Appendix B. Mill Creek MOIP TM

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Draft Mill Creek Multi-Objective Improvements Plan

Culvert Crossings Alternative Evaluation

City of Cosmopolis, Washington

April 1, 2026

Contents

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Abbreviations

1D	one-dimensional
AACE	Association for the Advancement of Cost Engineering
ADS	Advanced Drainage Systems, Inc.
BE	biological evaluation
Berglund Schmidt	Berglund Schmidt & Associates, Inc.
CFR	Code of Federal Regulations
cfs	cubic foot/feet per second
City	City of Cosmopolis
CMP	corrugated metal pipe
DAHP	[Washington State] Department of Archaeology and Historic Preservation
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
fps	foot/feet per second
ft	foot/feet
GIS	geographic information system
HDR	HDR Engineering, Inc.
HEC-RAS	Hydrological Engineering Center River Analysis System
LiDAR	light detection and ranging
MOIP	Multi-Objective Improvement Plan
N/A	not applicable
NAVD88	North American Vertical Datum of 1988
NGVD	National Geodetic Vertical Datum
NMFS	National Marine Fisheries Service
O&M	operations and maintenance
OPCC	opinion of probable construction cost
RCB	rectangular concrete box
ROW	right-of-way
SEPA	State Environmental Policy Act
TM	technical memorandum
USACE	United States Army Corps of Engineers
USC	United States Code
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WDFW	Washington Department of Fish and Wildlife
WISAARD	Washington Information System for Architectural and Archeological Records Data
WRIA	Water Resource Inventory Area

WSE	water surface elevation

Appendices

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1 Introduction

The purpose of this technical memorandum (TM) is to evaluate culvert crossing improvements and/or a high-flow bypass for localized flood reduction along a stretch of Mill Creek, located between C and Altenau streets in the City of Cosmopolis. Mill Creek is a perennial stream that outlets to the Chehalis River. Documented coho salmon spawning occurs in the creek downstream of Mill Creek Pond. It is recommended that fish passage characteristics at the culvert crossings should be maintained or improved. A location map depicting the evaluation limits and Mill Creek landmarks is provided as Figure 1-1. The feasibility and alternatives evaluation are part of the City of Cosmopolis's (City's) Mill Creek Multi-Objective Improvement Plan (MOIP).

1.1 Background

The City developed the Mill Creek MOIP following a dam breach in November 2008. The goal of the Mill Creek MOIP is to assess the Mill Creek system between the existing Mill Creek Pond and the three tide gates where Mill Creek outlets to the Chehalis River.

The original Mill Creek MOIP evaluation, which was completed in 2013, is outlined in the *Mill Creek Dam Improvements Project* TM, hereafter referred to as the Mill Creek Dam TM. The Mill Creek MOIP goals are detailed within the City of Cosmopolis *Multi-Objective Plan for Mill Creek* Memorandum from 2014. A copy of these documents are provided in Appendix F.

Key components of the Mill Creek Multi-Objective Improvement Plan include the following:

- **Repair or replace Mill Creek Dam and Mill Creek Pond:** The dam replacement, pond repair, gravel walking trail and footbridges near the pond, and construction of a fish ladder leading to the pond were all constructed and declared complete in 2018. Mill Creek Dam and pond are not a part of this evaluation.
- **Evaluate function for the tide gates on Mill Creek, located upstream of the confluence with the Chehalis River:** An assessment of tide gate operations may improve Mill Creek stream and localized flooding (because of backwater effects) and may also improve conditions at the fisheries. Recommendations for completion of a tide gate study will be included with the Cosmopolis Stormwater Comprehensive Plan and are not a part of this evaluation.
- **Address intermittent localized flooding downstream of Mill Creek Dam along F, G, H, and Altenau streets:** The culvert at C Street experienced issues during the 2008 dam breach event and contributed to flooding in Mill Creek Park and the footbridge area. This is included with this evaluation.

The focus of this TM is to evaluate the Mill Creek culvert crossings between Altenau and C streets and determine if culvert improvements and/or construction of a high-flow bypass are feasible and beneficial for flood reduction.

LOCATION MAP

Figure 1-1

MILL CREEK MOIP CULVERT CROSSING ALTERNATIVE EVALUATION

1.2 Objective and Authorization

The purpose of the Mill Creek Culvert Crossing Evaluation (hereafter called the Mill Creek Crossing Study) is to meet the 2008 Mill Creek MOIP goal to evaluate localized flood reduction benefits through culvert crossing replacements along a 0.7-mile-long section of Mill Creek, located within the city limits.

The Mill Creek Crossing Study includes evaluation of two alternatives. The first, Alternative A, evaluates culvert replacements at C, E, F, G, H, and Altenau streets coupled with localized channel improvements directly upstream and downstream of the crossings. The second, Alternative B, evaluates culvert replacements at C, F, and Altenau streets coupled with a high-flow bypass that diverts 98 cubic feet per second (cfs) from Mill Creek's main channel during the 100-year flood event. Alternatives evaluation criteria include feasibility and performance for flood reduction during flood events and fish passage improvements at the crossings. The Mill Creek Crossing Study scope includes the following activities:

1. Review available information, including the Mill Creek Dam and Mill Creek MOIP reports.
2. Survey the existing culvert crossings between C and Altenau streets to supplement available survey data obtained from the Mill Creek Dam replacement project. Berglund Schmidt & Associates, Inc. (Berglund Schmidt) completed survey work in May 2023 by as part of prior Mill Creek MOIP work.
3. Conduct a field review at the culvert crossings and accessible sections of the potential high-flow bypass alignment. HDR Engineering, Inc. (HDR) staff completed a field review on November 11, 2022. A copy of the photos is provided in Appendix A.
4. Conduct screening and development of potential alignment for the high-flow bypass, Alternative B.
5. Perform hydrologic and hydraulic modeling of Mill Creek between Mill Creek Dam to downstream of the Altenau Street crossing:
   a. Review hydrologic and hydraulic modeling completed with the Mill Creek Dam replacement project and adopted Mill Creek MOIP planning documents
   b. Update the existing-condition Mill Creek and culvert crossing hydraulic model from the Mill Creek Dam project based on survey data provided by Berglund Schmidt
      i. Develop a hydraulic model of existing conditions to establish a hydraulic baseline for comparison against the two alternatives
      ii. Complete a sensitivity analysis using the hydraulic model to evaluate potential backwater effects to the existing culvert crossings from the Mill Creek tide gates
   c. Develop proposed-condition hydraulic models for each proposed alternative.
6. Develop a qualitative evaluation matrix to score and rank the two alternatives. The evaluation matrix includes flood reduction, fish passage, and technical and cost criteria.
7. Develop improvement plan recommendations with prioritization for the selected alternative.

8. Prepare planning-level opinions of probable construction cost (OPCCs).

2 Existing Conditions

This section provides a brief overview of Mill Creek existing conditions and highlights conditions within the report study limits.

2.1 Land Cover, Topography, and Drainage

Mill Creek is a perennial stream that originates in the hillsides southeast of Mill Creek Pond and is fed by both runoff and groundwater seepage. The Mill Creek tributary basin is approximately 1,280 acres and contains a mix of residential development, recreational area, and undeveloped second-growth forest. Mill Creek Dam is located directly upstream of the C Street roadway; the dam does not provide adequate active storage to attenuate Mill Creek peak flow rates. Refer to Figure 1-1 above for the Mill Creek alignment through the city of Cosmopolis and to Figure 2-2 for an overview of the Mill Creek tributary basins.

Topography along the project limits is generally flat. Mill Creek invert elevation ranges from 16.5 to 10.0 feet between C and Altenau streets. Channel slopes along this section of Mill Creek average 0.4 percent. Drainage along the tributary subbasins generally flows to the northwest and either surface-flows into the creek or is collected within different localized storm sewer systems that directly outlet into the creek. This reach of Mill Creek is approximately 2,300 feet long and meanders through a developed residential area. The stream is channelized and artificially armored with riprap- and/or concrete-lined embankments in sections with little to no overhead cover. The Mill Creek MOIP report (Cosmopolis 2014) defined this reach of Mill Creek as a migratory corridor for coho salmon between the Chehalis River and Mill Creek Dam. See Section 2.3 for further discussion on fish passage and environmental considerations.

Mill Creek passes through six culvert crossings. The average open-channel depth in this reach is between 6.5 and 7.8 feet. All six roadway crossings are multiple circular culvert installations. Photos of the existing culvert crossings with bank conditions are provided in Appendix A, and Table 2-1 lists the existing culvert characteristics.

Downstream from the Altenau Street culvert crossing, located past I Street, Mill Creek banks to the east and enters a shallow estuary that is tidally influenced from the Chehalis River. The tide gates are normally open and close during high-tide or storm events. Water pressure causes the tide gates to close and block fish passage from the Chehalis River to Mill Creek during these periods. The Mill Creek Operations and Maintenance Manual (Cosmopolis 1998) notes that the tide gate floats are set at elevation 8.0 feet National Geodetic Vertical Datum (NGVD) from March through October and at 4.5 feet NGVD from November through February. When the water level reaches the float the tide gates close.

See Section 2.2 for peak flow events and 100-year water surface elevation (WSE).

2.1.1 Existing Culvert Crossings

There are six culvert crossings within the evaluation area. Table 2-1 below provides a summary of the existing Mill Creek culverts.

Table 2-1. Existing culvert crossing summary

Street	Culvert size, type, and length	Observed flow depth (in)[a]	Observed flow depth (in)[b]	Sediment in culvert	Fish barrier status	Stream conditions
C	Two 48-inch-diameter CMP with concrete headwall and wingwall, each 45 ft long	4	14	No	Yes	Upstream and downstream banks are earthen and vegetated. Culvert was identified by the Mill Creek Dam TM as a potential velocity barrier for smaller or weaker fish.
E	Two 60-inch-diameter lined CMP with concrete headwall and wingwall, each 67 ft long	6	15	No	Yes	Downstream: Sheet pile on downstream right bank (50 ft); rock wall on left bank.
F	Three 48-inch-diameter CMP with concrete headwall and wingwall, each 122 ft long	6–9	16	No	No	Downstream: Sheet pile on downstream right bank (50 ft). Survey noted that three of the pipes may be curved or have a bend.
	One 18-inch-diameter ADS pipe (high flow only), 118 ft long.	None	None	No	No	Pipe invert set at ±3 ft above the other three culverts within the same headwall. This culvert operates in high-flow conditions.
G	One 60-inch-diameter CMP with concrete headwall, culverts protruding on upstream side only, 96 ft long	6	8	Yes	Yes	Downstream: 4 ft rock wall with concrete chunks and sheet pile upstream; rock wall and poured concrete downstream.
H	One 60-inch-diameter CMP with concrete headwall and wingwall, 81 ft long	12	22	Yes	No	Upstream: 100% hydromodified between H and G streets.
Altenau	One 60-inch CMP that protrudes from a concrete headwall, 95 ft long	6–9	17	Yes	No	Downstream: Right bank is 100% hydromodified; left bank appears to be natural. Survey noted that a storm line tees directly into one of the culverts.

[a] Reported conditions from Mill Creek Park Dam Trip Report, 12/21/2011.
[b] Reported conditions at culvert crossings from Berglund Schmidt survey, 5/30/2023.
ADS = Advanced Drainage Systems, Inc.; CMP = corrugated metal pipe; ft = feet.

2.1.2 Site Reconnaissance and Photos

HDR conducted a site review on November 11, 2022, to obtain photos of the existing Mill Creek culvert crossings, Alternative B bypass alignment, and existing Mill Creek tide gates. Select photos from the site review are included in Appendix A. The majority of Mill Creek between C and Altenau streets is located on private residential property and access was available only from the road right-of-way (ROW) at the culvert crossings.

The site reconnaissance included review of the Alternative B high-flow bypass facility alignment. A section of the high-flow bypass alignment was accessed at the southwest end of E Street. Some sections of the high-flow bypass facility alignment were not accessible during the field reconnaissance. Information for areas that were inaccessible was sourced from geographic information system (GIS) data from Grays Harbor County online.

The city of Cosmopolis experienced a flooding event on January 6, 2022, with localized flooding that exceeded bank capacity in Mill Creek Park and C, E, F, H, and Altenau streets. Photos of the flooding event are provided in Appendix A. The Mill Creek Dam TM (HDR 2013) reported occasional localized downstream flooding along G, H, and I street crossings.

2.1.3 Soil and Groundwater

Soils information for Mill Creek within the analysis area was obtained from the Natural Resources Conservation Service's online Web Soil Survey (NRCS 2011). Soils within the Mill Creek culvert crossing area are primarily Mopang Silty Loam, which is described as well or moderately well drained soils that formed in glaciofluvial sediments. Refer to Figure 2-1 for the Mill Creek soils map. A copy of the area soils map and excerpts from the NRCS soils report are provided in Appendix B.

While soils within the area have the potential to be well drained because of their proximity to Mill Creek, the estimates prepared for this TM assume that soils will be saturated and unsuitable for reuse. A specific project geotechnical investigation is recommended early in the design process for the selected alternative.

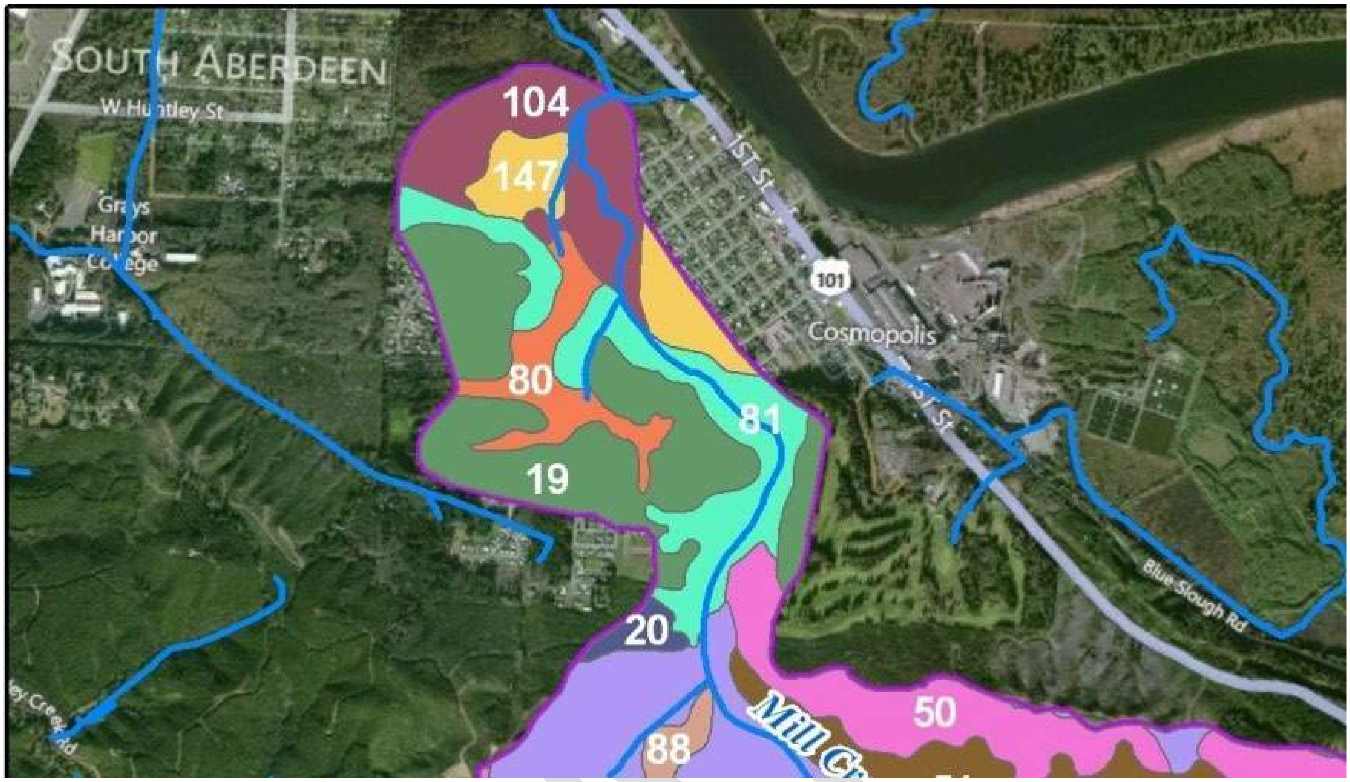


Figure 2-1. NRCS soil survey map

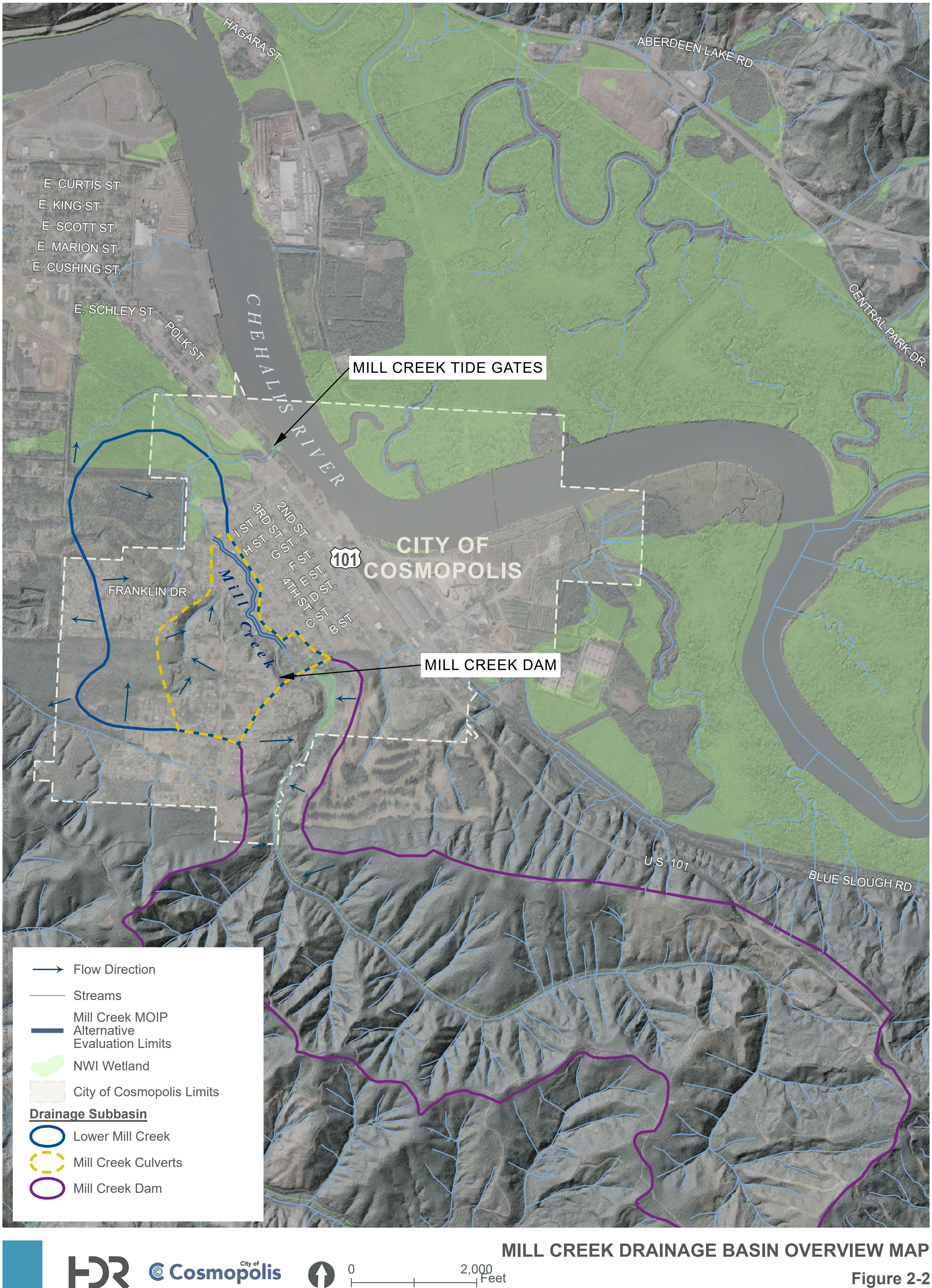
The Mill Creek Dam construction documents describe flows within the creek as variable and uncontrolled with no flow gages on Mill Creek. The construction documents included an estimated in-water flow exceedance for the fish ladder window. A copy of Mill Creek Dam construction documents with the in-water flow exceedance charts is provided in Appendix F. It is recommended that stream flow monitoring be considered as part of study of the tide gate or as part of the selected alternative preliminary design.

2.1.4 Drainage Basin

The Mill Creek drainage basin adopted by the United States Geological Survey (USGS) and referenced from Mill Creek Dam design is provided in Appendix F. The drainage basin contains the following two tributary subbasins:

- The first subbasin originates in the foothills and watershed area that drains to the Mill Creek Dam, spillway, and fish ladder area.
- A second subbasin is located between Mill Creek Dam to the Mill Creek estuary, downstream of Altenau Street.

Figure 2-2 depicts the Mill Creek drainage area that is referenced from the Mill Creek Dam TM and the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) for Grays Harbor County and Incorporated Areas (FEMA 2020). Mill Creek drainage tributary area and flows are detailed in Section 2.2.



HDR City of Cosmopolis

MILL CREEK DRAINAGE BASIN OVERVIEW MAP

Figure 2-2

2.2 Federal Emergency Management Agency

On February 23, 2017, FEMA issued an updated map that shows the effects of construction of a flood control levee along the Chehalis River in the vicinity of Mill Creek. Any proposed modifications to Mill Creek as part of the project will need to be made in accordance with the FEMA regulations (National Flood Insurance Act of 1968, as amended, United States Code [USC] Title 42 Sections 4001–4128 and Code of Federal Regulations [CFR] Title 44 CFR Part 65) that were established to ensure that base flood elevations do not increase.

A copy of Map 53027C0909D for the community of the City of Cosmopolis (530059) and select sheets from the associated Flood Insurance Study (FIS) for Grays Harbor County and Incorporated Areas (Rev. 9/18/2020), including Mill Creek drainage above Altenau Street, are included in Appendix F. Table 2-2 contains a list of peak discharge flows for various annual chance events.

Table 2-2. FEMA FIS Mill Creek annual chance event peak discharge summary

Location	Drainage area in square miles	10% annual chance event peak discharge (cfs)	2% annual chance event peak discharge (cfs)	1% annual chance peak discharge (cfs)	0.2% annual chance peak discharge (cfs)
Mill Creek at Altenau Street	2.00	144	281	331	530

The flood profile for the 1 percent annual chance flood event (aka 100-year flood event) for the Altenau Street crossing and downstream channel is listed as 11.5 feet in elevation (North American Vertical Datum of 1988 [NAVD88]). Because this WSE is based on the Mill Creek tide gate settings, the FEMA FIS flood profile indicates that the WSE remains at 11.5 feet for both the 2 percent and 10 percent annual chance floods.

2.3 Environmental and Critical Areas

This section of Mill Creek is located within Washington Water Resource Inventory Area (WRIA) 22. A biological evaluation (BE) and environmental fisheries habitat assessment study were completed as part of the Mill Creek Park and Dam Improvements project (HDR 2015), hereafter referred to as the Mill Creek Dam BE study. Per the Mill Creek Dam BE study, Mill Creek is a tributary to the Chehalis River and flows through timber-harvested land for approximately 3 miles, through Mill Creek Park, and through the city of Cosmopolis for another mile before discharging to the Chehalis River. Mill Creek was inventoried as a perennial stream with no natural barrier to the Chehalis River and is designated as a Type F stream. A replacement dam was constructed with fish ladder, park, and stream bank improvements in 2018. The Mill Creek Dam project improvements are upstream and outside of the evaluation limits.

Although Mill Creek is not on the 303(d) list of impaired water bodies in Washington, fish health in the creek may be impacted by 6PPD-quinone, a toxic tire derivative, likely entering the creek via roadway runoff. Future consideration for stormwater treatment retrofit of streets near Mill Creek should consider the impact of road runoff on coho salmon and other salmonids from this pollutant. Such consideration should focus first on higher traffic streets like Highway 101.

There are mapped critical areas on Mill Creek at Mill Creek Pond and in the estuary that is near the Mill Creek confluence with the Chehalis River. Both mapped areas are outside of the culvert crossing evaluation limits.

It should be noted that the Alternative B bypass alignment crosses a natural spring, located at the end of F Street. There may be additional environmental challenges associated with construction in this area.

2.4 Cultural Resources

A desktop review was completed using the Washington State Department of Archaeology and Historic Preservation (DAHP) Washington Information System for Architectural and Archeological Records Data (WISAARD), an online GIS-based interactive map, with the following results:

- The archeological risk assessment model indicates that the culvert crossings are within an area designated as a very high risk of archeological resources and a survey is highly advised.
- The project is located within the Confederated Tribes of the Chehalis Reservation area of interest.
- There were no listings for buildings or properties on the historic register along this section of Mill Creek.

It is recommended that a cultural-resources review be completed should the selected alternative proceed to the design phase. Alternative B crosses undeveloped areas with a natural spring where it crosses F Street projected ROW. There may be added risk of encountering cultural resources in this area.

3 Alternatives Options

Two alternatives were assessed for potential flood reduction benefits. This section outlines the steps used to identify and evaluate the potential flood reduction benefit for each alternative.

3.1 Alternative A: Culvert Replacement

Alternative A proposes the replacement of existing culverts at C, E, F, G, H, and Altenau streets. A list of proposed culvert replacements and improvements is provided in Table 3-1. Existing culvert characteristics are listed in Table 2-1 above. Altenau Street culvert replacement includes replacement of a failing boardwalk structure along its south edge.

Table 3-1. Alternative A proposed improvements

Street	Proposed culvert size, type, and length	Affiliated improvements	Stream conditions
C	10 ft wide × 5 ft high 3-sided concrete box culvert, 45 ft long	The box culvert includes a concrete headwall with 45-degree wingwalls; the culvert sides include 5 ft of wall depth and a concrete footing for stabilization and scour resistance	Improvements include 20 ft of upstream and downstream bank stabilization and stream bed replacement, along with restoration of preexisting fences, landscaping, etc.
E	10 ft wide × 5 ft high 3-sided concrete box culvert, 67 ft long	The box culvert includes a concrete headwall with 45-degree wingwalls; the culvert sides include 5 ft of wall depth and a concrete footing for stabilization and scour resistance	Improvements include 20 ft of upstream and downstream bank stabilization and stream bed replacement, along with restoration of preexisting fences, landscaping, etc.
F	10 ft wide × 5 ft high 3-sided concrete box culvert, 118 ft long	The box culvert includes a concrete headwall with 45-degree wingwalls; the culvert sides include 5 ft of wall depth and a concrete footing for stabilization and scour resistance	Improvements include 20 ft of upstream and downstream bank stabilization and stream bed replacement, along with restoration of pre-existing fences, landscaping, etc.
G	10 ft wide × 5 ft high 3-sided concrete box culvert, 96 ft long	The box culvert includes a concrete headwall with 45-degree wingwalls; the culvert sides include 5 ft of wall depth and a concrete footing for stabilization and scour resistance	Improvements include 20 ft of upstream and downstream bank stabilization and stream bed replacement, along with restoration of preexisting fences, landscaping, etc.
H	12 ft wide × 5 ft high 3-sided concrete box culvert, 81 ft long	The box culvert includes a concrete headwall with 45-degree wingwalls; the culvert sides include 5 ft of wall depth and a concrete footing for stabilization and scour resistance	Improvements include 20 ft of upstream and downstream bank replacement and stabilization, along with restoration of preexisting fences, landscaping, etc. Reconnection of an existing storm line that tees directly into the culvert.
Altenau	12 ft wide × 5 ft high 3-sided concrete box culvert, 95 ft long	The box culvert includes a concrete headwall with 45-degree wingwalls; the culvert sides include 5 ft of wall depth and a concrete footing for stabilization and scour resistance	Improvements include 20 ft of upstream and downstream bank replacement and stabilization, along with restoration of preexisting fences, landscaping, etc. Reconnection of an existing storm line that tees directly into the culvert.

ft = feet.

The culvert replacements include replacement and/or installation of new headwalls and bank stabilization on the upstream and downstream ends of the pipe. Figure 3-1 depicts the culvert replacement locations.

HDR City of Cosmopolis

0 500 Feet

ALTERNATIVE A
Figure 3-1

MILL CREEK MOIP CULVERT CROSSING ALTERNATIVE EVALUATION

3.2 Alternative B: Culvert Replacement with High-Flow Bypass

Alternative B includes construction of a 30-foot-long lateral weir and diversion structure on the west bank of Mill Creek, downstream of the C Street culvert crossing. This alternative includes the following features:

- C, F, and Altenau streets culvert replacements.
- A high-flow bypass off Mill Creek starting between C and E streets and reconnecting after the Altenau Street culvert. The high-flow bypass conveys diverted Mill Creek flows northwest in undeveloped City ROW to Altenau Street where it is aligned to the south. The conveyance system outlets on the downstream end of the Altenau Street/Mill Creek crossing.
    - An 8-foot-wide, 4-foot-high, rectangular concrete box (RCB) that is approximately 1,700 feet long
    - Maintenance access along the RCB bypass provided every 500 feet or less as maintenance hole chimney type access
    - Fish exclusion at upstream and downstream end of RCB bypass
- A 30-foot lateral weir with fish barrier on the upstream side of the RCB bypass. The weir is placed in a cast-in-place diversion structure and placed approximately 3 feet above the bottom of the channel. The weir crest elevation is set at 17.28 feet to allow 98 cfs to be diverted from Mill Creek.

Alternative B improvements are summarized in Table 3-2 below.

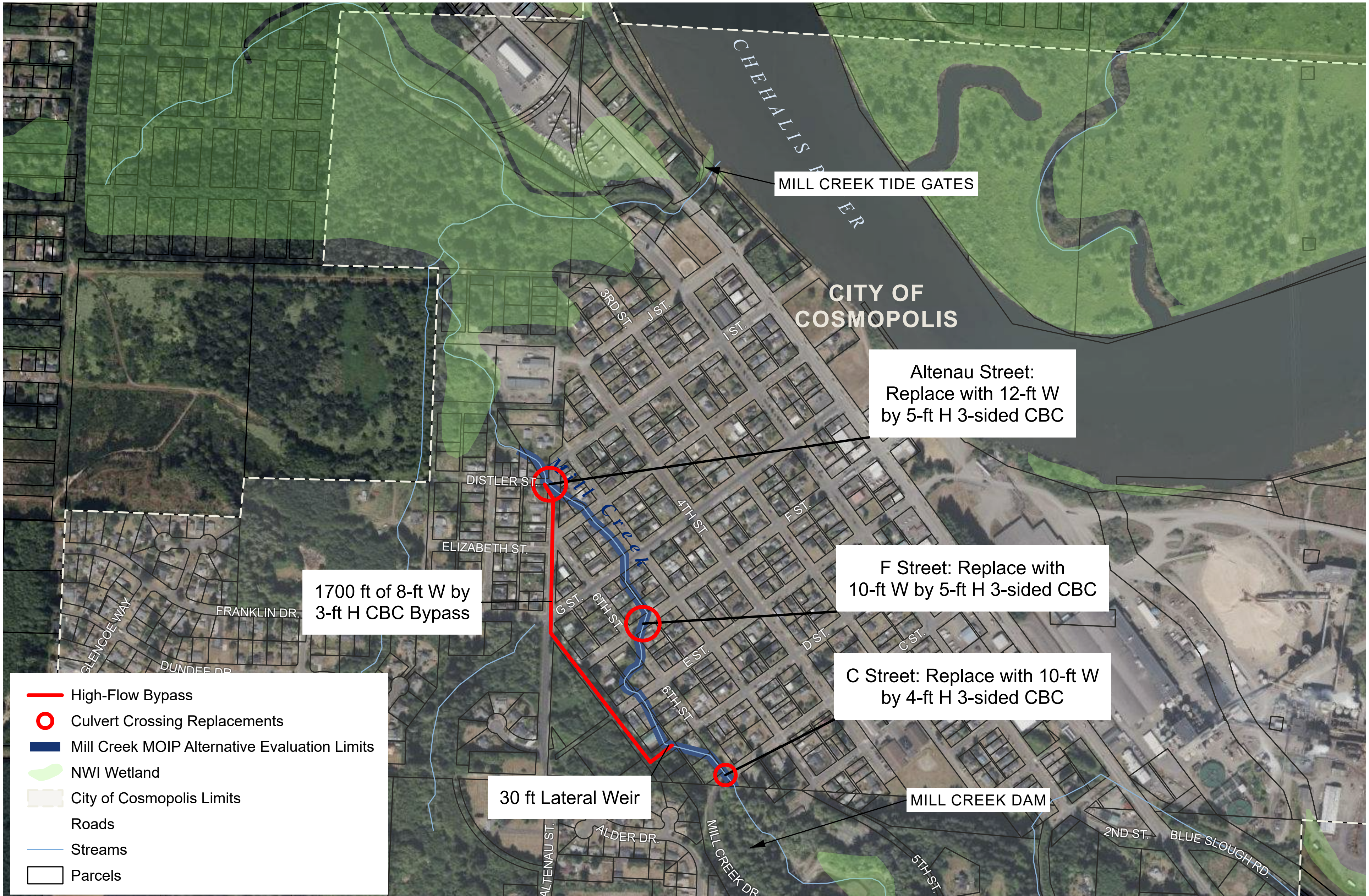
Figure 3-2 shows the culvert replacement, side channel, and new box culvert storm drain locations. Figure 3-3 shows a conceptual layout of the lateral weir.

Table 3-2. Alternative B proposed improvements

Location	Proposed culvert type and size	Affiliated Improvements	Stream Conditions
C Street	10 ft wide × 4 ft high 3-sided concrete box culvert	The box culvert includes a concrete headwall with 45-degree wingwalls; the culvert sides include 5 ft of wall depth and a concrete footing for stabilization and scour resistance	Improvements include 15 ft of upstream and downstream bank stabilization and stream bed replacement
High-flow bypass 480 ft downstream of C Street crossing in undeveloped ROW	8 ft wide × 4 ft high reinforced concrete box	A high-flow bypass consisting of a 30 ft long adjustable sharp-crested side weir and diversion structure. The weir diverts approx. 98 cfs during the 1% chance event.	Improvements include 20 ft of upstream and downstream bank stabilization and stream bed replacement
E Street	N/A	No improvements	N/A
F Street	10 ft wide × 5 ft high 3-sided concrete box culvert	The box culvert includes a concrete headwall with 45-degree wingwalls; the culvert sides include 5 ft of wall depth and a concrete footing for stabilization and scour resistance	Improvements include 10 ft of upstream and downstream bank stabilization and stream bed replacement

Location	Proposed culvert type and size	Affiliated Improvements	Stream Conditions
G Street	N/A	No improvements	N/A
H Street	N/A	No improvements	N/A
Altenau Street	12 ft wide × 5 ft high 3-sided concrete box culvert	The box culvert includes a concrete headwall with 45-degree wingwalls; the culvert sides include 5 ft of wall depth and a concrete footing for stabilization and scour resistance	Improvements include 10 ft of upstream and downstream bank replacement and stabilization. Reconnection of an existing storm line that tees directly into the culvert.

ft = feet; N/A = not applicable.



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ALTERNATIVE B
Figure 3-2

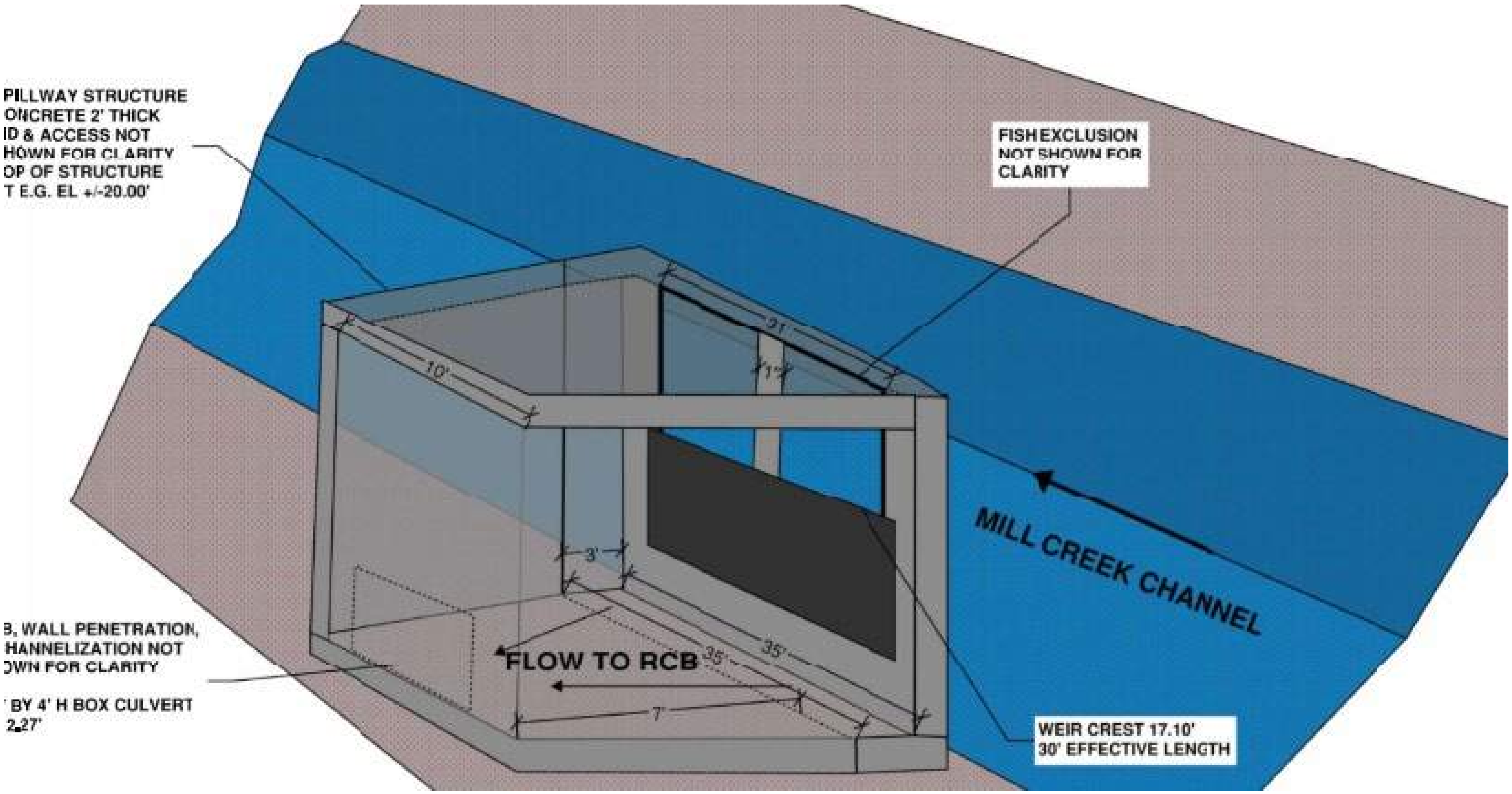

Figure 3-3 Lateral Weir Concept

4 Modeling Methodology

This section outlines the methods used to develop hydraulic modeling and the alternatives evaluation matrix scoring criteria.

4.1 Hydraulic Modeling and Assumptions

Hydraulic modeling was completed using the United States Army Corps of Engineers (USACE) Hydrological Engineering Center River Analysis System (HEC-RAS) version 6.5. Analysis objectives include:

- Create a one-dimensional (1D) steady-state, step-backwater hydraulic model of existing conditions
- Run sensitivity analysis for downstream WSE and culvert replacements
- Complete preliminary sizing of alternative improvements and associated flood reduction benefits

Prior hydraulic modeling was completed along Mill Creek for the Mill Creek Dam Restoration project in 2017. The 2017 model was expanded to include the MOIP study area from C Street crossing to just downstream of the Altenau Street crossing. The HEC-RAS analysis includes the following inputs:

- Current light detection and ranging (LiDAR) elevation data from the Washington State Department of Natural Resources (2017), which provides high-resolution topographic information
- Surveyed culvert and cross sections of the stream from the Mill Creek MOIP project that provide channel shape and slope at specific locations
- Channel roughness values (called Manning's n) for both the channel and overbanks—estimated from site reconnaissance photos and HEC-RAS manual recommendations (see Appendix A for photos)
- Peak flow values and starting WSEs were referenced from the FEMA FIS for Mill Creek at Altenau Street (FEMA 2020)

Where survey data were not available, LiDAR data were used to fill in the gaps for land surface elevation. However, LiDAR cannot accurately capture the shape of the channel bottom because it typically reflects off the water surface and does not penetrate to capture the true depth of the channel. Therefore, for cross sections added between surveyed sections, their channel shapes were modeled as simple trapezoids, with depth and width estimated based on adjacent survey data upstream and downstream.

4.1.1 Tide Gates Sensitivity Hydraulic Model Analysis

USACE installed Mill Creek tide gates as part of the Chehalis River Flood Damage Reduction project in 1996. The structure is composed of steel sheets with driven steel piling. There are three 6-by-6-foot RCBs, three manually operated backup sluice gates on the upstream end, and three vertical hinged flap gates on the downstream end. Refer to Appendix A for a photo of the gates on the downstream end. The gates appear to be hydraulically controlled to hold the gates open through much of the tide range, allowing tidal flushing of the interior drainage channel. When the water reaches a specific height, the tide gates close and create a backwater effect into Mill Creek.

A sensitivity analysis was performed using the 1 percent annual chance event peak discharge referenced from the FEMA FIS to assess if adjustments to the tide gate settings could alleviate flooding along Mill Creek. The analysis included the following:

1. The proposed-condition hydraulic model was completed using the starting WSE of 11.5 feet referenced from the FEMA FIS. The starting WSE reported by FEMA was based on Mill Creek tide gate settings.
    a. Modeling results indicated that there would be improvements with flows contained within the C, E, and G street crossings. There was a reduction in the flooding area footprint in the upper reach of Mill Creek above G Street.
    b. Flows overtopped the culverts at Altenau, H, and F streets. Flooding in this area was not alleviated by increasing culvert size and was sensitive to backwater from the Mill Creek tide gates. The model indicated limited reduction in flooded areas near Altenau and H streets.
2. A second proposed-condition hydraulic model was completed for Alternative A, reducing the starting WSE to 8 feet. The results indicate that flows were contained within the upsized culverts. The model indicated a significant reduction in flooded areas along Mill Creek upstream of Altenau Street.

While it may not be feasible to adjust the Mill Creek tide gates to accommodate a WSE drop to 8 feet, additional modeling indicates that even a WSE drop of 1 foot could result in flows being contained in most of the crossings and provide a reduction in the flooding area footprint.

Modeling indicated that flooding along Mill Creek is highly sensitive to the Mill Creek tide gate settings. In addition, culvert replacement alone may not eliminate area flooding along Mill Creek between Altenau Street to upstream of F Street without adjustments or upgrades to the tide gates. It is recommended that additional modeling and a tide gate study be completed to determine if upgrades or replacement of the existing tide gates could improve passage of peak event flows and reduce regionalized flooding between Mill Creek Dam and Altenau Street. The Mill Creek tide gate study and upgrade was added to the Cosmopolis Stormwater Comprehensive Study.

4.1.2 Alternative B High-Flow Bypass Model

Alternative B high-flow bypass was added as a separate river reach with an 8-by-4-foot culvert spanning the length of the bypass reach (1,700 feet). The bypass reach was disconnected from the main channel within the model because HEC-RAS automatically calculates the flow split between two connected reaches. To maintain control over the diversion, flow into the bypass was governed solely by the lateral weir located immediately upstream of the bypass entrance. The weir tailwater was defined as the first cross section of the bypass reach to ensure that all flow passing over the weir was routed directly into the bypass reach. This configuration prevents HEC-RAS from splitting the flow both at the junction and at the lateral weir, thus avoiding double-counting of diverted flow and ensuring that bypass discharge is determined by the weir hydraulics.

The lateral weir was modeled as a lateral structure on the left bank within the Mill Creek reach, just upstream of the bypass reach. The 30-foot-long sharp-crested rectangular weir has a crest elevation that slopes with the channel bed, with an upstream crest elevation of 17.28 feet and the downstream crest elevation of 16.79 feet.

Lateral weirs typically have lower weir coefficients than inline weirs of the same geometry because the approach flow is parallel to the crest rather than perpendicular. As a result, water spills laterally over the weir while the primary flow continues downstream, producing spatially varied flow conditions along the crest and reducing the effective head, contributing to overflow. For this reason, the standard sharp-crested weir coefficient of 3.33 is not applied. Instead, the discharge coefficient is computed using Hager's lateral weir equation. HEC-RAS 6.5 includes a built-in option to apply Hager's lateral weir equation, which computes the weir discharge coefficient while accounting for the angle between the lateral weir and the main channel flow. Because the weir is parallel to the main channel the angle is 0 degrees. This resulted in a computed weir coefficient of approximately 2.8. The weir crest height was iteratively adjusted within the model with the goal of achieving 100 cfs of overflow for the 100-year peak flow; the final configuration achieves a flow of 98.5 cfs over the weir.

5 Alternatives Evaluation

This section outlines the steps used to identify and evaluate the benefits and feasibility of each alternative. A total of eight categories were used to assess the alternatives, as listed in Figure 5-1.

Benefits

- Hydraulic improvements
- Fish passages

Feasibility

- Technical feasibility
- Construction implementation
- Environmental limitations
- Community impacts
- Operations and maintenance
- Construction cost

Figure 5-1. Alternatives evaluation criteria

5.1 Benefits and Feasibility Assessment Methodology

Each category is assigned a weight that signifies the importance of that category relative to the others; the total weight of all categories equals 1. The alternative's score is multiplied by the weight of the category to give the weighted score. The alternative with the higher total weighted score is more favorable overall.

Alternatives are scored between 1 and 5 in each category, with 1 being less favorable and 5 being more favorable conditions. Scoring criteria for each of the categories are provided in Appendix E and assigned scoring is discussed in Section 5.4.

5.2 Benefit Assessment

Two benefits were selected for assessing the alternatives: hydraulic improvements (flood reduction) and fish passage. The following sections discuss both benefit categories and present results from the HEC-RAS model to assess potential benefits.

5.2.1 Hydraulic Improvements

The WSE upstream of each culvert crossing was used to determine the flood reduction potential. As mentioned previously, WSE at each culvert crossing is significantly impacted by the tailwater elevation of 11.5 feet, downstream of the Altenau Street culvert.

- **Existing condition:** Road overtopping occurred at all culvert crossings except C Street.
- **Alternative A:** WSEs decreased at all culvert crossings, but road overtopping still occurred at F, H, and Altenau streets. Flooding at these locations is presumed to be caused by the backwater effect caused by the Chehalis River.
- **Alternative B:** WSEs decreased at all culvert crossings, but road overtopping still occurred at F, H, and Altenau streets. In the model, 98.5 cfs was diverted to the RCB bypass, leaving 232.5 cfs in Mill Creek after the lateral weir. WSEs decreased in all culverts downstream of the lateral weir between C and E streets because the flow was

reduced from 331.0 to 232.5 cfs. The C Street crossing WSE decreased because of a lowering of its downstream tailwater elevation to 18.01 feet. Refer to Appendix C for hydraulic modeling profiles. The results with hydraulic grade differential are presented in Table 5-1 below.

Table 5-1. Water surface elevation at culvert crossings summary

Culvert crossing	Road elevation	Existing-condition WSE	Alternative A WSE	Alternative A WSE reduction (ft)	Alternative B WSE	Alternative B WSE reduction (ft)
C Street	25.81	26.28	21.69	4.59	21.19	5.09
E Street	19.51	20.42	18.7	1.72	18.05	2.37
F Street	16.59	18.68	17.23	1.45	16.03	2.65
G Street	16.01	17.21	15.58	1.63	15.20	2.01
H Street	12.94	15.04	13.95	1.09	13.82	1.22
Altenau Street	12.76	13.72	13	0.72	12.97	0.75

5.2.2 Fish Passage

The reduction in flow velocity from culvert replacement has the potential to improve fish passage. Maximum fish-passage velocities according to WDFW (2013) are 4 feet per second (fps) for culverts 10 to 100 feet long and 3 fps for culverts 100 to 200 feet long. Although coho salmon currently pass through the existing culverts, the existing culverts' flow velocities exceed WDFW (2013) requirements.

The Mill Creek channel is located across various private properties, and bank widths constrain the ability for channel improvements and the feasibility of wider culvert crossings. The proposed culvert crossing sizes could improve upon the existing condition where site constraints allow. It is also recommended that the culvert crossings use three-sided boxes that span the channel and allow a more natural channel floor while lowering flow velocity. A cursory inspection of the bankfull width of the natural channel downstream of the Altenau Street crossing indicates that a culvert width of at least 18 feet would be needed to satisfy WDFW (2013) requirements.

The average culvert length over the six crossings is approximately 83 feet, ranging from 45 feet at C Street to 122 feet at F Street. Table 5-2 summarizes flow velocity reductions using the 20-year storm event flow of 115 cfs.

Table 5-2. Culvert flow velocity for the 20-year storm (115 cfs)

Culvert crossing	Existing condition (fps)	Alternative A (fps)	Alternative B (fps)
C Street	11.08	7.18	7.18
E Street	6.46	5.79	5.76
F Street	4.52	5.92	4.34
G Street	5.28	4.97	4.06

Culvert crossing	Existing condition (fps)	Alternative A (fps)	Alternative B (fps)
H Street	2.86	2.37	1.76
Altenau Street	2.94	2.03	2.04

As shown in Table 5-2, Alternatives A and B both show reduction in the velocity at all six culverts. Alternative A velocities improved because of the increase in effective area of each of the culverts. Alternative B shows a greater reduction in velocities between E and H streets than Alternative A because of the high-flow bypass lowering the flow through those culverts.

5.3 Feasibility Evaluation

The feasibility assessment was grouped into the following six categories:

- Technical feasibility (design complexity)
- Construction implementation challenges (utility conflicts, groundwater, staging/access, contaminated materials)
- Environmental limitations (sensitive areas, permitting)
- Community impacts (easements, detours)
- Operations and maintenance (O&M)
- Construction cost

Each category and specific factors influencing the score given for the alternatives are discussed in the following sections.

5.3.1 Technical Feasibility

Alternative A would require standard engineering methods to design the proposed culvert replacements. Alternative B would require more complex design to prevent fish from entering the bypass culvert, and more extensive modeling to accurately predict flow diversion between the two channels.

5.3.2 Construction Implementation Challenges

Both alternatives have utility conflicts. Alternatives A and B would require approximately 30 feet of water mainline replacement at all replaced culverts and approximately 60 feet of water mainline replacement at the Altenau Street crossing.

Alternative B’s bypass conveyance route would require approximately 580 feet of stormwater, 120 feet of sewer, and 150 feet of water replacements and realignments along the Altenau Street corridor.

Both alternatives have accessibility issues and would require temporary construction easements at the culvert crossings. Alternative B lacks drivable access to the bypass weir location and a maintenance access road would need to be constructed to this location.

Construction of the Alternative B bypass would require a longer construction window than Alternative A and would require a detailed schedule that considers construction during fish windows.

The Alternative B RCB bypass would pass near a rock outcrop and through an existing spring near the F Street projected ROW. Environmental controls and/or permitting restrictions may be required to address these challenges. Construction may disrupt the existing spring and the regulatory and permitting requirements could cause delays during both the design and construction phases. There is potential that this route could be infeasible.

5.3.3 Environmental and Permitting

Both alternatives would require numerous permits/approvals including State Environmental Policy Act (SEPA) determination, Clearing and Grading, United States Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) consultation, tribal approval, Section 401 Water Quality Certification, Hydraulic Project Approval, and a Construction Stormwater General Permit because the disturbance area is greater than 1 acre. Alternative B may also require a Critical Areas Exception Approval and a Nationwide Permit for wetland impact (because of the slope excavation and surface spring disturbance southwest of the flow diversion weir).

5.3.4 Community Impacts

Temporary construction easements will be needed for both alternatives from adjacent property owners. Based on conceptual design there are four adjacent property owners for Alternative A and six for Alternative B. A permanent slope easement would be needed for the two parcels located southwest of the flow diversion weir. All six street crossings would require temporary road closures for Alternative A, and Alternative B would temporarily close C, F, and Altenau streets.

5.3.5 Operations and Maintenance

Alternative A proposes replacement of existing culvert and would not add to the existing O&M burden. Alternative B includes a fish screen, lateral weir, diversion structure, and 1,700 feet of RCB conveyance. Because of the length of the RCB bypass (approximately 1,700 feet), removal of any blockage would be difficult using conventional methods. Frequent inspections/maintenance would be needed for any gravity fish screens installed as part of the Alternative B design. Additional equipment or contracting with private sources may be required.

5.3.6 Opinion of Probable Construction Cost

Association for the Advancement of Cost Engineering (AACE) Class 5 estimates were prepared for each alternative to allow for a cost comparison. Direct construction costs, not including indirect costs, for Alternative B are approximately $4.1 million higher than Alternative A because of construction of the bypass weir structure and 1,700 feet of conveyance. Alternative B also has a greater design complexity and more extensive permitting, and presents challenging construction implementation conditions. OPCC estimates are provided in Appendix D and the results are summarized in Table 5-3

Table 5-3. OPCC summary (2026 dollars)

Alternative	Low range (-50%)	Total project cost	High range (+100%)
Alternative A	$7,840,250	$15,680,500	$31,361,000
Alternative B	$12,274,850	$24,549,700	$49,099,000

5.4 Alternative Evaluation Scoring

The results of the alternative evaluation scoring are presented in Table 5-4.

Table 5-4. Alternative Evaluation Matrix Criteria and Score

Assessment category	Criterion	Weighting factor[a]	Alternative A		Alternative B	
			Score[b]	Weighted score[c]	Score[b]	Weighted score[c]
Benefits	Hydraulic improvements	0.25	4	0.40	4	0.80
	Fish passage	0.20	3	0.30	3	0.15
Benefits subtotal weighted score				*0.70*		*0.95*
Feasibility	Technical feasibility	0.10	3	0.15	2	0.05
	Construction implementation	0.10	3	0.36	1	0.24
	Environmental limitations	0.08	4	0.32	1	0.08
	Community impacts	0.05	3	0.10	2	0.10
	Operations and maintenance	0.07	5	0.30	2	0.10
	Construction cost	0.15	2	0.50	1	0.25
Feasibility subtotal weighted score				*1.73*		*0.82*
Total weighted score				**3.32**		**2.37**

[a] Weight factor: A higher weight factor indicates a greater importance assigned to this category.
[b] Score: Scores range from 1 for least favorable to 5 for more favorable. See Appendix E for rating criteria descriptions.
[c] Weighted score: Equals weight factor times the score.

6 Summary and Recommendations

This section summarizes the evaluation and presents recommendations for the Cosmopolis MOIP.

6.1 Recommended Alternative

Alternative A is recommended for implementation for the following reasons:

- Alternative A received a higher total weighted score (3.32) than Alternative B (2.37).
- While Alternative B would provide slightly better hydraulic performance than Alternative A, the WSE reduction at all the culverts was less than 1 foot. A greater flood reduction benefit is associated with reducing the backwater effect from the Mill Creek tide gates.
- Alternative A scored lower on the risk assessment. A copy of the risk assessment is provided with each estimate in Appendix D.
- The cost of Alternative A would be approximately $10.5 million less than Alternative B.
- Alternative A outperformed Alternative B in technical feasibility. Alternative B was found to have greater challenges related to construction complexity and environmental impact.

6.1.1 Tide Gate Study Recommendation

Hydraulic modeling indicates that Mill Creek is strongly affected by the downstream WSE where it meets the Chehalis River, which is tidally influenced. This backwater effect contributes to widespread flooding in residential areas along Mill Creek. A tide gate study is recommended to assess whether modifications to the existing tide gates could help lower downstream water levels, potentially reducing flooding in Mill Creek.

The tide gate study and any recommended upgrades to the existing tide gates is recommended as a high priority.

6.1.2 Alternative A Culvert Replacement Prioritization

Alternative A proposes that all six culverts within the evaluation area be replaced. It is recommended that the culvert crossings be replaced in order of downstream first and proceeding upstream. This will reduce the likelihood that replacement may increase flooding because of backwater from a downstream culvert constriction.

The recommended replacement priority (from highest to lowest) is as follows:

1. Altenau Street
2. H Street
3. G Street
4. F Street
5. E Street
6. C Street

7 References

City of Cosmopolis

1998 Mill Creek Operations and Maintenance Manual.

FEMA (Federal Emergency Management Agency)

2020 Flood Insurance Study (FIS) for Grays Harbor County and Incorporated Areas.

HDR (HDR Engineering, Inc.)

2015 Technical Memorandum: *Mill Creek Dam Improvements Project Fish Passage Criteria and Assessment of Alternatives.*

NRCS (Natural Resources Conservation Service)

2011 Web Soil Survey.

WDFW (Washington Department of Fish and Wildlife)

2013 *Water Crossings Design Guidelines.*