Toxic Contaminants Research Outcome

Management Strategy

(From K. Smalling, USGS)

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 CBP Toxic Contaminant Workgroup (TCW) and Water-Quality Goal Implementation Team 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 have been updated in 2018 to be:

- Supply 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.
- Provide science to help mitigate contaminants, and emphasize the co-benefits with nutrients and sediment reductions.
- Gather information on issues of emerging concern

I. Goal, Outcome and Baseline

This strategy identifies approaches for making progress toward the toxic contaminant goal and research 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, 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 have been updated during CBP review process in 2018, with issues 3 and 4 being substantially modified:

1. Supply information to make fish and shellfish safer for human consumption.
2. Understand the influence of contaminants degrading the health, and contributing to mortality, of fish and wildlife.
3. Document the sources, occurrence, and transport of contaminants in different landscape settings.
4. Provide science to help mitigate contaminants, and emphasize the co-benefits with nutrients and sediment reductions.
5. 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 emphasis of the research efforts.

Concept for Determining Highest Priorities for Research to Increase Understanding Impacts and Mitigation Options for Toxic Contaminants (Color codes are examples)

Contaminant Groups	Occurrence	Concentrations	Sources	Effects
PCBs				
Dioxins/Furans				
PAHs				
Petroleum Hydrocarbons				
Pesticides				
Bio. Hormones				
Pharms.				
HPCP				
PBDEs				
Metals				
Mixtures				

Uncertainty
Small
Mid
Large

Priorities for an agenda to increase certainty?

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 focus on the research strategy.

Issue: Supply information to make fish and shellfish safer for human consumption

Polychlorinated biphenyls (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 (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. The Policy and Prevention strategy has a specific management approach to provide science to inform reduction of PCBs and that strategy and work plan should be consulted for more detailed information.

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. As part of the revised management strategy, efforts will be made to improve the understanding of baseline conditions by compiling information on the extent of mercury impairments across the watershed. The jurisdictions will also work through the TCW to inventory data and assess if information exists to document changes in

mercury in response to air controls. The results will be used to help jurisdictions consider if additional efforts are needed to reduce the impacts of mercury.

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.

<u>Issue: Understand the influence of contaminants degrading the health, and contributing to mortality, of fish and wildlife.</u>

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.

Toxic contaminants may also contribute to fish and wildlife kills, in addition to degrading health, in the Bay and its watershed. Kills are generally defined as large numbers of fish or wildlife dying within a relatively short period of time. Some of the known fish and wildlife kills and their causes include:

- Acute kills of fish and wildlife due to hydrocarbon spills.
- Localized kills have been linked to a sequence of events resulting in algal blooms and die-off of the algae depleting available oxygen.
- Algal blooms of toxin-producing species have occurred in several years at Poplar Island, resulting in the deaths of hundreds of waterbirds. These are linked to Microcystis and possibly with avian botulism.
- Fish kills in the Chesapeake Bay watershed have also been associated with one or more pathogens and disease.

Fish kills have been associated with multiple potential causes, such as pathogens, parasites, disease, and contaminants. Kills of adult bass and sunfish in the Potomac basin and young-of-the-year smallmouth bass in the Susquehanna basin have occurred in multiple years and multiple sub-watersheds. These observations together with the concurrent observations of intersex and other indicators of contaminant exposure suggest multiple causes contribute to fish mortality and poor heath. Findings also suggest that toxic contaminants can influence immunosuppression, and making the fish more vulnerable to other factors.

Studies since 2015 continue to suggest that multiple factors affect fish health and mortality. For example, recent studies (2017-18) in the Susquehanna basin identified disease as an important

factor leading to fish health problems and mortality. These studies reveal the difficulties in identifying individual stressors or factors, and relating individual contaminants, to causes of degraded fish health and/or morality.

Finally, the appearance of estrogenic hormones, UV filters, and antibiotics in the environment has drawn increasing attention due to potential impacts on human and ecological health. Potential sources of estrogenic hormones and antibiotics include wastewater treatment effluents and animal feeding operations. New studies by UMBC in the Chesapeake Bay mainstem are examining the occurrence of these toxic compounds in the eastern oyster (Crassostrea virginica), and hooked mussel (Ischadium recurvum). Results highlight the ubiquitous bioaccumulation of CECs in aquatic and marine invertebrates.

The role of contaminants in the health of numerous wildlife species, including birds, amphibians and reptiles is not as well documented. Results from the 2013 federal report (Chesapeake Bay Program, 2013) reveal the indications of responses to contaminant exposure have also been found among wildlife in the Chesapeake Bay watershed, primarily wild birds. In a few locations, eggshell thinning associated with *p,p'*-DDE is apparent, and reproduction may be impaired. In some cases, organochlorine pesticides are found in eggs of predatory birds at concentrations associated with embryo lethality. Several studies are cited in which PCB concentrations in addled bald eagle eggs may have been high enough to contribute to the failure to hatch. Detectable concentrations of PBDEs have been found in eggs of predatory birds that approach the lowest-observed-adverse-effect level for pipping and hatching success. A summary of wildlife issues and toxic contaminants (conducted in 2016) found there was still very limited information to assess effects on wildlife.

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 had been 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 local 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 2019 and improve the certainty for these contaminant groups (figure 1). In the future, this issue will evolve 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.
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.

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

This management approach will evolve 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. This will 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.

Issue: Gather information on issues of emerging concern.
Issues of emerging concern identified in the original strategy were (1) contaminant toxicity to pollinators (including neonicotinoids), (2) microplastics, and (3) unconventional oil and gas drilling (known as "fracking"). Some information was gathered on these topics but not enough to understand background conditions across the entire watershed.

New issues suggested for the revised strategy are described below and include: (1) harmful algal blooms (HABs) and their associated toxins; and (2) the potential effects of poly- and perflouroalkyls (PFAS), (3) reducing the effects of road salts, and (4) runoff from coal combustion residual storage facilities and fly ash..

HABs: Cyanobacterial harmful algal blooms (cyanoHABs) are increasingly a global concern. CyanoHABs can threaten human and aquatic ecosystem health; they can cause major economic damage. The toxins produced by some species of cyanobacteria (called cyanotoxins) cause acute and chronic illnesses in humans. Harmful algal blooms can adversely affect aquatic ecosystem health, both directly through the presence of these toxins and indirectly through the low dissolved oxygen concentrations and changes in aquatic food webs caused by an overabundance of cyanobacteria. USGS scientists are leading a diverse range of studies to address cyanoHAB issues in water bodies throughout the United States, using a combination of traditional methods and emerging technologies in collaboration with numerous partners. However, despite advances in scientific understanding of cyanobacteria and associated compounds, many questions remain unanswered about the occurrence, the environmental triggers for toxicity, and the ability to predict the timing and toxicity of cyanoHABs. (https://www.usgs.gov/news/science-harmful-algae-blooms).

PFAS: PFAS compounds have been manufactured and used in a variety of industries in the United States since the 1940s. Some of the major compounds in this group (e.g., PFOA and PFOS) are no longer produced or in use in the United States; however, they are used internationally and can be introduced to the environment through imported products. These compounds are persistent in the environment and have been shown to have adverse health effects. Recently, New Jersey issued fish consumption guidelines for PFAS compounds (https://www.nj.gov/dep/dsr/). Another primary source of human exposure is drinking water. Little is known about PFAS in the Chesapeake Bay, but due to its wide use in many consumer (food packaging, non-stick cookware, fabric softeners) as well as industrial products (firefighting foams), there is the possibility for widespread extent in surface water.

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.

Coal Ash*:* Coal combustion residuals (CCRs or fly ash) and their associated storage sites are a large concern due to the potential negative impacts from metals leaching from sites into nearby waters. Several CCR storage sites are located along the rivers in the Potomac and Susquehanna River basins. There are potential beneficial reuses of the CCR material in cement production as an alternative to these riverside disposal sites. More information on current efforts by MD to minimize fly ash disposal in these storage sites is described in the next section.

II. 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
- Private sector organizations
- University of Maryland, Baltimore County
- Virginia Polytechnic Institute and State University
- Virginia Institute of Marine Science
- 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.

III. Factors Influencing

The revised factors for the strategy include:

Communicating the potential impacts of consuming contaminated fish and addressing their causes. Fish consumption advisories are established by the states, based on human health risks from different contaminants. The jurisdictions have different assumptions about human exposure through fish consumption, which can limit comparability across the watershed. There are also resource constraints to collect and analyze fish and associated samples every year to assess attainment of standards.

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 data on the occurrence and trends of contaminants: There is no watershed-wide monitoring program on the condition of fish and wildlife that is integrated with water and sediment sampling. There is a lack of consistent information (both spatial and temporal) on the occurrence and concentrations of toxic contaminants. 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 potential co-benefits with nutrients and sediment reductions: More 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 importance and implications of 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: This is a new factor which recognizes the findings from technical articles and reports need to be summarized and communicated to be used effectively by resource managers.

IV. Current Efforts and Gaps

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 (such as pesticides) and their relation to different sources.
- Research on effectiveness of management practices and mitigation techniques to reduce contaminants, and their potential co-benefits with nutrient and sediment reduction.

A brief description of the current efforts and associated research gaps for the five issues in this strategy are discussed. Efforts to address the research gaps are presented in the management approaches (next section).

Issue: Supply 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 and set fish consumption advisories. In most jurisdictions, PCBs or mercury are the primary driver of fish consumption advisories. Jurisdictions have progressed over the past two years in understanding the extent of the PCB impairments and sources and status in the environment. In addition, progress has occurred on the development of regional models such as the James River and Anacostia River watersheds, that can help with better understanding sources and occurrence of PCBs, and PAHs. Information from these models can help in the development of other regional models (such as the Upper Potomac or Conowingo) being considered within the watershed. A more detailed summary of the science related to PCBs is included in the Policy and Prevention strategy and work plan.

  For mercury, Maryland annually monitors the young of the year fish. To date, there have been no apparent trends in the fish concentrations; however, the sampling will continue, and data will be evaluated annually for trends. USGS, as part of the EDC project, also measured mercury in fish fillets in two locations within the watershed, one in the Potomac and another in the upper Susquehanna.

- ***Research gaps for PCBs****:* The policy and prevention strategy has a detailed discussion on the research gaps for PCBs, which focuses on Improve understanding of sources, status and change in environment, and BMP effectiveness (including co-benefits with nutrients and sediment).
- ***Research gaps for mercury***: For mercury reductions, the jurisdictions in the Bay watershed are depending on national air emission controls and less use of coal for energy production. However, data are lacking to determine the extent of mercury impairments throughout the watershed, and if mercury is decreasing in the environment from these controls.

Additionally, there is limited information on the amount of methyl-mercury in the Chesapeake watershed and its pathways to cause fish consumption advisories.

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 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. Some selected studies are described below.

  The USGS is completing a five-year study in 2019 to better understand the effects of known EDCs and CECs on fish and wildlife within the Chesapeake watershed. The study focused on assessing adverse effects in wild fishes, experimental exposures of key fish species to mixtures based on chemical concentrations measured in affected areas, assessing the role of mercury as an endocrine disruptor, and summarizing existing information on EDC effects on wildlife. The results will be provided during 2019.

  The US EPA National Aquatic Resource Survey (NARS)/National Coastal Condition Assessment (NCCA) evaluates a selection of metals, PCB congeners, PAHs, and pesticides in surficial sediment and in fish tissues on a five-year recurrent schedule. A number of sites in the national survey routinely fall within the tidal portions of the Chesapeake Bay watershed. The most recent sampling event was conducted in 2015 and the publication for these data will be relevant. In addition, the Virginia DEQ Estuarine Probabilistic Monitoring Program routinely analyzes the same group of sediment analytes at approximately 30 sites per year within the tidal portion of the Chesapeake Bay watershed. Sediment toxicity and benthic community health (CBP B-IBI) are concurrently evaluated at each site. Efforts are currently underway to recalibrate the CBP B-IBI using sediment chemistry, sediment toxicity, and benthic community data from probabilistic monitoring sites.

  Pennsylvania initiated a large-scale study of the Susquehanna River drainage in response to the decline of the smallmouth bass population. While results suggest disease is a major factor contributing to the population decline, additional studies by USGS suggest other factors may also play impact the overall health of several aquatic communities, including toxic contaminants and water-quality variables.

  US Fish and Wildlife Service recently completed a study looking at tumor prevalence in Bullhead catfish in the Anacostia and Potomac rivers. Results of the study showed a significant decrease in tumor prevalence between onset of sampling (1992) and recent sampling (2009-2011) in the Anacostia River (https://www.fws.gov/chesapeakebay/pdf/BrownBullheadTumorsFactSheet%2004162013.pdf). Samples were also collected in the Potomac River and decreases were observed during the same timeframe, but the decline was not significant.

State agencies usually 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 assesses 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 in selected landscape settings (agricultural and urban areas). 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 and some of the more specific research gaps suggested for fishery issues in the revised strategy include:

1. **Effects of contaminants on fish reproduction.** The role of contaminants and other factors on the reproduction of yellow perch has been a need identified by MD. Lack of reproductive success of yellow perch and other anadromous fishes has been documented in certain urban tributaries. A clear relationship between percentage of impervious surface and declining recruitment of yellow perch and river herring has been demonstrated. In yellow perch, effects on egg quality (abnormal yolk, thin chorions) have been observed. A better understanding of the multiple stressors including contaminants, hypoxia, sediment and nutrient loading and changes in salinity is necessary to prevent further declines.

2. **The causes of fish tumors.** Several states and DOI want a better understanding of the causes of tumors on several species, including important recreational species. A high prevalence of skin and liver tumors in brown bullhead catfish and liver tumors in mummichogs has been documented. While there is evidence for the role of PAHs in liver carcinogenesis, other factors acting as both promoters and initiators are not well studied. Research is needed on risk factors associated with these tumors

3. **The relation between contaminants and fish disease.** The complex interactions between contaminants and infectious disease need to be understood. While contaminants can adversely affect the ability of an organism to resist infectious diseases and parasites, the presence of these biological agents can also affect the ability of an organism to metabolize and otherwise deal with exposure to chemical contaminants.

<u>Issue: Document the sources, occurrence, and transport of contaminants in different landscape settings.</u>

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 evolved this issue to address the important link between sources, occurrence, and transport of contaminants in different landscape settings, (figure 2), and their relation to nutrients and sediment.

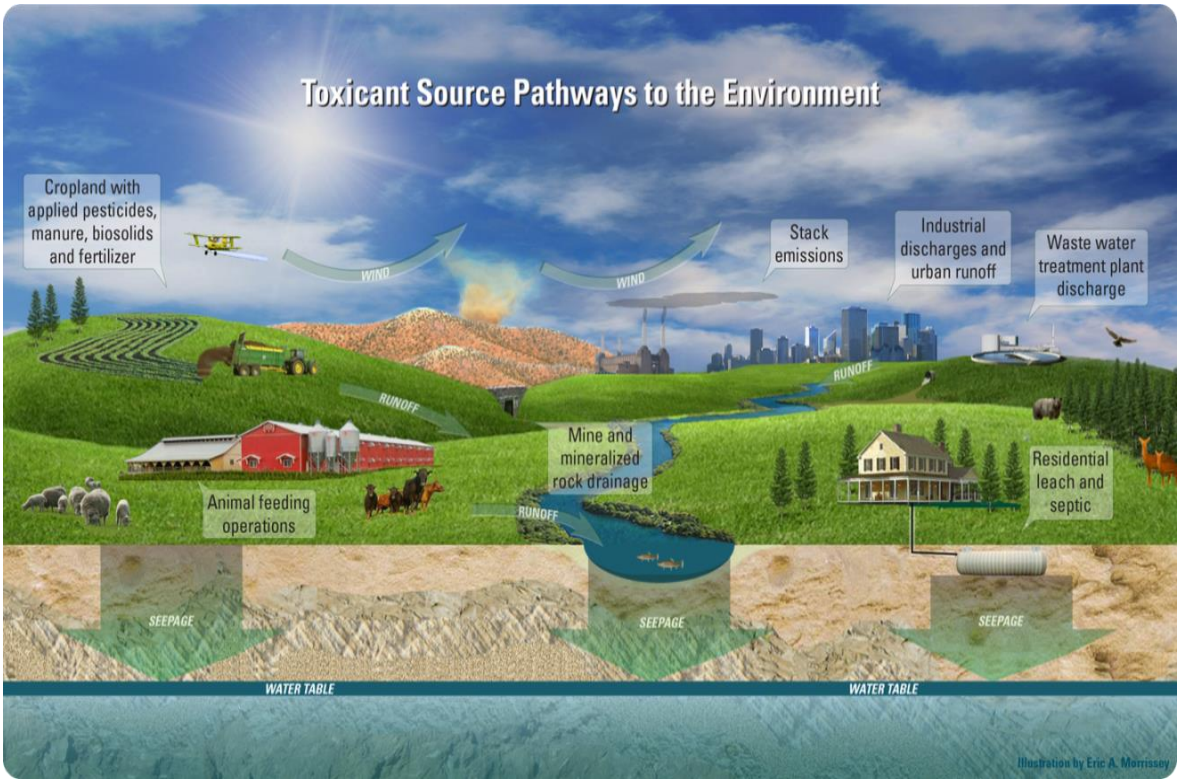

Figure 2: Conceptual diagram of sources, transport pathways of contaminants. Understanding the relation of contaminants with nutrients and sediment will help inform potential for their collective reduction. (from K. Smalling, USGS)

- **Current Efforts**: All the states and several federal agencies monitor different types of contaminants but only in selected areas and varying collection frequencies. There have been efforts to summarize the occurrence of selected contaminants in agricultural and urban areas.

  Partners at NOAA published work as part of the National Status and Trends estuarine monitoring program (including sediment, water, and bivalves) that included the Chesapeake Bay. Work has been expanded to included monitoring of pharmaceuticals, personal care products, current-use pesticides, and other chemicals of emerging concern (CECs) associated with human activities, as described below.

  Work is ongoing to understand the occurrence of contaminants in sediment, water, and bivalves in both the estuarine waters (NOAA, UMBC-USDA FS) and non-tidal waters (USGS, UMBC, USDA FS) in different landscape settings. Scientists from NCCOS' Oxford Laboratory

and Maryland Department of Natural Resources helped identify suitable survey areas including the Patapsco, Severn, Rhode and Choptank tributaries, which represent a range of land use from heavily urbanized to agriculture. The preliminary results indicate the detection of a number of CECs in both sediments and oyster tissues. Contaminants were detected more frequently in oyster tissue than in sediment (https://coastalscience.noaa.gov/project/mussel-watch-program-assessment-chesapeake-bay-charleston-harbor/). Maximum values of pharmaceutical and personal care products, current use pesticides, flame retardant and persistent organic contaminants were more frequently found in the Patapsco River than the other survey areas (https://coastalscience.noaa.gov/project/mussel-watch-program-assessment-chesapeake-bay-charleston-harbor/). Further studies by NOAA are looking at the linkages between river conditions (including toxic contaminants) and land use.

Researchers from UMBC and the USDA FS are investigating estrogenic hormones, UV filters, and antibiotics in water, sediment, and bivalves in some tidal and non-tidal portions of the Chesapeake Bay, with different land use settings (both agricultural and urban). Potential sources of estrogenic hormones and antibiotics include wastewater treatment effluents and animal feeding operations. Five UV-filters and three estrogenic hormones were measured in water, sediment and in virile crayfish (Orconectes virilis) tissue to better understand CEC occurrence in urban streams. Methods applied to the crayfish were adapted to test other aquatic and coastal invertebrates from multiple habitats including red swamp crayfish (Procambarus clarkii), eastern oyster (Crassostrea virginica), and hooked mussel (Ischadium recurvum).

Another objective of the USGS EDC project 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. Potential hotspots have been identified using GIS analysis. Vulnerability metrics have been assessed using this analysis and will be included in synthesis reporting. Ongoing, additional toxic contaminant sampling is occurring in jurisdictions, such as PA and DE.

- ***Research gaps:*** There is lack of consistent information (both spatial and temporal) on the occurrence and concentrations of toxic contaminants in different landscape settings or 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 water and sediment sampling. Some of these monitoring gaps are due to the high cost of generating new data on toxic contaminants. Additionally, there are few laboratories that have the capabilities to conduct the preferred analysis for all the contaminant groups (e.g., PCB congener method 1668). The current information currently should be summarized to provide an improved understanding of the co-occurrence of toxic contaminants with nutrients and sediment in different landscape settings. The improved understanding will help inform the next issue on options to mitigate contaminants.

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

The TCW will evolve this management approach to provide science to help decision makers (CBP Water Quality Goal Team, States, and Counties) 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 are two examples of many 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.

  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, detention basins. Further, work is ongoing to optimize media used in the construction of stormwater control structures to facilitate or enhance the removal of toxic contaminants.

- ***Research gaps****:* The research gaps include (1) summaries of existing studies on mitigation (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.

<u>Issue: Gather information on issues of emerging concern</u>

There are efforts to address both for the original issues of emerging concern and some of the new issues that were identified.

- ***Current efforts for original issues of emerging concern****:* A white paper detailing state of the science related to microplastics was completed during the previous work plan by STAC. USGS is currently conducting a study of microplastics occurrence in the northeastern US. About 8 sampling locations of this study are within the Chesapeake Bay watershed.

Water quality impacts of unconventional oil and gas exploration and drilling has been studied by USGS within the Upper Susquehanna River Basin, which drains portions of Pennsylvania and New York, and includes many high-quality and native brook trout streams (Maloney and others, 2018). Vulnerability models were developed to identify streams that are vulnerable to UOG development. This vulnerability framework can be applied to a variety of ecosystems or energy development scenarios. Other USGS efforts include assessment of biological impacts following a wastewater spill from UOG operations (Cozarelli and others, 2017). Endocrine disruption activities were also studied downstream of a wastewater disposal site and were determined to be higher than upstream reference surface water quality and above levels known to cause adverse health effects (Kassotis and others, 2016).

- ***Current efforts for new issues of emerging concern***: The state of MD is working to identify companies in the watershed that may beneficially reuse CCRs stored throughout the Chesapeake Bay watershed. Some of the storage facilities where the state of MD is working with companies to utilize CCR for cement productions in the Potomac watershed is shown on figure 3.

- ***Research needs***: While some information has been gathered over the past two years, there are continuing needs to better understand: (1) contaminant toxicity to pollinators (including Neonicotinoid pesticides), and (2) microplastics, (3) chemicals from UOG activities and their effects on fish and wildlife. Of these 3 issues, microplastics may be the highest priority because the Fisheries Goal Team would like information on potential impacts of microplastics on oysters and fish tissue.

  New research items have been suggested for HABs, PFAS, road salts, and coal ash. There will need to be efforts to better define the research needs for each of these emerging issues and identify the highest priorities to be addressed. Otherwise, some transfer of findings from existing efforts is needed.

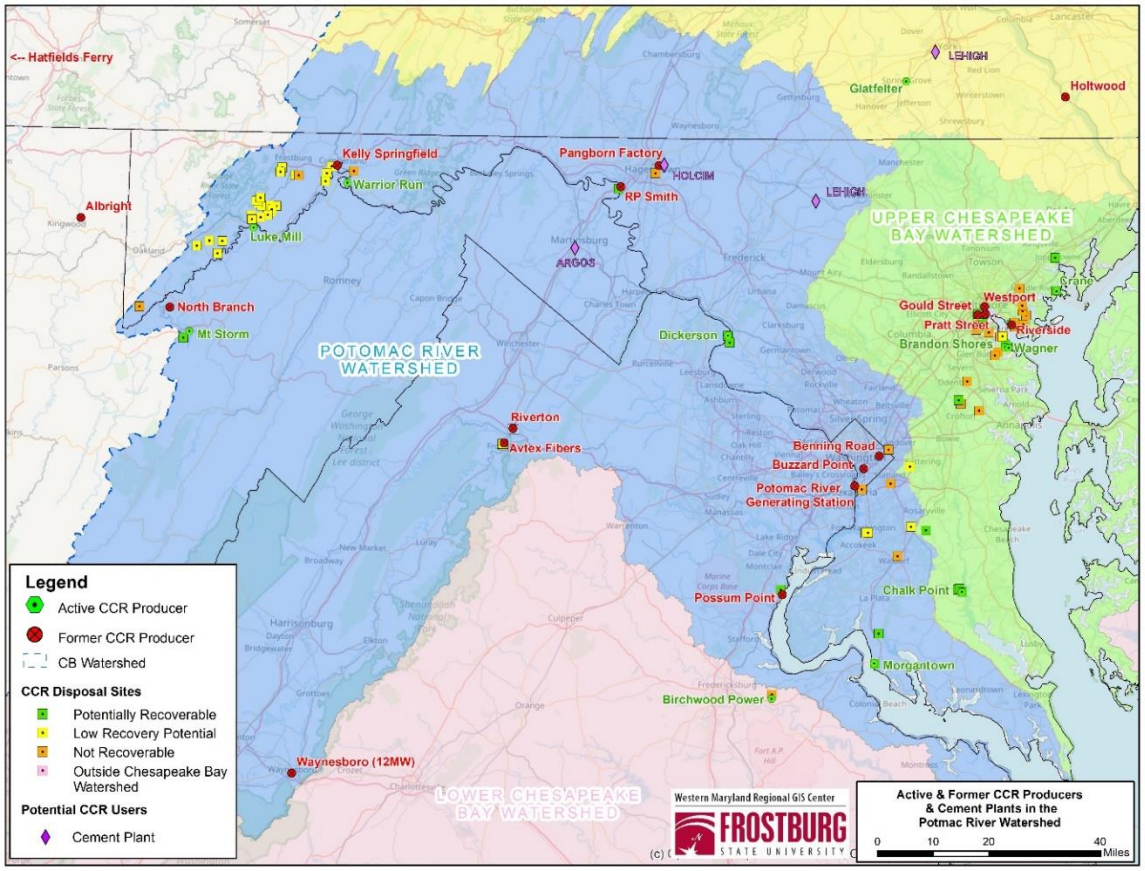

Figure 3. Locations of CCRs in Maryland (from B. Michael)

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 RiverKeeper 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 a 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.

V. 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 approach addresses each of the major issues identified at the beginning of the strategy. The management approach builds from existing research and monitoring efforts to address the research gaps and factors influencing our ability to meet the toxic contaminant goal. Since resources are limited, some guiding principles for the management approach are to:

- Focus studies on areas where fish and wildlife have been degraded and/or there are human health concerns.
- Better understand and identify the multiple stressors and mixtures of contaminant groups contributing to degraded fish and wildlife.
- Improve the understanding between sources of these contaminants (and mixtures), their pathways to the environment, and exposures to receptor organisms.
- Develop information so decision makers can consider an integrated approach to reduce toxic contaminants by taking advantage of practices being implemented for the Bay TMDL (reduction of nutrients and sediment).

<u>Approach: Supply information to make fish and shellfish safe for human consumption</u>
This approach will help address the factors (1) communicating the potential impacts of consuming contaminated fish and addressing their causes (2) resource constraints, and (3) synthesis. The resource constraints will be addressed through collaboration with additional partners. An effort will be undertaken to synthesize findings from different studies on selected topics, and communicate findings so decisionmakers can further reduce PCBs and associated fish consumption advisories.

The current toxic contaminants prevention and policy management strategy is focused on reducing the impacts of PCBs since they are the leading cause for fish consumption advisories in tidal waters. Additional science will be generated to help address several research needs about PCB including: (1) identifying sources, (2) status and change in the environment, and (3) BMP effectiveness.

Identify sources: Improve understanding of sources and fate of PCBs in the environment to inform mitigation options. The activities would range from summarizing best practices for PCB track down studies, informing stakeholders of results of atmospheric deposition studies, WWTP biosolids and effluent loads as well as reporting of other potential sources such as demolition/construction, dredged sediments.
Status and change in environment. Enhanced information on status and change through the more prevalent use of the 1668 congener based analytical method, communicate lessons learned from innovative monitoring approaches, and gather data from TMDL implementation plans to assess changes over time.
BMP effectiveness, Activities include conducting studies for removal of PCBs from specific practices, improving information on the co-benefits of potential PCB reduction with nutrient and sediment

BMPs, assessing of the feasibility of incorporating the results into CBP decision tools, (such as CAST), and working interacting with the WQ GIT to apply the findings.

Mercury: For the revised Management Strategy, efforts will be made to improve the understanding of baseline conditions by compiling information on the extent of mercury impairments across the watershed. The jurisdictions will work through the TCW to display the information on story maps similar to those prepared for PCBs. The TCW will also work with jurisdictions to inventory mercury data and assess if information exists to document changes in mercury in response to air controls. The results will be used to help jurisdictions consider if additional efforts are needed to reduce the impacts of mercury.

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 high value species (for commercial and recreational fishing, and rare and endangered species). The states in the watershed (as well as DC) have active projects, many in cooperation with USGS, FWS and academic partners, attempting to discern causes of declining fish health, and fish mortality, in their respective drainage areas of the Bay watershed. 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 several years. The USGS will complete its Chesapeake EDC study and summarizing the results on the sources, pathways and effects of these compounds on fish in selected agricultural areas. As the USGS EDC work is completed, they will be evolving to focus more the factors (including contaminants) affecting fish habitat and health in the watershed, and collaborating with NOAA on estuary habitats. In the watershed, there will be more targeted investigations in urban and agricultural areas to understand the multiple factors affecting fish and their habitats. The FWS and USGS, will also work with partners in MD and DC to address the factors affecting reproduction of yellow perch and cause of tumors. UMBC will be continuing research on the occurrence of selected toxic compounds in oysters throughout MD waters. To summarize the effects of toxic contaminants on wildlife, USGS will publish results from a data synthesis.

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 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. We will also look at the co-occurrence of contaminants with nutrients and sediment to find opportunities for mitigation options (next approach)

Approach: Provide 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 Goal Team, to identify and prioritize mitigation options to help mitigate contaminants and the potential co-benefits with nutrient and sediment reductions.

Both PCBs and mercury have widespread extent and severity and cause fish consumption advisories, so they are being addressed first for mitigation options. Science to support PCB reductions is further described in the Policy and Prevention Strategy and work plan, while information to better inform mercury is described in first management approach of this strategy.

For other contaminants and their mixtures, the TCW will depend on information learned in different from landscape settings, and several additional activities to help identify and prioritize mitigation options. The additional activities will include:

- Studies of mitigating contaminants in different landscape settings
- Determine the efficiencies of some management practices to reduce selected contaminants
- Explore the use of existing nutrient and sediment tools (such as CAST and watershed model) to address selected contaminants.
- Interact with WQ GIT teams on opportunities to achieve co-benefits between nutrient and sediment practice and contaminant reductions.

Information generated from the research strategy, will be continuously shared with the TCW, and key source WGs of the WQ GIT (WWTPs, storm water, and agricultural) so they can consider options for mitigation impacts of toxic contaminants. These efforts will address the factor for "**Limited information of the effects practices to mitigate contaminants, and their potential co-benefits with nutrients and sediment reduction"**

Approach: Gather information on issues of emerging concern

The TCW will keep abreast of efforts to understand the effects of microplastics, and consider several new issues of concern, including: (1) harmful algal blooms and their associated toxins; and (2) the potential effects of poly- and perflouroalkyls (PFASs), (3) coal ash reuse, and (4) reducing the effects of road salts. The TCW will reach out to investigators of on-going studies and have them provide updates on the latest findings to increase our understanding and implications for the Chesapeake watershed. Efforts to prioritize the issues and identify related tasks will be completed by the TCW.

Approaches Targeted to 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.

Collaborating 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).

VI. Monitoring Progress

Two types of monitoring are being considered: (1) programmatic and (2) environmental. Programmatic monitoring will focus on completion of planned activities for actions in the research strategy and biannual workplan. Environmental monitoring provides several types of information (1) to improve of knowledge of baseline conditions for occurrence, concentrations, sources and effects for the highest priority pollutants and (2) supports the policy and prevention outcome to help assess effects of management practices. Initial ideas for monitoring to improve information of environmental conditions for 5 major issues include:

- ***Human consumption***: Update the status of fish health consumption advisories and impairments in the Bay watershed due to PCBs and mercury.
- ***Fish and wildlife health***: Develop indicators for fish and wildlife health to better characterize their extent in the watershed. Possibilities include indictors of (1) intersex conditions in fish, and/or (2) presence of tumors in fish.
- ***Occurrence of contaminants***: Summarize the monitoring results of the selected compounds listed existing efforts to better document their extent.
- ***Management approaches***: Summarize and communicate information on the co-occurrence of contaminants, nutrients, and sediment so stakeholders can develop options for BMPs to provide collective improvements for water quality.
- ***Issues of emerging concern***: Summarize information on issues of emerging concern to assess if their need to be in future research strategies.

VII. Assessing Progress

Assessing programmatic progress (making sure planned activities are completed) will be at least annual so that 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.

Assessment of environmental conditions and change will be done less frequently (every 2 to 5 years) depending on availability of contaminant monitoring results. We will utilize the biannual reporting for impaired waters (305b) done by each state and DC to assess conditions for selected contaminants that monitored for these efforts. Monitoring for additional contaminants will be done less frequently due to efforts needed to collect, compile, and analyze information. The planning, completion and publishing of research is usually a multi-year process which affects the advancement in gaining more knowledge to reduce uncertainty.

Lessons Learned

The following lessons were learned during review of the Toxic Contaminant Research Strategy:

- Lesson: Multiple contaminants and additional factors are causing the degradation (and mortality) of fish so trying to identify specific causes is extremely difficult.
    - Actions: Evolving towards a more geographic approach to focus in areas where fish health issues are most prevalent. Greater emphasis on linkage between factors affecting fish habitat and health, including toxic contaminants.
- Lesson: There is a lack of data on the occurrence and trends of toxic contaminants.
    - Actions: Better utilize jurisdictions monitoring that is used for biannual integrated reports; design an integrated monitoring network to improve long-term information.

- Lesson: Limited information of the practices to mitigate contaminants, and their potential co-benefits with nutrients and sediment reductions.
    - Actions: Increased interaction with WQ GIT to develop and promote joint approaches to reduce toxic contaminants, nutrients, and sediment. Expand capacity through increased coordination with ongoing academic research, state, and federal efforts. Increase emphasis on toxic contaminants within CBP monitoring and modeling teams. More focus on co-benefits.
- Lesson: Findings from technical articles and reports need to be summarized and communicated to be used effectively by resource managers.
    - Actions: Summarize existing information and provide implications for better management of contaminants

VIII. Adaptively Manage

The Toxic Contaminants Workgroup will assess the management implications from the research findings and decide on updates (that are required every two years) needed to policy and prevention strategy to address contaminants beyond PCBs. There will be interchange between the research and policy and prevention teams of the TCW to discuss evolution of research issues every two years to support management needs.

IX. Biennial Workplan

The Biennial workplans for this strategy contains actions for 2018-20.