ABOUT SAM

Stormwater Action Monitoring

Stormwater Action Monitoring (SAM) is

Collaborative

Regional

Funded

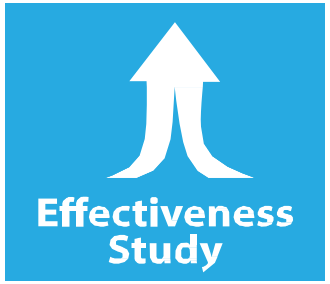
- By permittees in Western Washington: 91 cities, towns, counties; 2 ports; WSDOT
- In-kind from Ecology, WSDA, USGS, Redmond, Penn Cove Shellfish, Cedar Grove, hundreds of mussel monitoring volunteers

SAM's goal

- To improve stormwater management, reduce pollution, improve water quality, and reduce flooding by measuring stormwater impacts on the environment and evaluating the effectiveness of stormwater management actions

Today's agenda

- Permit context for monitoring
- First round of effectiveness studies
- Receiving water monitoring
- Project management and administration
- Source identification
- What's ahead



Stormwater Action Monitoring

SAM Symposium Agenda

June 1, 2017

8:30 am	**Registration, coffee and networking**	
9 am	**Opening & welcome**	*Dana de Leon; Stormwater WorkGroup Chair, Tacoma*
	Agenda and housekeeping	*Brandi Lubliner, Ecology*
	Context: Permit monitoring	*Bill Moore, Ecology*
9:25 am	**Effectiveness studies**	
	Context for bioretention	*Brandi Lubliner, Ecology*
	Soil media: Toxicity reduction	*Jay Davis; USFWS* *Jen McIntyre, WSU*
	Soil media: Fungi and PCBs	*Alex Taylo, WSU* *Jen McIntyre, WSU* *Richard Jack, King County*
	Hydrologic performance	*Bill Taylor, Taylor Aquatic Science*
10:30 am	**Break**	
10:45 am	**Effectiveness studies**	
	Context for other studies	*Brandi Lubliner, Ecology*
	Rain garden eval protocol	*Aaron Clark, Stewardship Partners* *Joy Rodriguez, Puyallup*
	Retrofits: Echo Lake Hwy 99	*Carly Greyell, King County*
	Retrofits: Hylebos facility	*Kate Macneale, King County*
	Retrofits: Paired watersheds	*Andy Rheaume, Redmond* *John Lenth, Herrera Env*
	Catch basin O&M	*Jenee Colton, King County*
	Small Business source control	*Greg Vigoren, Lakewood*
11:30 am	**Lunch**	
Noon	**SAM administration: How SAM works + study selection**	*Brandi Lubliner, Ecology*
12:15 pm	**Receiving water monitoring**	
	Context for status/trends	*Brandi Lubliner, Ecology*
	Streams	*Curtis DeGasperi, King County* *Rich Sheibley, USGS*
	Nearshore mussels	*Jennifer Lanksbury, WDFW*
	Nearshore sediment	*Bob Black, USGS*
1 pm	**Break**	
1:15 pm	**Receiving water monitoring: Nearshore bacteria**	*Debby Sargent, Ecology*
1:30 pm	**Source identification: Context and IDDE findings**	*Karen Dinicola, Ecology* *Greg Vigoren, Lakewood*
1:45 pm	**Closing: What's ahead**	*Brandi Lubliner, Ecology* *Dana de Leon, Tacoma*
2 pm	**Adjourn**	

Municipal Stormwater Permit Monitoring

Bill Moore, Water Quality Program PDS section manager
Washington State Department of Ecology

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Meaningful feedback

- Municipal permittees spend >$250 million per year managing stormwater
  - Is it working?
  - SAM represents about 1% investment for monitoring

Why this approach?

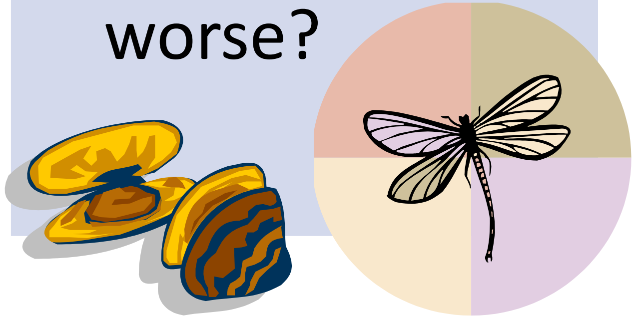
- Outfall monitoring is hard and expensive
- Permittees wanted a different approach
  - Pooled resources for economy of scale
  - Collaboration with existing programs
  - Pay-in equals permit compliance
- Stakeholders set the priorities
- Projects are regionally relevant
- Flexibility outside permit requirements

Collaborative approach

- Stormwater Work Group (SWG)
  - Started 10 years ago
  - Formal stakeholder representation
  - Makes specific recommendations
    - For the permits
    - For SAM projects
  - Many subgroups providing input

2010 Scientific Framework

Status and trends	Effectiveness studies	Source identification
• Are conditions in streams and nearshore areas getting better or worse?	• How well are management approaches working?	• Share results and identify regional solutions



SWG recommended we implement SAM via the permits, and require all permittees to pay

SWG investigated more than 40 options and decided Ecology should administer SAM for the first permit cycle because of:

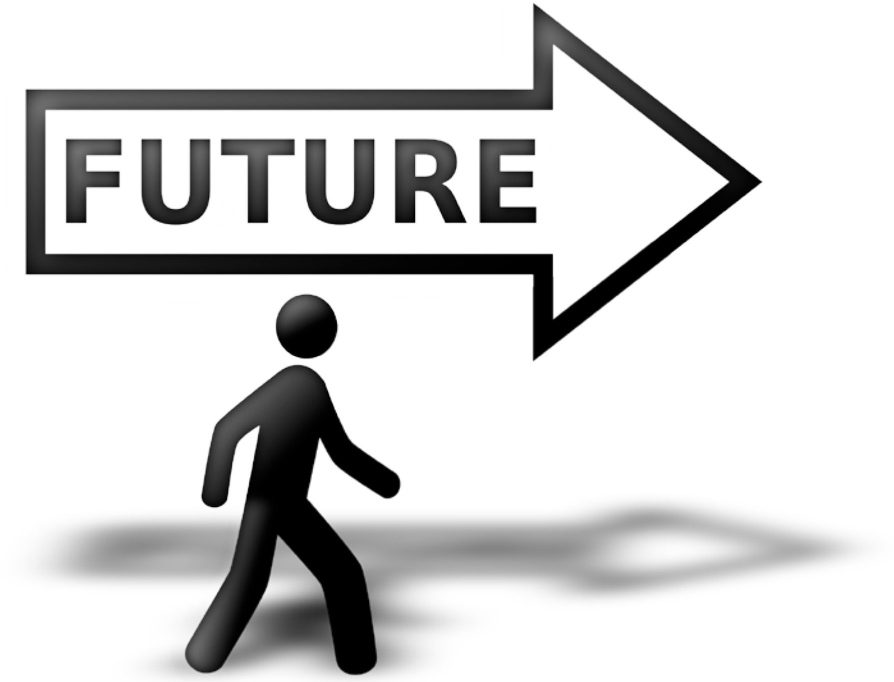
- Capacity & contracting experience
- Relatively low overhead
- No viable alternative

Governance and decision making

- SWG sets the budget and selects the projects
- Ecology writes the permits and manages the program
  - SAM Coordinator is on Ecology staff
  - SAM contracts are with Ecology
  - Private-local account protects the funds
- Oversight committee provides transparency and accountability
  - Approve Ecology's contracting decisions
  - Evaluate Ecology's overall performance

What's ahead for SAM?

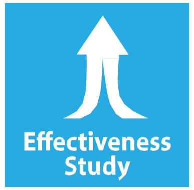
- Will carry on through the next permit
  - Very similar set of S8 requirements
- Stakeholders continue to set priorities
- Learning from the launch process
- Applying findings from first round projects



SAM: Western Washington's Regional Stormwater Monitoring Program

Brandi Lubliner, SAM Coordinator
Washington State Department of Ecology

SAM's three focus areas



How well are stormwater management practices working?

SAM effectiveness studies answer why or why not, and under what conditions.

What are the most common types of pollution in stormwater?

SAM source identification projects identify the most common problems and propose regional actions.

How do we know if water quality is getting better or worse?

SAM receiving water monitoring evaluates conditions in the water bodies that we are trying to protect. No other monitoring in the state gives feedback on permitted areas.

Context for SAM effectiveness studies

Brandi Lubliner, SAM Coordinator
Washington State Department of Ecology

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Context for effectiveness studies

- SWG determined topics & questions
  - Source Control
    - Temporary erosion control
    - Businesses inspections
  - O&M
    - Pollution Prevention
  - Low Impact Development
    - Benefits to receiving waters
    - Long term performance
  - BMP Retrofits

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Bioretention (LID) effectiveness studies

- Soil medium performance
- Soil medium amendments
- Facility performance

Bioretention Soil Mix Toxicity Reduction Study

Puget Sound Stormwater Science Team

USFWS (Jay Davis) / WSU (Jen McIntyre) / NOAA (David Baldwin)

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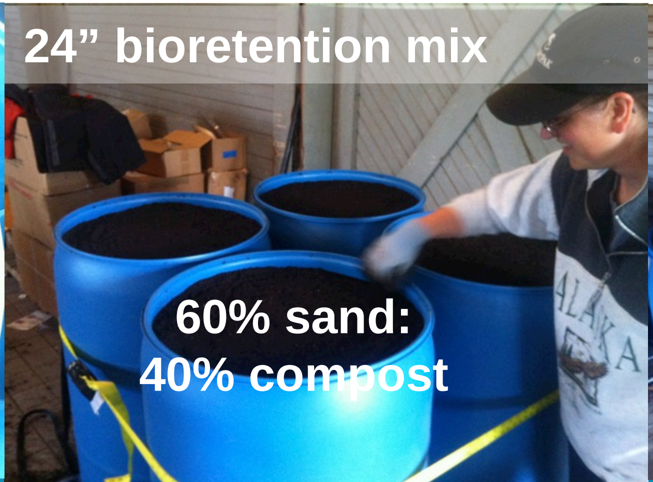
Study Question

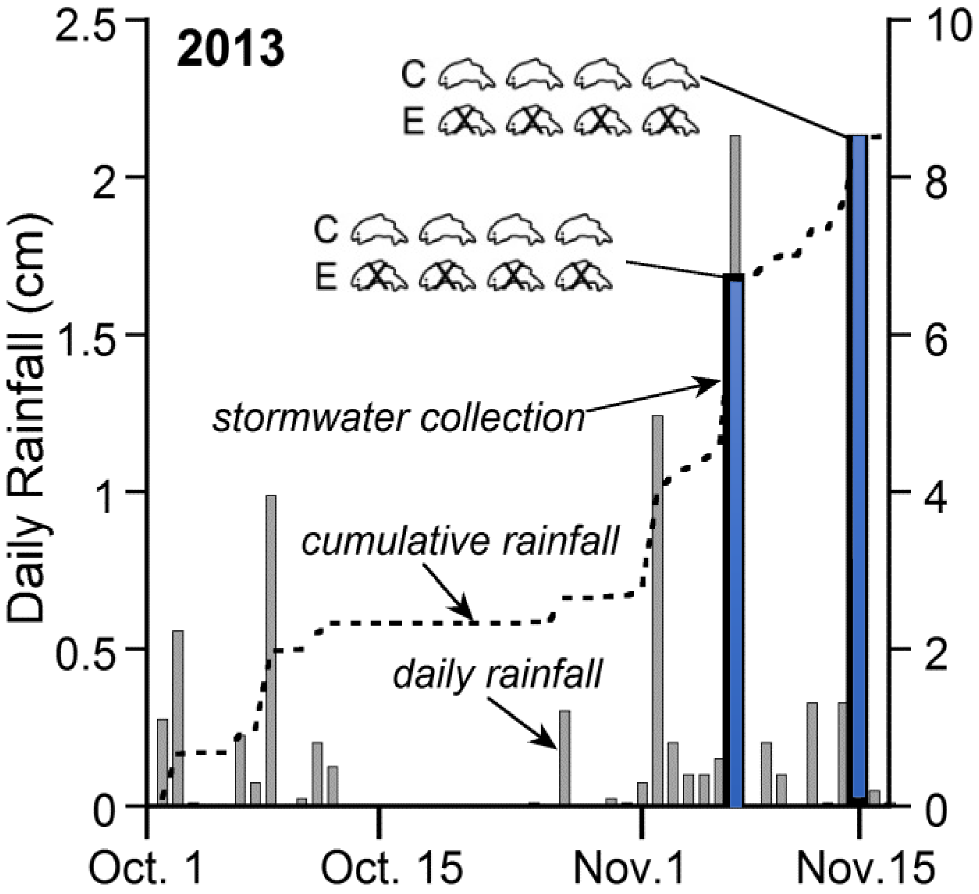
- Is the standard 60:40 (sand:compost) bioretention mix effective for preventing impacts of urban runoff from multiple storms to coho salmon at different life history stages?
    - Adult coho salmon
    - Coho salmon embryos

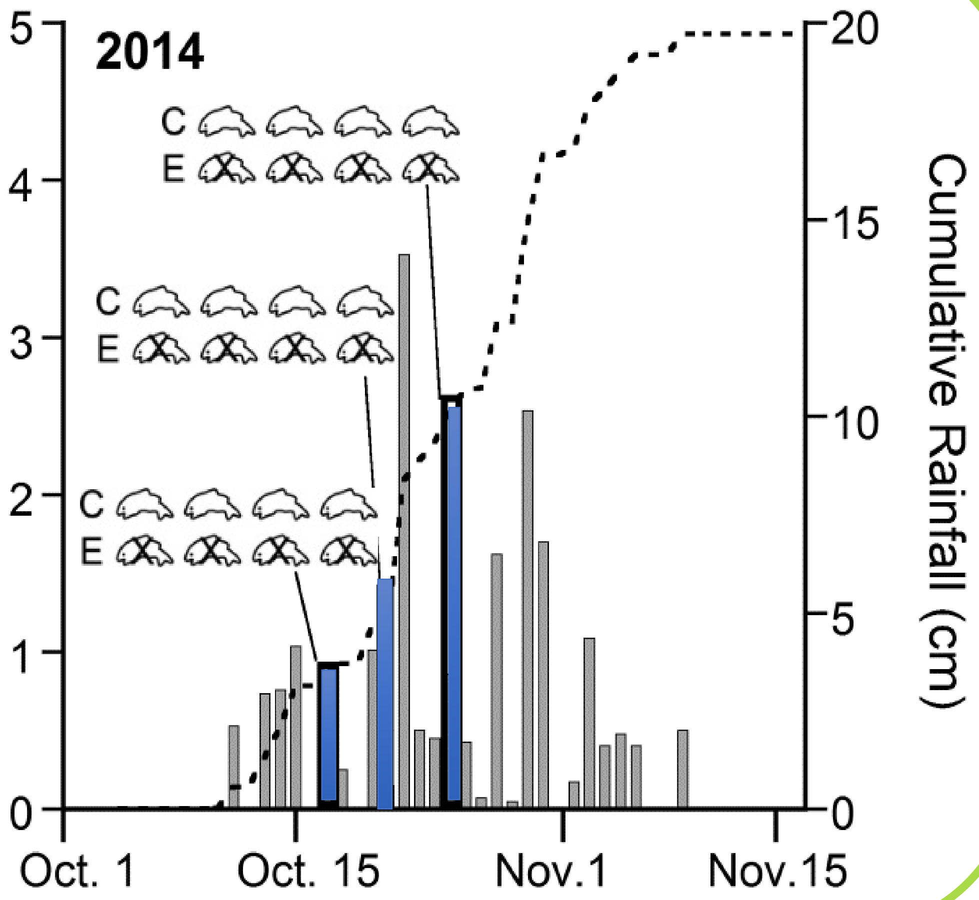
Adult Coho Tests

- Bioretention treatment prevented toxicity from road runoff in a single test with juvenile coho, mayfly nymphs, daphnia (McIntyre et al. 2014; 2015)
- **Could bioretention treatment prevent toxicity from road runoff to adult coho salmon spawners?**



Adult Coho Tests





Adult Coho Tests

- Could bioretention treatment prevent toxicity from road runoff to adult coho salmon spawners?

YES

Study Year	Test Date	Exposure (hours)	Control Water	Untreated Runoff	Treated Runoff
2013	Nov 8	4	100% Live	50% Dead; 50% Sick	100% Live
2013	Nov 18	24	100% Live	100% Dead	100% Live
2014	Oct 20	24	100% Live	100% Dead	100% Live
2014	Oct 22	24	100% Live	100% Dead	100% Live
2014	Oct 27	24	100% Live	100% Dead	100% Live

Adult Coho Tests

Adult Coho Tests

Published Open Access

Journal of Applied Ecology

British Ecological Society

Journal of Applied Ecology 2016, **53**, 398–407

doi: 10.1111/1365-2664.12534

Coho salmon spawner mortality in western US urban watersheds: bioinfiltration prevents lethal storm water impacts

Julann A. Spromberg[1], David H. Baldwin[2], Steven E. Damm[3], Jenifer K. McIntyre[4], Michael Huff[5], Catherine A. Sloan[2], Bernadita F. Anulacion[2], Jay W. Davis[3] and Nathaniel L. Scholz[2]*

[1]Ocean Associates, Under Contract to Northwest Fisheries Science Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112, USA; [2]Environmental and Fisheries Science Division, Northwest Fisheries Science Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112, USA; [3]U.S. Fish and Wildlife Service, Washington Fish and Wildlife Office, 510 Desmond Dr. S.E., Lacey, WA 98503, USA; [4]Puyallup Research and Extension Center, Washington State University, 2606 W. Pioneer Ave., Puyallup, WA 98371, USA; and [5]Suquamish Tribe, PO Box 498, 18490, Suquamish Way, Suquamish, WA 98392, USA

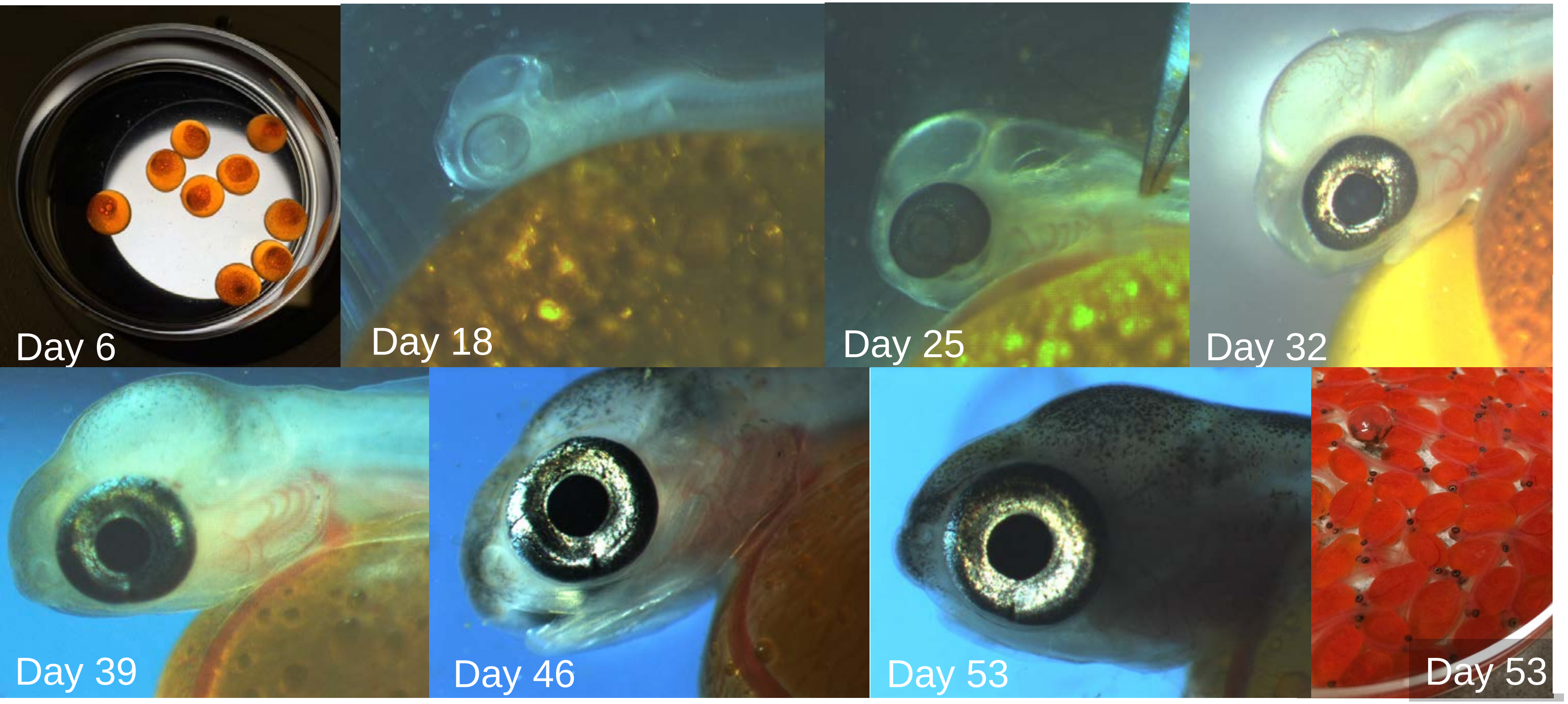
Summary

1. Adult coho salmon *Oncorhynchus kisutch* return each autumn to freshwater spawning

Coho Embryo Tests

- Bioretention treatment prevented toxicity from road runoff:
  - In a single test with juvenile coho, mayfly nymphs, daphnia (McIntyre et al. 2014; 2015)
  - In 3 consecutive tests with adult coho salmon spawners (RSMP Task 3.1)
- **Could bioretention treatment prevent toxicity from road runoff in coho salmon embryos exposed episodically during development? (RSMP Task 3.2)**

Coho Embryo Tests



Imaged 10 embryos

- x 3 cups
- x 4-5 treatments
- x 7 dates

Individual Metrics for:

- Survival
- Length
- Eye Area
- Development
- Cardiovascular abnormalities

Coho Embryo Tests

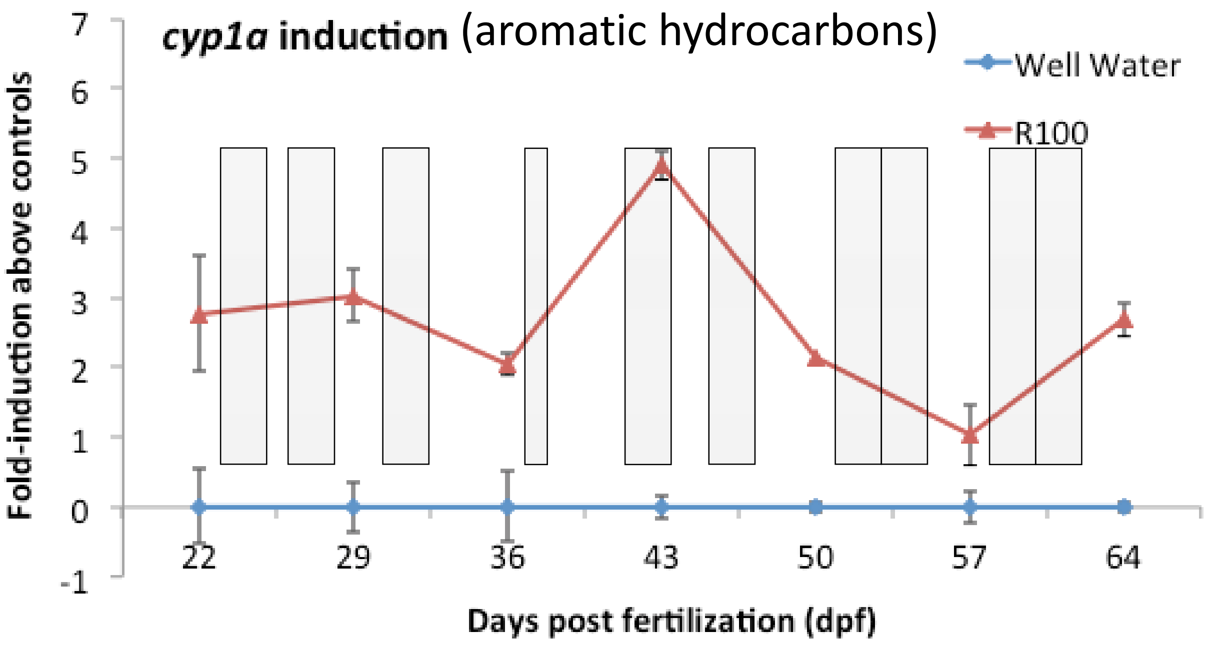
Nov 2014-Jan 2015 (RSMP): Well water, R10, R50, R100, F100

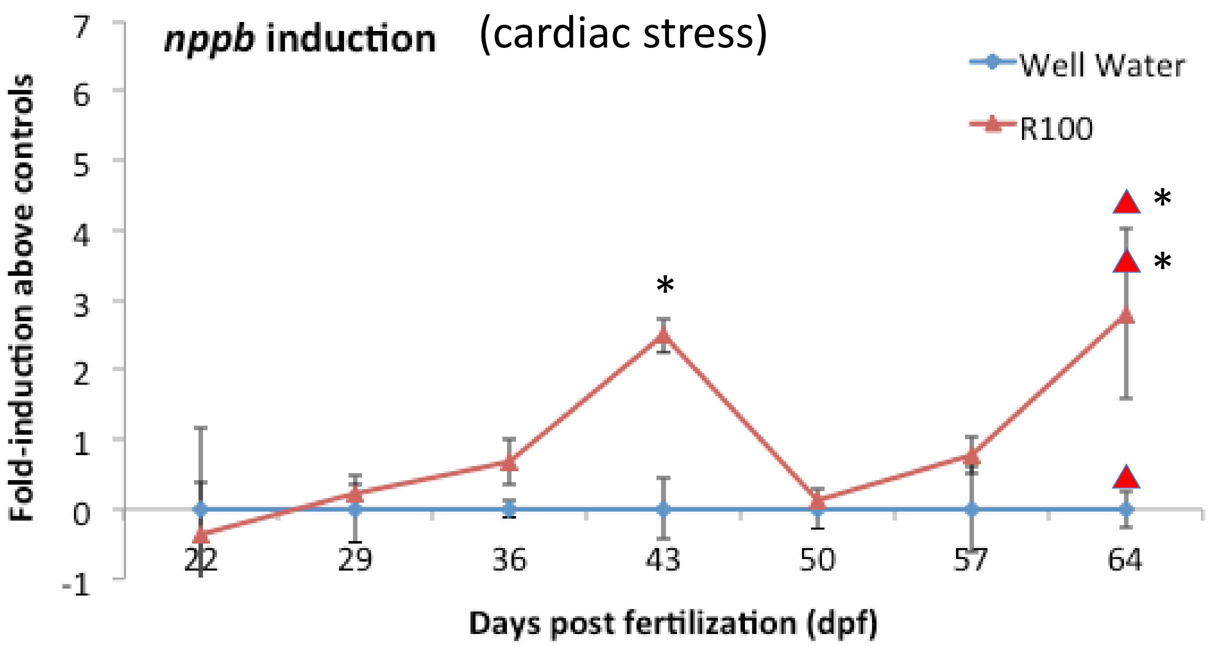
- 7 storms during 53-day development
- Sampled 7 dates during development
- Runoff impacted embryo size, eye area, and survival

Nov 2015-Jan 2016 (EPA Region 10): Well water, R50, R100, F100

- 15 storms during 64-day development
- Similar results in Year 2

Coho Embryo Tests: Sublethal

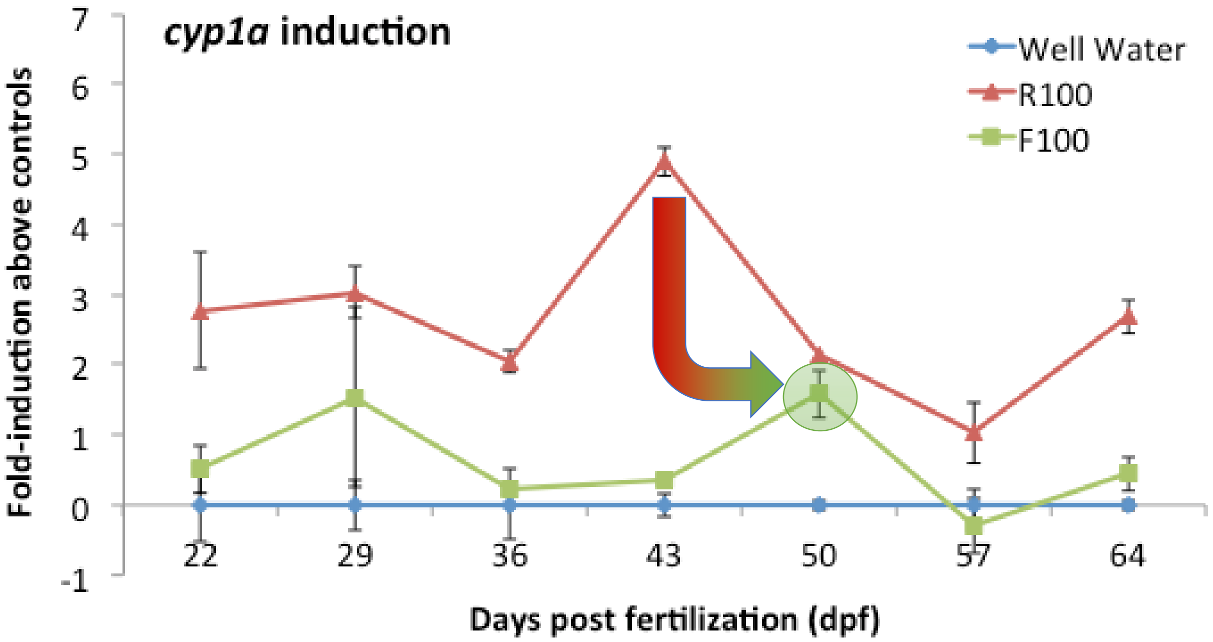


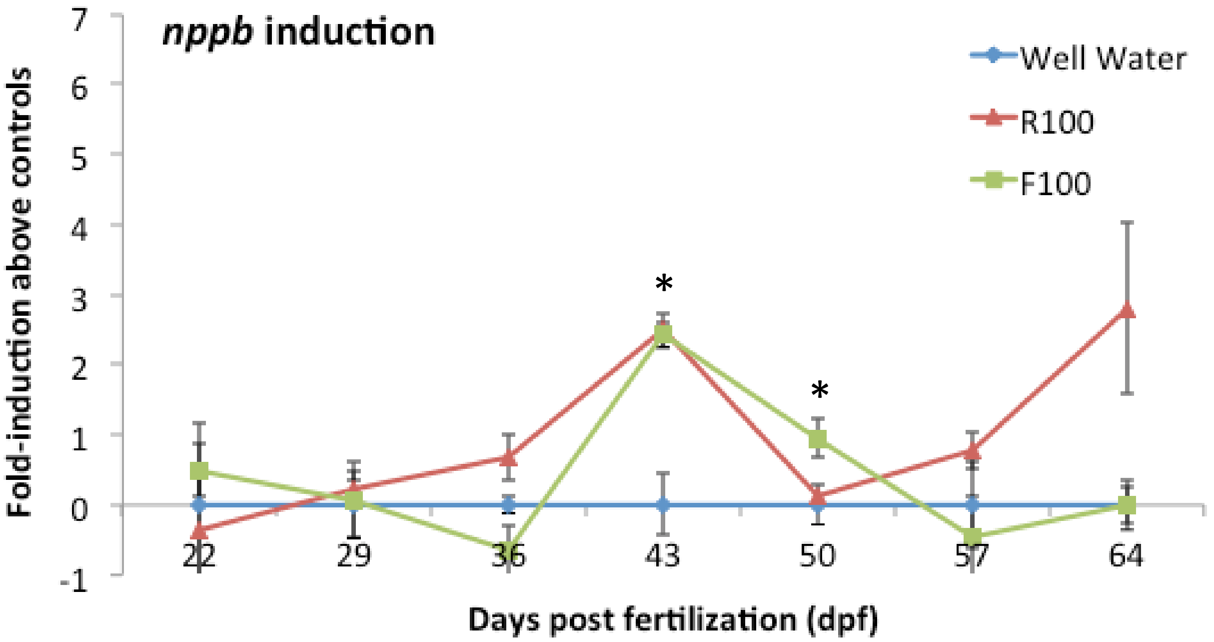


- Runoff induced *cyp1a* (PAH detox) on nearly all sampling dates
- Highest on Day 43, concurrent with exposure

- Runoff induced *nppb* (cardiac stress) only on Day 43
- Concurrent with highest *cyp1a* induction

Coho Embryo Tests: Sublethal

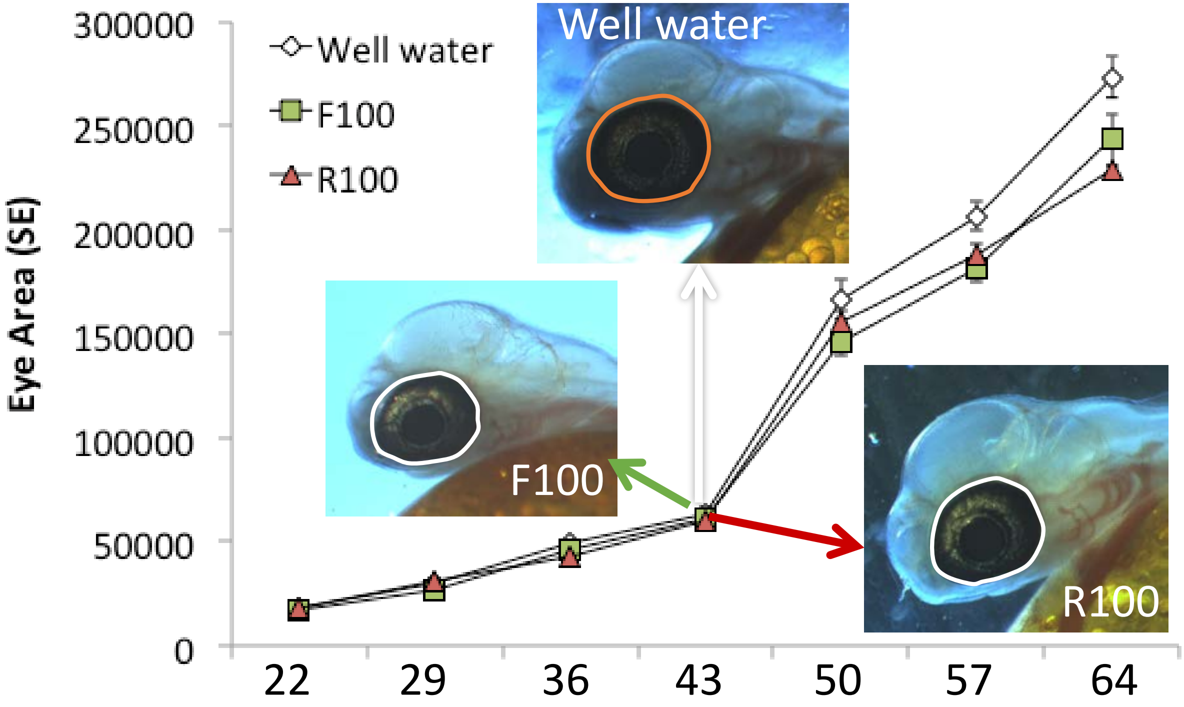


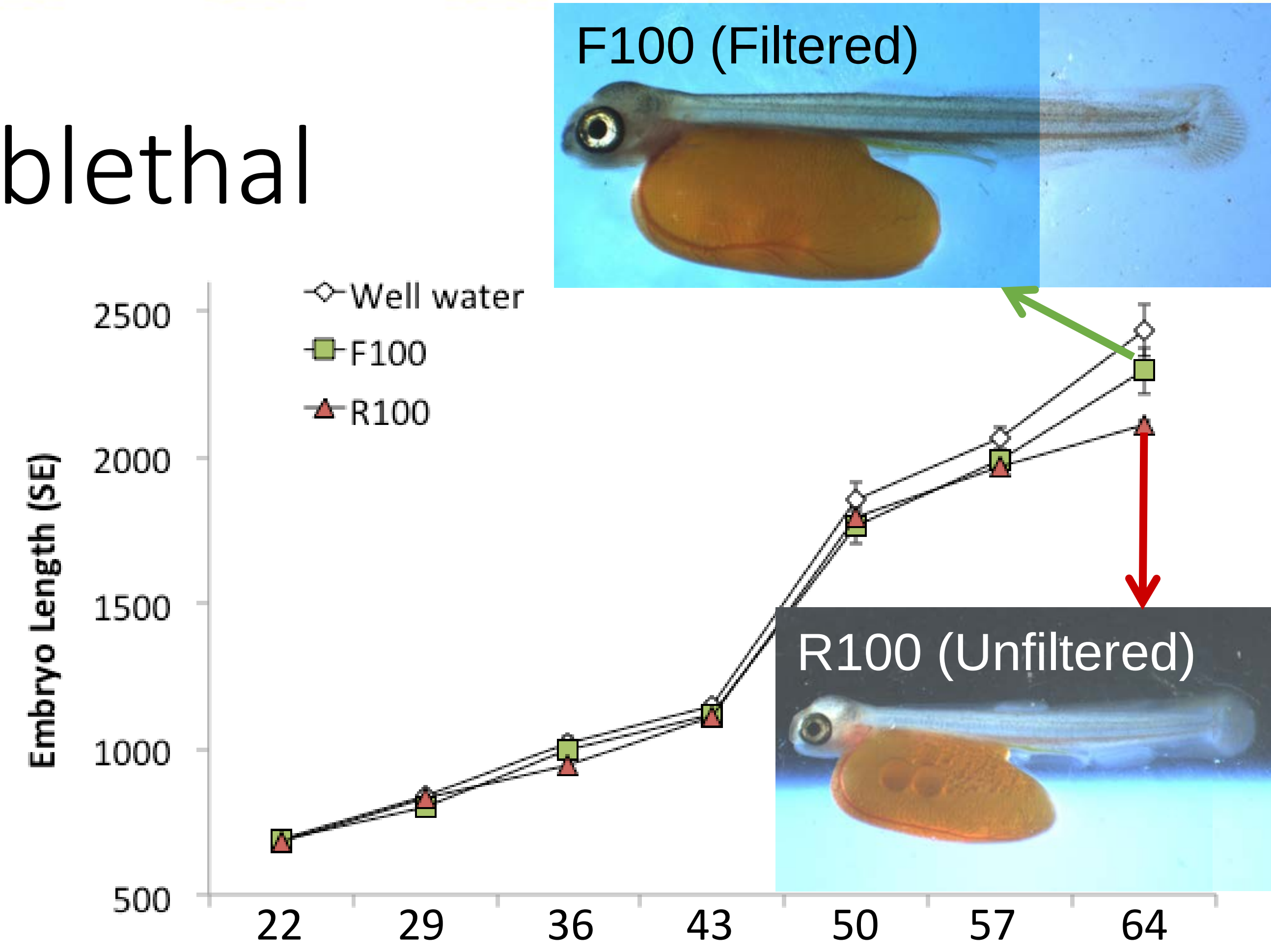


- Bioretention treatment prevented *cyp1a* induction on most sampling days
- Day 50: mobilization of inducers from Day 43

- Cardiac stress in F100 on two dates (43, 50)
- Chemicals that induce *nppb* may not be same as those that induce *cyp1a*

Coho Embryo Tests: Sublethal



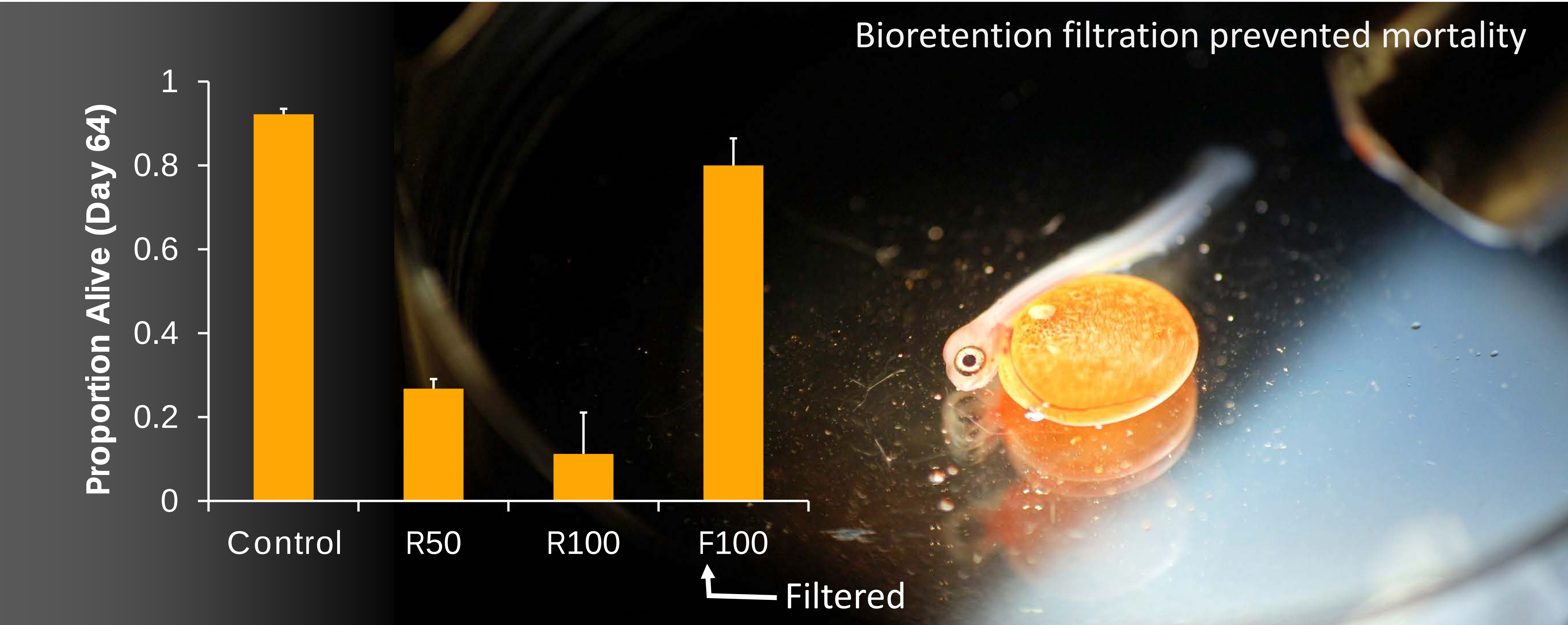


Days post fertilization (dpf)

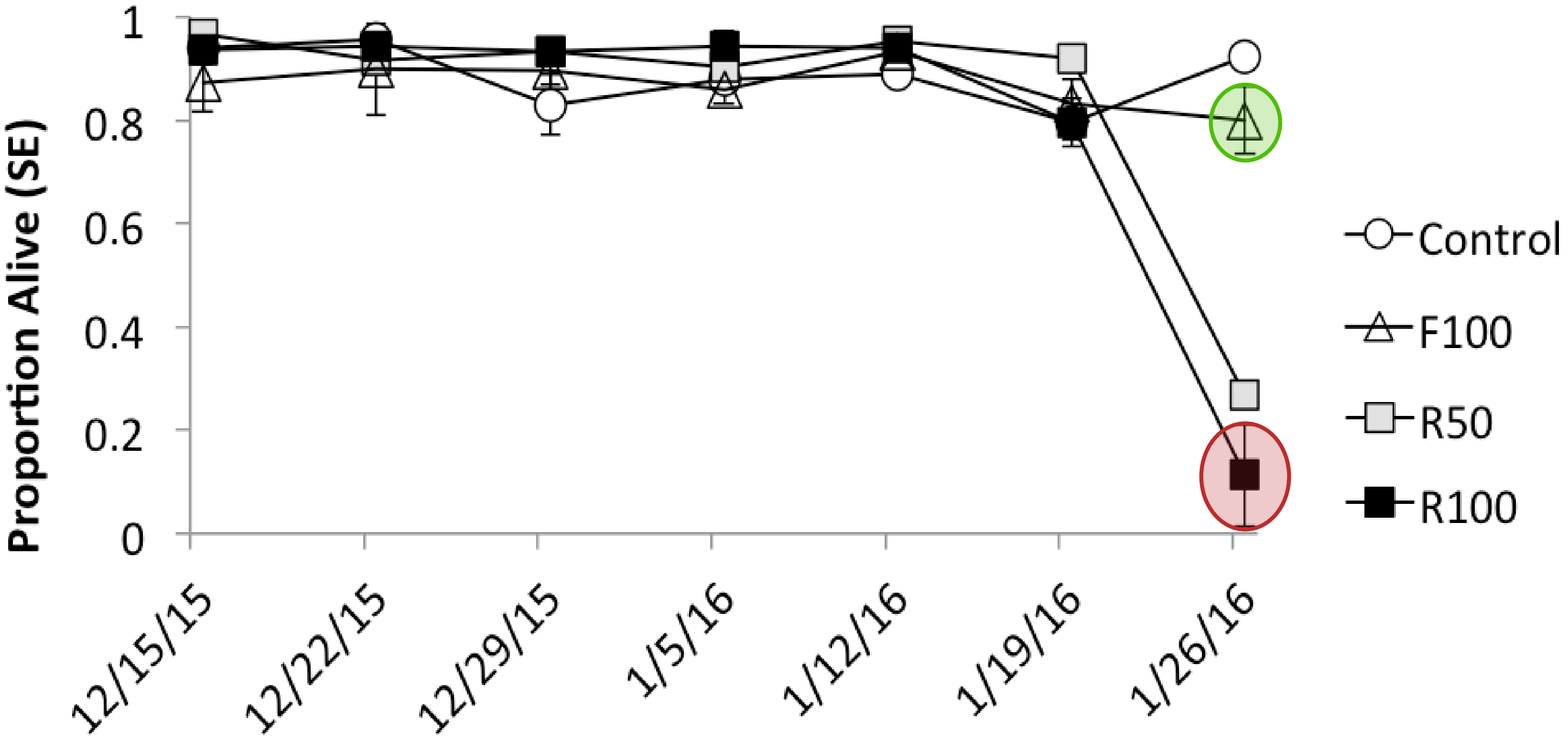
Embryo eye areas were typically smaller for both untreated and treated runoff

Cumulative impact on embryo length for untreated runoff only

Coho Embryo Tests: Survival

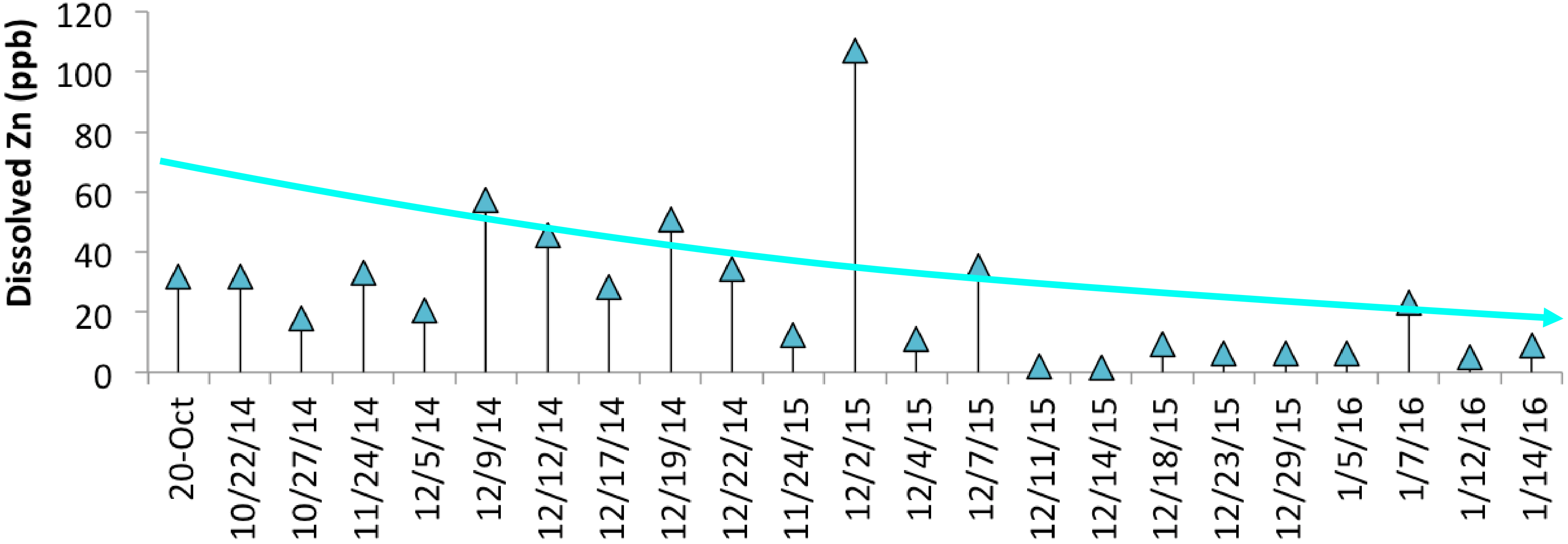


Coho Embryo Tests: Survival



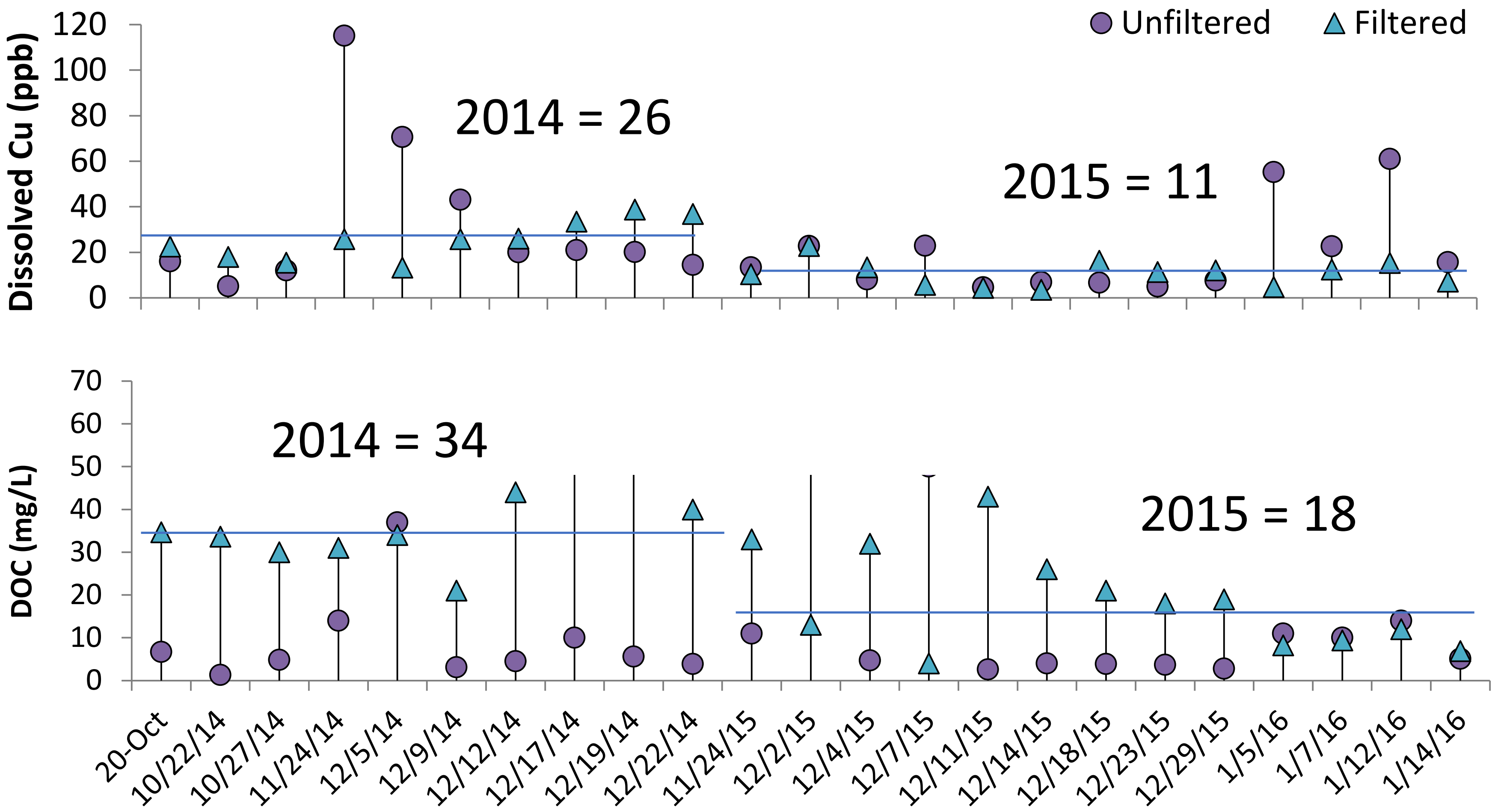
- Survival high until hatching
- Mortality high after hatch
- Bioretention filtration prevented most embryo mortality

Chemical Performance of Bioretention: Zn



Monitoring performance: Look for breakthrough over time

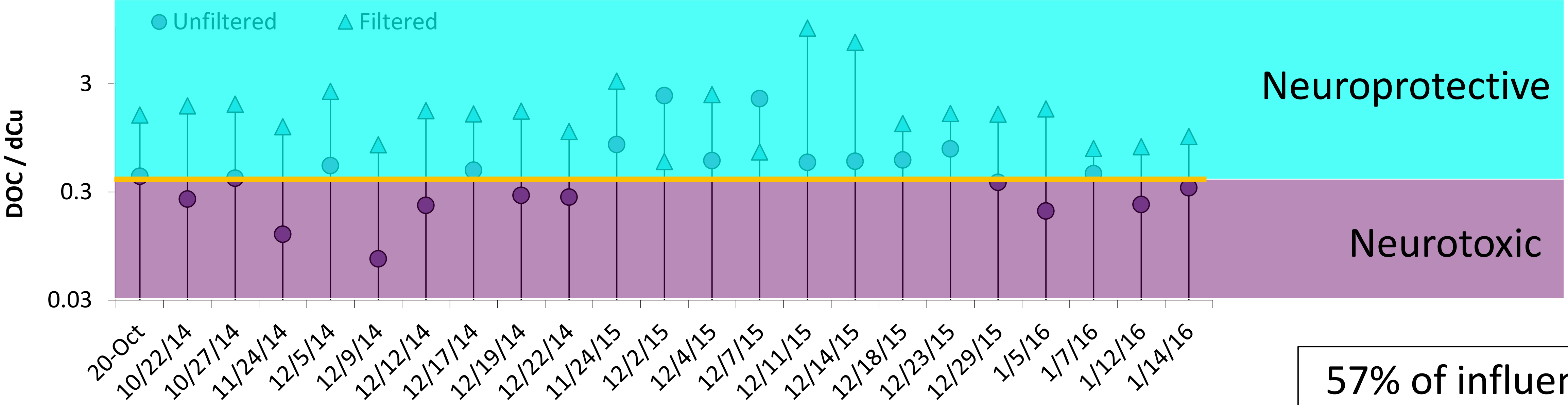
Chemical Performance of Bioretention



Copper in effluent decreased across treatment years

Neuroprotective DOC also decreased across treatment years

Chemical Performance of Bioretention



57% of influents were neurotoxic; All effluents were neuroprotective

Watch for downward trend in DOC:dCu over time

Summary

- The standard 60:40 (sand:compost) bioretention mix is effective for preventing impacts of urban runoff from multiple storms to coho salmon at different life history stages:
  - Adult coho salmon (Yes, 3 successive storm events)
  - Coho salmon embryos (Yes, 28 successive storm events)
- No apparent loss of chemical performance after repeated treatment of highway runoff through bioretention (28 discrete events)

Take Home

- The standard 60:40 (sand:compost) bioretention mix is biologically effective across numerous storms
- Installing green infrastructure with bioretention treatment cleans urban stormwater runoff sufficiently to help protect sensitive life history stages of iconic salmon species

Puget Sound Stormwater Science Team

King County

Field Test of Plants and Fungi on Bioretention Performance Over Time & Bioretention Capture Efficacy of PCBs from Stormwater

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CEDAR GROVE

FUNGI PERFECTI

What soil amendment and bioretention soil mixes combined with plant selection combines optimum removal of nutrients, bacteria, and metals?

- Cultivated plants and fungi as biological amendments to 60/40 Bioretention soil mix

A toxicity monitoring component of the research will also evaluate the subtopic:

Where and when are nutrient and metal outputs from LID of concern?

Hypotheses:

- Plant and fungal amendment will increase nutrient and metal retention
- Fungal amendment will reduce PAHs, bacteria, and toxicity of effluent
- Plant amendment will prevent loss of hydraulic conductivity

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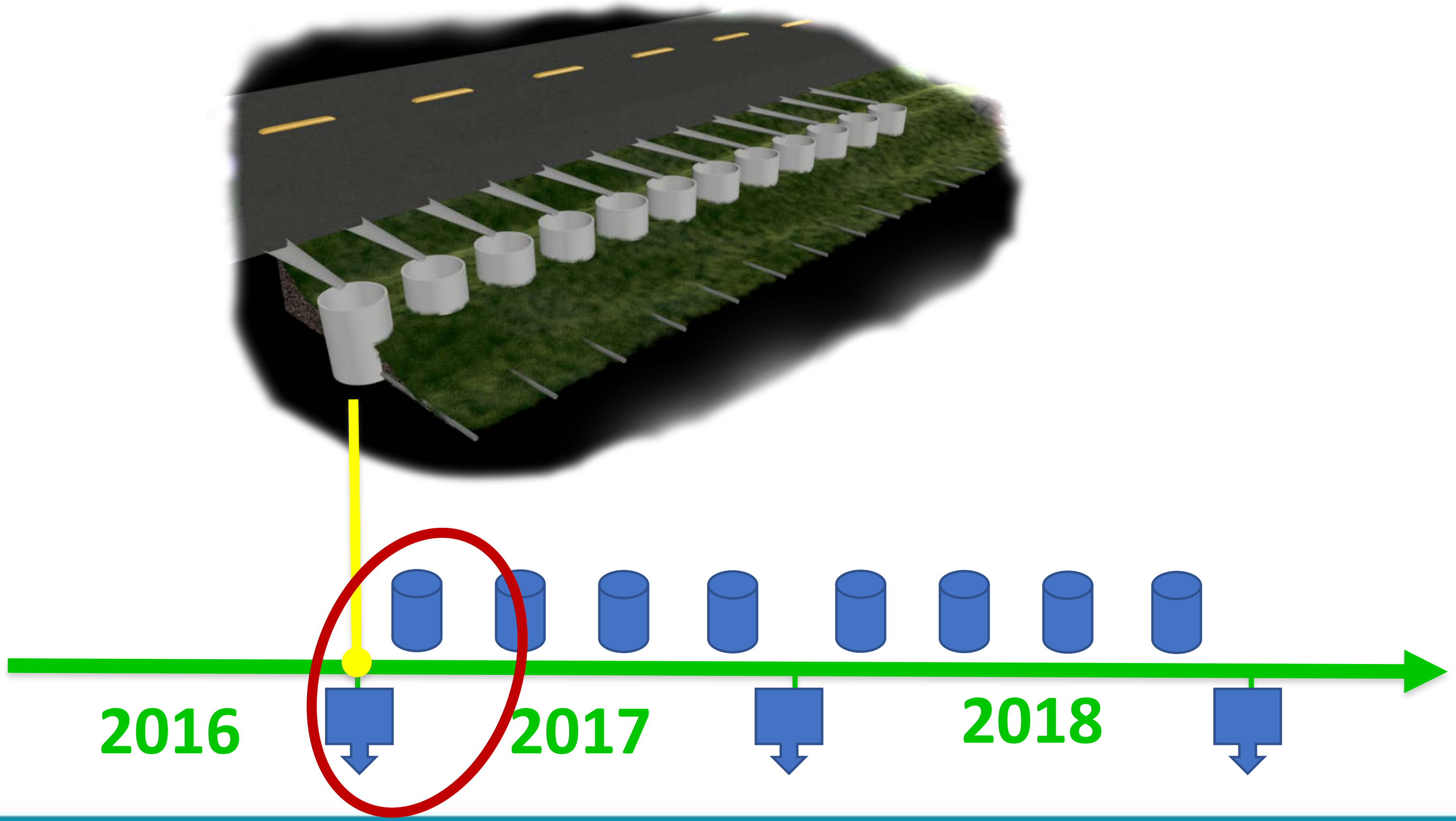
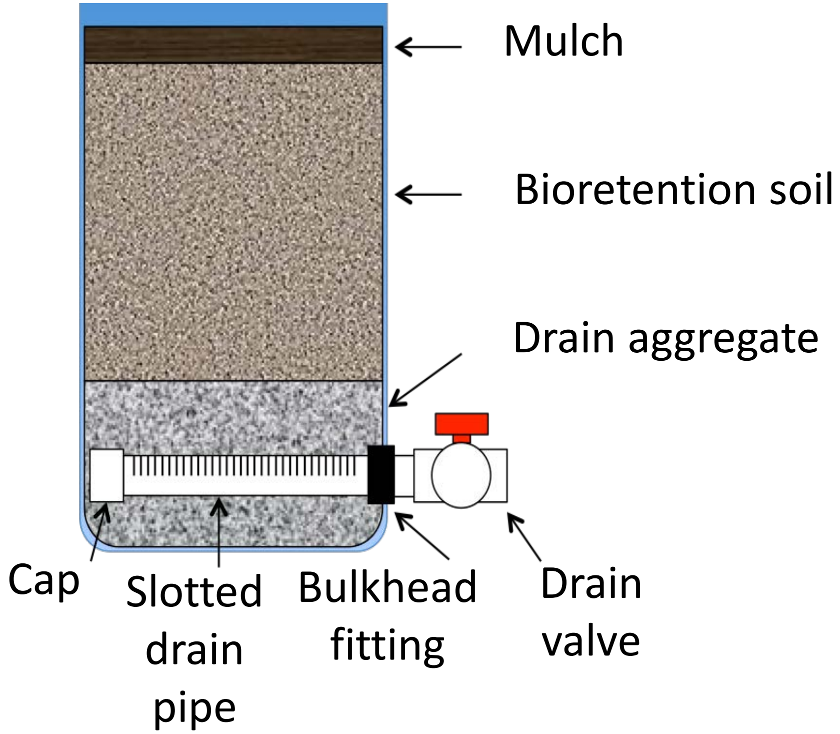
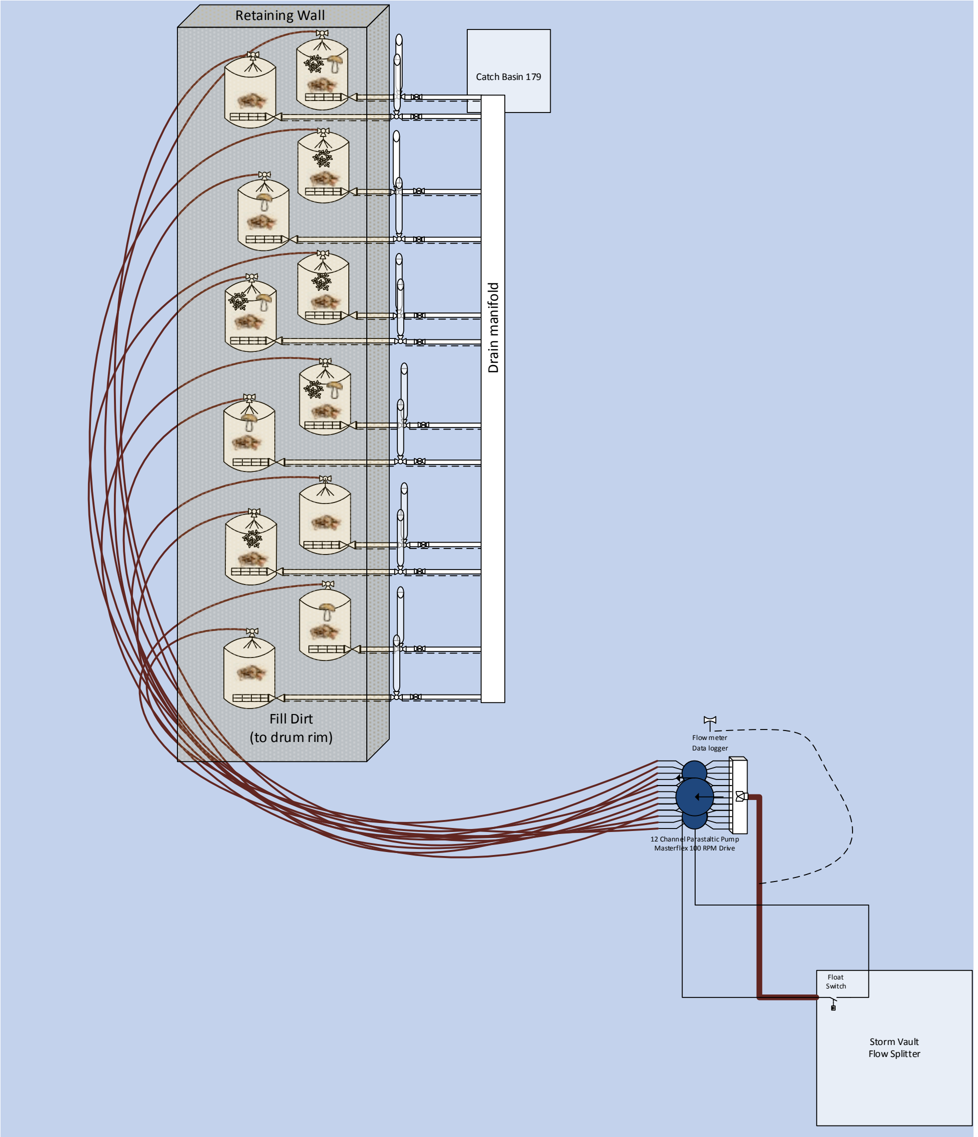


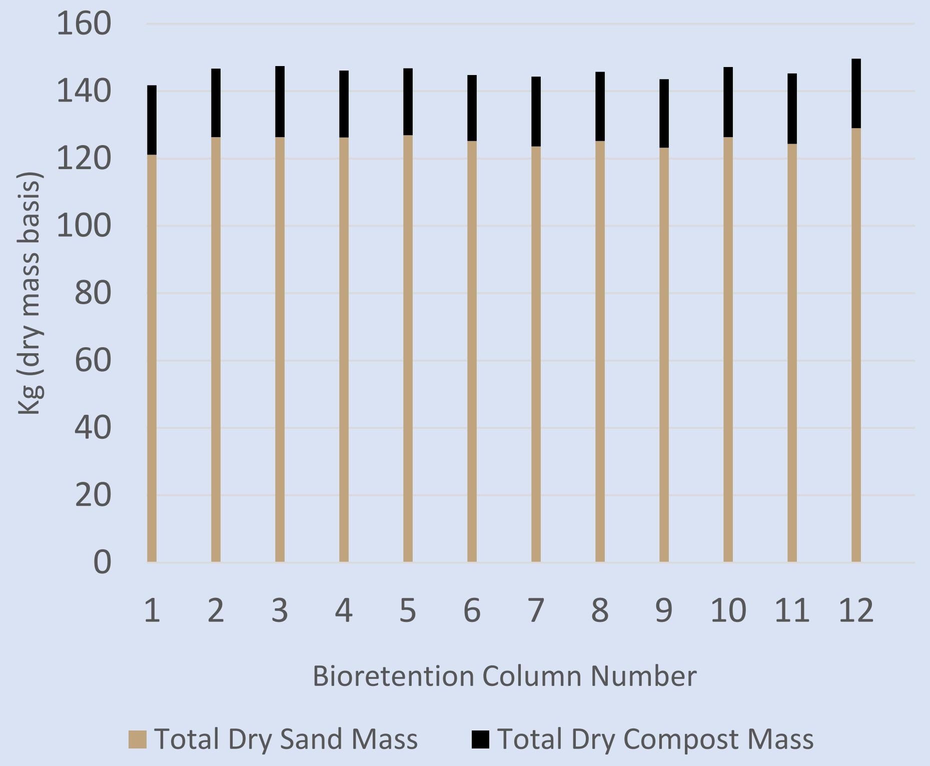




Retaining Wall
Catch Basin 179
Drain manifold
Fill Dirt
(to drum rim)
Flow meter
Data logger
12 Channel Parastaltic Pump
Masterflex 100 RPM Drive
Float
Switch
Storm Vault
Flow Splitter

Standardize soil mass across drums

- Proportion sand and compost into 30 kg bags according to volume
  (3 buckets sand : 2 buckets compost)
- Weigh each bucket, mix bag, collect moisture sample
- Calculate dry mass per bag for all 90 soil bags
- Fill barrels with select bags to standardize according to dry mass



total dry mass (145 ± 2.8 kg)

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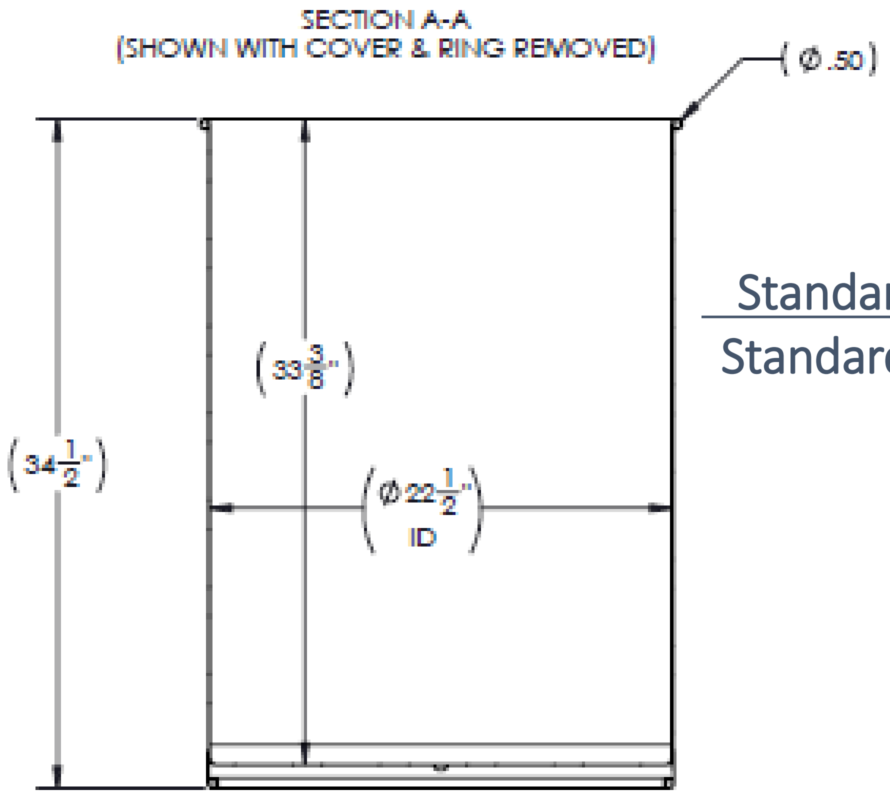
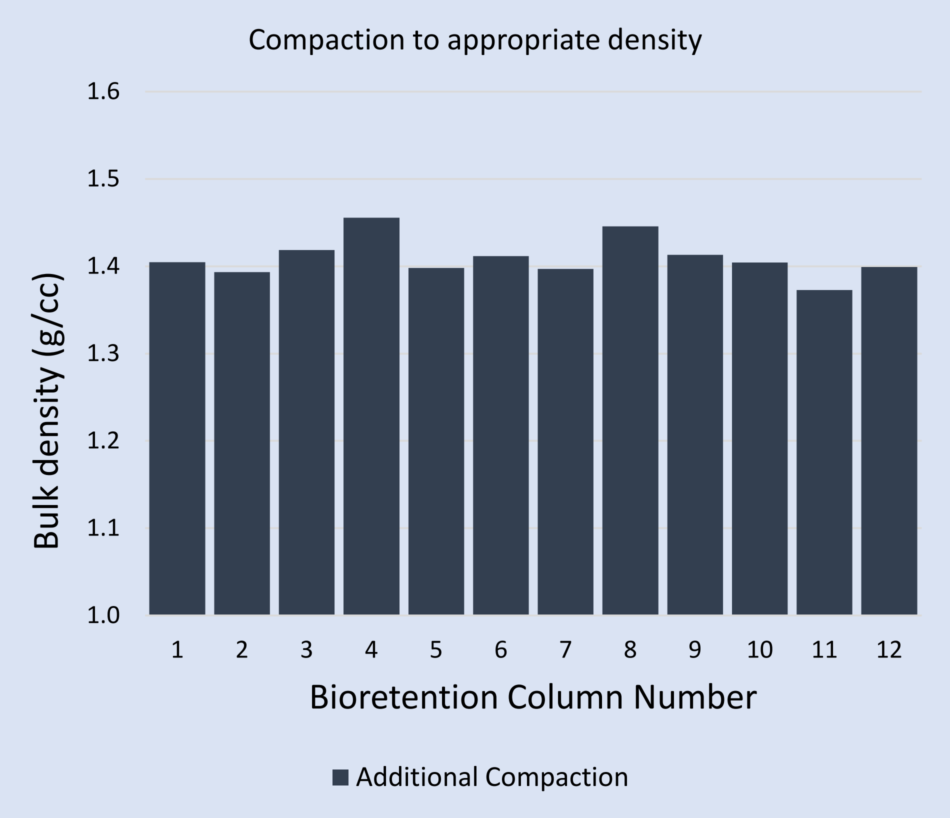
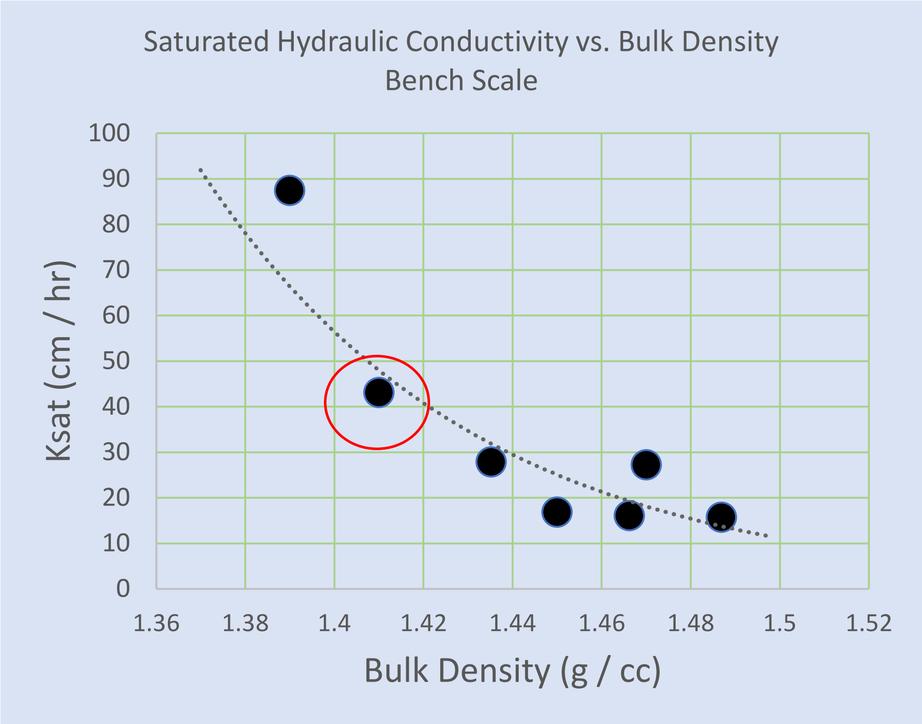


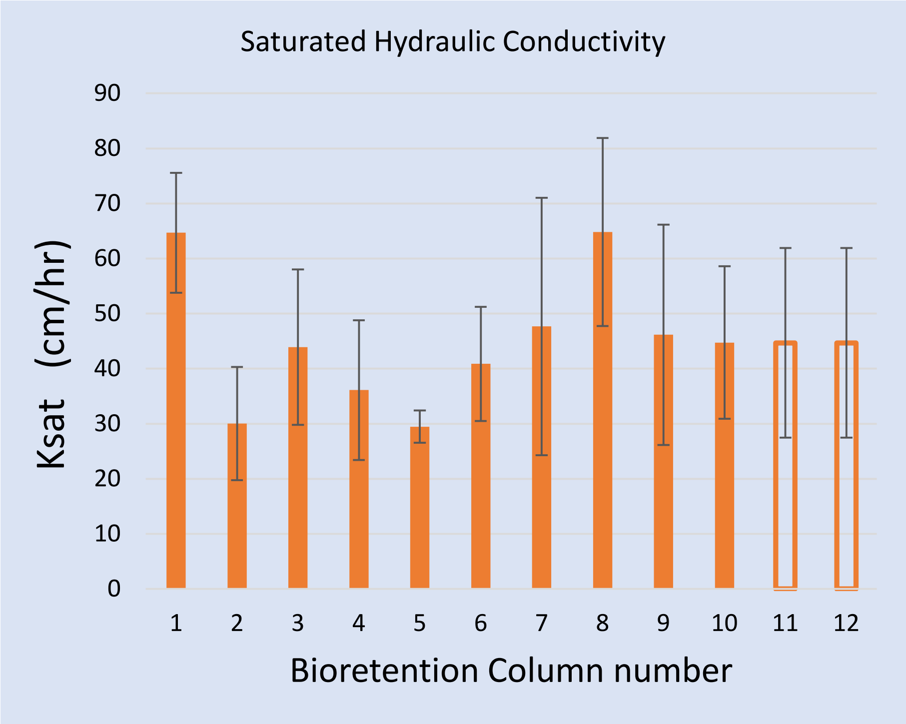
$$\frac{\text{Standard mass}}{\text{Standard volume}} = \text{Standard density}$$



Bulk density (1.41 ± 0.04 g/cc)



Standardize hydraulic conductivity across drums



Saturated Hydraulic Conductivity (45 ± 17 cm/hr)

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Bottle	Water Parameter	Method	Sample Size	Cont.	Holding Time	Preservation
1	Total Metals (Zn, Cu)/Hardness	EPA 200.7	250 mL	HDPE	6 months	HNO3, 6 °C
2	Dissolved Metals (Zn, Cu)	EPA 200.8	250 mL	HDPE	6 months	Filter, HNO3, 6 °C
3	Total Suspended Solids	SM2540D	500 mL	HDPE	7 days	6 °C
4	Total Organic Carbon	SM5310B	40 mL	Amber	28 days	H2SO4, 6 °C
	Dissol. Organic Carbon	SM5310B	40 mL	Amber	28 days	Filter w/in 48 hours, H2SO4, 6 °C
	Chem. Oxygen Demand	EPA 410.4	150 mL	Amber	28 days	H2SO4, 6 °C
5	Total Phosphorous	SM4500-PE	250 mL	HDPE	28 days	H2SO4, 6 °C
	TKN	SM4500-Norg	250 mL	HDPE	28 days	H2SO4, 6 °C
	Ammonia	EPA 350.1M	250 mL	HDPE	28 days	H2SO4, 6 °C
	Nitrate + Nitrite	EPA 353.2	250 mL	HDPE	28 days	H2SO4, 6 °C
6	Ortho-phosphorous	SM4500-PE	50 mL	HDPE	48 hours	6 °C
	pH	SM4500HB	250 mL	HDPE	8 hours	6 °C
7	Alkalinity	SM2320B	250 mL	HDPE	14 days	No head-space, 6 °C
8	Fecal Coliform	SM9222D	125 mL	Corning	8 hours	Sodium thiosulfate, 6 °C
9	E. coli	SM9222DG	125 mL	Corning	8 hours	Sodium thiosulfate, 6 °C
10	PAHs	EP 8270D-SIM	500 mL	Amber	7 days	6 °C
11	PCB *	EPA 1668C	1000 mL	Amber	12 mo	6 °C
12	D. rerio acute toxicity	McIntyre 2014	450 mL	Amber	6 months	store at -20 °C
	Total		5,470 mL			

*Water sample for PCB analysis will be collected by King County personnel (King County, 2016)

Influent	+ Plants + Fungi	+ Plants - Fungi	- Plants + Fungi	- Plants - Fungi
12 x 8	12 x 8	12 x 8	12 x 8	12 x 8
12 x 8	12 x 8	12 x 8	12 x 8	12 x 8
12 x 8	12 x 8	12 x 8	12 x 8	12 x 8

15 carboys x 12 analyses per carboy x 8 storms
=1,440 analyses over 2 years
***many more total analytes than that (metals suite, PAH suite)**

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Results

- Field site built and soil variables controlled to maximum practical extent
- 1 of 8 sampling events completed
- First year report March 2018
- Final report June 2019

Stormwater Action Monitoring

Impact

- Plants are expensive. Do they add functional value to bioretention installations?
- Can adding fungi to the mulch layer improve nutrient retention or pollutant removal?
- Improved soil hydraulic property data to understand lifespan, infiltration, clogging, and infiltration
- Do water quality concerns about 60/40 bioretention leachate/effluent have toxicological significance?

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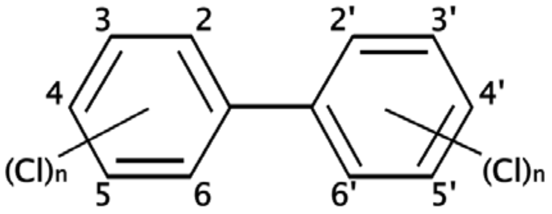
Bioretention Capture Efficacy of PCBs from Stormwater

Mesocosm Study Part 2

Stormwater Action Monitoring

PCB Behavior

- Banned in 1977 but remain in many existing in-use materials
  - Soils, sediments, caulks, paints
- 209 different forms called congeners



- Semi-volatile
  - Evaporate and condense according to humidity, temp, surface, material type and congener
- Attracted to organic carbon, dislike being dissolved in water
  - Fish! Almost all WA state consumption advisories are for PCBs
  - Oily surfaces, particulates (tires, dust)
  - Soils & sediments

Study Questions

- What is the PCB removal (capture) rate in BSM, and does it vary by congener? (within one storm)
- What is the wet season PCB sequestration (retention over multiple storm events) in BSM, and does this vary by congener?
  - Compare sequestered mass of PCBs with estimated stormwater loads.
- What is the PCB retention in BSM during the dry season, and does it vary by congener?

Mesocosm scale study

Data collected

- Using “Soil Only” and “Soil Plus Plants” mesocosms only

- Quarterly soil samples
- Quarterly storm samples
- Analysis for all 209 PCB congeners
- TOC, DOC, TSS

- Flow

Why do we care?

- Raise awareness about the need to validate stormwater management technologies for PCBs in general
  - New water quality standards are 0.000000007 mg/L (parts per trillion)
  - Achieving this is currently impossible, requires widespread source removal
  - Every little bit (permanently) sequestered helps
- If year over year PCB capture remains high, at what point might bioretention facilities become dangerous waste?
- If year over year PCB capture is not as high as per storm capture, will bioretention be effective at interrupting urban cycling of PCBs before they reach waterbodies?

Bioretention Hydrologic Performance Study

Bill Taylor, Taylor Aquatic Science
Doug Beyerlein, PE, Clear Creek Solutions, Inc.
Jenny Saltonstall, Associated Earth Sciences
Bryan Berkompas, Aspect Consulting
Anne Cline, Chris Wright, Raedeke Associates, Inc.

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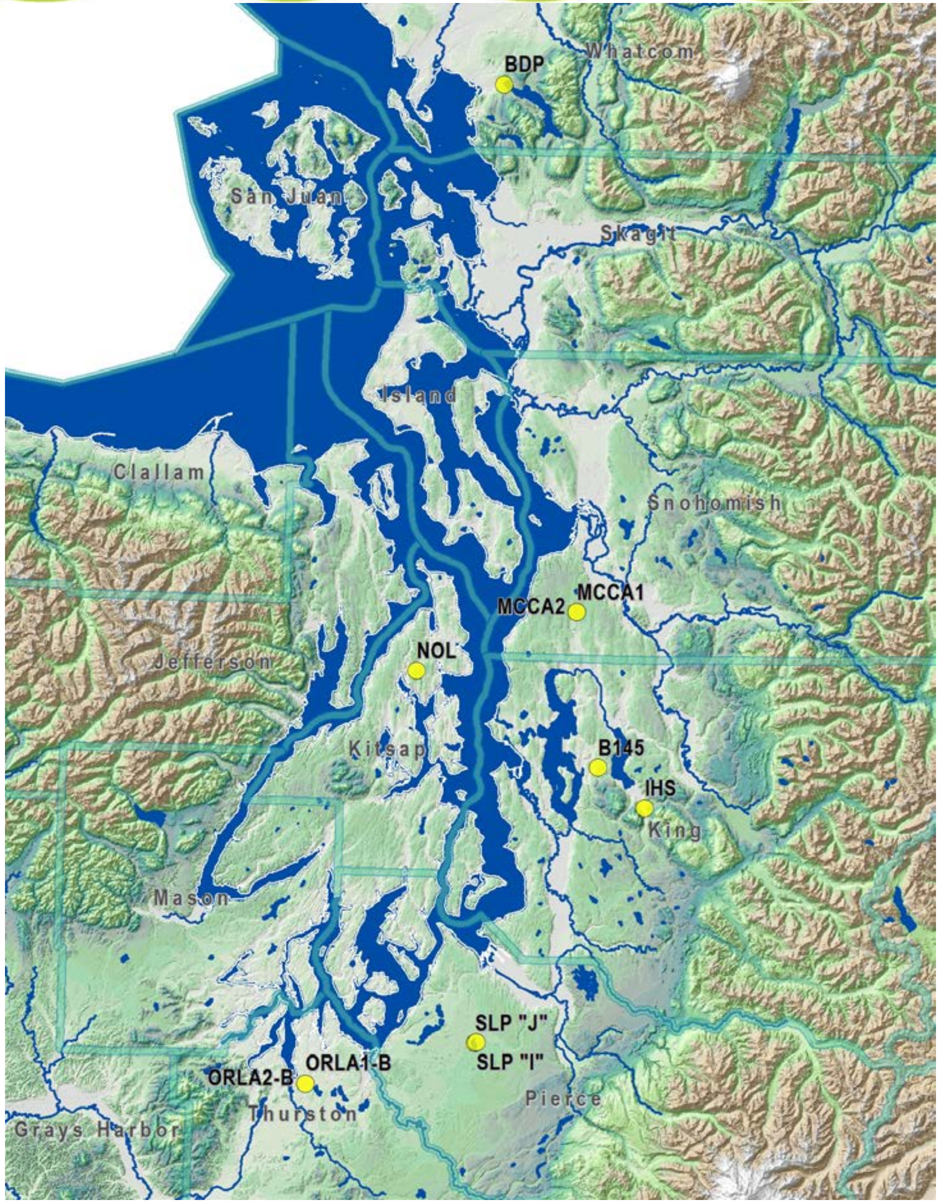
Study Question to Answer

- How well do actual constructed bioretention facilities' hydrology performance match the design models' results?

- What site conditions may be affecting any differences observed between actual performance and model performance?

Ten
Selected
Site
Locations

Wide
Range of
Subsurface
Conditions



Performance Monitoring Components

- Facility dimensions and contributing areas
- Bioretention soil and subsurface composition; infiltration tests
- Hydrology – rainfall, inflow, outflow, ponding and groundwater
- Vegetation – herbaceous and shrub composition

Analyze All the Component Data for Design Improvements

Initial Findings – Dimensions

- Generally sized to original design size
- Contributing areas to be further assessed for expected runoff volumes

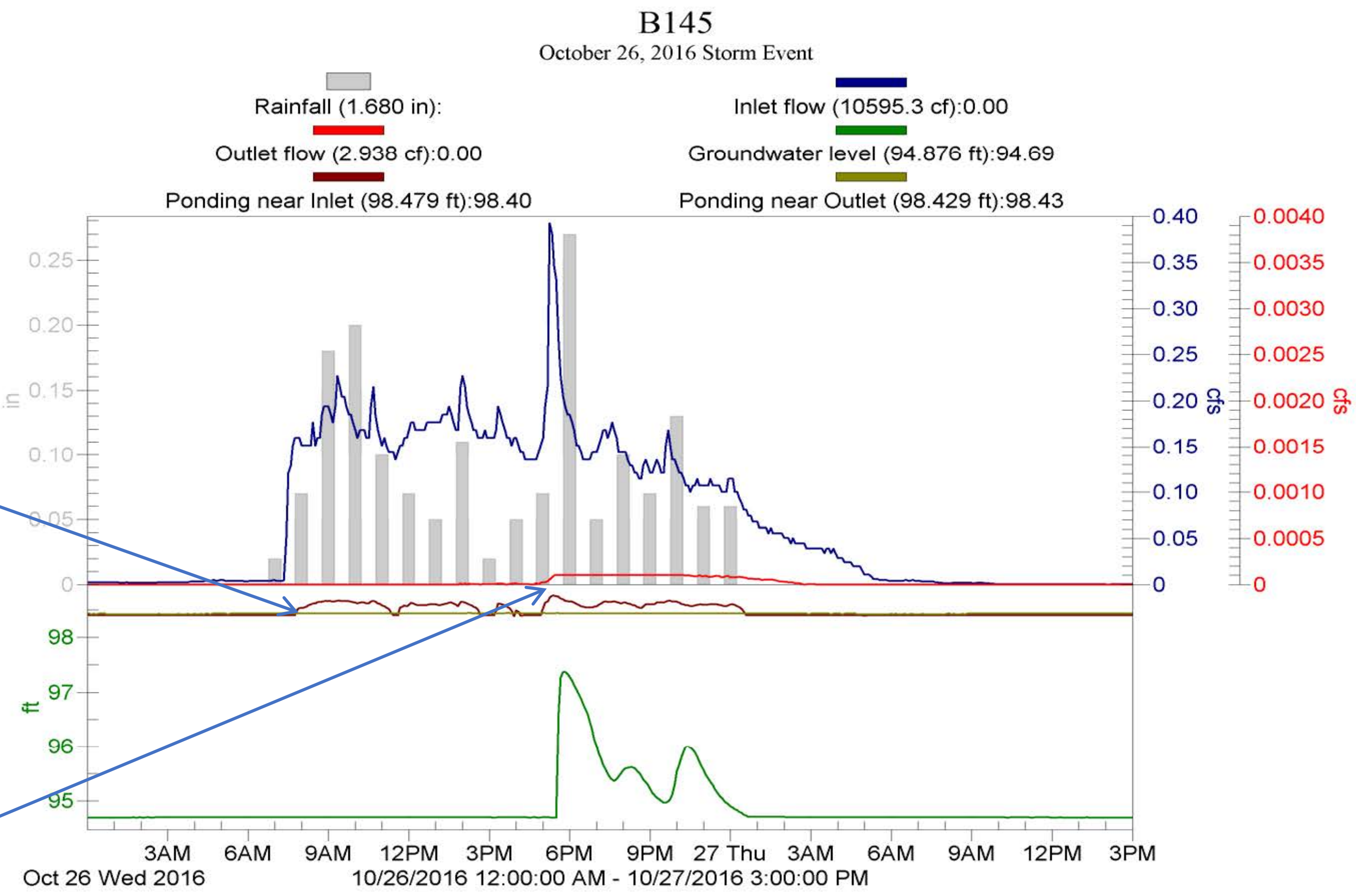
Initial Findings - Hydrologic Response

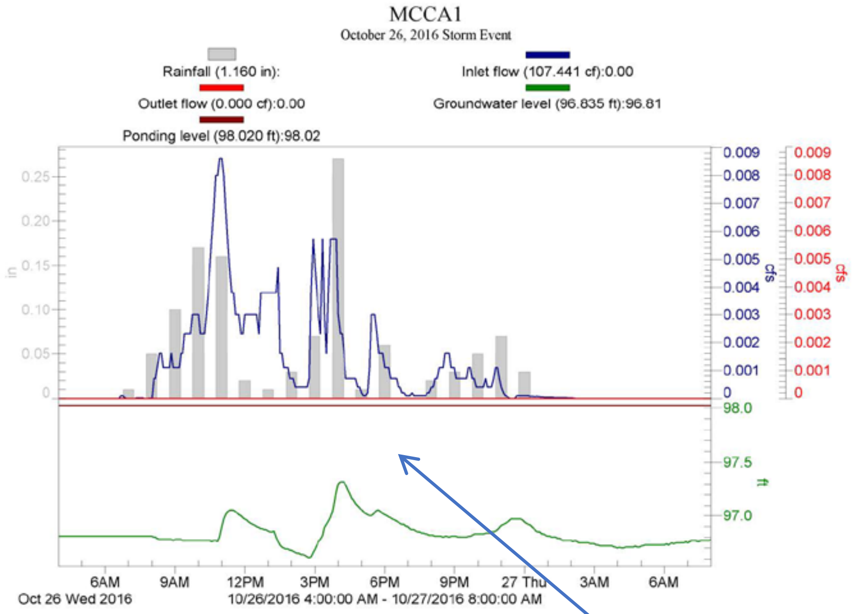
- 6 months of continuous wet season monitoring (October – March)
- 3 months additional monitoring for drier conditions (April – June)

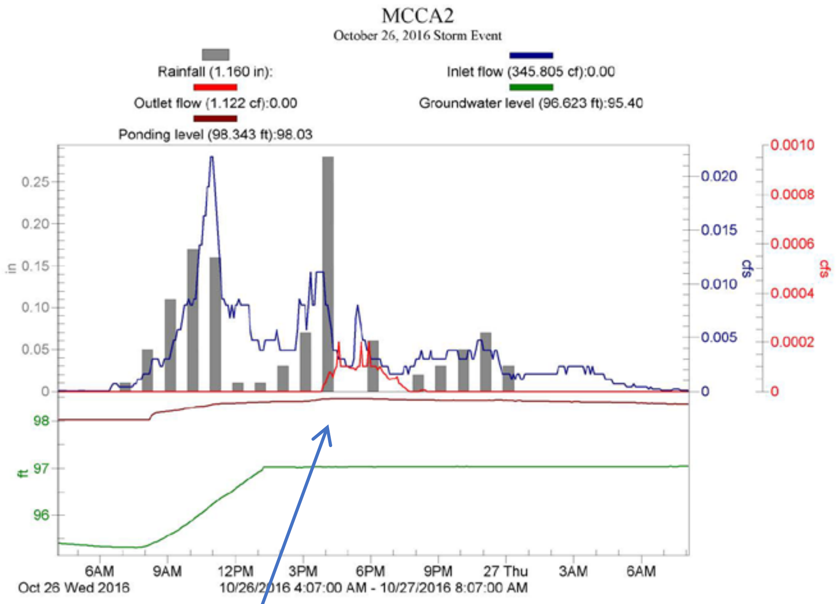
- Variable response depending on subsurface conditions
  - Evidence of oversizing in highly infiltrating sites
  - Evidence of shallow groundwater mounding
  - Evidence of possible lateral subsurface flow
  - Evidence of subsurface leakage to an overflow outlet
  - Evidence of short circuiting through soil directly to underdrain; almost no detention, reduced treatment

- Ponding at the inlet
- No ponding at the outlet
- Infiltrating in upstream area

- Small outflow occurring suggesting bypass leakage to overflow structure







- Two Cells Adjacent to Each other:
  - No ponding with subsurface groundwater receding
  - Ponding with continuous elevated groundwater and outflow

Stormwater Action Monitoring

No ponding

Ponding

Initial Findings – HydroGeo and Geotechnical

- Sites covered a wide range of geotechnical and infiltration conditions
- Bioretention soil texture generally coarser than guidelines
- Variable infiltration rate performance
- Little site specific hydro-geo data; analysis “borrowed” from adjacent infrastructure testing

Stormwater Action Monitoring

• PRELIMINARY FINDINGS – HYDROGEOLOGIC SETTINGS

Geomorphic and Hydrogeologic Setting

- Glaciated Upland – 4 cells
  - 1 in advance outwash, deep ground water
  - 2 in weathered till, perched ground water
  - 1 in unweathered till, but with underdrain
- Outwash Plain – 5 cells
  - 2 in gravel, deep ground water
  - 2 in sand, moderate ground water
  - 1 in gravel, shallow ground water
- Alluvial Valley – 1 cell, recent alluvium, shallow ground water

Flow Control Performance Relative to Design?

✓ Yes, high performing **outwash**

– ? – Uncertain, lateral flow

– ? – Unlikely, short circuiting to underdrain, no retention

✓ Yes, high performing **outwash**

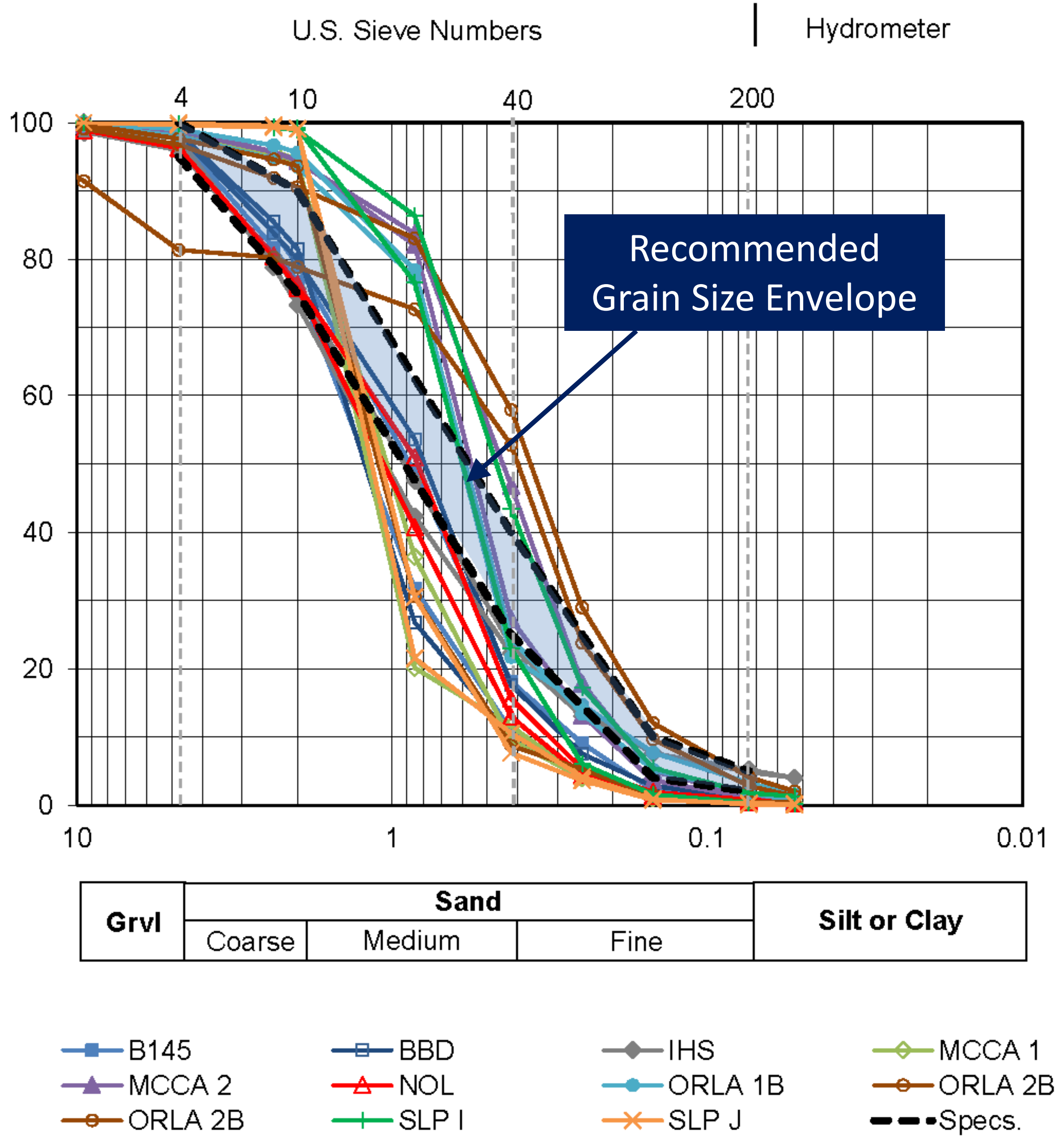
✓ Yes, high performing **outwash**

✓ Yes, high performing **outwash**

– ? – Uncertain, shallow ground water mounding influence

Ecology 2014 / Site	Bioretention Soil Characteristics				Coefficient of Uniformity
	Average	Average Grain Size, % Passing			
	% OM	#200	#100	#40	Cu
	5 to 8	2 - 5	4 - 10	25 - 40	4 or greater
B145	3.9	0.4	1.7	15	3.9
BBD	5.3	0.7	2.2	14	3.5
IHS#24	5.8	5.0	7.6	23	7.1
MCCA1	4.2	0.3	1.1	11	3.2
MCCA2	5.1	1.2	4.3	37	3.0
NOL	3.6	0.6	1.6	14	3.7
ORLA1B	6.2	2.5	6.5	23	3.6
ORLA2B	4.2	2.5	7.7	40	3.4
SLP I	2.5	1.0	3.5	33	2.7
SLP J	2.6	0.2	0.8	18	3.0

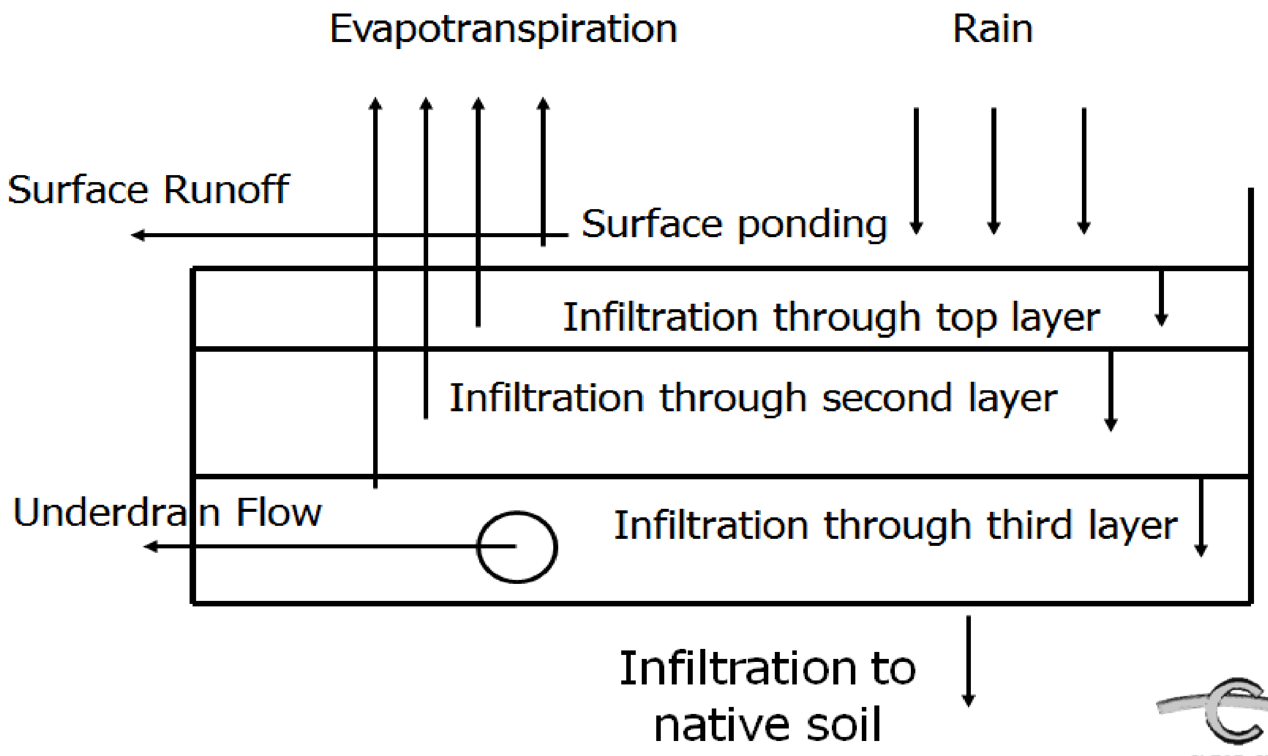
Out of Spec



Initial Findings - Vegetation

- Shrub species surviving well
- Herbaceous species less adaptable – depends on irrigation and species selected
- Selecting fewer successful species from will lead to greater survival and reduced cost with replanting

WWHM2012
Bioretention Element



Initial Findings – Design Modeling

- Wide variety of computer models used for design
- Approach to modeling was often not set up properly
- Final success of the facilities was more due to oversizing facilities for 100% infiltration, masking design errors or incorrect assumptions

Use of this Information to Improve Stormwater Management

- This Performance Analysis Suggests Design Guidance for Site Plan Review and Construction Inspection
  - Confirm site dimensions and inflow and overflow structures are at proper elevations
  - Use site-specific hydro-geotechnical analysis for infiltration rates
  - Select plant species that have proven to survive and remain
  - Use current modeling methods that properly represent infiltration

WHAT'S NEXT

- Monitoring is ongoing through June 2017
- Calculate volume reductions across multiple storms
- Compare field tested infiltration rates to variable infiltration performance from monitoring
- Compare reduction in infiltration rates due to ground water mounding
- Clear Creek Solutions will compare design model flow control to actual flow control using WWHM2012
- Report due late 2017

Context for SAM effectiveness studies

Brandi Lubliner, SAM Coordinator
Washington State Department of Ecology

Stormwater Action Monitoring

Other effectiveness studies

- Rain gardens
- Retrofits (3)
- Operation and maintenance
- Business inspection source control

Bioretention and Rain Garden Protocol Development

Joy Rodriguez, EIT – City of Puyallup
Bob Simmons, Chrys Bertolotto – WSU Extension
Philomena Kedziorski , Erica Guttman – WSU Extension
Aaron Clark – Stewardship Partners
Ani Jayakaran, PhD PE – WSU, Washington Stormwater Center

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Project Purpose

Develop a rain garden and bioretention assessment protocol to monitor basic functions of rain gardens and bioretention facilities.

- Assess factors influencing their success and failure.
- Protocol is being developed to allow for:
  - Ease of implementation
  - Repeatability across large geographic scales
  - Consistent data from multiple implementers
  - Provide data of scientific and adaptive management value.

Findings to date

Literature Review:

- A protocol like this does not currently exist
- There is little consensus on what metrics define effectiveness of rain gardens and bioretention
- Metrics that were shown to have strong relationships to function were compiled and assessed for feasibility and value in this protocol
- Social science research provides some key elements that are linked to public valuation of rain gardens and bioretention

  → Perceived value to the community best assessed through a separate protocol to be implemented at the same sites as the assessment protocol.

Findings to date

- Protocol DRAFT v1.0 –
  - Large # of metrics identified for testing
  - Hydrology metrics: inflow, outflow, overflow, soil conditions
  - Vegetation metrics: diversity, health and extent of any invasive species
  - Community metrics: some factors known to influence community perceptions of value, so those are included.

Training

- 35 Volunteers were trained via 1-day trainings in three counties: Snohomish, Thurston and Jefferson.
- Volunteers, working in teams of 2-3 assessed 14 sites, with each site repeated by a different team of volunteers to assess repeatability.

Findings to date

- Pilot round of data:
  - Protocol v1.0 was implemented successfully by volunteers
    - Determined which information was valuable, removed some of the metrics
    - Volunteer feedback is improving the data collection methodology for protocol v.2.0
  - When the same facility was assessed by 2 different volunteer teams, the results across most variables was highly consistent.
  - Volunteer and Technical Advisory Committee input provided guidance for changes for the protocol v2.0

Value of Protocol

- Consistent data from multiple implementers
  - Within jurisdictions and between jurisdictions
- Provide data of scientific and adaptive management value
- Improve community acceptance, improve voluntary maintenance and increase installation

Timeline

- Protocol v2.0 is ready now
- Training v2.0 scheduled for July: 4 counties: Snohomish, Pierce, Thurston, Jefferson
- Assessment of 40 sites/facilities - August-September 2017
- Analysis of 2nd round data and submission of results - November 2017
- Community valuation survey completed/assessed - November 2017
- Online training module - March 2018
- Final version of protocol - March 2018

Stormwater Retrofits for Treating Highway Runoff

Carly Greyell

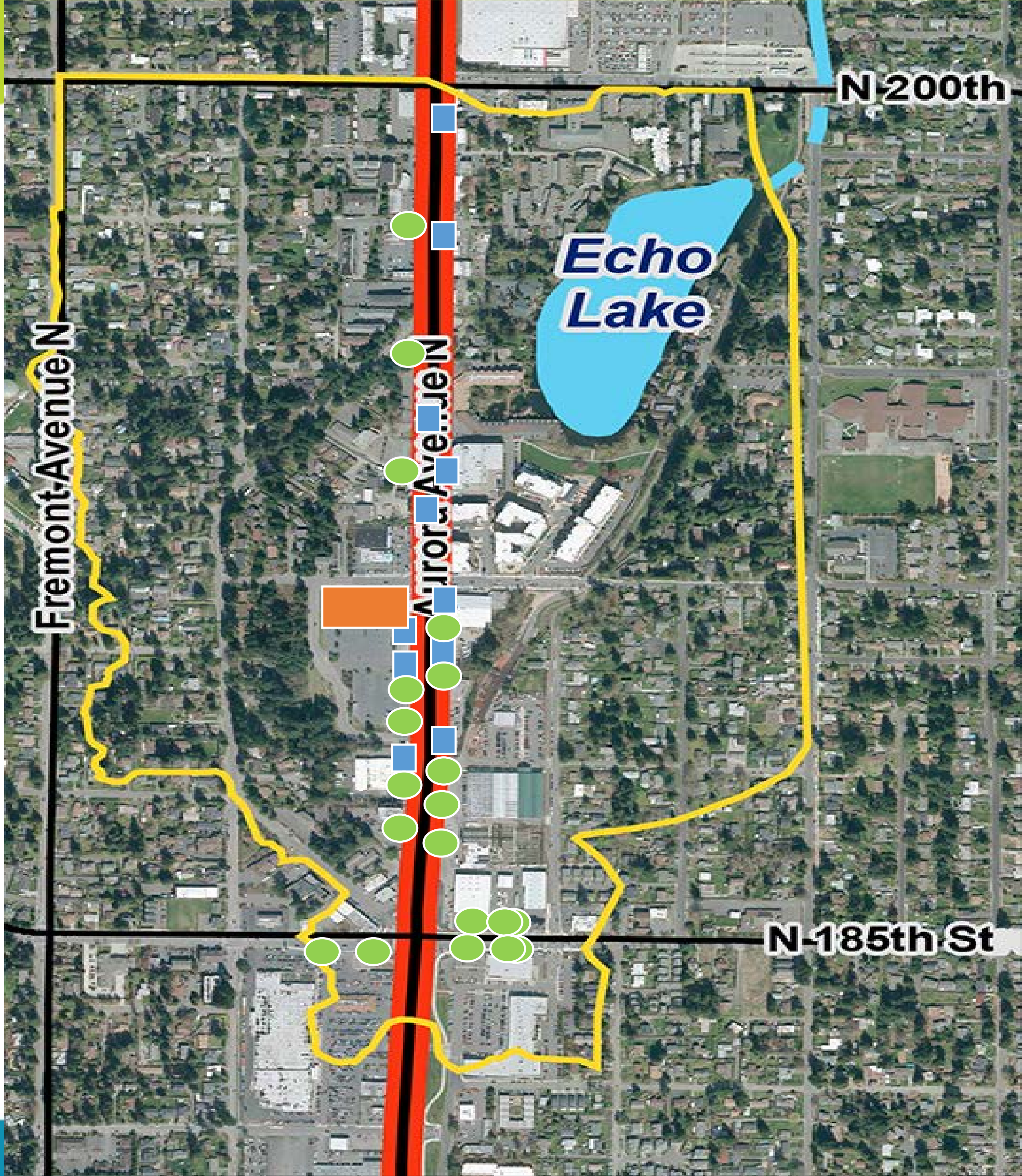
King County Water and Land Resources Division

Stormwater Action Monitoring

How well a retrofit improved water quality in a typical urban basin:

1. Individual BMPs
2. Larger stormwater system
3. Receiving water

SAM Stormwater Action Monitoring



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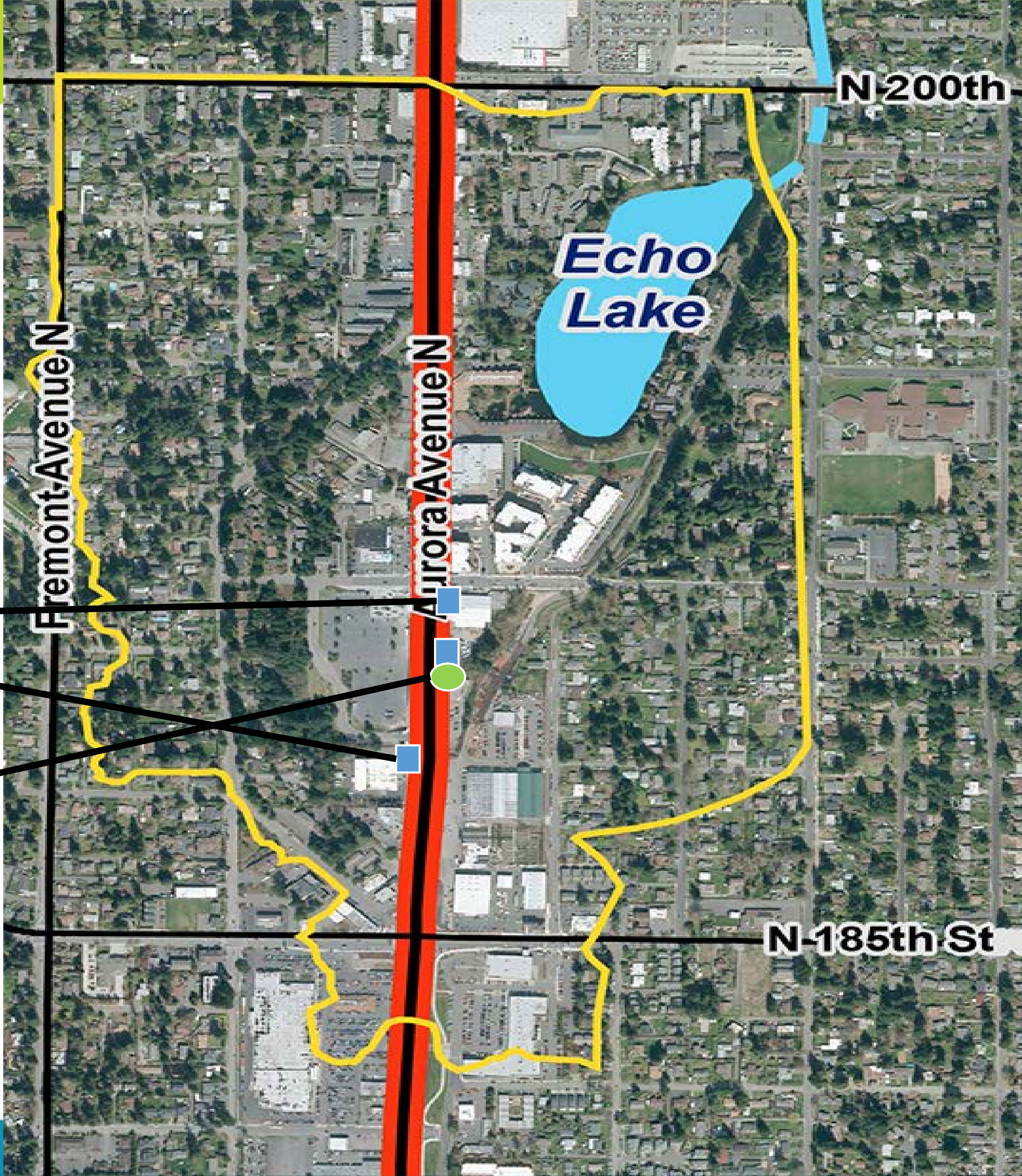
3 Bioretention Planter Boxes

1 Filterra



Stormwater Action Monitoring

VS

		
Suspended Solids	✓	? ✓
Dissolved Zinc	✓	✗
Dissolved Copper	?	✗
Total Phosphorus	✗	? ✓
Petroleum Hydrocarbons	✓	✓

Virtually Eliminated!

		
Suspended Solids	✓	?
Dissolved Zinc	✓	✗
Dissolved Copper	?	✗
Total Phosphorus	✗	?
Petroleum Hydrocarbons	✓	✓

Unexpected Maintenance Issues

SAM
Stormwater Action Monitoring

Stormwater Action Monitoring

SAM
Stormwater Action Monitoring

SAM
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Bioretention can treat your stormwater…


...but only if the stormwater can get in.

Acknowledgements

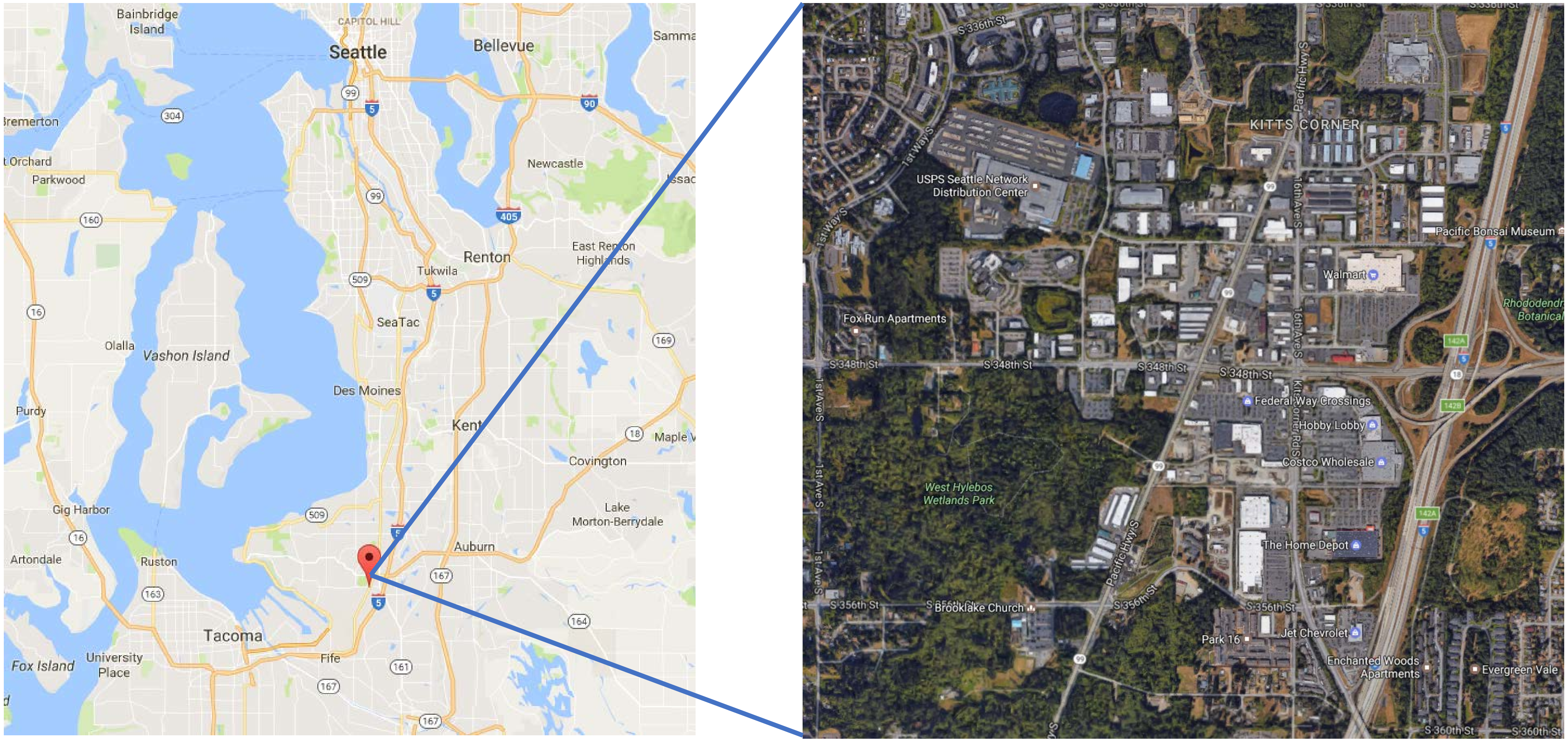
- Brandi Lubliner – Ecology RSMP/SAM Coordinator
- Fred Bergdolt –Project Liaison (WSDOT)
- KC Environmental Lab – Sampling & Analysis
- Pacific Rim Laboratories – PCB Analysis
- City of Shoreline – Site and Logistical Support
- Jenée Colton – Technical and Study Design Support

Federal Way S. 356th Street Project: Effectiveness of Retrofit and Expansion

Kate Macneale, King County Water and Land Resources
with
Fei Tang and Theresa Thurlow, City of Federal Way
King County Environmental Laboratory

Stormwater Action Monitoring

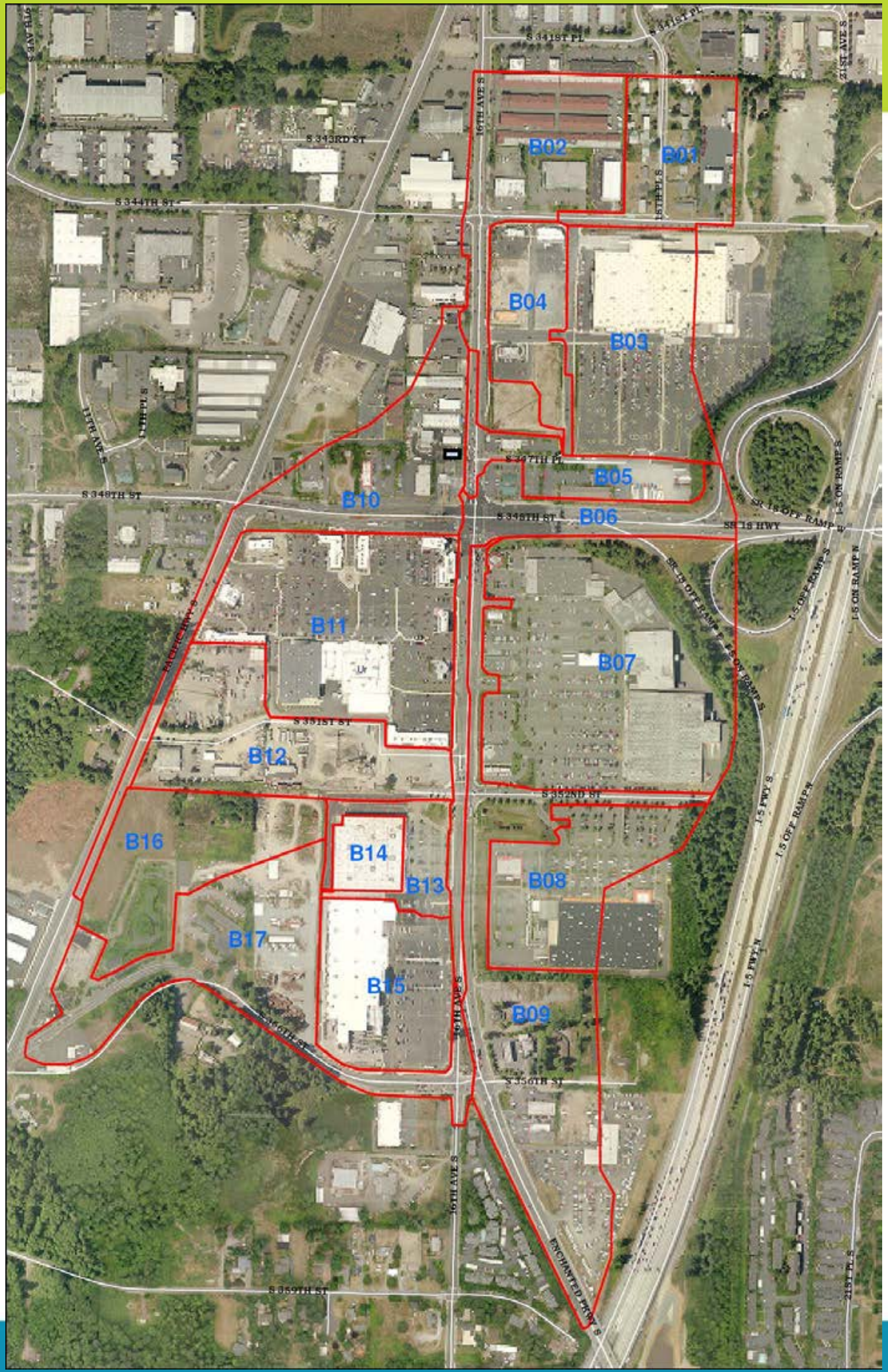
Did retrofit and expansion improve flow control and treatment?



SAM Stormwater Action Monitoring

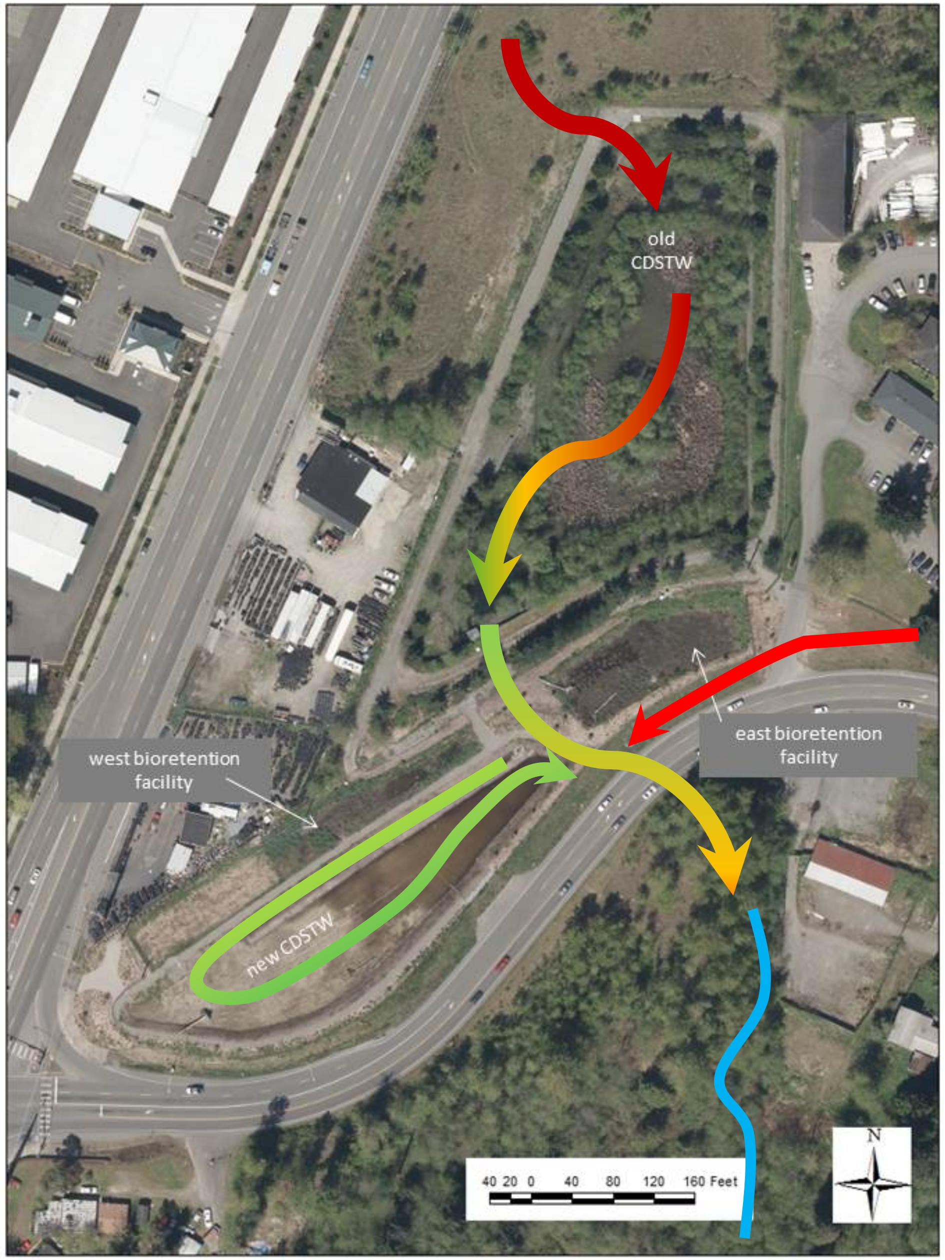
S. 356th Street Detention Facility

- Built in 1997 to treat runoff from 189-acre basin
    - combined detention and stormwater treatment wetland (“wetland”)
- Expanded in 2014
- In-series “wetland” to increase treatment
- 2 bioretention facilities to treat runoff from 22-acre basin that hadn’t been treated previously



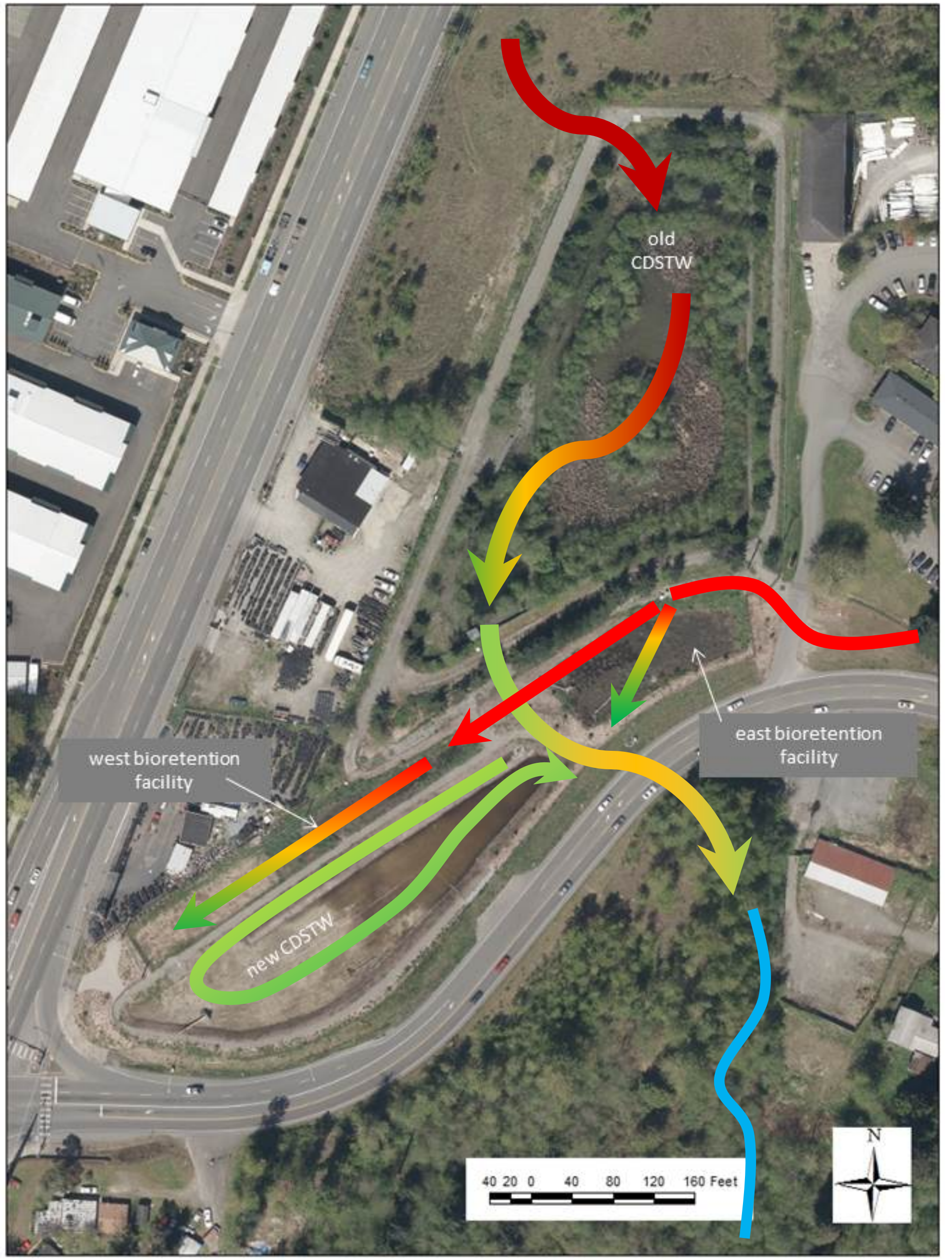
New “wetland”

- Increase capacity
- Unlined, but infiltration limited



New “wetland”

- Increase capacity
- Unlined, but infiltration limited



Bioretention facilities

- New capacity
- Underdrained
  - East: drains quickly
  - West: drains slowly

- East bioretention facility
- West bioretention facility
- Wetland complex

Untreated
In

Treated
Out

Receiving waters:
North Fork West Hylebos Creek

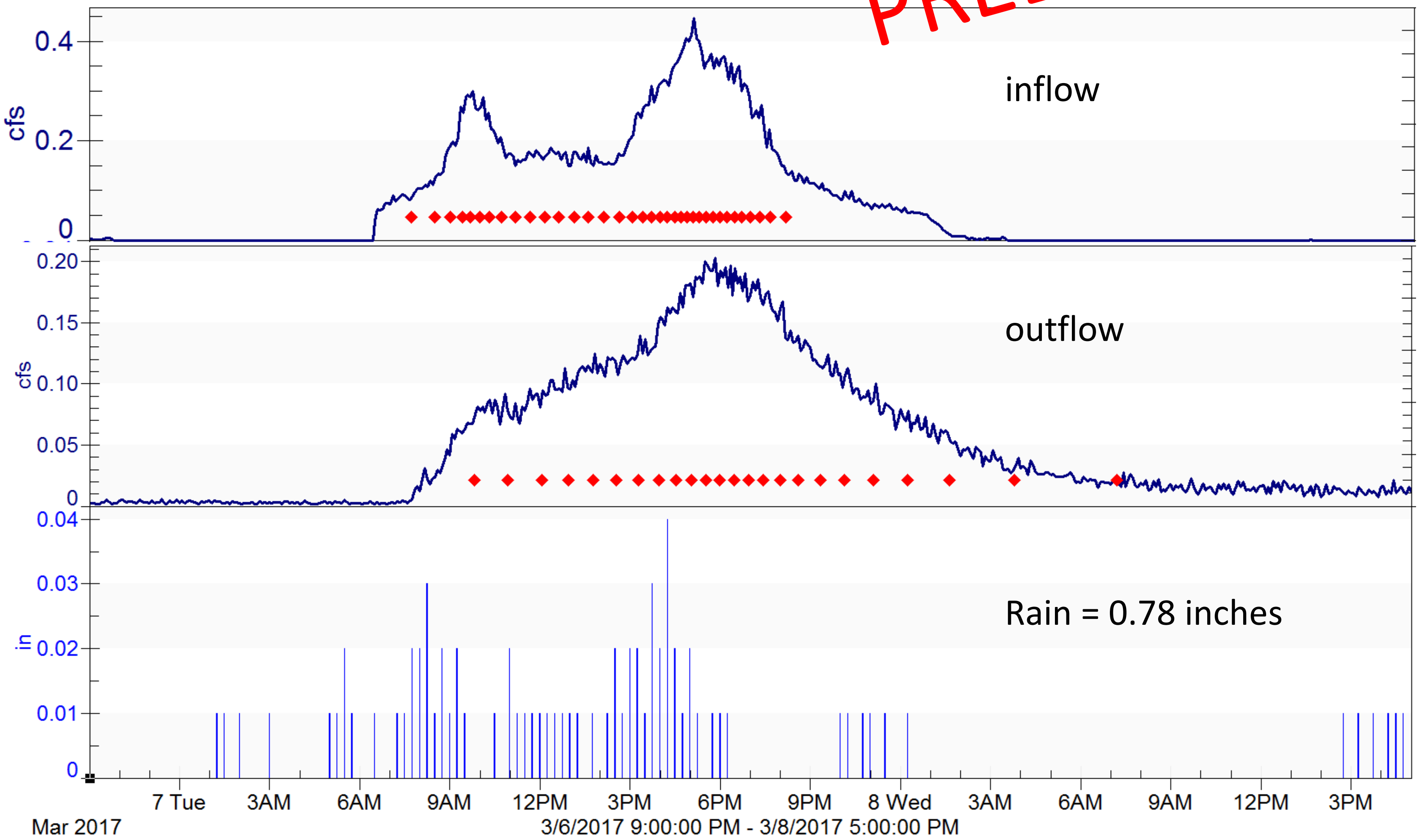
Sampling Complete

- Flow at 7 locations
- 18 storms sampled for TSS, metals, nutrients, PAHs
- 10 storms for PCBs, fecal coliforms
- 5 storms for toxicity
- Pre- and post-retrofit turbidity data

SAM
Stormwater Action Monitoring

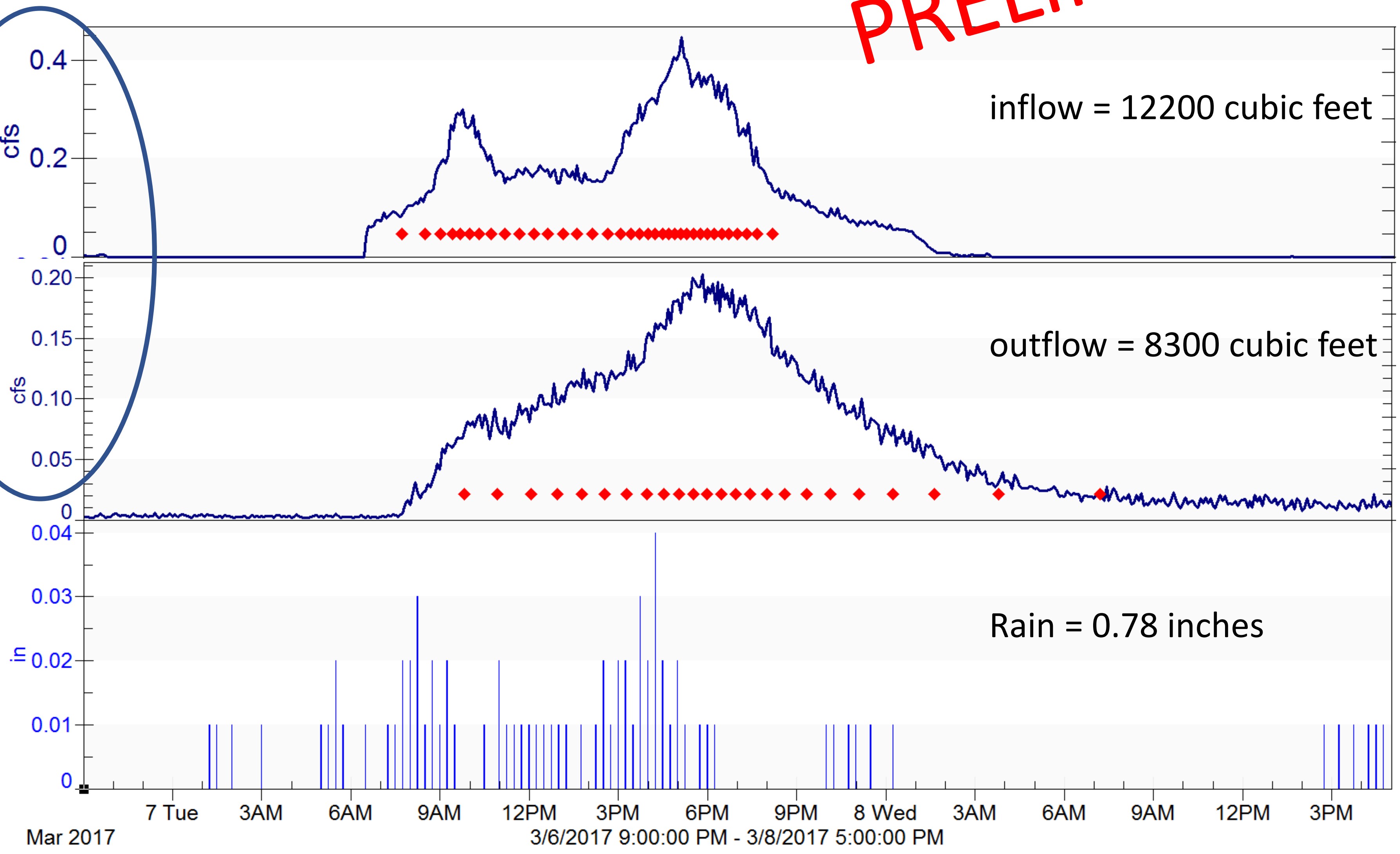
Example: Storm #10 East bioretention facility

PRELIMINARY!



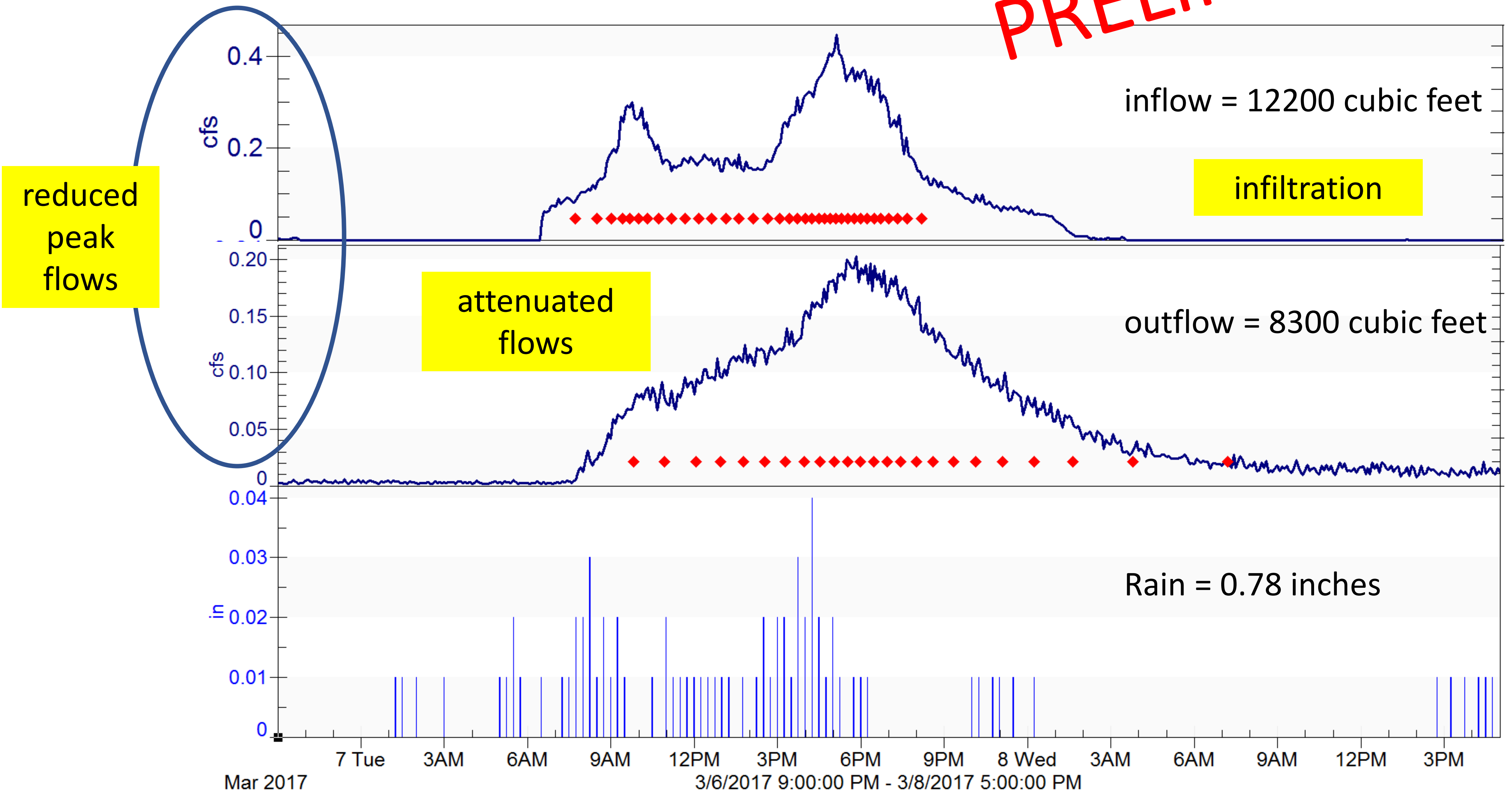
Example: Storm #10 East bioretention facility

PRELIMINARY!



SAM Stormwater Action Monitoring

Example: Storm #10 East bioretention facility

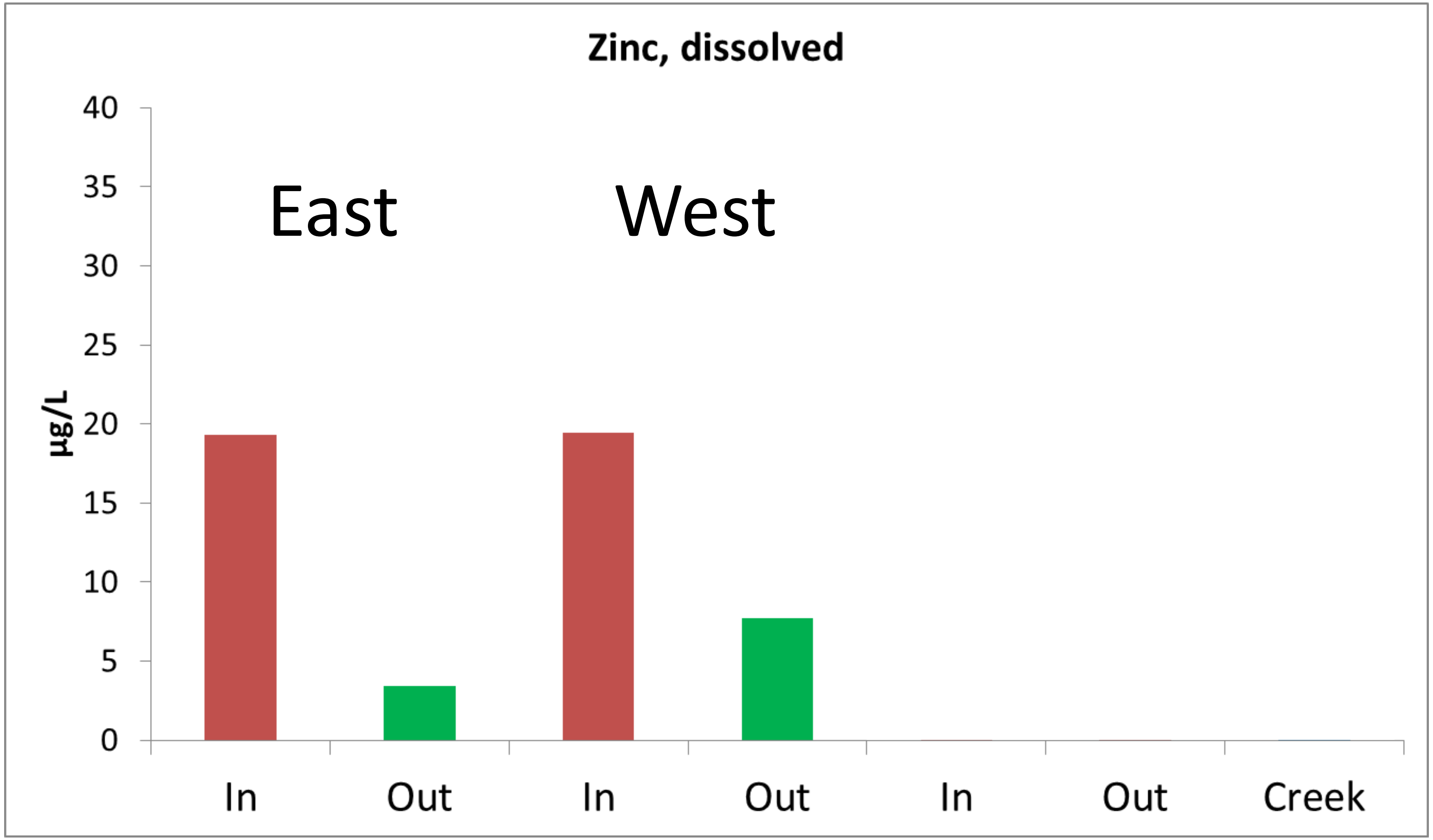


Stormwater Action Monitoring

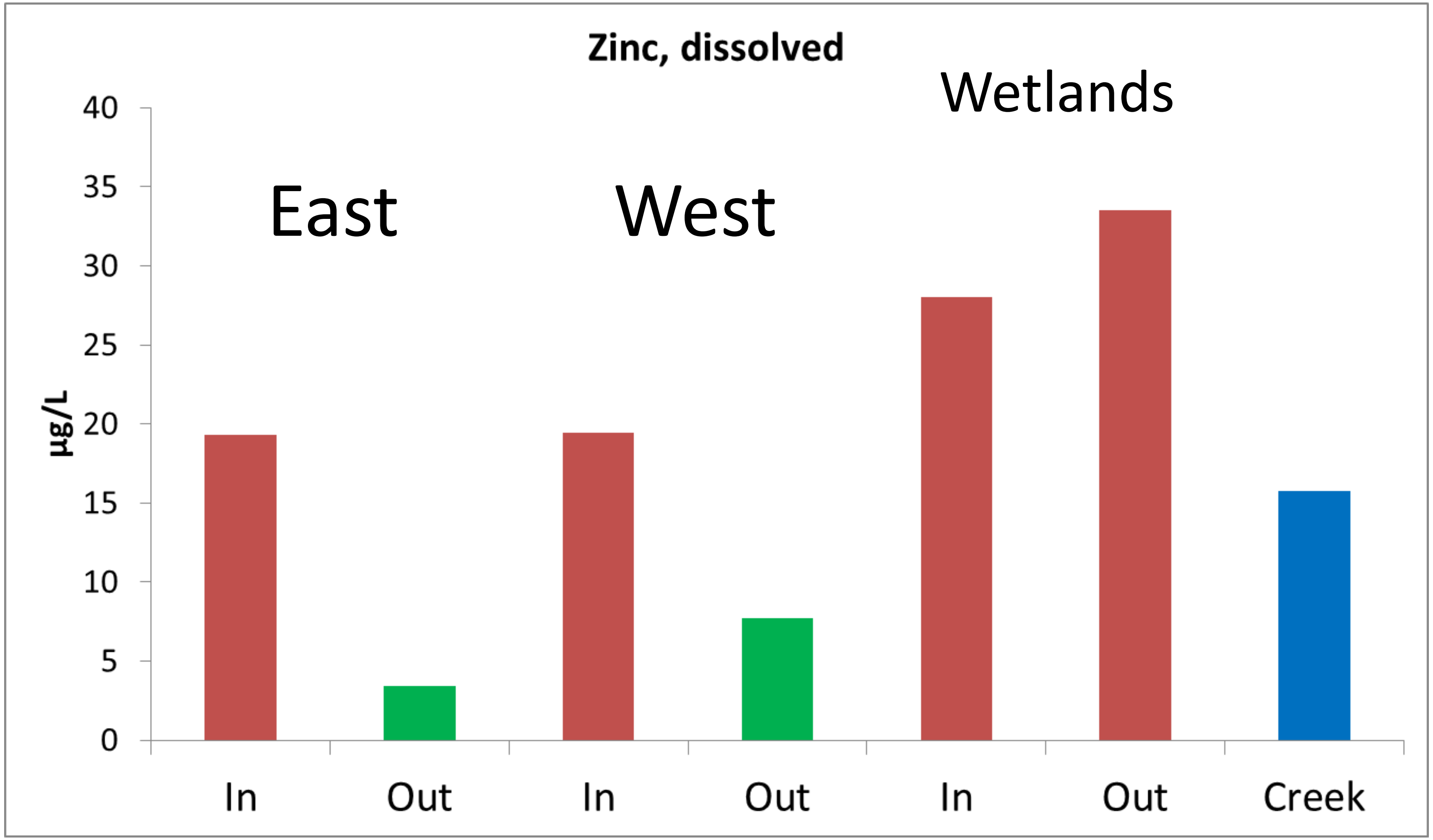
PRELIMINARY!

Treatment?

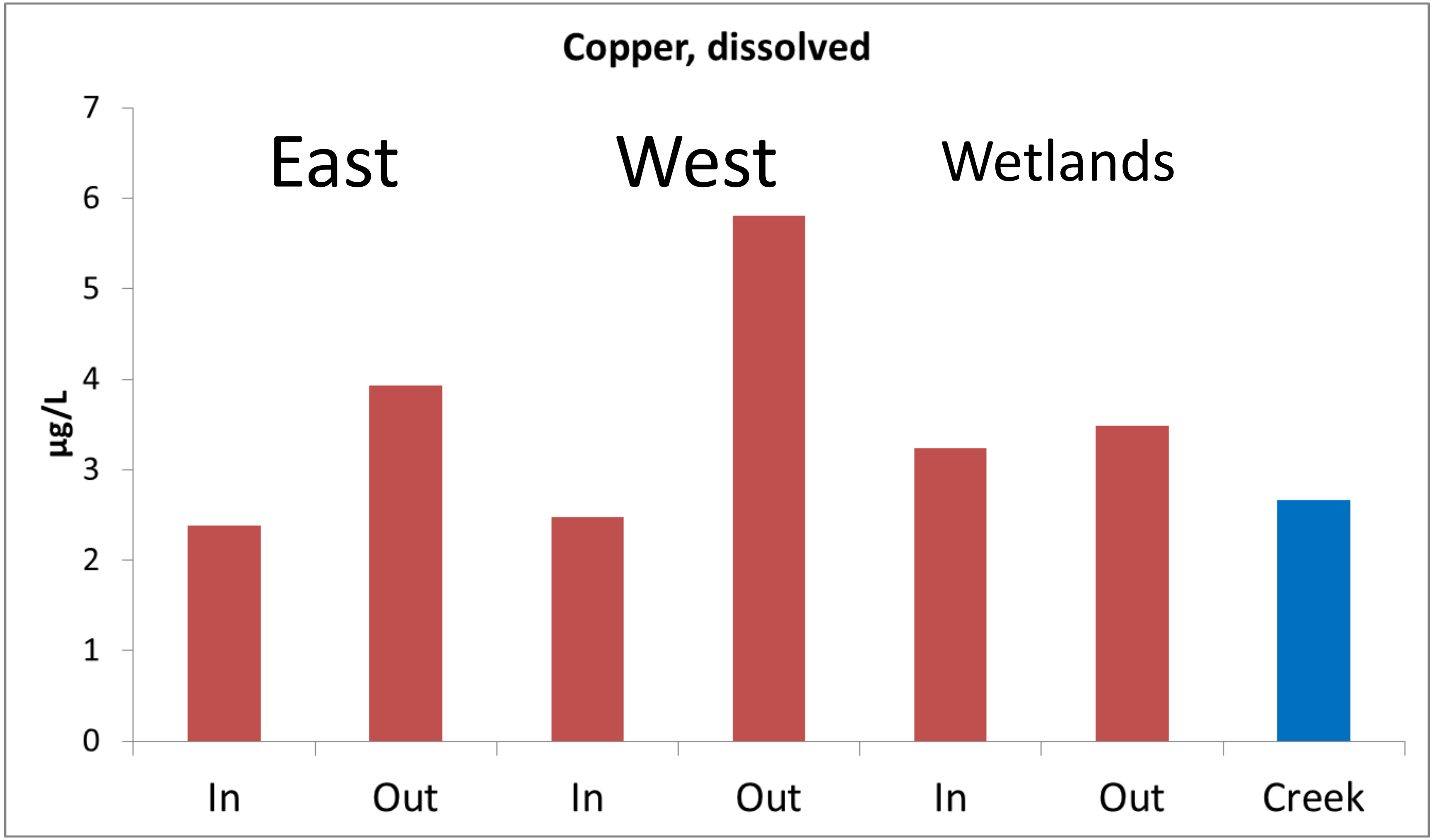
PRELIMINARY!



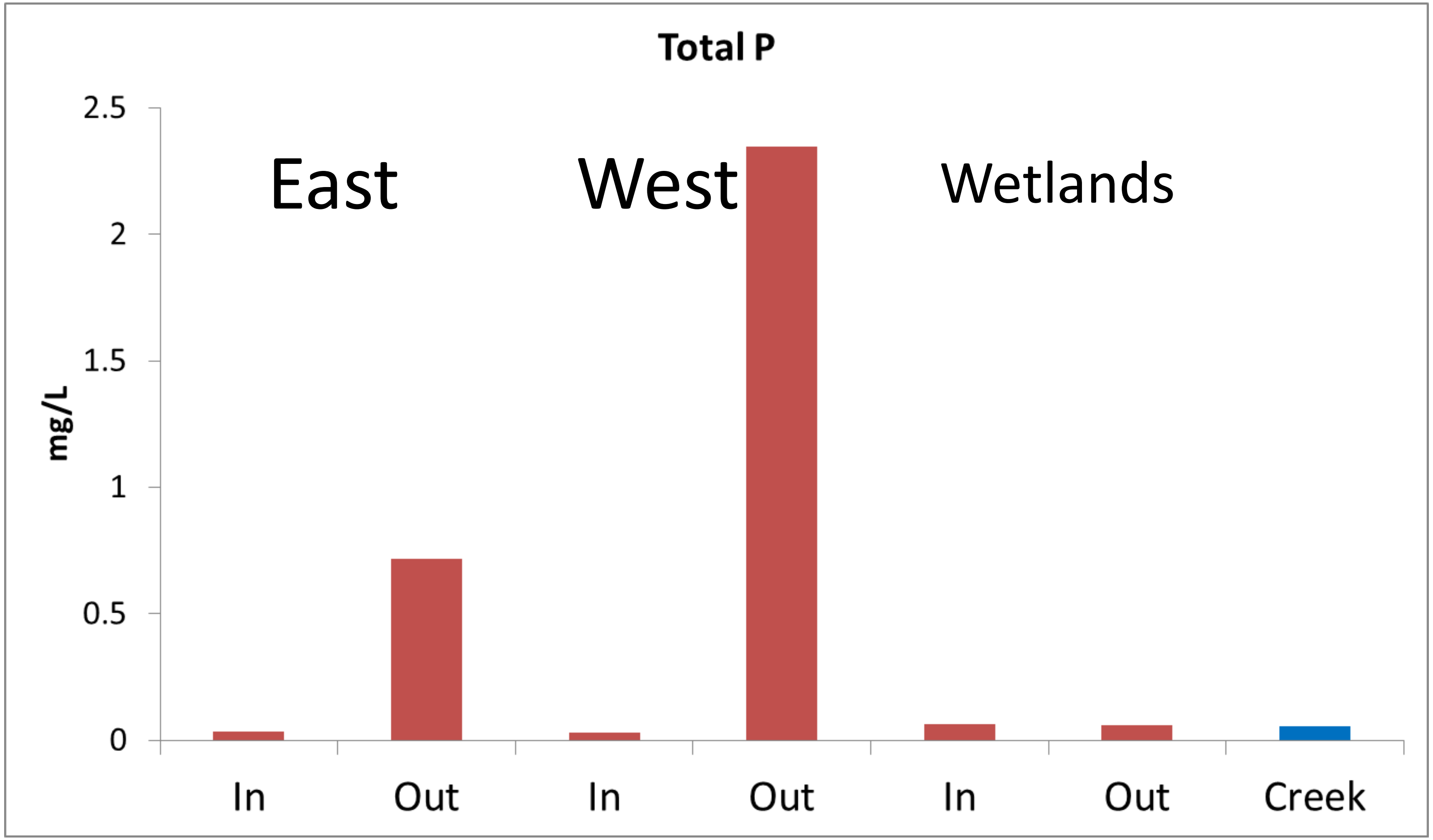
PRELIMINARY!



PRELIMINARY!



PRELIMINARY!



Stormwater Action Monitoring

Bioretention facilities

PRELIMINARY!

- Zinc
- TSS
- PAHs
- Hardness
- DOC
- Toxicity

- Bacteria

- Copper
- Lead

- Nutrients

Stormwater Action Monitoring

PRELIMINARY!

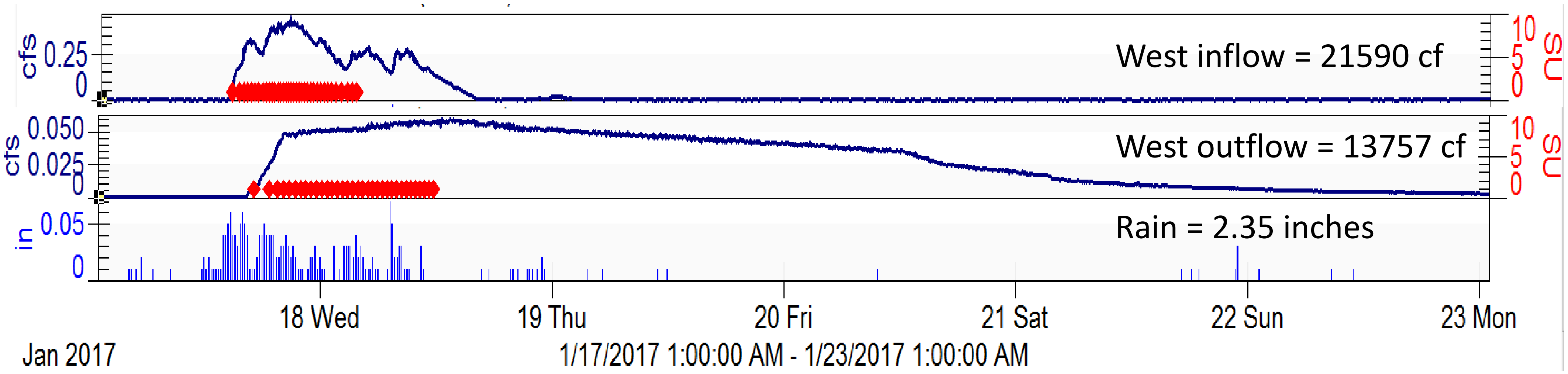
Take home messages

- Bioretention facilities
  - provided flow control and treatment
  - sources of nutrients, some metals
  - short retention times (east bioretention) sufficient for treatment
- Wetland complex
  - Still analyzing net and relative effect
- Final report completed by end of 2018

Questions?

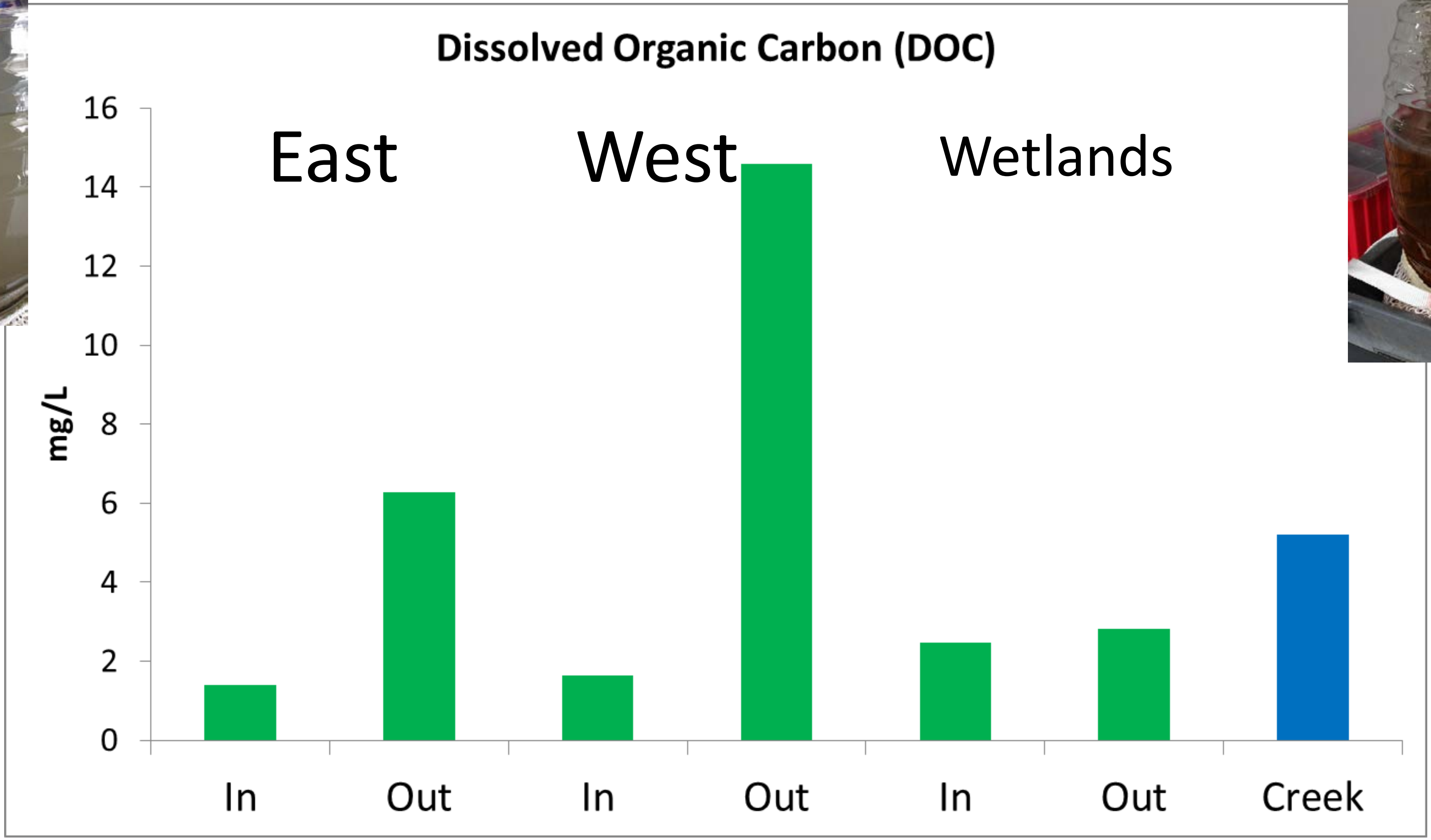
kate.macneale@kingcounty.gov

Flow control in West bioretention, but much slower



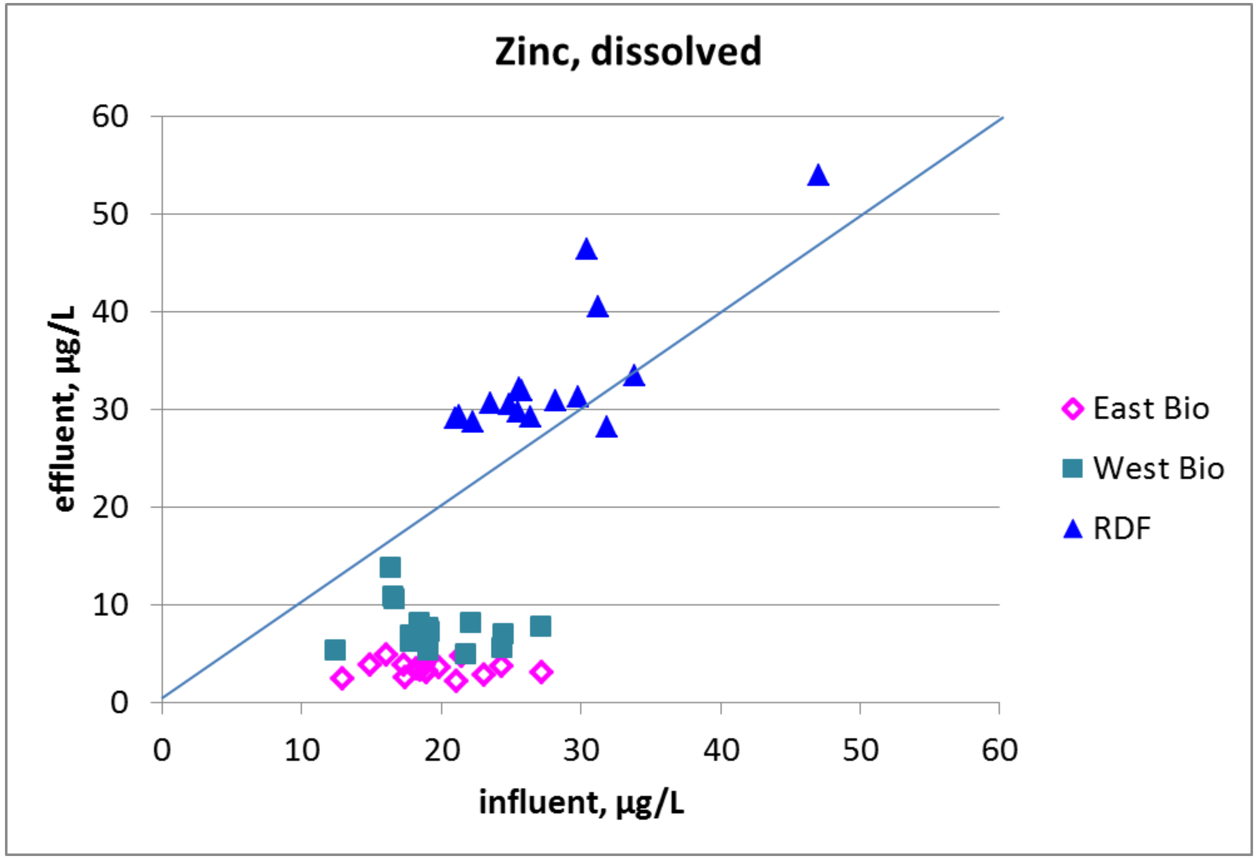
Stormwater Action Monitoring

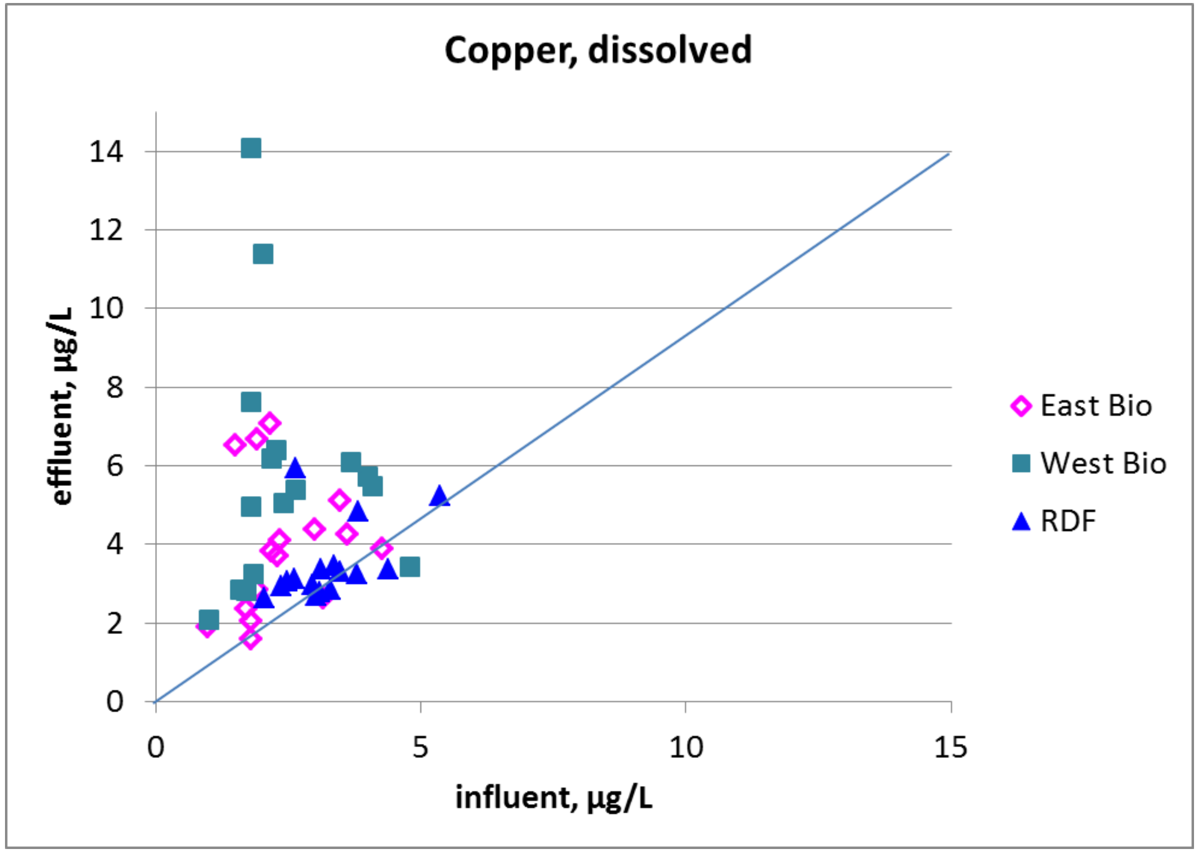
PRELIMINARY!

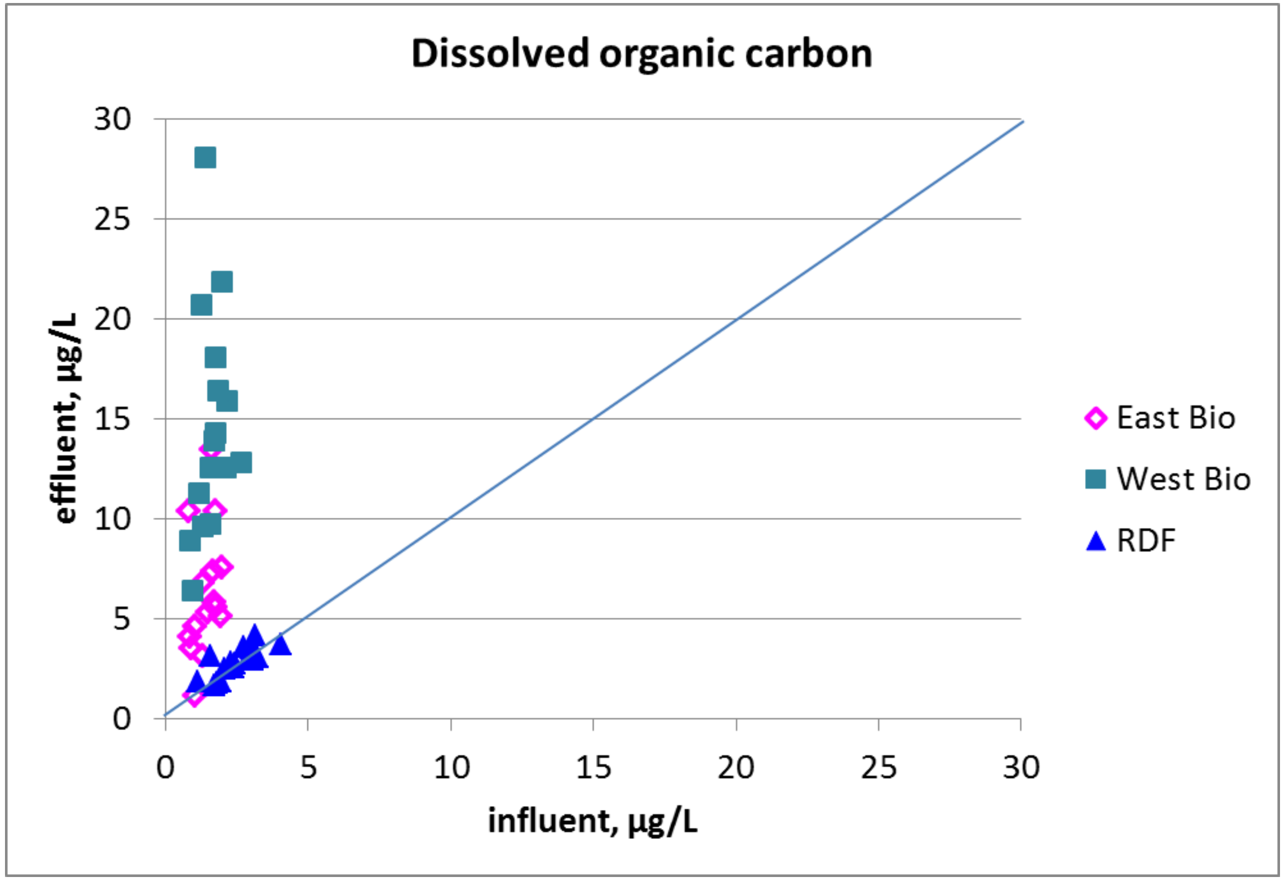


Metals

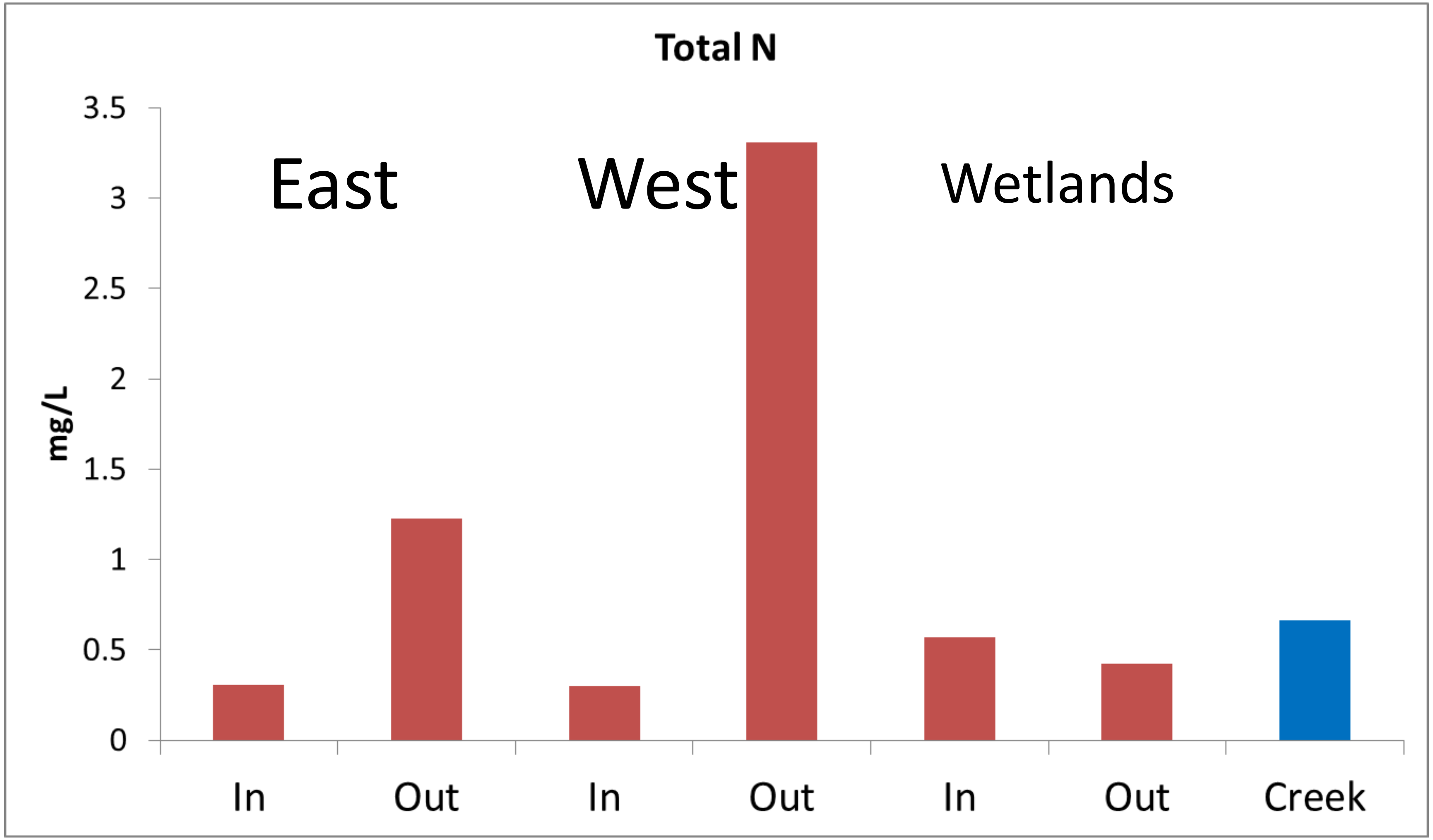
PRELIMINARY!






Dissolved organic carbon
effluent, µg/L
influent, µg/L
0
5
10
15
20
25
30
East Bio
West Bio
RDF

PRELIMINARY!




S 352ND ST
ENCHANTED PKWY S
PACIFIC HWY S
Drainage Basin: 22.6 ac
S 356TH ST
S 356TH ST
16TH AVE S

Paired Watershed Stormwater Retrofit Effectiveness Study

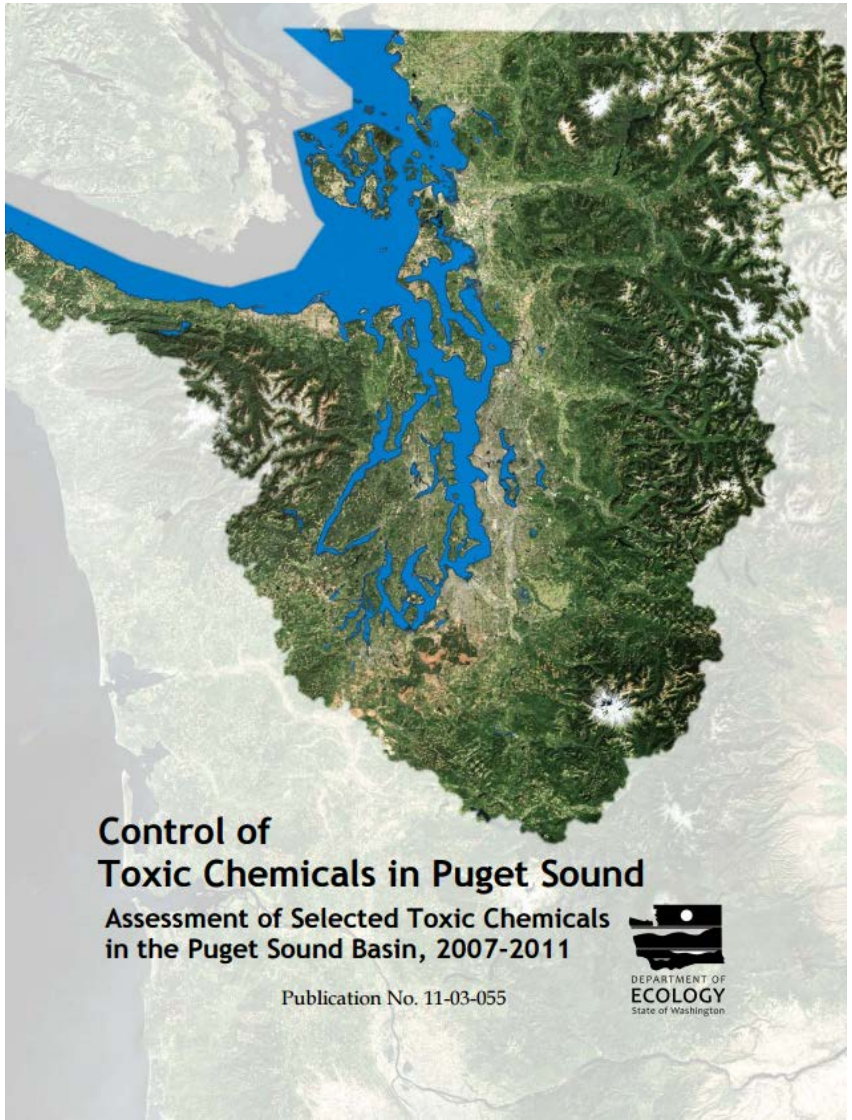
John Lenth – Herrera Environmental Consultants
Andy Rheaume – City of Redmond

June 1st, 2017 SAM Symposium

Stormwater Action Monitoring

The Dilemma

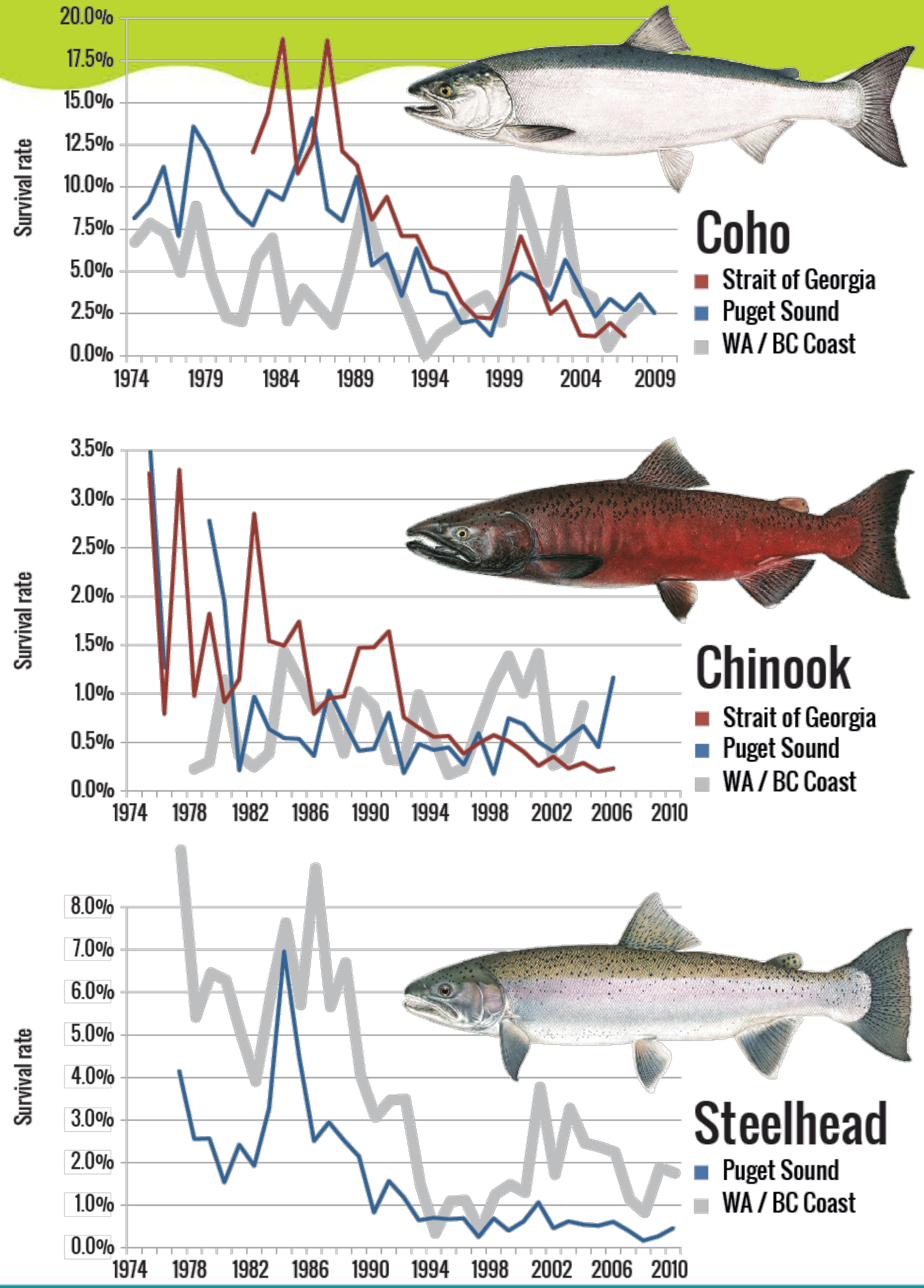
Stormwater runoff is a major contributor to aquatic habitat impairment in the Puget Sound watershed



Puget Sound Water Quality

- Surface water runoff during storms was identified as the major delivery pathway for most contaminants to Puget Sound

Puget Sound Salmon



Credit: Michael Schmidt, Long Live the Kings

Puget Sound Salmon

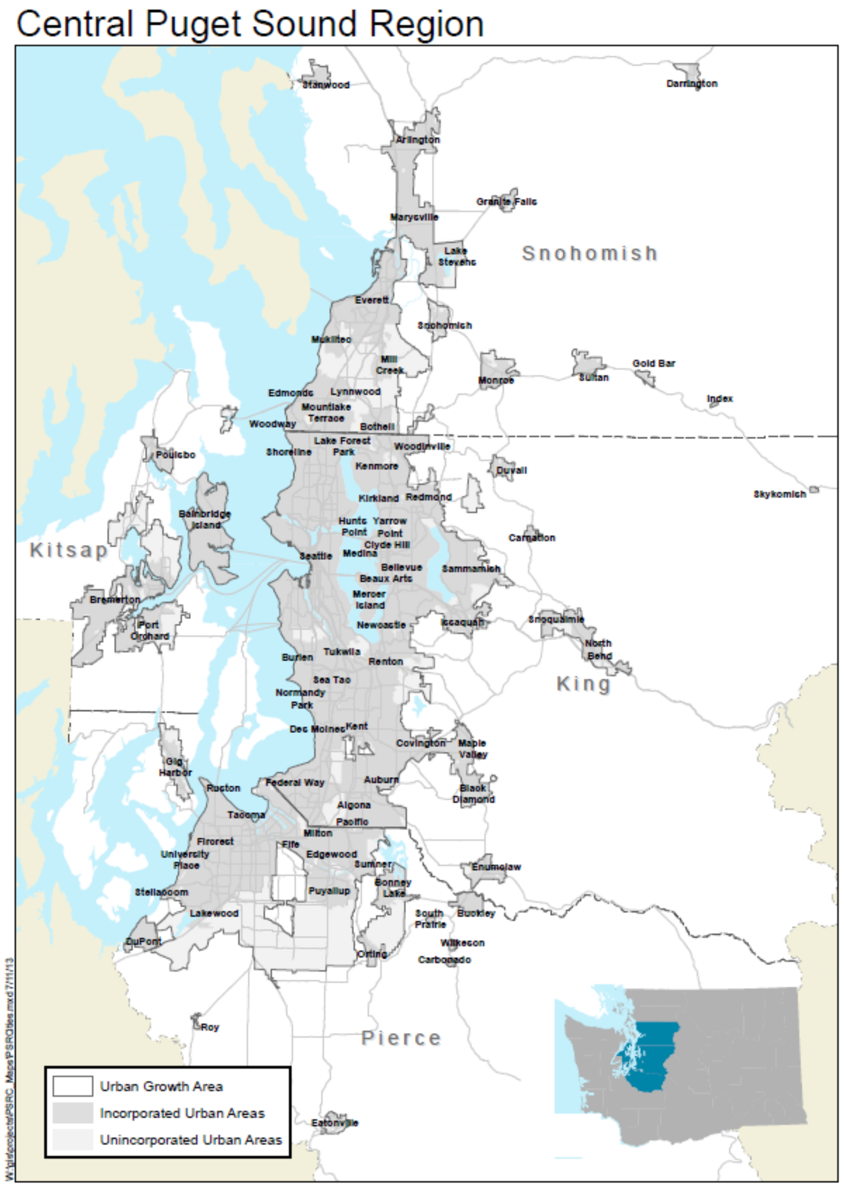
The Dilemma

Two more Seattles

and

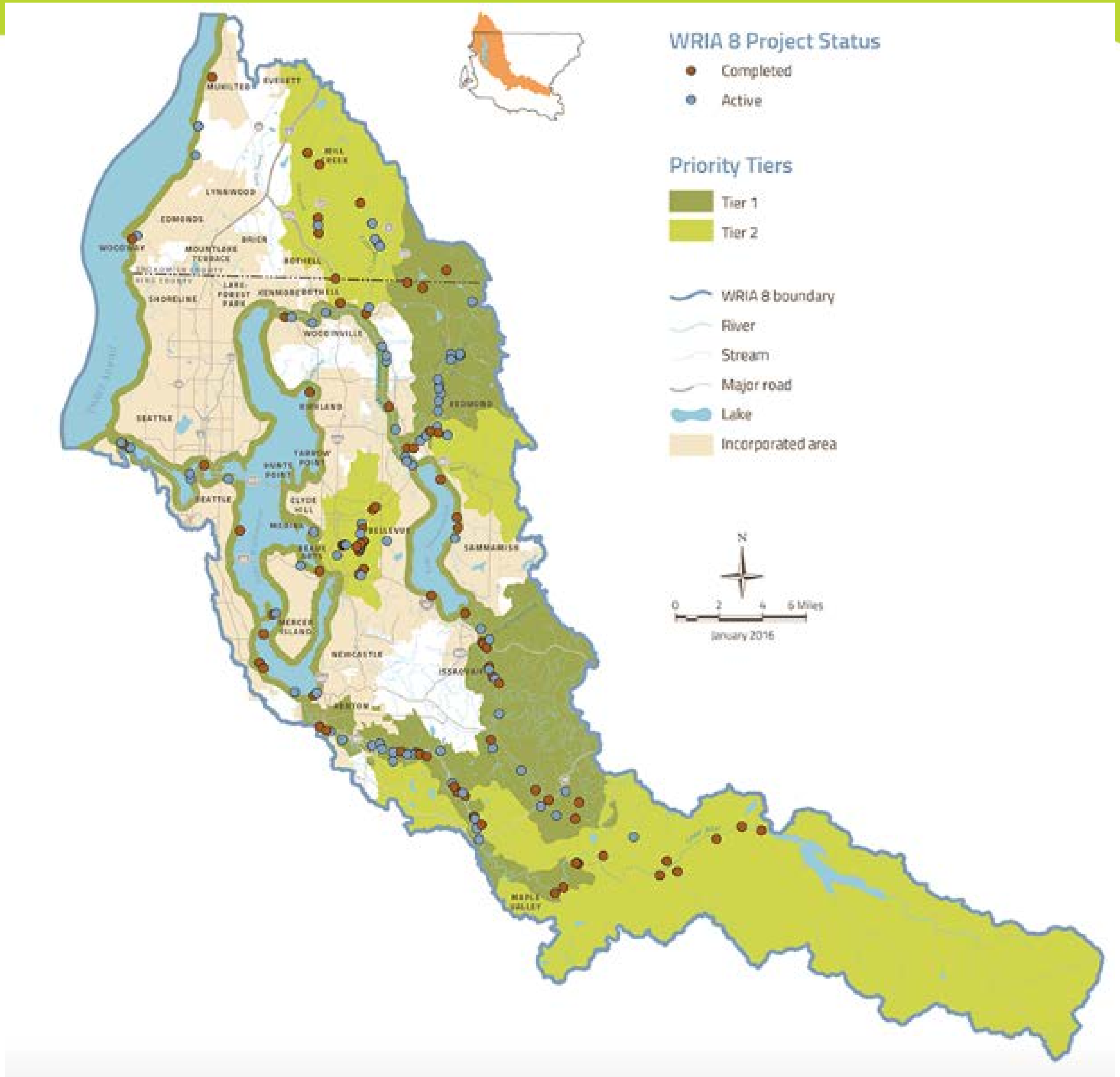
two more Tacoma's

by 2040!



The Dilemma

- Washington Municipal Stormwater Permit
  - Tied to new development and redevelopment
  - Treatment designed to improve conditions relative to existing conditions
  - New requirements for LID
  - <u>Does not specifically target areas of ecological importance</u>

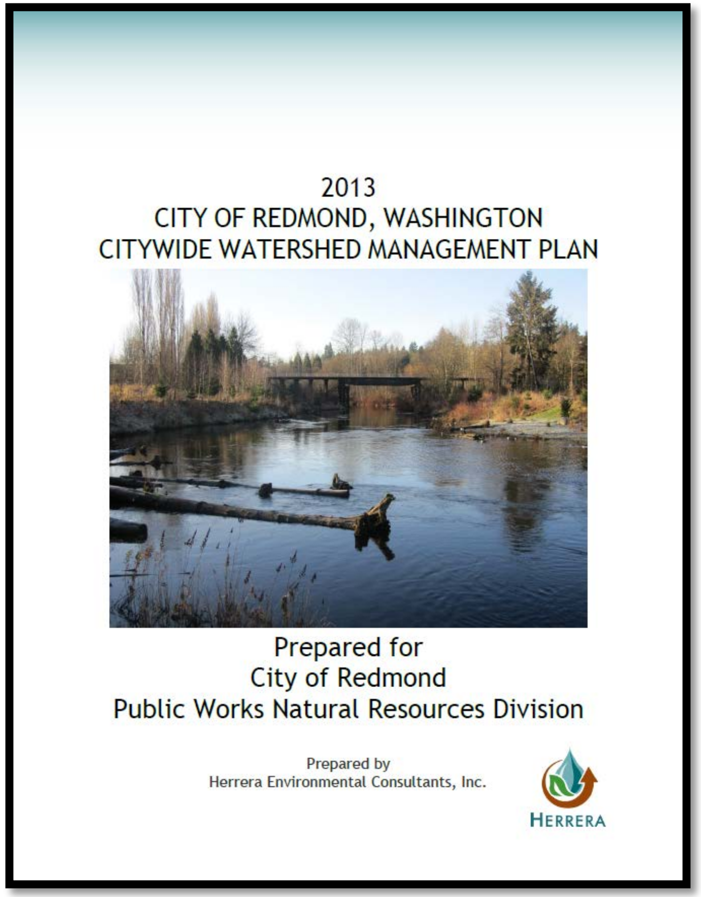


Stormwater Action Monitoring

Redmond Citywide Watershed Plan

Approved in February 2014

- Goals
  - Provide baseline of scientific information evaluating watershed rehabilitation potential
  - Prioritize a subset of watersheds with greatest potential to respond to rehabilitation efforts
  - Identify specific tools to rehabilitate highest priority watersheds by 2060



Redmond Citywide Watershed Plan

- Watershed Approach:
  1. Identify Priority Watersheds

     Moderate impairment = highest rehabilitation potential

  2. City builds facilities to improve stream hydrology and water quality

  3. Developers in other watersheds pay fee-in-lieu to reimburse City for facility costs

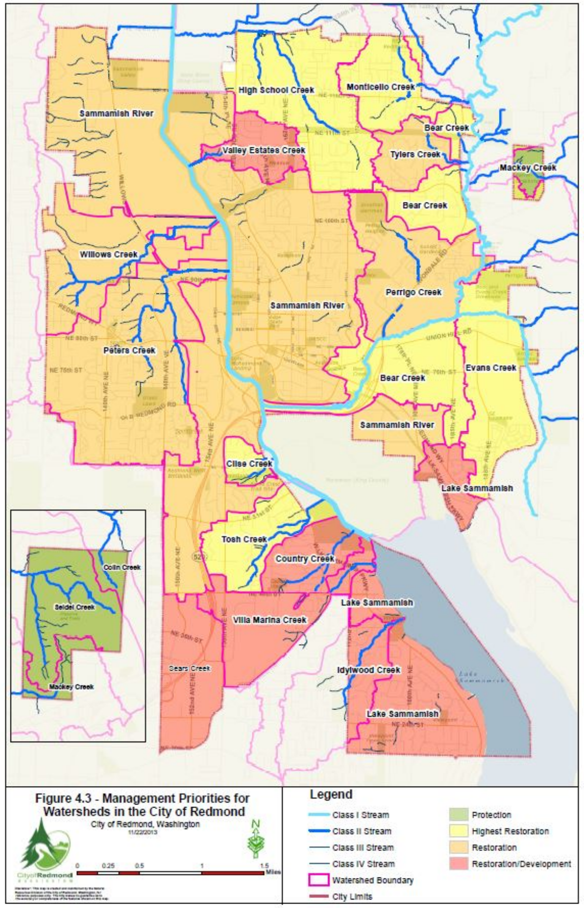


Figure 4.3 - Management Priorities for Watersheds in the City of Redmond

Redmond Citywide Watershed Plan

- Key Provisions:
  - *Retain requirements to prevent new impacts from development, regardless of watershed condition or priority*
  - *Allow for transfer of required flow control or runoff treatment to watersheds where they will provide the greatest benefit*

Regional Stormwater Monitoring Program

- Municipal Stormwater Permit established "pooled resource" funding for monitoring
  - Effectiveness of stormwater management program activities
  - Receiving water status and trends
  - Source Identification Repository

Redmond Paired Watershed Study

Can small urbanized streams that are moderately impacted by stormwater be rehabilitated?

BOOTH, et. al. (2002)

PUGET SOUND

JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION
VOL. 38, NO. 3 AMERICAN WATER RESOURCES ASSOCIATION JUNE 2002

FOREST COVER, IMPERVIOUS-SURFACE AREA, AND THE MITIGATION OF STORMWATER IMPACTS[1]

Derek B. Booth, David Hartley, and Rhett Jackson[2]

ABSTRACT: For 20 years, King County, Washington, has implemented progressively more demanding structural and nonstructural strategies in an attempt to protect aquatic resources and declining salmon populations from the cumulative effects of urbanization. This history holds lessons for planners, engineers, and resource managers throughout other urbanizing regions. Detention ponds, even with increasingly restrictive designs, have still proven inadequate to prevent channel erosion. Costly structural retrofits of urbanized watersheds can mitigate certain problems, such as flooding or erosion, but cannot restore the predevelopment flow regime or habitat conditions. Widespread conversion of forest to pasture or grass in rural areas, generally unregulated by most jurisdictions, degrades aquatic systems even when watershed imperviousness remains low. Preservation of aquatic resources in developing areas will require integrated mitigation, which must including impervious-surface limits, forest-retention policies, stormwater detention, riparian-buffer maintenance, and protection of wetlands and unstable slopes. New management goals are needed for those watersheds whose existing development precludes significant ecosystem recovery; the same goals cannot be achieved in both developed and undeveloped watersheds.
(KEY TERMS: urbanization; stormwater; BMP; land use planning; watershed management; urban water management.)

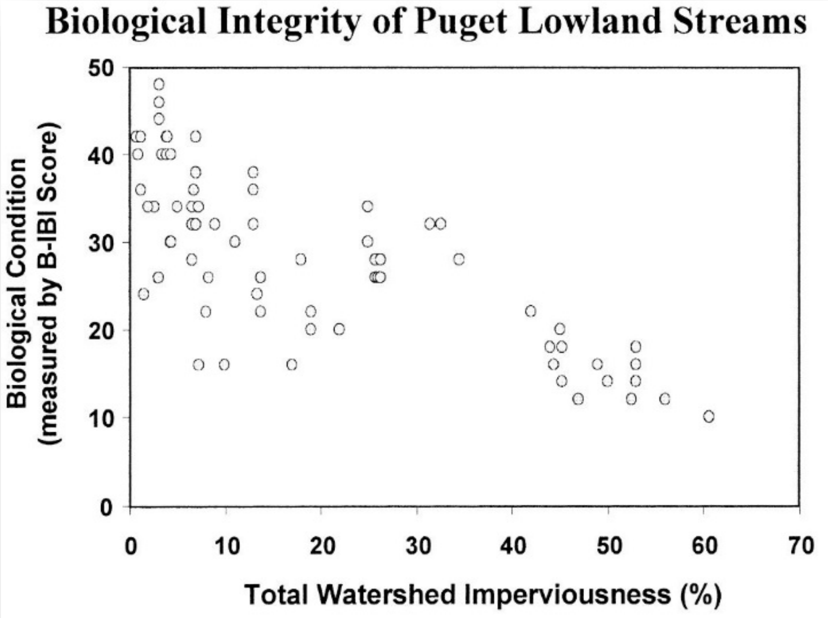
INTRODUCTION

For decades, watershed urbanization has been known to harm aquatic systems. Although the problem has been long articulated, solutions have been elusive because of the complexity of the problem, the evolution of still-imperfect analytical tools, and socioeconomic forces with different and often incompatible interests. King County, Washington, has been a recognized leader in the effort to analyze and to reduce the consequences of urban development, but even in this jurisdiction the path toward aquatic resource protection has been marked by well-intentioned but ultimately mistaken approaches, compromises with other agency goals that thwart complete success, and imperfect implementation of adopted policies and plans. This experience demonstrates the difficulty of meeting urban and suburban water-quality and aquatic-resource protection goals in the face of competing social priorities and variable political resolve on environmental issues that require sustained, long-term strategies to achieve progress.

King County provides a useful case study for resource managers in urbanizing regions across the country. It covers about 5,600 square kilometers with a population of 1.7 million people, the twelfth most populous county in the United States. Its western boundary is Puget Sound and its eastern boundary is the crest of the Cascade Range. It contains all or most of three major river basins, two large natural lakes, and numerous small rivers and streams (Figure 1). The streams and lakes support all species of anadromous Pacific salmon and resident trout. Land uses include urban, industrial, suburban, agriculture, rural, commercial timber production, and National Forest. Cities include Seattle, Bellevue, Renton, and Redmond; population growth has been explosive over the last 20 years.

Recent Endangered Species Act (ESA) listings of Puget Sound chinook and bull trout, and the potential for more salmonid listings, have brought new scrutiny to all aspects of watershed protection and urbanization-mitigation efforts in King County and

[1]Paper No. 01124 of the *Journal of the American Water Resources Association*. **Discussions are open until February 1, 2003.**
[2]Respectively, Research Associate Professor, Center for Urban Water Resources Management, Department of Civil and Environmental Engineering, University of Washington, Seattle, Washington, 98195-2700; Senior Hydrologist, King County Water and Land Resources Division, 201 South Jackson Street, Suite 600, Seattle, Washington 98104-3855; and Associate Professor, Daniel B. Warnell School of Forest Resources, University of Georgia, Athens, Georgia 30602-2152 (E-Mail/Booth: dbooth@u.washington.edu).



"Development that minimizes the damage to aquatic resources cannot rely on structural BMP's, because ***there is no evidence that they can mitigate any but the most egregious consequences of urbanization****."*

Stormwater Action Monitoring

Redmond Paired Watershed Study

Selbig, W. R., et al. (2008). A comparison of runoff quantity and quality from two small basins undergoing implementation of conventional and low-impact-development (LID) strategies : Cross Plains, Wisconsin, water years 1999-2005. Reston, Virginia, U.S. Geological Survey.

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Redmond Paired Watershed Study

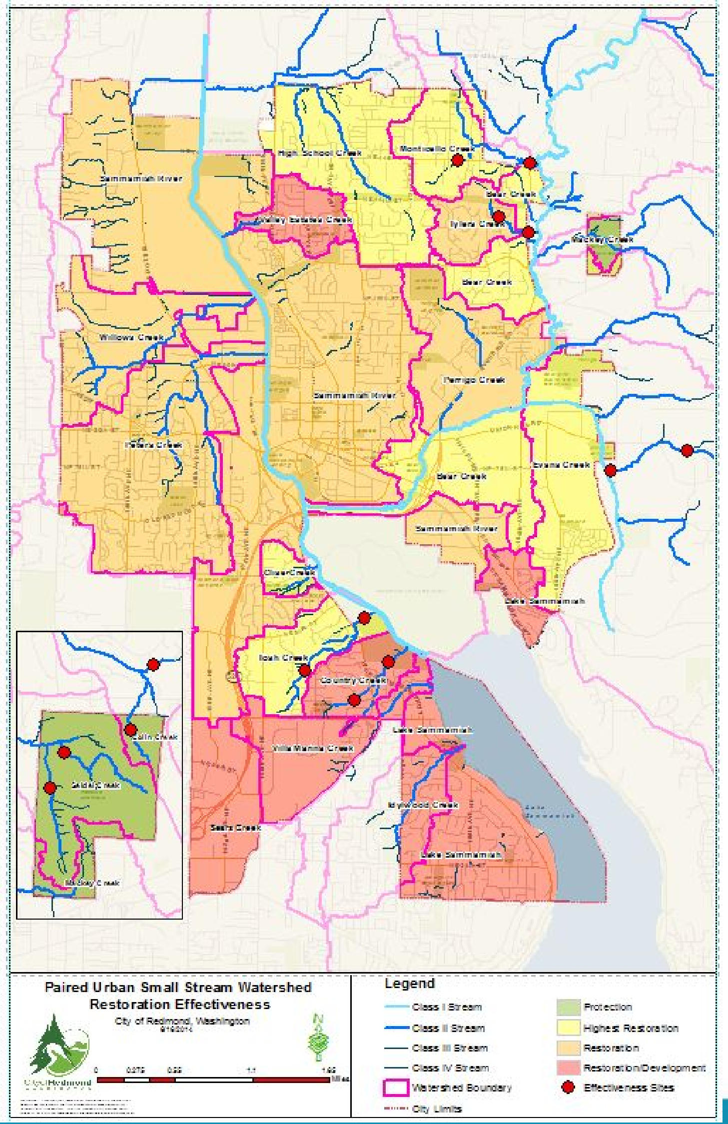
Project Team

- Project Lead
  - City of Redmond
- Technical Leads for QAPP
  - Herrera Environmental Consultants
  - King County
- Agency Oversight
  - Washington State Department of Ecology
- Steering Committee
  - City of Seattle
  - King County
  - Kitsap County
  - U.S. Environmental Protection Agency
  - U.S. Geological Society
  - Washington State Department of Ecology

Redmond Paired Wate

Experimental Design

- Three “Application” watersheds
  - Moderately impacted by urbanization
  - Prioritized for rehabilitation efforts
- Two “Reference” watersheds
  - Relatively pristine
  - Not subject to rehabilitation efforts
- Two “Control” watersheds
  - Heavily impacted by urbanization
  - Not subject to rehabilitation efforts



Redmond Paired Watershed Study

Experimental Design

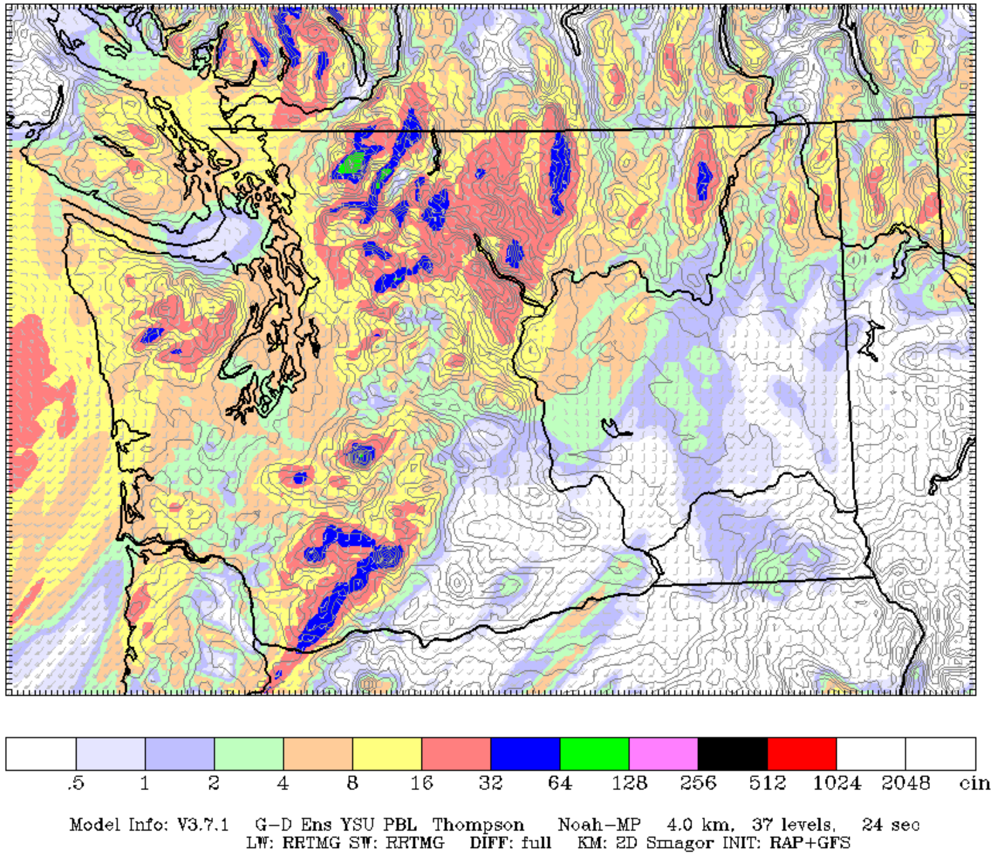
Watershed Type	Watershed Name	WQ Sites (#)	Physical Habitat Sites (#)	Dominant Land Use/Cover	Watershed Areas (acres)	Watershed Area in Redmond (acres)
Reference	Colin	1	1	Forest	1,990	90
Reference	Seidel	2	3	Forest	1,188	615
Application	Monticello	3	5	Residential/Commercial	345	264
Application	Tosh	2	4	Residential/Commercial	299	276
Application	Evans	2	2	Residential	397	NA
Control	Tyler's	3	2	Residential/Commercial	168	167
Control	Country	2	2	Residential/Commercial	212	212

Stormwater Action Monitoring

Redmond Paired Watershed Study

Experimental Design

- Water quality monitoring
  - 12 storm flow events annually
  - 4 base flow events annually
- Habitat monitoring
  - Annually
- Hydrologic modeling
  - Continuous
- Sediment monitoring
  - Annually
- Biological monitoring
  - Annually



Redmond Paired Watershed Study

Experimental Design

- Water Quality
  - Total suspended solids
  - Turbidity
  - Temperature
  - Conductivity
  - Hardness
  - Dissolved organic carbon
  - Fecal coliform bacteria
  - Total phosphorus
  - Total nitrogen
  - Nutrients
  - Copper, total and dissolved
  - Zinc, total and dissolved

Redmond Paired Watershed Study

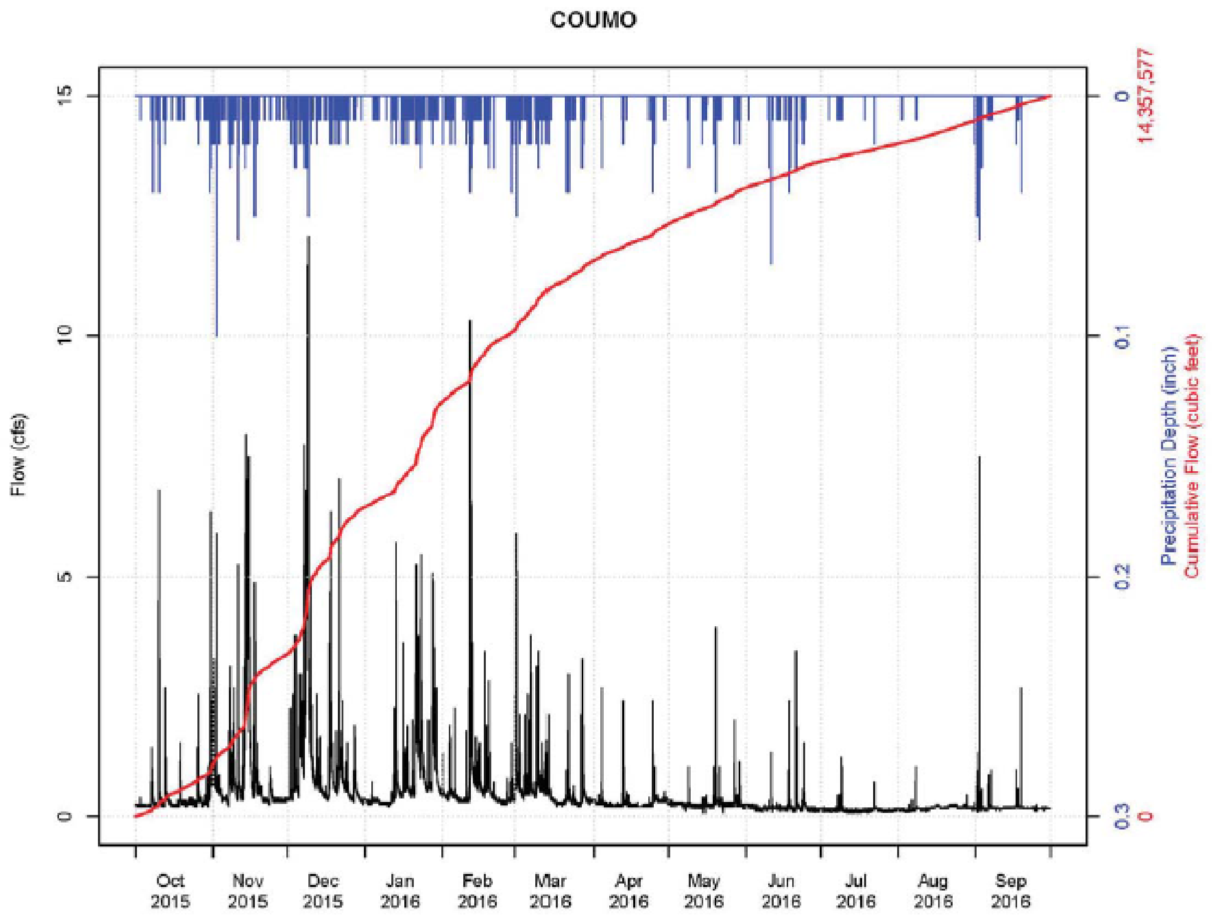
Experimental Design

- Sediment Quality
  - Total organic carbon
  - Copper
  - Zinc
  - Polycyclic aromatic hydrocarbons (PAHs)
  - Phthalates

Redmond Paired Watershed Study

Experimental Design

- Hydrology
  - Continuous Flow
  - Hydrologic metrics



Redmond Paired Watershed Study

Experimental Design

- Biological endpoints
  - Benthic Index of Biotic Integrity

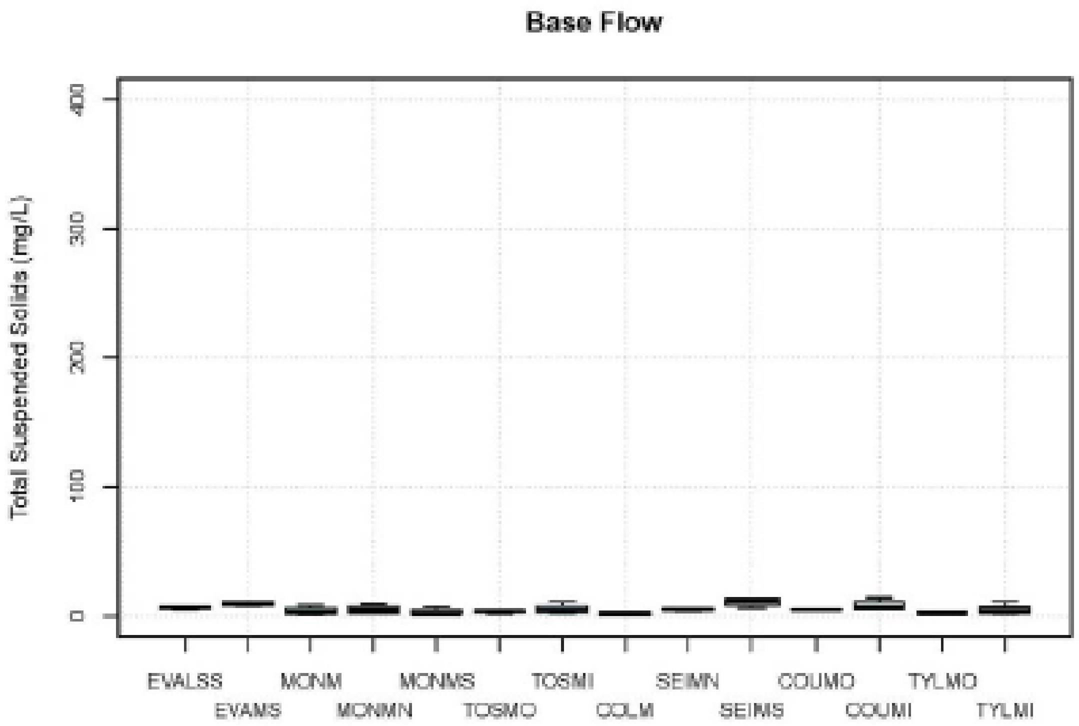
Redmond Paired Watershed Study

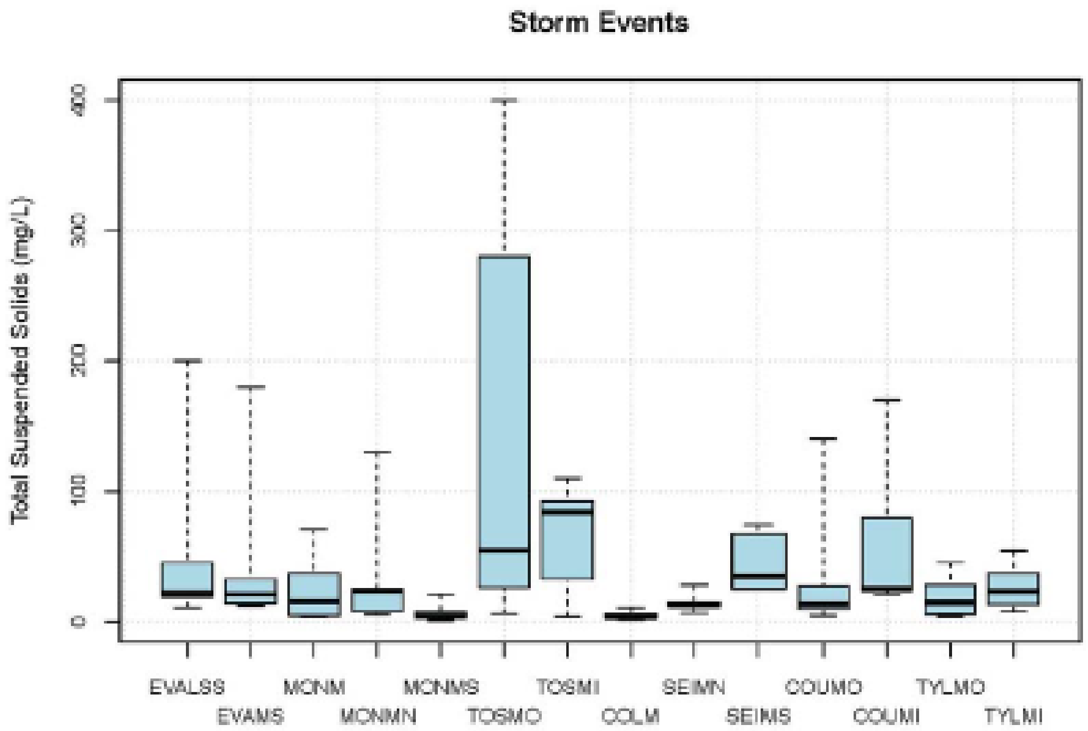
Experimental Design

- Physical habitat
  - Longitudinal profile
  - Channel dimensions
  - Substrate embeddedness
  - Fish cover
  - Human influence
  - Riparian shading
  - Riparian vegetative structure
  - Large woody debris
  - Habitat units

Redmond Paired Watershed Study

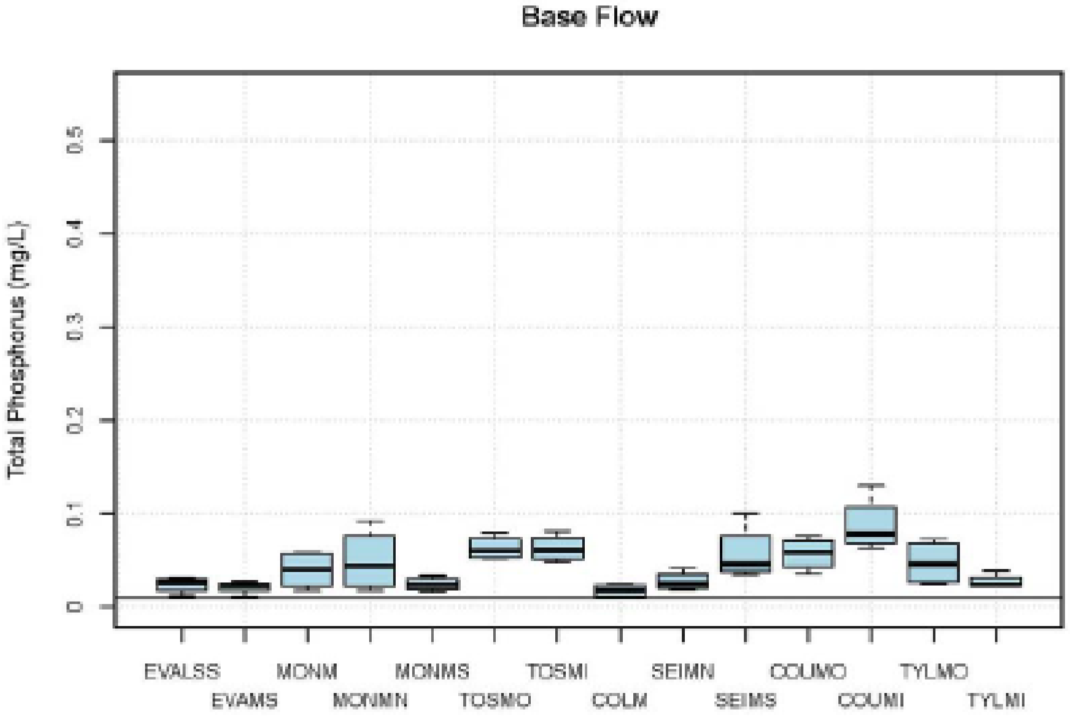
Initial Results

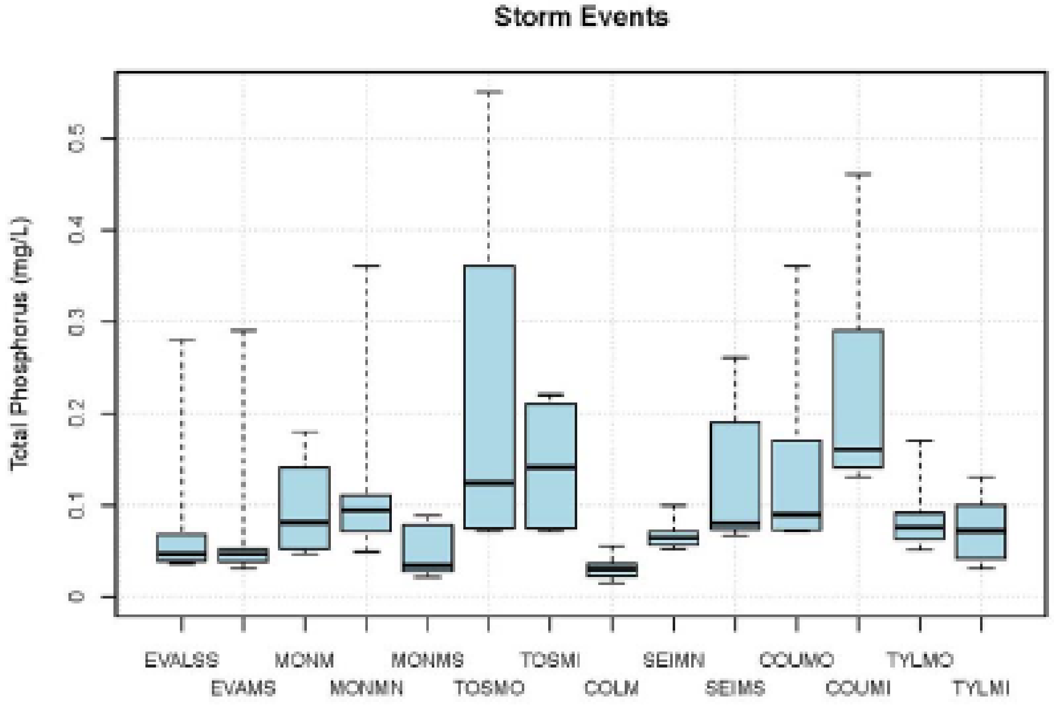




Redmond Paired Watershed Study

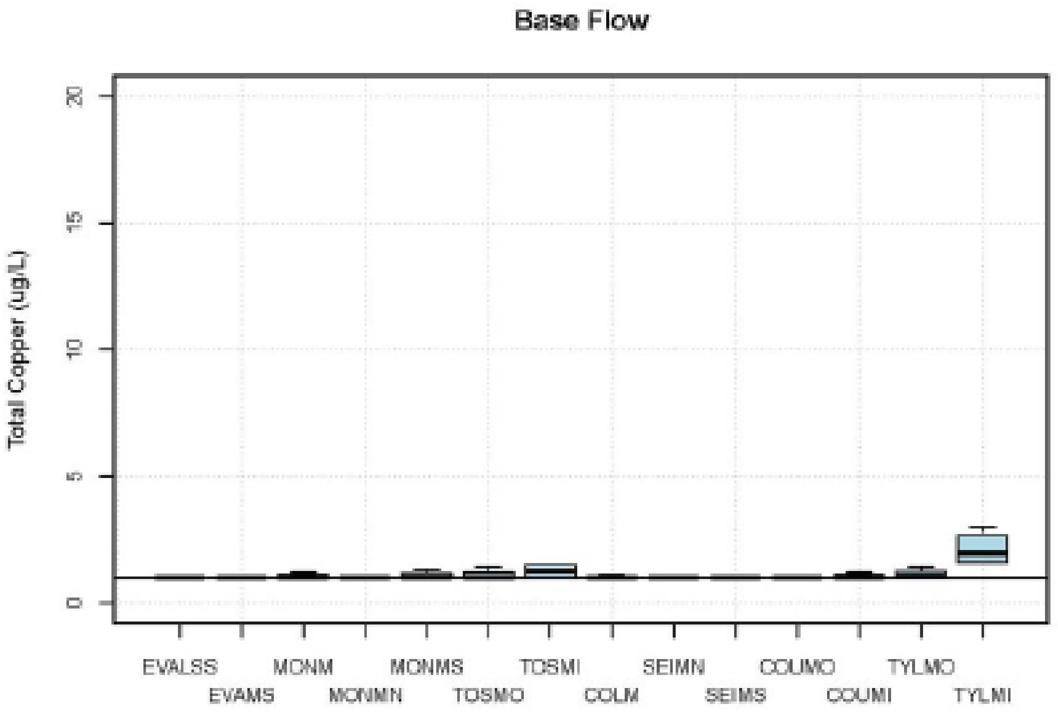
Initial Results

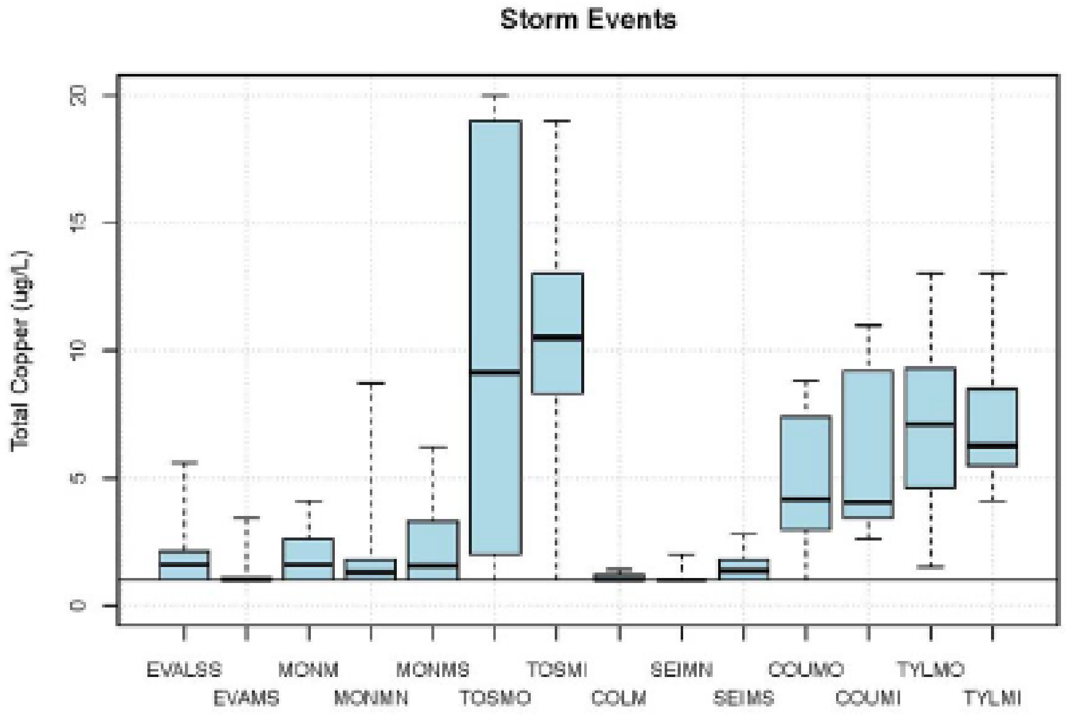




Redmond Paired Watershed Study

Initial Results

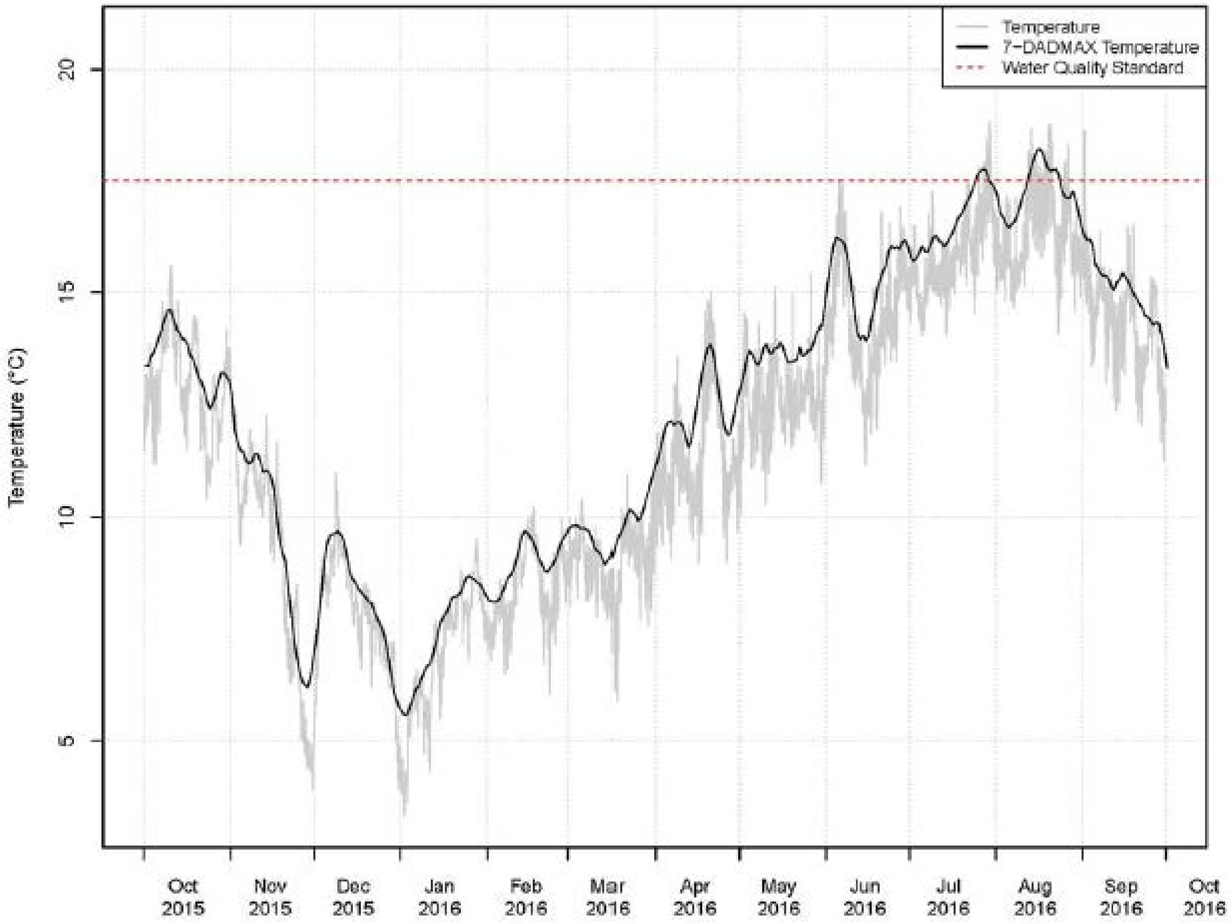




Redmond Paired Watershed Study

Initial Results

- Temperature



Redmond Paired Watershed Study

Initial Results

Watershed Type	Watershed Name	Stations	Overall Condition	B-IBI	Total Taxa Richness
Reference	Colins	1	Poor	27.9	22
Reference	Seidel	3	Fair, Good, Fair	56.0, 77.1, 57.6	30, 34, 31
Application	Monticello	5	Fair, Good, Very Poor, Very Poor, Poor	54.3, 65.8, 7.9, 19.7, 39.2	31, 35, 15, 21, 32
Application	Tosh	4	Fair, Poor, Poor, Poor	41.4, 35.0, 39.5, 22.2	25, 23, 27, 25
Application	Evans	2	Fair, Good	56.2, 76.0	27, 36
Control	Tyler's	2	Poor, Very Poor	25.9, 7.0	22, 12
Control	Country	2	Very Poor, Fair	9.0, 46.4	12, 31

Questions?

John Lenth

jlenth@herrerainc.com

(206) 787 - 8265

Andy Rheaume

ajrheaume@redmond.gov

(425) 556 – 2741

Western WA Catch Basin I&M Study

Jenée Colton, King County

Diana Hasegan, Osborn Consulting Inc.

Stormwater Action Monitoring

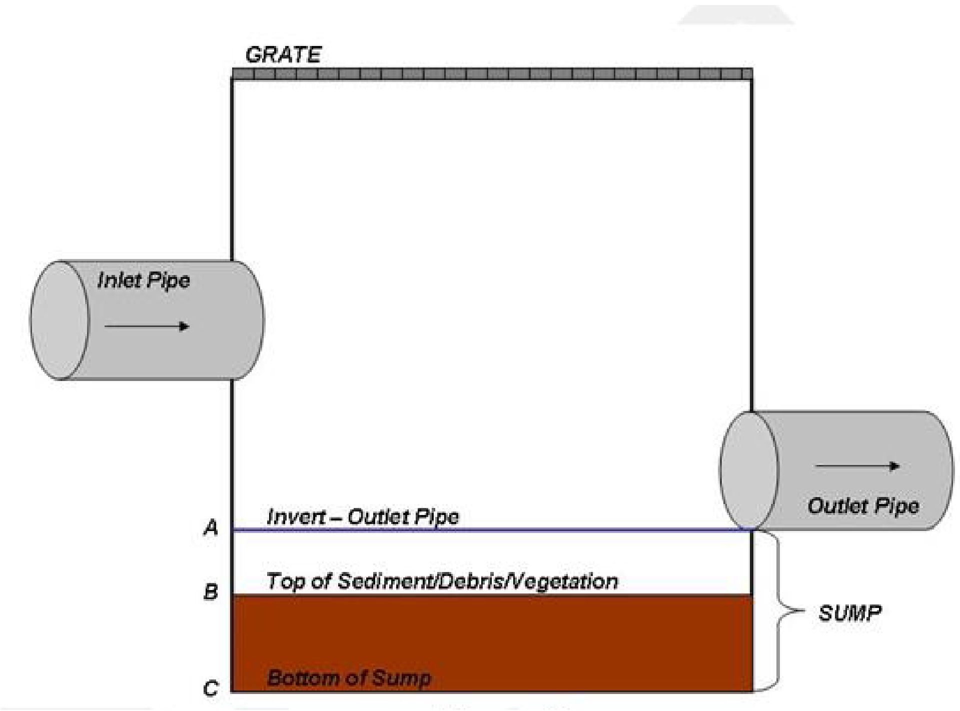
How can we use WW catch basin I&M records to inform individual inspection frequency needs?

Photo Credit:
WSDOT

Data Compilation Stage

Minimum Data Needed for Analysis

CB Info	Inspection Info	Cleaning Info
Location	CB ID	CB ID
Sump Depth	Date	Date
Sump Volume	Sediment Depth or % Full	



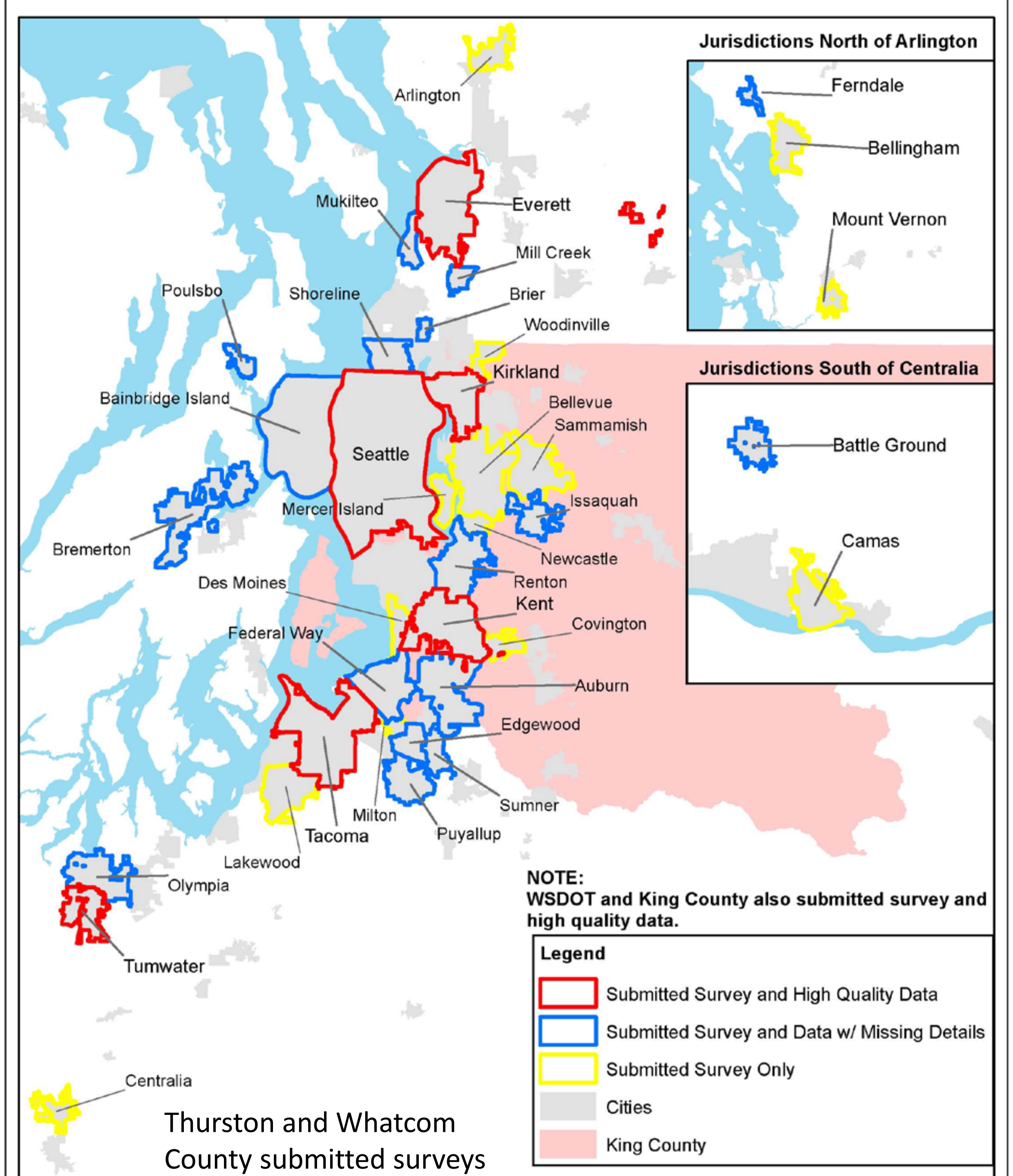
Response Rate

48/127 Answered Survey

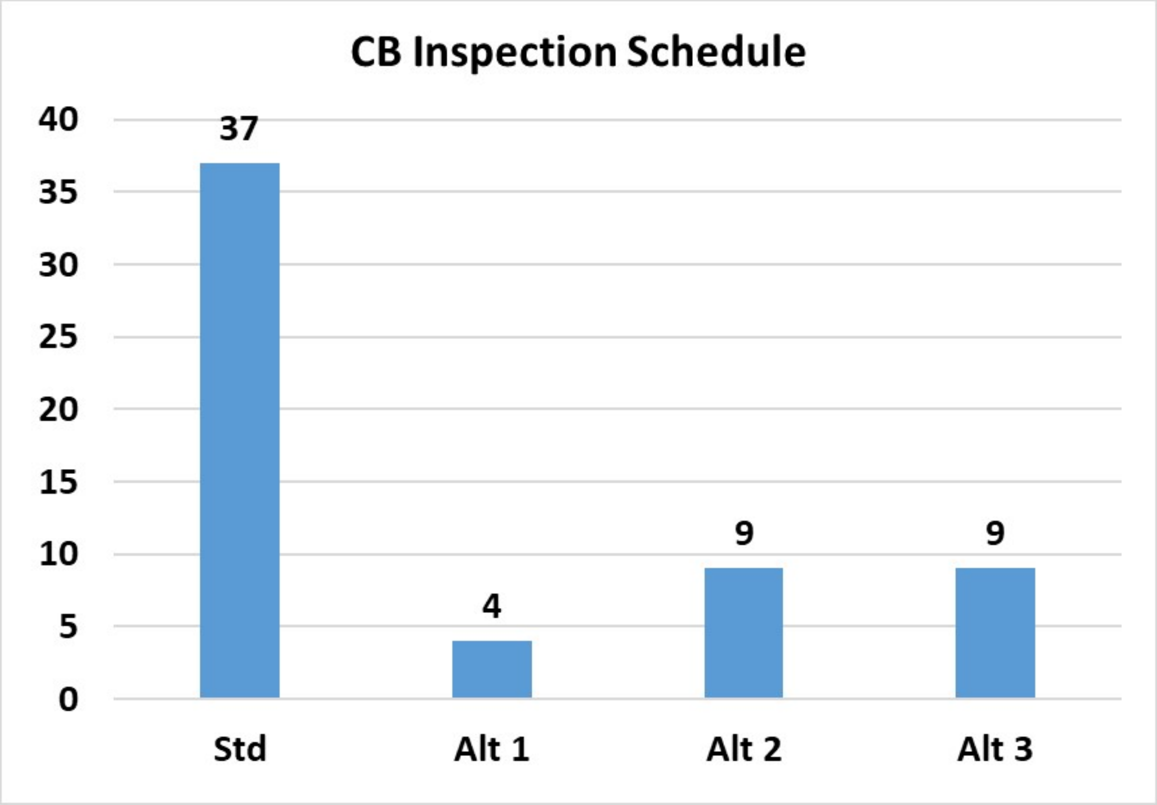
31/127 Provided Data

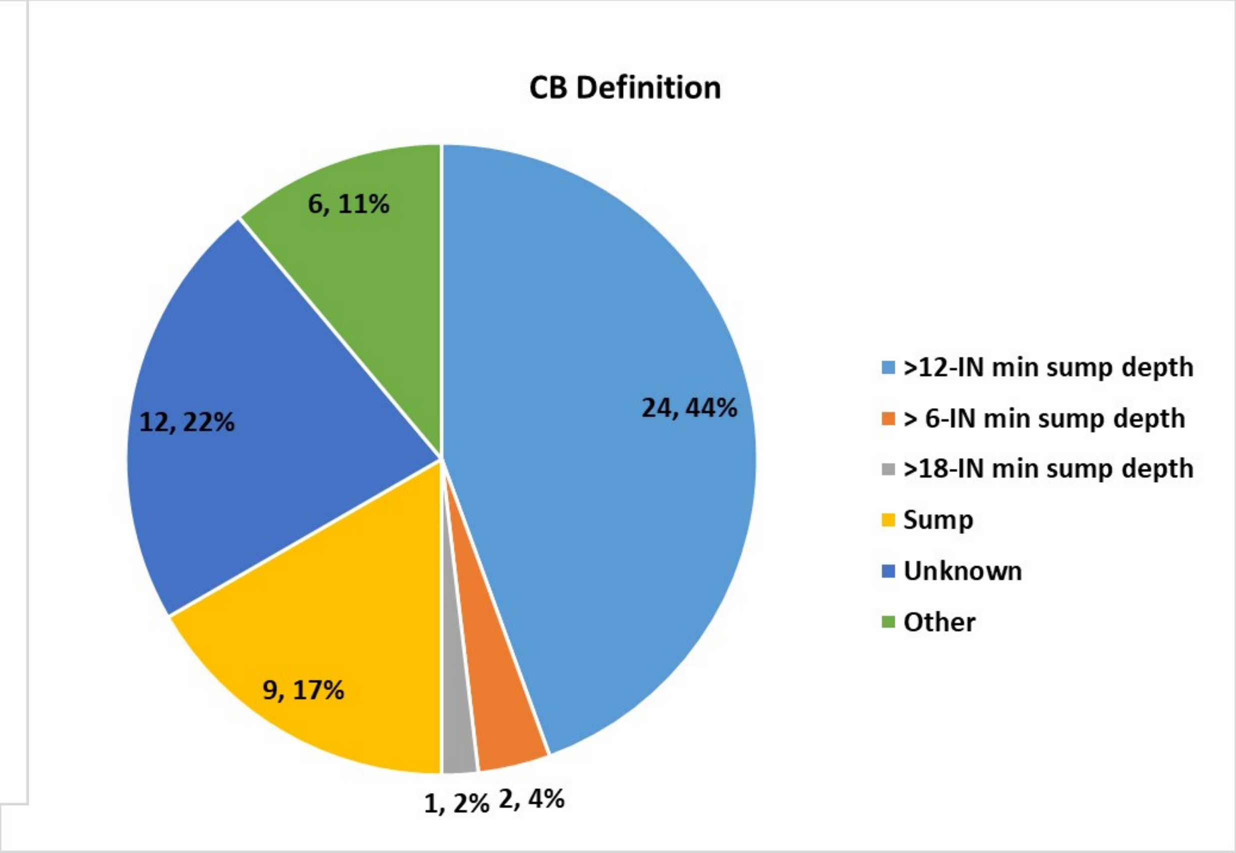
8 Permittees: Most Complete

Spatial Coverage



Preliminary Results



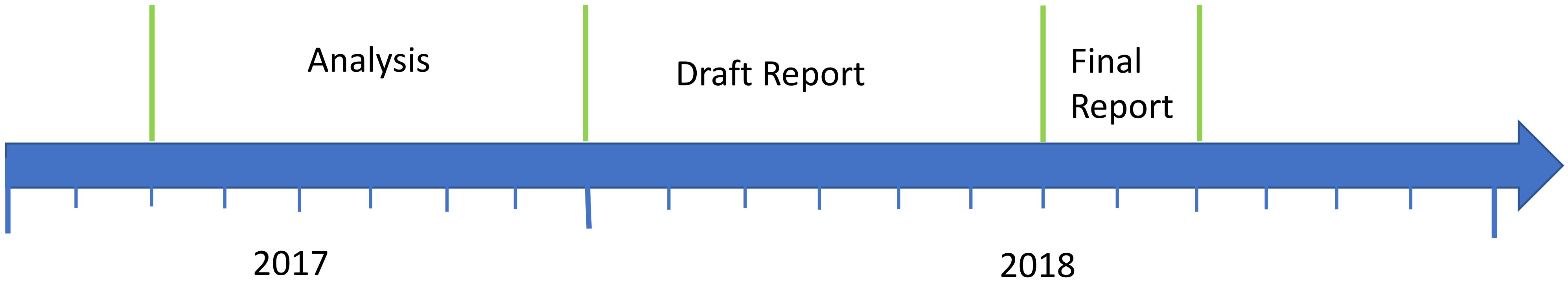


Project Benefits

- Know range of measurements collected & records kept across WW
- Identify information most helpful for assessing maintenance needs
- Potentially identify factors that help predict cleaning needs
- Propose alternative I&M schedules
- Cost-saving measures

Next step

Data loading and prep – June/July



Acknowledgements

King County – Blair Scott, Mark Preszler, Nick Hetrick, Brent Dhoore, and Doug Navetski

Technical Advisory Committee –Angela Gallardo, Laura Haren, Grant Moen, and Kate Rhoads

Osborn Consulting Inc. – Indulekshmi, Chang Liu, Madison Dreiger, Laura Ruppert

Cardno – Jonathan Ambrose

SAM coordinator – Brandi Lubliner

Stormwater Source Control Effectiveness Study

James Packman
Aspect Consulting

Greg Vigoren
City of Lakewood

SAM
Stormwater Action Monitoring

Funding provided by western Washington municipal stormwater permittees

What is Stormwater Source Control

- Prevent or reduce pollutants entering stormwater runoff.

How is Source Control Achieved?

- Best Management Practices (BMPs):

  Definition per SWMMWW (2012): schedules of activities, prohibitions of practices, maintenance procedures, managerial practices, or structural features that prevent or reduce pollutants or other adverse impacts to waters of Washington State.

  - Treatment and Flow Control BMPs
  - Operational BMPs
  - Structural BMPs

Stormwater Action Monitoring

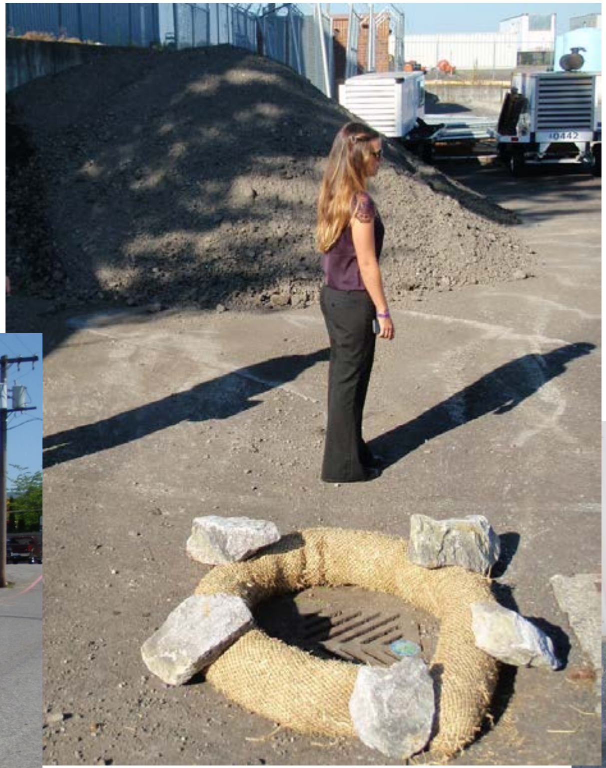
Effectiveness Questions

Six source control effectiveness questions identified:

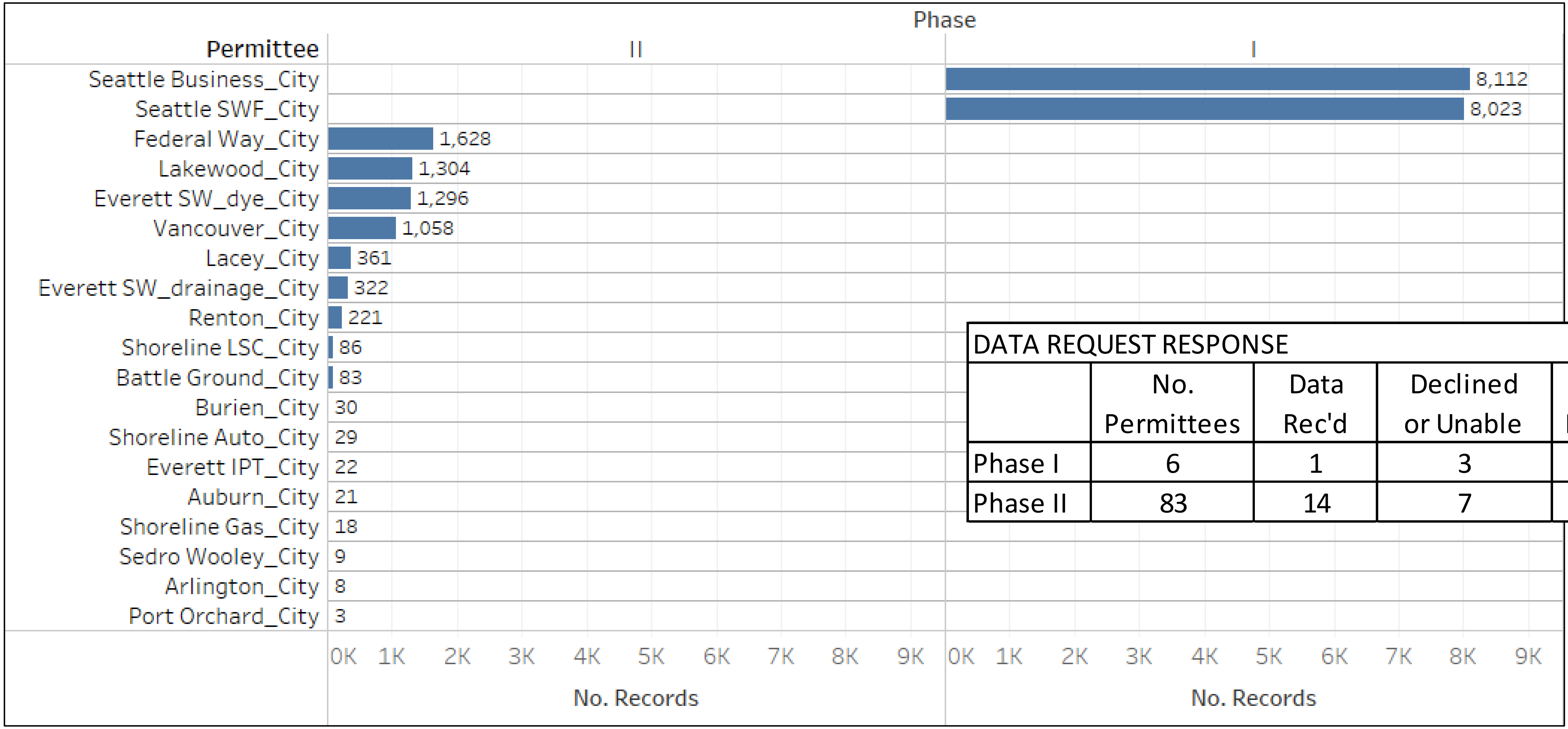
- Primarily about optimum frequency of inspection and BMP effectiveness at *businesses and on commercial properties*.
- Effectiveness of combined inspections? How can coordination of inspections among agencies and departments be improved?
- Focus on municipal NPDES permit, but implications for other NPDES permits since they require controlling pollution sources and use same/similar BMPs:
    - Industrial Permit
    - Boatyard Permit
    - Large Port Permits
    - ~~Construction Permit~~
    - ~~Sand and Gravel Permit~~
    - ~~WSDOT Permit~~

Stormwater Action Monitoring

Inspections at Businesses and Commercial Properties



Results: Permittee Data

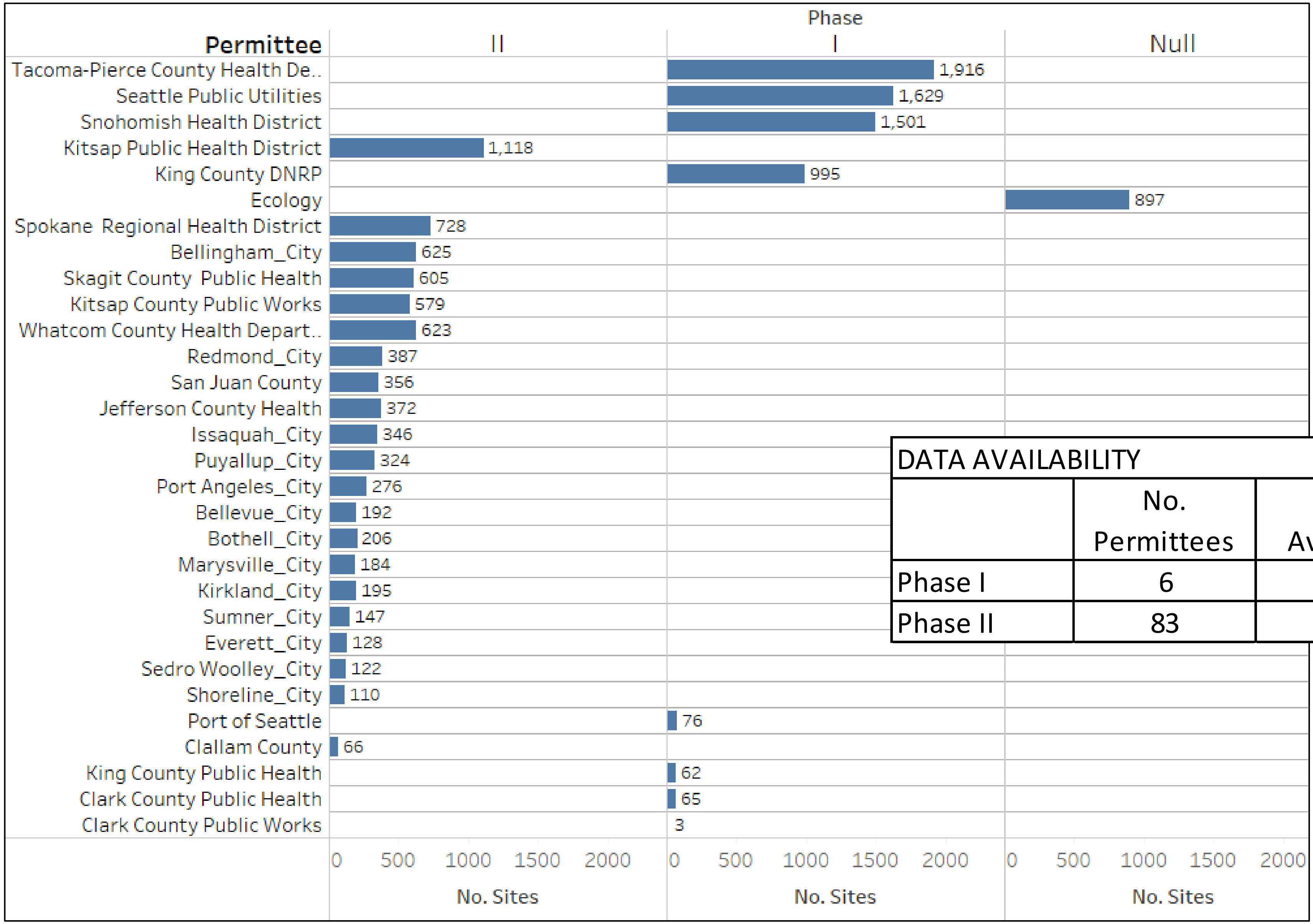


DATA REQUEST RESPONSE

	No. Permittees	Data Rec'd	Declined or Unable	No Response
Phase I	6	1	3	2
Phase II	83	14	7	62

Stormwater Action Monitoring

Results: Ecology LSC Data



DATA AVAILABILITY		
	No. Permittees	Data Available
Phase I	6	5
Phase II	83	22

How Are the Results Useful?

Big picture goal: reduce non-point stormwater pollution.

Useful to Permittees

Improve efficiency of inspection programs:

- Priority and frequency of inspections
- Standardized data
- Share information across jurisdictions about what works

Useful to Ecology

Improve regional stormwater management:

- Refine permit requirements for source control programs
- Identify common source control issues in the region
- Serve as model for Eastern WA source control permit requirements

Challenges to Addressing Effectiveness Questions

- Variable implementation of inspection programs = variable data type and quality.
- Inspection data is not standardized across the region.
- Inspection data are organized and stored in multiple formats from hand-written files to advanced databases.
- Data are mostly categorical and qualitative, not quantitative.
- Some effectiveness questions inquire about information not typically collected (e.g. use of required vs. optional BMPs).
- The study is a post-hoc analysis – a look back at existing data. Not a designed experiment to measure the impact of controlled variables.

Current Project Status

Completed

- Data Analysis Plan with study design
- Survey of permittees and data request
- Standardize data and create database (in process)

Coming up

- Summary of metadata
- Data analysis
- Report (summer 2017)
- Information transfer to permittees and others (workshops, conferences)

Questions?

James Packman
jpackman@aspectconsulting.com
206-780-7723
www.aspectconsulting.com

Aspect CONSULTING

Greg Vigoren
gvigoren@cityoflakewood.us
253-983-7771
www.cityoflakewood.us

CITY OF LAKEWOOD

How does SAM work?

Brandi Lubliner, SAM Coordinator
Washington State Department of Ecology

Stormwater Action Monitoring

SAM study selection by Stormwater Work Group

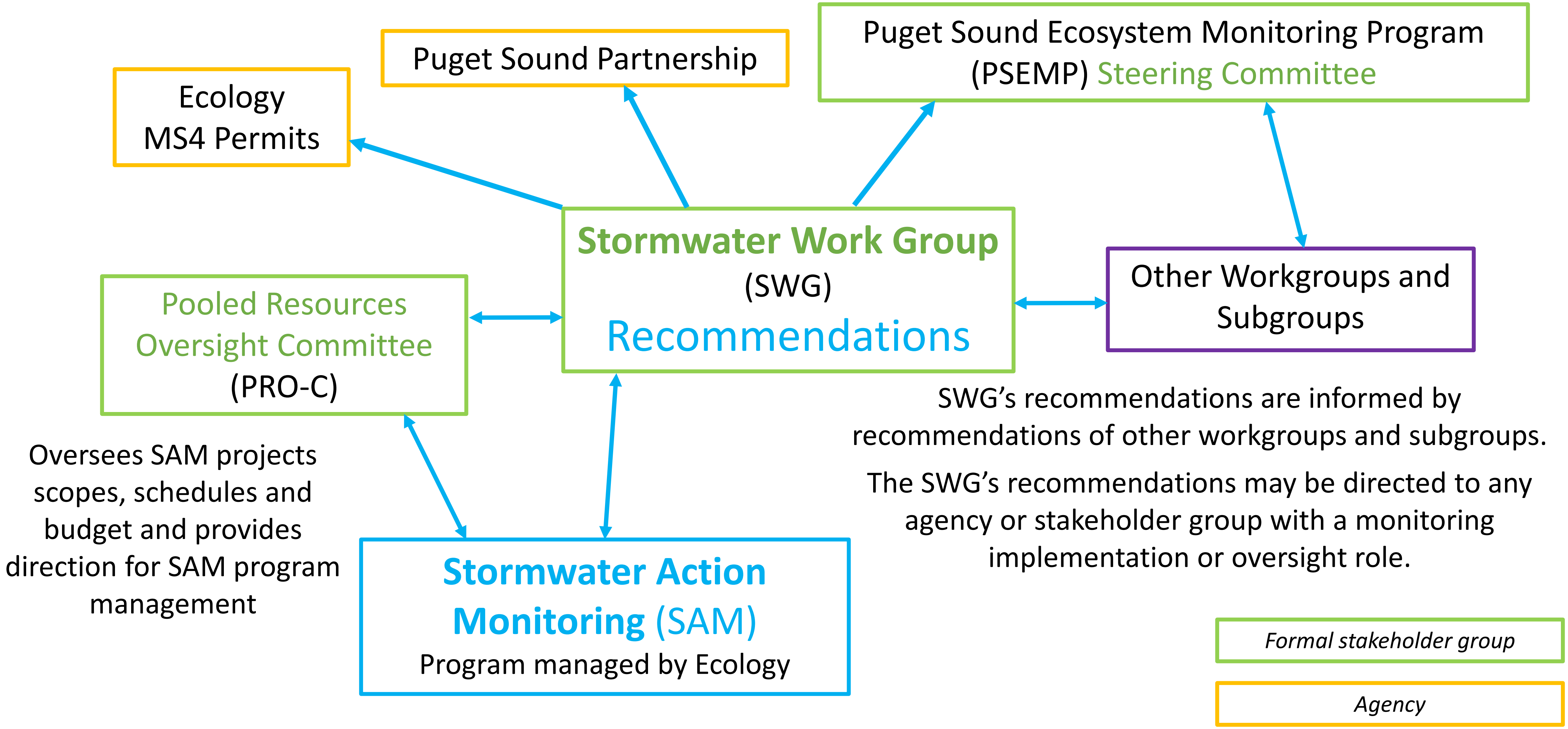
- SWG sets budget and selects the projects
  - Finishing 2nd round effectiveness study solicitation
  - Waiting for science recommendations on future receiving water monitoring to detect stormwater-relevant trends
  - Considering new proposals for source identification studies

SAM program management by Ecology

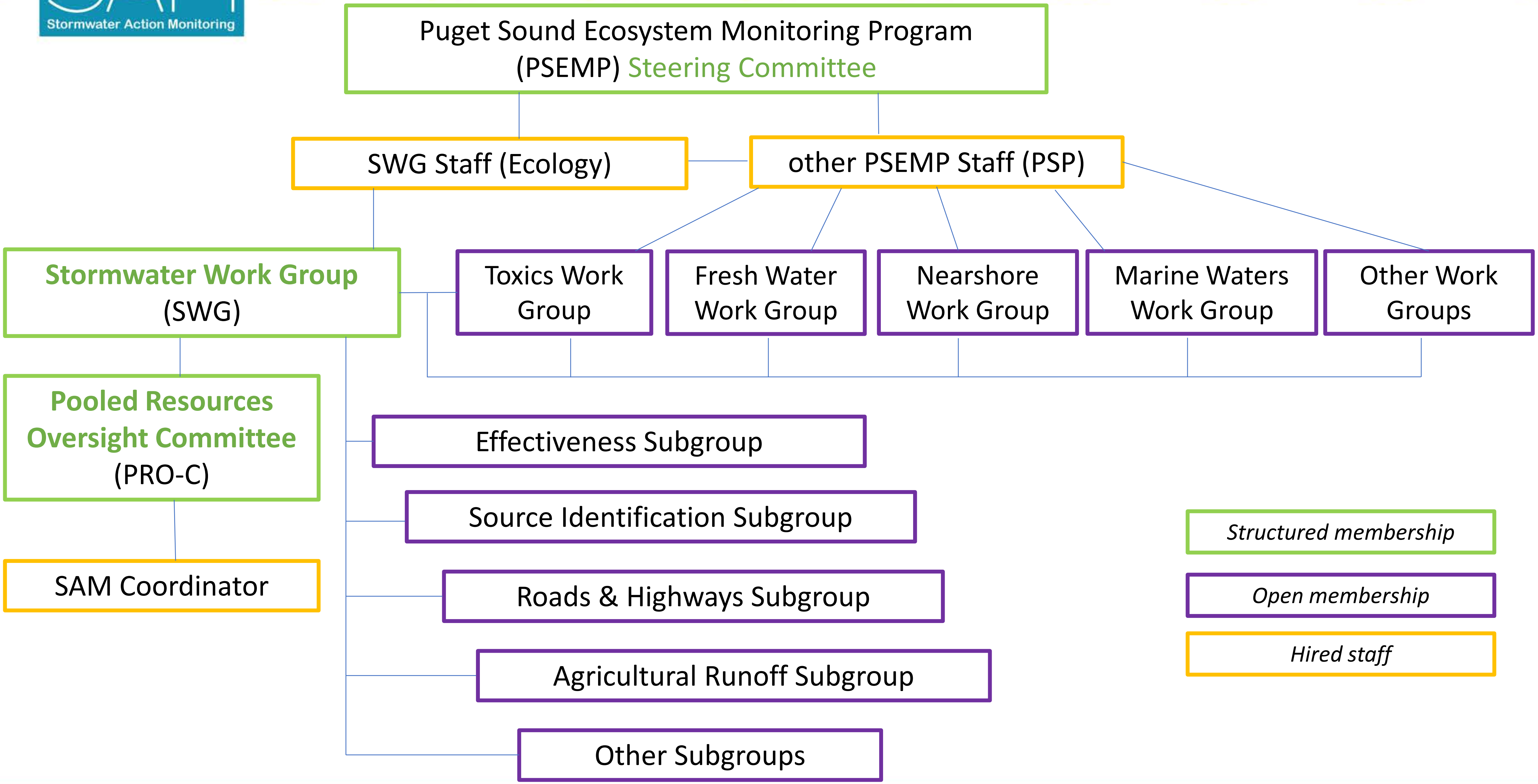
- Invoice permittees for amounts in S8
- Manage contracts for studies
- Coordinate reviews on deliverables
  - Assistance from project liaisons and TAC's
- Prepare quarterly and annual reports on income, expenditures, encumbrances
- Provide transparency via web on accounts and studies

SAM checks and reviews by the Pooled Resources Oversight Committee

- PRO-C oversees project management
  - Scope, schedule, budget
  - Approves Ecology's contracting actions
- PRO-C evaluates Ecology's performance
  - First review was done last year
- PRO-C meets 4-6 times per year
  - Some decisions by email


Ecology
MS4 Permits
Puget Sound Partnership
Puget Sound Ecosystem Monitoring Program
(PSEMP) Steering Committee
Stormwater Work Group
(SWG)
Recommendations
Pooled Resources
Oversight Committee
(PRO-C)
Other Workgroups and
Subgroups
SWG's recommendations are informed by
recommendations of other workgroups and subgroups.
The SWG's recommendations may be directed to any
agency or stakeholder group with a monitoring
implementation or oversight role.
Oversees SAM projects
scopes, schedules and
budget and provides
direction for SAM program
management
Stormwater Action
Monitoring (SAM)
Program managed by Ecology
Formal stakeholder group
Agency

SAM
Stormwater Action Monitoring



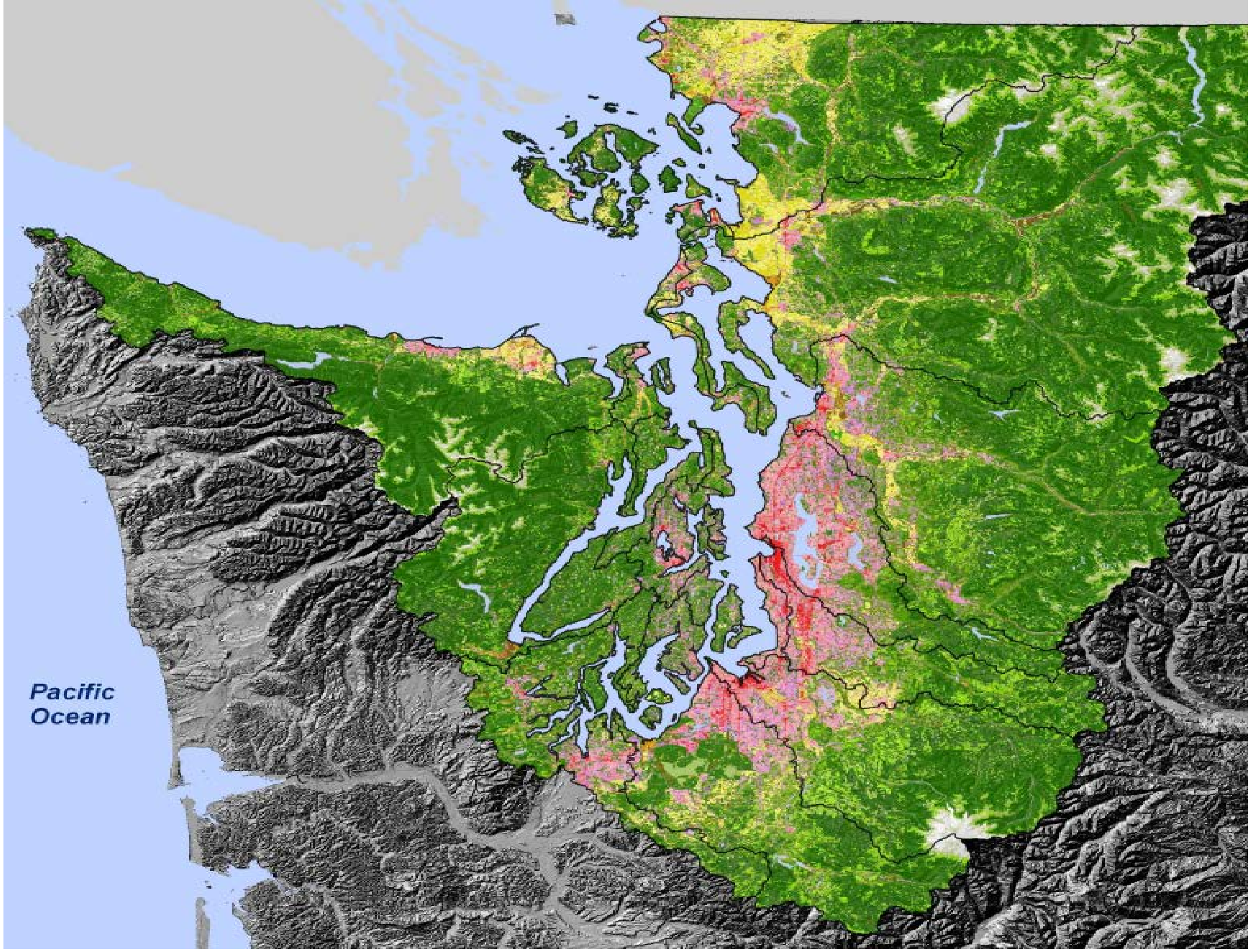
Context for SAM receiving water monitoring

Brandi Lubliner, SAM Coordinator
Washington State Department of Ecology

Stormwater Action Monitoring

Context for receiving water monitoring

- Regional priorities set by SWG:
  - Lowland streams
  - Marine nearshore
  - Water quality
  - Sediment quality
  - Biotic endpoints

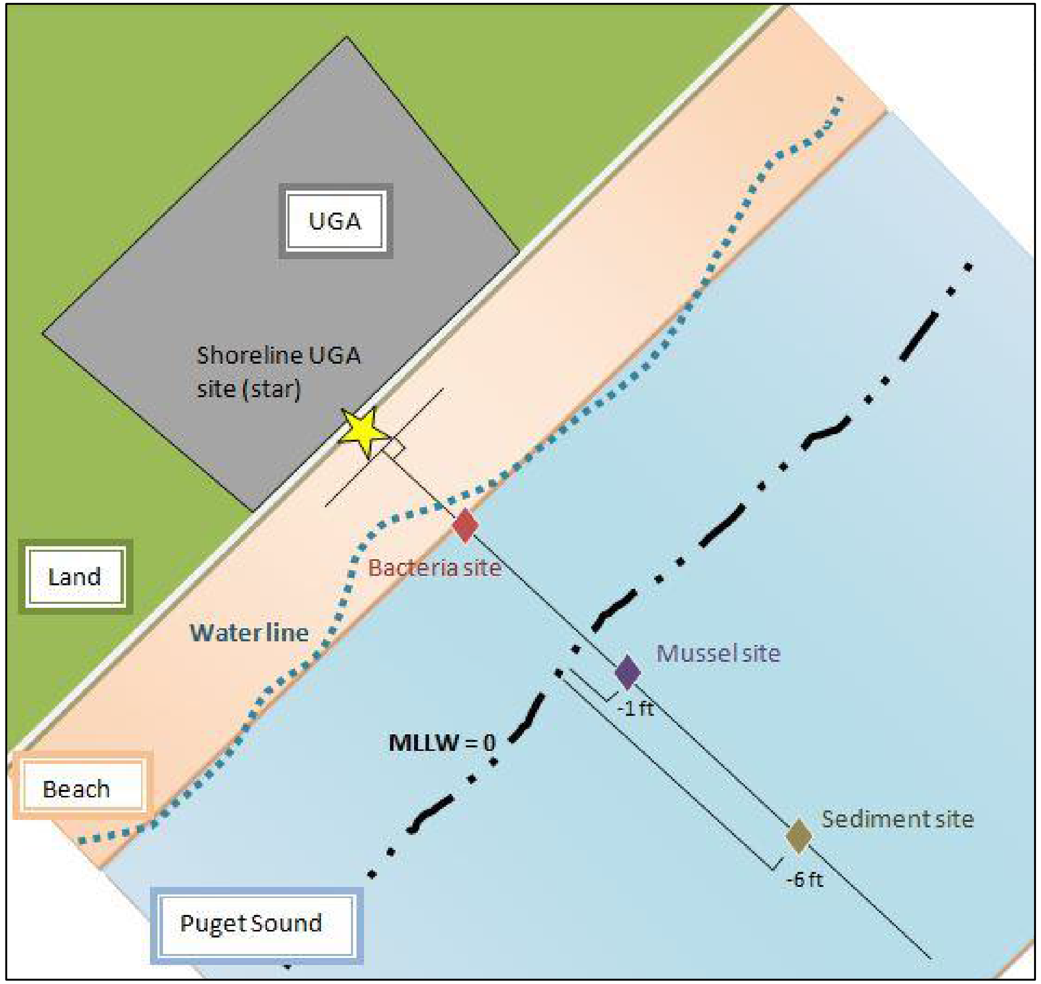


Context for regional stream monitoring

- Randomized site design
  - EPA approach limits bias in site selection
    - Puget Sound watershed
      - small lowland ecoregion streams
    - Urban Growth Area (UGA) In/Out
    - Each site represents 1 km
  - USGS, King Co, San Juan Island CD, Snohomish Co, Ecy EAP, & 13 labs

Context for regional marine nearshore monitoring

- Puget Sound nearshore sites
  - 40 randomized shoreline sites along UGAs
    - Along Urban Growth Area (UGA)
    - Each site represents 800m
  - Bacteria not sampled – too expensive
    - Existing data compiled and analyzed instead
  - Sediment and mussel sites rarely differed



Puget Lowland Ecoregion Streams Status & Trends

Brandi Lubliner, SAM Coordinator; Rich Sheibley, USGS; Curtis DeGasperi, King County; Chad Larson, Ecology; Leska Fore, Puget Sound Partnership

Stormwater Action Monitoring

Stormwater Action Monitoring

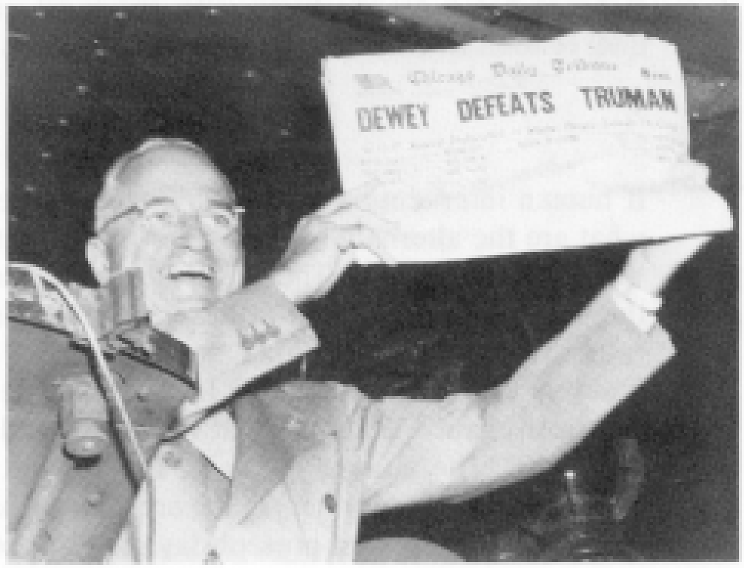
Study questions:

- **Q1:** What percent of streams meet biological, water, and sediment quality standards for beneficial uses within and outside urban growth areas (UGAs)?
- **Q2 & Q3:** What natural and human variables correlate with the status of streams within and outside the UGA?
- **Q4:** How do SAM results compare to other monitoring programs in Puget Sound?
- **Q5:** What parameters would be carried forward for trend assessment of SAM stream monitoring in the future, and at what timing and frequency?

Sampling design "survey-based"

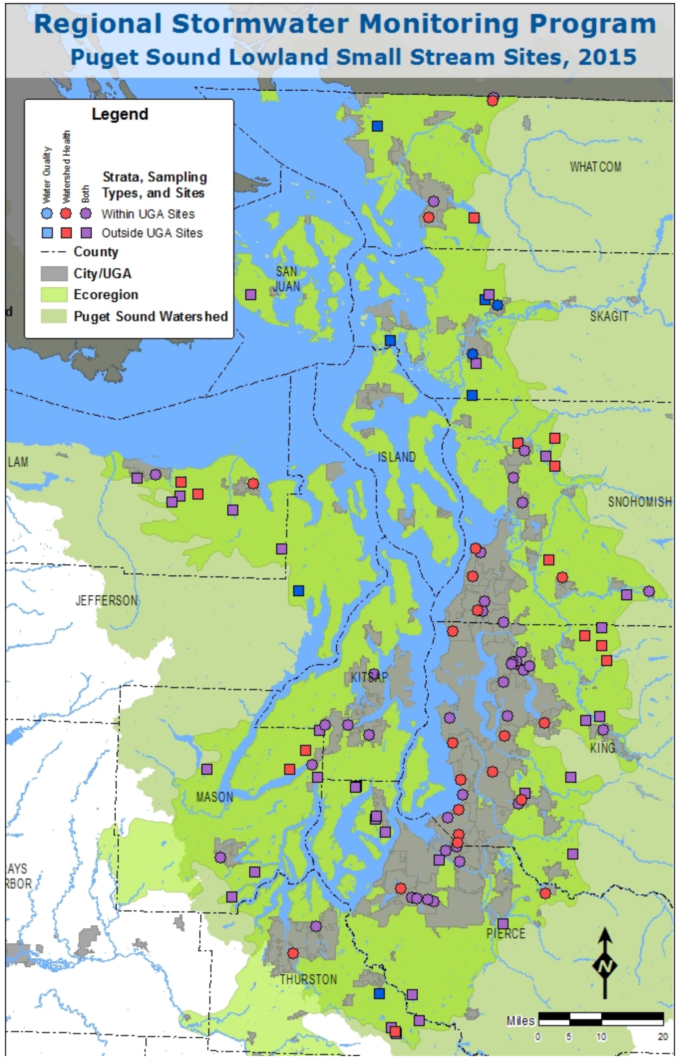
- Analogous to polling methods
- A complete census is not possible
- Survey-based sampling is efficient
- Survey-based sampling provides confidence bounds on results

We avoided this:



Sampled small Puget Lowland Streams within and outside urban growth areas (UGAs) for:

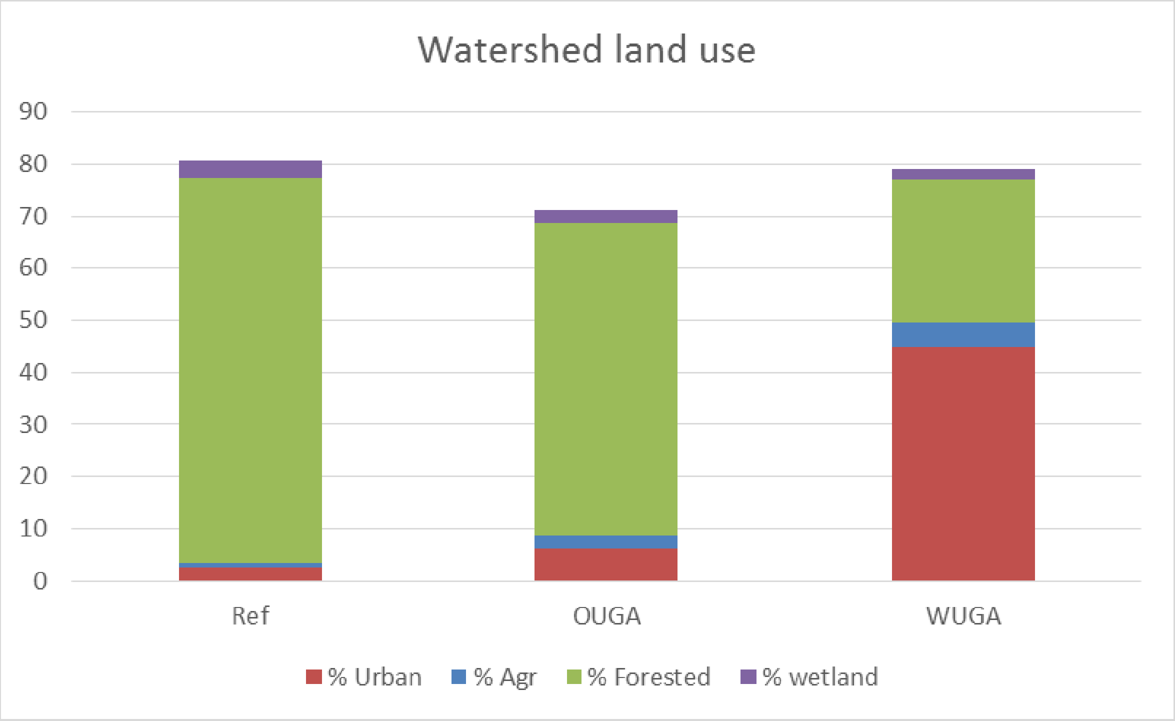
- Monthly water quality Jan-Dec 2015
  - Conventional parameters, metals, PAHs, stream flow
- Summer Watershed Health Monitoring
  - Water quality (conventional parameters)
  - Benthic macroinvertebrates
  - Periphyton
  - Sediment chemistry (TOC, metals, phthalates, PAHs, PCBs, PBDEs, common pesticides)

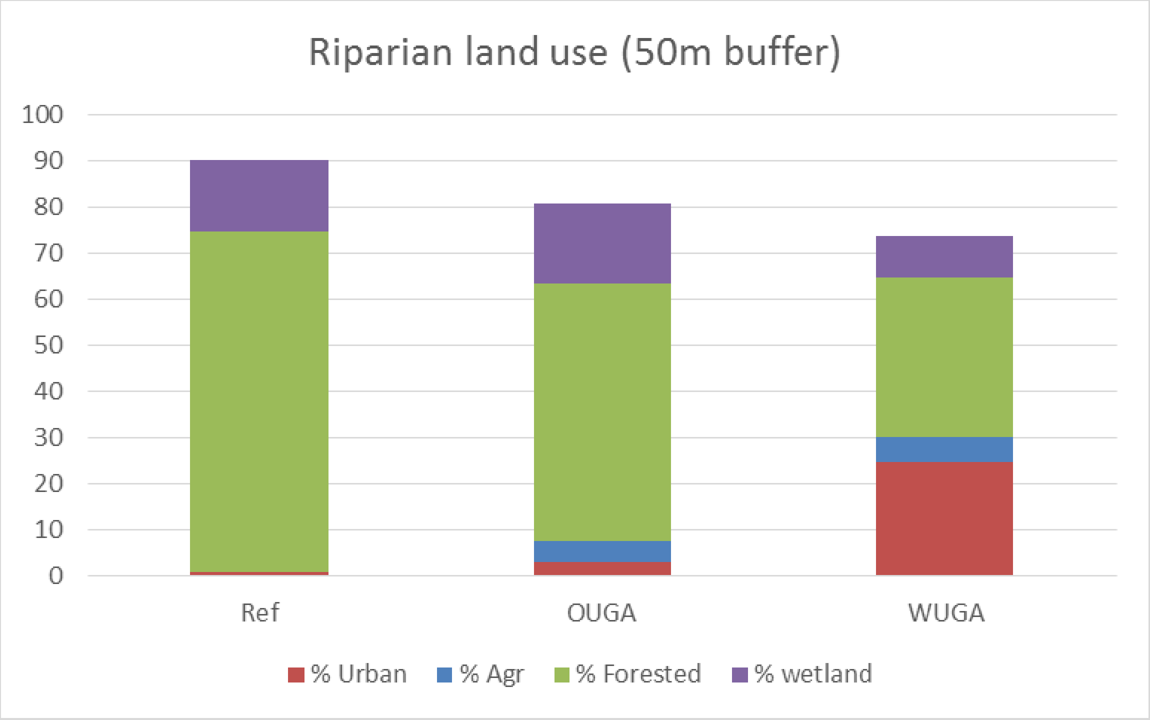


Included watershed and riparian GIS analysis

- Leveraged USGS NAWQA expertise (and USGS $) to derive land cover and other landscape parameters for all SAM PLES sites and 16 least-disturbed reference sites
- Why? Because local riparian and upstream land cover shown to be important factor for biological communities

Land cover summary within and outside UGAs





SAM
Stormwater Action Monitoring

Detected >50% of time	A
Detected 20-50% of time	B
Detected <20% of time	C

Water Quality ------------------

Parameter	Detection Freqency	
	Outside UGA	Within UGA
Ammonia	B	B
Arsenic	A	A
Arsenic dissolved	A	A
Chloride	A	A
Chromium	A	A
Chromium dissolved	B	B
Copper	A	A
Copper dissolved	A	A
Dissolved Organic Carbon	A	A
Fecal coliform	A	A
Hardness as CaCO3	A	A
Nitrite-Nitrate	A	A
Ortho-phosphate	A	A
Total Nitrogen	A	A
Total Phosphorus	A	A
Total Suspended Solids	A	A
Lead	B	B

Parameter	Detection Freqency	
	Outside UGA	Within UGA
Naphthalene	C	C
Zinc	C	C
Zinc dissolved	C	C
1-Methylnaphthalene	C	C
2-Methylnaphthalene	C	C
Acenaphthene	C	C
Acenaphthylene	C	C
Anthracene	C	C
Benz(a)anthracene	C	C
Benzo(a)pyrene	C	C
Benzo(b)fluoranthene	C	C
Benzo(g,h,i)perylene	C	C
Benzo(k)fluoranthene	C	C
Benzofluoranthenes, Total	C	C
Cadmium	C	C
Cadmium dissolved	C	C
Carbazole	C	C
Chrysene	C	C
Dibenzo(a,h)anthracene	C	C
Dibenzofuran	C	C
Fluoranthene	C	C
Fluorene	C	C
Indeno(1,2,3-cd)pyrene	C	C
Lead dissolved	C	C
PCN-002	C	C
Phenanthrene	C	C
Pyrene	C	C
Retene	C	C
Silver	C	C
Silver dissolved	C	C
Total Benzofluoranthenes	C	C

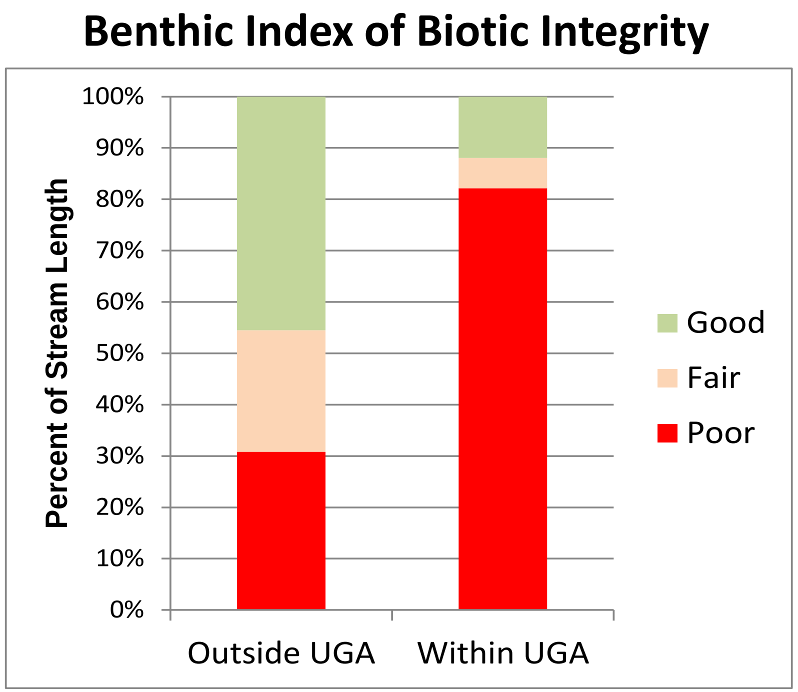
Sediment Quality -------------

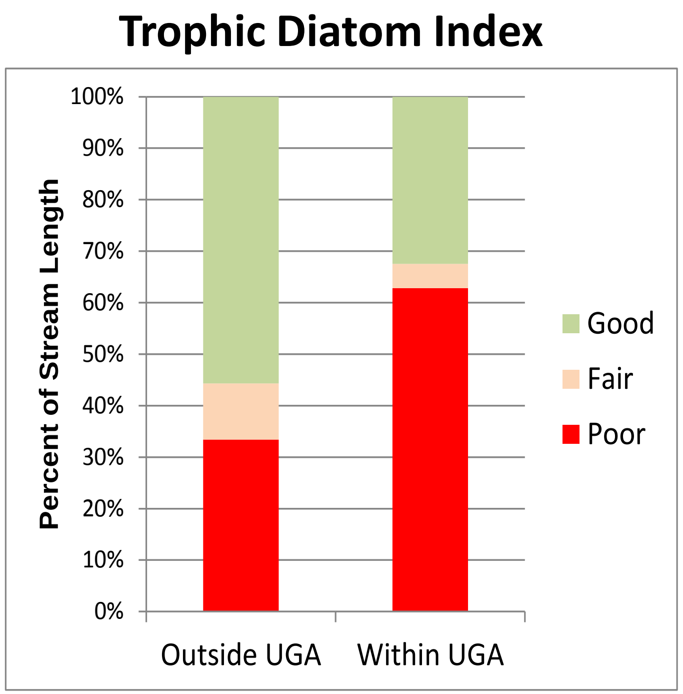
Parameter	Detection Frequency	
	Outside UGA	Within UGA
Arsenic	A	A
Cadmium	A	A
Chromium	A	A
Copper	A	A
Dichlobenil	A	A
Lead	A	A
Retene	A	A
Total PBDE	A	A
Total PCB	A	A
Zinc	A	A
Bis(2-Ethylhexyl) Phthalate	B	A
Silver	B	A

Parameter	Detection Frequency	
	Outside UGA	Within UGA
1-Methylnaphthalene	C	C
2,4-D	C	C
2-Methylnaphthalene	C	C
Acenaphthene	C	C
Acenaphthylene	C	C
Anthracene	C	B
Benz(a)anthracene	C	B
Benzo(a)pyrene	C	B
Benzo(b)fluoranthene	C	B
Benzo(g,h,i)perylene	C	B
Benzo(k)fluoranthene	C	B
Benzofluoranthenes, Total	C	A
Butyl benzyl phthalate	C	C
Carbaryl	C	C
Carbazole	C	C
Chlorpyrifos	C	C
Chrysene	C	A
DCPMU	C	C
Dibenzo(a,h)anthracene	C	C
Dibenzofuran	C	C
Dibutyl phthalate	C	C
Diethyl phthalate	C	C
Dimethyl phthalate	C	C
Di-N-Octyl Phthalate	C	C
Diuron	C	C
Fluoranthene	C	A
Fluorene	C	C
Indeno(1,2,3-cd)pyrene	C	B
Naphthalene	C	C
PCN-002	C	C
Phenanthrene	C	B
Pyrene	C	A
Total Benzofluoranthenes	C	B
Total PAH	C	A
Triclopyr	C	C

Q1: Biological Status

- Biological condition was generally worse in small streams within UGAs compared to streams outside UGAs





Q1: Comparison to water quality standards

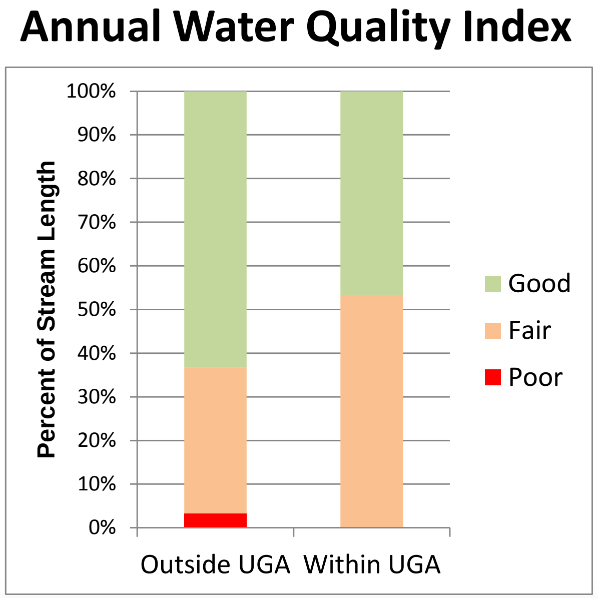
- Higher frequency of exceedance of fecal coliform standard at sites within UGAs
- Similar frequency of exceedance of temperature, pH, and dissolved oxygen standards at sites within and outside of UGAs
- Measured metals concentrations did not typically exceed relevant acute or chronic standards for the protection of aquatic life.

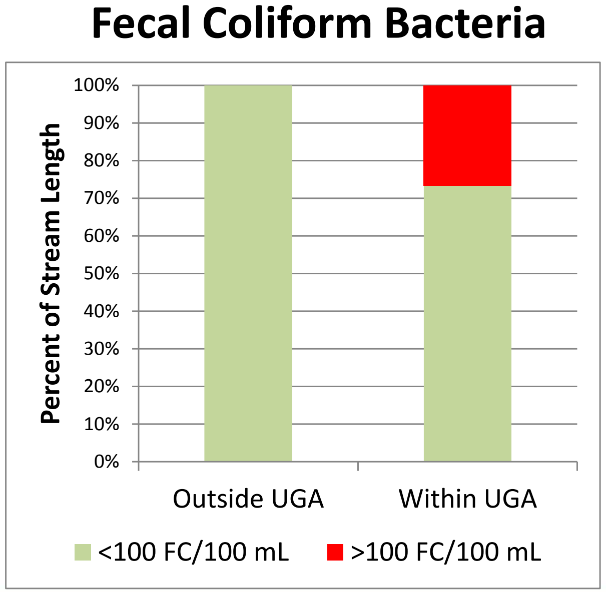
Q1: Comparison to sediment quality standards

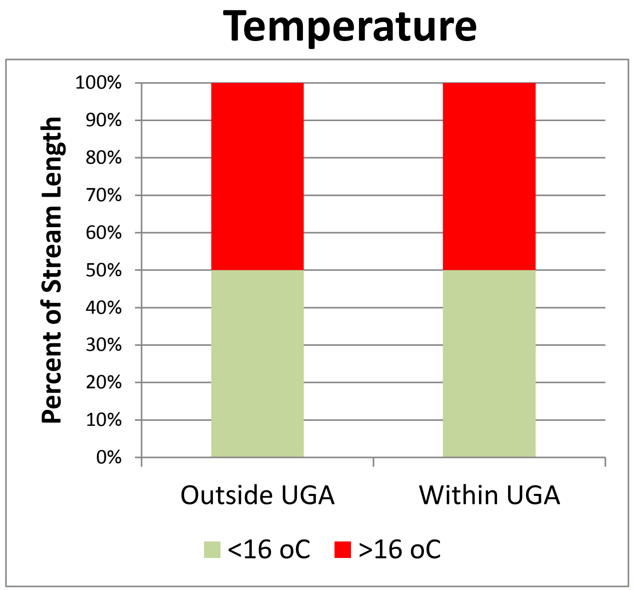
- Measured sediment contaminant concentrations did not typically exceed sediment quality standards within or outside UGAs

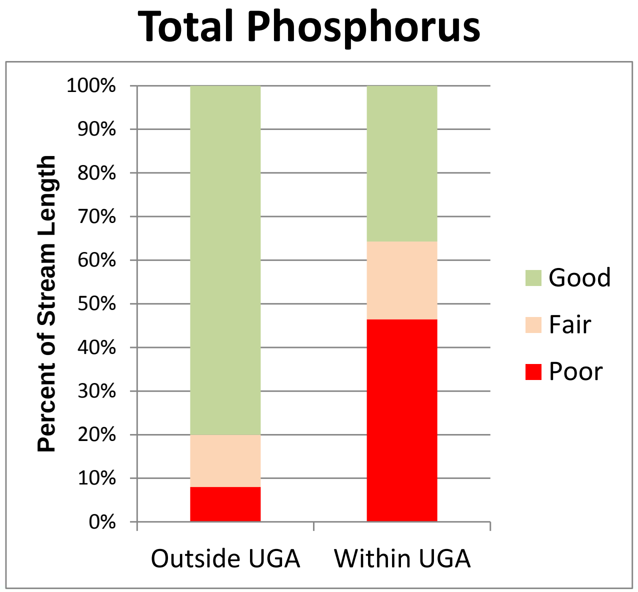
Q1: Water Quality Status

- Status based on WQI and temperature similar inside and outside UGAs
- Greater proportion of stream length within UGAs in poor condition based on Fecal Coliform bacteria and Total Phosphorus





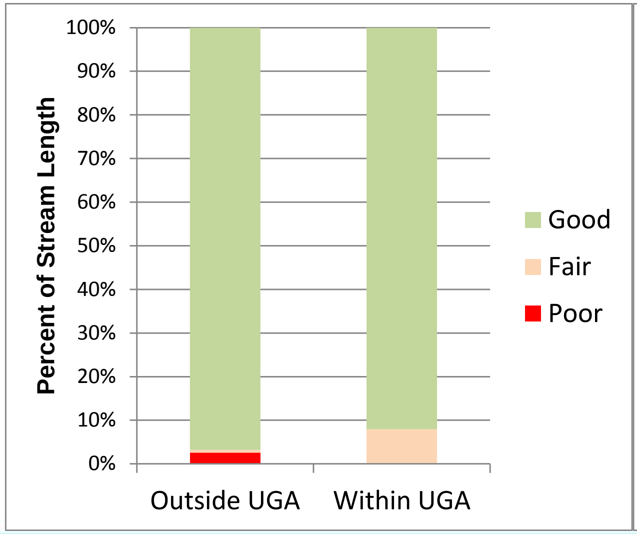




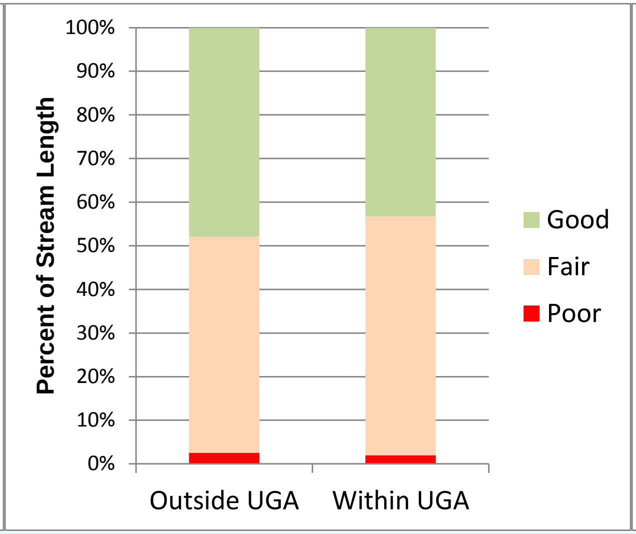
Q1: Sediment Quality Status

- Highest concentrations measured typically occurred within UGAs
- Zinc concentrations distinctly elevated within UGAs

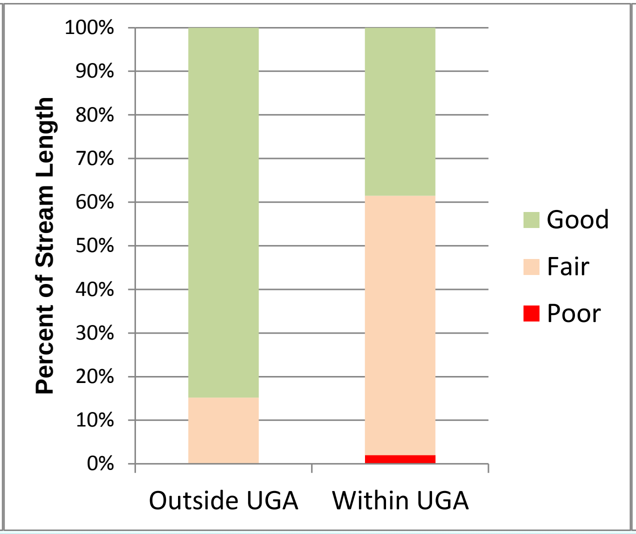
Cadmium



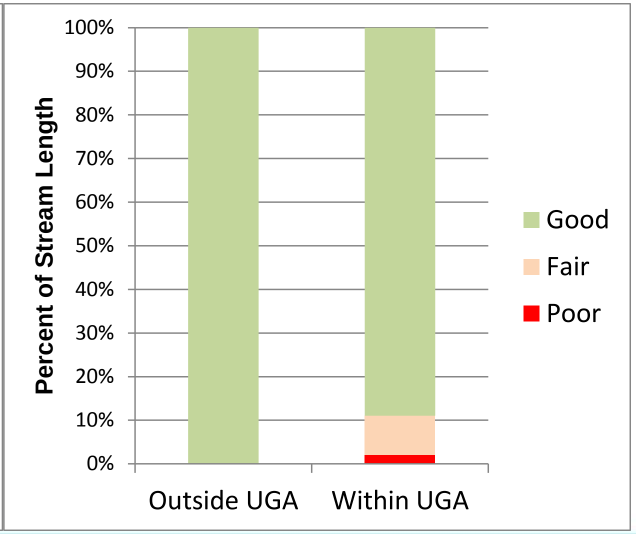
Chromium



Zinc



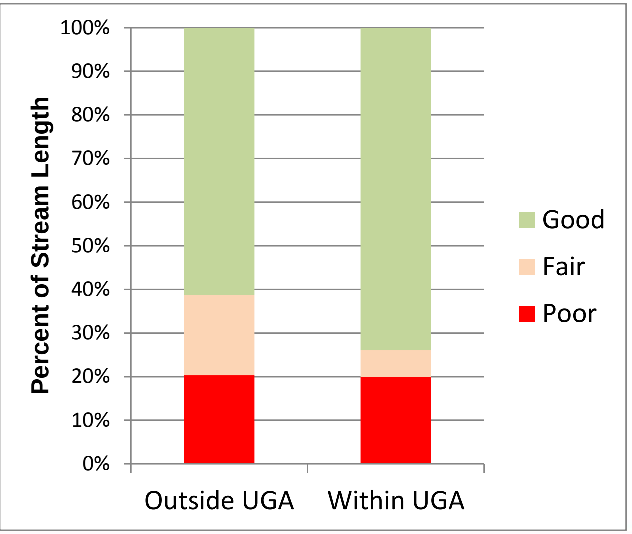
Total PAH



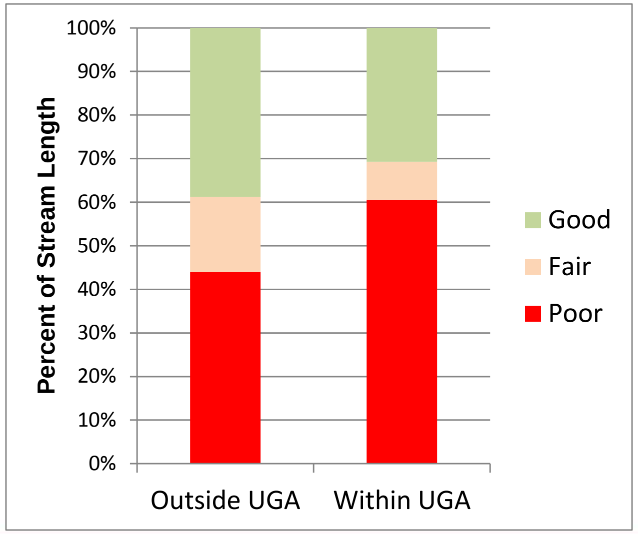
Q1: Habitat Status

- Habitat in poor condition similar within and outside UGAs except for wood volume and pool area
- Habitat poor + fair condition similar within and outside UGAs except for stream substrate status

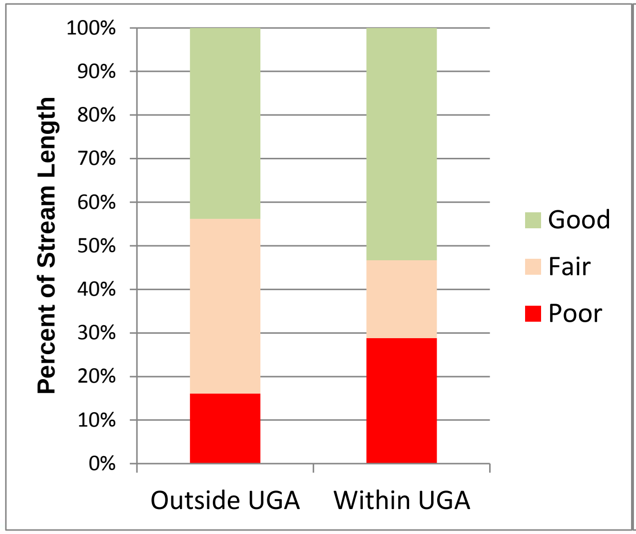
Riparian Condition



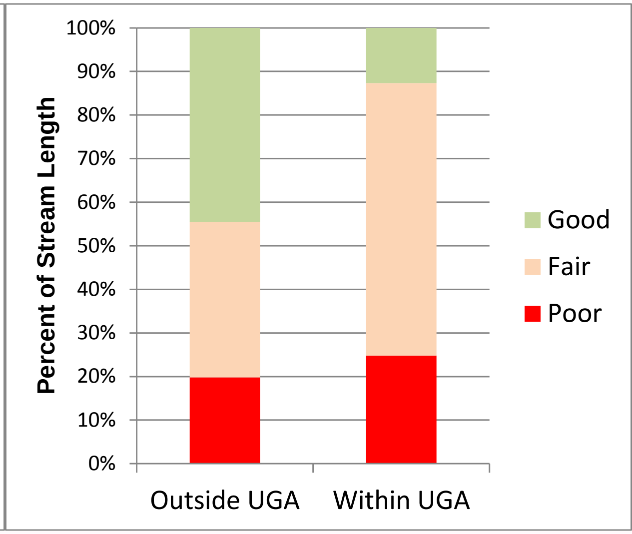
Large Wood Volume



Residual Pool Area

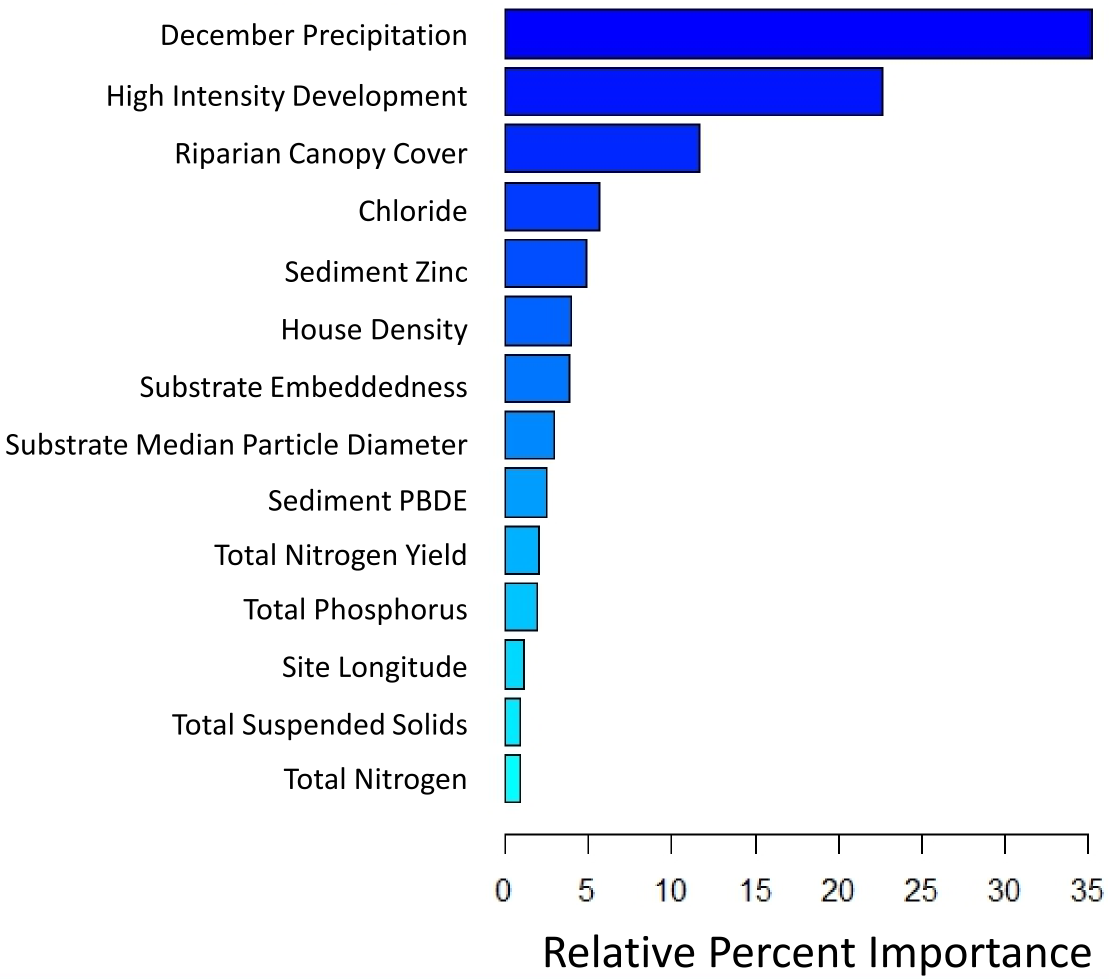


Median Particle Size (D50)



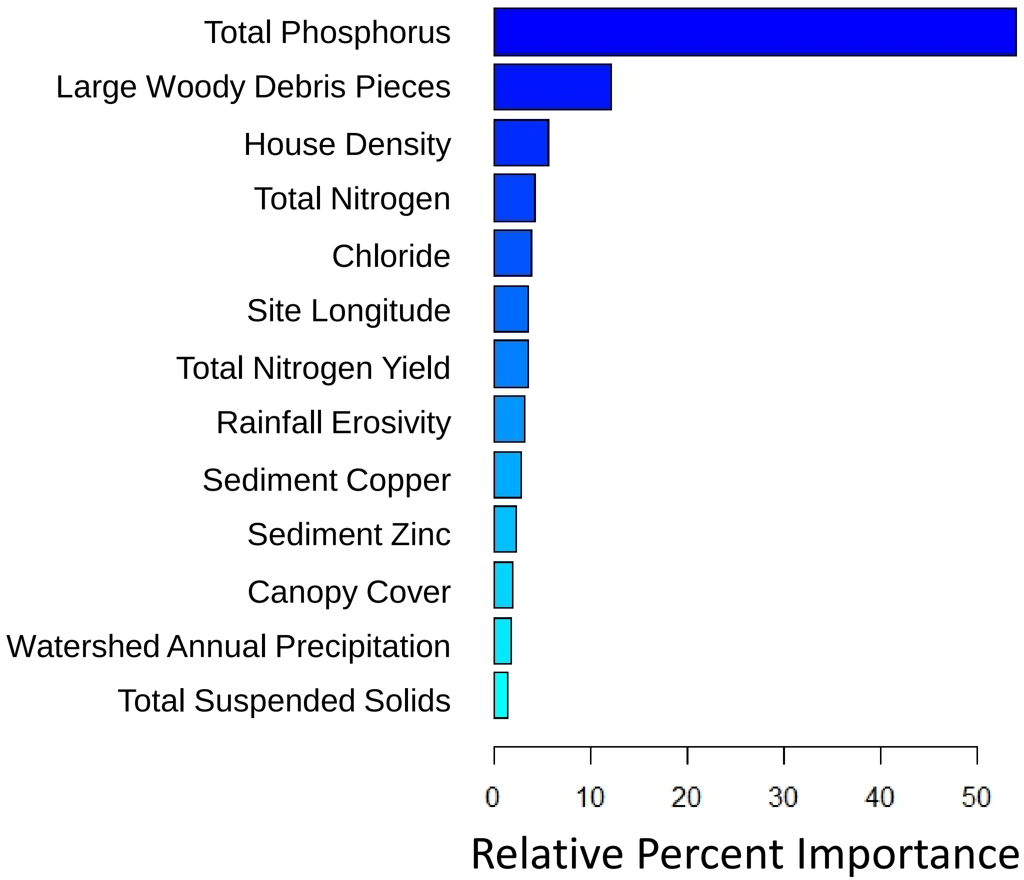
Q2/Q3: Natural and human variables that correlate with BIBI scores

- Natural variables
  - Mean December precipitation
  - Longitude
- Human variables
  - High Intensity Development
  - Riparian Canopy Cover
  - Chloride in water
  - Zinc in sediment
  - House density
  - Stream embeddedness
  - Etc



Q2/Q3: Natural and human variables that correlate with Trophic Diatom Index

- Natural variables
  - Longitude
- Human variables
  - Total Phosphorus
  - Large Wood Volume
  - House Density
  - Total Nitrogen
  - Chloride
  - Watershed Total Nitrogen Yield
  - Etc



Work on answering remaining questions in progress

- **Q4:** How does SAM results compare to other monitoring programs in Puget Sound?
- **Q5:** What parameters would be carried forward for trend assessment of SAM stream monitoring in the future, and at what timing and frequency?

SAM Puget Lowlands Streams Status & Trends Current Schedule

- Draft report in progress
- Compete draft report for review by August 2017
- Final report completed by December 2017

Questions?

Using Transplanted Mussels to Assess Contaminants in the Puget Sound's Nearshore Habitats

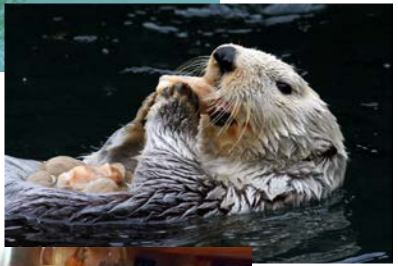
Jennifer Lanksbury, Laurie Niewolny, Andrea Carey, Mariko Langness,
Sandra O'Neill, James West

Toxics-focused Biological Observation System (TBiOS) for the Salish Sea
Washington Department of Fish and Wildlife

Stormwater Action Monitoring

SAM Stormwater Action Monitoring

Mussels are natural environmental samplers



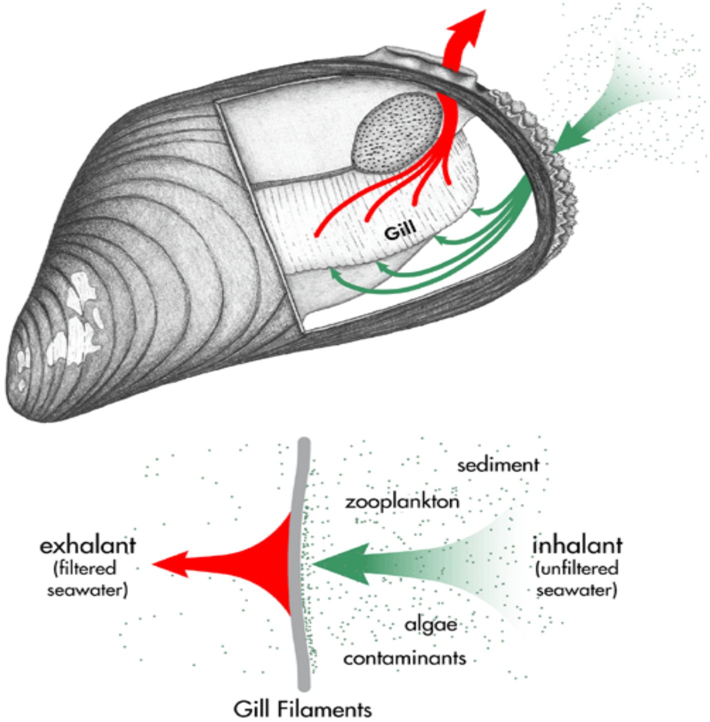
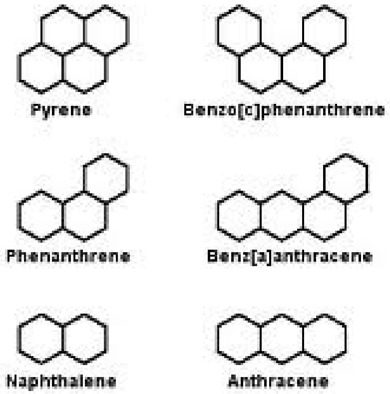


Illustration by [Ethan Nedeau]



Seawater, food, and contaminants

What does SAM nearshore mussel monitoring aim to accomplish?

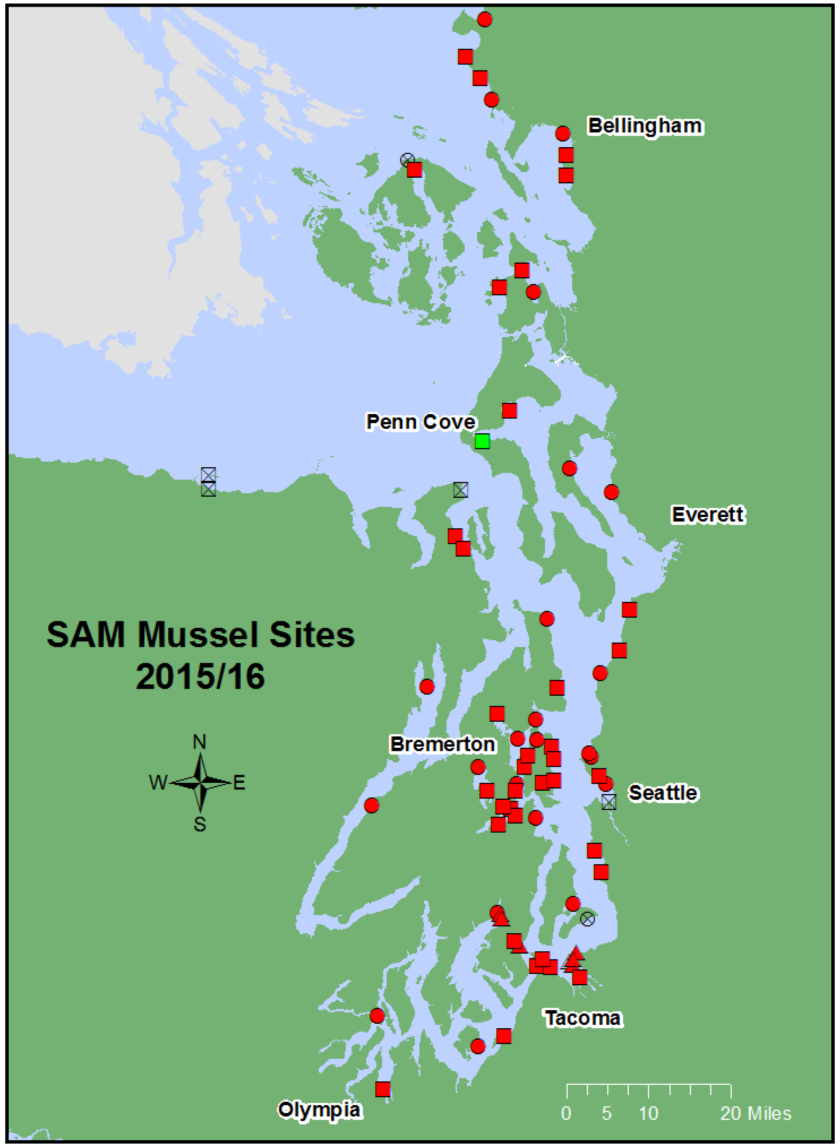
1. Characterizes the extent of tissue contamination in nearshore biota in urban growth areas (UGA) of Puget Sound, using mussels as the indicator species.

2. Will track changes in mussel contamination over time to answer the question: *Is the health of nearshore biota in Puget Sound improving, deteriorating, or remaining unchanged?*

Mussel Monitoring Sites:

- 73 nearshore sites (40 SAM + 33 additional)
- Winter exposure for 3 month (2015/16)
- Native mussels (*Mytilus trossulus*)
- Transplanted in cages



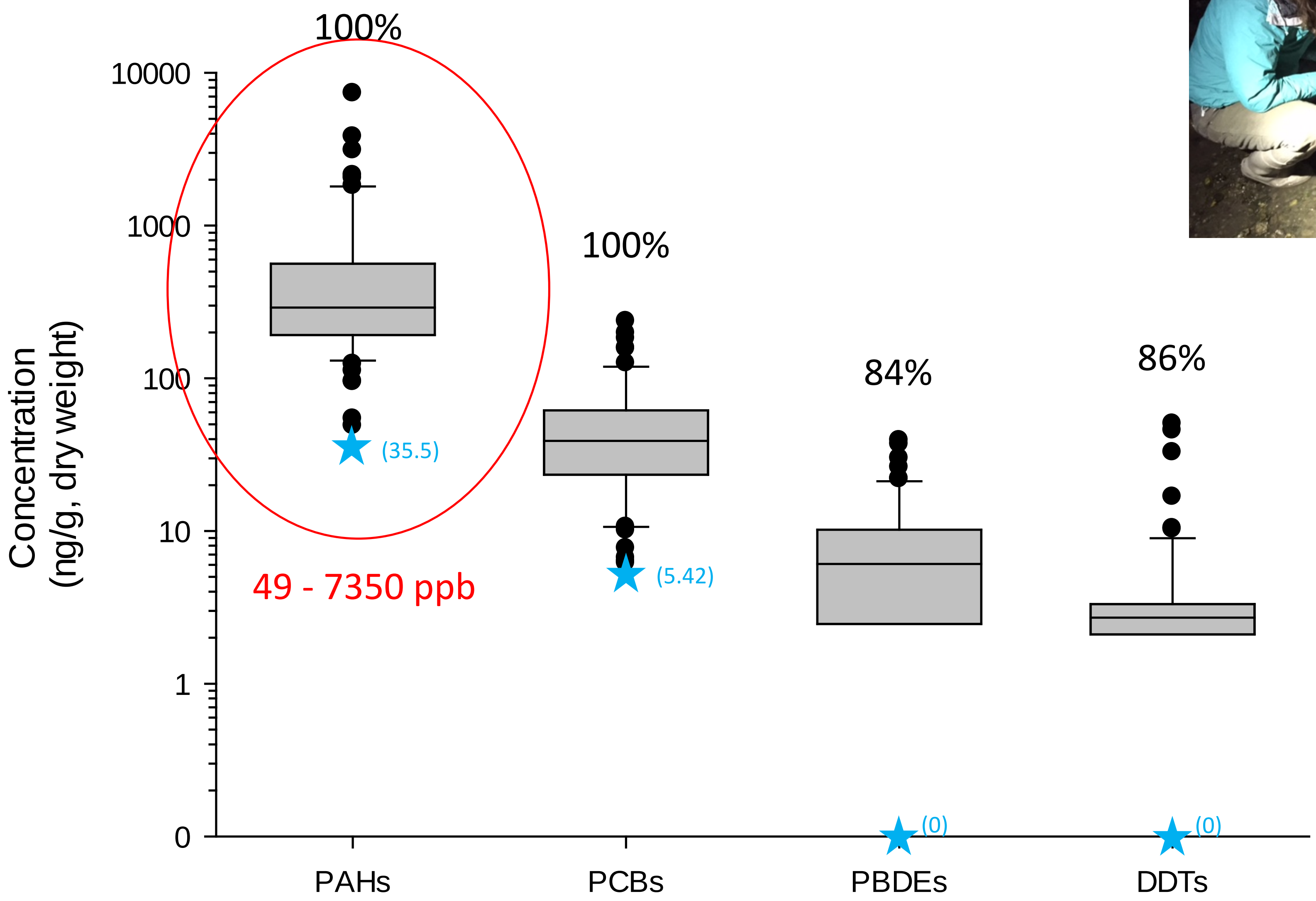



Chemical Analyses

- **Organic chemicals**:
  - Polycyclic aromatic hydrocarbons (PAHs)
  - Polychlorinated biphenyls (PCBs)
  - Polybrominated diphenylethers (PBDEs)
  - Organochlorine pesticides - DDTs, chlordanes, HCB, aldrin, dieldrin, HCHs, endosulfan 1, Mirex

- **Metals**:
  - Arsenic, Cadmium, Copper, Lead, Mercury, Zinc

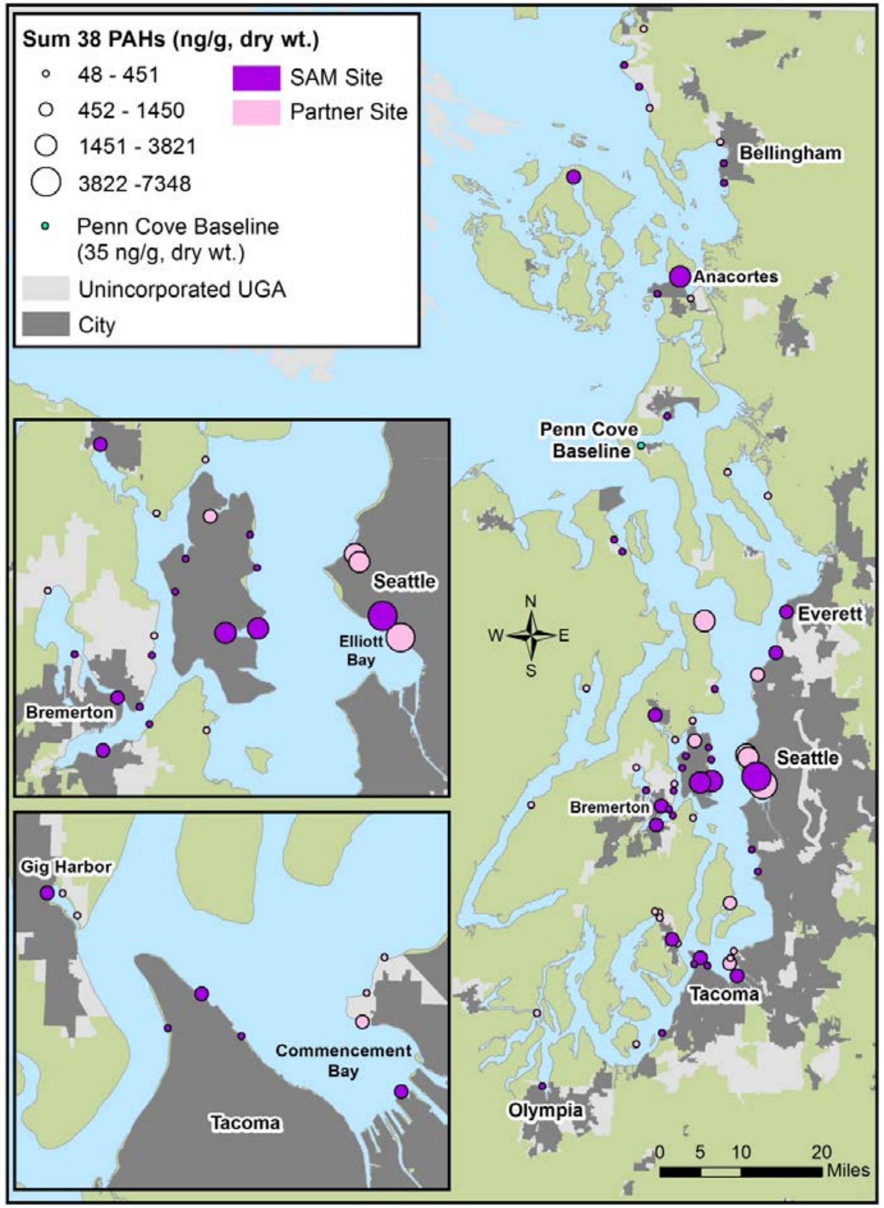
Stormwater Action Monitoring

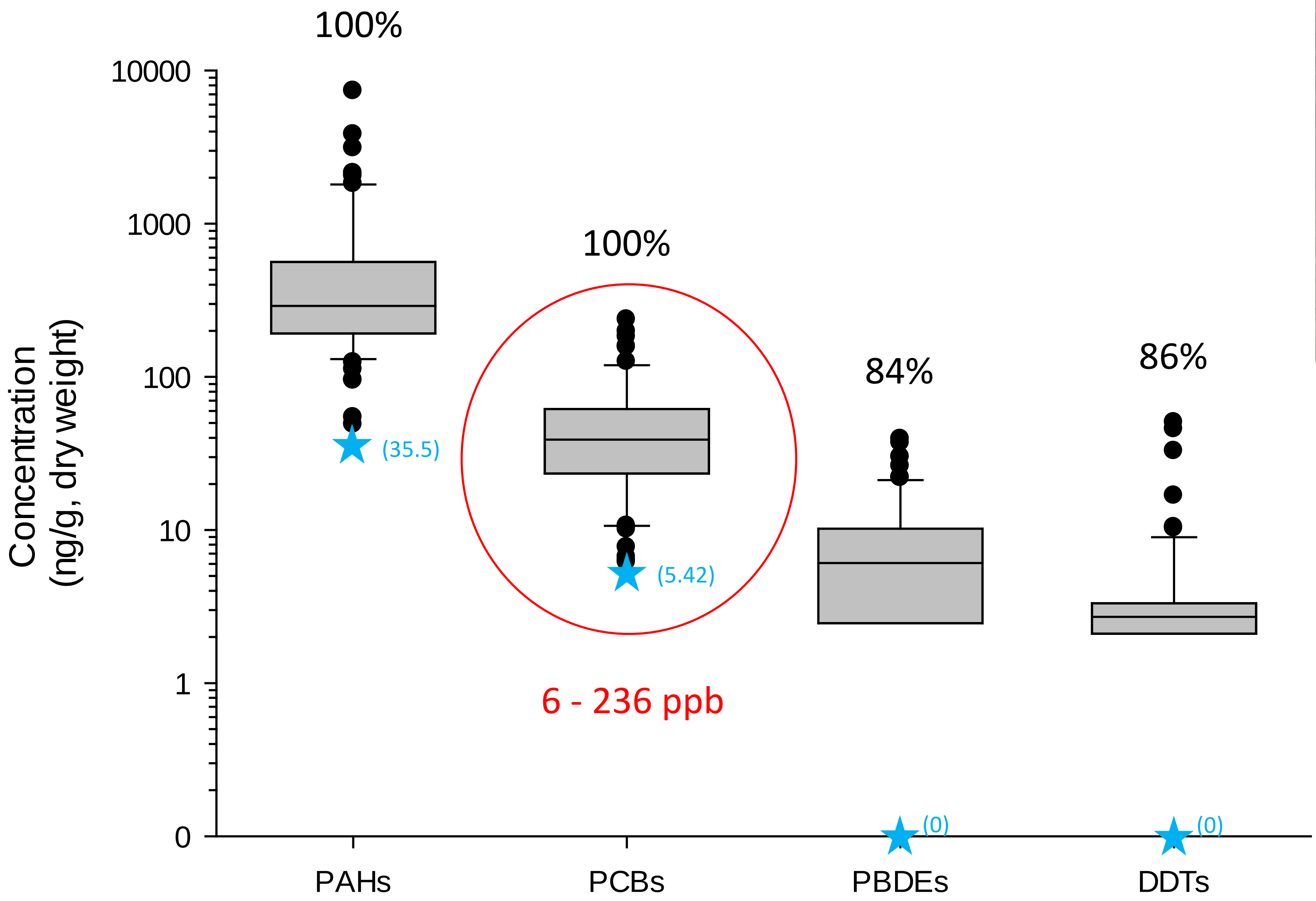


PAHs

PAHs highest in highly urbanized Elliott Bay.

Also elevated in Eagle Harbor, Anacortes, Sinclair Inlet, and Commencement Bay.

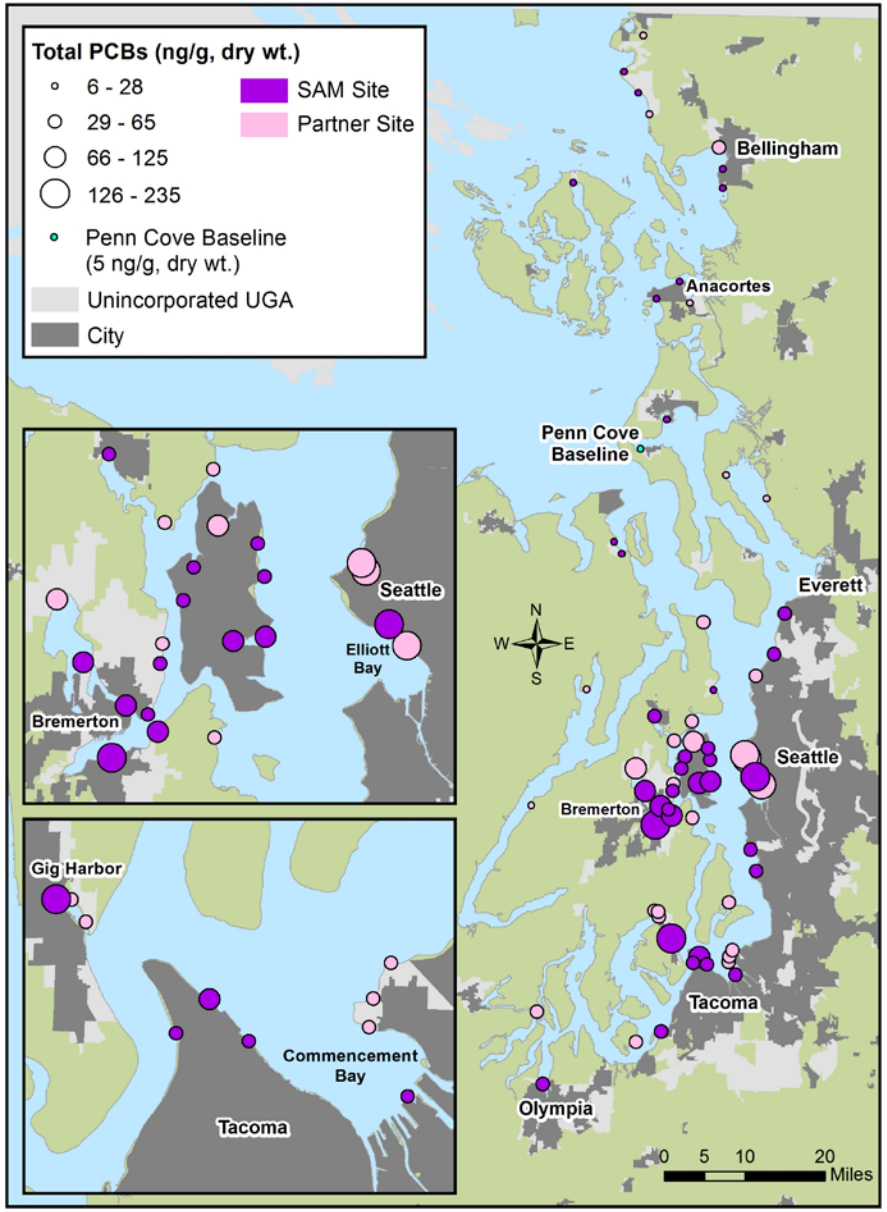


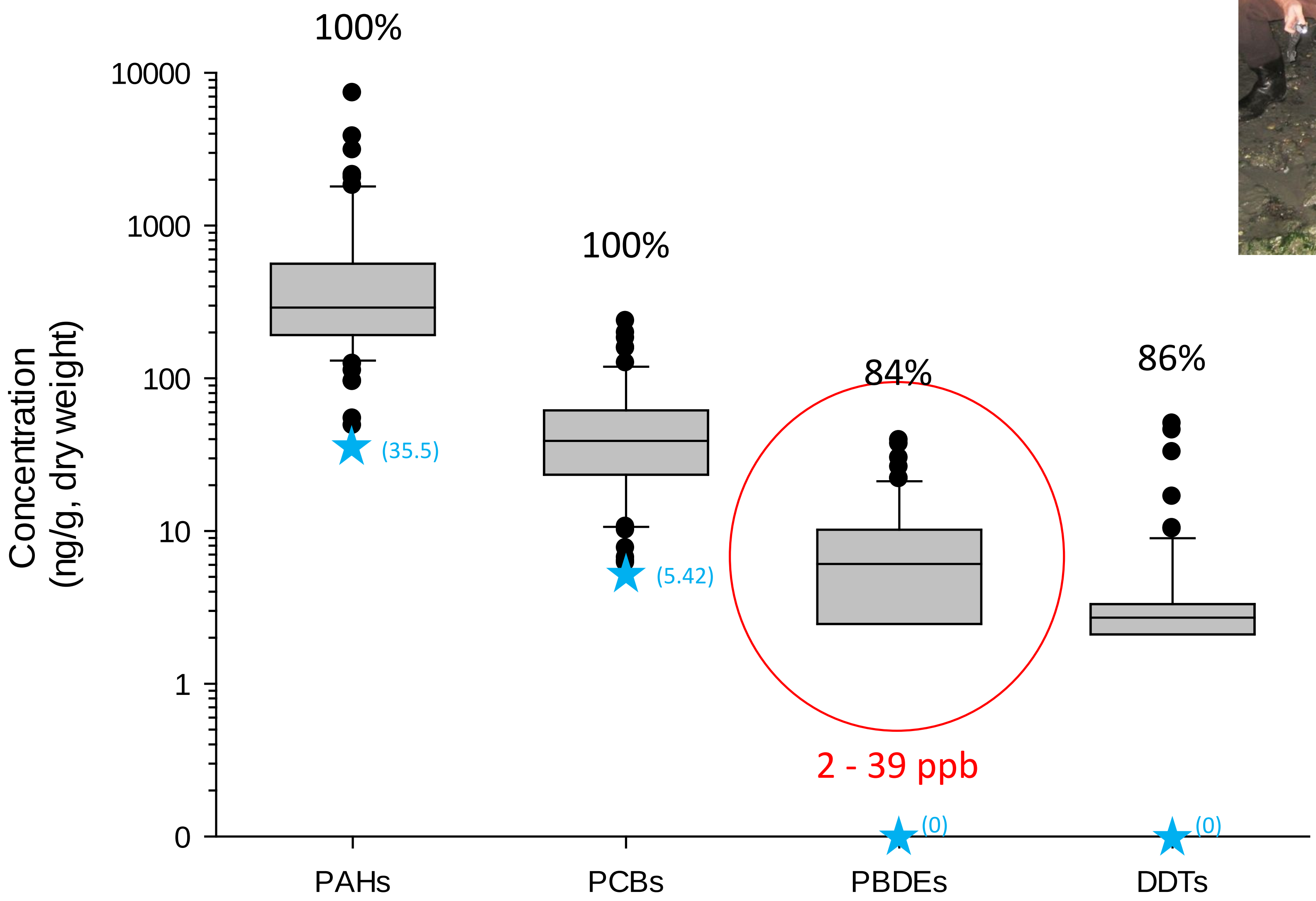

100%
10000
1000
100
10
1
0
Concentration
(ng/g, dry weight)
(35.5)
100%
(5.42)
84%
86%
(0)
(0)
6 - 236 ppb
PAHs
PCBs
PBDEs
DDTs

SAM
Stormwater Action Monitoring

PCBs highest in highly urbanized Elliott Bay and Salmon Bay.

Also elevated in Sinclair Inlet, and Gig Harbor.



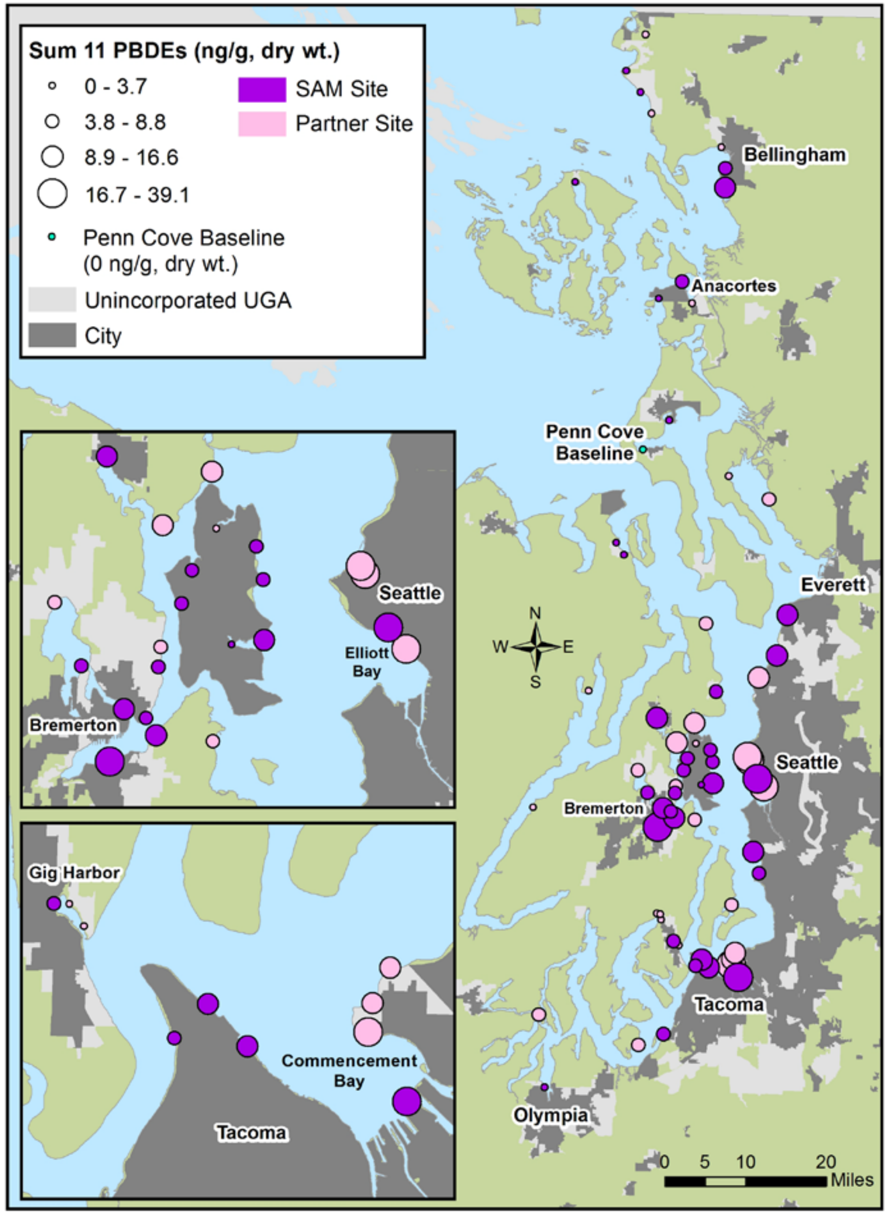


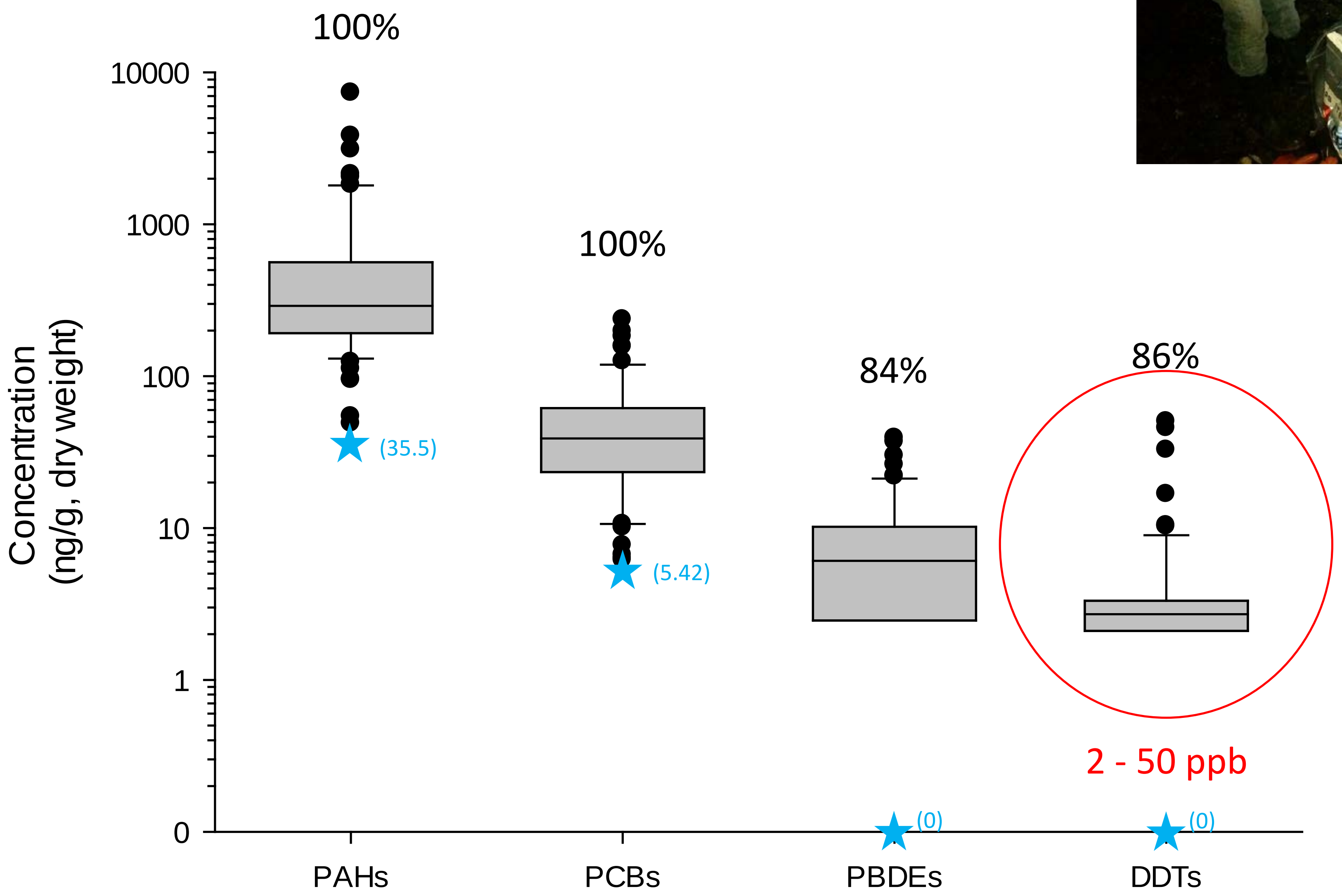
100%
100%
84%
86%
10000
1000
100
10
1
0
Concentration
(ng/g, dry weight)
(35.5)
(5.42)
(0)
(0)
2 - 39 ppb
PAHs
PCBs
PBDEs
DDTs

PBDEs

PBDEs highest in highly urbanized Elliott, Salmon, and Commencement Bays.

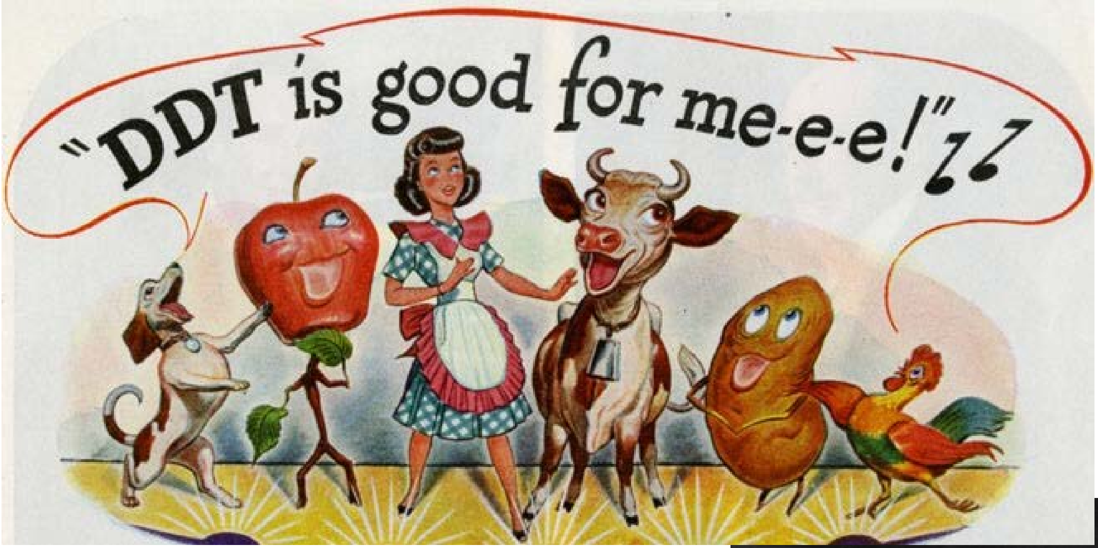
Also elevated in Sinclair Inlet.

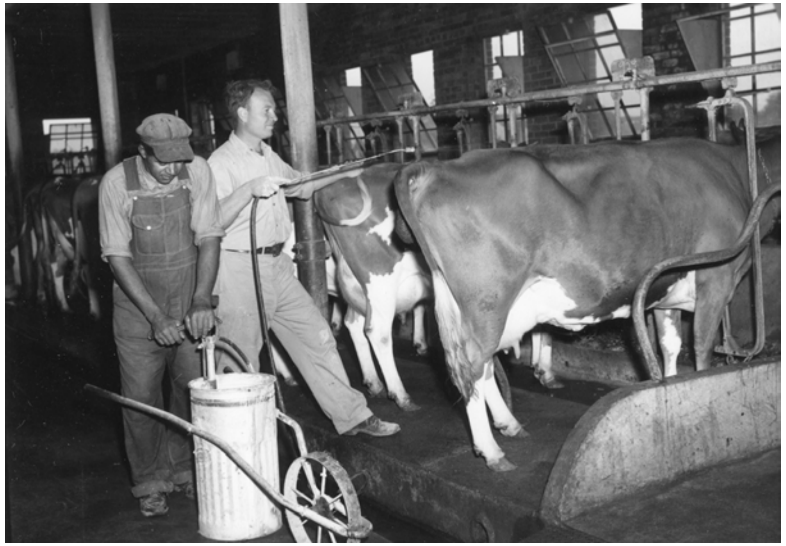


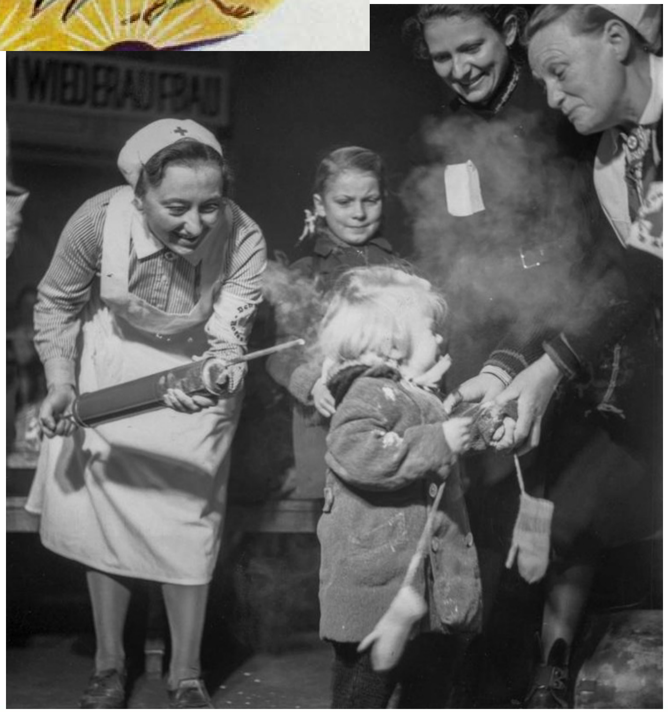


100%
100%
84%
86%
10000
1000
100
10
1
0
Concentration
(ng/g, dry weight)
(35.5)
(5.42)
(0)
(0)
2 - 50 ppb
PAHs
PCBs
PBDEs
DDTs

SAM
Stormwater Action Monitoring



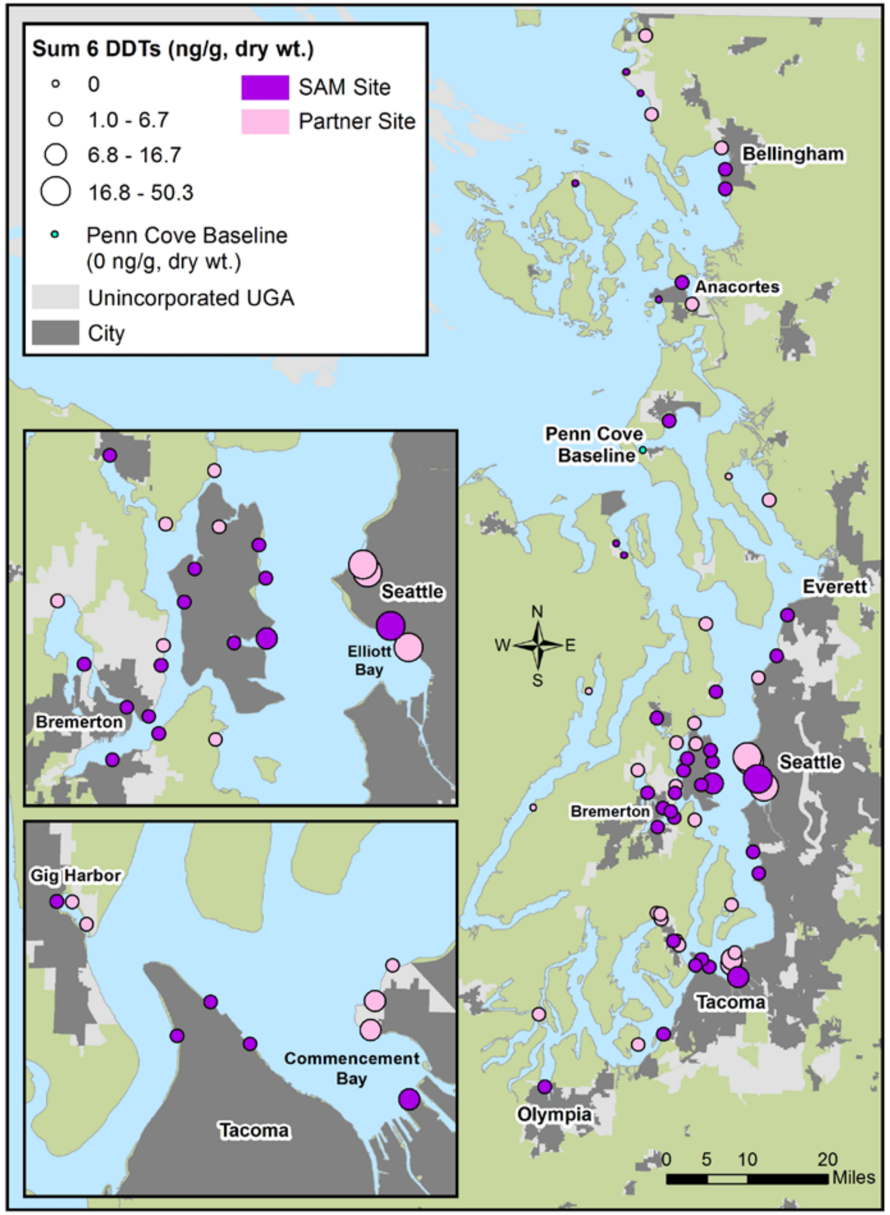




SAM
Stormwater Action Monitoring

DDTs highest in highly urbanized Elliott Bay and Salmon Bay.

Also elevated in Eagle Harbor and Commencement Bay.



SAM
Stormwater Action Monitoring

Factors Related to Mussel Contamination

1. Municipal land-use designation

2. Degree of impervious surface in nearshore-adjacent watersheds

- ➢ Both describe urban development in slightly different ways.
- ➢ Each accounted for 20-50% of the variability in PAHs, PCBs, PBDEs, and DDTs in nearshore mussels.

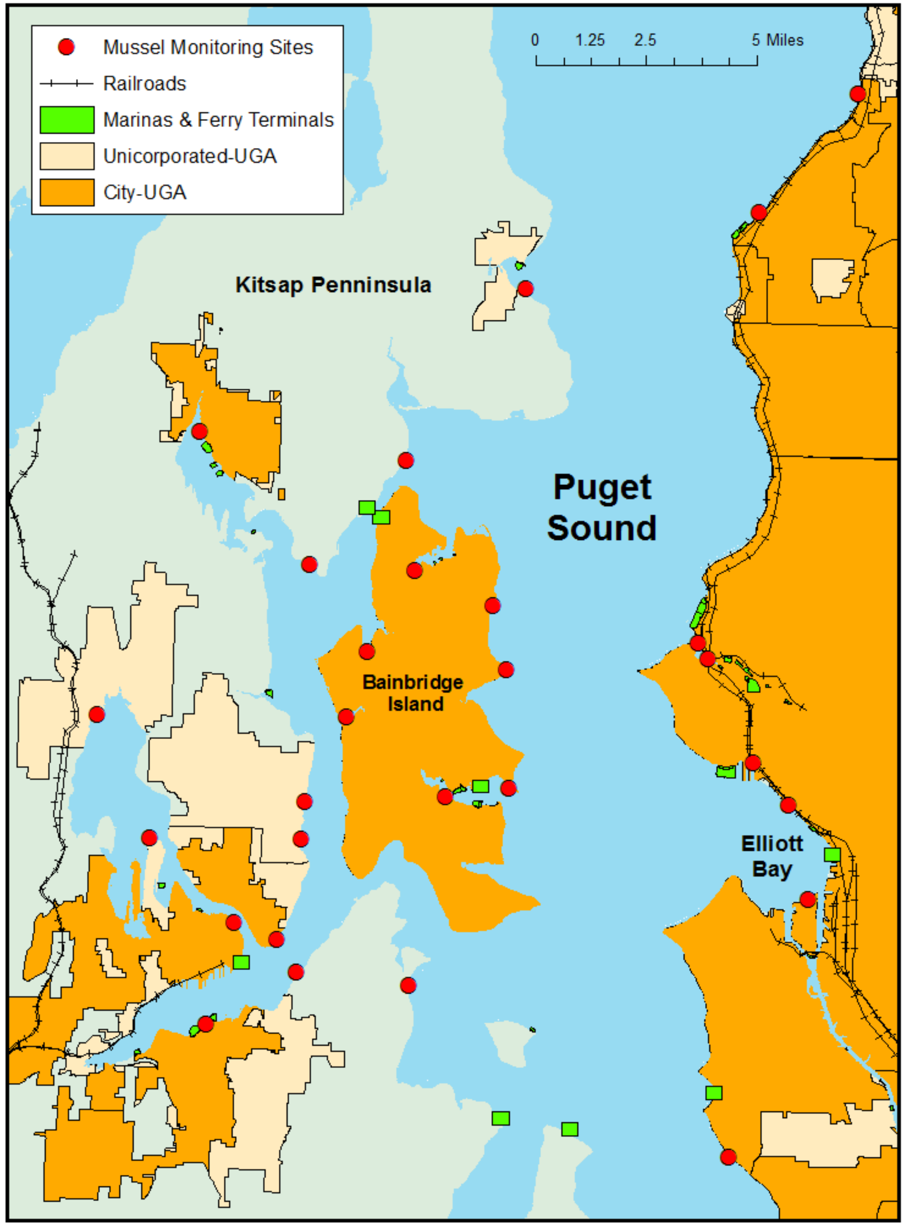
Type	Test	Significant Results (α <0.05) Organic Contaminants	Metals
Municipal land-use planning designations	UGA vs. Reference	PAHs, PCBs, PBDEs, DDTs	NS
	UGA class (city vs. unincorporated-UGA)	PAHs, PCBs, PBDEs, DDTs	Zinc
Largescale upland variables* measured in adjacent watersheds with an average area 8.8 km^2 (3.4 miles^2)	mean % Impervious Surface	PAHs, PCBs, PBDEs, DDTs	NS
	% Urban area	PBDEs, DDTs	NS
	% Forested area	NS	NS
	% Agricultural area	PCBs, PBDEs, DDTs	Lead
	% Wetland area	NT	NT
Small-scale upland variables† measured within 200 meters (656 ft) inland from shoreline	% Urban area	NS	NS
	% Forested area	NS	NS
	% Agricultural area	NS	NS
In-water or onshore point sources	Marina/ferry terminal presence	PAHs, PCBs, DDTs	Lead
	Railroad presence	PAHs, PBDEs, DDTs	NS
	Creosote observed	NS	NS
Natural geographical/geological features	Shoreline form (bay vs. open)	NS	Lead
	Substrate (depositional vs. coarse)	NS	Lead

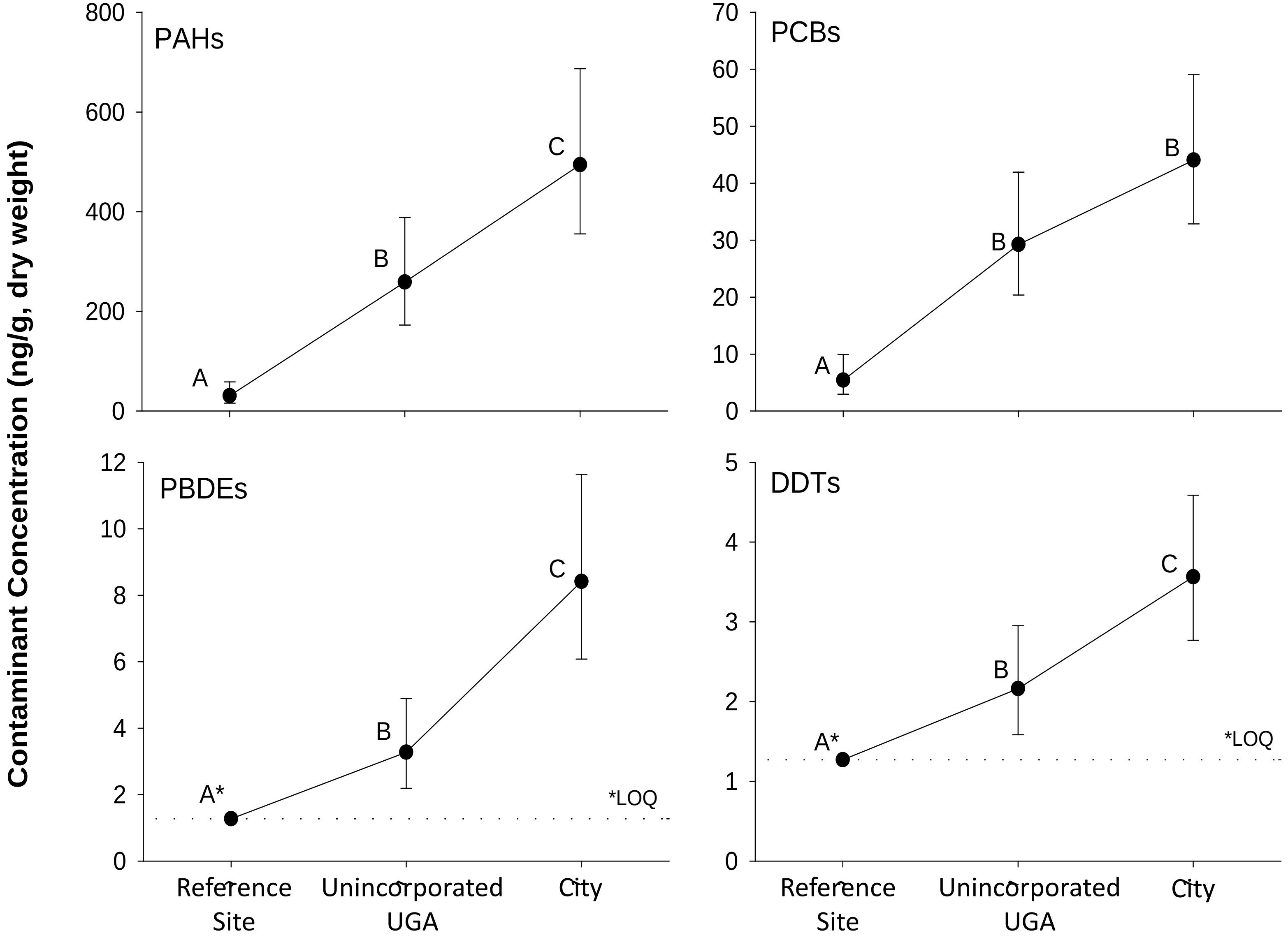
NS = not siginificant, NT = not tested due to lack of replicates
* Data from National Land Cover Dataset (NLCD) 2011
† Data from NOAA's C-CAP Land Cover Atlas shoreline characterization

Stormwater Action Monitoring

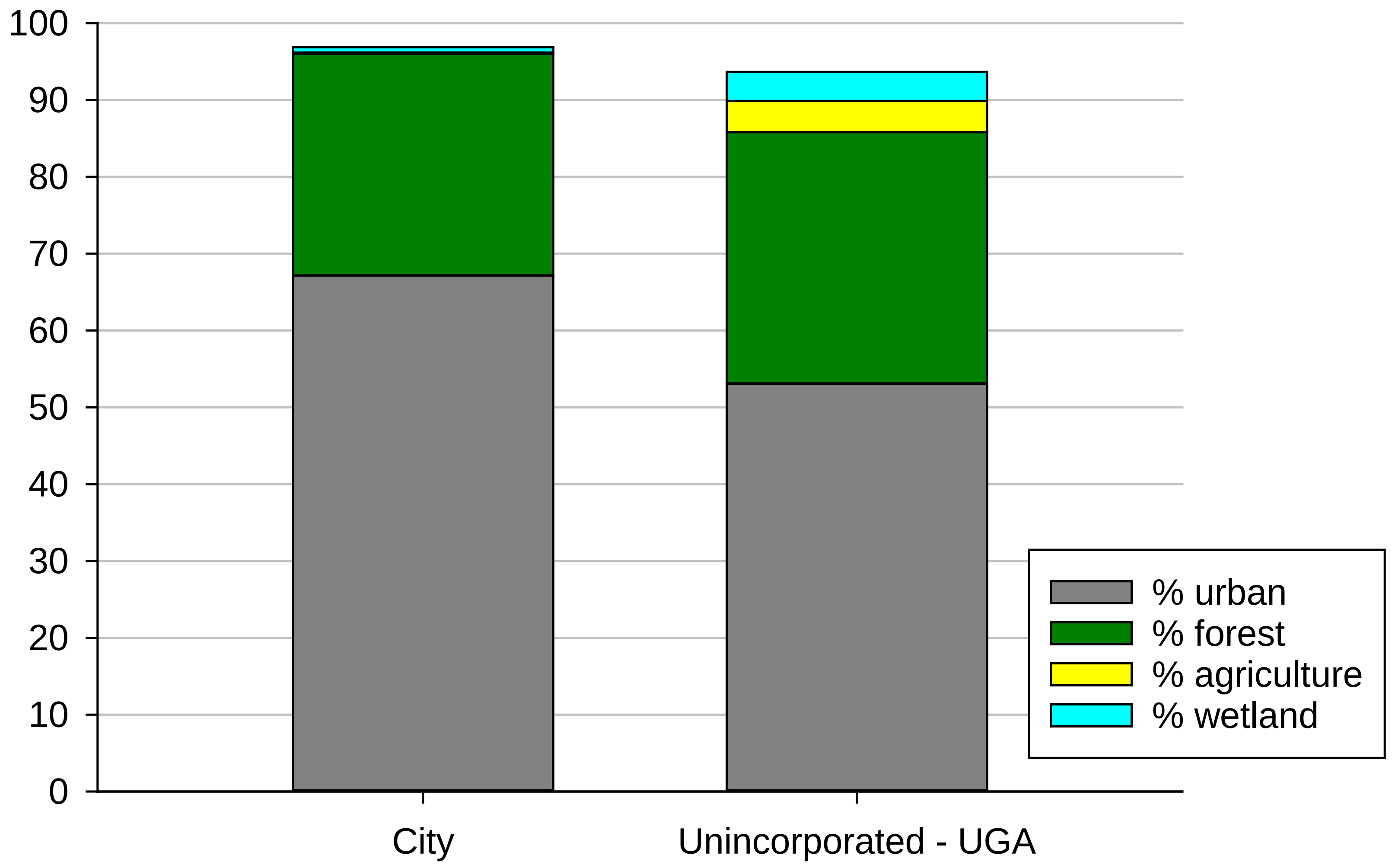
Municipal Land-Use Designations break the urban growth areas (UGAs) into:

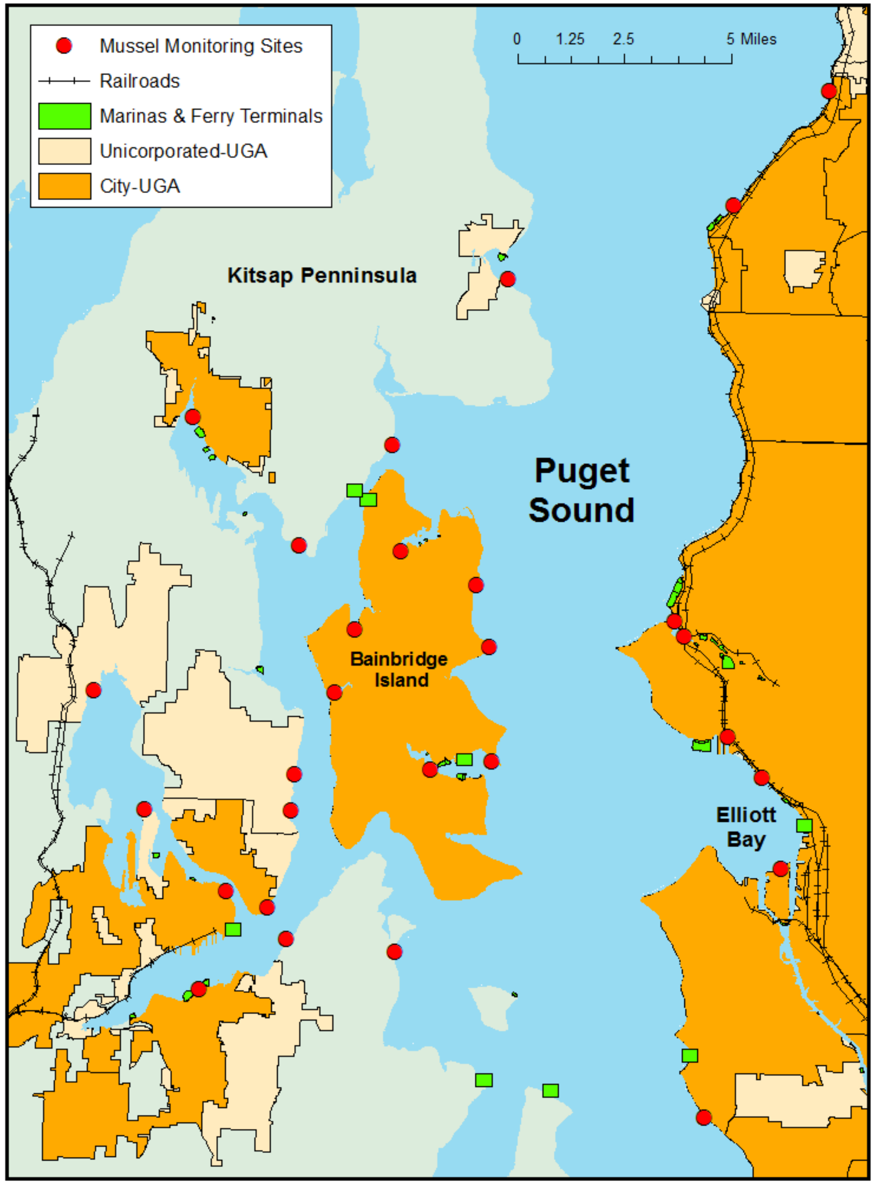
- **Cities**
- **Unincorporated-UGAs**

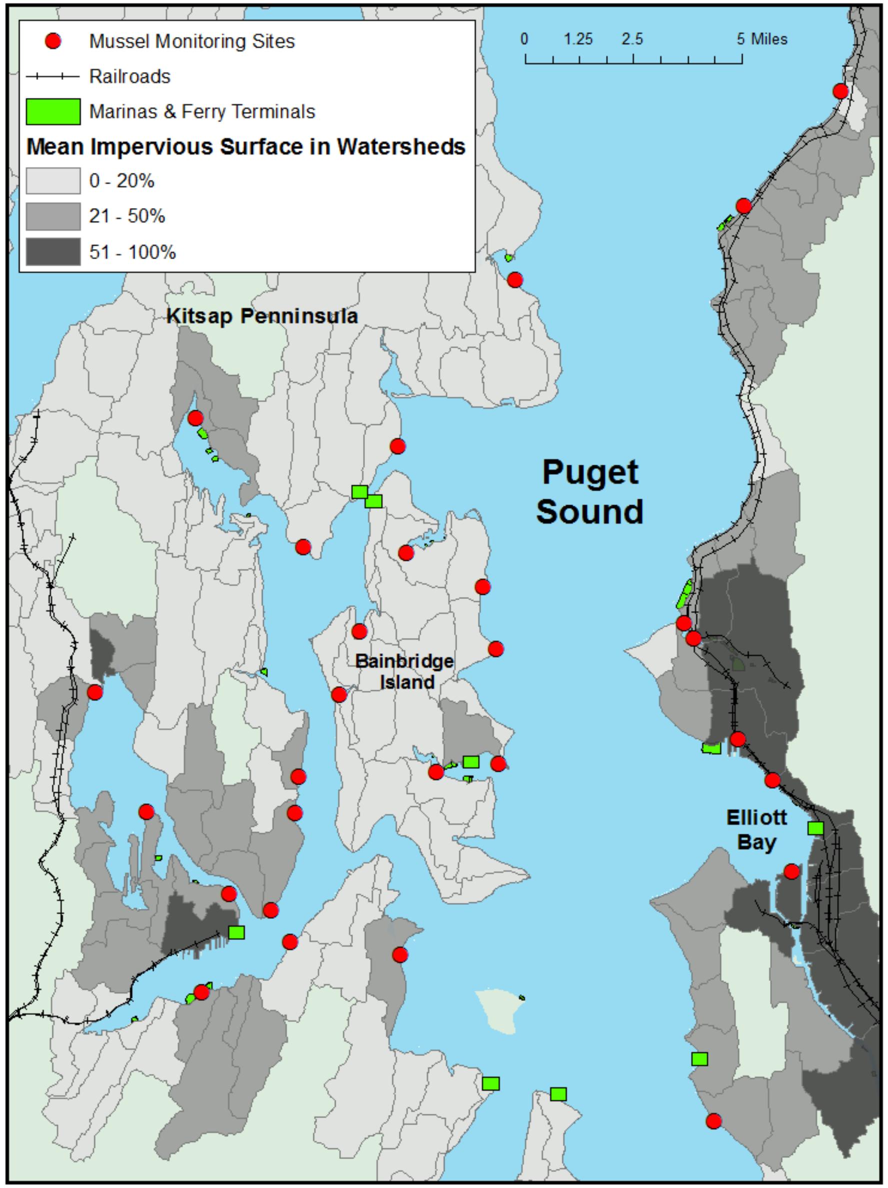


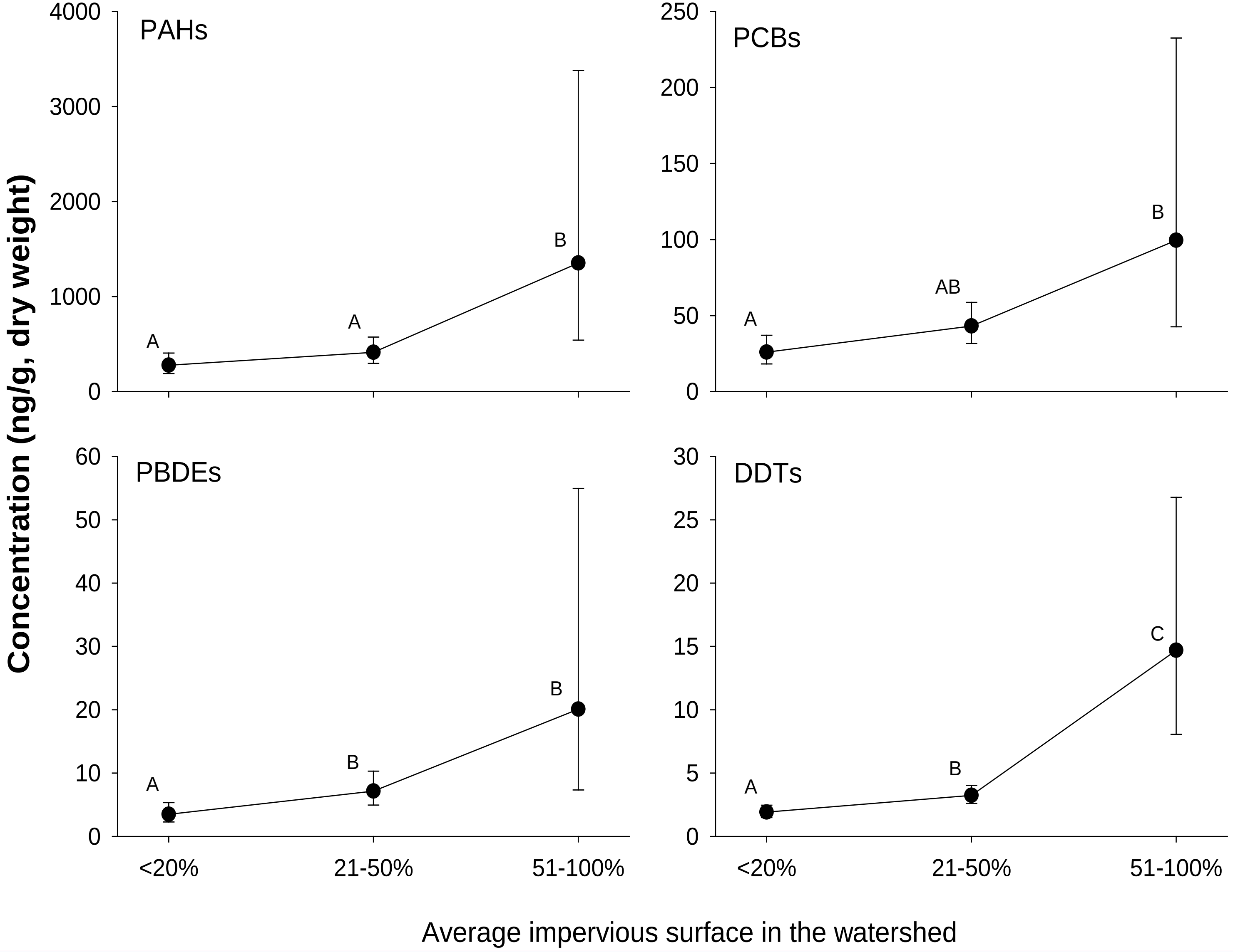


Level	Replicates
Reference	6
Unincorp.	17
City	26


100
90
80
70
60
50
40
30
20
10
0
City
Unincorporated - UGA
% urban
% forest
% agriculture
% wetland


Mussel Monitoring Sites
Railroads
Marinas & Ferry Terminals
Unicorporated-UGA
City-UGA
0 1.25 2.5 5 Miles
Kitsap Penninsula
Puget Sound
Bainbridge Island
Elliott Bay


Mussel Monitoring Sites
Railroads
Marinas & Ferry Terminals
Mean Impervious Surface in Watersheds
0 - 20%
21 - 50%
51 - 100%
0 1.25 2.5 5 Miles
Kitsap Penninsula
Puget Sound
Bainbridge Island
Elliott Bay



Level	Replicates
<20%	20
21-50%	23
51-100%	3

Conclusions

Toxic contaminants are entering the nearshore food web of the Puget Sound, especially along shorelines adjacent to highly urbanized areas.

- PAHs, PCBs, PBDEs, and DDTs were the most abundant organic contaminants
- Concentrations were significantly higher in urbanized areas as measured by;
  - Municipal Land-Use Classification (city vs. Unincorporated-UGA)
  - Impervious Surface in the Adjacent Nearshore Watershed
- Several organic contaminants were elevated in areas near marinas, ferry terminals, and railroad lines
- Concentrations of metals were relatively low

SAM Stormwater Action Monitoring

What is SAM mussel monitoring doing for you?

- Characterization of over 70 nearshore sites allows us to compare contaminant conditions on local and regional scales to conditions in the whole Puget Sound UGA.

- Tracking contaminants in mussel tissue over time will tell us (and Puget Sound decision-makers) about the bio-available contaminants still actively being delivered to the nearshore environment.

- Mussel monitoring data will contribute information about the effectiveness of stormwater management programs…
    - ➢ e.g. Can we see differences in nearshore contamination in Puget Sound UGAs implementing different levels of BMPs? Or remediation areas? Or???

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Education. Research. Stewardship.

The Port Gamble S'KLALLAM TRIBE

Feiro MARINE LIFE CENTER

CITY OF BELLINGHAM WASHINGTON

MRC Whatcom County

MARINE RESOURCES COMMITTEE SAN JUAN COUNTY WASHINGTON OUR WATERS ARE IMPORTANT

PORT TOWNSEND MARINE SCIENCE CENTER AT FORT WORDEN STATE PARK

KITSAP COUNTY 18 57 WASHINGTON

UNIVERSITY of PUGET SOUND

TULALIP TRIBES

SNOHOMISH COUNTY MARINE RESOURCES COMMITTEE

W UNIVERSITY of WASHINGTON TACOMA

the evergreen state college
olympia,washington

Vashon Nature Center, LLC

STILLAGUAMISH TRIBE OF INDIANS

HARBOR WILDWATCH

NISQUALLY REACH NATURE CENTER
OVER 30 YEARS OF EDUCATION AND RESEARCH

SEATTLE AQUARIUM

BAINBRIDGE BEACH NATURALISTS

King County

LEP
Lighthouse Environmental Programs of Island County

AMERICORPS 20 YEARS

Snohomish County

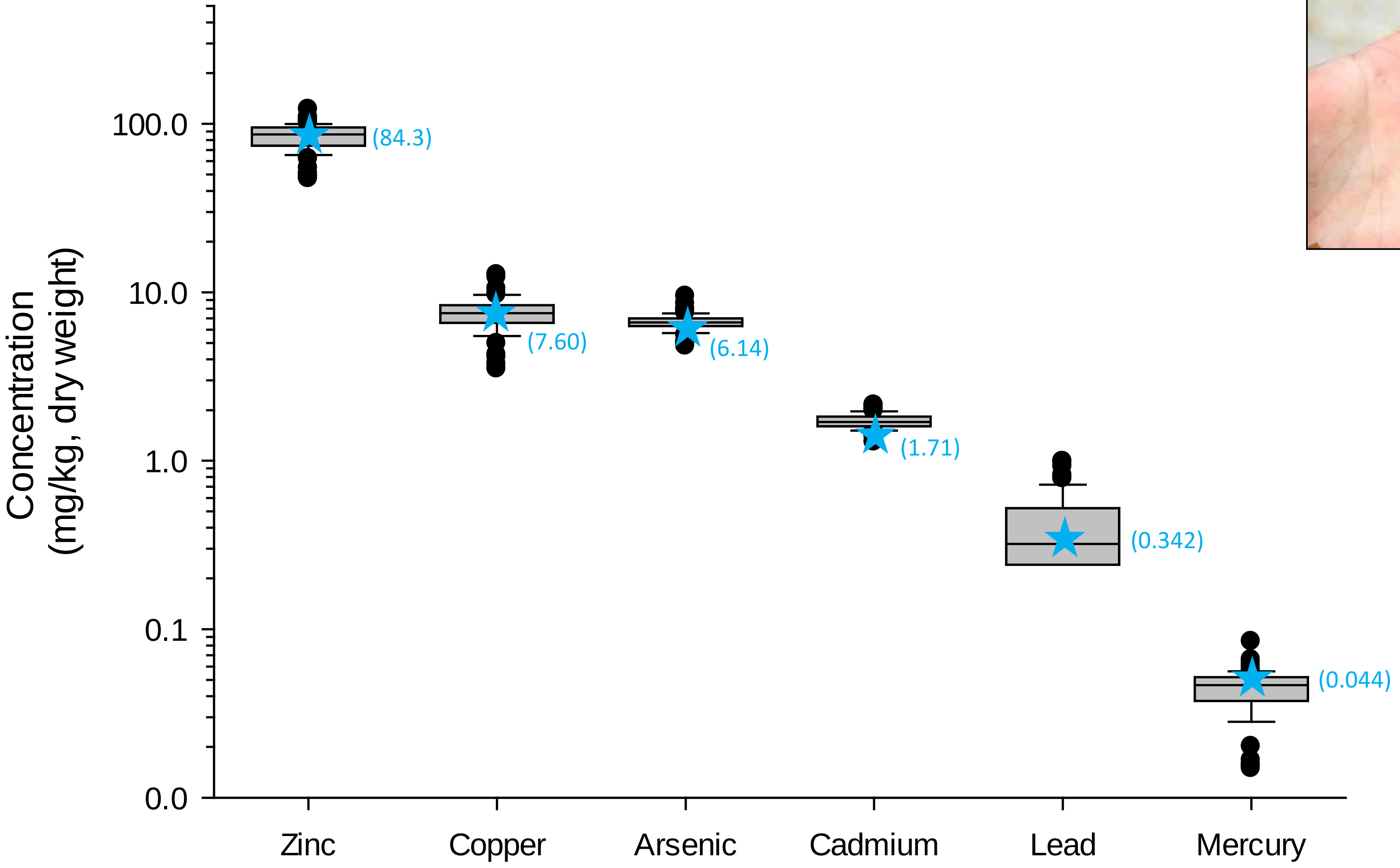
Thank you

Marina of ferry terminal <2 km from mussel site

Chemical	Marina or Ferry Terminal (n = 18)	None (n = 25)	t(41)	p-value
	Geometric mean conc. (ng/g, dry wt)			
PAHs	646	263	-3.76	0.001
PCBs	53.2	29.0	-2.54	0.015
DDTs	3.89	2.38	-2.29	0.027
	Geometric mean conc. (mg/kg, dry wt)			
Zinc	87.3	84.3	-0.49	0.629

Railroad <500 m from mussel site

Chemical	Railroad (n = 9)	None (n = 34)	t(41)	p-value
	Geometric mean conc. (ng/g, dry wt)			
PAHs	656	332	-2.13	0.039
PBDEs	10.9	4.89	-2.26	0.029
DDTs	4.51	2.61	-2.08	0.044


Concentration
(mg/kg, dry weight)
100.0
10.0
1.0
0.1
0.0
(84.3)
(7.60)
(6.14)
(1.71)
(0.342)
(0.044)
Zinc
Copper
Arsenic
Cadmium
Lead
Mercury

Puget Sound Nearshore Sediment Monitoring for the Stormwater Action Monitoring (SAM)

Robert Black[1], Brandi Lubliner[2], Abby Barnes[3] and Colin Elliot[4]

[1]Washington Water Science Center, US Geological Survey, Tacoma, WA.

[2]Washington State Department of Ecology, Olympia, WA.

[3]Washington State Department of Natural Resources, Olympia, WA.

[4]King County Environmental Lab, Seattle WA.

Stormwater Action Monitoring

Why Nearshore Sediment

- Stormwater is implicated as main pollution source to Puget Sound and gaining attention for salmon and orca recovery.
- Stormwater chemicals are often attached or become attached to sediment until aquatic plants and animals come in contact within them.

Project Goals

- Assess the chemical quality of Puget Sound sediment quality in the nearshore urban areas within Urban Growth Areas (UGAs).
- Document geographic patterns.
- Establish protocol to document natural and human-caused changes over time in Puget Sound nearshore sediments.

Project Goals (cont.)

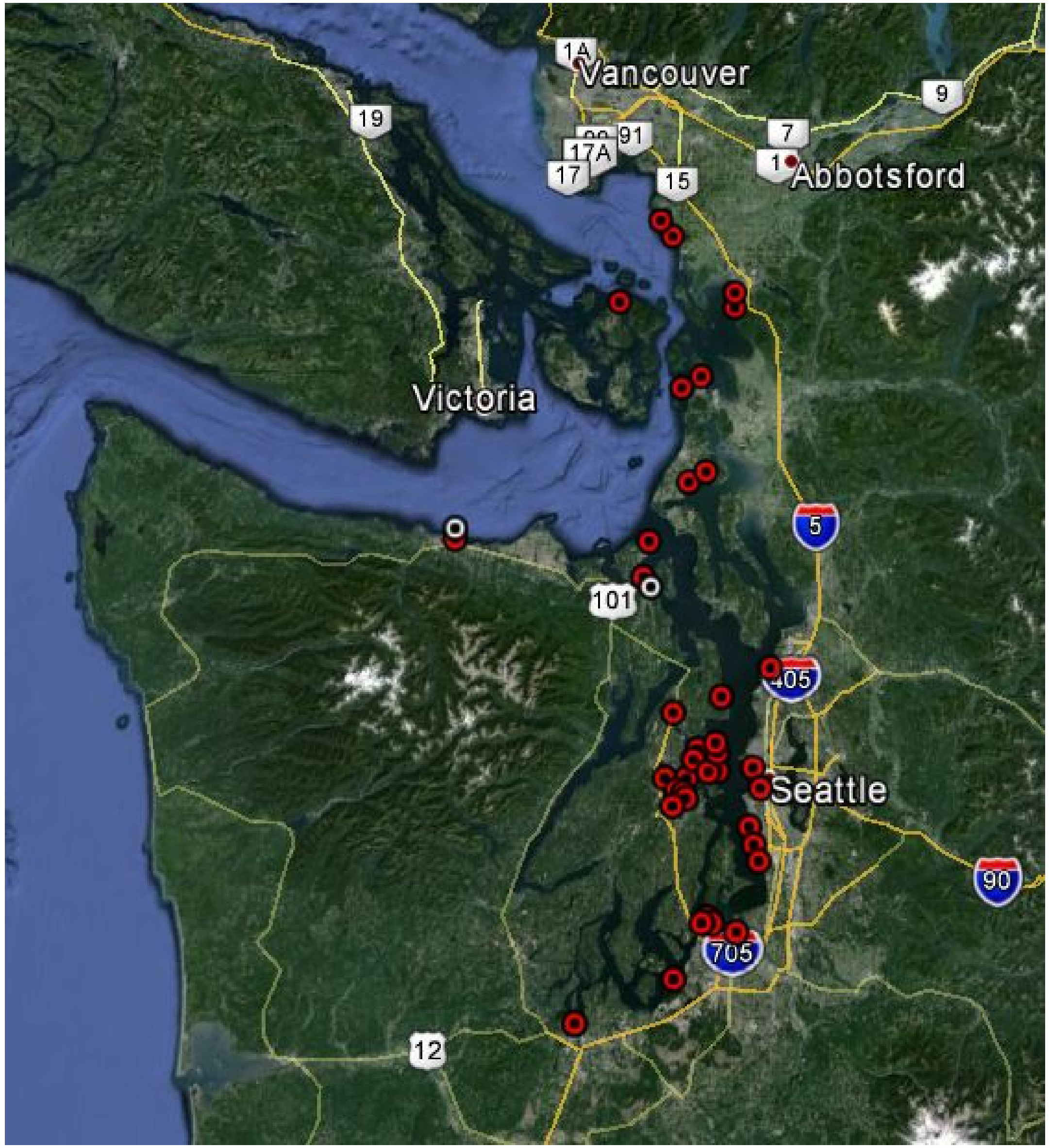
- Identify existing nearshore sediment quality problems and, where possible, provide data to help target sources.

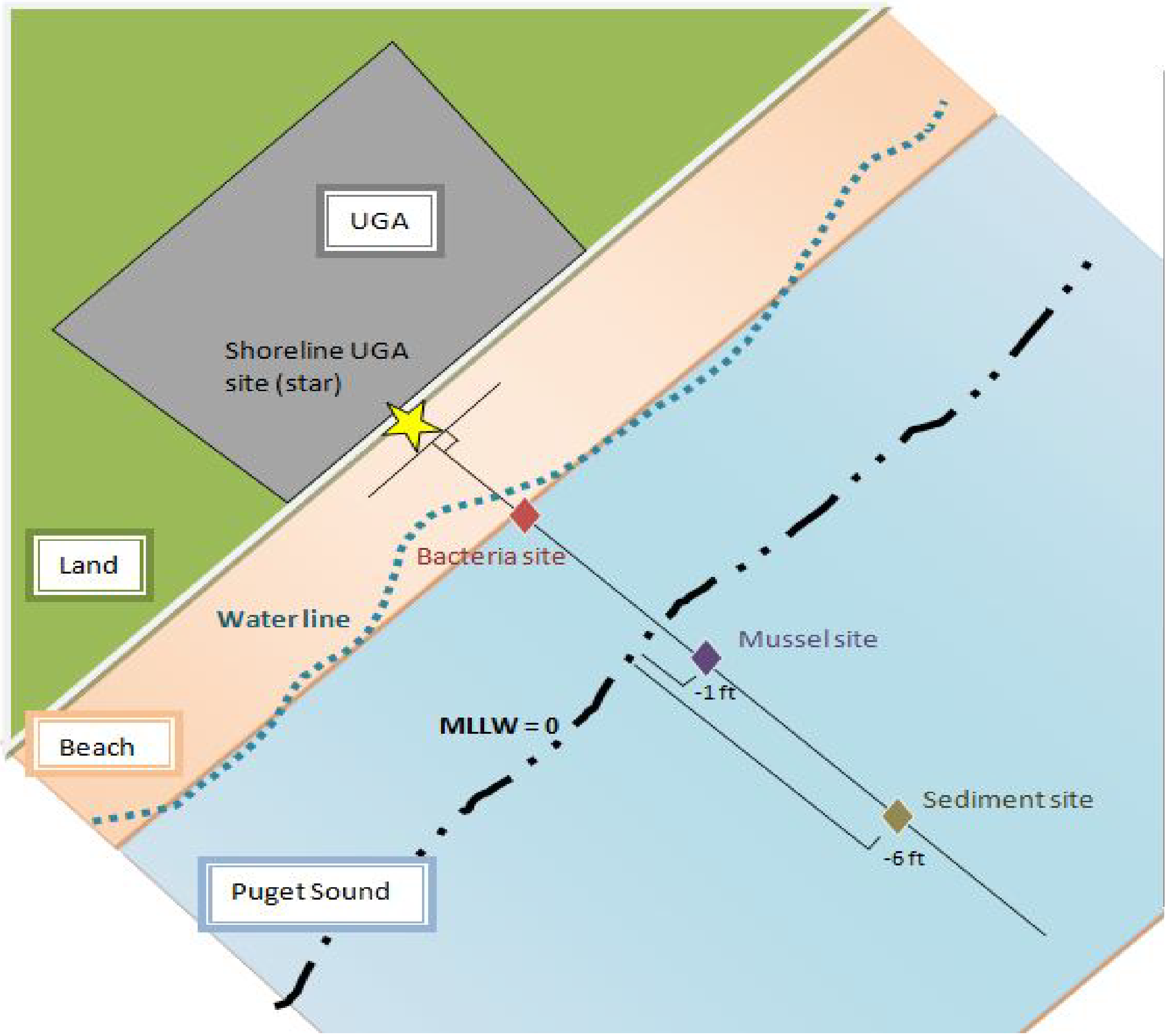
- Provide uniformly collected and documented high quality data that can assist the regulatory agencies in measuring the success of stormwater and other environmental management programs.

Location of Sites

- 40 sites randomly selected

- Allows for the evaluation of sediment chemistry “Sound-wide”
  - (ie. sites may not be in every jurisdiction and don’t need to be)





Integration

Nearshore sediment quality work is being collected, where possible, with bacteria and mussel sampling to provide information to efficiently, effectively, and adaptively manage stormwater to reduce negative impacts on the Puget Sound.

How, What and Why

<u>How?</u>
Samples were collected from a boat using specialized sediment sampling equipment and processed on the boat.

<u>What?</u>
Metals, PCBs, Oils, Combustion Chemicals, and other anthropogenic chemicals. Also Microplastics (USGS $)

<u>Why?</u>
All of the chemicals sampled have known effects on human and/or aquatic animal health, some at low levels.

Microplastics are suspected of physically impacting aquatic animals and carry anthropogenic chemicals.

When?

- Sampling done in summer of 2016.
- As of May 25, 2017, all chemical data is back from the labs.
- Microplastic analysis is underway at USGS Tacoma Lab.
- Draft report in late summer 2017.

Stormwater Action Monitoring

Preliminary Nearshore Sediment Study Observations

- Random design won't assure a site in every jurisdiction. 40 randomly identified sites are representative of "urban nearshore" across the region.
  - Will examine relationships between sediment quality and potential anthropogenic and natural sources
- Trend program - Stormwater runoff is source of contaminants to nearshore. Which parameters will be best to track over time?
  - Examples: metals (lead from gasoline, copper in moss treatments/brake pads, zinc in building sources) and/or flame retardants, microplastics, etc…

Preliminary Nearshore Sediment Study Observations

- Study leveraged design and protocols from Ecology, EPA, and USGS.
- Will compare to other programs to define the best trend program for SAM.
- Study also leveraged USGS funds to examine microplastics in nearshore sediment.
- Worked with King County and WA Dept. of Natural Resources which helps the effort remain relevant with other stormwater outfall/stormwater management efforts.

Bacteria Results for Nearshore Marine Areas in Puget sound, 2010-2015

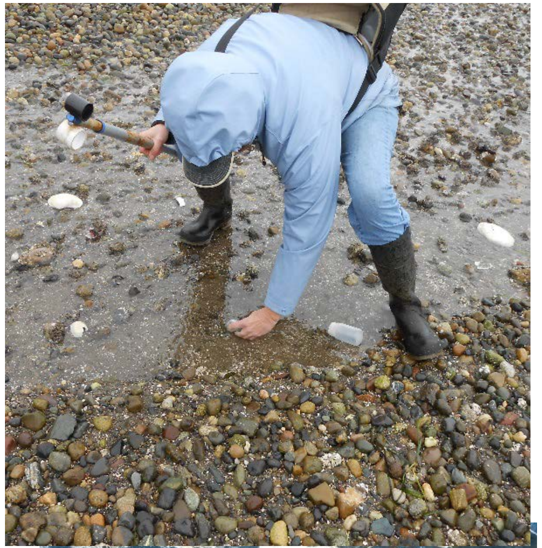
What kind of bacteria data is collected, and are there any data gaps?

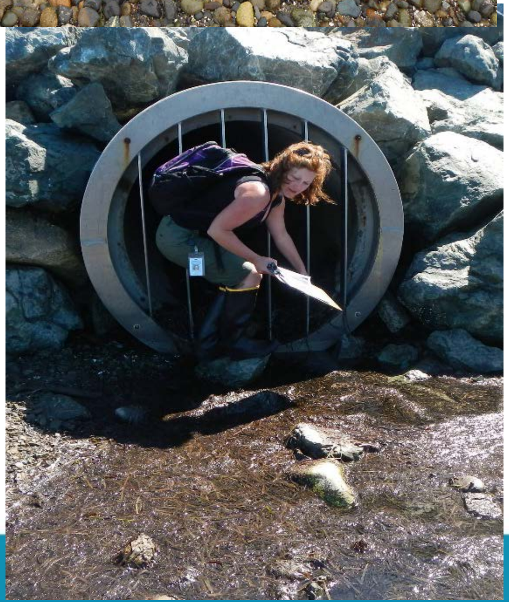
Stormwater Action Monitoring

SAM
Stormwater Action Monitoring

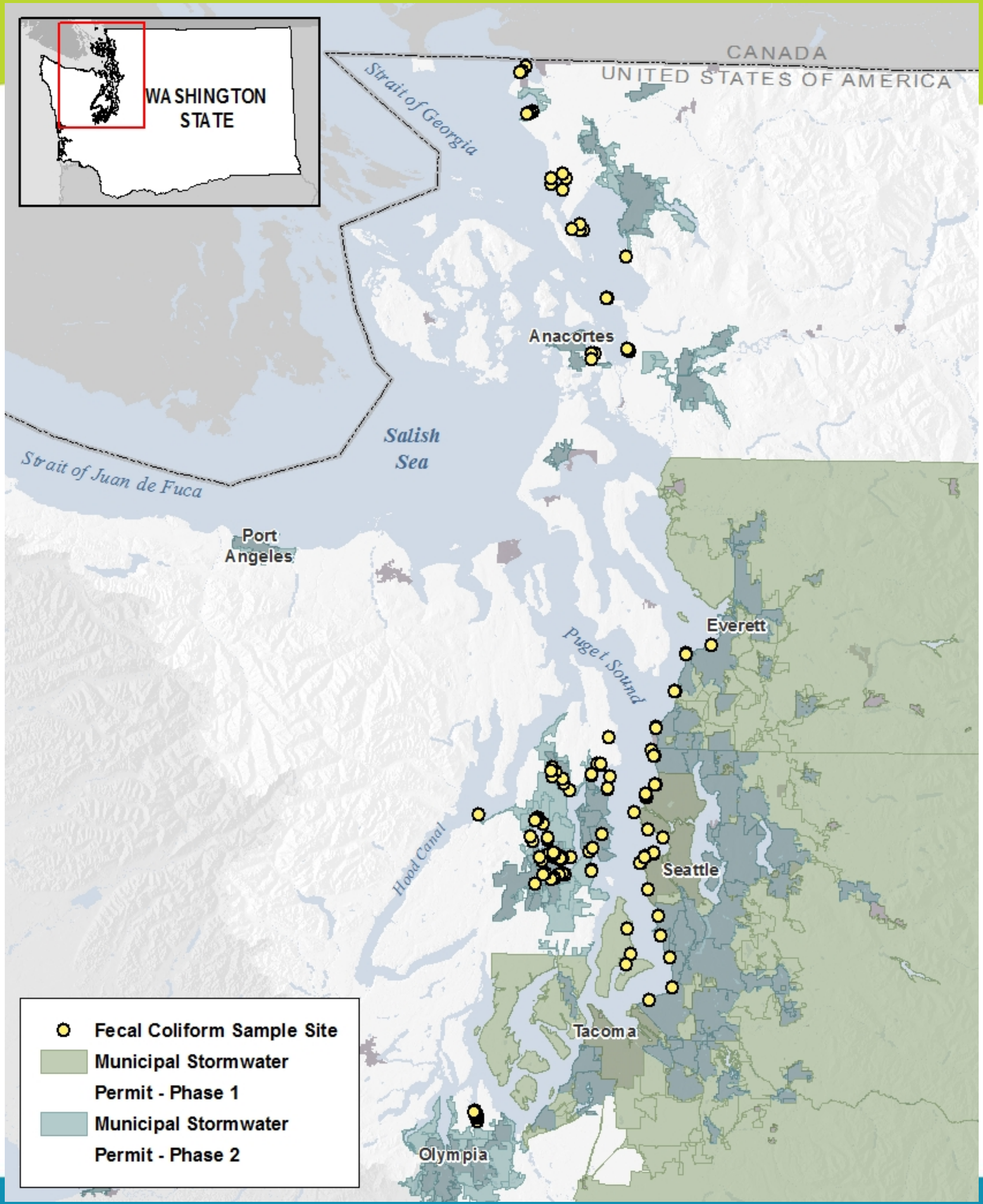
Who collects nearshore bacteria data and why?





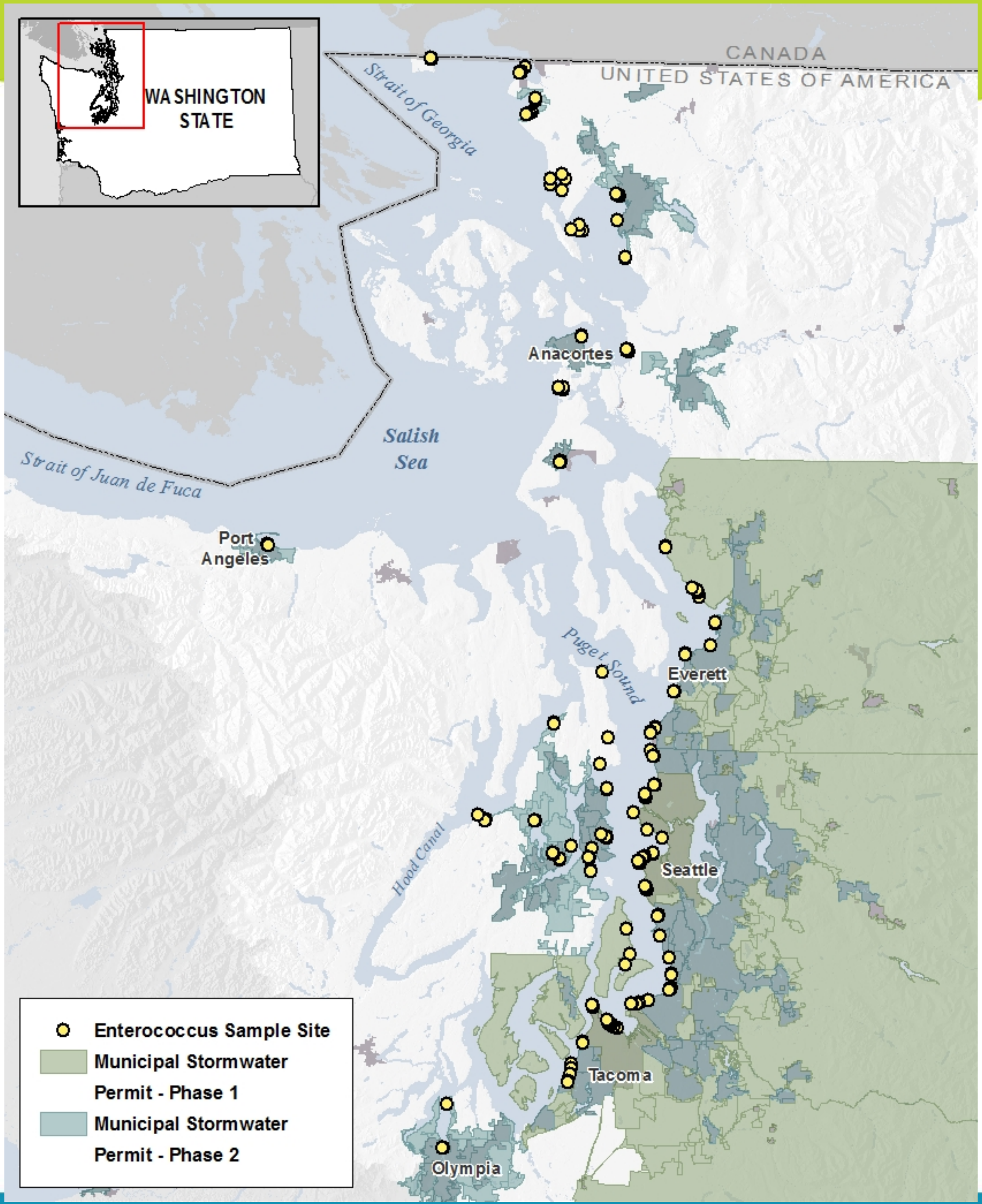




Where is bacteria collected?



Fecal Coliform Bacteria Sites

Where is bacteria collected?



Enterococcus Bacteria Sites

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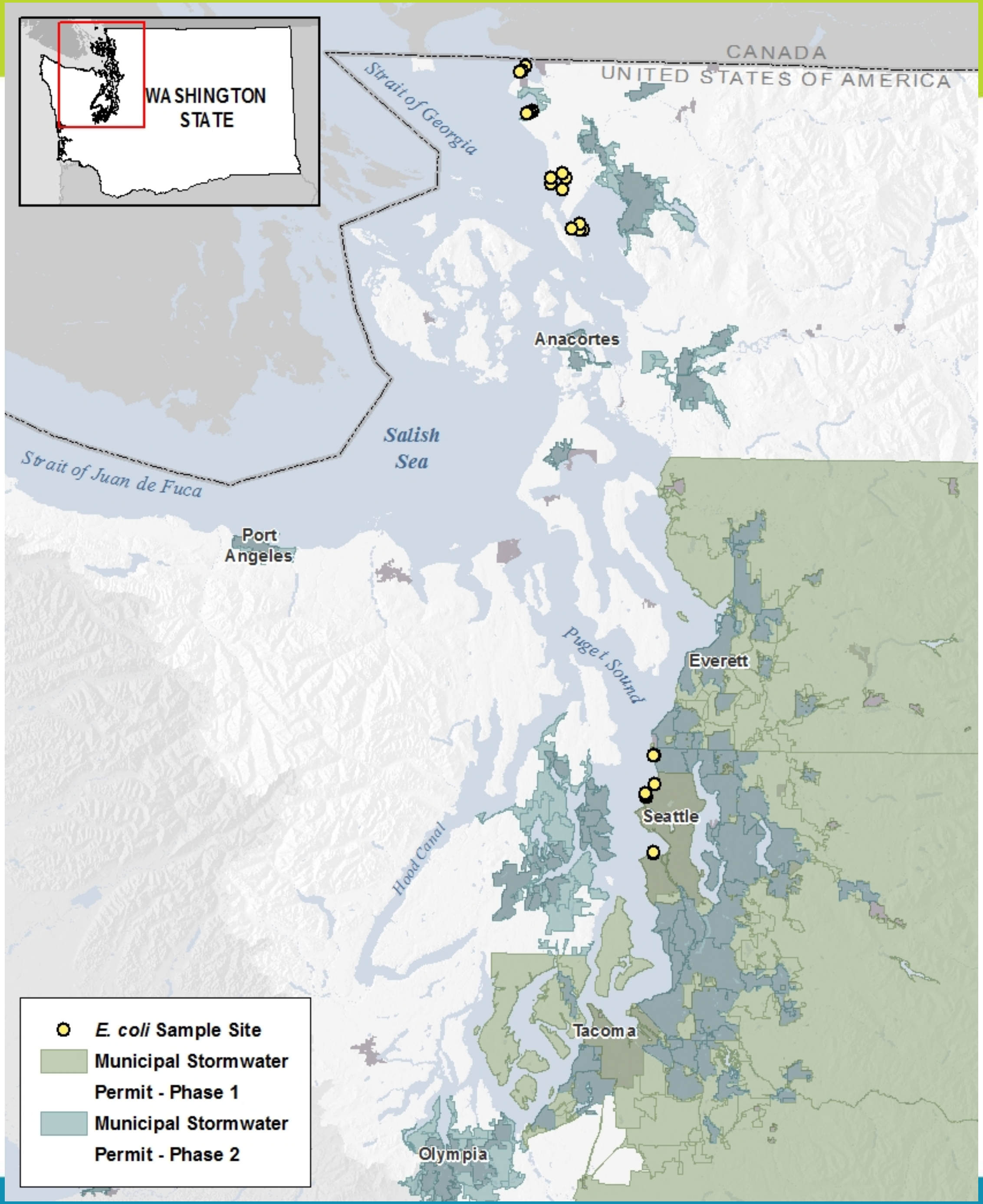
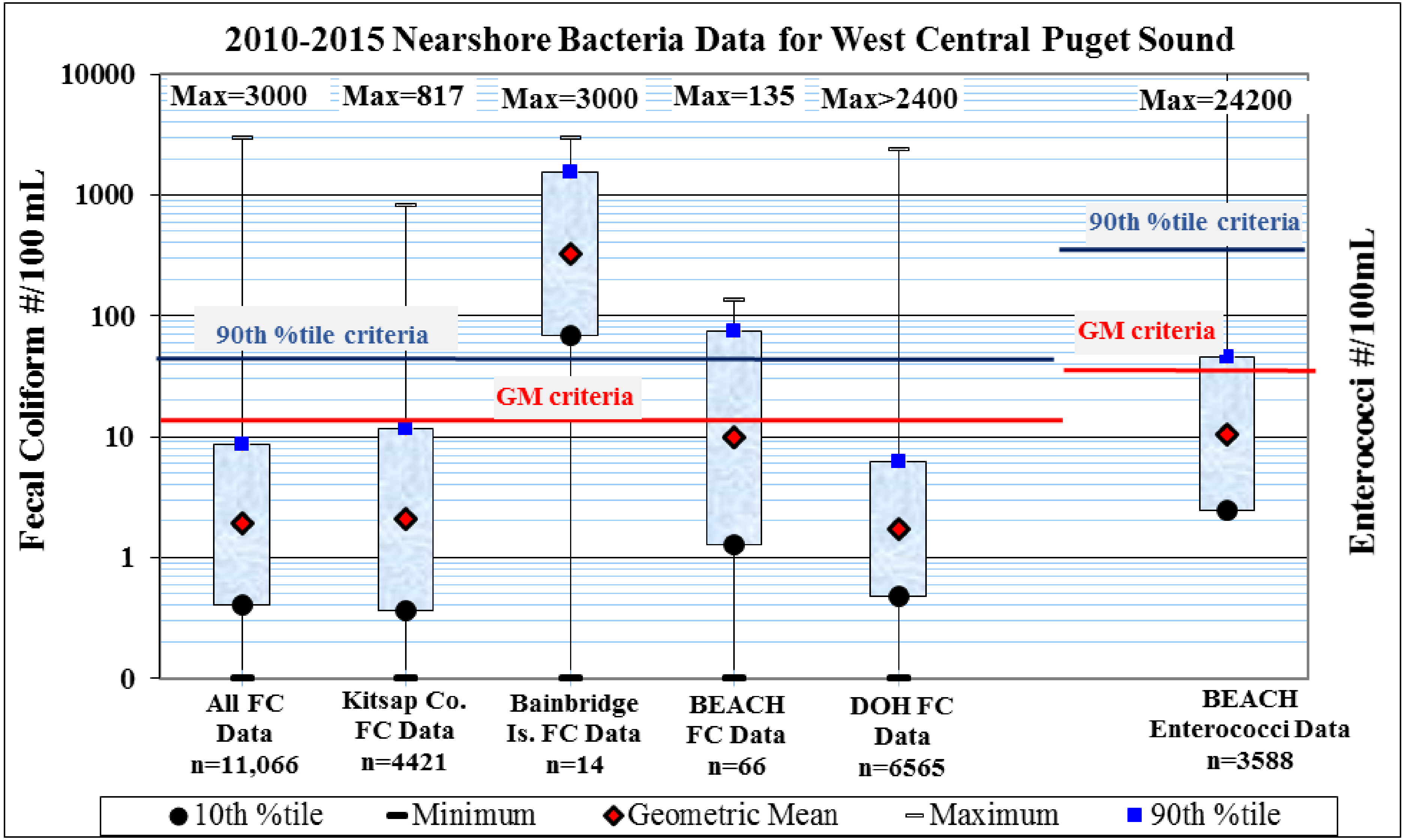
Where is bacteria collected?



E-coli Bacteria Sites

Data Analysis



Nearshore Bacteria Data Gaps

- State programs DOH and BEACH have the most consistent bacteria monitoring programs Puget Sound wide.
- Kitsap and King counties conduct bacteria monitoring program.
- Tribes conducted monitoring in the northern part of Puget Sound.
- Cities, even Phase I and II, did not conduct monitoring.

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What next?

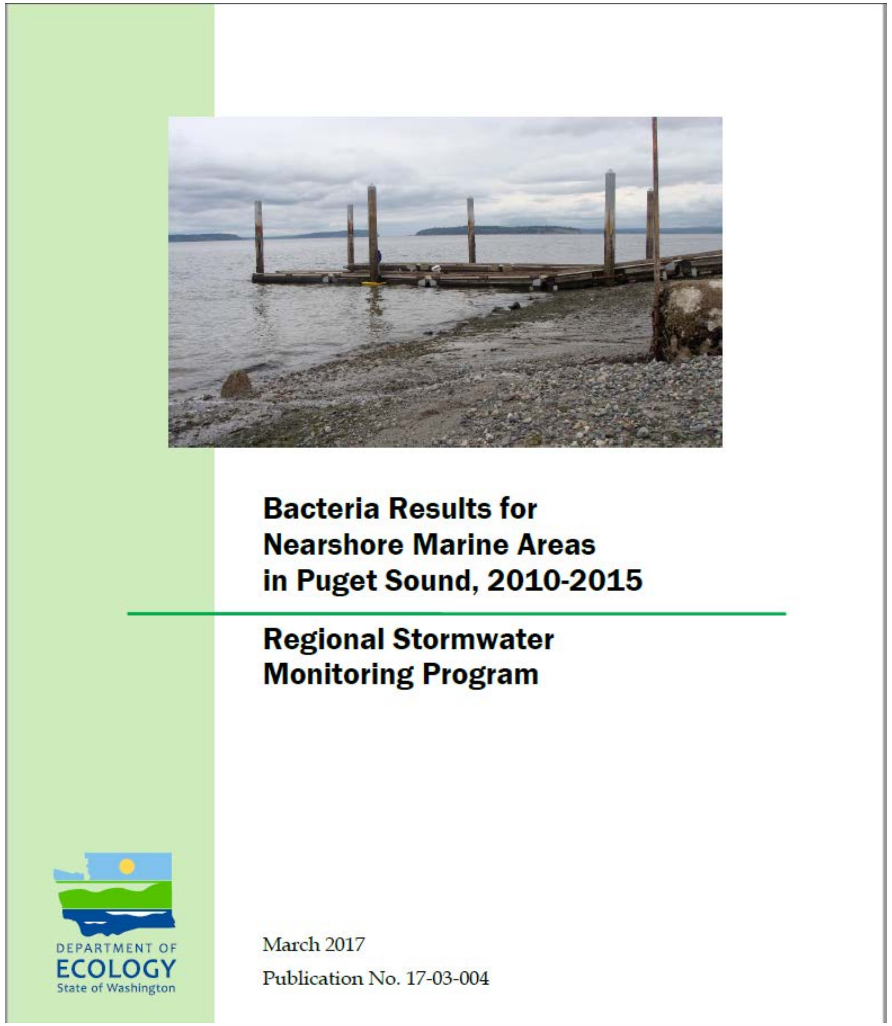
- Conduct Additional statistical analysis on 2010-2015 data set.
- Design Options for Bacteria Status and Trends Monitoring Program

Stormwater Action Monitoring

Questions ?

https://fortress.wa.gov/ecy/publications/SummaryPages/1703004.html

- Final Report at: https://fortress.wa.gov/ecy/publications/SummaryPages/1703004.html



Bacteria Results for
Nearshore Marine Areas
in Puget Sound, 2010-2015

Regional Stormwater
Monitoring Program

DEPARTMENT OF
ECOLOGY
State of Washington

March 2017

Publication No. 17-03-004

Context for SAM Source ID projects

Karen Dinicola, SWG Project Manager
Washington State Department of Ecology

Permit S8.D Source identification

- Goals:
    - Pollution identification and elimination methods
    - Regional solutions to common problems
- Objectives:
    - Priorities for reducing sources
    - Best ways to solve, reduce, prevent issues
    - Evaluate data to inform projects and funding

What is an illicit discharge?

- Any discharge that's not entirely stormwater
  - Some non-stormwater discharges are specified as "allowed" in the permit
- Permittees have requirements to detect and eliminate these discharges
  - Illicit Discharge Detection and Elimination (IDDE) program

2014 IDDE Data Evaluation

James Packman
Aspect Consulting

Greg Vigoren
City of Lakewood

SAM
Stormwater Action Monitoring

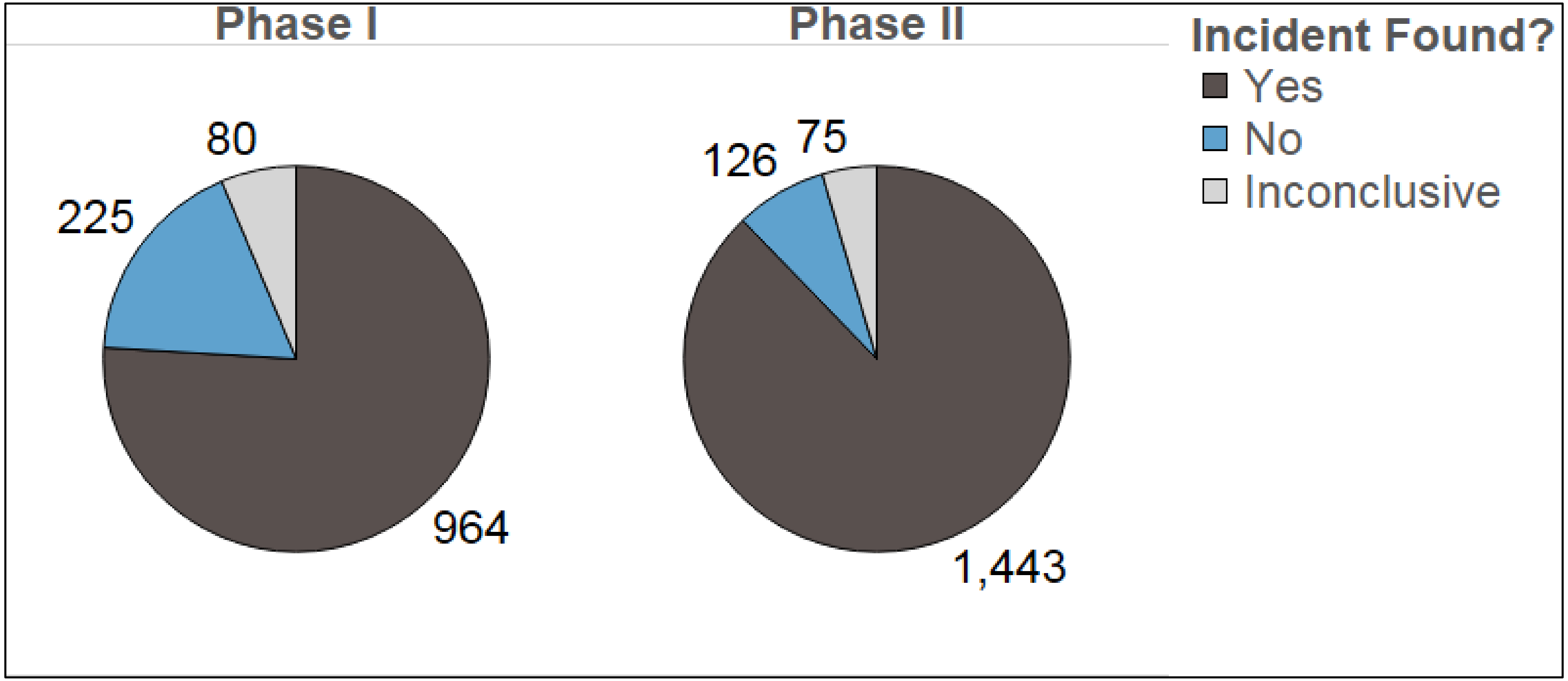
SAM's first Source ID project

- Collect and assemble one year of illicit discharge data reported by permittees
  - How are permittees keeping records and submitting data?
  - What types of pollution events are being reported?
  - What methods are being used to address the problems?

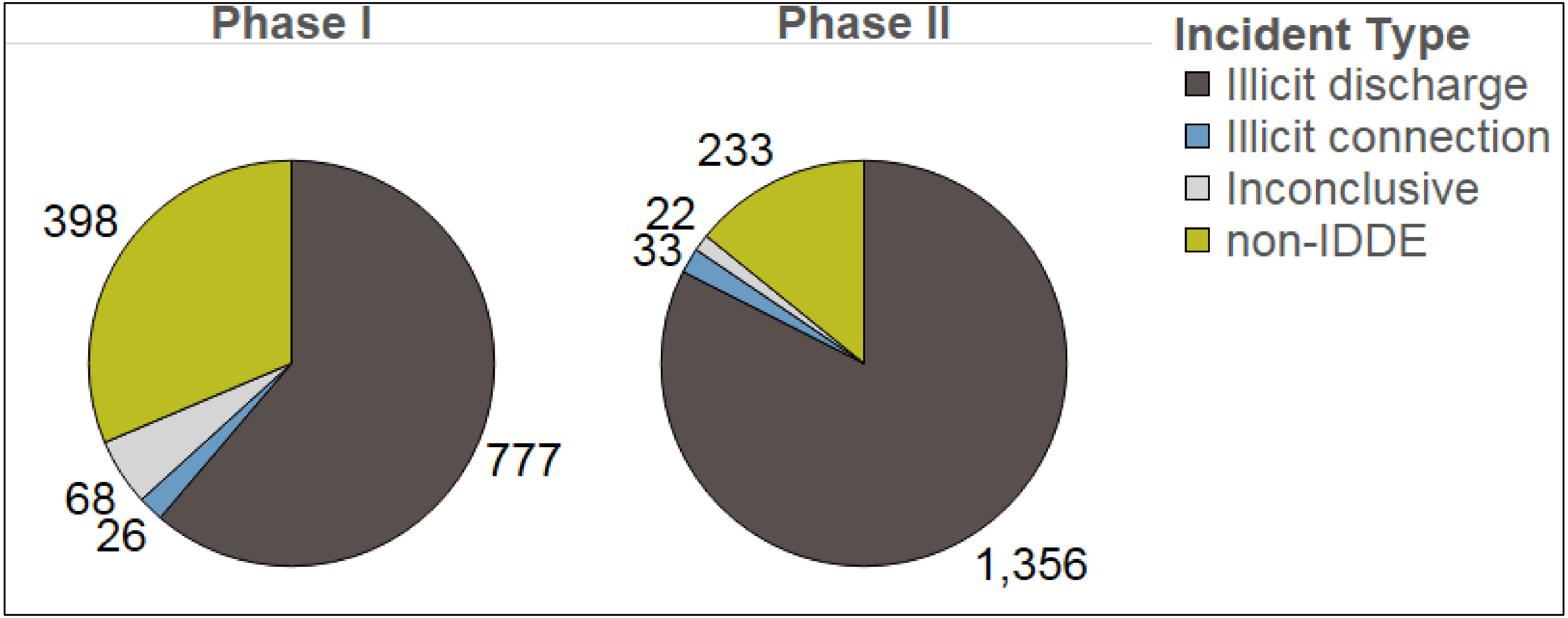
Evaluated data from 2014

- Permittee submittals for annual reports to Ecology
  - Number of illicit discharges
  - Summary of corrective actions
  - Description of timelines
- Very little consistency in the information provided by the permittees

2,913 possible incidents were reported in 2014



2,133 illicit discharges were confirmed in 2014



Most common pollutants found

1. Hydrocarbons and vehicle fluids
2. Sediment, soil, and construction waste
3. Industrial discharges
4. Sewage
5. Cleaning chemicals
6. Trash

Most common sources

1. Spills, accidents
    - Relatively few from auto repair shops
2. Dumping
3. Construction BMP failures
4. Illicit connections, leaks
5. Industrial activity

Most common indicators

1. Visual
   - Turbidity, flow
2. Null
   - Not reported
3. Chemical testing
4. Odor, pH, fecals

How are incidents reported?

1. Hotline calls
   - And direct reports to jurisdiction staff
2. Inspection or discovery by jurisdiction staff
3. Referrals from another agency

Some uses of a regional IDDE database

INQUIRE

- Local inquiry: look up how specific discharges in specific areas have been addressed

SHARE

- Jurisdictional inquiry: compare enforcement methods among jurisdictions

TRACK

- Regional inquiry: look up what type of pollution occurred over time in multiple areas

Future projects

- More analyses
  - Recommending that Permittees' reporting be standardized for next permit cycle
- Projects to enhance methods
- Recommendations for regional solutions

Questions?

James Packman
jpackman@aspectconsulting.com
206-780-7723
www.aspectconsulting.com

Greg Vigoren
gvigoren@cityoflakewood.us
253-983-7771
www.cityoflakewood.us

Karen Dinicola
karen.dinicola@ecy.wa.gov
360-407-6550
www.ecy.wa.gov

What’s ahead for SAM?

Brandi Lubliner, SAM Coordinator
Washington State Department of Ecology

Stormwater Action Monitoring

SAM Stormwater Action Monitoring

What's next for SAM?

- Communicating SAM work
  - Website, Listserv, Newsletter
  - SAM project fact sheets
- Select more stormwater management effectiveness studies
- Defining trends programs for receiving water studies
- Identify projects to help reduce pollution via source control

We need you to get involved with SAM!

- Help us develop SAM projects in an open, coordinated, and shared manner that capture a regional understanding of how management actions can lead to results.
- How to get involved:
  - Respond to SAM surveys or requests for data
  - Join a project advisory committee or serve as a liaison
  - Join SWG caucuses and subgroups

More information

SAM webpage: http://www.ecy.wa.gov (search "SAM")

- Ecology's website is getting overhauled in July, anticipate changes to bookmarks

SAM email: SAMinfo@ecy.wa.gov