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Technical Memorandum

Prepared for: LOTT Clean Water Alliance

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Executive Summary

Five scenarios were developed, which project the potential for Budd Inlet Treatment Plant (BITP) flooding related to climate change through 2050. The scenarios consider projections of sea level rise, extreme tides, tidal wave and storm surge phenomena. All five scenarios project site flooding, with the two worst-case scenarios projecting flooding of most of the BITP site as well as much of downtown Olympia.

In a flooding scenario, activities at the BITP should be focused on moving flow through the BITP. The inability to move flow would exacerbate flooding within downtown Olympia, as the BITP provides an important outlet for combined sewer flows. Critical areas therefore include the influent pumps and effluent pumps, and the electrical systems required to keep those pumps working. This report includes recommendations to protect those areas, which may be implemented gradually or incorporated into LOTT design standards.

Introduction

The purpose of this technical memorandum (TM) is to assess high-level vulnerabilities within the LOTT Clean Water Alliance (LOTT) Budd Inlet Treatment plant (BITP) to potential inundation as a result of sea level rise (SLR) and tidal and storm events for a planning horizon up to the year 2050. The year 2050 was used as a benchmark for this assessment as it is the general planning horizon for Thurston County. In addition, relevant studies conducted by local agencies also reference 2050.

This TM develops five flooding scenarios as a result of SLR, 100-year tidal flooding, and combinations of SLR, 100-year tidal flooding, and storm surge flooding. The five scenarios are used as a benchmark for assessing the vulnerability of infrastructure at the BITP against inundation. Major impacts, vulnerabilities, and potential mitigation methods are included for key areas within the BITP.

Section 1: Site Description

The Budd Inlet Treatment Plant is located in the city of Olympia and discharges treated waters to the southern end of Puget Sound, at Budd Inlet. It receives and treats wastewater from the cities of Olympia, Lacey, and Tumwater. The BITP's location near the waterfront (Figure 1-1) demonstrates its vulnerability to inundation.

Figure 1-1. Budd Inlet Treatment Plant location

The reference datum used in this TM is the National Geodetic Vertical Datum of 1929 (NGVD), which establishes a mean sea level at an elevation of 0.0 feet. For clarity and consistency with existing as-built drawings, this TM establishes the NGVD mean sea level as 100.0 feet. The ground elevation at the BITP varies throughout the site. Generally, the grade ranges from an elevation of 112.0 feet at the solids handling building to approximately 120.0 feet at the first anoxic basin.

Section 2: Model Floodwater Elevations

A number of factors contribute to the model floodwater elevations, including high tide, SLR, tidal waves, and storm surge. The following sections detail the sources of information for each scenario, and combine the various factors to project five flooding scenarios for the BITP.

2.1 High Tide

Tidal elevations were obtained from the Coast & Harbor Engineering (CHE) study conducted for the City of Olympia. These values were estimated for shorelines in Seattle and adjusted for Budd Inlet. Table 2-1 summarizes the projections.

Table 2-1. Tide Height at Budd Inlet Shoreline

Condition	Tide Height (feet)
Mean tide	0.89
Mean high water	6.13
Mean higher high water	7.14
100-year return tide	10.94

a. *Obtained from Coast & Harbor Engineering, 2011.*

2.2 Sea Level Rise

SLR is defined as the combination of global and local factors. Global SLR is contributed from the warming of oceans (causing water expansion) and melting of land ice (glaciers). Local factors include tectonic movement and seasonal atmospheric circulation effects. A review of literature for local SLR near Budd Inlet was conducted. The sea-level studies by the University of Washington (UW) (for the Washington Department of Ecology [Ecology]) and the National Academy of Science were used as the basis for evaluation of SLR. Table 2-2 summarizes the projections from those two studies.

Table 2-2. Local SLR for the Year 2050

	Natural Academy of Science (feet)	Ecology/University of Washington (feet)
Minimum SLR	-0.08	0.25
Average SLR	--[c]	0.50
Maximum SLR	1.58	1.83

a. *SLR is given for the entire coastline of Washington.*

b. *SLR is given for Puget Sound.*

c. *Not estimated.*

Values for SLR from both data sources are very similar. The Ecology values are used from this point forward because they are more specific to the Puget Sound region, and are slightly more conservative.

2.3 100-Year Tidal Flooding

High tides can cause flooding by direct inundation, where the tide rises above a certain point. More frequently, tidal flooding is caused by tidal waves, where a wave is generated such that it overtops the adjacent shoreline and travels a distance inland. Flooding potential from tidal waves is largely dependent on wind velocities, where the strongest wind velocities are generated during storm events.

The CHE study modeled the total tidal flooding potential, and estimated at 0.43-foot wave height, given the 100-year return high tide coupled with a 100-year return storm event.

2.4 Flood Model

Hydraulic modeling was performed as part of the CHE study to determine the amount of flooding from a combination of 2 feet SLR, tidal flooding, and 100-year storm runoff flooding. These values were digitized into a figure that illustrated the flooding above the ground. The flooding depth was extracted from the figure and cross-referenced with known ground elevations at the facility, to estimate a projected flood depth of 3.5 feet, which encompasses effects of SLR, and tidal wave effects.

2.5 Flooding Scenarios

Table 2-3 summarizes five flooding scenarios for the BITP, summarizing and combining the data presented above.

Table 2-3. Five Flooding scenarios for the BITP (ft)

Scenario	SLR	Tide	Wave	Datum	Flooding Model	Total
UW very low SLR	0.25	10.94	0.00	100		111.2
UW medium SLR	0.50	10.94	0.00	100		111.4
UW very high SLR	1.83	10.94	0.00	100		112.8
100-year tidal wave	2.00	10.94	0.43	100		113.4
Olympia flood model		10.94		100	3.5	114.4

Section 3: BITP Infrastructure Vulnerability

This section discusses at-risk areas at the BITP based on the flooding elevations established in Section 2. Key assets and infrastructure vulnerable to flooding are identified and ranked based on their direct and indirect impacts to the operation of the BITP.

3.1 At-Risk Areas Summary

Figure 3-1 through Figure 3-5 illustrate the flooding areas at the BITP for the five scenarios summarized in Table 2-3.

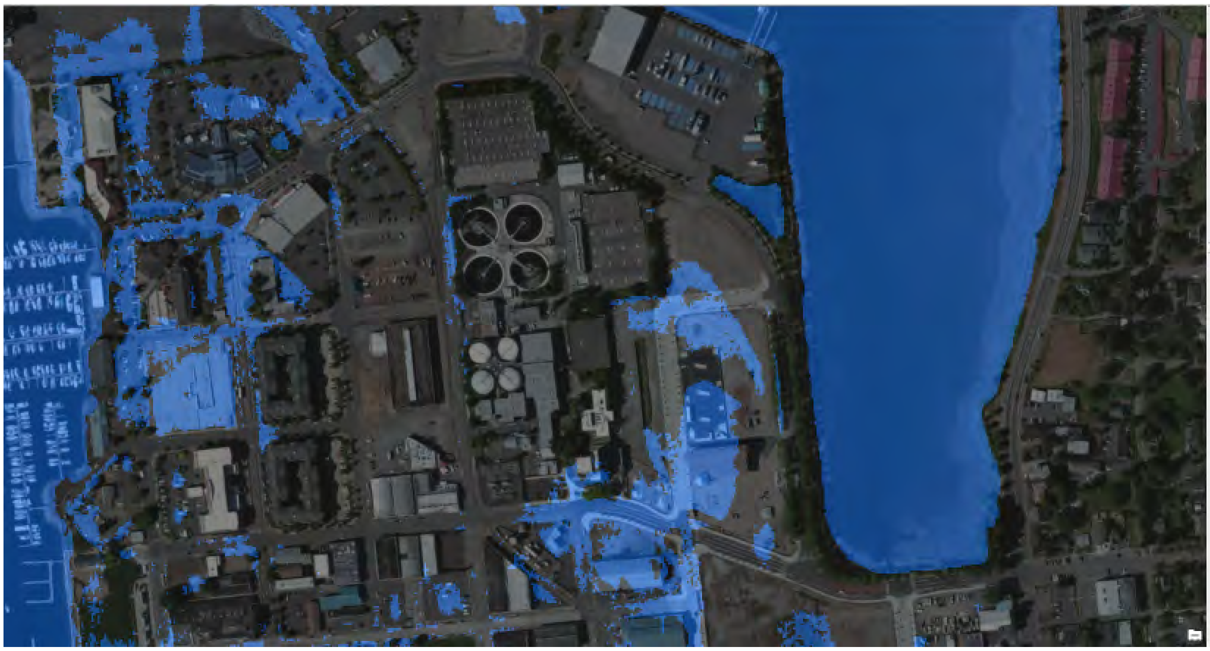

Figure 3-1. UW very low SLR (111.2 ft)

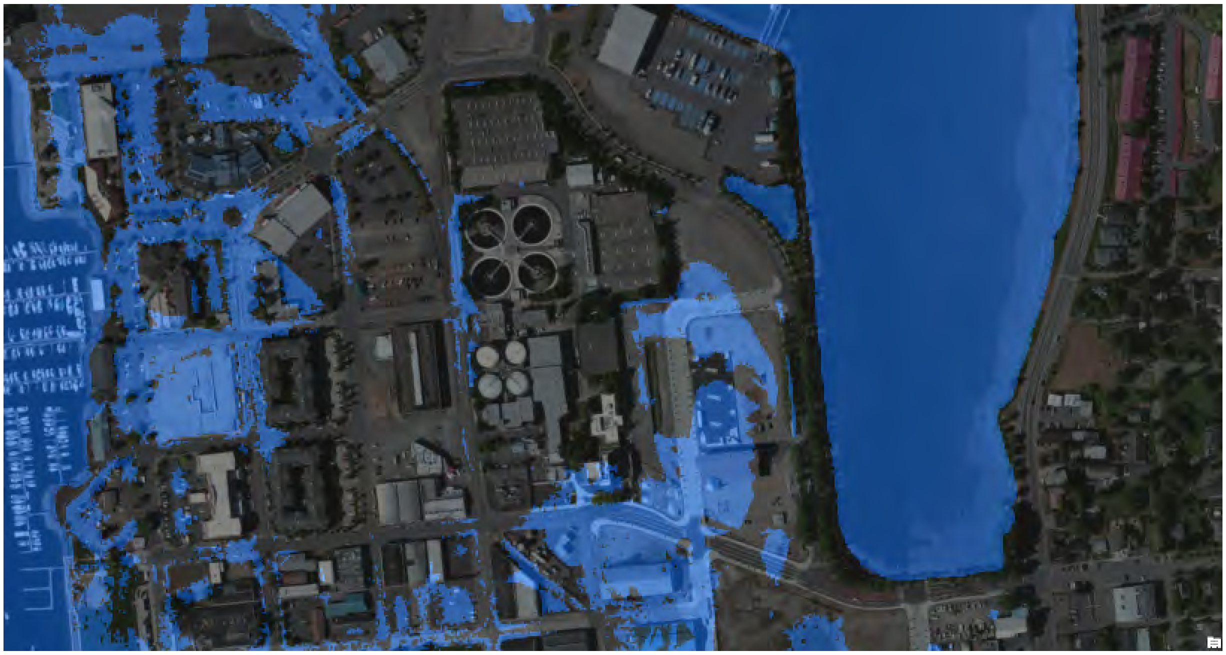

Figure 3-2. UW medium SLR (111.4 ft)

Figure 3-3. UW very high SLR (112.8 ft)

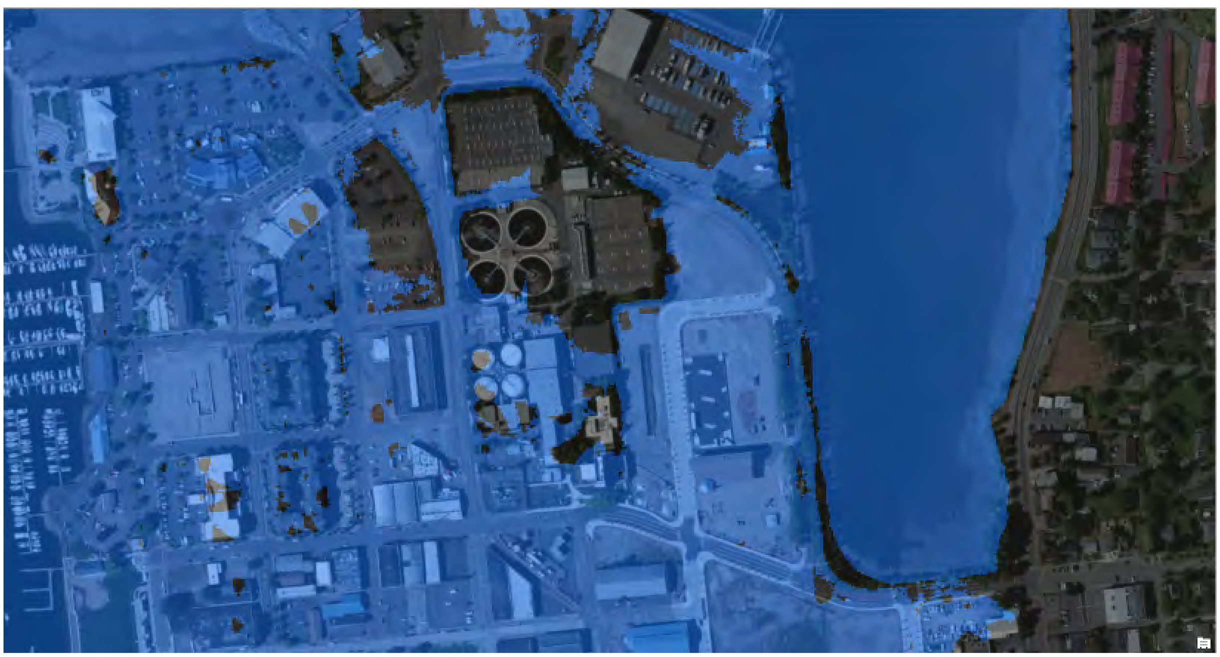

Figure 3-4. 100-year tidal wave (113.4 ft)

Figure 3-5. Olympia flood model (114.4 ft)

The five flooding scenarios were compared to the elevations of main areas of the BITP to identify areas at risk to flooding. Table 3-1 summarizes areas subject to potential flooding.

The following sections discuss some of the key process areas and the associated flooding risks. Under the worst-case conditions (100-year tidal wave or Olympia flood model), the majority of downtown Olympia is projected to flood (Figure 3-6). To effectively mitigate the vulnerability of key assets at the BITP flooding under these two scenarios, mitigation measures for the entire downtown Olympia Budd Inlet Corridor must be established. This is predominantly due to the direct overland flow passage via the abutting streets. In addition, many sewers servicing downtown Olympia are combined sewers that are connected directly to the streets via catch basins. Limitations at the BITP to pass this flow could result in increased flooding depths on streets.

Table 3-1. Projected Flooding of BITP Process Areas						
Area	Ground elevation (ft)	Potential Flooding? (Y/N)				
		UW very low SLR	UW medium SLR	UW very high SLR	100-year tidal wave	Olympia flood model
Projected flood elevation		111.2	111.4	112.8	113.4	114.4
Main utilidor	~100.5	Y	Y	Y	Y	Y
Puget Sound Energy electrical substation	~112	N	N	Y	Y	Y
Service entry switchgear	~112	N	N	Y	Y	Y
Maintenance building	112	N	N	Y	Y	Y
Solids handling building	112	N	N	Y	Y	Y
Digesters	112	N	N	Y	Y	Y
Effluent pump station	112.5	N	N	Y	Y	Y
Administration building	112.9	N	N	N	Y	Y
New primary clarifier substation	~113	N	N	N	Y	Y
Headworks building	113	N	N	N	Y	Y
Electrical substation A/B	113	N	N	N	Y	Y
Backup generators	113	N	N	N	Y	Y
UV building	114	N	N	N	N	Y
South RAS pump station	114.5	N	N	N	N	N
Secondary clarifiers	114.8	N	N	N	N	N
Electrical substation C/D	114.9	N	N	N	N	N
Electrical substation E/F	114.9	N	N	N	N	N
Electrical substation G/H	114.9	N	N	N	N	N
Blower building	115	N	N	N	N	N
Intermediate pump station	116	N	N	N	N	N
First aeration	116	N	N	N	N	N
Primary clarifiers (both)	118.2	N	N	N	N	N
First anoxic	119.2	N	N	N	N	N
Second anoxic	119.2	N	N	N	N	N

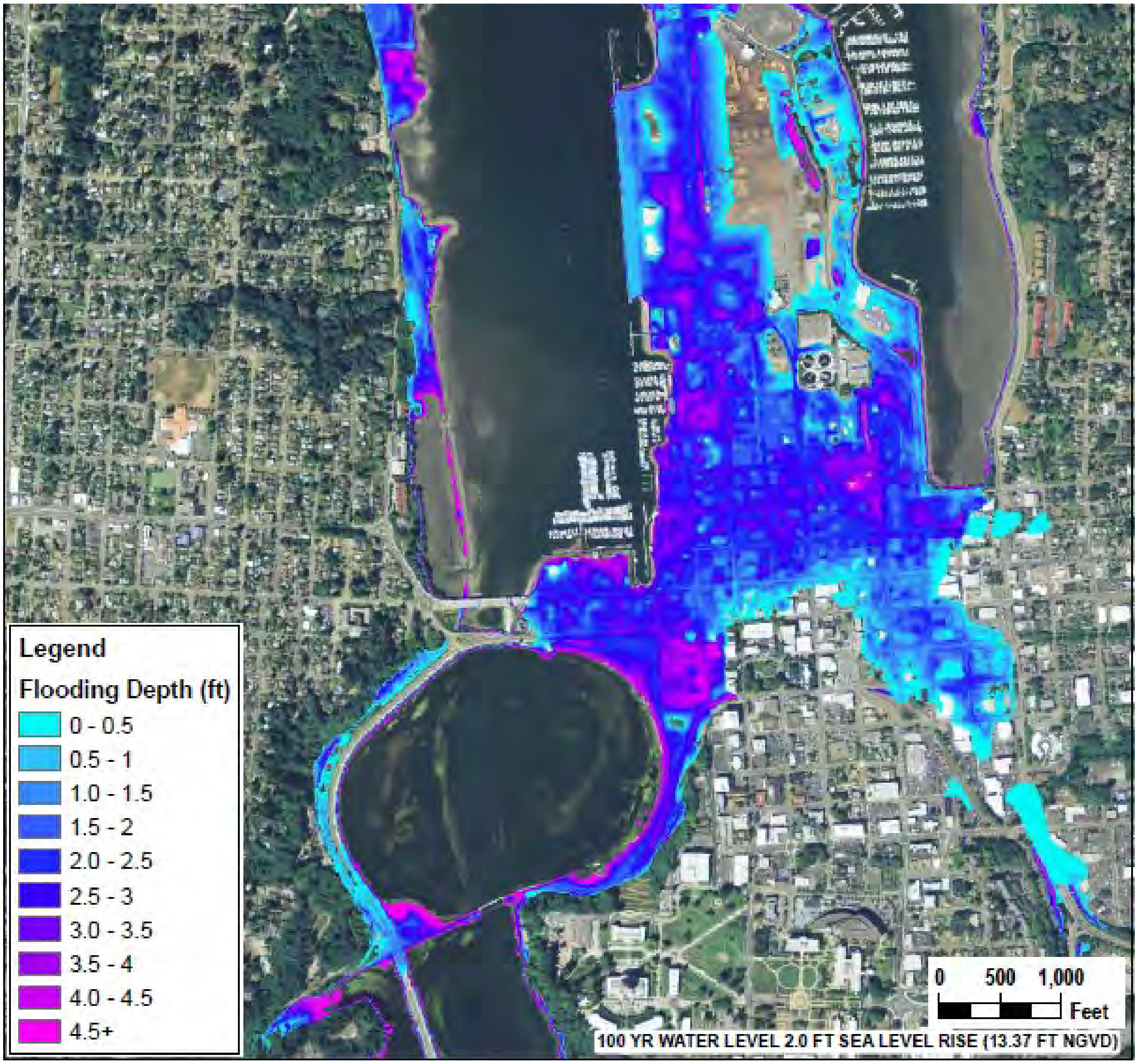

Figure 3-6. Downtown Olympia Budd Inlet Corridor flooding (Coast & Harbor Engineering, 2011)

3.2 Effluent Permit Criteria

The established target level of services is that there should be less than a ten percent chance annually that LOTT bypasses to Budd Inlet, This assumes that during a long-return-period flooding event, the BITP will not meet its National Pollutant Discharge Elimination System (NPDES) permit effluent criteria. The primary activity of the treatment plant under such conditions will be to convey floodwater (seawater, stormwater, and sewage) through the plant and discharge to Budd Inlet to alleviate flooding in downtown, and to prevent further backup of flow and flooding of upstream houses that may lie outside of the flooded corridor.

Key areas for routing flow through the plant are the headworks building and the effluent pump station (EPS). The headworks building houses the influent pumps and the effluent pump station houses the effluent and combined sewer overflow (CSO) pumps. The effluent pumps discharge to Budd Inlet at the North outfall, at the northern tip of the downtown peninsula, the CSO pumps can divert water from the plant to the Fiddlehead outfall.

3.3 Critical Areas

The most critical areas to protect during a major storm event are the systems that drive flow through the plant. The headworks and effluent pump station house the pumps that route flow through the plant. Also critical are those areas responsible for providing electricity to the plant—specifically, the substations and backup power generation systems. The areas of the plant most likely to flood are the utilidors and below-grade areas in the headworks.

3.3.1 Headworks Building

The headworks building ground floor is located at an elevation of 113.0 feet. The influent pumps are located one level below grade and the pipe gallery is located two levels below grade.

3.3.1.1 Equipment

Major equipment in the headworks building includes:

- influent pumps (one level below grade)
- standby generators (grade)
- influent pump ancillary equipment including motor control centers (MCCs) (grade)
- generator switchboard GS-2 (grade)

The influent pumps are critical for conveying flow through the plant and alleviating flooding in downtown Olympia. Proper function of the influent pumps requires a power source, and flooding prevention at the pump motor and MCCs.

The influent pump MCCs and other ancillary electrical equipment are housed in panels on the main floor of the headworks building. The panels stand on a concrete slab 2 inches above the ground floor elevation, as illustrated on Figure 3-7.

Figure 3-7. Electrical panel slab

If electrical power supply is not available due to substation flooding or electrical power grid disruption, the backup generator sets are able to provide power to four large influent pumps, plus the smaller pump. Staff estimate influent pumping capacity to be approximately 50 to 55 million gallons per day (mgd) under backup power.

Likewise, these generator sets provide power to the CSO pumps, which would have an estimated capacity of discharging 40 to 45 mgd of flow to the Fiddlehead outfall under backup power. At high-tide elevation, there is no ability for gravity flow through either outfall.

The generators are housed on the main floor of the headworks building and are 8 inches above the final floor elevation on a concrete slab, similar to that shown on Figure 3-7.

Figure 3-8 through Figure 3-10 illustrate the equipment in the headworks building.

Figure 3-8. Influent pump motors (one level below grade)

Figure 3-9. Backup generator sets (grade)

Figure 3-10. Influent pump volutes (two levels below grade)

3.3.1.2 Flooding Risks

The headworks building is vulnerable to flooding under the two worst-case flooding scenarios. Flow must be pumped from the headworks to downstream processes. Flow is typically pumped to the primary sedimentation basins, but can also be pumped via the CSO pumps to the Fiddlehead Outfall via a gated connection to the final effluent building.

3.3.1.3 Flood Entry Points

Water may enter the headworks building through its three access doors (Figure 3-11 through Figure 3-13), doors at the MCC room, the influent wet well area, and the grit box room. The grit box room also has floor penetrations which will allow water to enter under flooding conditions. Flood water may also enter the building through the generator exhaust grill, which is connected directly to the outside (Figure 3-14).

Figure 3-11. Headworks access door 1

Figure 3-12. Headworks access door 2

Figure 3-13. Headworks access door 3 (emergency exit)

Figure 3-14. Generator exhaust grill

Water entering through any of these access points may route downstairs, inundating the lower two levels, which include the influent pumps and motors.

Influent can back up within the headworks building, once the influent pump station (IPS) and all equalization basins are full. In the absence of adequate pumping, this could lead to flooding of the headworks building.

3.3.1.4 Impacts

If pump motors are flooded due to a presence of water or moisture, the pumps can malfunction, or short-circuit, while running. Even if power supply is available, the pumps will not operate.

If the influent pump MCCs are flooded, the pumps will not operate, even if there is a power source.

If the influent pumps do not operate for any of the above reasons, then the plant cannot convey water, and flow will back up—first at the headworks, contributing to flooding within the building, and then to the influent sewers, downtown Olympia, and further up the collection system. This would exacerbate flooding of downtown Olympia, and could result in flooding of basements and houses upstream.

If the backup generators are flooded, they cannot function. This vulnerability becomes critical if the main electrical power supply is interrupted.

Generator EG02-056 provides standby power to generator switchboard GS-1, which feeds standby power to CSO pumps P12-003and P12-004via individual automatic transfer switches (ATSs) and variable-frequency drives (VFDs) for each pump. Generator switchboard GS-1 also feeds standby power to transformer (XFMR) T-11A via a manual transfer switch (MTS).

Generator EG02-057 provides standby power to influent pumps P02-040 and P02-041 via MCC 2A and ATS-1N.

Generator EG02-058 provides standby power to generator switchboard GS-2 via ATS-2N, and three influent pumps (P02-042, P02-043, and P02-051) via MCC 2B and ATS-3N. Generator switchboard GS-2 feeds standby power to the following items:

- mini-power center PC11 (ultraviolet [UV] basin)
- mini-power center PC15 (IPS)
- panel LP-1A (administration building)
- mini-power center PC2 (headworks)
- mini-power center PC4 (solids)
- mini-power center PC8 (blower building)
- mini-power center PC12 (EPS)
- instrument air compressor (headworks)
- instrument air dryer (headworks)

Generator switchboard GS-2, ATS02-2A, ATS-2N, ATS-3N, MCC-2A, MCC-2B and VFDs for pumps P02-040 , P02-041, P02-042, and P02-043 are also located in the headworks building at an elevation of approximately 113.25 feet.

All three generators are critical for maintaining flow through the plant during power outages, as well as for providing some disinfection, and other critical utilities and processes.

3.3.1.5 Vulnerability Summary

Critical vulnerabilities within the headworks building include:

- influent pump motors (one level below grade)
- influent pump controls and MCCs (grade)
- backup generators (grade)

3.3.1.6 Mitigation

The following actions would make the headworks building less vulnerable to flooding. Simple mitigation methods include:

- sandbag access door entry points
- sandbag or provide watertight seals at the lower portion of the generator exhaust grill up to 1.4 feet from the ground
- provide watertight seals around access doors
- provide watertight seals around bottom entry electrical conduit

Infrastructure improvement projects include:

- raise elevation of generator and electrical panel concrete pads up to at least 1.4 feet from the floor

3.3.1.7 Further Evaluation

The three generators operate on diesel fuel. The sizes of the day tanks and the bulk fuel tanks are not shown on the drawings. 400 kW generators typically have maximum fuel consumption rates of approximately 32 gallons per hour. To operate continuously for 2 days (48 hours) the reserve fuel capacity for each of the generators should be 1,540 gallons.

3.3.2 Effluent Pump Station

The effluent pump station is located at an elevation of 112.5 feet.

3.3.2.1 Equipment

Major equipment near the effluent pump station includes:

- effluent pumps
- CSO pumps
- effluent pump ancillary electrical equipment including MCCs and VFDs
- generator switchboard GS-1 and the two ATSs for CSO pumps P12-003 and P12-004
- generator EG12-770

The effluent and CSO pumps are required to discharge flow at high tide. The Fiddlehead outfall may discharge by gravity under lower tidal conditions, but not under the conditions being evaluated in this TM. Failure of the effluent and CSO pumps could result in a backup of flow and flooding within the BITP. Proper function of the effluent pumps requires that there be adequate power supply, no machine malfunction or short-circuiting due to water presence, and functioning ancillary electrical equipment including MCCs and VFDs.

The CSO pumps have backup power supply from the generator sets located in the headworks building; the effluent pumps do not.

The effluent and CSO pump MCCs, VFDs, ATSs, and generator switchboard GS-1 are housed in panels on the main floor of the effluent pump station. The panels stand on a concrete slab 2 inches above the floor elevation. Two effluent pumps and two CSO pumps are located within the building while three effluent pumps are located outside the building.

If electrical power supply is not available due to either substation flooding or electrical power grid disruption, the backup generator sets are able to provide power to two CSO pumps, with a capacity of around 40 to 45 mgd.

Generator EG12-770 is the Jenbacher generator, and is not critical.

Figure 3-15 through Figure 3-17 illustrate the equipment in the effluent pump station.

Figure 3-15. Electrical panels

Figure 3-16. Outdoor effluent pumps

Figure 3-17. CSO pump

3.3.2.2 Flooding Risks

The effluent pump station is vulnerable to flooding under the two worst-case flooding conditions, as well as the UW maximum SLR condition.

The effluent pump station ground floor is not hydraulically connected to any other process facility at the BITP. The effluent pump suction lines and other floor penetrations are not water tight, and water may enter the building through the concrete floor during flooding.

The three effluent pumps located outside are exposed to the elements, and are subject to flooding due to their proximity and low elevation compared to adjacent streets. The pump and motor stand approximately 10 feet tall. Lower-elevation elements include terminal boxes and local hand-operated panels. The pump motors are high enough to be protected from flooding under all model scenarios.

3.3.2.3 Flood Entry Points

The main source of flooding at the effluent pump building are the two access doors and the truck roll-up door. Water can enter through the gaps in the doorway and flood the entire main floor, including the electrical panels, MCC, and VFDs. The motors of the CSO and effluent pumps are located above the pump volutes, and are high enough to be protected from flooding under all model scenarios.

3.3.2.4 Impacts

Effluent cannot be discharged by gravity when the tide is above the elevation of 105 to 106 feet (per discussions with LOTT staff).

The VFDs and MCCs feeding the indoor effluent and CSO pumps will short-circuit and shut down if the presence of water or moisture is detected. It is assumed that the electrical panels are not waterproof or watertight. The pumps will subsequently stop operating if those panels shut down. Similarly, ancillary equipment for the outdoor effluent pumps may short-circuit in the presence of moisture or water.

If the effluent or CSO pumps do not operate for any of the above reasons, then the plant cannot discharge effluent. Flow will back up within the plant, and flooding may be observed from the primary clarifiers through the disinfection building.

Generator EG02-058 would be required to operate UV disinfection under a power outage. While the plant's primary goal during a major event would be to pass flow through the facility, a secondary goal would be to provide as much treatment as possible, with disinfection having priority over other forms of treatment due to potential human-health impacts.

3.3.2.5 Vulnerability Summary

Critical vulnerabilities near the effluent pump building include the following:

- generator switchboard GS-1
- CSO pumps
- effluent pumps (within effluent pump building)
- effluent pumps (located outdoors)

3.3.2.6 Mitigation

Through a combination of simple and long-term capital improvements projects, the effluent pump station can be made less vulnerable to flooding scenarios. Simple mitigations include:

- sandbag access door entry points
- provide watertight seals around access doors

Infrastructure improvement projects include:

- raise elevation of electrical panel concrete pads to at least 1.9 feet above grade
- raise elevation of backup generator concrete pad to at least 1.9 feet above grade
- provide waterproof and watertight electrical panels
- provide watertight terminal boxes and local hand-operated panel for outside effluent pumps

3.3.3 Puget Sound Energy Substation

The Puget Sound Energy (PSE) substation is one of the lowest elevations in the area, and is projected to flood under the two worst-case flooding scenarios, as well as the UW very high SLR scenario.

3.3.3.1 Flooding Risks

The PSE substation is subject to downtown Olympia corridor flooding due to its exposed location, proximity to streets, and low elevation. Figure 3-18 and Figure 3-19 illustrate the location of the PSE substation and its proximity to adjacent streets. The ground elevation at the substation is approximately 112 feet.

Figure 3-18. Puget Sound Energy substation proximity to streets

Figure 3-19. Puget Sound Energy substation

The substation overhead electrical buses and air switches are mounted higher than any of the flooding scenarios, but some control systems and protective devices are located within enclosures at elevations below or at flood water levels. Additional coordination with PSE is required to obtain a better assessment of the effects of floodwater (2.5 to 3 feet above grade) within the PSE substation yard and in associated vaults where utilities have been "undergrounded".

3.3.3.2 Flood Entry Points

The PSE substation is outdoors, with no physical barrier to flooding aside from equipment enclosures. It is not known whether those enclosures are watertight.

3.3.3.3 Impacts

The Puget Sound Energy substation provides electrical power supply to the entire BITP. If the substation is flooded or otherwise inoperable, the BITP will be entirely dependent on backup power.

3.3.3.4 Mitigation

The PSE substation can be less vulnerable to flooding scenarios through a variety of mitigation efforts:

- raise the elevation of all equipment within the PSE substation to a minimum of 114.4 feet
- provide watertight enclosures for all vulnerable equipment within the PSE substation

3.3.4 Service Entry Switchgear

Power from the PSE substation is routed to the plant via 15 kV switchgear, located just outside the PSE substation, to the north. The service entry switchgear is scheduled to be upgraded in 2016 as part of capital project AM1311.

3.3.4.1 Flooding Risks

The 15 kV switchgear is located inside the plant secured fence directly north of the PSE substation (Figure 3-20). The elevation of this 15 kV switchgear is approximately 112 feet. This elevation is approximately 28 inches below the worst-case flood scenario.

Figure 3-20. Service entry switchgear

3.3.4.2 Flood Entry Points

The switchgear has bottom entry conduits, which are not likely to be watertight. These could flood as soon as water accumulates at grade, which, in this location, is at a relatively low elevation (112 feet).

3.3.4.3 Impacts

During flooding scenarios, the 15 kV switchgear will likely experience flash-over (short-circuit) and/or ground fault. The upstream electrical protective device should trip OPEN and de-energize one or both of the 15 kV circuits into the BITP. This could leave the entire BITP dependent on backup power.

3.3.4.4 Mitigation

The 15 kV switchgear can be less vulnerable to flooding scenarios through a variety of mitigation efforts. Simple mitigations include:

- provide watertight bottom conduit entries

Infrastructure improvement projects include:

- raise the elevation of the 15 kV switchgear to a minimum of 114.4 feet
- provide watertight enclosures for the 15 kV switchgear

3.3.5 Electrical Substations

The substations distribute electrical power throughout the plant. Substation A/B is located at a ground elevation of 113 feet, susceptible to flooding under the two worst-case flooding scenarios. Substations C/D, E/F, and G/H are all located at elevations higher than the worst-case flooding scenario. This section therefore focuses on substation A/B, which is located within the headworks building.

3.3.5.1 Flood Entry Points

The main source of flooding for substation A/B is through access doors to the east and west, which are not watertight. Even with sandbags placed around doors, floodwaters could enter the equipment enclosure from bottom entry conduits.

3.3.5.2 Impacts

Substation A/B feeds numerous systems in the headworks area, including influent pumps, screens, grit systems, and odor control. If the substation is flooded, those systems would need to function on backup power. Downstream electrical systems include MCC-2A, MCC-2B, MCC-2C,MCC-2D ATS2A, and generator switchboard GS-2. These are located in the headworks building at an elevation of approximately 113.2 feet, and are also susceptible to flooding.

3.3.5.3 Mitigation

The substations can be less vulnerable to flooding scenarios through a variety of mitigation efforts. Simple mitigations include:

- provide watertight bottom conduit entries to substation A/B
- sandbag access door entry points to substation A/B

Infrastructure improvement projects include:

- raise the elevation of the substation to a minimum of 114.4 feet
- provide watertight enclosures for the substation

3.3.6 Utilidor

An underground utilidor connects various locations within the BITP, and primarily acts as a pipe gallery.

3.3.6.1 Flooding Risks

Due to its relative elevation of 12.5 feet below grade, the utilidor will flood in all scenarios, unless its numerous access points are made watertight.

3.3.6.2 Equipment

The utilidor houses piping and appurtenances (valves, instrumentation). The utilidor also houses some ancillary electrical equipment, including panels.

3.3.6.3 Flood Entry Points

Numerous access doors may allow water to pass into the utilidor. Floodwater can enter through open doorways, door ducts, and non-watertight seals for conduit; piping; and heating, ventilation, and air conditioning (HVAC) equipment.

3.3.6.4 Impacts

Flooding within the utilidor could lead to short-circuiting and shutdown of ancillary electrical equipment, and instruments. It could also damage or degrade valves and pipe appurtenances. These systems are not involved in passing flow through the plant, and are therefore of relatively low criticality.

3.3.6.5 Mitigation

Flooding of the utilidor can be mitigated by providing watertight seals around access doors, sandbagging access doors, and actively pumping utilidor sump pumps (when electrical power is present). However, due to its below-grade elevation and numerous smaller entry points (electrical ducts, communication ducts, etc.), it is reasonable to assume that the utilidor would flood during events that inundate most of the plant (the UW very high SLR scenario and the two worst-case flooding events).

3.3.7 Electrical Systems (General)

When outdoor manholes and handholes become flooded, the electrical conduits become pathways for the floodwater to flow. If the conduits are routed to areas and electrical equipment/enclosures lower than or equal to the height of the floodwater, then floodwaters will flow into these areas and electrical equipment/ enclosures. The existing conduits may be sealed for dirt, debris, or rodents but most likely do not have watertight seals.

When energized electrical equipment and electrical controls are submerged in floodwaters, the equipment will experience either flash-over (short-circuit) or a ground fault. The main and feeder circuit breakers located in the substations are designed to trip OPEN in the event of a short circuit or ground fault. The solid-state motor protection devices found in VFDs and motor controllers with electronic protective devices are also designed to trip OPEN in the event of a short circuit or ground fault.

The electrical devices such as circuit breakers, fuses, receptacles, switches, motor controllers, VFDs, control power transformers, relays, and wiring are not designed to be submerged in water; they are typically discarded when they are submerged.

Floodwaters contain unknown chemicals, oils, silt, and other particles that can contaminate and impair the operation of electrical devices and damage cable insulation. Most electrical equipment must be replaced after contact with water. While some larger pieces of equipment might be salvaged depending on duration of submersion and the exposure to contaminants in the water, they will not be operable during the time it takes to be repaired (i.e., days, weeks, and in some cases months).

If the insulation on the power and plant control cable is not rated for the exposure to contaminants in the floodwater, the cable insulation could deteriorate and possibly fail.

3.4 Vulnerability Summary

Tables 3-2 through 3-5 summarize the vulnerability of equipment in at-risk areas. Vulnerability was measured as a product of two criteria, the probability of flooding and the relative importance of subsequent impacts.

Table 3-2. Headworks Building Vulnerability Summary			
Equipment	Impact priority	Probability of flooding	Vulnerability score
Influent pumps	High	High	Critical
Backup generator sets	High	High	Critical
Ancillary electrical equipment (including MCCs)	High	High	Critical

Table 3-3. Effluent Pump Station Vulnerability Summary			
Equipment	Impact priority	Probability of flooding	Vulnerability score
Effluent pumps	High	Low	Moderate
CSO pumps	High	Low	Moderate
Ancillary electrical equipment (including MCCs, VFDs)	High	High	Critical

Table 3-4. Substations Vulnerability Summary			
Equipment	Impact priority	Probability of flooding	Vulnerability score
Puget Sound Energy substation	High	High	Critical
15 kW switchgear	High	High	Critical
Substation A/B	High	High	Critical
Other substations	High	Low	Moderate

Table 3-5. Utilidor Vulnerability Summary			
Equipment	Impact priority	Probability of flooding	Vulnerability
Ancillary electrical equipment	Low	High	Low
Piping and appurtenances	Low	High	Low

3.5 Recommendations

The BITP is vulnerable to inundation due to its location. During such events, efforts should be focused on passing as much flow as possible through the Plant, in order to relieve upstream flooding including combined sewers. Treatment should be focused on providing disinfection, if possible. For these reasons, improvements should be focused on the following areas:

- Headworks
- Effluent Pump Building
- Electrical Systems, including standby power

LOTT should have a plan to sandbag key flood access points identified in the above sections, and to move towards installing water-tight doors and bottom entry conduit throughout the Plant. Key equipment, such as the Service Entry Switchgear, standby generators, electrical substation A/B, and equipment associated with the influent, effluent, and CSO pumps, should be raised above projected flood levels, or provided with watertight enclosures. LOTT should coordinate with PSE to ensure that the Thurston substation is provided with adequate protection for projected flood events.

Given the particular vulnerability of plant electrical systems, a more detailed condition assessment of the electrical system is recommended. Such an assessment should involve a comprehensive review of all electrical systems within the Plant, with a focus on flood-related vulnerability and design standards for future projects.

The recommended improvements discussed in this report typically involve design details, such as bottom entry conduits, water tight doors, waterproof panels, and pad elevations. One way to implement these recommendations is through updating the LOTT design standards. In this way, all future work at the BITP site will conform to practices which reduce flood vulnerability, and existing vulnerabilities will gradually be removed.

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