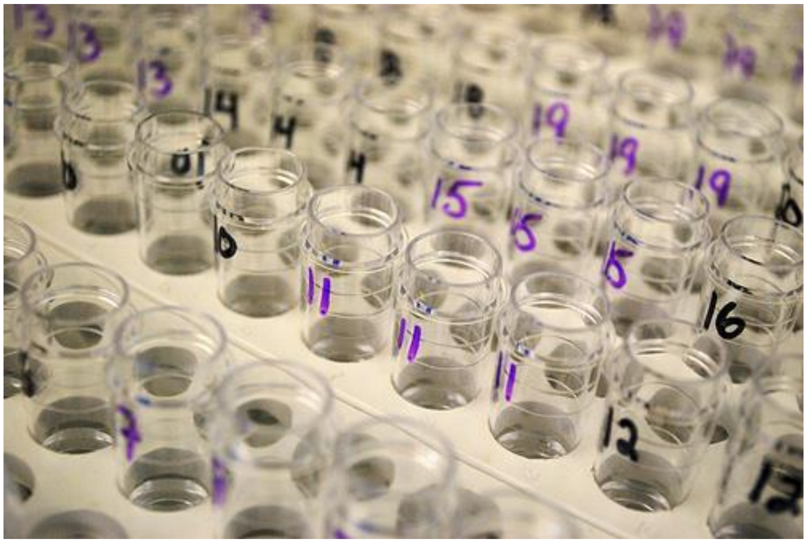
Toxics Contaminants Research Outcome

Management Strategy

2015–2025, v.3



I. Introduction

The Chesapeake Bay Agreement has a goal to ensure that the Bay and its rivers are free of effects of toxic contaminants on living resources and human health. The two associated outcomes are (1) research and (2) policy and prevention. The strategy for the research outcome will improve information about the occurrence, concentrations, sources and effects of toxic contaminants on fish and wildlife. The findings will be used by the Chesapeake Bay Program (CBP) Toxic Contaminant Workgroup (TCW) and Water-Quality Goal Implementation Team (WQ GIT) to consider policy and prevention approaches to reduce the effects of contaminants on living resources in the Bay watershed and make them safer for human consumption. The issues being addressed in the research strategy are consistent with those outlined in 2020 and include:

- Synthesize scientific information to make fish and shellfish safer for human consumption;
- Understand the influence of contaminants degrading the health, and contributing to mortality, of fish and wildlife;
- Document the sources, occurrence, and transport contaminants in different landscape settings.
- Synthesize and promote science to help mitigate contaminants and emphasize the co-benefits with nutrients and sediment reductions; and
- Gather information on issues of emerging concern.

II. Goal, Outcome and Baseline

This management strategy identifies approaches for achieving the following goal and outcome:

Toxic Contaminants Goal

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

Research Outcome

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

Baseline and Current Condition

The TCW originally worked with stakeholders in 2015 to identify the five priority issues to be addressed for this strategy. Aspects of these issues were updated during CBP review process in 2018 and issues remained the same in the 2020 and 2022 updates. They include:

- Synthesize scientific information to make fish and shellfish safer for human consumption.
- Understand the influence of contaminants degrading the health, and contributing to mortality, of fish and wildlife.
- Document the sources, occurrence, and transport of contaminants in different landscape settings.
- Synthesize and promote science to help mitigate contaminants and emphasize the co-benefits with nutrients and sediment reductions.
- Gather information on issues of emerging concern.

The baseline information for different contaminant groups being addressed by these issues originally came from the report "Extent and Severity of Toxic Contaminants in the Chesapeake Bay Watershed" (Chesapeake Bay Program, 2013), and are summarized in table 1. A qualitative assessment of the baseline understanding for the sources, occurrence, and effects for these contaminant groups was prepared by the TCW for the original strategy (figure 1). The contaminant groups with the greatest uncertainty are the primary emphasis of the research efforts; however, the remaining science needs related to PCBs and mercury are included in the strategy.

Progress over the past 2 years has improved our understanding for each of these issues and is summarized in the following text. The information on the current understanding is also used to update the research gaps that are presented in the section on "Current Efforts and Gaps".

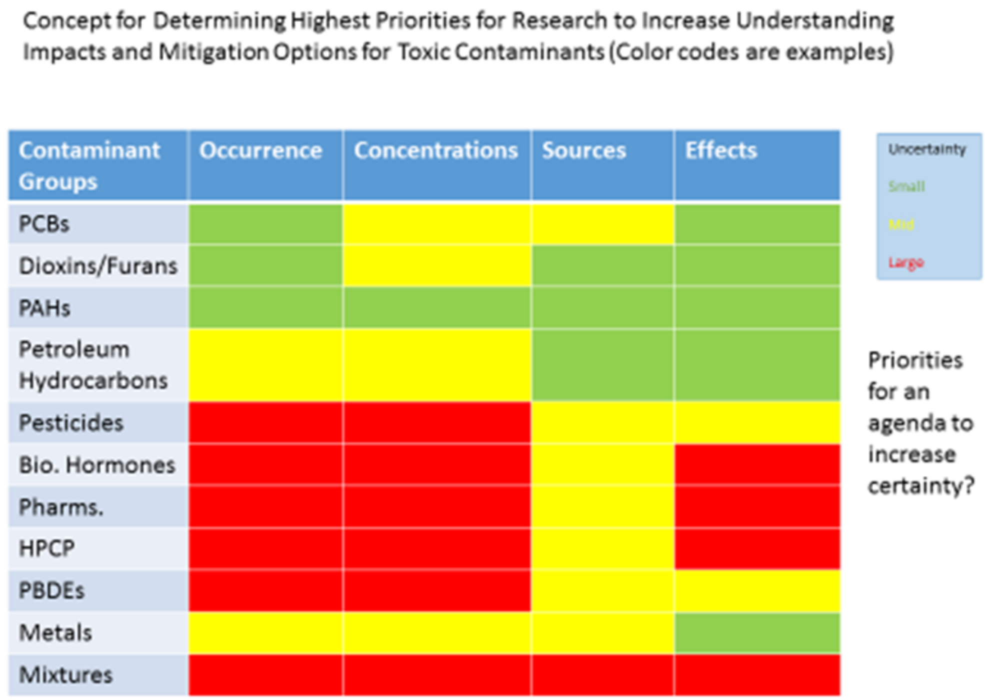


Figure 1: Level of uncertainty for ten contaminant groups about the occurrence, concentrations, sources, and effects on fish and wildlife. (Contaminants with the largest uncertainty are the primary focus on the research strategy, but gaps in the PCB science area also included.)

Issue: Synthesize scientific information to make fish and shellfish safer for human consumption.

PCBs and mercury are the primary causes of fish consumption advisories that have been issued in the Chesapeake Bay and its watershed. PCBs are suspected human carcinogens whereas methyl mercury (the dominant and toxic form of mercury that accumulates in fish) is known to cause impaired neurological development. In addition, these pollutants have adverse ecological impacts. The sources of these pollutants to fish and wildlife can be a combination of exposure to legacy deposits in sediments, ongoing inputs to the watershed from secondary sources that are highly site specific (e.g., PCB contaminated terrestrial sites, previously contaminated stormwater pipes), and ongoing releases (e.g., wastewater and stormwater releases, and atmospheric deposition, especially for mercury). Given these concerns, PCBs were the focus on the initial management strategy for Toxic Contaminant Policy and Prevention. Despite progress, there are still some science needs related to PCBs required to improve their management. Those science needs are included in this Research Strategy and associated Logic and Action plan. This is a change from the previous strategy, where these science needs were included in the Policy and Prevention strategy.

Current conditions highlight that fish consumption advisories continue to be widespread across the watershed, largely due to PCBs, mercury, and to a lesser extent organochlorine pesticide impairment.

Visualizing the impairments and associated management plans are an effective way to communicate and impacts across the watershed in the absence of watershed-wide TMDLs for these compounds. The impairments for both mercury and PCBs are shown below (figure 2) and the story maps are available for mercury https://gis.chesapeakebay.net/mercury/, and for PCBs http://chesbay.maps.arcgis.com/apps/MapSeries/index.html?appid=704ecbbb9f5943eca87d59b349edf1ab. Most emerging contaminants do not have thresholds to identify impaired waters or set fish consumption advisories. Therefore, the extent of impacts to waterways due to toxic contaminants are likely more extensive than shown on the story maps.

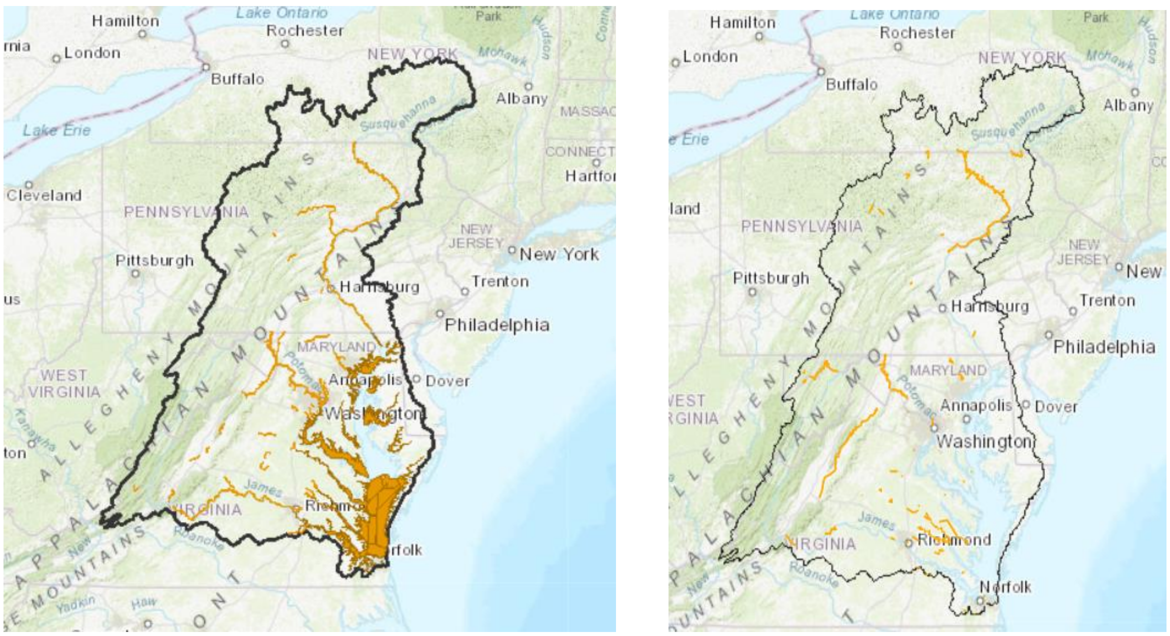


Figure 2. 2017 Impairments for PCBs (left) and mercury (right).

For mercury reductions in fish and shellfish, the jurisdictions in the Bay watershed are depending on national air emission controls and less use of coal for energy production, which should result in less mercury being deposited in the Chesapeake watershed. While statistical declines have not yet been observed in mercury in fish, most jurisdictions have prioritized other contaminants, such as PCBs and PFAS, over mercury. PCB TMDLs in the watershed are driven by risk to humans due to fish consumption. A study conducted in the Back River (Baltimore, Maryland) provided insight into primary drivers of PCB input to an urban, impaired river with a TMDL. Mass loading estimates were conducted from nontidal streams under lowflow conditions, during a storm event, and into and out of a wastewater treatment plant. Wastewater effluent and transport of PCBs on suspended solids during storms dominated PCB input to the receiving water, estimated to be an order of magnitude higher than targeted waste load allocations (WLAs). The study also highlighted the need to address land-application of biosolids, containing 2-orders of magnitude higher loading than wastewater effluent and non-tidal streams. Other highlights included:

- Passive samplers/freely dissolved concentrations can provide clues to areas of the sanitary sewer system that require further investigation suggesting that sewershed trackdown to refine sources should be considered concurrent with a watershed source trackdown.
- Evidence for considerable reductions in the wastewater system with enhanced nutrient reduction upgrades and capital improvements and maintenance, suggested that additional reductions may be observed with continued efforts.

Opportunities for further reduction are likely within the sanitary sewer system itself prior to reaching the plant influent.

(Majcher, E., Ghosh, U., Needham, T., Lombard, N., Foss, E., Bokare, M., Joshee, S., Cheung, L., Damond, J., and Lorah, M., 2022, Refining sources of polychlorinated biphenyls in the Back River watershed, Baltimore, Maryland, 2018–2020: U.S. Geological Survey Scientific Investigations Report 2022–5012, 58 p., https://doi.org/10.3133/ sir20225012)

There is a much broader set of issues related to the effects of toxic contaminants on human health. However, these issues are beyond the scope of the Chesapeake Bay Watershed Agreement, so they are not included in this Toxic Contaminants Research Management Strategy. Many of the human health issues, such as occupational exposure or exposure in residential setting (i.e., lead paint), are being addressed by other government agencies and research organizations and may be incorporated in future efforts if needed to meet the outcome.

Issue: Understand the influence of contaminants degrading the health, and contributing to mortality, of fish and wildlife

There are numerous indications of reduced general and reproductive health of fish populations throughout the watershed. Research findings to date strongly suggest the influence of toxic contaminants. Observed conditions include widespread occurrence of intersex and other gonadal abnormalities, reduced reproductive success of semi-anadromous fishes, occurrence of skin and liver tumors, skin lesions, high parasite loads and opportunistic infectious disease. The impact of endocrine-disrupting chemicals (EDCs) on reproductive systems of fish and wildlife has been documented by the U.S. Geological Survey (USGS), the U.S. Fish and Wildlife Service (FWS), and the National Oceanographic and Atmospheric Administration (NOAA). Chemical contaminants, including legacy and chemicals of emerging concern (CECs), particularly EDCs have had effects on fish (reproductive systems in several species) and selected waterbirds in the Bay ecosystem.

In urban areas, previous studies indicated fish exhibited abnormal tissue growth and reduced reproductive success. Bullhead catfish in the tidal Potomac had liver tumors, with the prevalence in Anacostia some of the highest in North America and were attributed to contaminants such as PAHs and PCBs (Pinkney and others, 2019: https://www.chesapeakebay.net/channel_files/27647/bullhead_fact_sheet_2018.pdf). The findings did reveal that a monitoring of this species can detect changes in tumors over time and this monitoring is ongoing in the Anacostia watershed. The reduced reproductive success of yellow perch, which is believed related to combined exposures to legacy (e.g., PCBs) and emerging contaminants, was observed with increased urbanization (Blazer and others, 2013) and is the focus of ongoing work.

In agricultural settings, The results of a multi-year study on the influence of EDCs and other factors degrading the health and contributing to the mortality of fish were synthesized in a geonarrative and discussed with the joint members of the agricultural workgroup and CBP NRCS staff. Several publications were released and briefed during this two-year period and include:

(Vicki S. Blazer, Stephanie Gordon, Daniel K. Jones, Luke R. Iwanowicz, Heather L. Walsh, Adam J. Sperry, Kelly L. Smalling, Retrospective analysis of estrogenic endocrine disruption and land-use influences in the Chesapeake Bay watershed, Chemosphere, Volume 266, 2021, 129009, ISSN 0045-6535, https://doi.org/10.1016/j.chemosphere.2020.129009.)

Major findings included:

- Intersex or vitellogenin was observed in all five major river systems sampled.
- Testicular oocyte prevalence in largemouth bass ranged from 22 to 100% at 12 of the 14 sites collected during the late season (June - December). Vitellogenin ranged from 0 to 100% across all sites.
- Smallmouth bass testicular oocytes prevalence ranged from 25 to 100% in the late season, and 56 to 100% during the early season (January - May).
- Vitellogenin prevalence in smallmouth bass ranged from 0 to 75% in the 26/40 sites sampled in the early season sampled, and 0 to 100% in the 23/34 late season sampled sites.

A population-level ecological risk model was developed to evaluate effects of environmental stress and bioactive chemicals, and subsequently used to model the impacts of changing water temperature, stream flow, and exposure to estrogenic endocrine disrupting compounds (EEDC) on smallmouth bass populations in the Chesapeake Bay Watershed.

(Yan Li, Vicki S. Blazer, Luke R. Iwanowicz, Megan Kepler Schall, Kelly Smalling, Donald E. Tillitt, Tyler Wagner, Ecological risk assessment of environmental stress and bioactive chemicals to riverine fish populations: An individual-based model of smallmouth bass Micropterus dolomieu, Ecological Modelling, Volume 438, 2020, 109322, ISSN 0304-3800, https://doi.org/10.1016/j.ecolmodel.2020.109322.)

Model results include four fish health population metrics: population size, abundance of spawning and recruit (portion of the population achieving adulthood) fish, and the proportion of fish within a size (quality-length) range.

- Flow and temperature increases demonstrated the most severe effects on all four population measures.
- An increase in exposure level to EEDCs, both year-round and in summer months, substantially reduced population size as well as spawner and recruit abundance, and the proportion of quality-length individuals.
- Acute exposure to EEDCs was more detrimental to the population than chronic exposure.
- Acute exposure during spawning season had the most severe impacts.

Opportunities for collaboration with agricultural workgroup have been ongoing and continue as an action item for the workgroup to address meaningful ways to integrate these findings into actions in the watershed's agricultural land.

Issue: Document the sources, occurrence, and transport of contaminants in different landscape settings

The extent, severity, and sources of ten groups of toxic contaminants in the Bay watershed was previously summarized from existing information (Chesapeake Bay Program, 2013) and are listed in Table 1. Contaminant groups, including PCBs, mercury, polycyclic aromatic hydrocarbons (PAHs), and some pesticides have widespread extent, while the remainder of the groups had localized extent. The findings for severity were based on impairments developed by watershed jurisdictions, which rely on the monitoring of select contaminants in water, sediment and fish tissue. Impairments included human health concerns (e.g., fish consumption advisory), or potential harm to aquatic organisms. During the past two years, there have been studies on sources and occurrence of EDCs, mostly related to pharmaceuticals, pesticides, and biogenic hormones in agricultural areas. These findings will be available in 2021 and improve the certainty for these contaminant groups (figure 1). This issue has evolved to focus more on specific landscape settings that are the primary sources of contaminants: urban (stormwater and WWTPs) and agricultural areas. There will be emphasis on defining the co-occurrence with nutrients and sediment to help take advantage of CBP efforts to improve water quality.

Table 1: Extent and Severity of Contaminant Groups (from Chesapeake Bay Program, 2013)

Contaminant Group	Extent, Severity, and Sources
Polychlorinated biphenyls (PCBs)	PCBs have widespread extent and severity. The severity was based on risk to human health through consumption of contaminated fish with impairments identified in all of the watershed jurisdictions. Some primary sources are contaminated soils, leaks from transformers, and atmospheric deposition.
Mercury	Mercury had both widespread extent and severity. The severity was based on risk to human health through consumption of contaminated fish. The primary source is air emissions from coal-fired power plants.
Polycyclic aromatic hydrocarbons (PAHs)	Widespread extent throughout the Bay watershed. The severity was localized based on impairments for risk to aquatic organisms in a limited number of areas in the watershed. The primary sources are contaminated soils, coal tar sealants, atmospheric deposition, and combustion.
Pesticides	Widespread extent of selected herbicides (primarily atrazine, simazine, metochlor, and their degradation products) and localized extent for some chlorinated insecticides (aldrin, chlordane, dieldrin, DDT/DDE, heptachlor epoxide, mirex). The chlorinated insecticides have localized severity based on risk to aquatic organisms. For many pesticides that had widespread occurrence, water-quality standards were not available to determine impairments. Research shows sublethal effects for some compounds at environmentally relevant concentrations. Primary sources are applications on agricultural and urban lands and legacy residue in soils.
Petroleum hydrocarbons	Localized extent and severity (to aquatic organisms) in a limited number of areas in the watershed.
Dioxins and Furans	Localized extent and severity (to aquatic organisms) in a limited number of areas in the watershed. The primary sources are spills, contaminated soils, and atmospheric deposition.
Metals and Metalloids	Localized extent and severity (to aquatic organisms) of some metals (aluminum, chromium, iron, lead, manganese, zinc) in a limited number of areas in the watershed. The primary sources are spills, industrial processes, and atmospheric deposition.

Contaminant Group	Extent, Severity, and Sources
Pharmaceuticals, Household and Personal Care Products, Flame Retardants, Biogenic Hormones	Information was not adequate to determine extent or severity. However, their use in the watershed suggests widespread extent is possible. Severity was not accessed but research shows sublethal effects to selected aquatic organisms for some compounds at environmentally relevant concentrations. Range of sources from wastewater treatment and septic tanks to animal feeding operations. Biogenic hormones assessment was focused on naturally occurring compounds from human or animals.

For urban areas, the STAC workshop and report concluded that the fate and transport of contaminants with suspected fish health effects (e.g., CECs) and their transformation products are largely unknown in urban areas, including degradation characteristics and partitioning (water, sediment preference) of these contaminants under different environmental conditions. For contaminants with known and unknown fish health effects, site-specific sources of the contaminants that are the primary risk drivers are largely unknown making selection of appropriate management actions difficult.

For agricultural areas, the sources of contaminants are relatively well defined but detailed information on many CECs is currently limited**.** Primary sources include pesticide use, manure storage/application, biosolid application, irrigation treated wastewater, and septic systems.

Long-term monitoring sites in agricultural watersheds across the Chesapeake Bay Watershed were assessed to document the effects of stream flow and landscape variables on contaminant concentrations and co-occurrence patterns.

(Kelly L. Smalling, Olivia H. Devereux, Stephanie E. Gordon, Patrick J. Phillips, Vicki S. Blazer, Michelle L. Hladik, Dana W. Kolpin, Michael T. Meyer, Adam J. Sperry, Tyler Wagner, Environmental and anthropogenic drivers of contaminants in agricultural watersheds with implications for land management, Science of The Total Environment, Volume 774, 2021, 145687, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2021.145687.)

Results

- Contaminant concentrations were often positively correlated with seasonal stream flow, although the magnitude of this effect varied by contaminant across seasons and sites. However, contaminant co-occurrence patterns were not affected by seasonal flow or proportion of agricultural land-use near the sampling locations.

- Land-use and other less utilized landscape variables including biosolids, manure and pesticide applications, and percent phytoestrogen producing crop cover were inversely related with site average contaminant concentrations.

Long-term monitoring sites in five agricultural watersheds across the Chesapeake Bay Watershed were established and sampled monthly from 2013 to 2018 to understand relationships between flow, contaminants, and landscape variables, as well as assess the effects of land management actions (also known as Best Management Practices (BMPs)) on contaminants in streams.

(Catherine M. McClure, Kelly L. Smalling, Vicki S. Blazer, Adam J. Sperry, Megan K. Schall, Dana W. Kolpin, Patrick J. Phillips, Michelle L. Hladik, Tyler Wagner, Spatiotemporal variation in occurrence and co-occurrence of pesticides, hormones, and other organic contaminants in rivers in the Chesapeake Bay

Watershed, United States, Science of The Total Environment, Volume 728, 2020, 138765, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2020.138765.

Results

- Of the 301 compounds analyzed in 370 surface-water samples, 109 (36%) were observed at least once. The compounds detected included eight hormones, 27 pesticides, 25 pharmaceuticals, 38 organic waste indicator compounds, and 11 phytoestrogens and mycotoxins.

- The highest probability of contaminant occurrence occurred in the spring and summer.

- Four pesticides (atrazine, metolachlor, fipronil and simazine) co-occurred frequently in surface water across sites. These findings provide baseline information on patterns of contaminant occurrence within agricultural watersheds of Chesapeake Bay Watershed.

Groundwater discharge zones could be a unique exposure pathway of chemicals to surface water systems and are a potential pathway for phytoestrogens entering streams.

In preparation for the STAC Workshop, an inventory of efforts underway to assess PFAS was conducted in the watershed and will be included in the forthcoming workshop report.

Issue: Synthesize and promote science to help mitigate contaminants and emphasize the co-benefits with nutrients and sediment reductions.

This issue was included in the previous revision to the Research Strategy to provide a scientific basis to help identify and prioritize options for mitigation instead of developing approaches based on the relative risk of different contaminant groups. It was envisioned that this would provide a more streamlined approach for decision makers to develop options for reducing the impacts of contaminants in settings where they are most prevalent and take advantage of nutrient and sediment reductions efforts already underway.

Further investigation into the potential co-benefits of BMPs included both agricultural and urban landscapes. Site comparisons between treated (with BMPs) and untreated agricultural and urbanized watersheds, wastewater treatment plants and combined sewer overflows allow for direct measurement of nutrient management techniques as a potential strategy to reduce estrogens in environmental waters. {(Kelly L. Smalling, Olivia H. Devereux, Stephanie E. Gordon, Patrick J. Phillips, Vicki S. Blazer, Michelle L. Hladik, Dana W. Kolpin, Michael T. Meyer, Adam J. Sperry, Tyler Wagner, Environmental and anthropogenic drivers of contaminants in agricultural watersheds with implications for land management, Science of The Total Environment, Volume 774, 2021, 145687, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2021.145687.)

Results

- The natural hormone estrone (E1) was widely distributed and positively correlated with total estrogenicity (E2Eq), water temperature, and dissolved organic carbon (DOC).
- Among nonpoint sources, E2Eq, E1, soluble reactive phosphorus (SRP) and total dissolved nitrogen (TDN) decreased in urban and agricultural streams with best management practices (BMPs) relative to streams without BMPs.

- >94% of E1, estrone-3-sulfate (E1-3S), estriol (E3), total estrogenicity and TDN were removed while SRP increased during the nitrification/denitrification part of advanced wastewater treatment.
- Concentrations of estrone in WWTP effluents were comparable or even lower than those observed in the receiving stream or river water.
- Highest total estrogenicity values and concentrations of E1, E3, and TDN were detected in combined sewer overflow (CSO).

The ability (i.e., statistical power) to detect regional declines in chemical contaminant concentrations in streams and rivers is currently unknown. A study was conducted to explore the statistical power to detect regional temporal trends in river contaminant concentrations within the Chesapeake Bay Watershed as a result of BMP implementation.

(Tyler Wagner, Paul McLaughlin, Kelly Smalling, Sara Breitmeyer, Stephanie Gordon, Gregory B. Noe, The statistical power to detect regional temporal trends in riverine contaminants in the Chesapeake Bay Watershed, USA, Science of The Total Environment, Volume 812, 2022, 152435, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2021.152435.)

Results

- For herbicides atrazine and metolachlor, that have had 30 years of regular sampling across the Chesapeake watershed, there were significant declining regional temporal trends in river concentrations of approximately 4% per year. Temporal trends for total estrogenicity and total PCBs were also negative, but not statistically significant –
- Monitoring programs aimed at detecting small annual declines (< 5 to 7 % declines per year) are underpowered and unlikely to detect these small rates of decreasing contaminant concentrations, unless sampling has occurred at roughly 100 or more sites for at least 20 years
- Monitoring for short time periods (e.g., 5 years) is inadequate for detecting regional temporal trends, regardless of the number of sites sampled or the magnitude of the annual declines –
- Annual sampling frequency had little impact on the ability to detect regional trends for any monitoring scenario. This suggests that sampling all sites every year is not necessary –
- Overall, the ability to detect temporal trends was greatest for total estrogenicity, suggesting that this aggregate measure of estrogenic activity may be a useful indicator.

Issue: Gather information on issues of emerging concern

In the past, issues of emerging concern included contaminant toxicity to pollinators (including neonicotinoids), microplastics, and unconventional oil and gas drilling (known as "fracking"). More recently, additional issues were identified for heightened focus including harmful algal blooms (HABs) and their associated toxins; the potential effects of poly- and perflouroalkyls (PFAS), reducing the effects of road salts, and runoff from coal combustion residual storage facilities and fly ash.

Chloride from Road Salt: Road salts, when applied in large amounts to reduce ice and snow, affect the quality of streams mainly due to chloride loading. The State of Maryland is working with the State Highway Administration to identify strategies that may reduce impacts to streams without compromising public safety. Further, Maryland is considering a TMDL for chloride to help reduce the impacts of road salts on stream health. Virginia has developed a chloride TMDL for the Accotink Creek watershed. As part of implementing that TMDL and proactively addressing chloride loads throughout

Northern Virginia, Virginia is developing a Salt Management Plan that will provide recommendations for best practices, education and outreach, salt tracking and reporting, and monitoring and research.

III. Participating Partners

The following partners participated in the revision of this strategy. A workplan with more details on actions for each partner during for 2018-19 has also been prepared.

Chesapeake Bay Watershed Agreement Signatories

- Maryland Department of the Environment
- Maryland Department of Natural Resources
- Virginia Department of Environmental Quality
- DC Department of the Environment
- Pennsylvania Department of Environmental Protection
- Delaware Department of Natural Resources and Environmental Control
- New York Department of Environmental Conservation
- West Virginia Department of Environmental Protection
- Chesapeake Bay Commission (CBC)
- U.S. Environmental Protection Agency
- U.S. Geological Survey
- U.S. Fish and Wildlife Service
- National Oceanic and Atmospheric Administration

Other Key Participants

- Non-Governmental Organizations
  - Bluewater Baltimore
  - Metropolitan Washington Council of Governments
  - MD Pesticide Network
  - Interstate Commission on the Potomac River Basin
  - Chesapeake Bay Commision
- Private sector organizations
- University of Maryland, Baltimore County
- Virginia Polytechnic Institute and State University
- Virginia Institute of Marine Science
- Morgan State University
- CBP Local Government Advisory Committee
- CBP Water Quality Goal Implementation Team Workgroups
- Baltimore Urban Waters Partnership Actionable Science Workgroup

Local Engagement

Most of the actions to plan and complete the actual research are expected to be the responsibility of federal, state and academic entities. In the original strategy, local governments and NGOs were helpful in identifying priorities. In the revised strategy we want to increase communication of science results in order to guide an integrated approach to addressing nutrient and sediment reduction (required under the Bay TMDL) with the potential benefits of concurrent reductions in toxic contaminants. Increasing the awareness of the impacts of toxic contaminants, especially safe consumption of fish and shellfish, will be carried out with local governments and non-governmental organizations. Efforts will be targeted towards areas with diverse and underrepresented populations in the Bay watershed.

IV. Factors Influencing Success

The revised factors for the strategy include:

Understanding and defining sources of contamination leading to fish consumption advisories

Fish consumption advisories are established by the states, based on human health risks from different contaminants. There are resource constraints to collect and analyze fish and associated samples every year to assess attainment of standards and to quantify explicit reductions from targeted management actions.

Multiple factors affecting the health and mortality of fish and wildlife

Studies suggest there are multiple contaminants and additional factors are causing the degradation (and mortality) of fish and wildlife. Therefore, trying to identify specific causes is extremely difficult and complicates developing management options. Lack of interaction with wildlife management agencies limits addressing impacts beyond fisheries.

Lack of data on the occurrence and trends of toxic contaminants

There is no watershed-wide monitoring program on the condition of fish and wildlife that is integrated with surface water and sediment sampling for specific toxic contaminants. Therefore, there is a lack of consistent information (both spatial and temporal) on the occurrence and concentrations of toxic contaminants, limiting trends analysis of any kind. Some of this is due to the high cost of generating new data on toxic contaminants. Additionally, there are few laboratories that have the capabilities to conduct analysis for all the contaminant groups. This limits the ability to understand the extent of contaminants in the watershed and their relation to fish and wildlife.

Limited information of the practices to mitigate contaminants, and their direct and potential co-benefits with nutrients and sediment reductions

While studies are being completed, information is limited and additional information on the effectiveness of practices to reduce selected contaminants will be needed to take advantage of CBP water-quality models and tools, which are currently focused on nutrients and sediment.

Emerging issues

There is limited knowledge and capacity to assess the state of the science for the numerous emerging issues, their occurrence in the watershed, and the implications (e.g., toxicity effects) of individual emerging issues.

Resource constraints

The ability to improve the understanding of contaminants is constrained by limited resources. The constraints include (1) minimal capacity within the CBP to address contaminants; (2) an emphasis on nutrients and sediment that limits the opportunity for increased CBP focus on toxic contaminants; and (3) minimal funding opportunities to conduct additional studies.

Synthesis

Limited capacity of resource managers and stakeholders in the Chesapeake Bay watershed to review and extract relevant information of from technical articles and reports that can be used for implications for Policy and Prevention.

V. Current Efforts and Gaps

The information from the "Baseline and Current Conditions" section of the strategy helped to identify the research gaps presented for each issue in this section of the strategy. The on-going efforts to address each issue are also summarized here and explained further in the management approaches (next section) of the strategy document.

There are ongoing efforts, by multiple organizations in the Bay watershed, to assess toxic contaminants and their effects on fish and wildlife. The types of studies and monitoring include:

- Monitoring to assess water-quality impairments and issue fish consumption advisories in state waters.
- Documenting the extent of degraded fish conditions and wildlife conditions and relation to toxic contaminants and other factors (such as disease). Specific examples include monitoring the prevalence of liver tumors in fish and the linkage with sediment contamination.
- Monitoring and assessment for occurrence and concentrations of selected contaminant groups (including legacy, emerging, and those of widespread occurrence) and their relation to different sources and landscapes.
- Research on effectiveness of management practices and mitigation techniques to reduce contaminants, and their potential stand alone and co-benefits with nutrient and sediment reduction.

Issue: Synthesize scientific information to make fish and shellfish safe for human consumption

- **Current Efforts:** All states and DC, in cooperation with USEPA, have existing monitoring programs to identify impairments in water bodies (303(d) list) and set fish consumption advisories. In most jurisdictions, PCBs and mercury are the current, primary driver of fish consumption advisories. Jurisdictions have progressed over the past two years in understanding the extent of the PCB impairments, developing TMDLs (VA), and implementing TMDLs (MD) in the watershed. Progress to better understand of sources of PCBs in the environment has been initiated by jurisdictions implementing approved PCB TMDLs (MD, DC). Geographic-focused remediation efforts through other regulatory programs also results in progress. In addition, progress has occurred on the development of regional models such as the James and Elizabeth River and Baltimore Inner Harbor watersheds, that can help with better understanding sources and occurrence of PCBs. Information from these models may help other jurisdictions in the development of other regional models being considered within the watershed.

For mercury, Maryland conducted fish tissue collections from 2018-2020 to reassess five remaining Hg listings in Western Maryland. The reassessment was completed in 2021 and demonstrated that four of the remaining Hg impairments can be delisted and removed from Category 5 of Maryland's Integrated Report (IR). Three Hg impairments were delisted in the 2022 IR and it is anticipated that one Hg impairment will be delisted in the 2024 IR. The Youghiogheny River Lake is the only remaining listing in Maryland that will remain on Category 5. At this time, MDE does not plan to move forward with Hg TMDL development to address this remaining listing as Hg concentrations in fish tissue continue to decline in Maryland. USGS, as part of the EDC project, will be reporting on results of mercury in fish fillets in two locations within the watershed, one in the Potomac and another in the upper Susquehanna.

Most jurisdictions have initiated or plan to initiate PFAS sampling of fish primarily for fish consumption assessment. …

- **Research Gaps for PCBs:** While progress on PCB source identification has occurred, gaps remain related to approaches to refine sources (including sampling and analysis methodology), status and change in environment, and BMP effectiveness (including co-benefits with nutrients and sediment) for toxic contaminant reduction. Gaps also remain to understand best methods and approaches for translation of BMP science for PCBs into decision tools.
- **Research Gaps for Mercury:** The Willacker and others (2020) study indicated that the pattern of fish mercury concentrations was not consistent with regional patterns in atmospheric mercury wet deposition; for example, mercury deposition is highest in the southern portions of the watershed and lowest in the north, whereas fish mercury concentrations displayed the opposite pattern. This apparent disconnect supports findings elsewhere that biogeochemical and ecological drivers are important determinants for fish mercury bioaccumulation, confounding the linkage with inorganic mercury loading from the atmosphere (Willacker and others, 2020). Despite these remaining gaps, jurisdictions have prioritized other contaminants (PFAS and PCBs) above mercury at this time.
- Research Gaps for PFAS – Numerous gaps were identified as part of the PFAS STAC Workshop and recommendations are forthcoming in the workshop report.

Issue: Understand the influence of contaminants degrading the health, and contributing to mortality, of fish and wildlife

Current efforts: Research is ongoing between jurisdictions, federal, and academic partners to better understand the influence of toxic contaminants on the health of fish and wildlife as well as confounding factors that may make them more susceptible to disease in the presence of these contaminants. In the Potomac and Susquehanna basins, studies are also addressing the complex interactions of chemical, pathogens and parasites, and other factors contributing to fish mortalities. Results from many of these studies have been summarized in the section on baseline and current conditions.

State agencies will continue to have the lead to respond to fish and wildlife kills and determine if the likely cause is a spill or accidental release of petroleum, toxic contaminants, or low dissolved oxygen conditions. Additionally, the NOAA Office of Response and Restoration has responsibility to assess fish kills due to chemical spills in coordination with the US Coast Guard and state agencies.

- **Research gaps:** Monitoring and research are still needed to further determine the occurrence of fish and wildlife health conditions and their primary causes. Biological monitoring is of fish and wildlife health conditions are not adequate to assess status across the watershed or even in selected landscape settings (agricultural and urban areas), but geographically focused efforts have provided insights for further study. Studies conducted over the past several years have had difficulty defining which contaminants (and mixtures), and factors contribute to 1) causing the greatest degree degradation of the health and reproductive systems of fish and wildlife, (2) compromising the immune systems of fish and making them more susceptible to other environmental stresses, such as pathogens, parasites; and the effects of hypoxia; 3) prevalence of for tumors; and 4) in embryo and larval survival. Therefore, research on the causing degradation of fish and wildlife population is still needed. Some specific gaps identified as part of the STAC workshop (Majcher and others, 2019) are still relevant and include:

    a. Evaluate the ways that multiple stressors (both chemical and non-chemical) lead to adverse effects at the individual and population level in both agricultural and urban settings.
    b. Establish the linkages between agricultural land use, contaminants, immunosuppression, water quality, and disease in agricultural watersheds.
    c. Examine the declines in anadromous and semi-anadromous fish populations associated with urbanization. Such information will help managers focus efforts to minimize these impacts as land use changes throughout the watershed.
    d. Determine the sources of the pollutants entering the food chain and the contribution of ongoing inputs on consumption advisories.

In addition to fish consumption gaps, research gaps associated with the effects of PFAS on the health of fish were also identified during the STAC workshop. Specific gaps are expected to be outlined in the STAC workshop report.

Issue: Document the sources, occurrence, concentrations, and transport of contaminants in different landscape settings

Better understanding sources, occurrence and transport of contaminants in different landscape settings helps (1) assess potential effects on fish and other organism (previous issues), and (2) formulate management options (next issue). We have identified the need to address the important link between sources, occurrence, and transport of contaminants in different landscape settings – even if geographically restricted, (figure 4), and their relation to nutrients and sediment.

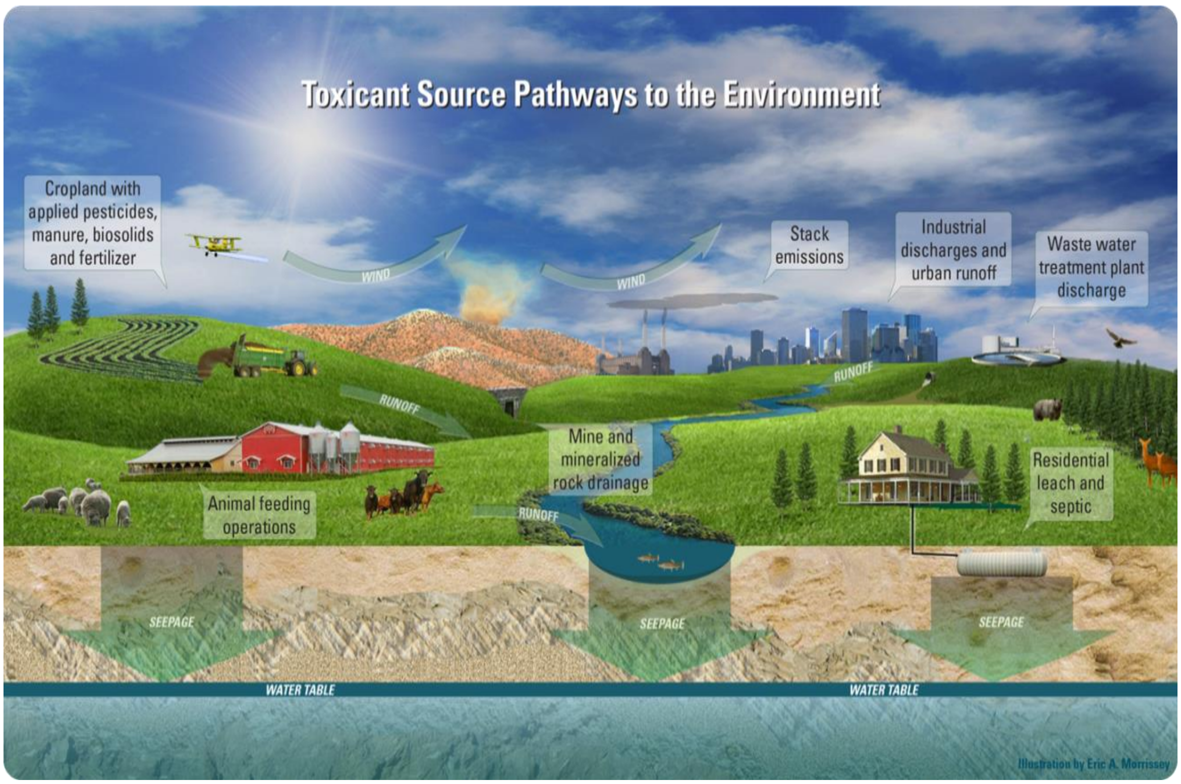


Figure 4: Conceptual diagram of sources, transport pathways of contaminants. Understanding the relation of contaminants with nutrients and sediment will help inform potential for their collective reduction. (from K. Smalling, USGS)

- **Current efforts:** All the states and several federal agencies are continuing to monitor different types of contaminants but only in selected areas and varying collection frequencies.

In addition, the USGS EDC project will release several publications was to better define the sources and occurrence of EDCs and other contaminant groups that affect health of fish and wildlife in agricultural settings in the watershed. Additional legacy and emerging toxic contaminant sampling is ongoing in surface waters of the jurisdictions, such as PA and DE.

- **Research gaps:** There is lack of consistent information (both spatial and temporal) on the occurrence and concentrations of priority toxic contaminants in different landscape settings and their co-occurrence with nutrient and sediment contamination. Additionally, there is no watershed-wide monitoring program on the condition of fish and wildlife that is integrated with nutrient and sediment sampling. Some of these monitoring gaps are due to the high cost of generating new data on toxic contaminants and the design of monitoring programs for purposes other than assessing status and trends. In addition, while jurisdictions, researchers, and federal agencies are initiated monitoring activities for PFAS, status, source, and cooccurrence with landscapes are relatively unknown the Chesapeake watershed. The existing information currently should be summarized to provide an improved understanding of the co-occurrence of prioritized toxic contaminants with nutrients and sediment in different landscape settings, where possible even if geographically limited. The improved understanding will help inform the next issue on options to mitigate contaminants.

Issue: Synthesize and promote science to help mitigate contaminants and emphasize the potential co-benefits with nutrients and sediment reductions.

The TCW identified this issue to provide science to help decision makers (CBP Water Quality Goal Team, States, and local jurisdictions) develop and prioritize options to reduce contaminants by taking advantage of nutrient and sediment reduction efforts. The research on the co-occurrence of nutrient, sediment and toxic contaminants, related to their sources, occurrence and transport, will help to better understand mitigation options in different landscape settings. For example, in urban settings, the focus will likely be related to wastewater and stormwater runoff, so states and counties can consider options to both meet the Bay TMDL and reduce toxic contaminants. In agricultural areas, focus will likely be on manure and row crop-related contaminants. The management approach to include summarize existing studies and provide the findings to the CBP source sector work groups and their members as they consider options to improve water quality.

- **Current Efforts:** There are efforts to assess mitigation potential for a limited number of contaminants in the context of TMDL compliance; however, research related to the remediation of toxic contaminants including many listed in Table 1 has advanced in other regulatory programs, such as Superfund, RCRA, and voluntary cleanup. Within the Chesapeake Bay, ongoing work as part of the Anacostia sediment mega-site (DC) and the Middle River (Dark Head Cove) in MD and Elizabeth and James Rivers in VA are examples where remediation technologies have been demonstrated at the pilot or full-scale for contaminants of concern to the Chesapeake Bay. Many other state and federal clean-up sites throughout the watershed have demonstrated success meeting site-specific remediation goals for sediment, groundwater, and surface water for toxic contaminants of interest.

  A primary focus of the STAC workshop in 2019 included the use of BMPs for toxic contaminant removal in agricultural and urban areas, as summarized below. The TCW will work with the WQ GIT to discuss potential several BMPs appeared promising in agricultural areas including:

  - Adding activated carbon or biochar to established BMPs effectively reduces contaminant transport.
  - Retention ponds and vegetative treatment are shown to reduce pesticide loading.

- Finally, manure management (including composting, subsurface application) and buffer strips, were shown to reduce antibiotics.

In urban areas, there were several examples at the workshop of studies demonstrating effective management that will be shared with the WQ GIT. These included:

- Sediment capture and reactive filter BMPs reduce concentration and toxicity related to urban stormwater runoff.
- Iron-enhanced sand filtration reduces concentrations of pesticides and wastewater indicators.
- In stream innovative treatment using activated carbon with and without bioamendments immobilizes and degrades PCBs.

In the context of TMDL compliance, the ability of BMPs to reduce or meet WLA goals is limited but ongoing. Theoretical assessments of primarily sediment-based BMPs have been completed for toxic contaminants while measurements of actual efficiencies and performance of BMPs for toxic contaminants are underway related to biofiltration and detention basins, but are limited. Further, work is ongoing to optimize media used in the construction of stormwater control structures to facilitate or enhance the removal of toxic contaminants. This information is needed to consider adapting decision tools to accommodate toxic contaminants and quantify reductions.

- **Research gaps:** The research gaps include (1) summaries of existing studies on mitigation using BMPs (2) more specific information on effectiveness of specific BMPs to degrade or remove select contaminants, (3) tools that integrate nutrient, sediment, and contaminant BMPs, and (4) interacting with decision makers to apply the findings. These gaps need to be filled in both the urban and agricultural landscape settings. Additional research on mitigation approaches is needed from the perspective of TMDL compliance for local impairments and aligning efforts under the Bay TMDL.

  Several gaps were identified as part of the STAC workshop.

  - In agricultural areas included the need to prioritize BMP implementation, the importance of defining the types of contaminants that require reduction (exposure), defining the desired outcome (e.g., improved fish health) and establishing how the BMP functions in relation to this outcome. Further understanding of the co-benefits of nutrient and sediment BMPs is needed to improve water quality (reduce toxic contaminants) and habitat quality and preserve aquatic resources. We need to further develop tools for the management community to identify areas/populations that would benefit from improved BMP implementation and/or monitoring. Finally, we need to build qualitative frameworks to answer questions related to co-benefits for toxic contaminants.
  - In urban areas, there is a need to improve information on removal efficiencies for certain BMPs to assess reduction.

Issue: Gather information on issues of emerging concern

There are numerous issues of emerging concern that are continuously evolving and are relevant to the Research strategy and more specifically understanding how emerging contaminants are impacting surface waters and biological resources of the Chesapeake Bay. Issues of concern addressed during the two year period included PFAS, road salt, and microplastics.

- **Current Efforts:** While some priorities varied between stakeholders, PFAS was identified as a priority by most workgroup members, followed by road salts. In addition to the topical TCW meetings, a STAC workshop on microplastics was held and many workgroup members attended the workshop. CBP as a whole has prioritized microplastics with the formation of a microplastics action team, and TCW will participate and engage with the group to bring findings particularly related to the toxicity effects of microplastics on biological resource of the Chesapeake Bay.

- **Research Needs:** With briefings and discussion of many issues over the last several years, there are continuing needs to better understand: (1) toxicity impacts of microplastics on fish and shellfish particularly threats to smallmouth bass, and (2) toxicity effects of road salts and development of TMDLs

Actions, Tools and Support to Empower Local Government and Others

- **Current Efforts:** During development of the initial strategy, the TCW has reached out to local organizations within some of the areas of most concern including the Baltimore Harbor and Anacostia watershed. In both the Susquehanna and Shenandoah watersheds, the USGS has been interacting with the respective River Keeper organizations on the fish health studies. As part of the Baltimore Urban Waters Partnership, local governments from MD counties near Baltimore and DC have met with researchers and regulators to discuss new research related to PCBs and stormwater.
- **Research Gaps:** There is an ongoing need to increase interaction with local governments and others who need science to better inform efforts to improve water quality. There is a lack of summary materials and tools to provide information on the potential co-benefits between reduction of toxic contaminants with practices for nutrients and sediment. Local governments could more effectively meet their requirements for the Bay TMDL (for nutrients and sediment) and address local water-quality issues with more integrated information. Also, there is a need to improve information about on the extent of fish consumption advisories, due to toxic contaminants and to better focus efforts to protect diverse communities.

VI. Management Approaches

The Partnership will work together to carry out the following approaches to make progress toward the Toxic Contaminants research outcome. These approaches seek to address the factors affecting our ability to meet the goal and the gaps identified above.

The management approaches address each of the major issues, and associated factors, identified at the beginning of the strategy. The management approaches build from existing research and monitoring efforts to address the research gaps and factors influencing our ability to meet the toxic contaminant goal. The factor of resource constraints applies to, and are discussed, for each management approach. The factor of synthesis is discussed in several management approaches.

Approach: Synthesize scientific information to make fish and shellfish safe for human consumption

This approach will help address the factors and gaps associated with (1) summarizing information on the occurrence of fish consumption advisories and the sources of contamination, (2) resource constraints, and (3) synthesis. This management approach is focused on PCBs and mercury since they are the primary contaminants causing fish consumption advisories. It addresses the factor "**Understanding and defining sources of contamination leading to fish consumption advisories"**.

The **approach for PCBs** includes actions ranging from:

- Refining PCB sources and methods for source identification through both literature and field study communication
- Compare and identify science-based commonalities and differences of source tracking and PMP guidance documents from jurisdictions and the new EPA TMDL Vision 2.0 document;
- Leveraging existing studies to enhance information on the sources of PCBs in environment. Examples include the Baltimore Areas study and several studies in the Anacostia and DC..
- Working toward a hierarchy of PCB monitoring and analytical methods for desired use to promote comparison of data across the watershed for similar needs and begin to assess feasibility, design, and funding of enhanced monitoring for PCBs to evaluate recovery of surface water/fish in areas where management for PCBs is occurring or planned.
- Stay informed on progress of models in James River, Anacostia, upper Potomac, any others as they may inform adaptive management decisions/areas of focus for others in the watershed.

These results will inform the current toxic contaminants prevention and policy management strategy, which is focused on reducing the impacts of PCBs.

The approach for mercury will focus on interaction with the jurisdictions on the opportunity for integrated monitoring of mercury given lack of data to assess effects of atmospheric reductions and other management approaches.

The approach for PFAS will be further defined in the forthcoming STAC workshop report and the recommendations that are identified in it. The workgroup will focus at least one meeting during each calendar year on fish consumption sampling and analysis, and bioaccumulation/biomagnification-related topics. At this time, most jurisdictions have started to or plan to start to include select PFAS in their rotation of fish sampling and would benefit from guidance and uniformity.

Approach: Understand the influence of contaminants in degrading the health, and contributing to mortality, of fish and wildlife

The research efforts will provide a better understanding of the factors affecting health of fish, shellfish, and wildlife, with a focus on fisheries. The states in the watershed (as well as DC) have active projects, many in cooperation with USGS, FWS, state and academic partners, attempting to discern causes of declining fish health, and fish mortality, in their respective drainage areas of the Bay watershed. Collectively, these efforts will help address the factor **"Multiple factors affecting the health and mortality of fish and wildlife."**

Several efforts will help improve understanding over the next two years, including:

- Assess the effects of contaminants on fish and shellfish in tidal waters. There will be a focus on Anacostia River sediment contaminants effects on fish health by USFWS, and also continue study and evaluate findings from condition of Yellow Perch in urban areas by USFWS, USGS, and UMCP.
- The USGS will continue to generate information to document fish health conditions in the Bay watershed. One effort will initiate studies designed to address temporal and spatial changes in fish health in mixed use watersheds in the freshwater portion of the watershed.
- State DELT data has been compiled and will be assessed to determine if the data are robust enough to conduct spatial and temporal analysis to understand regional shifts in DELT. Attempts to examine visible fish health responses to management, land-use and land-change will be conducted.
- Document impacts of PFAS compounds on the health of fish (CB Watershed and elsewhere), including PFAS in fish plasma from some long-term Chesapeake Bay monitoring sites.
- Document impacts of PFAS compounds on wildlife (e.g., tree swallows and terrapins) in the watershed.
- Interface with the Sustainable Fisheries GIT to consider toxic contaminants in tidal and freshwater fish-habitat assessments. NOAA and USGS, through the Fish Habitat work group, are collaborating on fish-habitat assessments. The TCW will provide an overview to the Fish Habitat WG of available toxic contaminant data that could be considered for the freshwater and estuary fish habitat assessments.

Approach: Document the sources, occurrence, and transport of contaminants in different landscape settings

This management approach will address the factor, **"Lack of data on the occurrence and trends of toxic contaminants."** This approach is focused on the settings where the sources of the contaminants are expected to have the maximum impact on fish and their opportunities to collectively address contaminants, nutrients, and sediment. These settings include urban and suburban areas, and agricultural lands. In agricultural lands, some of the primary sources to address animal manure, crops where pesticides are applied, and spreading of biosolids. In urban and suburban areas, some of the primary sources to address include aging sewer infrastructure, septic systems, urban runoff, and WWTPs.

Data inventories revealed conducting regional assessments of trends of contaminants was not possible. Therefore, the approach will evolve to focus on selected geographic areas where data can be used to look at status and change for selected contaminants. Some of actions to support this approach during the next two years include:

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- The USGS will continue to explore the occurrence and concentrations of PCBs, PFAS, and complex mixtures of toxic contaminants in wastewater effluent and its impact on receiving

waters. A study is ongoing exploring the occurrence and concentrations of PCBs and PFAS in stormwater runoff, associations with different land use, and the source of sediment bound PCBs in the runoff.

- Due to the increasing need to address PFAS occurrence and concentration, nearly all of the efforts in this management approach include PFAS. At this time, these are disparate studies without coordination for field and analytical methods and data interpretation.

Approach: Synthesize and promote science to help mitigate contaminants, and emphasize the co-benefits with nutrients and sediment reductions

This management approach will provide science to help the TCW, and other partners including those on the WQ GIT, to identify and prioritize mitigation options to help mitigate contaminants directly and through potential co-benefits with nutrient and sediment reductions. There will a close interaction between the TCW and Water-Quality Goal Team and their workgroups to apply findings from various studies. This approach addresses the factor "**Limited information of the practices to mitigate contaminants, and their potential direct and co-benefits with nutrients and sediment reductions".**

Some of the actions over the next two years for this approach include:

▪Ongoing implementation of CBP recommendations to the STAC workshop report. These have been reviewed and approved by the TCW, the WQ GIT and the Management Board. Select priority actions include:

CBP Action 1: Enhance Interaction with Stakeholders for Contaminant Information:
The best opportunities are to interact with stakeholders who are implementing practices to reduce nutrients and sediment, so they can consider actions to also mitigate toxic contaminants. The TCW is will increase interaction with jurisdictions, WQ GIT and associated workgroups, and local TMDL implementors.

CBP Action 3: Enhance Communication Materials to Inform Decisions:
The TCW will interact with stakeholders and the CBP Communications Team on the most useful approaches to provide new findings. In addition to presentations of results, the TCW will discuss opportunities to prepare Fact Sheets and other briefing materials to best communicate results to different stakeholder groups. Preparing communication materials will take additional resources.

CBP Action 4: Compile results and expand BMP studies of contaminant mitigation and relation to nutrients and sediment reductions:
Studies of the effectiveness of BMPs designed for nutrient and sediment reduction to mitigate contaminants are currently limited. However, expanding information about fate of toxic contaminants in BMPs is critical to understand within the current CBP framework of management actions. Ongoing efforts in the watershed include contaminant fate in bioretention, wet ponds, wastewater capital and operation and maintenance activities in urban areas. In agricultural areas, water quality response to BMP implementation using estrogenicity

as a surrogate for EDCs. Inform results of studies exploring management relevant timelines to detect regional change in stressors following BMP implementation.

Approach: Gather information on issues of emerging concern

The TCW kept abreast of several emerging issues over the past two years:: (1) the potential effects PFAS s (2) reducing the effects of road salts, and (3) microplastics. Over the next two years, the focus will be on support for the Plastic Pollution action team (PPAT), and chloride (road salt) toxicity). The rapidly evolving PFAS issue required that this topic be integrated into the other management approaches at this time.The workgroup will continue to bring new and important publications before the workgroup related to emerging issues, and field input from participants of new areas of interest, if any, as they emerge. Priorities will be reassessed as needed.

Approach: Targeted Local Participation

Scientists from different research efforts will provide findings to local organizations to inform them of ongoing studies. We will also utilize annual workshops put on by several organizations (such as Baltimore Urban Waters Partnership and the MD Pesticide Network) to share findings with local users and organizations. Finally, we will explore opportunities to work through the local government advisory committee to reach local governments and organizations.

Collaboration with other Management Strategies

There is potential cross-collaboration working with WQ Goal Team (to reduce nutrients and sediment); Habitats (improve stream health), and Fisheries (making fish and shellfish safer to eat, and the habitats on which they depend).

VII. Monitoring Progress

The Research Outcome does not have a numerical target so assessing progress is more qualitative. The overarching topic is to "Continually increase our understanding of the impacts and mitigation options for toxic contaminants". There are two supporting items in the outcome to provide a qualitative assessment of progress:

- Further characterize the occurrence, concentrations, sources and effects of mercury, PCBs and other contaminants of emerging and widespread concern.
- Identify which best management practices might provide multiple benefits of reducing nutrient and sediment pollution as well as toxic contaminants in waterways.

Monitoring our progress for these items is based on completion of planned actions and meeting their associated performance targets that are listed in the Logic and Action Plan.

VIII. Assessing Progress

Assessing progress on the actions is the LAP will be done at least annually under the TCW. The reviews will provide opportunities to make adjustments to the biennial workplan can be made to accommodate changing circumstances and availability of resources. Formal review of programmatic progress will be completed through the update of the biennial workplan.

For the previous two year period the qualitative assessment by the TCW was:

• Further characterize the occurrence, concentrations, sources and effects of mercury, PCBs, and other contaminants of emerging and widespread concern. **Progress: Good,** progress has continued to be made on mercury across the watershed and other contaminants of interest in local areas due to TMDL inclusion in the MS4 permits. Regional characterizations improved for agricultural chemicals in the Potomac and Susquehanna watersheds, and for PCBs related to restoration efforts in Anacostia watershed, and complex mixtures of contaminants in the Shenandoah watershed**.**.

• Identify which best management practices might provide multiple benefits of reducing nutrient and sediment pollution as well as toxic contaminants in waterways. **Progress: Fair.** Progress has been made to better understand reduction of specific contaminants in specific management actions (e.g., PCBs in gray infrastructure) and relevant response timelines from BMP implementation, but stormwater BMP removal efficiency studies continue to be limited. Additionally, jurisdictions WIPs don't have much emphasis on addressing co-benefits for contaminant reduction or have a way to quantify the reduction.

A similar assessment is expected at the end of 2022.

IX. Adaptively Manage

The Toxic Contaminants Workgroup used the information learned over the past two years to update the management strategy and associated LAP for the Research Outcome. There is interchange between the members of the TCW to discuss evolution of research factors and gaps every two year in alignment with the SRS reviews.

X. Biennial Logic and Action Plan

The Biennial workplan for this research strategy contains actions for 2023-2024.