February 19th, 2017

TO: Whom it May Concern

FROM: Thomas P. Jameson, Washington Department of Fish and Wildlife, Habitat Program, Fish Passage and Screening Division Manager, Chairman Fish Barrier Removal Board

SUBJECT: Resolution Honoring Mr. Brain Abbott

Whereas the Fish Barrier Removal Board lost a valued member and leader on December 31, 2016, with the passing of Brian Abbott;

Whereas Brain Abbott was a tireless and outspoken advocate of salmon recovery and environmental stewardship, whose dedication paved the way for the founding of the Fish Barrier Removal Board within the state of Washington.

Whereas Brain Abbott served with distinction as the executive director of the Governor's Salmon Recovery Office, fundamentally changing how Washington State manages its salmon recovery efforts.

Whereas Brain Abbott initiated the first salmon recovery conference and helped create the Kennedy Creek Salmon Trail.

Whereas Brain Abbott was much loved and respected by his family, friends, co-workers, his sense of humor, kindness, energy and graciousness enriched those fortunate enough to know and work with him, therefore, be it

Resolved that the members of the Fish Barrier Removal Board recognize the significant contributions of Brain Abbott over the course of his distinguished career, mourn his passing and extend our sincere condolences to his family and friends.

Moved by: Mr. Thomas P Jameson, FBRB Chairman, Fish Passage Division Manager, Habitat Program, Washington Department of Fish and Wildlife, 360-902-2612

______________________                                    _______________

Seconded by: Mr. Gary Rowe, FBRB Member, Managing Director, Washington State Association of County Engineers, 360-489-3014

______________________                                    _______________
Urban stormwater runoff

& Green infrastructure

Fish Barrier Removal Board, Feb 21, 2017

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- National Oceanic and Atmospheric Administration (NOAA)
- U.S. Department of Commerce
- Environmental Protection Agency
- National Oceanic and Atmospheric Administration (NOAA)
- U.S. Department of Commerce
- U.S. Fish and Wildlife Service
- Sea Grant
- Department of Ecology
- The Suquamish Tribe
Coho salmon as stormwater sentinel

- Widely distributed
- Lowland streams
- Sensitive to water quantity & quality
- Supported by a diverse food web
- More than 1 year in freshwater
Impact of stormwater on coho salmon
An urban stormwater outfall

West Seattle underwater footage by Laura James (www.diverlaura.me)
Urban Runoff: Water Quantity

Urban streams:
- Higher peak flow
- Lower baseline flow
- Shorter time to peak flow
- Shorter return to baseline

- Urban systems are ‘flashy’
- For aquatic animals, the rapid and intense change in water flow is a problem
Impact of stormwater on coho salmon

- Egg scour
- Nest suffocation
- Energetic challenge
- Lack of flow refugia
The pollution you see....

Montlake Cut, Seattle

Photo by Blake Feist, NOAA Fisheries
...& the pollution you don’t see

- Fluorenes
- Copper
- Phenanthrenes
- Cadmium
- Lead
- Dibenzothiophenes
- Phthalates
- Surfactants
- Nanomaterials
- Pyrethroid insecticides
- Zinc
- Xenoestrogens
- Polybrominated diphenyl ethers
- Nickel
- Herbicides
- Statins
- Triclosan
- Antidepressants
- Caffeine
- Polybrominated diphenyl ethers
- Fluorenes
- Mercury
- Perfluorinated compounds
- Dibenzothiophenes
- Caffeine
Impact of stormwater on coho salmon

Habitat
- fresh water
- estuary/nearshore
- Pacific ocean

Year 1-2
- Spring
- Summer
- Winter
- Spring

Year 2-3
- Fall
- Winter
- Summer
- Fall

Adult spawners
- adults return
- adults spawn and die
- egg incubation
- egg hatch and alevin incubation
- fry emergence

Adult ocean growth

Outmigration nearshore feeding
A common suite of symptoms

Longfellow Creek, 2002

Longfellow Creek, 2005

Pipers Creek, 2002

Longfellow Creek, 2012
Coho pre-spawn mortality is widespread & recurrent in urban creeks

Longfellow Creek, 2003: 67%
Des Moines Creek, 2004: 63%
Longfellow Creek, 2005: 72%
Longfellow Creek, 2012: 84%
Could we recreate the symptoms & mortality of coho pre-spawn mortality?
Collect stormwater runoff

Urban highway, Seattle

>15,000 AADT
Grovers Creek Facility, Suquamish Tribe
Adult coho exposures

clean well water

stormwater
Exposure to urban runoff is sufficient to cause adult coho pre-spawn mortality

Unexposed (3.5 hrs)  Stormwater-exposed (3.5 hrs)

Spromberg et al. 2015. J. Applied Ecology
Pathophysiology: Blood cells of coho exposed to runoff

More immature RBCs (hypoxia)

More WBCs (immune response)

Fewer thrombocytes (coagulation response)
iSTAT point-of-care blood analyzer
Arterial blood gas analysis

Diagnosis: Metabolic acidosis
Arterial blood chemistry analysis

- Increased blood cells and/or decreased plasma
- Hypoxia
- Anaerobic cellular respiration
- Hypoxia
- Hyponatremia
  - Diuresis
  - Heart failure
  - Kidney failure
Evidence for Hypoxia in Adult Coho

- **Behavioural**
  - Increased gilling
  - Surface gaping

- **Hematological**
  - ↑ HCT (Higher RBC counts / cell swelling)
  - Metabolic acidosis (low pH, low bicarb, base deficit)
  - Lactate production (anaerobic cellular respiration)
### Types of hypoxia

<table>
<thead>
<tr>
<th>Hypoxia Type</th>
<th>Caused by</th>
</tr>
</thead>
</table>
| Hypoxic      | Insufficient O$_2$ in environment  
e.g., low dissolved oxygen |
| Anemic       | Insufficient RBC or Hb  
e.g., nitrate poisoning - methemoglobinemia |
| Stagnant     | Insufficient blood flow  
e.g., cardiovascular failure, hypotension |
| Histotoxic   | Tissues cannot access/use O$_2$  
e.g., metabolic poisons |

2016 Field Season
Are other salmon as sensitive as coho?

Adult Coho Salmon

Run Timing: Oct-Dec

Adult Chum Salmon

Run timing: Nov-Jan
Are other salmon as vulnerable as coho?
Are other salmon as vulnerable as coho?
Are chum as vulnerable as coho?

Chum did not develop pre-spawn mortality behavioral symptoms
Coho and chum in Pipers Creek (2006)
Sensitivity of juvenile salmon?
Juvenile coho show PSM symptoms

Stage 4: Loss of equilibrium
Sensitivity of juvenile coho?

Juvenile coho very sensitive
Juvenile coho vs Chinook salmon?

Coho are by far more sensitive
Juvenile chum vs Chinook vs **coho** salmon?

Coho are by far more sensitive to urban runoff
Coho embryo-larval development
Coho Embryos: Episodic Exposure to Runoff

Fertilized 11/23/15

Exposures

Hatched 1/19/2016

Acute lethal response upon hatching
Zebrafish research model

Embryo

Larva

Hatch

days 0 1 2 3 4

1 day

4 days
Sublethal effects in zebrafish

Sublethal effects of runoff on developing fish include:

- Inability/delay to hatch
- Developmental delays
- Small eye phenotype (*)
- Pericardial edema (yellow arrow)
- Deformed jaws and hearts (black arrows)
Cardiac abnormalities from runoff

Urban runoff gives zebrafish bad hearts.
The heart is a target for road runoff contaminants

CYP1a = Detox gene for PAHs
Genes that scale with heart effects

Exposure to aromatic hydrocarbons
Toxicology evolving from:

What is the problem?

... to ...

What is the solution?
Green Stormwater Infrastructure

Emerging technologies for the built landscape may be less harmful to salmon and other aquatic animals.
WSU Puyallup GSI Facility

Permeable Pavement

Rain Gardens

Mesocosms
Could bio-retention treatment prevent coho pre-spawn mortality?

2013-2014: Bioretention treatment of urban road runoff
Constructing portable bioretention cells

- 55 gal. drum
- Slotted underdrain
- 12” drainage layer
- 24” bioretention medium
- 60% sand: 40% compost
- Mulch
Exposures & treatment at Suquamish Hatchery on Grover’s Creek
Can bioretention prevent coho prespawner mortality?

- Clean well water: 100% Normal
- Untreated runoff: 100% Symptomatic
- Treated runoff: ???????
### Stormwater runoff exposures 2013/14

<table>
<thead>
<tr>
<th>Study Year</th>
<th>Test Date</th>
<th>Exposure (hours)</th>
<th>Control Water</th>
<th>Untreated Runoff</th>
<th>Treated Runoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>Nov 8</td>
<td>4</td>
<td>100% Live</td>
<td>50% Dead; 50% Symptomatic</td>
<td>100% Live</td>
</tr>
<tr>
<td>2013</td>
<td>Nov 18</td>
<td>24</td>
<td>100% Live</td>
<td>100% Dead</td>
<td>100% Live</td>
</tr>
<tr>
<td>2014</td>
<td>Oct 20</td>
<td>24</td>
<td>100% Live</td>
<td>100% Dead</td>
<td>100% Live</td>
</tr>
<tr>
<td>2014</td>
<td>Oct 22</td>
<td>24</td>
<td>100% Live</td>
<td>100% Dead</td>
<td>100% Live</td>
</tr>
<tr>
<td>2014</td>
<td>Oct 27</td>
<td>24</td>
<td>100% Live</td>
<td>100% Dead</td>
<td>100% Live</td>
</tr>
</tbody>
</table>

- All fish exposed to untreated runoff were symptomatic or dead at <24 hours
- All control & treated fish were alive at 24 hours
Well water (4 hr)

Coho spawners before and after filtering runoff through bioretention

Filtered stormwater (4 hr)

All 4 fish alive at 4 & 24 hr

Unfiltered stormwater (4 hr)

0 of 4 fish alive at 24 hr

All 4 fish alive at 4 & 24 hr

Spromberg et al. 2015. J Ecol Applications
Coho Embryos: Episodic Exposure to Runoff

Bioretention filtration prevented mortality
Can bioretention prevent toxicity?
Juvenile coho - controls

Filtered

Runoff

100% Survival

100% Mortality

McIntyre et al. 2015. Chemosphere
Sublethal toxicity in zebrafish embryos

- Normal air bladders
- Normal length
- Normal hearts
- Normal eyes (almost)

McIntyre et al. 2014. STOTEN.
Cardiotoxicity lost after bioretention

Filtering runoff through bioretention eliminates induction of detox enzyme (CYP1A) in skin and heart of zebrafish

McIntyre et al. 2016. ES&T
Molecular markers in runoff exposed zebrafish

![Bar chart showing fold-change upregulation (log2) for cyp1a, nppb, cm1c1, and cm1c2 in runoff bioretention.](chart.png)
# Summary of bioretention effectiveness

<table>
<thead>
<tr>
<th>Animal Model</th>
<th>Effect</th>
<th>Exposure</th>
<th>Eliminated</th>
<th>Reduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Juv. coho</td>
<td>Mortality</td>
<td>96 h</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Adult coho</td>
<td>Mortality</td>
<td>24 h</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Mayfly nymph</td>
<td>Mortality</td>
<td>48 h</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Zebrafish</td>
<td>Mortality</td>
<td>96 h</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Daphnid</td>
<td>Mortality</td>
<td>48 h</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reproductive Impairment</td>
<td>7 d</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Zebrafish</td>
<td>Cardiac dysfunction</td>
<td>48 h</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Growth impairment</td>
<td>96 h</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cardiac edema</td>
<td>96 h</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Swim bladder</td>
<td>96 h</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Microphthalmia</td>
<td>96 h</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>PAH exposure gene (cyp1a)</td>
<td>48 h</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cardiac injury gene (nppb)</td>
<td>48 h</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>
Upcoming projects runoff impacts to salmon

Relative species sensitivity
• Testing other species of Pacific salmon

Coho pre-spawn mortality
• Uncover primary source of hypoxia
• Phenotypic anchoring of physiology to behaviour in coho
• Validating juvenile salmon as a model for adult pre-spawn mortality
Sources of Toxics in Road Runoff

Automobile Leaks:
- Fuel
- Engine Oil
- Brake Fluid
- Engine Coolant
- Transmission Fluid

Which are most toxic? Which contribute most to toxicity?
Bioretention Performance 2016-2018

- Alex Taylor – WSU M.S.
- 2-yr installation
- BSM + Plants + Fungi
- Real-time input from I-5
- Quarterly monitoring:
  - Hydrology
  - Chemistry
  - Toxicology
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Suquamish Tribe
Mike Huff et al.

Puyallup Tribe
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This is not a forest