Urban Toxic Contaminants: Removal by Urban Stormwater BMPs

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Presentation Outline

1. Introduction
2. Definition of Urban Toxic Contaminants
3. The Dirty Dozen UTCs in Urban Watersheds
4. Effectiveness of Urban BMPs in Removing Them
5. Risk that UTCs Accumulate in BMP Sediments
6. Watershed Strategies for Reducing Toxics
7. Discussion and Resources

Why Worry About Toxics?

- The N and P we deal with most often are not particularly cuddly, scary or photogenic
- Toxins exert a real impact on both human health and harm aquatic life, fish and wildlife
- The public is justifiably concerned about the presence of toxins in the environment
- Most of the TMDLs in the country are for toxins
- Rationale for industrial stormwater permits
- Implications for long term maintenance of stormwater practices

Toxics and TMDLs in the US

Rank	Pollutant	# of TMDLs in US
1	Mercury	21,545
2	Pathogens	13,016
3	Metals (excluding Hg)	9,828
4	Nutrients	6,034
5	Sediment	3,922
11	Pesticides	1,233
13	PCBs	698
17	PAH and Toxic Organics	158
Source: EPA OWOW Website, Accessed July 2015		

Project Background

One year research synthesis project that evaluated 35 group of toxins generated by the agricultural, urban and wastewater sectors

Goal: Investigate toxic reduction benefits associated with Bay BMP implementation for the TMDL

Chesapeake Bay Program
A Watershed Partnership

2. Criteria to Define Urban Toxic Contaminants

1. The toxin is primarily associated with **urban land use**, compared to other sectors in the watershed.

2. The toxin is either **generated within the urban sector** or is deposited from the atmosphere onto impervious surfaces and subsequently washed off.

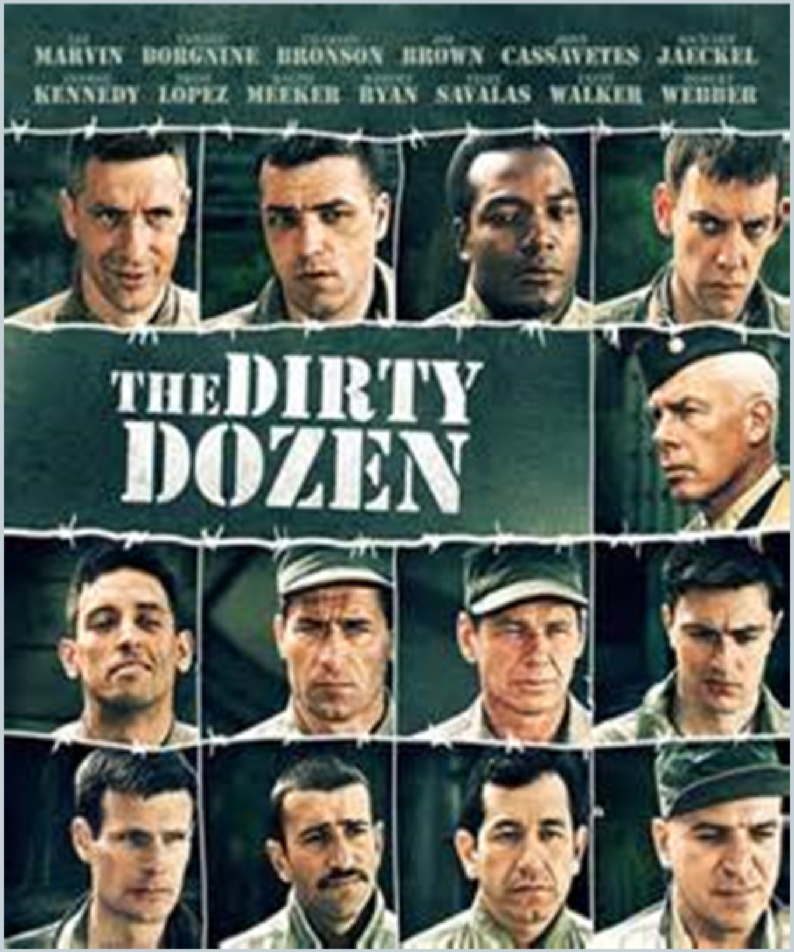
3. Urban **stormwater runoff** is the predominant pathway for transporting it thru the watershed.

4. The toxin has "**sediment-like characteristics**" and can be removed by settling or filtering practices.

5. The toxin is generated or produced in an **upland landscape position** in the watershed where it can be effectively treated by an urban BMP that captures surface runoff.

6. Physical evidence exists that the toxin is **captured** and/or retained within an **urban stormwater BMP**.

2. The Dirty Dozen UTCs



- PCBs
- PAH
- TPH
- Mercury
- UTM (Cd, Cu, Pb, Zn)
- OTM (As, Cr, Fe, Ni)
- Pyrethroid Pesticides
- Legacy OC Pesticides
- Legacy OP Pesticides
- Plasticizers (Phthalates)
- Flame Retardants (PBDE)
- Dioxins

Polychlorinated Biphenyls (PCBs)

- Still detected in fish and wildlife tissues four decades after they were banned (although levels are gradually declining)

- PCBs moving through urban watershed as contaminated sediments are mobilized, deposited and re-suspended

- Older commercial and industrial land use are key watersheds source

Polychlorinated Biphenyls (PCBs)

- Good data on sources, generating sectors, and pathways
- Less data to define levels in runoff and sediment and establish BMP removal rates
- Most data collected outside of Chesapeake Bay
- Meets UTC criteria and behaves like sediment
- Should be removed like sediments in urban BMPs

Polycyclic Aromatic Hydrocarbons (PAH)

- Highest contributor to overall toxicity in urban creeks
- Unique urban sources: coal tar sealants and vehicle emissions
- First flush pollutant, behaves like sediment
- BMP studies show high removal rates (80 to 90%)
- Strong concern about PAH accumulation in pond sediments and possible toxicity

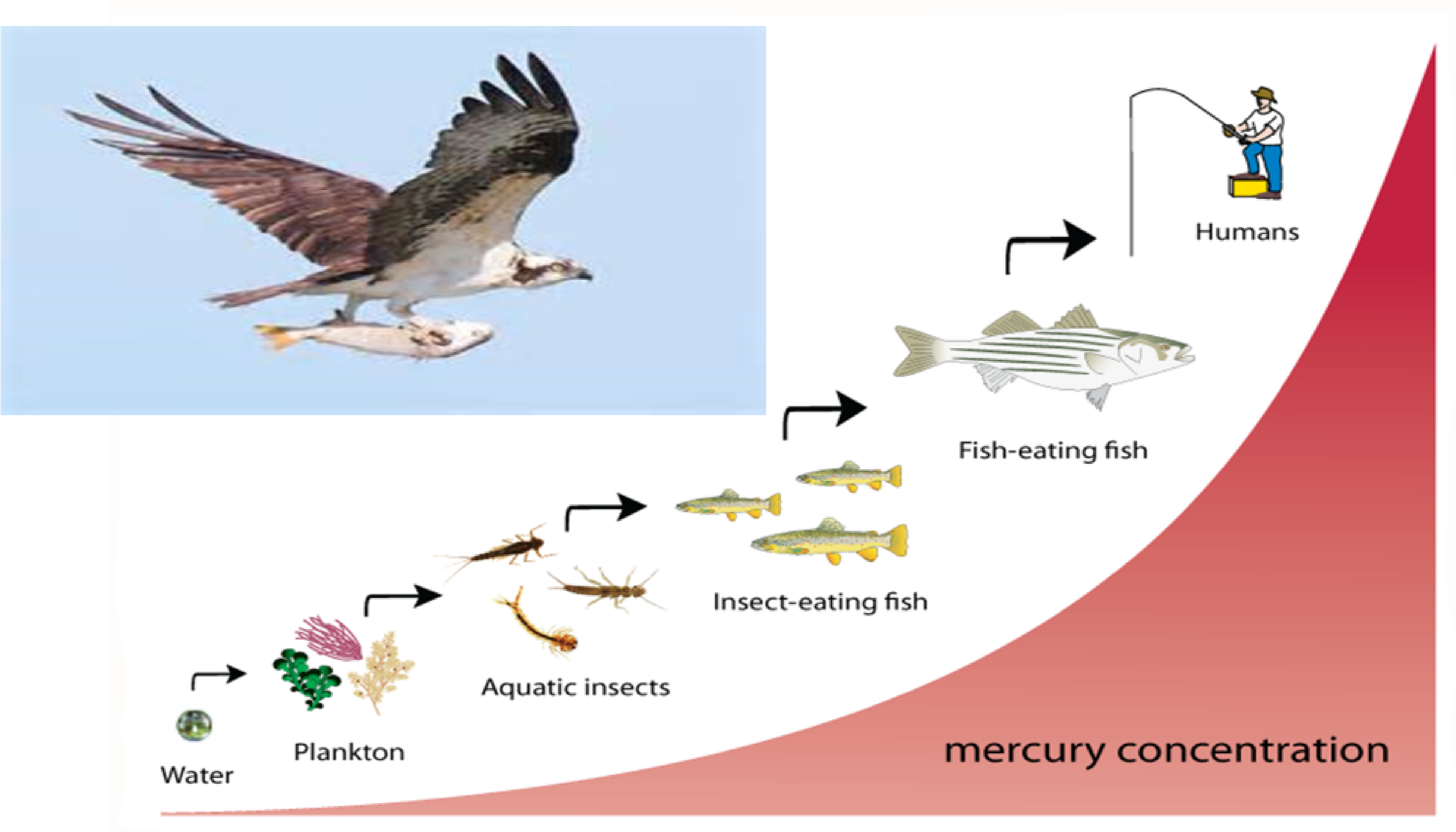
Total Petroleum Hydrocarbons (TPH)

- Term for the oil, grease, gasoline and other hydrocarbons found in urban runoff (i.e., the oil sheen)
- No numerical standards for TPH
- TPH meets all 6 UTC criteria
- Limited monitoring shows very high removal rates in most stormwater BMPs
- Microbes in bioretention media are especially effective in rapidly breaking down TPH

Mercury (Hg)

- Hg is a global pollutant and is deposited from the atmosphere across all Bay land uses (including open water)
- Hg accumulates in fish, birds of prey, and fish-eating mammals and humans
- Hg is leading cause of water quality impairment in the Bay watershed and across the nation
- Urban areas are a key source when Hg is deposited and washed off impervious surfaces or contaminated soils are eroded
- Acts like a UTC.
- Limited monitoring data show high Hg removal by stormwater BMPs

Hg Biomagnification



Mercury Methylation

- Methylation is the process whereby Hg rapidly accumulates in fish tissue and becomes magnified up the food chain
- The process is enhanced in anoxic and organic rich sediments of natural wetlands and estuarine sediments
- Hg is the least treatable UTC due to methylation and air deposition over open waters
- Limited data show that constructed wetlands also enhance methylation
- Hg bioacccumulation in eagles and osprey is <u>trending down</u> in the Chesapeake Bay

Urban Trace Metals (UTMs)

- Cd, Cu, Pb and Zn are detected in nearly 100% of urban stormwater samples, and soluble levels of these metals often exceed aquatic life standards
- Abundant research on EMC and BMP removal for all four metals
- Unique urban sources: roofing materials, brake pads, tire wear, vehicle emissions and air deposition
- Despite solubility, monitoring data generally show high to very high UTM removal by BMPs (especially bioretention).

Comparative Ability of Stormwater BMPs to Remove Urban Trace Metals

Stormwater BMP	Urban Trace Metals			
	Cadmium	Copper	Lead	Zinc
Bioretention	H	VH	VH	VH
Wet Pond	M	H	H	H
Wetland	M	H	M	M
Sand Filter	H	M	VH	H
Permeable Pavement	L	M	VH	VH
Dry Swale	L	H	--	VH
Grass Channel	M	L	L	M
Grass Filter	L	M	L	M
Dry Pond	L	L	M	M

VH: Very High Removal (76% to 100%) H: High Removal (50% to 75%)
M: Moderate Removal (26% to 50%) L: Low Removal (0% to 25%)

Other Trace Metals (OTM)

- Include Arsenic, Chromium, Iron and Nickel
- Greatest risks are for potential drinking water contamination
- Violations of water quality standards are uncommon but operators must closely monitor them during storms
- The source of OTMs are corrosion of urban landscape surfaces often by acid rain
- Most urban BMPs appears to have a moderate to very high ability to remove OTMs

Trends in Insecticides

- The insecticides applied to crops and urban areas have changed over time, and are now less persistent in the environment and do not bioaccumulate in tissues.
- However, they are still mobile in the environment and are deadly to aquatic invertebrates at the part per trillion level

Evolution in Insecticides Over Time

Era	Insecticide	Types	Notes
1940 to 1970	Organochlorines (OC)	DDT	Banned in the 1970s
		DDD/DDE	DDT degradation products
		Dieldrin	Banned in 1985
1960 to 2000	Organophosphate (OP)	Chlordane	Banned in 1978
		Chlorpyrifos	Restricted in 2002
		Diazinon	Restricted
		Dichlorvos	Increased use after 2002
2000 to present	Pyrethroids	Bifenthrin	Replacements for OCP and OPP
		Permethrin	Less toxic than bifenthrin
2005 to present	Fipronil	Fipronil	Most aquatic life toxicity in recent surveys
	Neonictinoids	Imdiacloprid	Emerging concerns about aquatic toxicity

Pyrethroid Pesticides

- Pyrethroid pesticides include bifenthrin, permethrin and others
- New class of insecticides introduced in the last decade
- Non-persistent in the environment and unlikely to bio-accumulate in vertebrates
- Extremely lethal to aquatic invertebrates in urban streams, even at part per trillion level
- Routinely detected in urban creek sediments

Pyrethroid Pesticides

- Meet criteria to qualify as an UTC, although some data gaps remain
- Strong affinity for sediment and organic matter
- BMP removal rates should be comparable to suspended sediment
- More research needed on persistence and toxicity in BMP sediments.

Legacy Organochlorine Pesticides

- Organochlorine (OC) pesticides include DDT, DDE and dieldrin that were banned decades ago but still persist in the urban and agricultural watersheds

- Soils contaminated by OC pesticides more mobile in urban watersheds. Likely present in older pond sediments

- Sharply declining trends in OC pesticide levels in urban runoff and creek sediments -- reduced bioaccumulation in fish, eagles and marine mammals.

Legacy Organophosphate Pesticides

- Organophosphate (OP) pesticides include chlorpyrifos, diazinon and dichlorovos and were introduced 15 to 20 years ago to replace OC pesticides.

- Relatively non-persistent but still very highly toxic to aquatic life in urban streams, most were banned by the turn of the century

- Found in urban watersheds, are highly mobile, are carried by urban stormwater runoff and generally behave like a sediment particle.

- Sharp declines in OP pesticides in stormwater runoff and urban creek sediments after they were banned

- Less persistent pesticides can be eliminated from the environment due to short watershed lag times.

Emerging Toxins of Concern

Flame retardants (PBDE)

Plasticizers (pthalates)

Dioxins

- Very limited monitoring data available -- most collected in Europe or West coast
- Municipal wastewater and biosolids are also key sources of emerging toxins of concern

4. Capability of Stormwater BMPs to Remove UTCs

Urban BMPs are Very Effective at Removing UTCs

- Most UTCs have sediment-like properties, so they are effectively trapped by most urban BMPs before they get to local waterways and the Bay.

Suspended sediment and UTCs

- Share many characteristics
  - UTCs bind, adsorb or otherwise attach to sediment particles
  - UTCs are hydrophobic, have very limited solubility and a strong affinity for organic matter.
  - Both are also relatively inert, persistent, and not very bio-degradable.
  - Both are often associated with fine and medium-grained particles that are easily entrained in stormwater runoff.
  - Both are subject to high removal rates simply through gravitational settling in the water column and/or filtering through sand, soils, media or vegetation.

BMP Treatability for Urban Toxic Contaminants

Toxin Category	BMP Removal Rate?	Measured or Estimated?	Behaves like Sediment?	BMP Retention?	Sediment Toxicity Concern?
PCBs	TSS	E	Y	Y	Mod
PAH	> TSS	E	Y	Y	High
TPH	> TSS	M	Y	Y	Low
Mercury	> TSS	E	Y	Y	Mod
UTM	< TSS	M	Y	Y	Mod
OTM	< TSS	M	Y	Y	Mod

BMP Treatability for Urban Toxic Contaminants
continued

Toxin Category	BMP Removal Rate?	Measured or Estimated?	Behaves like Sediment?	BMP Retention?	Sediment Toxicity Concern?
PP	TSS	E	Y	y	High
OCP	> TSS	E	Y	y	Low
OPP	< TSS	E	Y	?	Low
Plasticizers	Not Really Sure				
PBDE					
Dioxins					

UTC Accumulation In BMP Sediments

- Persistent UTCs accumulate in BMP sediments over many decades at levels that trigger sediment toxicity guidelines.
- As many as 8 UTCs pose a risk for sediment toxicity: PCB, PAH, Hg, Ni, Cr, Cu, Cd, and Zn
- Most research on older stormwater pond sediments

PAH and Pond Sediments

Percent of MD Stormwater Ponds with Potential PAH Sediment Toxicity		
Individual PAH	**TEC**	**PEC**
Napthalene	3%	0%
Flourene	12%	1%
Phenanthrene	46%	12%
Anthracene	15%	1%
Flouranthene	34%	13%
Pyrene	34%	15%
Benzo[a]anthracene	24%	7%
Chrysene	34%	10%
Benzo[a]pyrene	38%	7%
Dibenz[a,h]anthracene	44%	NA
Source: Gallagher et al, 2010		

Managing the BMP Sediment Toxicity Risk

- Are BMP sediments an acceptable place to trap toxics in the urban landscape ?
- Where is the **next** place that sediments should go after are cleaned out from BMPs ?
- Is UTC sediment accumulation only a concern for older stormwater ponds in highly urban/industrial watersheds ?

Not a Bad Place, After All ?

Toxicity risk to aquatic life in the stormwater pond environment may be limited:

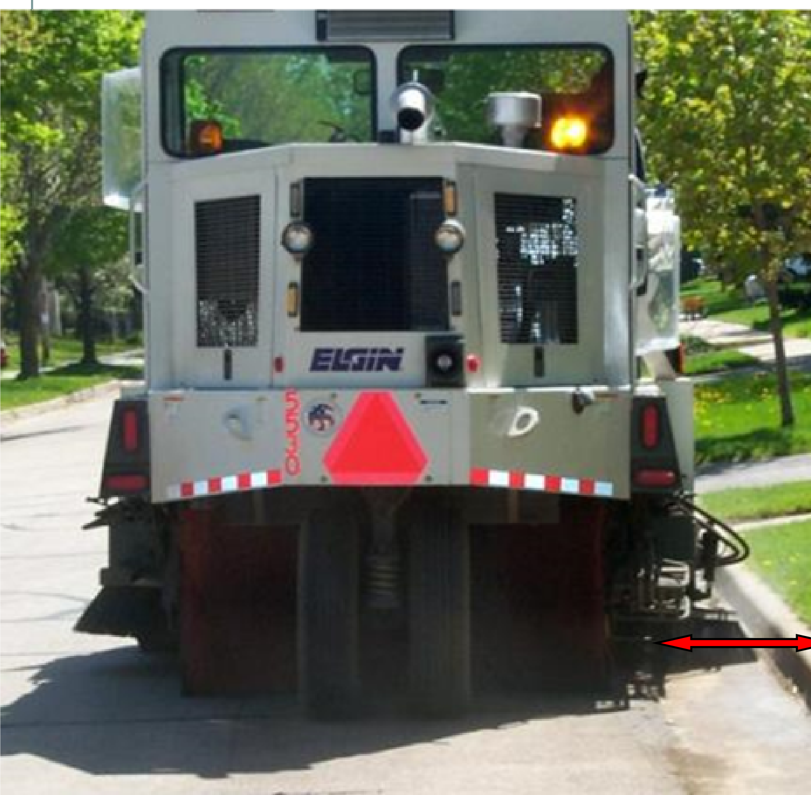
- Simplified food webs and low species diversity reduce bio-accumulation in urban fish and wildlife tissues.
- Not much of a benthic community in pond sediments
- Ponds appear to be effective at retaining UTCs over time
- UTC levels are also high in other non-BMP sediments (e.g., urban creeks, rivers and estuaries).
- Extremely limited fish consumption from ponds and recreational contact with sediments is non-existent

New LID practices (e.g., bioretention) do not create aquatic habitat and removal of surface sediments is frequent

Watershed Strategies for Toxic Reductions

1. Targeted Street Cleaning
2. Industrial and Municipal Pollution Prevention
3. Bans and Product Substitution
4. Stormwater Treatment and Retrofits

Targeted Street Cleaning in Older Watersheds with a lot of Legacy industrial land use



Street Dirt is Highly Contaminated

Toxic Contaminant	Sediment Concentration
Petroleum Hydrocarbons	Diesel range: 200 to 400 mg/kg Motor Oil: 2,200 to 5,500 mg/kg
PCB's	0.2 to 0.4 mg/kg
PAH	Total: 2,798 ug/kg Carcinogenic 314 ug/kg
Pthalates	1,000 to 5,000 ug/kg
Pesticides	Pyrethroids present
Chloride	980 mg/kg
Mercury	0.13 mg/kg
Based on 3 West Coast Studies of street dirt and/or sweeper waste contamination. Source: Expert Panel Report	

Industrial and Municipal Pollution Prevention

Potential Reduction By Pollution Prevention Practices

- No data on impact of pollution prevention practices in reducing toxins required under industrial and municipal stormwater permits.
- The potential effect of these practices could be considerable, given that:
  - 2,700 industrial sites have stormwater permits in Bay watershed (25,000+ acres of impervious cover)
  - 1,000 MS4 facilities and public works yards are subject to the same regulations.

Bans and Product Substitutions

- Past bans and/or product substitution have worked
  - Lead
  - PCB
  - DDT and Diazinon
- New bans and product substitution
  - coal tar sealant for PAH
  - brake pads and rotors for UTMs
  - more sustainable roofing materials for UTMs
- Improved recycling and disposal (batteries, thermostats, fluorescent light bulbs, etc).

Assessing Stormwater BMPs

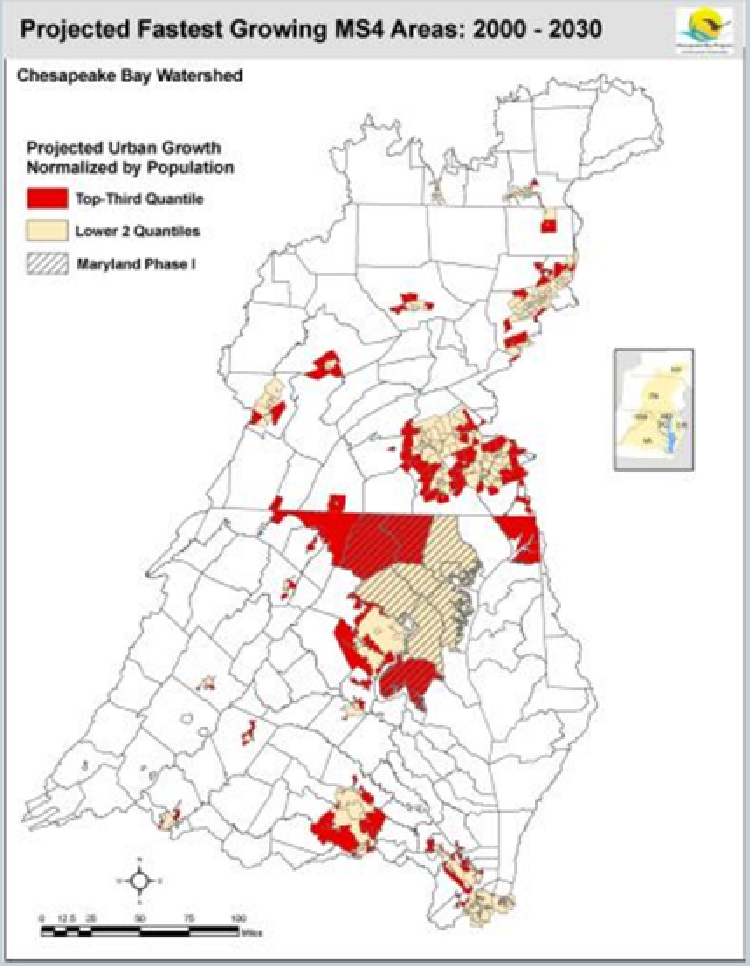
Step-wise Approach

1. Evaluate Urban Land Uses
2. Estimate Loading Rates w/ Simple Method
3. Use TSS Removal Rates as a Benchmark
4. Estimate TSS Removal Rates for Current and Future BMPs
   - Adjustor Curves
   - CBP Removal Rates
   - Estimating Existing BMP Coverage in the Watershed
5. Assess Impact of Other Toxin Reduction Strategies (e.g., Pollution Prevention and Street Cleaning).

Use TSS Removal as a Benchmark

- Linking UTCs to a benchmark TSS removal rate
- Allows users to project UTC removal rates based on known TSS removal rates
- Can calculate reductions based on much larger CBP database on sediment removal by urban BMPs

Urban BMP Coverage in Bay Watershed



- Urban BMPs now cover 30% of urban land in the watershed – most of any region in the nation
- BMP coverage could increase to 40 or 50% by 2025 due to TMDL compliance in the urban sector
- UTC removal by nearly all urban BMPs is moderate to very high

Conservation Tillage and Herbicides

- Profound shift to conservation tillage as a cornerstone BMP for corn and soybeans in the Bay watershed has changed herbicide use and impacts over the last 3 decades

Toxins Produced from Livestock Production and Wastewater Treatment

CSN Toxic Resources

- CSN Report on Urban Toxic Contaminants
- CSN Report on Toxics from the Agricultural and Wastewater Sectors
- Archived Webcasts on Industrial Stormwater
- Industrial Stormwater Benchmarking Tool

Available @ www.chesapeakestormwater.net

Other CSN Resources

- Street and Storm Drain Cleaning Expert Panel Report
- Floating Treatment Wetland EPR
- Pond Management Protocol
- Visual Indicators for LID Practices
- Nutrient Performance Enhancers for LID Practices
- FREE CSN Webcast Series

- Go To CSN WEBSITE AND JOIN 9,000 of YOUR STORMWATER COLLEAGUES

Questions and Answers