

# WELCOME!

6PPD & 6PPD-q Webinar  
Hosted by California FishPAC  
Thursday, Nov. 2, 2023  
10 a.m. - Noon PDT







# Agenda

- Welcome & Introductions
- General Housekeeping
- 6PPD & 6PPD-q Presentation (Subject-Matter Experts)
  - Heather Goss, National Transportation Liaison, US Environmental Protection Agency
  - Cindy Callahan, Senior Biologist, Federal Highway Administration
  - Nat Scholz, Ecotoxicology Program Manager, National Marine Fisheries Service
  - Washington State DOT
    - Tony Bush, Stormwater Branch Manager
    - Sheena Pietzold, Stormwater Permit Program Manager
    - Tatiana Dreisbach, Stormwater Retrofit Outreach & Innovation Lead
    - Jeff Dreier, Fish & Wildlife Program Manager
- Question & Answer Session
- Closing





# General Housekeeping

- All attendees automatically muted upon entry
- Chat box deactivated for duration of meeting
- Opportunity to ask questions during facilitated Q&A session
  - **Participation inactive until Q&A session begins. Instructions will be displayed onscreen**
    - Type questions/comments into Q&A box
- Meeting is being recorded and will be posted on FishPAC website





# Heather Goss

*National Transportation Liaison*  
US Environmental Protection Agency







**Cindy Callahan**  
*Senior Biologist*  
**Federal Highway Administration**







**Nat Scholz**

*Ecotoxicology Program Manager*  
**National Marine Fisheries Service**





# A brief history of the urban runoff mortality syndrome in Pacific salmon and steelhead

*Nat Scholz, NOAA Fisheries*

*Northwest Fisheries Science Center, Ecotoxicology Program*

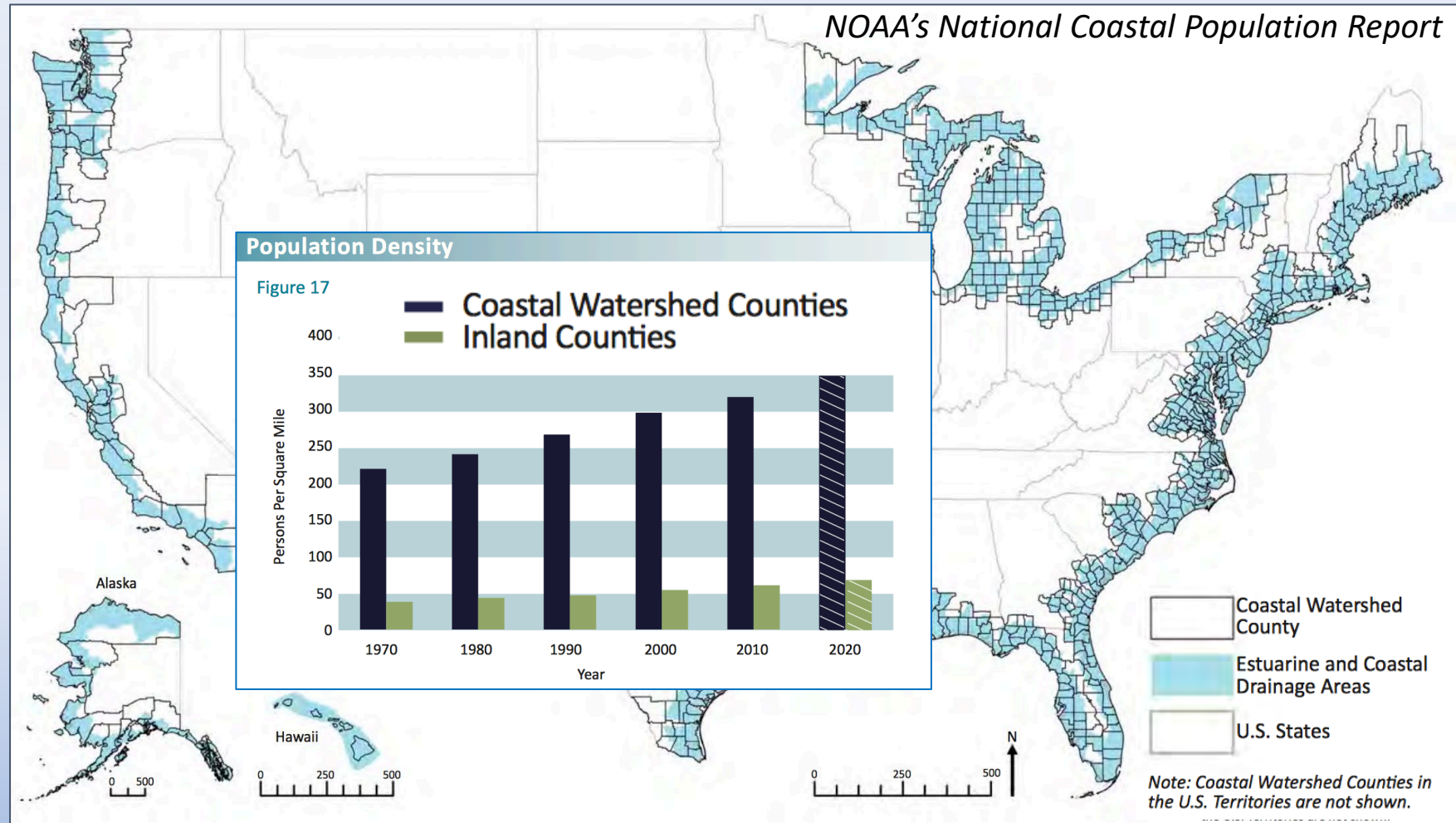
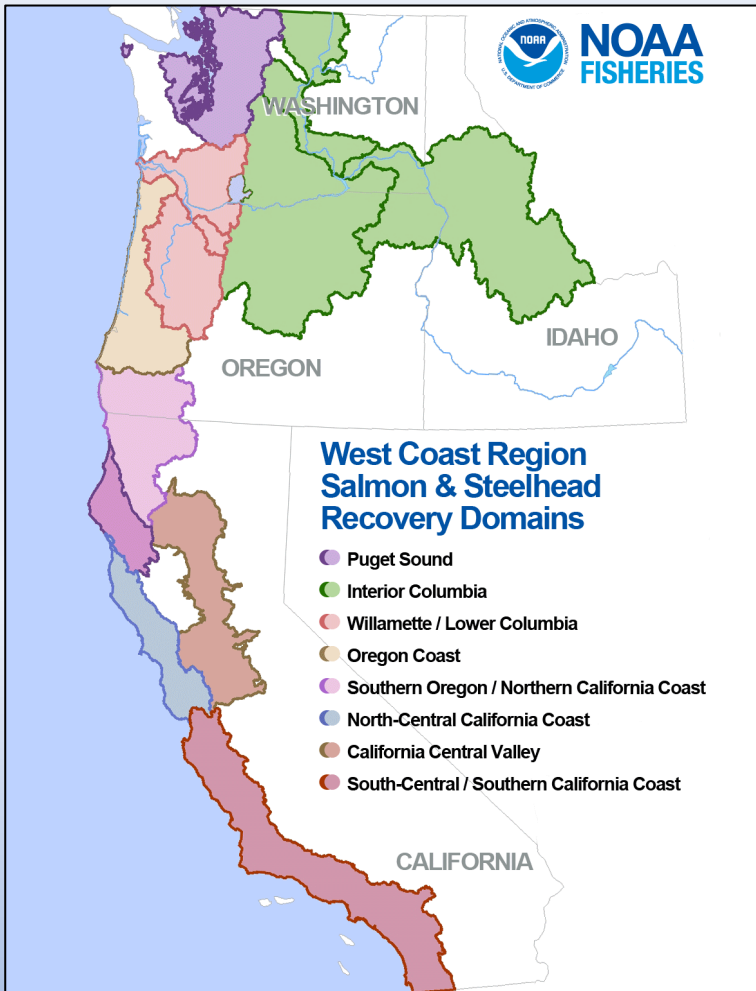


*California Fish Passage Advisory Committee  
6PPD(q) Webinar, Nov. 2<sup>nd</sup>, 2023*





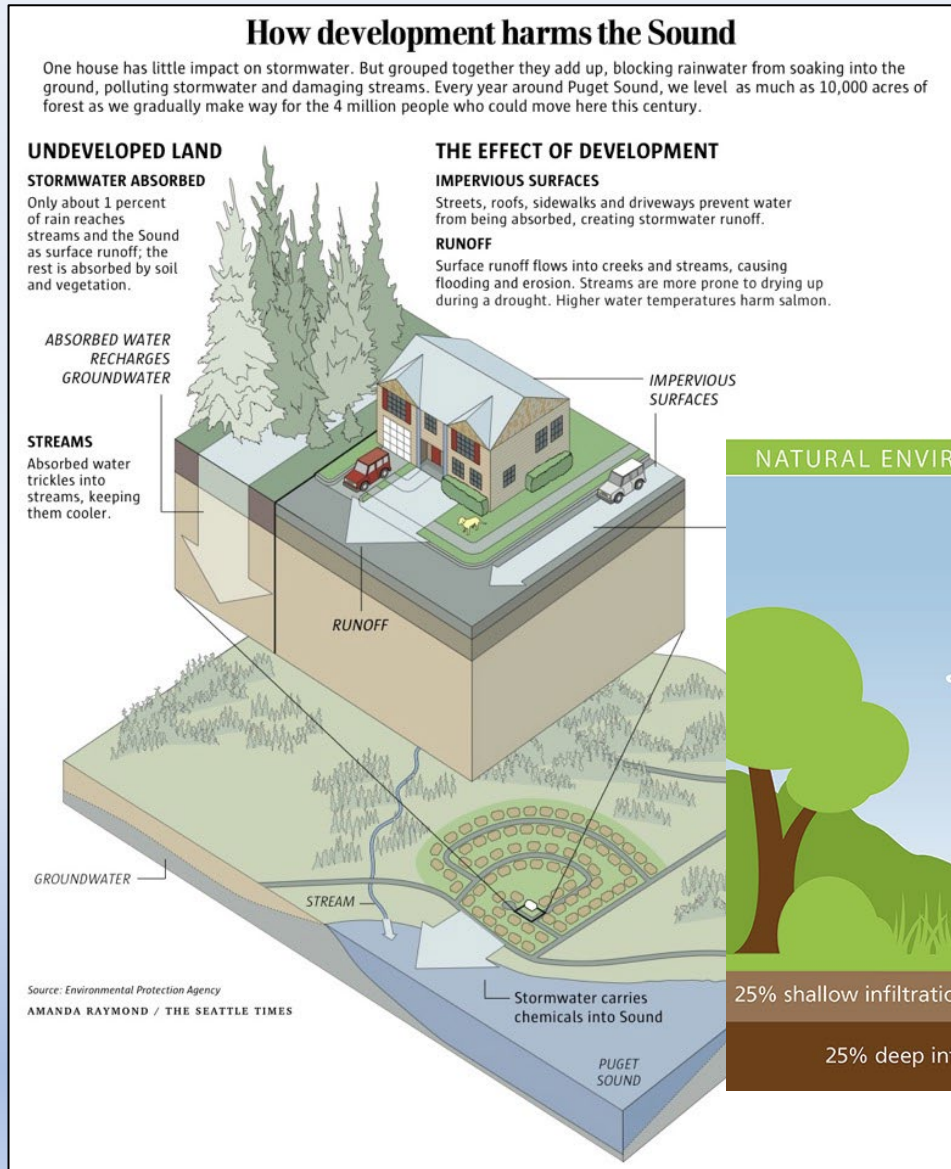
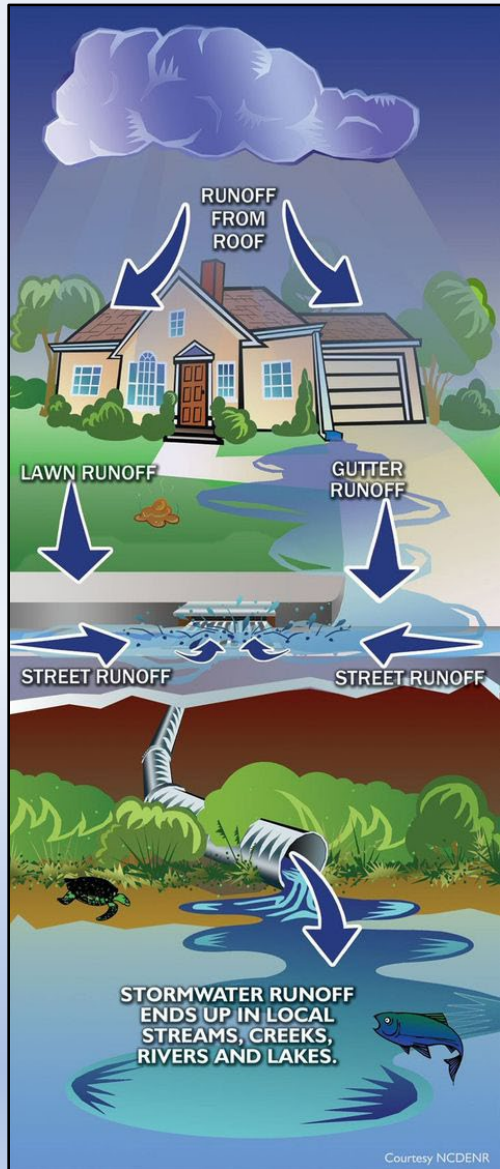
# Population growth and development are intensifying in U.S. coastal watersheds



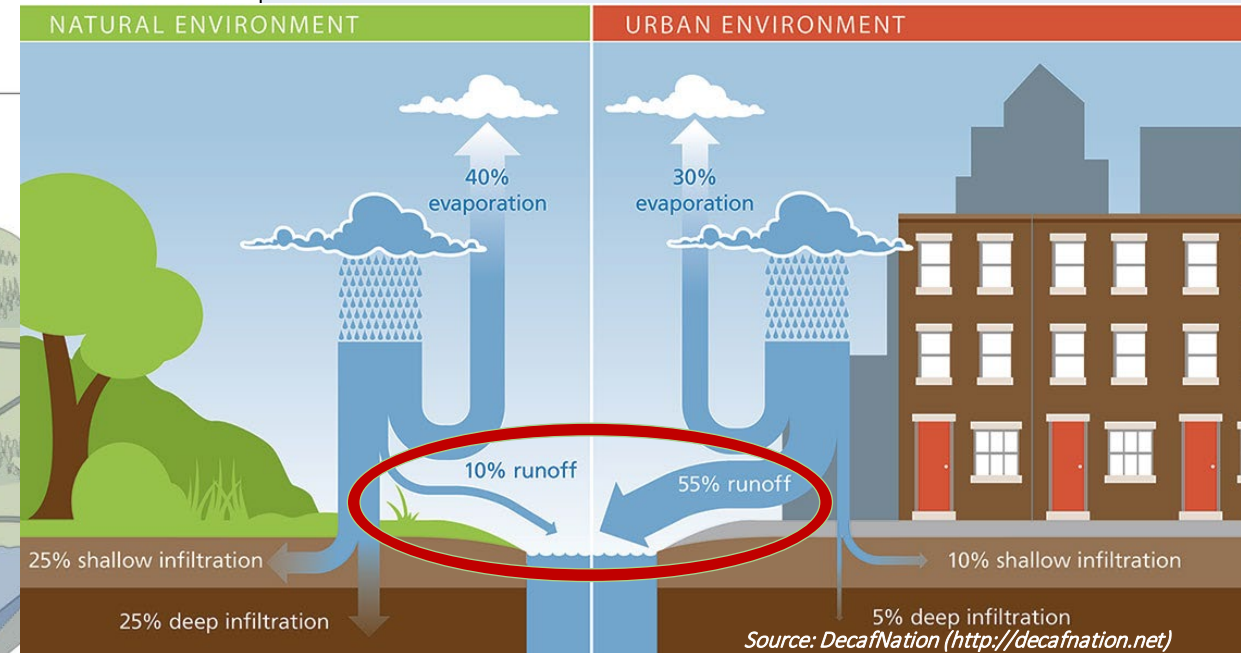
*Land conversion to imperviousness is an ongoing challenge for NOAA's salmon habitat conservation mission, particularly in the context of clean water and salmonid health*



# Land conversion increases non-point source pollution



Untreated runoff represents an exceptionally complicated and expanding habitat challenge for NOAA and other agencies





# The Urban Stream Syndrome: A global phenomenon of ecological decline

- The Urban Stream Syndrome describes a consistently observed ecological degradation of streams draining urban/suburban/exurban landscapes, at site-to-watershed scales.
- Mechanisms are complex and interactive, but are primarily driven by urban stormwater runoff.
- Symptoms include a flashier hydrograph, **elevated contaminants\*** and nutrients, altered channel morphology, and reduced biotic richness, with increased dominance of tolerant species.

*\*very poorly understood*

J. N. Am. Benthol. Soc., 2005, 24(3):706-723  
© 2005 by The North American Benthological Society

## The urban stream syndrome: current knowledge and the search for a cure

CHRISTOPHER J. WALSH<sup>1</sup>

*Cooperative Research Centre for Freshwater Ecology, Water Studies Centre, Sciences, Monash University, Victoria 3800, Australia*

## Global perspectives on the urban stream syndrome

Derek B. Booth<sup>1,5</sup>, Allison H. Roy<sup>2,6</sup>, Benjamin Smith<sup>3,7</sup>, and Krista A. Capps<sup>4,8</sup>

<sup>1</sup>Bren School of Environmental Science and Management, University of California Santa Barbara, Santa Barbara, California 93106 USA

<sup>2</sup>US Geological Survey, Massachusetts Cooperative Fish and Wildlife Research Unit, University of Massachusetts, Amherst, Massachusetts 01003 USA

J. N. Am. Benthol. Soc., 2005, 24(3):602-612  
© 2005 by The North American Benthological Society

## Stream ecosystem function in urbanizing landscapes

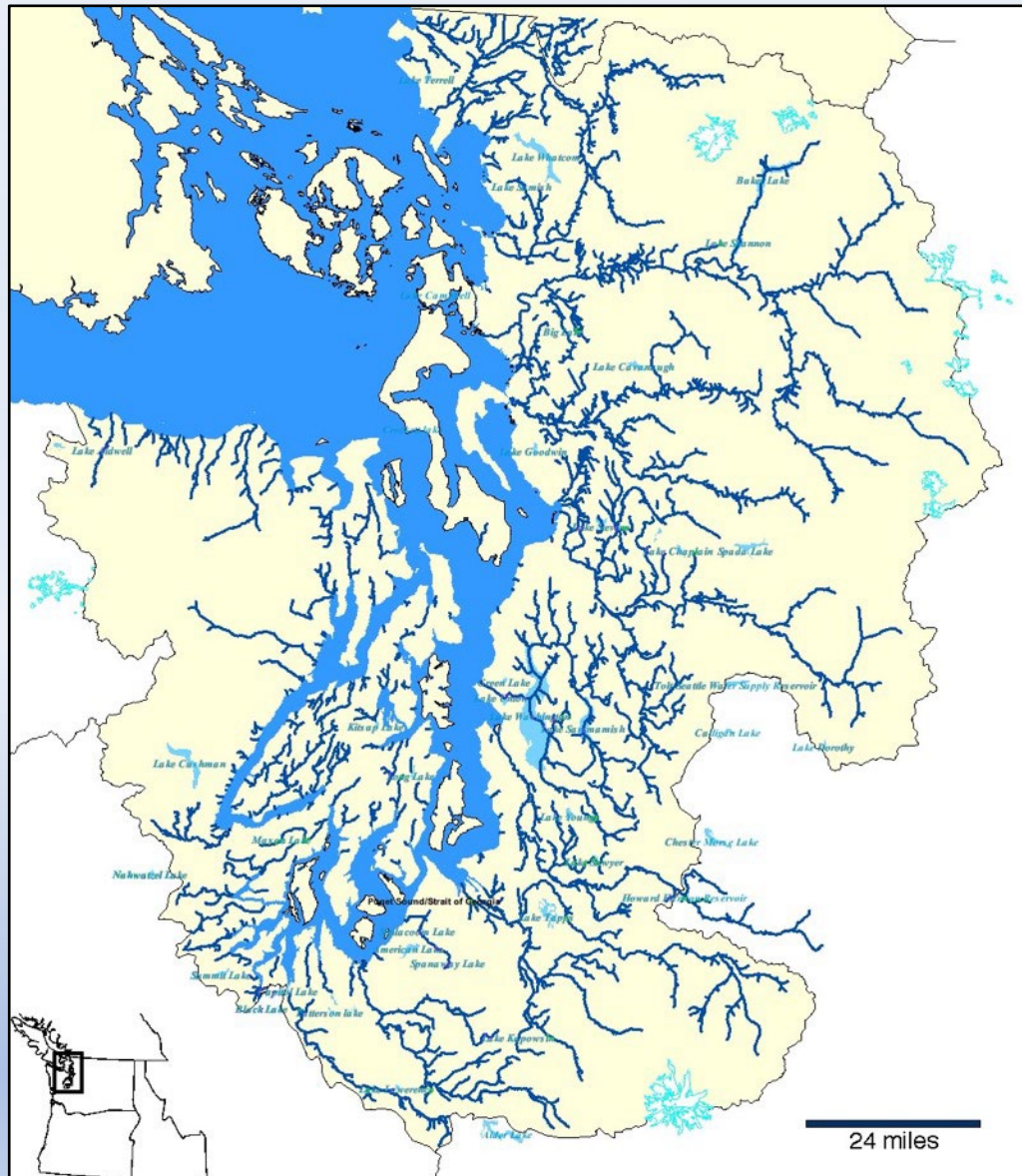
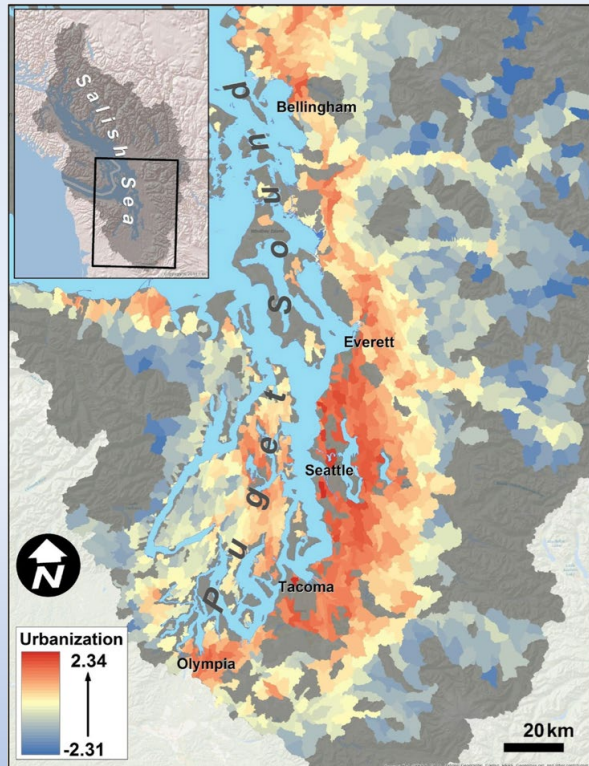
JUDY L. MEYER<sup>1</sup>, MICHAEL J. PAUL<sup>2</sup>, AND W. KEITH TAULBEE<sup>3</sup>

*Institute of Ecology, The University of Georgia, Athens, Georgia 30602 USA*



# Toxic runoff flows through coho habitats

## *Puget Sound*



StreamNet.org

- Widely distributed
- Lowland streams
- > 1 yr in freshwater
- Supported by a diverse food web
- (Very) sensitive to degraded water quality
- ESA focal species





# Coho as sentinels for stormwater runoff toxicity in restored urban streams

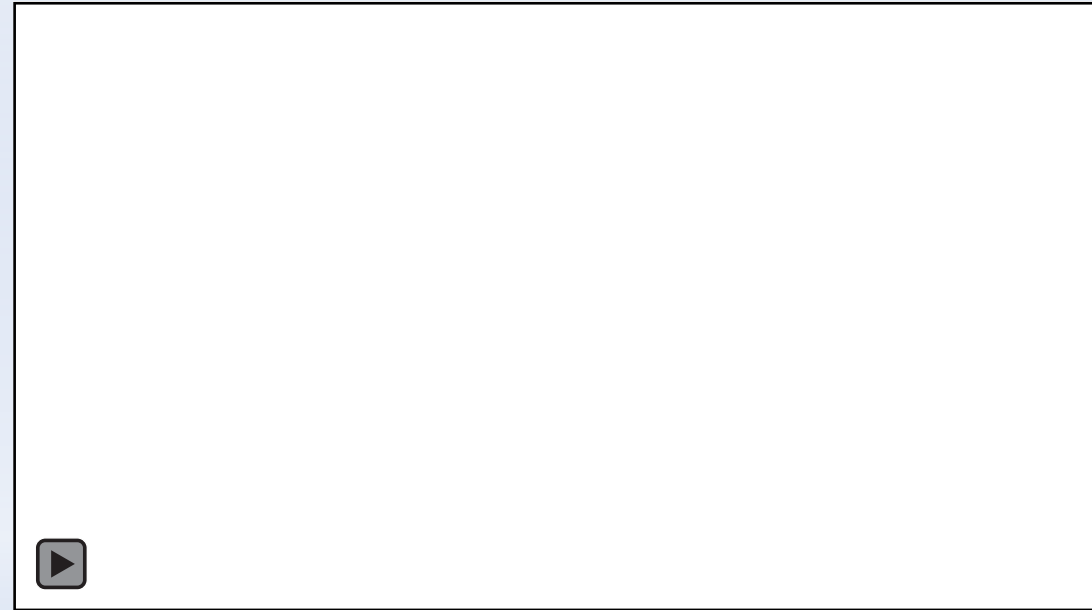
Pre-Restoration (1999)



Fall 2000



Fall 2014



Post-Restoration (2000)



*Katherine Lynch, Seattle Public Utilities*

*Puget Soundkeeper Alliance*



**Pre-spawn mortality in adult female coho – nearly 100% egg retention in carcasses (unspawned).**



# The urban runoff mortality syndrome has been a NOAA-F research focus for more than two decades

## 25<sup>th</sup> Salmonid Restoration Conference

March 7-10, 2007  
Santa Rosa, California



2007

*Celebrating a Generation of Salmonid Restoration and Recovery*

## The case for water quality: 2007



- Pre-spawn mortality is closely associated with small streams that are receiving waters for urban stormwater discharges.
- Symptomatic fish show signs of acute neurological distress, and coho often die within hours of entering spawning habitat.
- Dead fish show no signs of disease or pathogens that might be expected to be lethal. Conventional water quality parameters (e.g., temperature, dissolved oxygen) are also unlikely to be involved.
- Initial evidence indicates that the severity of pre-spawn mortality is linked to the amount and timing of fall rains. In certain years (i.e., 2002), fish only survived to spawn after several rain events.
- Initial evidence indicates that the severity of pre-spawn mortality is linked common sources of non-point source pollutants (e.g., roads).

NOAA FISHERIES  
NATIONAL MARINE FISHERIES SERVICE



## Toxic Runoff to Salmon Habitats: Major Findings From the NOAA Coastal Storms Program

2007

Nat Scholz, Sarah McCarthy, Jenifer McIntyre, Jana Labenia, Mark Myers, Julann Spromberg, John Incardona, Blake Feist, Linda Rhodes, Gina Ylitalo, and Tracy Collier

# The coho urban runoff mortality syndrome: initial findings circa 2010

1

OPEN ACCESS Freely available online PLOS one

## Recurrent Die-Offs of Adult Coho Salmon Returning to Spawn in Puget Sound Lowland Urban Streams

**Nathaniel L. Scholz<sup>1\*</sup>, Mark S. Myers<sup>1</sup>, Sarah G. McCarthy<sup>2</sup>, Jana S. Labenia<sup>1</sup>, Jenifer K. McIntyre<sup>1</sup>, Gina M. Ylitalo<sup>1</sup>, Linda D. Rhodes<sup>1</sup>, Cathy A. Laetz<sup>1</sup>, Carla M. Stehr<sup>1</sup>, Barbara L. French<sup>1</sup>, Bill McMillan<sup>3</sup>, Dean Wilson<sup>2</sup>, Laura Reed<sup>4</sup>, Katherine D. Lynch<sup>4</sup>, Steve Damm<sup>5</sup>, Jay W. Davis<sup>5</sup>, Tracy K. Collier<sup>1</sup>**

<sup>1</sup> Northwest Fisheries Science Center, NOAA Fisheries, Seattle, Washington, United States of America, <sup>2</sup> Department of Natural Resources and Parks, King County, Seattle, Washington, United States of America, <sup>3</sup> Wild Fish Conservancy, Duvall, Washington, United States of America, <sup>4</sup> Seattle Public Utilities, City of Seattle, Seattle, Washington, United States of America, <sup>5</sup> Washington Fish and Wildlife Office, U.S. Fish and Wildlife Service, Lacey, Washington, United States of America

As-yet unidentified toxics in stormwater are likely killing coho salmon. Yearly mortality rates are often high – i.e. > 70% of a total run.

2

OPEN ACCESS Freely available online PLOS one

## Landscape Ecotoxicology of Coho Salmon Spawner Mortality in Urban Streams

**Blake E. Feist<sup>1\*</sup>, Eric R. Buhle<sup>1</sup>, Paul Arnold<sup>2</sup>, Jay W. Davis<sup>2</sup>, Nathaniel L. Scholz<sup>1</sup>**

<sup>1</sup> Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, Washington, United States of America, <sup>2</sup> Washington Fish and Wildlife Office, United States Fish and Wildlife Service, Lacey, Washington, United States of America

Mortality is closely associated with land cover (urbanization). Many Puget Sound watersheds are currently at risk.

3

648 Integrated Environmental Assessment and Management — Volume 7, Number 4—pp. 648–656  
© 2011 SETAC

## Estimating the Future Decline of Wild Coho Salmon Populations Resulting from Early Spawner Die-Offs in Urbanizing Watersheds of the Pacific Northwest, USA

**Julann A Spromberg<sup>†\*</sup> and Nathaniel L Scholz<sup>†</sup>**

<sup>†</sup>National Oceanic and Atmospheric Administration (NOAA) Fisheries, Northwest Fisheries Science Center, 2725 Montlake Boulevard East, Seattle, Washington 98112, USA

Wild coho salmon cannot withstand the high rates of annual spawner die-offs observed in urban/urbanizing watersheds since 2000.



Pre-spawn female coho mortality

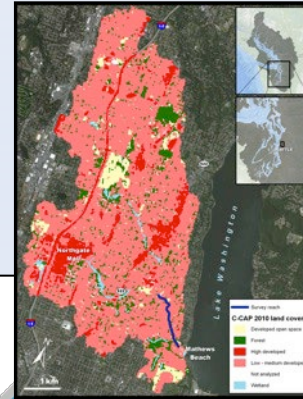


# Basin-wide vulnerability forecasting

*Field survey data  
(coho spawner mortality)*



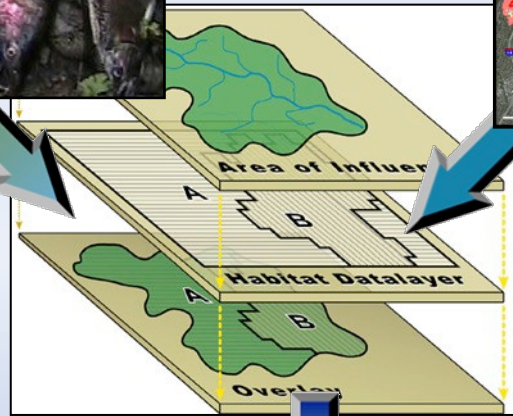
*Land cover data*



## MODEL OVERVIEW

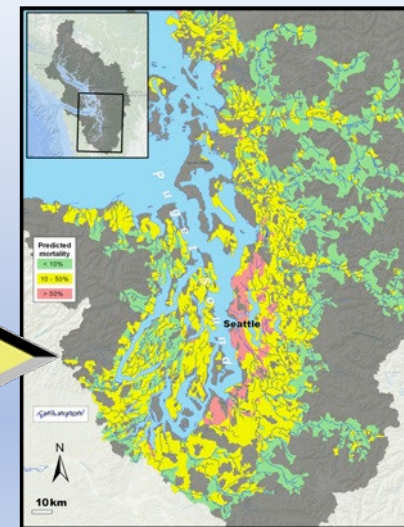
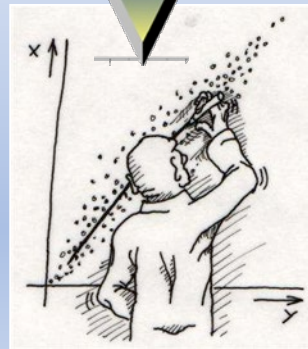
*Geospatial analyses*

**Blake Feist**



*Statistical analyses  
and modeling*

**Eric Buhle**

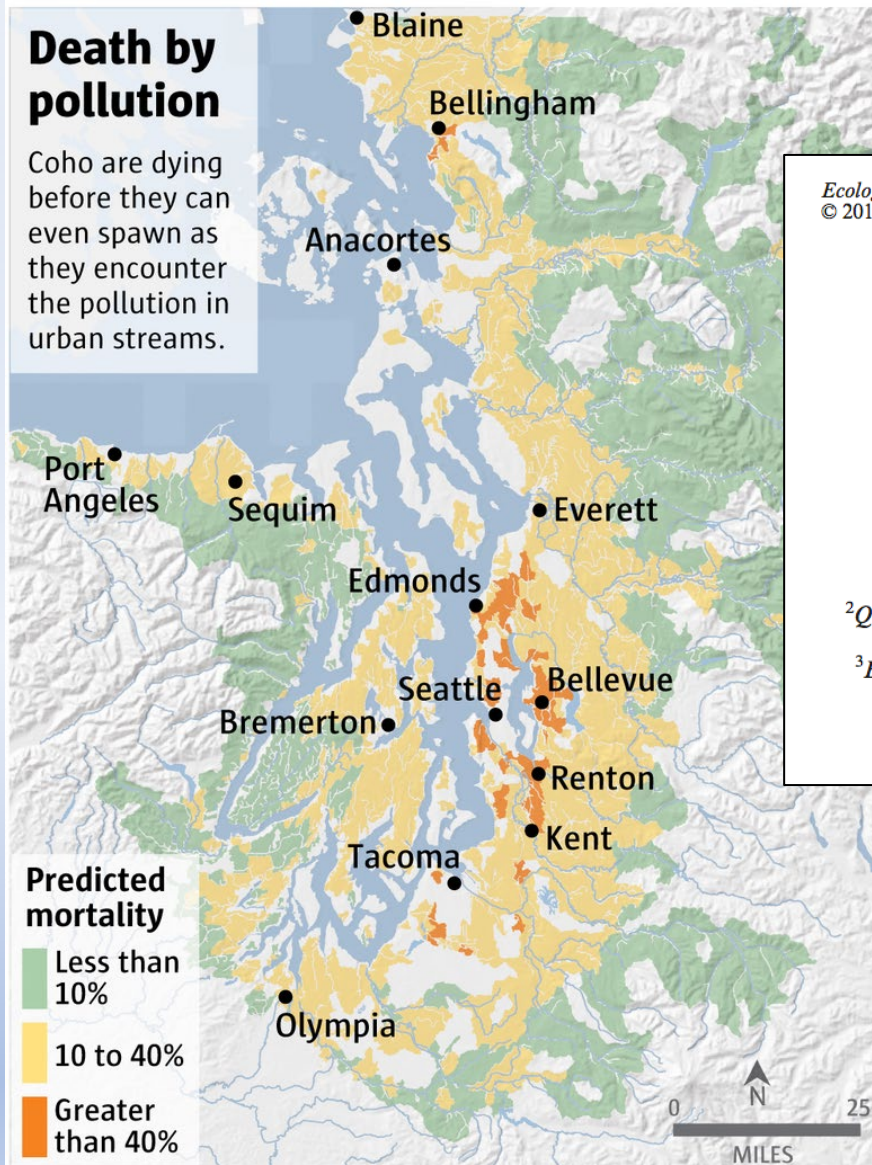


*Predictive  
model for coho  
die-offs in  
Puget Sound  
watersheds*

# Mortality hotspot mapping for coho

## Death by pollution

Coho are dying before they can even spawn as they encounter the pollution in urban streams.



Sources: Esri, NOAA Fisheries

MARK NOWLIN / THE SEATTLE TIMES

*Ecological Applications*, 27(8), 2017, pp. 2382–2396  
© 2017 by the Ecological Society of America

## Roads to ruin: conservation threats to a sentinel species across an urban gradient

BLAKE E. FEIST,<sup>1,5</sup> ERIC R. BUHLE,<sup>2</sup> DAVID H. BALDWIN,<sup>3</sup> JULANN A. SPROMBERG,<sup>3</sup> STEVEN E. DAMM,<sup>4</sup> JAY W. DAVIS,<sup>4</sup> AND NATHANIEL L. SCHOLZ<sup>3</sup>

<sup>1</sup>*Conservation Biology Division, Northwest Fisheries Science Center, National Marine Fisheries Service, NOAA, 2725 Montlake Boulevard East, Seattle, Washington 98112 USA*

<sup>2</sup>*Quantitative Consultants, Inc., Under contract to Northwest Fisheries Science Center, National Marine Fisheries Service, NOAA, 2725 Montlake Boulevard East, Seattle, Washington 98112 USA*

<sup>3</sup>*Environmental and Fisheries Sciences Division, Northwest Fisheries Science Center, National Marine Fisheries Service, NOAA, 2725 Montlake Boulevard East, Seattle, Washington 98112 USA*

<sup>4</sup>*Washington Fish and Wildlife Office, United States Fish and Wildlife Service, 510 Desmond Drive SE, Lacey, Washington 98392 USA*

*So... what's killing the coho?*



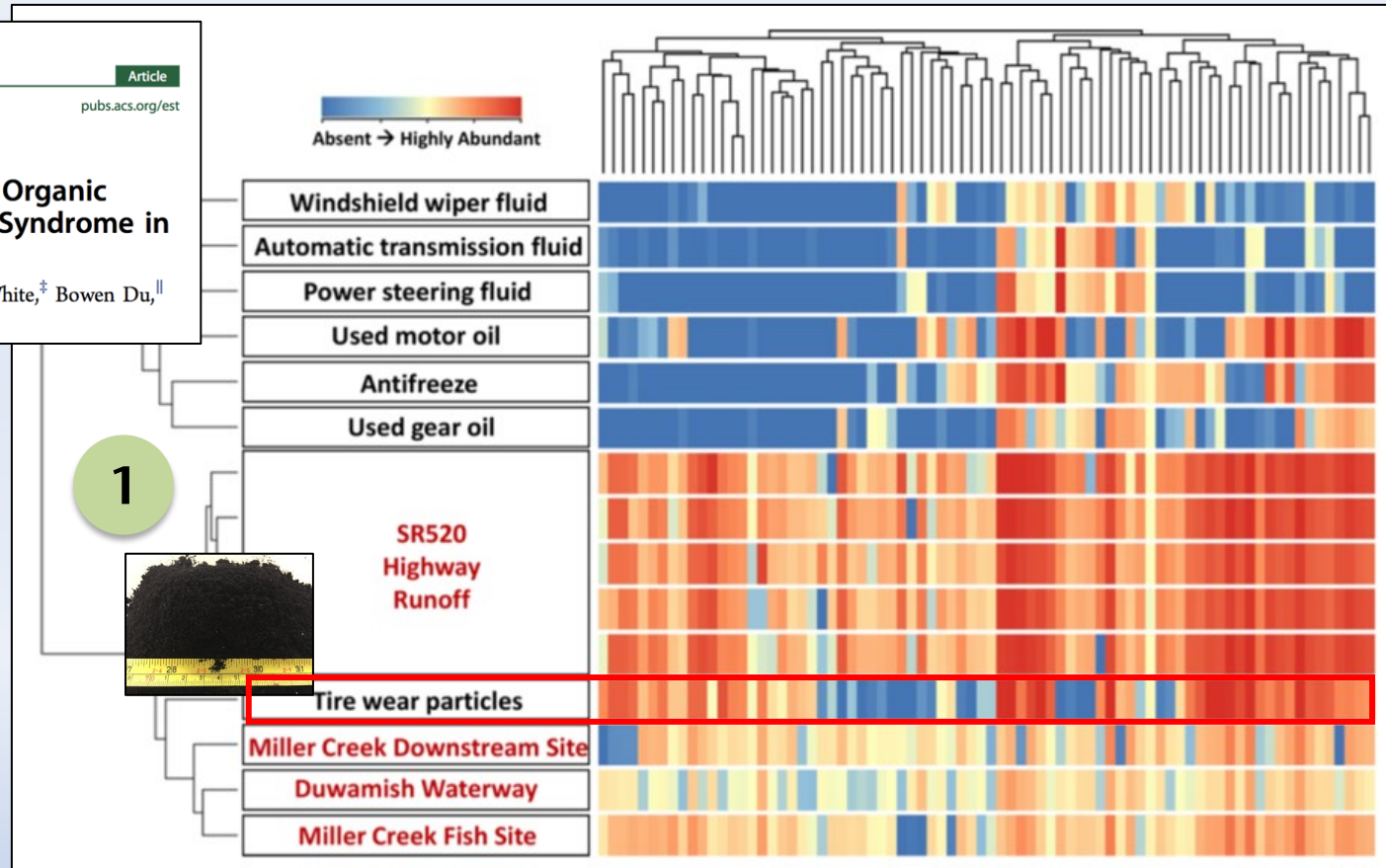
# A decade ago, two major obstacles

**ENVIRONMENTAL Science & Technology** Article  
 Cite This: *Environ. Sci. Technol.* 2018, 52, 10317–10327  
 pubs.acs.org/est

**Using High-Resolution Mass Spectrometry to Identify Organic Contaminants Linked to Urban Stormwater Mortality Syndrome in Coho Salmon**

Katherine T. Peter,<sup>\*,†,‡,§</sup> Zhenyu Tian,<sup>†,‡,§</sup> Christopher Wu,<sup>†,‡</sup> Peter Lin,<sup>‡</sup> Sarah White,<sup>‡</sup> Bowen Du,<sup>||</sup> Jenifer K. McIntyre,<sup>⊥</sup> Nathaniel L. Scholz,<sup>#</sup> and Edward P. Kolodziej<sup>†,‡,§</sup>

*Analytical methods to break complex stormwater mixtures into component chemical constituents*



Aquatic Toxicology 214 (2019) 105231  
 Contents lists available at ScienceDirect  
**Aquatic Toxicology**  
 journal homepage: [www.elsevier.com/locate/aqtox](http://www.elsevier.com/locate/aqtox)

An urban stormwater runoff mortality syndrome in juvenile coho salmon

Michelle I. Chow<sup>a</sup>, Jessica I. Lundin<sup>b</sup>, Chelsea J. Mitchell<sup>c</sup>, Jay W. Davis<sup>d</sup>, Graham Young<sup>a</sup>, Nathaniel L. Scholz<sup>e</sup>, Jenifer K. McIntyre<sup>c,\*</sup>

<sup>a</sup> University of Washington, School of Aquatic and Fisheries Sciences, 1122 Boat St., Seattle, WA 98105, USA

<sup>b</sup> National Research Council Research Associateship Program, Under contract to Northwest Fisheries Science Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112, USA

<sup>c</sup> Washington State University, Puyallup Research and Extension Center, 2606 W. Pioneer Ave., Puyallup, WA 98371, USA

<sup>d</sup> U.S. Fish and Wildlife Service, Washington Fish and Wildlife Office, 510 Desmond Dr. S.E., Lacey, WA 98503, USA

<sup>e</sup> Environmental and Fisheries Science Division, Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 2725 Montlake Blvd. E., Seattle, WA 98112, USA



*(Relatively) high throughput methods focused on juvenile salmonids*

# A novel chemical enters the mix

Science

EMBARGOED UNTIL 2:00PM US ET, THURSDAY 3 DECEMBER 2020

REPORTS

## 6PPD-quinone

Cite as: Z. Tian *et al.*, *Science*  
10.1126/science.abd6951 (2020).

### A ubiquitous tire rubber-derived chemical induces acute mortality in coho salmon

Zhenyu Tian<sup>1,2</sup>, Haoqi Zhao<sup>3</sup>, Katherine T. Peter<sup>1,2</sup>, Melissa Gonzalez<sup>1,2</sup>, Jill Wetzel<sup>4</sup>, Christopher Wu<sup>1,2</sup>, Ximin Hu<sup>3</sup>, Jasmine Prat<sup>4</sup>, Emma Mudrock<sup>4</sup>, Rachel Hettinger<sup>1,2</sup>, Allan E. Cortina<sup>1,2</sup>, Rajshree Ghosh Biswas<sup>5</sup>, Flávio Vinicius Crizóstomo Kock<sup>5</sup>, Ronald Soong<sup>5</sup>, Amy Jenne<sup>5</sup>, Bowen Du<sup>6</sup>, Fan Hou<sup>3</sup>, Huan He<sup>3</sup>, Rachel Lundeen<sup>1,2</sup>, Alicia Gilbreath<sup>7</sup>, Rebecca Sutton<sup>7</sup>, Nathaniel L. Scholz<sup>8</sup>, Jay W. Davis<sup>9</sup>, Michael C. Dodd<sup>3</sup>, Andre Simpson<sup>5</sup>, Jenifer K. McIntyre<sup>4</sup>, Edward P. Kolodziej<sup>1,2,3\*</sup>

<sup>1</sup>Center for Urban Waters, Tacoma, WA 98421, USA. <sup>2</sup>Interdisciplinary Arts and Sciences, University of Washington Tacoma, Tacoma, WA 98421, USA. <sup>3</sup>Department of Civil and Environmental Engineering, University of Washington, Seattle, WA 98195, USA. <sup>4</sup>School of the Environment, Washington State University, Puyallup, WA 98371, USA. <sup>5</sup>Department of Chemistry, University of Toronto, Scarborough Campus, 1265 Military Trail, Toronto, ON M1C1A4, Canada. <sup>6</sup>Southern California Coastal Water Research Project, Costa Mesa, CA 92626, USA. <sup>7</sup>San Francisco Estuary Institute, 4911 Central Avenue, Richmond, CA 94804, USA. <sup>8</sup>Environmental and Fisheries Sciences Division, Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, WA 98112, USA. <sup>9</sup>United States Fish and Wildlife Service, Washington Fish and Wildlife Office, Lacey, WA 98503, USA.

\*Corresponding author. Email: [koloj@uw.edu](mailto:koloj@uw.edu)

**In U.S. Pacific Northwest coho salmon (*Oncorhynchus kisutch*), stormwater exposure annually causes unexplained acute mortality when adult salmon migrate to urban creeks to reproduce. By investigating this phenomenon, we identified a highly toxic quinone transformation product of N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine (6PPD), a globally ubiquitous tire rubber antioxidant. Retrospective analysis of representative roadway runoff and stormwater-impacted creeks of the U.S. West Coast indicated widespread occurrence of 6PPD-quinone (<0.3-19 µg/L) at toxic concentrations (LC<sub>50</sub> of 0.8 ± 0.16 µg/L). These results reveal unanticipated risks of 6PPD antioxidants to an aquatic species and imply toxicological relevance for dissipated tire rubber residues.**



Zhenyu Tian, lead author, UW Center for Urban Waters (Kolodziej Lab)



# Conservation-oriented mitigation strategies



**bioretention**



*Examples of green  
stormwater  
infrastructure*



**permeable pavement**



*Over the next  
decade, a focus on  
mitigation (and  
mitigation  
effectiveness)*



# Simple bioretention methods are highly protective

## Journal of Applied Ecology



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<sup>1</sup>, David H. Baldwin<sup>2</sup>, Steven E. Damm<sup>3</sup>, Jenifer K. McIntyre<sup>4</sup>, Michael Huff<sup>5</sup>, Catherine A. Sloan<sup>2</sup>, Bernadita F. Anulacion<sup>2</sup>, Jay W. Davis<sup>3</sup> and Nathaniel L. Scholz<sup>2\*</sup>

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



Contents lists available at [ScienceDirect](#)

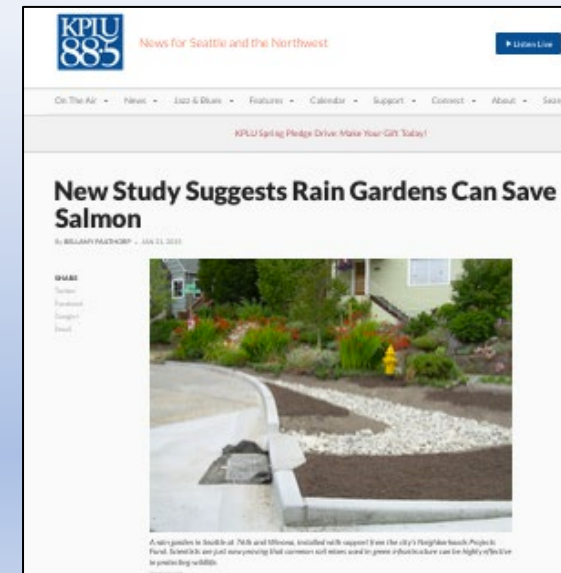
## Science of the Total Environment

journal homepage: [www.elsevier.com/locate/scitotenv](http://www.elsevier.com/locate/scitotenv)




### Bioretention filtration prevents acute mortality and reduces chronic toxicity for early life stage coho salmon (*Oncorhynchus kisutch*) episodically exposed to urban stormwater runoff

Jenifer K. McIntyre<sup>a,\*</sup>, Julann Spromberg<sup>b</sup>, James Cameron<sup>c</sup>, John P. Incardona<sup>b</sup>, Jay W. Davis<sup>d</sup>, Nathaniel L. Scholz<sup>b</sup>





# Infiltration protects other aquatic species as well



zebrafish

Article  
pubs.acs.org/est

**ENVIRONMENTAL Science & Technology**

**Confirmation of Stormwater Bioretention Treatment Effectiveness Using Molecular Indicators of Cardiovascular Toxicity in Developing Fish**


Jenifer K. McIntyre,<sup>\*,†</sup> Richard C. Edmunds,<sup>‡</sup> Maria G. Redig,<sup>§</sup> Emma M. Mudrock,<sup>†</sup> Jay W. Davis,<sup>||</sup> John P. Incardona,<sup>⊥</sup> John D. Stark,<sup>†</sup> and Nathaniel L. Scholz<sup>⊥</sup>

<sup>†</sup>Puyallup Research and Extension Center, Washington State University, 2606 West Pioneer Avenue, Puyallup, Washington 98371, United States  
<sup>‡</sup>National Research Associateship Program and <sup>⊥</sup>Environmental and Fisheries Science Division, Northwest Fisheries Science Center, National Marine Fisheries Service, NOAA, 2725 Montlake Boulevard East, Seattle, Washington 98112, United States  
<sup>§</sup>Evergreen State College, 2700 Parkway NW, Olympia, Washington 98505, United States  
<sup>||</sup>U.S. Fish and Wildlife Service, Washington Fish and Wildlife Office, 510 Desmond Drive S.E., Lacey, Washington 98503, United States



ELSEVIER

Chemosphere  
Volume 132, August 2015, Pages 213-219




Chemosphere

**Soil bioretention protects juvenile salmon and their prey from the toxic impacts of urban stormwater runoff**

J.K. McIntyre <sup>a</sup> ✉, J.W. Davis <sup>b</sup>, C. Hinman <sup>a</sup>, K.H. Macneale <sup>c</sup>, B.F. Anulacion <sup>c</sup>, N.L. Scholz <sup>c</sup>, J.D. Stark <sup>a</sup>


Science of the Total Environment 500-501 (2014) 173-180

Contents lists available at ScienceDirect



Science of the Total Environment


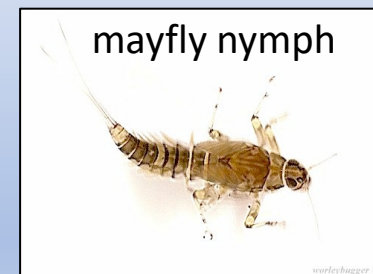
journal homepage: [www.elsevier.com/locate/scitotenv](http://www.elsevier.com/locate/scitotenv)



**Zebrafish and clean water technology: Assessing soil bioretention as a protective treatment for toxic urban runoff**

J.K. McIntyre <sup>a,\*</sup>, J.W. Davis <sup>b</sup>, J.P. Incardona <sup>c</sup>, J.D. Stark <sup>a</sup>, B.F. Anulacion <sup>c</sup>, N.L. Scholz <sup>c</sup>

<sup>a</sup> Washington State University Puyallup Research & Extension Center, 2606 W Pioneer Ave, Puyallup, WA 98371, USA  
<sup>b</sup> U.S. Fish & Wildlife Service Washington Fish & Wildlife Office, 510 Desmond Dr. SE, Lacey, WA 98503, USA  
<sup>c</sup> NOAA-NMFS Northwest Science Center, 2725 Montlake Blvd E, Seattle, WA 98112, USA

# Not all salmonids are equally vulnerable to 6PPD-q

Contents lists available at ScienceDirect

**Environmental Pollution**

journal homepage: [www.elsevier.com/locate/envpol](http://www.elsevier.com/locate/envpol)

Interspecies variation in the susceptibility of adult Pacific salmon to toxic urban stormwater runoff\*

Jenifer K. McIntyre <sup>a,\*</sup>, Jessica I. Lundin <sup>b</sup>, James R. Cameron <sup>c</sup>, Michelle I. Chow <sup>d</sup>, Jay W. Davis <sup>e</sup>, John P. Incardona <sup>f</sup>, Nathaniel L. Scholz <sup>f</sup>

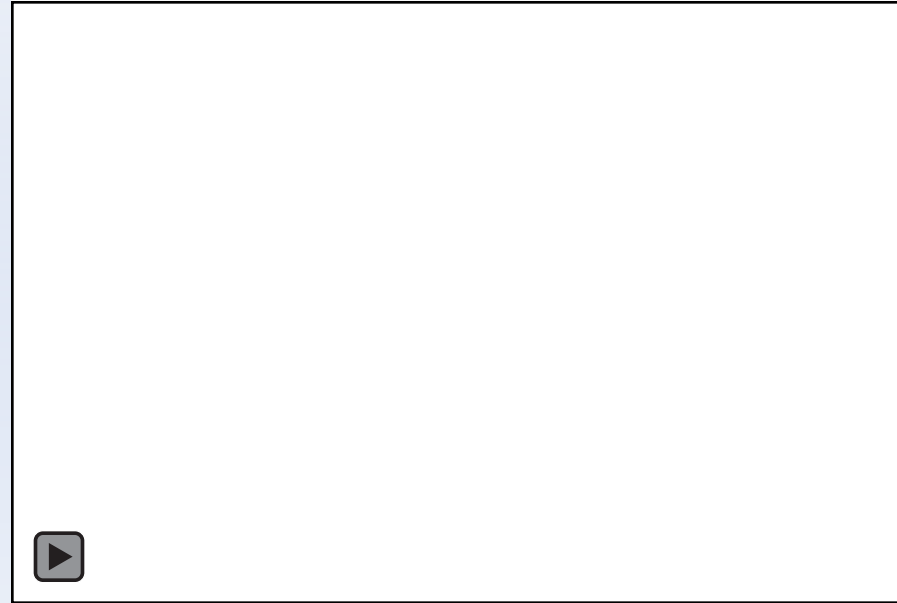
**ENVIRONMENTAL**  
Science & Technology

pubs.acs.org/est

Article

**Treading Water: Tire Wear Particle Leachate Recreates an Urban Runoff Mortality Syndrome in Coho but Not Chum Salmon**

Jenifer K. McIntyre,\* Jasmine Prat, James Cameron, Jillian Wetzels, Emma Mudrock, Katherine T. Peter, Zhenyu Tian, Cailin Mackenzie, Jessica Lundin, John D. Stark, Kenneth King, Jay W. Davis, Edward P. Kolodziej, and Nathaniel L. Scholz



coho



chum

Untreated urban runoff AND tire leachate are acutely lethal to coho and steelhead, but not chum or sockeye

**ENVIRONMENTAL**  
Science & Technology **LETTERS**

pubs.acs.org/journal/estlcu

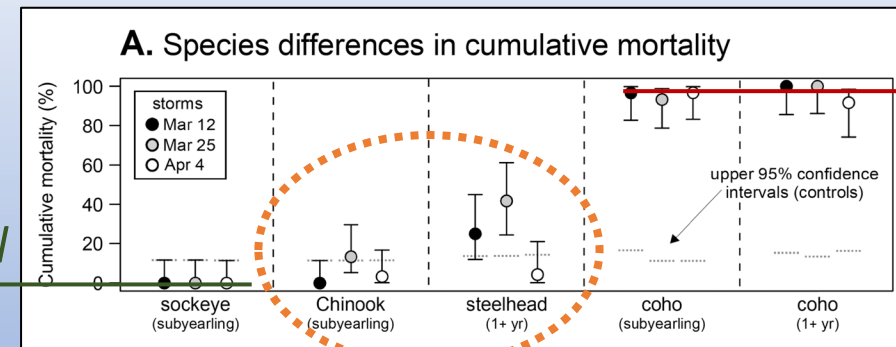
Letter

**Urban Roadway Runoff Is Lethal to Juvenile Coho, Steelhead, and Chinook Salmonids, But Not Congeneric Sockeye**

B. F. French, D. H. Baldwin, J. Cameron, J. Prat, K. King, J. W. Davis, J. K. McIntyre, and N. L. Scholz\*

Cite This: *Environ. Sci. Technol. Lett.* 2022, 9, 733–738

Read Online



100% survival

100% mortality

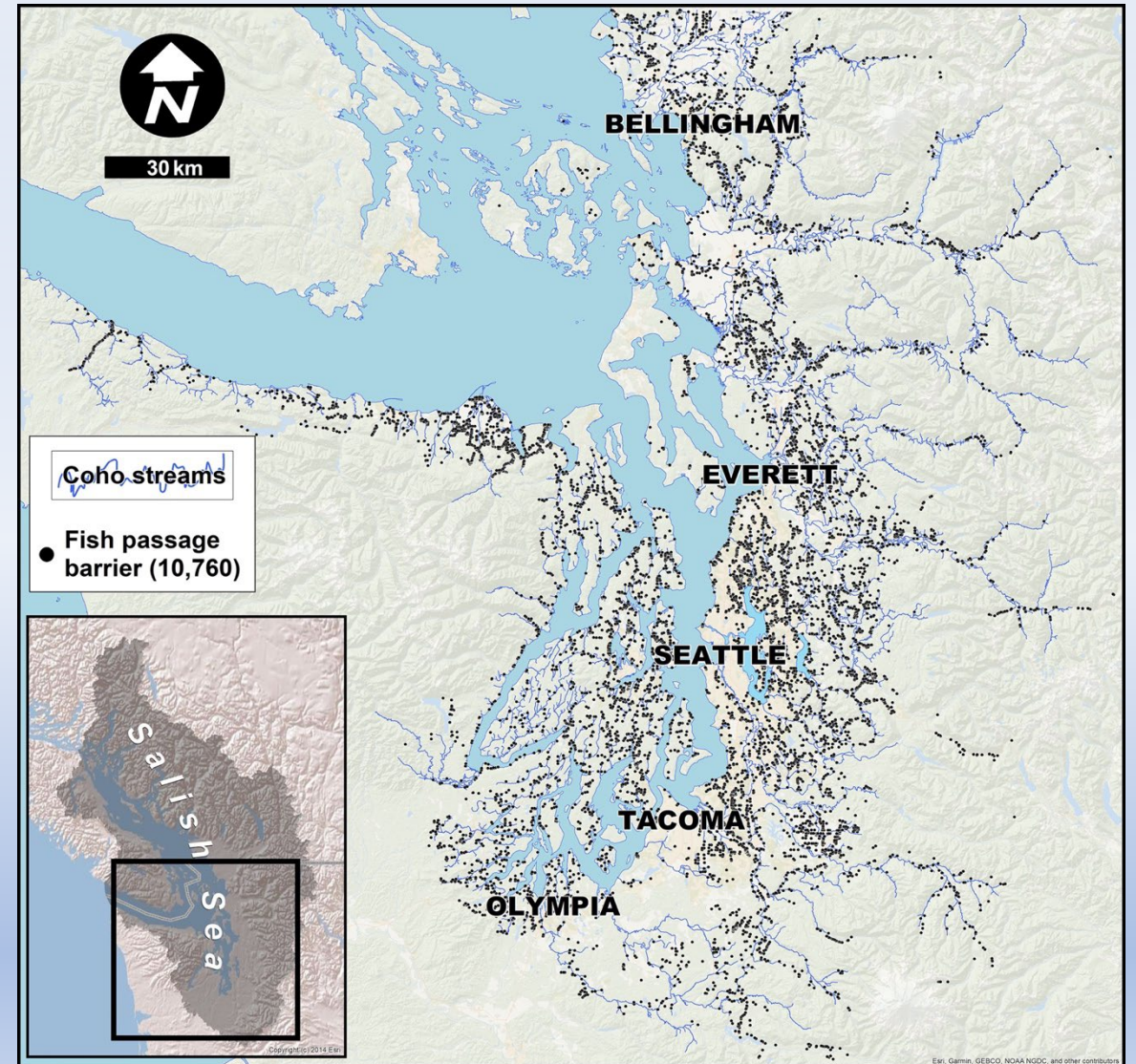
Future NOAA research will be extensively focused on sublethal toxicity, particularly in steelhead and Chinook



# Mapping coho and steelhead vulnerability: fish passage barrier locations in Puget Sound

Map indicates the approximate distribution of >10,000 salmon migration barriers in Puget Sound; many are priorities for physical habitat restoration by federal, state, and local agencies

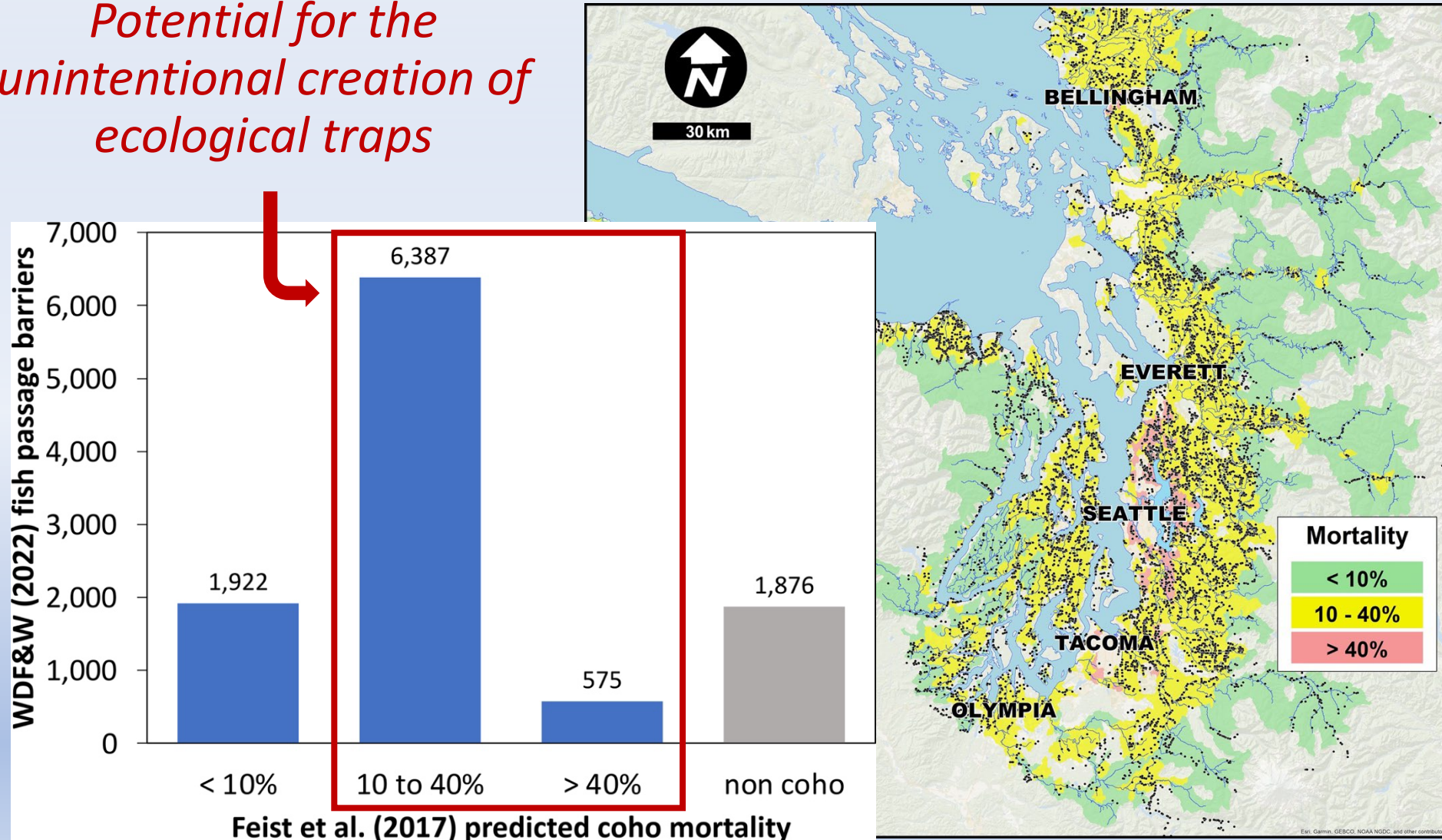
*Source: Washington State Department of Fish and Wildlife geodatabase (2022)*





# Mapping coho and steelhead vulnerability: fish passage barrier locations in Puget Sound

*Potential for the unintentional creation of ecological traps*





# Salmon are vulnerable to a wide range of known toxicants

## Urban Stormwater Runoff

*known contaminant threats, circa 2010*

### Copper

Found in vehicle brake pads and some boat-hull paint.

### PBDEs

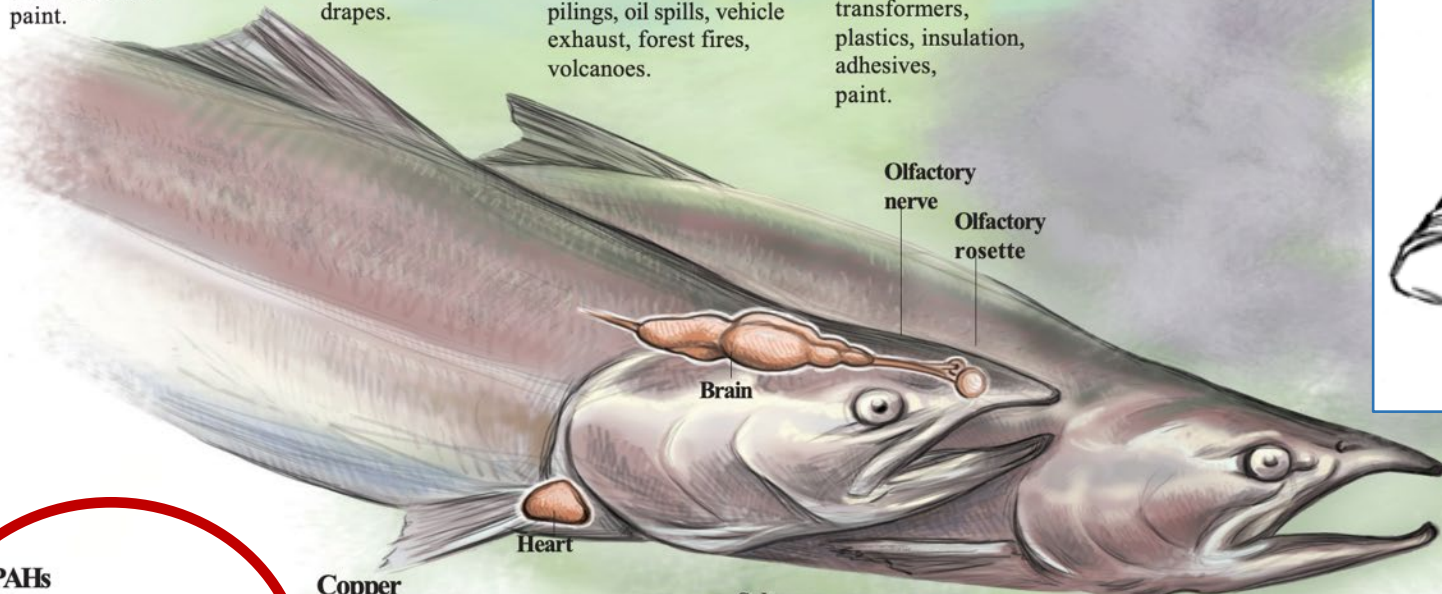
Flame retardants found in sofa cushions, computers, wire insulation, drapes.

### PAHs

Asuite of chemicals created by burning and released by creosote pilings, oil spills, vehicle exhaust, forest fires, volcanoes.

### PCBs

Banned but long-lived organic chemicals found in transformers, plastics, insulation, adhesives, paint.

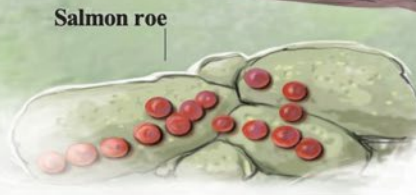


### PAHs

PAHs are attracted to fish embryos like magnets. Even tiny doses can change the shape of a developing fish's heart, causing the fish to be too slow to escape predators.

### Copper

Brief doses can alter how baby fish smell, which is key to eluding predators. It can also affect how fish sense water movements when predators approach.



### PBDEs/PCBs

These chemicals build up over time, especially in fatty fish like chinook — the preferred food for orcas. They can make marine life more susceptible to disease. May be harmful to children of pregnant women who eat contaminated fish.



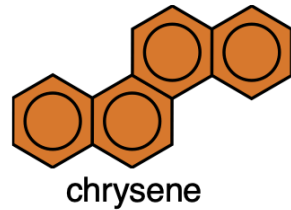
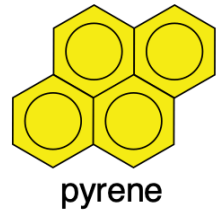
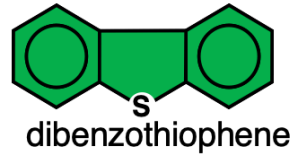
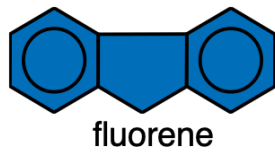
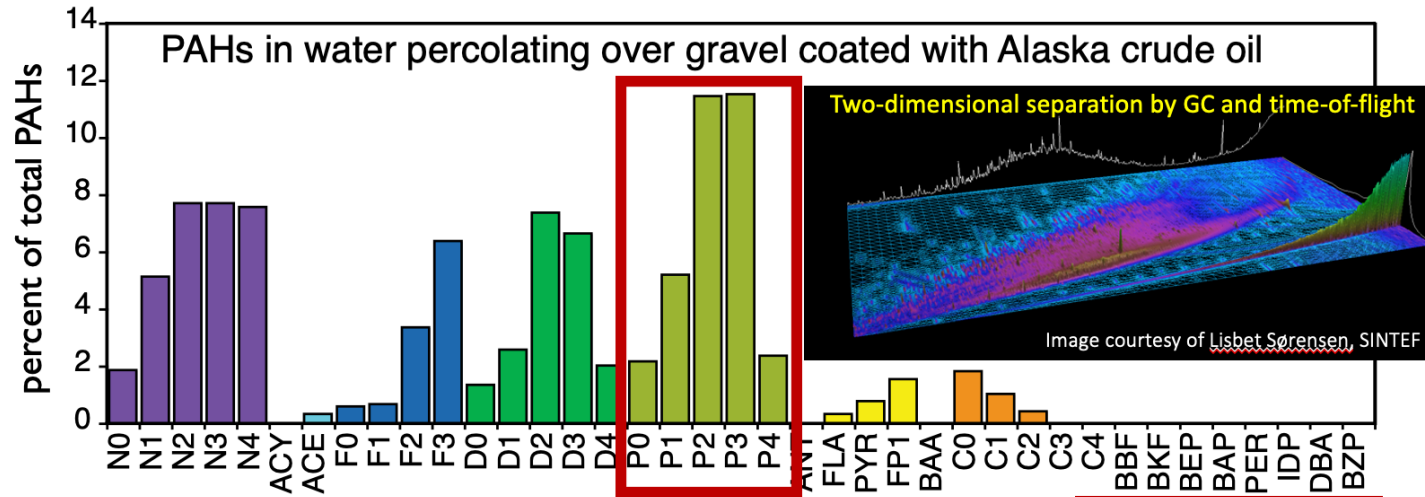
*Seattle Post-Intelligencer, 2004*

*Motor vehicles continue to be a major source of non-point source pollution*

Source: Department of Ecology; Northwest Fisheries Science Center; U.S. Geological Survey; Agency for Toxic Substances and Disease Registry; National Marine Fisheries Service Auke Bay Laboratory.



# Polycyclic aromatic hydrocarbons (PAHs) – major contaminants in crude oil and roadway runoff



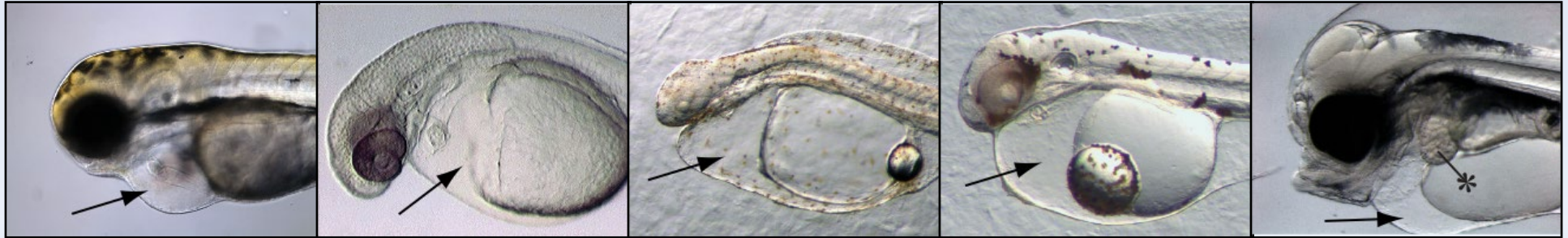


# PAHs that are ubiquitous in stormwater runoff cause heart failure in a diversity of fish species

*Unexposed*



*PAH-exposed*



**ZEBRAFISH**  
(cyprinid)  
Louisiana MC252

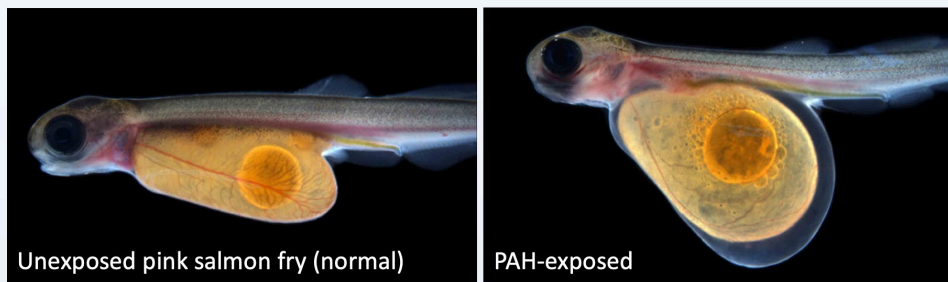
**HERRING**  
(clupeid)  
Alaska North Slope

**FLOUNDER**  
(perciform)  
Iranian heavy

**SEA PERCH**  
(perciform)  
Iranian heavy

**HADDOCK**  
(gadid)  
Norwegian Sea

*Scholz and Incardona, 2015, Environmental Toxicology and Chemistry, 34:459*



Unexposed pink salmon fry (normal)

PAH-exposed

*Suggests a conserved mechanism for tricyclic PAH-mediated toxicity to the developing fish heart*

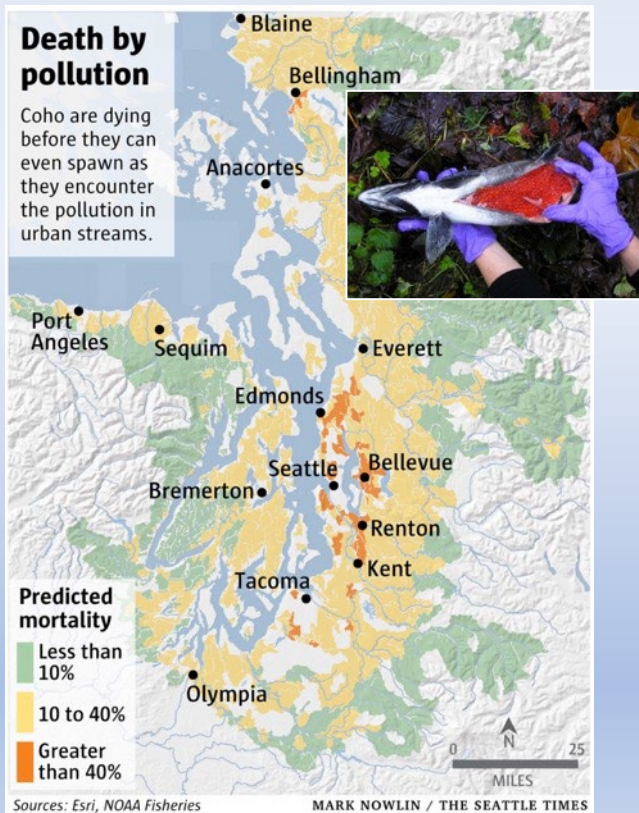


# 2017-2021 Federal Action Plan – Stormwater

## *Overarching and shared goals across federal natural resource agencies*

1

Define the nature and extent of stormwater threats to Puget Sound



2

Identify affordable and effective clean water mitigation strategies



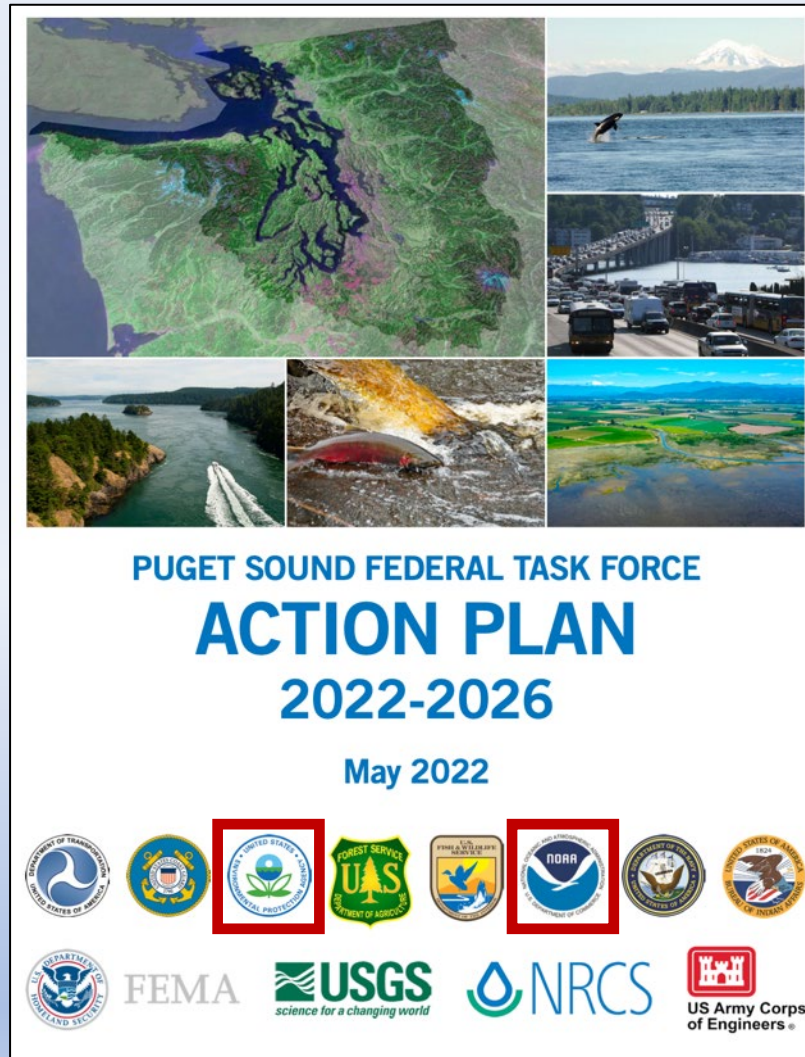
3

Promote the building of green cities and communities





# Reducing stormwater threats to the health of Puget Sound: a shared challenge across U.S. federal agencies



*EPA in particular is in a lead coordinating role for stormwater science and management in Puget Sound, including funding for targeted research to support the Federal Task Force Action Plan*

## 25<sup>th</sup> Salmonid Restoration Conference

March 7-10, 2007  
Santa Rosa, California

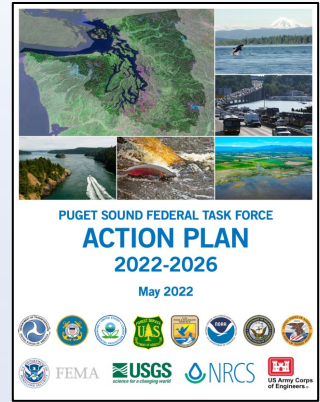


2007

Celebrating a Generation of Salmonid Restoration and Recovery

# NOAA-F research goals: back to the future

2024



## Research goals then

### Objectives for 2008 and beyond... 2007

- Clarify the role of toxics in stormwater as a limiting factor for salmon conservation and recovery.
- Forecast threats to wild populations using more sophisticated life cycle models and GIS-based land use/land cover analyses.
- Explore the interplay between regional climate change and urbanization as current and future drivers for toxic terrestrial runoff.
- Determine the indirect impacts of toxics on salmon via the aquatic food web.
- Focus new research on cost-effective mitigation strategies that work.
- More and better outreach to resource managers and local communities.



## Research goals now

- Enhance analytical throughput for known and emerging contaminants in roadway runoff, including 6PPD-q.
- Define toxic mechanisms for 6PPD-q, alone and in combination with other stormwater chemicals (i.e., PAHs).
- Determine sublethal, delayed-in-time toxicity for 6PPD-q and other tire-derived chemicals, particularly in juvenile steelhead.
- Multi-stressor studies to understand how ongoing urban growth (toxic stress) and climate change (thermal stress) converge.
- Updated life-cycle modeling to scale lethal and sublethal stormwater toxicity to ESA-listed wild salmonid populations.
- Updated and extended land use/cover threat modeling, to include other west coast watersheds, other species/life stages, etc.



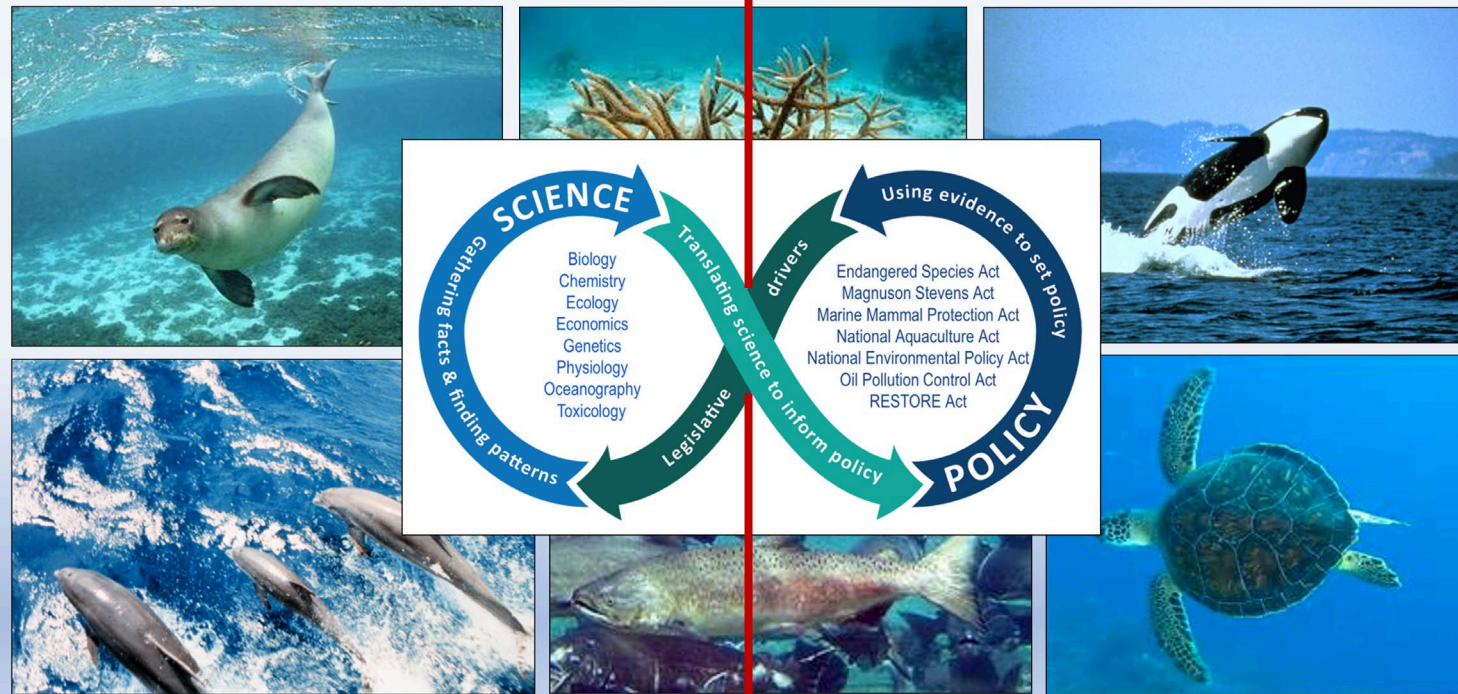
# The policy-science feedback loop for NOAA Fisheries

*Habitats and endangered species are major drivers for applied Ecotox research*

**Science** (Northwest Fisheries Science Center)

**Management** (West Coast Regional Office)

- Environmental monitoring
- Analytical chemistry
- Mechanisms of toxicity
- Threshold determination
- Chemical mixtures
- Multi-stressor interactions
- Population modeling
- Landscape-scale modeling
- Ecological risk assessment



*The WCRO applies emerging science in a wide range of natural resource management contexts – i.e., the “so what?” questions as they relate to the NOAA conservation mission*

*Follow-up questions specific to NOAA-F science:  
Nat Scholz ([nathaniel.scholz@noaa.gov](mailto:nathaniel.scholz@noaa.gov))*

*Follow-up questions specific to NOAA-F management:  
Joe Dillon ([joseph.j.dillon@noaa.gov](mailto:joseph.j.dillon@noaa.gov))*

To access scientific publications, search “nat scholz google scholar”



# Washington State DOT

Tony Bush, Stormwater Branch Manager

Sheena Pietzold, Stormwater Permit Program Manager

Tatiana Dreisbach, Stormwater Retrofit Outreach & Innovation Lead

Jeff Dreier, Fish & Wildlife Program Manager





# **WSDOT Response to 6PPD-quinone**

## **WSDOT STORMWATER MANAGEMENT**

Tony Bush, Stormwater Branch Manager

Tatiana Dreisbach, Stormwater Retrofit Outreach & Innovation Lead

Sheena Pietzold, Stormwater Management Program Manager

Jeff Dreier, Fish and Wildlife Program Manager

November 2, 2023

Roger Millar, Secretary of Transportation  
Amy Scarton, Deputy Secretary of Transportation

# Stormwater management organization at WSDOT



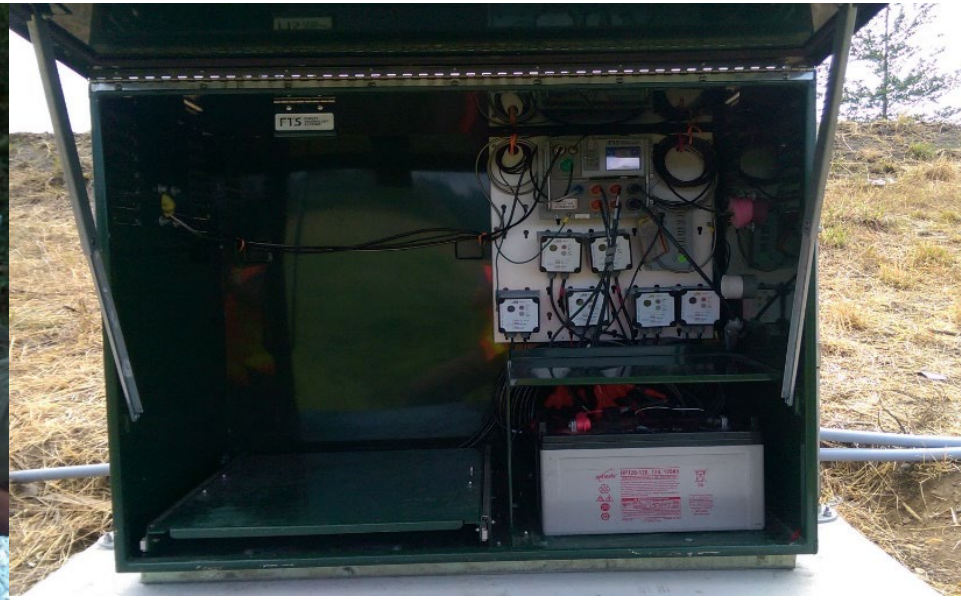
- Stormwater Branch (HQ)
  - Inventory
  - Monitoring
  - Retrofit
  - Overall management (NPDES)

- Hydraulics
- Maintenance
- Ferries
- Biology (ESA)



# WSDOT's ongoing programs

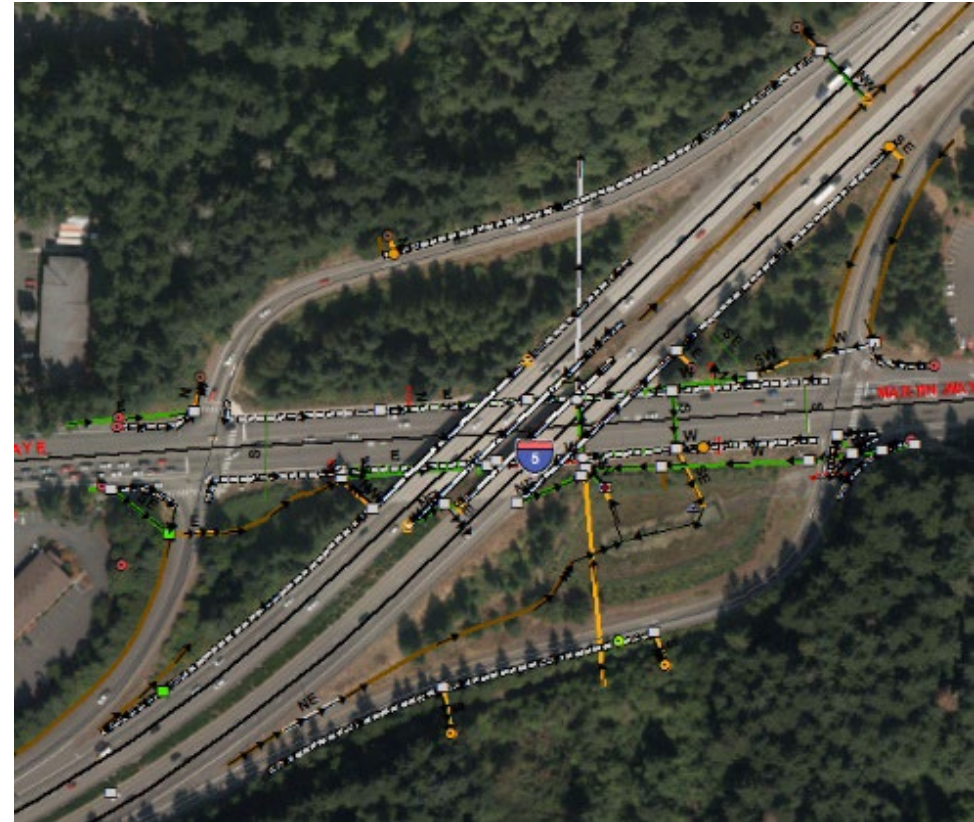
- Monitoring and research





# WSDOT's ongoing programs

- Mapping and inventory





# WSDOT's ongoing programs

- Maintenance



# WSDOT's ongoing programs

- Stormwater retrofits
  - Project-triggered
  - Opportunistic
    - Stormwater Retrofit Assessment conducted on every Fish Passage Project
  - Stand-alone





# WSDOT internal connections

## Stormwater Retrofit Assessment for Fish Passage Projects

SR 106 Twanoh Creek Fish Passage bioswale adds stormwater treatment above and beyond requirements



Compost Amended Biofiltration Swale - during and post construction



# WSDOT internal connections

## Complete Streets

Move Ahead Washington:

Purpose: “In order to improve the safety, mobility, and accessibility of state highways, it is the intent of the legislature that **the department must incorporate the principles of complete streets with facilities that provide street access with all users in mind, including pedestrians, bicyclists, and public transportation users**”

Applies to “state transportation projects starting design on or after July 1, 2022, and that are \$500,000 or more”





# Washington State & California approach to 6PPD-q

WA Department of Ecology taking the lead on science:

- Working to understand the problem (advance science)
  - 6PPD in Road Runoff - Assessment and Mitigation Strategies (October 2022)
- Reduce stormwater pollution (identify stormwater management approaches like effective BMPs)
  - Stormwater Treatment of Tire Contaminants Best Management Practices Effectiveness (June 2022)
  - Draft Stormwater Management Manuals & MS4 Phase I & II Permits
- Source control (identify alternatives)
  - Hazard Assessment (November 2021)
  - Hazard Criteria (October 2023)
  - Alternatives Assessment: identifies, compares, and selects safer alternatives (current/ongoing)

In California, this work is being undertaken by California Department of Toxic Substances Control (DTSC):

- Industry is preparing the alternatives analysis
  - to identify 1 or a couple alternatives
  - preliminary due March 2024
  - final may take up to 3 years
- 6PPD in tires already listed as a Priority Product in CA and in WA is comparable to the Safer Products for WA Program
  - both with the intent of reducing toxics in consumer products

# Washington State Agencies - collaborative approach

- Washington State Department of Ecology (Ecology)
- Washington State Department of Health (DOH)
- Washington State Department of Fish and Wildlife (WDFW)
- Puget Sound Partnership (PSP)
- Washington State Department of Transportation (WSDOT)





# What we know - BMP's that prevent and reduce 6PPD-q

## Source control BMPs

### BMP processes:

- BMPs that completely separate a 6PPD source (e.g., tire wear from roads) from precipitation and stormwater.

### BMP examples:

- Street sweeping
- Cleaning and maintenance of roadside ditches, catch basins, storm drains





# What we know - BMP's that prevent and reduce 6PPD-q

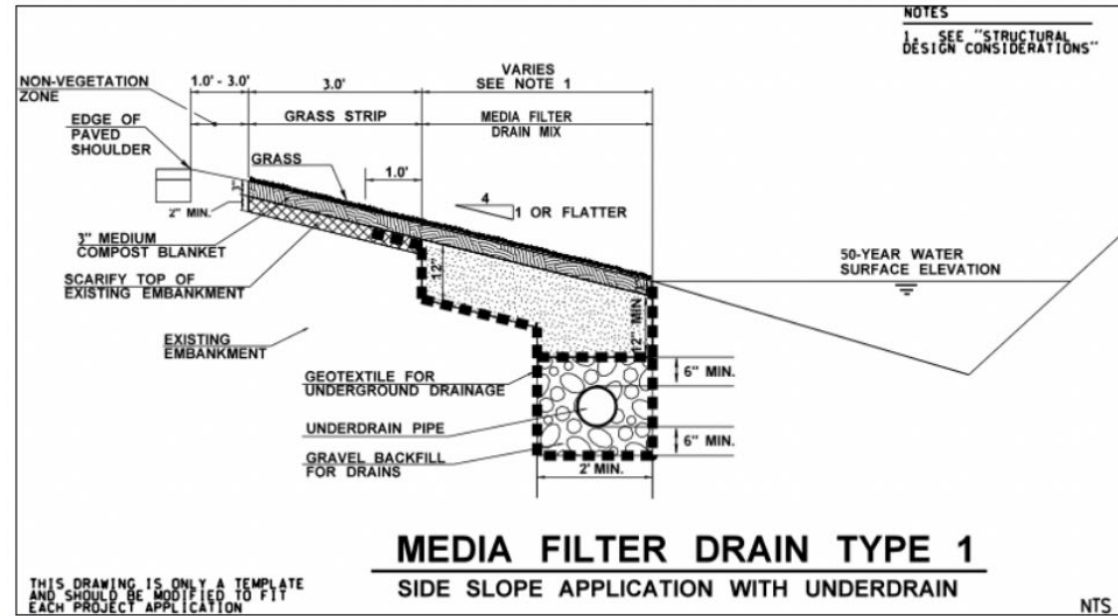
## Flow control & treatment BMPs

### BMP processes:

- Dispersion
- Infiltration
- Filtration
- Sorption

### BMP examples:

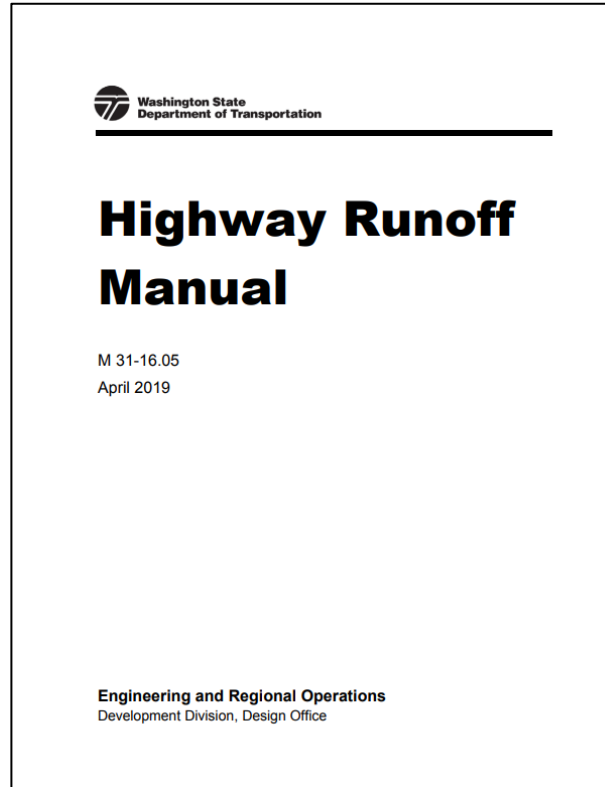
- Bioretention
- Infiltration Basins
- Bioinfiltration with bioretention soil media or compost
- Media Filter Drain
- Dispersion





# WSDOT Stormwater BMPs

- Avoid and minimize impacts on hydrology and water quality
  - Disperse and infiltrate water where feasible
  - Minimize impervious cover, conserve or restore natural areas
- Mitigate for impacts
  - Mimic natural drainage patterns
  - Low Impact Development (LID)/Green Stormwater Infrastructure (GSI)
  - Avoid concentrating runoff
  - End-of-pipe, pond type solutions considered last



## RT.07 – Media Filter Drain



Media Filter Drain Along SR 167 in King County

**Description:** Linear flow-through stormwater runoff treatment device along highway side slopes and medians. Also has end-of-pipe configurations.

**Geometry Limitations**

Contributing Flow Path ≤ 150'  
Embankment Slope 2%-25%

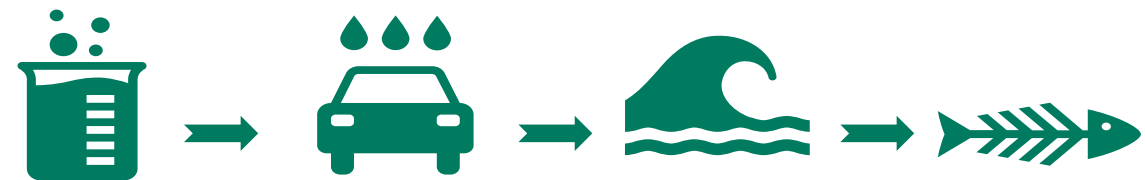
<p><b>BMP Function</b></p> <input checked="" type="checkbox"/> LID <input type="checkbox"/> Flow Control <input checked="" type="checkbox"/> Runoff Treatment <input type="checkbox"/> Oil Control <input checked="" type="checkbox"/> Phosphorus* <input checked="" type="checkbox"/> TSS - Basic <input checked="" type="checkbox"/> Dissolved Metals - Enhanced		<p><b>Effective Life (Years)</b></p> <p>↻ 25</p>																														
<p><b>Capital Cost</b></p> <p>↻ Low</p>	<p><b>M &amp; O Cost</b></p> <p>↻ Low to Moderate</p>																															
<p><b>Additional Constraints/Requirements</b></p> <table border="0"> <tr> <td><input type="checkbox"/> 4-5 Infiltration Design Criteria</td> <td><input checked="" type="checkbox"/> Soil Amendments/Compost</td> </tr> <tr> <td><input type="checkbox"/> Setback</td> <td><input type="checkbox"/> Energy Dissipater/Level Spreader</td> </tr> <tr> <td><input checked="" type="checkbox"/> Landscaping/Planting</td> <td><input type="checkbox"/> 5-4.3.3 Facility Liners</td> </tr> <tr> <td><input type="checkbox"/> Wetland Planting and Plant Establishment</td> <td><input checked="" type="checkbox"/> 5-4.3.7 Signing</td> </tr> <tr> <td><input type="checkbox"/> Inlet and Outlet Spacing</td> <td><input type="checkbox"/> Fencing</td> </tr> <tr> <td><input type="checkbox"/> Overflow</td> <td><input type="checkbox"/> Presettling/Pretreatment</td> </tr> <tr> <td><input type="checkbox"/> Multidisciplinary Team</td> <td><input checked="" type="checkbox"/> Underdrain (Where Permitted)</td> </tr> <tr> <td><input type="checkbox"/> WSDOT Pavement Engineer Approval</td> <td><input checked="" type="checkbox"/> Soil Preparation</td> </tr> </table>			<input type="checkbox"/> 4-5 Infiltration Design Criteria	<input checked="" type="checkbox"/> Soil Amendments/Compost	<input type="checkbox"/> Setback	<input type="checkbox"/> Energy Dissipater/Level Spreader	<input checked="" type="checkbox"/> Landscaping/Planting	<input type="checkbox"/> 5-4.3.3 Facility Liners	<input type="checkbox"/> Wetland Planting and Plant Establishment	<input checked="" type="checkbox"/> 5-4.3.7 Signing	<input type="checkbox"/> Inlet and Outlet Spacing	<input type="checkbox"/> Fencing	<input type="checkbox"/> Overflow	<input type="checkbox"/> Presettling/Pretreatment	<input type="checkbox"/> Multidisciplinary Team	<input checked="" type="checkbox"/> Underdrain (Where Permitted)	<input type="checkbox"/> WSDOT Pavement Engineer Approval	<input checked="" type="checkbox"/> Soil Preparation														
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<p><b>TMDL/303(d) – Considerations<sup>1</sup></b></p> <table border="0"> <tr> <td><b>Avoid</b></td> <td><b>Preferred</b></td> </tr> <tr> <td><input type="checkbox"/></td> <td><input type="checkbox"/> Fecal Coliform</td> </tr> <tr> <td><input checked="" type="checkbox"/></td> <td><input type="checkbox"/> Phosphorus (w/ compost blanket)*</td> </tr> <tr> <td><input type="checkbox"/></td> <td><input type="checkbox"/> Nitrogen</td> </tr> <tr> <td><input type="checkbox"/></td> <td><input type="checkbox"/> Temperature</td> </tr> <tr> <td><input type="checkbox"/></td> <td><input checked="" type="checkbox"/> Dissolved Metals</td> </tr> <tr> <td><input type="checkbox"/></td> <td><input checked="" type="checkbox"/> Total Suspended Solids/Turbidity</td> </tr> <tr> <td><input type="checkbox"/></td> <td><input type="checkbox"/> Dissolved Oxygen</td> </tr> <tr> <td><input type="checkbox"/></td> <td><input type="checkbox"/> pH</td> </tr> <tr> <td><input type="checkbox"/></td> <td><input type="checkbox"/> Oil/Grease</td> </tr> <tr> <td><input type="checkbox"/></td> <td><input type="checkbox"/> PAHs</td> </tr> <tr> <td><input type="checkbox"/></td> <td><input type="checkbox"/> Pesticides</td> </tr> </table> <p>1. See Table 3-1 and Section 2-4.2 for additional guidance.</p>		<b>Avoid</b>	<b>Preferred</b>	<input type="checkbox"/>	<input type="checkbox"/> Fecal Coliform	<input checked="" type="checkbox"/>	<input type="checkbox"/> Phosphorus (w/ compost blanket)*	<input type="checkbox"/>	<input type="checkbox"/> Nitrogen	<input type="checkbox"/>	<input type="checkbox"/> Temperature	<input type="checkbox"/>	<input checked="" type="checkbox"/> Dissolved Metals	<input type="checkbox"/>	<input checked="" type="checkbox"/> Total Suspended Solids/Turbidity	<input type="checkbox"/>	<input type="checkbox"/> Dissolved Oxygen	<input type="checkbox"/>	<input type="checkbox"/> pH	<input type="checkbox"/>	<input type="checkbox"/> Oil/Grease	<input type="checkbox"/>	<input type="checkbox"/> PAHs	<input type="checkbox"/>	<input type="checkbox"/> Pesticides	<p><b>Maintenance Requirements</b></p> <table border="0"> <tr> <td><input type="checkbox"/> Access Roads or Pullouts</td> </tr> <tr> <td><input type="checkbox"/> Vector Truck Access</td> </tr> <tr> <td><input checked="" type="checkbox"/> Mowing</td> </tr> <tr> <td><input type="checkbox"/> Valve Access</td> </tr> <tr> <td><input type="checkbox"/> Specialized Equipment</td> </tr> <tr> <td><input type="checkbox"/> Specialized Training</td> </tr> </table> <p><b>Further Requirements:</b> See Sections 5-3.7.1 and 5.5. Also, see Table 5-21.</p> <p>*if a compost blanket is not used over the media filter drain then this BMP is approved for phosphorous control.</p>	<input type="checkbox"/> Access Roads or Pullouts	<input type="checkbox"/> Vector Truck Access	<input checked="" type="checkbox"/> Mowing	<input type="checkbox"/> Valve Access	<input type="checkbox"/> Specialized Equipment	<input type="checkbox"/> Specialized Training
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# Move Ahead Washington funding for WSDOT stormwater retrofits

- 2022 State Legislature intends \$500 million over 16 years for WSDOT stormwater retrofits on existing infrastructure
- \$6M dedicated to the Urban Stormwater Partnership - I-5 Ship-Canal Bridge Pilot (Seattle)

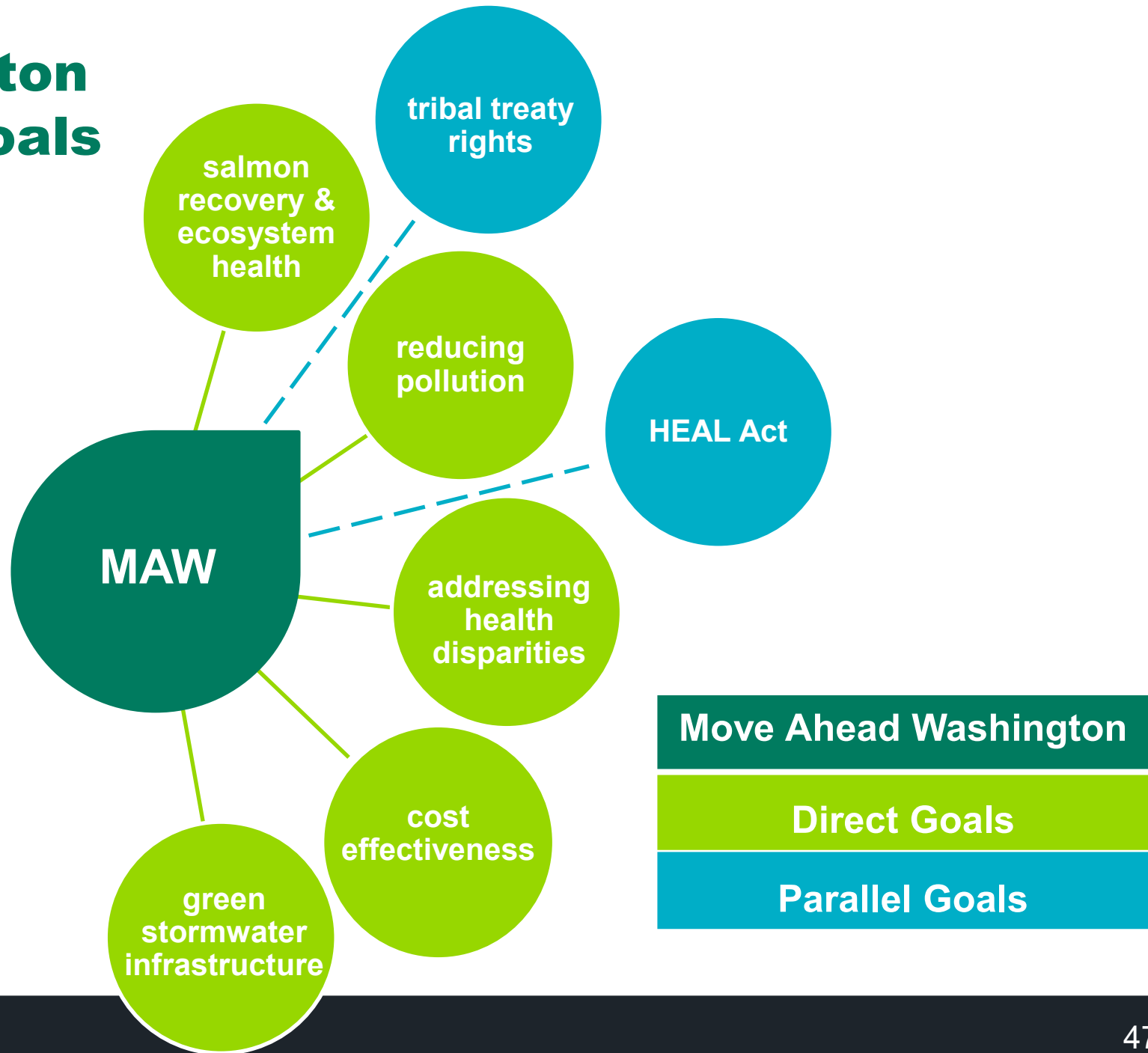


**6PPD-quinone**

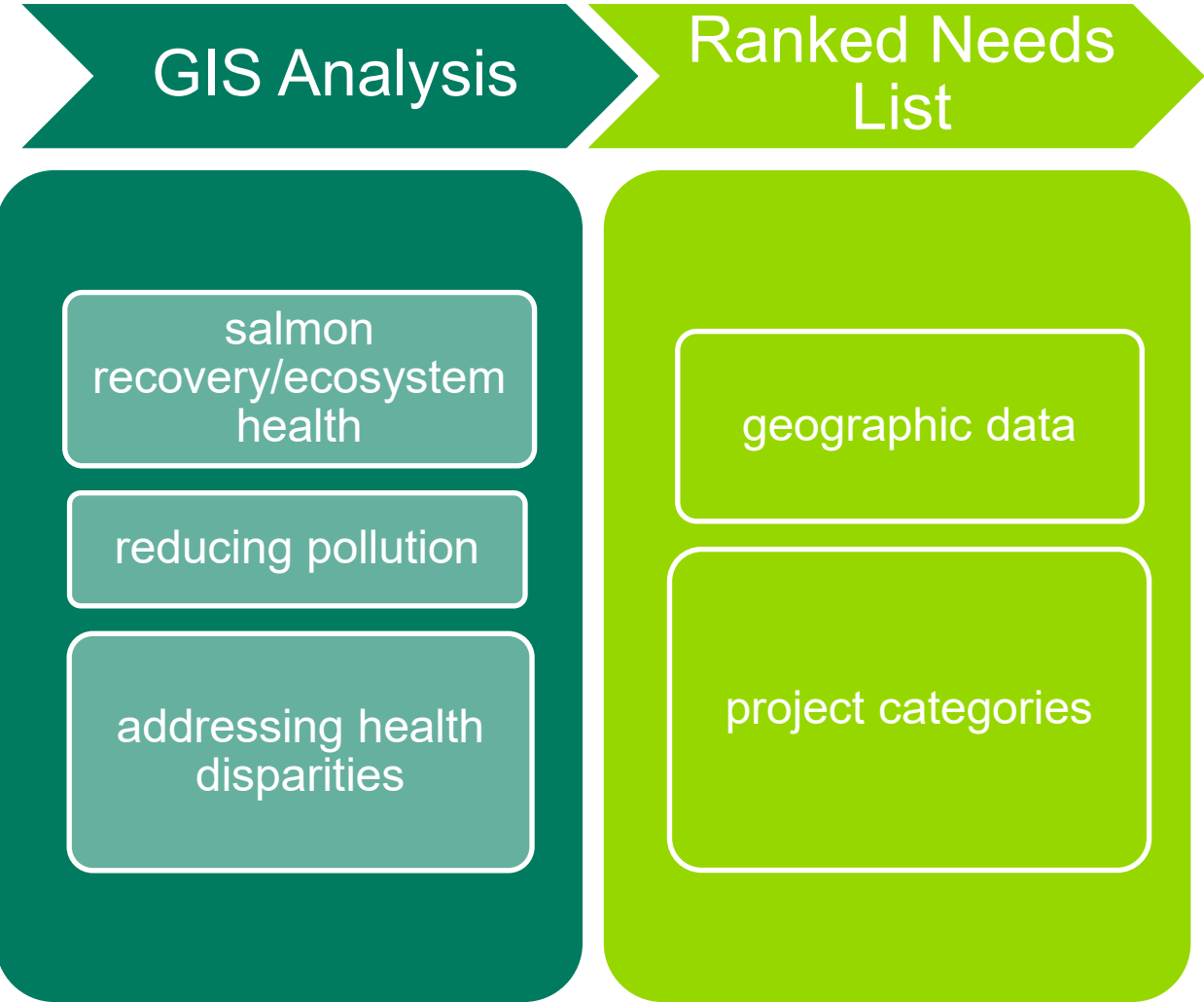




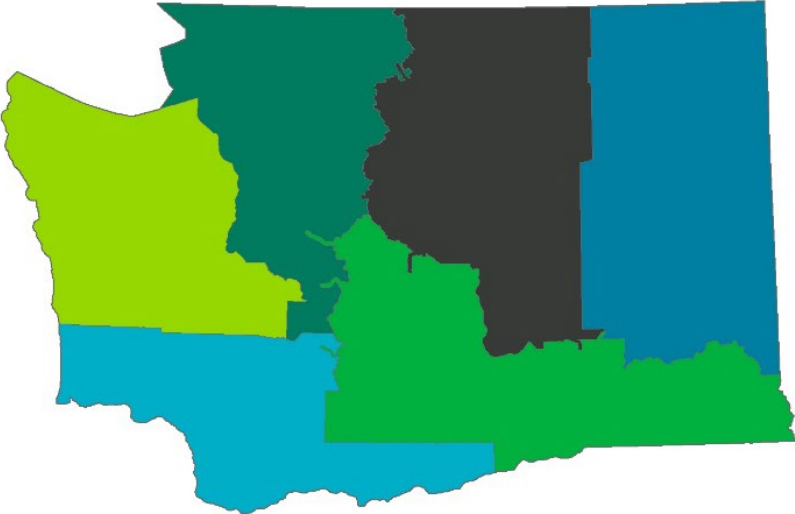
# Move Ahead Washington stormwater retrofit goals & parallel goals with other laws



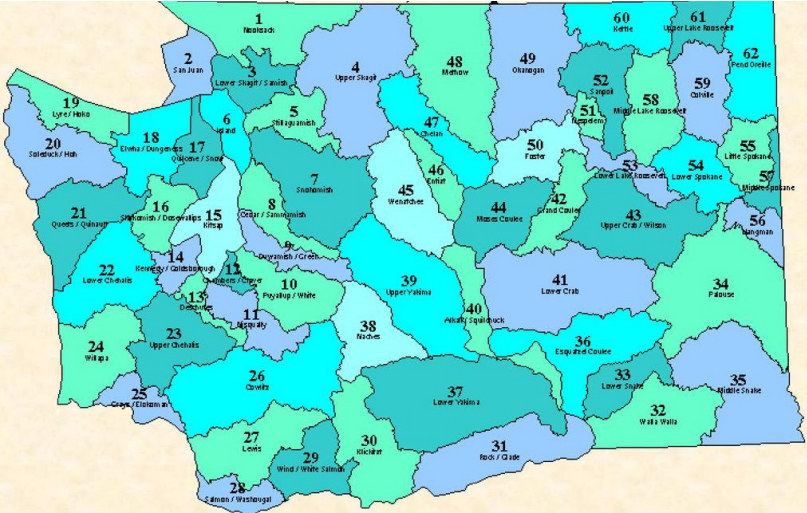
# Stormwater Retrofit Prioritization



WSDOT Regions



Water Resource Inventory Areas (WRIA)



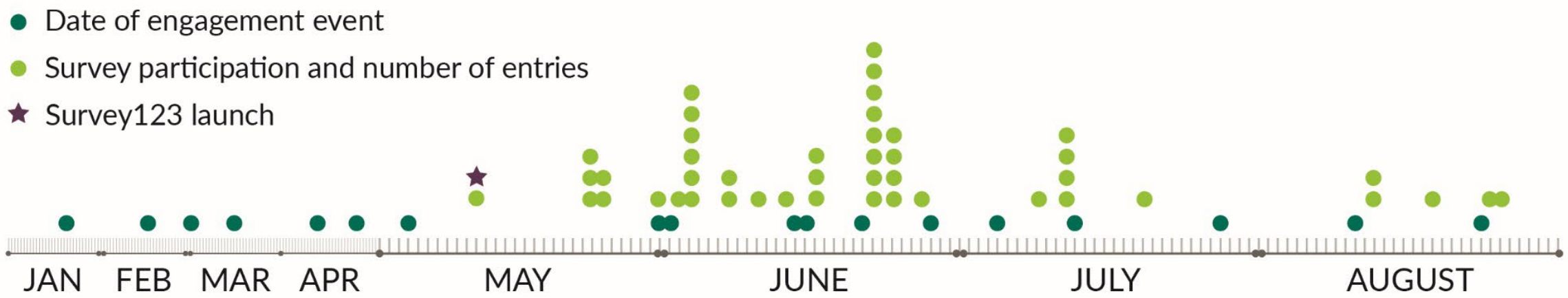


# Ranked Needs List - project categories

- General transportation infrastructure
- WSDOT facilities
- Large outfalls “super outfalls”
- Elevated structures over salmon and steelhead waters
- Fish passage projects



# Survey123 outreach efforts & partner participation





# Outreach efforts – Survey123 results

Produced valuable data:

- 50 recommended priority retrofit locations
- 27 different entities
- between May & September 13, 2023

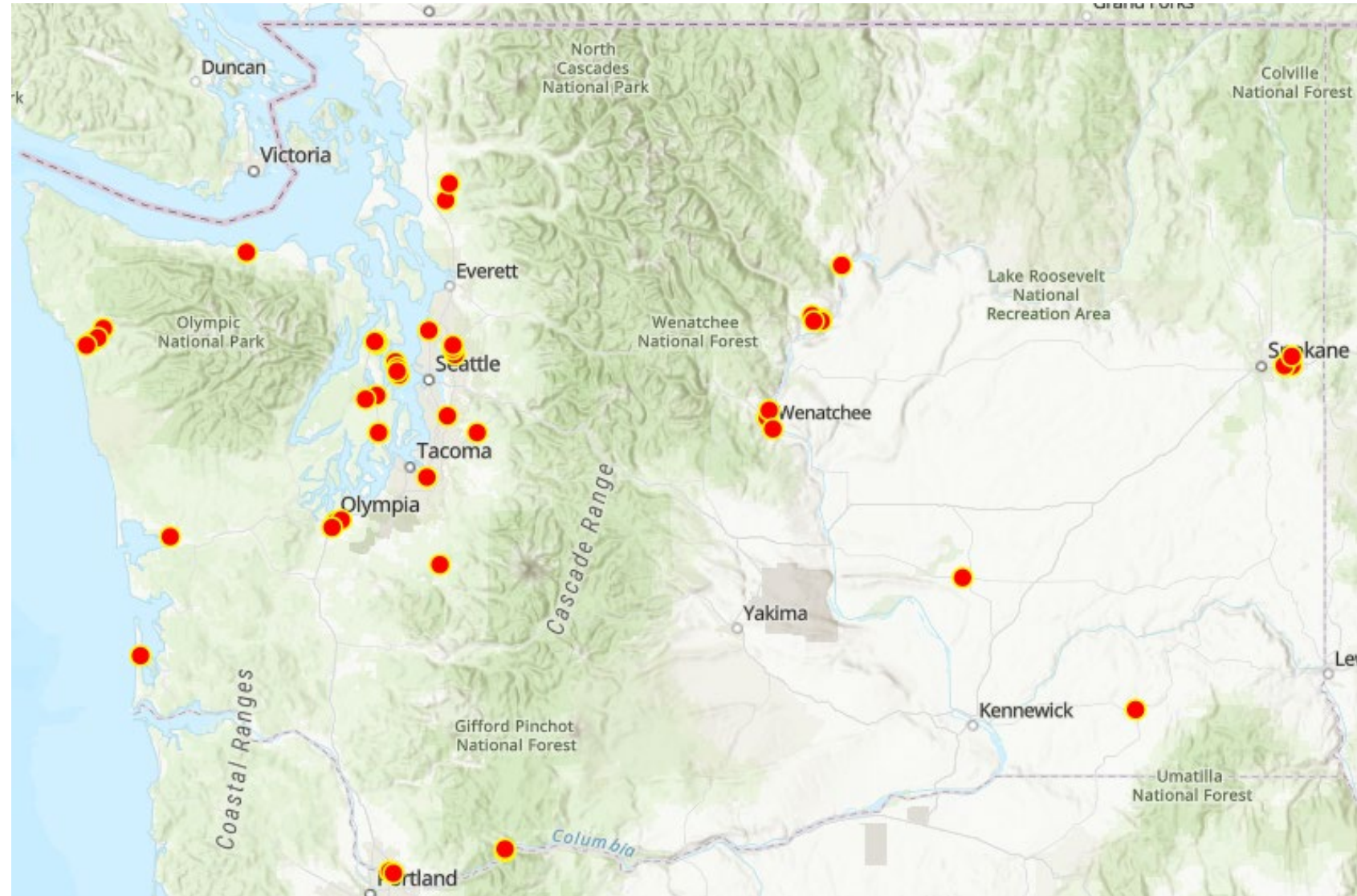






Image Credit: Stewardship Partners



Image Credit: Google

## Partnerships



- WSDOT working to create process to streamline and invite partnership opportunities
- Partner on:
  - prioritizing locations
  - science and updates
  - specific projects with tribal and community benefits and interest
- Workforce development for maintenance of green stormwater infrastructure



# Brief summary of WSDOT's ESA efforts regarding stormwater



**NOAA**  
**FISHERIES**





# Contact Information:

**Tony Bush**

**WSDOT Stormwater Branch Manager**

[Tony.Bush@wsdot.wa.gov](mailto:Tony.Bush@wsdot.wa.gov)

**Sheena Pietzold**

**WSDOT Stormwater Management Program Manager**

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Questions?





# How to Participate During Q&A Session

## Submit Questions

- Select appropriate icon
  - **Internet Browser:** select 
  - **Webex Software:** select “▼ Q&A”
  - **Mobile App:** select , then 
- Type question/comment into Q&A box
- Select **All Panelists**
- Click “Send”
- Moderator will read question/comment out loud





# Thank you!

For more info, visit [cafishpac.org](http://cafishpac.org)

