Core Monitoring Networks

Estuary Team	CBP Core Networks	Existing partners	New collaborators

	Tidal Water Quality	Environmental Protection Agency (EPA), Virginia (VA) and Maryland (MD) agencies and institutions	National Oceanic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration (NASA)
	Submerged Aquatic Vegetation (SAV) assessment	EPA, VA, and MD agencies and institutions	NASA
	Benthic surveys	Maryland Department of Natural Resources (MD DNR), Virginia Department of Environmental Quality (VA DEQ)	
	Community Science	Chesapeake Monitoring Cooperative (CMC)	
Watershed Team	Community Science	CMC	
	Nontidal WQ Network	EPA, United States Geological Survey (USGS), agencies in all 6 states and District of Columbia (DC)	Natural Resources Conservation Service (NRCS) and CMC
	Polychlorinated Biphenyl (PCB) monitoring	EPA, states and DC, USGS	Academic Institutions
Land cover and use Team	Land use and cover	EPA, Chesapeake Conservancy, USGS, University of Vermont	

Discussions would include investments needed for:

- *Capital improvements of existing CBP networks*, which are one-time purchases of equipment or infrastructure needed for constructing monitoring stations.
- *Operation and maintenance of existing CBP networks*, which requires a longer-term commitment. The new infrastructure funds, since they have a 5-year time horizon, could be used for initial operation and maintenance for CBP core networks. Partners would develop a longer-term strategy to maintain these CBP core monitoring enhancements, including the influence of annual cost-of-living adjustments.

Opportunities to enhance CBP networks in the estuary

There are existing partners and new collaborations to enhance monitoring in the estuary. The initial focus is on CBP outcomes for (1) attainment of water-quality standards, and (2) submerged aquatic vegetation. EPA, NOAA, and agencies and institutions in MD and VA are collaborating on estuary monitoring (Fig. 3.3). These existing partners, interacting with additional collaborators, could enhance monitoring for water-quality criteria and SAV (Table 3.1).

As summarized in section 2 of the report, MD and VA agencies and institutions, collaborating with NOAA, have a leadership role in partner-led monitoring for several CBP outcomes in the estuary, including blue crabs, oysters, and climate monitoring and assessment. Sustaining these partner-led networks, and considering developing new networks, such as fish habitat and forage, could also be considered by these partners.

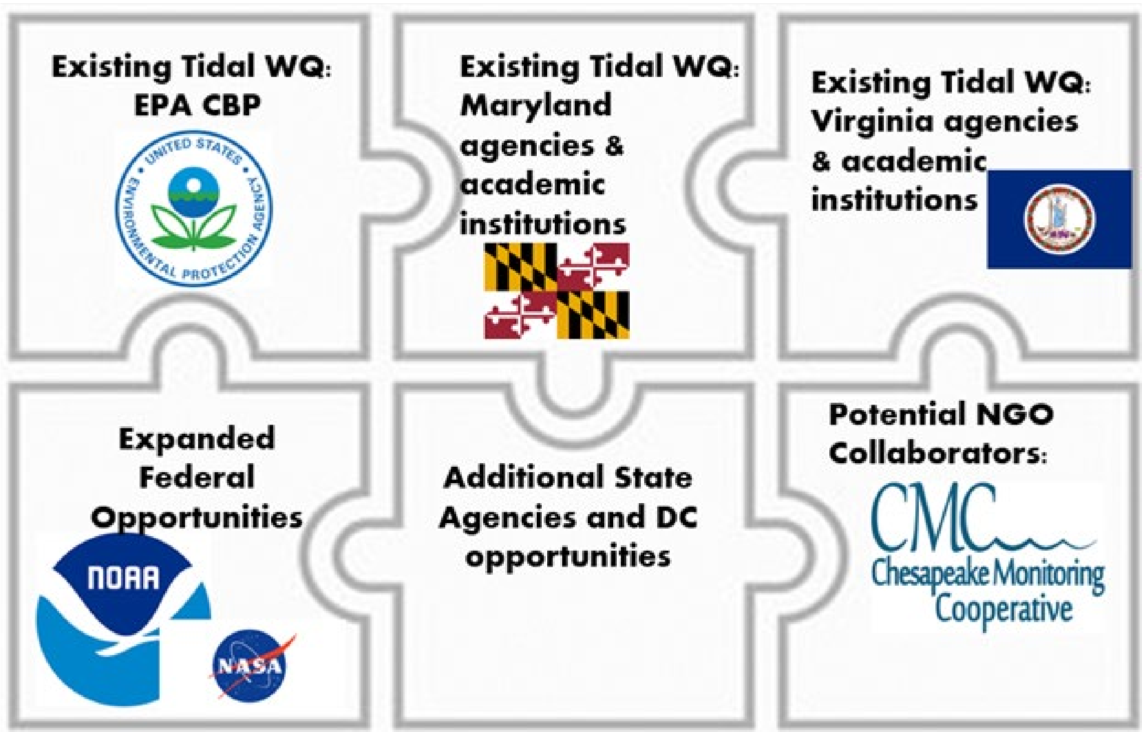

Figure 3.3 A vision for implementing a partner approach to sustaining and growing monitoring networks to address 2014 Chesapeake Bay Watershed Agreement outcome information needs to evaluate status and progress. In this example, Environmental Protection Agency (EPA), National Oceanic and Atmospheric Administration (NOAA), and agencies and institutions in Maryland (MD) and Virginia (VA) are collaborating on estuary monitoring. These existing partners, interacting with additional collaborators, could enhance monitoring for water-quality criteria, submerged aquatic vegetation (SAV) and potentially fish-habitat assessments.

Opportunities to enhance CBP core monitoring networks in the watershed

There are existing partners and potential new collaborations to help enhance monitoring in the watershed (Table 3.1). The initial focus is enhanced monitoring for response to practices being implemented for the CBP WIP 2025 Outcome for the Bay Total Maximum Daily Load (TMDL) (EPA 2010). EPA, USGS, and monitoring agencies in all 6 states and DC are partners in the Nontidal Monitoring Network (Fig. 3.4). These existing partners, interacting with additional collaborators such as those in the Chesapeake Monitoring Cooperative, could consider additional watershed monitoring to help target and assess nutrient and sediment practices.

These partners could also consider how existing CBP networks could be used to address watershed outcomes that need more coordinated monitoring such as stream health and fish habitat. These discussions would be best conducted with the appropriate workgroups overseeing the outcomes.

Land Change monitoring is another CBP Core monitoring network in the watershed (Table 3.1). The network is maintained by a partnership between EPA Chesapeake Bay Program Office (CBPO), the Chesapeake Conservancy, and USGS. As summarized in section 1 of the report, this monitoring provides tracking of multiple CBP outcomes such as forest buffers, tree canopy, and land change matrices. These partners could be a team moving forward to discuss enhancements to the land monitoring networks.

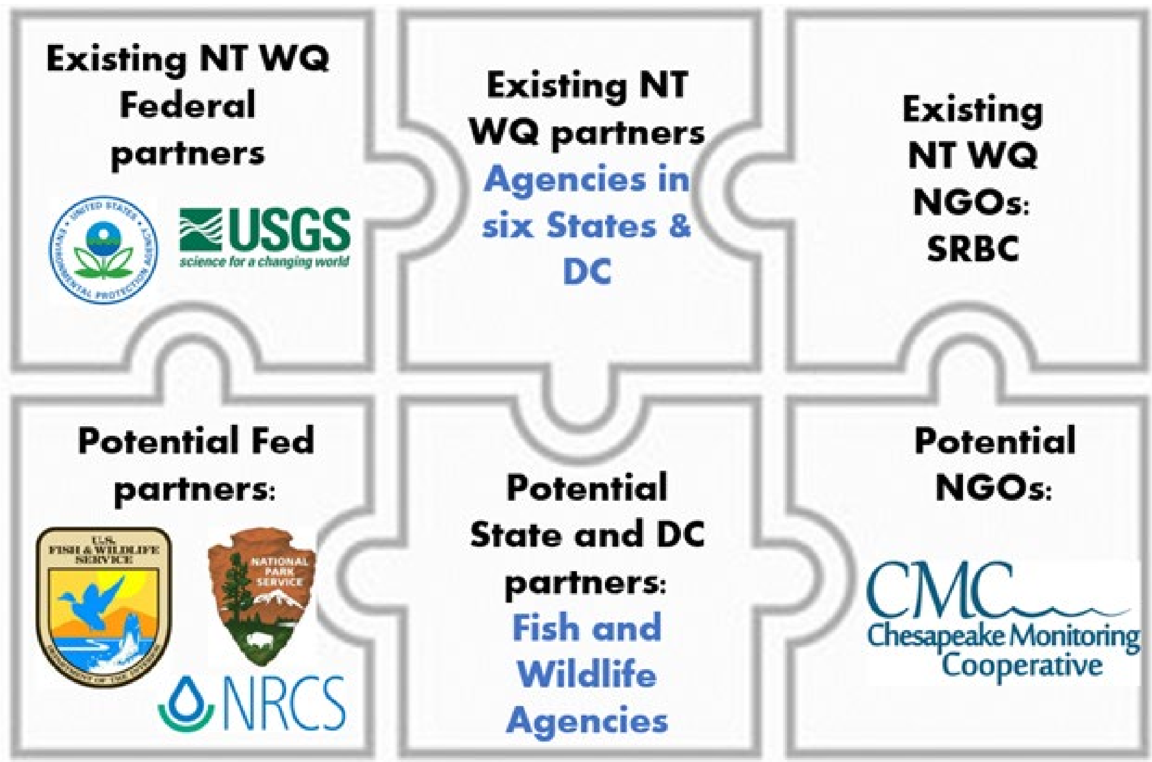

Figure 3.4 A vision for implementing a partner approach to sustaining and growing monitoring networks to address 2014 Chesapeake Bay Watershed Agreement outcome information needs to evaluate status and progress. In this example The United States Geological Survey (USGS) and Environmental Protection Agency (EPA) are collaborating with agencies in all 6 states and District of Columbia (DC) on the Nontidal Water-Quality Monitoring Network. There are opportunities for these partners to work with Natural Resources Conservation Service (NRCS) to improve monitoring to assess watershed response to conservation practices implemented for nutrient and sediment reduction. Investment in small watershed monitoring could help address this need.

3.2 Establishing new networks for CBP outcomes lacking sufficient monitoring data.

Section 2 of the report identified 9 of the 2014 Watershed Agreement's 31 outcomes which lack coordinated monitoring and 7 outcomes where new monitoring needs to be established. Improving monitoring coordination, or establishing new networks, for CBP outcomes is a difficult and time-consuming task. Some potential guiding principles for establishing new networks (or improving coordination) include:

- The GITs could have the lead, working with STAR, on approaches to improve coordination or establish new monitoring networks.

- Preparing a list of existing partner networks addressing the outcome could be prepared to help identify additional support. Some of the exiting federal programs are listed at the end of this section.
- Partners for closely related outcomes could work together, through the CBP Integrated Monitoring team, to explore changes to existing networks. Changes could include sample locations, media collected, collection frequency, and lab techniques.
- GITs may consider using CBP GIT Funding to support pilot projects or Scientific and Technical Advisory Committee (STAC) Workshops to help identify new technologies and methods for monitoring.
- Track status of current and future monitoring needs through the Strategic Science and Research Framework (SSRF)

Monitoring plans could be developed for outcomes that don't currently have an established network. Development of a monitoring plan will require the applicable CBP workgroup overseeing an outcome to work with the CBP Monitoring Team to:

- Identify the metric(s) to assess progress towards achieving the outcome
- Inventory of existing monitoring that could be considered
- Interact with monitoring partners on their ability and willingness to collaborate on a new network
- Assess the remaining gaps that must be addressed
- Design monitoring strategy to address gaps
- Ensure resources to fill the gaps and establish a new data collection network
- Ensure data management support is in place
- Ensure data integrity and quality assurance protocols are approved and adopted
- Ensure data analysis, assessment and reporting protocols are in place
- Support capacity to maintain new network.

Once a monitoring plan is developed for these outcomes, a designated STAR task is to create a portfolio for each outcome similar to those of the core CBP monitoring networks (Section 1). Program managers can then use the portfolios (Section 1) as a starting point for identifying their interest for potential investments.

The Toxic Contaminant Workgroup developed a monitoring plan for PCBs that can be used as a template for other outcomes. See Appendix A2 for the plan.

A key part of establishing new networks is to inventory ongoing monitoring efforts. As part of preparing the Federal Strategy for the Chesapeake Bay Restoration, an inventory of monitoring networks in the Bay and its watershed was conducted in 2009. The inventory identified 295 monitoring programs spanning a broad spectrum of scales and Chesapeake Bay program interests and were summarized according to subject area (CBP 2009). Water-quality monitoring programs outnumber all others in the inventory. Numerous monitoring programs have multiple components and collect data in multiple subject areas that are being addressed for ecosystem-based management. A special effort was made to capture the smaller scale state, county, city and volunteer monitoring programs which have been overlooked in past inventory efforts (CBP 2009). These programs are collecting data at scales critical to tracking changes due to local/small scale efforts to protect and restore the watershed and have been long an underutilized source of monitoring information.

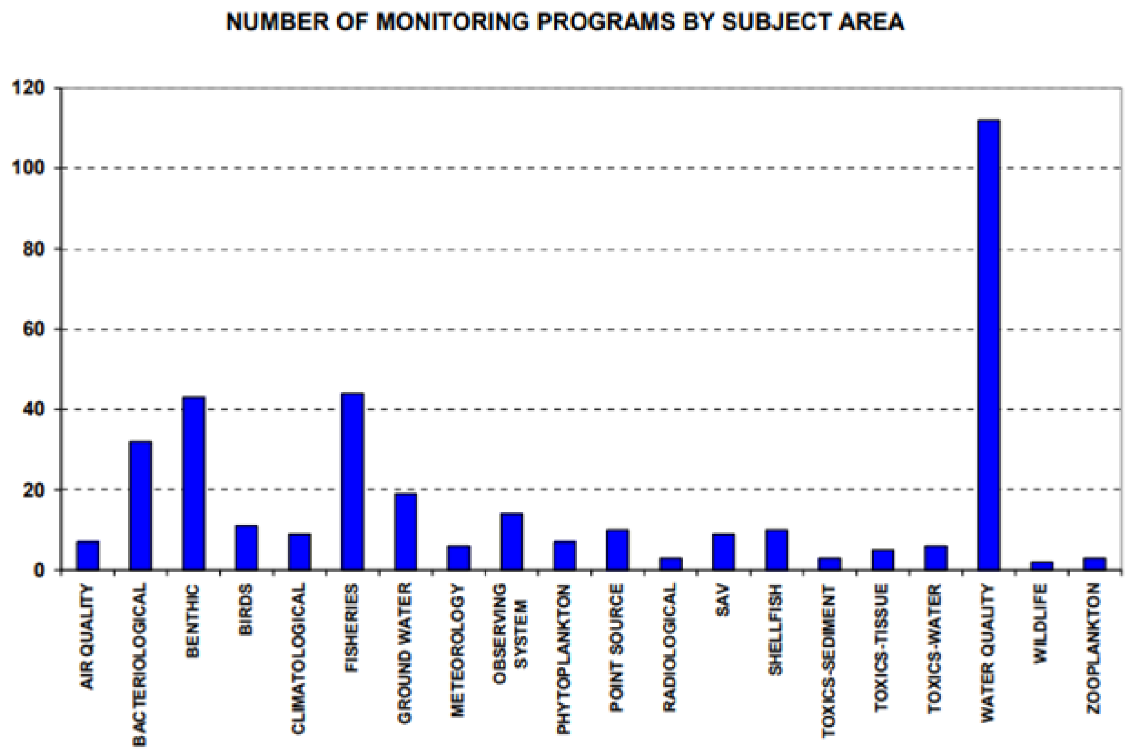

Figure 3.5. Monitoring programs by subject areas related to ecosystem – based management based on a 2009 survey of Chesapeake Bay and watershed monitoring programs conducted in the production of the report *Monitoring Needs and Partnership Opportunities Assessment: A Report to Chesapeake Bay Program Monitoring Re-Alignment Action Team*. (https://d18lev1ok5leia.cloudfront.net/chesapeakebay/monitoring_needs_and_partnership_oppertunities_assessment_to_the_mrat.pdf)

Selected Federal Monitoring Programs to be Considered for Chesapeake Efforts

Federal programs provide a key opportunity to address unmet needs of the CBP outcomes. Some of the key federal programs to be considered are described below.

U.S. Environmental Protection Agency (EPA)

Programs through the EPA are matched by state partners to support a majority of the CBP core monitoring networks under Clean Water Act grant awards. The new infrastructure funding available as a function of the 2021 Bipartisan Infrastructure Law and provided through EPA for monitoring support provides some of the best opportunities to have state partners enhance monitoring to address unassessed water-quality criteria or response to watershed management efforts.

- *Chesapeake Bay Program monitoring grants*. The CBP office provides over $6M in grants (Clean Water Act 117e grants) and awards to the states, DC, and other selected partners for O&M of all the core network activities. For the 117e grants, the recipient must match funding 1:1, or dollar-for-dollar on monitoring. The grantees could receive increased support through appropriate funding vehicles using the new infrastructure funding ($47M annually for 5 years) received in 2022 by EPA and the CBP office to address unassessed water-quality criteria or response to watershed management efforts.

- *EPA Clean Water 305b assessed waters program*: EPA provides funding to the states for assessing the quality of their waters. States in the Bay watershed use this funding to also support water-quality stations that are part of the CBP Nontidal Water-Quality Network. The infrastructure funding could be used to establish new sites and purchase equipment for either unassessed water-quality criteria or response to watershed management efforts.
- *EPA Clean Water State Revolving Fund (CWSRF)*: Each jurisdiction is slated to receive an increase in their SRF funds as part of the BIL. One percent each state's CWSRF funds (or $100,000 if greater) is allocated by section 604(b) of the federal Clean Water Act to support state water quality planning activities under Sections 205(j)(2) and 303(e). Water quality monitoring is an authorized use of those funds.

National Oceanic and Atmospheric Administration (NOAA)

- *Chesapeake Bay Interpretive Buoy System (CBIBS):* A network of observing platforms (buoys) that collect meteorological, oceanographic, and surface water-quality data and relay that information in near real time. NOAA is currently expanding its observing portfolio to assess water column hypoxia conditions and track fish movements with acoustic telemetry. These data, combined with existing surface-level observations, will increase understanding on how changing water quality affects habitat conditions for living resources.

U.S. Geological Survey (USGS)

The USGS leads the CBP nontidal network in partnership with all the states in the watershed and the D.C. The USGS uses funds from several national programs to support the NTN monitoring and has programs addressing other CBP watershed needs. The USGS has several programs that support monitoring in the Chesapeake and can therefore collaborate in partnership with other agencies (e.g., Fig. 3.4) but they did not receive BIL funding resources for use in supporting monitoring programs.

USGS Ecosystem Mission Area:

- *Land Management Research Program.* USGS is conducting investigations and monitoring of fish and macrobenthic habitat, and their response to management efforts in the Chesapeake watershed. There are other major restoration efforts across the nation.
- *USGS Land Change Monitoring Program.* The USGS land change monitoring program has been collaborating in the Chesapeake on approaches to assess past land change using the new categories being developed for high-resolution data.

USGS Water Mission Area:

- *USGS Cooperative Funding Program:* The USGS cooperative funding program is used to support monitoring and assessment, in collaboration with state and local partners across the nation. In the Chesapeake, the cooperative program is used to support the RIM with MD and VA, selected water quality and stream gaging sites, and studies of the relation between water quality and habitat conditions in the Chesapeake watershed.

- *Groundwater and Streamflow Information Program (https://www.usgs.gov/programs/groundwater-and-streamflow-information-program):* The Groundwater and Streamflow Information Program (GWSIP) serves as the national source of impartial, timely, rigorous, and relevant data for short- and long-term water decisions by stakeholders across the United States. In 2018, the USGS began piloting the Nation's Next Generation Water Observing System (NGWOS) that will provide high-fidelity, real-time data on water quantity and quality. However, this program is focused on the Delaware (DE) Watershed.
- *National Water Quality Program (https://www.usgs.gov/programs/national-water-quality-program):* The National Water Quality Program provides an understanding of water-quality conditions; whether conditions are getting better or worse over time; and how natural features and human activities affect those conditions. This program supports some water-quality monitoring in the Chesapeake watershed using match dollars from state and local governments.

U.S. Fish and Wildlife Service (USFWS)

- *National Fish Habitat Partnership:* The Partnership focuses on conservation of fish and their habitats as keystones for the full range of aquatic biodiversity and aquatic habitats in the United States. The Action Plan set an ambitious agenda for the Partnership, planning for a first-ever national assessment in 2006 of fish habitats and the development and support of as many as 12 voluntary regional Fish Habitat Partnerships (FHPs or regional partnerships), committed to high standards of science-based conservation. The objectives of the Action Plan support monitoring used to update fishery habitat conditions every 5 years.
- *Nature's Network (http://www.naturesnetwork.org/):* It is a collaborative effort facilitated by the U.S. Fish and Wildlife Service Science Applications program that brings together partners from 13 states, federal agencies, nongovernmental organizations, and universities to identify the best opportunities for conserving and connecting intact habitats and ecosystems and supporting imperiled species to help ensure the future of fish and wildlife across the Northeast region.

National Aeronautics and Space Administration (NASA)

- *Applied Sciences Division of the Earth Science Directorate at NASA (https://appliedsciences.nasa.gov/):* The Division builds partnerships with government, industry and nongovernmental agencies to develop projects that use data from NASA's Earth-observing satellites. Satellite imagery has the potential to improve monitoring of SAV in the Bay watershed. NASA, NOAA and others are actively working on enhancing use and interpretation of satellite imagery to support water quality assessment.

Section 4: Principals' Staff Committee Charge to the Monitoring Review Team and Foundational Assessment Results

The Charge to the Review Team

An overview was provided to the Principals' Staff Committee (PSC) at their March 2, 2021, meeting about the status of, and potential reductions to, the current Chesapeake Bay Program (CBP) monitoring networks under current funding levels and support. The CBP monitoring programs (termed "the Core Networks") included the nontidal nutrient and sediment monitoring network, tidal water-quality monitoring network, submerged aquatic vegetation (SAV) annual survey, tidal benthic monitoring network, and Community Science monitoring program. Land Use Land Cover (LULC) land-change monitoring program was further recognized as a Core program during the review process. The Scientific Technical Assessment and Reporting Team (STAR) listed the condition of the networks as "fair" during the August 2020 Strategy Review System (SRS) quarterly review to the Management Board (MB) in the context of its degree of capacity for addressing management decision-support needs of the Partnership.

The PSC recognizes that monitoring is foundational to the CBP's ability to assess status and progress toward meeting the Partnership's commitments to the goals and outcomes of the 2014 Watershed Agreement. In response to the March 2021 status report, the PSC requested information be provided on what is needed to improve the CBP monitoring networks, including:

(1) an overview of current status and threats to the networks, and

(2) how to address the monitoring networks capacity shortfalls.

Approach for Addressing the Request

The last comprehensive assessment of CBP networks was completed over a decade ago, when the MB oversaw a partnership effort through the Science and Technical Advisory Committee (STAC) termed "the Monitoring Realignment", led by the "Monitoring Realignment Action Team" (Wardrop and Haywood 2009). In 2021, a Monitoring Review Team was formed with representatives from the Scientific, Technical Assessment, and Reporting (STAR) leadership team, the Branch Chief of Science, Analysis and Implementation at the Chesapeake Bay Program Office (CBPO), and a STAC representative to collaborate with CBP partners currently responsible for CBP monitoring networks. The Monitoring Review Team worked together to address the March 2021 PSC information request (Figure 4.1).

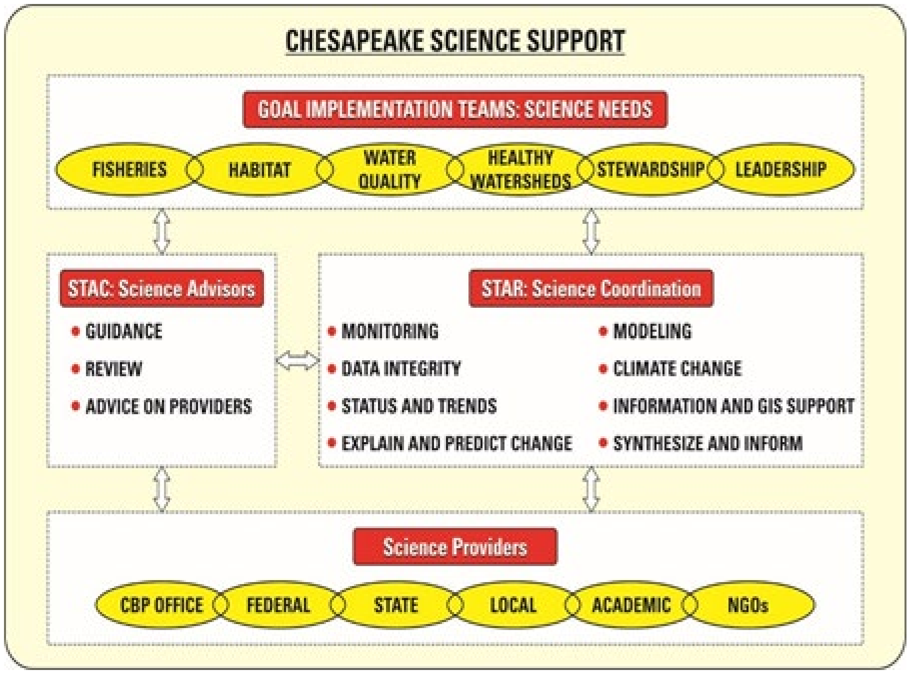

Figure 4.1 Science support at the Chesapeake Bay Program. The Scientific, Technical Assessment and Reporting (STAR) Team will lead the process to address the Principals' Staff Committee (PSC) information request by coordinating with Chesapeake Bay Program (CBP) Goal Implementation Teams (GITs) and additional science providers to utilize and expand networks for assessing progress on attaining goals and outcomes of the 2014 Chesapeake Bay Watershed Agreement.

The Monitoring Review Team developed a workplan to answer this request and presented it to the PSC for approval at their June 2, 2021 meeting. The presentation illustrating the work plan is available on the STAR webpage here: https://www.chesapeakebay.net/channel_files/42990/2021psc_may_update_mcdonnellsullivanphillipstangowardrop_v2_(1).pdf

For each of the monitoring networks, information was collected and considered to answer the following 8 questions (Figure 4.2):

1. What is the status of the network?
2. What are the monitoring network's vulnerabilities?
3. What is the program management strategy?
4. What gaps need to be filled to improve the CBP monitoring networks?
5. How can existing monitoring data and analysis be used to address these gaps?
6. What innovations are available?
7. Who are the partners in operationalizing the innovations?
8. What are the financial needs associated with sustaining, growing and innovating the networks?

The Monitoring Review Team synthesized the information gathered over 9 months of meetings across the partnership. Answers to the 8 questions are provided below. This background material informed the Monitoring Review Team on the structure for development of targeted recommendations addressing:

1) maintenance support funding needs to sustain the integrity of networks to continue to inform the partnership,

2) growth needed in existing networks to fill gaps in decision-support, and

3) development of new networks to address gaps in decision-support.

Outputs of the review process identified Capital (infrastructure) costs necessary to support gap-filling monitoring activities. Operations and maintenance (O&M) of network operations were forecast over 5 years. Total capital plus O&M costs were developed as guidance toward investment targets to address the capacity issues identified by the Partnership and synthesized in this review.

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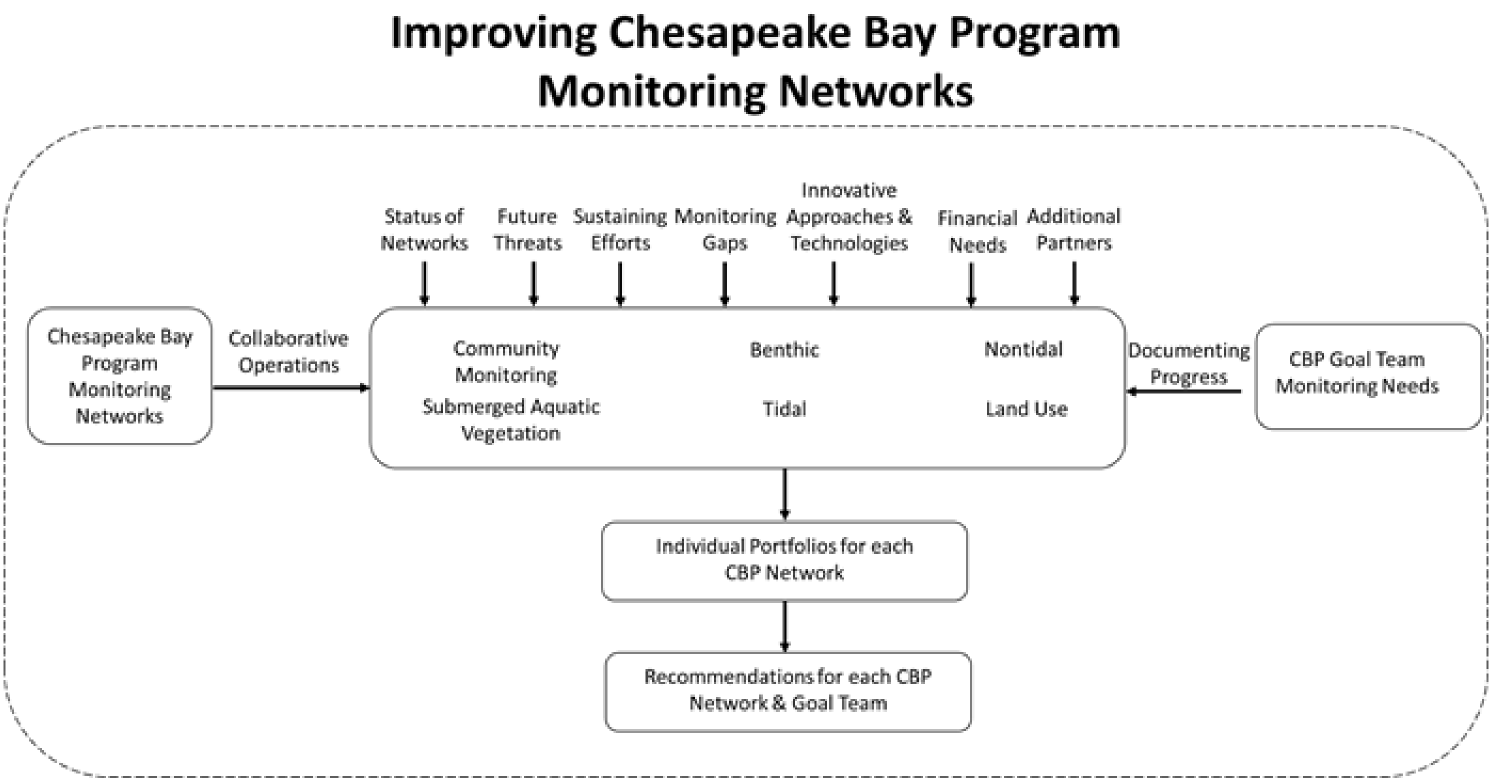
Figure 4.2 Conceptual model illustrating the process used for evaluating status and assessing needs for core



Chesapeake Bay Program (CBP) monitoring networks during the 2021-22 PSC-requested monitoring program review.

Review findings of the 8 questions

Question 1: What is the status of each network?

Tidal Monitoring

The current tidal monitoring network was established in 1984, its first full year of operation was 1985. There are 154 active stations sampled for physical, chemical, and biological measures throughout the water column, with baywide consistent collection and analysis protocols (Figure 4.3). One or more monitoring sites are located in each of the 92 Bay segments. MD and VA stations are sampled 1 or 2 times per month by their respective state depending on location and season. Targeted sampling occurs in shallow water in a limited number of Bay segments each year either mapping surface water quality or providing continuous (i.e., every 15 minutes) water quality measures at one depth for a fixed location in a season. DATAFLOW mapping of water quality is applied in select segments annually. This program is supported under the federal Clean Water Act (1972) 117e program which includes 1:1 matching support from State grant partners.

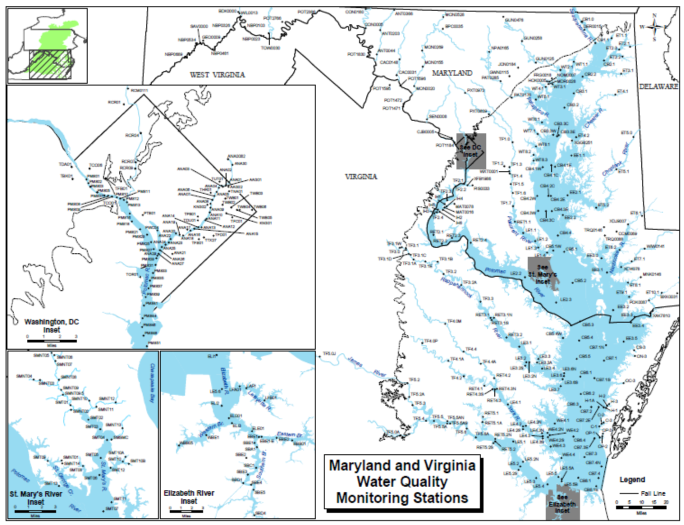


Figure 4.3 Mainstem Chesapeake Bay and tidal tributary monitoring stations in Maryland (MD) and Virginia (VA). Image source: Chesapeake Bay Program.

Since 2003, the tidal water quality monitoring network has only ever operated at a “marginal” or fair level of data collection on a scale of marginal (fair) -adequate (good) – recommended (excellent). The fair status applies with respect to capacity for collecting the data necessary to evaluate all the applicable scales of time and space expressed in the Chesapeake Bay water quality criteria. Such data are necessary to assess water quality standards (WQS) for dissolved oxygen, SAV & water clarity, and chlorophyll-a across all 92 tidal segments and their respective designated uses associated with the 2010 Chesapeake Bay TMDL (see pp 176-178 in EPA 2003).

Wardrop and Haywood (2009) highlight that senior managers of the Chesapeake Bay Program identified monitoring priorities during the 2007-09 monitoring re-alignment action team monitoring program review as:

- delisting the tidal segments of the Bay, and
- determining the effectiveness of management actions in the watershed.

In 2022, 19 years after Chesapeake Bay water quality criteria were published (EPA 2003), and over a decade since the MRAT findings with the Management Board (Wardrop and Haywood 2009), **the tidal network is still operating at marginal capacity to address partnership data needs and does not allow for a full accounting of Chesapeake Bay water quality standards**. Further, tidal water data collection per year is declining (Figure 4.4). Because there was insufficient data collection needed to assess all criteria for dissolved oxygen, SAV for water clarity, and chlorophyll *a*, a multi-metric water quality standards (WQS) indicator was developed to *estimate* water quality standards attainment of a full bay-wide assessment (Hernandez et al. 2020). The WQS indicator uses a small subset of the necessary information in a full water quality criteria attainment assessment by using a set of scientifically based rules to produce an estimate of water quality standards attainment which would otherwise require an accounting for over 1000 independent criterion-specific evaluations. The multi-metric WQS indicator is not a regulatory tool, it is a tracking tool to inform managers of conditions based on limited information. Unassessed criteria remain a hurdle for delisting decisions of state-adopted water quality standards with present funding and assessment methodologies applied under the existing monitoring framework.

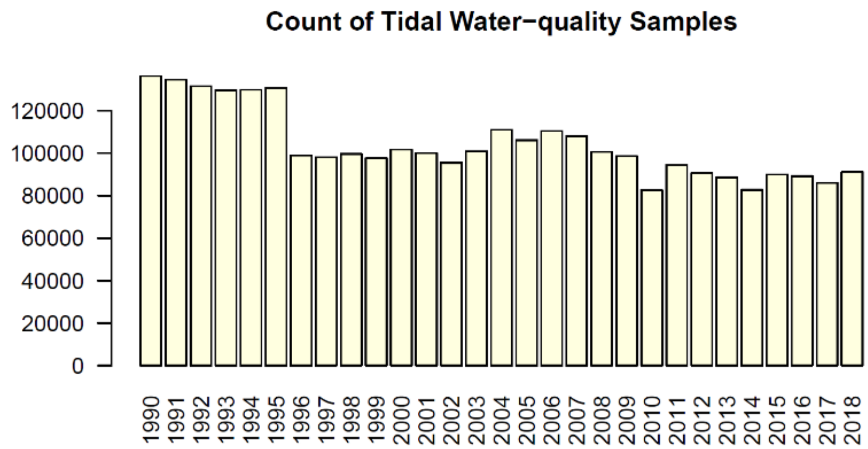


Figure 4.4 Tidal water quality sampling data availability, 1990-2018, showing a steady decline in water quality samples collected in the CBP long-term water quality monitoring program through time. Data source: Chesapeake Bay Program Data Hub, 2018. Image by Q. Zhang, University of Maryland Center for Environmental Science, Chesapeake Bay Program.

Nontidal Network

The coordinated, watershed-wide Chesapeake Bay Program nontidal water quality monitoring program was established with the signing of a memorandum of understanding (MOU) in 2004 (CBP 2004). . To establish the network, the Nontidal Workgroup of the CBP had compiled a database of nontidal water-quality monitoring stations in each partner's jurisdiction. The synthesis showed data were being or had been collected at more than 1,700 stations in the Chesapeake Bay watershed during the period 1972 to 2003. However, many of the stations were sampled for less than the desired minimum of three years and were eliminated from consideration in the design of the Chesapeake Bay Program partnership's Nontidal Network. In other cases, station sampling ended long before the current data collection time frame of the CBP (1985 to present). The result of this initial filtering of the original list showed 641 stations were part of active monitoring programs across the watershed in 2001 and were considered as potentially useful in better estimating nutrient and sediment loadings from the region's rivers and streams (CBP Nontidal Work Group 2004).

Final decisions were made on network design. Eighty-five stations formed the intial Nontidal Network. The network peaked at 125 stations in 2012. The present network of 123 stations includes stations located in all jurisdictions and includes 9 river input monitoring sites on the major tributaries to the Chesapeake Bay (Figure 4.5). River flow captured by the nine RIM stations represents about 2/3 of the flow above the fall line (i.e., the dividing line between upstream nontidal waters and downstream tidally influenced tributaries. These locations are considered the head of tide positions on the tribturies). Water quality monitoring stations are located near USGS stream-flow gages to permit estimates of nutrient and sediment loadings and trends in loadings delivered from the watershed downstream into the bay.

Routine water quality samples are collected monthly, and eight additional storm-event samples are collected per year targeting 2 quarterly samples each season to obtain 20 total samples per year at a station. Routine plus storm-focused sampling is conducted to represent a range of discharge and loading conditions given water quality parameter concentrations may be enhanced or diluted based on flow conditions. Sampling is performed by nine agencies in five states, with five laboratories analyzing the samples. To sustain the integrity of the data collections, all NTN participants follow standard operating procedures when sampling at NTN stations that conform to a common set of Nontidal Network protocols and quality control specifications, which are based on USGS sampling methods and EPA-approved analytical methods.

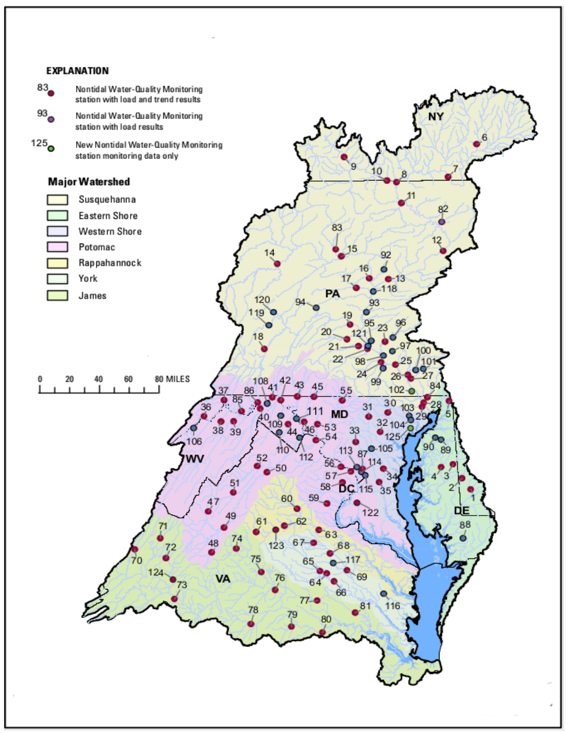


Figure 4.5 Chesapeake Bay Program Nontidal Monitoring stations. USGS Nontidal Monitoring Network.

SAV

Monitoring Submerged Aquatic Vegetation (SAV) in the Chesapeake Bay involves a 3-tiered hierarchical approach (Figure 4.6). Tier 1 is the Chesapeake Bay-wide Aerial Survey which is conducted by the Virginia Institute of Marine Science (VIMS). The survey takes place annually and determines SAV acreage and density by interpreting imagery collected from fixed-wing aircraft. Imagery is collected throughout the summer growing season and corresponds with peak biomass in the four salinity zones of the estuary. This survey is useful for quantifying SAV habitat distribution and density throughout the Bay and its tributaries, critical to life of living resources. The annual survey determines annual status and tracks progress towards Bay-wide and tributary-specific SAV restoration acreage cover goals. Regarding goals, the CBP restoration goal is 185,000 acres, and the water quality standards attainment goal is approximately 192,000 acres.

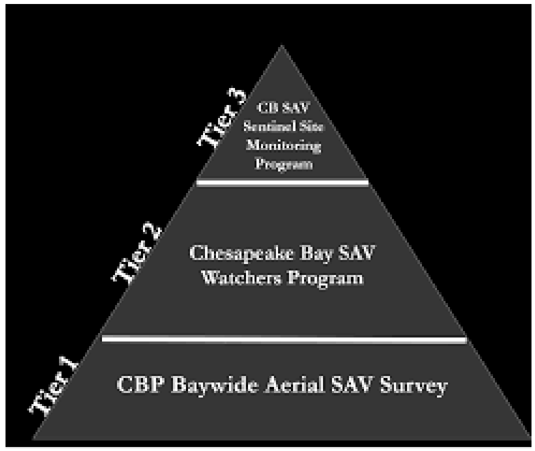


Figure 4.6 3-tiers of data collection which comprise of the Chesapeake Bay Submerged Aquatic Vegetation (SAV) monitoring program. Source: B. Landry, Maryland Department of Natural Resources.

Tier 2 is the volunteer-based effort Chesapeake Bay SAV Watchers Programs. The nascent effort is currently led by the CBP SAV Workgroup under the Healthy Watershed GIT, but it is envisioned to be led by the Chesapeake Monitoring Cooperative (CMC) with additional investments needed at this time to support their expanded capacity with a program coordinator. It was designed to provide volunteer scientists with an engaging and educational experience while also generating species composition and other data for Bay scientists and managers. Data are collected by trained volunteers throughout the summer but primarily during peak biomass. These data are useful for ground-truthing the Bay-wide aerial survey, for broad-scale resource assessment, and for identifying and quantifying management impact-resource response relationships.

Tier 3 of the SAV monitoring approach is designed but needs to be implemented. Chesapeake Bay SAV Sentinel Site data will complement acreage and density data collected via the VIMS Bay-wide annual SAV survey and local observational data collected via the Chesapeake Bay SAV Watchers Program and other ground surveys. Specifically, the Chesapeake Bay Sentinel Site Program for SAV will establish permanent transects at multiple locations throughout the Bay (present target: five in each of the four salinity regimes for a total of 20 sentinel sites) to monitor changes in SAV habitat characteristics, species composition, and resilience indicators. Tier 3 focuses on identifying causal relationships of habitat change by intensively monitoring drivers of change, ecosystem responses, and ecological processes. Changes in SAV habitat extent or condition detected at Tiers 1 and 2 can direct process-based investigations at Tier 3. Statistical and explanatory models built on Tier 2 and Tier 3 data can be used to interpret and predict resource patterns and conditions at larger scales.

In addition to the Tier 3 data needed to improve the understanding of SAV recovery in Chesapeake Bay, biomass data collected at SAV sentinel sites is essential to inform artificial intelligence/machine learning algorithm development for automated SAV detection and quantification from satellite imagery. Automated detection and quantification of SAV may improve efficiency and reduce the cost of the Bay-wide aerial survey as well as allow us to determine SAV carbon flux and storage potential. This information will be necessary for eventual participation in the Blue Carbon Market. Furthermore, the SAV Workgroup will coordinate with other CBP workgroups, goal teams (GITs), and partners to broaden the scope of monitoring at established SAV sentinel sites. The establishment of SAV sentinel sites will improve characterization of fish habitat and usage, invasive species threats and impacts, climate impacts, and other important parameters.

Benthic

The current Chesapeake Bay Long-term Tidal Benthic Monitoring Program samples the benthic invertebrate community (i.e., a group of animals that live on or in the bottom sediments of the Chesapeake Bay) across the tidal waters of Chesapeake Bay mainstem and its tidal tributaries (Figure 4.7). The benthic community includes diverse organisms such as clams, oysters, amphipods, and the blood and clam worms often used as bait. The program was initiated in Maryland and Virginia in 1984 and 1985, respectively.

The monitoring program consists of fixed and randomized sampling design monitoring efforts. The fixed-site design work revisits 53 sites annually. Sampling is conducted annually between July 15th and September 30th. Results are used to assess station level conditions for status and trends evaluations.

The second element of data collection is a probability-based sampling effort intended to support calculation of a benthic index of biotic integrity (B-IBI). The stratified random design sampling effort aims to collect samples at ≈200 sites each year. The B-IBI results are used to estimate the area in MD and VA tidal waters with benthic communities meeting or failing the Chesapeake Bay Program's Benthic Community Restoration Goals. The B-IBI evaluates the ecological condition of a sample by comparing values of key benthic macroinvertebrate community attributes to reference values expected under non-degraded conditions in similar habitat types. Outputs inform status and trends in tidal estuarine benthic habitat condition that informs regulatory assessment of the Aquatic Life designated use.

Historically, the program consisted of both the spring and summer season monitoring. Summer season results have supported jurisdiction's Clean Water Act (1972) evaluations of impairment for the Aquatic Life Use among segments in the bay. Spring season provided pre-hypoxia insights each year on the benthic community distribution and composition. However, the spring season was eliminated in 2009 due to funding constraints. During this 2021-22 PSC-requested monitoring program review, stakeholders were questioned on the need to revive the spring season portion of the work. Most stakeholders did not support restoring the spring season portion of the program and it was therefore not introduced as a monitoring need in the investment table produced by this review.

The estuarine benthic monitoring program is made possible through a partnership of the EPA Chesapeake Bay Program, the Maryland Department of Natural Resources, and the Virginia Department of Environmental Quality. Work is effectively conducted by Old Dominion University and Versar, Inc.

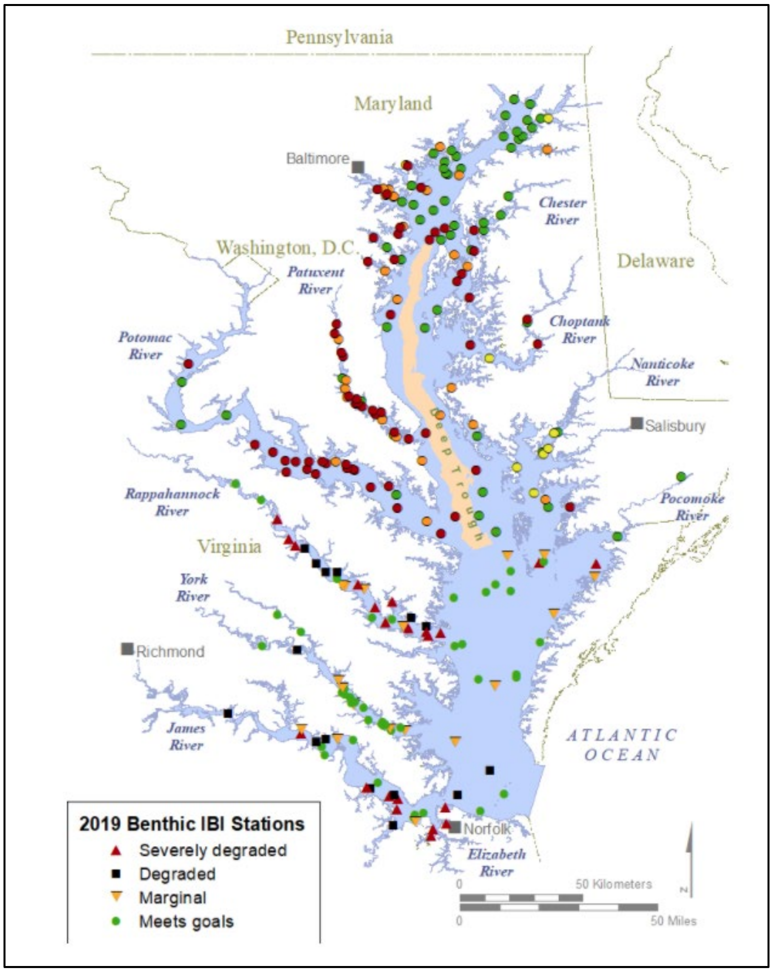


Figure 4.7 Chesapeake Bay Tidal Benthic Monitoring stations for 2019. Source: Versar, Inc.

Community Science

In 2015, the CBP expanded their monitoring program to improve data density by using non-traditional partner data sources. A Cooperative Agreement was awarded with EPA to a consortium of partner organizations to form the Chesapeake Monitoring Cooperative (CMC). The CMC is responsible for fostering relationships and establishing a cohesive Bay-wide monitoring program while networking with groups beyond those funded under the long-term Clean Water Act (1972) 117e grant funded monitoring programs that we refer to as "non-traditional" monitoring groups. The CMC team member organizations are: The Alliance for the Chesapeake Bay, The Izaak Walton League of American, Dickinson College's Alliance for Aquatic Resource Monitoring, University of Maryland Center for Environmental Science, and the Chesapeake Bay National Estuarine Research Reserve in Virginia.

In 2018, the CMC team successfully built watershed-wide support within the CBP partnership through an unprecedented multijurisdictional Memorandum of Understanding (MOU) for the use of Community-based data (CBP 2018) . The CMC works with diverse partners to collect and share new and existing water quality data of known quality and defined integrity. Through this collaboration, they aim to develop a comprehensive understanding of Chesapeake Bay watershed health, incorporate community science and non-traditional partner data into the CBP partnership's work, and inform progress towards the Bay's restoration goals.

The CMC began integrating data into the Chesapeake Data Explorer (https://cmc.vims.edu/#/home), the database developed by the CMC. There are currently (in 2022) over 600,000 volunteer-based water quality and nontidal macroinvertebrate monitoring data points in the Chesapeake Data Explorer. These data are publicly available and used to enhance the understanding of the health of the Chesapeake Bay and its watershed.

Land Use and Land Cover Monitoring

In February 2018, the EPA CBPO issued a Request for Proposals (RFP) to provide "geospatial analysis support for the CBP partnership in support of the targeted implementation of actions in support of reaching the goals and outcomes of the 2014 Chesapeake Bay Watershed Agreement." In the summer of 2018, a six-year, $7.5 million Cooperative Agreement was awarded to the Chesapeake Conservancy (CC) which allows the CBP Partners to actively participate in the development of products and enables adjustments to the scope to address evolving technology and partnership needs. The first objective of the proposal involves the production of comparable land cover and land use data for the years 2017 and 2021, an accuracy assessment, and corrections to the existing 2013 land use data so that it is directly comparable with the data produced for 2017 and 2021. The CC subcontracted with the University of Vermont's Spatial Analysis Laboratory to produce the 12-class land cover data while the CC leads the development of the 55-class land use data. Land cover and land use data are being developed for all 206 counties intersecting the Bay watershed, which equates to a 100,000 square mile area. Funding for this RFP was provided at the sole discretion of EPA and subject to the availability of funds on an annual basis.

In March 2022, USGS, CC, and University of Vermont released high resolution land cover and land use data products based on 2013/2014 and 2017/2018 National Agricultural Imagery Program (NAIP) data. The datasets will inform multiple outcomes in the 2014 Chesapeake Bay Watershed Agreement and inform the next generation of Bay models (e.g., watershed, estuary, and land change). Some of the applications of these data involve identifying BMP opportunities and locating BMPs where they may be most effective, targeting land conservation, informing land use planning decisions, contributing to CBP tools such as the Chesapeake Healthy Watersheds Assessment, and support indicators development or assessment (e.g., tree canopy, forest buffers). With this dataset completed, they will move forward with data assessment using imagery that reflects 2021/2022. The process to produce the data products is roughly two years to get the datasets, revise the methodology, allow time for the data to process, and evaluate accuracy.

Analysis and reporting of CBP Monitoring Networks are generally not represented in this review

Network enhancements may occur to address data gaps in space or time with more stations, new sensors, new partners, and implementing new and innovative approaches for monitoring and assessment. However, operationalizing any of these enhancements is more than just acquiring innovative technology or recognizing a viable means of acquiring new data. Considerations and challenges include analysis, synthesis of the data collected, and translating the findings into useful, informative communication products. The gaps, needs, and cost estimates associated with analysis and synthesis were not the target of this review and are not included in most of the line items of the investment needs table. Even though analysis and synthesis of the watershed and Bay monitoring data may not be included in this report, these factors are essential to understanding and communicating changes through time that support decision-making and adaptive management. Without first improving how the current monitoring networks operations are sustained and addressing how to improve monitoring capacities, the state of monitoring would not be able to keep up with the assessment needs of the CBP community.

Most of the CBP core monitoring networks have a long-term history of data collection lending themselves to be high value targets for use in applications such as characterizing status, developing and synthesizing trend analyses, indicator development, model development, calibration and verification, and more (Figure 4.8). As part of the work to enhance the monitoring networks there is a need to coincidentally continue refining analyses that improve understanding of major drivers of water quality and living resource change and to better distinguish the response of impacted resources around the watershed, within and across tidal tributaries, and along the mainstem Bay.

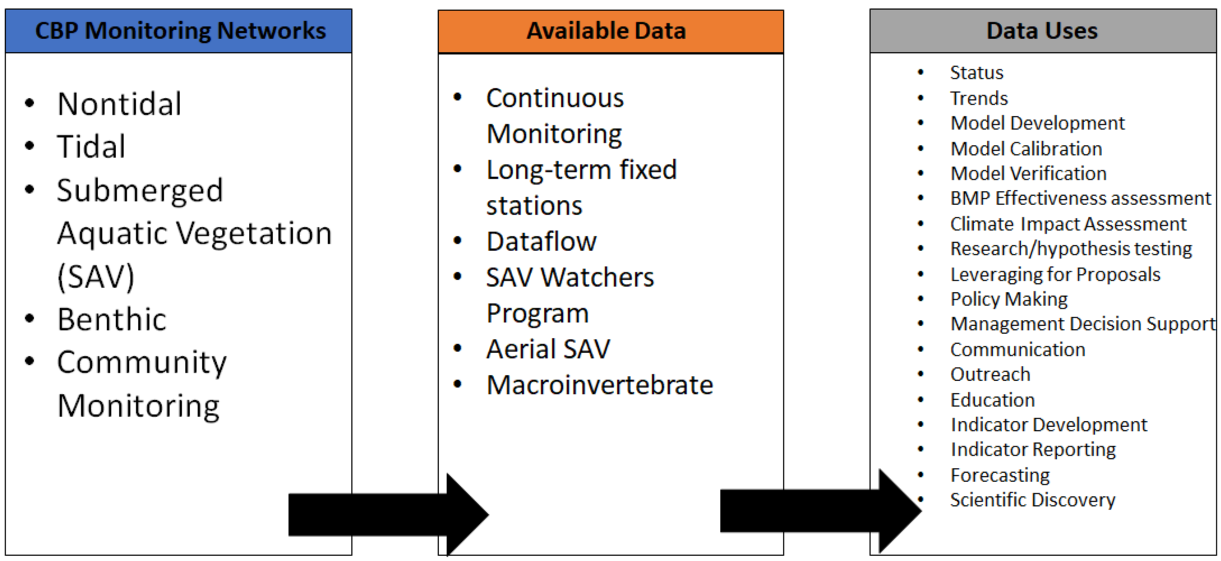


Figure 4.8 Classification of the core Chesapeake Bay Program (CBP) Monitoring Networks, the data available through those networks, and the potential data uses.

Continued collaboration and engagement with science providers will produce successful research and development and application of advanced analysis approaches. Reliable monitoring data will support their efforts and progress on addressing management-relevant questions for more effective targeting of management options and actions (Figure 4.9). In addition, the enhancements to the monitoring networks will put the CBP partnership in a better position to address questions about drivers of observed water quality and living resources changes and effectively target the next cycle of analysis to address management concerns.

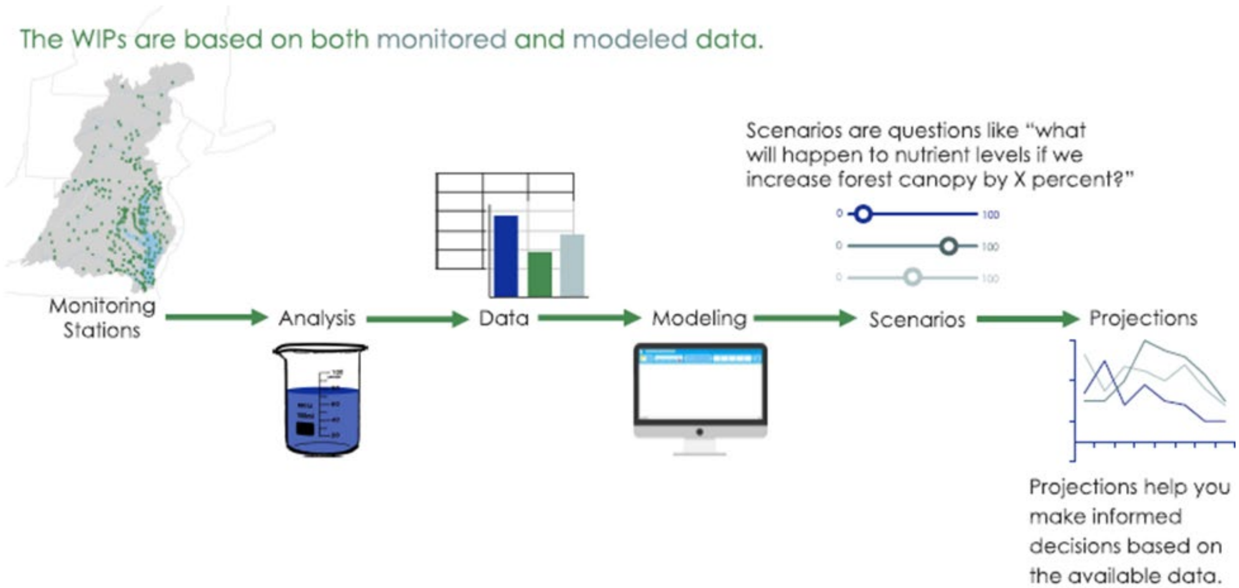


Figure 4.9 Conceptual example of the application of monitoring data to support addressing questions for management decisions. Image source: *A Local Government Guide to the Chesapeake Bay – Module 2: Foundations of Clean Water* (https://www.chesapeakebay.net/channel_files/42983/module_2_-_foundations_of_clean_water.pdf).

Question 2: What are Monitoring Network's vulnerabilities to maintaining their operation and integrity?

Vulnerability assessment refers to a continuous process or plan that:

- Defines what is classified as a vulnerability across the network impacting the capacity of a network to operate at existing levels of support to provide necessary data to provide outputs that meet decision-maker needs
- Identifies and prioritizes vulnerabilities in the network for remediation, based on greatest impact to risk reduction
- Determines remediation actions for vulnerabilities found in the assessment.

Assessing network vulnerabilities provides management teams with critical insights into the risks and weaknesses affecting consistent integrity of operations (i.e., data collection, data management, data analysis, synthesis, and reporting) for the network.

The CBP has long stewarded one of the most comprehensive and long-term estuarine water quality monitoring efforts in the world, supporting information needs to address diverse objectives. While the monitoring efforts have served many of these objectives very well, programming is not immune to vulnerabilities affecting sustained capacity to provide expected data collections used to generate essential decision-support information for the CBP partnership. An example of a SAV network vulnerability summary (Figure 4.10) was provided by Orth and Wilcox (2021).

Effect of Factors influencing the CBP Annual SAV monitoring program budget through time

+ = increased funding need in budget; - = decreases to the budget

- Inflation ($100,000 in 1984 = $233,489 in 2016) (+)
- Conversion of hourly staff to full time with benefits (+)
- Addition of flight lines in Virginia tributaries, 1999 (+)
- More SAV to map (+)
- Printed report transition to web-based reporting (-)
- GPS/IMU added to imagery 2007 (+$20 -30K)
- Added 4th full time staff early 2000s (+)
- Eliminated 4th full time person 2017 (-)
- Digital imagery requires more flight lines to cover SAV areas (+)
- Aerial contract costs increase with time (1989 to 2016) (+)
- Personnel raises, reallocation of positions (+)

Source: Adapted from B. Orth and D. Wilcox "The Chesapeake Bay Annual Survey Monitoring Program: Its Evolution – 1974-2019" *in* Landry, B., Tango, P., Bisland, C., Coffer, M., Dennison, B., Hill, V., Lebrasse, C., Li., J., Orth, R., Patrick, C., Schaeffer, B.,Witman, P., Wilcox, D., Zimmerman, R. 2021. Exploring Satellite Image Integration for the Chesapeake Bay SAV Monitoring Program – A STAC Workshop. STAC Publication Number 21 -001. Edgewater, MD. (45 pages)

Figure 4.10 Effects of factors influencing the Chesapeake Bay Program (CBP) Annual Submerged Aquatic Vegetation (SAV) monitoring program budget through time, 1974-2019. Source: Orth and Wilcox 2021 *in* Landry et al. 2021.

During this review, the Monitoring Review Team engaged workgroups and managers operating the networks on the themes of risk they have experienced influencing the ability to sustain operation and maintenance of each network. Internal and external program vulnerability factors influence sustained integrity of CBP networks to support monitoring functions. There are multiple issues identified as risk factors affecting the CBP partnership's ability to sustain the capacity of each network operations (Table 4.1). The implications of reduced monitoring capacity include:

- Greater uncertainty toward assessing progress toward attainment of water-quality standards in tidal waters
- Reduced ability to assess nontidal water-quality response to nutrient and sediment reduction efforts being implemented by the jurisdictions to achieve the Bay TMDL
- Increased economic investment needed by jurisdictions for significantly greater management investments with more BMPs to create a large enough signal in the environment that can be detected and overcome the increased uncertainty created by fewer data to estimate the health of the Bay
- Reduced ability to provide targeted implementation of actions in support of reaching the goals and outcomes of the 2014 Chesapeake Bay Watershed Agreement.
- Extended timelines to demonstrate progress and achievement of success.
- No dedicated "rainy day fund" to address unexpected costs each year – e.g., extra sampling needed in the event of a major water quality event in the Bay like an oil spill, a fish kill, a hurricane induced high flow event, a major algal bloom event, etc.

Table 4.1 further provides an explanation of the vulnerability with insights into how program management has influenced decisions on network adjustments or resource distribution to minimize or eliminate the effect of the issue. These are issues that continue to impact planning for maintaining network integrity into the future.

Table 4.1. Vulnerabilities of Chesapeake Bay Program (CBP) Monitoring networks to sustain monitoring operation capacity to collect data that addresses information needs of the CBP partnership.

Vulnerabilities	**Explained**	**Chesapeake Bay Program (CBP) Effects**
Annual rate of inflation	**Inflation** is a general rise in the price level (Cost of living) of an economy over a period of time. When the general price level rises, each unit of currency buys fewer goods and services; consequently, inflation produces a reduction in the purchasing power per unit of money available.	Fewer samples are collected and processed, staff support has been reduced. In recent years, Maryland Department of Natural Resources (MD DNR) has downsized sample collections in response to level funding at state and federal levels as inflation levels affect their buying power to accommodate increases in replacement parts, and service costs over time.
Flat funding in the budget for multiple years	**Flat funding** interacts negatively with **inflation**. Purchasing power declines resulting in program cuts that adjust to the available resources. Cuts have included samples, parameters, cruises, analysis support, upwards to elimination of program elements (like toxics or phytoplankton in the past).	Multiple agencies have proposed data collection and position cuts in response to level funding at state and federal levels to balance resources with available funding. Some cuts needed to be enacted, reducing staff of full time equivalents (FTEs) and data collections.
Clean Water Act (1972) 117e Grant Match	Environmental Protection Agency (EPA) allows States to match funding using non-monitoring restoration project efforts to federal investments in monitoring dollars.	At the extreme, a State could lose all its internal funding for any monitoring effort but match its EPA contribution with all non-monitoring restoration project funding, watering down the investment. Also, States may only have limited match opportunities and not be able to match more investments.
Partner support withdrawal	Sampling programs depend on a collaboration. Occasionally, a collaborator withdraws support in response to their priorities. Partner withdrawal results in threats to sustaining a network station.	A dam owner in West Virginia (WV) provided partial funding at a station. When ownership changed hands, the new owners did not continue monitoring support.
Contractor viability	Business viability can impact program operations. A change in contractor can change the cost structure, often costing	SAV program. A company doing aerial imaging was purchased by another company. Flight costs

	more and interacting with flat funding and inflation challenges to reduce buying power.	are subject to change with renegotiation of the contract for future work.
Aging Infrastructure	Life cycle of boats, motors, and sampling equipment needs to be factored into sustaining program operations as replacement costs.	A shift in boats used from an outdated State fleet boat to an academic institution boat comes with a different cost structure. Contracting the boat time is at a higher cost than the previous State-based boat costs.
Global pandemic	Safety rules impacted work capacity even though funding was available to perform the work under otherwise normal (pre-COVID-19 pandemic) work conditions.	Funding is available but rules of social distancing and boat or lab capacities affects when and how much work can get done while under constraints of safety rules at the height of the pandemic.
Global and national supply and demand dynamics affect fuel costs	Global security can affect fuel prices. Fuel is needed to travel to monitoring locations on the bay and in the watershed. Volatile gas prices introduce uncertainty into program management.	1999: Gas sold for $0.90 per gal. 2005: When Hurricane Katrina destroyed a significant portion of U.S. refining capacity in the Gulf of Mexico, gas prices increased to greater than $3 a gallon. 2022: Russia-Ukraine war pushed average per gallon gas costs in the U.S. over $4/gallon.
Program priorities	Monitoring reviews have identified shifts in management priorities and considerations for information return on investment within the Chesapeake Bay Program partnership. With no new resources, shifting resources between programs has affected monitoring programs positively and negatively.	2004-05: Zooplankton monitoring was defunded, Shallow-water monitoring program was initiated. 2009: Spring tidal benthic monitoring assessment was eliminated. Watershed monitoring was increased by about 40 stations. 2009-12: Tidal monitoring program was reduced, then funding was reinstated and restored a lost summer water quality cruise.
Continuity of data collections (Community Science)	Challenges to sustain community scientist engagement in data collections. Lack of sustainable funding for local groups.	Spatial and temporal gaps in community science monitoring data. Limits expansion of Tier 3 groups across the watershed meeting CBP requirements.

		2022: South River Federation monitoring team has changed, which requires retraining, auditing for adherence to sampling protocols, assuming a group's program priorities remain the same.
Equity and Accessibility (Community Science)	Underserved communities do not have the capacity and resources to apply to grants to start or support local monitoring programs.	Lack of data collected in underserved communities. Hindering streamline of environmental professionals in community.
Sustainable Funding	Funding is reserved for established monitoring programs, with no guarantee for funding to continue monitoring efforts that support enhanced analyses of Bay health and reduce the uncertainties of present assessments.	Community Science: Rise in lab costs. Land Use and Land Cover (LULC) Monitoring: In the summer of 2018, a six-year, $7.5 million Cooperative Agreement was awarded to develop 1-m^2 resolution LULC data. There is currently no funding or plan in place to continue this 1-m^2 resolution LULC monitoring effort.
Staffing	Periodically, staffing challenges impact sample collection, coordination	Uncommon, however, lost capacity during extended time off for one or more employees periodically limits staff availability and capacity.
Lack of utilization of monitoring and assessment results	The findings about the factors affecting trends in both nontidal and tidal waters have had limited use by most jurisdictions in developing their WIPs and Milestones.	To make better use of monitoring results, analysis and syntheses are being linked with other decision-support products like Chesapeake Assessment Scenario Tool (CAST).

Question 3: What budget and fiscal management strategies have been used in response to annual funding challenges for maintaining and growing the networks?

The most frequent annual financing approach from EPA delivering funding into the grants and interagency agreements supporting core monitoring programs is constant value interannual funding. This means that for much of the last 10 years, funding provided by EPA to grants was unchanging. Extended periods of level funding leads to reduced buying power over time for the goods and services required to operate the program as cost of living rises each year, i.e., effects of annual inflation on the value of a dollar. State matching funds under the Clean Water Act (1972) 117e program are required at a ratio of 1:1 which would also be static through time under this funding and program management model.

Six primary program management strategies have been identified for sustaining operation of networks influenced by negative financial pressures affecting the ability to sustain network integrity and operations:

- **Downsizing** of the traditional core Chesapeake Bay Program water quality monitoring operations is the primary strategy for program management under level funding through the CWA 117e grant support. Less data can be afforded to be collected and processed, monitoring site and staff reductions occur to compensate cost increases against level funding resources.
- **Reallocation of resources** within and between monitoring programs. Reallocation of funding has been used coincident with a shift in priorities. However, with this approach one or more programs is downsized sufficiently to save and/or grow capacity of another program effort. Overall programming capacity is again reduced.
- **Backfilling** by 1) EPA, or 2) other federal partners, States, Interstate agencies or new partners is typically sought to address shortfalls that arise under an EPA level-budget scenario or if an anomaly occurs (See examples in the Vulnerabilities table above).
- **Use alternative data sources** such as Community Science are starting to fill program gaps**.** There are many sources of environmental data. Analysts have specific requirements on data Quality Assurance (QA) and integrity of data collections and management. When data are found to be of sufficient quality and integrity, they may be adopted into an assessment. The Chessie BIBI used for watershed health assessment uses data from a variety of agencies and institutions that follow suitable protocols in collection, handling and laboratory assessment as an example.
- **Congressional support.** Any funds provided by Congress will be structured to support the program identified by Congress. (e.g., 2017 and the Chesapeake Bay SAV program)
- **New Program investment**. On occasion, a new program is created that affects data collection support separate from traditional resources, e.g. The community science program or Chesapeake Monitoring Cooperative was established with new EPA funding in 2015 https://www.chesapeakemonitoringcoop.org/)

Not all options used individually sustain full integrity of data collections when implemented to continue network operations. Used together strategically over a period of years, the suite of options has provided give and take of support to buffer a full network loss while new resources may be found to restore or grow the networks to address CBP partner information needs. Table 4.2 below highlights which programming strategies have been implemented to sustain CBP core network's integrity.

Table 4.2 Program elements and programming strategies addressing sustainability of existing program efforts.

Program Element	**Program Management Strategy addressing sustainability**	**Impact**
Tidal Water Quality Monitoring	Downsizing and reallocation	Operating under a flat funding scenario, sample collections are declining for the long-term monitoring program work.
	Alternative data resources	Tier 3 Community Science-based water quality profiles have been approved for water quality standards attainment assessments
Nontidal Water Quality Monitoring	Reallocation	In 2009, station numbers were increased in the watershed network through reallocated funds
	New programming	New funds were added to the nontidal program from 2010-2012.
	Backfilling	Annual station loss is a constant risk
	Downsizing	Operating under a flat funding scenario, the projected impact of inflation will require station reductions. In 2022, the Conocheague station faces potential elimination (*Note: Conococheague Creek is now fully funded in FY22/23 by Nontidal Network EPA-USGS Interagency Agreement in response to the monitoring review).
Tidal Benthic Monitoring	Reallocation	In 2009, the spring season benthic Index of Biotic Integrity (IBI) program was defunded with funding moved into the nontidal water quality monitoring program.
	Backfilling	Sustained summer sampling program occurs as States manage a summer-only benthic monitoring program as matching funds under the Clean Water Act (1972) 117e grants.
Submerged Aquatic Vegetation (SAV) Program	Congressional line item	2017 updates to the Water Resource Development Act, which amends Section 117 of the Clean Water Act (1972), now requires EPA to carry out an annual SAV survey in Chesapeake Bay.
	Alternative data resources	Free high-resolution commercial satellite imagery for bay assessments is supported by Federal contracts. Research and pilot studies show a satellite based SAV survey is approaching feasibility for the Bay.
Community Science	New program	In 2021, a new 6-year Agreement was awarded to Chesapeake Monitoring Cooperative (CMC). The awardee will continue under an approved 6-year

		budget plan designed with the proposed budget available to support programming.
Land Use Land Cover	Reallocation	Current Cooperative Agreements includes additional funding to award Chesapeake Conservancy and University of Vermont for support. If there is no additional support in the next agreement the Chesapeake Bay Program (CBP) Geographic Information Systems (GIS) team will perform all work, which will limit the capacity of the team to support GIS needs for the 31 outcomes.

Question 4: What (data collection) gaps need to be filled to improve the CBP monitoring networks?

Data collection is one element of the monitoring activities in the data life cycle supporting resource management. We focused this question on understanding data gaps. Data gaps are then linked with network design and monitoring strategy to understand the sample collection effort needed to address the gap.

For each of the Chesapeake Bay Program (CBP) core monitoring networks, monitoring program gaps were documented as targets for sustaining and improving the network operation for addressing management information and decision-support needs. The monitoring program related gaps were compiled from the CBP Science Needs Database, which tracks both the short- and long-term science needs of the partnership. However, additional insights are derived from ongoing CBP STAC activities and workshops focusing on data collection needs and the reason data are needed. In this review, we parsed out data collection needs for maintaining and growing the base of information necessary for filling gaps in decision-support needs (Table 4.3).

Table 4.3 Chesapeake Bay Program partnership-defined data collection needs for the existing Chesapeake Bay core monitoring networks along with the Toxic's monitoring program, collated from the Chesapeake Bay Program (CBP) Science Needs Database and CBP Scientific and Technical Advisory Committee (STAC) workshops in 2022.

Existing Monitoring Network	# of Science Needs	Specific data collection gap	Gap filling need	Reason
Tidal & Nontidal	42	High temporal density dissolved oxygen, salinity and temperature measures in open water	Water-quality measurements with vertical-arrays continuous monitoring sensors	Unassessed short- duration water quality criteria/fish habitat assessment
			River input continuous monitoring sensors	
			4-Dimensional (4D) interpolator for data analysis	

Tidal		Direct management effectiveness assessment	Nutrient limitation survey	Measurement of management effect controlling nutrients is directly linked to nutrient limitation
Submerged Aquatic Vegetation (SAV)	12	High frequency, high resolution satellite imagery	Full growing season assessment of diverse grasses in the bay	Expand seasonal criteria assessment of bay grasses, cost effective and efficient enhancement
			Artificial Intelligence/Machine Learning (AI/ML) algorithm for interpretation	
		Quantifying the ability of freshwater, mesohaline, and polyhaline SAV to sequester carbon	Invest in Sentinel Site Program	Necessary to obtain and process the samples needed to determine biomass, productivity, and consequently carbon sequestration of the Bay's SAV to help break into the carbon market
Community Science	1	SAV Watchers	Satellite calibration and verification	Support SAV program enhancement
Benthic	0	---	---	---
Land Use Land Cover	1	Watershed wide land use satellite imagery	1m (high resolution) every 3 years	Maintain watershed-wide land use change monitoring program
Toxics	6	Polychlorinated Biphenyls (PCB) monitoring of management actions	Monitoring in 1 geographic location of PCB response to mitigation efforts	Enhance PCB monitoring to establish current conditions and determine if remediation or management actions are resulting in downstream reductions of PCBs

Water quality and land use represent a subset of 2014 Watershed Agreement outcomes with monitoring programs needed to characterize status and assess progress to outcome and goal achievement. Some non-water quality and land use outcomes (e.g., oyster restoration, blue crab management) have long-term monitoring programs with sustained support by various agencies (e.g. NOAA). However, other outcomes lacking monitoring program support are still maturing in their program development, working on understanding their information needs in order to support sampling design and monitoring plan development. The Toxics WG is one additional outcome where information needed for management decision support on PCB's has been translated into a monitoring plan that addresses sampling design and sample collection needs (Table 4.3).

Question 5: How can existing monitoring data and analysis be used to address these gaps?

Options to fill data gaps in analyses when no new funding resources are available involve three basic choices:

1. Finding and using new data sets outside of traditional CBP data collection programs and sources
2. Applying alternative data analysis methods that leverage existing data
3. Adopting alternative data collection methods with better cost, time and sampling resolution efficiencies that create new data streams.

Significant investments in CBP-STAR workgroup time and effort are made every year to consider if any other data sets may be suitable to include in our CBP decision-support analyses. Data collections used by the CBP to produce annual products, explore hypotheses on how the bay and watershed function, or calibrate and verify models, are characterized as having specific, repeatable, published and approved protocols of data collection, sound quality assurance/quality control procedures and associated documentation, and extensive data and metadata management to support the integrity of the dataset.

With widespread participation by agencies and institutions in diverse and frequent workgroup meetings it is uncommon to discover new data that can be effectively used to address monitoring needs. For example, the 2009 Monitoring Realignment Action Team (MRAT) conducted a search of potential data sets that might be used by CBP for assessments. The MRAT surveyed CBP partners and identified nearly 300 monitoring programs operating historically or currently across the watershed and Bay (Wardrop and Haywood 2009). Physical, chemical and biological monitoring programs were identified. However, upon review, no data sets beyond the traditional CBP-funded programs matched the specific data needs with sufficient scale, rigor, integrity and resolution for CBP analysts to include them to generate more robust or new decision-support products. This is not surprising based on a study (Sprague et al. 2017) that considered the potential for secondary use of water quality data across the nation where approximately 60% of over 25 million water quality records reviewed were found to be of limited use. Sprague et al. (2017) showed challenges to secondary use of data included many data records with missing or ambiguous information for one or more key metadata elements including sample fraction, chemical form, parameter name, units of measurement, precise numerical value, and remark codes. As a result, metadata harmonization to make secondary use of multi-source data would be time consuming, expensive, and inexact. Further, different data users may make different assumptions about the same ambiguous data, potentially resulting in different conclusions about important environmental issues. While CBP remains open to the strategy of using alternative secondary data sources to address data gaps it is rarely a suitable strategy where decision support needs specific, targeted information.

Alternative analyses represent an active area of CBP work that has extended the use of existing data. Hernandez et al. (2020) published the multi-metric indicator that estimates water quality standards attainment by extending the use of limited data with decision rules to compensate for missing data necessary for a complete accounting of water quality standards attainment in the Bay. Zhang et al. (2018) published the “attainment deficit” accounting of water quality conditions in the Bay that moved the program beyond a pass-fail binary assessment and provided guidance on how close management segments in the Bay were to achieving attainment of their water quality standards. Trend analyses of nontidal and tidal data continue to evolve to better use available data (e.g., Zhang and Hirsch 2019 and Murphy et al. 2022, respectively). The CBP community is constantly working to extend the utility of the available data through innovative methods to help address decision-support needs.

Formally adopting new data collection methods at the program level that address data gaps has required extensive time to evolve from research, proof-of-concept results that get translated into an approved method or protocol that is adopted for application. A recent CBP-STAC Workshop (Landry et al. 2021) evaluated the potential for Chesapeake Bay SAV monitoring to be based on satellite dependent data collection instead of fixed-wing aerial overflight-based assessments. In 2022, a CBP STAC workshop on Advanced Monitoring was completed to document the state of the science for turning research into operational protocol for data collection and assessment for a broader set of water quality parameters. Land Use Land Cover work in the CBP has developed a process for monitoring land use change based on newly available 1m-scale resolution satellite imagery. The pursuit of new data collections is an active area of investigation for our CBP community, however, developing approved protocols for interpretation, assessment and reporting extend the time between identification of new data streams and their application to inform management and policy decisions.

Question 6: What innovations are available?

There are applications of innovations in data collection and interpretation being developed for water quality standards attainment assessment, assessing response to management actions in the bay and watershed, and the breadth of 2014 Watershed Agreement outcome indicator data gaps. The following innovations are the focus of active efforts in 2022 to advance their application to improve and grow network data collection and interpretation operations for CBP monitoring:

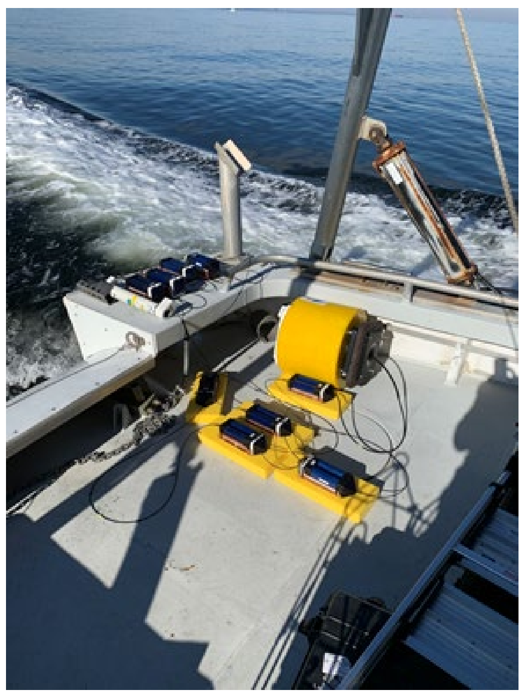
- Vertical arrays of continuous water quality monitoring sensors
- High-temporal frequency nitrate sensors
- 4-D interpolator tool for assessing water quality data
- High resolution satellite imagery
    - Land Use Land Change application
    - Aquatic resource annual monitoring program data collection needs
- Artificial Intelligence/Machine Learning algorithms for high through-put image assessment
- Community Science

The following sections provide detailed insights into the capacity for these innovations to fulfill data gap needs of the CBP.

Innovation: High temporal frequency vertical array infrastructure and sensor network design for Chesapeake Bay

Short-duration dissolved oxygen criteria are an explicit subset of criteria evaluations necessary to support water quality standards attainment assessment for the tidal waters of Chesapeake Bay. The 7-day mean, 1-day mean, and instantaneous minimum dissolved oxygen criteria are largely unmonitored and unavailable as complete data for any of the 92 bay segments. Dissolved oxygen, salinity and temperature data are needed to simultaneously characterize habitats (open water, deep water, and deep channel designated uses) to apply habitat-specific dissolved oxygen criteria thresholds to the time series in the analysis. Fixed-depth continuous monitoring sensor arrays located in shallow water offer an opportunity for subsegment evaluation of bay health (EPA 2017). Data collections are available for short periods at subsegment-level evaluation scale with monitoring in shallow water habitats since the late 1990s. Nearshore-offshore comparisons of sensor assessments have shown an inability to extend single depth nearshore assessments to represent the full water column conditions in offshore habitats. Offshore, open water habitats have been challenging to operate available instrument arrays in the dynamic currents and conditions of the Chesapeake Bay estuary until recently.

A GIT-funded pilot study in 2019 provided a contractor challenge to provide a cost effective, robust, reliable, easily deployable and retrievable sensor system to collect high temporal frequency (e.g., 10-minute intervals) data throughout the water column. These are the data missing since the creation of the criteria in 2003 (EPA 2003) necessary to produce a full dissolved oxygen criteria assessment of open water, deep water and deep channel habitats. Results of the pilot study (Wilson 2021) demonstrated the ability of a new monitoring array system to address program needs of targeted data collections in previously difficult habitats of the bay for continuous water quality data collection (Figure 4.11).



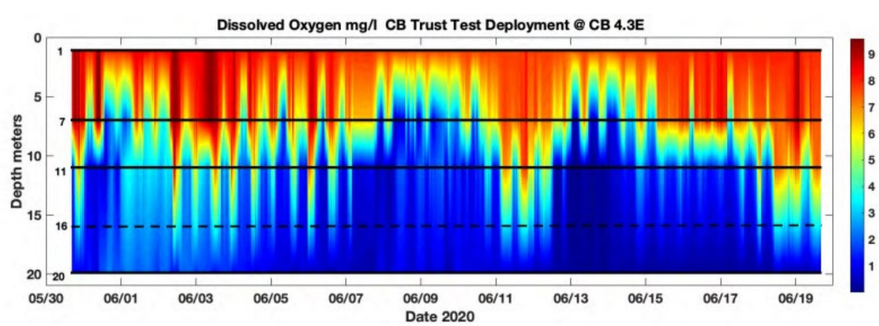


Figure 4.11a and 4.11b. 4.11a New easily deployable, robust sensor array for open water habitat data collections. 4.11b – Example data set for approximately 1 month in 2020, 20-meter water column depth, deployed near the

mouth of the Choptank River, Maryland (MD). (Upper image courtesy of National Oceanic and Atmospheric Administration (NOAA), lower image courtesy of Doug Wilson, Caribbean Wind LLC).

The Hypoxia Collaborative Team is a new workgroup, formed in 2021 of the Chesapeake Bay Program that formed under CBP-STAR in 2021 out of the successful work of the pilot study https://www.chesapeakebay.net/who/group/hypoxia_collaborative_team . The group of federal, state, and academic partners is working to develop a hypoxia monitoring network that coincidentally considers data needs to fill gaps for unassessed water quality criteria, fish habitat assessment, and model development calibration and verification. Meetings during 2021 and early 2022 focused on community input for strategic network design and initial placement of two NOAA arrays. NOAA and EPA are exploring partnership opportunities to build out a 10-array system with station locations based on recommendations from the Collaborative (Figure 4.12). The network may further be highlighted for supporting climate change indicators tracking pending the development of science need recommendations coming out of the 2021-2022 CBP STAC Rising Water Temperature workshop.

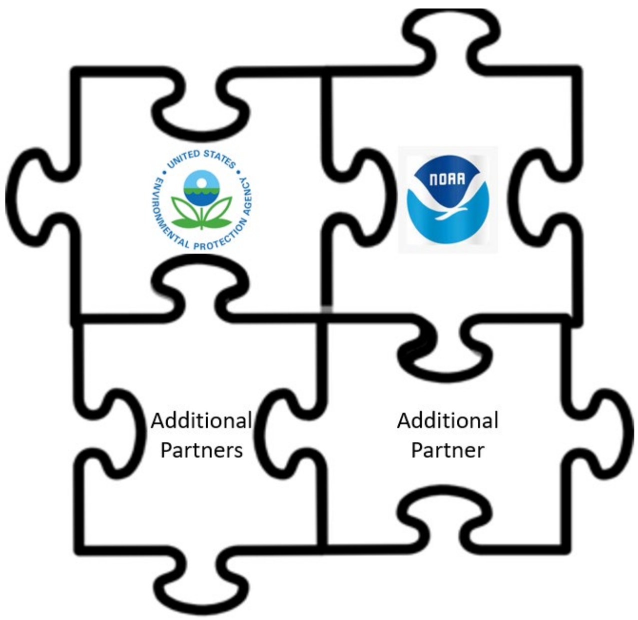


Figure 4.12 Environmental Protection Agency (EPA) and National Oceanic and Atmospheric Administration (NOAA) have expressed interest in collaborating to enhance tidal monitoring for dissolved oxygen and fish-habitat assessment in the estuary.

Innovation: 4D interpolator for water quality standards and fish habitat assessment.

Coincident with the development of the new vertical water column high temporal frequency data collections is the need for a tool to use the data to improve water quality criteria attainment assessments. The Bay Oxygen Research Group (BORG) formed in April 2021 under CBP STAR to evaluate methods that might be used to develop a Chesapeake Bay 4-dimensional interpolation tool and pursue development of the tool https://www.chesapeakebay.net/who/group/bay_oxygen_research_group .

A 2008 CBP-STAC Workshop originally posed the question regarding feasibility of our available methods, data, and technology to effectively support water quality criteria attainment assessment with 4-

dimensional interpolation (Curriero et al. 2008). The consensus of the expert panel was that there was insufficient information to evaluate the feasibility of a 4-D interpolator for use in water quality assessment or related activities at the time. However, the panel further recommended that a study be initiated to evaluate the different approaches available for developing a 4-D interpolator, and data analysis studies be initiated to develop the statistical basis for a 4-D interpolator.

Over the next decade, 4-D interpolation methods were developed, and applications have been published on their application in other systems like the dissolved oxygen conditions in the Gulf of Mexico (e.g., Obenour et al. 2013). Working under CBP-STAR guidance, a small team of analysts of the Chesapeake Bay Program's monitoring and modeling teams, with consultation and collaboration from independent statisticians and academicians, re-evaluated the state of the science on 4-D interpolation during spring and summer of 2021. The team agreed 4-D interpolation of Chesapeake Bay water quality was now feasible, and multiple options for approaches were available to address the issue.

A proof-of-concept example of applying the Generalized Additive Model approach to create a 4-D interpolation of dissolved oxygen conditions was developed between autumn 2021 and spring 2022 within the work of the BORG Leadership Team. For conceptual and computer power considerations, time steps in the model have been daily. Work is being considered now to apply high-temporal frequency measurements to the interpolations to address the sub-daily scale of resolution needed for water quality criteria assessment and other habitat characterization applications.

When the 4D interpolator is complete, it will complement existing work on DO, SAV/clarity and Chlorophyll-A (CHLA) to fulfill all assessment needs when combined with the new data streams and evaluation techniques. However, decisions of attainment or nonattainment may come with probability statements on attainment of a segment for a criterion when accounting for uncertainty. The latest advances of the 4-D interpolator were presented at the May 2022 CBP STAC-sponsored Advanced Monitoring Workshop event.

Innovation: High resolution satellite imagery (1). Accessibility of high spatial resolution satellite imagery for land use land change assessment (~ $1m^2$)

Under the Land Use Land Change Metrics outcome of the 2014 Watershed Agreement, Management Approach 1 is to monitor the rate of conversion of forests, wetlands, and farmland, and the rate of impervious surface change https://www.chesapeakebay.net/documents/Narrative_Analysis_LUMM_2021.pdf . Recent years have been focused on developing high-resolution ($1m^2$) land cover and land use data for 2017 (e.g., Figures 4.14a-c below), identifying hot spots of change with Landsat satellite data, and accurate, complete detection of land cover change from 2013 to 2017. Producing comparable land cover products for 2013 and 2017 based on existing data requires a custom approach for each county based on the type, quality, and vintage of ancillary data (e.g., planimetric impervious cover, leaf-off imagery, lidar normalized digital surface models). In addition, no product can achieve the targeted level of accuracy (90-95%) without significant manual editing. This is particularly true for targeting change because change is rare so a few large-area omissions could result in highly inaccurate results. Purchasing high-resolution imagery for 2021 and future years from Hexagon or Vexcel could be explored because both companies provide a digital surface model (elevation of the tops of objects in the images) with their imagery allowing for more accurate temporal representation (lidar is often +/- 3 or more years from the dates of the NAIP imagery) and higher quality spectral data may further reduce the need for and cost of manual editing. To address long term monitoring needs of land use change, investment in high resolution imagery of the watershed every 3-4 years is necessary to support the monitoring program.

Figure 4.13a-c. 4.13a 2017/18 Aerial Imagery (United States Department of Agriculture (USDA) National Agricultural Imagery Program); 4.13b 2017/2018 Land Use interpretation (CBP); 4.13c 2017/2018 Land Change (CBP).

Innovation: High resolution satellite imagery of the Bay (2). Accessibility and interpretability of commercial high-resolution satellite imagery for SAV area assessment supporting water quality criteria attainment measures in Chesapeake Bay.

Aerial imagery collected by fixed wing aircraft has been used to measure and track Chesapeake Bay SAV since 1975. Publicly available satellite imagery has been widely accessible for decades, however, pixel resolution was a limitation for effective, efficient and reliable characterization of SAV cover and therefore of limited use. Recently, new satellite image sources are producing publicly available imagery with improved pixel resolution (e.g., PLANET Scope $4m^2$ resolution). This is closer to the sub-meter resolution of the fixed wing aircraft data and, when aerial flight paths could not be covered on an ideal schedule in a year due to weather or other factors, newer satellite images have been sufficient to help backfill estimates of SAV cover.

Satellite image use has been opportunistic during these backfill efforts. Any consideration for a complete dependency on satellite-based SAV assessment in the program needs to address key monitoring issues including 1) bay-wide coverage, 2) effective targeting of specific areas in space and across time, 3) be affordable, and 4) be accessible. The 2021 STAC-sponsored workshop "Exploring Satellite Image Integration for the Chesapeake Bay SAV Monitoring Program" was used to evaluate details of options and opportunities for commercial satellite imagery (CSI) with meter-scale resolution comparable to the aerial image data collections could be engaged to provide support for the annual bay-wide SAV survey. Workshop findings indicated CSI could provide viable local estimates of SAV cover directly comparable to aerial image assessment approaches used today (Figure 4.14). However, a follow-up study to test implementation of a full bay monitoring program with CSI identified a series of challenges remaining before making such a data source transition (Figure 4.15).

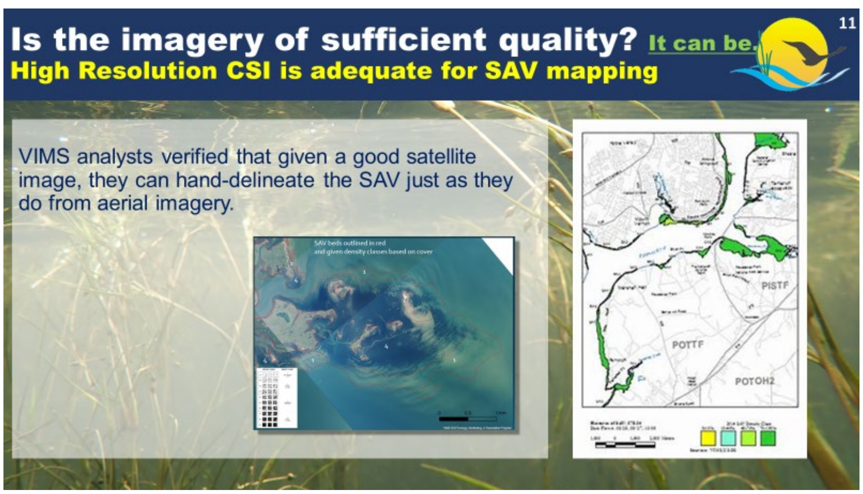


Figure 4.14 2021 Chesapeake Bay Program (CBP) Scientific and Technical Advisory Committee (STAC) Workshop presentation by Orth and Wilcox (2021) reporting of viability of local satellite images to produce comparable cover mapping in an area compared with aerial image-based assessment. Source: Brooke Landry, Maryland Department of Natural Resources, CBP SAV Workgroup Chair.

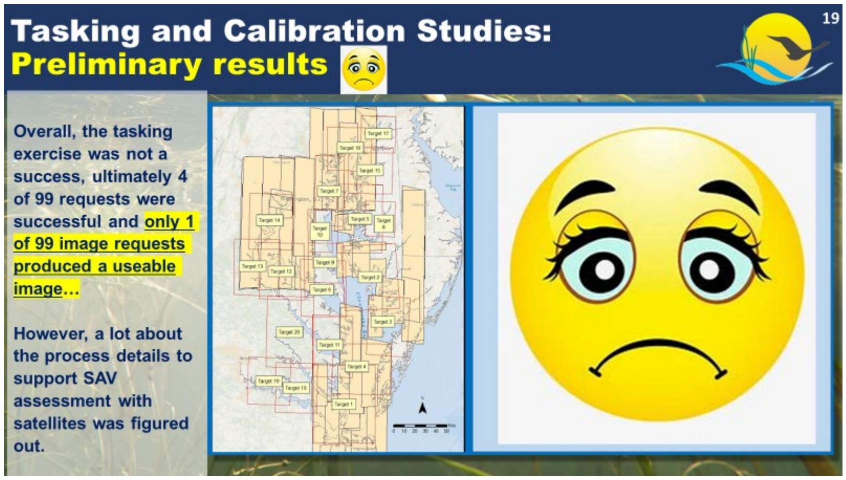


Figure 4.15 2021 Chesapeake Bay Program (CBP) Scientific and Technical Advisory Committee (STAC) Workshop presentation by Orth and Wilcox (2021) reporting challenges associated with targeted satellite images collection on a bay-wide scale. Source: Brooke Landry, Maryland Department of Natural Resources, CBP SAV Workgroup Chair.

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Research is tackling the challenges of effective commercial satellite imagery (CSI) accessibility, interpretability, reliability and dependability necessary to transition protocols from research phase into an annual, functional operational SAV monitoring program. Innovation is being targeted for testing on spring SAV resources (i.e., *Zannachellia)* as an extension of proof of concept from local area assessment to a viable, regional monitoring programming option.

Innovation: AI/ML algorithms for satellite image assessment of water quality and living resource measures.

The Annual Chesapeake Bay SAV monitoring program has produced estimates of bay-wide cover by hand mapping SAV beds since 1974 (Figure 4.16). New computer-based image interpretation methods are evolving to interpret images for target resources like SAVs in Chesapeake Bay. Artificial Intelligence/Machine Learning algorithm development is proving to be capable of mapping SAV resources in diverse estuaries with and satellite image sources (e.g., Coffer et al. 2020, Figure 4.18).

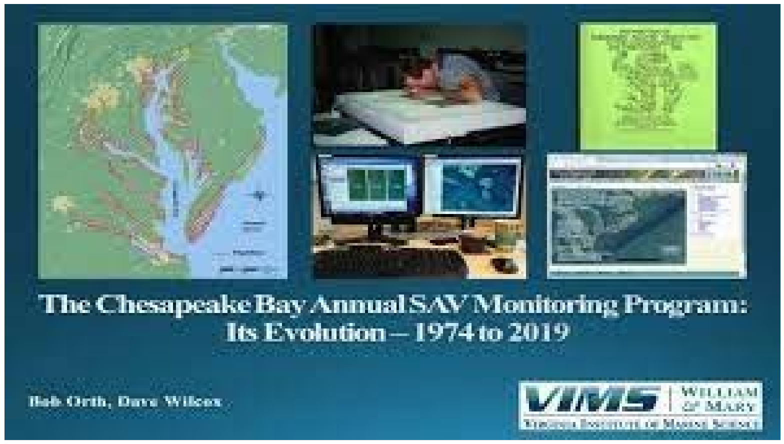

Figure 4.16 Hand drawing Submerged Aquatic Vegetation (SAV) beds remains the bed delineation approach to evaluating aerial or satellite imagery used in assessing annual SAV cover in Chesapeake Bay. Image source: Orth and Wilcox (2021).

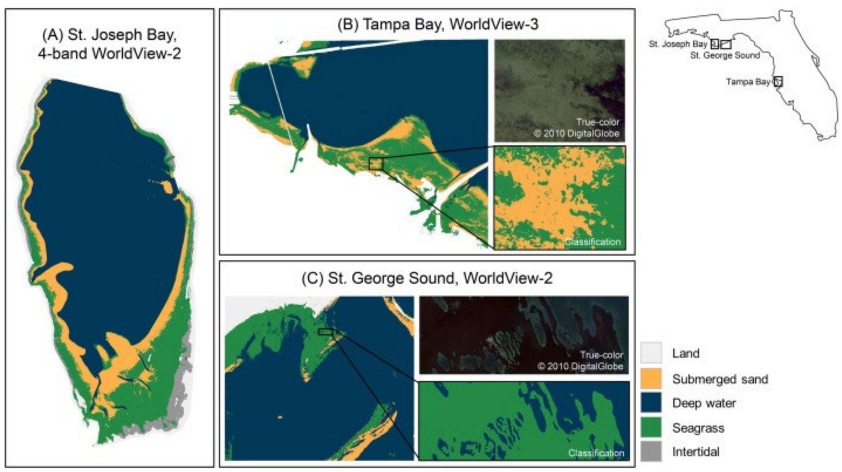

Figure 4.17 Multi-estuary assessment by satellite-based image classification assessment evaluated using a computer algorithm approach to image interpretation. Image source: Coffer et al. 2021. Copyrights are included on the True-color images for 2010 DigitalGlobe imagery on this figure.

Algorithm calibration and verification is needed for the highly variable and frequently turbid conditions in tidal waters of Chesapeake Bay. Algorithm development for mapping SAV in connection with availability and accessibility of new high resolution satellite image resources provide us with few remaining challenges to conducting regional SAV assessment with a new set of tools in the years ahead. Support for algorithm development that addresses remaining hurdles supporting a complete assessment process are necessary to move the CBP from research proof-of-concept into annual monitoring program operational mode with this technology.

AI/ML algorithms are already being used to characterize key water quality parameters in Chesapeake Bay including chlorophyll a (Gilerson et al. 2021) and water clarity (Tomlinson et al. 2019). Time series assessments are available for chlorophyll and water clarity related conditions (He et al. 2021 and Turner et al. 2021 respectively). Here again, CBP program work remains to assess the ability of such research output to address data gaps and establish a protocol suitable for adoption into a monitoring program.

Innovation: Community Science contributions

As described in Q5, the 2009 Monitoring Realignment Action Team (MRAT) conducted a search of potential data sets that might be used by CBP for assessments. The MRAT surveyed CBP partners and identified nearly 300 monitoring programs operating historically or currently across the watershed and Bay. However, no data sets beyond the traditional CBP-funded programs matched the specific data needs with sufficient scale, rigor, integrity, and resolution for CBP analysts to include them in existing decision-support product development. What was clear was that there was a widespread interest in monitoring by community scientists who were interested in contributing useful information for scientific and regulatory assessments.

The genesis of a new Community Science program within the CBP grew out of that recognition. The new CMC program (https://www.chesapeakemonitoringcoop.org/) resolved to coordinate data collection by community science groups with targeted applications, networking with efforts to expand space and time coverage to support CBP relevant monitoring data needs. In March of 2022, the CMC Chesapeake Data Explorer database (https://cmc.vims.edu/#/home) had over 500,000 data points of known integrity, integrity being a long-standing challenge to the otherwise limited utility of secondary datasets.

Expansion on collaboration with community groups is an experiment in social science. For example, protocols were developed and published for use by community groups to help support species assessment of SAV distribution in the bay, and calibration and verification of aerial and satellite-based assessments (Webster et al. 2021 and https://www.chesapeakemonitoringcoop.org/chesapeake-bay-sav-watchers , Fig. 4.18). Expansion of the programming is targeted as an innovative addition to traditional SAV assessment.

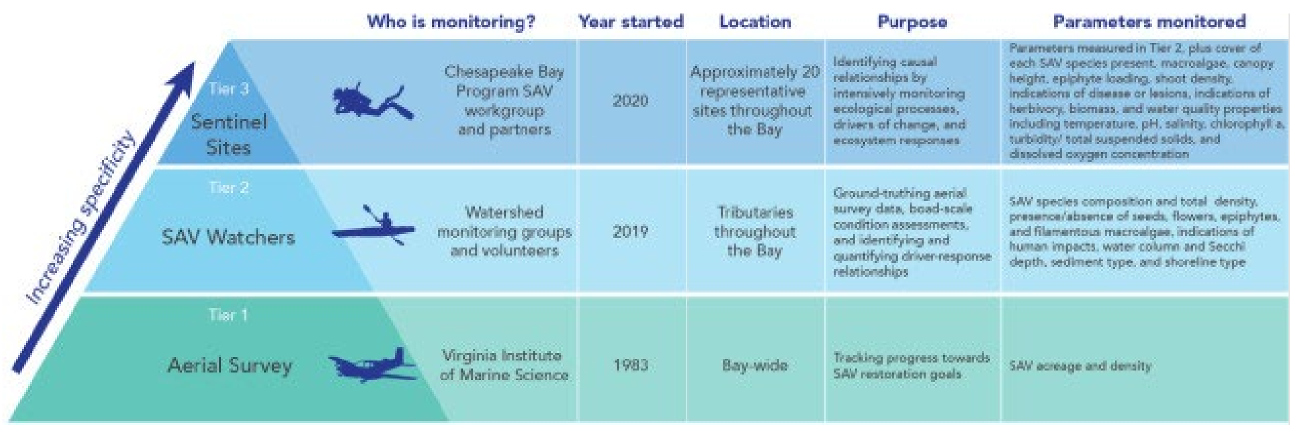

Figure 4.18 3 tiers of Submerged Aquatic Vegetation (SAV) monitoring program support including community science based SAV Watchers support. Image source: B. Landry, Maryland Department of Natural Resources, CBP SAV Workgroup Chair.

Question 7: Who are the partners involved in developing and operationalizing the gap-filling data collection innovations and applications?

Partners are actively conducting and collaborating on research to innovate data collection capacity and the data interpretation process. A list of agencies and institutions representing innovations identified during the PSC monitoring review to support gap-filling data collections and assessments include, but are not limited to, the following:

- EPA recently published an update on guidance for volunteer monitoring (EPA 2019) EPA is supporting the Community Science Program (Chesapeake Monitoring Cooperative https://www.chesapeakemonitoringcoop.org/) that is networking with community science groups to fill data gaps with grassroots monitoring efforts under guidance to maintain integrity of data collection protocols and data management.
- EPA is supporting development of the 4D Water Quality Interpolator https://www.chesapeakebay.net/who/group/bay_oxygen_research_group
- NASA, NOAA, USGS and EPA are independently, or in collaboration with academic institutions such as ODU, active in the research and development of accessing and interpreting old and new satellite data streams for assessment of water quality and living resource (I.e., SAV) in estuarine conditions. (e.g., see contributors with exploring SAV assessment with satellite-based imagery in Landry et al. 2021) and Chlorophyll a assessment https://coastwatch.noaa.gov/cw_html/NCCOS.html)
- NOAA, USGS, USDA-NRCS, EPA, State and Academic partners continue to research and develop guidance for the use of *in-situ* high temporal density data collection and its analysis. (e.g., Wilson (2021) and Sullivan et al 2018).
- USGS, EPA and collaborators are working on monitoring applications for land use change tracking with the CBP Land Use Workgroup https://www.chesapeakebay.net/who/group/land_use_workgroup

Question 8: What are the financial needs associated with sustaining, growing and innovating the networks?

The key findings of the monitoring assessment are based on engaging the CBP partnership on the status and needs of existing networks and addressing information gaps for the 2014 Watershed Agreement outcomes. All information on how to improve the monitoring networks was gained by the partners, and it was the role of the Monitoring Review Team to consolidate the information into this report and the recommendations expressed in Section 1. Recommendations and cost estimates for the initial priorities to improve existing networks are presented in Section 1 as a menu of investment opportunities. CBP partners may choose items that align with their priorities and will collectively improve monitoring toward multiple outcomes.

Evaluation of progress toward attaining outcomes revealed some lacking information to monitor and assess progress and others lacked targets or timeframes to evaluate progress. Monitoring needs associated with those outcomes are described in Section 2 of the report from the Goal Implementation Teams but are not included in Section 1. Monitoring needs mature at different rates and most of the GITs monitoring needs do not yet have associated funding estimates to share with partners. As GITs identify their metrics to assess progress toward the outcome, design monitoring considerations, and establish cost estimates, the monitoring needs will be brought forward to partners to work together on supporting these new priorities.

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Appendix A

Supporting Monitoring Programming Information for Select Chesapeake Bay Watershed Agreement Outcomes

A1. Producing High-resolution Land Cover and Land Use Data for the years 2025 and 2029 FACT SHEET

Authorship: CBP Land Use Workgroup and Leads of Land Use Methods and Metrics Development Outcome

In February 2018, the U.S. Environmental Protection Agency's Chesapeake Bay Program Office issued a Request for Proposals to provide "geospatial analysis support for the CBP partnership in support of the targeted implementation of actions in support of reaching the goals and outcomes of the *2014 Chesapeake Bay Watershed Agreement.* In the summer of 2018, a six-year, $7.5 million Cooperative Agreement was awarded to the Chesapeake Conservancy (CC). Funding for this RFP was provided at the sole discretion of EPA and subject to the availability of funds on an annual basis. It's important to note that this is a Cooperative Agreement and not a contract or grant. This is critical because it allows the CBP Partners to actively participate in the development of products and enables adjustments to the scope to address evolving technology and partnership needs.

The successful proposal consists of four objectives, the first of which involves the production of

comparable land cover and land use data for the years 2017 and 2021, an accuracy assessment, and corrections to the existing 2013 land use data so that it is directly comparable with the data produced for 2017 and 2021. The estimated total cost of this first objective is $4 million, distributed over six years. The CC subcontracted with the University of Vermont's Spatial Analysis Laboratory to produce the 12-class land cover data while the CC leads the development of the 55-class land use data. Land cover and land use data are being developed for all 206 counties intersecting the Bay watershed which equates to a 100,000 mi^2 (258,999 km^2) in area (note that the watershed area is 64,000 mi^2 or 165,759 km^2). The decision to include full-county coverage was made to ensure that the data would be useful for county-level decisions as called for in the Land Use Methods and Metrics Outcome in the 2014 Watershed Agreement.

The production of "land cover" involves the direct classification of aerial imagery based on the spectral properties of the imagery and height information derived from LiDAR. Land cover represents the surface characteristics of the land such as impervious cover, tree canopy, herbaceous, and barren classes. In contrast, "land use" represents how the land is used (e.g., turf grass, cropland, timber harvest, etc.). Producing land use from land cover data requires a variety of ancillary datasets (e.g., tax parcels, abandoned mine lands, solar panel arrays, landfills, and quarries) combined with spatial rules that leverage the contextual information inherent in the high-resolution land cover data. For example, “forest” land use is defined as patches of trees larger than 1 acre (0.4 ha) with a minimum width of 72m and further than 10-20m from structures.

These data are foundational, authoritative, and transformative to the Bay restoration effort. They are foundational because they inform most outcomes in the 2014 Watershed Agreement and will serve as the basis for developing the next generation of watershed models. They are authoritative due to their accuracy and transparency; any person viewing the data can recognize features and areas of interest and compare them to their local knowledge. They are transformative because they will ultimately change the way restoration and conservation actions are implemented, enabling both to be targeted at a fine scale to locations where they will be most effective. Moreover, establishing accurate trends in impervious cover, forests, and tree canopy will enable CBP Partners to improve the efficiency and effectiveness of stormwater and forest management activities.

The 2013-2017-2021 datasets only cover an eight-year period which constrains our ability to interpret trends and patterns and relate them to drivers of change and impacts which is the purpose of the Land Use Methods and Metrics Outcome. This data series needs to be continued through 2029 to fully leverage their transformative potential. The addition of land cover and land use data for the years 2025 and 2029 will enable the CBP partners to examine longer term trends and compare them with changes in management actions, stream flow, stream temperature, water quality, and species diversity. The total cost of extending the land data series through 2029 is expected to be $4 million.

Funding the production of new land cover and land use datasets for the years 2025 and 2029 could be accomplished with two separate Cooperative Agreements. The current six-year Agreement with the Chesapeake Conservancy expires in June 2024. To ensure the timely production of data for the year 2025, a new RFP will need to be issued by summer 2025 to establish a new Cooperative Agreement by winter 2025 (assuming the project will again rely on available imagery produced by the National Aerial Imagery Program). A separate Cooperative Agreement could be issued in 2029 to produce that dataset by the summer of 2031. The above timeline and estimated $4 million cost are contingent on the free availability of NAIP and LiDAR imagery to CBP partners. If it is decided that the paid acquisition of imagery is needed, Cooperative Agreements should be in place the year prior to each target year (e.g., 2024 and 2028) to provide time for scheduling flights or tasking satellites. While two separate

Cooperative Agreements may be fiscally practical, it is imperative that the data are comparable across all years, 2013 – 2029, and therefore it may be advantageous to have a single Agreement cover the production of data for both 2025 and 2029.

If the EPA agrees to continue funding this effort, then they will need to budget for $1 million per year for the years 2026-2027 and 2030-2031. While it would be wonderful for counties to collectively fund this effort (because they would be paying 75% less than purchasing similar data individually), this is unlikely to happen given the logistics of coordinating such a purchase. If the EPA does not foresee continuing its investment in high-resolution land cover and land use data, the Management Board should develop a strategy to do so by December 2023.

A2. Discussion Paper: Enhancing Monitoring to Address the CBP Toxic Contaminant Outcomes Updated Dec 17, 2021

Authorship: CBP Toxic Contaminants Workgroup

Purpose: The Chesapeake Bay Program Principals' Staff Committee (PSC) requested information to enhance the Chesapeake Bay Program (CBP) monitoring networks. While the request is focused on the existing CBP networks, information is included on monitoring needs of selected outcomes in the Chesapeake Bay Watershed Agreement.

This paper summarizes potential enhanced monitoring to address the Toxic Contaminant Outcomes in the Chesapeake Bay Watershed Agreement. The goal and outcomes were developed because of the widespread occurrence of toxic contaminants in the Bay and its watershed (EPA, 2012). In tidal waters the impairments from toxic contaminants increased between 2010 and 2016 (Fig. A1).

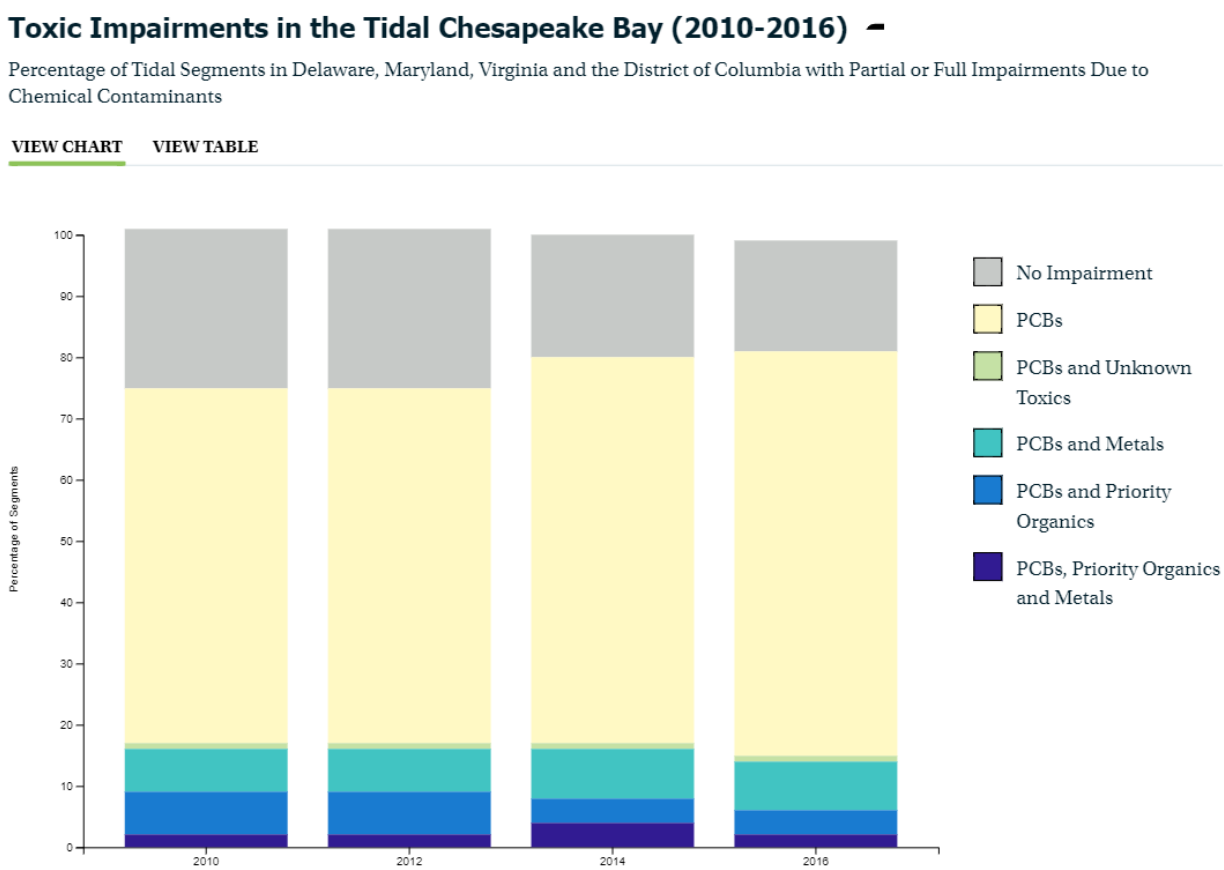

Figure A1. Biennial reporting (2010-2016) for percent of tidal water impairments due to PCBs or PCBs and other constituents in Chesapeake Bay Program tidal management segments for Delaware, Maryland, Virginia and Washington, DC. Source: Chesapeake Progress - https://www.chesapeakeprogress.com/clean-water/toxic-contaminants-policy-and-prevention) Toxic Impairments in the Tidal Chesapeake Bay (2010-2016) (PCBs, polychlorinated biphenyls).

Organization of the Discussion Paper

The Toxic Contaminant Workgroup (TCW) developed this paper based on the information requested by the CBP Science and Technical Assessment and Reporting (STAR) team, which included:

- *Need for enhanced monitoring*: how would the monitoring address CBP goals and outcomes- explained further in Section 1 below.
- *Objectives of enhanced monitoring*: The outcomes would be used to define monitoring objectives and priorities - explained further in Section 2 below.
- *Existing monitoring:* Assess monitoring that can be utilized to address the objectives and design considerations - explained further in Section 3 below.
- *Remaining gaps*: identify gaps that cannot be filled with existing monitoring - explained further in Section 4 below.
- *Monitoring design considerations and options*: These are general considerations for enhanced monitoring, not the design of a monitoring network, which would be a follow-up action if more funding became available. Identify options to address the gaps and recommend which may be most realistic. An estimate of funding needed to address the recommendations would be useful - explained further in Section 5 below.

The TCW undertook the effort during the summer and fall of 2021 and used these guiding principles for the discussions:

- A monitoring network for a wide range of contaminants would be extremely difficult and costly, so we need to prioritize the contaminant(s) to be addressed. For example, PCBs and mercury are listed in our outcomes so they could be a high priority.
- The monitoring objectives need to be specific to help focus the design considerations including the types of monitoring for different media.
- We need to take advantage of ongoing monitoring as a foundation for a network.

Section 1: Need for Enhanced Toxic Contaminant Monitoring

The TCW reviewed the two toxic contaminant outcomes in the Chesapeake Bay Agreement to identify items related to monitoring. The outcomes are:

<u>Policy and Prevention Outcome:</u>

"Continually improve practices and controls that reduce and prevent the effects of toxic contaminants below levels that harm aquatic systems and humans. Build on existing programs to reduce the amount and effects of PCBs in the Bay and watershed. Use research findings to evaluate the implementation of additional policies, programs and practices for other contaminants that need to be further reduced or eliminated".

<u>Research Outcome:</u>

"Continually increase our understanding of the impacts and mitigation options for toxic contaminants. Develop a research agenda and further characterize the occurrence, concentrations, sources and effects of mercury, PCBs, and other contaminants of emerging and widespread concern. In addition, identify which best management practices might provide multiple benefits of reducing nutrient and sediment pollution as well as toxic contaminants in waterways"

The TCW identified four monitoring needs associated with the two outcomes:

- Changes in PCBs levels as total maximum daily loads (TMDLs) and associated management actions are implemented.
- Changes in mercury as TMDLs and associated management actions are implemented.
- Assessing contaminants of widespread concern (such as pesticides).
- Assessing contaminants of emerging concern (such as per and polyfluoroalkyl substances [PFAS] and microplastics).

These four needs were prioritized by the TCW as follows:

- <u>Highest</u>: Changes in PCBs to management actions; Assessing contaminants of emerging concern (focus on PFAS and microplastics)
- <u>Middle</u>: Assessing contaminants of widespread concern (specifically, pesticides)
- <u>Lowest</u>: Changes in mercury from management actions.

Section 2: Monitoring Objectives

The TCW developed an initial objective for each monitoring need:

- Enhance PCB monitoring to establish current conditions and determine if remediation or management actions are resulting in downstream reductions of PCBs.
- Determine occurrence or status of PFAS and microplastics in surface waters of the major tributaries of the Chesapeake Bay. Establish monitoring in different types of land use to establish baseline conditions to track concentration and loading changes through time using consistent methods and analyses.
- Determine if implementation of BMPs and conservation practices over time results in declines in pesticide concentrations using a prioritized/standardized list of pesticides, and consistent sampling and analytical methods.
- Determine if reductions in air deposition of mercury are reflected in fish tissue declines, with a focus on species important for recreation and human consumption.

The TCW decided to focus efforts on the first objective for PCBs since it was one of highest priority needs. The other high priority need for emerging contaminants is being addressed through other efforts including (1) a CBP plastic pollution action team (monitoring for microplastics), and (2) an upcoming STAC workshop with a focus on PFAS monitoring.

The PCB objective was expanded to have multi-pronged approach with several inter-related components (Figure A2): *"Enhance PCB monitoring to (1) assess current conditions and identify impairments, (2) better define sources to focus mitigation efforts, (3) characterize PCB response to mitigation efforts and (4) evaluate fish conditions in relation to consumption thresholds."*

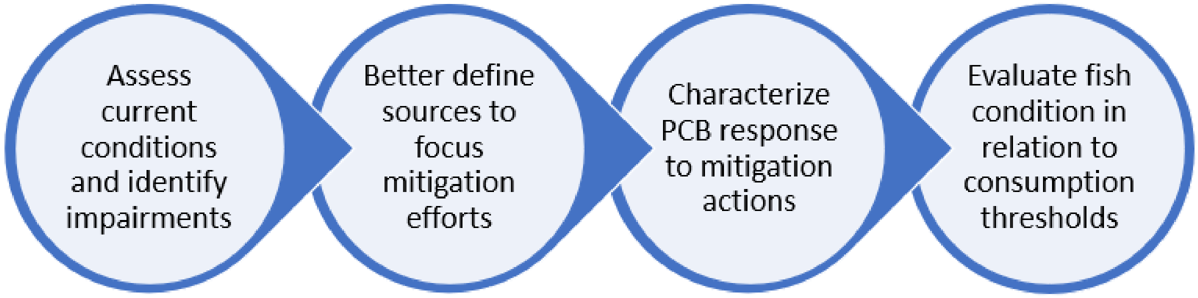

Figure A2. Components of the PCB monitoring objective. Source: CBP Toxics Workgroup.

Section 3*:* Existing Monitoring that Supports the PCB Objective

A data inventory for PCBs was conducted by USGS and additional information was requested from each jurisdiction and federal partners related to the components of the PCB monitoring objective. Some of the findings are summarized below and are presented in accordance with Figure 2 topics (shown in underlined italics in the paragraphs below).

<u>*Assess current conditions to identify impairments*</u>*:* Fish Tissue monitoring is done by all the jurisictions to assess current conditions and to track progress for fish consumption advisories. Sampling is usually done on a rotational basis to cover an entire jurisdctions every several years. These results are used to establish baseline conditions and identify impaired waters in each state (Fig. 3a), that is updated every two years, and development of local TMDLs to address the impairments (Fig. 3b). In selected places with impairments, additional sampling is often conducted to help develop and implement a local TMDL.

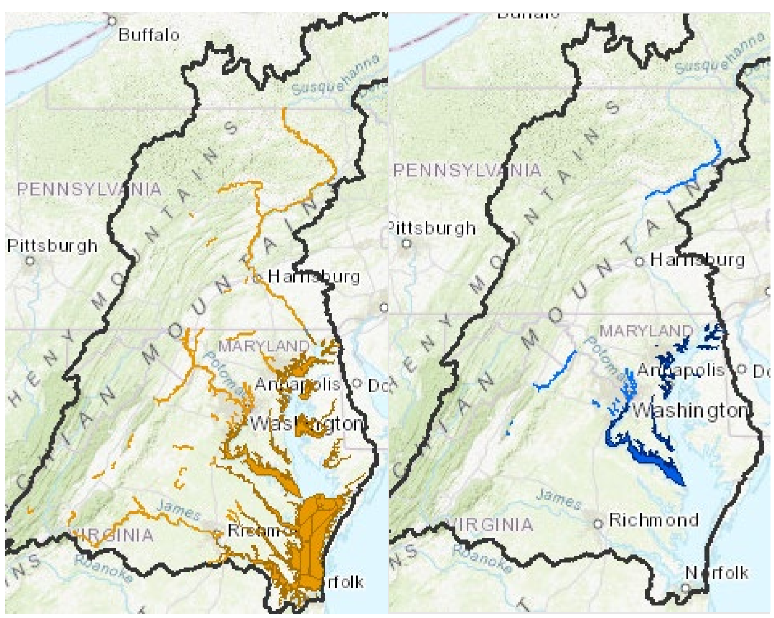

Figure A3a (left panel)—impaired waters based on PCBs, A3b (right panel)—TMDLs developed as of 2017. Source: CBP Toxics Workgroup.

<u>*Better define PCB sources to focus mitigation efforts*</u>*:* If a PCB TMDL is developed to address an impairment, "track-back studies" are often employed to better define the sources of PCBs to better

focus mitigation efforts. The number of current track-back studies varies by jurisdiction. For example, MD has a strong focus on track-back studies in selected places where TMDLs have been approved and DC is conducting source studies in the Anacostia watershed. VA currently has a significant focus on TMDL development and has in some instances (such as the Potomac TMDL) identified loads associated with unknown sources that necessitate track-back studies, but these are just getting underway. No additional monitoring for PCBSs is planned at this time in PA.

Characterize PCB response to migitation actions. In general, there is very limited monitoring for this component of the monitoring objective, particularly at a scale of interest to the CBP (i.e., broader than a single contaminated site). The primary reason is there are limited management actions being implemented for PCBs reductions at this time across the watershed.

Some additional considerations discussed by the TCW about this portion of the monitoring objective (PCB response to mitigation actions) included:

(1) a regional approach to detecting changes in PCBs is not practical for the entire Bay watershed.

(2) a more geographically targeted approach that focuses on areas where actions are being implemented or planned to address a local TMDL is more advantageous (including gray infrastructure improvements).

Evaluate fish conditions in relation to consumption thresholds: Monitoring of PCBs in fish is usually done across a state through rotational sampling as part of their impaired waters identification and fish consumption advisories. Each jurisdiction uses a PCB threshold level (which varies between jurisdictions) to issue fish consumption advisories. In addition, TMDLs are based on the fish condition in the estuary, with sediment and surface water targets based on the bioaccumulation modeling and criteria to meet the fishing designated use for the waterway. While the criteria may differ between states, all approved TMDLs in the Chesapeake Bay watershed are based on the fishable designated use in the tidal estuary.

Section 4: Remaining Gaps to Address the PCB Objective

With the current monitoring programs focused on assessing impaired waters and condition of fish, *the primary remaining gap is addressing PCBs response to mitigation efforts.*

A synthesis of feedback from TCW contributing to the formation of gaps:

- Jurisdictions and federal agencies reported limited monitoring that directly assess changes in PCBs due to mitigation actions. Aside from limited assessments in DE and by DC Department of Energy and Environment (DOEE) in Anacostia, there are gaps in assessing PCB reductions from mitigation actions in places where TMDLs have been established or are planned.
- The PCB data for fish are more robust than surface water in terms of frequency and consistency of collection. A focus on fish data and sampling would provide more opportunities for leveraging existing monitoring efforts and in some cases a comparison to historical data but may take longer to detect the reduction in PCB concentrations.
- Lab methods for fish analyses differ across jurisdictions. DE and DC are using EPA method 1668A for their fish analysis, which provides an ability to produce more detailed PCB “fingerprints” and low detection limits for PCB, which could be helpful for assessing response. MD and VA use a modified EPA method 8082, which provides similar detection limits to method 1668A and quantifies about

140 of the 209 critical congeners. Pennsylvania (PA) did not specify an analytical method. Historical data with differing methods are not comparable among jurisdictions.

- Methods to collect and analyze surface water samples also vary among jurisdictions and federal agencies (including both EPA methods 1668A and modified 8082). Types of field sample collection include both grab samples and use of passive polyethylene samplers. The lab methods and their detection limits are not consistent and would require the establishment of more comparable approaches among agencies.
- The number of monitoring stations are lacking in many places to detect a PCB response to mitigation efforts. The sampling locations near local TMDLs are limited both in number and frequency of samples collected. Many non-tidal sites lack streamflow gages for calculation of PCB loads. Temporal and spatial variability in surface water is high and would require a considerable quantity of samples to establish a representative condition in surface water.
- Limited numbers of samples in sediment and other media (e.g., shellfish) exist in more spatially limited locations of the watershed.

Section 5: Monitoring Design Considerations and Options

The TCW brainstormed various approaches and their advantages and disadvantages to fill the primary gap described in Section 4. These approaches included (1) targeted head of tide sampling in surface water similar to the proposed sampling program in Cargill (2021) to detect changes in either ambient contaminant concentrations or loads (with corresponding co-located flow information), (2) targeted fish species and analyses, or (3) a hybrid approach including various media. Each approach has distinct advantages and disadvantages that may differ between geographic areas depending on the conditions downstream (tidal, non-tidal, known flow rates, etc.), the desired observable response, or desired timeframe for response.

The TCW endorsed an overall approach for enhanced monitoring to help jurisdictions assess the PCB response to mitigation actions in selected geographic areas. If endorsed by the PSC, enhanced monitoring site selection would occur through the TCW according to steps in Figure A4. The primary recommendations for this monitoring design are summarized below.

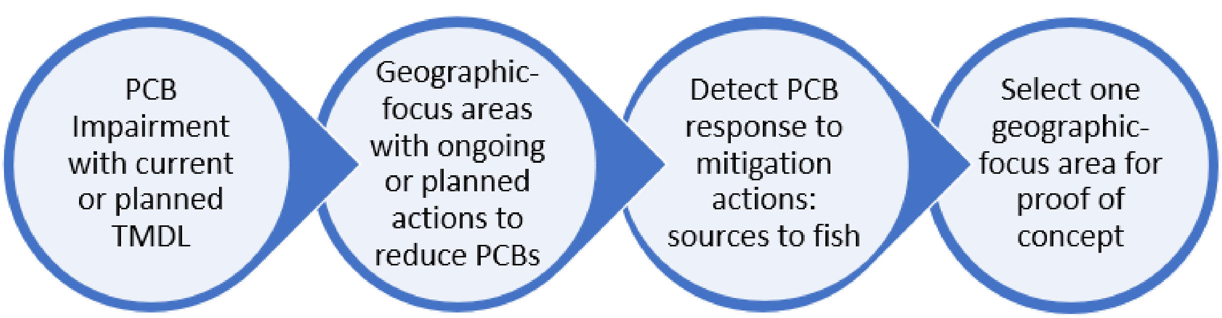

Figure A4. Components of sampling design. Source: CBP Toxic Contaminants Workgroup.

Recommendation 1: Focus monitoring in geographic focus-areas to help the jurisdictions assess PCB response where mitigation actions are being implemented or planned.

With enhanced monitoring, the jurisdictions working with the CBP, can tailor data collection in geographic focus-areas to help assess PCB response in places where mitigation actions are being implemented or planned for local TMDLs. Due to the variability discussed above, jurisdictions suggested providing some flexibility in the geographic focus-areas to allow for the consideration of variable ongoing or historical monitoring and specific activities in their respective locations. In general, the conceptual design would fill a gap that existing monitoring does not address, which could include adding monitoring sites to detect PCB response (Figure 4).

Recommendation 2: Have a monitoring design so PCB reductions resulting from mitigation actions can be detected. Within a geographic focus-area, there should be a design so the PCB response to management actions can be detected. These areas would need to have enough action/mitigation for collective, predicted reductions of greater than 25% (or a more appropriate reduction later specified) in concentration and/or loading. Monitoring of these areas will fill the gaps associated with *addressing PCBs response to mitigation efforts* and help to answer the following questions:

- At what spatial scale can a response (PCB decline) be observed downstream of actions?
- At what timescale can a response (PCB decline) be observed downstream of actions?
- Are there observable differences in the mitigation actions taken and the resulting PCB response?

The monitoring design would need to:

- Have a “source to receptor” approach to detect if mitigation actions are reducing PCBs near the sources, along their transport pathways, and in fisheries (the primary receptors). The design could involve having several sample sites, with one site near the source-reduction activity, while the additional sites would be downstream but in close enough proximity to detect PCB changes.
    - For example, in an area such as the Anacostia River, there could be sampling sites distributed near the remediation activities in a subbasin, and sites further downstream to detect PCB reductions in water or fish.
- Detect a change in PCBs over time. The design could consider having observations over time to graphically illustrate a change, like the indicator representation. This design would require less frequent sample collection compared to a statical assessment to detect change.
- Each geographic focus-area will be individually assessed for appropriate media to be sampled, with a similar approach across media for different areas depending on conditions present in each area.
- Be opportunistic with ongoing monitoring efforts to supplement jurisdiction efforts.
- Emphasize field and analytical methods for low-level detection of PCBs.

Further considerations for the set of sample sites in the geographic focus-area include media to be sampled and at what sampling frequency, which include:

- Be focused on sampling fish or shellfish (as indicator) or surface water and the uniformity of field and analytical methods for low-level detection of PCBs.
- Each site would be sampled at a frequency that will detect a change over time, after establishment of a baseline sampling event. Options for different frequency and media include:

- Sampling fish (or shellfish) every 1-2 years. Consideration should be given to young of the year collection at this time interval. For larger game fish, longer times may be required to observe a change (lesser frequency may be adequate).
- Time-integrated surface-water samples every quarter to estimate annual variability for a specified timeframe, then possibly less frequent (biannual at times of highest noted variability). If variability in flow conditions (e.g., storm events) was to be considered, baseline costs would need to be updated. Current cost estimates assume passive sampling of the water column.
- At this time, bulk sediment sampling as a stand-alone media is not being considered due to the inability to assess bioavailability of mass detected. Other considerations for sediment assessment include passive sampling of sediment porewater, which can assess bioavailability and inform sediment concentrations and passive sediment traps in non-tidal environments. (Current cost estimates do not include these alternate sediment considerations, are but noted here for consideration).

Recommendation 3: Initiate monitoring in a single geographic-focus area. The TCW proposes to start in one geographic-focus area as a proof-of-concept. The initial monitoring in one area will help better understand the amount of PCB reduction required to detect a response, timeframe to detect a response, proximity to collection actions to detect a response in surface water, fish, or other designated media, we propose initiating monitoring in a single geographic-focus area as a pilot test. Lessons learned from this proof-of-concept could be translated to other geographic focus-areas.

Possible options for geographic focus-areas were identified by the TCW and reflect efforts to implement TMDLs and clean-up activities and WWTP upgrades (listed below). One consideration could be to align with the EPA-designated Urban Waters Federal Partnership locations in the watershed, including Patapsco and Anacostia.

Table A1. Potential Geographic-Focus Areas Identified by the Jurisdictions for PCB monitoring.

Jurisdiction	**Potential Geographic-Focus Areas Identified by the Jurisdictions**
DC	Anacostia
MD	Tidal Patapsco River (Baltimore Harbor/Curtis Bay/Middle Branch), Anacostia tributaries (e.g., Lower Beaverdam Creek)
VA	Potomac tributaries at head of tide
DE	Nanticoke River

Estimated Costs

Given the site-specific nature of ongoing work and variability in geographic focus-areas already highlighted, it is possible that a hybrid approach may be adopted with mixed media sampling. The following general cost estimates are provided by media for a geographic focus-area with a minimum of three new sites (using 2021 costs):

- For a focus on fish or shellfish sampling, the estimated cost of a single sample site would be approximately $22,000, for a total of $66,000 for three sites, sampled once. This cost includes analysis of 10 individual samples at each sample site with time for sample collection, processing, and analysis. Fish composites, instead of individual samples, could be considered to provide a representative sample and added cost-savings with loss of statistical power and should be considered depending on data use.

- For a focus on water samples collected quarterly at a sampling site, the estimate would be approximately $70,000 for one year. Assuming a minimum of three sites in a geographic focus-area, the annual cost would be $210,000. This assumes that there is not an existing streamflow gage for estimated loads, and this would have to be constructed and installed, and that passive, time integrated sampling methods would be employed.
- For one geographic-focus area (with a minimum of three new sites) the estimated annual cost would range from $66,000 for fish sampling to $210,000 for surface-water sampling.

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A3. Chesapeake Bay Zooplankton Monitoring Program (Draft 2021)

Authorship: CBP Sustainable Fisheries Goal Implementation Team

A high priority monitoring need to support the CBP Forage Fish Outcome is re-establishing a zooplankton monitoring program, which has been a long-term core need for the Sustainable Fisheries GIT, but there is a lack of data for understanding the Chesapeake Bay's zooplankton community. A draft concept for the zooplankton monitoring program is included with the plan to gather additional support throughout the CBP partnership and eventually release it as an RFP. This draft concept was designed to meet the needs of the partnership, provide base information that allows a comparison with historic zooplankton monitoring datasets and have measurable outputs/criteria that can be used for the following:

- Development of key metrics/indicators
- Linkages with water quality, changing climate and fisheries

DRAFT Proposal

The Chesapeake Bay ecosystem is dynamic and changing. While it is expected that improvements in habitat due to nutrient reductions and reduced fishing mortality rates will drive improvement in the bay's living resources and fisheries, past monitoring (1984-2002 and 2011) indicated major negative shifts in phytoplankton, zooplankton, fish, and shellfish inconsistent with expectations from the bay cleanup. Zooplankton are an important link in the food chain that transforms nutrients to fish production by feeding fish larvae of many species and providing forage for forage fish. Zooplankton monitoring can be useful for understanding ecosystem changes associated with large scale efforts to improve water quality in Chesapeake Bay and is currently a missing building block of the framework for ecosystem-based fisheries management in Chesapeake Bay.

Zooplankton monitoring supports the Chesapeake Bay Program's Sustainable Fisheries Goal – To protect, restore and enhance finfish, shellfish and other living resources, their habitats, and ecological relationships to sustain all fisheries and provide for a balanced ecosystem in the watershed and the Bay. Specifically, the Forage Fish Outcomes:

1. ***Continually improve the partnership's capacity to understand the role of forage in the Chesapeake Bay.***
2. ***Development of indicators to help quantify relationships and provide insight into the status of the forage in the Bay.*** *Indicators are tools used to synthesize complex relationships and other factors to guide management. Indicators based on forage and predator abundance, forage consumption, and predator health can provide managers with information to judge balance.*

Re-establishing a time-series of zooplankton plankton data is needed for statistical, multispecies, and ecosystem models guiding managers' understanding of causes of shifts in food web structure, fish populations, and fisheries.

We are recommending re-establishing meso-zooplankton monitoring with an effort reduced from the full program conducted until 2002. It would be patterned after the 2011 NOAA-Cooperative Oxford Laboratory (NOAA-COL) Meso-zooplankton Monitoring Program. This monitoring would enable the following:

3. Direct comparison of metrics from proposed zooplankton monitoring data with those from historic zooplankton monitoring program data (1984-2002) and NOAA-COL in 2011. How does the past compare to the present?
4. Comparisons of temporal and spatial trends in phytoplankton, zooplankton, forage fish, and their predators that provide insight on the influence of bottom-up (nutrient enrichment, climate warming, etc.) and top-down processes (predation and exploitation) on fisheries production that are essential for ecosystem-based fisheries management. Past and proposed zooplankton monitoring are primarily located at existing long-term phytoplankton and water quality monitoring sites.

   Zooplankton monitoring ***objectives/products***

5. Provide long-term data sets for use in water quality assessment, ecosystem modeling, trend analyses, and ecosystem-based fisheries management.
6. Collect data for forage indicators to address food web, water quality, climate change, and other hypotheses. Some examples follow (others are possible):
   1. **Zooplankton Index of Biotic Integrity (Z-IBI).** This index provides an indicator of zooplankton diversity and its response to water quality changes (Carpenter et al. 2006).
   2. **Spring Larval Striped Bass Food Availability Index.** This index serves as an indicator of habitat suitability for the survival of striped bass and other anadromous fish larvae (Heimbach et al. 2003). Although monitoring is not temporally or spatially intense enough for detailed early life history studies, in the past it has provided an indication of higher zooplankton production in the early 1990s that was concurrent with rising striped bass and Yellow Perch juvenile indices. Has this higher production of zooplankton continued?
   3. **Indices of major zooplankton components of the Bay's food web.** Abundance and-or biomass indices of major zooplankton forage (copepods *Acartia* and *Eurytemora*, cladocerans, and others) and gelatinous predators (ctenophores and sea nettles).
   4. **Data to address whether major food web changes in the past have continued.** Historic (monitoring and monitoring in 2011) indicated big decreases in the copepod *Acartia* in Maryland's mainstem bay in 1997 and an upward shift in Cyanobacteria. These changes in primary and secondary production were followed by a serious decline in Bay Anchovy (perhaps the Bay's primary forage fish) in Maryland's seine survey that has continued. Is *Acartia* still low?
   5. **An index of Bay Anchovy eggs / larvae** for to provide a potential proxy time-series for adult Anchovy abundance in the Bay. Their eggs and larvae will be present along with meso- zooplankton. This is particularly important for Maryland's mainstem Bay, an area that has not been routinely monitored. This time-series could be compared to other long-term Bay Anchovy indices from other areas of the Bay to determine status of this important forage fish.

Monitoring Approach

Meso-zooplankton (e.g., cladocerans, copepods, and gelatinous zooplankton) will be monitored monthly during the months February through November in the mainstem of Chesapeake Bay and in two major tributaries to the Bay.

Seventeen historically sampled CBP stations were selected which will re-establish the historical record for meso-zooplankton throughout the mainstem Chesapeake and two ecologically important Chesapeake tributaries, the Potomac, and Choptank Rivers (see map below). In the Bay mainstem, meso-zooplankton will be collected at historic-CBP monitoring stations and one additional (CB3.15*) station in the upper Bay to fill in a spatial gap. In the Potomac River, sample historic-CBP stations and two additional (RET2.4*, TF2.4*) stations near the salt front (estuarine turbidity maximum), a location known to provide important spawning and nursery habitat for fishes. Three stations in the Choptank River including two historic-CBP stations and one additional station (ET5.15*) will be sampled.

At each station (Fig. A5), a CTD will be deployed to record hydrographic and water quality parameters. Both 202 uM and 500 uM twin-ring 50 cm diameter nets equipped with flow meters will be used to collect zooplankton and fish larvae at each station, respectively. Sampling gear and mesh sizes were chosen to maintain consistency with earlier CBP zooplankton survey methodology and to expand the size range of primary organisms sampled to include both zooplankton and fish larvae. Field collection methods and data collected will closely follow those outlined in the Maryland Chesapeake Bay meso-zooplankton program standard operating procedures. Samples will be preserved for later identification and enumeration. Sample preservation will allow for both immediate processing and archiving. Information generated at each station will include meso-zooplankton and fish larvae species-specific abundance, gelatinous zooplankton abundance, and meso-zooplankton biovolume and aggregate dry weight.

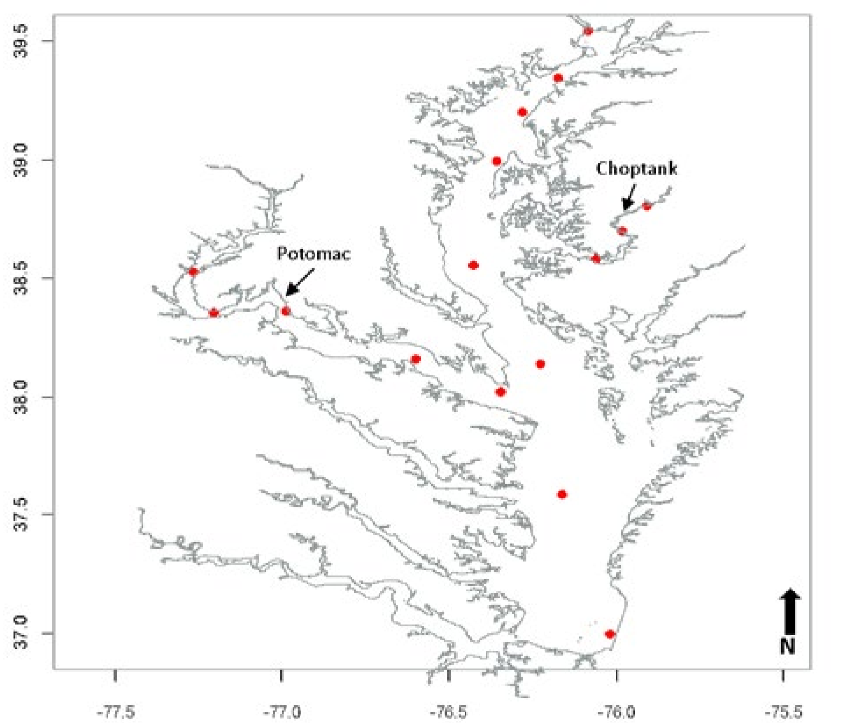

Figure A5. Map of proposed plankton monitoring survey stations including historic CBP stations and proposed (*) stations. Ordered upstream to downstream, labeled symbols indicate station locations where plankton will be collected in the Chesapeake Bay mainstem (CB1.1, CB2.2, CB3.3C, CB3.15*, CB4.3C, CB5.2, CB6.1, WE4.2, CB7.4), the Potomac River (LE2.3, LE2.2, RET2.2, RET2.4*, TF2.4*), and Choptank River (ET5.2, ET5.1, ET5.15*). Source image: National Oceanographic and Atmospheric Administration.

Tentative Cost: Baywide sampling for $250K to 300K per year

References

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Appendix B

Active Efforts to Outline Chesapeake Bay Watershed Agreement Outcomes' Monitoring Needs

STAC Workshop: "Evaluating a Systems Approach to BMP Crediting"
When: March 2022
Steering Committee: Reps from Wetland WG, Stream Health WG, SAV WG, Forestry WG, and Black Duck Action Team
Audience: Researchers, restoration practitioners, policymakers, BMP/watershed modelers, and CBP managers
Objective(s): The workshop will address 1) opportunities to incentivize habitat benefits in relation to TMDL and water quality outcomes, and that are part of Chesapeake Bay Agreement commitments; and 2) the efficacy of a more holistic "systems approach" to BMP accounting, specifically how wetlands are considered in multiple BMPs and multiple workgroups and GITs, and how wetland BMP functions are influenced by other BMP types in the connected landscape. Recommendations from this workshop would include suggestions for how to approach restoration projects at a systems level (e.g., creek, shoreline reach, watershed) in order to maximize synergies for multiple ecological outcomes and accurately calculate pollutant reductions along with habitat value to restoration projects that include multiple habitats, as well as recommend policies to incentivize habitat benefits and outcomes in addition to nitrogen, phosphorus, and sediment reduction goals.

STAC Workshop: "Rising Watershed and Bay Water Temperatures Workshop"
When: January 12th and March 15th, 2022 (Two-day workshop)
Steering Committee: Representatives from Forestry WG, STAR, Climate Resiliency WG, CAC, Fisheries GIT, Healthy Watersheds GIT
Audience: CBP managers, policymakers, resiliency planners
Objective(s): The objectives from the first day were: build a more complete picture of the interconnections between increasing water temperature and the important drivers that result in temperature rise; synthesize current scientific understanding of ecological impacts of increasing water temperature, including identifying particularly vulnerable species, landscapes, and communities and the specific aspects of temperature rise with the greatest potential to adversely impact tidal and freshwater ecosystems and habitats; identify critical knowledge gaps to be filled; account for both the causes and effects of rising temperatures, and consider a range of potential management implications. The objectives from the second day were: verify understanding of the major findings on the drivers and ecological impacts of rising water temperatures, identify actionable next steps by developing recommendations on how to mitigate the impacts or increase resilience for habitats and fishery resources under changing conditions, and identify uncertainties along with which additional information is needed to build the certainty that is needed for future actions.

Wetland Outcome Attainability Workshop
When: Summer 2022
Steering Committee: HGIT coordinator and staffer, reps from USFWS, Ducks Unlimited (DU), TNC, USGS, USACE, and contracted facilitator

Audience: High-level federal and jurisdiction decision-makers (PSC and up) who have the power to make decisions and allocate funding for restoration
Objective(s): Bring together key people to identify actions to overcome the barriers of implementing nontidal and tidal wetland restoration and accelerate progress towards the Wetlands Outcome identified in the 2014 Chesapeake Bay Watershed Agreement. Desired outcomes include: 1) Understanding of the barriers that limit the rate of nontidal and tidal wetland restoration that is necessary to achieve the 2025 Wetlands Outcome, 2) Identification of innovative approaches, including changes to existing programs and proposing new programs, to increase the implementation of nontidal and tidal wetland restoration, and 3) Within three months of the workshop, collaborate with partners and workshop participants to develop an action plan with metrics to dedicate resources to implementing these approaches.

ORD Workshop- "**Resilient coastal wetlands for resilient coastal communities"**
When: Spring 2022
Steering Committee: TBD
Audience: TBD
Objective(s): TBD

Jordan West (west.jordan@epa.gov) and Cathy Wigand (Wigand.Cathleen@epa.gov) at EPA ORD are planning this workshop and should have more details.

Workshop Aligning Stakeholder and Research Priorities for Collaborative Marsh Adaptation
When: Spring 2023
Steering Committee: Jurisdictional and CBP workgroup experts in marsh resilience, restoration and management, and a Diversity, Equity, Inclusion, and Justice expert
Audience: State and federal agencies, nongovernmental agencies, restoration practitioners, researchers, local and under-represented community representatives, land managers, land trusts, funders
Objective(s): This workshop will identify research needs and advance research partnerships that can increase understanding of marsh resilience and the success of marsh adaptation strategies. It will build capacity to implement large-scale tidal marsh restoration projects that have increased resilience to climate change impacts, while addressing corresponding DEIJ and local engagement needs. Outcomes include: capacity building across environmental stakeholders to build partnerships that could initiate large-scale shoreline and marsh restoration projects; fostering interest and momentum in short- and long-term action across federal, state and local jurisdictions, environmental stakeholders and research partners, and forming partnerships for collaborative marsh-restoration projects; transferring knowledge between natural resource managers, land trusts, and researchers about marsh condition, vulnerability, and resilience to climate change; identifying funding opportunities for tidal marsh research and tidal marsh restoration in identified regional focus areas that could be pursued by established partner networks; aligning future research with identified restoration opportunities; connecting existing research to marsh management and adaptation at regional scales; identifying data gaps and research needs; identifying funding opportunities; integrating and elevating the voices of nontraditional partners and evaluating social vulnerability metrics to prioritize areas with DEIJ impacts.

Chesapeake Riparian Forest Buffer 2022 Leadership Workshop

When: Spring 2022
Steering Committee: Sally Claggett (USFS), Katie Brownson (USFS), Sophie Waterman (CRC), Carin Bisland (EPA), Kristin Saunders (UMCES), and Emily Heller (EPA).
Audience: High-level federal and jurisdiction decision-makers (MB and up) who have the power to make decisions and allocate funding for Riparian Forest Buffers.
Objective(s): The Riparian Forest Buffer Workshop will attempt to address the scale and immediacy of the needed effort on accelerating Riparian Forest Buffer (RFB) implementation on a state-by-state basis. As part of the last Strategy Review System (SRS) review, the MB agreed that each state would develop an Action Strategy for Buffers. These Strategies will be at the core of the workshop. Immediate objectives for this workshop include **1) discussing state RFB Action Strategies for expanding forest buffers and 2) developing recommendations for specific roles for the Partnership in advancing buffer goals. 3) The longer-term objective is to greatly increase forest buffers on the landscape.**

GIT FUNDING PROJECTS

Title: Synthesis of Shoreline, Sea Level Rise, and Marsh Migration Data for Wetland Restoration Targeting
Status: Underway (expected to be completed in 2022)
Summary: This project will compile existing information about Sea Level Rise inundation, topography, shoreline condition, wetland area and migration corridors from Chesapeake Bay Program (CBP) partners and other organizations and provide a methodology for synthesizing and translating this information to assist with marsh conservation and restoration decisions under changing sea level rise scenarios. Additionally, where available, information on groundwater flow, subsidence and irrigation ditch networks should be included since these features can influence decisions related to marsh migration and restoration strategies. The final deliverable for this scope will include a full list of available data sources in the tidal regions of the Chesapeake Bay for the parameters mentioned above. From the compiled list of data sources, a specified geographic location that includes various marsh (e.g., conservation, restoration, migration) and land-use (e.g., preserving existing wetland habitat or converting agricultural, forested, or developed land to marsh) decisions related to SLR will be selected. Adjacent land use data can help inform decisions on areas available for marsh and an evaluation of tradeoffs in having to re-designate land use to allow marsh migration. The project team (including the contractor) will choose a location to inform the development of the data synthesis methodology that could also be utilized in other locations in the watershed. The general area of the project team's interest is the Middle Peninsula of Virginia, but the exact location chosen will depend on the results of the data collection. If available, demographic and socio-economic data for the chosen (selected) location will also be included in the analysis to better understand the community and social dynamics that may affect marsh migration, restoration, and conservation planning. The selected location will serve as a pilot for developing a methodology and applying the synthesized information to address various local decision-making needs on employing wetland conservation, restoration and/or adaptation strategies related to

projected SLR conditions.

Title: Understanding and Addressing the Impacts of Wetland Mowing to Facilitate Meeting the Chesapeake Bay Wetland Enhancement Goals
Status: Proposal approved but not yet out for bid (project expected to begin in summer 2022)
Summary: The purpose of this project is to inform a long-term, multi-phase effort to reduce the behavior and practice of wetland mowing and make progress towards Partnership wetland enhancement goals and outcomes. It will support progress toward the Wetland Outcome under the Vital Habitats Goal since the reduction of wetland mowing would contribute toward the goal of enhancing function of an additional 150,000 acres of degraded wetlands by 2025. The goal of this project is to provide a better understanding of the potential impact and scope of tidal wetland mowing in Chesapeake Bay. This phase of the project will be focused on characterizing mowing prevalence and estimating the extent of the practice in the tidal areas of Maryland and Virginia to establish a baseline. Estimating the spatial extent of the issue will provide the information necessary to determine the threat posed by wetland mowing and if there is a benefit to engaging in behavior change to reduce wetland mowing. For the first time, these findings can be provided to state and federal regulators for their awareness related to their mandate for wetland protection and for policy considerations. The findings can also help inform the next phase of this project, which would be proposed in the next cycle of GIT-funding. Subsequent phases would aim to reduce or eliminate this practice among landowners through a social marketing strategy for the behavior change of this target audience, the development of communications materials, technical assistance, and/or enhancements to statutory and regulatory programs, local policies, and state laws regarding wetland mowing.

Title: Data Review and Development of Multi-Metric Stream Health Indicators
Status: Proposal approved but not yet out for bid (project expected to begin in summer 2022)
Summary: The main project outcome is the identification of additional non-biological metrics focusing within geomorphology and hydraulics that may complement the Chesapeake Basin-wide Indicator of Biological Integrity (BIBI), the current Bay Program stream health indicator. These additional metrics will help us better understand the trajectory of stream health (e.g., improving or declining) by expanding the Stream Health Workgroup assessment of stream health to include factors beyond the biological stream community throughout the Chesapeake Bay watershed. The project outcome will also include a matrix that cross-references existing assessment programs and other resources (e.g., expert reports, databases) to recommend appropriate metrics for use in characterizing and quantifying stream health.

The project will focus on stream health metrics withing geomorphology and hydraulics because they comprise two of the lower levels of the Stream Function Pyramid. This Pyramid is a hierarchical framework that demonstrates that higher-level functions like biology (e.g., biodiversity, life history etc.) cannot occur without the support of lower-level functions such as hydrology, hydraulics, geomorphology, and physiochemical functions. So, in this case, geomorphics and hydraulics are the foundations that influence whether higher levels such as biological functions can occur in a given community. More info on this Stream Function Pyramid can be viewed at the following link: https://www.epa.gov/sites/default/files/2015-08/documents/a_function_based_framework_for_stream_assessment_3.pdf. To date, this type of resource does not exist and will aid to not duplicate existing efforts or research.