Strengthening Science and Decision Support for Ecosystem Management in the Chesapeake Bay and its Watershed

A Revised Report Fulfilling Section 202f of Executive Order 13508

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U.S. Department of Interior and Department of Commerce

Disclaimer:

This document reflects the Department of the Interior's (DOI) and Department of Commerce's (DOC) revised report under Section 202f of Executive Order 13508 (EO) making recommendations to the Federal Leadership Committee (FLC) for a strategy to strengthen scientific support for decision making to restore the Chesapeake Bay and its watershed, including expanded environmental research and monitoring and observing systems. This revised document is published to supplement the FLC's publication of a *Draft Strategy for Protecting and Restoring the Chesapeake Bay* (issued November 9, 2009). The revised report includes recommendations that may change as the FLC's draft strategy is further refined based on public comments developed. The revised document is not a final agency action to judicial review; nor is it a rule. Nothing in this revised document is meant to, or in fact does, affect the substantive or legal rights of third parties or bind DOI or DOC in the development of this report. While this revised document reflects DOI's, DOC's, and collaborating agencies current thinking regarding recommendations to protect and restore the Bay, DOI, DOC, and collaborating agencies reserve the discretion to modify the recommendations included in this report as they work with the FLC to refine the draft strategy, or to act in a manner different from this report as appropriate.

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EXECUTIVE SUMMARY

To meet the charge of the President's Executive Order, we need a new emphasis on achieving an ecologically and socially *sustainable* Chesapeake Bay and watershed. Addressing sustainability will require making decisions about the balance between (1) improving and sustaining fish and wildlife populations and their supporting habitats and water quality, and (2) meeting the increased demands for goods and services made by the 17 million people in the watershed and by an increasingly global economy. We recommend Ecosystem-Based Management (EBM) as the approach to improve monitoring and decision making to achieve a sustainable Bay and watershed.

Strengthening science will be critical to more effectively plan, implement, and evaluate the actions, policies, and associated trade-offs needed to improve the health of the Bay and its watershed. Federal agencies need to significantly improve the effectiveness of information, decision-support tools, and technical assistance to help key audiences make the difficult choices to improve the health of the Bay ecosystem while accommodating the needs of a growing population. The key audiences and priority efforts include:

- Citizens and watershed groups. Efforts should be focused on the agricultural community, suburban homeowners, urban dwellers, and watermen whose decisions influence the quality of agricultural, suburban, and urban lands, and the use of ecosystem goods and services.
- Local governments. Support local land-use planning and zoning decision makers as they address the sustainability of their communities, watersheds, and the Bay.
- Federal and State resources managers. A primary focus should be on providing technical assistance on the inter-relation of decisions affecting water quality, habitat, and living resources and their effectiveness in sustaining the Bay and its watershed.
- Elected officials. Provide science-based summaries that highlight the implications of proposed legislation and policies that will affect the Bay and watershed.

Our major recommendations to strengthen science and improve decision support are:

Focus the Chesapeake partnership on sustainability and adopt an adaptive, Ecosystem-Based Management approach to expand the current emphasis on water quality to incorporate all aspects of ecosystem sustainability (ecological integrity, socioeconomic well-being, and effective partnership performance). This will require revision of the existing Chesapeake Bay Program (CBP) goals to include more focus on socioeconomic changes affecting the Bay ecosystem, strategies to get local governments and people more engaged in the program, and measures to address the potential impact of climate change. The desired outcome is to transform the partnership to dramatically increase the involvement of citizens and local governments, and better align federal, state, NGO, and academic efforts to strive for a sustainable Bay and watershed through EBM.

Establish an Interagency Decision-Support Hub to integrate federal tools and information for more efficient and strategic decision making for ecosystem management. Most of the current decision-support activities in the CBP are focused on water-quality improvements and the same level of effort is needed to address the other CBP goals and new challenges. The Hub would bring together scientific information and decision-support tools and specialists to provide information in an adaptive-management framework. The Hub activities would provide for more timely and effective targeting and assessment of management policies and practices being implemented by federal, state, and local partners. The primary objectives of the Hub would be to:

- Provide GIS-based decision-support tools, visualization, and analysis for (1) targeted conservation and restoration actions for habitat, water quality, and vital lands; (2) coastal zone management; (3) fisheries and wildlife management; (4) hazard assessment, climate change, and resiliency planning; and (5) land-use planning. The tools would be Web-based to provide access to multiple partners.
- Forecast and assess implications of different management actions and policies.
- Prepare communication products for the public, local governments, resource managers, and elected officials.
- Have decision-support specialists directly interact with decision makers on the implications of different management options and the effectiveness of current practices.
- Integrate existing tools through the Chesapeake Online Adaptive Support Toolkit (COAST).

The Hub would interact closely with the CBP Technical Support and Services team to utilize scientific information being generated by federal, state, and academic partners. The key science information needed by the Hub to improve decision-support tools and analysis includes monitoring; spatial data, visualization, and information management; research; model-based forecasting; and an expanded suite of indicators. Selected outputs from the decision tools would be used in ChesapeakeStat, which is an accountability tool that will help determine whether partners are adequately aligning resources in priority locations.

Create the Chesapeake Bay Environmental Data Enterprise for timely, quality data and information sharing between partners. All environmental data archiving, assimilation, modeling, and information systems should transition into a fully integrated Chesapeake Bay data enterprise. The ultimate goal of improved data management should be to provide timely and agile access to data and information among partners so they can easily integrate data for analysis. In effect, the Chesapeake Bay data enterprise will enable partners to use the wide range of data needed to improve ecosystem management. Therefore, the partnership must design a blueprint for this new capability and fully leverage the internet for sharing and use information between the growing number of data producers and data consumers.

Expand partner alliances for a Chesapeake Monitoring and Observing System to provide coordinated monitoring of environmental conditions beyond water quality and into the watershed. The monitoring system should build from existing monitoring and

observing programs in the Bay and its watershed and be improved to better address fish and wildlife, foodweb interactions, disease, contaminants, climate variability, land cover and use, and tracking of management actions. The efforts to establish and improve the system would include:

- ***Coordinate with national monitoring networks*** to address needs in the Bay and its watershed (including the Integrated Ocean Observing System and the National Water-Quality Monitoring Network).
- ***Establish stronger partnerships*** with ongoing federal and state monitoring programs.
- ***Design and implement a climate change monitoring component*** to ensure that decision tools and models can forecast potential impacts of a changing climate.
- ***Expand monitoring to address gaps.*** Additional monitoring is needed to address critical gaps in the monitoring of fish and wildlife, habitat, contaminants, land use, natural disturbances, and socioeconomic factors, and tracking of management actions.

Align and conduct research to explain and forecast ecosystem changes and assess the effectiveness of management decisions. Better alignment of federal research, using an adaptive-management framework, will improve targeting and effectiveness of management actions. To address this recommendation, the federal government needs to:

- ***Align research in an adaptive management approach*** to explain changes and the effect of management actions.
- ***Prepare a federal research plan*** that identifies major gaps that need to be filled.
- ***Improve modeling capabilities to forecast ecological and human health conditions*** due to changes in land use, climate, socioeconomic conditions, or different management options.

CHARGE FROM THE EXECUTIVE ORDER (EXCERPT)

The Secretaries of Commerce and the Interior shall, to the extent permitted by law, organize and conduct their monitoring, research, and scientific assessments to support decision making for the Chesapeake Bay ecosystem and to develop the report addressing strengthening environmental monitoring of the Chesapeake Bay and its watershed required in section 202 of this order. The report shall make recommendations to strengthen scientific support for decision making to restore the Chesapeake Bay and its watershed, including expanded environmental research and monitoring and observing systems. This report will assess existing monitoring programs and gaps in data collection, and shall also include the following topics:

(a) the health of fish and wildlife in the Chesapeake Bay watershed;
(b) factors affecting changes in water quality and habitat conditions; and
(c) using adaptive management to plan, monitor, evaluate, and adjust environmental management actions.

SCOPE OF THIS REPORT

The report presents major items to address the E.O. topic "strengthen science and decision making for ecosystem management." A new approach for addressing sustainability and ecosystem management is presented. The science elements, including monitoring, needed to support ecosystem management and improve decision making are presented. Lastly, the report discusses current scientific efforts, identifies gaps needed to address ecosystem management, and provides recommendations to fill the gaps.

INTRODUCTION

The Chesapeake Bay, the Nation's largest estuary, has been severely affected by human population increase, which has resulted in poor water quality, degraded habitats, and low populations of many fish, shellfish and wildlife species. Since the mid-1980s, the multi-agency Chesapeake Bay Program (CBP) partnership has been working to restore the Bay ecosystem. Findings from the CBP Bay Barometer (USEPA, 2009) show there have been some improvements in ecosystem conditions but other key measures remain degraded:

- A moratorium on striped bass fishing during the late 1980's and commercial quotas and recreational harvest limits set since 1990 resulted in a rebound of the population. However, there is a high prevalence of disease (mycobacteriosis), and concern whether there is enough prey to adequately support the striped bass population.
- Almost 20 percent of the critical lands in the Bay watershed, which provide important ecological, recreational, or economic value, have been conserved.

- Major indicators of dissolved oxygen (DO), water clarity, and chlorophyll remain degraded (only 21 percent of desired levels). DO conditions have not improved since the late 1980s and water clarity has worsened.
- There has been an overall decline in blue crab abundance since 1990 and the oyster population remains depleted.

Even with the CBP effort over the past 25 years in bringing together the restoration activities of federal and state governments, localities, private industry, and citizens, the overall health of the Bay in 2008 averaged 38 percent, with 100 percent representing a fully restored ecosystem (USEPA, 2009).

The continued poor health of the Bay suggests that the Chesapeake partnership must adopt new approaches to improve the Bay and its watershed. The new approaches must address the difficult decision making for multiple, and at times competing issues:

- Focusing on ecosystem improvement and sustainability of priority fish and wildlife populations and the supporting habitat and water-quality conditions.
- Addressing multiple stresses of the Bay ecosystem (such as overharvesting of fish populations, loss of habitat, and impacts of nutrients, sediment, and contaminants).
- Conserving existing lands and habitats that provide ecological, economic, recreational, and cultural value.
- Meeting the socioeconomic demands for goods and services provided by the Bay and its watershed.
- Planning for the potential impacts of a changing climate.

The choices made by individuals, communities, and governments directly impact the health of fish and wildlife in the Bay ecosystem, so there is a need to get individuals and communities more involved in making decisions about the future health of the Chesapeake Bay and its watershed. The current goals and decision-making process of the CBP (which is further described in Appendix 1) will have to be expanded to address a sustainable Bay and watershed. A new focus on sustainability, which is supported by ecosystem-based adaptive management, will foster more direct involvement of the citizens and local governments to help rehabilitate the health of the Bay ecosystem. EBM emphasizes a multi-faceted approach to (1) improve and sustain living resources and supporting habitat and water quality, and (2) meet the increasing needs for goods and services of the 17 million people in the watershed.

Science and technical assistance needs to be strengthened to support EBM and better plan, implement, and evaluate the actions and policies needed to improve the health of the Bay and its watershed. The science needs to better inform several key audiences:

- Citizens and watershed groups. Efforts should be focused on the agricultural community, suburban homeowners, urban dwellers, and watermen whose decisions influence the quality of agricultural, suburban, and urban lands, and use of ecosystem goods and services.
- Local governments. Work with local land-use planning and zoning decision makers to address sustainability of their communities, watersheds, and the Bay.

- Federal and State resources managers. A primary focus should be on the inter-relation of decisions to improve water quality, habitat, and living resources and their effectiveness in sustaining the Bay and its watershed.
- Elected officials. Provide science-based summaries that highlight the implications of proposed legislation and policies that will affect sustainability of the Bay and watershed.

ELEMENTS OF SUSTAINABILITY AND ECOSYSTEM-BASED MANAGEMENT

Sustainability has been increasingly emphasized as a management goal for ecosystems since its simple definition by the Brundtland Commission over two decades ago (WCED, 1987), "to meet the needs of the present generation without compromising the ability of future generations to meet their own needs." Boesch (2006) provided a useful summary of several national efforts using EBM to achieve sustainability. The Pew Oceans Commission (2003) stated, "Ecosystem-based management should reflect the relations among all ecosystem components including human and nonhuman species and the environments in which they live." The report of the presidentially appointed U.S. Commission of Ocean Policy (2004) also pointed to EBM as the foundation for the nation's ocean policy. The Commission stressed that management should balance the competing uses while preserving and protecting the ocean and coastal resources and achieve sustainability by meeting the needs of the present generation without compromising the ability of future generations to meet those needs. To put these principles in practice requires aligning decision making within ecosystem boundaries, precautionary and adaptive management, and the use of the best available science and information. Ecosystem-based management is being recognized as a priority objective for comprehensive management of the ocean, coasts, and Great Lakes in the White House Council on Environmental Quality interim report on Ocean Policy (currently being prepared).

With these concepts in mind, successful restoration and management of the Chesapeake Bay will need to expand from a water-quality emphasis to one focused on sustainability and EBM. An ecosystem-based approach will need to address a balance between the needs of (1) growing populations and their demands for ecosystem goods and services and (2) improving conditions for critical fish and wildlife populations and their supporting habitats and water quality.

For purposes of this report, EBM is defined as: "An approach to maintaining or restoring the composition, structure, and function of natural and modified ecosystems for the goal of long-term sustainability. It is based on a collaboratively developed vision of desired future conditions that integrates ecological, socioeconomic, and institutional perspectives, applied within a geographic framework defined primarily by ecological boundaries" (Meffe and others, 2002).

The current decision making and supporting science will need to address the: (1) broader structure, function, and composition of the ecosystem that better links the expanded goals

with factors affecting condition and sustainability; (2) the socioeconomic needs and benefits of 17 million people in the watershed, and (3) the supporting partnership infrastructure needed for more comprehensive monitoring, effective partnership, alignment of resources, and accountability and adaptation of partner efforts.

Table 1 illustrates the three major elements --ecological, socioeconomic, and partnership performance--needed for sustainability and EBM and their relation to existing Chesapeake Action Plan (CAP) goals.

Table 1—Major components of sustainability and ecosystem management.

Sustainability Framework element	Chesapeake Action Plan (2008)	Proposed ecosystem-based management for Executive Order "Science for Ecosystem Management" report	Types of decisions for sustainability and ecosystem management
Vision	A system with abundant, diverse populations of living resources, fed by healthy streams and rivers, sustaining strong local and regional economies and our unique quality of life	**Ecosystem Sustainability and Management** - the capacity of an area to meet the needs of the present generation without compromising the ability of future generations to meet their own needs, and management that integrates ecological, socioeconomic, and institutional elements.	**Decisions about balance and trade-offs between (1)** improving and sustaining living resources, habitat, and water quality, and (2) meeting increased needs for goods and services for human population.
Goals and Components	**CBP Goals** Protect & Restore Fisheries Protect & Restore Vital Aquatic Habitats Protect & Restore Water Quality Maintain Healthy Watersheds Foster Chesapeake Stewardship	**Ecological Element** • Diversity and Productivity o Living Resources o Habitats o Land Use • Chemical Cycling o Water Quality o Air Quality o Biogeochemical interactions • Natural Disturbances o Climate variability o Episodic events **Socioeconomic element** • Physical well being o Swimmable waters o Fishable waters o Adequate drinking water o Housing and transportation • Societal value o Public access o Recreation o Cultural heritage • Economic value o Cost of seafood	**Ecological Decisions** *Fish and wildlife harvest limits *Quality and location of habitat *Compatible land use for human needs and priority fish and wildlife species *Manage for acceptable levels of nutrients, sediment, and contaminants *Resilience to natural disturbances **Socioeconomic Decisions** *Take actions to ensure that contaminant concentrations within limits for fish consumption, safe drinking water, and swimmable waters *Take actions to ensure air quality within limits *Land planning for housing density and transportation *Individual's decisions for housing type and location, commute to employment, and recreational needs *Land planning and purchase

		o Value of ecosystem services o "Green" jobs	for public access, recreation, and enjoyment *Individual's decision on type and cost of food products
	Enhance Partnering, Leadership, and Management	**Partnership Performance Element** • Consensus-based • Results-oriented • Capacity to align and implement resources • Sound science • Adaptive process	**Partnership Performance** ***Set realistic goals and outcomes *Measure progress *Collaborate to achieve progress *Adapt and improve

The ecological element needs to emphasize the inter-relation of major ecosystem components: biodiversity, sustainable living resources, habitat, water quality, land-use activities, and climate variability and change. The socioeconomic element addresses the basic goods and services needed by watershed citizens. The partnership structure must also be in place to foster stewardship and support decisions by governmental and non-profit entities to effectively balance the health and sustainability of natural ecosystems with the socioeconomic demands for the goods and services they provide to the people who live within and outside the watershed. More explanation is provided in Appendix 1.

ADAPTIVE MANAGEMENT FRAMEWORK

The CBP needs to further employ adaptive, ecosystem management to improve decision making. This will complement the proposed CBP adaptive management process (USEPA, 2008), which is focused on improving the accountability and operation of the CBP. The suggested ecosystem-based, adaptive management framework for the Chesapeake Bay ecosystem (figure 1) is based on approaches developed by the DOI (Williams and others, 2007) and Integrated Ecosystem Assessments (Levin and others, 2009). The adaptive management framework incorporates research into conservation action by aligning the decision-making process with the supporting science elements. Specifically, adaptive management integrates the design, management, and monitoring to systematically test assumptions in order to adapt and learn (Salafsky, et al. 2001). Major components of the proposed ecosystem-based, adaptive management framework and supporting science are:

- **Refine Goals**-The CBP goals need to be refined to address the new elements of ecosystem management--ecological, socioeconomic, and partnership performance. The supporting science will include collecting observations and conducting assessments to define the extent and causes of problem(s) so goals can be refined and indicators can be refined or established.
- **Plan and Prioritize**-Management strategies and actions will need to be planned and prioritized to meet the revised goals. For CBP strategies that are already in place, most of the emphasis will be on prioritizing the locations and types of practices to be implemented. Science elements to support prioritization would

mostly be GIS-based decision tools to show areas of high nutrient, sediment, and contaminant loads, or habitats conditions and vulnerability. For new strategies, such as implementing the new TMDL or addressing climate change, models are needed to forecast potential future conditions and conduct scenario testing of strategies and actions that may provide the greatest ecosystem benefit and associated optimal cost. Monitoring will need to be designed to document changes in ecosystem response and evaluate the effect of management actions. Monitoring will need to be begun prior to implementation or enhancement of management actions so baseline conditions are documented.

- **Implement**-Policies and actions are implemented through coordinated partner efforts that effectively align resources.
- **Monitor**- Monitoring is critical to document changes in ecological conditions, tracking of management actions, and progress toward performance measures. Monitoring will need to include the major ecological components (living resources, habitat, land use, water and air quality, and natural disturbances), socioeconomic attributes and attitudes, and tracking of types and locations of management actions. Due to the scope of the issues, the monitoring will have to occur at different spatial and temporal scales in selected areas and results used to extrapolate to areas that cannot be monitored.
- **Evaluate**-Indicators are used to synthesize monitoring data and assess changes in ecological and socioeconomic elements. Research facilitates integrated assessments to improve understanding of the factors affecting ecological and socioeconomic change and to help evaluate the effective of management strategies and actions. Evaluation includes assessing effectiveness of management actions to achieve desired outcomes, adequacy of supporting science (models, monitoring, and research) to predict and detect ecosystem change, and partnership capacity to implement programs and actions.
- **Adjust**-Based on the outcomes of the evaluate step, both short- and long-term adjustments may need to be for management actions, science, and partnership performance. Short-term adjustments (1 year or less) may be made to management actions or strategies or partnership capacity to implement programs. Longer-term adjustments (1 year or more) may include modifying goals and management strategies and adjusting long-term monitoring and research programs. Long-term adjustments to science elements include improving models, monitoring, or research to improve understanding of ecological and socioeconomic changes and effect of management actions.

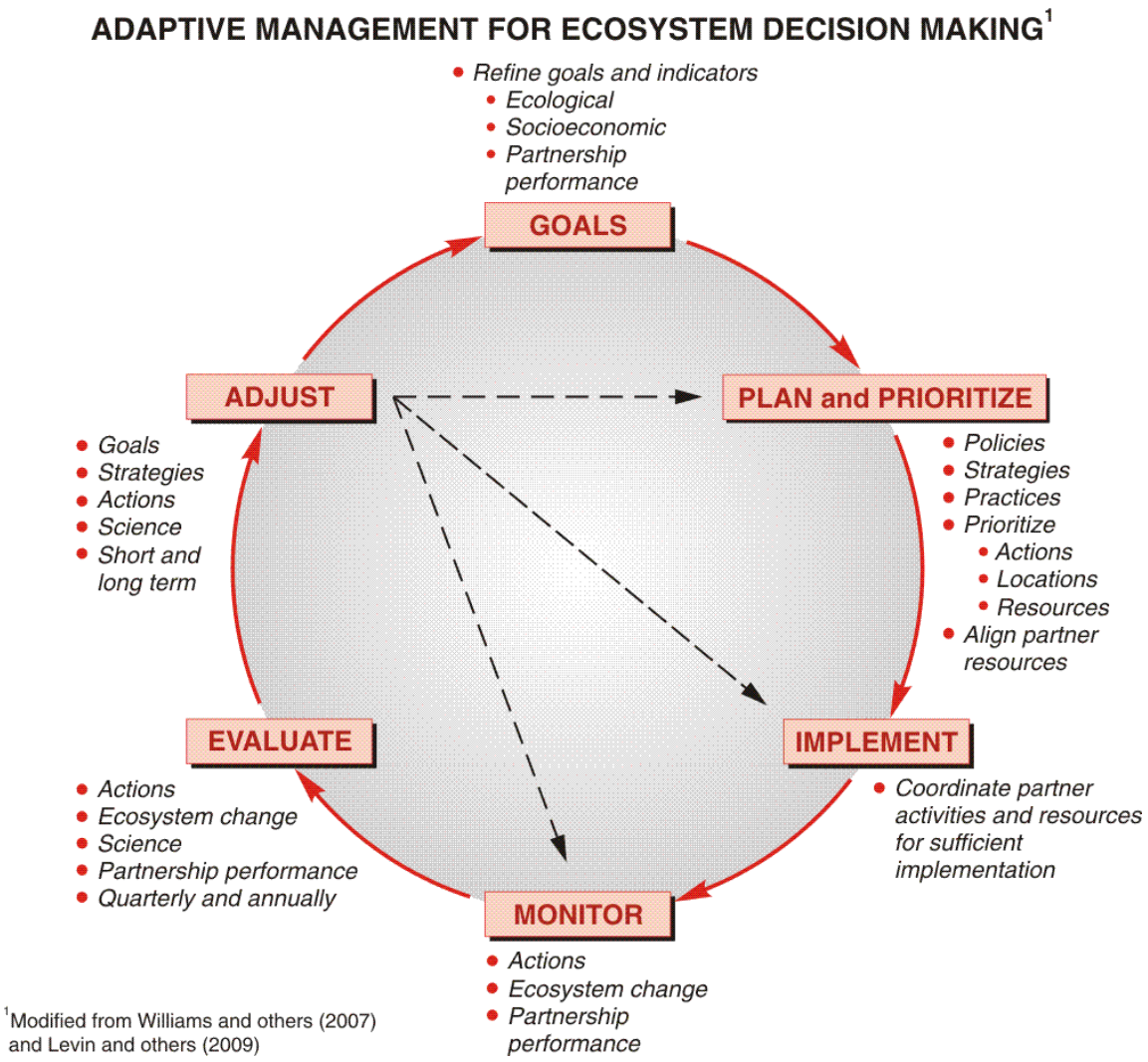

Figure 1—Proposed ecosystem-based adaptive management framework and supporting science elements for Chesapeake Bay partnership.

The adaptive management framework will depend on supporting science elements, which are:

- Observations and monitoring- provide the raw data that form the basis for all other science elements and adaptive management. Monitoring and observations are needed to define the status of ecosystem integrity, prepare models to forecast ecological conditions and test management scenarios, and document changes in management actions and ecosystem condition.

- Information management - ensures that the observations and monitoring data are of sufficient quality to be used for all the science applications, are accessible in databases to ensure long-term integrity, and systems are in place to provide rapid access to and application of the information.

- Assessment and research- monitoring data are assessed to define the extent of problems and track changes over time. Research is conducted to understand and explain the ecological conditions, examine the effectiveness of potential solutions, and develop models to test hypotheses and forecast outcomes of different management and socioeconomic scenarios.

- Modeling- models are used to test hypotheses of factors affecting ecological and socioeconomic conditions and inter-relation of ecological components (living resources, habitat, water quality, land use, and natural disturbances). Models are used to forecast future conditions and assess management alternatives based on different scenarios of socioeconomic conditions, climate change, and management policies and actions.

- Indicators- selection of a full suite of variables to that can be measured and analyzed is crucial so scientists and managers can track ecological, socioeconomic and institutional trends and compare them to the objectives. The development of a clear set of measurable indicators and benchmarks for the health of the Chesapeake Bay watershed will allow tracking of restoration progress and the ability to report back to the public.

- Communication Process- provide the assessment and synthesis of scientific information to improve decision making for federal and state managers and policy makers, local governments and land-use planners, elected officials, and the general public. Products for Federal and state resource managers would be focused on helping them adjust management policies and actions based on an improved understanding of the ecosystem and effectiveness of management actions. Products for local governments and land-use planners would provide implications for a balance between economic growth and a sustainable ecosystem. Products for the general public would help them understand how their economic and social decisions affect, and derive benefit from, ecosystem goods and services. Products for elected officials would provide implications of how laws, policies, and budget decisions affect sustainability and ecosystem conditions.

- Decision support tools- Improved decision-making will depend on delivering the information to each audience in a timely and user-friendly fashion.

Each of the science elements fits into an adaptive management cycle to adjust and improve management policies and actions, and the research needed to support ecosystem-based decision-making. Further discussion of the adaptive management cycle and the alignment of these elements are covered in Appendix 2.

ADAPTIVE MANAGEMENT IN PRACTICE: BLUE CRAB STOCK ASSESSMENT

The cycle of stock assessment and regulation modification employed in managing Chesapeake Bay Blue Crab Stock is a good example of how an adaptive management approach is employed by resource managers in the region. On an annual cycle, managers use data gathered from ecological surveys/monitoring programs to provide input for a stock assessment model. The model is used to assess the population and fishing status and an advisory report is generated. From there, state managers and fisheries commissions make decisions about any necessary modifications to the current harvesting regulation. The process is revisited on a 3-5 year cycle, when biologists and modelers convene to revise and review the current models used and to make recommendations on additional monitoring and research necessary to improve the assessment. New models are used to explore potential impacts of various policy scenarios and stakeholder groups are convened to discuss management alternatives.

The blue crab management cycle was never explicitly designed to be an "adaptive management" process; however, it has evolved to one. Over the past 15 years, this has spurred the development of extensive blue crab research and improved monitoring. Future cycles may help to incorporate more of an ecosystem-based management approach. For example, managers and biologists may determine that habitat and population recruitment factors are necessary for improving stock assessment and exploring potential management options resulting in future research, monitoring, and models that could be incorporated in the iterative phase of management to help reduce uncertainty in management decisions.

ESTABLISHING AN INTERAGENCY DECISION-SUPPORT HUB

To better integrate and synthesize information and provide results to key audiences for sustainability and ecosystem management, we recommend a Decision-Support Hub be established. Most of the current decision-support activities in the CBP are focused on water-quality improvements and the same level of effort is needed to address the other CBP goals and new challenges. The Hub would bring together decision-support tools and have decision-support specialists to provide a similar level of effort to support the other CBP goals. The primary responsibilities of the Decision Support Hub would be to:

- Provide GIS-based decision-support tools and analysis for (1) target conservation and restoration actions for habitat, water quality, and vital land (2) coastal zone management, (3) fisheries and wildlife management, (4) hazard assessment, climate change, and resiliency planning, and (5) land-use planning.
- Forecast and assess implications of different management actions and policies,
- Prepare communication products for the public, local governments, resource managers, and elected officials, and

- Have decision-support specialists to directly interact with decision makers on the implications of different management options and effectiveness of current practices.

The Hub would interact closely with the CBP Technical Support and Services team to utilize scientific information being generated by federal, state, and academic partners. The key science information needed by the Hub to improve decision-support tools and analysis includes monitoring, improved spatial data and information management, research results, model forecasts, and an expanded suite of indicators (see figure 2).

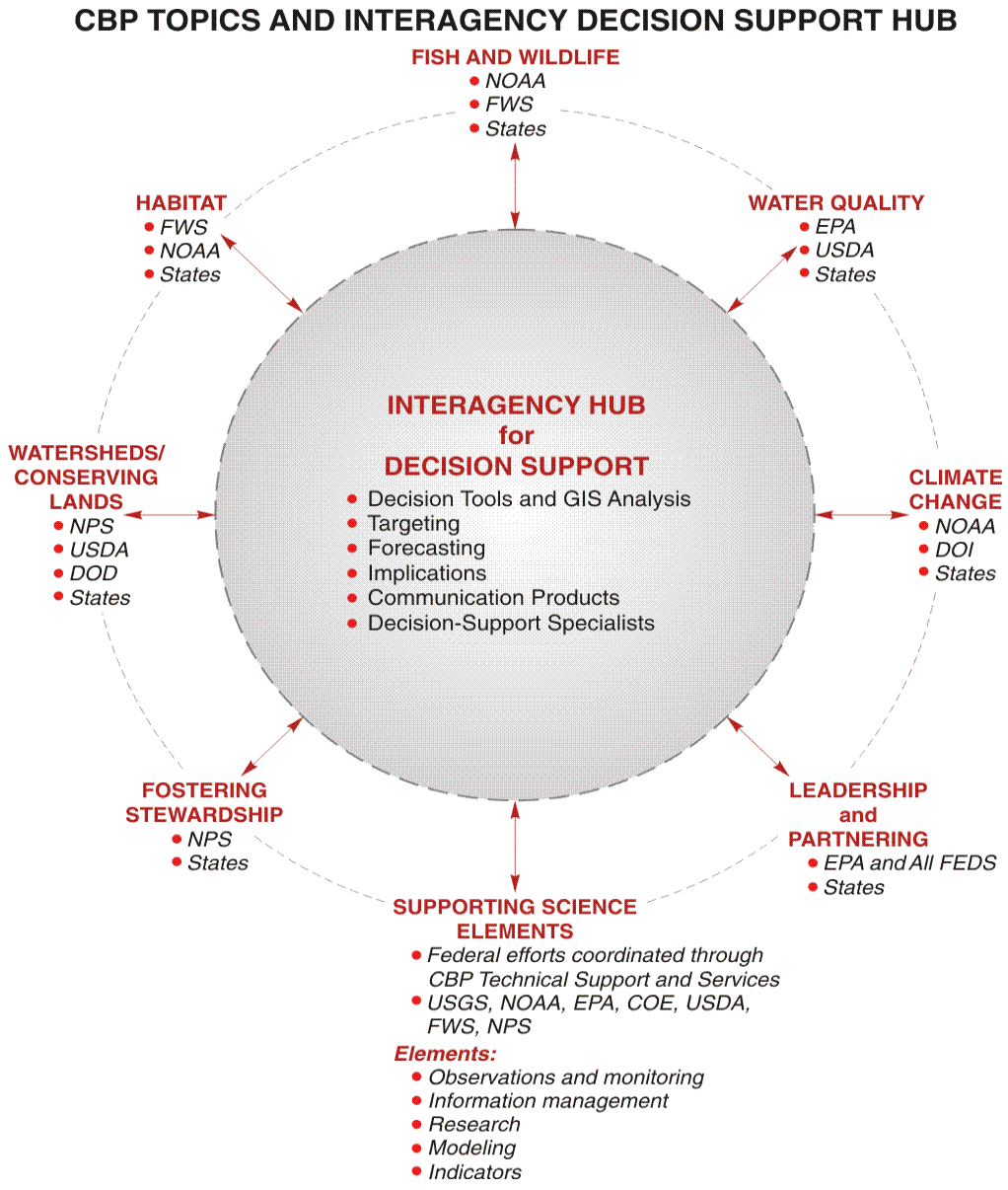

Figure 2: Relation of Decision Support Hub to CBP Goals and Technical Support and Services Team

Specific recommendations to be addressed by the Hub include:

- The partnership needs to integrate existing decision tools (examples of existing tools include Chesapeake Online Adaptive Support Toolkit (COAST)-USGS/USEPA; SLAMM-USFWS; Habitat Priority Planner-NOAA). The existing decision tools should be enhanced to address new ideas being developed for targeting agricultural practices (NRCS), Clean Water Act activities (USEPA), stormwater (DOD and USEPA), and protecting ecosystems (NPS). We recommend that the COAST be developed as a portal to provide improved access to other decision tools.
- Improve tools to include socioeconomic factors so improved decisions can be made for sustainability of living resources and the needs of 17 million people in watershed.
- Improve communications products, technical assistance, and social marketing campaigns to effectively translate scientific findings and illustrate the consequences of management options and decisions by the public, local governments, resource managers, and elected officials. Improved communication strategies and products would help link and simplify the technical concepts of ecosystem management with the sustainable benefits they provide to people in the watershed (USGS and NOAA).
- Enhance the Bay Barometer to reflect sustainability and additional socioeconomic indicators (USEPA).
- Revising partner "state of the environment" reports and "report cards" to reflect sustainability and EBM.
- Utilize research in human dimensions and social marketing to enhance effectiveness of products to improve decision making for target audiences

CREATING A DATA ENTERPRISE

Given current technology capabilities, senior level decision makers should be able to view indicators of the health of the Bay geographically from their desktops and collaborate in real time on different policy scenarios for restoration. This requires a set of agreed upon information management practices adopted by the partners so that silo systems or information management approaches do not impede progress. All environmental data archiving, access, sharing, and information systems should transition into a fully integrated Chesapeake Bay Data Enterprise. The ultimate goal of improved data management should be to provide timely and agile access to data and information among partners so they can easily integrate data for analysis. The Chesapeake Bay Data Enterprise will enable partners to use the wide range of data needed to improve ecosystem management. Therefore the partnership must design a blueprint for this new capability and fully leverage the Internet for sharing and use information between the growing number of data producers and data consumers.

The Chesapeake Bay Program has foundational pieces of an enterprise wide system in place. It has built and deployed an activity integration system, reports information to the public through the Bay Barometer, and maintains and runs models leveraging federal supercomputing capabilities. However, to be a truly effective and agile information and

knowledge-based partnership, enterprise-wide best practices for information management and future investments need to be accepted by the partners. Investment in the data housing, data-serving infrastructure is critical to be able to conduct integrative analyses in support of diverse decision making needs.

Specific recommendations to be addressed by the Data Enterprise include:

- Make extensive improvements to obtain, manage, and share information to support EBM and improve decision-making. Design and implement effective enterprise architecture to share and use information between the growing numbers of data producers (USEPA)
- The partners will have to greatly increase their capacity to assess, obtain, manage, and utilize appropriate information from multiple monitoring programs. CBP should develop partnership guidance documents that lay out analytical-quality assurance requirements for a monitoring program to become a partner in our monitoring networks. Guidance for data management, data standards, data submission and metadata currently exists, but will need modification for working with small data providers (CBP 1998, CBP 2001, and CBP 2006). (USEPA, NOAA, and USGS)
- Design and implement effective enterprise architecture to share and use information between the growing number of data producers (USEPA)
- Participate in the Open Geospatial Consortium Interoperability Program and the Federal Geographic Data Committee to ensure compatibility of information (USEPA, NOAA, DOI, USDA, and DOD)
- Manage existing information and plan for the increased needs of EBM. Take advantage of existing Interagency national data management programs, such as the Integrated Ocean Observing System and the National Water Quality Monitoring Network (USEPA, NOAA, and USGS)
- Ensure full utilization of the data standards being developed for map and remotely sensed data (by the Federal Geographic Data Committee) to ensure interoperability and utilize national ideas for data management being implemented by IOOS and the NWQMN (USEPA, NOAA, and USGS)

CREATING THE CHESAPEAKE MONITORING AND OBSERVING SYSTEM

The importance of monitoring for EBM can be stated in a single sentence: *You cannot recognize, understand, improve or maintain what you do not or cannot measure* (Draggan, 2006). This places monitoring as a fundamental need for achieving sustainability. In this report we primarily deal with ecological monitoring, but we recognize the need for monitoring socioeconomic and performance indicators. Scientifically-defensible and credible measurements and observations in each of these areas can provide powerful bases for decisions and management actions that are focused upon a variety of goals including those related to sustainability (Draggan, 2006).

EXISTING SCIENCE PROGRAMS AND GAPS TO ADDRESS ECOSYSTEM BASED MANAGEMENT

As part of the 202f report, a gap analysis was conducted to assess the ability of existing federal programs to address the science elements needed for adaptive ecosystem-based management. Table 2 summarizes the results of the gap analysis by illustrating the science elements to support EBM are adequate (green), need to be integrated or improved (yellow), or do not currently exist (red). Within the existing Chesapeake Bay partnership, many of the science elements to address the ecological components are in place, but need to be improved. Many of the science elements to support the socioeconomic component do not exist or need to be improved, and most science elements to support partnership performance exist but need to be improved.

A major aspect of the gap analysis focused on current monitoring programs. The current USEPA CBP funded monitoring programs are shown in Table 3.

Program region	**Program Areas**	**Parameters**
Tidal	Mainstem Water Quality Tributary Water Quality Shallow Water Monitoring	Physical Chemical: Nutrient suite (totals and or certain fractions of N, P, C, Si), Turbidity, Secchi, Temperature, Salinity, Conductivity, dissolved oxygen, Kd. Biological: Phytoplankton, Benthic invertebrates, Submerged Aquatic Vegetation
Watershed	Nontidal Tributaries River Input Monitoring Program	Nutrients and sediments, Nutrients and sediment, chlorophyll, toxic elements (at a limited number of sites),

Table 3—Current CBP USEPA funded monitoring programs

Other federal, state and local agencies and nongovernmental programs also carry out extensive monitoring efforts. The CBP office prepared an inventory of monitoring programs being conducted by federal, state, and local governments to address both the EO requirement to assess existing monitoring programs and gaps in data collection and to provide information to help re-align the CBP water-quality monitoring programs. Results of the inventory are shown in figure 2. More information about how the inventory was conducted and lists of federal programs are presented in appendix 4.

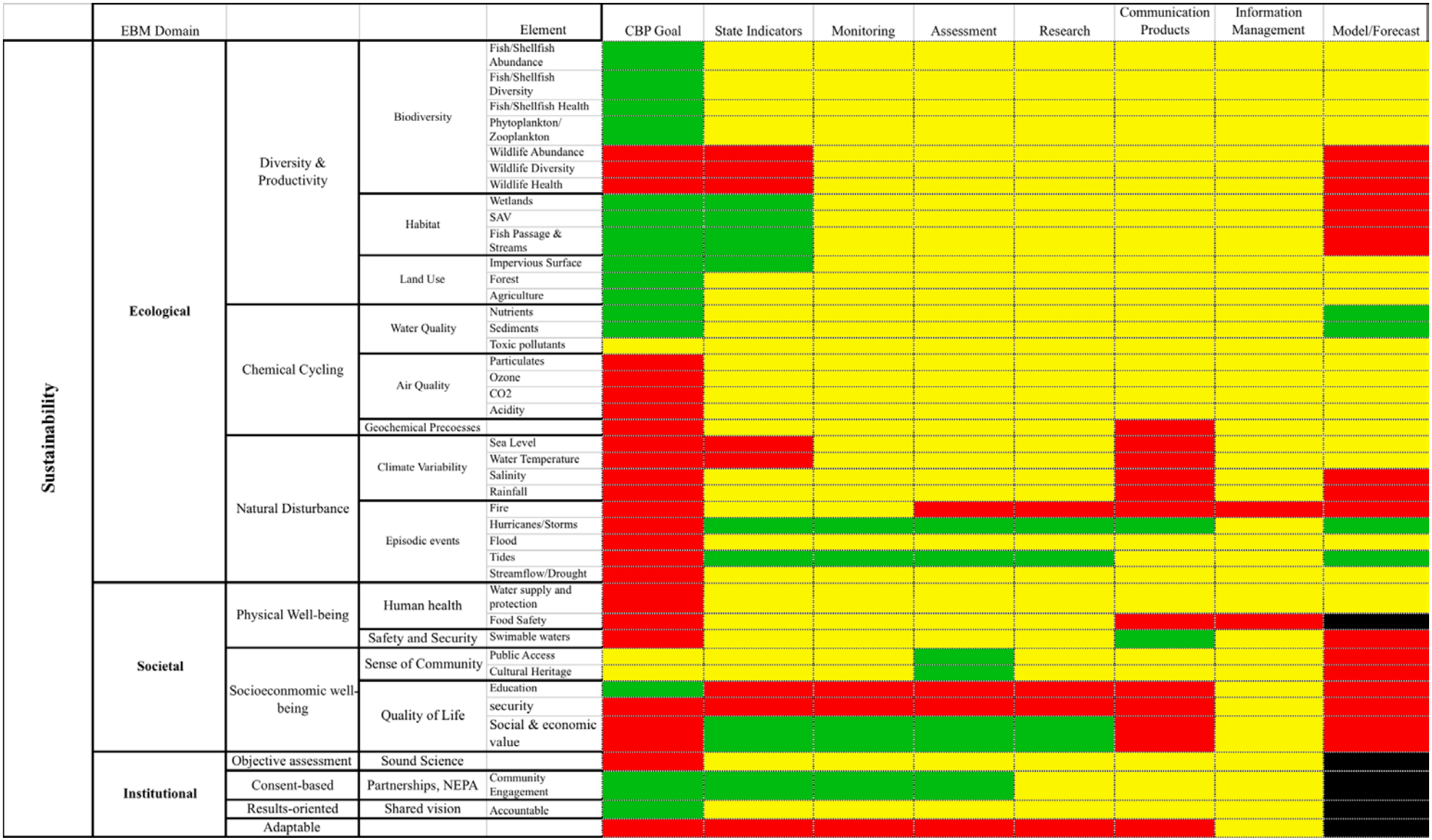

Table 2. Gap analysis for existing Chesapeake Bay ecosystem based management components. Green indicates current efforts sufficient; yellow denotes work in progress, but either lack of coverage or lack of integration; red denotes no current effort.

The additional monitoring programs offer opportunities to build alliances to utilize existing programs to address aspects of EBM. However, there is a need for additional resources to assess the adequacy of the information and to manage the data. These existing programs cannot address all the gaps in monitoring. The recommendations to address these gaps and those of the other science elements are fully discussed in Appendix 5 and summarized below.

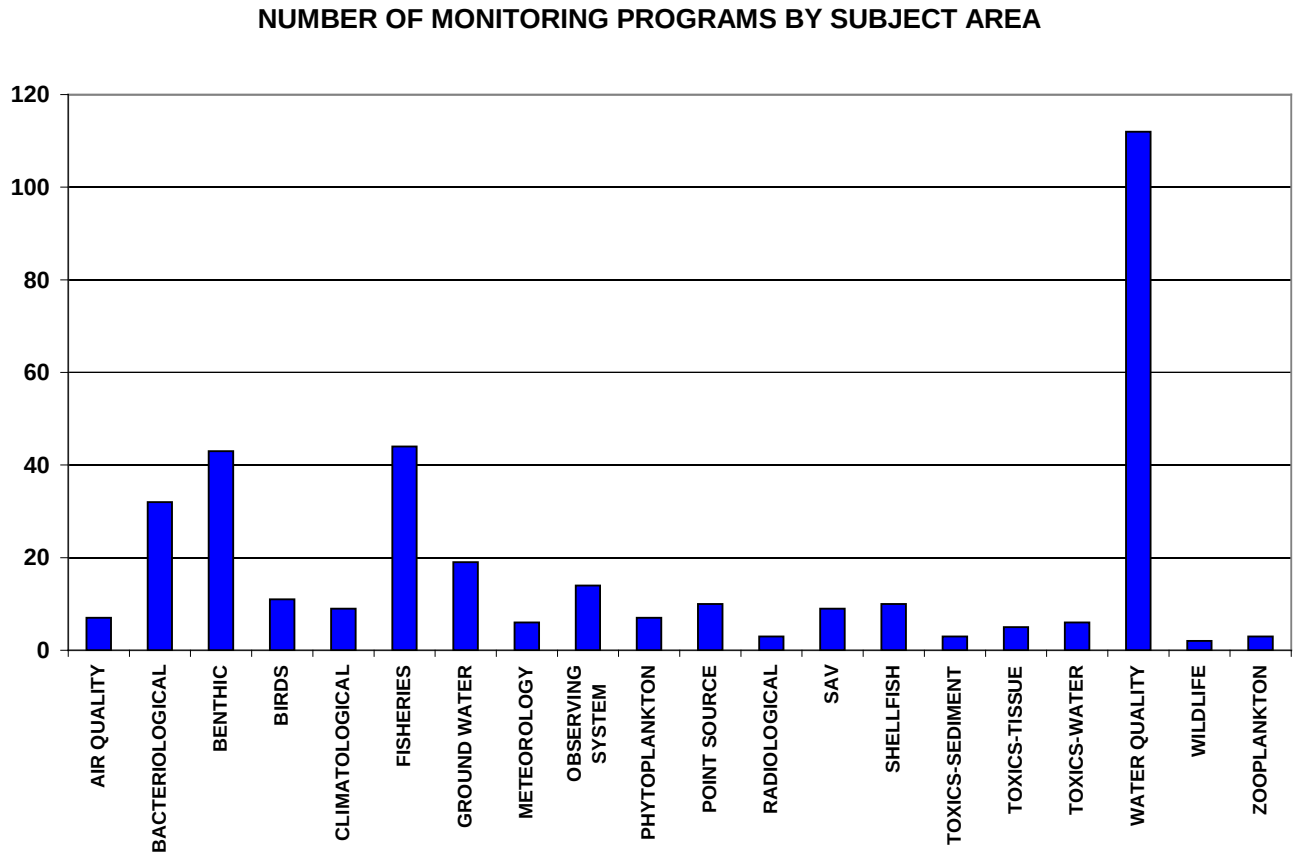

Fig. 2 Monitoring programs by subject areas related to ecosystem-based management

The Chesapeake Bay partners will need to expand partner efforts for a Chesapeake Monitoring and Observing System to provide integrated monitoring of upland watersheds, estuaries, and the coastal ocean using common criteria and standards. The monitoring system should build from existing monitoring and observing programs in the Bay and its watershed and be improved to better address fish and wildlife, foodweb interactions, disease, contaminants, climate variability, land-cover and use, and tracking of management actions. The monitoring should occur at several scales ranging from the entire basin and contributing coastal waters down to small watersheds to assess effectiveness of agricultural and suburban practices. There are opportunities to build on

existing networks and better align with national programs to improve the current monitoring system. The efforts to establish and improve the system would include:

- ***Coordinate with national monitoring networks*** to address needs in the Bay and its watershed (including the Integrated Ocean Observing System and the National Water Quality Monitoring Network).
- ***Establish stronger partnerships*** with ongoing federal and state monitoring programs.
- ***Design and implement a climate change monitoring component*** to ensure decision tools and models can forecast potential impacts of a changing climate.
- ***Expand monitoring to address identified gaps.*** Additional monitoring is needed to address critical gaps in monitoring of fish and wildlife, habitat, contaminants, land use, natural disturbances, and socioeconomic factors, and tracking of management actions.

Summary recommendations include:

- Interact with key national observation systems to further implement regional components of these federal systems in the Chesapeake Bay and its watershed. The federal systems include the Integrated Ocean Observing System (Interagency, led by NOAA) and the National Water-Quality Monitoring Network (led by USGS and USEPA)-see p. 23. Other relevant national programs with monitoring programs include the National Fish Habitat Action Plan (USFWS), the National Water-Quality Assessment (NAWQA) program (USGS), and the proposed Climate Effects Network (DOI).
- Utilize and increase partnerships with existing federal, state, and local monitoring programs. The majority of the existing programs are best suited to address water-quality conditions in the watershed and the physical well-being of the human population (drinking water and air quality, fish and shellfish consumption, and swimmable waters). Additional work is needed to assess, obtain, and interpret this information to address EBM needs (USEPA, NOAA, and USGS).
- Improve monitoring in tidal waters for foodweb interactions, habitats, contaminants, and disease to improve management of fisheries and wildlife species (NOAA and USFWS).
- Improve the CBP tidal water-quality monitoring program to enhance assessment of water-quality standards in the Chesapeake Bay (USEPA).
- Improve the CBP nontidal water-quality monitoring network to better document nutrient and sediment reductions in the Bay watershed (EPA and USGS).
- Establish long-term monitoring and assessment in small watersheds to evaluate and explain the effectiveness of restoration practices. There are opportunities to partner with on-going studies conducted by federal, state, and NGOs to assess changes in nutrients, sediment, contaminants, and habitats (USEPA, USDA, USGS, FWS, and COE).
- Establish monitoring programs of critical wildlife species and their habitats in the Chesapeake Bay watershed (including recreational fish species, fish with compromised health, and selected migratory birds). There are opportunities to better utilize federal and state monitoring programs to determine the health and

abundance of wildlife species and the impacts of pathogens, disease, contaminants, and invasive species (USFWS, USGS, and USEPA).

- Improve spatial resolution and consistency of land-cover and impervious surface monitoring for the watershed every 5 years (NOAA and USGS).
- Create a geo-referenced database to track changes in land-use activities and management actions on agricultural, urban/suburban, and forested lands (USDA, USEPA, USGS, and DOD).
- Improve observing systems and monitoring of climate variability and extreme events to better assess changes in ecosystem conditions and long-term effects of climate change (NOAA and USGS).

THE INTEGRATED OCEAN OBSERVING SYSTEM AND THE NATIONAL WATER-QUALITY MONITORING NETWORK

To reduce the effort needed to create the Chesapeake Monitoring and Observation System, existing monitoring programs should be utilized. Recommendations by the U.S. Commission on Ocean Policy previously led to the creation of the National Water-Quality Monitoring Network for U.S. Coastal Waters (NWQMN) and strong endorsement of the Integrated Ocean Observing System (IOOS). The NWQMN design addresses physical characteristics (flow, sediments, habitat), chemical constituents (organics and inorganics), and biological characteristics (chlorophyll and algae, bacteria and viruses, macroinvertebrates, and fish). It is a multi-organizational framework that addresses issues at multiple scales, including fixed station and probabilistic designs, discrete and continuous data, and point and spatial data (such as along buoy lines or trawls). The IOOS framework includes *in situ*, remote, and other coastal and ocean observation, technologies, and data management, modeling and communication subsystems. IOOS is designed to gather specific data on key coastal and ocean variables, and to ensure timely and sustained dissemination and availability of these data.

The two systems are aligned at the national and regional levels. Both IOOS and the NWQMN provide local infrastructure for Chesapeake Bay monitoring; the combination provides integrated monitoring of coastal and upland watersheds, estuaries, and the coastal ocean using common criteria and standards. The community needs to leverage existing capabilities of IOOS and the NWQMN to enhance Chesapeake Bay observing and decision-support capabilities that would enable us to better understand and respond to the interactions among ocean, atmospheric, and terrestrial processes. More information on these and other programs is provided in Appendix 3.

ALIGNING AND INTEGRATING RESEARCH TO EXPLAIN AND FORECAST ECOSYSTEM CHANGES AND THE EFFECT OF MANAGEMENT ACTIONS

Better alignment of research efforts and models will improve targeting of management actions, develop forecasting capabilities of ecological and land-use conditions and outcomes of management options, explain ecosystem change and evaluate the effects of

management actions, and develop the cost and value information needed as a foundation for development of ecosystem market banking and trading. This recommendation proposes the federal government will:

- ***Align research in an adaptive management approach*** to explain changes and the effect of management actions.
- ***Prepare a federal research plan*** that identifies major gaps that need to be filled.
- ***Improve modeling capabilities to forecast ecological and human health conditions*** due to changes in land use, climate, weather, socioeconomic conditions, or different management options.

Aligning and expanding research into the proposed adaptive-management framework will improve our ability to assess the effectiveness of management actions and explain ecosystem linkages between living resources, habitats, water quality, land use, natural disturbances, and socioeconomic factors. Some specific recommendations include:

- Understand and explain ecosystem linkages between living resources, habitats, water quality, land use, natural disturbances, and socioeconomic factors. (NOAA, USFWS, USGS, USEPA, USDA, DOD).
- Improve models of ecosystem interconnections to forecast potential future conditions and test different management scenarios. Conduct integrated assessments of the effectiveness of management policies and actions to improve ecosystem conditions (NOAA, USFWS, USGS, USEPA, USDA, and DOD).

A new Chesapeake Bay Federal Research Plan is needed to help align Federal research efforts. The Plan will identify priority research needs through stakeholder (scientist and technical experts, policy makers and the public) input, and describe the implementation of strategies to address those needs. The Plan should be modeled after the National Science and Technology Council's Joint Subcommittee on Ocean Science and Technology (JSOST) Ocean Research Priorities Plan, to help guide Federal research as well as Federal external funding opportunities. Specific recommendations are:

- Prepare a federal research plan to address highest priorities (NOAA, USFWS, USGS, USEPA, USDA, and DOD working with STAC).
- Work with STAC to align academic and federal research efforts and needs.

Attempts to integrate existing models, and develop additional models, are needed to simulate the ecological factors affecting fish and wildlife and the relation to socioeconomic changes of the human population. Integrated ecological models are needed at different scales to run scenarios to make tactical decisions (such as fishing harvest) and long-term, strategic decisions for management policies. Some specific recommendations include:

- Better link existing models to forecast ecosystem changes of different management actions. Work to link outputs from land-change model (USGS), with watershed models (USEPA and USGS), estuary water-quality models (USEPA and COE), and fisheries models (NOAA).
- Enhance existing models to include socioeconomic factors and climate-change variables (NOAA, USEPA, USGS), and develop new models of critical wildlife species (USFWS and USGS).

- Develop models to run as analytical web services using existing standards so they can be applied to consider management decisions at multiple scales (watershed wide, state, and local scales) (USEPA, NOAA, USGS, and USFWS).

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APPENDIX 1. DISCUSSION OF DECISION MAKING FOR ECOSYSTEM SUSTAINABILITY AND MANAGEMENT

This appendix summarizes the current CBP management goals and decision making process and provides the rationale to evolve to a decision making framework that emphasizes the goal of sustainability to be achieved through ecosystem-based management. An integrated observing and assessment system based on adaptive management and supporting science elements is outlined.

Current CBP Goals and Decision-Making Process

The Chesapeake Bay Program partners, in the 2000 Restoration Agreement, developed a collaborative vision for the Bay ecosystem-- "a system with abundant, diverse populations, of living resources, fed by healthy streams and rivers, sustaining strong local and regional economies and our unique quality of life." The Chesapeake 2000 agreement set over 100 commitments to address major goals for living resources, habitat, water quality, land use, and stewardship. Since 2000, the CBP partners have had to prioritize restoration efforts due to limited resources to address all of the Chesapeake 2000 commitments. The CBP placed an emphasis on restoring water quality because the Bay had been listed as an impaired water body under the Clean Water Act.

In 2008, the CBP prepared the Chesapeake Action Plan (CAP) (USEPA, 2008) that modified the Chesapeake 2000 goals and showed the inter-connection of the goals. The restoration and protection of living resources was the primary goal supported by habitat and water-quality restoration, maintaining healthy watersheds, and fostering stewardship (figure A1-1). A new goal to enhance partnering, leadership, and management was also established to improve the institutional capacity and accountability of the CBP partnership to achieve the ecological goals. The CAP contained a strategic framework that unified CBP's goals and plans, developed dashboards and updated indicators to show progress toward the major goals of CAP, developed a data base of federal and state activities so partners can better align efforts and resources, and proposed an adaptive-management process that begins to identify how this information will provide critical input to the CBP partners actions, emphasis, and future priorities.

Even with the CAP, the current decision making process of the CBP is mostly focused on addressing individual CAP goals, with an emphasis on the water-quality goal. The decision making about the inter-relation of CAP goals, such as assessing how changes in water-quality conditions will improve the abundance and health of living resources in the Bay, is not emphasized at this time. Water-quality criteria for dissolved oxygen, water clarity and chlorophyll a have been developed based on the needs of living resources in the bay. The criteria have progressively been phased in by States as water-quality standards. Clean Water Act litigation has led the Chesapeake Bay partnership to develop nutrient and sediment load reduction targets under the Total Maximum Daily Load (TMDL) approach. Water-quality monitoring networks in the Bay are used to assess progress toward attainment of the water-quality standards. A CBP nontidal watershed

monitoring network was established by the CBP partners in 2004 to document changes in nutrients and sediment loads in the watershed to help to assess progress towards load restoration goals.

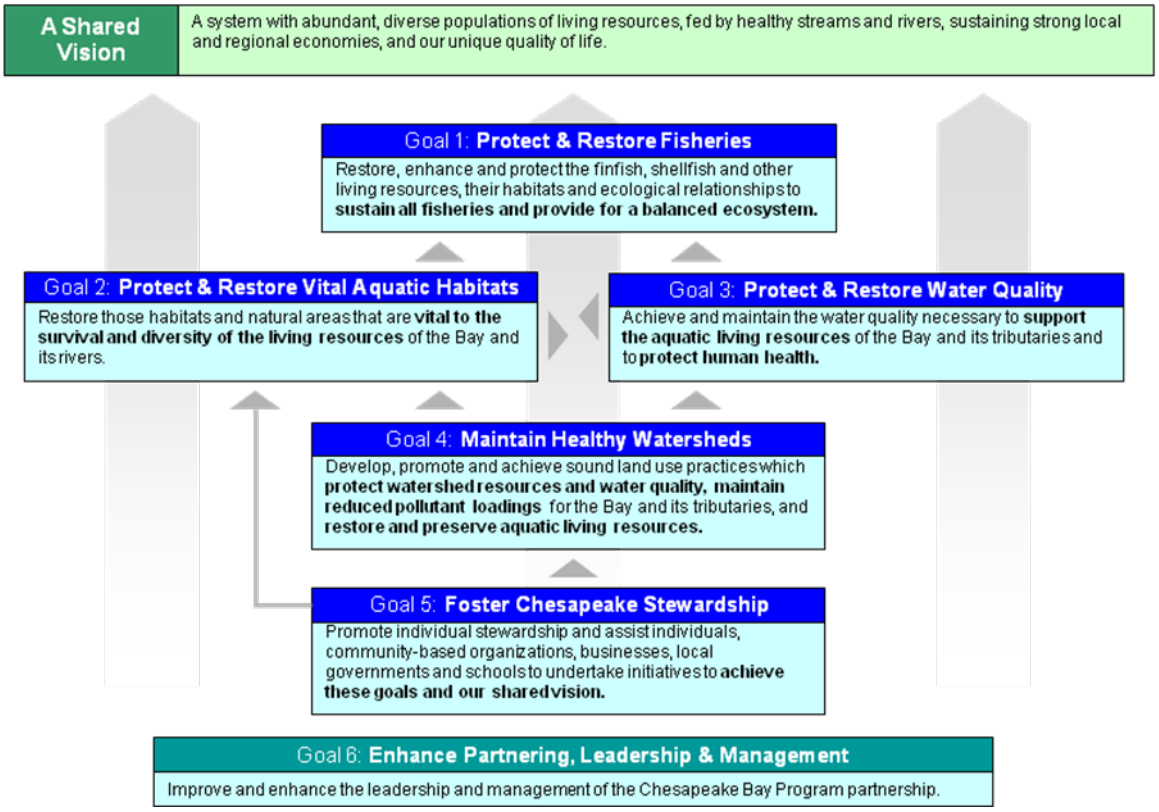

Figure A1-1 Current goals of the Chesapeake Bay Program

Despite these substantial monitoring and assessment efforts, a recent CBP-STAC monitoring program review (2008) has found the CBP monitoring efforts insufficient to address critical aspects of the CBP goals for living resources, habitat, watersheds and stewardship and some aspects of water quality. CBP monitoring realignment activities, generally focused on water quality, are underway during summer 2009. Outcomes of the realignment process are anticipated to address water-quality elements of monitoring program deficiencies in autumn 2009, and are considered in this report. The inter-relation of the CBP goals, and supporting science, needs to be more thoroughly examined and integrated using ecosystem-based management to improve the decision making for restoring and protecting the Bay and its watershed.

Decision Making for Sustainability and Ecosystem-Based Management

The President issued Executive Order 13508 on May 12, 2009 for Chesapeake Bay protection and restoration. The E.O. directs the federal government, in consultation with the states, to “protect and restore the health, heritage, natural resources, and social and economic value of the Nation’s largest estuarine ecosystem and the natural sustainability of its watershed.” The E.O. addressed multiple ecological, social, and institutional topics including: (1) Shared Federal Leadership, Planning, and Accountability, (2) Restore

Water Quality, (3) Agricultural Practices to Protect the Chesapeake Bay, (4) Reduce Water Pollution from Federal Lands and Facilities, (5) Protect Chesapeake Bay as the Climate Changes, (6) Expand Public Access to the Chesapeake Bay and Conserve Treasured Landscapes, (7) Monitoring and Decision Support for Ecosystem Management, and (8) Living Resources Protection and Restoration.
To more effectively address the E.O. and goals in the CAP, the CBP needs to evolve from a program that emphasizes water-quality restoration to one focused on sustainability that is achieved through ecosystem-based management.

For purposes of this report, ecosystem-based management is defined as:
"An approach to maintaining or restoring the composition, structure, and function of natural and modified ecosystems for the goal of long-term sustainability. It is based on a collaboratively developed vision of desired future conditions that integrates ecological, socioeconomic, and institutional perspectives, applied within a geographic framework defined primarily by ecological boundaries" (Meffe and others, 2002).
The current decision making and supporting science will need to be expanded to address the:

- Broader structure, function and composition of ecosystem that better links the CBP goals and other factors affecting the condition and sustainability,
- Socioeconomic needs and benefits of 17 million people in the watershed, and
- Supporting partnership infrastructure needed for more comprehensive monitoring, effective partnership, alignment of resources, and accountability and adaptation of partner efforts.

Table A1 illustrates the 3 major elements --ecological, socioeconomic, and partnership-- needed for sustainability and ecosystem-based management and their relation to existing CBP goals. The ecological element needs to emphasize the inter-relation of major ecosystem components: biodiversity, sustainable living resources, habitat, water quality, land-use activities, and climate variability and change. The socioeconomic element needs to address the basic goods and services needed by the 17 million people in the watershed. The institutional structure must also be in place to foster stewardship and support decisions by governmental and non-profit entities to effectively balance the health and sustainability of natural ecosystems with the socioeconomic demands for the goods and services they provide to the people who live within and outside the watershed.

Table 1—Major components of sustainability and ecosystem management.

Sustainability Framework element	Chesapeake Action Plan (2008)	Proposed ecosystem-based management for Executive Order "Science for Ecosystem Management" report	Types of decisions for sustainability and ecosystem management
Vision	A system with abundant, diverse populations of living resources, fed by healthy streams and rivers, sustaining strong local and regional	**Ecosystem Sustainability and Management** - the capacity of an area to meet the needs of the present generation without compromising the ability of future generations to meet their own needs, and management that integrates ecological,	**Decisions about balance and trade-offs between (1)** improving and sustaining living resources, habitat, and water quality, and (2) meeting increased needs for goods and services for human population.

	economies and our unique quality of life	socioeconomic, and institutional elements.	
Goals and Components	**CBP Goals** Protect & Restore Fisheries Protect & Restore Vital Aquatic Habitats Protect & Restore Water Quality Maintain Healthy Watersheds Foster Chesapeake Stewardship Enhance Partnering, Leadership, and Management	**Ecological Element** • Diversity and Productivity o Living Resources o Habitats o Land Use • Chemical Cycling o Water Quality o Air Quality o Biogeochemical interactions • Natural Disturbances o Climate variability o Episodic events **Socioeconomic element** • Physical well being o Swimmable waters o Fishable waters o Adequate drinking water o Housing and transportation • Societal value o Public access o Recreation o Cultural heritage • Economic value o Cost of seafood o Value of ecosystem services o "Green" jobs **Partnership Performance Element** • Consensus-based • Results-oriented • Capacity to align and implement resources • Sound science • Adaptive process	**Ecological Decisions** *Fish and wildlife harvest limits *Quality and location of habitat *Compatible land use for human needs and priority fish and wildlife species *Manage for acceptable levels of nutrients, sediment, and contaminants *Resilience to natural disturbances **Socioeconomic Decisions** *Take actions to ensure that contaminant concentrations within limits for fish consumption, safe drinking water, and swimmable waters *Take actions to ensure air quality within limits *Land planning for housing density and transportation *Individual's decisions for housing type and location, commute to employment, and recreational needs *Land planning and purchase for public access, recreation, and enjoyment *Individual's decision on type and cost of food products **Partnership Performance** *****Set realistic goals and outcomes *Measure progress *Collaborate to achieve progress *Adapt and improve

The proposed framework for ecosystem sustainability and management was modified from several approaches being conducted to address ecosystem sustainability and indicators. The Millennium Ecosystem Assessment (2005) focused on ecosystem services and human well being. Yale University has provided an evolution of indices from a 2004 Environmental Vulnerability Index and further published the Environmental Sustainability Index (2005) and provided an 'ideal set of indicators' that are organized under 1) systems, 2) stresses, 3) human vulnerability, 4) social and institutional capacity and 5) global stewardship; metrics are closely linked with human activities and human impacts. In 2006, Yale University further piloted the Environmental Performance Index

(EPI). The EPI (2006) has 16 indicators, but there is a greater breadth of coverage linked with 6 Policy categories (Environmental health, air quality, water resources, biodiversity and habitat, productive natural resources, and sustainable energy). Another example of an ecosystem-based management approach is the Puget Sound Program, which has goals for (1) Diverse species and food webs; (2) abundant and healthy habitats; (3) fishable, swimmable waters; and (4) human health and well being.

Appendix 2. Adaptive Management Principles

Many authors and entities have addressed improved and more structured decision making for ecosystem-based management. One recent reference is the US Department of Interior (DOI) Adaptive Management Technical Guide (Williams and others, 2007). The DOI guide states that "Resource management usually involves decision-making wherein managers must consider multiple (often competing) management objectives, constrained management authorities and capabilities, dynamic ecological and physical systems, and uncertain responses to management actions." This requires managers to have some ability to predict how ecological or physical systems are likely to respond to interventions, but also identifying what management options are available, what outcomes are desired, how much risk can be tolerated, and how best to choose among a set of alternative actions. The challenge confronting managers is to make "good" decisions in this complex environment, recognizing that the quality of decision making in the face of uncertainty should be judged by the decision-making process as well as progress towards desired outcomes. Management of problems like these increasingly involves a systems approach with explicit and agreed-upon objectives, management alternatives, and analytical approaches that can identify the most appropriate management strategies. Adaptive management exemplifies such an approach; however, its focus is not only on making good decisions in the present, but also on gaining experience and knowledge so that future management decisions can be improved.". Adaptive management needs to emphasize a two-phase learning process including a "set-up phase" and an iterative phase of improving implementation of management policies and actions based on monitoring and assessment (see figure A2-1).

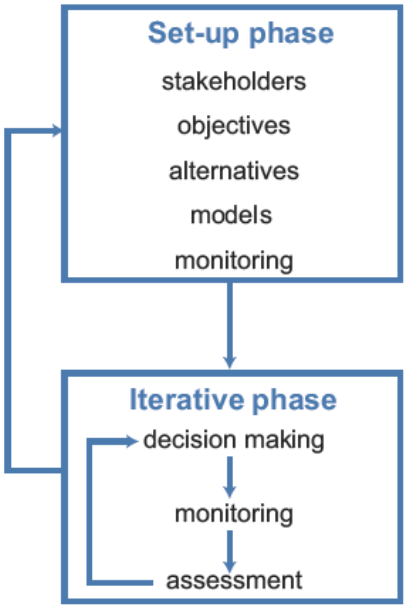

Figure A2-1. Adaptive management cycle that illustrates two phases of learning – a set up phase and iterative phase (from Williams and others, 2007)

The CBP needs to further employ adaptive management to improve decision making for ecosystem management. This will complement the proposed CBP adaptive management process (USEPA, 2008), which is focused on improving the accountability and operation of the CBP. The suggested ecosystem-based, adaptive management framework for the Chesapeake Bay ecosystem (figure A2-2) is based on approaches developed by the DOI (Williams and others, 2007) and Integrated Ecosystem Assessments (Levin and others, 2009). The adaptive management framework closely aligns the ecosystem decision-making process with the supporting science elements. The adaptive-management process will result in adjusting and improving (1) management policies and actions, and (2) the science needed to support ecosystem-based decision making.

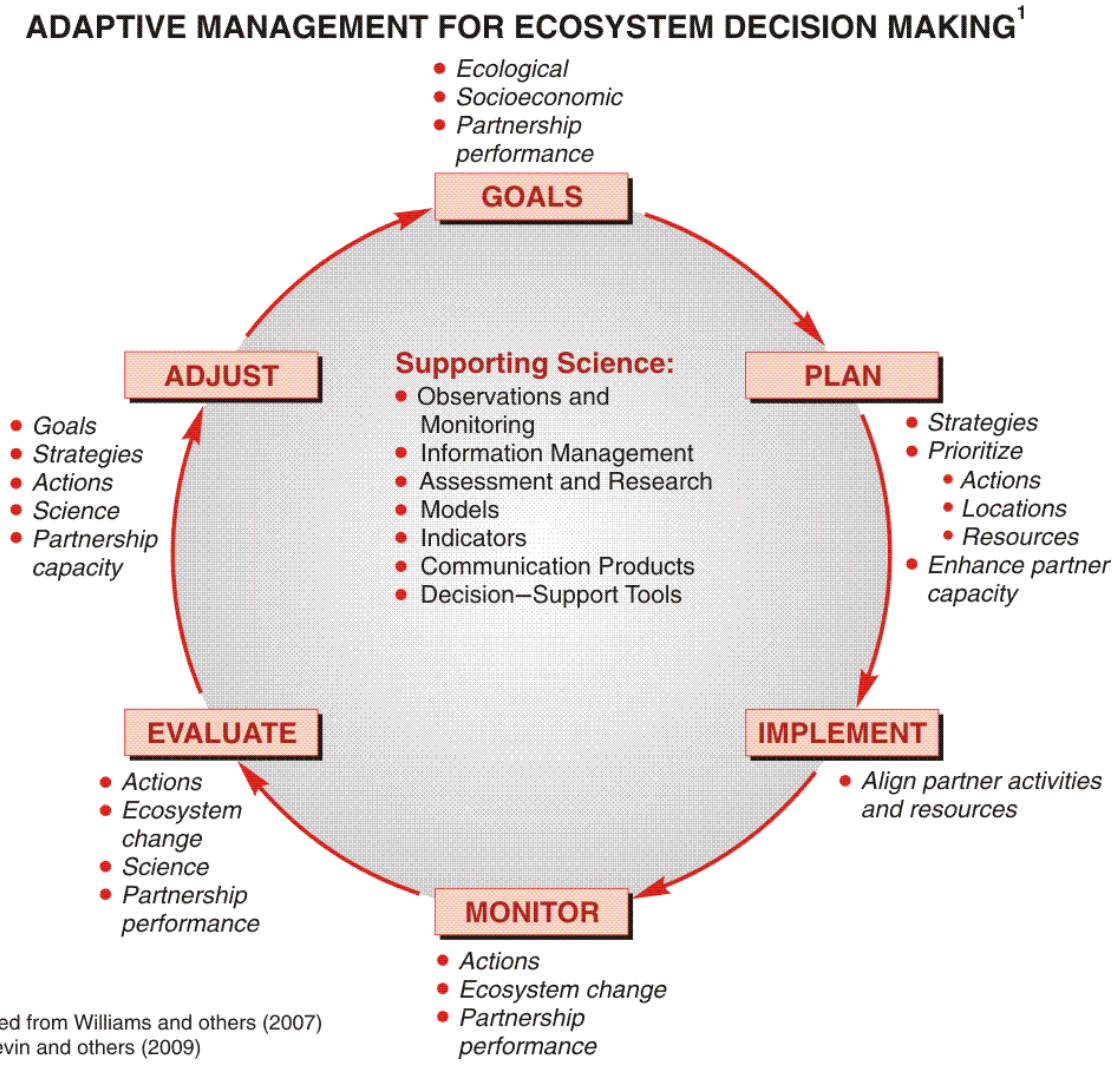

Figure A2-2 proposed adaptive management and supporting science framework for the Chesapeake Bay Integrated Observing and Assessment System.

Major components of the ecosystem-based, adaptive management framework and supporting science are:

- Set **Goals**-Goals are developed (or refined) for major elements of ecosystem management--ecological, socioeconomic, and partnership performance. The ecological topics are in table A1 and include fish and wildlife populations, habitat, and land use; air and water quality; and areas and habitat providing important biogeochemical processing of nutrients, sediment, and contaminants. Socioeconomic goals would be developed for drinkable and swimmable waters, foods that are safe to consume, protecting valuable ecosystem and cultural lands, and improving access to public lands. The partnership performance goals would focus on improving capacity to implement management actions and assess progress toward ecological and socioeconomic goals. The supporting science elements include collecting observations and conducting assessments to define the extent and causes of problem(s) so goals can be set and indicators established.
- **Plan**-Management strategies and actions are planned to meet ecological, socioeconomic, and institutional goals. The types and locations actions are prioritized based on ecological and socioeconomic benefit and cost. Science elements include models to forecast potential future conditions and conduct scenario testing of strategies and actions that may provide the greatest ecosystem benefit and associated optimal cost. Monitoring and assessment are planned to document and understand changes in ecosystem response and evaluate management actions. Monitoring is begun prior to implementation or enhancement of management actions so baseline conditions are documented.
- **Implement**-Policies and actions are implemented through coordinated partner efforts.
- **Monitor**- Monitoring is conducted of major ecological components (living resources, habitat, land use, water and air quality, and natural disturbances), socioeconomic attributes and attitudes, and tracking of types and locations of management actions. Depending on the scope of the problem, the monitoring will have to occur at different spatial and temporal scales.
- **Evaluate**-Indicators are used to synthesize monitoring data and assess changes in ecological and socioeconomic elements. Research facilitates integrated assessments to improve understanding of the factors affecting ecological and socioeconomic change and to help evaluate the effectiveness of management strategies and actions. Evaluation includes assessing effectiveness of management actions to achieve desired outcomes, adequacy of supporting science (models, monitoring, and research) to predict and detect ecosystem change, and institutional capacity to implement programs and actions.
- **Adjust**-Both short- and long-term adjustments can be made to all aspects of EBM. Short-term adjustments (1-5 years) may be made to management actions or strategies or capacity to implement programs. Short-term adjustments to science elements include improving models, monitoring, or research to improve understanding of ecological and socioeconomic changes. Longer-term adjustments (> 5 years) may include modifying goals and management strategies and adjusting long-term monitoring and research programs.

APPENDIX 3. SELECTED NATIONAL MONITORING PROGRAMS WITH INTEGRATED SCIENCE

A few examples of integrated monitoring and assessment systems are listed below and aspects described in the appendix that provide elements that could be used for a Chesapeake Monitoring and Assessment System. These include:

- Integrated Ocean Observing System (IOOS)
- National Water-Quality Monitoring Network for U.S. Coastal Waters and their tributaries
- National Atmospheric Deposition Network
- National Fish Habitat Action Plan

THE INTEGRATED OCEAN OBSERVATION SYSTEM

In March 2009, President Obama signed the Omnibus Public Lands Act of 2009, containing the Integrated Coastal and Ocean Observing Systems Act of 2009. The Act:

> (1) [Establishes] a national integrated System of ocean, coastal, and Great Lakes observing systems, comprised of Federal and non-Federal components coordinated at the national level by the National Ocean Research Leadership Council and at the regional level by a network of regional information coordination entities, and that includes in situ, remote, and other coastal and ocean observation, technologies, and data management and communication systems, and is designed to address regional and national needs for ocean information, to gather specific data on key coastal, ocean, and Great Lakes variables, and to ensure timely and sustained dissemination and availability of these data to--
>
> (A) support national defense, marine commerce, navigation safety, weather, climate, and marine forecasting, energy siting and production, economic development, ecosystem-based marine, coastal, and Great Lakes resource management, public safety, and public outreach training and education;
>
> (B) promote greater public awareness and stewardship of the Nation's ocean, coastal, and Great Lakes resources and the general public welfare; and
>
> (C) enable advances in scientific understanding to support the sustainable use, conservation, management, and understanding of healthy ocean, coastal, and Great Lakes resources;
>
> (2) improve the Nation's capability to measure, track, explain, and predict events related directly and indirectly to weather and climate change, natural climate variability, and interactions between the oceanic and atmospheric environments, including the Great Lakes; and
>
> (3) authorize activities to promote basic and applied research to develop, test, and deploy innovations and improvements in coastal and ocean observation technologies, modeling systems,

> and other scientific and technological capabilities to improve our conceptual understanding of weather and climate, ocean-atmosphere dynamics, global climate change, physical, chemical, and biological dynamics of the ocean, coastal and Great Lakes environments, and to conserve healthy and restore degraded coastal ecosystems.

The System is being developed to meet the needs of the Chesapeake Bay (and other coastal) managers, decision-makers, and above all, *users*. The conceptual basis for the coastal component of this US Integrated Coastal and Ocean Observing System – IOOS - stems from the coastal strategy for the Global Ocean Observing System (GOOS), whose overarching goal is the development of an operational observing system for the marine environment that supports an integrated approach to detecting and predicting changes in coastal marine and estuarine systems. Implementation of such a system is a necessary component for successful ecosystem-based management.

The system requires a managed and efficient flow of data and information among three essential subsystems:

(1) an analysis and modeling subsystem that will deliver the products necessary for management; its needs define the data requirements and guide the development of

(2) an integrated data communications & management subsystem that provides data of known quality in real-time or delayed mode as needed, and

(3) an observing subsystem for monitoring the required variables on specified time-space scales, precision and accuracy.

It is clear that most of the components of such a system exist in the Chesapeake Bay to some degree; but there are numerous gaps, including integration of the three subsystems. Aspects of the IOOS program provide the tools necessary for successful ecological forecasting and ecosystem based management for the Chesapeake Bay region.

THE NATIONAL WATER QUALITY MONITORING NETWORK FOR U.S. COASTAL WATERS AND THEIR TRIBUTARIES

The Network (http://acwi.gov/monitoring/network/) integrates physical, chemical, and biological characteristics of water resources and extends from the uplands to the coastal zone. The Network, which was initiated by the National Water-Quality Monitoring Council in response to the recommendation of the U.S. Commission on Ocean Policy in 2004, provides critical information for the management of coastal waters and their tributaries at regional and national scales. The design was orchestrated by more than 40 organizations (including representatives from NOAA, USEPA, USGS, Tennessee Valley Authority, selected states, and academia), described in a report—*A National Water Quality Monitoring Network for U.S. Coastal Waters and their Tributaries, 2006 (*accessible at http://acwi.gov/monitoring/network/design/Entire_Report_v18_060506.doc) and summarized in a brochure (http://acwi.gov/monitoring/network/network_brochure.pdf). In general, the Network design is an ideal model for Chesapeake Bay monitoring as it provides integrated monitoring of coastal and upland watersheds, estuaries and the

coastal ocean using common criteria and standards of the Council (described above). It is designed to determine the flow of water and loads of contaminants into estuaries and the Great Lakes, and allow for trend detection. The Network outlines clear objectives towards management issues such as nutrient enrichment, oxygen depletion, toxic contamination, and habitat degradation, and is aligned with NOAA's IOOS and their regional associations (http://usnfra.org), which provide and use data and information needed by decision makers to protect and restore the health of coastal ecosystems. The Chesapeake Bay is part of the MACOORA regional association, which coordinates and facilitates observations of the oceans and estuaries between Cape Cod and Cape Hatteras (http://www.macoora.org/).

The Network includes nine resource compartments, including estuaries, nearshore, offshore, Great Lakes, coastal beaches, wetlands, rivers, atmosphere, and groundwater. The design addresses physical characteristics (flow, sediments, habitat), chemical constituents (organics and inorganics), and biological characteristics (chlorophyll and algae, bacteria and viruses, macroinvertebrates, and fish). It is a multi-organizational framework that addresses issues at multiple scales, and serves, in a sense, as a collaborative "network of networks," including fixed station and probabilistic designs, discrete and continuous data, and point and spatial data (such as along buoy lines or trawls).

The National Atmospheric Deposition Network/National Trends Network (NADP/NTN)

NADP/NTN is a multi-agency effort including over 250 stations across the U.S. and measures precipitation chemistry such as pH, nitrate, and ammonium on a weekly basis (http://nadp.sws.uiuc.edu/) including a number of sites within the Chesapeake Bay watershed. A subset of these sites is part of the Mercury Deposition Network with sites in all Bay watershed states but not in the District of Columbia. A high resolution sub-project with the NADP/NTS is AirMon, a daily precipitation chemistry monitoring network, implemented by NOAA, including stations in Bay watershed states. AirMon previously measured dry deposition of ozone, sulfur dioxide, and nitric acid. However, national dry deposition monitoring of gas and particulate chemistry is now collected weekly by USEPA as part of CASNET (http://www.USEPA.gov/castnet/). Green house gases such as carbon dioxide are measured from ground-based stations globally by NOAA using a collective network of sites (http://www.esrl.noaa.gov/gmd/index.html).

Appendix 4. Inventory of Monitoring Programs and List of Federal Programs

A draft 2009 monitoring inventory was compiled from three previous monitoring inventories. The only full inventory of water-quality monitoring programs was conducted in 1989 (Chesapeake Bay Program, 1989a). Living Resource programs had been inventoried twice over the life of the Bay Program, once in 1989 and in 1997 (Chesapeake Bay Program, 1989a, and 1997). The Tidal Fisheries portion of living resources had an additional inventory in 2006 (Bonzek and others, 2007). The draft 2009 inventory compiled from previous efforts consisted of 151 monitoring programs throughout the watershed. This list of monitoring programs consisted mostly of the large state and federally funded monitoring efforts in the Chesapeake Bay region. There were numerous gaps in knowledge of national scale monitoring activities in the region, remote observation systems, wildlife programs, and smaller scale state, county, city and volunteer monitoring programs. The inventory was updated during June 2009 and information on additional programs is still being collected.

A 1-month data call for monitoring programs was conducted in June 2009 to attempt to update information on programs in the draft inventory and obtain information on missing programs to fill known gaps in our monitoring inventory. The following criteria were used to define a monitoring program: (1) minimum of five years of data collection, (2) data must be collected using a consistent scientifically sound methodology, and (3) program must be planned to continue monitoring efforts into the foreseeable future. Short- term research studies and one-time assessments were not included, but are being maintained on separate lists by Bay Program data managers and quality assurance personnel.

The final inventory (as of June 30, 2009) consists of 295 monitoring programs spanning a broad spectrum of scales and Chesapeake Bay program interests (summarized in Figure 2 in the body of the report). 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. 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 known to be an underutilized source of monitoring information. We also summarized a list of federal programs (table A4-1) which includes updated information.

Several limitations of the inventory include underreporting of programs by federal, state, and local partners, and incomplete information submitted for the inventory. There may be underreporting of monitoring programs for terrestrial wildlife, vegetation, and remote sensing. Currently, there is no reporting of monitoring for agricultural and other best management practices in the inventory. A second known deficiency was the incomplete

reporting of information. Estimate of annual project cost was the field most often left blank in the inventory. There appears to be an incomplete list of monitoring programs reported by some federal partners. We are attempting to update the federal programs.

Table A4-1. Summary of Federally Funded Monitoring Programs Reported to the 2009 Chesapeake Bay Program Monitoring Inventory as of 1 July 2009. CDC=Centers for Disease Control, COE-Army Corps of Engineers, USEPA-Environmental Protection Agency, NASA-National Aeronautics and Space Administration, NOAA-National Oceanic and Atmospheric Administration, NPS-National Park Service, NSF- National Science Foundation, USDA-United States Department of Agriculture, USFWS-United States Fish and Wildlife Service, USGS- United States Geological Survey.
***represent programs are listed by not yet evaluated if they meet criteria for monitoring programs**

Agency	Monitoring Program
CDC	Virginia Harmful Algal Bloom Surveillance Program
COE	Poplar Island Monitoring Program-Benthic Monitoring
COE	Poplar Island Monitoring Program-SAV Monitoring
COE	Poplar Island Monitoring Program-Toxics Monitoring
COE	Poplar Island Monitoring Program-Water Quality Monitoring
USEPA	Boshers Dam Vertical Slot Fish Way Evaluation And Fish Passage Monitoring Program
USEPA	Cat Point Creek Virginia Project
USEPA	Chesapeake Bay Program Nontidal Water Quality Network
USEPA	Delaware Air Quality Monitoring Program
USEPA	District Of Columbia Air Quality Monitoring Program
USEPA	District Of Columbia Aquatic Macro Invertebrate Monitoring Program
USEPA	District Of Columbia Phytoplankton Monitoring Program
USEPA	District Of Columbia Water Quality Monitoring Program
USEPA	District Of Columbia Zooplankton Monitoring Program
USEPA	District Of Columbia-Point Source Compliance Monitoring Program
USEPA	Friends Of Stafford Creeks-Alliance For Chesapeake Bay Citizen Monitoring Program
USEPA	Maryland Shallow Water Quality Monitoring Program
USEPA	Maryland Ambient Air Monitoring Program
USEPA	Maryland Chesapeake Bay Water Quality Monitoring Program: Long-Term Tidal Tributary Chemical/Physical Component
USEPA	Maryland Chesapeake Bay Water Quality Monitoring Program: Mainstem Chemical/Physical Components
USEPA	Maryland Chesapeake Bay Water Quality Monitoring Program: River Input Chemical/Physical Component
USEPA	Maryland Nontidal Tributary Water Quality Monitoring Program-Core Trend Program
USEPA	New York Ambient Air Quality Monitoring
USEPA	Pennsylvania Air Quality Monitoring Program
USEPA	Potomac River Shad Monitoring
USEPA	Susquehanna River Basin Commission Interstate Macro Invertebrate Monitoring Program
USEPA	Susquehanna River Basin Commission Nutrient Monitoring Program
USEPA	United States Environmental Protection Agency-National Study Of Chemical Residue In Lake Fish
USEPA	Virginia Air Quality Monitoring Program
USEPA	Virginia Ambient Water-Quality Monitoring Program
USEPA	Virginia Chesapeake Bay Water Quality Monitoring Program: Mainstem And Tidal Tributary Chemical/Physical Components
USEPA	Virginia Lake Monitoring Program
USEPA	Virginia Striped Bass Monitoring And Tagging Survey
USEPA*	National Coastal Assessment Survey/National Coastal Condition Survey

USEPA*	National Rivers And Streams Survey/Wadeable Streams Assessment/ EMAP-Mid-Atlantic Highlands Area/Mid-Atlantic Integrated Assessment
USEPA,NOAA NASA	Eyes On The Bay
USEPA,USF WLS, NOAA	Chesapeake Bay Submerged Aquatic Vegetation Aerial Survey
NASA	National Aeronautics And Space Administration- Earth Observing System- MODIS AM And PM Missions
NASA	National Aeronautics And Space Administration- SeaWiFs Mission
NOAA	Chesapeake Bay Multispecies Monitoring And Assessment Program
NOAA	Delaware National Oceanic And Atmospheric Administration-National Weather Service Climatological Data Network
NOAA	Maryland American Eel Population Study- Silver Eel Survey
NOAA	Maryland American Eel Population Study- Yellow Eel Survey
NOAA	Maryland American Eel Population Study- Young Of Year Survey
NOAA	Maryland National Oceanic And Atmospheric Administration-National Weather Service Climatological Data Network
NOAA	Maryland Oyster Stock Assessment Program
NOAA	National Atmospheric Deposition Program-National Trends Network
NOAA	National Estuarine Research Reserve System-Monitoring Program
NOAA	National Oceanic And Atmospheric Administration- National Weather Service Solar Radiation Network
NOAA	National Oceanic And Atmospheric Administration-CoastWatch
NOAA	National Oceanic And Atmospheric Administration-National Data Buoy Center- National Weather Service
NOAA	National Oceanic And Atmospheric Administration-National Water Level Observation Network
NOAA	National Oceanic And Atmospheric Administration-Physical Oceanographic Real-Time System
NOAA	National Weather Service-Airport Weather Monitoring Network
NOAA	New York National Oceanic And Atmospheric Administration-National Weather Service Climatological Data Network
NOAA	Virginia Juvenile Blue Crab Survey
NOAA	Virginia Juvenile Fish And Blue Crab Survey
NOAA	Virginia National Oceanic And Atmospheric Administration-National Weather Service Climatological Data Network
NOAA	Virginia Shark Long Line Survey
NOAA	West Virginia National Oceanic And Atmospheric Administration- NWS Climatological Data Network
NOAA,NPS	United States Park Service-Chesapeake Bay Interpretive Buoy System
NOAA	National Oceanic And Atmospheric Administration-Coastal Change Analysis Program
NOAA	Chesapeake Bay Observing System
NPS	National Park Service- Fredericksburg And Spotsylvania National Military Parks-Water Quality Monitoring
NPS	National Park Service- National Capital Region Network-Water Quality Monitoring
NPS	National Park Service- Richmond Area National Parks-Water Quality Monitoring
NPS	National Park Service- Shenandoah National Park-Water Quality Monitoring
NPS	National Park Service-Ground Water Internal Compliance Monitoring
NPS*	Mid-Atlantic Inventory and Monitoring Network-Benthic Bird Monitoring
NPS*	Mid-Atlantic Inventory and Monitoring Network-Benthic Forest Vegetation Monitoring
NPS*	Mid-Atlantic Inventory and Monitoring Network-Benthic Invertebrate Monitoring
NPS*	Mid-Atlantic Inventory and Monitoring Network-Water Quality Monitoring
NPS*	Northeast Coastal And Barrier Inventory And Monitoring Network-Assateague Island National Seashore/George Washington Birthplace NM Fish Monitoring
NPS*	Northeast Coastal And Barrier Inventory And Monitoring Network-Assateague Island National Seashore/George Washington Birthplace NM- Salt Marsh Vegetation Monitoring
NPS*	Northeast Coastal And Barrier Inventory And Monitoring Network-Assateague Island National Seashore/George Washington Birthplace NM- SAV Monitoring

NPS*	Northeast Coastal And Barrier Inventory And Monitoring Network-Assateague Island National Seashore/George Washington Birthplace NM- Water Quality Monitoring
NPS*	Northeast Coastal And Barrier Inventory And Monitoring Network-Colonial National Historical Park- Fish Monitoring
NPS*	Northeast Coastal And Barrier Inventory And Monitoring Network-Colonial National Historical Park- Salt Marsh Vegetation Monitoring
NPS*	Northeast Coastal And Barrier Inventory And Monitoring Network-Colonial National Historical Park- Water Quality Monitoring
NPS*	Northeast Coastal And Barrier Inventory And Monitoring Network-George Washington Birthplace – Forest Vegetation Monitoring
NSF,USDA	Baltimore Ecosystem Study
USFWS	Bald And Golden Eagle Monitoring
USFWS	Bog Turtle Monitoring In Maryland
USFWS	Citizens Submerged Aquatic Vegetation Hunt Program
USFWS	Interjurisdictional Species Stock Assessment For Adult Migratory Fin Fish
USFWS	Maryland Adult American Shad Hook And Line Survey
USFWS	Maryland Adult Shad And Herring Pound And Fyke Net Survey
USFWS	Maryland Fisheries Dependant Fyke Net Survey
USFWS	Maryland Fisheries Dependent Striped Bass Hook And Line Survey
USFWS	Maryland Juvenile Shad And Herring Surveys
USFWS	Maryland Largemouth Bass Surveys
USFWS	Maryland Shoal Water Trawl Survey
USFWS	Maryland Striped Bass Spawning Stock-Gill Net Survey
USFWS	Maryland Striped Bass Young Of Year Beach Seine Survey
USFWS	Maryland Survey Of Coldwater Streams
USFWS	Maryland Survey Of Freshwater Impoundments
USFWS	Maryland Upper Bay Trawl Survey
USFWS	Maryland Warm Water Rivers Survey
USFWS	Maryland Waterfowl Breeding Survey
USFWS	Peregrine Falcon Monitoring
USFWS	Tiger Beetle Monitoring
USFWS	Virginia American Eel Young Of Year Survey
USFWS	Virginia Shad And Herring Gill Net Survey
USFWS	Virginia Striped Bass Young Of Year Beach Seine Survey
USFWS	Wintering Waterfowl Survey
USFWS*	Blackwater NWR Monitoring Program-Bald Eagle Mid-Winter Survey
USFWS*	Blackwater NWR Monitoring Program-Bald Eagle Nest Count
USFWS*	Blackwater NWR Monitoring Program-Christmas Bird Count
USFWS*	Blackwater NWR Monitoring Program-Delmarva Peninsula Fox Squirrel Benchmark Site Monitoring
USFWS*	Blackwater NWR Monitoring Program-FWS Water Quality
USFWS*	Blackwater NWR Monitoring Program-National Amphibian Monitoring Program
USFWS*	Blackwater NWR Monitoring Program-Water Quality Monitoring
USFWS*	Blackwater NWR Monitoring Program-Waterfowl Survey (non-breeding)
USFWS*	DC Bird Survey Program
USFWS*	DC Wildlife Survey
USFWS*	District of Columbia Angler Survey
USFWS*	District of Columbia Habitat Monitoring And Enhancement Survey
USFWS*	District of Columbia Resident And Anadromous Fish Survey
USFWS*	Eastern Neck NWR Monitoring Program-Christmas Bird Count

USFWS*	Eastern Neck NWR Monitoring Program-National Amphibian Monitoring Program
USFWS*	Eastern Neck NWR Monitoring Program-Non-Breeding Waterfowl Survey
USFWS*	Eastern Neck NWR Monitoring Program-SAV and Marsh Vegetation Monitoring
USFWS*	Land bird Breeding Point Count Surveys – Rappahannock River Valley, Presquile, and James River NWRs
USFWS*	Land bird Fall Migration Surveys – Rappahannock River Valley NWR
USFWS*	Monitoring Of Bog Turtle Colonies At Sites In Immediate Proximity To Development In Southeastern Pennsylvania
USFWS*	NWRC Monitoring Programs-Bald Eagle Nest Count
USFWS*	Patuxent NWR Monitoring Programs-Deer dusk index survey
USFWS*	Patuxent NWR Monitoring Programs-Deer night-light index survey
USFWS*	Patuxent NWR Monitoring Programs-Frog call survey
USFWS*	Patuxent NWR Monitoring Programs-Gypsy moth egg mass survey
USFWS*	Patuxent NWR Monitoring Programs-Water bird survey
USFWS*	Patuxent NWR Monitoring Programs-Whip-poor-will survey
USFWS*	Patuxent NWR Monitoring Programs-Woodcock survey
USFWS*	Pennsylvania Angler Use, Harvest, and Opinions on Warm/Cool water Resources
USFWS*	Pennsylvania Pond, Lake and Reservoir Inventory, Reporting and Management
USFWS*	Pennsylvania River Inventory, Reporting and Management
USFWS*	Pennsylvania Trout Stream Inventory, Data Entry, and Management Plans
USFWS*	Pennsylvania Warm water/Cool water Stream Inventory, Reporting and Management
USFWS*	Plum Tree Island NWR -NE Beach Tiger Beetle Surveys
USFWS*	Prothonotary Warbler Nest Box Productivity and Banding Project – Presquile
USFWS*	Rappahannock River Valley NWR -Secretive Marsh bird Callback Survey
USFWS*	Rappahannock River Valley NWR -Winter Grassland Bird Surveys
USFWS*	Rappahannock River Valley NWR-Anuran Callback Surveys –
USFWS*	Rappahannock River Valley NWR-Bald Eagle Winter Trapping, Banding, and Tracking Project
USFWS*	State of Virginia Annual Piping Plover survey
USFWS*	Summer and Winter Bald Eagle Shoreline Surveys within the Rappahannock River Bald Eagle Concentration Area
USFWS*	Summer Bald Eagle Shoreline Surveys at James River NWR and adjoining lands
USFWS*	Timber Rattlesnake Site Assessment and Inventory Project
USFWS*	TNC, Virginia Annual Oystercatcher survey
USFWS*	Virginia Coldwater Stream Investigations (Trout stream mgmt)
USFWS*	Virginia Large Impoundment Creel Surveys
USFWS*	Virginia Large Impoundment Investigations
USFWS*	Virginia Small Impoundment Creel Surveys
USFWS*	Virginia Small Impoundment Investigations (Sampling)
USFWS*	Virginia Trout Angler Surveys
USFWS*	Virginia Trout stream acidification investigation
USFWS*	Virginia Trout Stream Classification Review And Update
USFWS*	Virginia Warm water Stream Creel Surveys
USFWS*	Virginia Warm Water Stream Investigations (Sampling)
USFWS/COE	Poplar Island Monitoring Program-SAV Monitoring
USFWS\ NOAA*	Eastern Neck NWR Monitoring Program-SAV Monitoring
USFWS\ USDA*	Eastern Neck NWR Program-Gypsy Moth Monitoring
USFWS\ USGS*	Blackwater NWR Monitoring Program-USGS/MDE Hydrologic Monitoring

USGS	International Breeding Bird Survey
USGS	United States Geological Survey-Biological Status and Trends Program*
USGS	United States Geological Survey-Groundwater Observation Well Networks (all states in watershed)
USGS	United States Geological Survey-Stream Flow Network (all states in watershed)
USGS	United States Geological Survey-River Input Monitoring Program (MD and VA)
USGS	United States Geological Survey-CBP Nontidal Monitoring Network (all states in watershed)
USGS	United States Geological Survey-Land Cover Change Monitoring
USGS	United States Geological Survey-National Hydraulic Bench Mark Program
USGS	United States Geological Survey-National Water Quality Assessment Program*
USGS	United States Geological Survey-Amphibian Research and Monitoring Initiative (ARMI)*
USGS/NASA	University Of Maryland's Regional Earth Science Applications Center-Impervious Surface Monitoring And Land Use Change Monitoring

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APPENDIX 5. DISCUSSION OF GAPS AND SPECIFIC RECOMMENDATIONS FOR STRENGTHENING SCIENCE AND MONITORING

We have conducted an assessment of the existing federal monitoring programs to address the needs for ecosystem-based management. For each science element (monitoring, information management, assessment and research, models, indicators, communication products, and decision-support tools), we have summarized remaining gaps and provided recommendations for federal agencies to address the gaps. The discussion for monitoring is further divided into major ecological components.

MONITORING Overall, the Chesapeake partnership should better align with National monitoring efforts including the Integrated Ocean Observing System (lead by NOAA), the National Water-Quality Monitoring Network (lead by USGS and USEPA), the National Fish Habitat Action Plan (FWS), and the Climate Effects Network (DOI). There are opportunities to utilize and increase partnerships with existing federal, state, and local monitoring programs. The majority of the existing programs are best suited to address water-quality conditions in the watershed and the physical well being of the human population (drinking water and air quality, fish and shellfish consumption, and swimmable waters). This information needs to be assessed, obtained, and interpreted to address:

1. Living Resources

In general, monitoring for ecosystem-based management requires information on the abundance, diversity, and health of fish and shellfish in tidal watersheds, priority wildlife species in the Bay and its watershed, and food-web components that support living resources. The E.O. team addressing living resources and habitat is developing a list of critical species that could be monitored for ecosystem-based management.

1a. Fish and shellfish monitoring in the estuary-

There are multiple monitoring programs, conducted by CBP partners, to monitor the diversity, health, and abundance of “priority” fish and shellfish species that have identified by the CBP (crabs, oysters, striped bass, and alosines populations). Funding for the majority of the programs comes from the states of Maryland and Virginia, the Potomac Fisheries Commission, the USFWS, NOAA, and the National Science Foundation.

With respect to fish stock monitoring, value of fishery independent surveys has been clearly established. The current programs for fishery-independent monitoring in the Chesapeake region yields reasonable coverage and address many of management needs (Bonzek and others, 2007). However, fisheries dependent surveys and fish catch monitoring are less well developed in the Bay. This would include both commercial and recreational catch monitoring.

Recommendations for single species monitoring:

- At present, the fishery-dependent information is less reliable and should be a focus of increased attention - particularly for the recreational sector for which extent surveys are chiefly designed to provide coast-wide estimates, not regional ones. (NOAA, USFWS, and states of MD and VA)

- Bay-wide oyster stock assessment still has gaps in monitoring so managers can understand the current distribution of the oyster population and future restoration activities (NOAA and ACOE).

There is a need to evolve from single-species management to ecosystem-based fisheries management. It will be critical to have monitoring information about habitat conditions (water quality and SAV) in spawning, juvenile, and adult habitats since these conditions can influence biomass production. Additionally, an understanding of the foodweb dynamics (phytoplankton, zooplankton, benthos, and forage fish interactions) is a critical monitoring need for ecosystem-based management. Information needs require monitoring data pertaining to:

- Spatial and temporal variations in critical habitats.
- Spatial and temporal variations in key foodweb elements including zooplankton and phytoplankton.
- Multispecies sampling that tracks variations in juvenile and forage fish species.
- Invasive species assessments targeting potential threats to key stocks (i.e., blue catfish, mitten crab etc).
- Socioeconomic factors and stakeholder elements of stakeholder engagement

Recommendation: CBP USEPA Bay Program should maintain monitoring of phytoplankton and benthos. Additional partners need to address gaps in monitoring of phytoplankton (NOAA) and other forage fish interactions (NOAA and FWS).

Recommendations for EBM monitoring: monitoring for ecosystem-based management needs to address the abundance, diversity, and health of fish and shellfish in tidal watersheds, priority wildlife species in the Bay and its watershed, and food-web components that support living resources.

- The partners should assess how all existing monitoring can be used and then propose additional monitoring to fill in gaps needed for EBM (NOAA, USGS, USFWS, USEPA and the states of MD and VA)
- Expand monitoring in tidal waters for foodweb interactions, habitats, contaminants, and disease to improve management of fisheries and wildlife species (NOAA and USFWS).

<u>1b. Fish and Wildlife in the watershed</u>

The CBP does not have specific management goals for fish and wildlife in the watershed. To support EBM, goals need to be developed for critical species, their communities, and supporting habitats. The EO Living Resources report team is developing a list of critical species in different landscapes of the Bay and its watershed. These species include freshwater fish species that are important for recreational activities and fish species exhibiting compromised health (such as species impacted by endocrine-disrupting

chemicals). Priority wildlife species include threatened or endangered species and migratory birds that depend on the Bay and its watershed for critical habitat as part of the Atlantic flyway.

Recommendations:

- Assess existing programs to address critical species. The USFWS has the most extensive monitoring programs to address wildlife species, including fish and birds in the watershed. The USGS and NPS have monitoring programs that can be used to address some species in selected study areas and National Parks. USEPA programs, mostly implemented by the states to monitor the condition of streams (including fish and invertebrate sampling) would also provide useful information on watershed conditions. However, many states use different collection protocols so the comparability of the results for the entire bay watershed will be limited. An assessment would be needed to further identify monitoring gaps once the list of critical species is finalized (USFWS, USGS, NPS, and USEPA).

- Utilize the National Wild Fish Health Survey to encompass the entire Chesapeake Bay watershed to determine viral, bacterial, and parasite pathogens impacting fish and wildlife health, survival, reproduction, and sustainability in key tributaries and estuarine areas. Investigate the cause and effect of toxic algal blooms and their effects on migratory birds, declines in fish populations due to endocrine disruptors, and nutrient loading from nonpoint source runoff. (USFWS Environmental Contaminants Program, USFWS Fisheries Program; USGS Fisheries and Contaminant Biology Programs)

- Utilize the Atlantic Coast Joint Venture partnership to protect water bird and shorebird habitats by developing a Chesapeake Bay Marsh Bird monitoring protocol, applying bird population habitat models for key habitat types, and predicting impacts of urban growth and climate change (USFWS Migratory Bird program, Neotropical Migratory Bird Conservation Act grant program; USGS Wildlife Program).

- Increase monitoring, evaluation, and law enforcement efforts to prevent both intentional and unintentional introductions of terrestrial and aquatic invasive species at the ports of Baltimore and Norfolk, and Dulles International Airport. Once detected, rapid response teams would be initiated to eradicate or control infestation of invasive species before they can become established. (USFWS Law Enforcement Operations, USDA)

<u>2.0 Habitat-</u> The ecosystem-based approach for habitat includes addressing the diversity, abundance, and health of key habitats in the Bay and its watershed. The habitats listed in the CAP include submerged aquatic vegetation (SAV), wetlands (coastal and freshwater), and fresh-water streams. Additionally, for EBM there are a wider range of habitats that need to be considered. The EO Living Resource Report team has developed a draft list of habitats by major regions in the Bay watershed: Coastal Plain, Piedmont, and Appalachia. Specific objectives related to monitoring needs for habitats listed in the CAP include:

- Prioritize fish passage opportunities- with special emphasis on removing blockages on the James and Susquehanna Rivers.
- Assess effectiveness of new and existing fish passages for restoring habitat range for diadromous fish.
- Assess quantity, quality and function of SAV, wetlands and stream habitats.
- Prioritize restoration opportunities for SAV, wetlands and streams.
- Assess Effectiveness of Habitat Restoration Activities.

There will be additional needs depending on the number of critical habitats presented in the EO Living Resources report.

Recommendations:

- The current CBP USEPA funded monitoring and partner programs provide the needed information for SAV and should be continued (USEPA and Virginia Institute of Marine Sciences). Explore new capabilities and partnerships to cost effectively map SAV, shallow water habitat, update shallow bathymetry and regularly monitor bay water conditions via emerging air and US space-borne satellite sensors such as the Hyperion and Advanced Land Imager (ALI) (NOAA).

- Monitoring other estuarine habitats needs to be done with a more integrated approach (NOAA and USFWS).

- More systematic monitoring of wetlands acreage and condition (vegetation, hydrology, and soils), including use of remote sensing tools, is needed to assess change over time and the ecosystem services and benefits they provide. Multiple wetland types should be monitored since they are challenged by different types of stressors and serve distinct roles in supporting the health of Bay and surrounding landscapes. Mapping of forested wetlands must be improved through the use of active remotely sensed data (radar and LiDAR) (USFWS, USDA/ARS and USGS).

- Monitoring of stream conditions to support living resources should first assess using current federal, state, local and NGO monitoring streamwater quality and benthos-monitoring programs to provide information on stream condition and associated fisheries. The programs will have to be further examined to determine data compatibility to for regional habitat assessments. Monitoring for more specialized problems, such as impact on endocrine-disrupting chemicals on fish needs to have a more comprehensive monitoring program (USEPA, USGS, and USFWS).

- There is a need to better assess the effectiveness of multiple habitat restoration activities (including fish passage, stream restoration, and wetland and forest buffer restoration) in small freshwater watersheds. Ideally, watersheds can be selected to enhance monitoring where multiple restoration projects are occurring (USFWS, USDA, COE, USEPA, USGS).

- The EO team preparing the living resources report has also expressed potential monitoring needs for habitat related to birds, exotic species, and wildlife. There is

potential to use existing programs to address changes in these habitats (USFWS, USGS, and NPS).

- The enhanced collection and analysis of remotely sensed data is critical to monitor dynamic ecosystem changes over large expanses. The partners need to support acquisition of satellite and airborne imagery over the Chesapeake Bay watershed (USDA/ARS, USEPA, USGS, USFWS and NOAA).

3.0 Land Use

Activities on the land have a direct effect on the water quality as well as terrestrial and aquatic living resources in the watershed, and directly impact the Bay ecosystem. Knowing the location of land cover, use, and management activities, and the geographic factors affecting ecosystem function is critically important for EBM of the Bay and its watershed In the CAP, some of these issues are addressed within the maintain healthy watersheds goal:

- Preserve valuable resource lands.
- Minimize conversion of forests, wetlands, and working farms
- Minimize impacts to pre-development hydrology

In addition, the EO report teams for living resources (202g), protecting ecosystems (202e), and strengthening science for ecosystem management (202f) have identified the importance of monitoring land cover, land use, management practices, and the spatial extent of characteristics affecting the ecosystem function.

Recommendations:

- Assessments of changes in forests, wetlands, agricultural lands, and urban/suburban land cover (including impervious cover), are needed at five-year intervals (2005, 2010, 2015, 2020, 2025) at 30-meter resolution or better. Currently, remote sensing data from the LANDSAT series of satellites is used to analyze change. Consider supporting procurement of a national annual land-change product derived from Landsat data (NOAA and USGS).
- Impervious surface acreage for all HUC 14-digit watersheds on 5-year intervals (2005, 2010, 2015, 2020, and 2025) calculated from impervious cover data and geo-referenced stormwater BMP implementation (USGS).
- Geo-referenced tracking of implementation of protection and restoration actions on agricultural, urban/suburban, and forested lands (USDA, USEPA, USGS, and DOD).
- Perform an inventory of existing data from state and Federal agencies to identify data gaps which can be filled by partnering with State and Federal agencies to acquire complementary LiDAR, radar and high spatial or spectral resolution data to develop a comprehensive Bay Watershed characterization including significant improvements in hydrogeomorphology delineation, vegetation and habitat characterization, land-cover change, biomass/carbon sequestration quantification, water quality and coastline tracking, and ecological hot-spot targeting for intensified land management practices.(USGS, USEPA, NOAA, FWS, USDA).

- Leverage existing federal programs, including the proposed "Imagery for the Nation" program to coordinate and fund the acquisition and specifications of leaf-on and leaf-off aerial/satellite digital imagery collections across the Bay states so that the imagery includes a near-infrared band and is temporally, spatially, and spectrally consistent across states (NOAA, USGS, and USEPA).

- Develop a coordinated federal strategy through USGS, FSA, and NOAA to:
    - Perform a coverage and quality gap analysis of existing LiDAR data among the Bay states and assess its relative utility and cohesiveness.
    - Provide tools and analyses to demonstrate and assist in the use of multi-return and full waveform LiDAR technology for watershed analysis.
    - Develop a collaborative partnership program (government and private) for standardizing, prioritizing, and funding LiDAR acquisition projects in the Bay states.
    - Develop a data management standard to ensure data from various LiDAR campaigns throughout the Bay states can be re-used for multiple purposes and shared among Bay partners.
    - Provide tools and analyses to demonstrate and facilitate the use of Radar technology for mapping forested wetlands and measuring wetland services.

4.0 Water and Air Quality

The overarching objective of the current CBP water-quality goal is to "Achieve and maintain the water quality necessary to support the aquatic living resources of the Bay and its tributaries and to protect human health." One of the major outcomes is to "delist" the Bay from the impaired waters list based on meeting water-quality standards (DO, clarity, chlorophyll). The water-quality standards are based on the needs of fish, shellfish, and submerged aquatic vegetation in the Bay. The primary objectives of current water-quality monitoring are:

-Assess attainment of water-quality criteria in the Bay (DO, water clarity/SAV, chlorophyll, and contaminants).

-Determine status and trends of water-quality conditions related to the criteria (nutrients).

-Determine status and trends of nutrients, sediment, and contaminants in the watershed.

-Estimate nontidal loads to help assess progress toward nutrient and sediment allocations.

-Assess effectiveness of management actions.

-Communicate results to managers and public.

-Improve CBP models used to help plan management activities.

The capacity for existing CBP-funded WQ monitoring programs and partner programs will have to be improved to meet the goals of EBM.

4a. Tidal water-quality monitoring

Most of the tidal monitoring programs were designed to measure status and trends at the scale of a tidal segment and are useful for assessing water-quality criteria. The tidal

monitoring information is also useful to communicate information to the public through the indicators and the Bay Barometer, and to improve CBP estuary models. There are fewer partner monitoring programs in tidal waters that have not been fully exploited. Many of these programs are citizen monitoring programs in selected tidal rivers. The programs have the greatest potential to enhance information on the status (or condition) of local tidal waters. The programs would have to be further assessed to determine if they can be used to help assess water-quality criteria is shallow water areas. The current CBP programs do not address assessing contaminants such as pesticides, heavy metals, and pharmaceuticals in the Bay.

Recommendations for tidal water-quality monitoring:

- Expand monitoring in tidal waters for foodweb interactions, habitats, contaminants, and disease to improve management of fish and wildlife species (NOAA and USFWS).
- Expand the CBP tidal water-quality monitoring program to enhance assessment of water-quality standards in the Chesapeake Bay (USEPA).

4b. Nontidal water-quality monitoring

The sites in the nontidal network, which represent drainage areas of several hundred to several thousand square miles, were designed to provide information on the status and trends of concentrations within Bay watershed and Tributary Strategy basins. The nontidal network sites also are used to estimate nutrients and sediment loads. The load results are used to help identify areas to enhance management actions, assess progress toward allocation goals, and improve watershed models. The nontidal data are also used in selected CBP indicators and the Bay Barometer to communicate information to the public.

Recommendations for nontidal water-quality monitoring:

- Improve the CBP nontidal water-quality monitoring network to better document nutrient and sediment reductions in the Bay watershed (EPA and USGS).
- Support continued monitoring of toxic and exotic compounds in the watershed—including pesticides, volatile organic compounds, pharmaceuticals, and potential endocrine-disrupting compounds as their presence may have a significant effect on the aquatic life (USGS, FWS, USDA/ARS, and USEPA).
- Partner and utilize the additional monitoring programs identified in the inventory to address the status of nutrient and sediment conditions in the Bay basin and in smaller watersheds. The enhanced information on status will be useful to help identify areas to enhance water-quality management actions for restoration or protection. However, many programs do not have corresponding measurements in streamflow so they cannot be used to assess load reductions or trends in water quality (USGS, USEPA, and the states in the watershed).
- Better utilize information from ground-water networks to address base-flow concentrations of nitrogen and pesticides to streams and in drinking water supplies (USGS).

4c. Monitoring water-quality response to management actions.

Neither the current tidal or nontidal monitoring programs meet the needs of resource managers to assess the effectiveness of agricultural, urban, or residential management practices. This type of assessment often requires use of smaller watersheds (less than 100 square miles) where the water-quality effects of particular BMPs can be better isolated and other data including land-use information and locations of management actions can be obtained. However, even in smaller watersheds the effectiveness of an individual management practice cannot be determined unless field-scale studies are conducted.

Recommendations for assessing BMPs:

- Establish long-term monitoring and assessment in small watersheds to evaluate and explain the effectiveness of restoration practices. There are opportunities to partner with on-going studies conducted by federal, state, and NGOs to assess changes in nutrients, sediment, contaminants, and habitats. (USEPA, USDA, USGS, FWS, and COE).

- Provide improved access to USDA National Agricultural Statistics survey data.—USDA farm survey data are held confidential and are unavailable to support assessments of the effectiveness of agricultural practices at a watershed scale. An improved partnership between USDA and Federal research agencies can improve the support of environmental assessments while maintaining the personal privacy of individual land owners.

- Support continuing assessment of agricultural BMP implementation—BMP implementation is funded through FSA grant programs; however, no program follows the life span of these practices or reports on the modification or changes to the plan as implemented. This lack of information severely limits the management community from adapting BMP strategies (USDA and USGS).

- Support additional studies of sources and transport of fluvial sediment in the environment as significant knowledge is needed on the sources, residence times, and delivery to the Chesapeake Bay. This information, in conjunction with refined information on the effectiveness of BMPs, is essential for effective implementation of restoration activities (USGS, USDA-ARS).
- Support development of new remote sensing tools to allow for larger scale studies of BMPs and their effectiveness within a particular watershed and providing data for water-quality models (USDA/ARS and USGS).

4d. Monitoring of water quality related to human health

The current CAP goal does not meet the original aspects of the Chesapeake 2000 water quality goal related to “protect human health”. The EBM approach emphasizes socioeconomic element addressing “physical well being.” Monitoring needs include components for the (1) quality of drinking water and air, (2) safe consumption of fish and shellfish products, and (3) swimmable waters. The 2009 monitoring inventory identified partner programs conducting different types of water-quality and public health monitoring in the Bay and its watershed that can help meet these needs. The programs

range from air monitoring, bacterial water monitoring, groundwater, toxics, and ambient water-quality monitoring in tidal and nontidal waters.

Recommendations for water-quality related to human health:

- Better utilize existing federal, state, and private monitoring of water supplies to develop indicators of the quality of surface and groundwater drinking supplies (USEPA, USGS, and states in the watershed).
- Better utilize existing federal and state monitoring programs to develop indicators of air quality (USEPA, NOAA, and states in the watershed).
- Use information from monitoring of fish and shellfish to develop indictors for fish and shellfish consumption (USDA, USEPA, NOAA and states in the watershed).

4e. Air quality monitoring

The National Atmospheric Deposition Network/National Trends Network (NADP/NTN) is a multi-agency effort including over 250 stations across the U.S. and measures precipitation chemistry i.e., pH, nitrate and ammonium on a weekly basis (http://nadp.sws.uiuc.edu/) including a number of sites within the Chesapeake Bay watershed.

Recommendation: The partnership can better utilize air data to relate to human health needs of EBM (USEPA and NOAA).

5.0 Climate Variability and Episodic Events

There is a need to observe and monitor the climate variability affecting ecosystem conditions and extreme events such as hurricanes, floods, droughts, and fire and how they can accelerate transport of nutrients, sediment, and contaminants into waterways. Attributes for climate variability include daily and seasonal changes in tides, temperature, salinity, rainfall, streamflow, and winds. Monitoring of these conditions is addressed through several existing observing and monitoring systems including NOAA estuary and weather observing systems and DOI/USGS programs to measure streamflow. Primary information gaps and challenges are improved spatial coverage for tides, winds, and streamflow to improve assessment and models.

Recommendations:

- Better utilize and expand observing systems for climate attributes and streamflow (NOAA and USGS).
- Use EO climate report (202d) recommendations to establishing monitoring for a climate effects network (DOI and NOAA).

6.0 Socioeconomic conditions

Information is needed to assess physical well-being of humans, societal value of the ecosystem, and economic benefits. Attributes to monitor for physical well-being provided by the ecosystem include water supply and protection (clean drinking water and flood protection), food safety (fish and food products for human consumption, and swimmable waters. Societal values include public access and cultural and recreational services provided by the Bay ecosystem. Finally, economic benefits include the value of goods, services, and jobs related to the ecosystem. Primary goods include harvesting of seafood, services include recreational fishing and hunting, and jobs related to environmental protection, restoration, and education. The attitudes of people in the watershed toward the value of these goods, services, and jobs are also an important attribute to measure.

Recommendations: Utilize existing information to develop indicators for socioeconomic components. Establish additional monitoring to address gaps. (NOAA, USEPA, USGS)

7.0 Partnership performance

This topic focuses on the ability of program(s) to have a (1) consensus-based approach to develop defined outcomes for a sustainable ecosystem, (2) results oriented to developed defined outcomes for the ecosystem and actions to be implemented (3) capacity to align resources and implement the most effective policies and actions, (4) sound science to monitor effectiveness of actions and ecosystem improvement, and (5) have a system so decision making can adapt policies and plans. The CAP provides a foundation to address many of these items including a strategic framework, dashboards, activity database, and an adaptive-management process.

Recommendation: Continue to develop and expand the management systems and tools in the CAP (dashboards, activity database) to improve accountability and performance of the CBP partnership (USEPA and other federal agencies).

INFORMATION MANAGEMENT

The information management approach of the Chesapeake Bay partners is characterized by multiple data suppliers and users for different levels of decision-making. Such a partnership organizational framework yields great benefits in the data and resources brought to bear on restoring the Bay. However, to be truly effective and agile information and knowledge based consortium, enterprise-wide best practices for information management and future investments need to be accepted by the partners. The CBP has foundational pieces of an enterprise wide system in place. It has built and deployed an activity integration system, reports information to the public through the Bay Barometer, and it maintains and runs models leveraging federal supercomputing capabilities. It also is in the process of building out three new capabilities: a Chesapeake Bay Stat – a web site to track progress and indicators geographically; a scenario builder- to provide the impacts analysis of how possible actions and strategies would affect nutrient and sediment load reductions; and a new web interface that leverages new social networking tools to engage the public including video, online chat, Facebook, and micro blogging (short messages) on Twitter.

When considering enhanced information capabilities for the Chesapeake Bay, it is important to consider two emerging forces. The first is the transformational change occurring in the information technology sector where the internet provides the platform for the access and sharing of data. The second is the emergence of a set of methodologies for strategic planning and deployment of information technology (IT) for mission results. These strategic planning methodologies are called enterprise architecture, which fights silo systems and inefficient investment in data and IT. It is a methodology that allows a partnership to take a current state picture of all its data and information technology and to develop a migration plan to a set of new capabilities. It recognizes that many people own their own systems but finds ways to easily share data for common mission results and identifies important shared capabilities that can be built cost effectively. The future state

is then planned, budgeted for, and deployed with the capabilities designed to ensure data reaches the right people at the right time for the decisions they need to make.

With today's technology capabilities, senior level decision makers should be able to view the health of the Bay geographically from their desktops and collaborate in real time on different policy scenarios for restoration. This implies a set of agreed upon information management practices adopted by partners so that silo systems or information management approaches do not impede progress. Shared capabilities can also be part of the future picture, and in fact the CBP already has proceeded in this direction.

Recommendations:

- Make extensive improvements to obtain, manage, and share information to support EBM and improve decision making. Design and implement effective enterprise architecture to share and use information between the growing number of data producers (USEPA).
- The partners will have to greatly increase their capacity to assess, obtain, manage, and utilize appropriate information from multiple monitoring programs. CBP should develop partnership guidance documents that lay out analytical-quality assurance requirements for a monitoring program to become a partner in our monitoring networks. Guidance for data management, data submission and metadata currently exists, but will need modification for working with small data providers (CBP 1998, CBP 2001, and CBP 2006). (USEPA, NOAA, and USGS).

- There is a need for a unified, quality assured/quality control database. No single repository or data access infrastructure currently exists that unifies the breadth of available monitoring information. Investment in the data housing, data serving infrastructure is critical to be able to conduct integrative analyses in support of diverse decision making needs. (USEPA, NOAA, and USGS).

- Data meeting standards - Existing analysis efforts have demonstrated the need for a sound, reproducible, commonly available database for decision-making analyses. The MRAT process has further demonstrated that whereas there are many potential partners with an abundance of possibly valuable data, there are also many levels of data quality due to variations in sampling approaches, sample handling, analysis, and reporting protocols. (USEPA, NOAA, and USGS).

- Ensure full utilization of the data standards being developed for map and remotely sensed data (by the Federal Geographic Data Committee) to ensure interoperability and utilize national ideas for data management being implemented by IOOS and the NWQMN (USEPA, NOAA, and USGS).

ASSESSMENT AND RESEARCH

Observations and monitoring are assessed to define the extent of problems and changes over time. Assessments of water-quality standards in Chesapeake Bay and basin are tracked through federal 303d and 305b Clean Water Act reports. These assessments

include Bay habitat health on scales of CBP management units in the tens of square kilometers, but also tributary and main stem Bay measures of water quality. Regional scale assessments of composite effectiveness to landscape combinations of management actions are represented by nutrient and sediment loading trends at the 9 River Input Monitoring stations. Multiscale measures of effectiveness are needed and small watershed assessments that are more closely linked with management practice implementation scales on the landscape are still severely lacking in all but research level projects. There is further recognition that data for assessing effectiveness are insufficient or of ineffective quality on (1) location of implementation practices, (2) planned versus actual level of management implementation, (3) operational effectiveness of the practices, and (4) maintenance of practice function.

Research is conducted to understand and explain the inter-relation of major ecosystem components and examine effectiveness of potential solutions, and develop models to test hypothesis and forecast outcomes of different management and ecological scenarios. The STAC (2005) has developed an extensive set of research needs and recommendations. Additional research needs are being developed for the EO reports on living resources and climate.

Recommendations:

- Align federal research activities through development of a research plan. Consult with STAC and academic partners to prioritize and address highest priorities. (NOAA, FWS, USGS, USEPA, USDA, and DOD).
- Understand and explain ecosystem linkages between living resources, habitats, water quality, land use, natural disturbances, and socioeconomic factors. (NOAA, FWS, USGS, USEPA, USDA, and DOD).
- Improve models of ecosystem interconnections to forecast potential future conditions and test different management scenarios. Conduct integrated assessments of the effectiveness of management policies and actions to improve ecosystem conditions (NOAA, FWS, USGS, USEPA, USDA, and DOD).

<u>MODELING</u>

The EBM Tools Network, which is an alliance of EBM tool developers coordinated through NatureServe, suggested different types of models are needed for EBM:

- **Model Development Tools-** These tools help develop models of ecological or socioeconomic processes.
- **Geographic Information Systems-** Geographic information systems (GISs) can integrate, store, edit, analyze, manage, share, and display geographic information. GIS applications allow users to create searches, analyze spatial information, edit data, and create and edit maps.
- **Watershed Models-** These models simulate watershed processes and the influence of watershed changes (generally due to changes in land use) on freshwater and coastal ecosystems.
- **Estuarine and Marine Ecosystem Models-** These models simulate interactions between species and benthic and pelagic habitat in estuarine and marine environments.

- **Oceanographic and Dispersal Models-** These models simulate current flows and/or the dispersal of organisms and pollutants in the marine environment.
- **Habitat Suitability and Species Distribution Models-** These models estimate the habitat requirements or suitability of a given habitat for a species.
- **Socioeconomic Models-** These models simulate economic and social processes, often in response to potential management actions.

A wide variety of models are used in the region (see Chesapeake Community Modeling Program for larger list - http://ches.communitymodeling.org/models.php). As of this writing, monitoring and ecological survey data are not used extensively for forecasting the ecosystem condition and exploring the impacts of management options; however, tools (such as Atlantis software, habitat suitability models, atmospheric dynamics models) are being developed and refined to strengthen this capacity in the region. Such tools will be invaluable for understanding tradeoffs in ecosystem services inherent in resource management of the Bay as well as for evaluating climate effects on Bay resources.

The Chesapeake Bay Water-Quality Model provides a signature means of using existing data and developing futurecast scenarios for decision making. SPARROW represents a nutrient loading model for fixed points in time. These models use monitoring measurements and information on nutrient and sediment sources, to predict the distribution of nutrient and sediment loads to the Bay.

Recommendations:

Overall, the partnership needs to better integrate existing models, and develop additional models, to simulate the ecological factors affecting fish and wildlife and the relation to socioeconomic changes of the human population. Integrated ecological models are needed at different scales to run scenarios to make tactical decisions (such as fishing harvest) and long-term, strategic decisions for management policies. Some specific recommendations include:

- Better link existing models to forecast ecosystem changes of different management actions. Work to link outputs from land-change model (USGS), with watershed models (USEPA and USGS), estuary water-quality models (USEPA and COE), and fisheries models (NOAA).
- Enhance existing models to include socioeconomic factors and climate-change variables (NOAA, USEPA, USGS), and develop new models of critical wildlife species (FWS and USGS).
- Develop models to run as analytical web services using existing standards so they can be applied to consider management decisions at multiple scales (watershed wide, state, and local scales) (USEPA, NOAA, USGS and USFWS)

INDICATORS

National and international environmental programs have begun to develop indicators of ecosystem health largely from biophysical perspectives, but increasingly they also integrate socioeconomic and human health considerations (Rapport and others. 1997). The importance of using a broader array of indicators establishes data and reporting that

allows introspective, intensive, within-basin analyses as well as illustrating ecosystem condition and trends within the context of national and globally tracked parameters. Future monitoring would then diversify from the largely water-quality focus on sustainability and EBM. The CBP has a fairly extensive list of indicators for many of the ecological components of the ecosystem-based framework and has developed institutional integrity indicators in the CAP (dashboards). There is a need to develop more indicators to address the socioeconomic components of the framework. Indicators should also allow for rapid assessment of the status of the ecosystem and be spatially explicit to foster marine and watershed planning.

Recommendation: The partnership should reexamine the suite of indicators and consider a broader array, to ensure monitoring for ecological, socioeconomic and partnership performance for sustainability (USEPA, USGS, FWS, and NOAA).

COMMUNICATION PRODUCTS –

Improved communication products are needed to improve decision making for different target audiences:

- Local governments. Work with local land-use planning and zoning decision makers to address sustainability of their communities, watersheds, and the Bay.
- Citizens and watershed groups. Efforts should be focused on the agricultural community, suburban home owners, and urban dwellers whose decisions influence the quality of agricultural, suburban, and urban lands, and use of ecosystem goods and services.
- Federal and State resources managers. A primary focus should be on the inter-relation of decisions to improve water quality, habitat, and living resources and their effectiveness in sustaining the Bay and its watershed.
- Elected officials. Provide improved tools and implications of proposed legislation that will affect sustainability of the Bay and watershed.

The CBP Bay Barometer provides measures of bay health assessment by tracking a select suite of water quality (source sector-based nitrogen, phosphorus and sediment load to goal estimates), living resource indicators in the Bay (blue crab, oyster, striped bass, shad, menhaden, submerged aquatic vegetation) and Basin (macrobenthic index of biotic integrity), habitat (wetland resources, fish passage restoration, bay grass plantings), protection of watersheds (forest buffer plantings, watershed management plans, land acres preserved), and stewardship (public access, education and interpretation, citizen community action). The measures are not synthesized into a single, integrated index that has been done locally through the IAN-Ecocheck Bay Health Report Card or more globally in the recent Millennium Ecosystem Assessment.

Recommendations:

- Improve the Bay Barometer to reflect sustainability and additional socioeconomic indicators (USEPA)
- Consider revising partner state of the environment reports report cards to reflect sustainability and EBM.
- Improve use of research in human dimensions and social marketing to enhance effectiveness of products to improve decision making for target audiences.

DECISION-SUPPORT TOOLS

The EBM Tools Network, which is an alliance of EBM tool developers coordinated through NatureServe, suggested different types of decision-support tools including: (1) conservation and restoration site selection tools, (2) ocean zoning and coastal zone management tools, (3) fisheries management tools, (4) hazard assessment and resiliency planning tools, and (5) land-use planning tools.

Currently, the CBP partners do not have an extensive collection of decision-support tools. The Chesapeake Online Adaptive Support Toolkit (COAST), which was developed by USGS and USEPA, was used by NRCS to make water-quality decisions to select priority watersheds to focus conservation actions for the USDA 2008 Farm Bill funds. The CBP is also working to construct ChesapeakeBayStat, which would be a decision-support system to provide information to managers about current goals, resources, and indicators.

Recommendations:

- Develop tools to facilitate decision making using the adaptive-management framework including (1) conservation and restoration site selection for habitat and water quality, (2) coastal zone management, (3) fisheries and wildlife management, (4) hazard assessment, climate change, and resiliency planning, and (5) land-use planning.
- The partnership needs to better utilize ChesapeakeStat to be a portal to existing decision tools (existing tools include COAST-USGS/USEPA; SLAMM-USFWS; Habitat Priority Planner-NOAA). The existing decision tools should be enhanced to address new ideas being developed for targeting agricultural practices (NRCS), clean water act activities (USEPA), storm water (DOD and USEPA), and protecting ecosystems (NPS).
- Improve tools to include socioeconomic factors so improved decisions can be made for sustainability of living resources and the needs of 17 million people in the watershed.