



Stormwater Runoff Characterization for Evaluation of BMP Effectiveness

**Analysis of 6PPD-quinone and TAPE parameters
at the Ship Canal Testing Facility in Seattle,
Washington**

By

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For the

Water Quality Program

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- [Quality Assurance Project Plan](#)

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- Aquatic Toxicology, Conventional, and Trace Metals unit staff provided analytical support for this project.

Analytical Resources, LLC

- Shelly Fishel served as the laboratory project manager.
- Organics staff provided analytical support for this project.

Introduction

This report presents the results of a pilot study conducted from April 2023 to June 2025 to characterize stormwater runoff across multiple storm events from a mixed highway and residential drainage area for concentrations of multiple contaminants, including 6PPD-quinone (6PPDQ). The project is funded by the Washington State Department of Ecology (Ecology).

Background

Ecology administers the Technology Assessment Protocol-Ecology (TAPE) program, which is a regulatory certification process for many types of stormwater treatment technologies including best management practices (BMP) (Ecology, 2018a,b). For BMP treatment effectiveness studies, it is crucial to know the character of the contaminant concentration profile of stormwater runoff across the storm hydrograph for treated contaminants. Stormwater runoff is the “influent” to the BMP undergoing testing.

The Ship Canal Test Facility (SCTF), an established TAPE testing facility in Seattle, Washington, provides access to stormwater that drains directly from Interstate Highway 5 (I-5) and adjacent densely developed urban residential land. The highways and interstates that contribute stormwater runoff to this location have annual average daily traffic of 197,000 vehicles (WSDOT, 2025). At this location, sampling of stormwater runoff can be safely performed using existing sampling infrastructure, including two vaults that receive a mix of right-of-way and paved runoff from I-5 above. This facility also contains multiple testing bays to assess BMP treatment technologies.

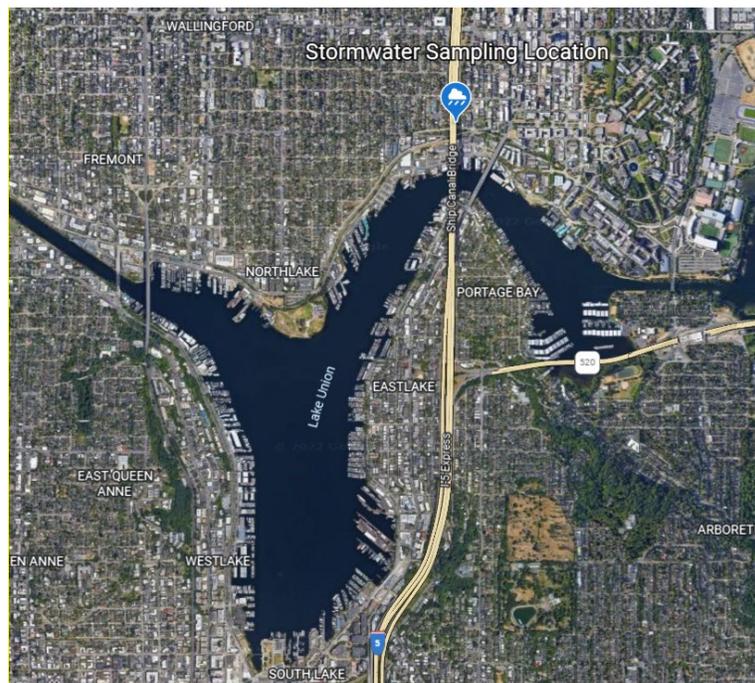


Figure 1. Site vicinity map, Ship Canal Test Facility, Seattle, Washington.

In 2020, researchers identified a new chemical in stormwater that forms from an antioxidant used in tires to extend their lifespan, that upon oxidation becomes 2-anilino-5-(4-methylpentan-2-ylamino)cyclohexa-2,5-diene-1,4-dione, a.k.a. 6PPD-quinone (6PPDQ). 6PPDQ has been found to be toxic to coho salmon and several other aquatic species (Tian et al. 2021, 2022; Brinkmann et al. 2022; Hiki et al. 2021). Treated and untreated stormwater runoff from I-5 discharges into nearby waters, potentially affecting migrating salmonids.

King County Environmental Lab (KCEL) conducted the study described in this report to characterize stormwater runoff at the SCTF for 6PPDQ and TAPE parameters. This report describes the results obtained from grab samples collected over 15 storm events.

Project goals

The project goals are to:

- Collect storm event data from 15 storms to characterize 6PPDQ and select TAPE parameters in stormwater runoff collected across the hydrograph at the SCTF.
- Gain insight into the behavior and concentration profile of 6PPDQ across the hydrograph, aiming to gain a better understanding of 6PPDQ levels in stormwater runoff. This is an important first step to assess if existing field protocols for treatment evaluations of stormwater will need to be modified to address 6PPDQ.
- Characterize the influent into the SCTF for use in determining the effectiveness of BMPs undergoing testing at this site.
- Gather data to help determine if there may be positive associations between 6PPDQ and TAPE parameters.

Methods

The goal for this project was to collect fifteen storm events comprised of 2 to 3 grab samples each at the SCTF in Seattle to be analyzed for 6PPDQ and TAPE parameters. A quality assurance project plan (QAPP) outlining the study overview, sampling plan, analytical methods, and data reporting was created in March 2023 (King County, 2023).

Field procedures

Field sampling was targeted toward wet-weather events that met the criteria outlined in Table 1. Field staff collected 2 or 3 grab samples per event – one at the start of the event, one toward the end of the event, and one during the event if possible. As a part of each grab sample collection field data for Conductivity, pH, and Temperature was also collected following KCEL SOP #245v1. Within 15 minutes of collecting each grab sample, the dissolved metals and dissolved nutrients sample aliquots were field filtered.

Table 1. Wet weather criteria for stormwater sampling.

	Wet season	Dry season
Seasonal period	October 1 through April 30	May 1 through September 30
Minimum amount of rainfall	0.20" min. No fixed maximum	0.2" min. No fixed maximum
Rainfall duration	No fixed minimum or maximum	No fixed minimum or maximum
Antecedent dry period	≤0.05" rain in previous 6 hours	≤0.02" rain in previous 24 hours
Inter-event dry period	6 hours	6 hours

Laboratory procedures

Stormwater samples collected by KCEL field staff were delivered to the lab on the date of sample collection. Samples designated for analysis at Analytical Resources, LLC (ARI) were shipped via courier as soon as possible after sample delivery, within 1-2 business days after collection. All samples were analyzed for the parameters outlined in Table 2.

No laboratories were accredited for 6PPDQ analysis at the start of this project. Ecology's Lab Accreditation Unit (LAU) signed an accreditation waiver for KCEL to complete analysis of samples collected in support of this project. KCEL later received accreditation in Spring 2025.

Table 2. Parameters measured and associated methods used in this study.

Parameter	Method	Laboratory
6PPD-quinone	KCEL SOP #4077	KCEL
Turbidity	SM 2130-B	KCEL
Total Suspended Solids	SM 2540-D	KCEL
Total Phosphorus	SM 4500-P-B,F	KCEL
Orthophosphate Phosphorus	SM 4500-P,F	KCEL
Total Kjeldahl Nitrogen	EPA 351.2	KCEL
Total Nitrogen	SM 4500-N-C	KCEL
Nitrate-nitrite Nitrogen	SM 4500-NO3-F	KCEL
Ammonia Nitrogen	Kerouel & Aminot 1997	KCEL
Total Organic Carbon	SM 5310-B	KCEL
Dissolved Organic Carbon	SM 5310-B	KCEL
Hardness as CaCO ₃	SM 2340B	KCEL
Total Metals	EPA 200.8	KCEL
Dissolved Metals	EPA 200.8	KCEL
PCB Aroclors	EPA 8082A	ARI
Semivolatile Organic Compounds	EPA 8270E	ARI
Semivolatile Petroleum Products	NWTPH-Dx	ARI

Monitoring Events

Storm event data was collected from 15 storms. Event-specific information is presented in Table 3. Two to three grab samples were collected for all parameters during each storm event with exceptions listed in Appendix A.

Table 3. Storm event sampling summary.

Event	Sample Date	Lab Report ID	Number of Grab Samples Collected
1	4/6/2023	L81244	2
2	4/10/2023	L81375	3
3	4/18/2023	L81406	2
4	9/25/2023	L81954	3
5	9/27/2023	L82573	3
6	11/2/2023	L82606	2
7	1/8/2024	L82842	3
8	1/17/2024	L83191	3
9	1/31/2024	L83215	3
10	3/27/2024	L83302	3
11	10/30/2024	L83576	3
12	11/4/2024	L85044	3
13	11/13/2024	L85068	3
14	2/24/2025	L85124	3
15	4/7/2025	L85649	3

Quality Assurance

All results were compared to data quality objectives (DQOs) in the QAPP and reviewed for appropriateness of use in this report. Several deviations from the QAPP (King County, 2023) occurred and are outlined in Appendix A.

Results

Summary statistics from all grab samples collected across 15 events are presented in Table 4.

Table 4. Summary statistics for characterized stormwater runoff.

Parameter	units	N	Detection Frequency (%)	Median ¹	Mean ¹	Standard Deviation ¹	Min	Max
6PPD-quinone	ug/L	42	100	0.61	0.56	0.30	0.03	1.27
Turbidity	NTU	42	100	26.0	26.20	13.60	0.96	60.3
Total Suspended Solids	mg/L	42	97.6	26	36.96	33.84	<MDL	155
Total Phosphorus	mg/L	41	100	0.096	0.11	0.09	0.0201	0.59
Orthophosphate Phosphorus	mg/L	41	100	0.0329	0.04	0.03	0.0119	0.11
Total Kjeldahl Nitrogen	mg/L	42	100	0.957	0.98	0.31	0.411	1.8
Total Nitrogen	mg/L	42	100	1.27	1.54	0.51	0.947	2.95
Nitrate-nitrite Nitrogen	mg/L	42	100	0.605	0.74	0.45	0.242	1.93
Ammonia Nitrogen	mg/L	42	100	0.174	0.17	0.10	0.016	0.416
Total Organic Carbon	mg/L	42	100	12.4	13.47	4.78	7.1	29.8
Dissolved Organic Carbon	mg/L	40	100	6.88	7.18	2.21	4.13	11.4
Hardness	mg CaCO ₃ /L	42	100	54.7	77.57	58.35	25.4	306
Cadmium, Total	ug/L	42	95.2	0.11	0.14	0.08	<MDL	0.387
Cadmium, Dissolved	ug/L	42	31	0.067	0.10	0.06	<MDL	0.23
Copper, Total	ug/L	42	100	28.5	29.72	15.87	8.52	79.8
Copper, Dissolved	ug/L	42	100	9.74	11.25	3.99	5.52	21.2
Lead, Total	ug/L	42	100	9.67	10.95	7.41	1.82	32.2
Lead, Dissolved	ug/L	42	100	1.11	1.32	0.75	0.34	3.48
Zinc, Total	ug/L	42	100	98.6	110.06	63.95	26.3	308
Zinc, Dissolved	ug/L	42	100	33.9	35.40	11.18	17.2	69.6
Diesel Range Organics (C12-C24)	mg/L	42	76.2	0.271	0.30	0.14	<MDL	0.66

Parameter	units	N	Detection Frequency (%)	Median ¹	Mean ¹	Standard Deviation ¹	Min	Max
Motor Oil Range Organics (C24-C38)	mg/L	42	90.5	1.21	1.22	0.65	<MDL	3.12
PCB Aroclors - all	ug/L	42	0	N/A	N/A	N/A	<MDL	N/A
Semivolatile Organics ²								
bis(2-Ethylhexyl)phthalate	ug/L	42	81	1.2	1.46	0.83	<MDL	2.8
Di-n-Octylphthalate	ug/L	42	47.6	0.15	0.28	0.30	<MDL	1.3
Phenol	ug/L	42	47.6	0.10	0.11	0.06	<MDL	0.2
Benzyl Alcohol	ug/L	42	23.8	0.09	0.11	0.06	<MDL	0.2
Dimethylphthalate	ug/L	42	38.1	0.06	0.07	0.04	<MDL	0.2
4-Methylphenol	ug/L	42	31	0.08	0.09	0.06	<MDL	0.3
Fluoranthene	ug/L	42	31	0.07	0.08	0.04	<MDL	0.2
Pyrene	ug/L	42	57.1	0.09	0.11	0.07	<MDL	0.3
Diethyl phthalate	ug/L	42	61.9	0.10	0.12	0.05	<MDL	0.2
pH	pH units	42	N/A	7.50	7.51	0.29	6.86	8.14
Temperature	deg C	42	N/A	10.516	10.74	3.32	2.477	17.563
Conductivity	umhos/cm	42	100	282.3	398.79	330.58	61	1653

¹ Results <MDL omitted from median, mean, and standard deviation calculations

² Select Semivolatile Organics results presented in this table. Parameter shown only if max result is ≥RDL and there are 10 or more results >MDL

Results are graphed for each parameter below, except where most sample concentrations were less than the reporting detection limit (<RDL) and these exceptions are noted below. All events had 3 grab samples collected, except for events 1, 3, and 6 which had only 2 grab samples collected. Graphs that include data points that are less than the method detection limit (<MDL) have <MDL noted where appropriate. All 6PPDQ samples exceeded the Aquatic Life Toxics Criteria of 0.012 ug/L for freshwater acute mortality (Ecology, 2024)

6PPD-quinone

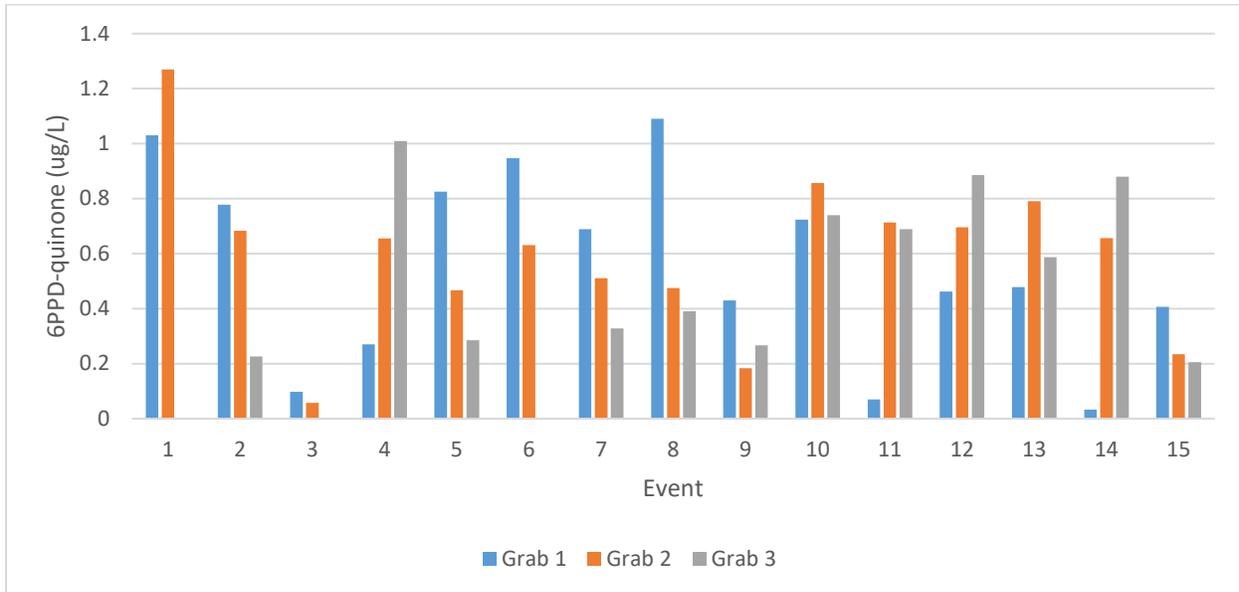


Figure 2. 6PPDQ concentrations in stormwater runoff.

Turbidity

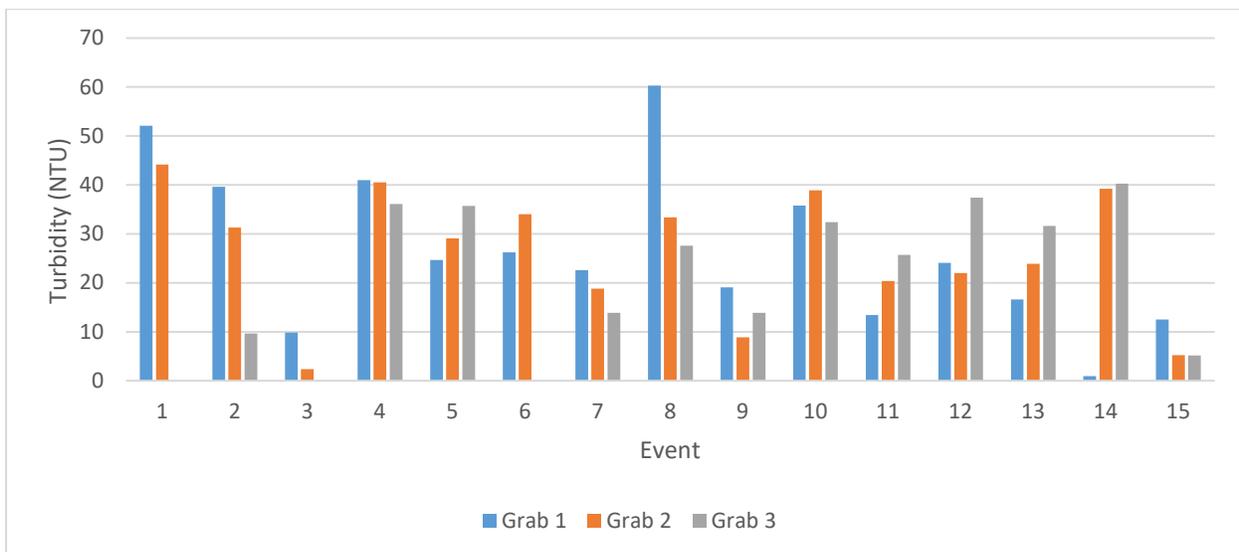


Figure 3. Turbidity of stormwater runoff.

Total Suspended Solids

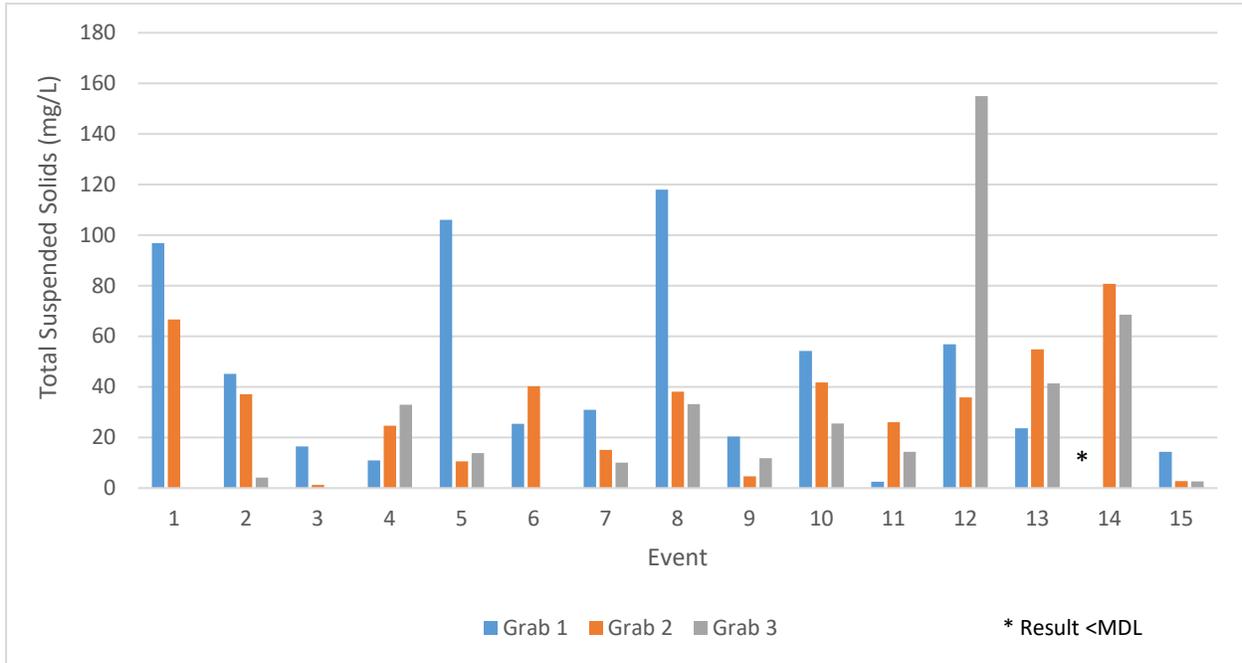


Figure 4. Total Suspended Solids in stormwater runoff.

Nutrients

Grab 1 results for Event 13 not included for Orthophosphate Phosphorus (Figure 5) or Total Phosphorus (Figure 6) due to a comparison issue and subsequent estimated results.

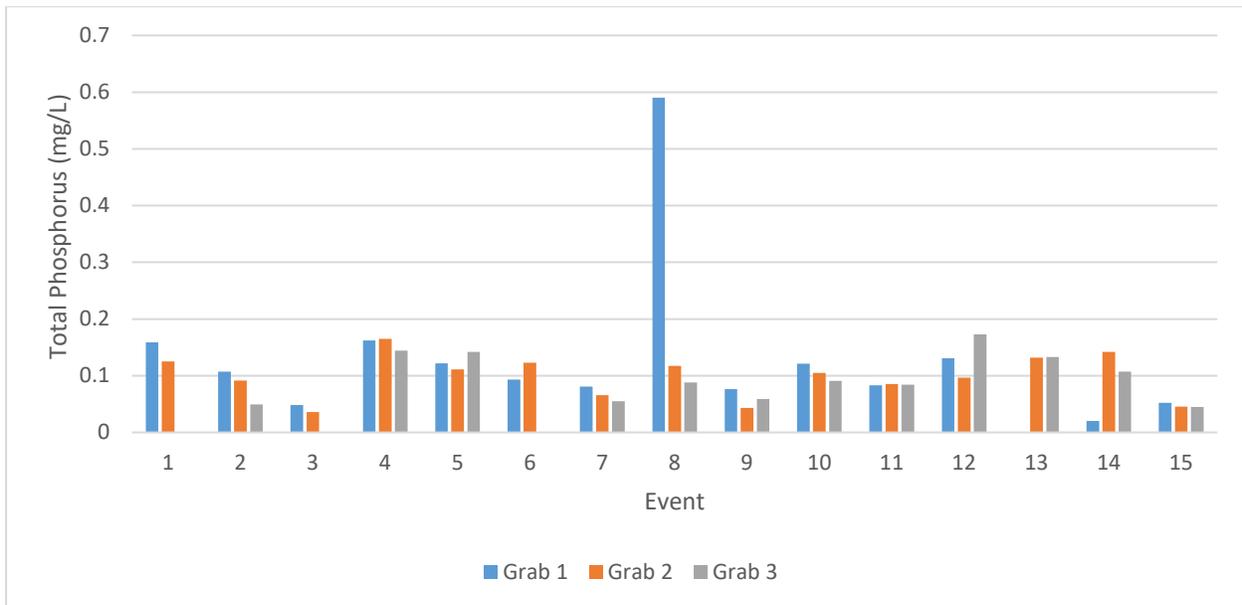


Figure 5. Total Phosphorus concentrations in stormwater runoff.

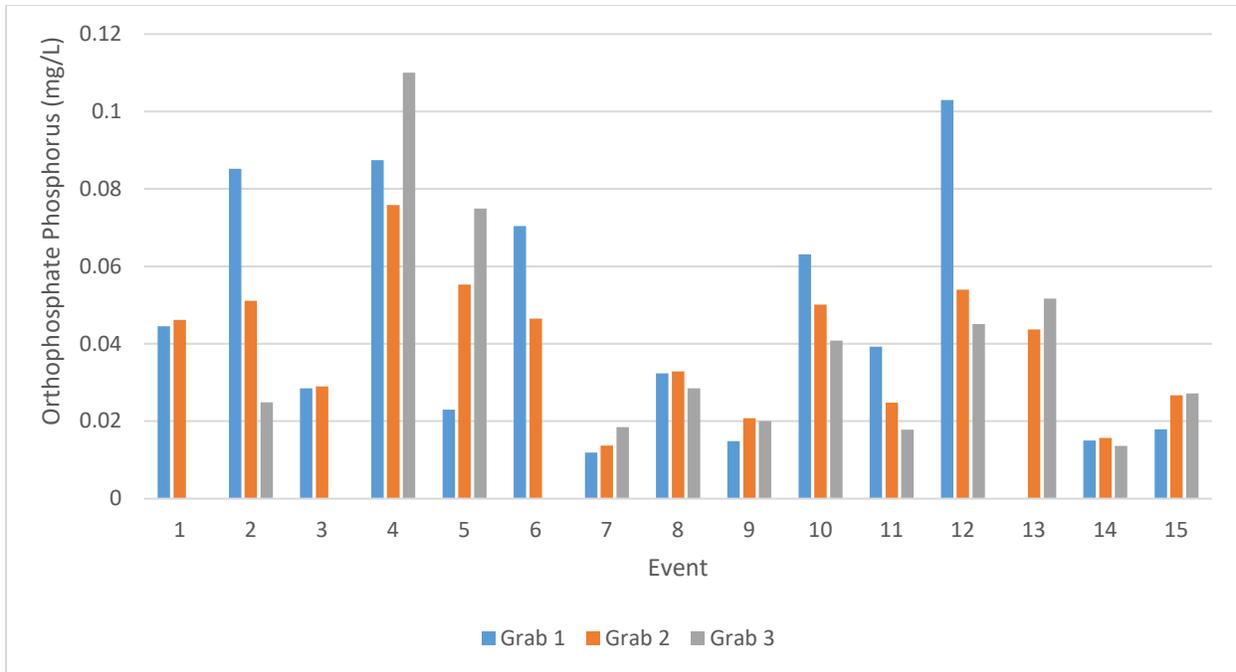


Figure 6. Orthophosphate Phosphorus concentrations in stormwater runoff.

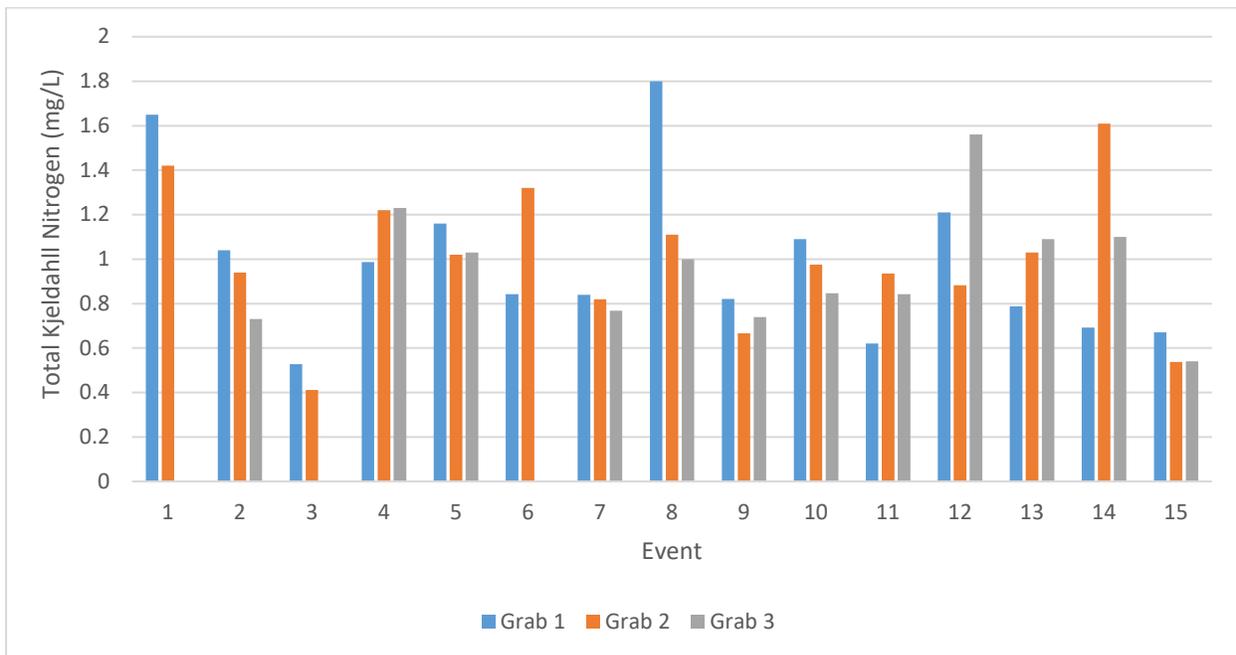


Figure 7. Total Kjeldahl Nitrogen concentrations in stormwater runoff.

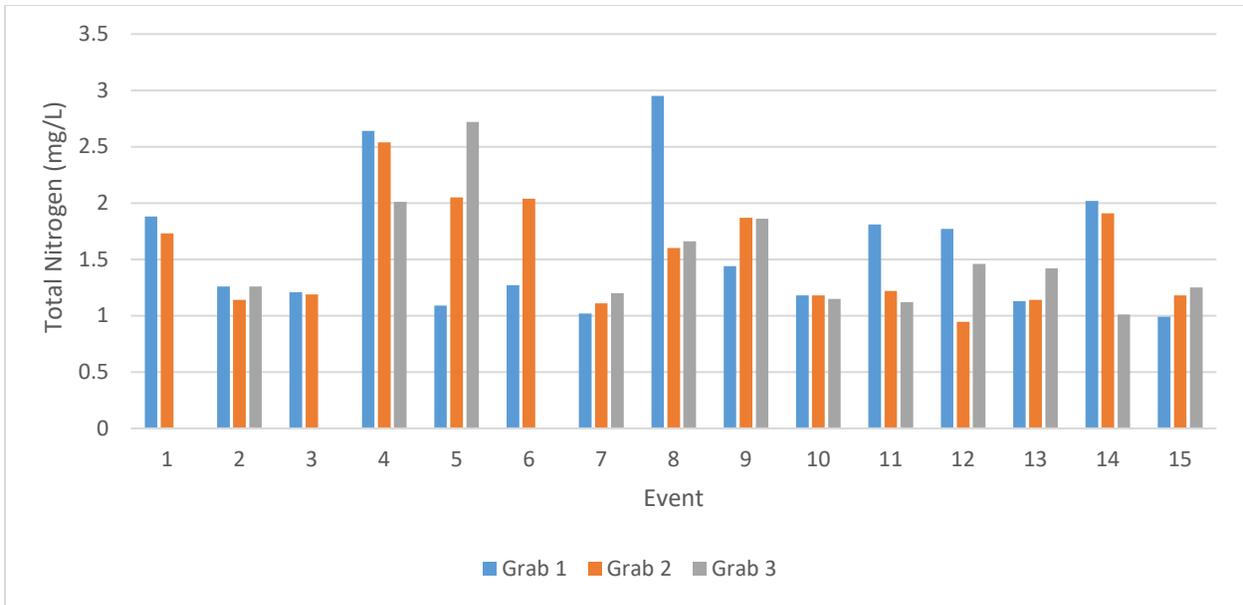


Figure 8. Total Nitrogen concentrations in stormwater runoff.

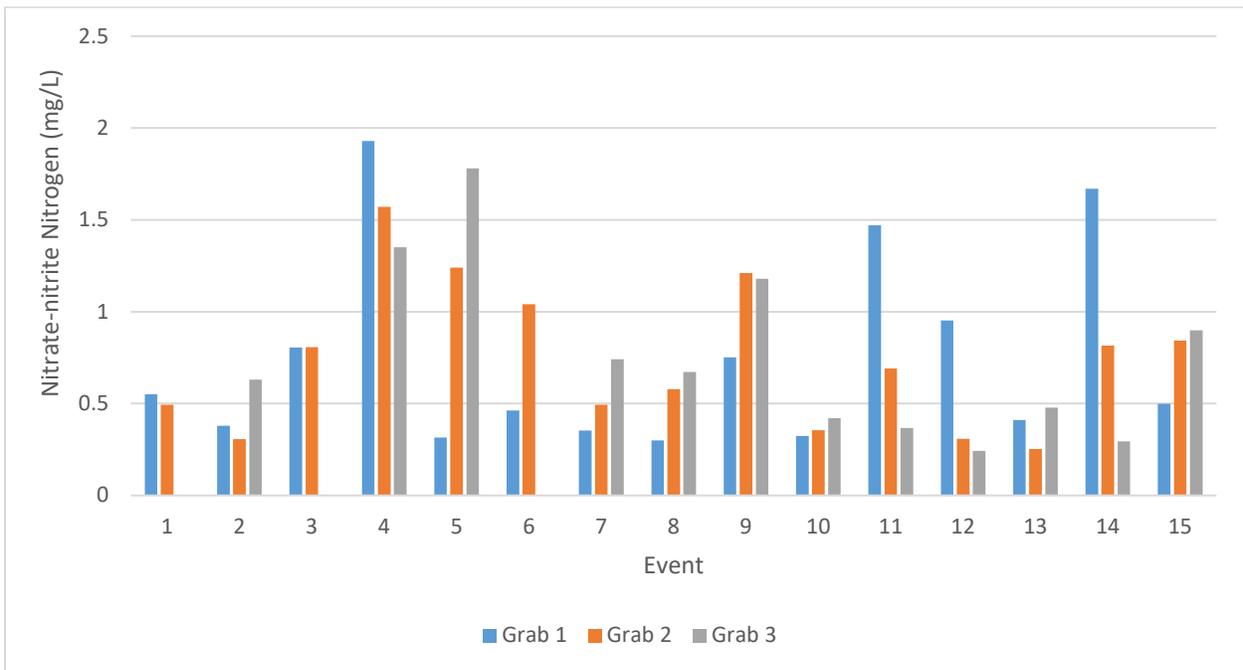


Figure 9. Nitrate-nitrite Nitrogen concentrations in stormwater runoff.

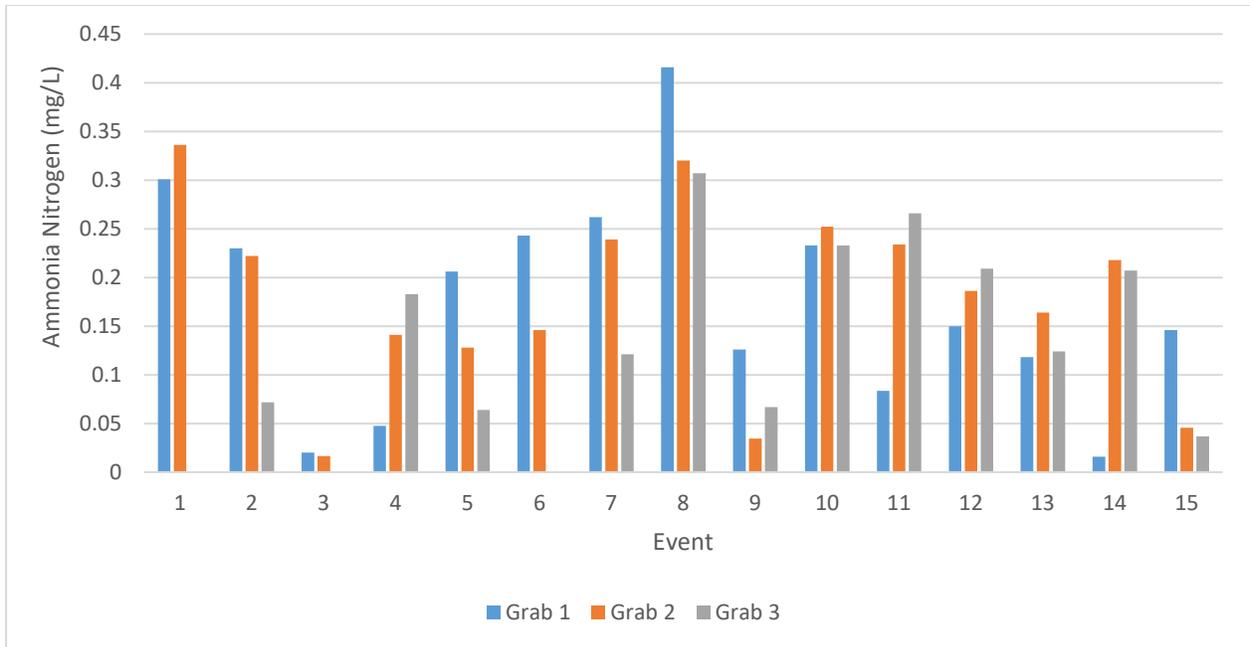


Figure 10. Ammonia Nitrogen concentrations in stormwater runoff.

Total and Dissolved Organic Carbon

No Dissolved Organic Carbon data reported for Event 3, see Appendix A for details.

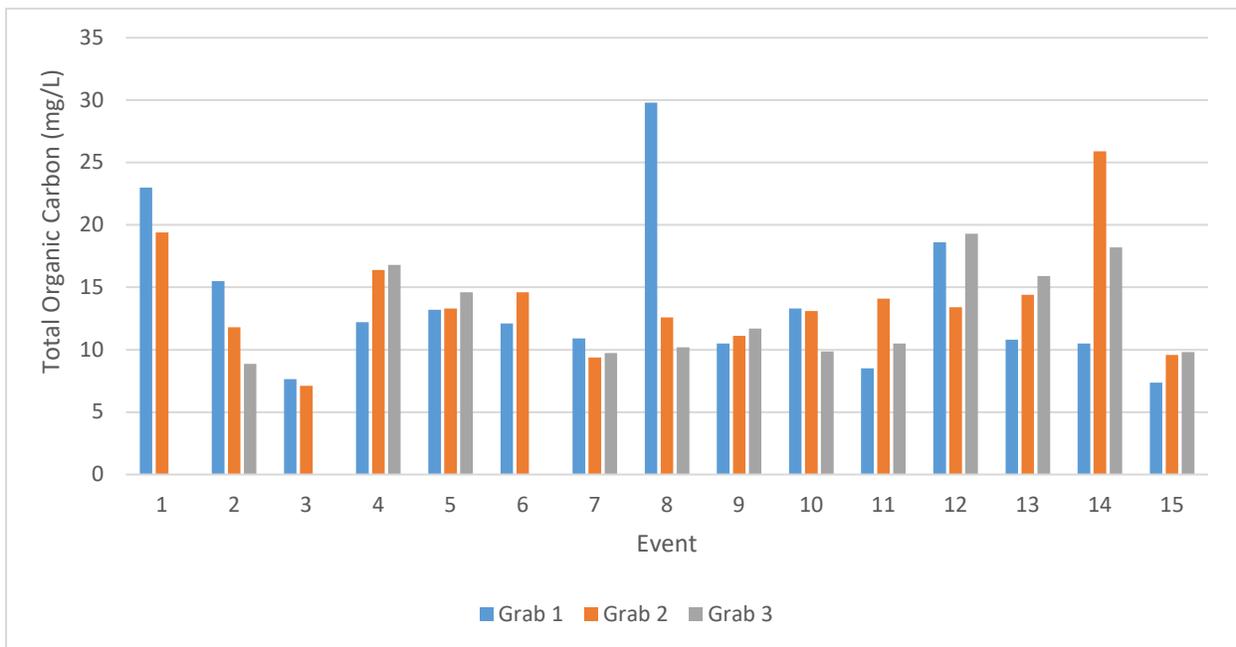


Figure 11. Total Organic Carbon concentrations in stormwater runoff.

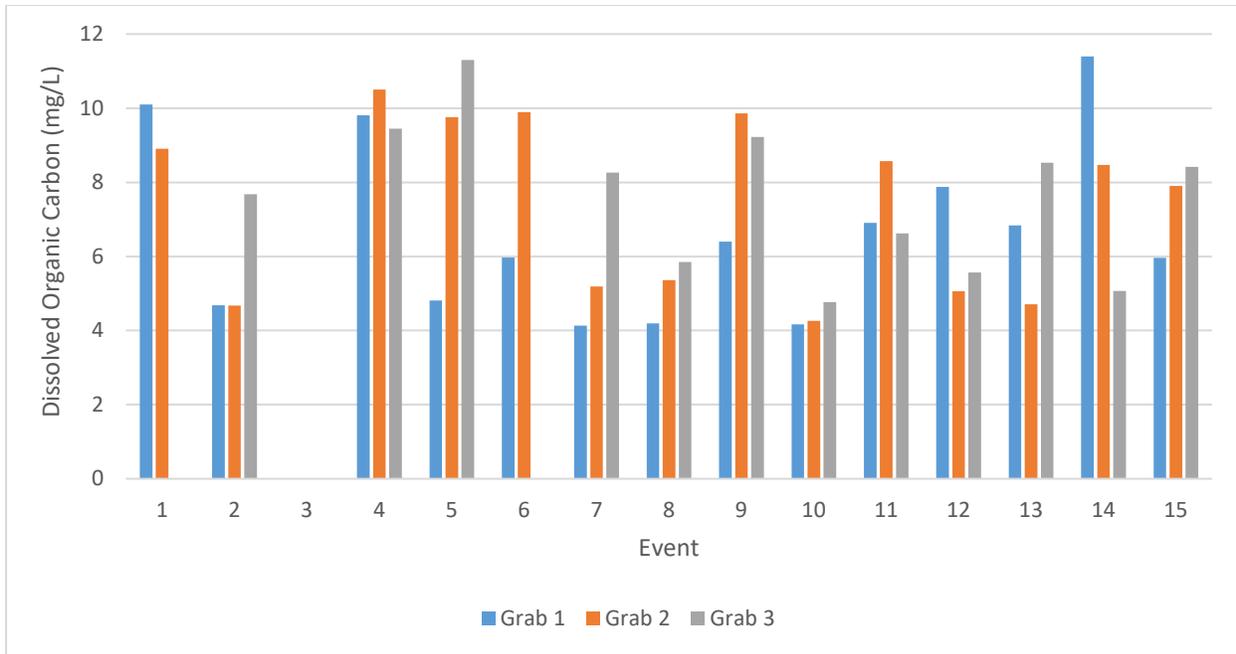


Figure 12. Dissolved Organic Carbon concentrations in stormwater runoff.

Metals and Hardness

Total Cadmium was <RDL except for in four samples, all 3 grabs from event 8 and the third grab from event 12. See Table 4 for Total Cadmium summary statistics. All dissolved cadmium results were <RDL.

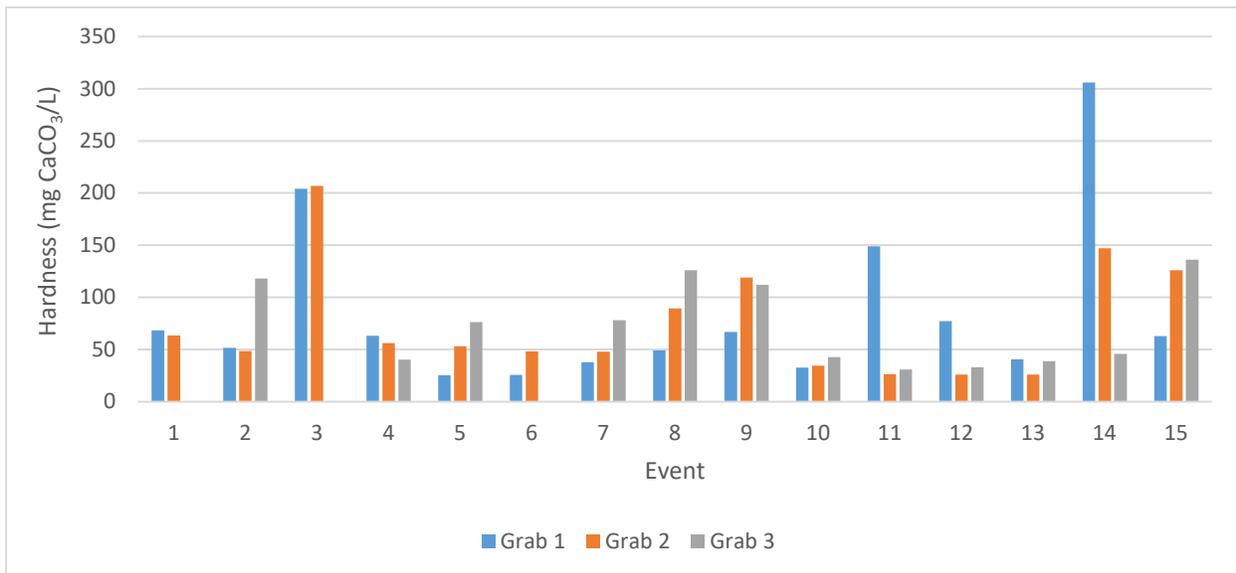


Figure 13. Hardness of stormwater runoff.

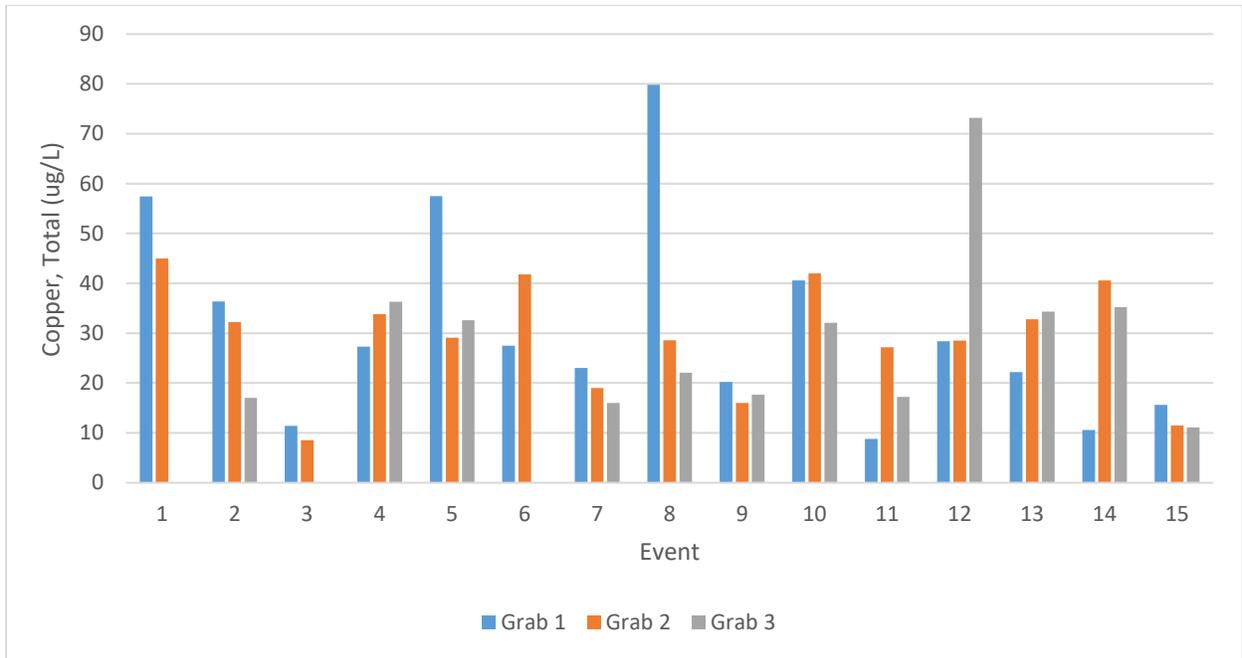


Figure 14. Total Copper concentrations in stormwater runoff.

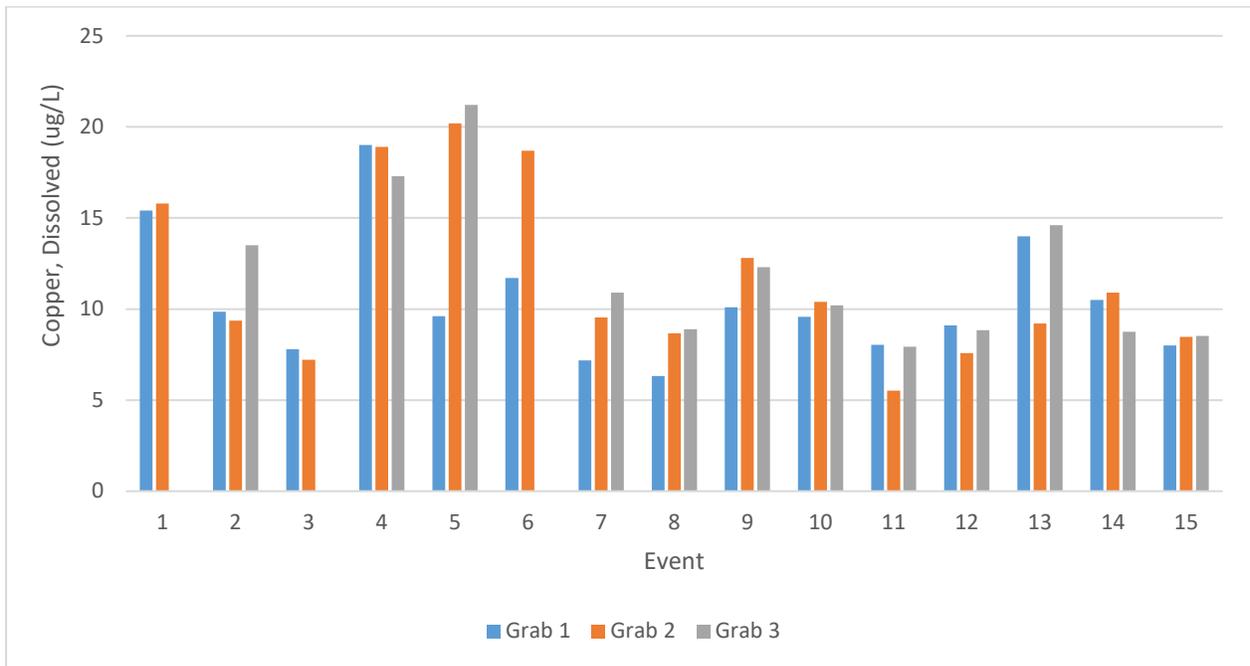


Figure 15. Dissolved Copper concentrations in stormwater runoff.

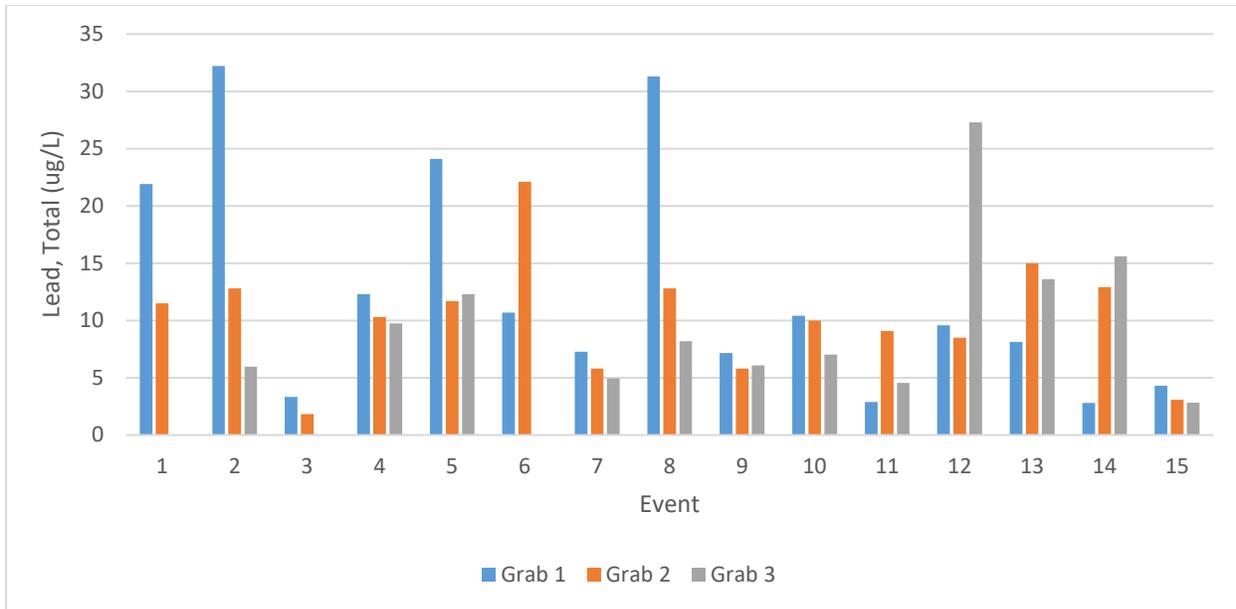


Figure 16. Total Lead concentrations in stormwater runoff.

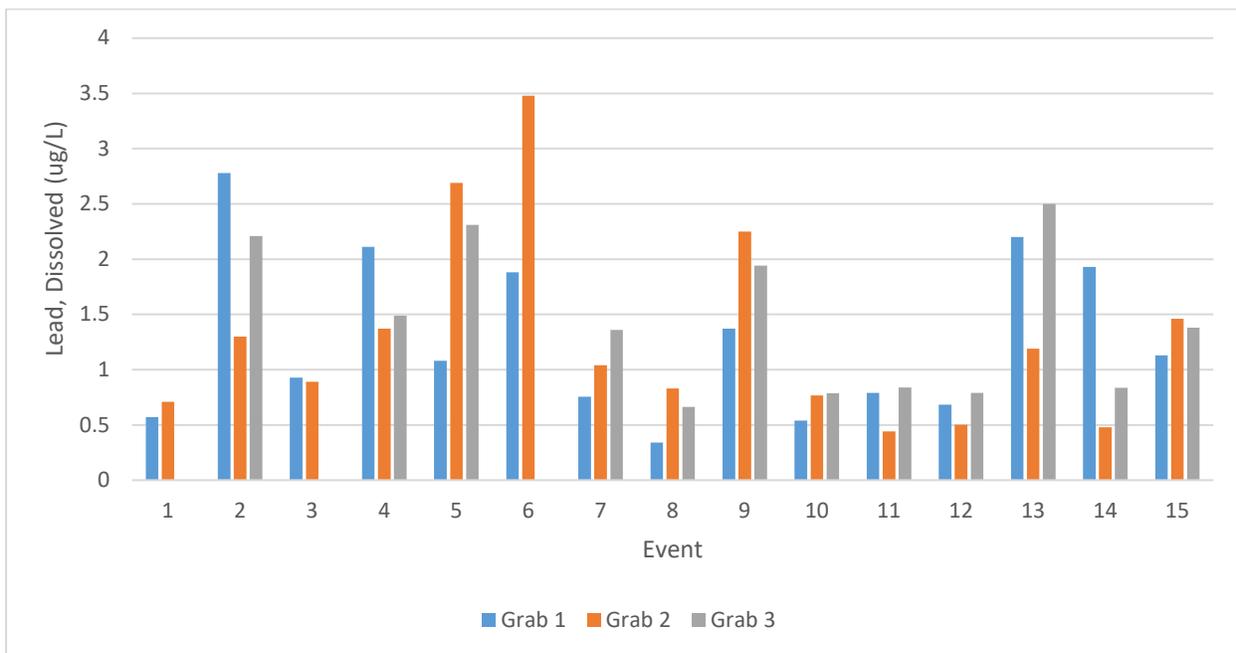


Figure 17. Dissolved Lead concentrations in stormwater runoff.

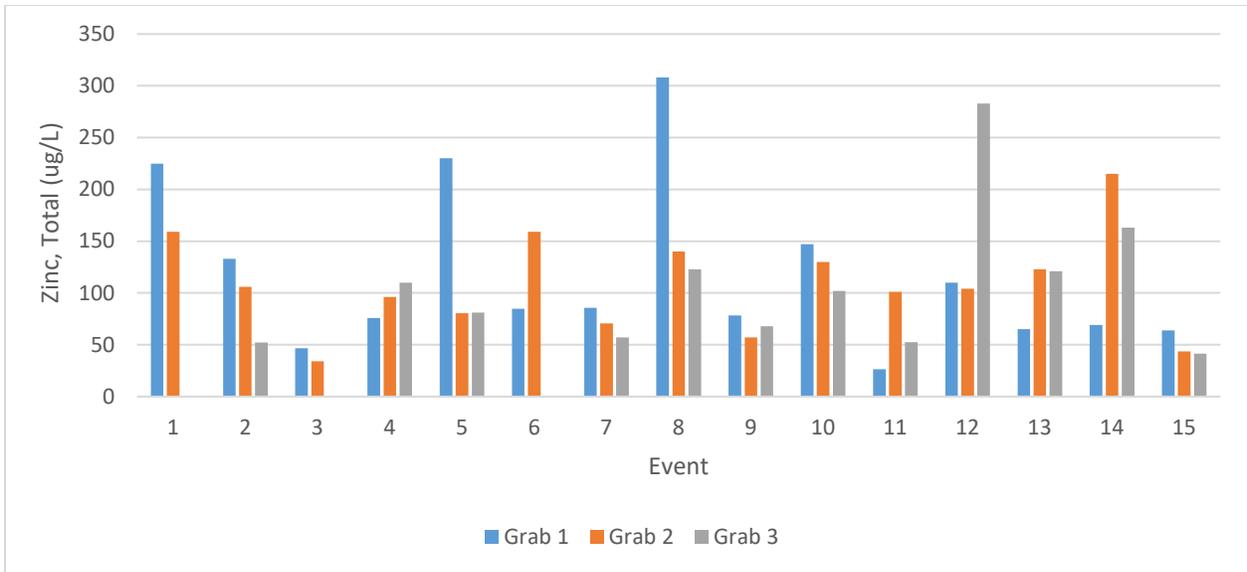


Figure 18. Total Zinc concentrations in stormwater runoff.

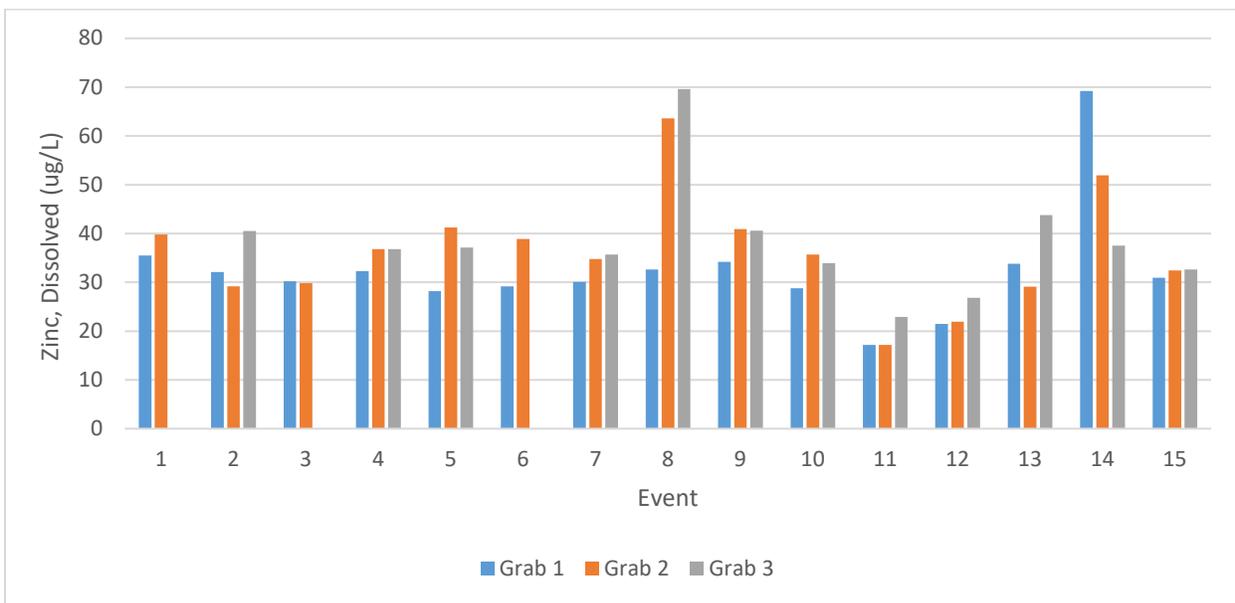


Figure 19. Dissolved Zinc concentrations in stormwater runoff.

PCB Aroclors

All samples collected had PCB Aroclor results that were <MDL.

Semivolatile Organic Compounds

The only Semivolatile Organic Compound with reported results regularly \geq RDL was bis(2-Ethylhexyl)phthalate. Results for this compound are presented in Figure 20. Selected Semivolatile Organic compounds have summary statistics presented in Table 4.

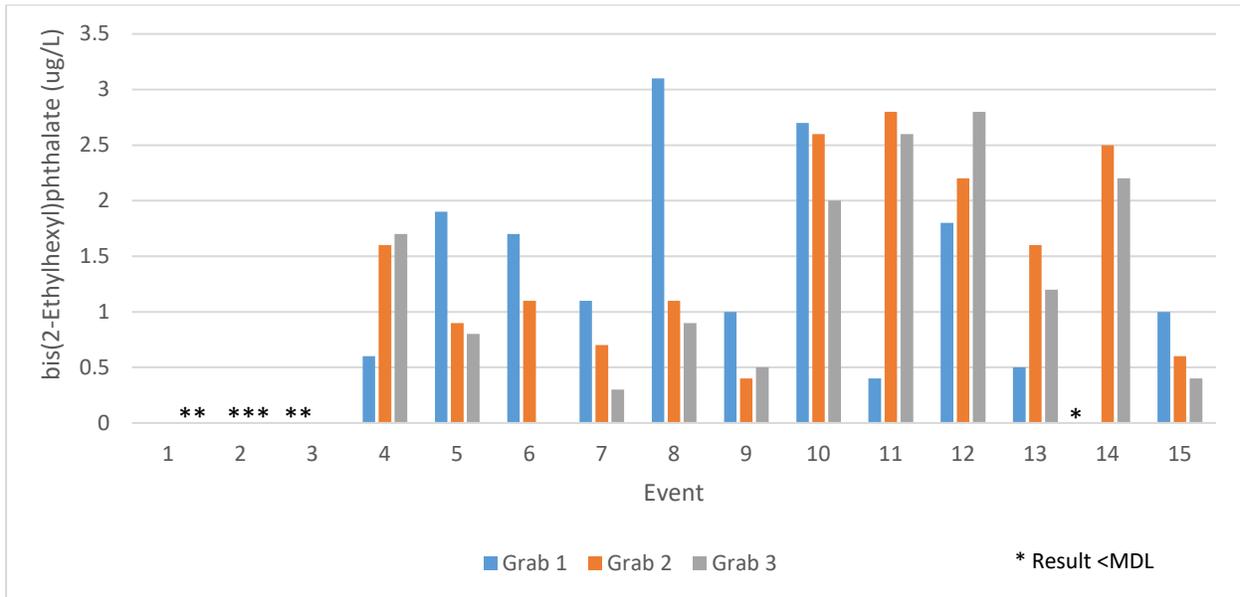


Figure 20. bis(2-Ethylhexyl)phthalate concentrations in stormwater runoff.

Semivolatile Petroleum Products

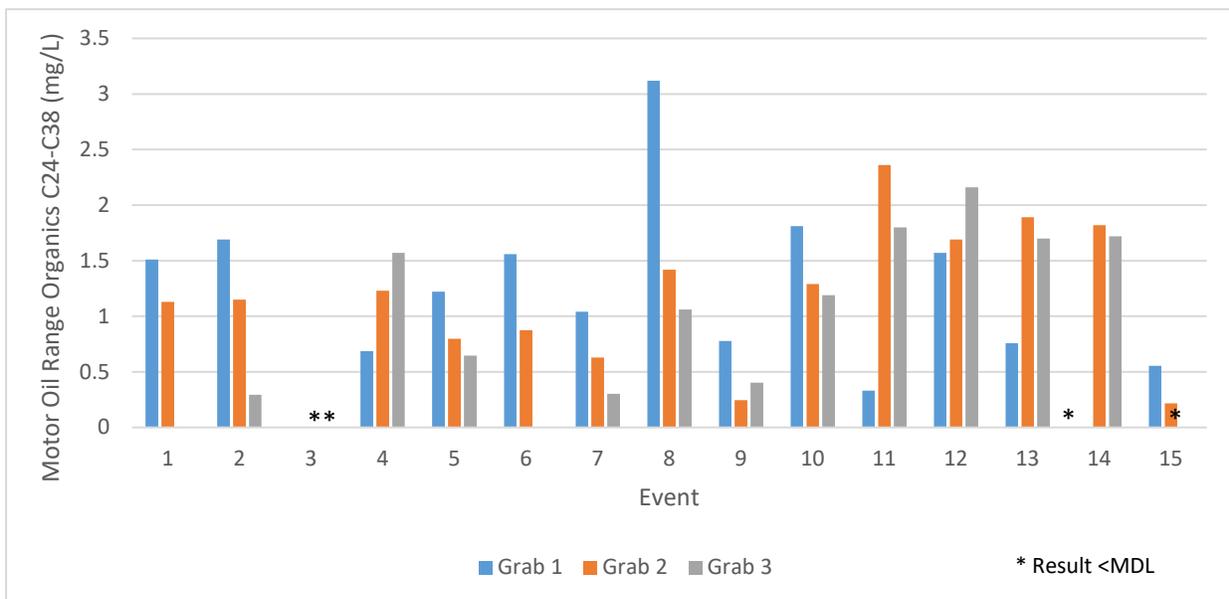


Figure 21. Motor Oil Range Organics (C24-C38) concentrations in stormwater runoff.

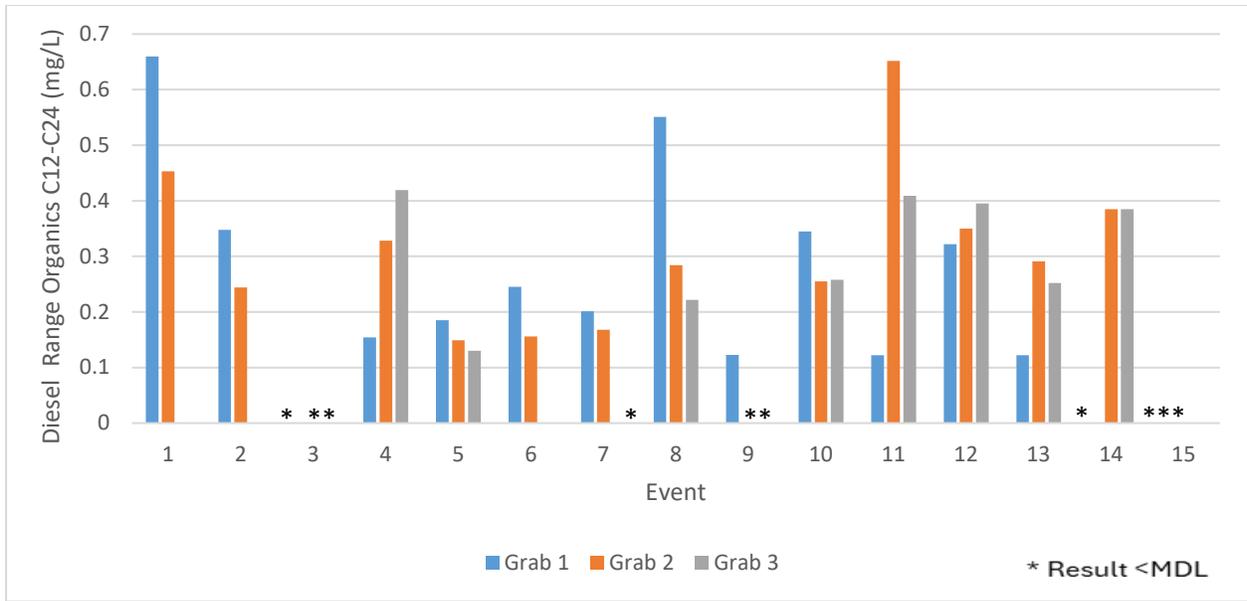


Figure 22. Diesel Range Organics (C12-C24) in stormwater runoff.

Field parameters

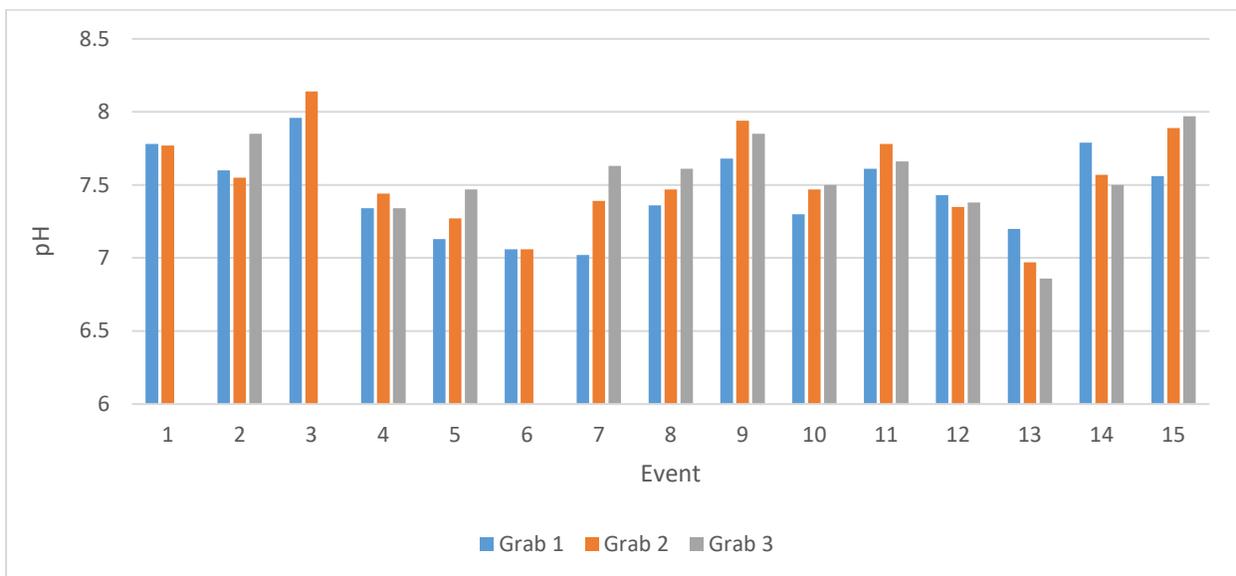


Figure 23. pH of stormwater runoff.

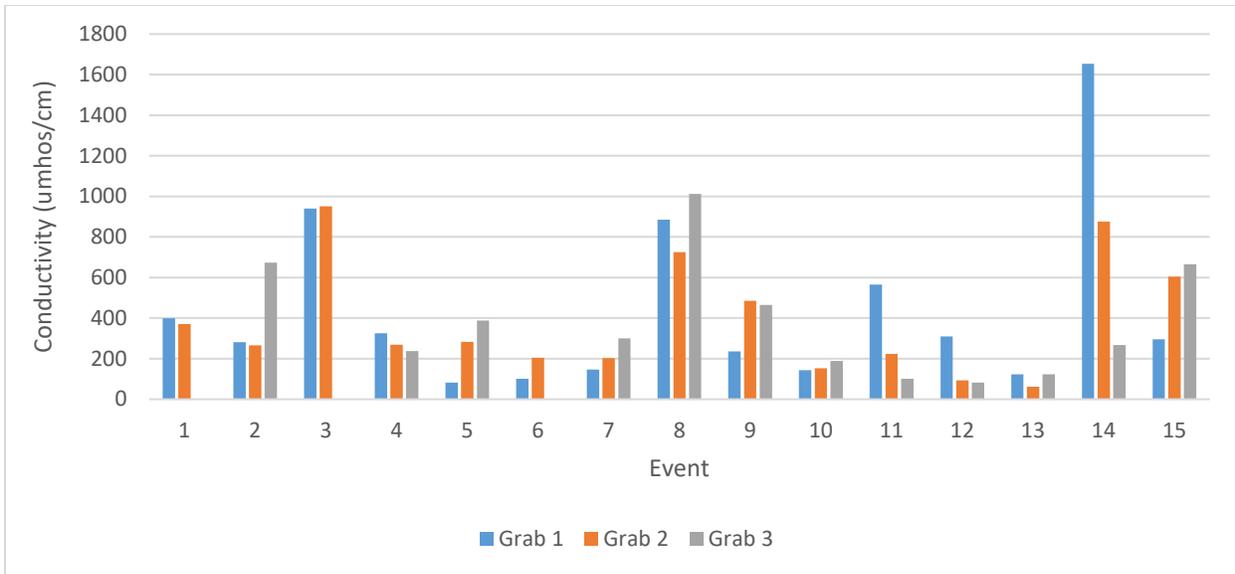


Figure 24. Conductivity of stormwater runoff.

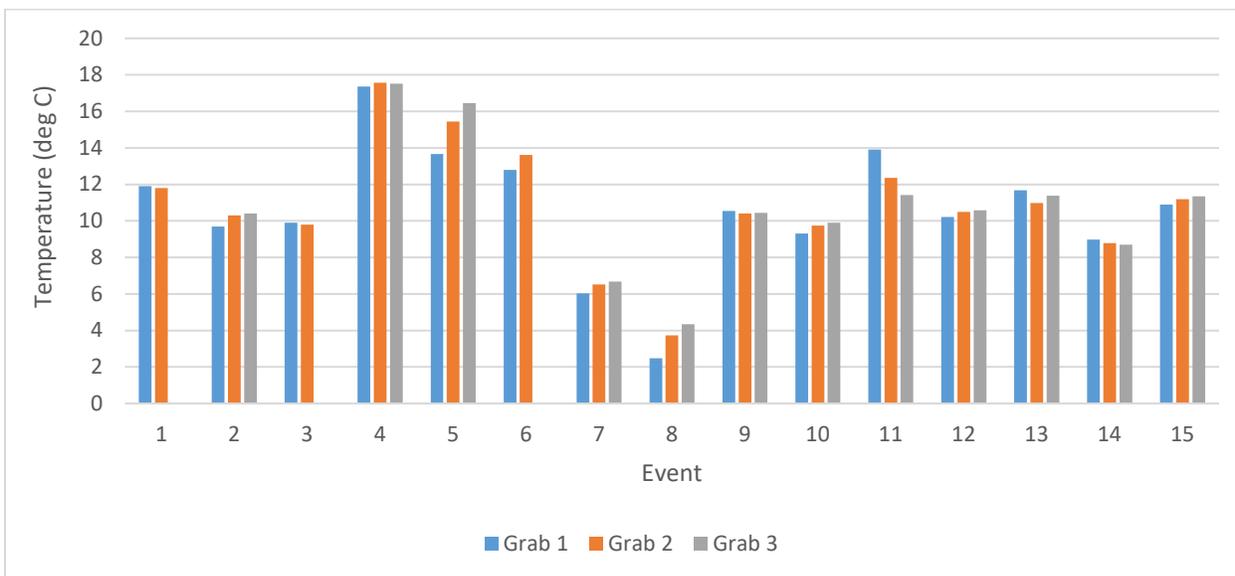


Figure 25. Temperature of stormwater runoff.

Discussion and Findings

In August of 2024, Ecology adopted an acute, freshwater Aquatic Life Toxics Criteria value for 6PPDQ of 0.012 ug/L under the 173-201A-240 Washington Administrative Code (Ecology, 2024). In this study, 6PPDQ concentrations in untreated stormwater runoff collected at SCTF had median concentrations of about 0.6 ug/L. All 6PPDQ results reported in this study exceeded the aquatic life criteria value by varying orders of magnitude.

Many TAPE parameters were measured to gather data for future statistical analysis on how they might correlate with 6PPDQ concentrations. The relationships between water quality parameters and 6PPDQ concentrations were visualized with bar graphs (Figure 2 to Figure 25). A potential strong positive relationship with 6PPDQ was observed for Ammonia Nitrogen and Motor Oil Range Organics (C24-C38). There may be a positive relationship with 6PPDQ and Diesel Range Organics (C12-C24), Total Copper, and Total Zinc. These potential relationships were determined based on a visual comparison between 6PPDQ bar graphs and other analytes. Further data and statistical analyses are needed to confirm this visual observation.

For future stormwater runoff characterization at the SCTF removing PCB Aroclors, Total Cadmium, Dissolved Cadmium, and Semivolatile Organics from the list of parameters to be tested can be considered since most of these results in this study were <RDL, if not <MDL.

Areas for future investigation include:

- Additional statistical evaluation of this characterization data to determine if there is a relationship between 6PPDQ and analyzed TAPE parameters, particularly for Ammonia Nitrogen and Motor Range Organics (C24-38). If a positive relationship is determined for stormwater runoff at SCTF, then researchers should determine if this relationship remains consistent for stormwater runoff at other TAPE facilities.
- More frequent 6PPDQ sampling over the hydrograph to determine if there is a consistent contaminant concentration profile.
- Researching BMPs and other types of stormwater treatment that will reduce 6PPDQ concentrations and other contaminant concentrations of stormwater runoff at SCTF and other stormwater collection facilities.

References

- Brinkmann, M., D. Montgomery, S. Selinger, J.G. Miller, E. Stock, A.J. Alcaraz, J.K. Challis, L. Weber, D. Janz, M. Hecker and S. Wiseman. 2022. Acute toxicity of the tire rubber-derived chemical 6ppd-quinone to four fishes of commercial, cultural, and ecological importance. *Environmental Science & Technology Letters*, 9(4), pp.333-338.
- Ecology, 2007. Washington State Department of Ecology. Phase I Municipal Stormwater Permit. Olympia WA. January 17, 2007
- Ecology, 2015. Western Washington NPDES Phase 1 Stormwater Permit: Final S8.D Data Characterization. Washington Department of Ecology, Olympia. Publication No. 15-03-001. 154 pp.
- Ecology, 2018a. Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies: Technology Assessment Protocol - Ecology (TAPE). Washington State Department of Ecology, Olympia, WA. Publication No. 18-10-038.
- Ecology, 2018b. Technology Assessment Protocol-Ecology (TAPE) Process Overview. Washington State Department of Ecology, Olympia, WA. Publication No. 18-10-039.
- Ecology, 2019. Washington State Department of Ecology. Phase I Municipal Stormwater Permit Appendix 9, Olympia, WA.
- Ecology, 2024. Aquatic Life Toxics Criteria Rulemaking Concise Explanatory Statement Chapter 173-201A WAC. Washington State Department of Ecology, Olympia, WA. Publication No. 24-10-032.
- Hiki, K., K. Asahina, K. Kato, T. Yamagishi, R. Omagari, Y. Iwasaki, H. Watanabe and H. Yamamoto. 2021. Acute toxicity of a tire rubber-derived chemical, 6PPD quinone, to freshwater fish and crustacean species. *Environmental Science & Technology Letters*, 8(9), pp.779-784.
- King County, 2023. Quality Assurance Project Plan for Stormwater Characterization for BMPs Study. Prepared by Meghan Elkey and Brandi Lubliner. Seattle, Washington. March 2023.
- University of Washington, 2025. Time Series Plots at Northwest Stations. Seattle, Washington. < https://www-k12.atmos.washington.edu/k12/grayskies/nw_weather.php>
- Tian, Z., H. Zhao, K.T. Peter, M. Gonzalez, J. Wetzel, C. Wu, X. Hu, J. Prat, E. Mudrock, R. Hettinger and A.E. Cortina. 2021. A ubiquitous tire rubber-derived chemical induces acute mortality in coho salmon. *Science*, 371(6525), pp.185-189.
- Tian, Z., M. Gonzalez, C.A. Rideout, H.N. Zhao, X. Hu, J. Wetzel, E. Mudrock, C.A. James, J.K. McIntyre and E.P. Kolodziej. 2022. 6PPD-quinone: Revised toxicity assessment and

quantification with a commercial standard. Environmental Science & Technology Letters, 9(2), pp.140-146.

WSDOT, 2025. Traffic count data. Olympia, Washington.

< <https://wsdot.wa.gov/about/transportation-data/travel-data/traffic-count-data>>

Appendix A: Summary of QAPP Deviations

Field procedures

There were no QAPP deviations for field procedures.

Analytical procedures

- Samples for Event 3 (April 18, 2023) were not lab filtered for Dissolved Organic Carbon (DOC) due to analyst oversight. The affected DOC results were rejected and reported as null values.
- The Ammonia sample for the first grab for Event 5 (September 27, 2023) was reported above the calibration range of the analysis and it was not possible to dilute and reanalyze the sample. The affected sample result was J qualified, and the result is considered an estimate.
- The method blank (MB) associated with the Total Suspended Solids (TSS) result for the second grab for Event 9 (January 31, 2024) had a result greater than the MDL. The TSS result was B qualified to indicate the qualifiable result was >MDL and <5x the contamination in the method blank before the dilution factor was taken into account. This sample result may have a potential positive bias due to MB contamination.
- There was an unusual comparison between the Total Phosphorous and Orthophosphate Phosphorus results for the first grab for Event 13 (November 13, 2024). The Orthophosphate Phosphorus result was greater than the Total Phosphorous result, both sample results were J qualified, and the results are considered estimates.
- For Event 13 (November 13, 2024), bis(2-ethylhexyl)phthalate and Di-n-Octylphthalate were re-extracted out of hold time due to an internal standard issue that occurred during the initial analysis. All bis(2-ethylhexyl)phthalate and Di-n-Octylphthalate results for this event are H qualified to indicate holding time criteria were not met.
- For Event 14 (February 24, 2025) Diethyl phthalate and Benzo(g,h,i)perylene were re-extracted out of hold time due to analytical issues. All Diethyl phthalate and Benzo(g,h,i)perylene results for this event are H qualified to indicate holding time criteria were not met.
- The 6PPDQ result for the first grab for Event 15 (April 7, 2025) had an ion ratio failure likely due to matrix interference. The affected sample result was J qualified, and the result is considered an estimate.
- For Event 15 (April 7, 2025), Motor Oil Range Organics and Diesel Range Organics were re-extracted out of hold time due to analytical issues. All Motor Oil Range Organics and Diesel Range Organics results for this event are H qualified to indicate holding time criteria were not met.

Field filter blanks

Dissolved metals

Field filter blanks for the first three events (April 6, 10, and 18, 2023) were >MDL for Copper and Zinc. The Copper and Zinc field blank contamination seen in the reported data for these events was shown to originate in the infrequently used RO water faucets in the KCEL splitting room. Because the contamination came from the source water, the contamination is isolated to the filter blanks themselves and the sample results are unaffected. Lab water for all future events was sourced from a pre-purged reverse osmosis water faucet in the Trace Metals Lab. Field staff filtered the new source water at the sample site to confirm no contamination was present prior to future events and to rule out contamination during filtration at the site, these results were all <MDL and not reported. All other field filter blanks results were <MDL except Zinc for Event 5 (September 27, 2023). For this event the Zinc result in the field filter blank was <10x all associated Zinc sample results so there is no effect on the sample data.

Dissolved nutrients

Field filter blanks for Event 2 (April 10, 2023), Event 3 (April 18, 2023), and Event 6 (November 2, 2023) were >MDL for Orthophosphate Phosphorus. For Events 2 and 6 the Orthophosphate Phosphorus results in the field filter blanks were <10x all associated Orthophosphate Phosphorus sample results so there is no effect on the sample data. For Event 3 the Orthophosphate Phosphorus result in the field filter blanks were >10x all associated Orthophosphate Phosphorus sample results so these sample results may be biased high. This high result for the field filter blank is likely due to inadequate rinsing of the filter with reverse osmosis water prior to filtering the blank sample but that cannot be confirmed.

The field filter blank for Event 2 was >MDL for Nitrate-nitrite Nitrogen. For this event the Nitrate-nitrite Nitrogen result in the field filter blank was <10x all associated Nitrate-nitrite Nitrogen sample results so there is no effect on the sample data.

Appendix B: Field Procedures Report

Chain of custody documents for all events are at the end of Appendix B.



Figure 26. KCEL field staff collecting a sample at the SCTF from the sampling valve.



Figure 27. Layout of sampling area at SCTF.

Project event summary

- Sufficient sample volume was collected to test for all parameters requested for each event.
- Field measurements were taken at the same time each grab sample was collected.
- Samples were dark in color and turbid, typical of dirty urban stormwater. There is an exception noted in Event 14, where the first grab sample was clearer and resembled baseflow conditions.
- Dissolved metals and dissolved nutrients were filtered at the sampling location within 15 minutes of sample collection. Field filtration blanks were collected as a part of each event.
- Chain of custody for all samples was maintained by KCEL staff for the duration of sample collection and delivery to lab.
- Rain gauge information was determined from nearby rain gauge at UW Rooftop (University of Washington, 2025).

Event 1 - April 6, 2023

- First grab collected at 14:40.
- Second grab collected at 16:20.
- Third grab not collected as storm had tapered off.
- 1.67 hours elapsed between grab 1 and 2.
- Weather conditions: 0.17 inches of rain at start of sample collection, 0.26 inches of rain prior to collecting grab 2.

Event 2 – April 10, 2023

- First grab collected at 9:41.
- Second grab collected at 12:18.
- Third grab collected at 14:23.
- 2.62 hours elapsed between grab 1 and 2.
- 2.08 hours elapsed between grab 2 and 3.
- Weather conditions: 1.35 inches of rain at start of sample collection, 1.66 inches of rain prior to collecting grab 2, 1.67 inches of rain prior to collecting grab 3.

Event 3 – April 18, 2023

- First grab collected at 14:58.
- Second grab collected at 16:03.

- Third grab not collected due to staff work hours.
- 1.08 hours elapsed between grab 1 and 2.
- Weather conditions: 0.25 inches of rain at start of sample collection, 0.27 inches of rain prior to collecting grab 2.

Event 4 – September 25, 2023

- First grab collected at 7:47.
- Second grab collected at 11:47.
- Third grab collected at 14:35.
- 4.00 hours elapsed between grab 1 and 2.
- 2.80 hours elapsed between grab 2 and 3.
- Weather conditions: 0.75 inches of rain at start of sample collection, 0.83 inches of rain prior to collecting grab 2, 0.91 inches of rain prior to collecting grab 3.

Event 5 – September 27, 2023

- First grab collected at 9:40.
- Second grab collected at 11:50.
- Third grab collected at 14:10.
- 2.17 hours elapsed between grab 1 and 2.
- 2.33 hours elapsed between grab 2 and 3.
- Weather conditions: Heavy rain noted at time first grab sample was collected. 0.61 inches of rain at start of sample collection, 0.65 inches of rain prior to collecting grab 2, 0.66 inches of rain prior to collecting grab 3.

Event 6 – November 2, 2023

- First grab collected at 8:45.
- Second grab collected at 10:30.
- Third grab not collected as storm had tapered off.
- 1.75 hours elapsed between grab 1 and 2.
- Weather conditions: 1.02 inches of rain at start of sample collection, 1.08 inches of rain prior to collecting grab 2.

Event 7 – January 8, 2024

- First grab collected at 10:30.
- Second grab collected at 13:32.
- Third grab collected at 16:12.
- 3.03 hours between grab 1 and 2.
- 2.67 hours between grab 2 and 3.
- Weather conditions: More than 0.3 inches of rain prior to start of sampling. Steady rain at start of sample collection transitioning to light misty rain when grabs 2 and 3 were collected. System was flowing for all samples.

Event 8 – January 17, 2024

- First grab collected at 10:54.
- Second grab collected at 12:15.
- Third grab collected at 13:30.
- 1.35 hours elapsed between grab 1 and 2.
- 1.25 hours elapsed between grab 2 and 3.
- Weather conditions: 0.41 inches of rain at start of sample collection, 0.59 inches of rain prior to collecting grab 2, 0.6 inches of rain prior to collecting grab 3.
- Site conditions: Very high Conductivity values, presumably due to deicer running off roadway.

Event 9 – January 31, 2024

- First grab collected at 8:25.
- Second grab collected at 11:20.
- Third grab collected at 12:30.
- 2.92 hours elapsed between grab 1 and 2.
- 1.17 hours elapsed between grab 2 and 3.
- Weather conditions: 0.25 inches of rain at start of sample collection, 0.27 inches of rain prior to collecting grab 2, 0.29 inches of rain prior to collecting grab 3.

Event 10 – March 27, 2024

- First grab collected at 7:45.
- Second grab collected at 10:30.
- Third grab collected at 11:15.
- 2.75 hours elapsed between grab 1 and 2.
- 0.75 hours elapsed between grab 2 and 3.
- Weather conditions: 0.23 inches of rain at start of sample collection, 0.34 inches of rain prior to collecting grab 2, 0.34 inches of rain prior to collecting grab 3. Rain tapered off as third grab was collected; system was flowing more slowly.

Event 11 – October 30, 2024

- First grab collected at 13:12.
- Second grab collected at 14:20.
- Third grab collected at 15:30.
- 1.13 hours elapsed between grab 1 and 2.
- 1.17 hours elapsed between grab 2 and 3.
- Weather conditions: 0.20 inches of rain at start of sample collection, 0.25 inches of rain prior to collecting grab 2, 0.28 inches of rain prior to collecting grab 3.

Event 12 – November 4, 2024

- First grab collected at 7:43.
- Second grab collected at 8:47
- Third grab collected at 9:46
- 1.07 hours elapsed between grab 1 and 2
- 0.98 hours elapsed between grab 2 and 3
- Weather conditions: 0.20 inches of rain at start of sample collection, 0.29 inches of rain prior to collecting grab 2, 0.31 inches of rain prior to collecting grab 3

Event 13 – November 13, 2024

- First grab collected at 7:57.
- Second grab collected at 9:01.
- Third grab collected at 9:45.
- 1.07 hours elapsed between grab 1 and 2.
- 0.73 hours elapsed between grab 2 and 3.
- Weather conditions: 0.8 inches of rain at start of sample collection, large downpour between grab 1 and 2 adding an additional 0.2 inches of rain, storm tapered a lot between grabs 2 and 3.

Event 14 – February 24, 2025

- First grab collected at 11:59.
- Second grab collected at 13:06.
- Third grab collected at 14:07.
- 1.12 hours elapsed between grab 1 and 2.
- 1.02 hours elapsed between grab 2 and 3.
- Weather conditions: Grab 1 was more like baseflow conditions with only 0.05 inches of rain at start, the system at that time was less like stormwater. The first grab sample had fewer solids and was clearer in color. There was heavy rain, up to 0.22 inches prior to grab 2, and this sample had more stormwater characteristics and had significant solids and was very dark in color. Grab 3 was after heavy rain tapered off with around 0.30 inches prior to sampling. This sample had significant solids and was very dark in color.

Event 15 – April 7, 2025

- First grab collected at 7:15.
- Second grab collected at 9:15.
- Third grab collected at 10:30.
- 2.00 hours elapsed between grab 1 and 2.
- 1.25 hours elapsed between grab 2 and 3.
- Weather conditions: 0.50 inches of rain at start of sample collection, showers during grab 2 sample collection, 0.51 inches of rain prior to collecting grabs 2 and 3. Sunny at grab 3 sample collection but system still had flow. Rain tapered off more than predicted between grabs 2 and 3.