11/5/2020

Final Technical Memorandum

Lake Stevens Outlet Study

Indicator Engineering PLLC

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Executive Summary

The City of Lake Stevens frequently experiences flooding in the low-lying areas north and east of Lake Stevens with some roads being overtopped by flood waters several times a year. Flood management has been an ongoing issue for the City, but other related issues are also important including lake level management, stream health and protection of aquatic species. This study was conducted to identify and assess existing hydrologic issues then develop and evaluate alternatives to address the identified issues. Figure ES-1 below, shows the location of existing infrastructure and some of the identified flooding issues.

Existing Conditions:

Figure ES-1. Lake Stevens Outlet Channel existing conditions

Lake Outlet Weir:

The existing weir does not provide hydraulic control of the lake level during the wet season months, October through May. Instead, the stream channel configuration (width/height/slope etc.) is the control during the wet season. During the dry season (May through September), lake levels often drop below the bottom of the weir not allowing control or maintenance of low flows in the lake outlet and Catherine Creek. Despite the City's Public Works Crew's programmatic management of the weir to control the lake level the limitations of the weir make it impossible to manage level for much of the year.

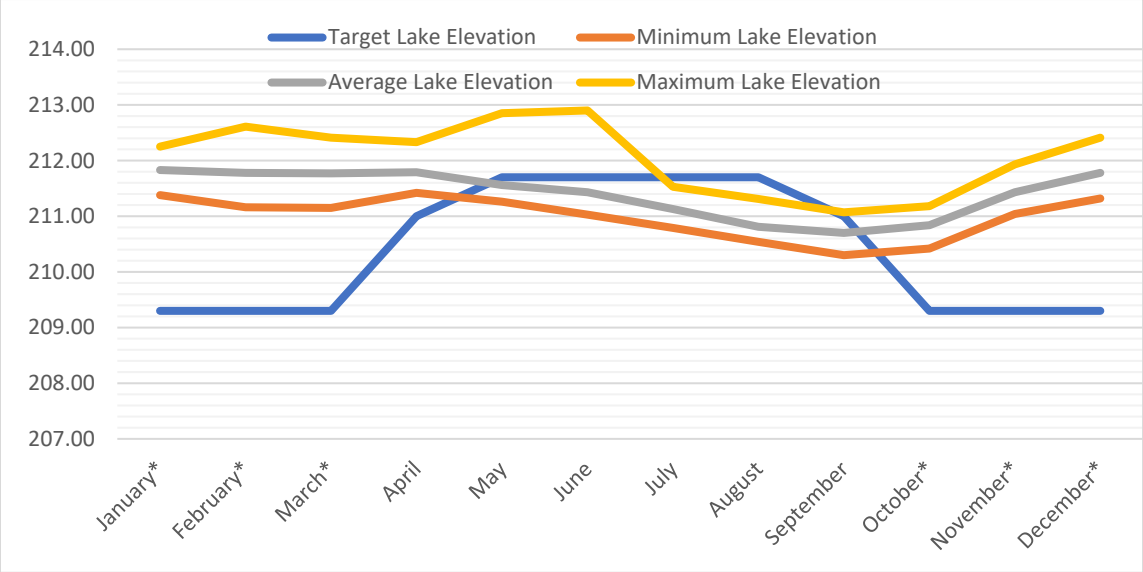


Figure ES-2. Graph of Tabulated Lake Elevations Relative to Targeted Elevations (2008 through 2019).

Lake Outlet Stream Channel:

During intense rain events the outlet channel along Hartford Drive lacks capacity to accommodate high flows. This is further exacerbated by the lack of outlet control at the weir during the wet season and potentially a backwater issue from the Catherine Creek floodplain/wetland north of the fire station. In addition, inadequate hydraulic diversity (pools and riffles) and lack of large woody debris does not support aquatic species (salmonids).

Infrastructure:

Low-lying areas where transportation and conveyance infrastructure intersect, specifically at 18th Ave NE and 20th Ave NE, the roadways tend to flood during intense rainfall events. Causes included inadequate culvert sizes, sags or broken conveyances, and low roadway elevations. Additionally, the Catherine Creek culverts crossing Hartford Drive are inadequately sized and constrict the flow from the Creek which contribute to the backwatering north of the fire station (described above). The Catherine Creek culvert replacement project is in preliminary design by another organization so was not included as an alternative considered in this Study.

Proposed Solutions:

There are several issues that need to be addressed between the lake outlet and the confluence with Catherine Creek. In order to prioritize the projects identified in this study the project team, including City Staff, ranked them according to the following criteria:

1. Project provides better management of the lake level and lake outlet flows.
2. Project reduces the severity and occurrence of flooding.
3. Project improves stream channel habitat and overall health.

This triage-style approach is necessary to ensure the scarce resources of the City provide the highest benefit to the community and environment.

The following alternatives were evaluated and prioritized using the criteria above:

Priority 1: Lake Outlet Control and Outlet Channel Restoration (Alternative #'s 1A and 1E): Replace lake outlet weir and upper channel modifications. Weir will provide lake level and stream channel control for both high and low lake levels and the channel will be modified to improve habitat and channel capacity.

-Planning level cost estimate for design and construction is $1.65 million

Lake Outlet Control Illustration

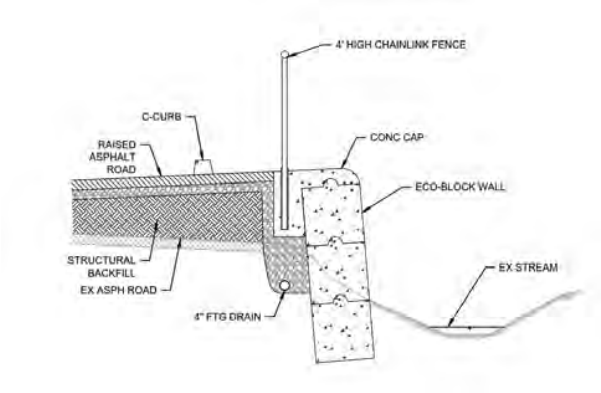
Lake Outlet Channel Restoration

Priority 2: Catherine Creek Confluence (Alternative 5F):
Additional modeling and analysis is necessary to understand the interaction of the lake outlet stream at its confluence with Catherine Creek, the backwater condition from the wetland north of the Fire Station and the impact on Hartford Drive residences and roadway.

-Cost of additional study is $100K.

Photo looking upstream of Catherine Creek at confluence

Photo looking upstream of Lake Outlet at confluence



Priority 4: Replace Culvert and Inadequate Stormwater Infrastructure at 20th St. NE and Roadway Grading (Alternative 5C):
Replace the culvert under 20th St. NE with box culvert, modify stormwater infrastructure to improve conveyance, and roadway grading. This will alleviate flooding experienced on 20th St. NE and adjacent private property.

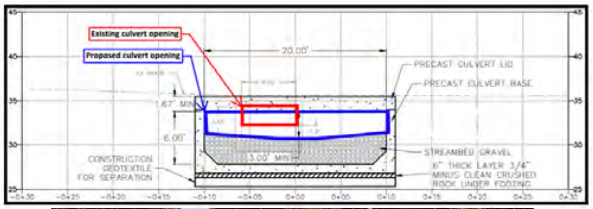
-Planning level cost estimate for design and construction is $1.28 million.

Priority 5: Replace Culvert and Inadequate Stormwater Infrastructure at 18th St. NE and Roadway Grading (Alternative 5B):
Replace the culvert under 18th St. NE with box culvert, modify stormwater infrastructure to improve conveyance, and roadway grading.

-Planning level cost estimate for design and construction is $1.78 million.

Priority 3: Hartford Drive Flood Mitigation and Stream Channel Restoration (Alternative 2C & 5D):
Improve channel capacity, elevate Hartford Drive above the floodplain, and improve stormwater infrastructure near the fire station. This solution may potentially address backwater issue from Catherine Creek wetland. This will alleviate flooding of Hartford Drive.

-Planning level cost estimate for design and construction is $939K.



Project/Priority	Planning Level Cost Estimate
Priority 1: Lake Outlet Control and Outlet Channel Restoration	**$1,650,000**
Priority 2: Catherine Creek Confluence	**$100,000**
Priority 3: Hartford Drive Flood Mitigation and Stream Channel Restoration	**$939,000**
Priority 4: Replace Culvert and Inadequate Stormwater Infrastructure at 20th St. NE and Roadway Grading	**$1,280,000**
Priority 5: Replace Culvert and Inadequate Stormwater Infrastructure at 18th St. NE and Roadway Grading	**$1,780,000**
Total	**$5,749,000**

Conclusion:

Despite the City's best efforts, the lake level and outlet flows cannot be managed during the dry and wet seasons with the existing weir. Further, the lake outlet stream confluence with Catherine Creek likely creates a backwater condition along Hartford Drive causing flooding in the downtown area. This flooding is exacerbated by inadequately sized culverts and stream channels. Several alternatives have been prioritized and cost estimates have been prepared as part of this study. A pragmatic approach to address these issues has been formulated:

1. Improve management of lake level and lake outlet flows by replacing the weir and improving the outlet stream channel capacity.
2. Reduce the severity and occurrence of flooding by replacing undersized culverts and improving stream channel capacity.
3. Improve stream channel habitat and health as an element of each of the projects.

The planning level cost estimate to design and construct the project alternatives is $5.74 million. These projects can be designed and constructed over several years using local stormwater funds and grants.

Additional operational recommendations to alleviate on-going flooding concerns include the following:

1. Continue robust catch basin inspection and maintenance program to ensure that catch basins and enclosed stormwater conveyance infrastructure is free and clear of debris, especially in advance of predicted rainfall.
2. Continue beaver management program to alleviate back-ups and conveyance blockages due to beaver dams.
3. Remove vegetation cut from outlet channel banks during mowing operations, rather than allowing material and debris to fall into channel. This will keep channel open for conveyance.

1. Introduction and Background

The City of Lake Stevens is a rapidly growing community in Snohomish County situated west of the Cascade foothills. Snohomish County predicts the City of Lake Stevens and surrounding areas will grow to a population of over 46,000 and provide approximately 8,000 jobs by 2035. Lake Stevens is a recreational, aesthetic, and natural resource enjoyed by the community and makes up approximately ¼ of the surrounding area that drains to the lake. There are flooding and fish habitat concerns associated with lake level management and surface water conveyance downstream of the lake and the City is interested in identifying potential solutions to address these concerns while providing more consistent lake level management.

The purpose of this study was to evaluate historic, current and potential future hydrologic conditions in the Lake Stevens basin and outlet as it relates to lake level management and downstream conveyance, evaluate on-going and potential future flooding and/or habitat issues associated with different precipitation or flow scenarios, and develop alternative solutions to address the identified issues.

Figure 1 shows the project vicinity including the existing and historic alignment of the Lake Stevens outlet channel and areas evaluated in this study.

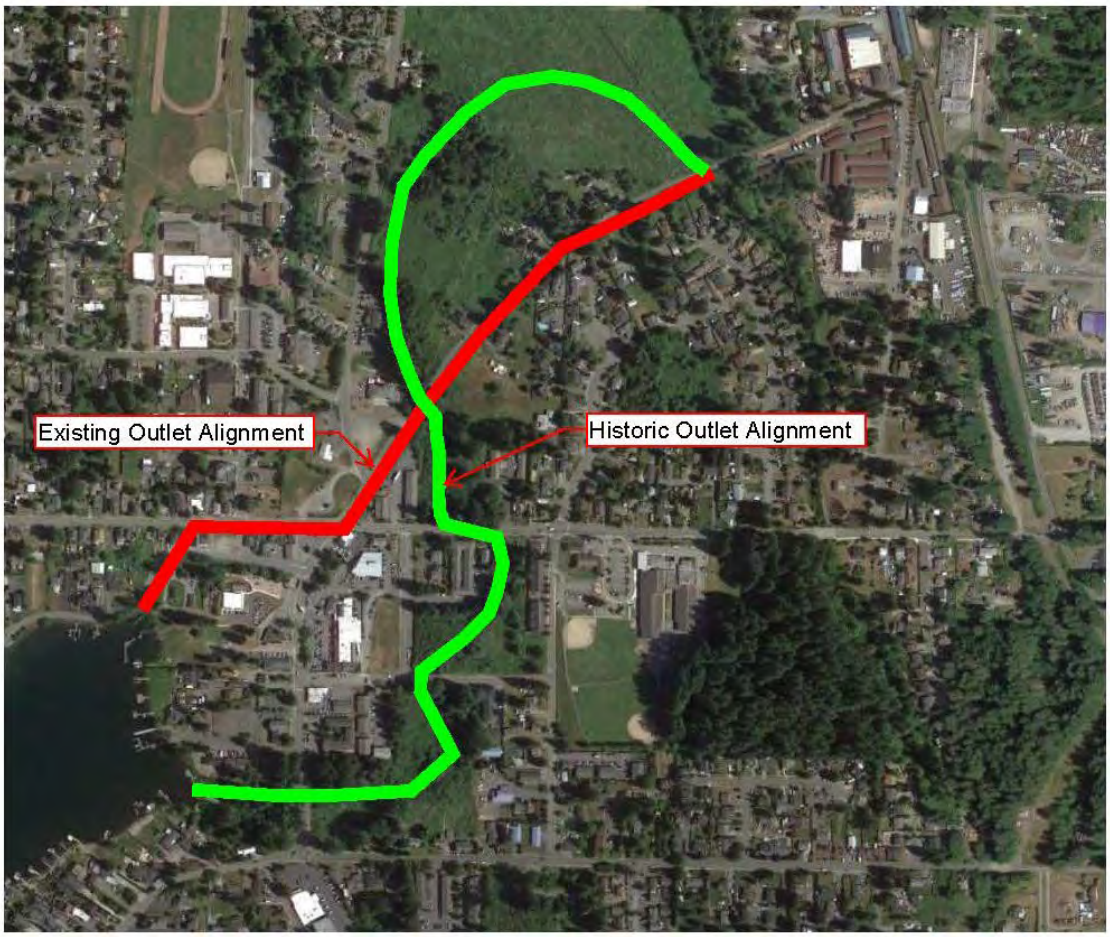


Figure 1. Lake Steven Outlet Study Vicinity and Relevant Features

1.1 Goals and Objectives

The goal of this phase of the project was to broadly identify hydrologic and habitat issues related to the outlet and downstream conditions in Lake Stevens through preliminary evaluation of existing documents, data, and field verification.

The specific project objectives include:

- Analysis and confirmation of flooding and fish habitat issues related to lake level management and/or downstream conveyance of surface water from the outlet of Lake Stevens.
- Geomorphic and biological analysis of existing outlet channel and historic outlet channel.
- Development of alternatives to address identified flooding and/or fish habitat issues including general hydraulic feasibility analysis and preliminary cost estimates. Specific alternative goals include:
    - Extend or increase base flow in creek during the end of the summer/early fall months (August – October)
    - Increase hydraulic diversity
    - Increase biodiversity and habitat uplift
    - Alleviate flooding
    - Improve high flow capacity
    - Potential realignment of the outlet stream to historic alignment
    - Keep existing conveyance system, if existing outlet channel is retired

2. Methodology and Data Sources

The methodology for conducting this study involved using existing data sources provided by the City and available in the public domain, conducting field visits to verify existing conditions, and doing limited analysis to evaluate current issues and potential solutions.

2.1 Data Sources

The following data sources were used in this preliminary analysis:

- Lake Stevens/Catherine Creek Watershed Management Plan prepared for Drainage Improvement District #8, City of Lake Stevens, Gray and Osborne, June 1999
- Geographic Information System (GIS) coverages provided by Lake Stevens, including infrastructure data (pipes, catch basins, maintenance holes, outfalls, culverts, and stormwater facilities), drainage basin boundaries, and drainage basin easements.
- GIS coverages downloaded from other sources (i.e., Snohomish County, Washington State Department of Natural Resources, Puget Sound LiDAR consortium, and ArcGIS Online) including hydrography, geology, aerial imagery, streets, and LiDAR.
- Historical photographs and narrative about Rucker Mill, outlet channel and life in early 1900s Lake Stevens downloaded and excerpted from the Lake Steven Historical Museum Facebook page.
- Excerpt from the 1977 U.S. Army Corps of Engineers, “Water Resources Development by the U.S. Army Corps of Engineers in Washington,” regarding Lake Stevens Outlet Project.
- Excerpts from Lake Stevens Subarea Plan, including proposed improvements on Hartford Drive.
- Sound Salmon Solutions Preliminary Catherine Creek Culvert Replacement Plans, July 31, 2019.
- Element Solutions Geotechnical Report- Catherine Creek Fish Passage Project, March 22, 2019.

- January 2011 Integrated Aquatic Plant Control Plan for Lake Stevens.
- September 6, 2011, Lake Stevens Lake Level Management Plan.
- Lake Stevens Hydrologic Simulation Program Fortran (HSPF) Model created by Clear Creek Solutions

2.2 Field Evaluation

Stormwater and surface water infrastructure and natural resources in the vicinity of the Lake Stevens outlet and downstream of the historic outlet channel were field evaluated by staff from Davido Consulting (DCG), The Watershed Company (Watershed) and Altaterra Consulting LLC (Altaterra) on September 25 and October 3, 2019. Additionally, a flood event in early February 2020 presented an opportunity to observe conditions following flooding. Indicator Engineering PLCC (Indicator) visited Lake Stevens on February 11, 2020, five days after peak flooding to photograph conditions and observe evidence of flooding in areas of interest and/or concern.

2.2.1 Infrastructure Evaluation

Stormwater and surface water infrastructure downstream of the historic outlet channel and in the vicinity of known flooding areas was evaluated by Jack Lasley (DCG) and Erin Nelson (Altaterra) on September 25, 2019. Observations were made on the condition of catch basins, connecting pipes, outfalls, conveyance ditches, and cross culverts in the vicinity of known flooding areas including the following that were reported by City staff:

- Intersection of 16th Ave NE and Main Street
- Intersection of 18th Ave NE and NE 125th Street
- 20th Ave NE near intersection of 20th Ave NE and NE 125th Street

The purpose of the field evaluation was to assess conveyance system conditions as a potential factor for reported and observed flooding.

2.2.2 Natural Resources and Geomorphic Evaluation

Fisheries Biologist Greg Johnston of The Watershed Company (Watershed) and Geomorphologist Erin Nelson of Altaterra walked the outlet stream channel from the confluence with Catherine Creek to the lake on October 3rd, 2019. Observations were made about the channel condition, including physical dimensions, vegetation type and condition, presence or absence of wood or debris, substrate, bank condition, erosive processes, bank stabilization efforts, and location, type and condition of road, bridge and culvert crossings and/or outfalls into the channel. Information along this stream section was gathered towards providing an overview of existing fish habitat conditions, any noted fish use, and potential conveyance or erosion issues. Primary habitat elements evaluated at a qualitative level included channel substrate, abundance or lack of in-stream wood, pool formation, riparian vegetation type and maturity, functional buffer width, and any fish passage barriers. In addition to identifying and summarizing habitat deficiencies, potential solutions and opportunities for possible improvement were noted for follow-up and development into or as part of Capital Improvement Projects (CIPs).

2.2.3 Wetland Evaluation

Field investigations for the reconnaissance study were conducted on October 3, 2019 by ecologist Sam Payne (Watershed). Wetland field investigations included a brief inspection of wetlands along the

proposed conceptual stream relocation to the historic alignment and portions of the existing Lake Stevens outlet channel.

The study area was evaluated for wetlands using methodology from the *Corps of Engineers Wetland Delineation Manual* (Environmental Laboratory 1987) and the *Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Western Mountains, Valleys, and Coast Region Version 2.0* (U.S. Army Corps of Engineers 2010). Presence or absence of wetlands was determined on the basis of an examination of vegetation, soils and hydrology. Wetlands classifications were approximated using the Department of Ecology's 2014 rating system (Hruby 2014).

Characterization of climatic conditions for precipitation in the Wetland Determination Data Forms were determined using the WETS table methodology (USDA, NRCS 2015). The "Seattle Tacoma Intl AP" station from 1981-2010 was used as a source for precipitation data (http://agacis.rcc-acis.org/). The WETS table methodology uses climate data from the three months prior to the site visit month to determine if normal conditions are present in the study area region.

2.3 Hydrologic and Hydraulic Evaluation

Indicator conducted an evaluation of lake level management and historic lake levels, and a review of previous hydrologic and hydraulic models of Catherine Creek and the lake outlet channel.

2.3.1 Lake Level Evaluation

Indicator reviewed historic monthly lake levels in Lake Stevens between 2008 and 2019. Minimum, average, and maximum levels for each month over the eleven-year range was evaluated to understand how the lake levels are currently being managed. Additionally, the low and high recorded lake levels were evaluated in the context of all available data and the target lake levels and weir elevations specified in the lake level management plan.

2.3.2 Model Review

Previous modeling efforts and results were reviewed to determine flood frequency, location, and sequencing (i.e., how flooding occurs from upstream or downstream).

3. Historical Documentation

The history of the Lake Stevens outlet channel, lake level management and flooding issues in downtown Lake Stevens was gleaned from review of historical photographs, maps, documents, and studies provided by the City and obtained in the public domain from online resources. Figure 2. Historical Timeline in Lake StevensFigure 2 shows a timeline of significant events in Lake Stevens that relate to the development of Lake Stevens and the outlet channel.

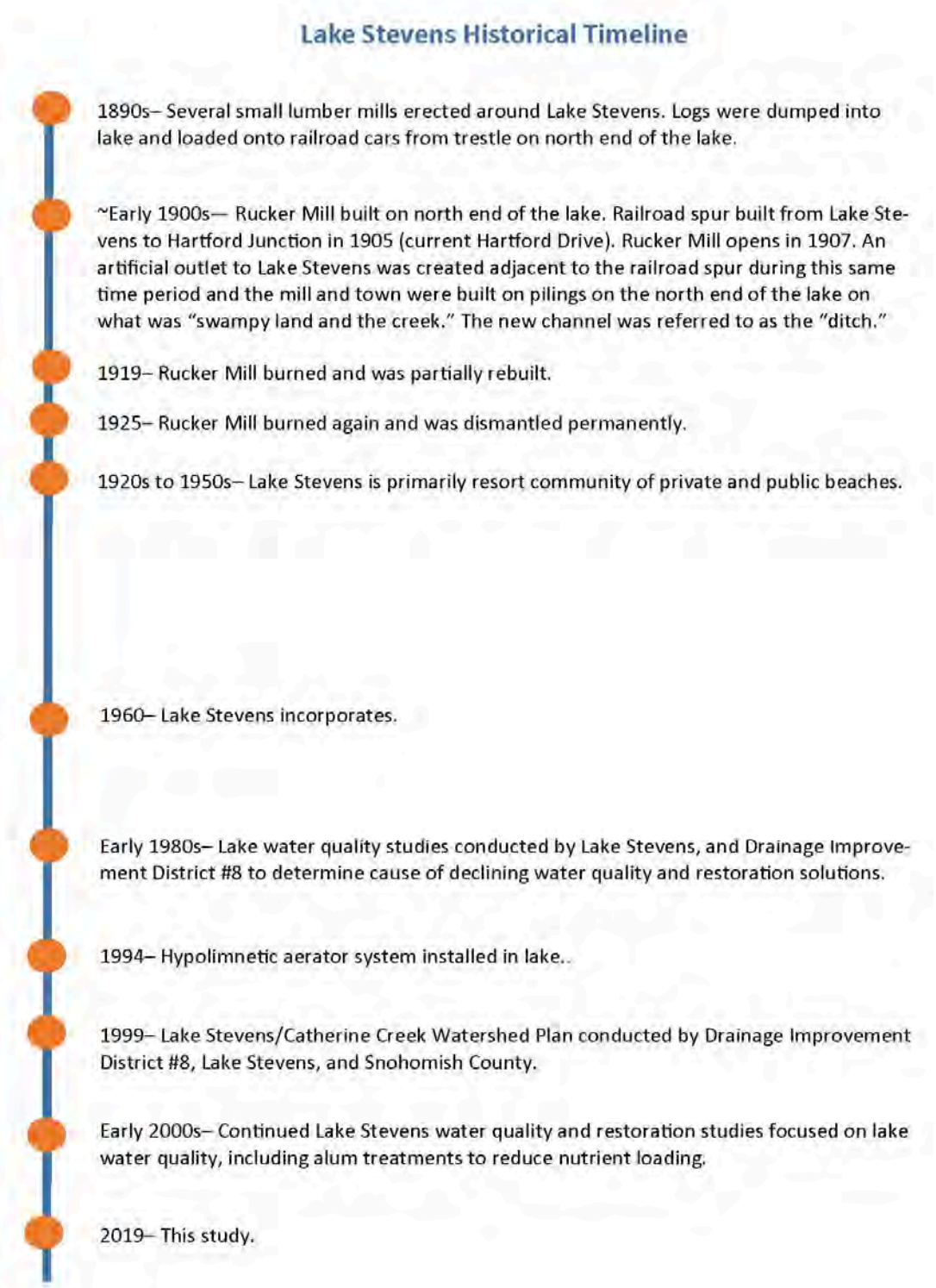


Figure 2. Historical Timeline in Lake Stevens

Approximate significant events relevant to outlet channel and development in Lake Stevens (sources include: Lake Stevens City webpage, Lake Stevens Historical Museum Facebook page, and Snohomish County webpage listing Lake Stevens documents)

As shown on Figure 2, the outlet channel in its current location was constructed in the early 1900s. The previous outlet of Lake Stevens was reportedly near the current boat dock and by the current Boys and Girls Club at the intersection of 16th Ave NE and Main Street. Figure 3 shows a historical map indicating the location of the constructed channel and the location of the Rucker Mill. This historic outlet was in the location of the mill on the south side of the cove. Figure 4 is a photo of the outlet channel from 1908.

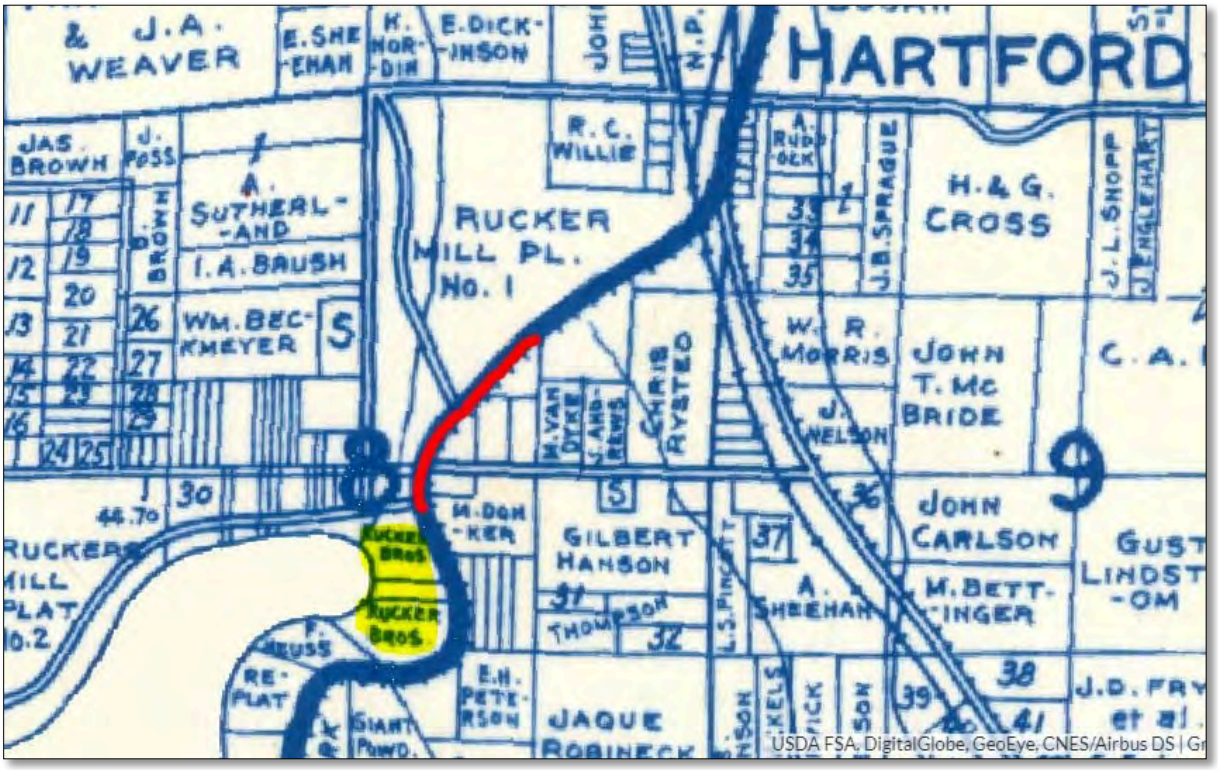


Figure 3. 1927 Lake Stevens Map.

Yellow area shows where the Rucker Mill was located, in the area that is now downtown Lake Stevens. Red shows the route to Hartford and where the "ditch" is located. Note that Hartford is labeled but Lake Stevens hasn't been incorporated yet and therefore was not labeled on the map. .

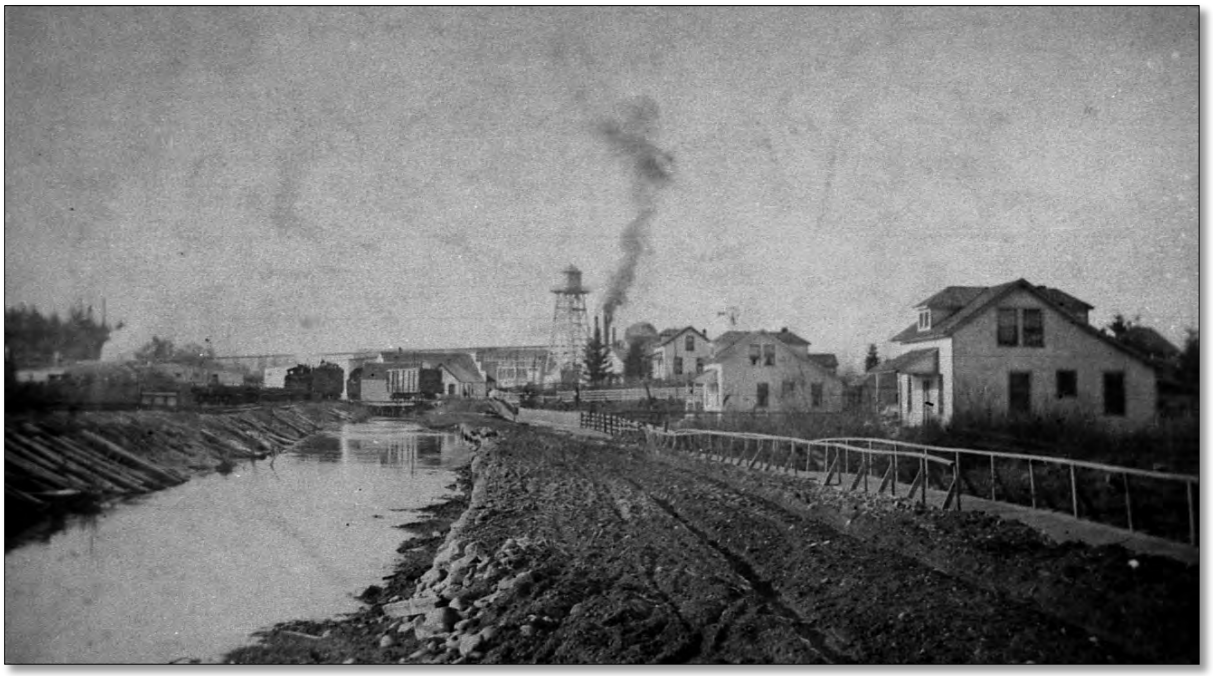


Figure 4. Rucker Mill Photo, circa 1908.

This is a view of Rucker Mill looking south with the water tower visible in center background. A boardwalk followed the present-day Grade Road from Lake Stevens to the nearby town of Hartford. The Grimm House, now located next to the town museum, can be seen on the right. The railroad spur to Hartford can be seen on the left of "The Ditch," the name townspeople gave the artificial outlet that the Rucker brothers created. Photo loaned by Jim Mitchell. (Photo caption is from Lake Steven Historical Museum Facebook page).

3.1 Relevant Data

The 1999 Lake Stevens/Catherine Creek Watershed Plan (Gray and Osborne 1999) provides detailed information and analysis about drainage issues in the vicinity of Lake Stevens and lists recommended actions. Among the relevant findings in the 1999 report, are the following:

Fisheries:

Lake Stevens and Catherine Creek watershed traditionally supported a variety of fish runs. Among those species have been kokanee, coho and chinook salmon, cutthroat trout and bass.

Groundwater:

Groundwater is restricted to two aquifers. The upper, outwash aquifer supplies baseflow to the creeks. Groundwater does support year-round baseflow in lower Catherine Creek and the Lake Stevens outflow channel.

Baseflows:

The baseflows in the Lake Stevens outflow channel are estimated to be 2 cubic feet per second (cfs) in the summer and 40 cfs in the winter, but this is dependent on the weir. Baseflows in Catherine Creek at 20th Street are estimated to be 11 cfs in the summer and 80 cfs in the winter.

Flooding:

Significant flooding has occurred in the watershed in three locations, including Stevens Creek (outside this Study area), the north side of Hartford Drive opposite the outlet channel in a wetland area, and in the downtown business loop of Lake Stevens. Figure 5 shows flooding in 1997 on Hartford Drive.

Figure 4-2

Flood Conditions along Hartford Road
January, 1997

Figure 5. Photos from 1999 Watershed Plan showing flooding on Hartford Drive.

Stream Gauging:

Stream gauges were installed and monitored in the Lake Stevens outlet channel near 124th Avenue NE and on Catherine Creek at the 20th Street bridge between September 1996 and February 1997. Figure 6 and Figure 7 shows the simulated and observed flow data from those gauges, respectively.

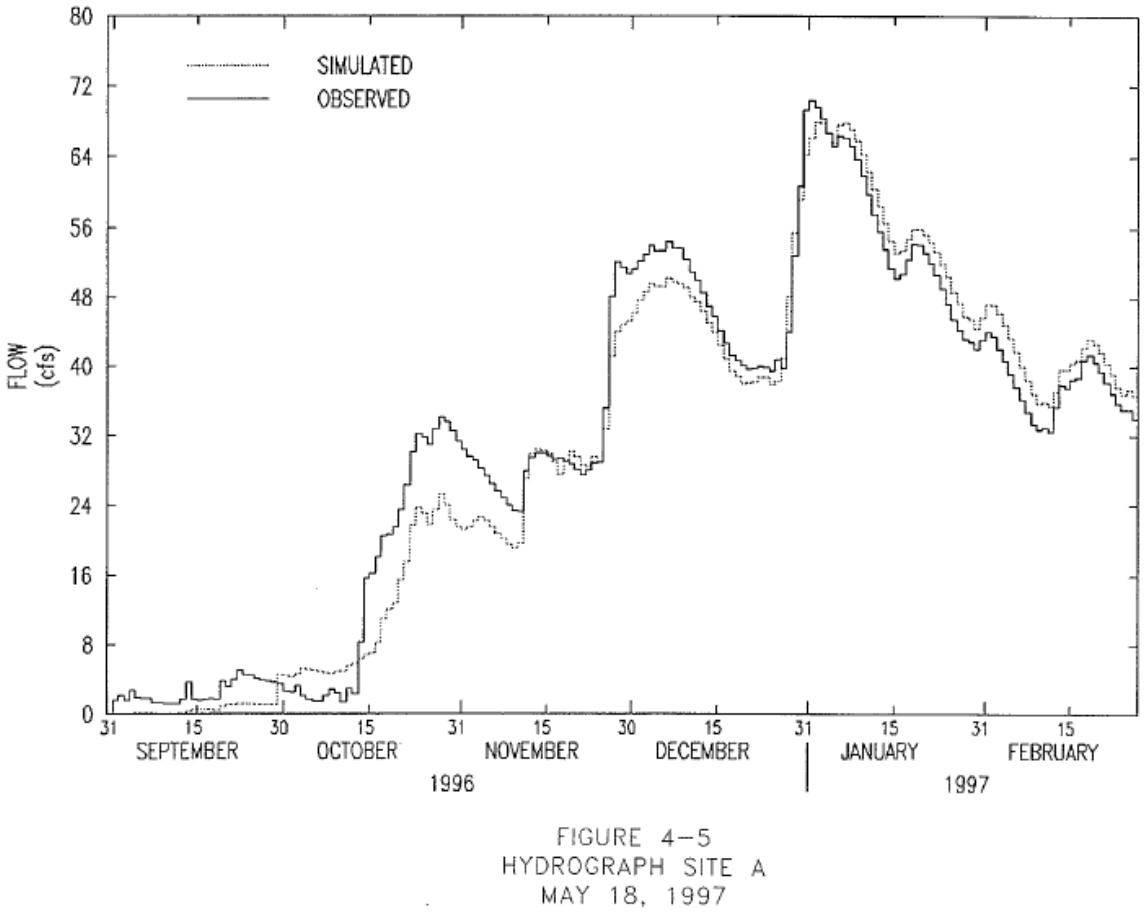


Figure 6. Hydrograph from Gauge Station on Lake Stevens outlet channel near 124th Avenue NE.

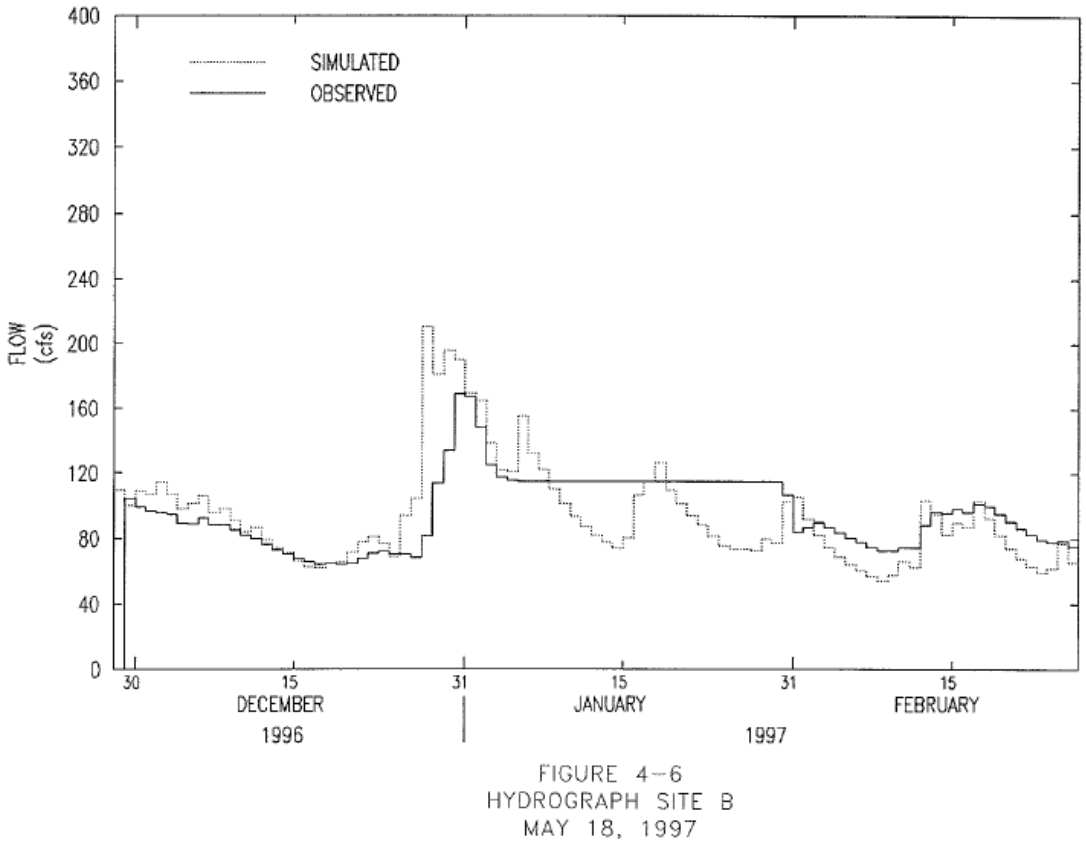


Figure 7. Hydrograph from Gauge Station on Catherine Creek near 20th Street bridge.

Discharge Results:

Predicted current (1999) and future flood frequency data for the Lake Stevens outlet channel and Catherine Creek at the 20th Street bridge were reported in the 1999 Watershed Plan and are summarized below in Table 1.

Table 1. Summary of predicted flood frequency results.

Location	2-year Discharge (cfs)		10-year Discharge (cfs)		100-year Discharge (cfs)	
	Current	Future	Current	Future	Current	Future
Lake Stevens Outlet Channel	43	44	55	56	68	69
Catherine Creek near 20th Street bridge	129	156	188	232	273	347

Stream Habitat:

Stream habitat within the outflow channel to the confluence of Catherine Creek was described as being low gradient (<0.5 to 1.0 percent), with and average width of 12 feet, trapezoidal shape and high, steep

side banks. The banks within the City are reinforced with riprap; downstream the banks are covered with grass, vines and occasional willows. There is limited overhead canopy.

The substrate in the upper portion was described as gravel, whereas further downstream it was described as silt and sand. There was limited instream complexity and no large woody debris, off-channel habitat or eddy areas present for high flow protection. Bridges and streambanks with vegetation on the right side provide some shade, and riparian vegetation consists of blackberries and other brush. There is limited refuge habitat for fish.

The stream bank material consists of non-cohesive coarse sand and gravel and there were few signs of erosion, however, there were some signs of road slope failure and recently placed bank protection.

3.2 Previously Recommended Actions

The 1999 Watershed Plan recommended several relevant structural and non-structural alternatives for addressing flooding and habitat concerns outlined in the plan. These included:

Non-structural alternatives:

"Maintenance- All structures should be maintained so that they perform as designed. This includes the removal of accumulated sediment from detention ponds and catch basins as well as routine cleaning of filters."

Structural alternatives:

"Outlet Channel Realignment – The outlet channel used to flow out of Lake Stevens south of downtown Lake Stevens cross the current location of the outflow channel and return to Catherine Creek approximately where the outflow channel joins Catherine Creek. This project would reestablish the old realignment and create fisheries habitat in so reestablishing the alignment."

"Increase Lake Water Level – If water levels were increased in Lake Stevens in the spring, more water would potentially be available at the end of the summer and the early fall to augment flows in the outflow channel and Catherine Creek."

The plan further explains that a plan for lake level management would include dredging of the gravel bar upstream of the current outlet weir to allow the lake drawdown approximatley one foot further in the late summer and early fall. The additional drawdown would supply approximately 1,000 acre-feet of additional water to the stream, on the order of 5 cfs during September and October, to the Outflow Channel and lower Catherine Creek. The disadvantage is that some users may be restricted in the use of their docks and boat launches for this portion of the year due to the lower water levels.

Discussion of the outlet channel realignment was limited to a description of reestablishing the old outflow channel through the City of Lake Stevens and continuing north of Hartford Drive. The Plan described how completion of the project would provide additional fisheries habitat and additional flood control protection by retaining floodwaters north of Hartford Drive but did not provide specifics on quantitative benefits or project costs.

4. Lake Level Evaluation

Lake Stevens is controlled by the manually operated outlet with 5 boards; one board is 12 inches wide, and the remaining are in 4-inch widths. Table 2 shows the outlet weir elevations. Table 3 shows the target monthly lake levels and corresponding weir elevations according to the current lake level management plan (Lake Stevens 2011).

Table 2. Lake Outlet Weir Elevations

Weir Board	Base	1	2	3	4	5
Total Height (in)	0	12	4	4	4	4
Top Elevation (ft)	209.3	210.3	210.6	210.9	211.3	211.6

Table 3. Target Lake and Weir Elevations by Month

Month	Target Lake Elevation (ft)	Typical Weir Elevation[1] (ft)
January	209.3	none
February	209.3	none
March	209.3	none
April	211.0	210.9
May	211.7	211.3
June	211.7	211.6
July	211.7	211.6
August	211.7	211.6
September	211.0	210.6
October	209.3	none
November	209.3	none
December	209.3	none

[1]Where "none" is indicated, weir is not controlled by the City during these months.

Monthly average lake levels between 2008 and 2019 were evaluated to determine the range of lake elevations observed relative to the targeted lake elevations. Table 4 shows the monthly averages, minimum and maximum lake elevations for each month. Figure 8 depicts the data graphically.

Table 4. Monthly Average Lake Elevation Data (2008 through 2019)

Month	Target Lake Elevation (ft)	Minimum Lake Elevation (ft)	Average Lake Elevation (ft)	Maximum Lake Elevation (ft)
January*	209.3	**211.38**	**211.83**	**212.25**
February*	209.3	**211.16**	**211.78**	**212.61**
March*	209.3	**211.15**	**211.77**	**212.41**
April	211.0	211.42	211.79	**212.33**
May	211.7	211.26	211.56	**212.85**
June	211.7	211.03	211.43	**212.90**
July	211.7	210.79	211.13	211.53
August	211.7	**210.54**	210.81	211.31
September	211.0	210.30	210.70	211.07
October*	209.3	210.42	**210.84**	**211.18**
November*	209.3	**211.04**	**211.43**	**211.93**
December*	209.3	**211.32**	**211.78**	**212.41**

*Weir is not in operation during these months.
Bold values indicate a deviation (plus or minus) of greater than 1-foot elevation from targeted lake elevation.

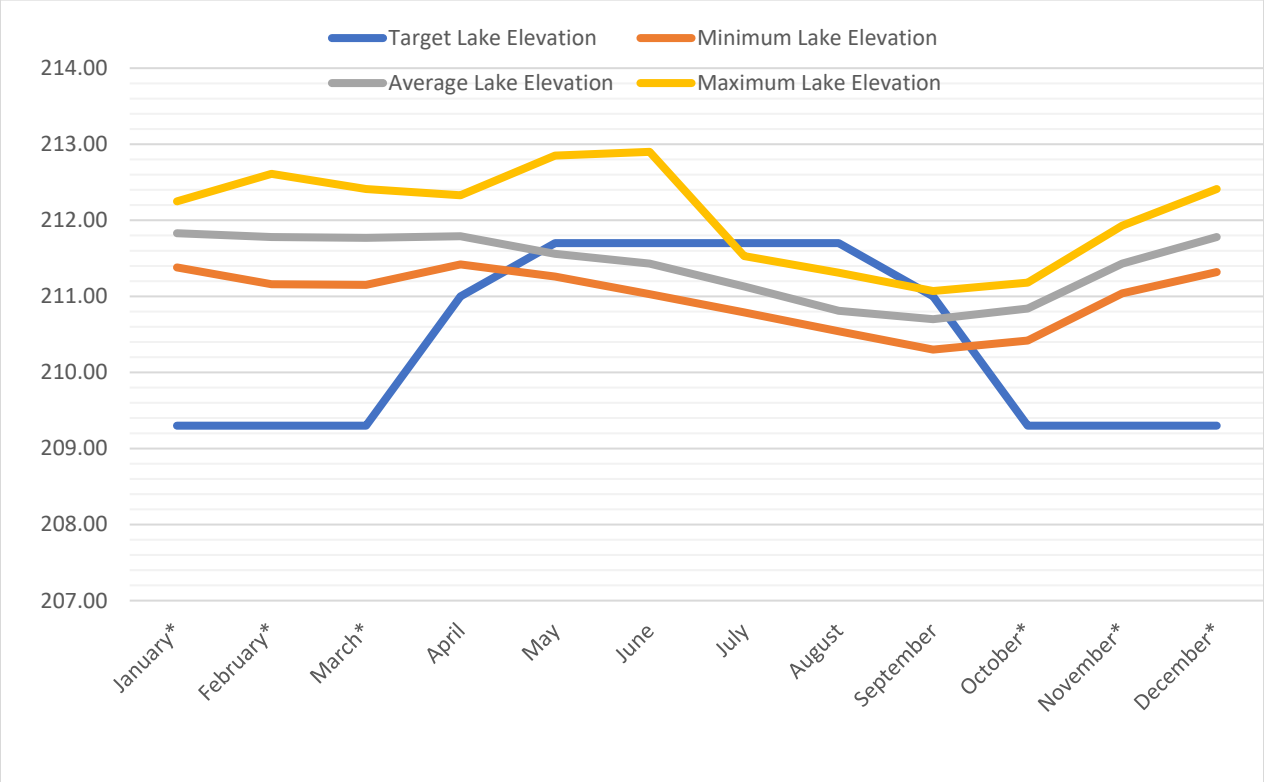


Figure 8. Graph of Tabulated Lake Elevations Relative to Targeted Elevations (2008 through 2019).

The following table notes significant lake level data info found from researched documentation:

Table 5 Notable Historic Lake Level Elevations

Lake Level Elevation	Event or Information
213.1	Highest Lake Level Recorded from 1991-2006. Assumed to be 100-year flood elevation in "Lake Stevens/Catherine Creek Watershed Management Plan prepared for Drainage Improvement District #8, City of Lake Stevens, Gray and Osborne, June 1999" report. Recorded New Year's day 1997. The outlet channel flowrate associated with this flood elevation was 71 +/- cfs.
213.22	Highest Lake Level Recorded. February 2020
209.9	Lowest Lake Level Recorded October 2004
213.6	All Property Owners Advised to Build Above

5. Hydrologic and Hydraulic Review

Models developed by others for 1999 Catherine Creek Basin Study were reviewed in the context of reported flooding then and now. One major flood event occurred in 1997, during a precipitation event that is assumed to be a 100-year recurrence event. A flow gauge at the outlet channel recorded flow at 71 cfs (cubic feet per second), whereas the modeled flow was 92 cfs. At Hartford Drive in the vicinity of the confluence with the historic channel flow during this event converged from two directions; the outlet channel provided 21 cfs and Catherine Creek backwater flow provided 132 cfs, which contributed to flooding on Hartford Drive. The results of our review show that the current culvert constriction of flow in Catherine Creek at Hartford Drive potentially has the effect of backing water up in the wetland area and historic channels on the north side of Hartford drive during high flows to the point of contributing to flooding upstream where conveyance is impeded by high water.

6. Infrastructure Evaluation

Conveyance infrastructure including catch basins, pipes, outfalls and ditches were evaluated in the field on September 25, 2019. A photo log of the infrastructure evaluation is available in Attachment A. Special attention was paid to infrastructure in the vicinity of known flooding issues shown on Figure 9. Observed conditions during the February 2020 flooding event are described for the locations evaluated. Below are descriptions of infrastructure in the vicinity of each location. Additionally, descriptions of other infrastructure issues or potential issues noted during the field evaluation are provided below.

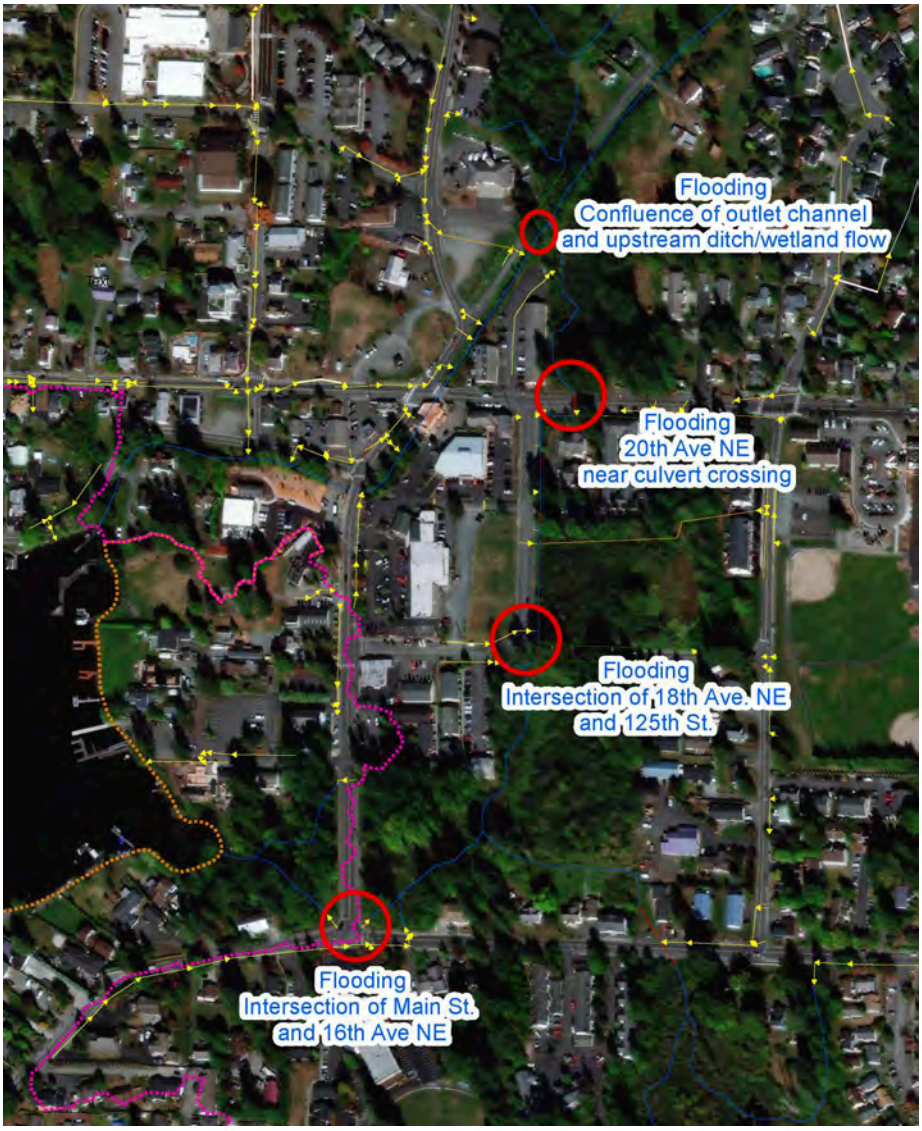


Figure 9. Known Flooding Areas where Infrastructure Conditions were Evaluated.

6.1 Intersection of Main Street and 16th Avenue NE

Drainage pipes conveying stormwater runoff from 16th Avenue west of the intersection of Main Street and 16th Avenue NE route meets with runoff draining 16th Avenue NE from the east just east of the intersection at a low point. The pipes and catch basins in this location had significant deposits of sediment and/or were submerged under water. The parking lot of the Boys and Girls Club to the south is also connected to the drainage system at this location. One of the catch basins was equipped with a new bypass pipe that appeared to be installed to alleviate flooding at this location (Photo 1). The most downstream catch basin is not submerged (Photo 2), whereas upstream catch basins are (such as in Photo 1) indicating there is either a blockage in the pipes, a sag in the line, or the grades are not aligned properly for positive flow.

Photo 1. Upstream Catch Basin in Vicinity of Intersection of Main Street and 16th Avenue NE on September 25, 2019.

Photo 2. Most Downstream Catch Basin in Vicinity of Intersection of Main Street and 16th Avenue NE on September 25, 2019.

According to residents, 16th Avenue NE did not overtop during the February 2020 flood event, and there was no evidence of such during the February 11, 2020 site visit (Photo 3).

Photo 3. 16th Avenue NE on February 11, 2020 looking East. near Boys and Girls Club.

6.2 Intersection of 18th Avenue NE and 125th Street

Staff report that flooding occurs at the intersection of 18th Avenue NE and 125th Street on an annual or biannual frequency. This intersection is at the low point of 18th Avenue NE which crosses a large wetland

complex that runs in the north-south direction parallel to NE 125th Street. During our field investigation, conveyance ditches were full of water and adjacent catch basins and pipe systems conveying stormwater runoff to the conveyance ditches were submerged. Photo 4 shows the catch basin closest to the conveyance ditch on the east side of 125th Avenue NE and the ditch in the background on September 25, 2019. Within the catch basin in photo 4, the pipe is submerged and the ditch is full of water. Positive flow away from the roadways and upland would be challenging in this situation during heavy or sustained precipitation because of the low lying, saturated conditions of the surrounding area. Photo 5 shows this same location on February 11, 2020, after the intersection was likely flooded in the previous five days. Photos 6 and 7 show the culvert crossing at 18th Avenue NE on September 25, 2019. The culvert is nearly submerged. Additionally, beaver activity in the wetland backs water up into the conveyance ditches on occasion. City personnel remove dams and beavers, as required to maintain positive flow.

Photo 4. Catch Basin on NE 125th Street on East Side of Street nearest intersection with 18th Avenue NE on September 25, 2019.

Photo 5. Intersection of NE 125th Street and 18th Avenue NE looking North on February 11, 2020. Intersection was flooded during February 2020 event.

Photo 6. Upstream side of 18th Avenue NE Culvert on September 25, 2019.

Photo 7. Downstream side of 18th Avenue NE Culvert on September 25, 2019.

6.3 Intersection of 20th Avenue NE and 125th Street

Staff report that flooding occurs at the intersection of 20th Avenue NE and 125th Street two to three times a year. This intersection is at the low point of 20th Avenue NE and crosses the same large wetland complex that runs in the north-south direction parallel to NE 125th Street. However, this area has been developed on the south side of 20th Avenue NE with apartment buildings, confining flow to the ditch between developed multi-family residential properties and the roadway on NE 125th Street and 20th Avenue NE. During our field investigation, the conveyance ditch was full of water (within 0.5 feet of the sidewalk elevation), adjacent catch basins and pipe systems and the 20th Avenue NE culvert were submerged. Photos 8 and 9 show the location of a submerged catch basin on 20th Avenue NE near the low point in the road in the location of frequent flooding on September 25, 2019 and February 11, 2020. The catch basin was full of water at the time of our September site visit and submerged in February 2020 from the previous week's flooding. Photo 10 shows the catch basin upstream of the low point on 20th Avenue NE, which was also submerged during the September 25, 2019 field visit. Photo 11 shows the conveyance ditch south (upstream) of 20th Avenue NE near the culvert crossing and that the water elevation is within 0.5 feet of the sidewalk. Photo 12 shows the downstream side of the culvert. The water elevation is approximately 2 feet below the road. The culverts appear to be a constriction to flow in this location, either due to a physical blockage or culvert sizes, as indicated by water backing up on the upstream end of the culvert. Photo 13 shows flooded conditions on 20th Avenue NE at the low point on February 6, 2020.

Photo 8. Catch Basin at low point on 20th Avenue NE near culvert crossing.

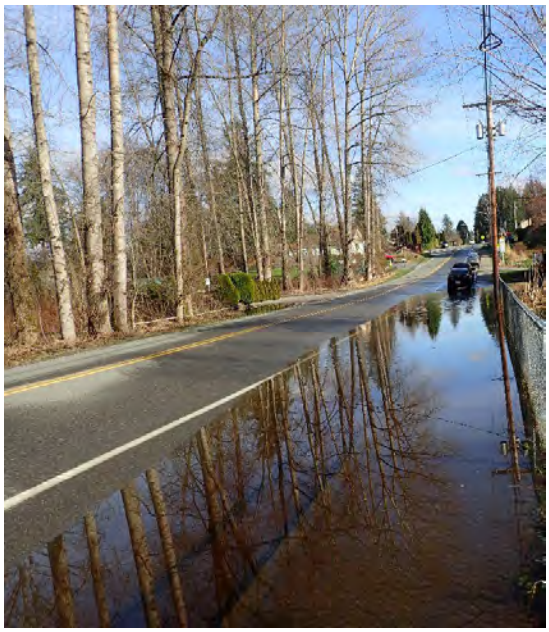


Photo 9. Approximate location of Photo 8 on February 11, 2020.

Photo 10. Catch Basin on 20th Avenue NE upstream of low point to the west.

Photo 11. Water in conveyance ditch south of 20th Avenue NE upstream of culvert crossing.

Photo 12. Conveyance ditch downstream of culvert crossing on north side of 20th Avenue NE.

Photo 13. Flooding on 20th Avenue NE on February 6, 2020, looking west.

6.4 Confluence of Outlet Channel and Conveyance Ditch/Wetland Complex

Flooding is reported to occur at the confluence of the outlet channel and the conveyance ditch/wetland complex at Hartford Drive. As shown in Figure 5, photographs from flooding in 1997 show water over the roadway in this location. Again in February 2020, water crested the roadway in this location and was still present during our site visit on February 11, 2020. Photo 14 shows conditions in February after flooding, before the water had completely receded. A review of modeling results indicates that backwater from the confluence of Catherine Creek and wetland complex on the north side of Hartford Dr. combine with high flows from upstream to create high water in both upstream and downstream directions during heavy precipitation events. The outlet channel in the vicinity of the confluence is shallow with low banks relative to upstream and downstream conditions, which could also contribute to flooding in this vicinity. Geomorphic conditions are described in Section 7.

Photo 14. Hartford Drive in the vicinity of historic outlet channel on February 11, 2020. Hartford Drive was closed due to water over the roadway (approximately 1.5 inches deep on 2/11/2020).

7. Geomorphic Evaluation

Geomorphic evaluation of the stream channel included observations of channel planform, dimensions, and substrate during a field visit on October 3, 2019. The outlet channel was walked to observe physical and biological characteristics (biological conditions are described in Section 8) and photographic documentation is provided in Attachment B. As described in Historical Documentation Section 3, the outlet channel is not natural and was created around 1908 in association with the Rucker Lumber Mill located on the northeast side of Lake Stevens, near the current City Hall. The channel has consistent dimensions from upstream at the lake outlet to downstream at the confluence of Catherine Creek, ranging from 12 to 18 feet in width, and banks of 4.5 to 8 feet high. The channel length is approximately 3,160 feet (0.6 miles). The LiDAR image in Figure 10 illustrates the channel depth relative to the surrounding landscape. The shallow location is near the confluence of the historic channel. At this location the bank height is only 4.5 feet compared to an average bank height of 7.5 for the remainder of the channel. Water depth ranged from 0.3 to 1.2 feet on the day of our site visit. Because the channel is artificial, it has an artificial planform as well. It is relatively straight and ditch-like, confined to the south side of Hartford Drive for most of its length with no floodplain connection except in the location of the confluence where banks are low and the road overtops and floods during heavy precipitation (see Photo 14).

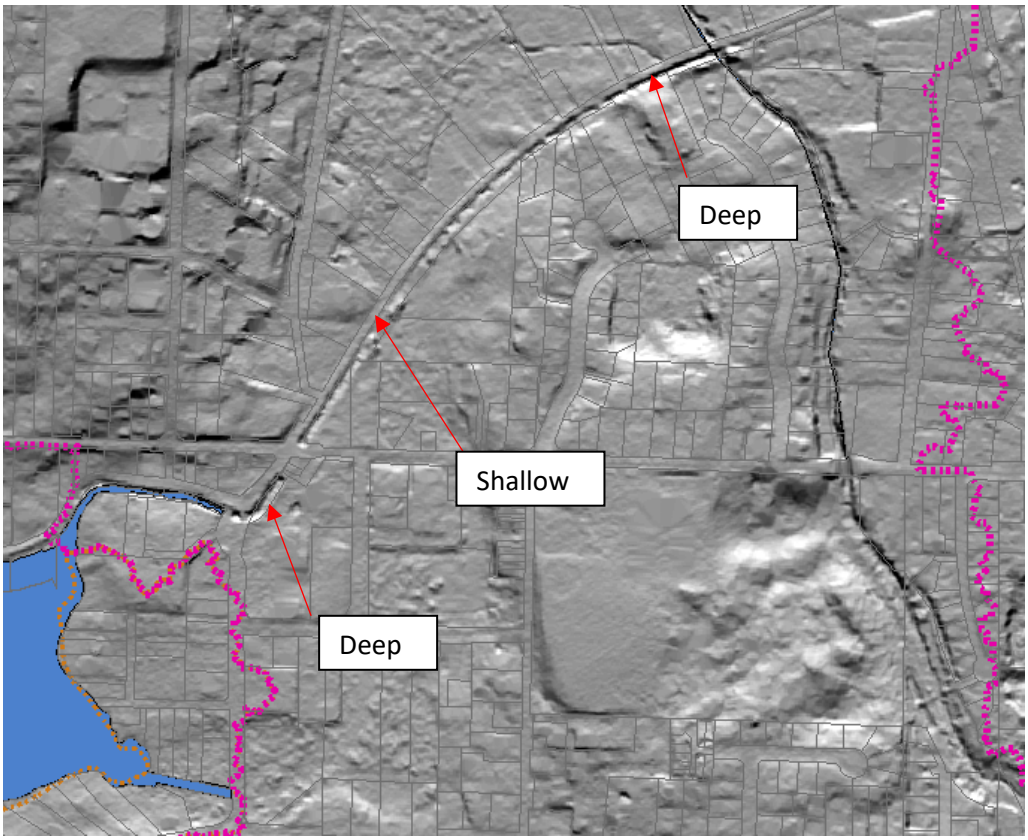


Figure 10. LiDAR imagery with deep and shallow locations indicated in the outlet channel. Darker contrast indicates greater relief; lighter contrast indicates less relief.

Channel substrate generally consists of small gravel and silt with occasional larger gravel and/or small riprap. Two locations had noticeably different channel bed conditions – in the vicinity of the second and

third private bridges upstream of the confluence with Catherine Creek the channel consists of large angular riprap that has been placed or fallen into the channel for bank or streambed protection (Photo 10). A large gravel bar was present in the vicinity of the Main Street bridge during our site visit (Photo 11).

Photo 15. Angular riprap in channel near private bridges 2 and 3.

Photo 16. Gravel bar in the vicinity of Main Street bridge.

Sources of sediment in the outlet channel include the channel banks, bed, and surface water inputs that transport and deposit material to the channel. Surface water flow inputs into the outlet channel are shown in Figure 11 and include the following:

- Lake Stevens;
- Seven outfalls conveying stormwater from the north side of the outlet channel and one outfall conveying stormwater from the south side of the outlet channel;
- A bioswale conveying stormwater from the south side of the channel upstream of the Catherine Creek confluence;
- Historic outlet channel; and
- Two culverts conveying stream flow from the north side of Hartford Drive.

Transport and deposition of fine sediment in the channel is likely from all of the surface water inputs, however, coarser materials are unlikely to be transported from the lake environment or the historic outlet channel due to the low gradient environment and large extensive wetlands that are present prior to reaching the outlet channel. Large storms that create high energy flow situations could transport large gravel from upstream ditches and stormwater catchment areas to outfalls that eventually reach the outlet channel.

Figure 11. Location of surface water inputs to outlet channel.

The banks of the outlet channel have been hardened with various materials, including solid concrete, concrete blocks, timber walls, and large riprap at several locations between the historic outlet channel and the Catherine Creek confluence. Most of these bank stabilization efforts are in the vicinity of private bridges or outfalls conveying flow from the ditches on the north side of Hartford Drive. Many of the timber crib walls appeared to be in poor condition and attempts have been made to repair them. The solid concrete walls appeared to be stable but were generally covered with vegetation and difficult to observe.

A schematic of the outlet channel showing general locations of bridges, outfalls, notable channel conditions, and significant bank stabilization is shown in Figure 12.

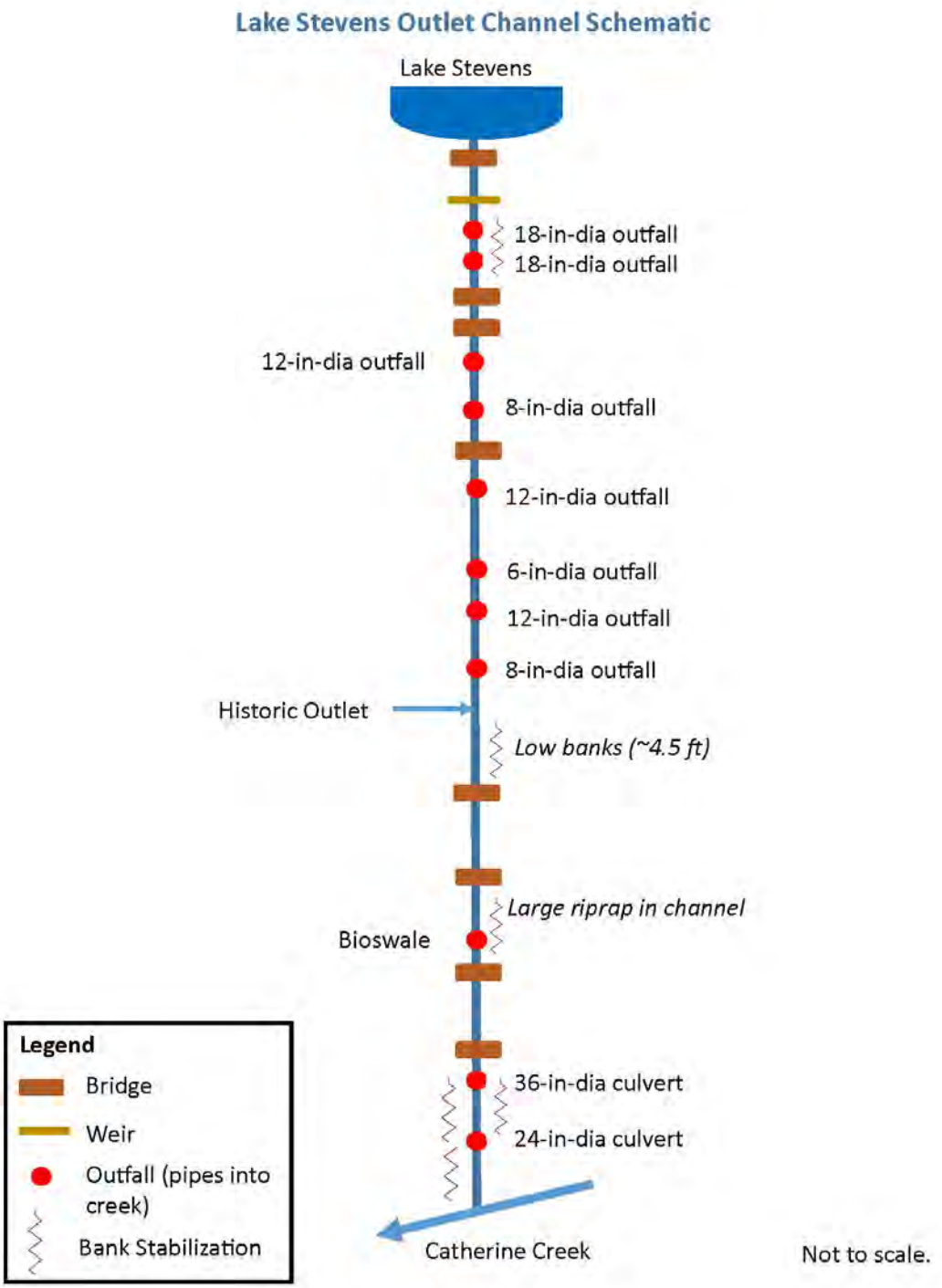


Figure 12. Lake Stevens Outlet Channel Schematic

8. Biological Evaluation

The biological evaluation included observations of habitat and channel conditions, review of fisheries data and life histories for fish known or suspected to be present in the outlet channel and Catherine Creek and observations of wetlands connected to the channels, conveyance system and project area of interest.

8.1 Fish Habitat

Habitat and channel conditions are described for two stream segments below: Upper Outlet Channel and Lower Outlet Channel.

Nearly all the channel length consists of relatively deep, ditch-like channel sections along North Lakeshore Drive, Main Street, and Hartford Drive (see LiDAR imagery in Figure 10).

8.1.1 Upper Outlet Channel

The Upper Outlet Channel described here extends from the lake to downstream near the fire station.

A lake outlet flow control weir is present (Photo 17) but may present a fish passage barrier at some flow levels, particularly at low flows. There is potential for weir improvements such that fish passage would be improved and water stored in the lake for metered release throughout the late summer and early fall dry season.

The channel tends to be deep, heavily armored along both banks, and flanked largely by non-native vegetation including Himalayan blackberry, reed canarygrass, and Japanese knotweed (Photo 18). Little or no in-stream wood is present. Notably, this upper channel section is moderately steeper than the lower, and so supports a gravellier substrate (Photos 19 and 20). Unlike the lower section, several short, gravelly riffles are present. The channel flows through more developed areas including primary roadway and utility crossings.

Photo 17. Existing lake outlet control weir is manually-operated. It does not regulate low flows well due to leakage and may be an upstream fish passage barrier during low flow periods as well. 10/3/19

Photo 18. Facing upstream, channel section along N. Lakeshore Dr. Note elevated sanitary sewer crossing and invasive vegetation. Extensive bank armoring is obscured by shrubby vegetation. 10/3/19

Photo 19. Main Street crossing from the downstream side. 10/3/19

Photo 20. Facing downstream between the 20th Street NE and Main Street crossings. Note the increased stream slope and associated gravel substrate. Knotweed is overhanging the channel. 10/3/19

8.1.2 Lower Outlet Channel

The Lower Outlet Channel described here extends near the fire station to the confluence of Catherine Creek.

As shown in Photos 21 through 26 below, the lowermost channel sections flow at a low gradient such that most of the length is glide habitat with slow-moving, medium-depth water with neither well-formed pools nor riffles. The substrate consists mostly of fines in the lowermost section (sand and very small gravel) with some areas of medium gravel proceeding upstream. Emergent wetland vegetation is present along the channel. The south bank (right bank facing downstream), is fairly well vegetated with shrubs and immature trees, though invasive vegetation including Himalayan blackberry, reed canarygrass, and Japanese knotweed is also present. However, the effective buffer width along the right bank is fairly narrow bordering residential development. The left bank, along Hartford Drive, is mowed to the water's edge resulting in little or no effective buffer width. Very little wood, almost none, is present along the lower channel.

Photo 21. Approaching downtown Lake Stevens in the background, upstream.

Creek is low-gradient with standing water (glides or standing pools). Aquatic emergent vegetation in channel, diversely vegetated wetland to the left (south), though it includes invasive Himalayan blackberry and reed canarygrass. 10/3/19

Photo 22. Section of improved overhanging vegetation, but only on the bank to the left in the photo.

Hartford Drive shown on right in photo. 10/3/19

Photo 23. Remnant bed and bank armoring. 10/3/19

Photo 24. Typical lowermost channel section with low-gradient quiet-water, little wood, some vegetation on the left, but a mowed roadway embankment on the right. 10/3/19

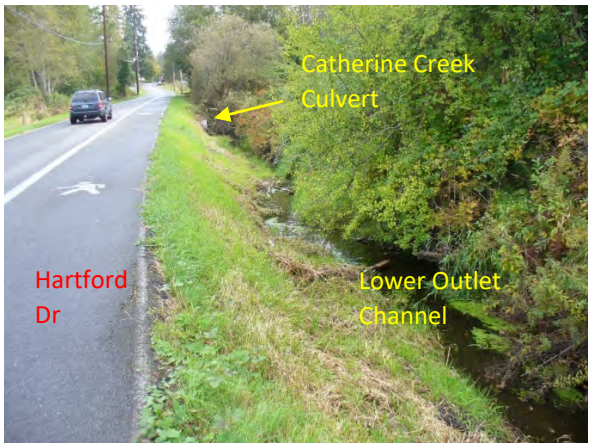


Photo 25. Facing downstream towards the Catherine Creek confluence.10/3/19

Photo 26. Facing upstream from the Catherine Creek confluence. 10/3/19

8.2 Fish Use and Life Histories

The Lake Stevens outlet stream is listed as being used by coho salmon, cutthroat trout, steelhead, and bull trout by various sources (WDFW 2019, USFWS 2019, SalmonScape 2019). Kokanee, which are landlocked sockeye salmon, are also present in the lake and inflowing tributaries and may use the outlet channel as well. Of these salmonid fish species, coho salmon and cutthroat trout are expected to make the most and the most frequent use of the ditch-like outlet stream channel along North Lakeshore Drive and Hartford Drive extending downstream from the lake. Steelhead and bull trout use may occasionally occur, but their use is anticipated to be infrequent.

8.2.1 Coho Salmon

Coho salmon present in the streams in the Lake Stevens area are part of the Snohomish coho stock, identified as a stock due to their distinct spawning distribution. Most spawning takes place in tributaries of the Snohomish, Skykomish, and Snoqualmie Rivers, including the Pilchuck River and its tributaries in the Lake Stevens area. Genetic analysis of coho sampled from the Pilchuck River in 1987 showed that they were distinct, however hatchery-origin coho from other areas and rivers were released into the Pilchuck River system between 1952 and 1969. (WDFW ScORE website accessed 10/28/19).

The Washington Department of Fish and Wildlife's (WDFW's) Priority Habitats and Species (PHS) on-line data (http://wdfw.wa.gov/mapping/phs/) and SalmonScape (https://apps.wdfw.wa.gov/salmonscape/) accessed on October 16, 2019 indicate coho salmon spawning and rearing presence in streams upstream of the lake. Since these fish are anadromous (ocean-going) this infers the upstream migration of adults and downstream migration and rearing of juveniles through the lake's outlet channel, which is the study area for this project. Adult coho spawners enter Lake Stevens and its tributaries to spawn in the late fall, primarily during November and December. Juvenile coho emerge in the spring and rear in fresh water for an additional year before migrating to the ocean. Since coho typically spend a full year rearing in fresh water before migrating to sea, they can be present as rearing juveniles in suitable habitat at any time of year.

8.2.2 Cutthroat Trout

Of the salmonid fish species using the lake and nearby streams, cutthroat trout are the most versatile and so their life history the most variable. They are pervasive in local streams where access is available

and habitat suitable. PHS on-line data accessed on October 16, 2019 indicates potential cutthroat trout presence throughout the outlet channel study area. In addition to migrating to lakes and salt water to rear and grow in size, cutthroat can also exist as non-migratory or resident forms. As such, they can sometimes remain to complete their entire life history upstream of migration barriers, so long as there are some stream sections with perennial flow above such barriers. Unlike kokanee or coho, cutthroat spawn in the late winter or early spring. Like coho but unlike kokanee, they can be present in stream habitats at any time of year.

8.2.3 Lake Stevens Kokanee.

Unlike their larger relative sockeye salmon, kokanee (both Oncorhynchus nerka) spend their entire life cycle in freshwater. They migrate to Lake Stevens in the spring from inlet streams as inch-long fry and spend three to four years in the lake before reaching maturity. Adults enter their home or nearby tributary streams in the late fall, primarily November and December, but may need to ripen up in deeper pools, preferably with wood for protection, until they are ready to spawn. The life history of kokanee differs from that of cutthroat and coho, in that kokanee do not rear as juveniles in streams. When the fry hatch and emerge from the gravel in the spring, they tend to head straight for the lake, with the journey completed possibly in a single night. They do not rear in creek habitats and are not present in creeks at any life history stage during the summer. They may be present in the outlet channel downstream of the lake as spawners or strays, but such presence has not been documented to the same extent as for the lake's tributary streams (WDFW Area Habitat Biologist Jamie Bails, Pers. Comm. with Greg Johnston, 10/28/19).

8.2.4 Non-Salmonid Fish

According to the WDFW website, the following non-salmonid fish are found in Lake Stevens in addition to the salmonid fish described above: largemouth and smallmouth bass, yellow perch, brown bullhead catfish, and crappie. Any of these fish could find their way out of the lake and into the outlet stream.

8.3 Wetlands

All the wetlands identified by the City of Lake Steven Critical Areas Atlas within the study area were determined to meet wetland criteria for hydrophytic vegetation, hydric soils, and wetland hydrology. The historic Lake Stevens outfall channel (and potential re-alignment) contains a series of wetlands that create a continuous corridor to Catherine Creek (mapped in Appendix A – Lake Stevens Outfall Streams and Wetlands). Wetlands in the historic outlet channel are approximated as Category II or Category I wetlands, using the 2014 Wetland Rating System for Western Washington. Figure 13 shows the approximate locations of these wetlands (as inventoried by Snohomish County) and the historic outlet channel.

Excluding a lake fringe wetland that is hydrologically disconnected from the others, all the wetlands in the corridor have retained wetland hydrology following the original disconnection with Stevens Creek and frequently flood nearby roads during periods of heavy precipitation. Another stream conveys water from a large wetland complex to the south that drains a separate and distinct basin than Lake Stevens. This stream flows through the wetland corridor and likely is the primary hydrology source, although hydrology is likely supplemented by a high groundwater table. The hydrogeomorphic classification of each wetland (excluding the disconnected lake-fringe wetland) is depressional, and all are similar in character: depressional wetlands with a stream flowing through the center. Beavers are present in the area and one dam and associated pond was observed during the site visit.

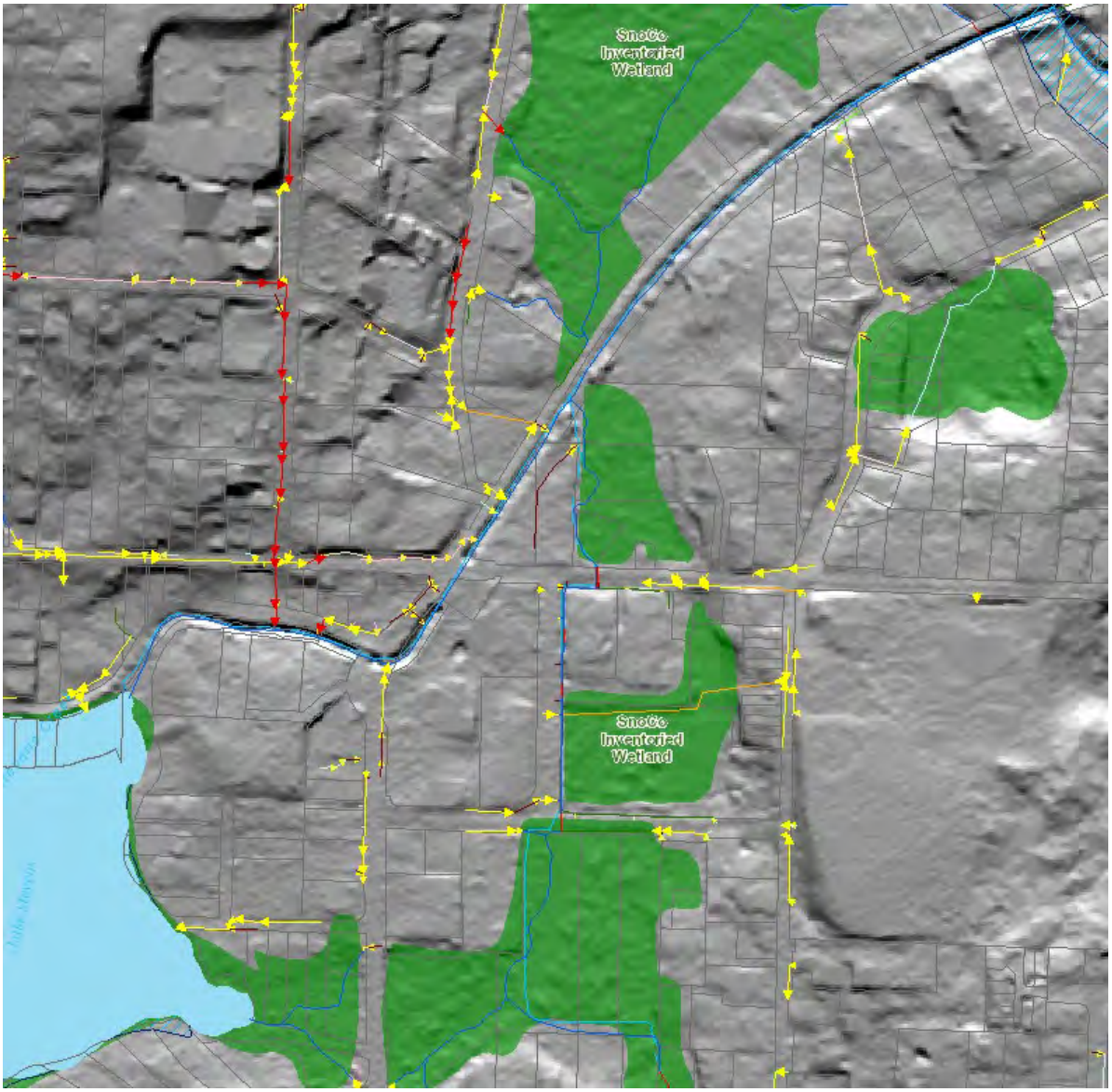


Figure 13. Map showing Snohomish County Wetlands Inventoried in the vicinity of the historic channel.

Vegetation in the wetlands range in character and include communities dominated by forested, scrub-shrub, emergent, and aquatic bed vegetation. The largest wetland is primarily dominated by a reed canarygrass (Phalaris arundinacea) monoculture. The potential outlet re-alignment would be located through the center of these features, where regular flooding and inundation has prevented the establishment of forested plant communities. Therefore, the potential outlet re-alignment would not result in much, if any removal of forested wetland communities. However, some areas, particularly near the lake fringe wetland, may require some forest removal for construction of a new channel.

The existing Lake Stevens channel outlet is vegetated with emergent wetland vegetation including both emergent and aquatic bed plant species. Although located entirely below the OHWM, this area would meet the three wetland parameters for hydrophytic vegetation, hydric soils, and wetland hydrology. Dominant wetland plants observed in the channel include reed canarygrass (Phalaris arundinacea), pond

water-starwort (Callitriche stagnalis), swamp smartweed (Persicaria hydropiperoides), bur-reed (Sparganium sp.), forget-me-not (Myosotis sp.), slender cinquefoil (Potentilla gracilis), and water purslane (Ludwigia palustria). Much of the channel is unvegetated, although some areas contain significant plant cover.

9. Issues Identified and Potential Solutions

Flooding issues previously known to the City were confirmed during this analysis, review, and field evaluation. The most problematic locations are low-lying areas where transportation and conveyance infrastructure intersect, including 18th Avenue NE, and 20th Avenue NE where surface water is stored and conveyed in a series of large wetlands and conveyance ditches and road culverts, and Hartford Drive where this upstream conveyance converges with the Lake Stevens outlet channel. According to City staff and our observations during field visits in fall 2019, beaver activity also contributes to flooding due to water being backed up by beaver dams. Flooding in Lake Stevens causes a public safety and transportation problem when roads are closed due to flood waters, or high water threatens properties.

Other drainage issues identified included catch basin debris that could contribute to flooding and/or water quality issues, and potential pipe defects (sags or broken pipes) that may need repair.

As discussed in Section 8, habitat is lacking in the outlet channel due to the absence of hydraulic diversity (pools and riffles) and large woody debris which contributes to pool formation and provides cover for juvenile salmonids. Additionally, there are reports of low dry season flows that stress fish populations in Catherine Creek, of which the outlet channel is tributary.

As discussed in Section 4, a weir in the outlet channel serves to control the lake level during the summer months to keep lake levels high in the summer and allow the lake to fluctuate naturally during the winter months. Managing the lake level continues to be a challenge to meet competing needs of reducing winter flooding, managing low summer stream flows, and assuring higher summer lake levels for summer recreation and residential dock access.

A preliminary list of alternatives was evaluated to address the ongoing flooding, habitat, infrastructure, and lake level management issues identified. The alternatives were packaged into stand-alone and packaged projects and divided system locations to address the goals identified for this project. A sub-set of the alternatives were selected to move forward with planning level conceptual designs and cost estimates.

Table 6 lists the full set of preliminary alternatives, associated improvements and related goals for the following locations and/or focus areas (see Figure 14):

- Existing Outlet Channel Alignment- Upper Reach
- Existing Outlet Channel Alignment- Lower Reach
- Historic Outlet Channel Alignment- Upper Reach
- Historic Outlet Channel Alignment – Lower Reach
- Local Drainage Improvements

Table 6. List of Alternatives and Related Goals

Note: Prioritized alternatives are highlighted in yellow which are discussed in more detail in Section 9, shown in Figure 15 and summarized in project summary sheets in Attachment E.

Alternative	Component Number	Option/Improvement Description	Goal Addressed	Stand-alone or Packaged Project
1. Existing Outlet Channel Alignment- Upper Reach	1A	Revise Lake Outlet Structure	Better lake level management to reduce flooding and increase stream baseflow in summer.	Stand-alone
	1B	Streambed revitalization/channel improvements	Increase hydraulic diversity, habitat uplift, alleviate flooding.	Stand-alone
	1C	Engineered woody debris	Increase hydraulic diversity, habitat uplift	Stand-alone
	1D	Re-route existing utilities	High flow capacity management	Stand-alone
	1E	Revitalized lake outlet	Increased biodiversity, habitat uplift	Stand-alone
2. Existing Outlet Channel Alignment- Lower Reach	2A	Streambed revitalization/channel improvements	Increase hydraulic diversity, habitat uplift, alleviate flooding.	Stand-alone
	2B	Engineered woody debris	Increase hydraulic diversity, habitat uplift	Stand-alone
	2C	Road improvements (Hartford Dr)	Alleviate flooding	Stand-alone
3. Historic Outlet Channel Alignment- Upper Reach	3A	Revise Lake Outlet Structure	Better lake level management to reduce flooding and increase stream baseflow in summer.	Packaged with 3B
	3B	Re-channelization of historic outlet path	Increase hydraulic diversity, habitat uplift, alleviate flooding.	Packaged with 3A
	3B-I	Re-channelization of historic outlet path- Lake to Main St.		
	3B-II	Culvert crossing under Main St. between 16th Avenue NE and 17th Pl NE		
	3B-III	Re-channelization of historic outlet path- Main St. to 18th Ave NE		
	3B-IV	Culvert crossing under 18th Ave NE and regrading		
	3B-V	Re-channelization of historic outlet path- 18th Ave NE to 20th Ave NE		
	3B-VI	Culvert crossing under 20th Ave NE and regrading		
	3B-VII	Re-channelization of historic outlet path- 20th Ave NE to Hartford Dr		

Alternative	Component Number	Option/Improvement Description	Goal Addressed	Stand-alone or Packaged Project
4. Historic Outlet Channel Alignment- Lower Reach	4A	Culvert crossing under Hartford Dr (NE of the fire station)	Increase hydraulic diversity, alleviate flooding.	4C
	4B	Backwater habitat (20th Ave NE to Hartford Dr.	Increase hydraulic diversity, habitat uplift	Stand-alone
	4C	Re-channelization of historic outlet path- Hartford Dr. to Catherine Creek	Increase hydraulic diversity, habitat uplift	4A
5. Local Drainage Improvements	5A	Improve storm infrastructure near intersection of 16th Ave NE and Main St.	Alleviate flooding	Stand-alone
	5B	Culvert crossing under 18th Ave NE and regrading	Alleviate flooding	Stand-alone
	5C	Culvert crossing under 20th Ave NE and regrading	Alleviate flooding	Stand-alone
	5D	Improve storm infrastructure near fire station	Alleviate flooding	Stand-alone
	5E	Existing outfalls to creek	Keep existing conveyance system (if existing outlet channel retired)	Stand-alone
	5F	Improve/analyze the culvert at the confluence between Catherine Creek/Lake Stevens outlet and Hartford Dr.	Alleviate flooding	Stand-alone

Note: Prioritized alternatives are highlighted in yellow which are discussed in more detail in Section 9, shown in Figure 15 and summarized in project summary sheets in Attachment E.

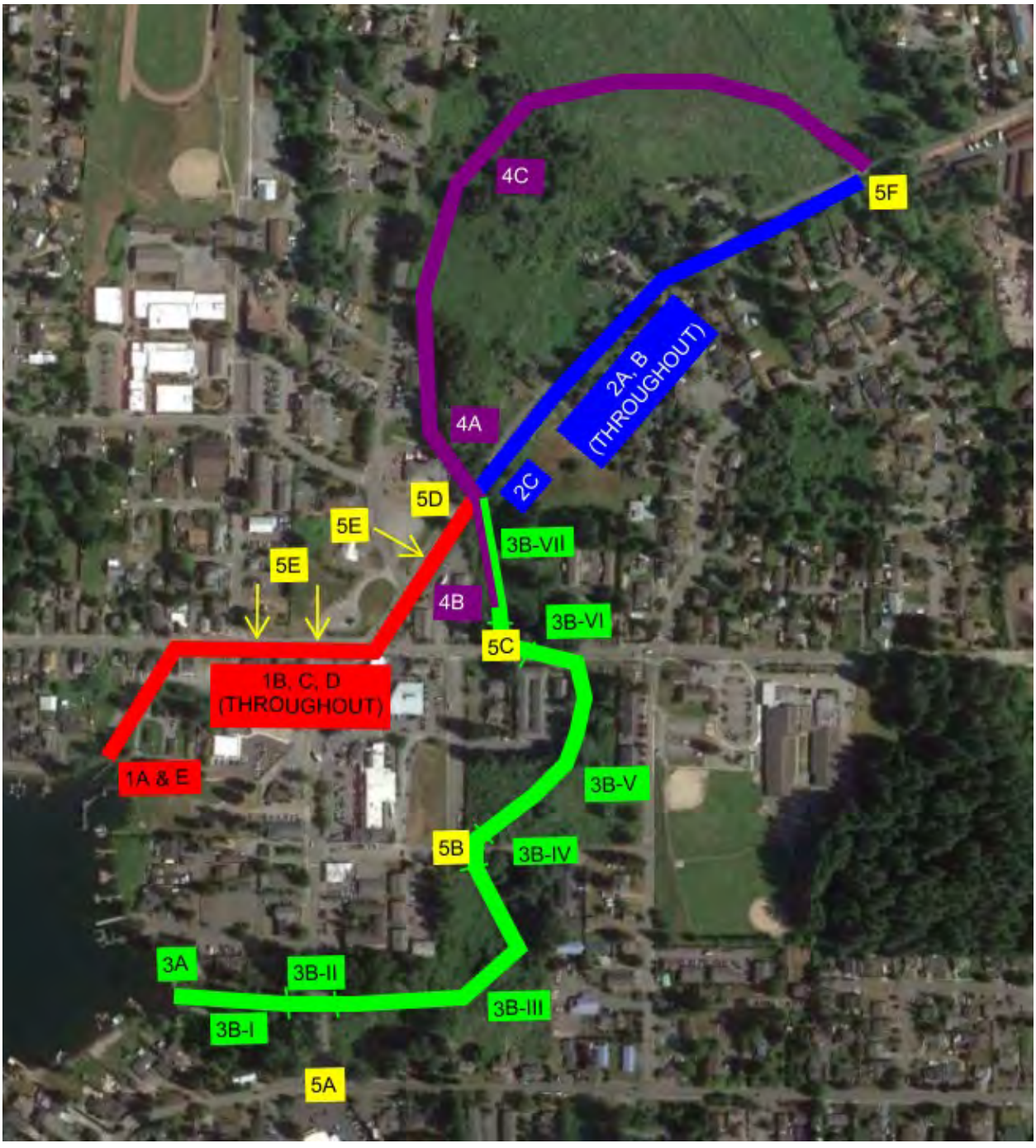
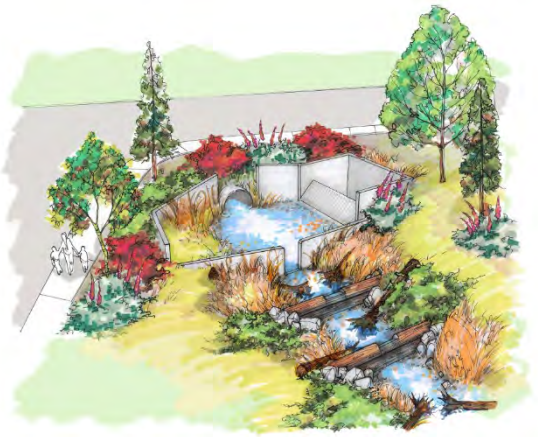


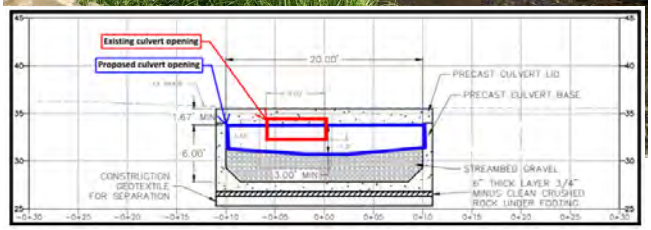
Figure 14. Location of Alternatives

The preliminary alternatives discussed below are described by their association with a geographic location or channel reach in the system that was evaluated. Preliminary cost estimates and project summary sheets were developed for the highest priority components within these alternatives. Components for which project summary sheets and preliminary costs were not developed were not evaluated in as much detail, and as such, do not have as much detail below.

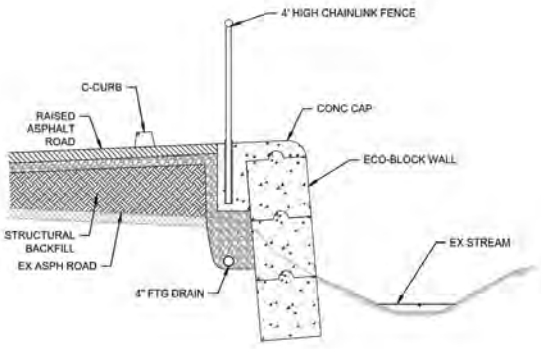
Alternative 1A & 1E



Alternative 5B and 5C



Alternative 2C & 5D



1A and 1E = Revise lake outlet structure and upper reach outlet channel modifications

2C and 5D = Improve stormwater infrastructure in the vicinity of the fire station and road improvements on Hartford Drive

5B = Improve culvert crossing under 18th St. NE and regrading.

5C = Improve culvert crossing under 20th St NE and road re-grading.

5F = Improve/analyze the culvert at the confluence between Catherine Creek/Lake Stevens outlet and Hartford Dr.

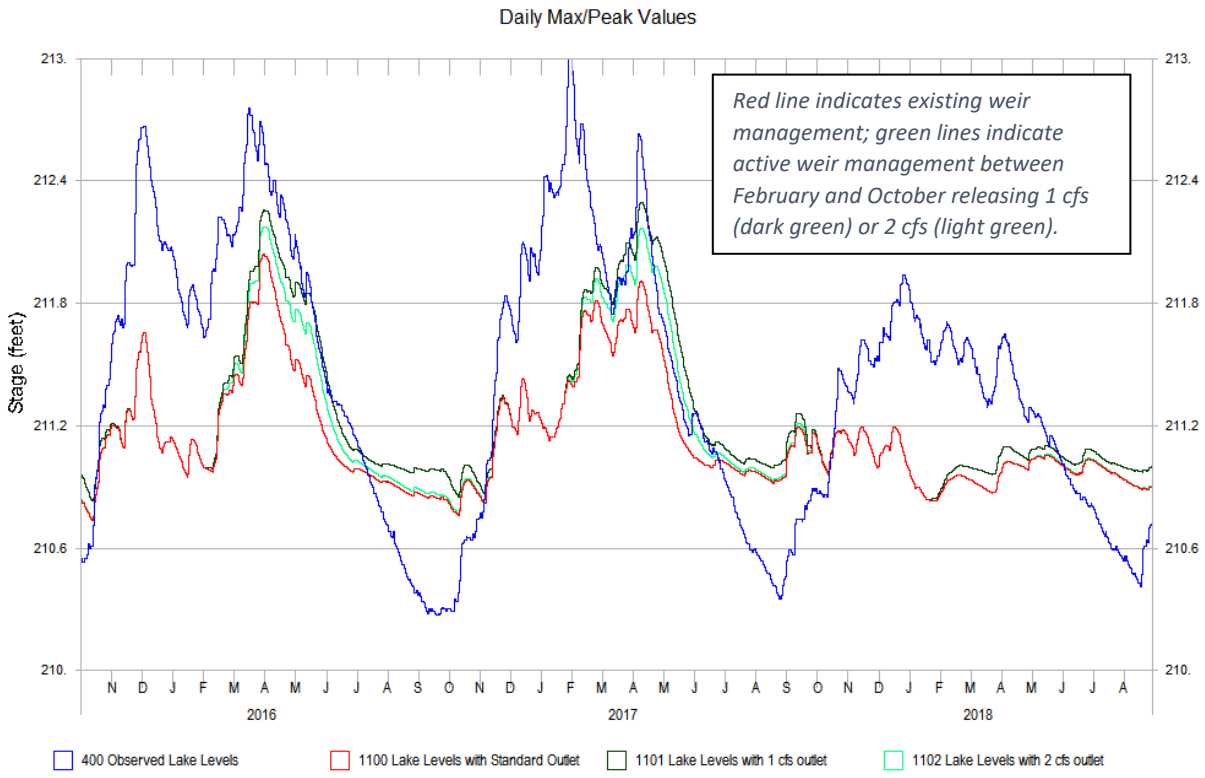
Figure 15. Representative Graphics and Photos of Prioritized Alternatives

9.1 Alternative 1 Existing Lake Outlet Alignment- Upper Reach

Alternative 1 and its subcomponents address the existing lake outlet from Lake Stevens to the confluence of the historic outlet channel near the fire station. The primary feature of this reach is the existing weir that is used to manage the lake level elevation and control summer flow in the outlet channel and subsequently downstream in Catherine Creek. As for the rest of the outlet channel, this reach is lacking in hydraulic diversity and is devoid of much habitat value. There are several roadway bridge crossings, and stormwater outfalls throughout the reach.

Components of Alternative 1 include modification to the existing weir, including repair and/or replacement of the weir system and modified operation (Alternative 1A), and improvements to habitat conditions in the channel and floodplain, particularly on property owned by the City in the vicinity of the Lake outlet (Alternatives 1B through 1E). Where needed to protect infrastructure, such as an upgraded and reconstructed weir, or to prevent excessive erosion, the channel would be stabilized primarily with rounded large cobble and small boulders. Large woody debris placed in conjunction with these cobbles and boulders would provide habitat function and also contribute to channel stability.

A preliminary evaluation of the lake elevation and existing weir indicates that the weir might not be operating as intended. This needs to be confirmed. Preliminary modeling shows that the weir could be actively managed between February and October to continually release 1 or 2 cfs which would be sufficient to provide minimum flows for aquatic species. This would result in slightly higher lake levels (green lines in Figure 16) than currently modeled with the existing outlet (red line in Figure 16). The observed lake levels (blue line in Figure 16) indicate that the weir is not providing the intended function, since it does not match the red line.



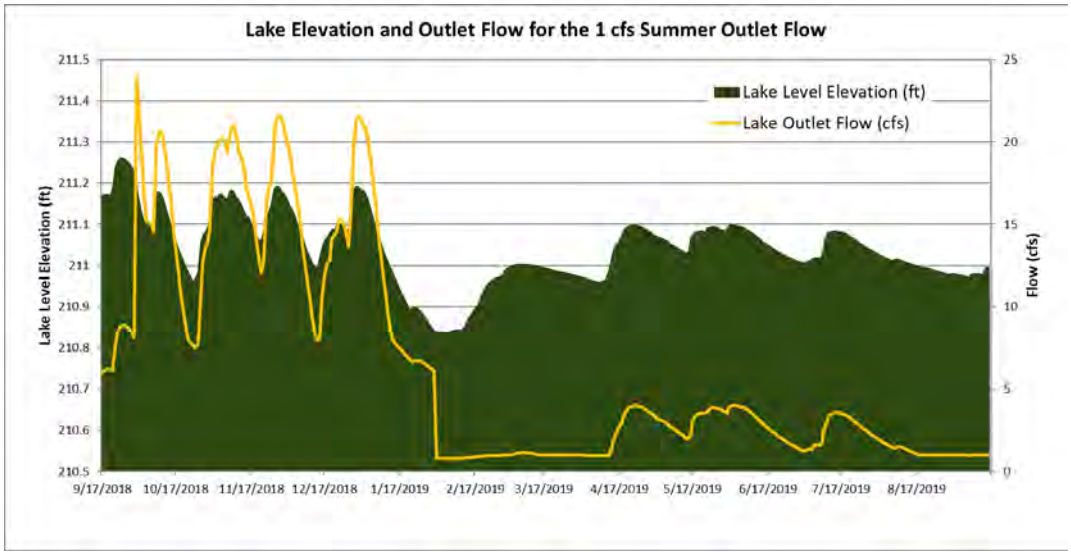


Figure 16. Modeled Lake Elevations with Different Weir Management and Lake Elevations with Outlet Flow for One of the Scenarios (1cfs outlet flow in summer).

Note in Figure 16 in the lower graph for the scenario managing lake level outlet flow to 1cfs in the summer, the weir is raised in February to increase the lake level/storage to achieve higher lake levels and a minimum of 1cfs outlet flow in the Summer.

Components 1A and 1E were determined to be highest priority by the City. Project summary sheets and preliminary cost estimates for these components are provided in Attachment D and Attachment E.

Component 1E involves habitat improvements in the channel and floodplain that could include installation of large woody debris for improved local hydraulic diversity and fish refuge and modifications to channel geometry to improve floodplain connection on City property. Habitat improvements in the channel and floodplain will need to be coordinated with the weir repair or replacement to ensure all improvements are mutually compatible.

Benefits of alternative 1A and 1E are expected to involve improvements to instream flows, including potential reduction in flooding. Increasing channel dimensions, primarily width, in association with these alternatives would generally allow the outlet channel to carry more flow during peak flow periods. However, care would need to be taken to enlarge the channel uniformly to minimum dimensions along the entire length where flows may be inhibited. Any narrower pinch point would largely negate the increased flow capacity effects of a bigger channel. Likewise with any channel bottom height that is too high along the channel profile, however excavating the channel deeper than the streambed farther downstream would not help to increase flow capacity. The preliminary estimates of channel excavation quantities for cost estimating purposes (see Appendix D) indicate approximately 2,200 cubic yards of net channel excavation that may be associated with channel excavation associated with existing weir removal, proposed weir placement, and stream channel modifications near the mouth of Lake Stevens to the outlet channel. Further analysis is needed to quantify flood reduction and summer flow benefits. Instream habitat benefits in conjunction with weir modification could provide increased refuge for juvenile salmonids and improved fish passage at the weir for access to the lake.

9.2 Alternative 2 Existing Lake Outlet Alignment- Lower Reach

Alternative 2 and its subcomponents address the existing channel outlet from the confluence with the historic outlet to the confluence with Catherine Creek. The components of this alternative mostly involve habitat improvements (Alternatives 2A and 2B), as the channel is lacking in hydraulic diversity and habitat diversity, as described in Section 8. Additionally, Component 2C involves modifications to Hartford Drive in the vicinity of the historic channel confluence where the road is prone to flooding due to the channel overtopping. As described in Section 7, the channel is much shallower in the vicinity of the historic outlet channel confluence (up to 3 – to 3.5 feet less deep than the average depth of the entire outlet channel), and the road profile is low in this location as well.

A preliminary analysis of the road profile shows Hartford Drive is lower in the vicinity of the historic channel confluence (Figure 17). The plan and profile for Hartford Drive and other roads evaluated in this analysis are provided in Attachment C.

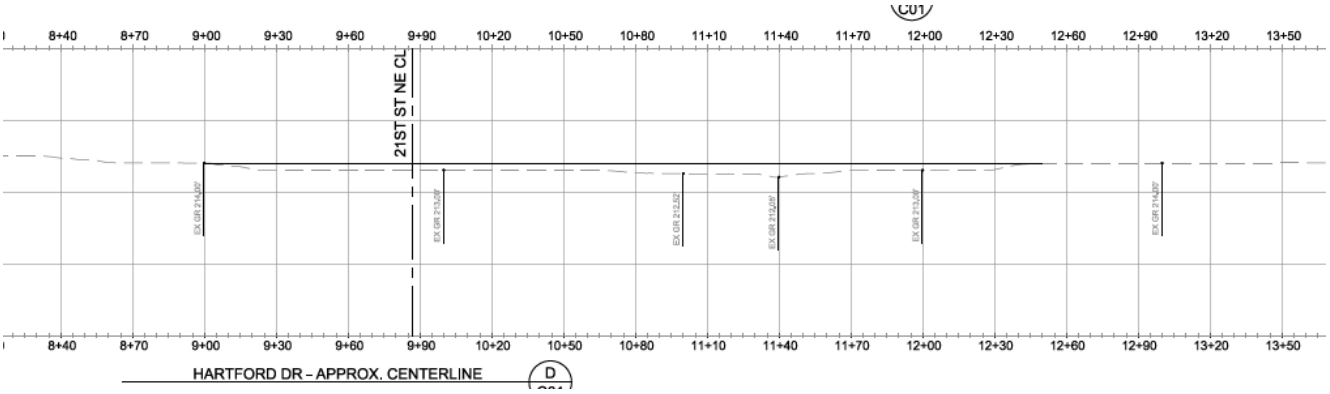


Figure 17. Hartford Dr. preliminary existing road profile in vicinity of historic channel confluence which is approximately at station 11+00. Grid lines on the y-axis represent 10-ft elevation intervals.

Channel improvements in this reach would focus on improving hydraulics so that fine sediment does not accumulate and reduce channel capacity in the vicinity of Hartford Drive. Additional evaluation will be needed to determine appropriate site-specific solutions because there are a number of factors that could be contributing to channel conditions in the vicinity of Hartford Drive that are not fully understood, including the nature and volume of stormwater inputs from the north, and the historic outlet channel from the south.

Component 2C (which has also been combined with improving storm infrastructure near the fire station (component 5D)), raising the road profile at Hartford Drive, was determined to be high priority by the City. A project summary sheet and preliminary cost estimate for this component is provided in Attachment D and Attachment E. Raising the road profile of Hartford Drive is expected to reduce localized flooding that occurs frequently on Hartford Drive.

9.3 Alternative 3 Historic Lake Outlet Alignment- Upper Reach

Alternative 3 and its subcomponents address the historic lake outlet alignment (circa 1907) from the northeast shore of Lake Stevens to the confluence with the existing outlet channel. This alternative involves potential re-channelization of the historic outlet channel and retirement of the existing channel. The historic outlet channel route proceeds through an expansive wetland and open space area, much of which is owned by the City of Lake Stevens. It is very flat and prone to flooding, particularly at road crossings where water from the upstream wetland complexes is conveyed in a ditch system to the existing outlet channel.

- The components of this alternative include the following:
- A new lake outlet control structure or weir to manage lake levels because the existing weir would be retired (Alternative 3A).
- Upgraded or replaced culvert crossings at 18th Avenue NE and 20th Avenue NE, which experience frequent flooding (Alternatives 3B- IV and 3B – VI).
- New culvert crossing at Main Street (Alternative 3B – II).
- New channel construction from Lake Stevens to the confluence with the existing outlet channel (Alternative 3B-I, -III, -V, and -VII).

The components of this alternative could be completed in phases, with the culvert crossings being upgraded first to address an immediate need to alleviate flooding and the longer term need to

accommodate higher flows and a new channel crossing. There are many elements of this project that require further investigation to determine feasibility, including the (1) feasibility of establishing and maintaining a new channel in a low-gradient, wetland environment that is frequently flooded, (2) potential permitting challenges with construction and implementation in wetlands, and (3) ability of alternative to meet City goals.

Additionally, the existing lake outlet receives stormwater flow from several outfalls along its entire reach. It would be difficult to abandon the channel in its entirety without constructing replacement infrastructure to convey stormwater currently discharging to the channel.

Alternative 3 was not determined to be high priority by the City, therefore a project summary sheet or preliminary cost estimate was not prepared for this alternative. However, subcomponents of this alternative are described in Alternative 5 (5B and 5C, culvert crossings at 18th Ave and 20th Ave) that are high priority. These are discussed below.

9.4 Alternative 4 Historic Lake Outlet Alignment- Lower Reach

Alternative 4 and its subcomponents address the historic lake outlet alignment (circa 1907) between the confluence with the existing outlet channel and Catherine Creek. A channel exists on the north side of Hartford Drive that is connected to the existing outfall channel on its downstream end via a 36-inch diameter culvert, but is not connected on the upstream end except during flood conditions when the road overtops. This alternative would involve connecting the historic channel with a new culvert crossing (Alternative 4A) and enhancing or reconstructing the existing channel to the north (Alternative 4C). Additionally, this project could involve construction of backwater habitat in the vicinity of the current historic outlet channel confluence with the existing outlet channel to provide refuge for juvenile salmonids in the wetlands south of Hartford Drive (Alternative 4B).

Project benefits could include expanded juvenile salmonid habitat refuge.

Alternative 4 was not considered high priority by the City and therefore a project summary sheet or planning level cost estimate was not prepared for this alternative.

9.5 Alternative 5 Local Drainage Improvements

Alternative 5 includes local drainage improvements that can be completed independently and address an infrastructure problem that is not necessarily associated with the surface water and lake management system. These include stormwater infrastructure improvements and culvert upgrades that are also listed as components of previous alternatives.

Alternative 5A improves infrastructure near the intersection of Main Street and 16th Avenue NE where there is a suspected defect with a pipe.

Alternatives 5B and 5C improve culvert crossings at 18th Avenue NE and 20th Avenue NE, respectively. Flooding occurs at these locations frequently. The 18th and 20th Avenue NE culvert upgrade may also require road regrading to resolve the flooding issues. These alternatives are also part of Alternative 3 if the historic lake outlet channel project proceeds. Alternatives 5B and 5C were considered high priority by the City. Project summary sheets and planning level cost estimates are provided in Attachment D and Attachment E

These projects are expected to alleviate flooding in the near vicinity of their respective locations.

Alternative 5D involves improving stormwater infrastructure in the vicinity of the fire station. A maintenance hole at the intersection of Hartford Drive and 21st Place NE surcharges during heavy precipitation, causing flooding at the intersection. This alternative involves replacement of the infrastructure to resolve surcharging conditions. Alternative 5D (which has also been combined with Hartford Dr grading improvements (2C)) was considered high priority by the City. A project summary sheet and planning level cost estimate is provided in Attachment D and Attachment E.

This project is expected to result in recommendations for the City to modify the drainage system or replace the surcharged manhole.

Alternative 5E involves addressing existing stormwater conveyance if the existing outlet channel is retired.

Alternative 5F involves evaluation of hydraulic conditions in the vicinity of the Catherine Creek confluence, including the north side of Hartford Drive, the current culvert crossings near Catherine Creek and the outlet channel.

10. Findings and Recommendations

As described above, in discussion with the City, the alternatives that were recommended to move forward for further evaluation and preliminary engineering design are noted and described below. Additionally, in collaboration with the City, the alternatives have been prioritized in Table 7 and also show preliminary cost estimates. Additional detail on Preliminary planning level cost estimates are provided in Attachment D.

Table 7. List of Recommended Alternatives and Planning Level Cost Estimates

Alternative	Description	Priority	Goal(s) Addressed/Benefits	Estimated Total Project Cost ($K)
1A and 1E*	Revise lake outlet structure and upper reach outlet channel modifications	1	Better lake level management to reduce flooding and increase stream baseflow in summer as well as increased biodiversity/habitat uplift.	$1,652,726
5F	Improve/analyze the culvert at the confluence between Catherine Creek/Lake Stevens outlet and Hartford Dr.	2	Alleviate flooding, supports culvert improvements for fish passage in Catherine Creek at Hartford Dr. crossing.	$100,000
2C and 5D*	Improve stormwater infrastructure in the vicinity of the fire station and road improvements on Hartford Drive	3	Reduced flooding.	$938,999
5C	Improve culvert crossing under 20th St	4	Reduced flooding and habitat uplift.	$1,284,132

	NE and road re-grading.			
5B	Improve culvert crossing under 18th St. NE and regrading.	5	Reduced flooding and habitat uplift.	$1,783,213
			Total Planning Level Costs	**$5,759,070**

* Alternatives 1A and 1E have been combined into a single alternative to analyze. The same can be said for Alternatives 2C and 5D.

Additional operational recommendations to alleviate on-going flooding concerns include the following:

4. Continue robust catch basin inspection and maintenance program to ensure that catch basins and enclosed stormwater conveyance infrastructure is free and clear of debris, especially in advance of predicted rainfall.
5. Continue beaver management program to alleviate back-ups and conveyance blockages due to beaver dams.
6. Remove vegetation cut from outlet channel banks during mowing operations, rather than allowing material and debris to fall into channel. This will keep channel open for conveyance.

11. References

Gray & Osborne, Inc. 1999. Lake Stevens/Catherine Creek Watershed Management Plan. Seattle, WA.

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_____ 2017. SalmonScape http://apps.wdfw.wa.gov/salmonscape/ 16 October 2019.

_____ 2005. 2002 Washington State salmon and steelhead stock inventory (SaSI). Wash. Dep. Fish Wildl. http://wdfw.wa.gov/fish/sasi/

Attachment A
Infrastructure Photo Log

Attachment B
Stream Walk Photo Log

D|C|G
civil structural

Attachment C
Preliminary Plan and Profiles

D|C|G
civil structural

Attachment D
Planning Level Cost Estimates

Attachment E
Project Summary Sheets