CLEAR CREEK TIDE GATE ASSESSMENT

Technical Memorandum
Farming in the Floodplain Project

Prepared for
PCC Farmland Trust

July 2017

Photo courtesy of Pierce County Surface Water Management

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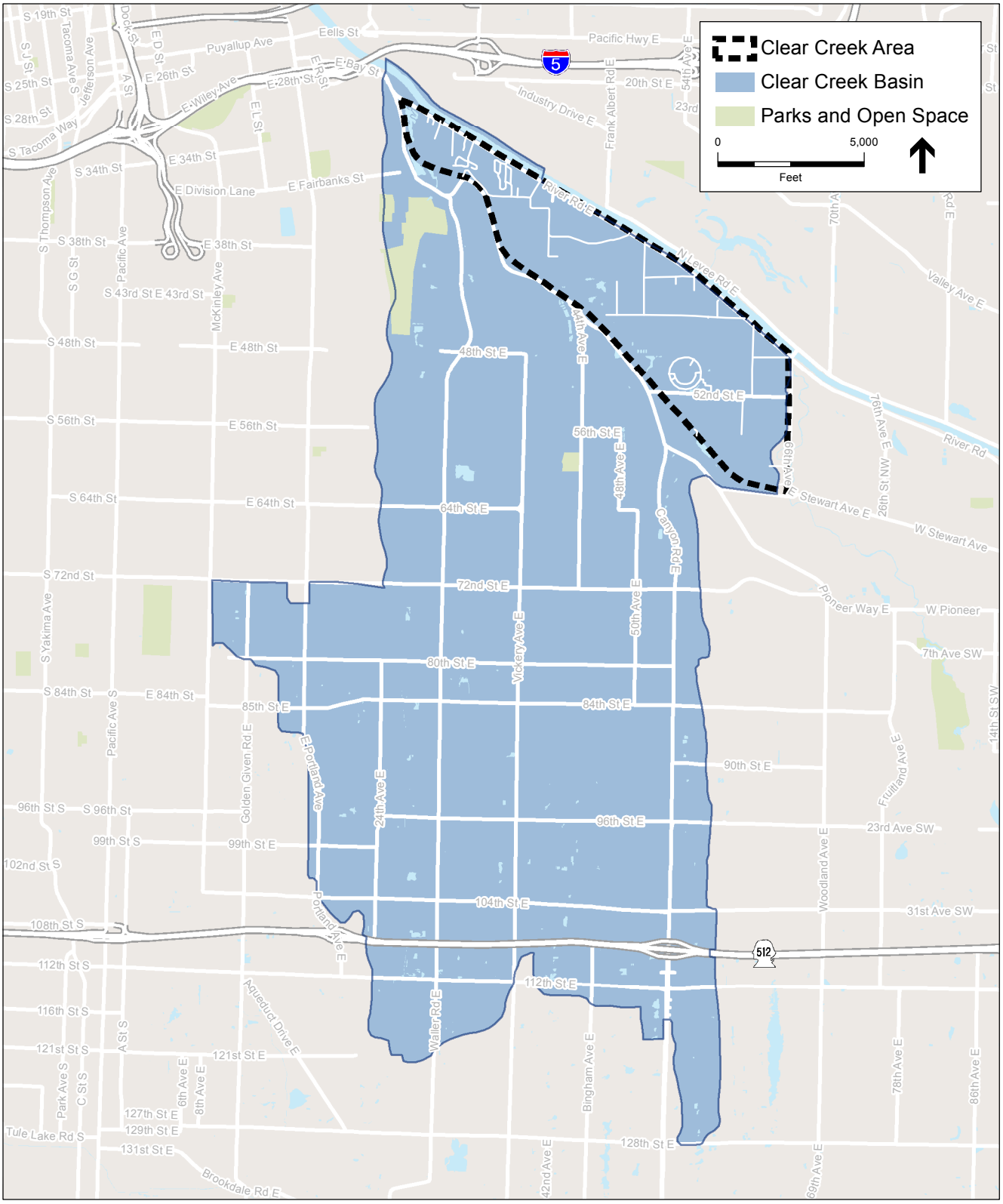
1.0 Project Background and Description

The purpose of this memorandum is to describe the current operations of the tide gates at the mouth of Clear Creek. This memorandum also reviews potential actions to improve operations of the tide gates and recommends some that could be implemented as interim measures. The potential actions described in this memorandum are not presented as alternatives to eventual removal of the Clear Creek tide gates, but as interim measures that could provide improvements in drainage and fish passage benefits in the near term. The description of current operations of the tide gates is based on water surface elevation data derived from water level loggers installed by Pierce County Surface Water Management (SWM) in fall 2016; photographs of the tide gates; and as-built plans and other documentation of the tide gates. It was not within the scope of this memorandum to conduct field work to assess the tide gates in person. Recommended potential actions are described at a conceptual level; additional analysis would be needed to determine the feasibility of the recommended actions before they could be implemented.

This technical memorandum has been prepared as part of Phase 2 of the Farming in the Floodplain Project (FFP). The FFP is one of four components of the Floodplains for the Future: Puyallup, White, and Carbon Rivers project, which is funded by a Floodplains by Design grant from the Washington Department of Ecology (Ecology). The purpose of the FFP is to advance progress toward a collectively agreed upon plan for the Clear Creek area that improves agricultural viability in the area while also meeting goals for flood risk reduction and salmon habitat enhancement. The FFP is intended to clarify the needs and interests of the agricultural community within the Clear Creek area.

2.0 Study Area

The study area for the FFP is the Clear Creek area, part of the Clear Creek Subbasin of the Puyallup River Watershed (Figure 1). The Clear Creek Subbasin is within the Puyallup River Watershed and is located south of the Puyallup River, north of 128th Street East, west of 66th Avenue East, and east of McKinley Avenue East. The Clear Creek area is roughly 1,140 acres in size and bounded by the Puyallup River to the north, Pioneer Way East to the south and west, and 52nd Street East to the east.



SOURCE:
ESA 2016, ESRI 2016

PCCFT Farming in the Floodplain. 150678

Figure 1

Clear Creek Basin and Area

3.0 Description of the Tide Gates

Clear Creek passes under River Road East (State Route (SR) 167) through a two-barrel, 120-foot long box culvert with an invert[1] elevation of 1.1 feet measured in North American Vertical Datum of 1988 (NAVD 88)[2] and no slope (flat). A trash rack on the upstream end prevents debris from entering the culvert and the tide gates are mounted on the downstream (river) side of the box culverts.

A tide gate is a gated opening through which water flows toward the tide water when the tide is low and which closes automatically when the tide is high, with the goal of preventing tidal waters from inundating the landward side of the gate. The two tide gates installed on the Clear Creek culverts are of different types, ages, and states of repair. The newer gate, which is shown in the raised position on the left in Figure 2, consists of a 6-foot wide by 7-foot tall metal slide gate assembly (Port of Tacoma, 1997b). This gate was installed in 1997 to replace a previous wooden flap gate at the same location. The slide gate was installed as part of the Port of Tacoma's Clear Creek Mitigation Project, a habitat restoration project located just upstream on Clear Creek. The tide gate is intended to improve fish passage at the culvert at the mouth of Clear Creek and allow a larger number of salmonids to access the mitigation area.

The older gate, shown on the right, is a top-hinged wooden flap gate approximately 8 feet wide by 7 feet tall in a wooden frame. The gate is set at an angle of approximately 10 to 15 degrees, with the top set back and the bottom set forward, as shown below in Figure 4 (Port of Tacoma, 1997a). This is a common design for flap gates to make them close more effectively. Ownership of this gate is unclear, and there is no evidence of recent maintenance.

[1] The invert elevation is the elevation at the base of the interior of a culvert.
[2] NAVD 88 is a U.S. standard datum for elevation measurements. Pierce County Surface Water management uses NAVD 88 for all elevation data.

Figure 2 Clear Creek Tide Gate (viewed from the Puyallup River)

SOURCE: Mike Neville, 2016

4.0 History and Ownership

It is uncertain when the existing box culverts and original wooden tide gates at Clear Creek were installed and by whom. Records suggest that some type of control structure was in place at this location in the early 1930s, as one was mentioned in the original WSDOT right-of-way easement when State Road (SR) No. 5, the precursor of the existing SR 167, was constructed along the top of the levee (ICRIC, 1932).

In 1966, a letter from the Washington State Highway Commission to the Division of Flood Control regarding the Clear Creek tide gates stated that the commission had "accumulated considerable data… which indicates that we have a responsibility for this structure and maintenance" (State Highway Commission, 1966). The statement that they had to gather data to reach this conclusion implies that responsibility for the tide gates was unclear even in the 1960s.

A 1982 court decision in a case involving flood damages in the Clear Creek area described the tide gates' origins as follows:

> In 1933, at the confluence of the Puyallup River and Clear Creek, the State of Washington built two 'tide gates' which were designed to prevent the Puyallup's water from backing up along the smaller tributary and flooding the adjoining land. The commissioners of Drainage District No. 10, established in 1912, had responsibility under RCW 85.06.080 and RCW 85.07.170 for maintaining drainage systems within their district. These commissioners routinely inspected the 'tide gates,' performed the necessary maintenance, and paid for expenses out of their annual budget of approximately $4,000. (Geppert v. State of Washington, 31 Wn. App. 33)

The court's account of the tide gates' origins is based on the parties' testimony and is not necessarily complete or accurate. The lawsuit was brought by a group of landowners in the Clear Creek area against the commissioners of Drainage District 10, alleging that poorly executed repairs to the tide gates had caused flood damage to their properties. The lawsuit does indicate that in the early 1980s, Drainage District 10 maintained the tide gates.

A December 1996 letter from the Washington State Department of Transportation (WSDOT) to a commissioner of Drainage District 10 shows that, at that time, WSDOT's bridge maintenance crew performed regular maintenance on the tide gates (at that time, two wooden flap gates). The crew removed debris from the culvert trash rack and tires that were propping open the flap gates. The letter states that the crew had removed debris from the trash rack four times in 1996. The letter states that "[t]his six-person crew is responsible for maintaining almost 600 structures in seven counties and they are stretched very thin." This implies that the Clear Creek tide gates were among the structures that WSDOT considered itself responsible for maintaining at that time (WSDOT, 1996).

In a 2016 email to Puyallup Watershed Floodplains for the Future partners, Carl Ward of WSDOT stated that the north half of the SR 167 right-of-way at the Clear Creek crossing is owned by the Inter-County River Improvement Commission of King and Pierce County, which has granted a perpetual easement to WSDOT. According to Ward, WSDOT does not own the land the tide gates are on and is only responsible for "establishment, construction, and maintenance" of SR 167 as established in the easement. The email stated that, "in our opinion, WSDOT does not have ownership or jurisdiction over the tide gates or the land upon which the tide gates are constructed. Thus, WSDOT has no maintenance obligations" (Ward, 2016). At this time, it is unclear who owns and is responsible for maintenance of the culverts and the wooden flap gate.

In 1997, the Port of Tacoma replaced one of the wooden flap gates with a metal slide gate as part of its Clear Creek Mitigation Site Project. The Clear Creek Mitigation Site Project was required as part of a Consent Decree between the U.S. Environmental Protection Agency (EPA), the Port of Tacoma, and other parties to offset unavoidable environmental impacts related to cleanup of the Commencement Bay Nearshore/Tideflats superfund site. The Consent Decree does not specify the design or the operations of the slide gate, but does specify performance objectives for the mitigation site, including "improve fish passage at the culvert at the mouth of Clear Creek" (US District Court of Western Washington, 1993). While the open/close elevations are not explicitly stated in the Consent Decree, they may have been included in subsequent EPA-approved design submittals for the mitigation area, which would be equally legally binding. The Port is required to operate the slide gate in accordance with the Consent Decree, and changes to the open/close elevations would require EPA approval.

5.0 Description of Current Operations

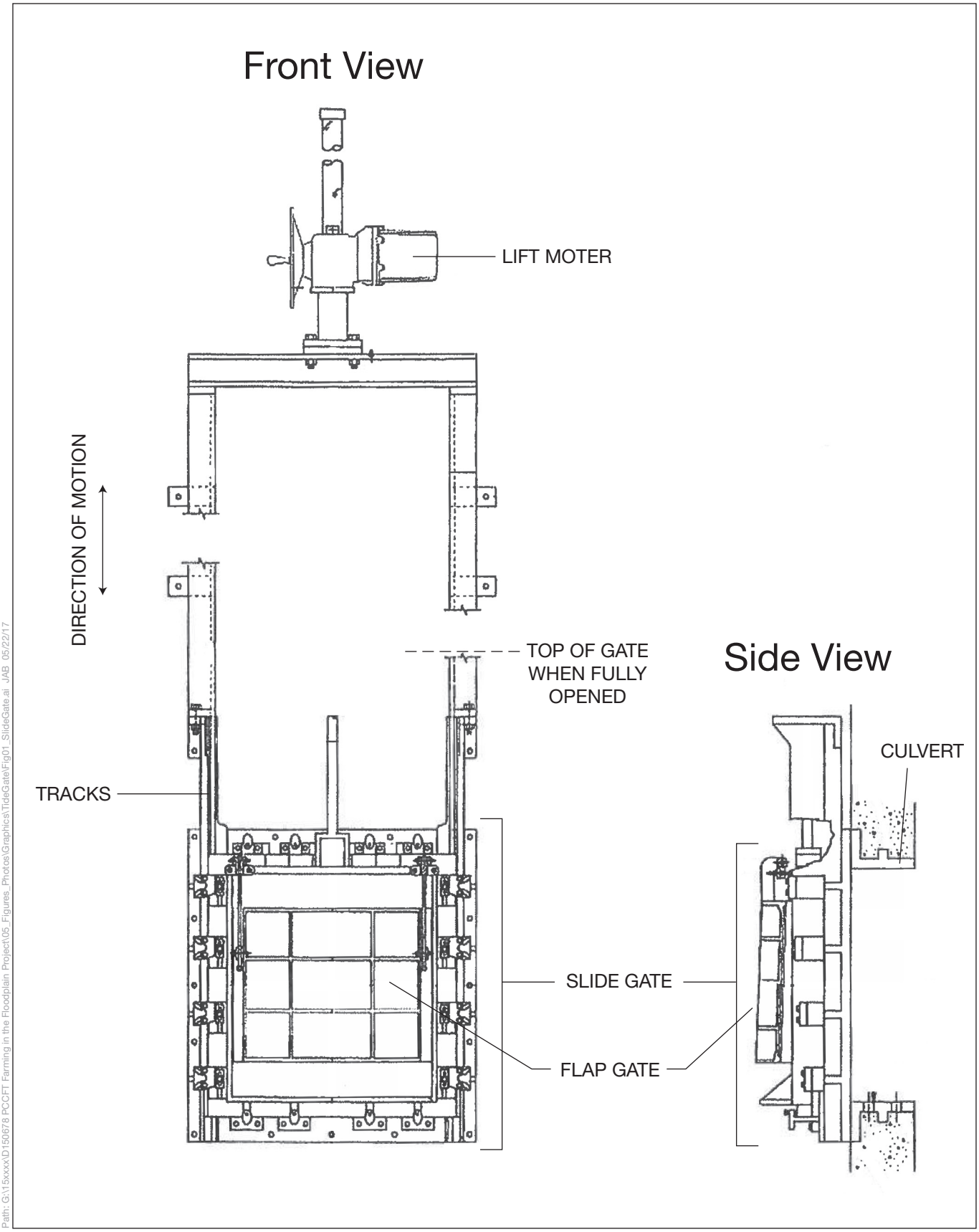
5.1 Metal Slide Gate

The metal slide gate assembly (on the left in Figure 2) operates using a float-trigger system, which triggers raising and lowering of the slide gate when water levels in the Puyallup River meet

certain, pre-set elevations. A diagram of the slide gate is shown in Figure 3. The slide gate's default position is up, with the gate completely clear of the water to maximize the area of the opening so that the gate does not influence flows through the culvert. A generator-driven screw assembly closes the gate when river elevation exceeds the pre-defined threshold (Stebbings, 2016). The slide gate assembly is owned and maintained by the Port of Tacoma.

The metal slide (sluice) gate has a 5-foot by 5-foot flap gate inset into the front (Port of Tacoma, 1997b). This flap gate is designed to allow water to flow from Clear Creek to the Puyallup River when there is a head difference and the slide gate is lowered, allowing for greater drainage. Head is defined as the difference in elevation between two points in a body of water – in this case between the water in the culvert draining from Clear Creek and the water in the Puyallup River. However, according to Port of Tacoma staff, when the slide gate is fully lowered, the flap gate latches shut and cannot open (Myers, 2017b).

In late December 2016 or early January 2017, ice buildup jammed the slide gate during regular operations, causing the motor to burn out and damaging a gear in the gate assembly. Due to difficulties in obtaining replacement parts, the slide remained stuck partially open until May 11, 2017, when it was repaired. According to Port of Tacoma staff, they were unaware how far open the gate was from the time it was stuck until late April 2017 (Myers, 2017a). At that time the Port of Tacoma manually raised the slide gate to allow for better drainage and fish passage (Myers, 2017b). The gate is now functioning normally.



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SOURCE: Reference, 2017

PCCFT Farming in the Floodplains

Figure 3

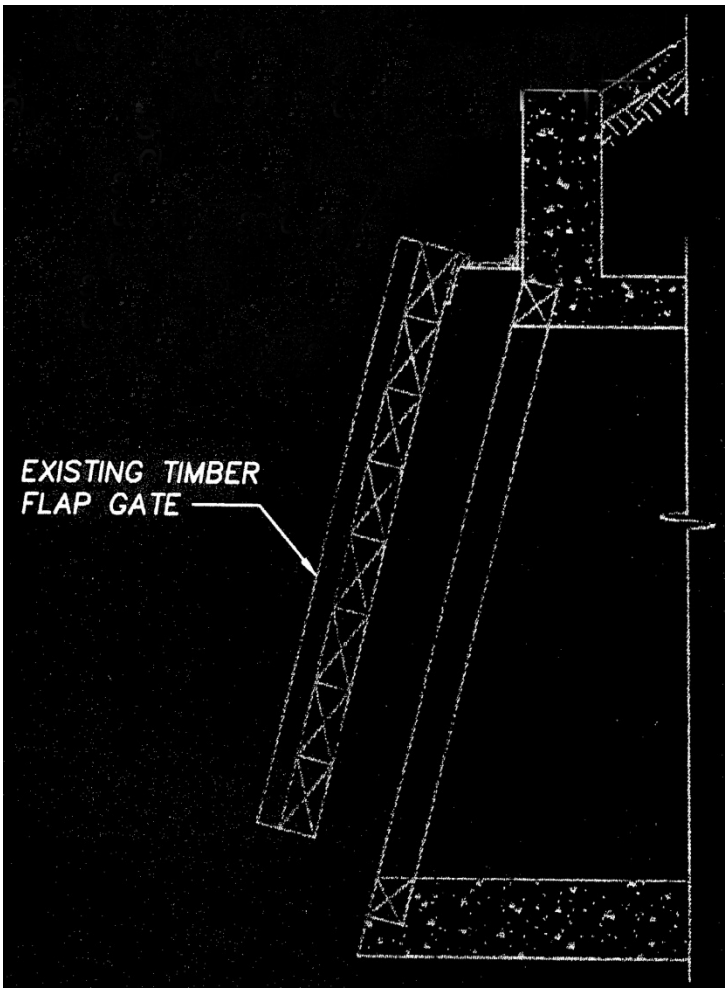
Slide Gate Schematic

ESA

5.2 Wooden Flap Gate

The wooden flap gate (on the right in Figure 2) is a simple balance system that opens and closes based on head differences between the river and Clear Creek. A diagram of the wooden flap gate is shown in Figure 4. The gate is hinged at the top, and water pressure from the river pushes the gate closed when water levels in the river exceed water levels in Clear Creek. Then, when water levels in Clear Creek exceed water levels in the river, water pressure from Clear Creek pushes the gate open. The angled position of the gate increases the amount of force required to open it, so there will be some minimum head difference required to push the gate open. The greater the head difference, the faster the outflow and the more the gate will open. When there are small differences in water levels, the gate opens only slightly, resulting in small outflow rates and little to no opportunity for fish passage. Since this type of gate remains in the water at all times, flow though this barrel of the culvert is never entirely unobstructed.

Figure 4 Wooden Flap Gate Schematic



SOURCE: Port of Tacoma,1997a

Wooden Flap Gate Schematic showing angled gate and frame.

The existing wooden flap gate is old and, based on photographs, appears to be in poor condition. From photographs taken by a Drainage District 10 commissioner in 2016, there appears to be a hole in the top edge of the gate, possibly caused by a beaver chewing the gate (shown on the upper left of the right gate in Figure 2). It is unclear whether the age and lack of maintenance of the gate have led to impairment in the function of the gate because there has been no known recent assessment of the gate's condition. It is possible that its function is impaired, and uncertainty about its condition has created concern that it could fail in a flood event. Due to its weight and the angle at which it is installed, it is unlikely that this gate opens frequently under current conditions. The slide gate side of the culvert provides less resistance, so water would preferentially flow out that direction. Even when the wooden flap gate does open (most likely only during high flows on Clear Creek) it is unlikely to open very much, which may impede drainage from Clear Creek.

5.3 Tide Gates and Flooding

Some reports characterize the tide gates as "causing" flooding when closed by preventing Clear Creek from draining freely to the Puyallup River during high flow events (Pierce County, 2013). However, as described above, the gates are only fully closed when water elevations in the Puyallup River are higher than water elevations in Clear Creek. Even in the absence of the tide gates, Clear Creek would not be able to drain into the Puyallup River under these circumstances. Instead, floodwaters from the Puyallup River would flow into the Clear Creek area, increasing the amount of local flooding.

As part of feasibility planning for the Clear Creek Floodplain Reconnection Project, Pierce County hired Northwest Hydraulics Consulting (NHC) to model a variety of scenarios for the outlet of Clear Creek into the Puyallup River. The results of the modeling show that the tide gates reduce flood levels in the Clear Creek area. The modeling results allow comparison of existing conditions to conditions with two open culverts (i.e., removal of the tide gates) (NHC, 2016). Model results indicate that removal of the tide gates would:

- increase the 10-year flood stage from approximately 16.9 feet to approximately 18.6 feet (1.7 foot increase);
- increase the 50-year flood stage from 19 feet to approximately 20 feet; and
- increase the 100-year flood stage from approximately 20.1 feet to approximately 20.4 feet (NHC, 2016).

NHC is currently updating this modeling, and flood stages could change by several inches. Generally, however, these results indicate that the tide gates, when operating properly, protect agricultural properties (particularly those at elevations between 17 and 21 feet) from more frequent flood inundation.

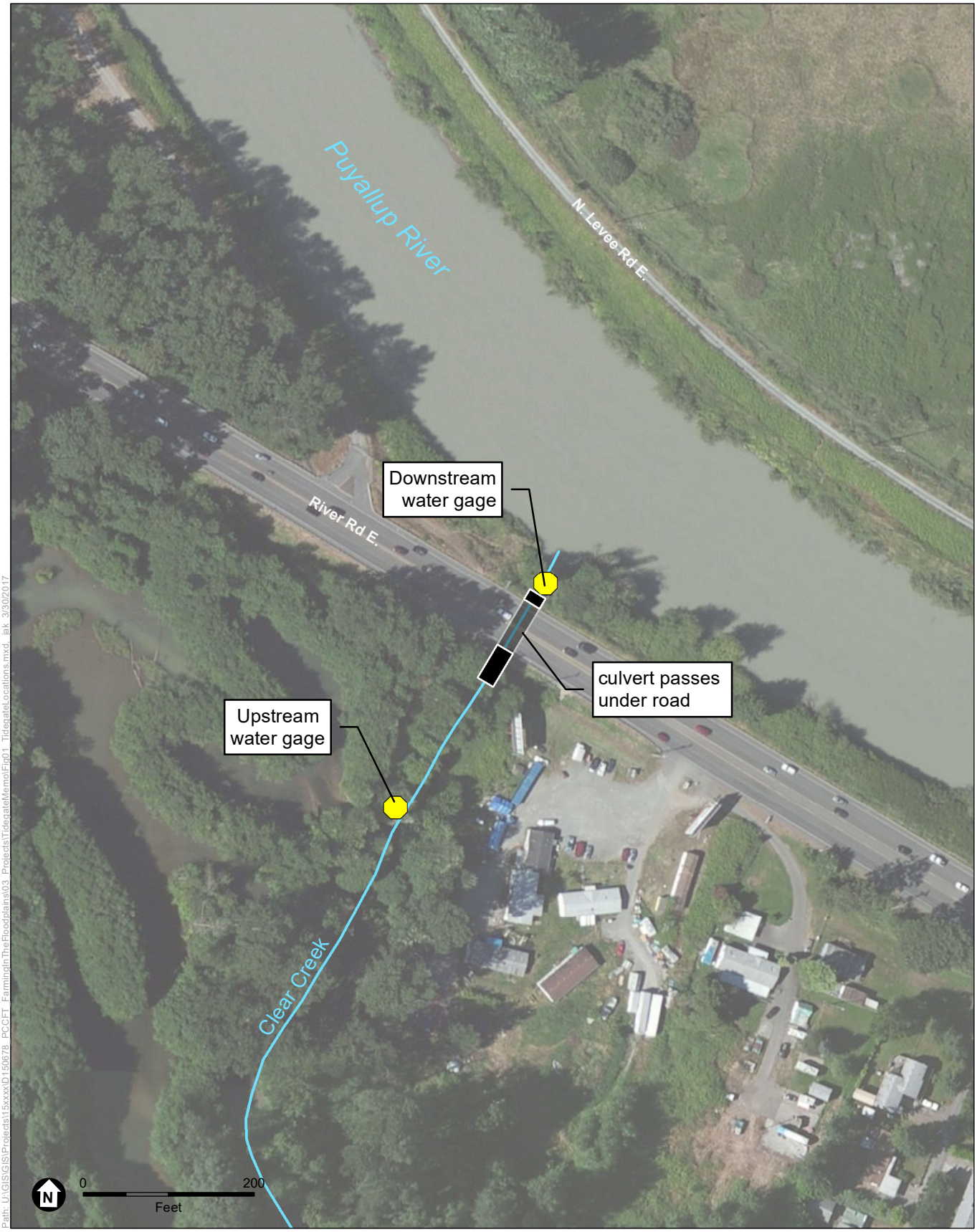
Pierce County SWM's understanding, based on information reported by Clear Creek area residents, is that one or both tide gates were not functioning properly during the 2009 flood event and that Puyallup River floodwaters were able to enter the Clear Creek area. While this cannot be confirmed, aerial photographs of the Clear Creek area show that floodwaters were brown,

suggesting that they included water from the Puyallup River. By comparison, floodwaters from the 2015 flood were clear (Hunger and Schmidt, 2017).

6.0 Analysis of Current Operations

Pierce County staff installed several gages in the lower Clear Creek area in September 2016 to measure water levels on each side of the tide gates as shown in Figure 5. The discussion in this memorandum is based on 5 months of water level data from these gages. Pierce County installed the following gages:

- Water level gage on the Clear Creek side of River Road East, approximately 200 feet upstream of the culvert entrance (shown in the lower left in Figure 5).
- Water level gage on the Puyallup River side of River Road East, just outside of the tide gates (shown in the upper right in Figure 5).
- Uncalibrated pressure gage attached to the back of the slide gate that was used to detect gate opening and closing (not shown).



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SOURCE: NAIP 2016; ESA 2017

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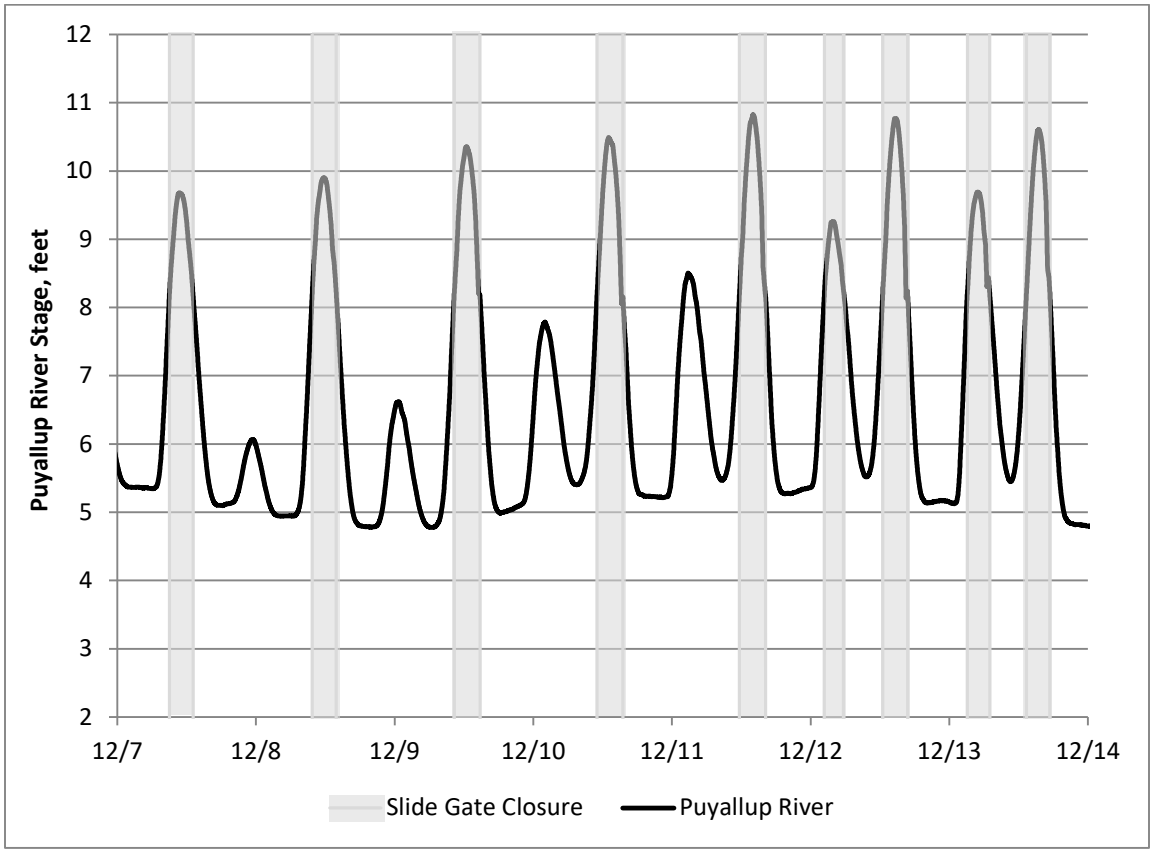
Figure 5

Gage Locations

ESA

ESA analyzed four months of rainy season gage data, a representative sample of which is shown in Figures 6 and 7, below. Rapid changes in the readings of the pressure gage attached to the gate indicate the times when the slide gate was raised or lowered. Cross referencing those times with the water levels in the Puyallup River, it appears that the set point for the slide gate to be raised or lowered is approximately river elevation 8.2 feet NAVD 88. Figure 6 shows one week of water level data from the Puyallup River gage, shown as a black line, superimposed over the periods of tide gate closure, shown as gray bars. During this time period, variations in tidal elevations due to the normal tidal cycle caused the slide gate to shift from closing once per day (12/7 to 12/11) to closing twice per day (12/12 to 12/13).

Figure 6 Slide Gate Operations



SOURCE: Pierce County water level logger data

Water levels recorded in the Puyallup River at the Clear Creek tide gates are shown by the black line. Periods of time when the slide gate was closed due to high water are indicated by the shaded bars.

Design documents from the Port of Tacoma indicate that the slide gate was not originally intended to be lowered daily (Port of Tacoma, 1995a). These documents indicate that the gate should close during the 2-year instantaneous peak flow, but not during the annual maximum daily-average flow, even if concurrent with a high tide. Consequently, if operating as originally envisioned, the slide gate should be lowered less than once per year. The preferred closing and opening elevations listed in the design report are when the river reaches 12.5 and 12.0 feet NAVD 88, respectively – significantly higher than the observed lowering of the slide gate at elevation 8.2

feet NAVD 88 (Port of Tacoma, 1995a). Design documents correlate the preferred gate closure trigger elevations to Puyallup River flows of approximately 16,000 cubic feet per second (cfs) (Port of Tacoma, 1995b). However, during the December 7 through December 14, 2016 period shown in Figure 6, Puyallup River flows were only 2,140 cfs to 3,040 cfs as measured at the USGS gauge at Puyallup, 3.7 miles upstream of the Clear Creek confluence. Puyallup River flows did not reach 16,000 cfs during winter 2016 – 2017, although they came close (15,200 cfs) in early February and again (15,600 cfs) in mid-March (USGS, 2017). If the slide gate was operating as originally envisioned, it would have lowered no more than twice, if at all, in the past year, as opposed to once or twice per day as observed.

The design documents note that gate settings might need to be adjusted lower in response to observations by the local landowners of impacts to their properties, but no record could be found of the actual settings applied during gate installation or any subsequent adjustments (Port of Tacoma, 1995a; 2016). The Port of Tacoma is investigating the discrepancy between the elevations proposed in the design document and observed trigger elevations (Stebbings, 2017).

The wooden flap gate operates much differently from the slide gate. It opens and closes based on differences in head between the stream and the river. It is closed when the water is higher on the river side. Because the gate is mounted at an angle 10 to 15 degrees from vertical, it likely remains closed until the water level in the culvert rises some amount above the water level on the river side of the gate. Due to significant variations in the stages[3] of the stream and river, the flap gate can open and close across a wide range of water levels. However, since there is no gage on the back of the flap gate to detect its motion, the operations of the flap gate cannot be measured with the current gage array. Additional gaging would be required to determine operation of the flap gate.

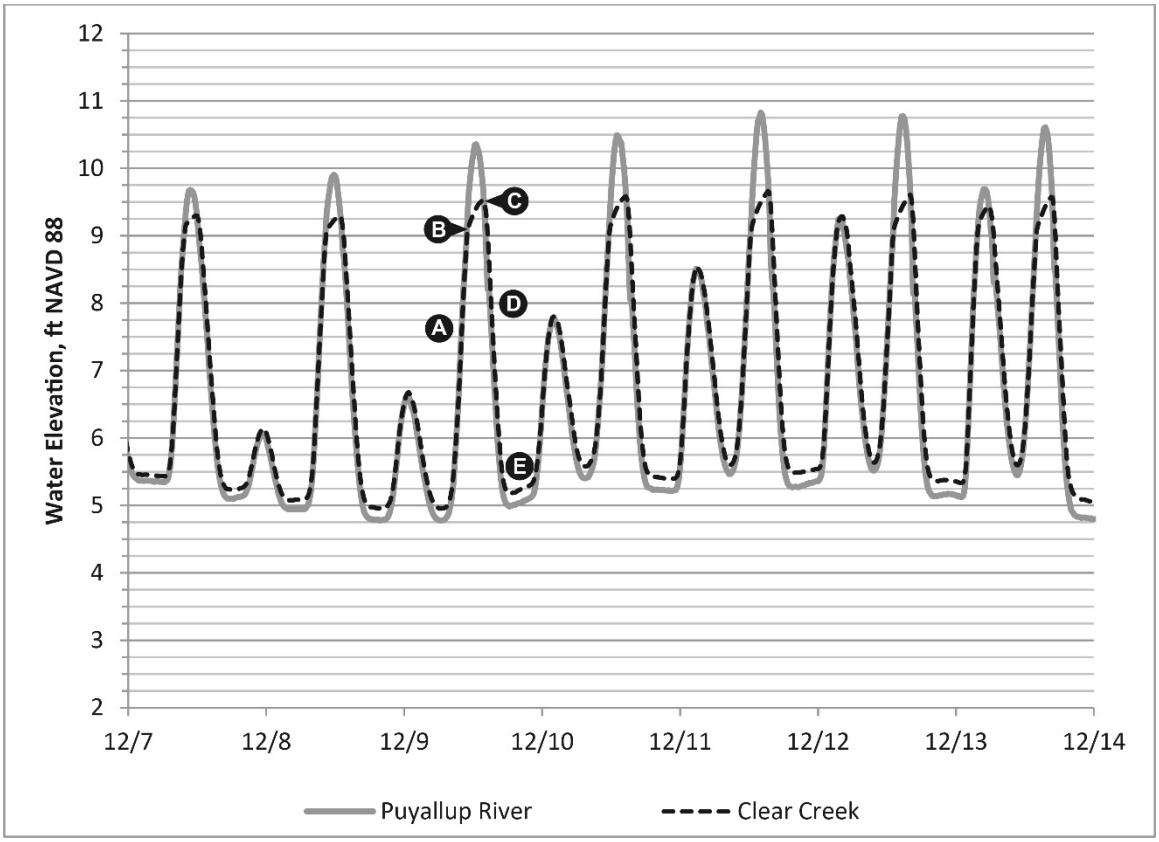
Given the current condition of the wooden flap gate, there is also a strong possibility of leakage when the gate is closed, which cannot be accounted for with the data available. The amount and potential importance of leakage could be assessed by physical examination of the flap gate at low water. This would include measuring the size of any gaps between the gate and its frame and holes in the surface and by observing the flow back through the culvert when both gates are in the closed position. With the gates closed, flow in either direction would be caused by leakage around or through the gates. This leakage is expected to be relatively trivial in relation to Clear Creek or Puyallup River flows and is not expected to contribute significantly to observed water levels in the Clear Creek area.

The tide gates are only effective at preventing Puyallup River water from entering Clear Creek when both the slide gate and flap gate are closed. Periods when both gates are closed can be identified by when water levels in the Puyallup River exceed levels in Clear Creek. Flap gate operations can be inferred by comparing these periods of total closure to the known operations of the slide gate, closing at river elevations of 8.2 feet NAVD 88. Fundamental differences in how the gates operate make comparisons difficult, but in general, the flap gate appears to close and reopen at a higher river stage than the slide gate. This indicates that the timing of the slide gate

[3] Stage is defined as the height of the surface of a stream or river above an arbitrary zero point.

operations may be off, with the slide gate beginning to close while Clear Creek is still draining to the Puyallup River, potentially impeding drainage from the Clear Creek area.

Figure 7 Water Levels in Clear Creek and Puyallup River



SOURCE: Pierce County water level logger data

Water Levels in Clear Creek and the Puyallup River over a representative one week period.

Figure 7 shows the effects of the tide gates on water levels in Clear Creek. The solid line shows Puyallup River water elevation and the dashed line shows the Clear Creek water elevation. Water levels in Clear Creek and the Puyallup River rise in synchrony (A) with the rising tide until both gates close (B), blocking peak high tide from entering Clear Creek. After both gates close, Clear Creek can no longer drain, so water levels on the Clear Creek side of the gates slowly rise. The flap gate opens when the rising water level in the stream matches the elevation of the falling limb of the tide in the river (C). The slide gate opens at its preset point. Water levels then fall in synchrony (D) until a control on the base water elevation of Clear Creek prevents water levels in Clear Creek from falling further, creating a difference between the stream and river levels (E) at low tide.

The magnitude of this low tide difference ranged from less than 0.01 feet to approximately 0.75 feet during the monitoring period, with the larger differences correlated to lower stages in both Clear Creek and the Puyallup River. Given the distance between the two gages, the difference is most likely caused by the slope of the channel and differences in base water surface elevation when not backwatered by the tide. Other explanations for the difference could include:

- The inlet of the culvert or some other obstruction could be acting as a barrier at low flows.
- Debris accumulation on the trash rack may be impacting drainage.
- There may be a small survey error in the measured gage elevations.

The explanation for the difference could be resolved by surveying the area to derive accurate distance and elevation relationships or by observation of the culvert at low water.

7.0 Review of Potential Actions to Improve Tide Gate Function

Pierce County is currently pursuing the Clear Creek Floodplain Reconnection Project, which would include removal of the Clear Creek tide gates and construction of a ring levee to protect properties from flooding caused by removal of the tide gates. The timeline for implementation of the Clear Creek Floodplain Reconnection Project is at least 10 years. Because the project would not be constructed for at least 10 years, interim actions could be taken to improve tide gate function. ESA reviewed the feasibility of potential tide gate improvements to determine their feasibility as interim actions. The potential actions described in this section are not presented as alternatives to removal of the Clear Creek tide gates and the actions would not provide the same benefits to fish passage during high flows and flood events. The recommendations are presented at a conceptual level only. Further engineering design and analysis would be necessary to fully assess the suitability of any action for the Clear Creek area.

Potential actions to improve tide gate operations could include installation of new tide gates, structural modification of the existing tide gates, or modified operations of the existing tide gates. Actions could be undertaken to:

- Improve flood protection or the reliability of flood protection
- Increase drainage from Clear Creek into the Puyallup River
- Increase fish passage during normal conditions
- Increase fish passage during high flow conditions (flood events)

7.1 Flood Protection and Drainage Considerations

When the tide gates are functioning properly, they help to protect farms in the Clear Creek area from Puyallup River flooding. However, this area is also subject to flooding from Clear Creek and its tributaries. It should be noted that no modification to the tide gate would be able to completely prevent flooding in the Clear Creek area. In the 2009 flood event, it appears that the tide gates did not function properly and that Puyallup River floodwaters inundated the Clear Creek area. As described in Section 5, the slide gate was stuck partially open for a portion of winter 2016 - 2017; fortunately, no flood event occurred during that period. Potential actions could be undertaken to modify the tide gates in order to increase the reliability of the flood protection they provide.

Drainage through the Clear Creek tide gates could be improved by maximizing the amount of water flowing out from Clear Creek to the Puyallup River while limiting the amount of water

flowing back in from the Puyallup River to Clear Creek. The two most important factors in determining the amount of flow through a flap gate are the area of the gate opening and the head difference (difference in water level) from one side of the gate to the other. Studies have found that changes in the area of the opening are twice as effective at increasing flow as changes in the head difference (Repogle and Wahlin, 2003). Thus the most effective way to improve drainage through the tide gates would be to increase the amount of gate opening when Clear Creek is draining to the Puyallup River.

7.2 Fish Passage Considerations

Because the Farming in the Floodplain Project is focused on agricultural viability, this memorandum is primarily focused on flood protection and drainage for agricultural properties in the Clear Creek area. However, improvement to fish passage is also considered for each potential tide gate action discussed below. Tide gates affect fish passage in many ways. The most obvious effect is that when the gates are fully closed, fish access to potential refugia (i.e., shelter from high flows and predators) is blocked. Tide gates can also inhibit fish passage even when the gates are open and allowing water to pass. The two major considerations for fish passage through tide gates are the size of the gate opening and the water velocity. Studies have found that flap gates can remain fully closed up to 75 percent of the time (Giannico and Souder, 2005). Increasing the duration of gate opening would improve fish passage.

In addition, some types of tide gates, particularly older flap gate designs, may open only a few inches even when draining, which is insufficient for fish passage. The size of the opening required for unimpeded fish passage varies by species and life stage. For example, the Oregon Department of Fish and Wildlife (2015) recommends a minimum opening width of 4 feet. The existing wooden flap gate is unlikely to provide this large of an opening under almost any conditions.

High flow velocities coming out of the gate can also be a barrier, making it difficult for smaller fish to swim upstream. Larger gate openings also help to reduce flow velocity. Tide gates can also be predation hot spots where larger fish and birds wait for smaller fish forced through the narrow openings or disoriented by the sudden change in flow pattern.

7.3 Summary of Potential Interim Actions

This section describes the benefits, drawbacks, and feasibility considerations of the following potential actions:

- Modify operations of the slide gate by changing the open/close trigger
- Modify operations of the slide gate with a programmable logic controller
- Modify the wooden tide gate to reduce the amount of head needed to open the gate
- Replace the wooden tide gate with a new flap gate
- Install orifices for fish passage from the Puyallup River to Clear Creek

Section 7.3.6 includes descriptions of two additional potential actions which were considered but are not recommended.

7.3.1 Modify Operations of the Slide Gate by Changing the Open/Close Trigger Elevation

This action would modify the slide gate's set point to lower and raise the gate at higher river elevations. This is likely the simplest step that can be taken to improve both drainage and fish passage through the culvert. The current settings for the slide gate assembly cause it to lower while Clear Creek is still draining to the Puyallup River. The frequency of operation (once or twice daily) also contributes to unnecessary wear and tear on the slide gate assembly's mechanical components.

This action would keep the gate in the raised position longer. As suggested in the original 1995 design report, an iterative calibration period may be required to find the right balance between maximizing drainage and preventing flow from the Puyallup River from entering the Clear Creek area (Port of Tacoma, 1995a). During the monitoring period (described in Section 5), the river elevation at which the culverts switched from draining towards the Puyallup to filling towards Clear Creek was between 9.0 and 10.0 feet NAVD 88. This elevation range may provide a starting point for adjusting the slide gate assembly settings.

Alternatively, depending on the level of ongoing effort and maintenance desired, a schedule could be developed where maintenance staff would change the open/close set point seasonally to reflect variations in hydrology and drainage needs. During the dry season when water levels in the drainage ditches are down and the risk of flooding is low, the slide gate assembly could be left open longer. More protective settings could be implemented during the wet season. The slide gate could also be modified by preventing the flap gate mounted on the slide gate from latching shut when the slide gate is fully down.

This action could:

- Improve drainage from Clear Creek to the Puyallup River
- Allow for greater fish passage opportunities both into and out of Clear Creek
- Potentially reduce aquatic weed growth by providing greater flow circulation in the dry season
- Reduce wear and tear on slide gate components

A potential drawback of this action is that floodwaters from the Puyallup River could potentially enter the Clear Creek area. This would depend on the open/close set point elevation chosen and how quickly the river rises during flood stage. As described above, some iteration and calibration could be required.

Assuming that the mechanism is in good working order, resetting the open/close elevations for the slide gate should be simple and straightforward from a technical standpoint. More maintenance effort would be required to initially adjust the settings, and on an ongoing basis if a seasonally varying schedule were chosen.

As noted in Section 4, any alteration to the slide gate operations would require EPA concurrence to ensure the modifications are consistent with the Consent Decree. The Port and Pierce County would need to work closely together to ensure any changes do not increase flood risk.

7.3.2 Modify Operations of the Slide Gate by Installing a Programmable Logic Controller

Adding a programmable logic controller (PLC) and sensors to the slide gate assembly would provide a more complex and versatile option for controlling the raising and lowering of the slide gate assembly. A PLC is a simple computer which can be programmed to respond to preset schedules or triggers. This would allow for seasonal changes in slide gate operations without requiring a maintenance person to manually reset it. If paired with an array of water level sensors, the PLC could begin to make “smart” decisions about when to raise and lower the gate based on the time of year, how full the Clear Creek drainage ditches are, and tide predictions. This would make the system more complex, but would optimize the slide gate assembly’s operations by maximizing gate opening during periods when the risk or consequences of flooding are low and providing more protective gate closures when the drainage ditches are full or very high tides are predicted. This type of system may also have the capability to send notifications if the gate is not operating properly.

This action could:

- Allow the gate to be operated more flexibly based on real-time conditions
- Potentially allow for quicker repairs through automatic notification of problems
- Improve drainage by optimizing gate opening times and allowing Clear Creek to drain freely more frequently
- Improve fish passage into and out of Clear Creek by increasing gate opening durations

PLCs are relatively inexpensive, with the price depending on the level of complexity desired. PLCs are designed to be extremely durable. They require minimal training to program and are easy to reset.

Incorporating the PLC would add one more fallible part to the slide gate assembly because a reliable and persistent power supply and secure housing would be required. Also, the current gate components are 20 years old and may not be compatible with a modern PLC. There could be a learning curve for Port of Tacoma staff to learn how to program and troubleshoot the PLC. Developing a programming schedule could require significant physical data collection, analysis, and iteration. This would require ongoing engagement and cooperation from Drainage District 10,,the Port of Tacoma, and SWM. As described in Section 4, any modification to the slide gate operations would require concurrence from EPA. Port of Tacoma staff have stated that the PLC may not be a viable option due to complications associated with operations and maintenance (Port of Tacoma, 2017).

7.3.3 Modify the Wooden Flap Gate

The efficiency of the existing wooden flap gate could be increased by making it "lighter" so that less force would be required to open it and hold it open. This would result in a wider gate opening for the same head difference, reduce head loss, and promote better drainage. Lightening the gate could be accomplished by removing some of the counterweights from the gate, if it is weighted (many wooden gates are); replacing the hinges to ensure it hangs level and opens without resistance; or adding an additional opening force, as described below.

The most common approaches for applying a supplemental opening force to a tide gate involve some type of device, such as a winch and cord that support a portion of the gate's weight or by modifying the geometry of the hinges or gate itself to change the location of the center of mass relative to the hinge axis. These modifications would allow the gate to open more easily from the closed position, but to still close promptly when water levels rise on the Puyallup River.

This action could:

- Improve drainage by reducing the head difference required to open the gate, increasing the amount of time the gate is partially open and allowing Clear Creek to drain more effectively
- Potentially improve fish passage by causing the gate to open more widely and increasing the amount of time the tide gate was open

The retrofits discussed here would be relatively inexpensive and simple to implement, provided the wooden flap gate has sufficient structural integrity to be modified. Retrofits that apply an additional opening force can generally be easily adjusted to achieve the desired level of gate opening.

Since ownership of the wooden flap gate is uncertain, it is unclear who would undertake and maintain any modifications. Before the tide gate was modified, its condition would need to be assessed as described below in Section 8.1. Adding an opening force to the tide gate could require structural modifications to the tide gate to withstand the force. Additional maintenance and monitoring would be required in the period immediately following gate modification to ensure that it is functioning as desired and to identify and implement any needed adjustments.

7.3.4 Replace the Wooden Flap Gate with a New, Fish-Friendly Flap Gate

Flap gate design has advanced significantly since the existing wooden flap gate was installed on Clear Creek. Modern tide gates are lighter and come in a wide range of different geometries that allow for larger gate openings when the culvert is draining, but provide the same level of flood protection during high water events. This option may be the most appropriate if inspection finds the existing gate to be substantially deteriorated. Replacing the existing wooden flap gate with an aluminum gate would make the gate easier to open and more resistant to beavers and decay.

There are many types of tide gates available that might operate more efficiently than the existing flap gate, both for drainage and for fish passage. New tide gate designs that optimize fish passage

are widely available. New, fish-friendly flap gates operate passively and have a low probability of failure.

Revising the geometry of the existing flap gate to make the gate vertical instead of angled would reduce the amount of force required to open the gate and could lead to longer periods of opening wide enough to allow fish passage. This would require physical modifications to the downstream end of the culvert, likely adding additional concrete, to change its angle. This work would be similar to the modifications that were likely done to the other barrel of the culvert when the slide gate assembly was installed.

Side hinged tide gates have been shown to be effective at increasing drainage and fish passage, while providing equivalent flood protection (Giannico and Souder 2005). Because they are hinged on the side, like doors, they require very little head difference to open fully. Side-hinged tide gates require a vertical frame, so this option would also require physical modifications to the culvert.

The document *Tide Gates in the Pacific Northwest* (Giannico and Souder, 2005) includes a broad discussion of types of tide gates and the advantages and disadvantages of each. Selection of a specific tide gate design would need to be part of a collaborative process involving agricultural, fish habitat, and flood risk reduction stakeholders.

This action could:

- Improve drainage and fish passage by increasing how wide the gate opens and the duration of favorable conditions for fish passage
- Potentially reduce ongoing maintenance costs
- Likely increase the reliability of flood protection over the current wooden flap gate, which has not been maintained

Replacing the existing wooden flap gate would be more expensive than the other options discussed thus far. Modifications to the end of the culvert are likely to be a significant portion of the cost, so if cost is a controlling factor, it could be worth further exploring replacement options that work with the existing culvert geometry. Side hinged tide gates can be very sensitive to the geometry of the frame and the hinges and require more monitoring and maintenance than top-hinged designs to ensure proper functioning.

In-water work to revise the geometry of the gate would require a number of federal, state, and local permits. Acquiring these permits could be time consuming and expensive. Since ownership of the wooden flap gate is uncertain, it is unclear who would be the lead for permitting and who would have responsibility for installing a replacement gate and undertaking the required maintenance.

7.3.5 Orifices for Fish Passage

Another option to provide fish access to the Clear Creek area even when the tide gates are closed would be to add fish passage orifices to the tide gates. Fish passage orifices are small openings located beside or above the tide gates which are designed to allow juvenile fish passage during

high flow events. Juvenile salmon prefer to stay near the water's surface and the river edge, especially during floods. Consequently, the orifices should be positioned at appropriate elevations to be near the water surface during the design flood. Multiple orifices can be stacked vertically to provide fish passage at a range of water surface elevations. Because the orifices are small, they do not allow enough flow through to significantly increase water levels upstream of the tide gates.

This action was implemented by Drainage District 7 in King County, just north of Duvall, over 10 years ago as part of a larger fish passage retrofit of its tide gate system which also included a side-hinged tide gate and fish-friendly pump systems. The District installed three 4-inch wide by 8-inch tall orifices, each at a different elevation on their flood wall, so that the rising floodwaters would encounter them one by one.

Installing fish passage orifices on the Clear Creek culvert would require physical modifications to the end of the culvert. Because flood elevation is generally above the top of the tide gates, a riser would have to be added to the top of the culvert to allow water and fish to enter the culvert at higher water levels. The orifices would be stacked vertically on the front of the riser, and water would free-fall from the orifice to the water surface within the culvert. Because this option requires a physical modification to the culvert it is more likely to be cost effective when paired with one of the tide gate replacement options rather than as a stand-alone action.

This action could:

- Improve fish passage from the Puyallup River to Clear Creek during high flows (flood events)
- Create access to otherwise inaccessible flood refugia

This action would create small, likely insignificant, increases in water level in the Clear Creek area during floods. Modeling of the change in flood water levels during floods would be required. Because this method has not been widely implemented or studied, it is not known how effective it would be at providing fish passage. This action would not improve drainage.

The costs and complexity of physical modifications to the culvert and the uncertainties relating to ownership have been discussed above. However, incorporating fish passage orifices as part of a larger tide gate replacement project would not significantly increase the overall cost and effort involved.

It is unclear whether this approach has been implemented by other entities than King County Drainage District 7. In addition, no follow-up monitoring has been conducted to verify if fish are using the orifices installed by Drainage District 7. Before such an approach could be considered for the Clear Creek area, it would first need to be demonstrated that it could be effective. Follow-up monitoring of the Drainage District 7 fish orifices could be conducted. Alternately, observations of fish use of similar orifices could be conducted in a controlled setting, such as a hatchery.

7.3.6 Actions Considered But Not Recommended

Two additional actions were considered during the preparation of this memorandum, but are not described in detail or recommended because the review of potential interim actions determined

they are not feasible for the Clear Creek area. These actions include modifying operations of the slide gate by keeping the gate in a closed position at all times and replacing the wooden tide gate with a new slide gate.

Keeping the slide gate in a closed position at all times could improve the reliability of protection from Puyallup River flows entering the Clear Creek area through the tide gates during a flood and would also eliminate the risk of the slide gate becoming stuck in the open position. However, this action would also impair drainage, have a negative impact on fish passage, and be in direct conflict with the Consent Decree that governs operations of the slide gate. Therefore, the action would be infeasible and undesirable.

The wooden flap gate could be replaced with a slide gate assembly similar to the one on the other culvert barrel. This would improve drainage and fish passage. However, this action would also add to the complexity of maintenance and operation of the tide gates, be difficult to permit, and be expensive to install. If the wooden flap gate were to be replaced with a new tide gate, a fish-friendly flap gate (as discussed above in Section 7.4) would be preferable.

8.0 Recommendations

This section includes two general recommendations for the Clear Creek tide gates and four recommendations relating to the potential actions described in Section 7.

8.1 General Recommendations

Recommendation #1: Determine responsibility for operation, ownership, and maintenance of the tide gates

Pierce County Surface Water Management, Drainage District 10, the Port of Tacoma, EPA, the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, the Puyallup Tribe, and potentially WSDOT should meet to determine the ownership and maintenance responsibilities for the tide gates. The entities should evaluate current operation of the tide gates to determine if they are operating as they should and develop a plan to provide the best flood protection, drainage, and fish passage. This plan should be captured in an interlocal agreement that defines responsibility for maintenance of the tide gates. Reaching an agreement on culvert and tide gate ownership would be a prerequisite to any successful improvement to the wooden flap gate.

Recommendation #2: Assess condition of wooden tide gate and repair if needed

The physical condition of the wooden flap gate should be assessed. The assessment should include evaluation of the water tightness of the gate and seal against opening, the structural condition of the gate itself, and the condition of the hinges. Assessing the physical condition of the wooden flap gate would need to be conducted by a qualified structural engineer. After assessing the gate, the engineer could prepare a memorandum with recommendations for repairing any weaknesses, including a discussion of the risk of delaying repair actions. Based on the recommendations, any urgent repairs should be conducted to ensure the continued reliability of flood protection and tide gate operations. This action could identify needed repairs that could

improve the reliability of flood protection, improve the ability of water to drain out through the tide gate, and improve fish passage.

Assessing the current condition of the wooden tide gate is a relatively simple action that should be undertaken in the short term. If the wooden tide gate is not in good structural condition, it would be helpful to know that as soon as possible. Information about the condition of the wooden tide gate would also provide useful information about the feasibility of modifications to the gate. This action should be considered for inclusion in the next phase of the Farming in the Floodplain Project.

8.2 Recommended Actions

Table 1 below summarizes the benefits, drawbacks, and feasibility considerations of the seven actions discussed above in Section 7. Recommendations 3 through 6 are based on the benefits and drawbacks of each potential action.

TABLE 1 SUMMARY OF POTENTIAL TIDE GATE ACTIONS

Section where Action is Described	Potential Action	Impacts				Feasibility Considerations
		Reliability of Flood Protection from the Puyallup River	Drainage (Clear Creek to Puyallup River)	Fish Passage (normal conditions)	Fish Passage (high flow conditions)	
7.3.1	Adjust Open/Close Set Point of the Slide Gate	Potential for minor negative or positive	Positive	Positive	Unchanged	More maintenance potentially required. Iterative calibration period required to set up. Adaptive management with local landowners and Drainage District 10 required.
7.3.2	Install Programmable Logic Controller for Slide Gate	Unchanged	Positive	Positive	Unchanged	Adds more mechanical parts to the slide gate that could fail. Minor costs and learning curve.
7.3.3	Modify Wooden Gate	Unchanged	Positive	Positive	Unchanged	Unclear ownership complicates implementation. Requires gate to be in good physical condition. Relatively inexpensive.
7.3.4	Replace Wooden Gate with New Flap Gate	Positive	Positive	Positive	Unchanged	Unclear ownership complicates implementation. More expensive than other options. Permitting and construction needs would be substantial.
7.3.5	Install Orifices for Fish Passage During High Flow Conditions	Minor negative	Unchanged	Unchanged	Positive	Examples of this approach have not been monitored to assess success. Relatively inexpensive if paired with other tide gate alterations.

Recommendation #3: Modify wooden tide gate

Modifying the wooden tide gate so that less force is needed to open the gate and keep it open is a relatively low-cost action that should be pursued. This action could be implemented as an interim measure even if the tide gates were eventually removed as part of the Clear Creek Floodplain Reconnection Project. The next phase of the Farming in the Floodplain Project could include feasibility analysis for this action. The feasibility analysis could include modeling to determine whether the modification would provide measurable benefits to drainage in agricultural areas.

Recommendation #4: Discuss options to modify operations of the slide gate with the Port of Tacoma

Two of the potential actions include changes to the operation of the slide gate to increase the amount of time the slide gate is open, allowing greater drainage and fish passage. One would use a period of calibration to determine the ideal open/close set point for the slide gate while the other would install a programmable logic controller to make the slide gate operations more dynamic. Both actions would be a benefit to agricultural drainage as well as fish passage by allowing the slide gate to be in a raised position more frequently and for longer periods of time. These actions would need to be undertaken by the Port of Tacoma, the owner and operator of the slide gate. The Port of Tacoma may be reluctant to pursue these actions, which would require an investment of staff time and could increase maintenance needs for the slide gate. Floodplains for the Future partners should discuss these potential actions with the Port of Tacoma and encourage the Port to consider implementing them.

Recommendation #5: The Floodplains for the Future Habitat Group could explore the idea of adding orifices to the tide gates

Installing orifices that could allow fish passage from the Puyallup River to Clear Creek during flood events could benefit fish passage, but would not improve agricultural viability. The Floodplains for the Future Habitat Group should explore this potential action. As described in Section 7.5, no follow-up monitoring has been conducted where fish orifices have been constructed. If this approach was to be implemented in the Clear Creek area, it would first need to be demonstrated that it could be effective. As with other potential actions discussed in this memorandum, installation of fish orifices would not achieve the level of fish passage benefits that would be realized by removal of the tide gates and is not recommended as an alternative to that action.

Recommendation #6: Pursue replacing the wooden flap gate as a long-term option if the tide gates will not be removed

Replacement of the wooden flap gate with a new, fish-friendly flap gate would improve drainage, fish passage, and the reliability of flood protection. However, the action would be expensive and the permitting and construction needs would be substantial. Therefore, this action is unlikely to be cost effective if the tide gate would be removed in the future as part of the Clear Creek Floodplain Reconnection Project. If that project is not pursued in the future, or if the project plans change and no longer include removal of the tide gates, this action should be considered as a long-term option to improve operation of the tide gates.

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