Deliverable 4.7: Progress Report 7

Overview of Work Period: 1/20/22 –11/9/22

		Water Quality		Toxicology		Stormwater	
Water Year	Event	Basic	Full	Zfish	Coho	Collection Date (2022)	Treatment Dates
9	51	x				1/20	1/20-1/21
9	52	x				2/28	2/28-2/29
9	53	x				3/3	3/3-3/4
9	54	x	x	*		5/3	5/3-5/4
10	55	x				5/6	5/6-5/7
10	56	x				5/12	5/12-5/13
10	57	x				5/16	5/16-5/17
10	58	x				10/23**	10/25-10/26
10	59	x				10/31**	11/1-11/2
10	60	x	x	*	x	11/7**	11/8-11/9

*Zebrafish molecular assays have not yet been completed for Events 54 or 60.
**Access to the new SR16 collection site is unavailable Friday-Sunday. Collection Date is the last rain date while the tank was set out for collection, resulting in aging of runoff up to 2 days.

Report Summary

Work Progress Status

Project Tasks	% Completion
1. QAPP development	100
2. Prepare experimental columns	100
3. Condition experimental columns	100
4. Bioretention performance throughout accelerated aging	77
5. Outreach and communication	0

Discussions/decisions made since last report period

- In coordination with Ecology, the number of simulated water years was increased from 10 to 13, with 'full sampling' continuing for the event ending each water year but with coho testing only at the end of WY13.
- Due to a homeless encampment located at the site of our runoff collection at the WSDOT property at the intersection of SR16 and I-5, we had to move runoff collection to a new location. Selecting a new site required coordination with WSDOT and took several months. In August 2022, collection equipment was installed at the WSDOT Tacoma Narrows Bridge Maintenance Facility at the east end of the bridge. The downspout is on the North side of the old Toll Plaza and captures water from SR 16 W. The full sampling for WY10 (Event 60) was the first time the full suite of chemistry analytes was measured for the new site.

Summary of Events

Summary of Full Water Chemistry

Event 54 (Post WY9)

- A net export of As, DOC, and nutrients was observed for all treatment depths, with significantly higher effluent concentrations from the deeper than the shallower BSM depths.
- While total Cu and Ni were greatly reduced by bioretention treatment, more was released from the deeper BSM treatments. The same was true for Ca and Na. In contrast, less total Zn was released from the deeper BSM treatments.

Summary of Maintenance intervention (pre-Event 58)

- During WY8 we conducted maintenance after consulting with Ecology by removing the top 1" of BSM (reported on in Deliverable 5.5), which improved the hydraulic conductivity but only for a few events. We therefore backflushed all columns before the end of WY9 which again improved the Ksat (Figure 1). This effect was temporary as there was a depth-dependent decrease in Ksat by the end of WY10. We anticipate that these maintenance activities will continue to provide diminishing returns.

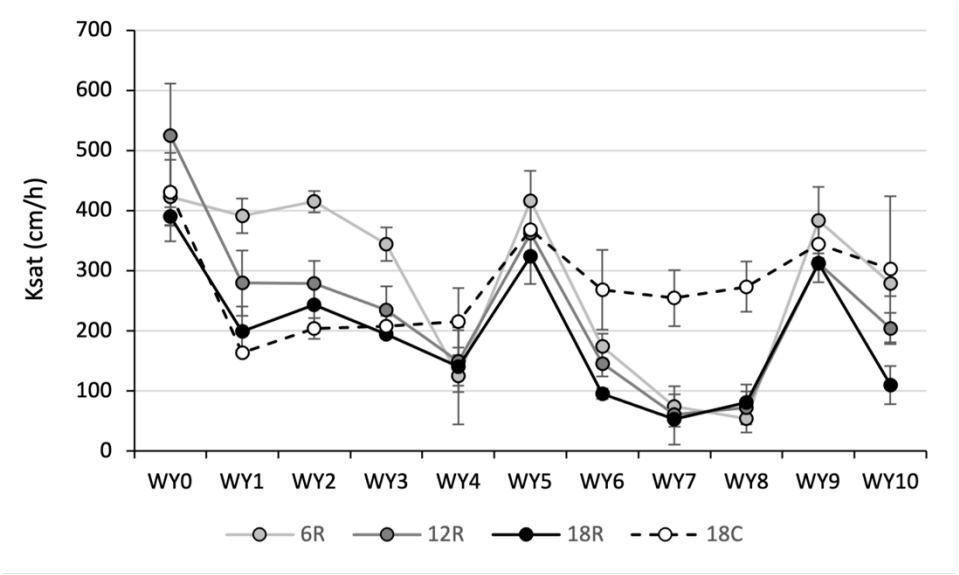

Figure 1. Saturated hydraulic conductivity (mean ± SE) following each water year for the three depths of bioretention receiving runoff (6", 12", 18") and the clean water control (18"). Maintenance consisting of removing the top 1" of bioretention soil media followed by backflushing took place during WY9, with limited long-term benefit.

Event 60 (Post WY10)

- A net export of nutrients was observed for all treatment depths, with significantly higher effluent concentrations from the deeper than the shallower BSM depths.
- Less Ca and Mg were released from deeper BSM, but more Na.

Summary of Toxicology: Event 60 (Post WY10)

All bioretention depths continued to protect juvenile salmon against the acute lethal effects of runoff (Figure 2).

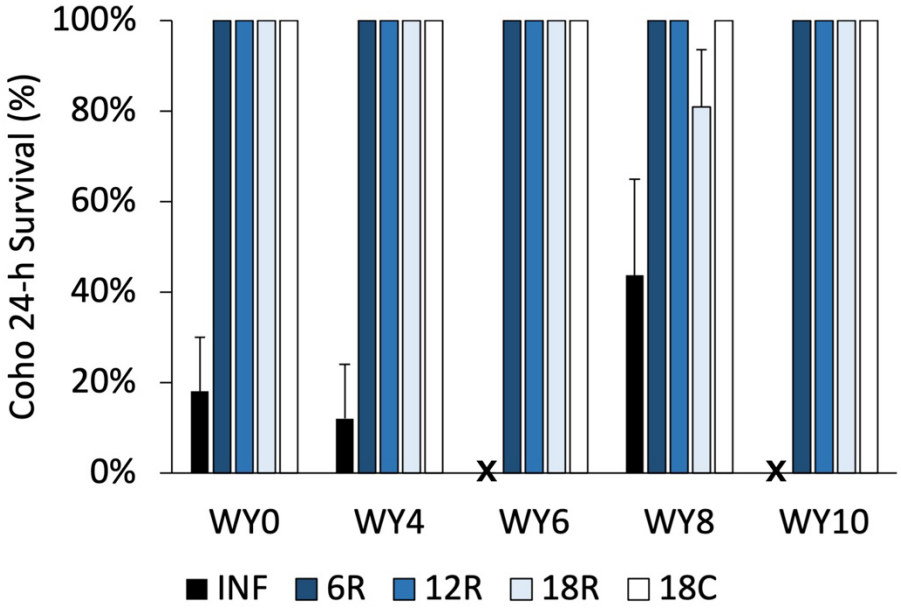

Figure 2. At the end of WY10, all columns continue to protect juvenile coho salmon from the acute lethal effect of runoff. Values are average of three replicates of 8 fish, errors are one standard error of the mean. 'X' indicates 0% survival in runoff.

Full Water Chemistry

Full water chemistry analysis was conducted for Events 54 (End of WY9) and 60 (End of WY10). Samples for water chemistry were collected and analyzed as previously (Deliverable 4.1: Progress Report 1). Statistical differences are shown when they exist between the depths of bioretention treating runoff (6R, 12R, 18R).

Event 54 (End of WY9)

Metals

Table 1. Average concentrations of dissolved and total metals in ppb (standard error) for influent waters (clean water and influent stormwater runoff) and triplicate effluent waters from each of the three runoff treatment (R) depths (6", 12", 18") plus the clean water control (C) for the event ending Water Year 9. One-half of the value of the detection limit was substituted for the value of non-detects in calculating means; used when the compound was detected in at least one replicate for the treatment. Values following '<' are equal to the detection limit.

Compound	MDL	Clean Water	Influent Runoff	6R	12R	18R	18C
Dissolved As	0.05	0.367	0.577	1.18 (0.02)a	1.46 (0.06)b	2 (0.03)c	0.92 (0.06)
Dissolved Cd	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Dissolved Cu	0.05	<0.05	3.74	5.1 (0.2)	5.3 (0.6)	6.28 (0.05)	1.7 (0.2)
Dissolved Pb	0.079	<0.079	<0.079	<0.079	<0.079	<0.079	<0.079
Dissolved Ni	0.2	<0.2	<0.2	<0.2	0.5 (0.2)	0.68 (0.03)	0.5 (0.4)
Dissolved Zn	0.19	1.12	22.3	4.5 (0.9)	4.7 (0.6)	6 (1)	1.5 (0.4)
As	0.05	0.45	0.87	1.18 (0.01)a	1.57 (0.04)b	2.12 (0.07)c	0.94 (0.04)
Cd	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cu	0.2	0.583	17.7	6.8 (0.1)a	7.5 (0.5)ab	8.8 (0.3)b	3.1 (0.3)
Pb	0.079	<0.079	2.89	<0.079	<0.079	<0.079	<0.079
Ni	0.2	<0.2	1.63	<0.2a	0.59 (0.04)a	1.04 (0.05)b	0.3 (0.2)
Zn	0.19	0.683	84.7	7.3 (0.1)a	6.8 (0.2)ab	6.9 (0.2)b	2.1 (0.6)

Nutrient & Conventional Water Chemistry

Table 2. Average water chemistry values in mg/L (standard error) for influent waters (clean water and influent stormwater runoff) and triplicate effluent waters from each of the three runoff treatment (R) depths (6", 12", 18") plus the clean water control (C) for the event ending Water Year 9. One-half of the value of the detection limit was substituted for the value of non-detects in calculating means; used when the compound was detected in at least one replicate for the treatment. Values following '<' are equal to the detection limit. n.m. = not measured for this event.

Compound	Clean Water	Influent Runoff	6R	12R	18R	18C

Dissolved Organic Carbon	1.41	3.44	3.1 (0.1)a	4.12 (0.04)b	4.5 (0.1)b	2.2 (0.3)
Total Suspended Solids	1.6	38.8	1.2 (0.2)	1.5 (0.5)	1.4 (0.6)	1.5 (0.3)
Turbidity	0.03	36.3	6.5 (0.1)	6 (0.4)	6.4 (0.4)	2.4 (0.4)
Conductivity	1478	82.8	120 (2)	142 (2)	155 (3)	1502 (2)
pH	7.836	7.605	7.91 (0.01)	7.837 (0.006)	7.842 (0.006)	7.66 (0.04)
Alkalinity	78.9	37.5	36 (3)	40 (2)	41.1 (0.6)	63 (2)
Temperature	NA	37.2	38.6 (0.3)	35.1 (0.5)	35 (1)	35.1 (0.3)
Dissolved Calcium	7.22	11.7	0.23 (0.02)a	0.33 (0.02)b	0.43 (0.03)c	8 (0.04)
Dissolved Magnesium	23.6	0.349	0.3 (0.3)	0.018 (0.002)	0.03 (0.006)	22.3 (0.2)
Dissolved Sodium	321	2.79	23.6 (0.3)a	28.7 (0.4)b	30.7 (0.3)c	320 (1)
Nutrients						
Nitrate/Nitrite	0.265	0.2	0.328 (0.003)a	0.37 (0.010)a	0.479 (0.007)b	0.43 (0.05)
Orthophosphate, as P	<0.01	<0.01	0.12 (0.006)a	0.257 (0.009)b	0.41 (0.02)c	0.147 (0.003)

PAHs

Table 3. Average polycyclic aromatic hydrocarbon (PAH) concentrations in ppb (standard error) for influent waters (clean water and influent stormwater runoff) and triplicate effluent waters from each of the three runoff treatment (R) depths (6”, 12”, 18”) plus the clean water control (C) for the event ending Water Year 9. One-half of the value of the detection limit was substituted for the value of non-detects in calculating means; used when the compound was detected in at least one replicate for the treatment. Values following ‘<’ are equal to the detection limit.

PAHs	Clean Water	Influent Runoff	6R	12R	18R	18C
1-Methylnaphthalene	0.003	0.007	0.004 (6e-04)	0.004 (3e-04)	0.005 (0)	0.005 (0.002)
2-Methylnaphthalene	0.004	0.011	0.004 (3e-04)	0.004 (3e-04)	0.004 (3e-04)	0.005 (0.002)
Naphthalene	0.007	0.02	0.005 (3e-04)	0.006 (0)	0.005 (6e-04)	0.004 (3e-04)
Acenaphthene	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003

Acenaphthylene	<0.002	0.004	<0.002	<0.002	<0.002	<0.002
Anthracene	<0.001	0.004	0.002 (5e-04)	0.001 (2e-04)	0.001 (8e-04)	<0.001
Carbazole	<0.001	0.006	<0.001	<0.001	<0.001	0.001 (2e-04)
Dibenzofuran	0.002	0.005	0.002 (3e-04)	0.002 (0)	0.003 (3e-04)	0.001 (3e-04)
Fluorene	<0.002	0.007	0.002 (3e-04)	<0.002	<0.002	0.001 (3e-04)
Phenanthrene	0.002	0.038	0.003 (3e-04)	0.002 (0)	0.003 (3e-04)	0.001 (5e-04)
Benz[a]anthracene	<8e-04	0.01	<8e-04	<8e-04	<8e-04	<8e-04
Chrysene	<9e-04	0.029	0.001 (3e-04)	0.001 (3e-05)	0.001 (0)	<9e-04
Fluoranthene	<0.002	0.056	0.002 (3e-04)	0.001 (3e-04)	0.001 (3e-04)	<0.002
Pyrene	<0.001	0.083	0.004 (3e-04)	0.004 (0.002)	0.002 (3e-04)	0.001 (2e-04)
Benzo(a)pyrene	<0.002	0.013	<0.002	<0.002	<0.002	<0.002
Benzo(b)fluoranthene	<5e-04	0.022	0.001 (0)	0.001 (7e-05)	0.001 (3e-05)	<5e-04
Benzo(j)fluoranthene	<0.002	0.005	<0.002	<0.002	<0.002	<0.002
Benzo(k)fluoranthene	<0.003	0.01	<0.003	<0.003	<0.003	<0.003
Dibenzo(a,h)anthracene	<0.001	0.002	<0.001	<0.001	<0.001	<0.001
Perylene	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Benzo(ghi)perylene	<0.001	0.059	0.003 (3e-04)	0.02 (0.02)	0.002 (0)	<0.001
Indeno(1,2,3-cd)pyrene	<0.001	0.013	<0.001	<0.001	<0.001	<0.001
Total PAHs	0.033	0.408	0.042 (0.001)	0.05 (0.02)	0.041 (0.001)	0.032 (0.003)
Sum High Molecular Weight (HMW)	0.011	0.305	0.019 (7e-04)	0.03 (0.02)	0.016 (5e-04)	0.011 (2e-04)
Sum Low Molecular Weight (LMW)	0.022	0.104	0.024 (0.001)	0.022 (5e-04)	0.025 (0.001)	0.021 (0.003)

Event 60 (End of WY10)

Metals

Table 1. Average concentrations of dissolved and total metals in ppb (standard error) for influent waters (clean water and influent stormwater runoff) and triplicate effluent waters from each of the three runoff treatment (R) depths (6", 12", 18") plus the clean water control (C) for the event ending Water Year 10. One-half of the value of the detection limit was substituted for the value of non-detects in calculating means; used when the compound was detected in at least one replicate for the treatment. Values following '<' are equal to the detection limit.

Compound	PQL	Clean Water	Influent Runoff	6R	12R	18R	18C
Dissolved As	0.2	<0.2	0.355	0.512 (0.008)	0.499 (0.02)	0.593 (0.04)	0.362 (0.02)
Dissolved Cd	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Dissolved Cu	0.3	0.346	10.1	6.79 (0.2)	5.82 (0.2)	6.20 (0.5)	1.90 (0.09)
Dissolved Pb	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Dissolved Ni	0.5	<0.5	0.832	0.510 (0.009)	0.671 (0.3)	0.752 (0.03)	<0.5
Dissolved Zn	0.3	2.12	43.6	6.12 (0.9)	6.01 (0.1)	5.34 (0.5)	2.55 (0.5)
As	0.2	<0.2	0.768	0.675 (0.02)	0.684 (0.02)	0.751 (0.02)	0.510 (0.02)
Cd	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Cu	0.3	1.31	31.7	9.39 (0.3)	8.37 (0.3)	8.31 (0.3)	3.23 (0.05)
Pb	0.5	<0.5	3.46	<0.5	<0.5	<0.5	<0.5
Ni	0.5	<0.5	2.42	0.864 (0.06)	1.32 (0.4)	1.16 (0.03)	0.705 (0.08)
Zn	0.3	1.24	116	8.07 (2)	7.54 (1)	5.97 (0.2)	3.71 (0.6)

*PQL (practical quantitation limit) set by Spectra Laboratories.

Nutrient & Conventional Water Chemistry

Table 2. Average water chemistry values in mg/L (standard error) for influent waters (clean water and influent stormwater runoff) and triplicate effluent waters from each of the three runoff treatment (R) depths (6", 12", 18") plus the clean water control (C) for the event ending Water Year 10. One-half of the value of the detection limit was substituted for the value of non-detects in calculating means; used when the compound was detected in at least one replicate for the treatment. Values following '<' are equal to the detection limit. n.m. = not measured for this event.

Compound	Clean Water	Influent Runoff	6R	12R	18R	18C

Dissolved Organic Carbon	<0.5	3.5	3.53 (0.03)	3.60 (0.07)	3.93 (0.09)	0.848 (0.04)
Total Suspended Solids	0.8	48.8	<0.5	0.617 (0.2)	1.02 (0.5)	0.567 (0.3)
Turbidity	0.03	18.28	5.90 (3.4)	5.88 (0.1)	6.54 (0.9)	1.79 (0.4)
Conductivity	1436	49.1	52.7 (0.8)	51.8 (1)	52.4 (0.4)	1465 (5.8)
pH	7.64	6.93	6.90 (0.07)	6.67 (0.02)	6.66 (0.04)	7.40 (0.02)
Alkalinity	56.6	13	13.4 (0.3)	12 (0.3)	11.7 (0.06)	53 (0.2)
Temperature	n.m	n.m	38.6 (0.3)	37.9 (0.4)	37.4 (1)	36.3 (0.9)
Dissolved Calcium	6.42	4.51	4.82 (0.1)a	3.24 (0.1)b	1.89 (0.4)c	7.42 (0.07)
Dissolved Magnesium	20	0.535	0.532 (0.04)a	0.58 (0.05)a	0.29 (0.05)b	20.7 (0.2)
Dissolved Sodium	256	3.76	4.82 (0.1)a	6.30 (0.3)a	8.69 (0.6)b	264 (1)
Nutrients						
Nitrate/Nitrite	0.106	0.352	0.612 (0.02)a	0.684 (0.03)ab	0.803 (0.05)b	0.290 (0.07)
Orthophosphate, as P	<0.004	0.008	0.041 (0.001)a	0.067 (0.002)a	0.095 (0.01)b	0.124 (0.003)

PAHs

Table 3. Average polycyclic aromatic hydrocarbon (PAH) concentrations in ppb (standard error) for influent waters (clean water and influent stormwater runoff) and triplicate effluent waters from each of the three runoff treatment (R) depths (6”, 12”, 18”) plus the clean water control (C) for the event ending Water Year 10. One-half of the value of the detection limit was substituted for the value of non-detects in calculating means; used when the compound was detected in at least one replicate for the treatment. Values following ‘<’ are equal to the detection limit.

PAHs	Clean Water	Influent Runoff	6R	12R	18R	18C
1-Methylnaphthalene	0.004	0.009	0.003 (6e-04)	0.007 (6e-04)	0.002 (0)	0.003 (6e-04)
2-Methylnaphthalene	0.004	0.016	0.005 (3e-04)	0.004 (3e-04)	0.004 (0)	0.004 (0)
Naphthalene	0.008	0.018	0.007 (3e-04)	0.007 (6e-04)	0.007 (6e-04)	0.006 (3e-04)
Acenaphthene	0.01	0.01	0.01 (0)	0.01 (0)	0.01 (0)	0.01 (0)

Acenaphthylene	0.01	0.004	0.01 (0)	0.01 (0)	0.01 (0)	0.01 (0)
Anthracene	0.01	0.006	0.005 (0.003)	0.008 (0.002)	0.008 (0.002)	0.007 (0.003)
Carbazole	0.01	0.01	0.01 (0)	0.01 (0)	0.01 (0)	0.01 (0)
Dibenzofuran	<0.002	0.005	0.01 (0.003)	0.007 (0.003)	0.007 (0.003)	0.007 (0.003)
Fluorene	0.01	0.005	0.005 (0.003)	0.01 (0)	0.01 (0)	0.01 (0)
Phenanthrene	0.002	0.036	0.004 (9e-04)	0.005 (0.002)	0.006 (0.003)	0.005 (7e-04)
Benz[a]anthracene	0.001	0.012	0.001 (3e-04)	0.005 (0.003)	0.001 (0)	0.007 (0.003)
Chrysene	0.002	0.036	0.003 (7e-04)	0.004 (9e-04)	0.003 (3e-04)	0.004 (0.003)
Fluoranthene	<0.002	0.057	0.003 (6e-04)	0.01 (0.002)	0.005 (0.002)	0.005 (0.003)
Pyrene	0.002	0.089	0.004 (0)	0.008 (0.003)	0.005 (0.002)	0.005 (0.003)
Benzo(a)pyrene	0.01	0.016	0.01 (0)	0.01 (0)	0.01 (0)	0.01 (0)
Benzo(b)fluoranthene	0.0009	0.023	0.002 (3e-04)	0.002 (6e-04)	0.002 (3e-04)	0.004 (0.003)
Benzo(j)fluoranthene	0.01	0.011	0.01 (0)	0.01 (0)	0.01 (0)	0.01 (0)
Benzo(k)fluoranthene	0.01	0.013	0.01 (0)	0.01 (0)	0.01 (0)	0.01 (0)
Dibenzo(a,h)anthracene	0.01	0.003	0.007 (0.003)	0.01 (0)	0.01 (0)	0.01 (0)
Perylene	0.01	0.01	0.01 (0)	0.01 (0)	0.01 (0)	0.01 (0)
Benzo(ghi)perylene	0.01	0.043	0.003 (7e-04)	0.003 (9e-04)	0.005 (0.003)	0.01 (0)
Indeno(1,2,3-cd)pyrene	0.01	0.013	0.002 (7e-04)	0.004 (0.003)	0.001 (0.003)	0.01 (0)
Total PAHs	0.158	0.492	0.14	0.169	0.158	0.177