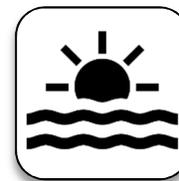


SURFACE WATER QUALITY



A. APPROACH

This section reviews changes in surface water and water quality and potential effects that the Seattle-Tacoma International Airport has had to the immediate vicinity and in the study area cities. Given the nature of water and streamflows, Seattle-Tacoma International Airport was identified as the point source for water quality data. The area of study would be the airport and all streams and wetlands downstream that receive or intercept flows out of the airport properties. Additionally, the consultant team also reviewed the effects of the developments associated with the 1997 study, which most notably included constructing a third runway to the west of the existing airfield.

The overall approach of the surface water quality analysis of the study involved the following steps:

- Collected qualitative and quantitative water quality data ranging from 1997 to 2019 related to Seattle-Tacoma International Airport stormwater systems that are on-site. This step also includes descriptions of the industrial wastewater system (IWS) and industrial wastewater treatment plant (IWTP), and the storm drainage system (SDS) outfalls, which capture runoff from the portions of the existing airport that do not drain to the IWS.
- Identified the changes to the various stream and wetlands affected by Seattle-Tacoma International Airport developments and operations from 1997 to 2019. This step includes restoration activities on Miller, Walker, and Des Moines creeks, and associated wetlands.
- Used the U.S. Geological Survey's (USGS) National Land Cover Database (NLCD) to measure overall land use changes in the study area over the period of study. Specifically, this study was able to use the land cover change index developed by the USGS, covering years from 2001 through 2016.

B. WATER QUALITY IN ON-SITE STORMWATER

The consultant team collected and reviewed readily available data and reports to generate an analysis of water quality conditions at and around Seattle-Tacoma International Airport since 1997, and to identify the potential effects on water quality to the study area cities.

First, the team compiled and reviewed the airport's National Pollutant Discharge Elimination System (NPDES) and state waste discharge permit and supporting documentation from Port of Seattle. These documents describe the stormwater management system on the site, the monitoring requirements, the state water quality benchmarks, and, importantly, provide a history of the changes and improvements to the system in relation to the NPDES requirements and the developments of the 1997 Master Plan Update, which most notably included constructing a third runway to the west of the existing airfield.

Water quality data from 1997 to 2019 was downloaded from the Washington Department of Ecology's (Ecology) Water Quality Permitting and Reporting Information System (PARIS) (Ecology 2020b). This data includes analytical results from the multiple stormwater outfalls within the air operations area (AOA) and surrounding airport industrial support facilities that are reported to Ecology on a quarterly basis. To provide a general summary of the water quality trends time, the consultant team selected a subset of seven outfalls with the most continuous data series over the study period, and five water quality parameters that were most frequently sampled (Table 8.1) to graphically present in a series of graphs (Figures 8.2 to 8.19).

Graphs depict maximum values reported during a monitoring year, which would reflect exceedances. No new or special water quality studies originated from this analysis. All values were taken from the data provided in the PARIS database (Ecology 2020b). Locations are provided in Figure 8.1.

**Figure 8.1
Selected Airport Outfalls and Water Quality Parameters**

Outfall Site (current)	Previous Outfall	Receiving Water	Drainage Subbasin Area (acres)	Water Quality Parameters Reviewed in this Report
001	001	Puget Sound	375 acres	Biochemical Oxygen Demand (BOD), Glycols, pH (min., max.), Copper, Zinc, Oil and Grease
SDE4/S1 (combined in 2007)	002, SDE4	Des Moines Creek (East Branch)	172.2 acres (SDE4 only: 159.3 acres)	Copper, Zinc, Turbidity, pH (min., max.)
SDS3/5 (combined in 2007)	005, SDS3	Des Moines Creek (West Branch) via NW Ponds	457.4 acres (SDS3 only: 359.6a acres)	Copper, Zinc, Turbidity, pH (min., max.)
SDN2/3/4 (combined in 2011)	011, SDN4	Miller Creek via Lake Reba	112.87 acres (SDN4 only: 30.6 acres)	Copper, Zinc, Turbidity, pH (min., max.)
SDW1A	na	Miller Creek	70.1 acres	Copper, Zinc, Turbidity, pH (min., max.)
SDW2	na	Walker Creek	37.5 acres	Copper, Zinc, Turbidity, pH (min., max.)

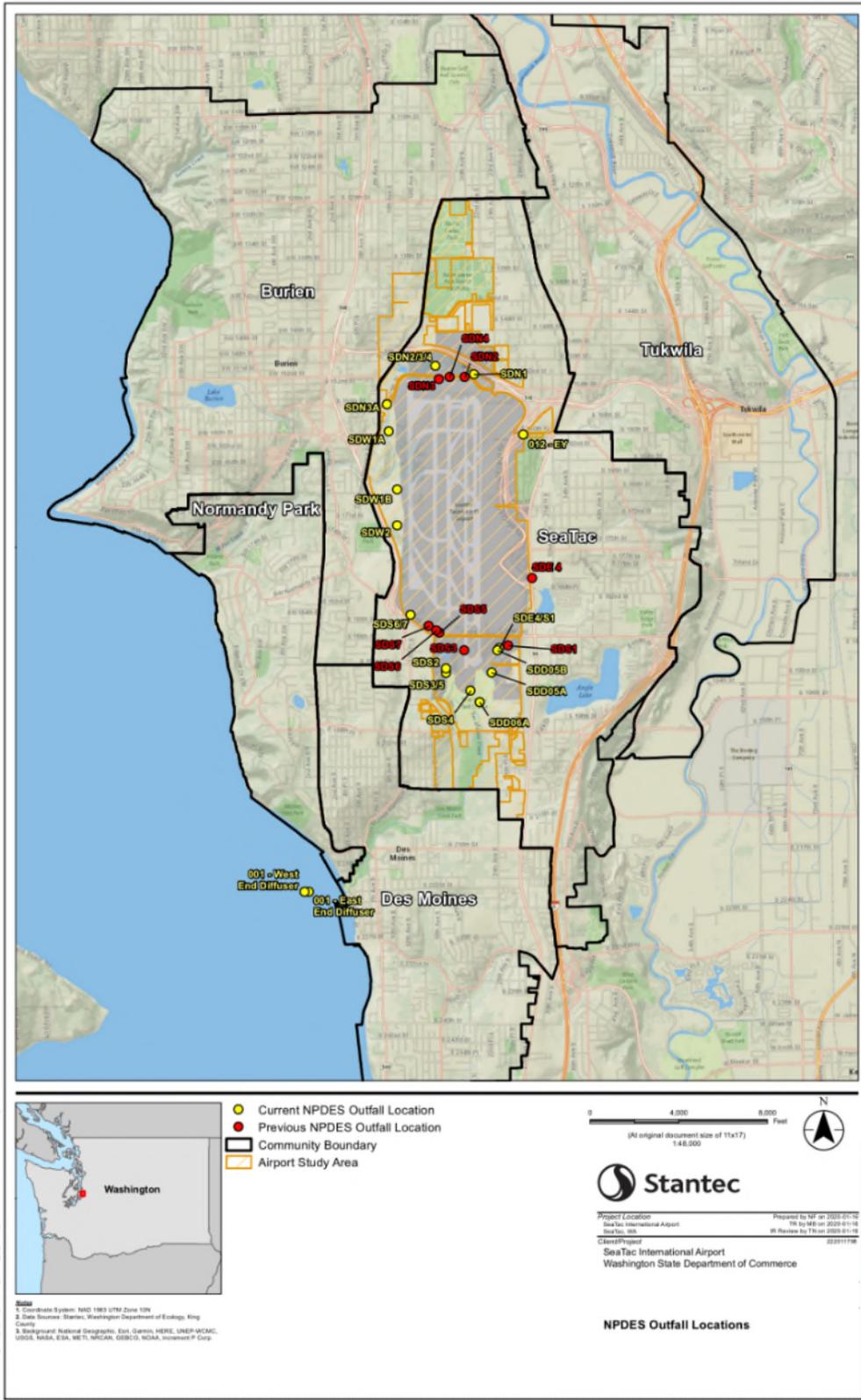
Sources: Port of Seattle 2015a, 2019a

It is important to note that water quality testing limits, sample collection methods, and laboratory analysis methods have changed over the past 22 years, which presents difficulties in assessing trends over such a long period. The consultant team was able to make adjustment to scalable measurements for copper and zinc measurements (i.e., milligrams per liter to micrograms per liter), but some of the results from the 2008-2009 period appeared to have mislabeled units. In these cases, adjustments were made based on the data ranges immediately preceding or following the questionable data entries.

Some water quality parameters shifted the name of the analysis method that report results at noticeably different ranges, giving the appearance of difference in results across the time period. This was the case for copper (Cu) results, switching from total recoverable copper to copper (as Cu) to total copper. The same changes occurred for zinc (Zn). As another example, Outfall 001 tested for total glycols from 1997-2008; in 2009, tests instead monitored for propylene glycols and ethylene glycols.

Additionally, some outfalls were consolidated with the issuance of the new NPDES permit. In these cases, the summary results shown in this report use the data from old outfall and the new consolidated outfall together to complete a continuous data set over the 22-year period. For this report's summary analysis, this was limited to three outfalls: SDS3 (SD35), SDN4 (SD234), and SDE4 (SDE4/S1).

Figure 8.2
NPDES Outfall Locations



C. INDUSTRIAL WASTEWATER SYSTEMS

The IWS and IWTP were initially built in 1963/1964, and the system currently manages stormwater from the approximately 375 acres associated with industrial activities. Such activities include aircraft fueling, maintenance operations, and wastewater from other airport related operations. Industrial wastewater may result from any process or activity of industry, manufacturing, trade, or business, and includes (but is not limited to) water used for industrial processes, such as pipe integrity pressure testing and vehicle and aircraft wash water; stormwater contaminated with fuel, lubricants, firefighting foam, cleaning agents, and aircraft and ground surface de-icing/anti-icing agents; contaminated construction dewatering waters; excess water from groundwater well construction and monitoring; and leachate from contaminated sludge management (Port of Seattle 2019a). These are all permitted discharges to the IWS. The IWS includes collection and conveyance facilities, biochemical oxygen demand runoff segregation, runoff storage, and the IWTP.

Industrial wastewater system components and upgrades

Aircraft maintenance, fueling and deicing operations are restricted to those areas served by the IWS stormwater collection and conveyance system, consisting of 21 miles of piping, 510 manholes and catch basins, two below-grade vaults in the parking garage, and 11 pump stations (Port of Seattle 2015a, 2019a). Each pump station functions as a key structural source control (SSC) best management practice (BMP), diverting runoff from various drainage areas that would otherwise drain to the SDS to the IWS instead. Originally designed for a 10-year, 24-hour storm event, computer modeling of the conveyance system determined that portions of the system might be overloaded during the current stormwater regulation standard of 25-year, 24-hour storm events. In response to this analysis, the Port installed watertight manhole covers in 1997 through 1998 to prevent flooding in areas that would pose a safety problem or may overflow to the storm drainage system (SDS) (Port of Seattle 2016).

The storage of runoff from the IWS collection system is a critical component of the overall system as it allows for temporary containment of flows in excess of the plant's treatment capacity. Three lagoons provide storage capacities of 1.6, 3.3, and 76 million gallons at a maximum normal operating water depth (Port of Seattle 2019). Lagoons 1 and 2 were lined with a polyethylene liner in 1996 and 1997 respectively. In 2002, Lagoon 3 was cleaned, lined, and expanded from 20.2 to 76 million gallons (Port of Seattle 2015a, 2019a).

In preparation for its "all known, available, and reasonable methods of treatment" (AKART) compliance as well as overall plant improvement, the Port began implementing a series of upgrades in 1995. A total of 36 improvements were made to IWS and IWTP from 1996-2009, according to Table E-2 in Port of Seattle (2015a). The total capital cost of these improvements is over \$65 million. Among the improvements was the ability to segregate biochemical oxygen demand runoff. While the IWTP is highly effective in treating stormwater pollutants, it was less capable of reducing high biochemical oxygen demand (BOD) concentrations caused by aircraft deicing operations. Runoff with high BOD levels must be segregated and pumped off site to the Valley View Sewer District, which then sends it to King County's South Wastewater Treatment Plant (SWTP) for secondary treatment and discharge. BOD segregation is facilitated by in-stream monitoring for total organic carbon (TOC), which is used as an analytical surrogate for BOD. The real-time data from the influent TOC analyzers allow plant operators to segregate the high concentration runoff to designated lagoons. Effluent TOC meters allow IWTP operators to monitor the concentration and mass loading of treated effluent being sent to the King County's SWTP or directly to Puget Sound via Outfall 001. Since the segregation process became operational in January 2007, the Seattle-Tacoma International Airport has reduced BOD loading to Puget Sound by over 95% while reducing unnecessary use of the sanitary sewer conveyance and treatment capacity and overall energy consumption (Port of Seattle 2015a).

Water quality trends for Outfall 001

Water quality data associated with BOD, glycols, copper, zinc, pH (maximum and minimum), and oil and grease are shown in Figure 8.3 through Figure 8.9, emptying into Puget Sound from Outfall 001 annually from 1997 through 2019 (from data downloaded from Washington Department of Ecology PARIS database for NPDES Permit WA0024651).

As discussed, the segregation of BOD runoff became operational in January 2007. Results of daily maximum BOD measurements are shown to have decreased to maximums generally lower than 100 milligrams per liter (mg/L), as compared to levels before 2007, which ranged from 210 to 13,000 mg/L. Measurements of total glycols (mg/L) show a similar trend, with amounts dropping to less than 100 mg/L after 2007 segregation began.

Levels of copper and zinc have not been measured during the entire 22-year period of study, with samples taken quarterly starting in 2005-2006. During the period of 2005-2015 under the previous NPDES permit, the two metals remained at relatively lower concentrations and normally did not exceed the daily maximum limits. The copper limit was 83 micrograms per liter (ug/L), and the limit for zinc was 164 ug/L. According to the current NPDES permit requirements (for 2016-2020), heavy metal sampling is not required each year. Priority pollutant sampling was conducted during the wet season and dry season during year three of the permit (2018), but those measurements were not included in the data downloaded from Ecology's PARIS database.

The maximum and minimum levels of pH generally stayed within the 6.0 to 9.0 limits set by the NPDES permit. It appears that only two potential violations of those limits occurred during the study period, once in 2007 (5.8), and the other in 2018 (9.3).

Measurements for oil and grease have stayed under the NPDES limit of 15 mg/L, except during 2019, when a daily maximum was measured at 17.35 mg/L. Generally, the levels of oil and grease appear to have decreased since 2009 in comparison with levels from 1997 to 2008.

Figure 8.3
Maximum Biochemical Oxygen Demand Measurements sat Outfall 001

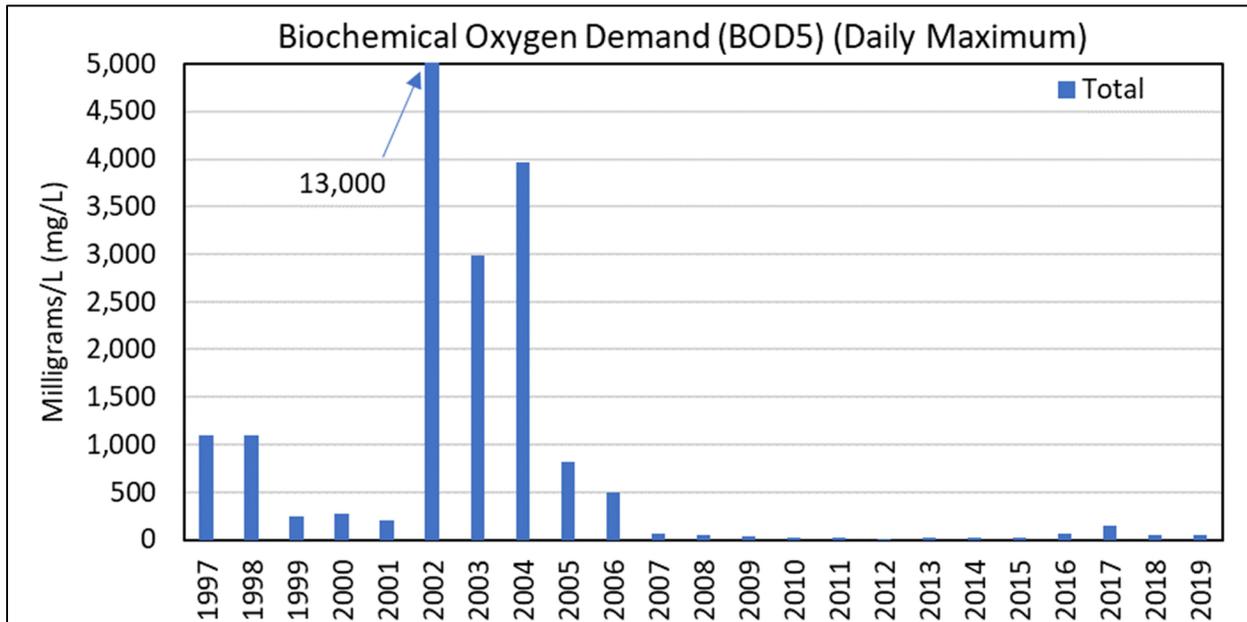


Figure 8.4
Maximum Glycol Measurements at Outfall 001

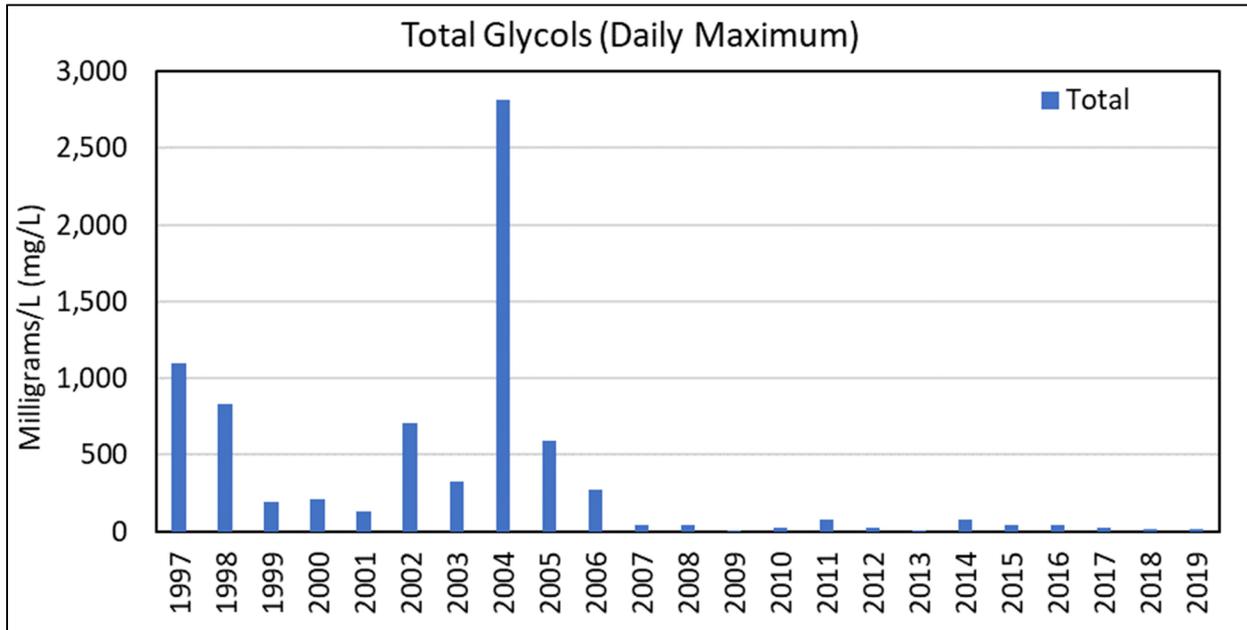


Figure 8.5
Maximum Total Copper Measurements at Outfall 001

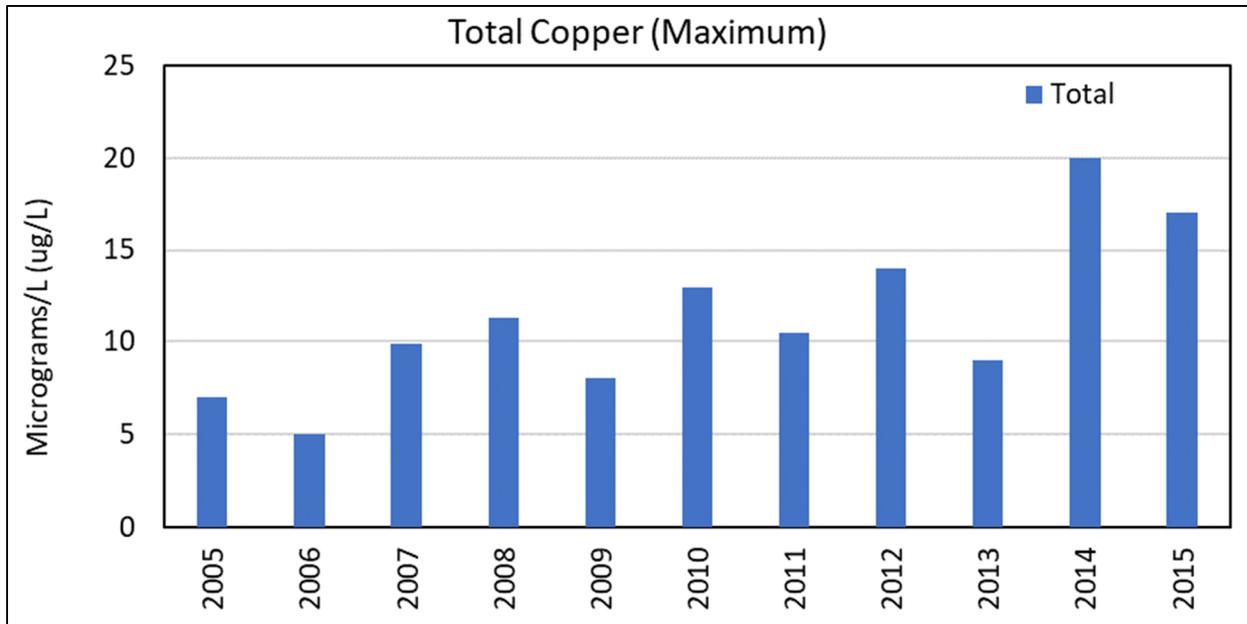


Figure 8.6
Maximum Total Zinc Measurements at Outfall 001

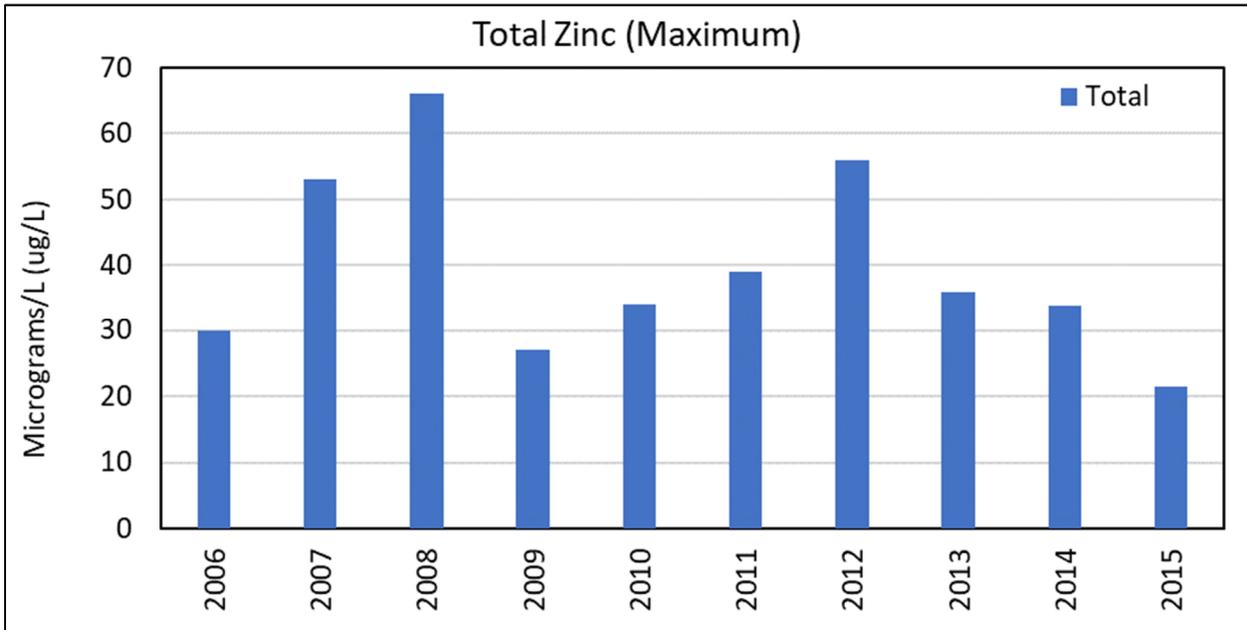


Figure 8.7
Maximum Total pH Measurements at Outfall 001

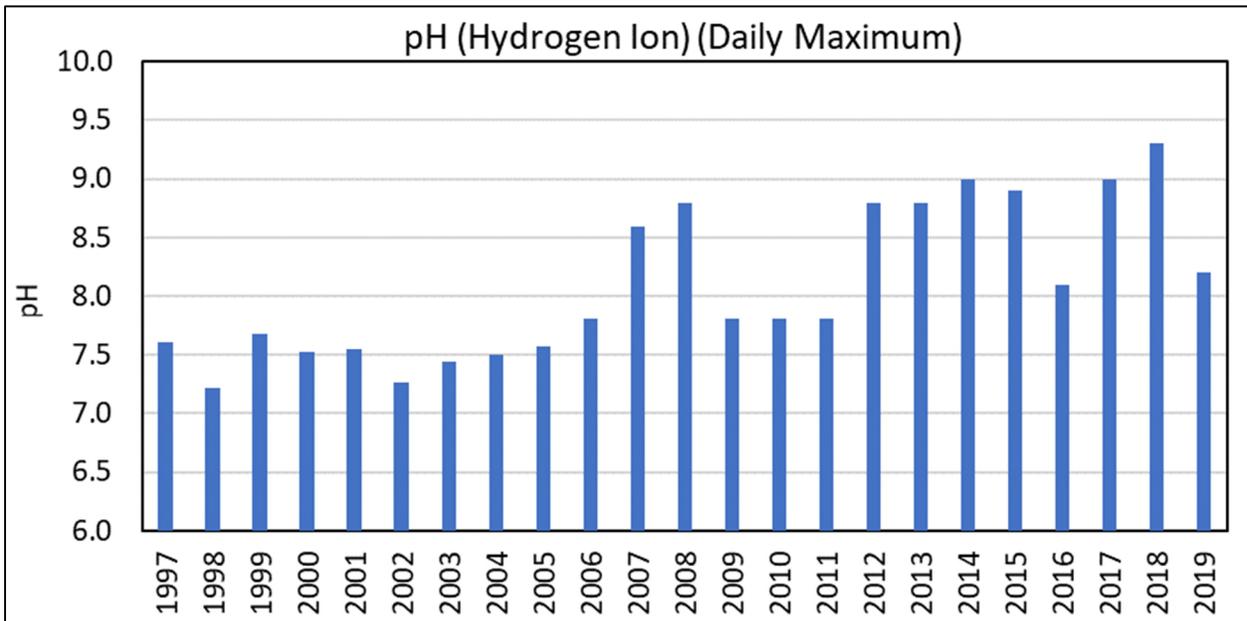


Figure 8.8
Minimum pH Measurements at Outfall 001

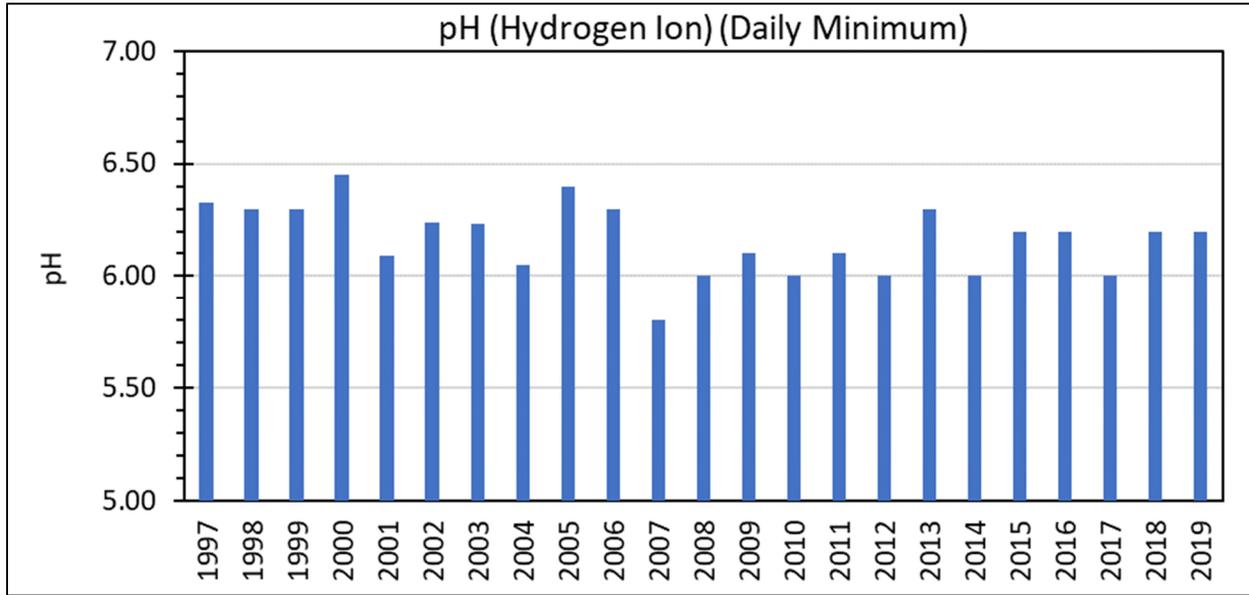
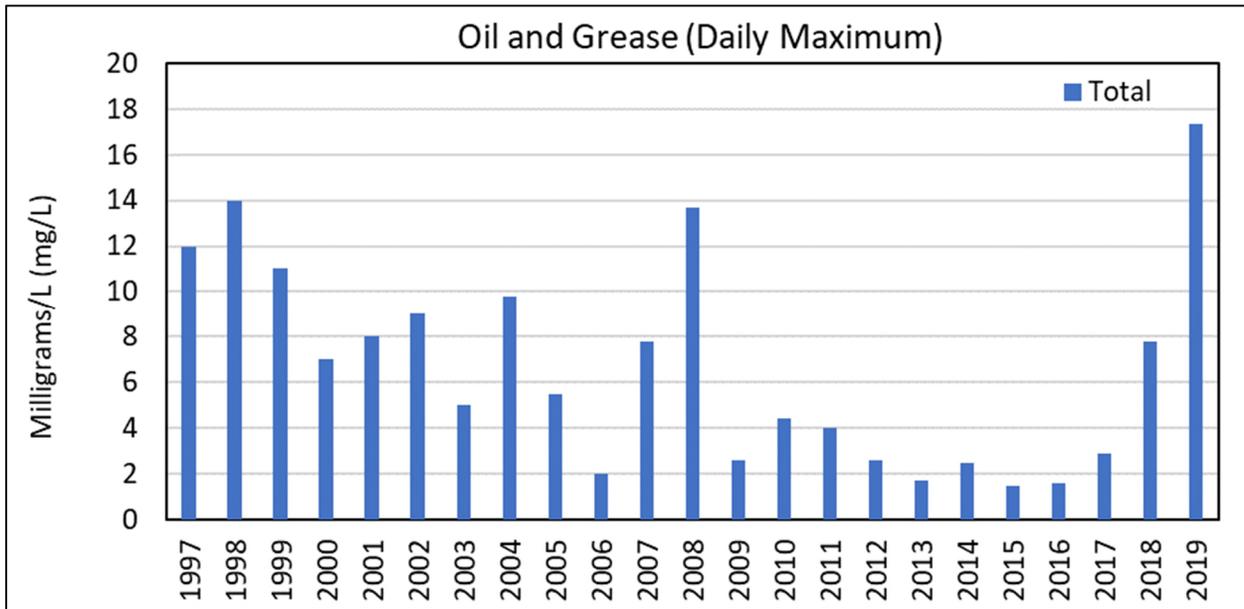


Figure 8.9
Maximum Oil and Grease Measurements at Outfall 001



D. STORM DRAINAGE SYSTEM

The storm drainage system (SDS) drains over 1,200 acres. Nearly one-half of this area is impervious, consisting of the airport's runways, taxiways, parking lots, roads, and roofs. Stormwater draining from the SDS makes its way to two different watersheds: Miller Creek (which includes Walker Creek) to the north and west, and Des Moines Creek to the south. Approximately 282 acres (23.5 %) of the SDS area drains to Miller Creek, which represents about 7 % of Miller Creek's total watershed area (Port of Seattle 2015a). Approximately 852 acres (71 %) of the SDS area drains to the south to Des Moines Creek, representing about 21 % of the creek's watershed (Port of Seattle 2015a).

Components and upgrades

There are five active Seattle-Tacoma International Airport subbasins in the Miller Creek Basin. SDN1 and SDN-2/3/4 discharge to Lake Reba (see Figure 8.10). The SDN-2/3/4 subbasin is located on the north end of the airport and combines the previously separate SDN2, SDN3, and SDN4 subbasins into a single outfall. The three subbasins were combined due to reconstruction of the Pond M (SDN2/3/4) detention facility, which was activated in November 2011 (Port of Seattle 2019a). Seattle-Tacoma International Airport subbasins SDN3-A, SDW1-A, and SDW1-B are located along the western edge of the airport to provide drainage from the third runway. Each subbasin drains into Miller Creek. Runoff treatment current in place for these subbasins include Level 2 (duration based) flow control detention pond and filter strips located along the runway provide flow control and treatment (Port of Seattle 2019a).

Walker Creek watershed receives Seattle-Tacoma International Airport discharges stormwater from one subbasin, SDW2 (Figure 8.9). The outfall was activated in November 2008 after commissioning of the third runway. This area receives runoff from the runway, taxiways, and infield areas associated with the west portion of the third runway. BMPs for the subbasin include filter strips adjacent to runways and taxiways provide additional treatment, and a Level 2 detention pond (11.9 acres) for flow control to Walker Creek (Port of Seattle 2019a).

The Des Moines Creek watershed draining Seattle-Tacoma International Airport is divided into an east and west branch. The west branch basin is approximately 1,243 acres, with 600 acres within the boundaries of the Seattle-Tacoma International Airport (Port of Seattle 2015a). The west branch flows into a series of ponds known as the Northwest Ponds, which were enlarged to provide regional detention to control high flows in the middle and lower reaches of Des Moines Creek. The three Seattle-Tacoma International Airport subbasins in Des Moines West Basin (SDS-3/5, SDS-4, and SDS-6/7) all receive runoff from runways, taxiways, and service roads (Figure 8.9). During 2003-2008, these subbasins were improved through the addition of a variety of water quality and flow control BMPs (Port of Seattle 2019a). In addition, a bioretention swale was constructed to provide additional treatment in the SDS-4 subbasin in August 2011.

Des Moines Creek East begins at Bow Lake, one-quarter mile east of Seattle-Tacoma International Airport. The east branch basin is approximately 1,032 acres, with 218 acres within the boundaries of the Seattle-Tacoma International Airport (Port of Seattle 2015a). The creek flows mostly within pipes through the city of SeaTac and along the east side of Seattle-Tacoma International Airport, finally daylighting in the southeast corner of the airport. The SDE-4/S1 subbasin is located along the eastern portion of the airport (Figure 8.9) and combines the SDE4 and the SDS1 subbasins into a single outfall (in August 2007; Port of Seattle 2019a). The SDS1 area receives runoff from aircraft maintenance building rooftops, parking areas, cargo building rooftops, roads, and parking lots. The SDE4 subbasin drains the passenger terminal area on the east side of Seattle-Tacoma International Airport. This area receives runoff from roads, parking lots, terminal area roofs, and taxiways. The combined subbasin has had multiple BMPs implemented to meet basic treatment (AKART) requirements and to provide additional enhanced treatment for dissolved metals. These include a Level 1 flow control extended detention pond, a 600-cartridge media filtration vault which provides enhanced treatment, and a bioswale (Port of Seattle 2019a).

Water Quality Trends

Over the past two permit cycles (2003-2008, and 2009-2015), the Port of Seattle invested over \$80 million in stormwater infrastructure improvements through the construction of AKART BMPS followed by an adaptive management program (Port of Seattle 2015a). As a result, water quality test results required by the current NPDES permit has shown a high attainment of permit effluent limits and low variability in stormwater data over the years. The NPDES Fact Sheet for the current permit (Port of Seattle 2015a) summarized the stormwater data for each of the Seattle-Tacoma International Airport outfalls from April 1, 2009 through March 31, 2013. Overall, stormwater discharges from the SDS were well below NPDES permit limits. The summary noted there were only four permit limit exceedances for turbidity out of 342 samples collected. The permit limit for zinc was only exceeded once out of 334 samples collected, and copper had only four exceedances out of 334 samples collected during that same period.

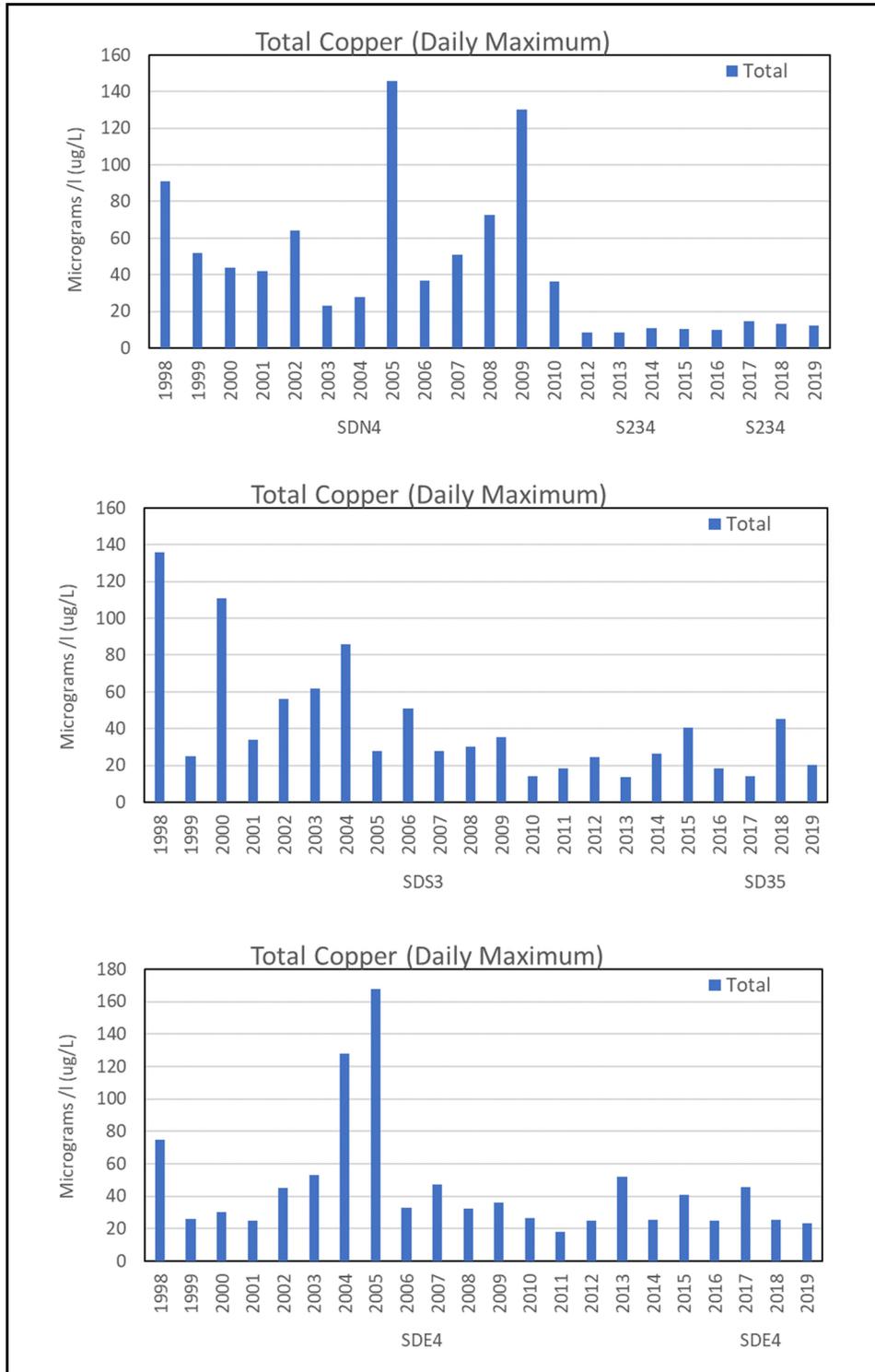
Analysis of the wider 22-year study period examined five water quality parameters: copper, zinc, pH (maximum and minimum), and turbidity. Results are shown in Figure 8.11 through Figure 8.20.

The daily maximums of total copper for the outfalls SDS4-SDN2/3/4, SDE4, and SDS3/5 show higher concentrations in the earlier part of the study period, suggesting benchmark exceedances are less common now by comparison (Figure 8.11). Additionally, results from SDN4 still show maximum total copper concentrations would be in exceedance for that site (a limit of 63.6 ug/L) in 2008 and 2009, but maximum concentrations drop in 2010, and again to lower levels in 2011 and beyond. This would coincide with the consolidation of the SDN4 outfall with SDN2 and SDN3, due to the upgrade of the detention facility there, and increased BMPs at that time. Total copper concentrations at the two newer western outfalls have been well below their NPDES limits (59.2 ug/L for SDW1A, and 47.9 ug/L for SDW2) indicating that BMPs on the third runway are appropriate/effective in reducing total copper concentrations, contributions of total copper in stormwater runoff from activities related to the third runway are lower, or that the stormwater system is successful at filtering total copper from the runoff (Figure 8.12).

Similar to trends for total copper, the daily maximums of total zinc for the outfalls SDS4-SDN2/3/4, SDE4, and SDS3/5 show higher concentrations in the earlier part of the study period (Figure 8.13). This is especially true for SDE4; however, SDE4 drains the passenger terminal area and would have the potential for higher levels. The higher maximum concentrations are reduced considerably after 2007, coinciding with the upgrades in BMPs implemented at that time, suggesting their effectiveness. Again, results from SDN4 show maximum concentrations that would be in exceedance for that site (a limit of 117 ug/L) in 2007 and 2009, but maximums drop to 40 ug/L in 2010, and again to lower levels through 2019. This coincides with the consolidation of the SDN4 outfall and the upgrades of BMPs there.

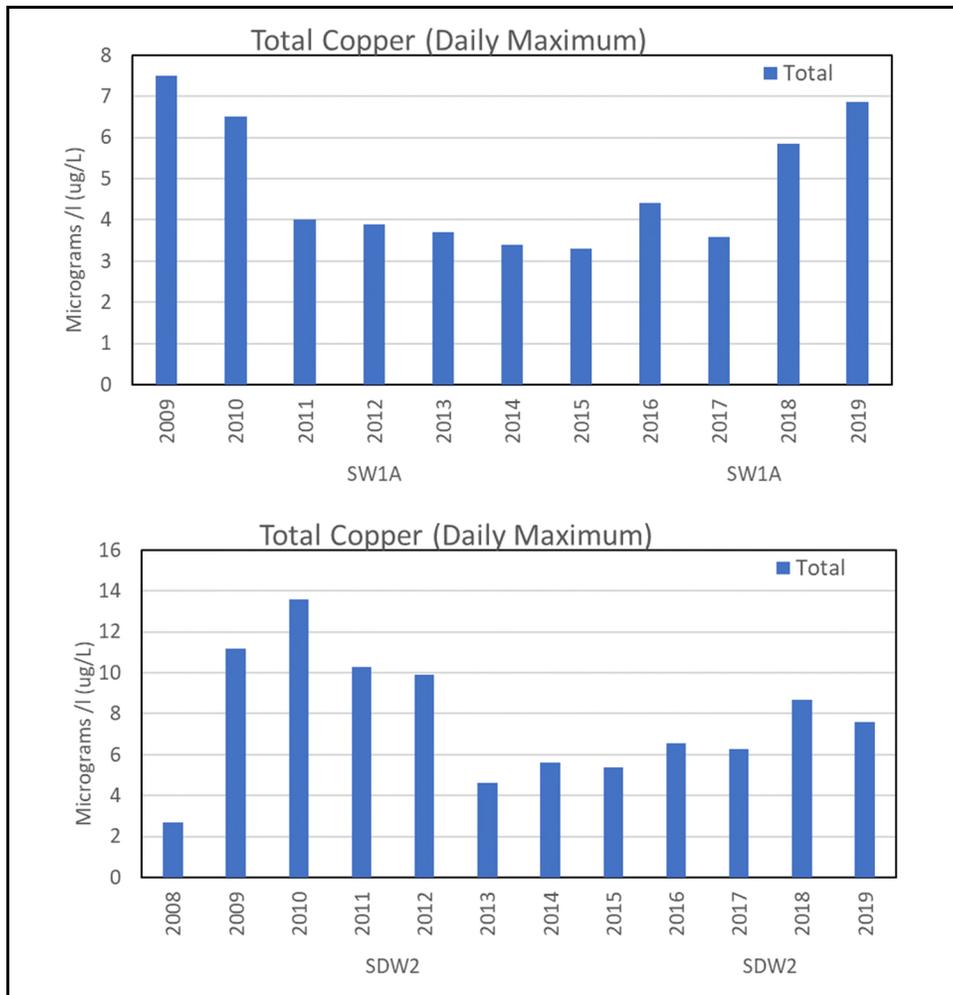
Zinc concentrations at the two newer western outfalls have been well below their NPDES limits (117 ug/L) indicating that either contributions of zinc are low on the third runway, or that the stormwater system is successful at filtering zinc from the runoff (Figure 8.14).

Figure 8.11
Daily Maximum Total Copper Measurements at SDS Outfalls
SDN4-SDN2/3/4, SDE4, and SDS3/5: 1998-2019



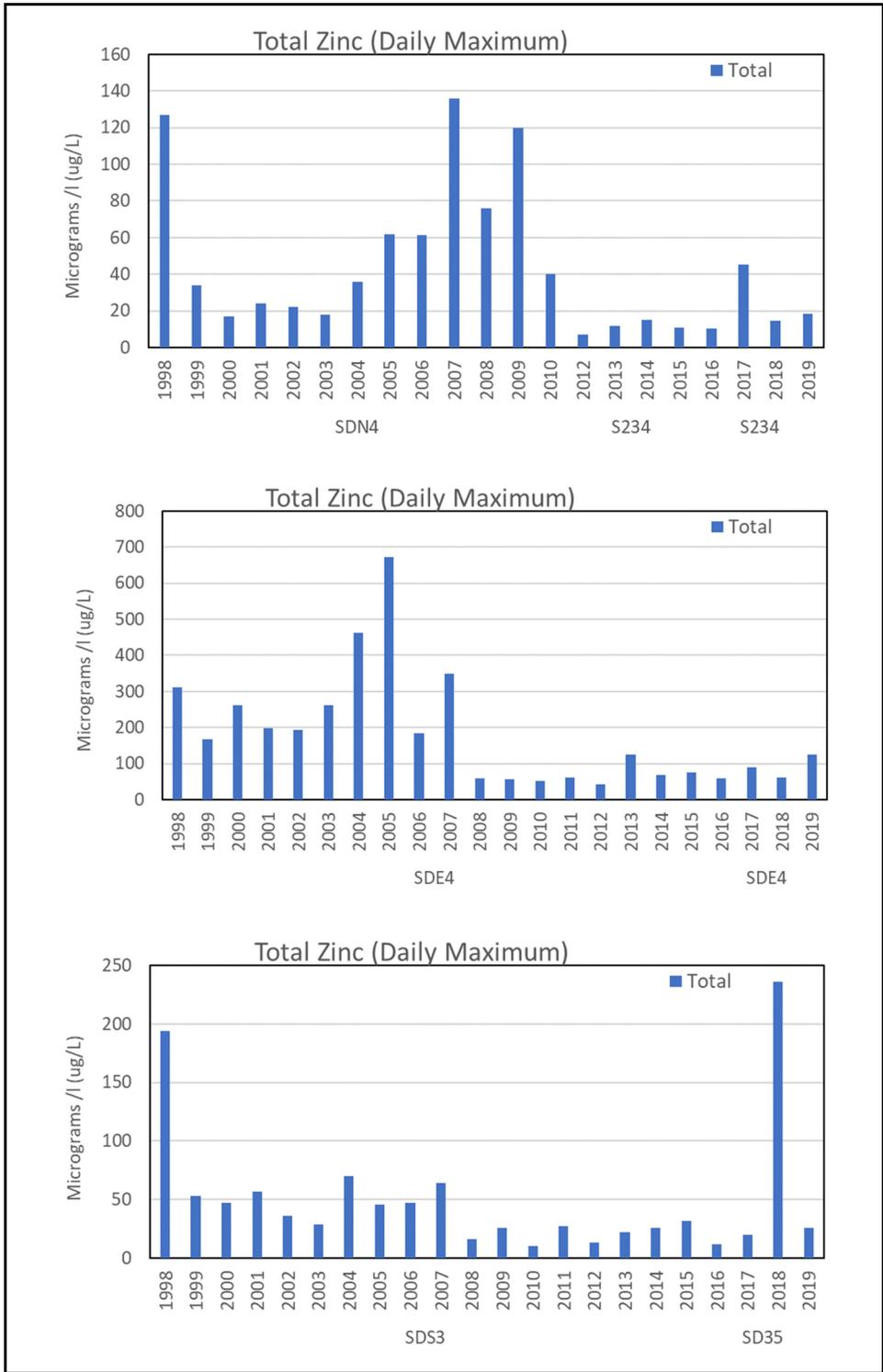
Source: Data downloaded from Washington Department of Ecology PARIS database for NPDES Permit WA0024651.

Figure 8.12
Daily Maximum Total Copper Measurements at SDS Outfalls
SDW1A and SDW2: 2008-2019



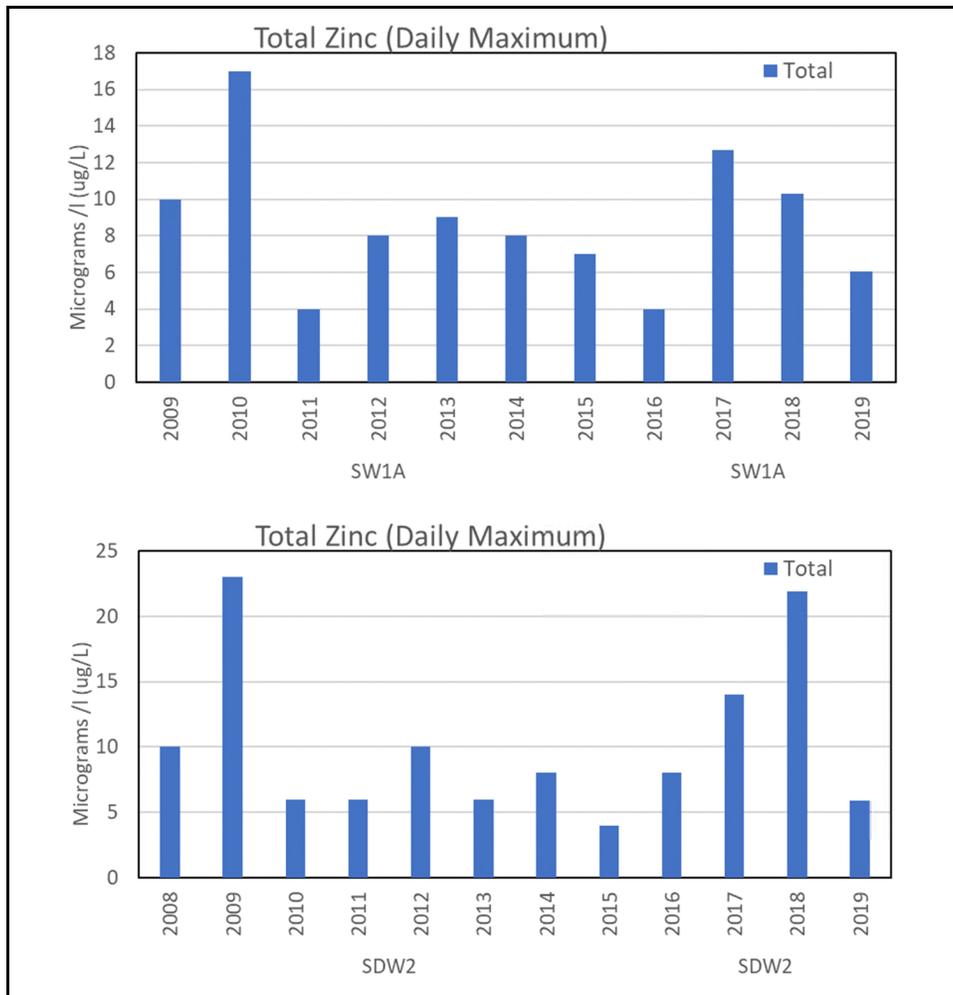
Source: Data downloaded from Washington Department of Ecology PARIS database for NPDES Permit WA0024651.

Figure 8.13
Daily Maximum Total Zinc Measurements at SDS Outfalls
SDN4-SDN2/3/4, SDE4, and SDS3/5: 1998-2019



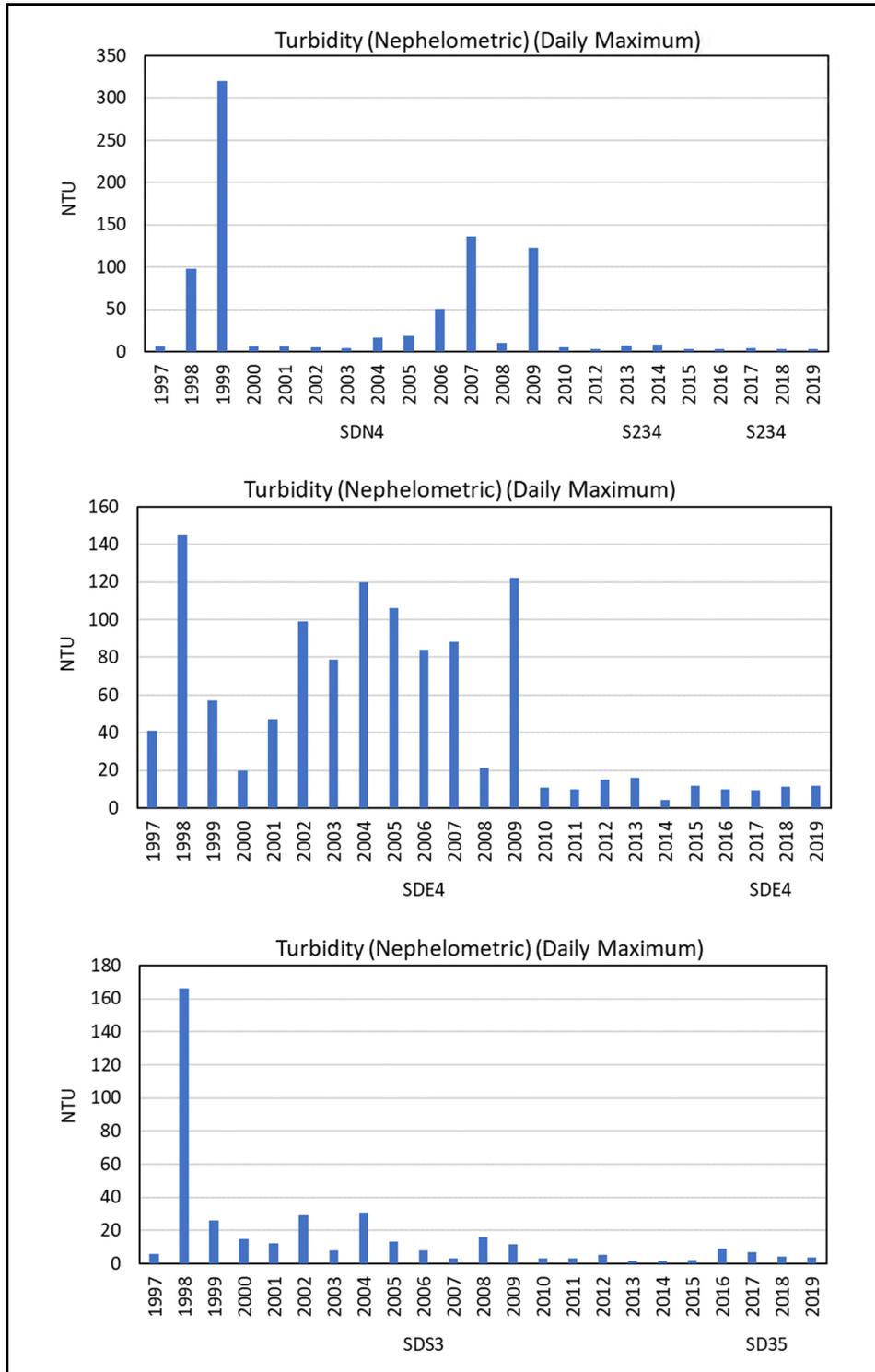
Source: Data downloaded from Washington Department of Ecology PARIS database for NPDES Permit WA0024651.

Figure 8.14
Daily Maximum Total Zinc Measurements at SDS Outfalls
SDW1A and SDW2: 2008-2019



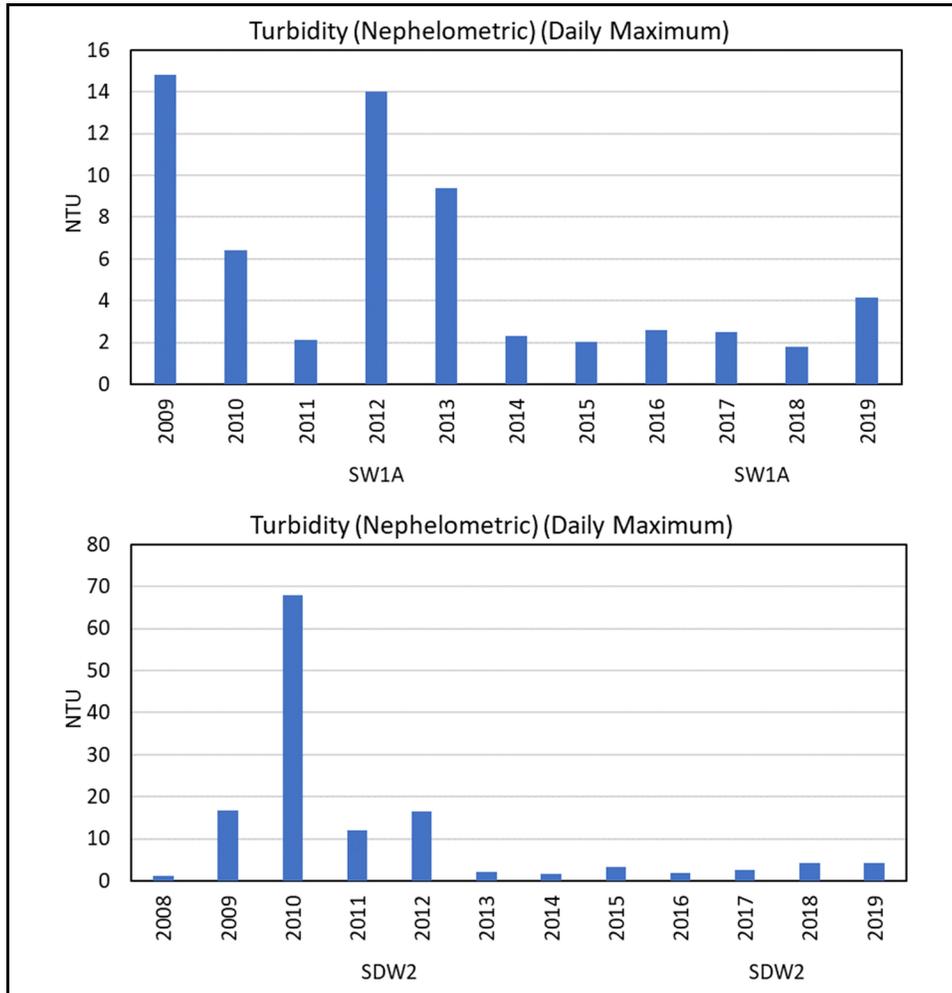
Source: Data downloaded from Washington Department of Ecology PARIS database for NPDES Permit WA0024651.

Figure 8.15
Daily Maximum Turbidity Measurements at SDS Outfalls
SDN4-SDN2/3/4, SDE4, and SDS3/5: 1998-2019



Source: Data downloaded from Washington Department of Ecology PARIS database for NPDES Permit WA0024651.

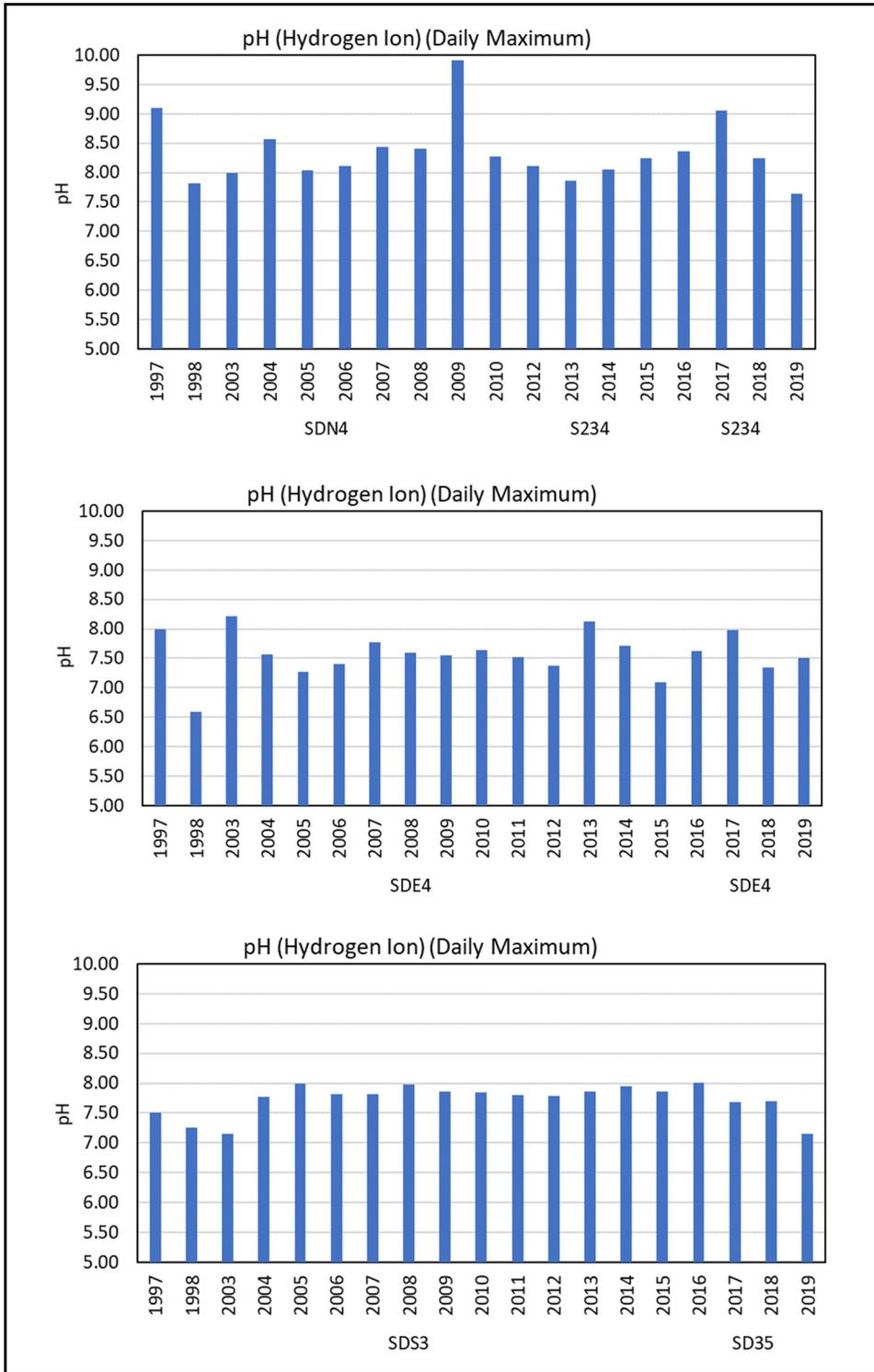
Figure 8.16
Daily Maximum Turbidity Measurements at SDS Outfalls
SDW1A and SDW2: 2008-2019



Source: Data downloaded from Washington Department of Ecology PARIS database for NPDES Permit WA0024651.

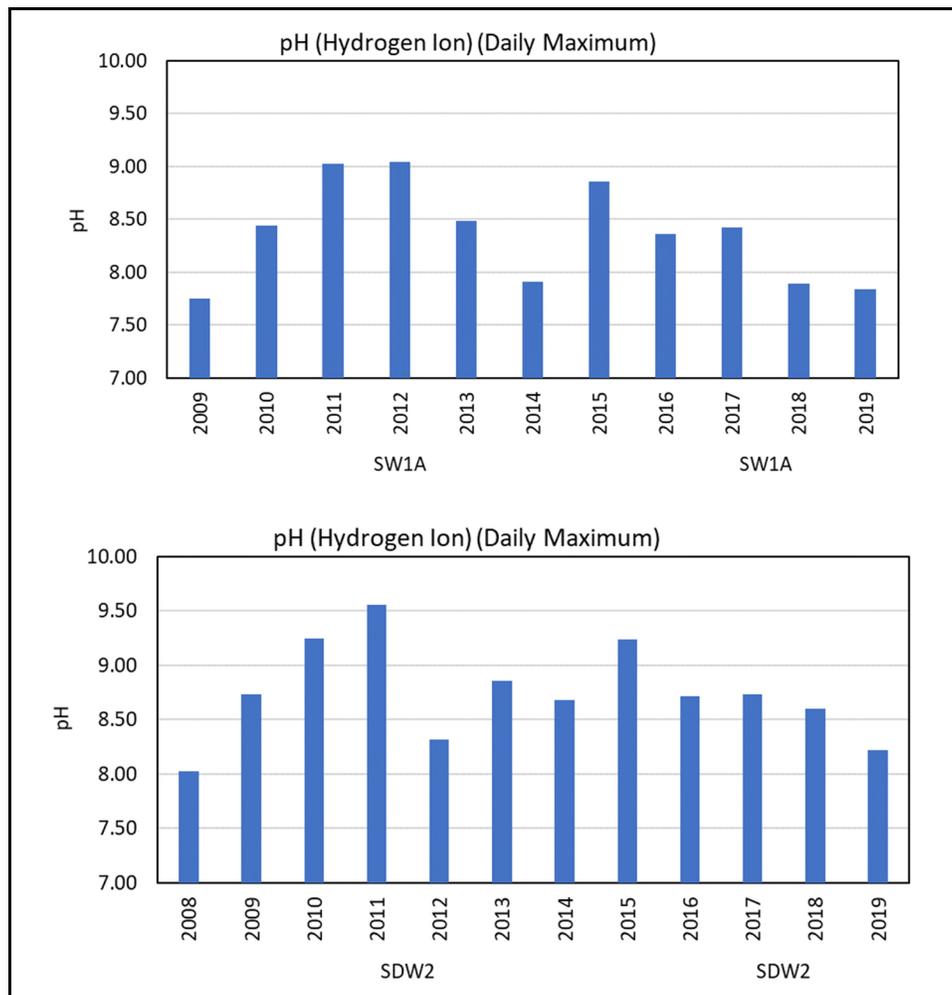
Turbidity limits under the NPDES permit is a daily maximum of 25 NTUs. For SDN4-SDN2/3/4 and SDE4, this limit was exceeded each year up to 2009 (Figure 8.14). For SDN4-SDN2/3/4, this would coincide with the consolidated outfall and the upgraded detention facility. For SDE4, BMP upgrades were brought online in 2007, and there was a substantial maximum turbidity measurement recorded in 2009. Over the past 10 years, however, turbidity levels have remained under the 25 NTU benchmark. Turbidity at the two newer western outfalls have been well below 25 NTUs, except for in 2010 at SDW2 (Figure 8.15). These results indicate that the SDS is successful at controlling turbidity in runoff from Seattle-Tacoma International Airport.

Figure 8.17
Daily Maximum pH Measurements at SDS Outfalls
SDN4-SDN2/3/4, SDE4, and SDS3/5: 1997-2019



Source: Data downloaded from Washington Department of Ecology PARIS database for NPDES Permit WA0024651.

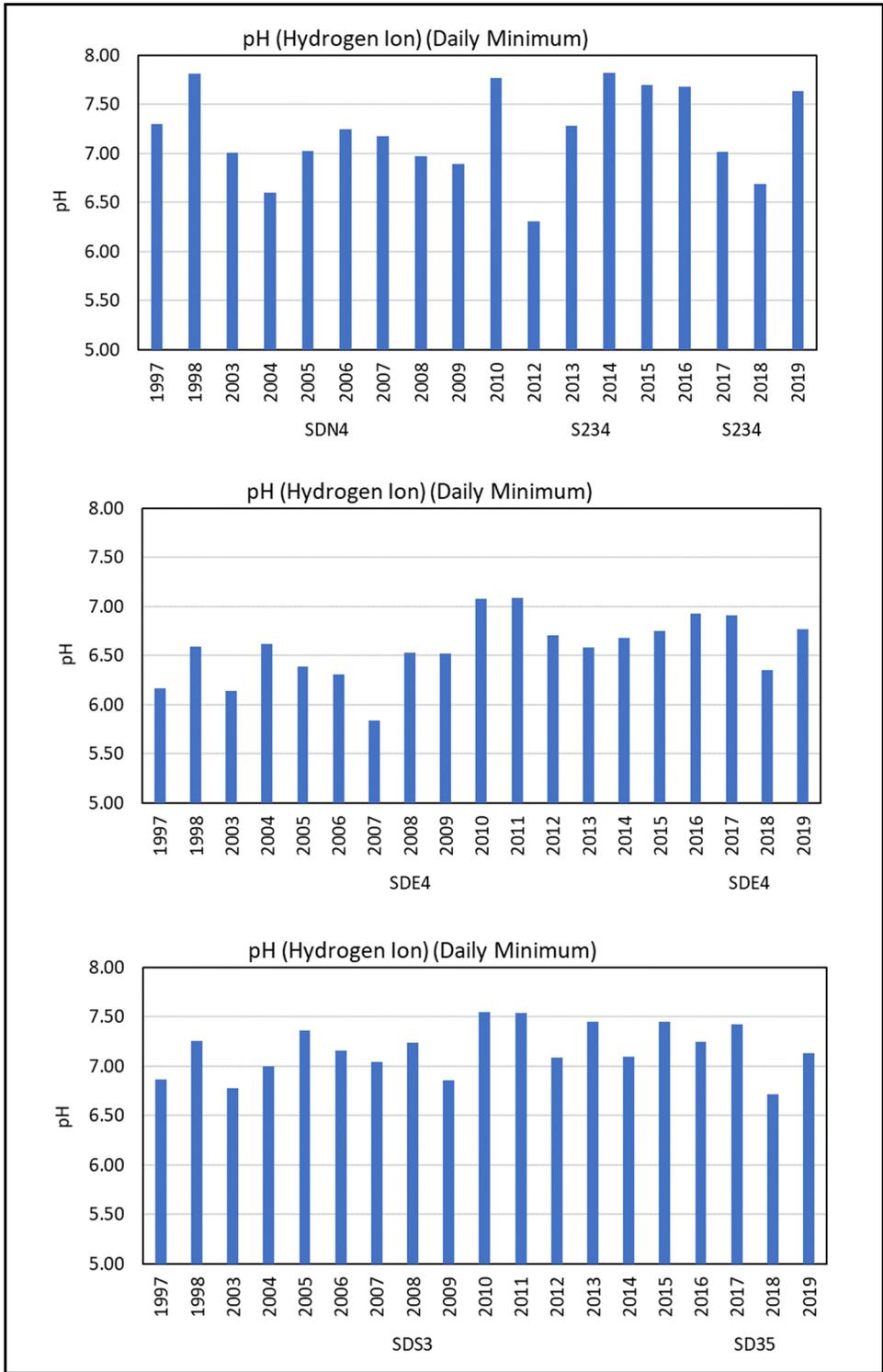
Figure 8.18
Daily Maximum pH Measurements at SDS Outfalls
SDW1A and SDW2: 2008-2019



Source: Data downloaded from Washington Department of Ecology PARIS database for NPDES Permit WA0024651.

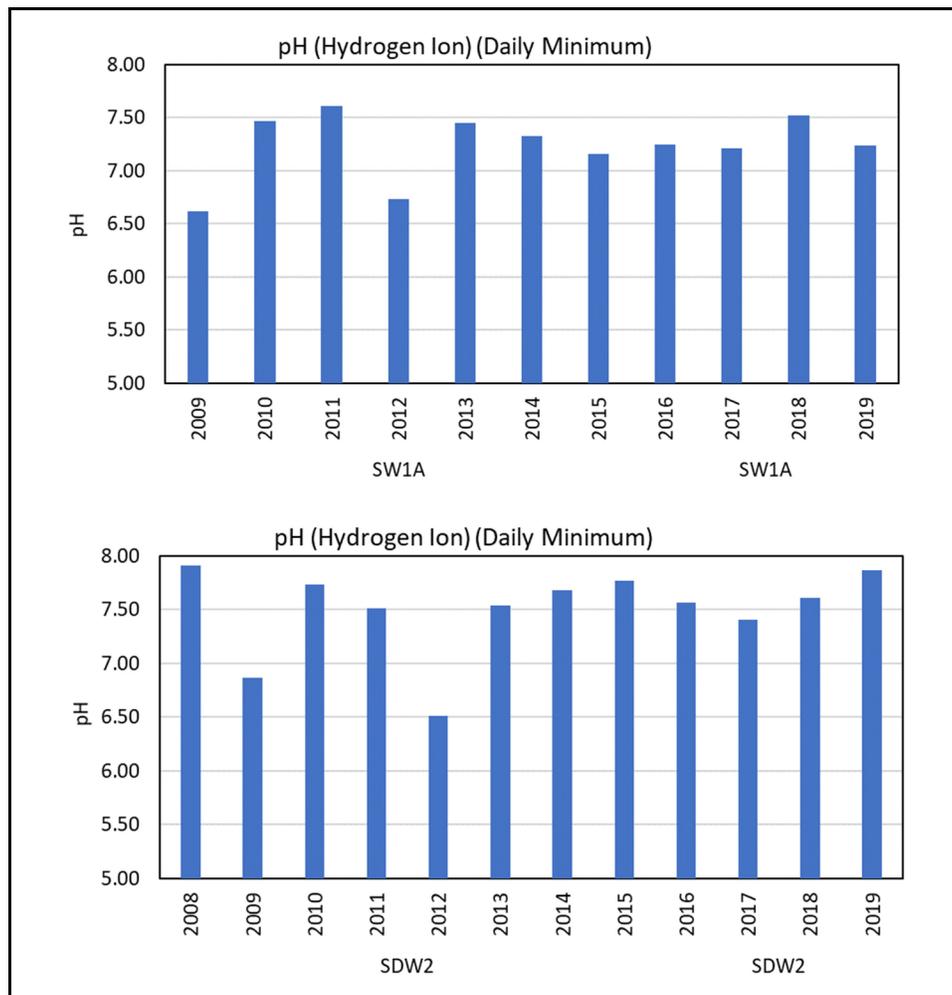
Levels of pH are limited to the range of 6.5-8.5 at the north, south, and east SDS outfalls. Results show that while SDE4 and SDS3/5 have not exceeded the 8.5 maximum, SDN4-SDN2/3/4 has recorded exceedances in four years (Figure 8.16). Daily maximum pH measurements at SDS outfalls SDW1A and SDW2 have slightly different pH limits, ranging from 6.3-9.0. These outfalls have exceeded at pH of 9.0 several times over the study period. The Port conducted a study from November 2011 through May 2012 to identify the potential causes of elevated pH in discharges from the western stormwater ponds and their associated outfalls (SDN3A, SDW1A, SDW1B and SDW2), and to assess if these discharges affected pH levels in the receiving waters of Miller and Walker creeks. The resulting Stormwater pH Study Final Report (Port of Seattle 2012) concluded that primary productivity within the stormwater ponds was the cause of elevated pH levels at the pond outfalls. The pH data collected in Miller Creek and Walker Creek showed that the pH downstream from the pond discharge locations met the water quality criterion (6.5-8.5 standard units) in both wet and dry weather conditions (Cardno TEC 2014). The Port of Seattle has implemented BMP measures to limit algal blooms in the stormwater ponds to keep pH levels lower.

Figure 8.19
Daily Maximum pH Measurements at SDS Outfalls
SDN4-SDN2/3/4, SDE4, and SDS3/5: 1997-2019



Source: Data downloaded from Washington Department of Ecology PARIS database for NPDES Permit WA0024651. Note that 1999-2002 were missing from the data downloaded

Figure 8.20
Daily Maximum pH Measurements at SDS Outfalls
SDW1A and SDW2: 2008-2019



Source: Data downloaded from Washington Department of Ecology PARIS database for NPDES Permit WA0024651.

Minimum pH levels at the SDS outfalls are generally above the lower limits. SDN4-SDN2/3/4 recorded pH below 6.5 in 2012, and SDE4 recorded six years of instances with pH minimums. Most were still above a pH of 6.0, indicating minor violations, likely due to heavy rainfall events. The western outfalls were above their pH minimum limit of 6.3 in all years. These results indicate that the SDS is successful at controlling pH levels in runoff from the airport.

E. RECEIVING STREAMS AND WETLANDS

The consultant team collected and reviewed readily available reports corresponding to the changes to the receiving waters of Miller Creek, Walker Creek and Des Moines Creek as a result of airport activities. First, the team compiled reviewed documents and reports, including the airport's Natural Resource Mitigation Plan (NRMP) (Parametrix 2004), the Miller and Walker Creeks Basin Plan (Miller and Walker Creeks Basin Project Management Team 2006), and the most recent mitigation monitoring plans for stream and wetland

restorations conducted by the Port of Seattle (Port of Seattle 2019a, 2019b). These documents describe the overall conditions of the stream watersheds, the effects that the third runway project had, and give details on the ongoing restoration efforts that the Port of Seattle is conducting within these basins.

The consultant team accessed the King County Hydrologic Information Center to assess the availability of water quality data collected on the receiving streams. County water quality data was limited to only a few stations downstream from Seattle-Tacoma International Airport, and most of those stations collect only streamflow, stage, and water temperature on a semi-continual basis. Basic water quality parameters were not regularly collected, and not at every station. If they were collected, typically they were at stations established farther downstream toward the mouth of the stream. Water quality parameters were limited to conductivity, turbidity, dissolved oxygen (DO), and pH, and several were available for only limited periods between 2010 and 2016. For instance, station 11f is Des Moines Tributary 0377 at Tyee Weir, the closest station to Seattle-Tacoma International Airport that collects water quality. Station 11f collected discharge, stage, and air temperature from 1995 to present, water temperature and conductivity from 2000 to present, DO and %DO from 2000 to 2015, and turbidity and pH from 2012 to 2013. Because the data sets were limited, both in the available parameters and in the time period collected, and because the locations of that data were too far from the airport outfalls to provide any useful comparison or analysis on potential effects, this data was not used in further analyses.

The consultant team also compiled orthoimages of the airport, and each of the surrounding cities to get a visual indication of any changes in land cover or land use. The team further used the USGS's Land Cover Change Index, developed from the National Land Cover Database (NLCD), to measure overall land use changes in the study area over the period of study, covering years from 2001 through 2016. The area of land use change over that period was calculated and tallied for the airport property and for each of the six surrounding cities, and graphical displays were created.

Miller Creek Watershed

Miller Creek is six miles in length and its watershed covers approximately 4,800 acres, which includes portions of Normandy Park, and the cities of Burien and SeaTac. Flows in Miller Creek originate at three locations:

- The Arbor, Burien, Tub, and Lora Lakes complex
- Lake Reba
- Seeps located on the west side of Seattle-Tacoma International Airport.

Miller Creek flows south under State Route 518 and through the in-stream Miller Creek Regional Detention Facility, passing Lake Reba and Lora Lake and southwest toward Puget Sound. Approximately 62% of the land use in the Miller Creek Basin is residential, 19% is commercial/industrial, and the remainder is open (parks, cemeteries, or forests/wetlands) (Port of Seattle 2019a).

A part of the Miller Creek watershed, Walker Creek is the major tributary of Miller Creek approximately two miles in length, draining about 900 acres. The creek originates in Wetland 43 west of State Route 509 and the Airport. After exiting its headwater wetland, the stream meanders within the urban environment, through backyards, along road shoulders, and through numerous road and driveway culverts (Parametrix 2004). Walker Creek flows for approximately 1.3 miles southwest and generally parallel to Miller Creek before joining Miller Creek less than 500 feet upstream of Puget Sound. Walker Creek receives stormwater runoff originating from residential and commercial development within the basin, which has likely increased the frequency and magnitude of peak flows. Riparian vegetation is predominantly immature and deciduous, and often non-native, with homeowner landscaping frequently extending to the stream banks (Parametrix 2004).

Prior to the construction of the third runways and other 1997 Master Plan Update improvements, the natural channel conditions of Miller Creek had been greatly altered due to urban development, especially in reaches above South 160th Street. Most stream reaches featured streambanks extensively armored with riprap or retaining walls, and channels altered by dredging or straightened to protect adjacent properties, or to increase conveyance (Parametrix 2004). With the additional filling of adjacent wetlands due to urban development, Miller Creek lacked connections to adjacent floodplains, floodplain wetlands, or riparian areas. These changes resulted in “a lack of habitat complexity, a lack of woody debris in the channel, a lack of shading from riparian vegetation, the loss of surface water storage, and degraded water quality and biotic integrity in much of the basin” (Parametrix 2004).

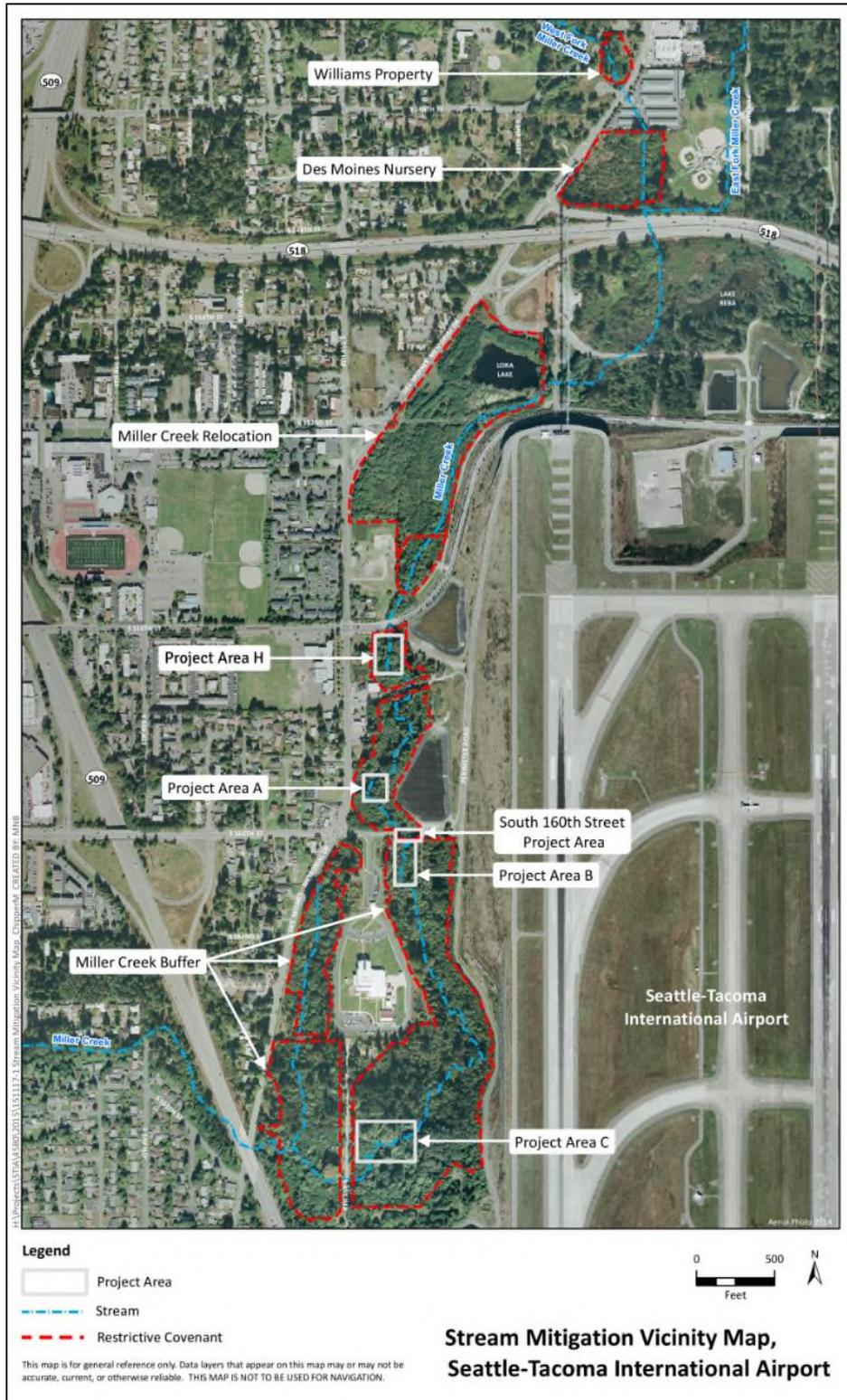
Since Miller and Walker Creeks drain urban watersheds, they are subject to the cumulative effects of pollution typical of an urban environment supporting an assortment of residential, commercial, and industrial activities. Urban streams receive heavy metals (i.e., copper and zinc), oils, and grease from nearby urban streets, highways, and parking lots; increased levels of phosphorus and nitrogen from fertilization from landscaping; and high levels of fecal coliform from failing residential septic systems (Parametrix 2004). As a result, Miller Creek has been listed under Section 303(d) of the federal Clean Water Act, viewed as a Category 5 (polluted water) water body for bacteria, dissolved oxygen, and temperature (Ecology 2020a). Miller Creek is also listed as a Category 2 Waters of Concern for pH, copper, and zinc. Walker Creek is on the 303(d) list for bacteria and temperature (Ecology 2020a).

Construction activities associated with third runway and other 1997 Master Plan Update improvements affected approximately 18 acres of wetland and required relocating approximately 1,200 feet of Miller Creek. The Port of Seattle developed the Natural Resources Mitigation Plan (NRMP; Port 2004) to guide compensatory mitigation for wetlands, streams, drainage channels, floodplains, as well as stream and wetland buffers in the Miller Creek basin. Components of the mitigation included:

- Miller Creek Relocation, completed in 2006, relocated and enhanced approximately 1,080 linear feet of the Miller Creek stream channel extending from just upstream of South 156th Street to the outlet of Lora Lake. The mitigation also excavated 5.9 acre-feet of floodplain while also creating or restoring approximately 10.5 acres of wetlands at the former Vacca Farm site.
- Miller Creek Buffer, completed in 2006, enhanced existing stream and riparian habitat from the Miller Creek Relocation site downstream to Des Moines Memorial Drive.
- Des Moines Nursery restoration, completed in 2009, enhanced and restored stream habitat and floodplain connectivity along approximately 480 feet reach of the West Fork Miller Creek just upstream of its confluence with the East Fork Miller Creek at the former 5.33-acre Des Moines Nursery site north of State Route 518.

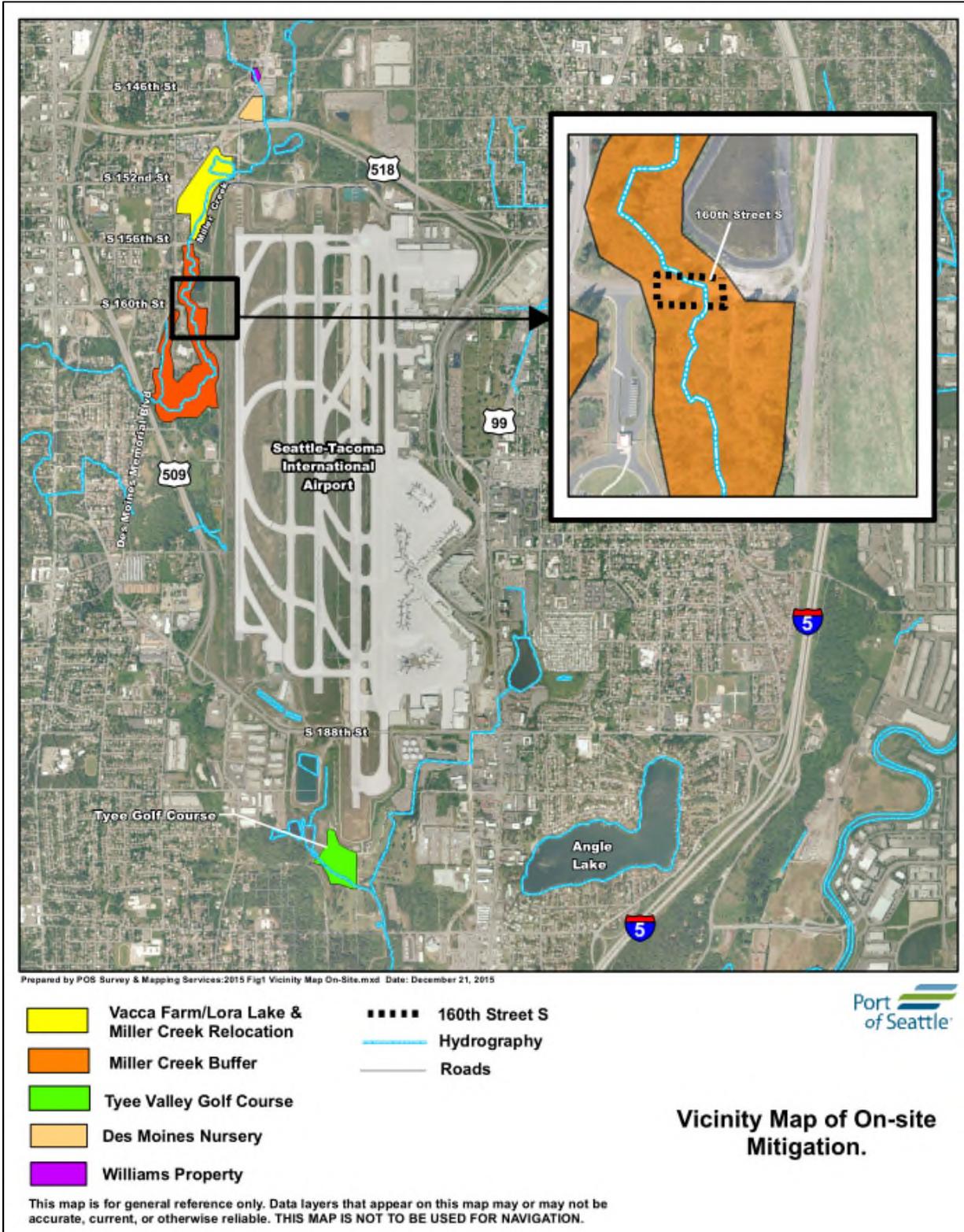
The above information is also depicted in Figures 8.21 and 8.22.

Figure 8.21
Stream and Buffer Mitigation Projects



Source: Port of Seattle (2019b)

Figure 8.22
Location of On-Site Mitigation Projects



Source: Port of Seattle (2019b)

Following construction of the Miller Creek Relocation site, post-construction monitoring efforts from 2007 to 2009 found that the project did not meet design criteria for streamflow velocity and substrate, leading Ecology and the U.S. Army Corps of Engineers (USACE) to conclude that the salmonid spawning could not be achieved at the site (Port of Seattle 2019b). In response, the Port of Seattle agreed to additional alternative mitigation actions to provide a functional lift not achieved by the stream relocation as designed and built. These actions included additional gravel augmentation to promote meanders, removing riprap at the downstream end of the new channel, and planting additional woody vegetation to create a closed canopy. It also established two additional restoration sites:

- South 160th Street site, completed in 2012, removed a partial fish passage barrier located within the Miller Creek Buffer Site (Figure 8.21).
- Williams Property site, completed in 2012, removed a culvert and ensured bank stability north of State Route 518 and upstream of Des Moines Memorial Boulevard (Figures 8.21 and 8.22).

Additionally, the Des Moines Nursey site is undergoing a change to daylight a tight-lined stream segment just upstream that failed in 2017, discharging a volume of sediment into the Des Moines Nursery site and filling a portion of the stream channel (Port of Seattle 2019c). The site will receive a full restoration in 2020 as part of the city of Burien's West Fork Miller Creek restoration project. A new stream channel will run mostly outside mitigation credit area through an existing stormwater easement, and the abandoned stream channel will be converted to wetland (Port of Seattle 2019c).

Stream mitigation sites are subject to performance standards intended to indicate the ecological function of stream habitat, channel stability, and riparian structure. The NMRP requires a 15-year monitoring period for mitigation. Performance monitoring for the additional relocation improvements and South 160th Street culvert removal were integrated into ongoing performance monitoring for the relocation and Miller Creek Buffer sites, respectively. The Williams Property is a distinct project and is being monitored independently for a 10-year monitoring period (Port of Seattle 2019b; 2019c).

Monitoring results from the most recent reporting in 2018 (Port of Seattle 2019b; 2019c) indicate all sites achieved performance standards for all design criteria. Stream habitat complexity has remained stable or increased during the period of monitoring. Channel stability is generally good across all sites with a few localized exceptions. Installed habitat logs have remained in place, substrate composition remains dominated by gravel for the period of monitoring, and bank wasting has been minimal. In addition, riparian vegetation has rapidly established and is providing more than 90% cover over the stream at all sites. Likewise, fish passage projects at South 160th Street and Williams Property have stable banks, with habitat logs remaining in place, and the establishment of riparian vegetation within the sites.

Des Moines Creek

The Des Moines Creek basin covers approximately 3,600 acres, including most of Seattle-Tacoma International Airport and the cities of Des Moines, Normandy Park, and SeaTac, and a small portion of the city of Burien. Des Moines Creek originates in two branches:

- Des Moines Creek East begins at Bow Lake, one-quarter mile east of Seattle-Tacoma International Airport. The creek flows mostly within pipes through the City of SeaTac and along the east side of Seattle-Tacoma International Airport, daylighting in the southeast portion of Seattle-Tacoma International Airport. From there, the creek flows through a golf course and the Tyee Detention Facility (constructed by King County in 1989).

- Des Moines Creek West has its origins in the area southwest of the runways, in a highly developed area. The creek flows into the Northwest Ponds, and through the Tye Valley Golf Course wetland mitigation site. Des Moines Creek East joins with Des Moines Creek West a short distance downstream of Tye Detention Facility, south of the runways, and then crosses under South 200th Street. Des Moines Creek flows an additional two miles south and west to Puget Sound.

Des Moines Creek also drains an urban watershed and suffers from the cumulative effects of urban pollution from residential, commercial, and industrial activities. Land uses in the basin that have likely contributed the majority of nonpoint source pollution include urban development and roadways, land conversion, failing septic systems, and highways (Des Moines Creek Basin Committee 1997). Currently, Des Moines Creek is listed under Section 303(d) of the federal Clean Water Act, viewed as a Category 5 (polluted water) water body for bacteria, copper, dissolved oxygen, and temperature (Ecology 2020a). The East Tributary of Des Moines Creek is also on the 303(d) list for bacteria, copper, and dissolved oxygen (Ecology 2020a).

The Washington State Department of Ecology conducted a study from October 2008 through December 2010 to reassess levels of copper and zinc in Des Moines, Massey, and McSorley Creeks in King County, Washington. Surface water was sampled twice during baseflow and three times during storm events. Analysis included dissolved and total recoverable copper and zinc as well as hardness, turbidity, and total suspended solids. All dissolved copper results taken at baseflow were less than 10% of the acute copper criteria, while zinc was less than 5%. During storm events, no violations of water quality metals criteria were found at 303(d) listed sites. Dissolved copper and zinc in Des Moines Creek decreased from upstream to downstream, while hardness increased. One of the recommendations of the study was to remove Des Moines, Massey, and McSorley Creeks from the 303(d) list for dissolved copper and remove Des Moines and Massey Creeks for dissolved zinc.

Construction activities associated with third runway and other 1997 Master Plan Update improvements affected approximately 3.88 acres of wetlands in the Des Moines Creek basin (Parametrix 2004). The Port proposed to mitigate these effects through restoration and enhancement projects designed to increase wetland function, enhance aquatic habitat, and improve stream conditions within Des Moines Creek. These mitigation projects included:

- Restored wetland functions to a portion of the Tye Valley Golf Course by replacing the existing turf grass wetland with a native shrub wetland community.
- Enhanced water quality and aquatic habitat and improve stream functions by restoring a forested riparian buffer along an 870-ft of the west branch of Des Moines Creek, also located on the Tye Valley Golf Course.
- Established a \$150,000 trust fund for restoration projects located in the Des Moines Creek Basin.
- Provided for additional stream enhancement projects and local restoration efforts.
- Avoid, minimize, and mitigate potential indirect hydrology effects to wetlands adjacent to the borrow areas by directing groundwater seepage and surface water runoff to wetlands near Borrow Areas 1 and 3.

The former Tye Valley Golf Course wetland mitigation site now encompasses 10.53 acres in Des Moines Creek basin along the south runway boundary (Figure 8.21). It also contains mitigation constructed by the Des Moines Creek Basin Committee (DCBC) that relocated and stabilized the portion west branch Des Moines Creek flowing through the Port mitigation site. The Port integrated the existing mitigation area into its 2011 design and construction, including the monitoring plan. Specific mitigation objectives were also revised and now include:

- Establish 5.57 acres of native shrub wetland in a currently degraded wetland.
- Improve water quality and aquatic habitat in Des Moines Creek by planting a 100-foot forested buffer along both banks.

The mitigation site is subject to performance standards intended to indicate the ecological function of stream and wetland habitat, channel stability, and riparian structure. The NMRP requires a 15-year monitoring period for mitigation. The Port of Seattle is currently performing maintenance of the site, replacing dead or dying trees, controlling blackberries and noxious weeds, controlling tree density to allow better understory growth and vigor, and enhanced shrub plantings to meet shrub density performance standards.

Auburn offsite wetlands

Construction activities associated with third runway and other 1997 Master Plan Update improvements affected 13.46 acres of wetlands, and the Port implemented a suite of mitigation actions, including creating, restoring, or enhancing 177.77 acres (75.23 mitigation credits) of wetlands and upland buffer (Port of Seattle 2019c). One of those mitigation actions was to replace 18.37 acres of wildlife habitat at an off-site location. Wetland mitigation adjacent to Seattle-Tacoma International Airport is constrained by the need to avoid habitat for avian wildlife that can present a safety hazard for airplanes. Hence, off-site mitigation at Auburn is designed to restore and enhance forested, shrub, emergent, and open water wetland habitat and to provide habitat for avian species, which when present, create a flight hazard to airplanes. The mitigation site is located in the city of Auburn, Washington, south of South 277th Street between the Green River and Auburn Way North (outside of the study area). Mitigation construction occurred in 2006.

The general mitigation goals for Auburn are:

- Achieve an overall increase in wetland acreage and function at a mitigation ratio of at least 2:1.
- Mitigate lost habitat functions outside of the 10,000-foot aircraft operations safety radius of Seattle-Tacoma International Airport to protect public safety by reducing wildlife hazards to aircraft.
- Create diverse wetland habitats (including forest, shrub, open water, and emergent) as well as upland forested habitat on a large site adjacent to existing habitat corridors along the Green River.
- Enhance wetland functions in the existing degraded wetlands, which are dominated by non-native species, by converting them to diverse, native forested, shrub, and emergent wetlands.
- Provide long-term protection for the mitigation site by providing a 100-foot forested buffer around the perimeter of the site.

This off-site mitigation created approximately 30 acres of new wetlands, enhance 19.5 acres of existing emergent wetlands, and created approximately 15.9 acres of forest and buffer habitat (Parametrix 2004). The site includes four ponds for waterfowl usage. The Port recently performed a full suite of required vegetation monitoring in 2018, which served as Year 11 in the 15-year monitoring plan (Port of Seattle 2019c). The Port also continues to conduct hydrology monitoring every year, and data indicate site hydrology meets all performance standards, with inundation depths and duration remaining consistent with previous years. Vegetation monitoring efforts found that all shrub and forest zones are achieving for tree density and cover. The assessment stated that the Auburn wetland is:

“A high-performing site that is meeting all standards for wetland hydrology and most for vegetation cover. Shrub density is lagging in enhanced areas, but this is likely due to the very high alder and cottonwood recruitment, as tree density is more than double the minimum standard in every enhance forest zone. In addition, relative abundance of willow in these zones is high, and willows tend to mature to densities well below planting density due to their large habit.” (Port of Seattle 2019c).

National Land Cover Database Cover Change Index

The Multi-Resolution Land Characteristics (MRLC) consortium is a group of federal agencies that coordinate and generate consistent and relevant land cover information at the national scale for a wide variety of environmental, land management, and modeling applications. This coordination has produced the comprehensive land cover product called the National Land Cover Database (NLCD). The NLCD provides nationwide data on land cover and land cover change for years 2001, 2003, 2006, 2008, 2011, 2013, and 2016. New to the NLCD is the Land Cover Change Index. This index provides a simple and comprehensive way to visualize change from all seven dates of land cover in a single layer.

Using this database, the study team examined the overall changes to Seattle-Tacoma International Airport and the study area cities from 2001 (the earliest year data is available) to 2016 (the most available current data set). Those results are summarized in Table 8.2 and tabulated in Table 8.3. Visual maps of locations of the changes were overlaid on orthographic images of the airport and each city area from 2002 and 2016 (Figures 8.22 through 8.28). An additional series of side-by-side orthoimages of the airport, and each of the surrounding cities, in 2002, 2009, and 2018 is included as an appendix.

Overall, the area of change from a natural land cover category to an urban or barren land use totaled 1,988 acres from 2001-2016. Federal Way displayed the largest percentage of that total area, at 715.43 acres, or 36% of the total (Figure 8.25). SeaTac had the second highest area of change, at 542.62 acres (Figure 8.27), but nearly 376 acres of this were contributed by changes with the airport properties (Figure 8.22). The airport accounts for 18.9% of the total area of change that occurred from 2001-2016 for the study area of the six cities. The shaded red areas indicating areas of change are largely located around the third runway area, but also show change along the side of the taxiways and other runways, possibly due to clearing and grading of the shoulders for runoff buffers (Figure 8.22). Burien and Des Moines each accounted for 10% of the change in area, and Normandy Park accounted for the least change, with 41.91 acres, or 2% of the study area’s change.

Figure 8.23
Summary of NLCD Change Index Calculations

Airport	Total Area (acres)	Total Area of Changes* (acres)	% of Change in Study Area	% of Change on Airport
Airport Industrial 1	78.12	6.75	0%	1%
Airport Industrial 2	58.38	5.63	0%	1%
Aviation Business	76.91	12.01	1%	2%
Aviation Commercial	438.45	16.52	1%	3%
Aviation Operations	2,035.11	335.03	17%	62%
Airport Total	2,686.96	375.95	18.9%	69%
City	Total Area (acres)	Total Area of Changes* (acres)	% of change in study area	
City of Burien	6,425.30	200.64	10%	
City of Des Moines	4,193.68	197.32	10%	
City of Federal Way	14,379.61	715.43	36%	
City of Normandy Park	1,621.82	41.91	2%	
City of SeaTac	6,572.57	542.62	27%	
City of Tukwila	6,104.92	290.17	15%	
City Total	39,297.91	1,988.10	100%	

*Urban or barren changes

Figure 8.24
NLCD Change Index Calculations by Airport Use Type and City (in acres)

Airport	No Change	Urban Change	Barren Change	Forest-Theme Change	Hay/Pasture Change	Herbaceous Wetland Change	Water Change	Wetland Within Class Change	Woody Wetland Change
Airport Industrial 1	71.36	6.75							
Airport Industrial 2	52.75	5.40	0.22						
Aviation Business	64.89	12.01							
Aviation Commercial	421.92	16.52							
Aviation Operations	1,700.08	334.14	0.89				0.22	0.22	
Airport Total	2,311.01	374.84	1.11				0.22	0.22	
City	No Change	Urban Change	Barren Change	Forest-Theme Change	Hay/Pasture Change	Herbaceous Wetland Change	Water Change	Wetland Within Class Change	Woody Wetland Change
City of Burien	6,224.65	199.98	0.67				2.00		
City of Des Moines	3,996.36	197.32		2.45		13.32	6.92	0.44	
City of Federal Way	13,664.18	712.54	2.89	22.56	1.11	3.81	50.31	0.44	0.22
City of Normandy Park	1,579.91	41.69	0.22			1.26	1.38		
City of SeaTac	6,029.95	540.84	1.78	0.22			2.45	0.22	
City of Tukwila	5,814.75	289.51	0.67	8.23	4.00	3.11	34.51	0.22	
City Total	37,309.81	1,981.87	6.22	33.45	5.12	21.51	97.57	1.33	0.22

Figure 8.25
City of Burien NLCD Change Index: 2001-2016

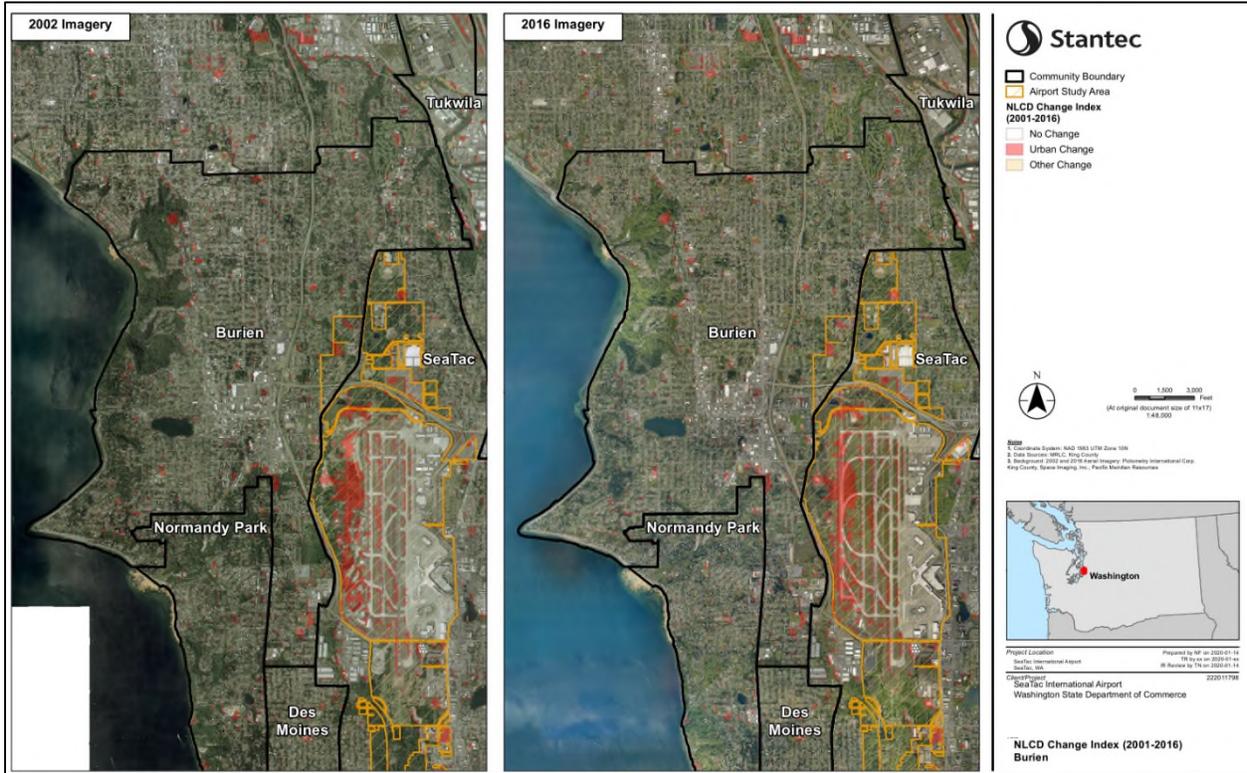


Figure 8.26
City of Des Moines NLCD Change Index: 2001-2016

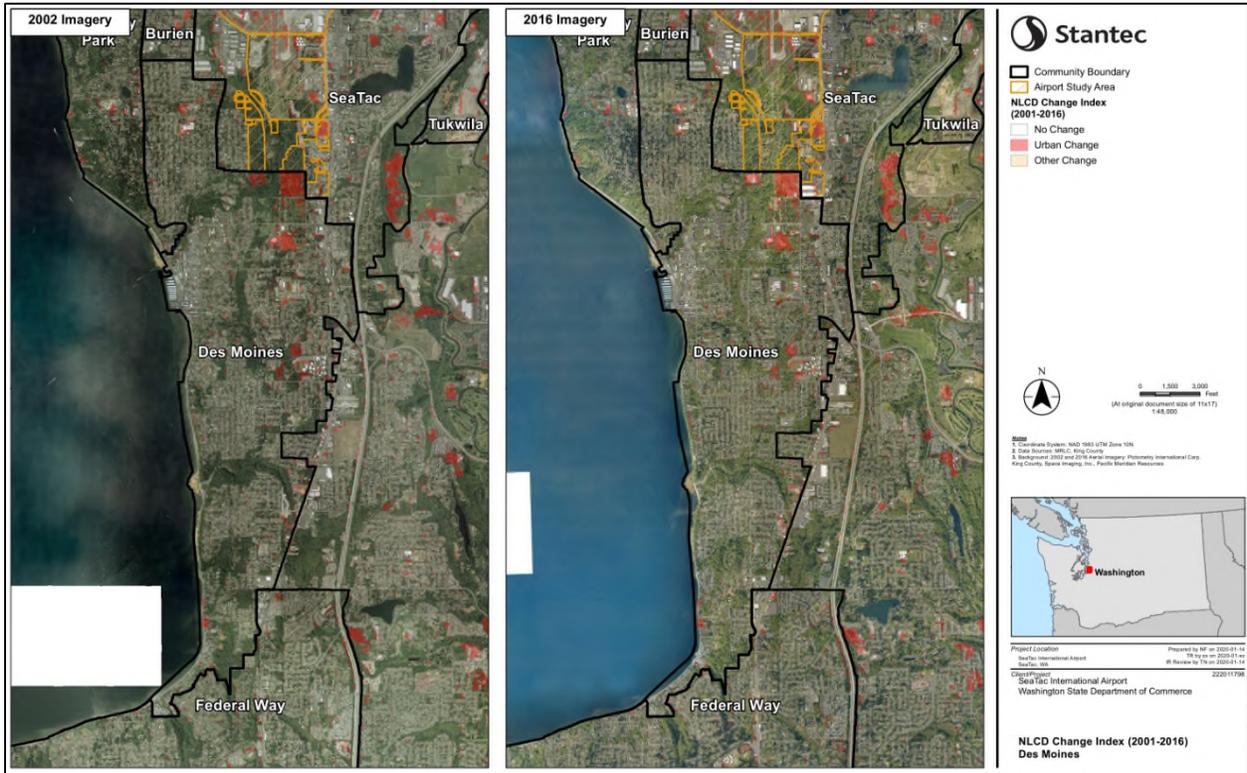


Figure 8.27
City of Federal Way NLCD Change Index: 2001-2016

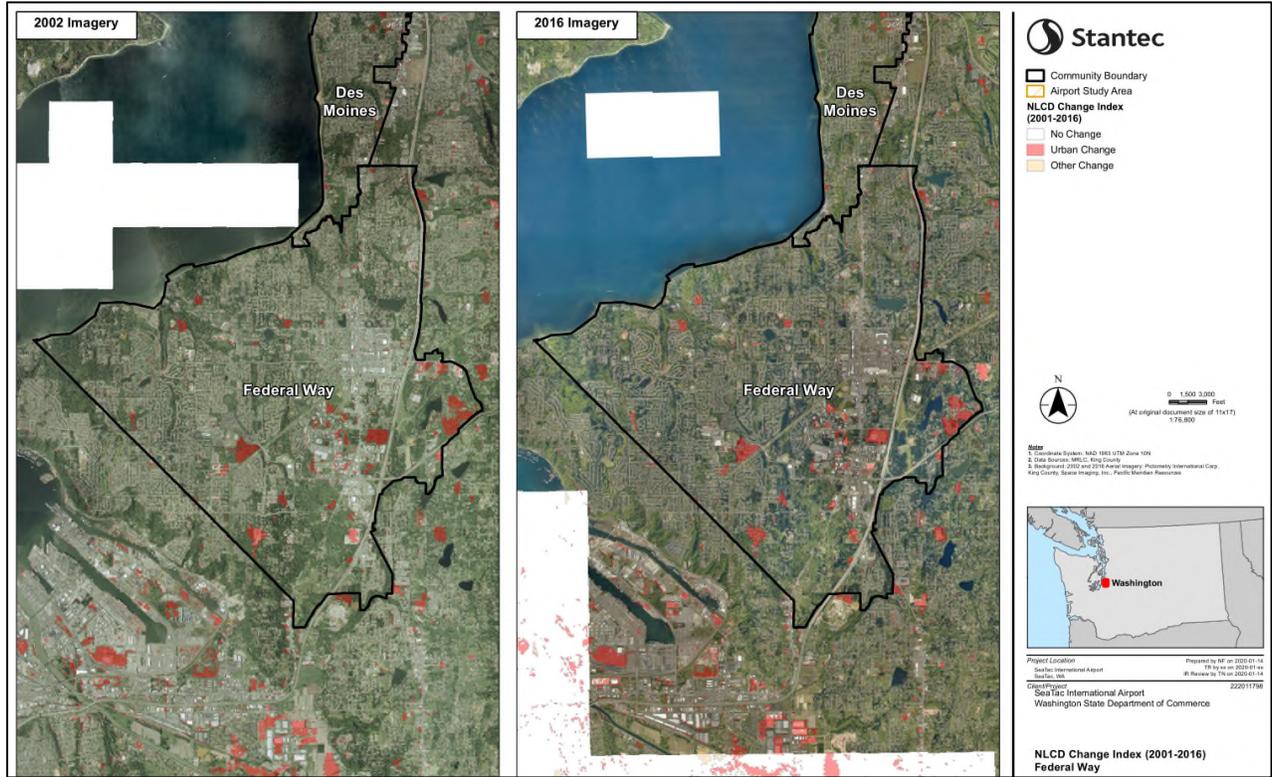


Figure 8.28
City of Normandy Park NLCD Change Index: 2001-2016

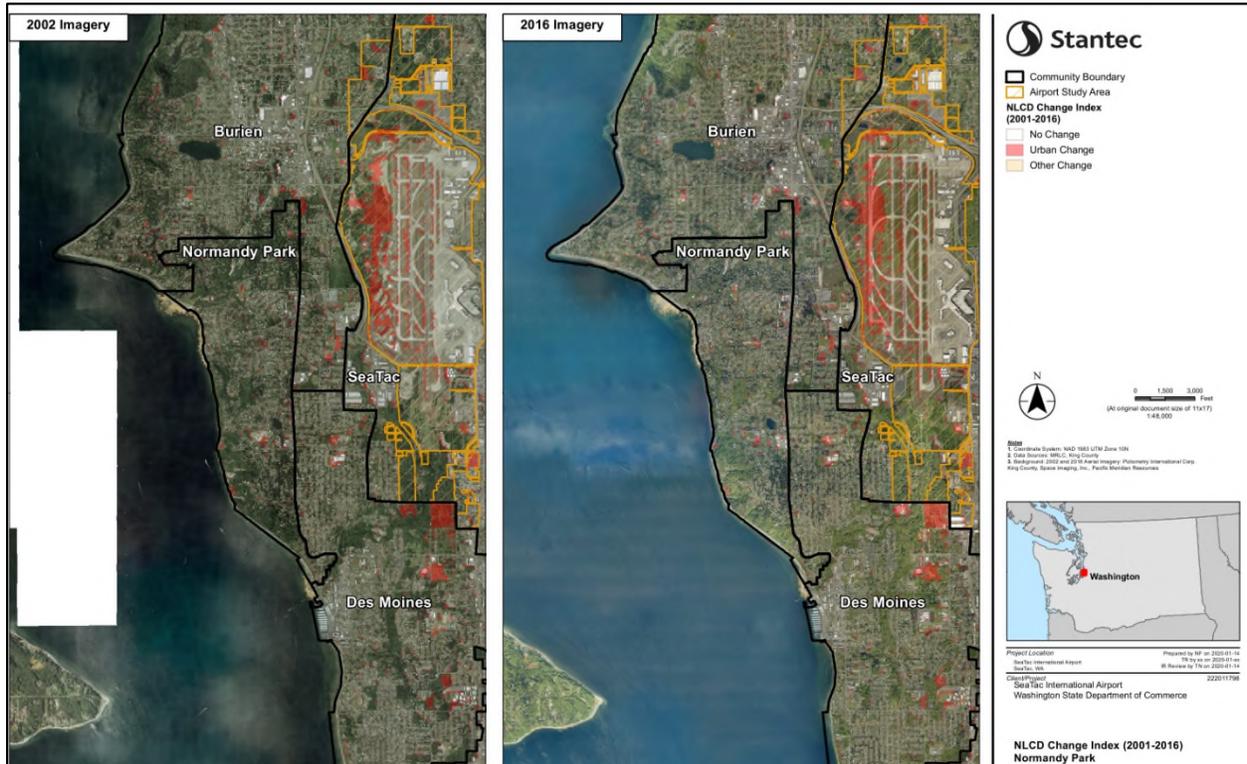


Figure 8.29
City of SeaTac NLCD Change Index: 2001-2016

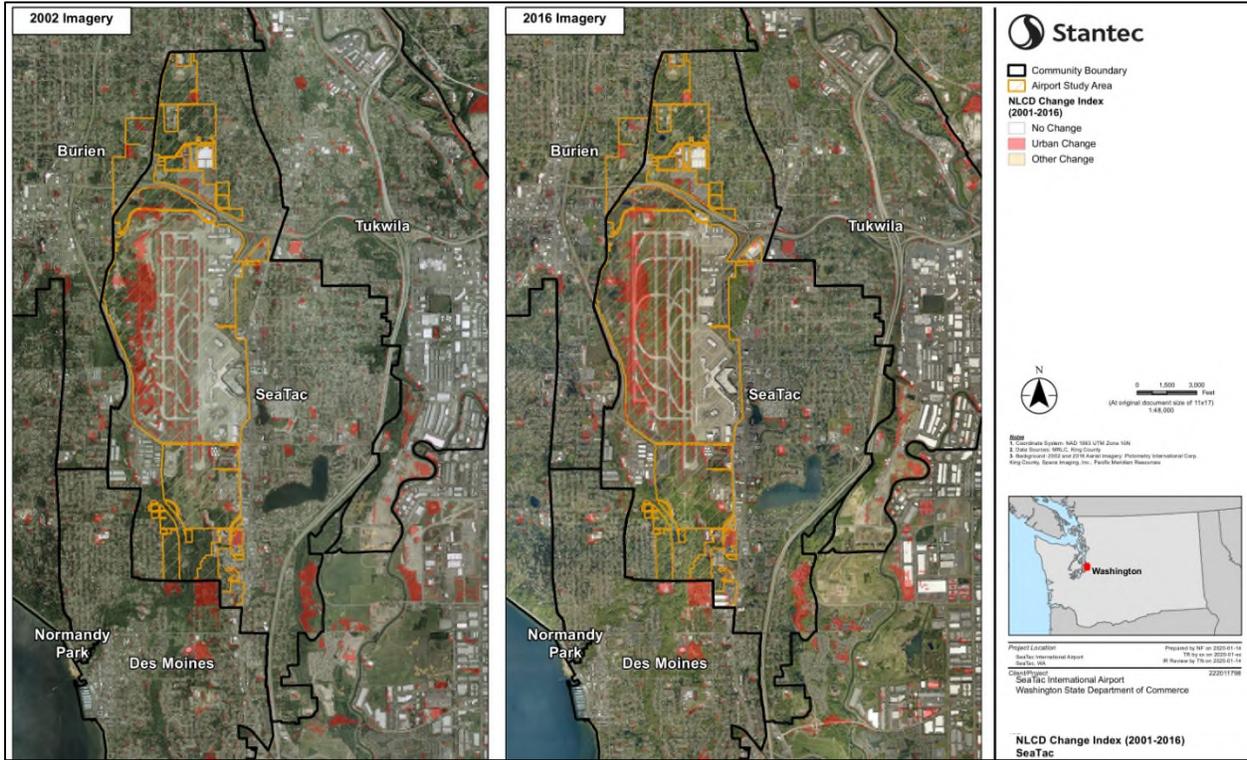
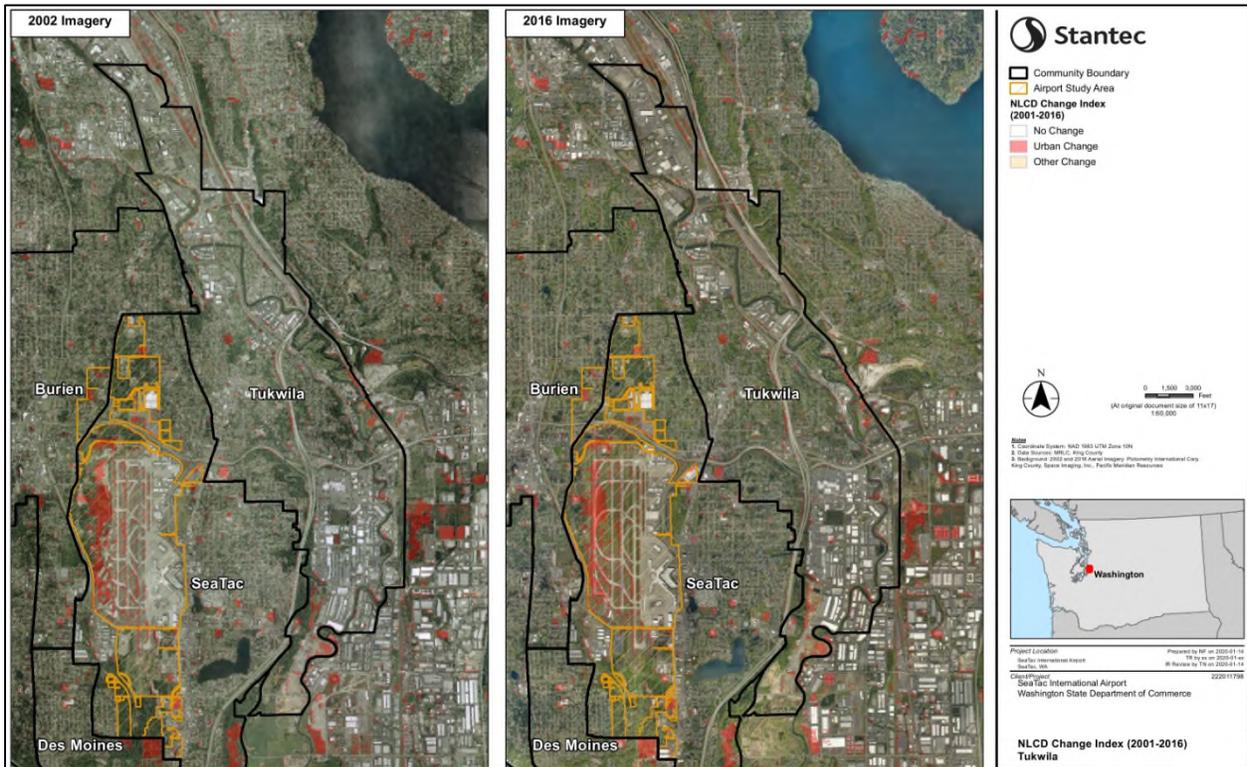


Figure 8.30
City of Tukwila NLCD Change Index: 2001-2016



F. SURFACE WATER EFFECTS ATTRIBUTABLE TO AVIATION ACTIVITY

Positive effects on surface water

In general, the actions of the Port in the Seattle-Tacoma International Airport and surrounding vicinity have improved water quality and the receiving waters' habitat conditions from what they were before.

The review of the activities and conditions on surface water quality and habitat conditions has found that the Port of Seattle has been responsive to the effects that Seattle-Tacoma International Airport has had and the potential to incur on water quality and aquatic habitats downstream of the airport. To mitigate for these effects, the Port of Seattle has:

- Constructed 112 acres of wetland near the airport
- Enhanced about two miles of stream habitat, including the relocation of 1,000 feet Miller Creek's stream channel
- Excavated 60-acre feet of floodplain storage capacity.

To improve fish habitat, stream mitigation has installed 200 pieces of large woody debris, removed two culverts that blocked fish passage, and focused on stabilizing four eroded portions of Miller Creek's stream channel. Additionally, the Port of Seattle supplements streamflow to Miller and Des Moines creeks every summer to ensure adequate water levels for fish. The Port of Seattle has also created and enhanced 65 acres of off-site wetland and wetland buffer adjacent to the Green River in Auburn to mitigate the loss of wetland habitat for waterfowl near the airport.

The Port of Seattle has also upgraded the IWS and SDS stormwater management systems to more efficiently capture and treat stormwater runoff from Seattle-Tacoma International Airport. As part of the Master Plan improvements, the airport's stormwater management systems were completely retrofitted and upgraded to meet the most stringent environmental standards. Through these improvements, runoff containing high concentrations of deicing fluids are captured, separated, and treated before being discharged to Puget Sound. Review of the available NPDES reported water quality data for BOD levels in their Outfall discharge supports this statement.

Through its stormwater pollution prevention plan (SWPPP), implementation and regular and frequent NPDES water quality sampling program, metals and other pollutants harmful to salmon and other aquatic organisms have been reduced to safe levels before entering Miller, Walker, and Des Moines creeks. The airport applies a proactive approach and evaluates water quality monitoring results to determine if additional BMPs are necessary to prevent permit limit exceedances. As a result, stormwater discharges from the airport are well below permit limits with low variability in comparison to other airports and industrial stormwater. Review of the available NPDES reported water quality data supports this statement.

Neutral effects on surface water

There are no known neutral effects on the surface water system.

Negative effects on surface water

The required mitigation in response to master plan improvements, plus the near-constant monitoring of stormwater runoff water quality required by the NPDES permitting program and adjustments to stormwater management in response to water quality results, leave little in the way of negative effects to surface water quality and habitat in the immediate area.

While effluent levels are usually below the state water quality criteria, Seattle-Tacoma International Airport is still a contributor of pollutants, and occasionally exceeds those criteria, despite its best management practices and treatments. As fish habitat continues to improve in the receiving streams, such violations, even short-term ones, could affect salmon present. With instances of pre-spawning mortality already recorded in Miller and Walker Creeks (Peter et al. 2018; Goehring 2019), Des Moines Creek (Scholz et al. 2011), and throughout the Puget Sound region (Feist et al. 2011; 2017), it is important to understand the effects any pollution can have on salmon populations. .

Surface water effects attributable to aviation activity

The graphs and tables in this section present various aspects of how surface water may be affected, including magnitude and intensity. However, Figure 8.31 presents a general assessment of noise and vibration effects in the study area attributable to aviation activity, categorized into four effect types:

- Positive effect attributable to aviation activity
- Negative effect attributable to aviation activity
- Neutral or no effect attributable to aviation activity
- Inconclusive data/needs additional study.

Figure 8.31
Summary of Surface Water Effects Attributable to Aviation Activity – 1997 to 2019

 Positive effect attributable to aviation activity	 Neutral/no effect attributable to aviation activity
 Negative effect attributable to aviation activity	 Inconclusive data/needs additional study

SURFACE WATER METRIC	STUDY AREA CITY																	
	Burien			Des Moines			Federal Way			Normandy Park			SeaTac			Tukwila		
	1997	2009	2019	1997	2009	2019	1997	2009	2019	1997	2009	2019	1997	2009	2019	1997	2009	2019
Stormwater Runoff	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Floodplains	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Wetlands	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Surface water effects in the study area have generally been contained to airport property and have been improved over the 22-year study period. The Port of Seattle has improved water quality and the receiving waters’ habitat conditions from what they were before. Improvements to on-airport wetlands, floodplains, and storm drainage infrastructure has also contributed to this improvement.

Off-airport, these improvements benefit areas downstream on the way to Puget Sound outfalls, principally the cities of Burien, Des Moines, Federal Way, and Normandy Park (effects were generally neutral in the cities of SeaTac and Tukwila). Ongoing monitoring is a requirement in order to ensure the quality and health of area habitats and streams fed by surface water systems.

G. RECOMMENDATIONS

The analysis of NPDES water quality data from the PARIS database revealed that, for the parameters examined in this study, runoff from the six Seattle-Tacoma International Airport outfalls selected in this study have shown a reduction in concentration levels, and met the state’s water quality criteria once the systems’ retrofit and upgrades had been completed.

The following recommendations are proposed to improve the protection of the surface water system and associated habitats:

▪ **Surface water quality recommendation #1 – Correct potential errors and data gaps**

This study found potential errors in the data (discrepancies in the labeling of measurement units) and found periodic changes in sampling methodology from NPDES permit periods that may or may not be completely comparable over the 22 years examined (1997 to 2019). If there is a need for a more complete analysis of these NPDES water quality results for all outfalls and all parameters over the 22-year time period, then an additional study with the focus on these datasets will be required.

▪ **Surface water quality recommendation #2 – Improve receiving stream data**

The 2020 study found a lack of continuous water quality data on the receiving streams within close downstream proximity to the outfalls. Water quality measurements were limited to basic parameters and were collected sporadically across the study period. Measurements were not taken so they are comparable to Seattle-Tacoma International Airport outfall measurements, as that was not the intent of either the county or Port programs. If there is a concern for the effect of Seattle-Tacoma International Airport outfall effects on downstream receiving waters, more permanent monitoring stations should be established downstream of those outfalls, and collect a suite of water quality parameters that are collected at outfalls on a schedule that coincides, so as to make results more comparable.

Studies conducted by Dr. E.P. Kolodziej at the University of Washington-Tacoma have been focusing on water quality analysis work in Miller Creek for several years, using high resolution mass spectrometry methods to examine what chemicals are present in runoff that may cause salmonid pre-spawning mortality events (Peter et al. 2018). While Dr. Kolodziej explained the work did sample above and below the area where airport runoff enters the creek, but the analyses have focused on tire rubber compounds and roadway runoff (personal communication, Sept. 24, 2019). Airport operations were not part of the study at the time, and did not have any direct airport runoff samples to make a clear comparison relative to the highway runoff from State Route 509, although he did state that “we do know the highway.” This would present an opportunity to research the potential effects of Seattle-Tacoma International Airport runoff on the issues of pre-spawning mortality in Miller and Walker Creeks. Therefore, it is recommended that additional measures, sources, and data be collected to fully determine the effects that may be experienced by receiving streams in the study area.

▪ **Surface water quality recommendation #3 – Further study of air pollution effects on surface water**

The consultant team heard concerns from community members about the effect of fine air particles as a source of pollution on the soils and waters surrounding Seattle-Tacoma International Airport. However, no known studies have researched that issue to date. The University of Washington recently conducted a study assessing ultrafine particle (UFP) concentrations within 10 miles of the airport in the directions of aircraft flight (UW-DEOHS 2019). The study was able to detect and distinguish traffic and aircraft emissions. One of the identified gaps was in developing a better understanding of the toxicity of traffic- and aircraft-related UFPs. Studying the toxicity would help identify potential sources of heavy metals and other pollutants that may settle on surrounding surfaces, including standing waters of ponds, lakes, and wetlands. Similar studies have been conducted at airports in California (Boyle 1996), Greece (Massas et al. 2018), and India (Ray et al. 2012). Therefore, it is recommended that additional studies be undertaken to research and evaluate the potential effects of air pollution and ultrafine particulate matter on surface water systems and habitats.

H. THE FUTURE

Ongoing growth and urbanization are concerns for any developed region's surface water systems and habitats. As the Seattle region, King County, and the study area continue to grow, the potential exists to stress these systems through increases in air pollution and polluted stormwater runoff. There are hopeful signs, should electric vehicles eventually comprise a majority of vehicles on the area's roadways. That will have an associated decrease in mobile source pollution.

The preservation of key habitats, headwaters, wetlands, and coastlines is also an ongoing challenge as the area continues to grow. The Port of Seattle and the study area cities should continue to take these issues into account for future master plans.

I. SUMMARY

The consultant team investigated 22 years of data from numerous sources to determine what affects the operation and growth of Seattle-Tacoma International Airport may have on the study area cities. The data suggests that the Port of Seattle has improved water quality and the receiving waters' habitat conditions.

There are some areas of concern on the part of the public, but these have been largely limited to the effect that air pollution has on the surface water systems. That concern, coupled with some areas of data gaps or inconsistencies suggests that existing studies, modelling and sampling could be improved to address these concerns.

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