Summary Report of the Urban Waters Monitoring Assets Workshop, 18 June 2014

DRAFT

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Executive Summary

On June 18, 2014 representatives from the water monitoring community of the Baltimore metropolitan area gathered for a workshop to discuss regional monitoring assets and initiate a dialog regarding a coordinated urban monitoring approach to support the Baltimore program of the Urban Waters Federal Partnership. During the workshop, representatives of city, county, state, and federal governments, non-governmental organizations (NGOs), and researchers summarized their respective urban monitoring efforts and engaged in group discussions related to developing and designing an integrated monitoring network.

Monitoring Assets Inventory Presented During the Workshop

Extensive surface water monitoring is being conducted in the Baltimore region in urban areas. Efforts are primarily led by local (city and county) governments and supplemented in some cases by NGOs, researchers, and state and federal government agencies. State and federal agencies and researchers are also conducting monitoring in the same geographic areas to achieve independent yet overlapping goals. The participation of NGOs, researchers, and federal agencies are good examples of current collaboration between different monitoring groups for the advancement of similar goals.

City and County Government

Under the provisions of the Maryland Watershed Protection Restoration Program (which became law in 2012), all large municipalities with separate sewer systems serving a population greater than 250,000 people, which includes Baltimore City, Baltimore County, Howard, Harford, Carroll, and Anne Arundel Counties, are required to obtain MS4 permits from Maryland Department of Environment (MDE). Monitoring to fulfill municipal separate storm sewer system (MS4) permit requirements is common between these jurisdictions and serves as the foundation for their monitoring programs. To differing extents and with differing maturity of their monitoring programs, all MS4 jurisdictions perform monitoring associated with watershed assessments and implementation plans and TMDLs as well as chemical, biological, and physical monitoring of storm-water controls. All local governments expressed the desire to increase and improve monitoring activities in their jurisdictions beyond the requirements in their MS4 permits, if resources were available to do so. Improvements to monitoring programs desired by the local governments commonly included increased water-quality monitoring to existing flow monitoring stations, expanded bacteria analysis, and better defining pre- and post-restoration monitoring protocols.

Non-Governmental Organizations

NGOs play a unique and vital role in the engagement of citizen monitoring and data collection in the regional urban environment via grants and other funding sources not available to governments. Blue Water Baltimore conducts monitoring within Baltimore City and Baltimore County. South River Federation conducts monitoring within the South River watershed in Anne Arundel County. These two organizations assist and supplement monitoring programs at different levels of government, provide outreach, and are positive examples for other jurisdictions.

Researchers

The Baltimore region is the focus of significant and long-term urban ecosystem research on the watershed scale by both Baltimore Ecosystem Study (BES) and the Center for Urban Environmental Research and Education (CUERE). These long-term studies conducted in urban environments can be used as models and offer improvements for monitoring techniques, locations, and protocols. Local governments and NGOs benefit from the results of these studies as well as possibly being able to coordinate data needs with local research efforts.

State Government

Two state agencies have a monitoring focus within their mission in Maryland, MDE and Department of Natural Resources (DNR). MDE monitoring efforts are regulatory in nature and support public health protection, water-quality protection and restoration, and incident response. DNR leads the Maryland Biological Stream Survey (MBSS) sampling program, which is conducted to assess the current conditions of ecological resources in Maryland's streams, identify stressors, provide an inventory of biodiversity, and document changes in ecological conditions and biodiversity status.

Federal Government

The primary federal agency collecting monitoring data in the region is the US Geological Survey (USGS). These monitoring efforts, including stream gages and water-quality sites, often serve multiple purposes for both the USGS as part of their long-term monitoring networks as well as local government needs.

The multi-agency Chesapeake Bay Program (CBP) monitoring network includes both non-tidal and tidal stations according to CBP protocols to achieve CBP goals. Tidal monitoring consists of water-quality and habitat assessment, shallow water stations, and benthic invertebrate monitoring stations.

Design of an Integrated Monitoring Network

The ultimate goal of the Monitoring, Modeling, and Research workgroup of the Baltimore Urban Waters Initiative is to design and implement a long-term monitoring network that adds value, maximizes

efficiency, aids in decision making, and is also comprehensive enough for evaluating trends and other stories in the data. The workgroup envisions a network or network of network(s) that will enable stakeholders to:

(1) track watershed level improvements to water quality,

(2) assess impacts and success of restoration and management efforts, and

(3) provide flood-related information and help answer resilience and sustainability questions.

Data Gaps and Recommendations

Preliminary discussions between workshop attendees centered on these three goals and resulted in the identification data gaps and recommendations. All three groups (as well as many stakeholders) identified the following needs and recommendations:

- More engagement of citizen groups and NGOs in the region,
- Development of an integrated database or data portal to access management and restoration project inventories and status, pre-and post-restoration monitoring plans, contact information, as well as raw monitoring data facilitated by USGS or Baltimore Neighborhood Indicator Alliance) BNIA, and
- Continued and expanded collaboration between research community (BES, CUERE, USGS) and the city and county governments.

Data gaps and recommendations offered by specific groups are summarized below.

Watershed Level Improvements to Water Quality:

- Improve the conceptual model of the urban water sources in order to better define where the water ultimately goes (i.e., stormwater, sanitary sewers, groundwater and streams) and what controls the amount and partitioning of water between the various pathways ,
- Define the causes (e.g., land use change, BMP implementation, climate change) and resulting effects (e.g., improved or degraded water quality) for watershed improvements. Infrastructure improvements, land cover, population, and infiltration and inflow (I and I) data were all mentioned as causes that need more focus, and
- Define optimal timeframe of data collection needed to detect a change in the long-term trends.
- Use analytical models as a way to better relate cause and effect in the watershed, and
- Develop a case study watershed (or subwatershed) such as the BES Gwynns Falls location, to possibly fill these data gaps and then translate understanding to other watersheds in various jurisdictions.

Impact and Success of Restoration and Management:

- Determine the effectiveness of management projects at variable scales, and
- Account for the lag time in biology, groundwater impacts, and other typical monitoring measures from the time of implementation through the typical monitoring cycle.
- Develop protocols for short-term and long-term impacts and success based on experience in the field, and
- Shift to more functional process restoration and evaluation methods in order to aid in the determination of impacts of management and restoration.

Resilience and Sustainability:

- Understand how flooding and drought impact water resources (both quality and quantity).
- Assess the long-term shoreline data and how flooding changes over time.
- Use modeling for predictive purposes and design monitoring accordingly.
- Consider drought, coastal surge (long-term impacts) and catastrophic storms (short-term impacts) in monitoring design.

Next Steps

Volunteers for a steering committee were solicited from the attendees of the workshop. It is recommended that the steering committee meet to develop a set of strategic initiatives based on workshop identified data gaps and recommendations and prioritize selected recommendations for action. A strategic planning meeting may be convened to discuss strategic initiatives with the larger group of stakeholders in Spring 2015, led by the steering committee, and to plan the annual workshop (Summer 2015).

Introduction

On June 18, 2014 representatives from the water monitoring community of the Baltimore metropolitan area gathered for a workshop to discuss regional monitoring assets and initiate a dialog regarding a coordinated urban monitoring plan to support the Baltimore program of the Urban Waters Federal Partnership. The workshop objectives were introduced by Mr. Robert Shedlock (US Geological Survey) and a vision of the goals for the monitoring subgroup of the Baltimore Urban Waters Partnership was provided to the group. During the workshop, representatives of city, county, state, and federal governments, non-governmental organizations (NGOs), and researchers summarized their respective urban monitoring efforts (Appendix). Information exchange and discussion toward development of a coordinated monitoring network were further facilitated through three smaller groups. The small groups focused on identifying data gaps and making recommendations related to selected goals of the monitoring subgroup of the Baltimore Urban Waters Partnership. The small group discussions related to monitoring associated with watershed level improvements, resiliency, and restoration and management. The workshop concluded with a larger group discussion about possible next steps.

Purpose and Scope

The purpose of this report is to document the urban monitoring assets of the greater metropolitan area presented at the workshop and to summarize the data gaps and recommendations discussed at the workshop on June 18, 2014. Specifically, monitoring program highlights in Baltimore City, Baltimore, Anne Arundel, Carroll, Harford, and Howard counties, selected NGOs, Maryland Department of the Environment (MDE), Maryland Department of Natural Resources (DNR), research projects including Baltimore Ecosystem Study (BES)/US Forest Service, Center for Urban Environmental Research and Education (CUERE), and US Geological Survey (USGS) Water Science Center and Chesapeake Bay Program (CBP) efforts are summarized.

In addition, data gaps and recommendations resulting from small group discussions at the workshop are summarized. The small group topics included (1) tracking watershed level improvements in water quality and inputs to the Baltimore Harbor and Chesapeake Bay, (2) providing flood-related information and considering resilience and sustainability questions, and (3) assessing success of restoration and management efforts (e.g, best management practices [BMPs], and stream restoration).

This document provides a summary of workshop information to interested parties who were unable to attend in person. In addition, it provides information necessary for the Baltimore Urban Waters

Partnership Monitoring steering committee to progress toward the development of immediate strategic initiatives and a more long-term strategic plan for the larger group. Finally, it may provide information necessary to solicit additional resources, engage agency leadership, and provide an update to the Urban Waters Federal Partnership.

Urban Waters Federal Partnership

The Urban Waters Federal Partnership is a multi-government agency effort to reconnect urban populations with their waters, and to demonstrate the environmental, social, and economic benefits of environmental restoration activities in cities and their surrounding metropolitan areas (EPA, 2014). It is comprised of a consortium of federal agencies including the Environmental Protection Agency (EPA), Departments of Health and Human Services, Agriculture, Interior, Transportation, Commerce, Housing and Urban Development, Energy, Army, and Education, and is inspired by the President's America's Great Outdoors initiative. These agencies have committed to work together and with communities and other local agencies to promote a clean, safe, accessible, urban environment.

EPA has developed a strategic framework to outline a general path toward achieving the goals of the Urban Waters Federal Partnership. The primary goals are to restore and protect urban water quality and revitalize adjacent neighborhoods by engaging communities in activities that increase connections to and understanding of local urban waterways (EPA, 2014). The strategic approach put forth by the EPA promotes enhancing existing EPA efforts to protect and improve urban waters through the alignment of EPA programs and resources to assist a broader set of communities and to engage communities actively in protecting urban waters. The federal government members of the Partnership are encouraged to assist communities in building their capacity to protect urban waters and their adjacent lands. The strategic approach recommends that federal organizations partner with community-based organizations, the private sector, and local government agencies and collaborate with one another, offer expertise, technical assistance, and resources, and align and target federal government investments and regulations in ways that respond to community priorities (EPA, 2014).

Baltimore Urban Waters Partnership

In June 2011, the Baltimore-Patapsco was one of seven pilot projects across the country initiated to further the work of the Urban Waters Federal Partnership. In 2012, The Urban Waters Federal Partnership introduced the Ambassador's program intended to coordinate and advance the work of the

pilot projects. Michael Gavlin (SavATree) serves as the Ambassador of the Baltimore Urban Waters Partnership and facilitated the workshop on June 18, 2014. Since June 2011, an additional 11 communities have been introduced as part of the program.

Through regular, ongoing discussions between primarily EPA, USGS, US Forest Service, DOT, Baltimore City, Baltimore County, local researchers, and numerous community organizations, the Baltimore Urban Waters Partnership has worked to promote the goals of the Urban Waters Federal Partnership outlined in the previous section. Specifically, four key adaptive-management and educational pillars (workgroups) have been outlined to support these goals: Mapping, Local Projects, Green Patterns Book, and Monitoring, Models, and Research (fig. 1). The latter workgroup, Monitoring, Models and Research, is intended to support the other three pillars (Mapping, Local Projects, and the Green Pattern Book) by providing quantitative data and analysis. Through its collaborative work, the Baltimore Urban Waters Partnership has recognized a need to inventory and evaluate monitoring assets in the Baltimore region in order to develop and design a regional monitoring network. This working group was designed to support mapping efforts aimed at targeting water and water-quality problems on a spatial level, and relate demographic and land-use information to data from local monitoring efforts, to assess the level of success of local projects that are implemented for the purpose of improving water-quality conditions, and quantify the success of a range of community greening projects, which are described in a technical support document known as the Green Pattern Book.

Long-term, the intent is for the Monitoring, Models, and Research workgroup to focus efforts to:

(1) improve the City's water-monitoring networks and adjusting many existing stakeholder monitoring efforts to add value, maximize efficiency, and aid in management decision making,

(2) assess protocols used for all stakeholder monitoring, and developing consensus among stakeholders on the best sampling and data analysis protocols to use,

(3) establish selected reference "best-management practice" monitoring stations to quantify water-quality improvements at smaller scales that can be directly related to the implementation of local greening projects, and

(4) outline needed research and modeling projects that will focus on integrated analyses and overall ecosystem function, and determining candidate areas for these projects.

This workshop was designed to be the first step in establishing the regional monitoring network(s) to support these goals and strategic initiatives of the workgroup and Partnership.

Regional Urban Monitoring Assets Inventory

Extensive monitoring is being conducted in the Baltimore regional area in urban settings. An attempt to compile a comprehensive inventory of all existing sampling efforts in Baltimore City and surrounding areas (Baltimore, Anne Arundel, Howard, Carroll, and Harford counties) is being conducted in support of the Baltimore Urban Waters Partnership with the intent of (1) optimizing the sampling network to enhance coverage and remove overlap and duplication of efforts among various stakeholders, and (2) developing a consensus on consistent sampling and data-analysis protocols. This section of the report summarizes the primary monitoring activities being conducted by local, state, and federal governments, as well as NGOs and researchers. It is not a comprehensive discussion of all monitoring efforts, but rather a summary of the major monitoring assets in the region as summarized by spokespeople for each organization, how different jurisdictions and organization prioritize their efforts, and how resources are currently used to achieve monitoring goals. Efforts are primarily led by local governments (compliance) and supplemented in some cases by NGOs or researchers. However, state and federal agencies are also conducting monitoring in the same geographic areas. The participation of NGOs, researchers, and some federal agencies are good examples of current collaboration among different monitoring groups for the advancement of similar goals.

Local Government

Section 402 of the Clean Water Act (CWA) prohibits the discharge of any pollutant to waters of the United States from a point source, unless that discharge is authorized by a National Pollutant Discharge Elimination System (NPDES) permit (40CFR 1.402[2006]). Under the provisions of the Watershed Protection Restoration Program (COMAR26.17.02 [2012]), all large municipalities with separate sewer systems serving a population greater than 250,000 people, which includes Baltimore City, Baltimore County, Howard, Harford, Carroll, and Anne Arundel Counties, are required to obtain municipal separate storm sewer system (MS4) permits from MDE. Monitoring to fulfill MS4 permit requirements is common between these jurisdictions and serves as the foundation for their monitoring programs. Common permit requirements are summarized in the following paragraphs.

MS4 permits require county-wide watershed management plans to be developed at the beginning of the permit term to assess water quality conditions of the watershed, identify and rank water quality

problems, and identify applicable structural and non-structural controls for water quality improvements. Completion of these assessments results in a watershed implementation plan(s).

All MS4 permits specify that an assessment of stormwater controls must be conducted consisting of at least one outfall and that one in-stream station be monitored for chemical, biological, and physical parameters. Chemical monitoring in these watersheds consists of the collection of samples during 8 to 12 storm events per year (at least 2 per quarter). Discrete samples of stormwater flow are required at the monitoring stations using automated or manual sampling methods and analyzed for pH and water temperature. At least 3 samples representative of each storm are required to be submitted for analysis of biological oxygen demand (BOD), total Kjeldahl nitrogen (TKN), nitrate+nitrite, total suspended solids (TSS), total petroleum hydrocarbons, *E. coli* or *enterococcus*, total lead, total copper, total zinc, total phosphorous, and hardness. In addition, continuous flow measurements are required at the in-stream monitoring stations in order to calculate loads.

Biological monitoring is required each spring between the outfall and in-stream stations. The acceptable protocols are specified in the permits to be the EPA Rapid Bioassessment Protocols and the Maryland Biological Stream Survey (MBSS).

Physical monitoring consists of a geomorphologic stream assessment between the outfall and in-stream station. In addition, a stream habitat assessment is required (with defined protocols). Finally, a hydrologic and/or hydraulic model (specific examples include TR-20, HEC-2, HEC-RAS, HSPF, and SWMM) is required in the fourth year of the permit to analyze effects of rainfall, discharge rates, stage, and if necessary continuous flow on channel geometry.

Similar to the watershed assessment, a stormwater assessment is a requirement of the MS4 permits. The assessment consists of an annual stream profile and survey located in a permanently monumented cross-section to evaluate channel stability as it relates to ongoing, surrounding development. A comparison of the stream profile and survey to the baseline conditions is required to assess change (aggradation or degradation). Finally, a hydrologic/hydraulic model is required in the fourth year of the permit to analyze effects of rainfall, discharge rates, stage, and changes to channel geometry.

The City and counties in the metropolitan area all have impaired waters within their boundaries, as determined by MDE, and have established total maximum daily loads (TMDLs) for the waterway. These are enforced by MDE specified in the appendices of the respective MS4 permits. Stormwater controls via BMPs are required to meet waste load allocations (WLAs) for the respective TMDLs. Monitoring

may be conducted to demonstrate and document improvement after BMPs are in place and be reported as part of the annual report to MDE.

All local governments expressed the desire to increase and improve monitoring activities in their jurisdictions beyond the requirements in their MS4 permits, if resources were available to do so. Specific desired additions to the monitoring programs are noted from the respective governments in the following sections following the noted highlights of their monitoring programs.

Baltimore City

Baltimore City manages water monitoring within the Department of Public Works. Under the Bureau of Water and Wastewater, two divisions (Environmental Compliance and Laboratory Services and Environmental Services) house the City's staff of 16 full-time employees (FTE) to manage, conduct, and comply with monitoring requirements. Ms. Kimberly Grove presented highlights of Baltimore City's monitoring programs to the group. Monitoring programs are conducted for the reservoirs that provide water to the City (outside of City limits) and within the City's watersheds (fig. 2). Reservoir monitoring consists of the collection of samples from 12 tributary locations within the Loch Raven, Pretty Boy, and Liberty watersheds monthly (between late fall to spring) and bi-monthly by boat (between spring to late fall). Multi-probes are used to collect data at 5 foot intervals to a depth of 60 feet. Discrete samples are also collected for algae, TOC, and specific water-quality requirements. Reservoir monitoring has been conducted since the mid-1980s.

Sampling of waterways within the City limits is comprised of various efforts designed to meet various requirements of the MS4 program and the Consent Decree between the US Government, the state of Maryland and the City, which is aimed to remedy the sewer system. More specifically, ammonia sampling is conducted weekly at 47 locations for illicit discharge detection (leaky infrastructure) to surface water. *Enterococci* counts are analyzed monthly at 33 surface water locations as part of the stream impact sampling program to evaluate bacteria trends. Storm samples are collected from four locations between 8 and 12 times per year.

Baltimore City also collaborates with several ongoing, long-term research projects and NGO sampling programs described in later sections that supplement their monitoring programs. The City would like to further expand their monitoring in both the reservoirs (and associated watersheds) and within the City. Specifically, reservoir monitoring could be improved by including wet weather sampling, real-time water- quality monitoring, the development of a formal phytoplankton model, and bathymetric surveys

to evaluate loss of reservoir capacity. Watershed monitoring within the City could be improved by conducting a more accurate storm sewer inventory, adding water-quality analysis at existing USGS stations, analyzing stormwater for bacteria DNA, expanding sample locations to include in-line pipe monitoring, and developing a comprehensive flow model calibrated by real-time ALERT gages. Understanding of current monitoring data could be improved with additional resources for analysis and evaluation. A desire to create a portal to share information on monitoring, data, management and restoration projects was expressed.

Baltimore County

Baltimore County manages its monitoring programs within the Department of Environmental Protection and Sustainability, Watershed Management and Monitoring Section. Mr. Steve Stewart highlighted Baltimore County's monitoring programs to the workshop attendees. The county monitoring program is large and data have been collected for long periods of time. Monitoring programs encompass chemical, physical, biological and bacteria analysis, trash, BMP effectiveness, special studies, stream corridor assessment, and upland data collection (fig. 3). The objectives of these broad programs are to satisfy permit requirements, provide data for small watershed action plans (SWAPs), identify pollution sources for targeted remediation, provide data for trend (TMDL) analysis, evaluate BMP effectiveness, and assist in development of TMDL endpoints.

More specifically, the chemical monitoring program (established in 2003) consists of samples collected from 40 fixed locations at fixed intervals for phosphorous and sediment TMDL trend analysis. In addition, synoptic sampling events are conducted annually in the spring to evaluate one time baseflow quality and provide increased sampling density for SWAPs.

The biological monitoring program consists of the Random Point Program (established in 2003), which historically was comprised of 100 collection sites analyzed for benthic macroinvertebrates. This program was recently modified (2013) to include 50 stream and 25 tidal locations. Submerged aquatic vegetation (SAV) monitoring has been conducted since 1993 to establish coverage and species composition in targeted, dredged subestuaries.

Bacteria trend monitoring (initiated in 2010) is conducted at 8 locations within the City, 5 locations in Carroll County, and 19 locations within Baltimore County in support of waste load allocation (WLA) calculations. In addition to the TMDL sampling, the County conducts sampling to identify areas with higher bacteria counts for investigation as part of the Subwatershed Ranking Monitoring Program. In

addition, the Bacteria Source Monitoring program similarly identifies stream reaches impacted by high bacteria counts for remediation.

Illicit discharge detection and elimination (IDDE) monitoring (initiated in 1993) consists of sample collection and analysis from outfalls throughout the county. Samples are analyzed on-site (and select samples sent off-site) for analysis of temperature, pH, chlorine, copper, phenols, ammonia, and boron. This monitoring program supports the MS4 requirement of detecting and correcting illicit connections to the storm drain system.

Currently, Baltimore County is considering the addition of bioaccumulation and fish tissue studies to their monitoring program. The bioaccumulation studies would provide subwatershed information for targeting sources for remediation. Similarly, the fish tissue sampling and analysis would provide information to MDE on the level of accumulation, for mercury, chlordane, and PCBs (all TMDLs in Baltimore County).

Anne Arundel County

Anne Arundel County manages its monitoring program within the Department of Public Works, Watershed Protection and Restoration program. Mr. Erik Michelsen presented an overview of Anne Arundel County's monitoring program to the group. The county monitoring program is large and data have been collected for long periods of time. Monitoring occurs throughout the county (fig 4) and is centered on MS4 control assessments (Picture Branch and Church Creek), a restoration project (Cowhide Branch), DNR Trust Fund projects (Dividing Creek and North Cypress Branch), and biological (county-wide) monitoring.

Chemical and physical parameters are consistent with MS4 requirements. Biological monitoring is conducted via the Perennial Streams Biological Condition assessment. Monitoring timeframes range from 3 years (pre-restoration monitoring at Cowhide Branch) to 15 years (Church Creek).

With appropriate resources, Anne Arundel County would enhance the monitoring program by expanding pre- and post-restoration monitoring to include fish and herpetology and bacteria count during pre- and post-restoration conditions, including chemical assessments with biological monitoring, and improving the understanding of legacy sediment impacts on the coastal plain.

Howard County

Howard County manages its monitoring program within the Department of Public Works, Bureau of Environmental Services, Stormwater Management Division. Mr. James Caldwell provided a summary of

monitoring in Howard County (fig. 5). Data are collected for watershed management plans using both chemical and biological data for stream assessments. In addition, compliance monitoring is performed as part of the MS4 requirements. Monitoring is conducted for certain stream parameters before and after stream or pond restoration/retrofit projects.

Challenges to the monitoring program in Howard County were presented. The cost of sampling was described as a hindrance to comprehensively assessing a stream through all seasons and all rainfall variances. Data are lacking somewhat in order to assess stream health and impacts on management practices. With additional resources, Howard County would like to expand monitoring frequency and assessment in the county. Howard County would like to expand monitoring to adequately assess the function of the new control practices being used such as those practices implemented to better control runoff as required by MS4 and TMDL mandates. Since these practices are relatively new and unproven, better monitoring is desired to identify the effectiveness of the practices and to demonstrate their value in controlling runoff pollution. Concern was raised that if progress cannot be demonstrated, there will be increased opposition to the collection of fees in the community.

Carroll County

Carroll County manages its monitoring programs within the Department of Land Use, Planning, and Development, Bureau of Resource Management, Division of Water Resources Planning with a staff of four FTE. Mr. Byron Madigan presented a summary of Carroll County's monitoring program. Overall, the monitoring program is young and largely centered around MS4 permit requirements. The program consists of TMDL, storm event, reservoir, and NDPES monitoring (fig. 6).

TMDL sampling is conducted within two county watersheds. Double Pipe Creek watershed is monitored bi-weekly for TSS and nutrients, and annually in the spring for benthic communities. Liberty watershed is monitored monthly for bacteria counts.

Monthly baseflow sampling and storm sampling (2 events per quarter) are conducted at sites identified for retro-fit in order to establish pre-restoration data. Currently, this sampling is conducted within the South Branch Patapsco watershed and includes monitoring for TSS, nutrients and benthic communities.

Piney Run Reservoir is monitored bi-weekly between April and November for nutrients, *E-Coli*, iron, magnesium, pH, temperature, dissolved oxygen, specific conductance, turbidity, plankton, and zooplankton. The outfall of the reservoir is continuously monitored (every 15 minutes) for temperature between April and October.

Harford County

Harford County manages its monitoring program within the Department of Public Works, Office of Watershed Management. Ms. Michele Dobson summarized the County's monitoring program as relatively small, with a staff of 2.5 FTE whose primary responsibility is meeting the monitoring requirements of Harford County's MS4 permit. The program receives funding through the County's capital and operating budget yet depends heavily on grant funding and partnerships with state and federal agencies as well as consultants in order to effectively meet the monitoring goals. Monitoring parameters are typically limited to those specified in the MS4 permit or by those required if grant funding was awarded for a targeted watershed project, stream restoration project or a stormwater retrofit project. Specifically, the chemical component consists of monthly base flow and stormflow monitored at 4 stations, the biological component consists of annual monitoring at 9 stations, the physical component consists of annual monitoring at 5 stations and daily discharge monitored at 5 stations (Fig. 7).

With increased resources, Harford County would like to expand the monitoring program and its partnerships with both DNR and USGS. Specifically, the County would like to establish a county-wide baseline chemical and biological monitoring program, develop a bacterial source tracking program in urban areas to help identify areas of failing infrastructure, and expand chemical monitoring efforts to include researching the impacts of personal care products and toxics on County waterways.

NGOs

NGOs play a unique and vital role in the engagement of citizen monitoring and data collection in the urban environment via grants and other funding sources not available to governments. These organizations can assist and supplement monitoring programs at different levels of government and provide the outreach needed for success of restoration projects in urban environments. Two NGOs who assist and supplement local government monitoring programs presented an overview of their efforts at the workshop and are summarized in this section.

Blue Water Baltimore

A summary of monitoring conducted by Blue Water Baltimore was presented Mr. David Flores. Blue Water Baltimore has an active monitoring program within Baltimore City and Baltimore County in the non-tidal reaches of Jones and Gwynns Falls watersheds, as well as the tidal Patapsco River in Baltimore City, Baltimore County and Anne Arundel County. (fig. 8). The non-tidal ambient monitoring program consists of monthly year-round sampling for temperature, DO, specific conductance, pH, turbidity,

nutrients, *Encteroccocus* bacteria, chlorides, and ammonia. Monitoring locations are comprehensive of every subwatershed tributary. The tidal ambient monitoring program consists of biweekly sampling between April and November for temperature, depth, DO, specific conductance, salinity, pH, water clarity, blue-green algae, chlorophyll A, nutrients, and *Enterococcus* bacteria. Blue Water Baltimore also leads, educates, and trains volunteers for illicit discharge detection monitoring through its "Outfall Screening Blitz" program. This monitoring effort was initiated in 2014 and involves 53 volunteers trained to perform Center for Watershed Protection (CWP) outfall reconnaissance inventory procedures covering approximately 10 stream miles per year. To-date, 101 dry-weather discharges have been screened and 68 dry-weather illicit discharges identified and referred to local jurisdictions for source investigations.

In collaboration with the University of Baltimore, Blue Water Baltimore is supporting ongoing advancement of microbial source tracking (MST) for fecal contamination in the Patapsco River watershed by Dr. Wolf Pecher. Dr. Pecher described the work he and his team are doing using molecular probes and analyzing samples via quantitative polymerase chain reaction (qPCR) to identify the host of fecal contamination in urban waters (i.e., human or pet sources). Current sampling sites are within the tidal Patapsco (mesohaline, 10 sites), the Jones Falls (7 sites), and Gwynns Falls (5 sites). Continued work is ongoing to continue refinement of current and develop new molecular probes to distinguish between rat, raccoon, deer, and fox fecal materials.

South River Federation

The South River Federation has an active monitoring, evaluation, and assessment team within the South River watershed of Anne Arundel County. A summary of monitoring efforts by the South River Federation was presented by Captain Diana Muller. They conduct non-tidal, tidal, bacteria, and SAV monitoring within the watershed and the data collected are used for TMDL/Watershed Implementation Plan (WIP) reports, permit applications, and other technical publications. More specifically, the tidal and non-tidal monitoring consists of weekly to bi-weekly (plus storm events) sample collection from 20 stations to evaluate restoration both pre- and post-construction. Samples are analyzed for nutrients, TSS, optical brighteners, oils, and chromophoric dissolved organic matter.

Researchers

The Baltimore region is the focus of significant and long-term urban ecosystem research on the watershed scale. These long-term studies conducted in urban environments can be used as models and offer improvements for monitoring techniques, locations, and protocols. Local governments and NGOs

may benefit from the results of these studies as well as possibly be able to coordinate data needs with local research efforts. Summaries of research efforts in the region are included in this section.

BES

The Baltimore Ecosystem Study (BES) is part of the National Science foundation's Long-term Ecological Research (LTER) network. Dr. Peter Groffman (co-principal investigator) summarized monitoring efforts conducted as part of the BES. The project is a collaborative effort between the Cary Institute of Ecosystem Studies, government agencies (US Forest Service, USGS) and several universities including the University of North Carolina, the University of Maryland Baltimore County (UMBC), the University of Maryland College Park, Johns Hopkins University, the University of Missouri, the University of California at Davis, and the Parks and People Foundation. Components of the study include watershed studies, soil, plant and hydrologic dynamics, modeling and spatial analysis, social science, historical analysis, and education and outreach. The BES employs the watershed approach to examine the influence of urban land use on ecosystem dynamics.

The Gwynns Falls watershed of Baltimore County and City is a primary focus of the study. Specifically the BES project is studying how urbanization influences nitrogen export and retention and the soil, plant, microbial and hydrologic processes that control these variables. Weekly monitoring of 12 to 15 locations in and near the Gwynns Falls for nitrate, phosphate, chloride, sulfate, total nitrogen, total phosphorus, dissolved oxygen, pH, turbidity and temperature has been ongoing since October 1998 (fig. 9).

BES has also been a participant in the Paired Watershed Experiment in W263 that is evaluating ecological and socio-economic change in dense urban neighborhoods. This study evaluated social and water-quality responses to installation of green infrastructure.

CUERE

CUERE, in addition to being a co-principal investigator for the BES, conducts research intended to better understand the urban water cycle and associated biogeochemical cycles. Dr. Claire Welty summarized associated monitoring for the group. Primary monitoring locations are within the Dead Run subwatershed, which is located within the Gwynns Falls watershed. Data are primarily collected for assimilation into models and consist of six stream gages located on all lower order streams up to the headwaters. High-frequency (30-minute) sensors have been deployed since 2010 and collect nitrate, specific conductance, temperature, DO, and turbidity measurements (fig. 10).

Ongoing research at CUERE will focus on detecting effects of BMPs at the watershed scale, improving quantification of groundwater-surface water interactions, and upscaling processes from point measurements to stream reach and watershed scales. In addition, future work will begin to look at constituents other than nitrogen, including pharmaceuticals and toxics. Finally, observations at multiple spatial scales will be integrated into models.

With appropriate resources, CUERE would like to expand research and additional monitoring in the watersheds of interest to include stream gages and water-quality sensors at the mouth of every tributary, installation and water-level monitoring of bedrock wells in each hill. These data would be assimilated into models to support predictive tools of the hydrologic cycle in near real-time, and support a unified, mapped, and interactive database for the region.

State Government

Two state agencies have a monitoring focus within their mission in Maryland, MDE and DNR. The monitoring efforts conducted by these two agencies are detailed in this section.

MDE

MDE's monitoring role in the region is primarily regulatory focused and was summarized by Mr. Matthew Rowe. Specifically, MDE monitoring efforts support public health protection, water quality protection and restoration, and incident response. In addition, MDE is responsible for issuing MS4 permits to and reviewing MS4 annual reports submitted by local governments. As part of the annual report submittal, monitoring data are submitted to MDE to demonstrate compliance with WLAs and WIPs.

In support of public health protection, MDE monitors surface water for fish and shellfish consumption on an annual and monthly timeframe, respectively. Beaches are monitored weekly, bi-weekly, or monthly for bacteria counts to conduct a water contact recreation determination.

MDE is currently monitoring the Jones Falls, Back River, Baltimore Harbor and Centennial Lake for project specific TMDLs. The frequency and parameters monitored vary depending on the TMDL being evaluated.

MDE's monitoring data is largely used to compare to risk-based thresholds and water-quality criteria in regulations and for predictive modeling to connect loading to criteria attainment. Data are available via the Ambient Water Quality Monitoring System (AWQMS).

MDE would like to see an expansion of pre-and post-restoration monitoring as well as expanded monitoring for the development of Maryland-specific standards and criteria. They would also like to increase the understanding of the types and scale of practices (management or restoration) required to effectively protect and restore impaired waters of the region.

DNR

DNR performs monitoring statewide (including the Baltimore metropolitan region) for assessments and trends as part of the MBSS program, which was initiated in 1995. This program was summarized by Mr. Dan Boward. Some jurisdictions work cooperatively with DNR to complete the biological monitoring component of their MS4 requirements, while others utilize the MBSS established protocols. The MBSS sampling program is conducted to assess the current conditions of ecological resources in Maryland's streams, identify stressors, provide an inventory of biodiversity, and document changes in ecological conditions and biodiversity status. They also engage citizens in monitoring via the Stream Waders Program and communicate findings to various stakeholders.

The MBSS program consists of fish and benthic macroinvertebrate sampling, which results in a ranking within the Indices of Biotic Integrity (IBI), developed by DNR. In addition, water quality, fauna, and physical habitat sampling and assessment are conducted. As part of this program, a statewide monitoring round is conducted every three to five years, and sentinel sites are sampled annually.

The data collected as part of the MBSS program have various uses by other state and local agencies including the 303(d) list (MDE's list of impaired streams completed every two years per EPA requirements), criteria development, MS4 compliance, restoration monitoring, land preservation programs and endangered species evaluations. DNR would like to improve the program by filling identified data gaps, including more spatial and temporal coverage, more targeted sample locations and the addition of more sentinel sites. With appropriate resources, DNR would expand the analysis of samples collected to include periphyton, bacteria, and various contaminants as well as include geomorphology in their assessments.

Federal Government

The primary federal agency collecting monitoring data in the region is the USGS. These monitoring efforts often serve multiple purposes for both the USGS as part of their long-term monitoring networks as well as local government needs (e.g., MS4 calculations). Monitoring conducted either as part of the

Maryland-Delaware-DC Water Science Center (WSC) surface-water networks and the Chesapeake Bay Program are summarized in this section.

USGS WSC

USGS monitoring in the region was summarized by Mr. Ed Doheny. The USGS maintains 31 continuous record urban/suburban (defined as having greater than 10 percent impervious surface) stream discharge gages in the five county/city region, including two new (2014) gages (Herring Run and Long Quarter Branch, fig. 11). An additional 33 stations are maintained in this region, but are not considered to be in urban areas. The drainage area of the gaged urban watersheds ranges significantly from 0.21 to 65.9 square miles. Continuous record stream gages typically record data values on 1 to 15 minute intervals. For urban watersheds, USGS collects data on 5 minute intervals (or less).

Additional monitoring in the region conducted by USGS includes continuous water temperature on the Gunpowder Falls near Parkton station (Baltimore County), initiated in 2011. Since 2010, continuous turbidity and suspended sediment sampling has occurred at 3 main stem stations of the Patapsco River (Baltimore County). Since 2013, continuous water temperature, specific conductance, turbidity, and base flow sampling has occurred at Plumtree Run (Harford county) station. Storm sampling is also conducted at this station to fulfill MS4 requirements and analysis consists of nutrients, chloride, dissolved organic carbon, SS, bacteria, and TSS.

USGS would like to improve their monitoring in the urban areas of the region by including water-quality measurements (i.e., real-time sampling for nutrients, metals, and bacteria) at the Herring Run gage as well as restarting the Jones Falls (at Maryland Avenue) gage for the same parameters. USGS would like to incorporate the Gwynns Falls at Washington Boulevard gage (Baltimore City) into the USGS non-tidal water-quality network and adding real-time water-quality parameters to this station. In general, the addition of stream gages in Baltimore City and Anne Arundel County would improve coverage of the region, as would restarting the gage on South Branch Patapsco River at Henryton.

Chesapeake Bay Program

The CBP conducts tidal and non-tidal water-quality monitoring within the metropolitan region. Monitoring conducted as part of the CBP was summarized by Dr. Peter Tango. The CBP Long-term Water Quality Monitoring Network is intended to monitor and assess status and trends of nutrient and sediment concentrations (tidal and non-tidal) and loads (non-tidal), measure and assess the effect of targeted management actions and land-use changes on water quality and living resources (e.g., SAV and

plankton), support prioritization of management activities and targeting of resources, and improve calibration and verification of CBP partner's Chesapeake Bay and watershed models.

Within Baltimore, there are 3 CBP long-term load-trend non-tidal water-quality monitoring network stations (fig. 12). Collection and analysis of water quality and living resource samples are conducted according to U.S. EPA and CBP established protocols. Non-tidal station samples are analyzed for various forms of nitrogen and phosphorous, sediment, carbon, and more. At non-tidal load-trend monitoring sites, water-quality samples are collected monthly. In addition quarterly storm samples are collected with an effort made to sample two storms per quarter providing eight storm samples per year and twenty water-quality samples per year. Non-tidal load-trend sites use USGS protocols approved by U.S. EPA collecting depth and width-integrated samples using an isokinetic sampler.

Tidal monitoring consists of water-quality and habitat assessment of off-shore and shallow water habitats. For tidal water-quality monitoring, a subset of all CBP water-quality monitoring stations have water collected twice per month in vertical profile of the water column during summer, and otherwise monthly. Water samples are analyzed for various physical, chemical and biological parameters including forms of nitrogen and phosphorous, DO, temperature, salinity, and TSS. Fixed station shallow water monitoring collects data for a smaller suite of water-quality measurements in near real time (typically 15 minute intervals) while water-quality mapping with DATAFLOW collects surface sample measures every 3 to 4 seconds over a region. The tidal water-quality monitoring stations in the region have been primarily in the Patapsco and Back Rivers; however the SAV monitoring is comprehensive for all shoreline shallow water acres of the Bay and therefore the Baltimore County region and benthic invertebrate monitoring stations (a blend of fixed and random sites) are representative of regional conditions based on the sampling strategy of this assessment.

Unanswered questions remain regarding the factors affecting changes in nutrient and sediment concentrations and loads. Enhanced monitoring and coordination could provide data to conduct assessments to better understand what drives changes in this region. Network improvements for non-tidal (watershed) areas might include assessments of small watersheds of singular land-uses through time, groundwater monitoring, open access, high resolution land-use and change, and better accounting and tracking of restoration activities. In the long-term, desired improvements include monitoring of contaminants of emerging concern and living resources. Currently, the strongly urban land use is not well represented within the non-tidal network across the Bay watershed. Better geographic distribution

of small urban watershed assessments could be incorporated into the network to help remedy this data gap.

Specific desired network improvements for tidal areas might include, in the near-term, high frequency vertical profiling of water-quality conditions and diverse living resource response assessments. In the long-term, desired improvements include monitoring of contaminants of emerging concern, unified bacteria monitoring and reporting, determination of disease prevalence, better integration of monitoring with citizen programs, and increased data analysis and synthesis support.

Recommendations for the Design of an Integrated Monitoring Network

As previously discussed, this workshop was intended to be a first step in establishing a regional monitoring program (i.e., a network of networks), in support of the Monitoring, Modeling, and Research workgroup of the Baltimore Urban Waters Partnership. In addition to inventorying the assets of the major stakeholders in the region, the workshop organizers wanted to capitalize on the diverse representation of the monitoring community at the workshop and allow the attendees the opportunity to engage in discussions relevant to challenges faced by all stakeholders engaged in monitoring. More specifically, the Monitoring, Modeling, and Research workgroup has the ultimate goal of designing and implementing a long-term monitoring network that adds value, maximizes efficiency, aids in decision making, and is also comprehensive enough for evaluating trends and other stories in the data. The workgroup envisions a network or network of networks that will enable stakeholders to:

(1) track watershed level improvements in water-quality, and inputs to Baltimore Harbor and the Chesapeake Bay,
(2) assess impacts and success of restoration and management efforts, and
(3) provide flood-related information and answer resilience and sustainability questions.

These three network goals were the topics of discussion for the three breakout groups at the workshop. The groups were asked to identify data gaps in current monitoring efforts and make recommendations that would support the development of data assessment questions to design an integrated monitoring network(s). Summaries of their discussions and recommendations are provided in the following sections.

Watershed Level Improvements in Water Quality

Tracking watershed level improvements in water quality (and quantifying urban inputs to the Baltimore Harbor and Chesapeake Bay) via an integrated network poses many challenges as is evident in identified existing data gaps. The breakout group identified the need to improve the conceptual model of the urban water sources in order to better define where the water ultimately goes (i.e., stormwater, sanitary sewers, groundwater and streams) and what controls the amount and partitioning of water between the various pathways. The group suggested that a higher-level assessment of natural (e.g., groundwater, surface water) and built systems (sanitary and storm) would aid the understanding of what is controlling supply. Defining the conceptual model may be improved by the collection of additional discharge and concentration data thus allowing the calculation of loads; however, the assessment may provide better insight into what additional monitoring may be most helpful.

The group also identified the need to better define the causes (e.g., land use change, BMP implementation, climate change) and resulting effects (e.g., improved or degraded water quality) for watershed improvements. Data gaps in infrastructure improvements, land cover, population, and infiltration and inflow (I and I) data were all mentioned. The challenges of attributing the upstream watershed activities to observed water quality changes in streams were acknowledged, using the Gwynns Run, Gwynns Falls/Carroll Park and Watershed 263 examples. The group also acknowledged that the timeframe of data collection needed to detect a change in the long-term trends remains an unknown. Analytical models were mentioned as a way to better relate cause and effect in the watershed. The development of a case study watershed (or subwatershed) such as the BES Gwynns Falls location, was discussed to possibly fill these data gaps and then translate understanding to other watersheds in various jurisdictions.

The group discussed that many agencies and groups are collecting data but no one is charged with compiling and storing it holistically in the region. Due to the lack of a comprehensive database, coupled with variable monitoring frequencies, the group noted difficulties in assessing redundancies and gaps. The group suggested that USGS possibly lead a data integration effort.

Restoration and Management Effort Impact and Success

Similar to the discussion in the previous section, the group was reluctant to zoom out to the subwatershed scale for an evaluation of restoration or management impacts generally due to the difficulties of teasing out the causes and effects already presented. Representatives from MS4 jurisdictions within the group indicated that there are many requirements for individual TMDLs and monitoring of restoration and management efforts. Variability in each restoration or management effort and location was also cited by the group as a hindrance to assessing more broadly the impacts of BMP implementation and stream restoration efforts on the subwatershed or watershed scale. The issue of scale and how to determine the effectiveness of management projects at variable scales was identified as an important data gap by this group.

Gauging success of management and restoration efforts was identified as problematic, since the group thought success was measured in different ways and required both scientific and social inputs. For example, if the engineering and implementation of a project is done correctly but the community is not engaged, the group indicated that the project will not succeed. The need for more community engagement (e.g., phone surveys, volunteer monitoring, fees, maintenance requirements) was identified as a requirement for success. The lack of qualified, professionally-trained monitoring staff for

the intense monitoring required for particular BMPs was identified by the group as a gap. The group suggested that community members may be able to perform some aspects of monitoring of nearby projects, thus engaging them and improving odds for success of the project as a whole.

The challenge of establishing the appropriate monitoring duration for restoration and management efforts and how it relates to the success or failure of a project was a data gap raised by the group. The group indicated that there can be a lag time in biology, groundwater impacts, and other typical monitoring measures from the time of implementation. Suggestions were made to develop protocols for short-term and long-term impacts and success based on experience in the field. In addition, it was recommended that a shift to more functional process restoration and evaluation methods would aid in the determination of impacts of management and restoration.

Since the group did not think monitoring could be distilled to capture impact and assess success on the watershed or subwatershed scale, a need to develop an inventory of management and restoration projects in the region and their monitoring programs (pre- and post-construction) was identified. Since an integrated database may be beyond the scope of this group, a portal was recommended to provide access to existing information, data, and contacts. Both USGS and Baltimore Neighborhood Indicators Alliance (BNIA) were suggested as possible facilitators.

Resilience and Sustainability

Many data gaps and needs were identified by the group in order to provide flood-related information and answer resilience and sustainability questions via monitoring and modeling efforts. The group expanded the need to include drought-related information as well as coastal surge (long-term impacts) and catastrophic storms (short-term impacts) in this assessment. The group acknowledged that different monitoring may be required for these various conditions. Generally, data gaps exist in understanding how flooding and drought impact water resources (both quality and quantity). Further, the group identified the need to assess the long-term shoreline data and how flooding changes over time. The group identified the need to use modeling as well as monitoring for predictive purposes.

It was discussed that some existing data are currently being used and could be used further to inform the public and policy-makers about drought and flood. Stream gages are and could be expanded to evaluate loads. Similarly, some stormwater retrofit work may mitigate flood impacts and this should be assessed. Real-time data can provide warning in some situations (e.g.,, Baltimore City ALERT sites).

The economic and political impacts of this topic were acknowledged by this group, for example, the potential need for zoning changes to create resiliency and minimize future infrastructure needs. Further, the group discussed the difficulty in prioritizing assessment efforts since drinking water, life, and property are all very important. The group suggested that justification of this work may be required to demonstrate that it can be more expensive to fix impacts of flooding than to protect resources.

Next Steps in the Design of an Integrated Monitoring Network(s)

The workshop in June 2014 was intended to be the first step in the development of an integrated monitoring network (or network of networks) to fulfill the goals of the Monitoring, Modeling, and Research pillar of the Baltimore Urban Waters Partnership. A summary of the common data gaps, the development of strategic initiatives by a steering committee, and plans for future meetings are provided in this section and are intended to provide stakeholders, workshop organizers, and the steering committee with some recommended next steps.

Common Themes

A number of common data gaps and needs resonated throughout the stakeholder presentations and in the small group discussions. While MS4 jurisdictions have extensive monitoring requirements, extent of data interpretation is limited by extent of resources. Typically, regulatory required monitoring and reporting does not tell a good story and is not easily translatable between jurisdictions. Agreed upon specific improvements to urban monitoring included increased water-quality monitoring (e.g., chemical assessments and toxics) to existing flow monitoring stations, expanded bacteria analysis, and better defining of pre- and post-restoration monitoring protocols.

There was agreement that all jurisdictions would benefit from a more holistic approach to data collection and analysis and information sharing. Overall workshop feedback from stakeholders reaffirms the need for the integrated, comprehensive monitoring network(s) to answer key questions. Attendance and interest in the workshop reflected the need for a forum to exchange ideas, advancements, and lessons learned in urban monitoring. Webinars (e.g., bi-monthly) and an annual workshop organized by a steering committee were discussed as possible ways to continue to work toward the network development.

All small groups identified the need for more engagement of citizen groups and NGOs in the region. Some positive examples of how NGOs work to fulfill and supplement the jurisdictional requirements of some stakeholders were presented at the workshop. These relationships can be used as a model to

secure additional resources in order to further data collection and analysis efforts and conduct outreach to the surrounding urban communities. Additional outreach needs exist particularly in jurisdictions where resources are limited and there are political obstacles (e.g., "rain tax" opposition) to expanding monitoring programs. More citizen training and data collection can also serve to ensure success of restoration and management efforts. This common need is aligned with the Federal Urban Waters Partnership objectives.

There was a call for an integrated database or data portal to access management and restoration project inventories and status, pre-and post-restoration monitoring plans, contact information, as well as raw monitoring data. The group discussed challenges with data integration efforts attempted in the past; however, the data portal may allow for a linkage of resources without the challenges of combining all data into one database. The portal would allow for queries of data but would require the user to do the actual compilation for their specific needs. Both USGS and BNIA were suggested as possible facilitators for this effort.

There was an acknowledgement throughout the workshop of the critical role that research and long-term monitoring stations play in the region (BES, CUERE and USGS) and the need for continued collaboration between USGS, BES, CUERE, NGOs and the city and county governments. These relationships can facilitate rapid transfer of knowledge from researchers to the practitioners as well as MS4 jurisdictions with more resources to those with less resources. Many of the data gaps identified by the group require a broader, longer term approach and analysis than the individual jurisdictions can undertake. The metropolitan area should continue to capitalize on the existing research projects within the region and expand these projects where possible.

Steering Committee and Action Items

Following the workshop, volunteers for a Steering Committee were solicited by the workshop organizers to further the goals of the Baltimore Urban Waters Partnership, Monitoring, Modeling, and Research workgroup. It is intended that the steering committee will develop a set of strategic initiatives based on the workshop identified data gaps and recommendations and in keeping with the strategic plan outlined by the EPA (2014). In addition, the committee will prioritize and solicit assistance from members of the breakout groups (and other volunteers as needed) to move forward on selected items from each group. These action items can be selected from the common data gaps or small group recommendations.

It is proposed that the strategic initiatives developed by the steering committee be presented in a strategic planning meeting open to all stakeholders to be held in April 2015. At this time, feedback will be solicited regarding both short-term and long-term strategic initiatives outlined by the steering committee. Plans for the annual workshop (to be held in June 2015) will be made at the April meeting. Major topics to be discussed at the annual workshop will be determined, speakers solicited, and logistics arranged at this time.

REFERENCES

U.S. Environmental Protection Agency (EPA), 2014, Urban Waters Strategic Framework. Accessed August 8, 2014, http://www2.epa.gov/urbanwaters/urban-waters-strategic-framework .

FIGURES

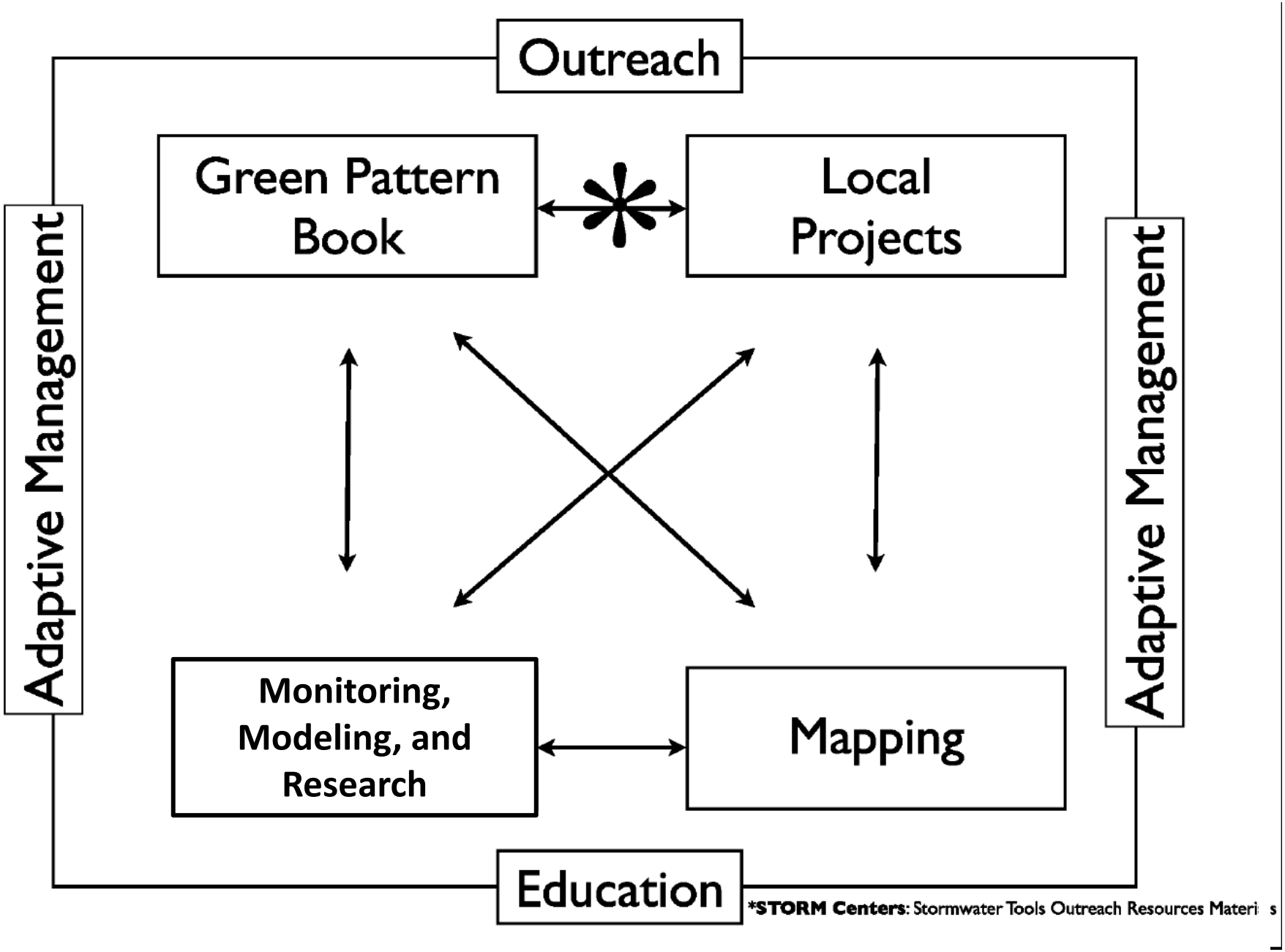


Figure 1. Strategic template for the Baltimore Urban Waters Partnership

Figure 2. Select Baltimore City monitoring asset locations

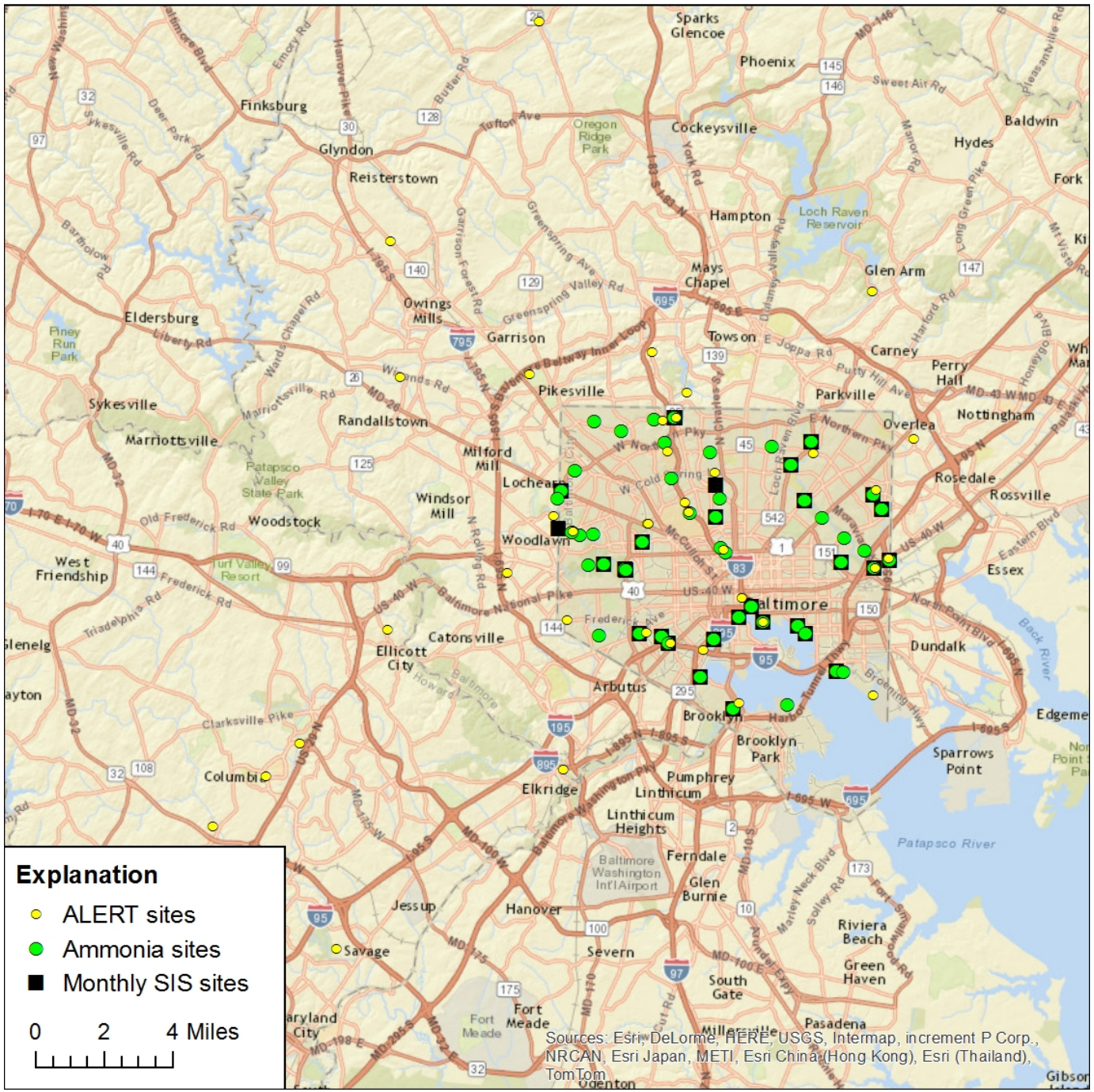


Figure 3. Select Baltimore County monitoring asset locations

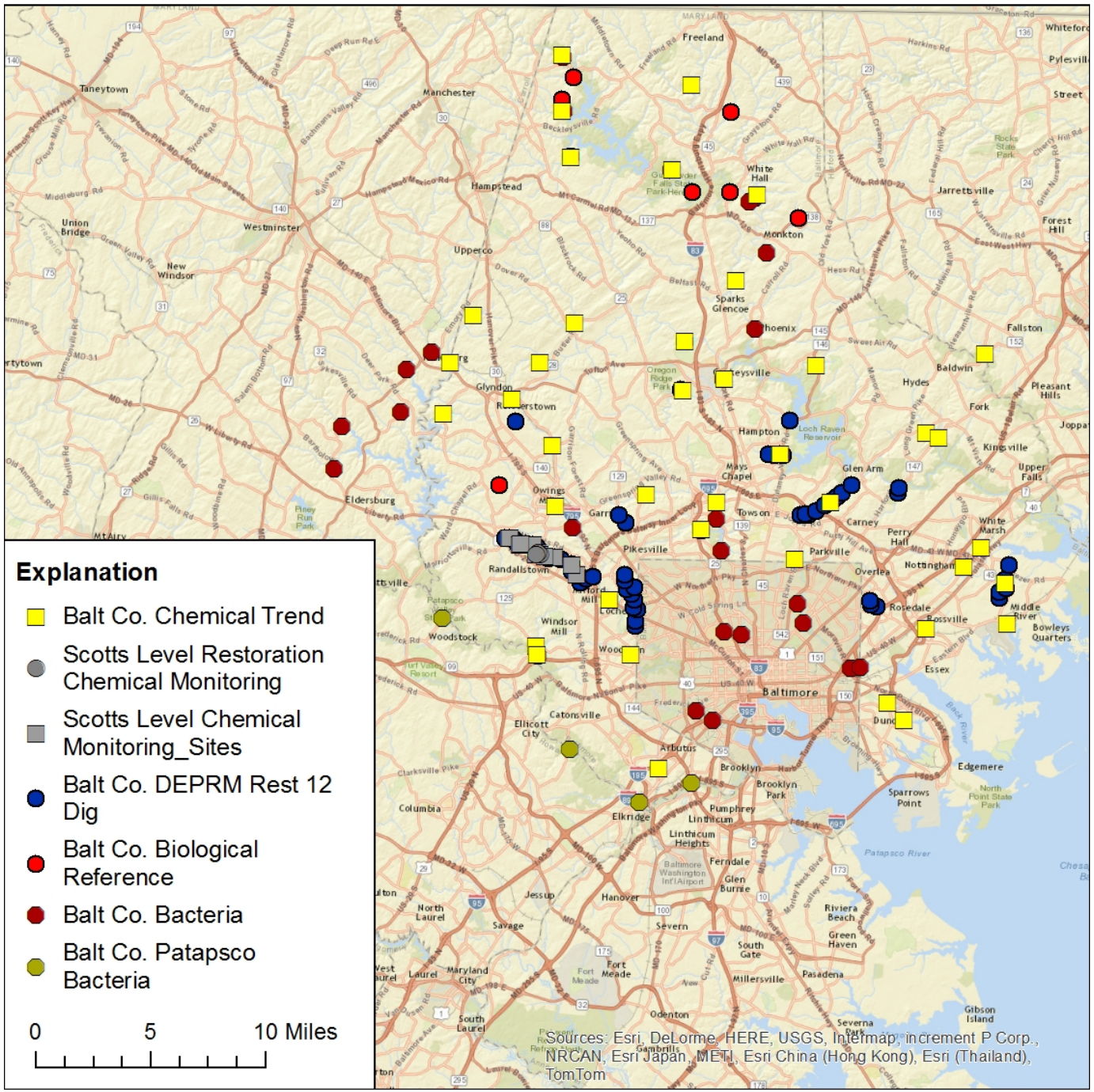


Figure 4. Select Anne Arundel **County monitoring asset locations**

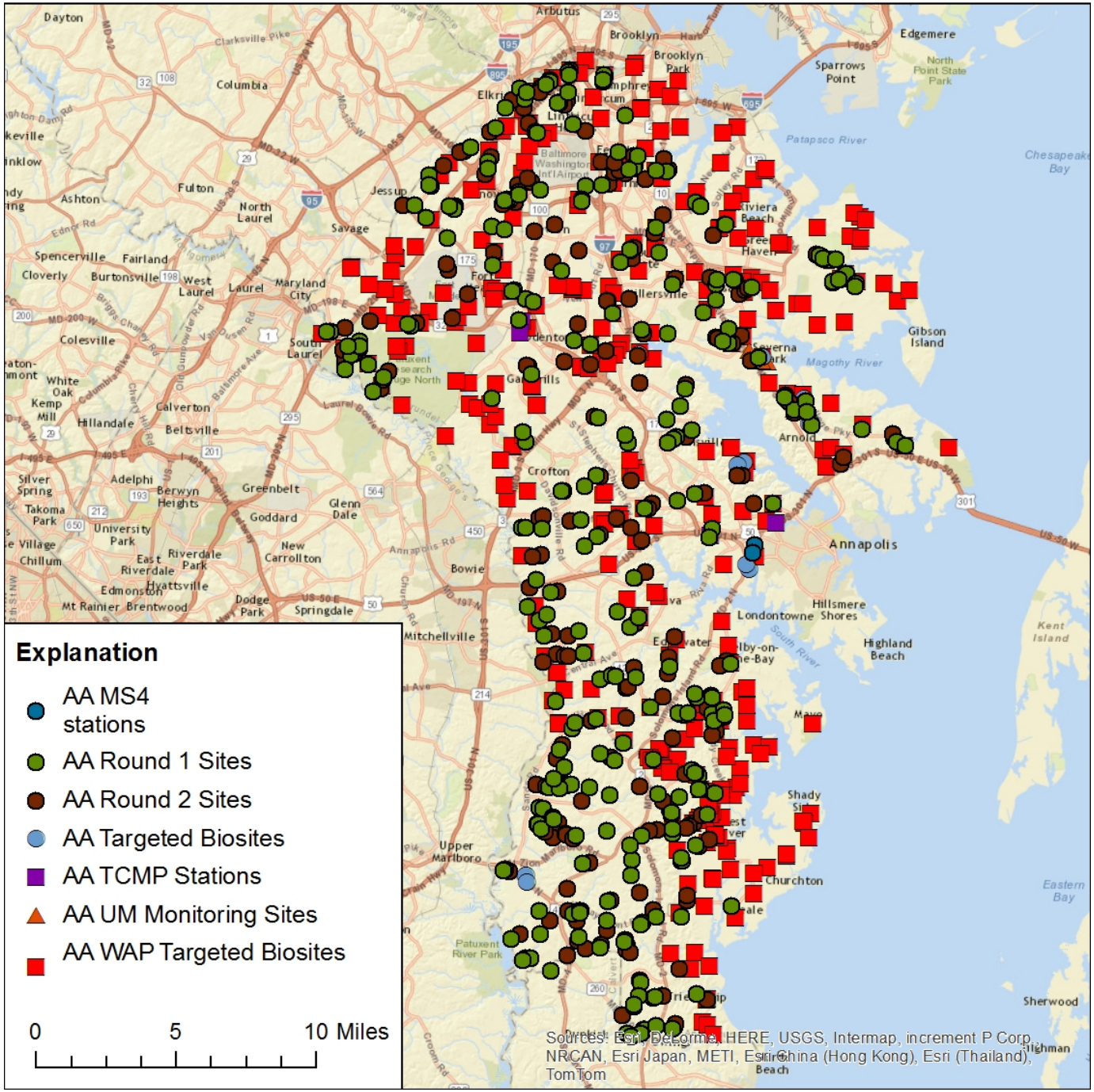


Figure 5. Select Howard County monitoring asset locations

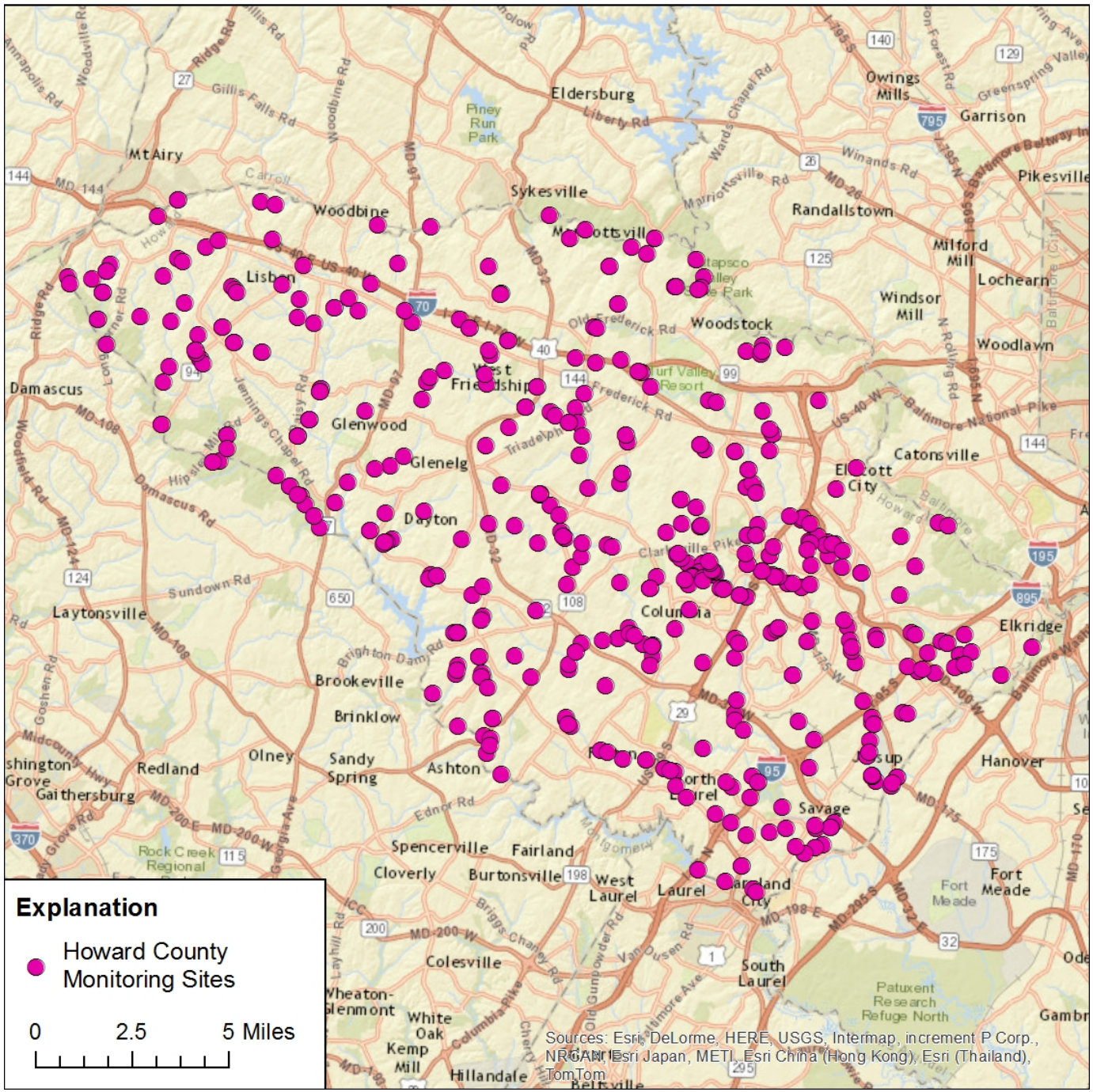


Figure 6. Carroll County monitoring asset locations

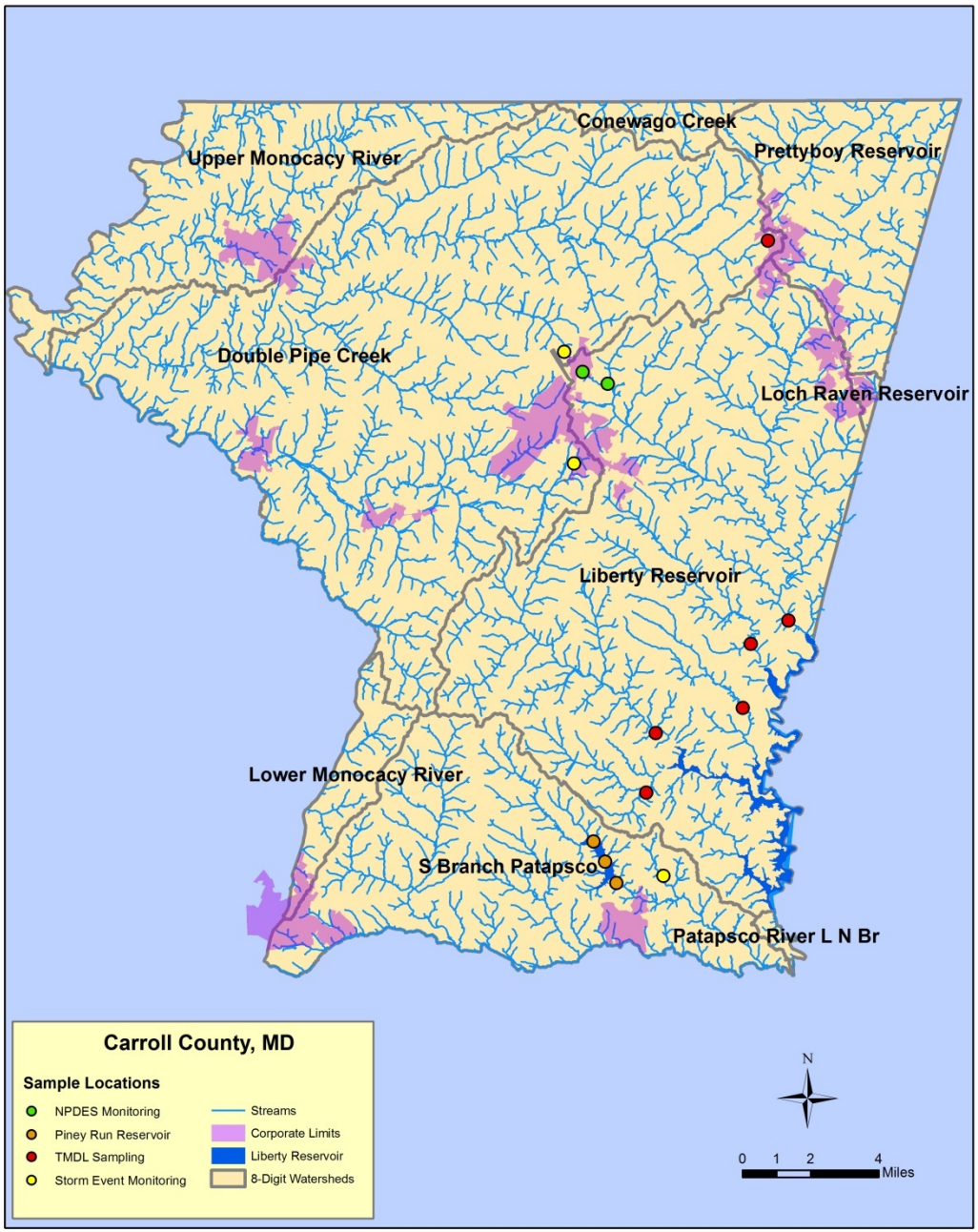


Figure 7. Select Harford County monitoring asset locations

Figure 8. Blue Water Baltimore monitoring asset locations

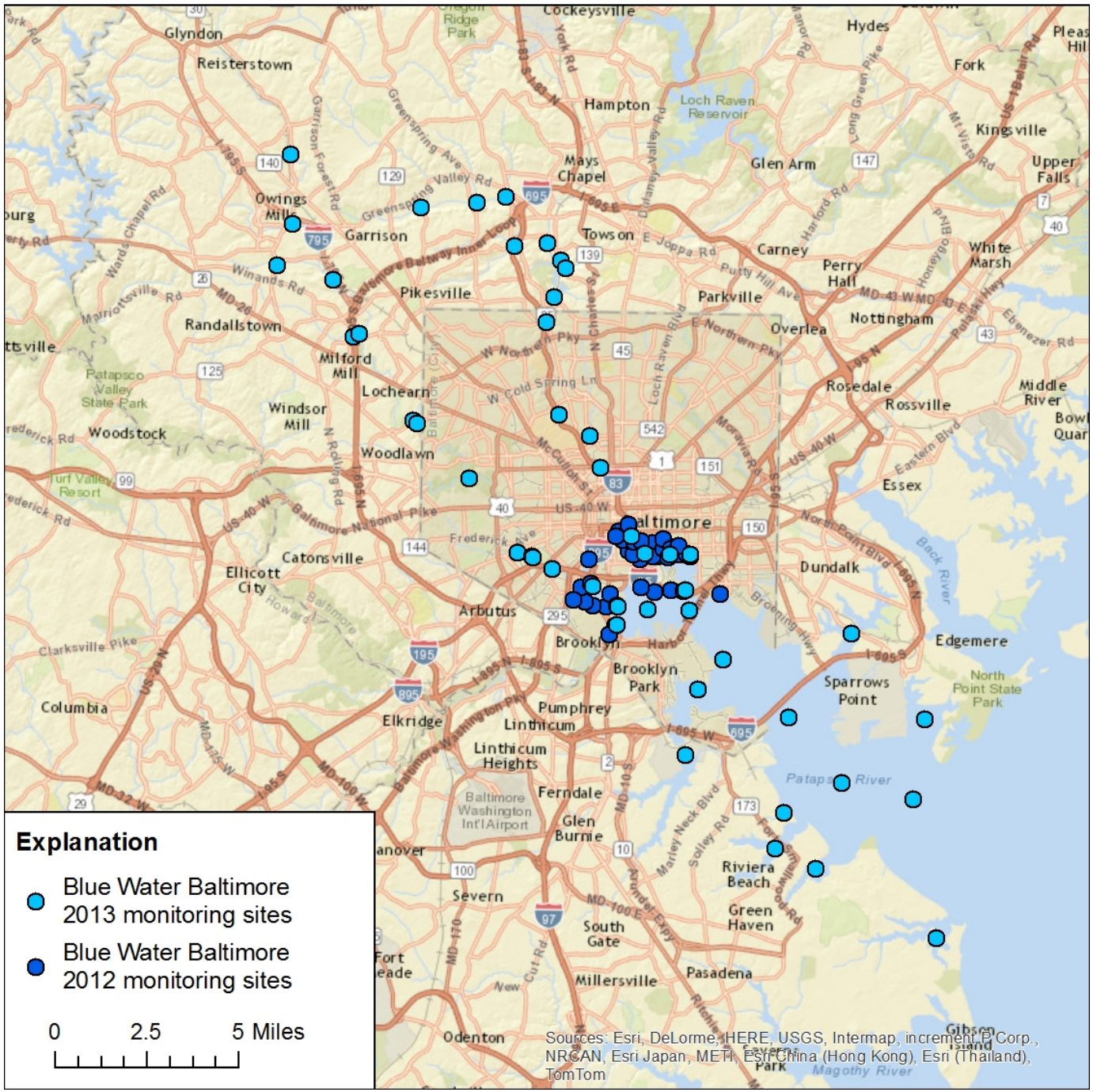


Figure 9. Baltimore Ecosystem Study
LTER monitoring asset locations

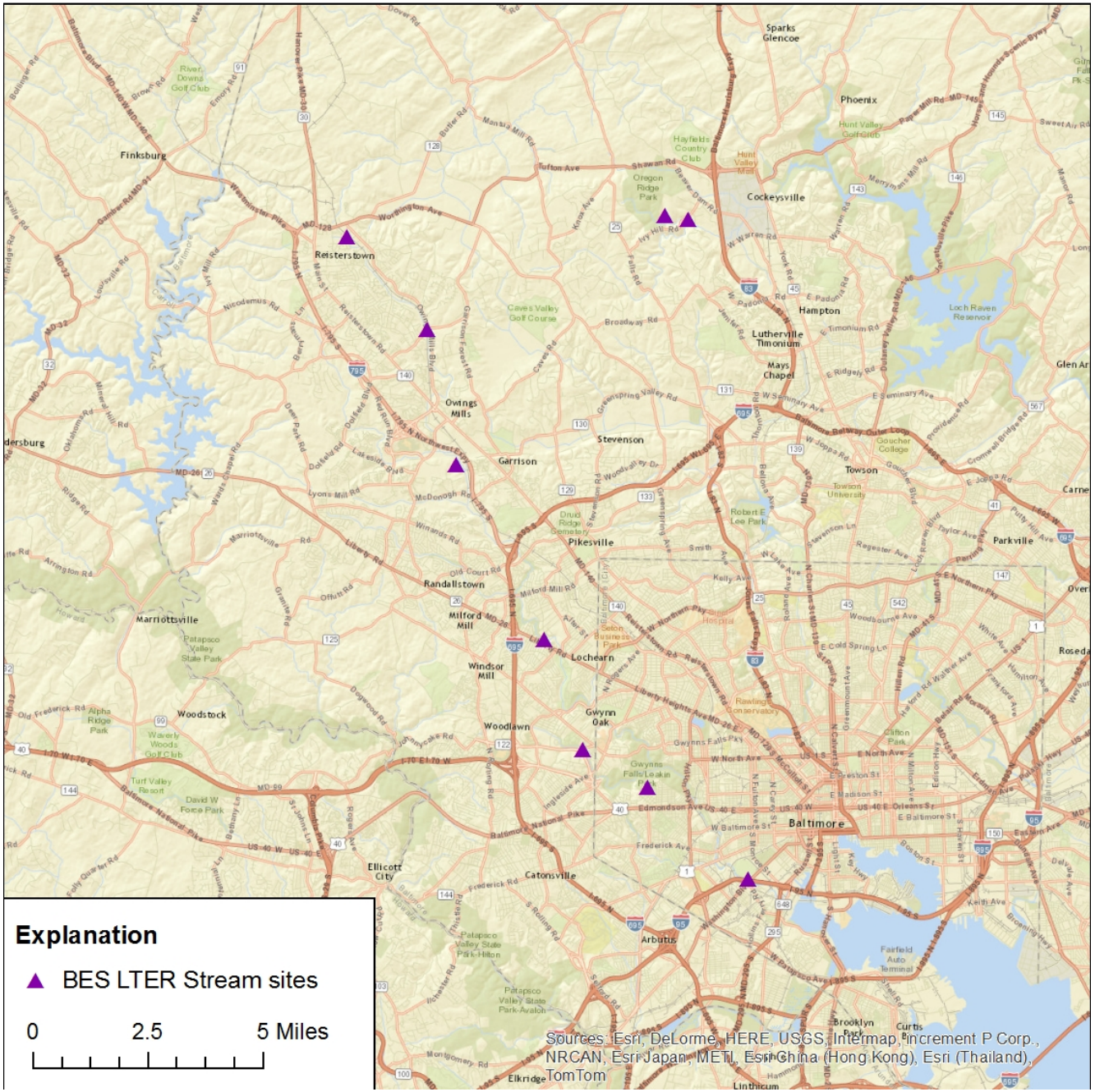


Figure 10. Select CUERE monitoring asset locations

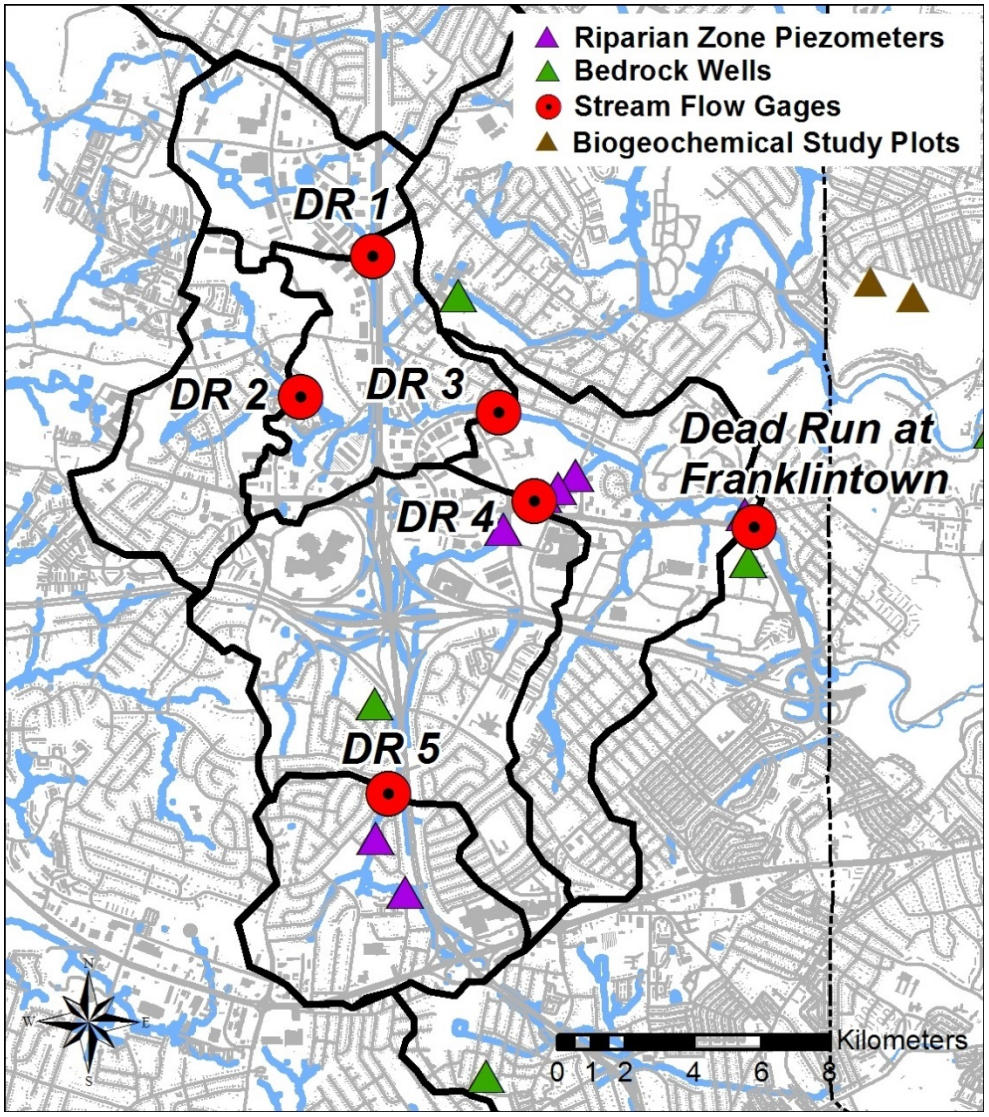


Figure 11. Active and inactive USGS surface water gages

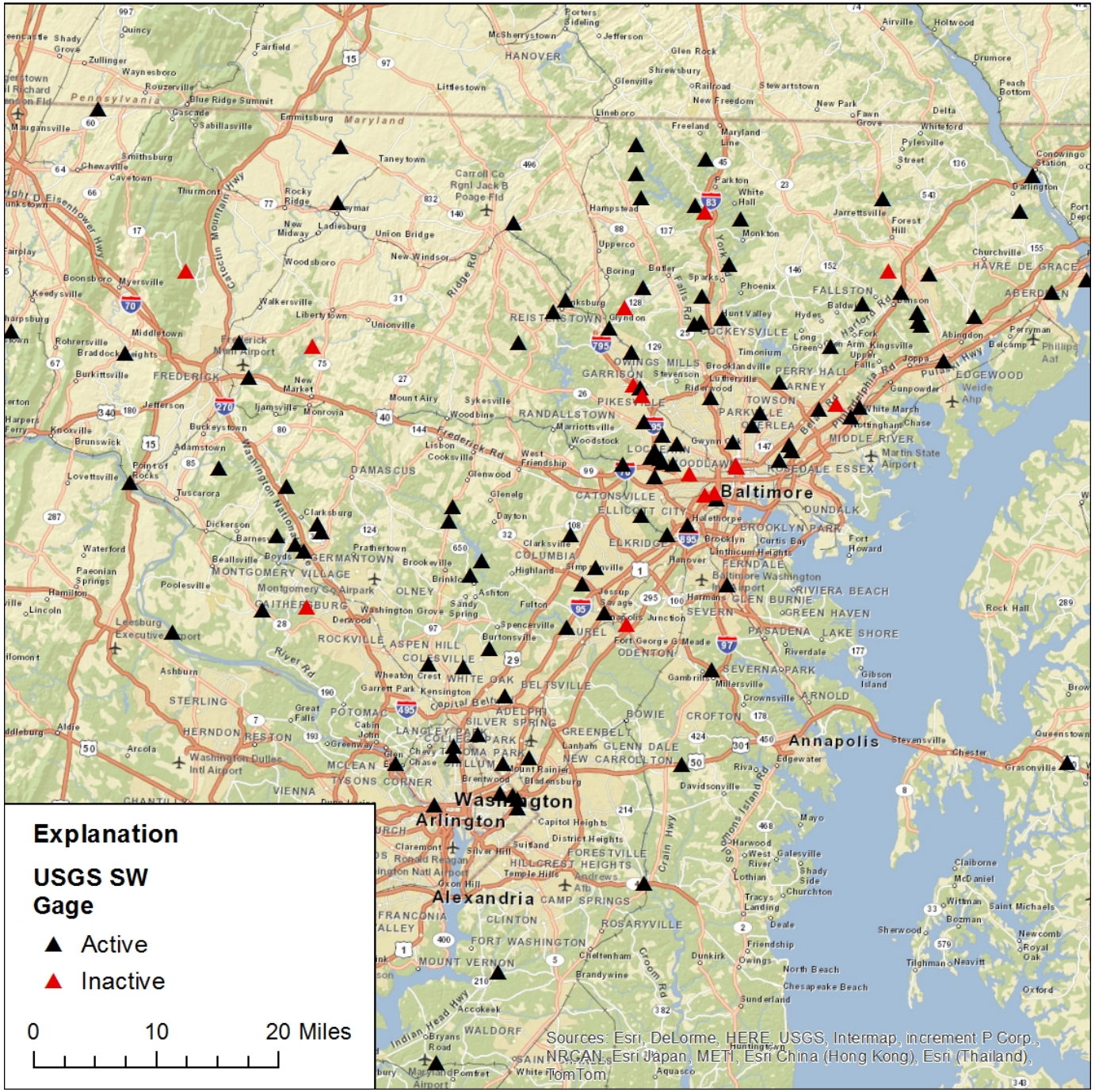
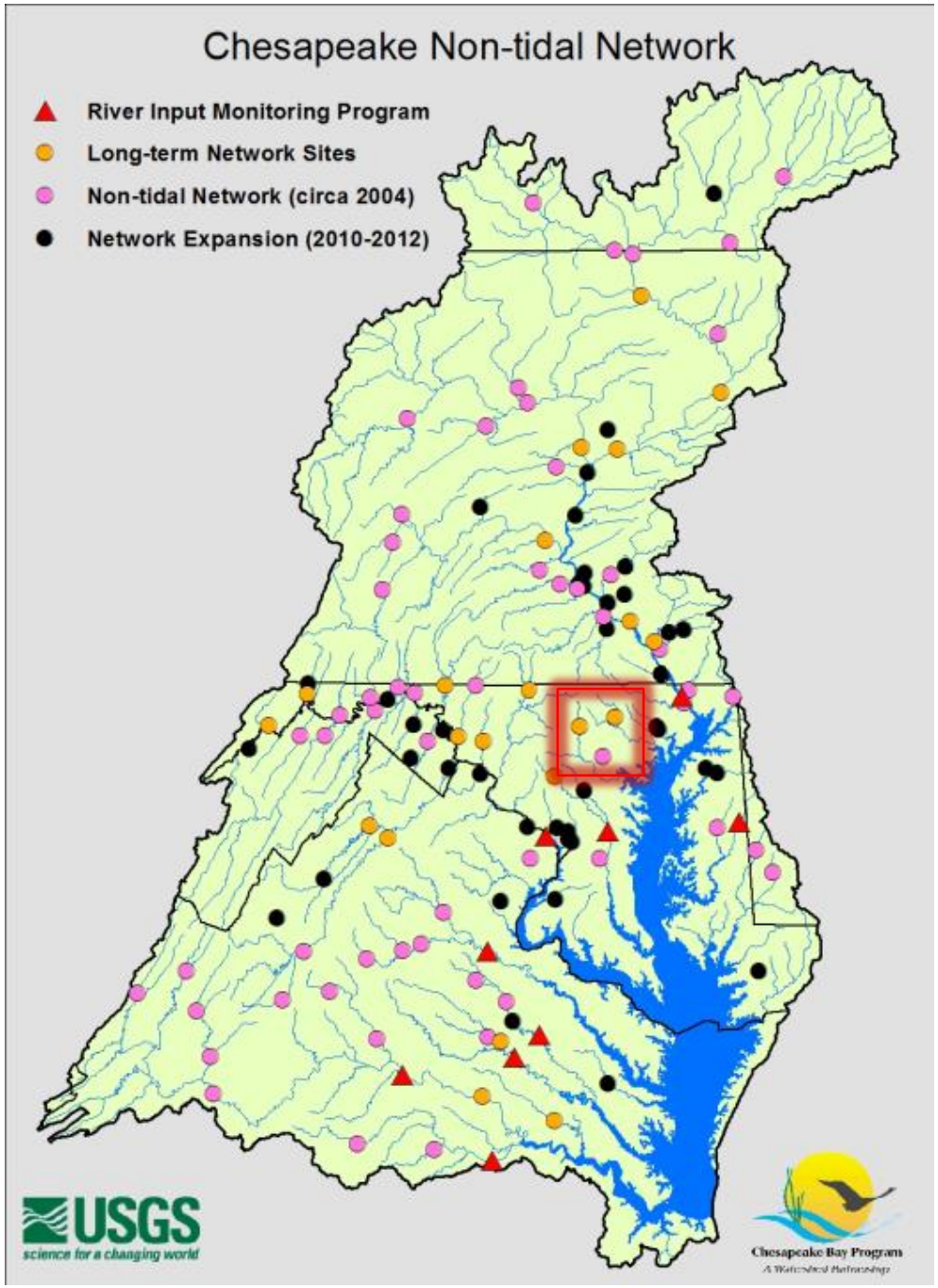


Figure 12. Select Chesapeake Bay Program monitoring asset locations



APPENDIX

FINAL ATTENDEES

Urban Waters Monitoring Assets Workshop

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FINAL ATTENDEES

Urban Waters Monitoring Assets Workshop

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