Synthesis Report on Impacts to Puget Sound from West Point Flooding Event in 2017

June 2022

King County

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Synthesis Report on Impacts to Puget Sound from West Point Flooding Event in 2017

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Acknowledgements

This report was a collaborative effort with several of the authors of the individual subject reports. The contributions of the authors of the individual subject reports are gratefully acknowledged (in alphabetical order):

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- Wendy Eash-Loucks
- Stephanie Jaeger
- Jeff Lafer
- Jennifer Lanksbury
- Bruce Nairn
- Rory O'Rourke
- Kimberle Stark
- Jeff Stern
- Jennifer White
- Debra Williston

Internal reviewers in alphabetical order included: Jim Bolger, Jenée Colton, Jennifer Lanksbury, Wendy Eash-Loucks, Jeff Lafer, Josh Latterell, Bruce Nairn, Jim Simmonds, Kimberle Stark, Jeff Stern, and Debra Williston.

This report was also reviewed by Lester McKee, Ph.D., Senior Environmental Scientist at the San Francisco Estuary Institute, and Ken Schiff, Deputy Director, Southern California Coastal Water Research Project.

Citation

King County. 2022. Synthesis Report on Impacts to Puget Sound from West Point Flooding Event in 2017. Prepared by Curtis DeGasperi, Water and Land Resources Division. Seattle, Washington.

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ABSTRACT

This report synthesizes the results presented in seven subject reports that assessed the impacts of the February 2017 flooding event and subsequent period of reduced treatment at the West Point Treatment plant. The flooding event caused two untreated emergency discharges at the West Point emergency bypass outfall (EBO) in February 2017. Damage from the flooding event resulted in the discharge of less-than-secondary treated effluent from West Point's main outfall for three months before full treatment could be restored. Water quality monitoring along Puget Sound beaches began the morning after the flooding event. Focused additional monitoring of effluent quality, Puget Sound water quality, sediment chemistry, and marine biota tissue chemistry occurred during the recovery period and for up to two years after restoration of full treatment. Data were compared to routine monitoring data collected prior to the event, to contemporaneous data collected elsewhere in Puget Sound, and/or during the period of reduced treatment vs post recovery of full treatment.

The clearest impacts were the transient increases (of no more than three days after each release) in bacteria levels in water at nearby beaches immediately following both emergency bypass overflow events. In addition, during the post-overflow period when less-than-secondary treatment was achieved, effluent quality from the West Point treatment plant did not meet National Pollutant Discharge Elimination System (NPDES) permit requirements for total suspended solids, carbonaceous biochemical oxygen demand, and residual chlorine, but continued to meet other requirements. The reduced effluent quality resulted in increased loads of some chemicals (such as copper and lead) to Puget Sound. Some increases of some chemicals were detected in Puget Sound water, sediment, and biota, during the period of reduced treatment or for few months following (e.g., in biota), although concentrations returned to background levels in subsequent sampling. It is not clear whether all changes were associated with the flooding event due to the confounding influence of other sources (e.g., direct stormwater runoff and river discharges) and normal variability. Ongoing monitoring does not detect any long-term impacts from the flooding event or period of reduced treatment.

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EXECUTIVE SUMMARY

What happened at the West Point Wastewater Treatment Plant?

Under normal conditions, King County's West Point Wastewater Treatment Plant (West Point WWTP; West Point hereafter) provides secondary wastewater treatment prior to discharge via an outfall to Puget Sound, meeting all National Pollutant Discharge Elimination System (NPDES) permit limits.[1] But on February 9, 2017, during a winter with record high rainfall, West Point experienced equipment failure. Equipment failure resulted in flooding which severely damaged the plant's mechanical and electrical systems. To avoid further damage to the plant, West Point discharged 244 million gallons of untreated stormwater and sewage through a shallow-water emergency bypass outfall (EBO) on February 9 and again on February 15–16, 2017. West Point operated with reduced treatment until April 27, 2017. After that, all effluent discharged from West Point received full secondary treatment. On May 10, 2017, West Point once again met all NPDES permit limits.

To facilitate treatment system recovery, King County transferred a substantial volume of solids from West Point to South Plant. While West Point was being repaired, more wastewater flow than usual was diverted to wet weather treatment stations (WWTSs)[2]. During the first half of 2017, heavy rainfall caused discharges from combined sewer overflows (CSOs), and stormwater outfalls to be higher than normal. Thus, while West Point was impaired, WWTSs, CSOs, and stormwater also contributed contaminants to Puget Sound.

After the initial overflow event, King County evaluated the potential impacts of the emergency discharge and reduced treatment on Puget Sound, leading to a series of studies and reports.

What is this report about?

This report synthesizes results at a high level from seven reports and the evidence of effects on Puget Sound water, sediment, and biota quality. The objectives of these studies were to:

- Monitor West Point effluent quality during the recovery period and compare to historical data to quantify the transient changes in effluent quality and loading.

[1] Secondary treatment consists of an initial primary treatment stage where heavy solids settle out and lighter oil and grease float to the surface. The settled and floating materials are removed, and the remaining effluent is subjected to secondary treatment. Secondary treatment involves a biological process designed to oxidize dissolved and particulate organic matter followed by a settling step. These secondary treatment processes reduce the biochemical oxygen demand and suspended solids concentrations in the final effluent to meet NPDES permit limits. The treated effluent is disinfected to meet bacteria standards prior to discharge to Puget Sound.

[2] A Wet Weather Treatment Station is a satellite combined sewer overflow treatment facility. These facilities provide primary treatment by removing solids through settling and screening and by disinfecting the water before discharge to receiving waters.

- Monitor Puget Sound receiving waters in the vicinity of West Point, including beaches, to quantify changes during the EBO discharges and the period of reduced treatment.
- Monitor Puget Sound intertidal sediment and subtidal sediment in the vicinity of West Point to quantify changes following the EBO discharges and the period of reduced treatment.
- Monitor Puget Sound biota (clams, zooplankton, Dungeness crab, and English sole) to identify any substantial changes following the EBO discharges and the period of reduced treatment.
- Compare results to applicable Washington State Water Quality Standards and historical conditions.

The seven reports were on (1) treatment plant effluent and Puget Sound water quality, (2) subtidal sediments, (3) intertidal sediments and clam tissue, (4) zooplankton tissue, (5) Dungeness crab tissue, (6) English sole muscle tissue Year 1, and (7) English sole tissue final report. The following summary addresses seven interrelated questions.

How do the untreated Emergency Bypass Outfall and additional Combined Sewer Overflow discharges compare to historical CSO discharge volumes?

To put the volume of untreated flow bypassed from the EBO in context, the 244 MG was substantial relative to the historical (2007-2016) untreated CSO discharges for the same time of year (February average 52 MG) (Figure ES-1). The average February CSO discharge from all CSOs in the King County system was 52 MG and ranged from 0.39 MG (2013) to 214 MG (2014) in the previous 10-year period. The total untreated CSO discharge in February 2017 was 749 MG due to record rainfall and the West Point event. The total EBO bypass flow of 244 MG was about one-seventh of the total annual untreated CSO discharge of 1,710 MG in 2017, and about one-fourth of the average annual CSO volume of 913 MG for the previous ten-year period. For additional perspective, the three main rivers that discharge to the Central Basin of Puget Sound (Puyallup, Green, and Cedar-Sammamish), delivered approximately 200,000 MG of freshwater runoff in February 2017, while the top 50 m of water in the Central Basin of Puget Sound contains about 6,660,000 MG. Central Basin water is primarily marine (~95%) mixed with freshwater from rivers and streams (~5%) and very small contributions from direct rainfall, wastewater, shoreline stormwater runoff, and CSOs.

These comparisons indicate that in addition to the EBO discharges, CSO discharges in 2017 (February in particular) were greater than would typically occur, but these discharges were much smaller than February 2017 freshwater river runoff. Furthermore, the CSO and EBO discharges quickly become mixed and diluted in a large body of water once delivered to Puget Sound.

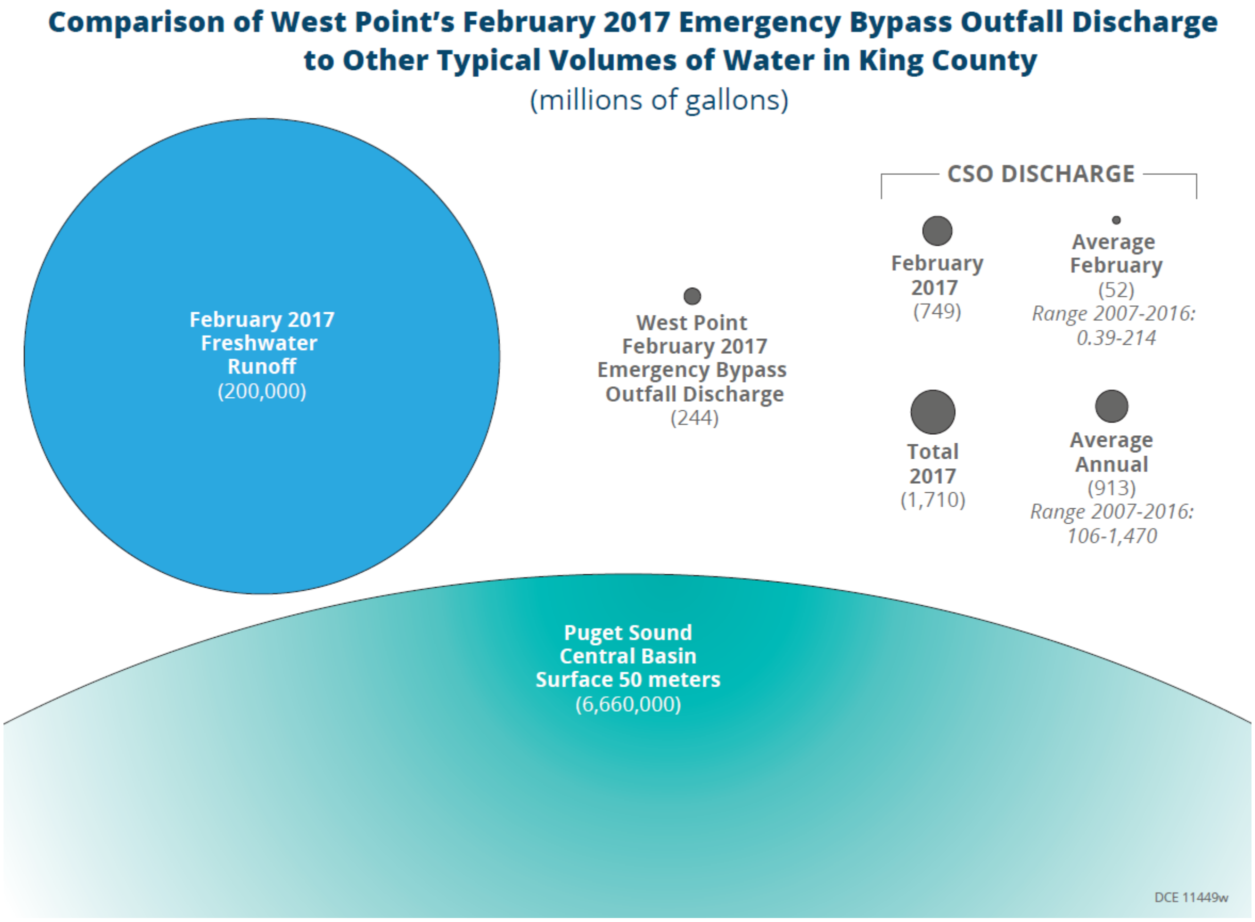

Figure ES-1. Estimated total discharge resulting from the February 2017 West Point flooding event compared to other more typical King County wastewater discharges, February 2017 freshwater runoff to the Central Basin, and the volume of the surface 50 m of the Central Basin.

How were the treated and untreated wastewater from WWTPs and WWTSs affected by the West Point flooding event?

West Point NPDES limits for TSS, CBOD, and residual chlorine were exceeded. During the period of reduced treatment, King County monitored West Point effluent for bacteria, solids, nutrients, organic matter, metals, organic compounds, and toxicity. Treated effluent from February 9 through May 9 did not meet NPDES permit limits for total suspended solids (TSS) and carbonaceous biochemical oxygen demand (CBOD). During March and April, the effluent occasionally exceeded permit limits for residual chlorine, the disinfectant used to eliminate pathogens. All other constituents in West Point effluent met permit limits throughout the period of reduced treatment.

In March, the Elliott West WWTS exceeded bacteria permit limits. Effluent from the Elliott West WWTS near Myrtle Edwards Park, which handled some of the additional flows during storm events, did not meet its monthly bacteria permit limit in March. Effluent at all other

WWTSs and King County's other wastewater treatment plants met permit limits during this period.

Ammonia concentrations were elevated in South Plant effluent. West Point effluent concentrations of most nutrients were lower or comparable to historical conditions (2007–2016), in part because the biological secondary treatment was impacted and some solids were transported to South Plant for treatment. Consequently, ammonia concentrations in South Plant effluent were slightly elevated when processing the additional solids. Once secondary processes at West Point were restored all nutrient concentrations in effluent returned to normal levels.

West Point effluent during the period of reduced treatment was not predicted to be toxic to aquatic life. A modeling analysis for water quality at the edge of the West Point main outfall's effluent mixing zone indicated that during the period of reduced treatment, ammonia or metals concentrations in effluent never exceeded applicable acute (short-term) and chronic (long-term) criteria in Puget Sound receiving waters. Acute and chronic effluent toxicity tests also verified that the effluent met permit standards for toxicity and were comparable to past results. During the period of reduced treatment, no short-term or long-term toxicity impacts to aquatic life were expected.

Loadings increased for solids, metals, and organic chemicals. Increased TSS loading and the period of reduced treatment resulted in a short-term increase in solids and associated metal and organic chemical loading to the Central Basin of Puget Sound. For some perspective, the additional TSS load was more than ten times the normal amount and approximately 25 percent of the total sediment load from the Green River during the same time period. During the recovery period, some metals were notably elevated in effluent. These included copper, chromium, lead, and zinc. While elevated, these concentrations were much lower than typical concentrations historically observed in West Point effluent prior to implementation of City of Seattle's projects to reduce corrosion of metal pipes in the water supply system, King County's industrial pre-treatment programs, and the upgrade to secondary treatment at West Point. Therefore, the elevated concentrations were not the highest ever recorded, and were lower than typically observed when the NPDES-permitted West Point effluent received only primary treatment.

How were public uses of beaches affected?

High bacteria levels closed nearby beaches for three days following each EBO discharge event. Discharge of untreated stormwater and sanitary sewage from the EBO on February 9 and 15–16 resulted in short-term water quality impacts along the adjacent marine shorelines. Starting February 9, Public Health–Seattle & King County closed several Seattle-area beaches to public recreation to protect public health. At nearby beaches, monitoring revealed elevated levels of bacteria, but those concentrations fell to safe levels within three days of each event. On February 21, Seattle-area beaches were re-opened. They remained open throughout the remainder of the West Point recovery period. Due to a concern that untreated discharges could reach Kitsap beaches across the Central Basin of Puget Sound, Kitsap Public Health District announced a no-contact advisory for Kitsap beaches for a short time.

How was Puget Sound dissolved oxygen and phytoplankton growth affected?

Dissolved oxygen levels were within standards except where they historically have exceeded standards in deeper waters of the Central Basin. These lower levels were within historical ranges and were not considered to be due to the West Point event. Dissolved oxygen concentrations were at healthy levels to support marine life for all Central Basin sites in offshore waters throughout the monitoring period. All concentrations were above the numeric state water quality standard except in late June. At that time, oxygen levels in bottom waters at most sampling sites throughout the Central Basin fell slightly below the numeric state standard. But levels remained within normal historical ranges for each site and above the threshold for potential biological stress. Oxygen levels observed at West Point did not fall below the state standard.

Phytoplankton blooms were typical except for one site. The timing and magnitude of the spring phytoplankton bloom was within typical seasonal ranges. Chlorophyll-a levels—a measure of phytoplankton biomass—were within historical values at all sites, including the West Point outfall, except for one site in the southern portion of the Central Basin of Puget Sound where levels were above the historical range in May.

What effects were observed regarding trace metals in water, sediment, and biota?

In water, metal concentrations did not exceed standards. In water sampled in the vicinity of the main West Point outfall during two sampling events in 2017, all metal concentrations were below state water quality standards for the protection of both aquatic life and human health.

In sediments, metals concentrations did not exceed standards, although copper was elevated in intertidal sediment at the West Point north beach station. In sediments collected from locations near West Point's main outfall, metals concentrations were all well below their respective state marine sediment standards. Also, 2017 concentrations were similar to those in 2011 and 2018. In addition, metals concentrations of intertidal sediments were well below their applicable state marine sediment standards and within expected ranges relative to historical concentrations. There was one exception: intertidal sediment copper concentration at the West Point north beach station was more than twice the maximum historical level but was still well below the marine sediment standards.

In butter clams, copper and lead were elevated at the West Point north beach station. In butter clams from the same West Point north beach intertidal sampling sites, metals concentrations were within or lower than expected ranges relative to historical data except for copper and lead. The copper levels in butter clams were almost twice as high as the maximum historical tissue concentration. This pattern is similar to that in sediment at the West Point north beach station. Lead levels in clams were approximately one and half times the historical maximum at the West Point north beach station.

In crabs from Shilshole Bay, some metals were elevated. Metals concentrations in crab muscle and hepatopancreas from North Elliott Bay were not discernably different from available historical data. Analysis of data from the Shilshole Bay Marina site suggested the West Point flooding event may have influenced chromium and possibly copper concentrations in crab muscle, and chromium, lead, and nickel in crab hepatopancreas for a few months to a year.

In zooplankton and English sole, no increased metals concentrations related to the West Point flooding event were identified.

What effects were observed regarding organic contaminants in sediment and biota?

In sediments, benzoic acid was briefly elevated and exceeded standards, although this was observed at sites throughout the Central Basin in 2017; the widespread elevation makes it unclear whether the flooding event was the cause. At half of the subtidal sediment stations near the West Point main outfall, benzoic acid concentrations exceeded state marine sediment standards. When resampled in 2018, sediments at these stations no longer exceeded criteria. But based on other King County monitoring data, benzoic acid was elevated across the Central Basin of Puget Sound in 2017. This acid has natural and human sources and elevated levels were unlikely the result of effluent from West Point. Benzyl alcohol, which degrades to benzoic acid, exceeded the standard at one station. No other organic contaminants exceeded marine sediment standards.

In zooplankton, PBDE concentrations were briefly elevated. No increases in zooplankton total polychlorinated biphenyl (PCB) concentrations were identified in response to the 2017 West Point event. In spring 2017, zooplankton from two Central Basin locations had total polybrominated diphenyl ether (PBDE) concentrations that were substantially higher than in subsequent samples. By late summer of 2017, concentrations fell by an order of magnitude. In 2018, they remained lower. Therefore, we concluded PBDE increases in zooplankton may have resulted from the West Point flooding event but were short-lived.

No increases in crab organic contaminant levels were identified. In Dungeness crab collected in 2017, no polycyclic aromatic hydrocarbons (PAHs) were detected. Total PCB levels were not substantially higher than levels observed prior to the West Point flooding event. Crab total PBDE data did not identify an increase due to the West Point flooding event.

There was some evidence of increased exposure to organic contaminants (PCBs, PBDEs, and DDTs) in English sole sampled near West Point and the Elliott West WWTS in 2017. However, similar values at nearby stations and similar patterns across years at other locations make it unclear whether the flooding event was the cause. A higher percent of vitellogenin-positive male fish (a biomarker of sub-lethal exposure of fish to estrogenic chemicals) at West Point North in 2017 compared to 2019 suggested environmental estrogens may have been higher there. However, the limited amount of available data and high variability seen at other Puget Sound locations makes it unclear whether these differences were the result of the flooding event.

Would Washington State Department of Health fish consumption advisories for people likely have changed because of the event?

No changes to existing advisories, which already directed people to limit consumption of certain fish and shellfish species, would have been made as a result of this event. The Washington State Department of Health (WDOH) issues seafood consumption advisories to inform the public when levels of toxic chemicals in seafood pose a health risk to people eating them. Several advisories were in place before the West Point flooding event. They recommended people limit consumption of seafood from Puget Sound. Contaminants measured in fish and shellfish were compared to WDOH screening levels. These levels were used as guidelines to evaluate whether concentrations were high enough to warrant a change in seafood consumption advisories. Based on this comparison, the West Point flooding event would result in no changes to existing Puget Sound seafood consumption advisories for butter clam, Dungeness crab, and English sole.

Are there any qualifications to the conclusions above?

Puget Sound monitoring programs are generally designed to track long-term trends in water, sediment, and biota quality or human health risks due to fecal contamination at public beaches. Data from these programs were combined with additional sampling efforts to assess the impacts of the West Point event on Central Puget Sound. However, such Before-After sampling designs are unable to account for background temporal variability, nor are they able to clearly separate effects of multiple input sources (i.e., treated wastewater, WWTSs, CSOs, stormwater, rivers).[3] When monitoring receiving waters, other sources of contamination confound attempts to link the event directly to observations. This makes it difficult to definitively link any observed increases in contaminant levels in part or exclusively to the West Point flooding event, except for the elevated bacteria following untreated discharges. Co-occurring factors such as heavier than normal rainfall and increased stormwater inputs to Puget Sound between February and April 2017 likely contributed to increases in observed contaminant concentrations. In the context of total annual contaminant loadings discharged to Puget Sound, the relatively small and transient increase in contaminant loading combined with the substantial dispersion characteristics of the receiving waters also make it difficult to detect impacts of the West Point event.

Furthermore, statistically, it is never possible to prove there was no impact–the West Point event had some level of effect. The ability of an individual study to detect an impact depends on the statistical power of the study and the magnitude of the actual impact. In some of our monitoring efforts, it appears that the magnitude of change was smaller than could be reliably detected by the study designs. If similar assessments are needed in the future, a starting point might include establishment of biologically relevant changes as the foundation for the study design. This would shift the focus from rejecting a hypothesis of no-effect to studies designed to detect ecologically relevant effects.

[3] Zooplankton PBDE and English sole vitellogenin data were only collected after the West Point event, so inferences regarding potential linkages to the West Point event are even weaker.

What are the overall findings?

The clearest impact was due to the two untreated emergency discharge events at the West Point EBO in February 2017. These two events resulted in transient increases (of no more than three days after each release) in bacteria levels in water at nearby beaches. West Point NPDES permit limits for TSS, CBOD, and residual chlorine were exceeded at times during the recovery period. No other permit limits were exceeded. Furthermore, there were no exceedances of relevant water quality standards resulting from discharges from the main West Point outfall from this event. Sediment quality standards for benzoic acid and benzyl alcohol were exceeded at four stations near the West Point outfall in 2017, but concentrations above standards were also observed at sites throughout the Central Basin of Puget Sound that were not expected to be affected by the event. No exceedances were observed following resampling of the West Point outfall sites in 2018. It is not uncommon to observe transitory standard exceedances of these chemicals at Puget Sound reference sites. The transient sediment standard exceedances near the West Point outfall are not believed to be associated with the flooding event. These conclusions are based on evidence from West Point outfall mixing zone analyses, sediment deposition modeling of the EBO, and water and sediment monitoring.

However, because of reduced treatment and treatment capacity at West Point and the related EBO discharges, TSS loading to the Central Basin of Puget Sound substantially increased during a period from February to April 2017. The additional TSS loading resulted in higher loading of metals (copper, chromium, lead, and zinc) and organic contaminants that are typically associated with wastewater solids. This transient increase in West Point TSS and associated contaminant loading appears to have resulted in:

- A localized increase in receiving water TSS near West Point during recovery (February-March 2017) and
- Short-term increases potentially due to West Point discharges of:
    - copper in intertidal sediments and copper and lead in clams at one beach near West Point,
    - copper, chromium, lead, and nickel in Dungeness crab from Shilshole Bay,
    - PBDEs in zooplankton collected from one location in both the northern and mid-Central Basin.

1.0 INTRODUCTION

King County's West Point Wastewater Treatment Plant (West Point WWTP; West Point hereafter) is located near the west side of Magnolia Bluff, adjacent to Seattle's Discovery Park (Figure 1).[4] Early in the morning on February 9, 2017, an emergency bypass event occurred due to equipment failure and subsequent flooding of West Point during peak inflows. This bypass resulted in the release of 186 MG of untreated stormwater and wastewater into Puget Sound through West Point's emergency bypass outfall (EBO). A smaller bypass event occurred over the course of February 15 and 16 resulting in 58 MG of untreated discharge through the EBO. In total, about 244 MG of untreated flows were discharged via the EBO.

Following the February 9 flooding event, West Point operated using reduced treatment while efforts to restore secondary treatment processes were underway. This included some solids settling, screening, disinfection, and dechlorination. The event severely damaged mechanical and electrical systems necessary to provide heat to the secondary system biological treatment, which essentially crippled West Point's ability to handle solids. To facilitate the recovery of the treatment system, a substantial volume of solids was transferred from West Point to South Plant in Renton during the restoration process. Inflows to West Point during storm events were also carefully managed to protect recovery of the biological treatment processes and prevent further damage to the plant.

To control flows conveyed to West Point, three of the County's Wet Weather Treatment Stations (WWTSs) that provide solids removal and disinfection (Alki, Carkeek, and Elliott West) were used to treat excess flows during storm events. To a lesser degree, additional flows during storm events were routed to King County's Brightwater and the City of Edmonds wastewater treatment plants. Additionally, untreated overflows from combined sewer overflows (CSOs) were exacerbated due to reduced West Point operation, particularly during the emergency bypass events, as well as during storm events that required management of peak inflows to West Point. Discharges from stormwater outfalls were also higher during the first half of 2017, due to the heavy rainfall. Thus, WWTSs, CSOs, and stormwater also contributed contaminants to Puget Sound during this period.

Restoration of West Point's primary and secondary treatment processes was completed by the end of April 2017, and after April 27 all wastewater was receiving full secondary treatment. West Point began meeting all National Pollutant Discharge Elimination System (NPDES) permit limits on May 10. The current NPDES permit can be accessed at http://www.kingcounty.gov/depts/dnrp/wtd/system/npdes.aspx. After the initial overflow event, King County mobilized to evaluate the potential impacts of the emergency discharge and the period of reduced treatment on the marine environment, leading to a series of studies and reports. A timeline of events, including the timing of collection of water, sediment, and aquatic biota tissue samples, can be found in Figure 2.

[4] King County's regional wastewater treatment facilities discharge to Elliott Bay and the Central Basin of Puget Sound (Figure 1). The Central Basin extends southward from Whidbey Island to Commencement Bay.

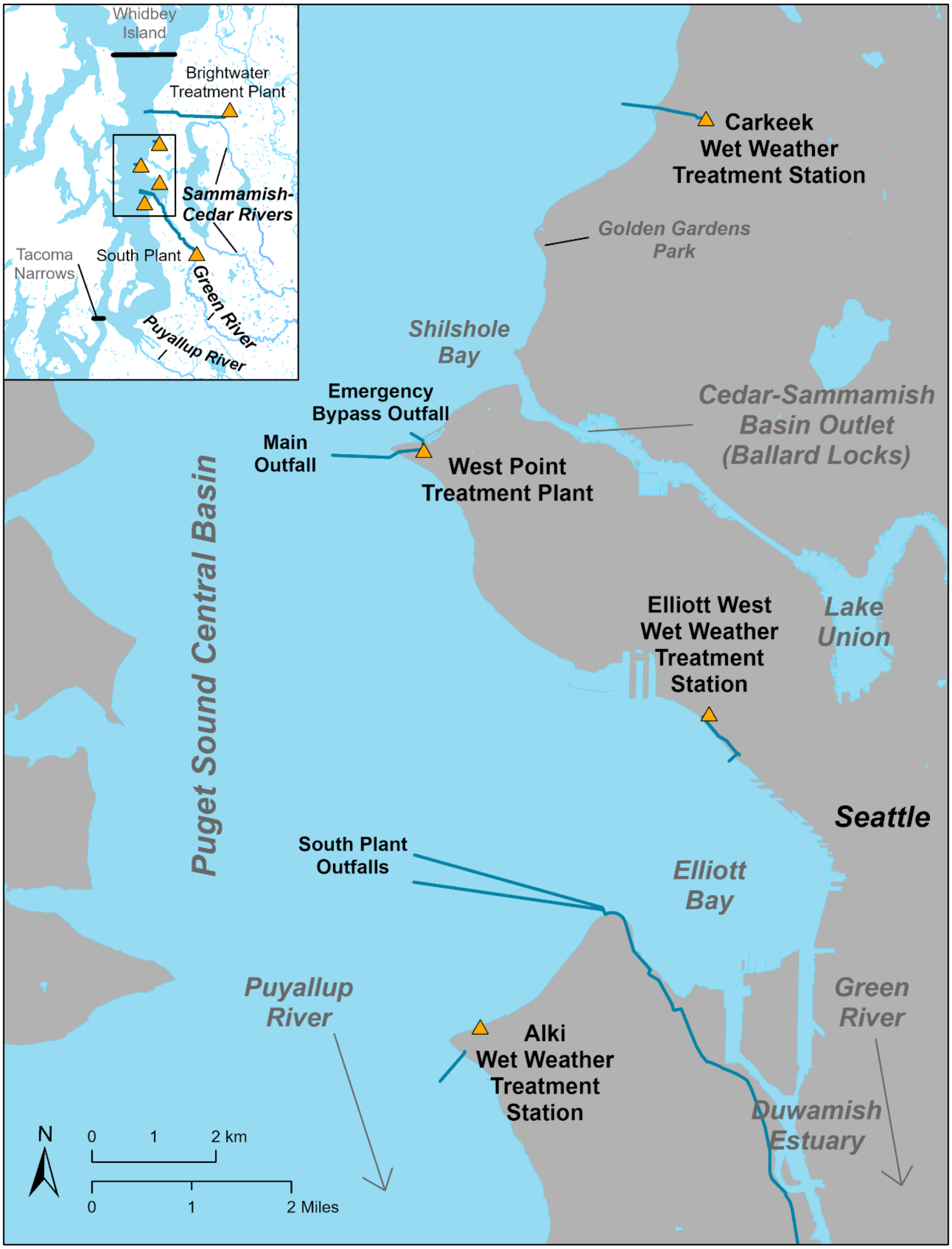

Figure 1. **Location of West Point Wastewater Treatment Plant outfalls and other King County treatment plant outfalls. The inset shows northern (Whidbey Island) and southern (Tacoma Narrows) boundaries of the Central Basin of Puget Sound and the major tributary inputs (Puyallup River, Green River, and Cedar-Sammamish). Note that the Green River flows into the Duwamish and becomes the Green-Duwamish River.**

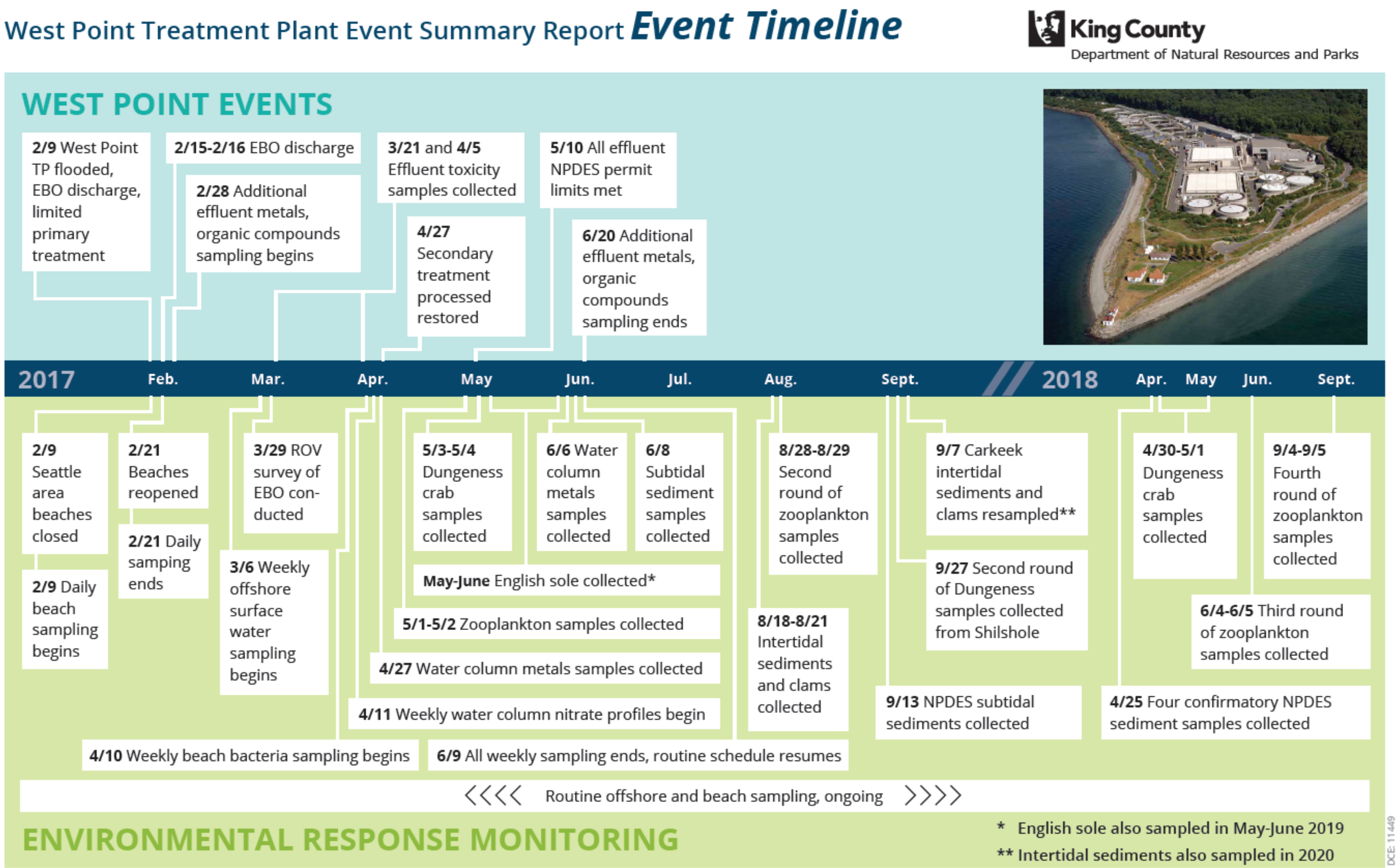

Figure 2. **Generalized timeline of West Point events and monitoring activities in receiving waters. Note that relevant monitoring data collected prior to 2017 were included in analyses when appropriate. The historical data used in any particular case are described in the individual reports referenced below.**

Less than eight hours after the emergency bypass at West Point on February 9, King County posted warning signs and closed nearby beaches as a precautionary measure. In addition to the emergency response to manage wastewater flows and restore the secondary treatment capability of West Point, King County developed and implemented a plan to conduct additional effluent monitoring beyond existing NPDES permit requirements and additional receiving waters monitoring beyond the County's long-term Marine Water Quality Monitoring Program. The objectives of these sampling efforts were to:

- Monitor West Point effluent quality during the recovery period and compare to historical data to quantify the transient changes in effluent quality and loading.
- Monitor Puget Sound receiving waters in the vicinity of West Point, including beaches, to quantify changes during the EBO discharges and the period of reduced treatment.
- Monitor Puget Sound intertidal sediment and subtidal sediment in the vicinity of West Point to quantify changes following the EBO discharges and the period of reduced treatment.
- Monitor Puget Sound biota (clams, zooplankton, Dungeness crab, and English sole) to identify any substantial changes following the EBO discharges and the period of reduced treatment.
- Compare results to applicable Washington State Water Quality Standards and historical conditions.

These additional studies have been completed and seven reports have been published that describe the study designs, methods, results, and conclusions of this body of work. The published reports are as follows, including a brief summary of the contents of each report:

- Effluent monitoring and receiving water quality study (King County, 2018)
    - This report provides background on the wastewater treatment system, describes the flooding event and initial response, and precipitation, air temperature, and river flows in 2017 relative to historical conditions. In addition to summarizing the effluent and receiving water quality monitoring results (including comparisons to historical data), the report also summarizes a mixing zone analysis for effluent ammonia and metals measured during the period of reduced treatment and the results of effluent toxicity testing.
- Intertidal sediment and clam tissue study (King County, 2019a)
    - This report summarizes the collection and analysis of intertidal sediment for metals (no organic contaminants) from six stations and butter clams from five of those stations (butter clams are not typically found at the sediment only station) in 2017 and compares these results to historical data from the same locations. The sampling locations ranged from Carkeek Park to the north of West Point and Alki to the south of West Point.
- Subtidal sediment study (King County, 2019b)

  - This report summarizes the collection and analysis of subtidal sediments for ammonia, sulfide, metals, and organic contaminants (including polycyclic aromatic hydrocarbons [PAHs] and polychlorinated biphenyls [PCBs]) in the vicinity of the West Point outfall in 2017 and 2018. These results were compared to historical data from previous West Point outfall sampling efforts. Sediment toxicity and benthic invertebrate sampling was conducted at a subset of sediment sampling sites. The report also describes the results of a remotely operated vehicle survey and near-field sediment deposition modeling of the EBO.
- Zooplankton tissue study (King County, 2020a)
  - This report summarizes the collection and analysis of zooplankton for metals, PCBs, and polybrominated diphenyl ethers [PBDEs] from two locations on four dates between 2017 and 2018. One location was to the north of the West Point outfall in the northern Central Basin and the other location was south of Alki in the mid-Central Basin. Only limited historical PCB data were available to compare to these results.
- Dungeness crab tissue study (King County, 2020b)
  - This report summarizes the collection and analysis of Dungeness crab for metals, PAHs, PCBs, and PBDEs from two areas – Shilshole to the north of the West Point outfall and North Elliott Bay to the south of the West Point outfall and in the vicinity of the Elliott Bay WWTS. The results were compared to historical crab data from these areas from King County and the Washington Department of Fish and Wildlife (WDFW) and to 2018 data collected by King County.
- English sole muscle tissue chemistry report (King County and WDFW, 2021)
  - This report summarizes the collection and analysis of English sole for metals, PCBs, PBDEs, and chlorinated pesticides in 2017. English sole were sampled from eight locations by King County and/or WDFW, including two sites north and south of the West Point outfall. These results were compared between locations and to WDFW results from additional locations throughout Puget Sound and the Strait of Georgia analyzed for organic contaminants.
- English sole tissue study final report (King County and WDFW, 2022)
  - This report is an update to the 2021 report above and includes additional results from sampling conducted in 2019 at the same stations sampled in 2017. In addition, the report covers sampling and analysis of three biomarkers (measures of the sub-lethal response of fish to exposure to PAHs and natural and synthetic estrogenic compounds), although 2019 results for two of the three biomarkers were still pending at the time of publication. An addendum will ultimately be published that will include the additional 2019 biomarker results.

The objective of this report is to provide a high-level summary and synthesis of the above seven reports. For details regarding field sampling, laboratory analysis, and statistical methods, and historical data used, the reader is referred to the above referenced reports.

1.1 Putting the Releases into Perspective

To put the volume of untreated flow bypassed from the EBO in context, the 244 MG was substantial relative to the historical (2007-2016) February untreated CSO discharges for the same time of year (February) (Figure 3). The average February CSO discharge from all CSOs in the King County system was 52 MG in the previous 10-year period. Over those same ten years, the February CSO discharges ranged from 0.39 MG in 2013 to a maximum of 214 MG in 2014. The total untreated CSO discharge in February 2017 was 749 MG as a result of record rainfall and the West Point incident. The total EBO bypass flow of 244 MG was about one-seventh of the total annual untreated CSO discharge of 1,710 MG in 2017, and about one-fourth of the average annual CSO volume of 913 MG for the previous ten-year period. For additional perspective, the three main rivers that discharge to the Central Basin of Puget Sound (Puyallup, Green, and Cedar-Sammamish), delivered approximately 200,000 MG of freshwater runoff in February 2017, while the top 50 m of the Central Basin of Puget Sound contains about 6,660,000 MG (Babson et al., 2006). The Central Basin is primarily marine water (~95%) mixed with freshwater from rivers and streams (~5%) and very small contributions from direct rainfall, wastewater, shoreline stormwater runoff, and CSOs (Galvin et al., 1984; Osterberg and Pelletier, 2015).

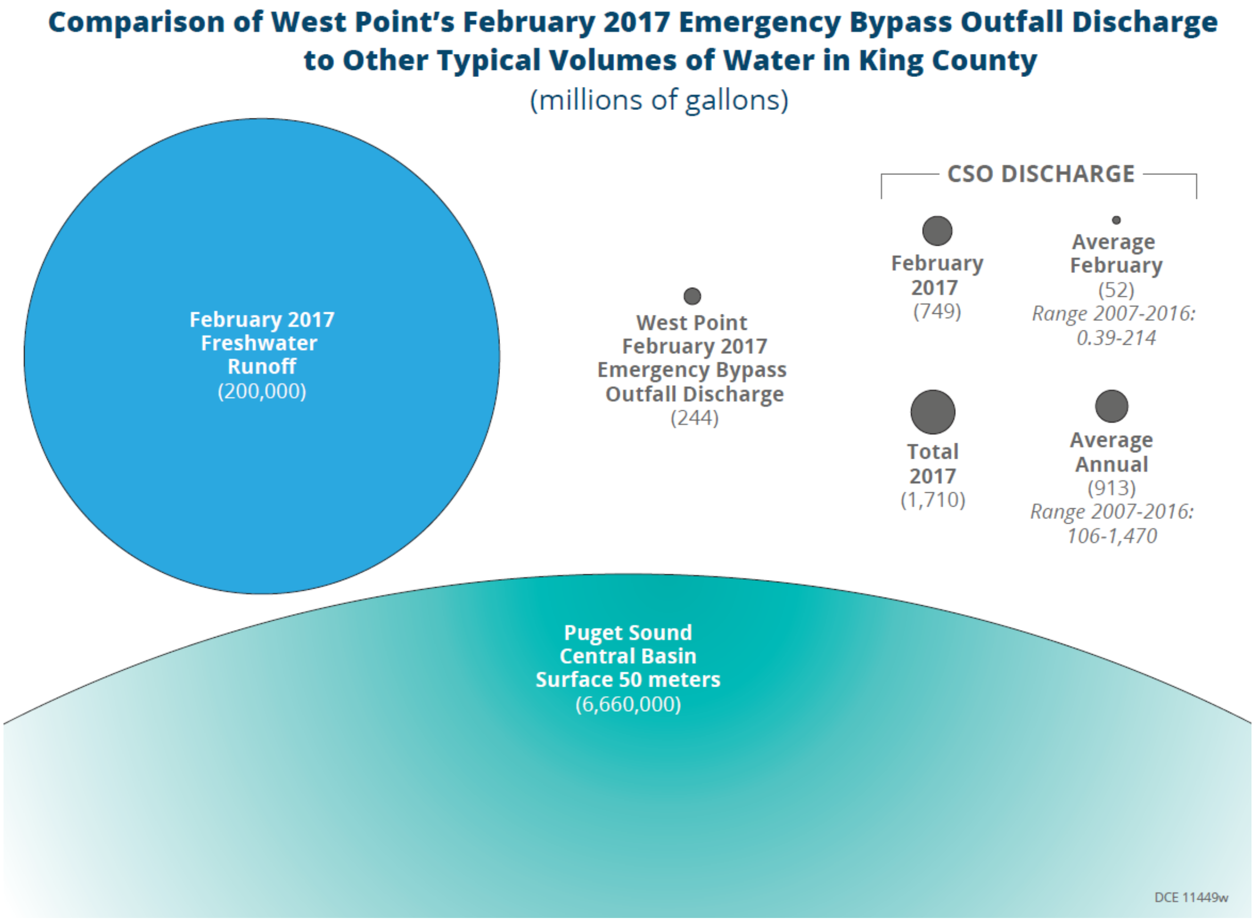

Figure 3. Estimated total discharge resulting from the February 2017 West Point flooding event compared to other more typical King County wastewater discharges, February 2017 freshwater runoff to the Central Basin, and the volume of the surface 50 m of the Central Basin.

In addition to flows from the EBO and increases in CSO discharges, West Point discharge rates were also elevated during the recovery period albeit due primarily to stormwater inputs within the combined system. The volume of water discharged through the West Point outfall in February 2017 was about 4,000 MG compared to the historical (2007-2016) average for the same period of 2,900 MG.

West Point effluent total suspended solids (TSS) concentrations increased during the period of reduced treatment. This resulted in a short-term increase in solids and associated metal and organic contaminant loading to the Central Basin of Puget Sound. For some perspective, the additional TSS load from West Point, including EBO bypass events, between February 9 and May 9 was more than ten times the normal amount. For more context, the additional TSS load was equal to about 25 percent of the sediment load from the Green River during the same time period.[5]

1.2 How Contaminants get into Puget Sound

Although there are a variety of human sources of contaminants, the focus of this report is on the largest pathways for sources entering the Central Basin of Puget Sound during the West Point event: wastewater discharges from West Point (including the EBO), WWTSs, CSOs, separated stormwater system inputs, and river discharges.

Human activities have the potential to alter water quality, most notably through releases of pathogens (e.g., enteric bacteria and viruses), oxygen-depleting organic wastes, sediment from erosion, and nutrients such as nitrogen that can feed algae blooms. Historically, these have been called "conventional pollutants". Human activities can also result in the release of contaminants that include metals and synthetic organic compounds. The inherent toxicity of a contaminant to any organism (i.e., the potential that it might result in lethal or sublethal effects) depends on its relative toxicity, its dose, and the route and duration of exposure to the contaminant. In addition to toxicity, some of these contaminants can bioaccumulate in organisms to levels that have the potential to affect people and other organisms that eat the contaminated food item.

In addition to human inputs, there are naturally occurring inputs of organic matter, nutrients, metals, and some organic compounds (e.g., benzoic acid). These inputs enter the Central Basin from rivers and the Pacific Ocean. The Pacific Ocean is a significant source of water because of the two-layered estuarine circulation that brings in saltier ocean water flowing along the bottom into the Central Basin. This water is a significant source of nutrients and some contaminants (Paulson et al., 1989; Mackas and Harrison, 1997; Johannessen et al., 2014; Osterberg and Pelletier, 2015) and brings in water with low dissolved oxygen in the fall. Atmospheric deposition directly to the surface of Puget Sound can also be a substantial source of some metals and organic contaminants (Paulson et al., 1989; Osterberg and Pelletier, 2015).

West Point (and South Plant) provides secondary wastewater treatment that involves a solids removal and biological process that breaks down organic waste both of which can significantly reduce the concentration of many contaminants in the discharge. The discharge is also disinfected to kill human pathogens (e.g., bacteria). Untreated wastewater is expected to have higher concentrations of solids, bacteria, and contaminants. Greater amounts of untreated wastewater are expected to result in greater mass loading of solids, bacteria, oxygen-demanding material, nutrients, and contaminants.

CSOs are the result of a decision made over a century ago for Seattle to build what is known as a combined sewer system – one that collects stormwater and wastewater in a single

[5] The Green River flows into Duwamish Estuary and Elliott Bay in the Puget Sound Central Basin (see Figure 1).

conveyance system. This was an economical approach at the time, and today, when the capacity of the conveyance system is not exceeded, the combined stormwater and wastewater receive treatment at King County treatment plants. However, when the capacity of the conveyance system is exceeded by high inflows of stormwater during large storm events, a combination of wastewater and stormwater is discharged at system relief points. Typically, a CSO is 90% stormwater and 10% untreated wastewater. Over the years, the frequency and amount of CSOs has been reduced through wastewater system improvements. Four WWTSs (Alki, Elliott West, Carkeek, and Henderson/Norfolk) help prevent untreated CSO discharges by providing primary treatment, including disinfection to reduce bacteria, before discharge.

1.3 Weather and River Discharges

Weather impacts freshwater inputs and marine water column conditions such as currents and density stratification. Currents and density stratification are receiving water characteristics (see Section 1.4) that determine the dilution, dispersion, residence time, and fate of contaminant inputs. Precipitation, air temperature, and river discharge were evaluated and compared to historical data to provide some context for the West Point Treatment Plant flooding event and subsequent monitoring results. Overall conditions in the Puget Sound region are summarized below:

- Higher than normal precipitation occurred in the first half of 2017 including record-breaking precipitation in February (see Figure 4).[6]
- Cooler than average conditions occurred in the winter of 2016-17, followed by slightly warmer than average conditions in the spring and early summer of 2017.
- Higher than normal river discharge increased the freshwater input into Puget Sound for the first half of 2017 (Figure 5 and 6).

These anomalies resulted in greater freshwater input to the Central Basin of Puget Sound coupled with stronger spring density stratification. Note that total precipitation in February and March 2017 exceeded the historical 90th-percentile of total rainfall for those months. Record precipitation translated into exceedances of the historical 90th-percentile of monthly average flow in the Green River in March and the Puyallup River in March and May 2017. The Green River is regulated by the Howard Hanson Dam; a flood control facility operated by the U.S. Army Corps of Engineers.

[6] A daily precipitation record total was set at the Seattle rain gage on February 9, 2017 (1.49 in). Daily precipitation records were set at the Seattle and Seattle-Tacoma Airport rain gages on February 15, 2017 (1.81 and 1.63 in, respectively).

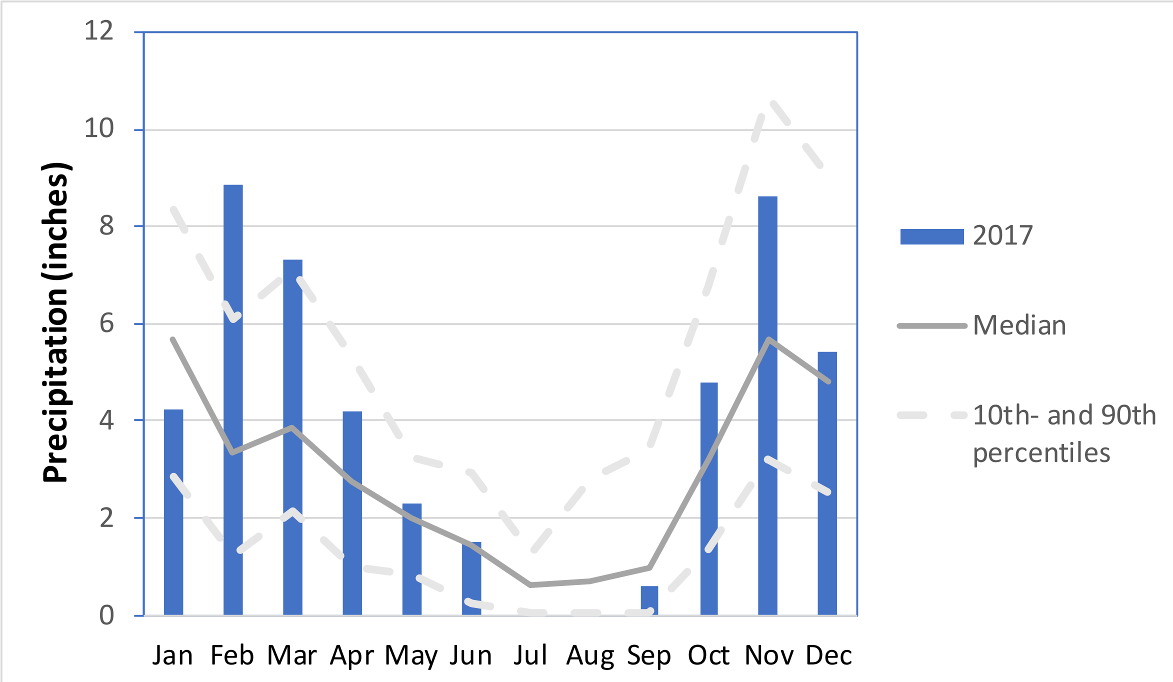

Figure 4. **Total monthly precipitation at Seattle-Tacoma Airport for 2017 and historical 30-yr percentiles. Percentiles shown are the 10th-, 50th- (median), and 90th-percentiles based on data from 1987-2016. (Source: Western Regional Climate Center; https://wrcc.dri.edu/).**

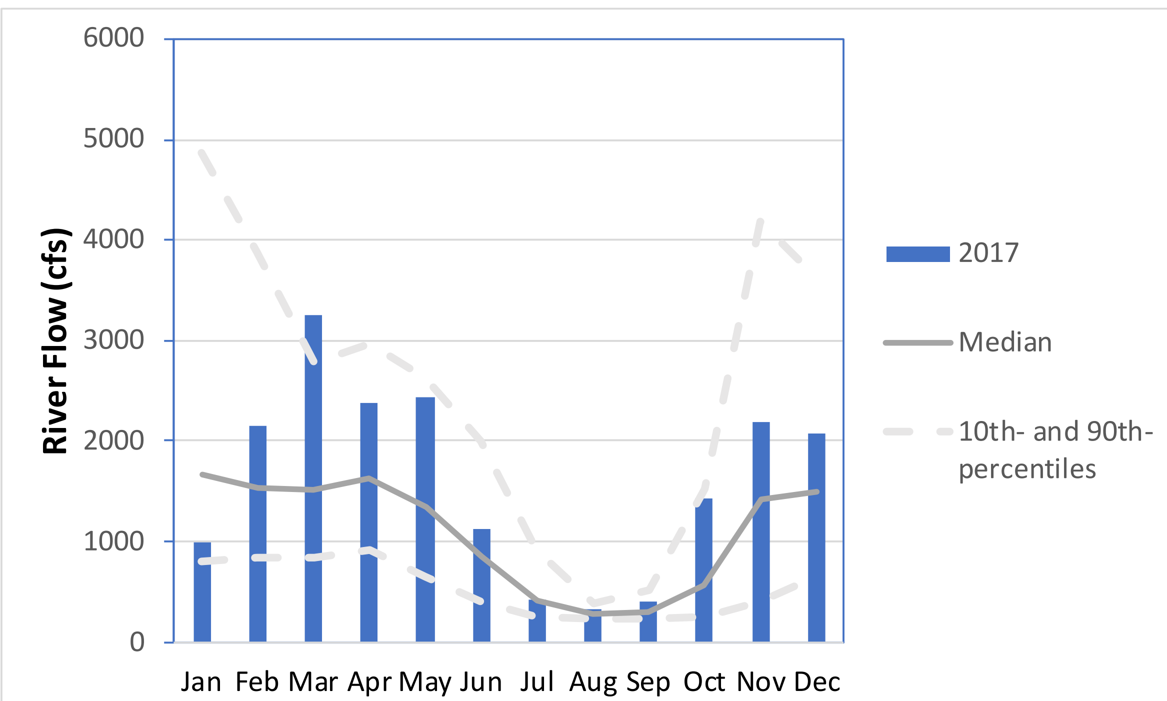

Figure 5. **The monthly average flow in the Green River near Auburn (USGS 12113000) for 2017 and historical 30-yr monthly average flow percentiles. Percentiles shown are the 10th-, 50th- (median), and 90th-percentiles based on data collected 1987-2016. (Source: U.S. Geological Survey; https://waterdata.usgs.gov/nwis/uv?site_no=12113000).**

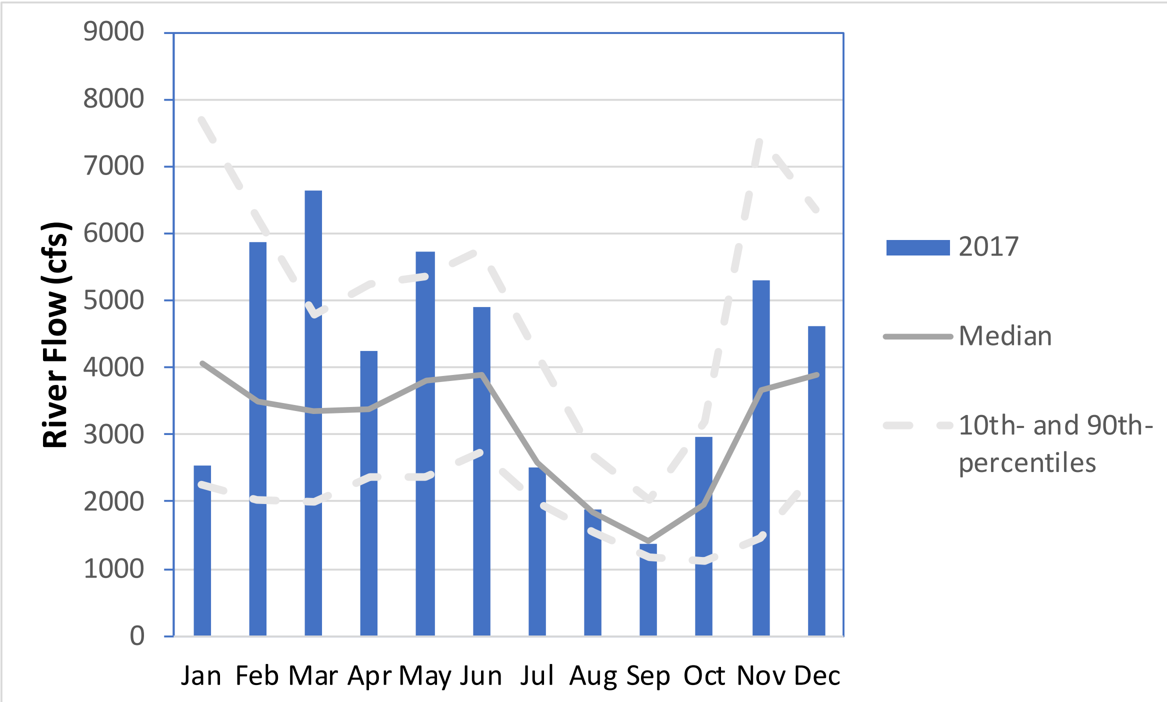

Figure 6. The monthly average flow in the Puyallup River at Puyallup (USGS 12101500) for 2017 and historical 30-yr monthly average flow percentiles. Percentiles shown are the 10th-, 50th- (median), and 90th-percentiles based on data collected 1987-2016. (Source: U.S. Geological Survey; https://waterdata.usgs.gov/nwis/uv?site_no=12101500).

1.4 Receiving Water Characteristics

Receiving water characteristics determine the dilution, dispersion, residence time, and fate of contaminant inputs. Puget Sound is a fjord-like basin connected to the Pacific Ocean via Admiralty Inlet and the Strait of Juan de Fuca. The Central Basin is 37 miles long, on average 3 miles wide, with a maximum depth of 900 ft. The Central Basin is bounded by shallower sills at the north and south. The concentration and transport of materials in Puget Sound is influenced by the amount of incoming water from the ocean and the circulation within the Sound itself. Puget Sound circulation generally consists of a two-layered flow, with incoming, saltier oceanic water flowing along the bottom and a fresher, less dense water layer flowing out at the surface, with some mixing of the two layers at the sills. All of King County's marine waters are within the Central Basin of Puget Sound. The Central Basin bottom waters have near-oceanic salinity throughout the year. They are supplemented with cold, dense, nutrient-rich, and low-oxygenated deep oceanic water upwelled off the Washington coast during the late summer months that enters Puget Sound from the Strait of Juan de Fuca.

The residence time of water in the Central Basin, or average amount of time a parcel of water spends in the basin, can vary between 9–55 days depending on the depth and time of year, with an estimated annual average of roughly 50 days for deep waters (Babson et. al, 2006; Sutherland et. al, 2011). Spring and early summer stratification can result in longer seasonal residence times. Year-to-year variability, such as differences in weather and the timing and volume of freshwater flows, can also impact circulation and thus, the residence time.

1.5 West Point Outfall Characteristics

The West Point outfall was designed, sited, and constructed to provide a high amount of mixing and subsequent dilution of treated effluent. Tidal currents near the West Point outfall influence how effluent is transported within and out of Puget Sound. Tidal currents and effluent plume dispersion at the West Point outfall determine ambient concentrations of solids and contaminants. This in turn determines the degree and extent of beaches exposed to effluent bacteria, the amount and extent of solids deposited in marine sediments, and the potential exposure of aquatic biota to diluted effluent.

Measuring and understanding several key water-movement characteristics is necessary to help predict effluent-related water, sediment, and biotic exposure. Mixing and dilution near the outfall result from a combination of density differences (lighter freshwater effluent entering denser marine waters), tidal currents, and the momentum of the discharge through the diffusers. The combination of these factors determines the initial dilution of the treated effluent and the vertical distribution of the effluent throughout the water column.

The West Point outfall ends in a multi-port diffuser located approximately 3,600 feet offshore at a depth of 240 feet relative to mean lower low water. As a result, the effluent tends to disperse in a northerly direction in the out-flowing surface water, moving further north on an ebb tide than it moves south on a flooding tide. Typical tidal dispersion of West Point effluent from the main outfall is depicted in Figure 7.

The EBO is an open-ended 8-foot diameter pipe located closer to shore and in shallower water on the north side of West Point (525 feet offshore at a depth of 40 feet relative to mean lower low water). Closer to shore, West Point has a stronger influence on tidal currents (Brown and Caldwell, 1958). Water moving southward on a flood tide generally parallels the shoreline on the north side of West Point and is then deflected in a southeasterly direction toward Elliott Bay. At the same time, an onshore eddy can develop on the south side of the point. During an outflowing tide, water flowing close to the point turns to a northeasterly direction toward the Golden Gardens beach area. This flow divides as it approaches Golden Gardens, with the more offshore flow continuing northward and the rest eddying southward following the Shilshole Bay shoreline.

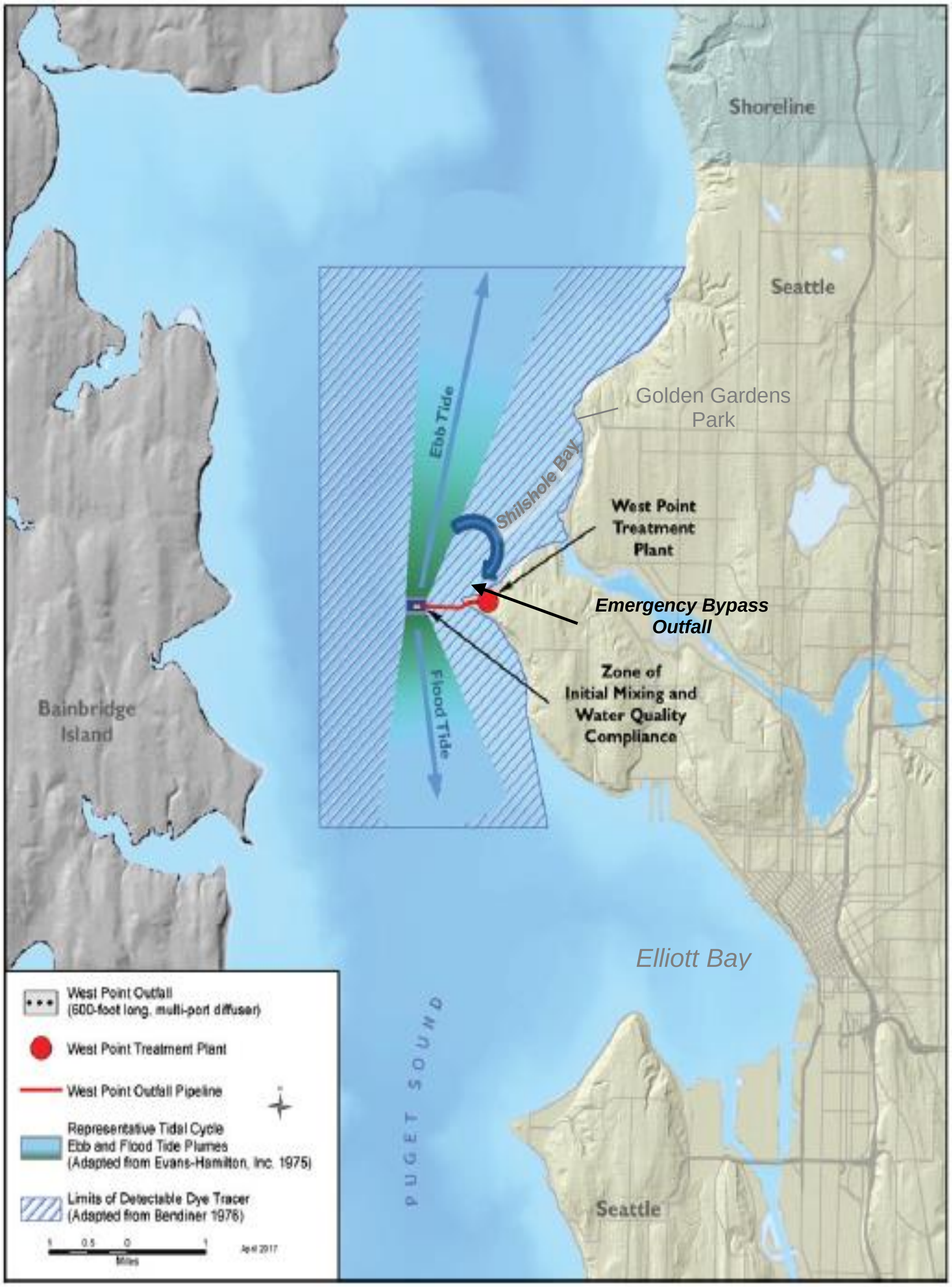

Figure 7. **Typical dispersion in the winter and spring of the West Point treatment plant effluent over a tidal cycle. The blue box shows the extent of detectable dye tracer released from the main outfall in prior tracing studies (Bendliner, 1976). A clockwise eddy forming to the north of West Point has been observed in current data during ebb tides as well (Lincoln, 1976; King County, 2005).**

2.0 BACTERIA

Treated wastewater, like that from West Point and the WWTSs, is disinfected to kill human pathogens. Untreated municipal wastewater, like that from the EBO and untreated CSOs, is known to contain high concentrations of a variety of potential human pathogens (e.g., viruses, bacteria, and protozoa). These pathogens are primarily a concern with activities such as shellfish consumption and swimming in water bodies where the untreated wastewater is discharged.

Fecal indicator bacteria concentrations at all four beaches sampled near West Point (north and south West Point beaches, Golden Gardens, and Carkeek) were high following both EBO discharge events. The highest concentrations of Enterococcus and fecal coliform bacteria occurred on February 9 at the beach nearest the EBO (Figure 8). Values after each event quickly declined within three days–falling below the criterion for reopening the beaches. Daily beach monitoring ended, and all beaches were reopened for swimming and other recreational activities on February 21. There were no exceedances of applicable bacteria water quality standards at beaches in the vicinity of West Point after February 21. There were three exceedances of the peak water quality standard between April and June at three beaches that are near a freshwater source and historically prone to higher bacteria levels.

The flooding of West Point resulted in a period of reduced treatment that changed effluent characteristics from February 9 through May 9. Fecal coliform levels in West Point effluent were variable and generally elevated relative to normal treatment conditions (Figure 9). Although the flooding event did not damage the capacity of the chlorine disinfection process to effectively treat wastewater, the disinfection system effectiveness was variable while the primary and secondary treatment processes were being restored. However, effluent levels complied with the weekly and monthly effluent permit limits. The Elliott West WWTS, was the only King County WWTS that did not meet its monthly fecal coliform effluent permit limit in March 2017.

Offshore bacteria concentrations near the West Point outfall were slightly elevated above historical values during the period of reduced treatment but returned to normal by April 28. Bacteria concentrations at other offshore sites were highest in May when no untreated discharges occurred and secondary treatment was restored, indicating a different source. There were no exceedances of applicable state fecal coliform standards.

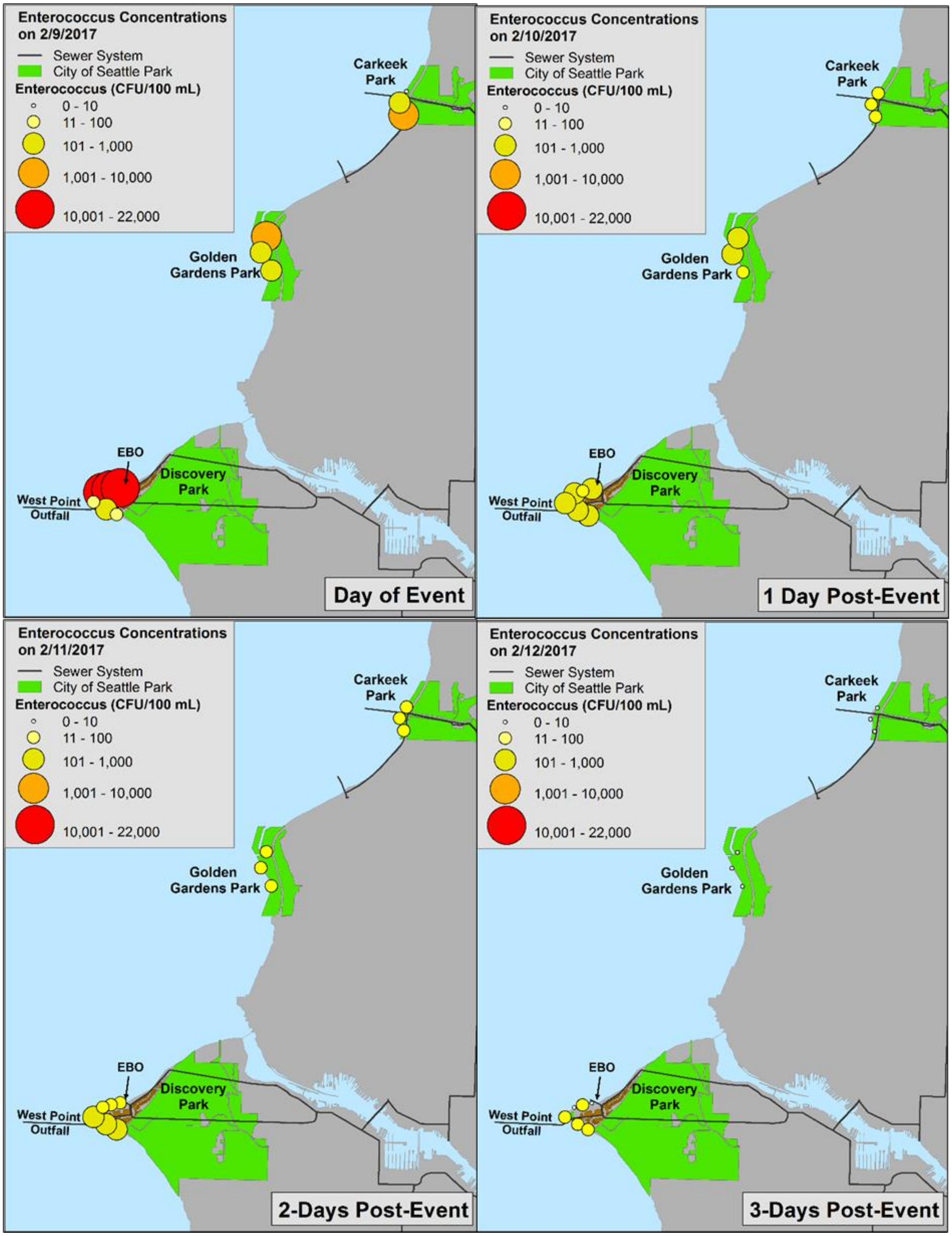

Figure 8. Enterococcus concentrations at beaches near the West Point Wastewater Treatment Plant for four consecutive days following the initial plant flooding and discharge event (King County, 2018). The criterion for reopening beaches at the time of the flooding event was a mean of 104 CFU/100 mL.

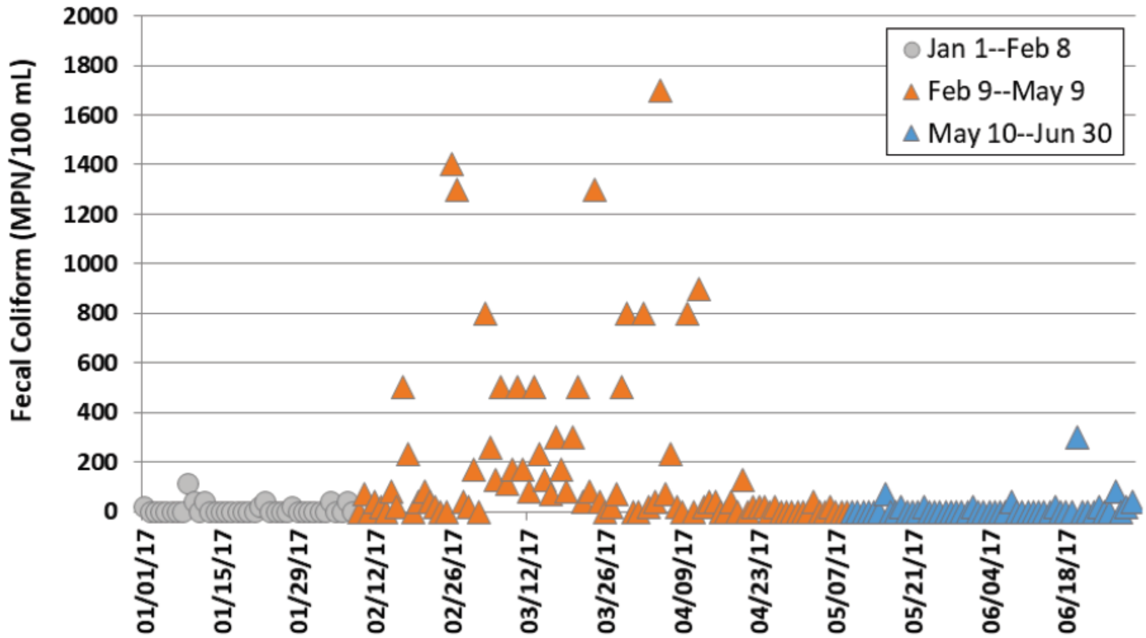

Figure 9. Daily concentrations of fecal coliform bacteria measured in West Point effluent, January 1-June 30, 2017 (King County, 2018).

3.0 NUTRIENTS, PHYTOPLANKTON, AND DISSOLVED OXYGEN

The flooding of West Point resulted in a relatively large increase in effluent carbonaceous biochemical oxygen demand (CBOD) through mid-April. CBOD is a measure of the potential oxygen demand of the oxidizable organic matter in the effluent. West Point effluent did not meet permit limits for average weekly and average monthly CBOD during this period.

Receiving water dissolved oxygen concentrations were at healthy levels and within historic ranges for all offshore Central Basin sites throughout the monitoring period from the surface to bottom. All sites in the Central Basin met (i.e., were higher than) the state water quality numeric standard for dissolved oxygen, except for late June, where near bottom dissolved oxygen levels were slightly below the standard at the deep water sites.[7] Dissolved oxygen levels in deep waters in June were within historic ranges and typical of early summer conditions. From February through June, oxygen levels observed at West Point met the state standard.

West Point effluent nutrient concentrations were variable, particularly dissolved inorganic nitrogen (DIN, comprised of ammonia and nitrate/nitrite) that can stimulate algae growth. However, DIN concentrations were generally lower or comparable to historical concentrations. Total nitrogen and phosphorus loadings were generally higher than normal due to the reduced level of solids removal and biological treatment activity at West Point during February through April (Figure 10).

Based upon a dilution factor calculation, at all times predicted levels of ammonia met the applicable water quality standards at the edge of the mixing zone in receiving waters at the West Point and South Plant outfall. Observed ammonia levels at the West Point outfall were similar to or below historical ranges, and other Central Basin sites generally showed typical conditions. Although not sampled directly, analyses showed that ammonia levels in the EBO discharge likely met water quality standards. Ammonia levels at all beach sites, including beaches near West Point, WWTS, and CSO outfalls, were well below the chronic water quality standard. Near-bottom ammonia levels at the South Plant outfall were slightly elevated during some sampling events. These elevated levels may have been due to the elevated ammonia in South Plant effluent resulting from the transfer of solids from West Point during recovery.

Surface nutrient levels across Puget Sound were at times lower than historical ranges due to phytoplankton uptake from a vigorous spring bloom resulting from favorable physical conditions. The spring phytoplankton bloom resulted in a sharp increase in chlorophyll-a (a measure of phytoplankton biomass) values and the bloom was evident the first week in

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[7] Dissolved oxygen concentrations below state standards in deeper waters of Puget Sound have been recognized as being due at least in part to physical and biological factors associated with intrusion of low oxygen waters from the Pacific Ocean and naturally occurring seasonal algae production (Newton et al., 1998; Cope and Roberts, 2013).

April at all stations. Phytoplankton bloom timing was within typical seasonal ranges of the spring bloom. Chlorophyll-a levels at 14 sites throughout the Central Basin, including the West Point outfall, were within historical values except for high levels in May at East Passage. The phytoplankton present and the seasonal progression were similar to those observed during the past several years (2014–2016).

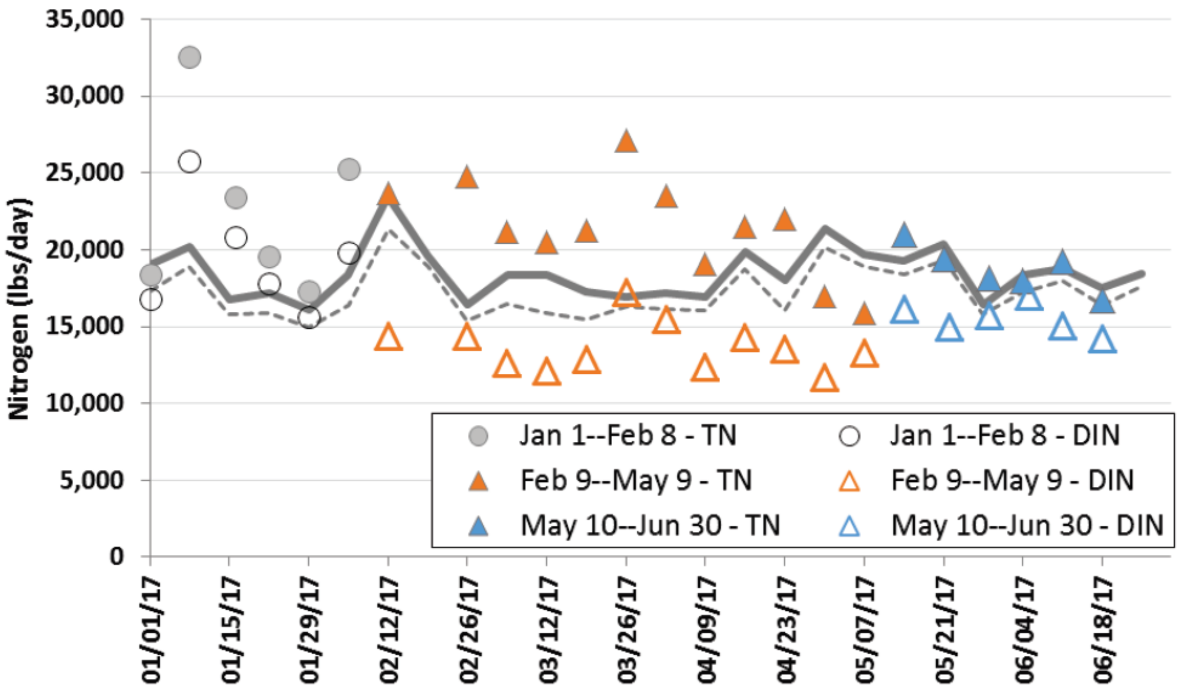

Figure 10. Weekly average DIN and TN loading from West Point, January 1-June 30, 2017. Historical average DIN (dotted gray line) and TN (solid gray line) loading (2007-2016) provided for reference (King County, 2018).

4.0 METALS

West Point effluent did not meet permit limits for average weekly and average monthly TSS through mid-April. West Point effluent metals concentrations and overall loading to receiving waters increased, particularly copper, chromium, lead, and zinc associated with the increased effluent TSS concentrations (a substantial fraction of the metals would typically be removed and concentrated in settled solids). While temporarily elevated, these concentrations were much lower than typical concentrations historically observed in West Point effluent prior to implementation of Seattle's projects to reduce corrosion of metal pipes in the water supply system (in the early 1980s) and the upgrade to secondary treatment at West Point in1996. King County's development and implementation of an industrial waste pretreatment program, which received EPA delegation authority in 1981, also has likely resulted in some reduction in metals (and organic contaminant) loading to West Point.

Although the effluent concentrations of some metals were elevated during the recovery phase, at no time did predicted levels of any metal exceed applicable water quality standards at the edge of the West Point outfall receiving water mixing zone based upon a dilution factor calculation. Acute and chronic effluent toxicity tests conducted during the period of reduced treatment confirmed that the effluent met permit performance standards for toxicity and were comparable to past results. Therefore, no short-term or long-term toxicity impacts to aquatic life were expected during the period of reduced treatment.

TSS levels in the water column at the West Point outfall site were elevated during the period of reduced treatment particularly at mid-water depths. All metals concentrations measured during the two 2017 water column metals sampling events (4 sites, 3 depths each, April 27, and June 6) were below state water quality standards for protection of both aquatic life and human health. Several of the metals measured in Puget Sound during the 2017 sampling events were elevated above historical values, particularly in April. While West Point effluent likely contributed to small increases in some metals at the edge of the mixing zone, it did not explain all observed increases. A combination of additional factors likely contributed to the differences in water column metals concentrations. These factors include field contamination, variability in oceanic inputs, and heavy spring rainfall increasing inputs of metals into Puget Sound from stormwater/runoff.

NPDES permit-required sediment sampling was conducted in September 2017 at eight stations located near the West Point outfall. Sediment metals concentrations were all well below their respective state marine sediment standards and were similar to those measured at the same stations in 2011, as well as in follow up sampling at four stations in 2018. Modeled solids deposition of the EBO releases did not predict that metals concentrations would exceed Washington's Marine Sediment Management Standards near the EBO outfall.

Sediment and butter clam samples were collected from five beaches potentially influenced by West Point discharges for which historical data were available for comparison. All detected beach sediment metals concentrations were well below their associated state marine sediment standards. In sediments, copper (at West Point's north beach) was the only metal greater than historical concentrations, at more than twice the maximum historical value.

All metals in clam samples were below available Washington Department of Health (WDOH) human health seafood consumption advisory screening values, though copper and lead lack screening values.[8] Some of the highest metals concentrations in butter clams were detected at West Point's north and south beach sampling stations: these were for copper and lead. All other metals were within typical ranges relative to available historical data. Similar to sediment samples, copper concentration in clams collected at West Point's north beach were almost twice as high as the historical maximum at that station. To a lesser extent than copper, the lead concentration in butter clam samples from West Point's north beach was also slightly elevated at approximately one and a half times the historical maximum. Increases in clams appeared to have been short-lived and intertidal sediment concentrations were within normal ranges based on sampling conducted in 2020.

Zooplankton samples were collected in spring and summer of 2017 and 2018 from two Central Basin locations and analyzed for metals. Increases in zooplankton metals concentrations associated with the West Point flooding event were not identified.

Dungeness crab were collected in 2017 and 2018 from two different areas within King County marine waters as part of the monitoring response related to the West Point flooding and analyzed for contaminant concentrations. Crabs were collected near the Shilshole Bay Marina, located north of West Point, and in north Elliott Bay near the Elliott West WWTS outfall. Results were compared to data from 2012 and 2014.[9]

Metals concentrations in crab muscle and hepatopancreas samples from north Elliott Bay were not different from available historical data. Results from the Shilshole Bay Marina site suggested the West Point flooding event may have increased chromium and possibly copper concentrations in crab muscle, as well as chromium, lead, and nickel in crab hepatopancreas for a short-term period (few months to one year). Mean metals concentrations in crab were compared to WDOH human health seafood consumption advisory screening levels and all, were below screening levels except for cadmium. Cadmium concentrations in crab hepatopancreas exceeded seafood advisory screening levels in all years including 2012 and 2014 indicating no change from pre-flooding event conditions.

English sole samples were collected in May and June of 2017 and 2019 from stations near the West Point and Elliott West outfalls and analyzed for chemical contaminants and biochemical markers of exposure. These results were compared to those from other Puget

[8] WDOH does not have a standard screening level for copper. WDOH does not use a standard screening level for lead but uses a predicted blood lead level in children based on EPA's Integrated Exposure Uptake Biokinetic Model. Therefore, lead could not be screened with available data.
[9] Crab tissue data were not available from Shilshole Bay area in 2012.

Sound locations sampled in 2017 and to pre-event 2015 data collected by King County. Metals concentrations in English sole collected in 2017 and 2019 near the West Point and Elliott West outfalls were not significantly higher than in 2015 or at other Puget Sound stations in 2017. At all stations located near the West Point outfall, Shilshole Marina, and in Elliott Bay, the mean mercury concentration in English sole muscle exceeded the WDOH human health seafood consumption advisory screening levels for high consumers, but not screening levels for the general population; no other metals exceeded these WDOH screening levels. In general, English sole contaminant data collected following the West Point flooding event was consistent with existing seafood consumption advisories for Central Puget Sound and Elliott Bay.[10]

[10] Although other factors, including data sufficiency, would be evaluated before an advisory would be issued by WDOH, comparisons to WDOH screening levels were used in the West Point flooding studies to evaluate consistency of study results with existing fish consumption advisories.

5.0 ORGANIC CONTAMINANTS

Effluent organic contaminant concentrations and overall loading increased in association with increased solids concentrations. A substantial fraction of the organic contaminants would typically be removed and concentrated in settled solids in the WWTP and some organic compounds are broken down through biological-physical treatment processes.

Twelve of 141 organic compounds analyzed in effluent were detected during the period of reduced treatment, and 6 were detected in samples once secondary processes were restored. Concentrations of the detected semivolatile and volatile organic compounds were generally highest in February and subsequently declined over time to historical levels once secondary processes were restored. The semivolatile organics that were only detected during reduced treatment are compounds that typically serve as a food source for microbes in secondary treatment. No polycyclic aromatic hydrocarbons (PAHs), pesticides, or polychlorinated biphenyls (PCBs) were detected above laboratory reporting limits in any samples. Although polybrominated diphenyl ethers (PBDEs) were not measured[11], WWTPs are a significant source of PBDEs (Johannessen et al., 2015), including to the Central Basin of Puget Sound (Osterberg and Pelletier, 2015). The concentration and overall loading of PBDEs in West Point effluent likely increased during the period of reduced wastewater treatment.

Considering the difficulty of detecting organic contaminants in ambient water at concentrations at or below the part per billion level, their lack of detection in receiving waters in the past, and their infrequent detection in West Point effluent during the recovery phase, no receiving water measurements of organic contaminants were made. However, hydrophobic organic contaminants that are known to sorb to sediments or known to bioaccumulate were analyzed in subtidal sediments and aquatic biota where detection is possible.

Modeling of solids deposition from the EBO releases did not predict organic contaminant concentrations would exceed Washington's Marine Sediment Management Standards near the EBO outfall. Subtidal sediments in the vicinity of the West Point outfall had benzoic acid concentrations exceeding state marine sediment standards at four of the eight stations sampled in September 2017. Benzyl alcohol, which degrades to benzoic acid, exceeded sediment standards at one station. Elevated benzoic acid concentrations were also observed at other King County sediment monitoring stations in the Central Basin during 2017. Subtidal sediments sampled again in April 2018 at the four stations with initial exceedances showed benzoic acid and benzyl alcohol concentrations no longer exceeded standards at those stations. No other organic chemicals exceeded state marine sediment standards. Laboratory toxicity testing of sediments collected near the West Point outfall met testing criteria (i.e., no evidence of toxicity) for three independent toxicity tests.

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[11] Effluent monitoring for PBDEs is not required as part of the West Point NPDES permit and were not evaluated due to lack of historical comparison data.

Benthic invertebrate communities at the main outfall also appeared to be similar to past monitoring events.

Zooplankton data indicated that there was no increase in total PCB concentrations in response to the 2017 West Point event. However, total PBDE concentrations measured in the spring of 2017 were substantially higher than samples collected following this period; concentrations observed in fall of 2017 fell by an order-of-magnitude and remained lower in samples collected in 2018.

PAHs were not detected in Dungeness crab collected in 2017. Total PCB levels in crab collected in 2017 were not substantially higher than levels observed prior to the West Point flooding event. No historical PBDE data for locations near West Point were available for comparison, but comparison of 2017 and 2018 data indicated that crab muscle and hepatopancreas concentrations were higher in 2018 than 2017. Total PBDE concentrations in crab from North Elliott Bay were highest in 2012 muscle and hepatopancreas samples compared to 2017 and 2018 samples; the lowest muscle concentrations were detected in 2017. Overall, the limited data do not suggest an increase in total PBDE concentrations in crab due to the West Point flooding event.

When mean contaminant concentrations in crab were compared to WDOH human health seafood consumption advisory screening levels, only total PCBs were above screening levels. Mean total PCBs concentrations in the hepatopancreas and in muscle exceeded seafood advisory screening levels for both the general population and high seafood consumers. These findings are consistent with WDOH's conclusions based on WDFW's 2012 crab tissue data collected from Central Basin and Elliott Bay. Therefore, contaminant concentrations measured in crab tissues around the time of the West Point flooding event would not have changed existing WDOH health consumption advisories for crab.

Organic contaminants in English sole sampled near West Point and the Elliott West WWTS in 2017 were compared to those from other locations in Puget Sound, to data collected at the same locations in 2019, and to pre-event historical data collected in 2015. Three classes of bioaccumulative organic compounds (PCBs, PBDEs, and dichloro-diphenyl-trichloroethane [DDT] and its degradation products) were consistently detected in English sole in all years. Although there was some evidence of higher concentrations in fish sampled near West Point and the Elliott West WWTS in 2017, similar values occurred at other nearby urban stations and similar patterns often occurred across years at other locations. When considered in the context of spatial and temporal variation at other nearby stations, the data indicate the West Point flooding event by itself did not substantially change exposures of English sole to organic chemicals near West Point and the Elliott West WWTS.

English sole data collected prior to 2017 had already led to a WDOH human health seafood consumption advisory for PCBs in Elliott Bay. At all stations located near the West Point outfall, Shilshole, and within Elliott Bay, the mean total PCBs concentrations in English sole were not significantly higher than data collected prior to 2017. PCB results were generally consistent with existing fish consumption advisories limiting consumption of English sole in Elliott Bay. Therefore, no change in fish consumption advisories is expected for English sole based on observed 2017 or 2019 tissue concentrations.

A biomarker is a measure of a biological response that can be related to exposure to environmental chemicals. Three biomarkers (PAH-metabolites in bile, vitellogenin in blood, and estrogenic compounds in bile) were measured in English sole samples collected in June 2017 and 2019 from stations near the West Point and Elliott West outfalls, although 2019 results for two of the biomarkers (those measured in bile) were still pending at the time of publication.[12] These biomarkers characterize the exposure of fish to PAHs and xenoestrogens (i.e., natural and synthetic substances entering the water that act as feminizing hormones; male fish only). These data were compared to historical data collected by WDFW from urban and non-urban areas throughout Puget Sound. PAH-metabolites and xenoestrogen concentrations in bile were statistically similar between stations and/or years and did not suggest influence from the West Point flooding event. Though vitellogenin-positive blood plasma in males near West Point indicated estrogen exposure, the limited amount of available data and high variability seen at other Puget Sound locations makes it unclear whether these differences were the result of the flooding event or indicative of pre-existing variability at that location.

[12] An addendum will ultimately be published that will include the additional 2019 biomarker results.

6.0 CONCLUSIONS

King County used a combination of monitoring efforts to assess potential impacts to the aquatic environment after the West Point flooding event on February 9, 2017. The largest impact observed was a transient increase (no more than 3 days) in bacteria levels in water at beaches following the two untreated emergency discharge events at the West Point EBO in February. No other significant water or sediment quality impacts were predicted by mixing zone or sediment deposition models or effluent toxicity testing.

Overall, water quality observations in Puget Sound showed typical conditions compared to the last decade. Besides bacteria and deep dissolved oxygen at some sites (albeit within normal ranges), all measurements of marine water quality met applicable water quality standards throughout the monitoring period. Additionally, except for TSS, CBOD, and residual chlorine, treatment plant effluent also met applicable permit limits.

During the period of reduced treatment, higher concentrations of bacteria, solids, organic matter, metals, total nitrogen and phosphorus, and some organic chemicals were in the effluent relative to normal conditions. Increased loads of copper and lead from West Point during the period of reduced treatment may explain why concentrations of these metals were elevated in intertidal sediment (copper only) and clam tissue (copper and lead) collected from the West Point north beach station. Increases appeared to have been short-lived and returned to within normal ranges based on intertidal sediment sampling conducted in 2020. The West Point flooding event may have influenced chromium and possibly copper concentrations in crab muscle, and chromium, lead, and nickel in crab hepatopancreas for a short-term period (few months to a year). Significant increases in metals concentrations of English sole were not seen in 2017 or 2019.

Increased loads of organic contaminants from West Point were not observed to have had a discernible impact on subtidal sediment or biota contamination, except possibly for PBDEs in zooplankton. Municipal wastewater effluent is a known significant source pathway of PBDEs to Puget Sound. However, only a short-term increase in zooplankton PBDE concentrations was observed.

Temporarily elevated concentrations of some metals (clams and crab) and PBDEs (zooplankton) were observed in some species. However, the fish and shellfish data collected for these species following the West Point flooding event would not have resulted in changes to any existing WDOH Puget Sound Central Basin or Elliott Bay seafood consumption advisories.

Puget Sound monitoring programs are generally designed to track long-term trends in water, sediment, and biota quality or human health risks due to fecal contamination at public beaches. Data from these programs were combined with additional sampling efforts to assess the impacts of the West Point event on Central Puget Sound. However, such Before-After sampling designs are unable to account for background temporal variability, nor are they able to clearly separate effects of multiple input sources (i.e., treated wastewater, WWTSs, CSOs, stormwater, rivers) (Schmitt and Osenberg, 1996; Christie, et al. 2020; Orr et al. 2020).[13] Inclusion of control sites in a Before-After-Control-Impact (BACI) or beyond-BACI design is recommended for consideration if the need to evaluate a future pulse disturbance like the West Point flooding event occurs (Underwood, 1994).

When monitoring receiving waters, other sources of contamination may confound attempts to link the event directly to observations. This makes it difficult to definitively link any observed increases in contaminant levels in part or exclusively to the West Point flooding event, except for the elevated bacteria following untreated discharges. Co-occurring factors such as heavier than normal rainfall and increased stormwater inputs to Puget Sound between February and April 2017 likely contributed to increases in observed contaminant concentrations. In the context of total annual contaminant loadings discharged to Puget Sound, the relatively small and transient increase in contaminant loading combined with the substantial dispersion characteristics of the receiving waters also make it difficult to detect impacts of the West Point event. If desired, more robust sampling designs could be explored that might better separate the effects of multiple inputs. Such designs might be informed by simulation models of effluent plume dilution and transport under various flow and weather conditions.

Furthermore, statistically, it is never possible to prove there was no impact–the West Point event had some level of effect–from the most obvious immediate increases in bacteria levels at nearby beaches to much more subtle effects beyond the immediate vicinity of the discharge. To put it another way, the absence of enough evidence to disprove the null hypothesis is not evidence of the null hypothesis (Steele et al., 2013). The ability of an individual study to detect an impact depends on the statistical power of the study and the magnitude of the actual impact. In some of our monitoring efforts, it appears that the magnitude of change was smaller than could be reliably detected by the study designs. If similar assessments are needed in the future, a starting point might include establishment of biologically relevant changes as the foundation for the study design (Steele et al., 2013). This would shift the focus from rejecting a hypothesis of no-effect to studies designed to detect ecologically relevant effects.

[13] Zooplankton PBDE and English sole vitellogenin data were only collected after the West Point event, so inferences regarding potential linkages to the West Point event are even weaker.

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