ANCHOR QEA

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TECHNICAL MEMORANDUM

To:	Janice Flagan, Skagit County Kara Symonds, Skagit County	**Date:**	May 24, 2010
From:	Simon Page, Anchor QEA, LLC	**Project:**	070434-04.01
Re:	Lake McMurray Lake Level and Beaver Control Improvement Needs Evaluation Services		

This technical memorandum documents the results of the Lake McMurray lake level and beaver control improvement needs evaluation conducted for the Skagit County Department of Public Works (County) by Anchor QEA, LLC.

LAKE MCMURRAY HYDROLOGIC SETTING AND LAKE LEVEL CONCERNS

Lake McMurray is located in a glacial moraine valley in southwestern Skagit County at the intersection of State Route 9 and SR 534, about 4 miles east of Interstate-5 (Figure 1). Lake McMurray is a 160-acre lake that discharges to the north via Lake Creek to Big Lake. Big Lake, in turn, discharges to Nookachamps Creek, the Skagit River, and ultimately the Puget Sound.

Anchor QEA staff previously studied the hydrology of Lake McMurray for the Big Lake Drainage Management Plan (DMP; Anchor 2005). For that plan, hydrologic and hydraulic analyses were conducted for assessment of infrastructure improvement needs and Big Lake water levels. A continuous simulation hydrologic model (Hydrologic Simulation Program-FORTRAN [HSPF]) was developed for the Big Lake watershed, including the area tributary to Lake McMurray. Current data available in the Big Lake DMP (Anchor 2005) for the Lake McMurray watershed include hydrologic characterization parameters (land cover, soils, surficial geology, and slope), numerous aerial photographs, and surveys of major culvert crossings along Lake Creek. Those collective data and the previously developed modeling tools were used in the analyses conducted for this assessment, thus providing consistency and continuity with that prior plan analysis.

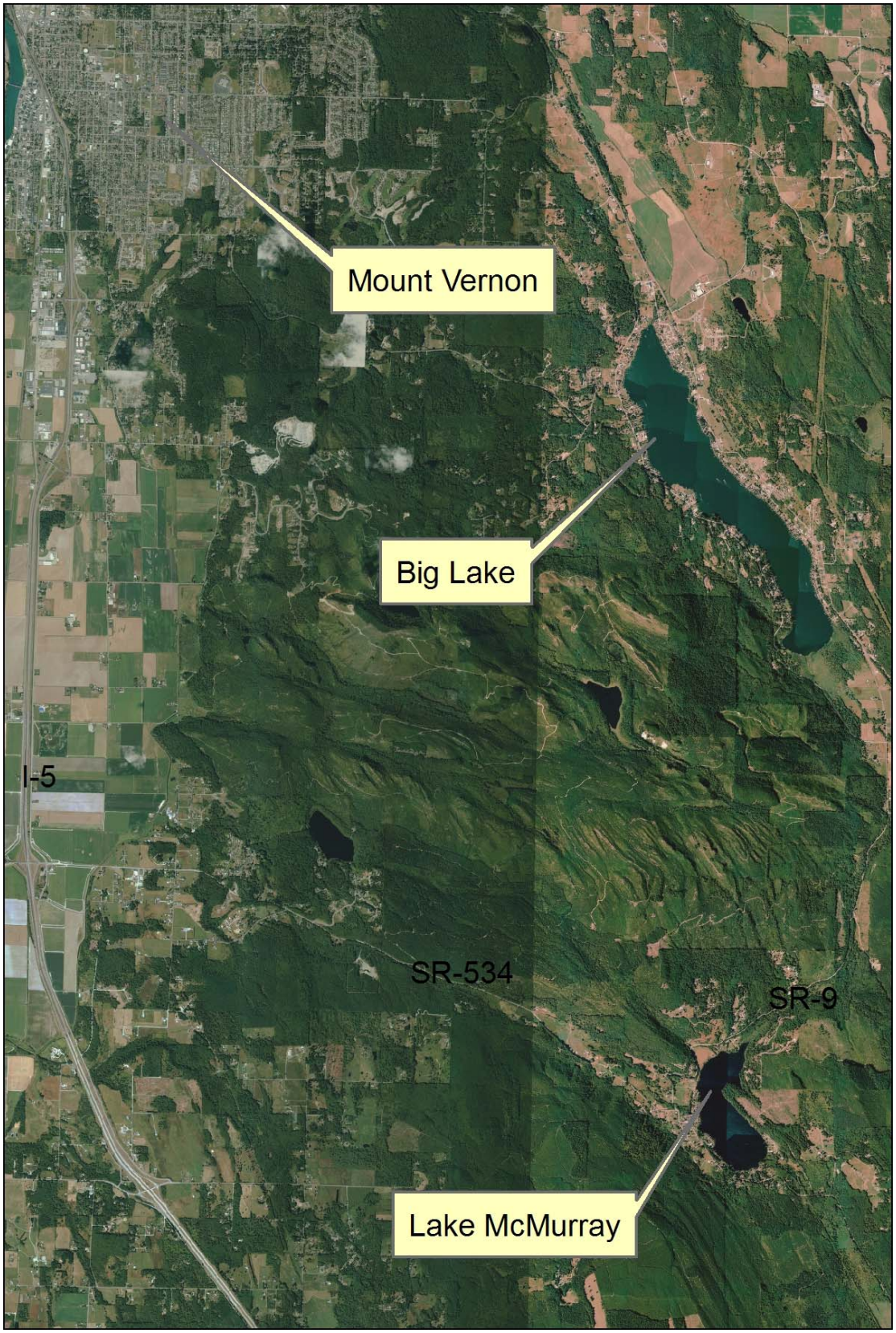

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Figure 1
Lake Murray Vicnity Map
Skagit County Department of Public Works

A significant flood event occurred in Skagit County on January 7 through 9, 2009. Several Lake McMurray residents contacted the County to express their concerns about rapid rising water levels. The residents reported that the flood water was destroying their docks, reaching their foundations, and flooding their septic tanks. They were very concerned about their drinking water and lake water becoming contaminated from the flooded septic tanks. Residents asked if the County could move debris that might be blocking the flow. County staff went to the site, assessed the situation, and determined that no action could be taken at that time (Patton 2009).

After the flood, the residents requested a meeting with their County Commissioner to discuss lake levels and other drainage issues near Lake McMurray. The following bulleted items were the key items from the meeting notes, provided by the County (Patton 2009; Appendix A) and related to lake levels. Although concerns about regarding erosion control, WSDOT drainage improvements, and Shoreline Management Act development restrictions were identified by the residents, these issues are not related to lake level management and are not discussed or evaluated in this memorandum.

- Lake McMurray residents claim that they have had flooding issues with their lake since 1968 and the problem seems to worsen every year.
- Tesidents used to be allowed to remove beaver dams without a permit to help alleviate some of the flooding. Now, it is extremely difficult to get a permit.
- Residents claim that the Lake Creek outlet channel used to be wide and deep, but the amount of debris has increased and the channel has become more narrow and shallow causing the lake level to rise.
- The Lake Management District for Lake McMurray (LMD No. 2) was formed in 1999. Resolution No. 17887, which defines the purpose and goals of the District, did not include lake level management.
- Water level complaints from Lake McMurray residents were first recorded in 2001

Since 2001, the County has taken numerous actions to attempt to manage or study the lake level problems. Table 1 identifies the year and the actions taken by the County to manage the Lake McMurray water levels.

Table 1

Previous Actions Taken by the County to Manage Lake McMurray Water Levels

Year	Previous County Action
2001	Breached dam in the wetland at the south end of Lake McMurray. Breaching the dam had no effect on lake level.
2001	Trapped and relocated beavers. Beavers returned.
2001	Installed two beaver deceiver devices at the north end of the lake.
2002	Installed 4 lake level gages (2 in Lake Creek, 1 in the lake at the boat launch, 1 in the wetland at the south end of the lake). Monitored water levels for four years (2001 to 2005). Lake elevations varied by approximately 1 foot.
2002	Breached large beaver dam upstream (end of Lake Creek?). Beavers reconstructed dam.
2002	Installed a third beaver deceiver (downstream?). This device has the greatest effect on lake level.
2002	Installed a second culvert to the upstream beaver deceiver. Seemed to lower the elevations about 1-foot over time.
2002	Cleaned debris from upstream twin culverts (Lake McMurray Estates?).
2003	Lowered the upstream beaver deceiver (upstream) an additional 6 inches.
2004	In response to the petition to amend the Resolution to include lake level management, the Commissioners suggested conducting a study to quantify the problem.

2004	The County identified several possible causes for the increases in Lake McMurray water levels including:
	• Beaver dams
	• Fallen trees and debris from the old mill
	• Dense vegetation
	• Increased upland development and deforestation:
	  o Increased volume and rate of water reach the lake during rain events.
	  o Increased sedimentation. Increased runoff velocity can lead to greater soil erosion and ultimately decreases the volume capacity of the lake.
	• Rain events(increase lake levels in a relatively short period of time and lake levels decrease at a very slow rate)

2005	Treated water lilies in the outflow. Beaver deceivers and lily treatments appeared to increase water flow.
2006	Assessed lowering the beaver deceiver (upsteam?), but discovered a large old growth log located directly beneath the device. Could not lower the device.
2007	Treated water lilies in the outflow.

ANALYSIS APPROACH, METHODS, ASSUMPTIONS, AND RESULTS

This section documents the analysis methods, key assumptions, and results on which the findings and recommendations reported in this technical memorandum are based.

Analysis Approach and Methods

Initially, it was thought that the water level concerns were primarily related to the presence of several beaver dams located along Lake Creek and the performance of beaver deceivers that were previously installed by the County. However, after meeting with lake-side residents and visiting the site on several occasions while the topography survey was completed it appeared that several issues had to be addressed to identify possible solutions to the lake level concerns. Therefore, the evaluation of lake level and beaver control improvement needs was approached from several perspectives:

- What is the appropriate range of lake's levels?
- How has the lake outlet changed over time?
- What measures could be implemented to better manage lake level?

Several methods were implemented to answer each of these questions.

First, in order to identify the appropriate range of lake levels, several long-time residents were interviewed and survey stations were established to identify the current water level, the high water that occurred in January 2009, and what residents identified as the normal water level. Topographic maps, LiDAR data, aerial photography, existing survey data, water level monitoring data, and geologic maps were also reviewed.

To identify potential changes in the Lake Creek outlet conditions, long-time residents were interviewed, the County's record of management actions were used, and aerial photographs were reviewed.

Finally, to evaluate potential management measures, the HSPF model developed for the Big Lake DMP (Anchor 2005) was modified to output exceedence probability flows and flood frequencies of discharges from Lake McMurray. Survey data was collected at each of the existing beaver deceiver culverts, old beaver dams, and various water levels identified by the

long-time residents. A hydraulic model (HEC-RAS) was developed to model the existing conditions and potential corrective alternatives.

Key Assumptions

The following general assumptions are included in the analysis as the basis for reporting of the results, findings, and recommendations: .

1. Prior hydrologic modeling tools applied from the Big Lake DMP analysis are adequately robust to provide modeling results that are technically sound and defensible.
2. Modeling results should generally be viewed as screening level and comparative rather than absolute at this level of assessment.

More specific assumptions are included in the discussion in the Hydrologic and Hydraulic Modeling Analysis and Results Section of this memorandum.

Results

Lake Levels

The current lake levels, reported high water marks, and reported normal lake levels were surveyed at two locations along Lake McMurray. Water levels upstream and downstream upstream of each beaver deceiver were also surveyed. Interestingly, the long-time residents reported that both the highest level and lowest levels they recall were in 2009. Table 2 reports the surveyed water levels.

Table 2
Survey of Reported Water Levels

	Water Levels along West Shore (feet; NGVD1988)	Water Levels along South Shore (feet; NGVD1988)
High	234.28	235.82
Low	230.63	230.60
Normal	231.65	232.57
Top of Dock	234.01	233.65

It is believed that the high water level reported at the south end of the lake is not entirely accurate. The lake shore in this area is relatively steep, and there were no clear indicators of high water such as a debris line. The property owner also reported that the flood levels were about 1 foot above the top of his dock, which would be 234.65 feet and constant with the water level reported on the west side of Lake McMurray. Comparison of photographs provided by the west side resident and the LiDAR topographic data shows that high water during the January 2009 flood event was at an elevation between 234 and 235 feet.

As reported previously, the County recorded water levels for several years at the boat launch, upstream of the Lake McMurray Estates culverts, and upstream of the upstream most beaver deceiver. Figure 2 shows the County measured data adjusted to the NAVD88 datum.

The County water level data show that the installation of the beaver deceivers provided increased discharge from the lake, which can be seen by the close tracking of water levels in the lake and at the Lake McMurray Estates culverts since 2003 when the beaver deceivers were last modified (Table 1).

The low water level (which is the water level at the time of survey) was 230.6 feet, which is presumed to be controlled by the hydraulics of the lake outlet. Table 3 reports the surveyed water levels at each of the beaver deceivers. The water levels upstream and downstream of all the beaver deceivers are essentially equal at approximately 230 feet. The invert of the lower of the Lake McMurray Estates culverts, surveyed during the Big Lake project is at an elevation of 228.67. During the site visits during the summer of 2009, water was observed to be ponded in the culverts to an elevation of approximately 229.8 feet, which is consistent with the low levels recorded in the late summer of 2002, 2003, and 2004 by the County (Figure 2).

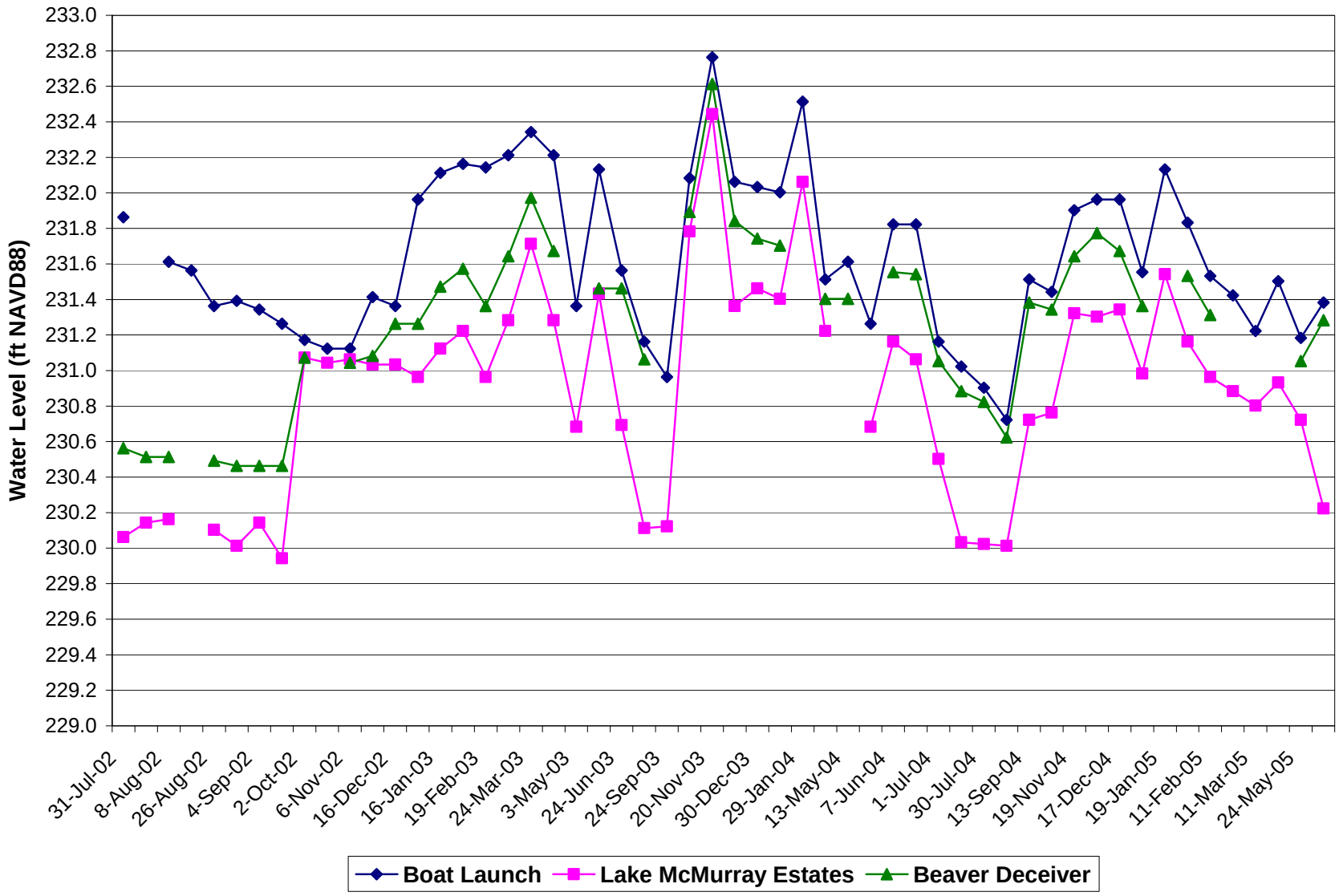

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Figure 2
County Recorded Water Levels, 2002 to 2005
Skagit County Department of Public Works

Table 3
Survey of Water Levels at Beaver Deceivers

Beaver Deceiver (upstream to downstream)	Water Levels Upstream of Beaver Deceiver (feet; NGVD1988)	Water Levels Upstream of Beaver Deceiver (feet; NGVD1988)
1	230.01	229.99
2	229.89	229.96
3	230.00	229.88

At the time of survey, there was essentially no discharge to Lake Creek. Consequently, if the outlet channel was completely open, the water levels in the lake would be expected to be the same as the water level observed at the Lake McMurray Estates culverts. Furthermore, the lake level would have been about 229.8 feet, which is about 0.8 foot lower than the measured lake level. The survey data indicates that there is a hydraulic control between the lake and the upstream beaver deceiver at an elevation of approximately 230.6 feet, that from upstream beaver deceiver the channel generally freely drains to the Lake McMurray Estates culverts, and that there is a hydraulic control below the Lake McMurray Estates culverts. The geologic map of the McMurray 7.5-minute Quadrangle shows several faults crossing Lake Creek approximately 800 and 2,400 feet downstream of the Lake McMurray Estates culverts. The geologic profile shows that the block between the faults is uplifted (Dragovich, J. D. and A. J. DeOme 2006). This uplifted block of bedrock materials may ultimately control the outlet of Lake McMurray, although no effort was made to see if the geologic unit was exposed along the stream banks.

Based on the measured water level data, the natural minimum lake water level is approximately 230 feet. Currently, channel obstructions cause the minimum lake level to be approximately 0.8 foot above the "natural" minimum level. The following section describes changes that have occurred in the lake outlet that probably cause the measured increase in minimum lake elevation.

Outlet Changes

The County previously identified several potential hydraulic controls that affect Lake McMurray water levels:

- Fallen trees and debris from the old mill
- Beaver dams
- Dense vegetation

It is believed that all of the items identified by the County contribute to the control of the lake levels. In the past, Atlas Shingle and Lumber Company used a portion of Lake McMurray as a log pond in their milling operations. There are remnants of pilings in the wetlands upstream of upstream most beaver deceiver and a large number of logs visible in the current aerial photography. A series of aerial photos from 1969 to present were collected and reviewed. It appears generally that the accumulation of logs and aquatic vegetation in the outlet are similar in all of the aerial photos (Figures 3 through 7). Although logging has occurred in the watershed, it is not believed that a significant number of new logs have accumulated among the debris at the lake outlet.

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Figure 3
Lake Outlet – 1969
Skagit County Department of Public Works

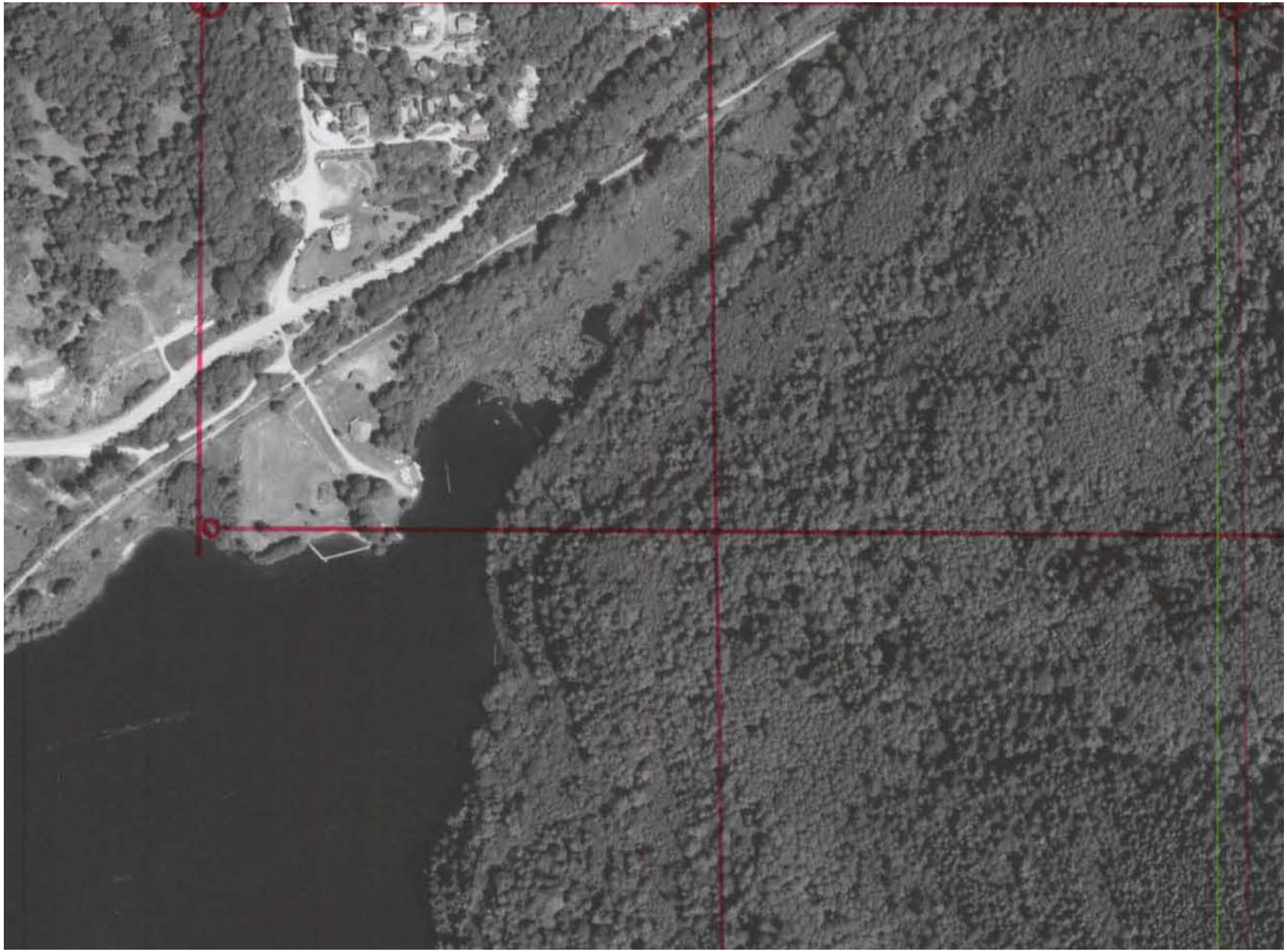

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Figure 4
Lake Outlet – 1978
Skagit County Department of Public Works

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Figure 5
Lake Outlet – 1993
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Figure 6
Lake Outlet – 2001
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Figure 7
Lake Outlet – 2007
Skagit County Department of Public Works

The County has added beaver deceivers to three beaver dams. Based on observations during this study, it does not appear that beavers currently inhabit the lake outlet channel, although they may be present at the south end of the lake, for the following reasons:

- No fresh vegetation had been cut by beavers in the vicinity of the areas surveyed
- No debris had accumulated on the debris cages protecting the upstream ends of the beaver deceivers
- The beaver dams had not been repaired where the beaver deceivers were cut previously into the dams
- The survey of the dam crests showed areas that were equal to or lower in elevation than the inverts of the beaver deceivers
- Woody vegetation was becoming established on the old beaver dams

The types of vegetation present in the lake outlet cannot be determined from the older aerial photos, but it can be assumed that, at one time, there was a large amount of floating vegetation due to the County's past vegetation management activities (Table 1). Currently there are clumps of emergent wetland vegetation, floating vegetation, and woody vegetation visible on the recent aerial photos. The LiDAR topographic data also indicates a varied surface because the bare earth signal is not clear in the location where a good signal would be expected (due to open water reflection and floating vegetation). The varied signal, from experience, usually indicates dense emergent wetland vegetation. As previously mentioned, it was observed during visits to the site in 2009 that woody vegetation was becoming established on the beaver dams.

Several potential hydraulic controls were identified from aerial photographs; however, upon inspection, the surveyors found a jumble of woody debris in dense emergent wetland vegetation. Probing the bottom, inspectors found that the water was often less than 2 feet deep but soft sediments existed to a depth of more than 5 feet, making it unsafe to survey particular logs or obstructions to flow.

Management Measures

In order to identify potential water level management opportunities, an understanding of the basin hydrology and the hydraulics of the outlet is necessary. As previously described, a HSPF continuous simulation model had been developed for the Big Lake DMP. At that time, it was assumed—based on our field observations—that the lake level was ultimately controlled by the culverts under the McMurray Shore Drive. Additional topographic survey data was collected at each beaver deceiver to develop a more robust hydraulics model using HEC-RAS that could be used to evaluate potential management alternatives.

HSPF Flow Analysis

The HSPF model was run for the existing conditions (2005) and future build-out conditions, which are reflected in the Big Lake DMP analysis (Anchor 2005). Since the HSPF model is run as a continuous streamflow simulation, analysis of the runoff time series data was completed using post-processor programs to generate statistically-based results for the long-term simulation record. Tables 4 and 5 document the resulting flood frequency and exceedence probability of flows discharged from Lake McMurray.

Table 4
HSPF Model Results at the Lake McMurray Outlet – Flood Frequency

Return Interval (years)	Existing Conditions Peak Outflow (cfs)	Future Conditions Peak Outflows (cfs)
1.01	14	16
1.5	33	35
2	38	41
5	54	56
10	66	71
25	79	86
50	93	102
100	102	109

Table 5

HSPF Model Results at the Lake McMurray Outlet – Exceedance Probability

Month	Mean Daily Flow (cfs)					
	95%	90%	50%	10%	5%	1%
Oct	1.06	1.20	2.59	7.4	10.2	17.5
Nov	2.08	2.56	7.12	19.1	24.4	42.4
Dec	3.69	4.82	11.64	26.6	32.7	48.3
Jan	4.51	5.49	11.98	27.7	34.3	51.9
Feb	4.51	5.70	12.56	27.2	32.9	49.5
Mar	4.45	5.36	11.26	23.9	28.6	39.8
Apr	3.38	4.10	7.85	17.9	22.3	33.2
May	2.28	2.65	4.58	11.5	15.0	22.2
Jun	1.40	1.86	3.14	7.0	9.6	16.7
Jul	1.01	1.09	2.01	3.7	4.6	8.1
Aug	0.22	0.45	1.31	2.4	3.0	4.2
Sep	0.38	0.79	1.57	3.5	4.4	7.8
All Season	1.08	1.35	4.98	18.7	24.4	38.0

HEC-RAS Hydraulic Analysis

A HEC-RAS model was developed using surveyed sections along the beaver dam crests and the inverts of the beaver deceiver culvert inverts. Manning's roughness values and ineffective flow areas were used to retard flows so that the water surface elevations matchedthe surveyed water levels reasonably well under very low flows. The model results show that the beaver dams and beaver deceivers would be completely inundated during flood events. Figure 8 provides the HEC-RAS flood profiles for the existing conditions. Because of the very low gradient of the outlet and Lake Creek, the velocities remain very low at significant distance downstream of the McMurray Shore Drive culverts, and stage does not increase appreciably between the culverts and the lake. This is consistent with what was shown by the County water level monitoring data (Figure 2).

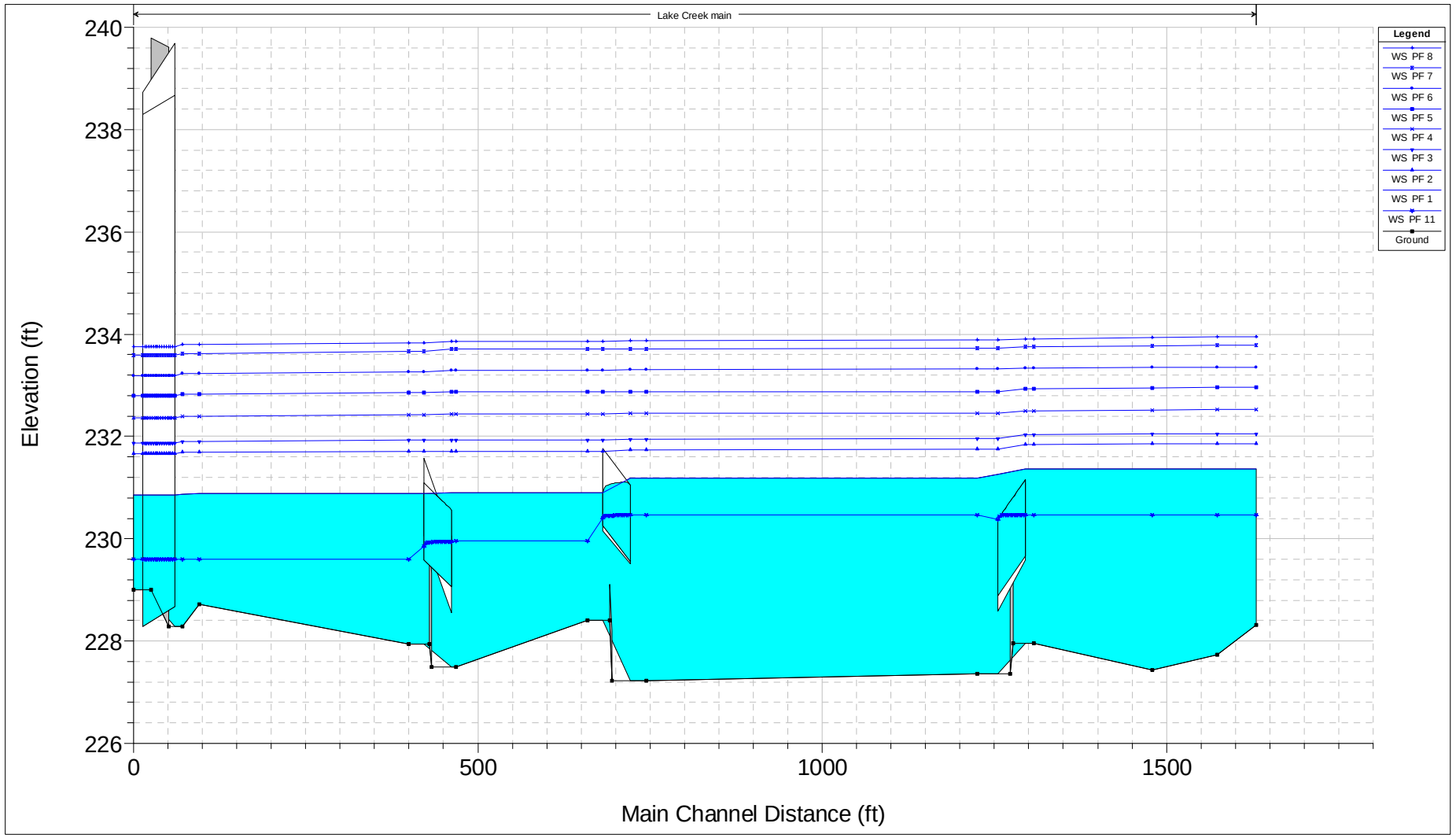

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Figure 8
Existing Conditions HEC-RAS Flood Profiles
Skagit County Department of Public Works

SUPPLEMENTAL DATA COLLECTION

After completing the previously- described initial hydraulic analysis, it additional channel obstructions located downstream of the McMurray Shore Drive culverts were believed to controlthe water levels in the lake (rather than the culverts). This information was presented to the County, which then authorized additional survey of the Lake Creek channel downstream of the culverts.

The supplemental survey was conducted on December 9, 2009. The creek was waded for approximately 500 feet downstream of the culverts, where possible. Additionally, the creek was observed from the abandoned railroad grade an additional 0.5 mile. Elevations were also checked at the County staff gages around the lake.

Because neighbors had recently reported rapidly rising waters, the County staff gage at the boat launch was visited for evidence of high water marks. Photo 1 shows a clear debris line about 0.7 foot above the staff gage's current water level read of 227.9 local datum (231.66 NAVD88; high water was approximately 232.36).

Photo 1

December 9, 2009 Lake Level and High Water Debris Line

As previously mentioned, about 500 feet of the channel was waded from the culverts downstream during the December 2009 creek survey. Water was found to be 2 to 3 feet deep for the first 200 feet until a gravel bar was encountered that created a riffle (Photos 2 and 3).

Photo 2

Gravel Bar and Riffle 200 feet Downstream of McMurray Shore Drive Culverts

Photo 3

Gravel Deposits 200 feet Downstream of McMurray Shore Drive Culverts

This gravel deposit is located at the mouth of an unnamed tributary that enters Lake Creek from the west. The gravel deposit is relatively recent as appears to have buried the existing vegetation and there was limited new growth of the surface (Photos 3 and 4).

Photo 4
Gravel Deposits on the Floodplain Upstream of Confluence, December 2009

Photo 4 also shows that active erosion of the gravel deposit. Photo 5 shows the same location as Photo 2 in August 2009. Photo 6 shows the tributary looking downstream from the foot bridge in August 2009. Photo 7 shows a scour hole at the downstream end of the tributary culvert under SR 9.

It appears that the tributary is transporting sediment at an accelerated rate; this may be due to land management practices in the tributary watershed or removal and replacement of a restrictive culvert under the abandoned railroad grade with a bridge. It appears that between significant flood events, gravel accumulates at the mouth of the tributary in Lake Creek, gradually closing off and raising the lake outlet. High flows from the lake gradually erode the gravel deposits lowering the lake level. Because the gradient of Lake Creek is low and flood peaks are attenuated by the lake, Lake Creek is not very effective at eroding the gravel bar.

Photo 5

Mouth of Tributary with Lake Creek, August 2009

Photo 6

Tributary Channel Downstream from Foot Bridge, August 2009

Photo 7
Scour at Outlet of SR 9 Culvert, December 2009

The January 2009 flood event may have destabilized the bed and bank of the tributary or lowered the elevation of the mouth causing accelerated channel erosion. It is likely that during the fall of 2009 andbecause of peak flow timing issues, the tributary transported a significant amount of gravel in the Lake Creek channel forming a gravel bar that temporarily reduced the capacity of the lake outlet and causing the rapid rise in lake level reported by the lake shore residents. In early 2010, representatives from the County, the Skagit Fisheries Enhancement Group, and the Washington State Department of Fish and Wildlife (WFDW) visited the site and concurred with these conclusions (Alker, personal communication).

Revised Hydraulic Modeling

With additional survey data, the previously-described hydraulic model was extended downstream to the gravel bar (Figure 9). It was assumed that the starting water surface elevation would be the critical depth over the controlling cross section. Figure 9 shows the revised existing conditions results.

With the initial analysis lowering the existing beaver deceivers, adjusting the beaver deceivers slopes to prevent an adverse grade and conducting vegetation management to maintain an open channel from the lake to the culverts was evaluated. Figure 10 shows the

hydraulic profile with those improvements with the gravel bar, as it was surveyed in December 2009. As shown in the profile, the improvements have essentially no effect compared to existing conditions (Figure 9).

Figure 11 shows the hydraulic profile of a condition with the gravel bar completely blocking the channel (channel filled to the crest of the riffle observed in December 2009). Although it is unlikely that this condition could be maintained for a significant period of time or that it could persist at the highest flows, Figure 11 shows that filling the channel would cause a significant rise in lake level under frequent flood events (e.g. the annual flood would increase the lake level about 6 inches compared to the existing condition, and a 5-year flood would have similar results to the January 2009 flood).

Figure 12 shows the hydraulic profile of a condition with the gravel bar removed across the full channel width (approximately 20 feet) to a depth of the surveyed invert. Figure 12 shows the maximum benefit that could be achieved. This is because after clearing the channel and making the upstream improvements, the channel may refill after a single large storm event or more gradually over a longer period of time. Figure 12 also shows that the minimum lake level would be slightly reduced, and that more significant floods would not result in lake levels experienced in the January 2009 flood.

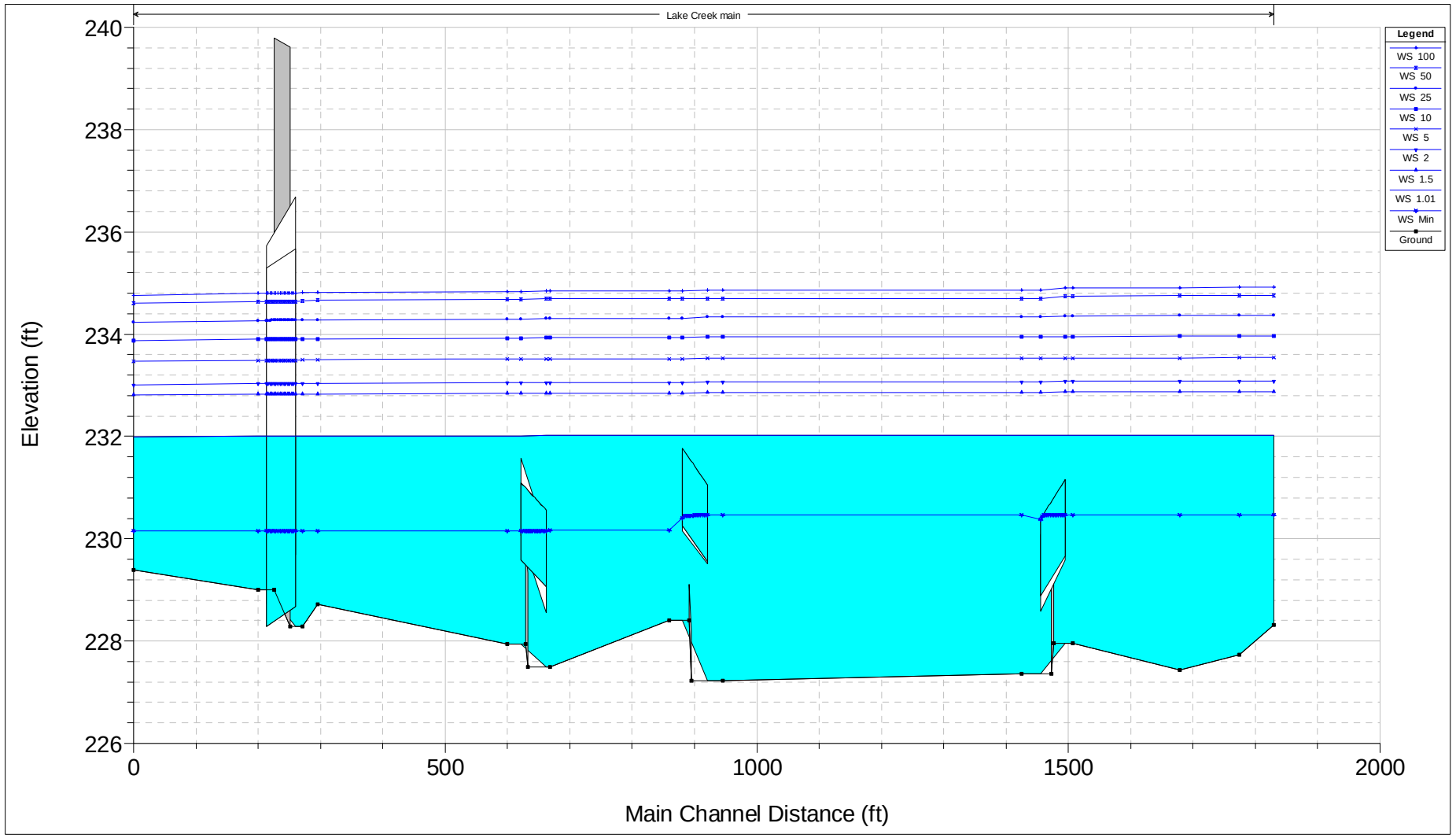

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Figure 9
Existing Conditions HEC-RAS Flood Profiles
Skagit County Department of Public Works

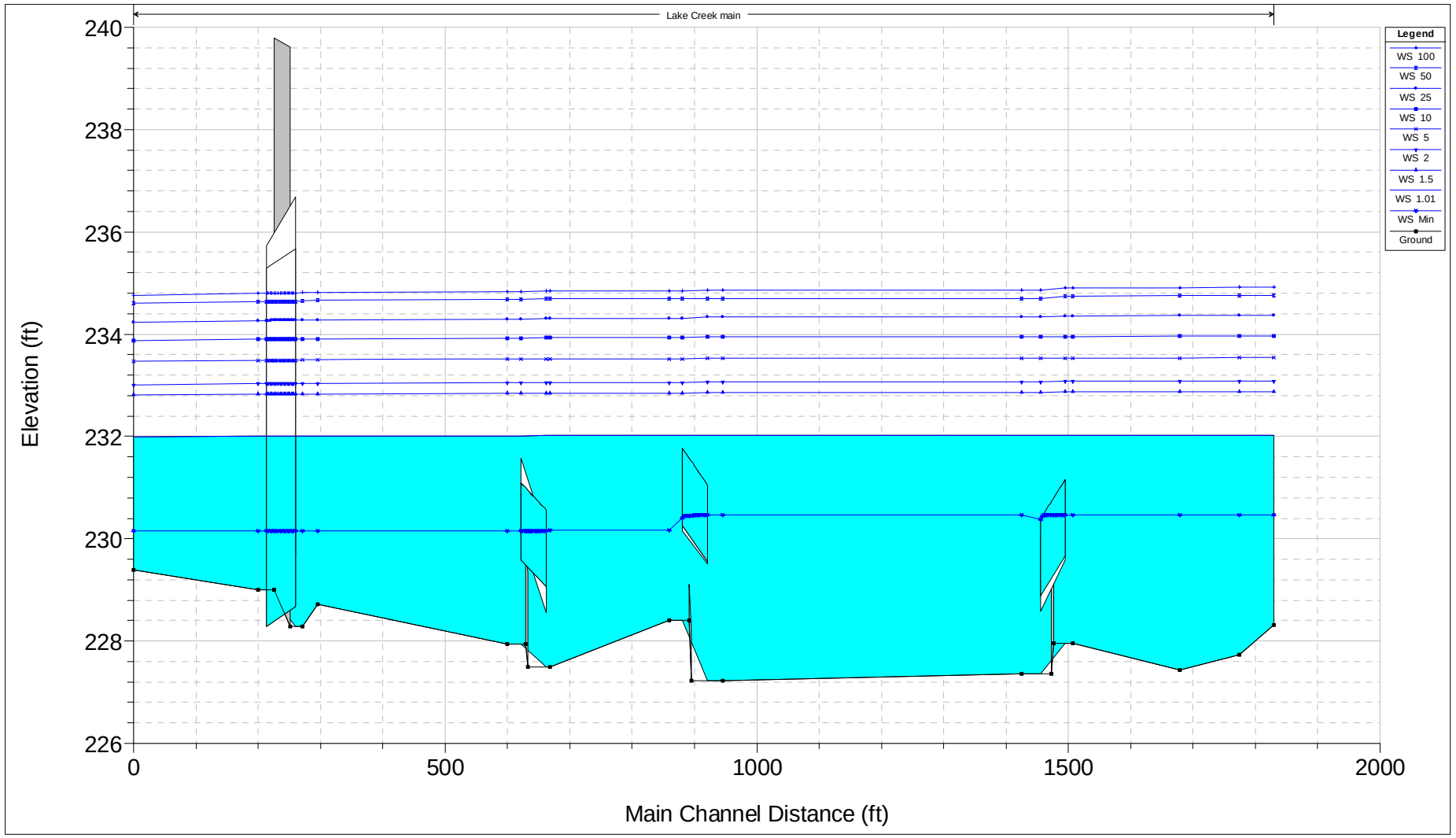

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Figure 9
Existing Conditions HEC-RAS Flood Profiles
Skagit County Department of Public Works

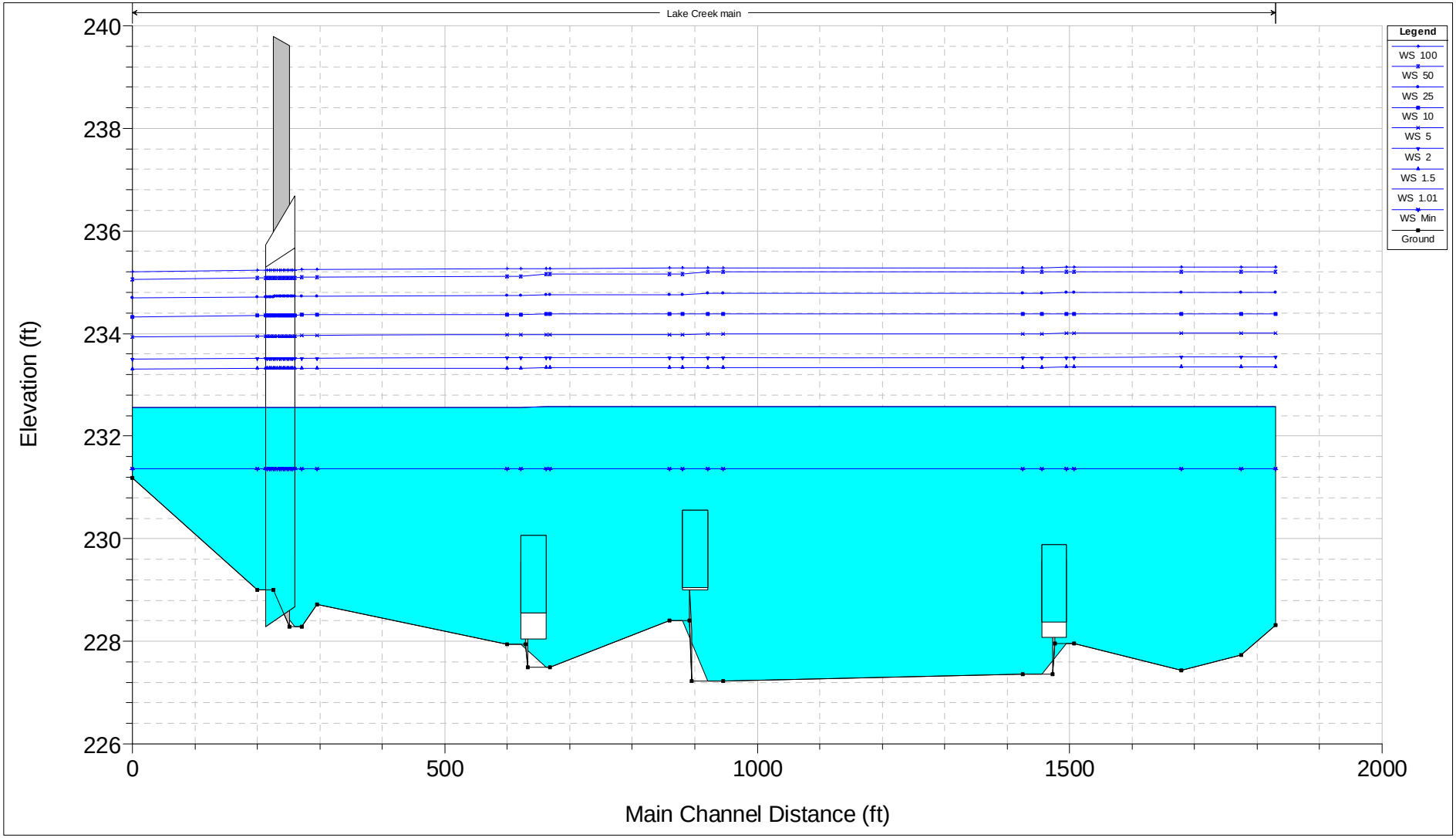

Figure 11
HEC-RAS Flood Profiles Including Recommended Improvements and Complete Blockage by Gravel Bar
Skagit County Department of Public Works

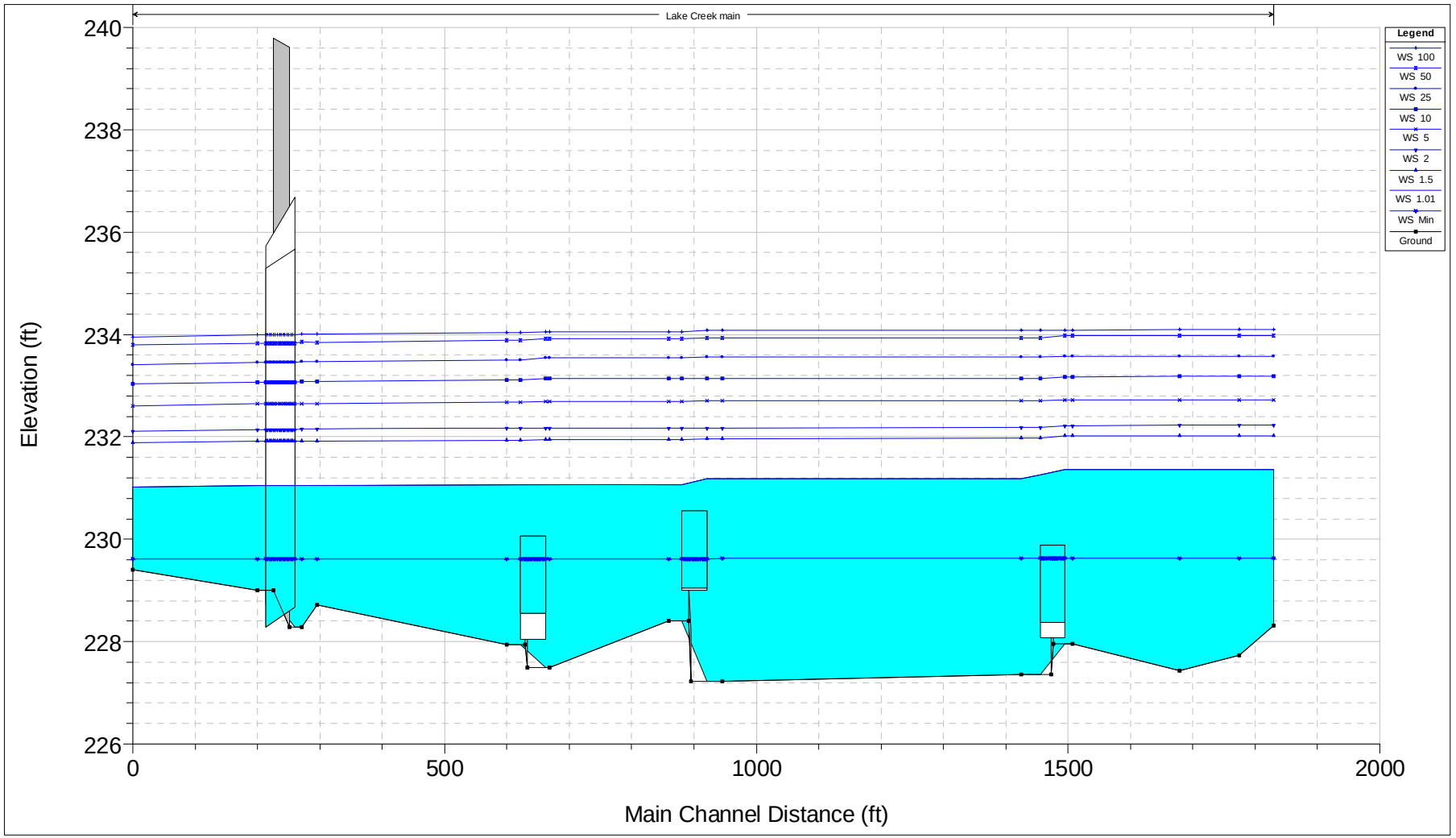

Figure 12
HEC-RAS Flood Profiles Including Recommended Improvements and Removal of Gravel Bar
Skagit County Department of Public Works

SUMMARY OF FINDINGS AND RECOMMENDATIONS

The County had previously developed a matrix of potential water level management activities that included an evaluation of the ability to permit the activities. A key limitation identified in that analysis was that only limited work in the outlet channel would be allowed due to the presence of Coho salmon *(Oncorhynchus kisutch*). Previously, only hand tools usage was allowed and removal off large woody debris was not allowed. It is likely that similar restrictions would be imposed for any future project.

The findings of this analysis show that there are limited opportunities to reduce flooding at Lake McMurray by making channel improvements or modifying the beaver deceivers between the lake and the McMurray Shore Drive culverts. Currently, the lake outlet flow rate is limited due to a restricted channel about 200 feet downstream of the McMurray Shore Drive culverts by gravels transported by an unnamed tributary that enters the creek from the west. The existing beaver dams and dense vegetation do cause some increase in lake water elevation, but the hydraulic models and monitoring data show that the increase is less than 1 foot. The hydraulic analysis results demonstrate that eliminating adverse slopes of the beaver deceivers and lowering them about 6 inches; limited vegetation management near the upstream end of the outlet, and lowering the tail water would reduce the minimum lake level by about 0.8 foot and increase the flood storage by about 130 acre feet compared to existing conditions. However, the hydraulic models show clearly that the gravel deposited at the confluence of the tributary and Lake Creek are controlling the lake levels.

Therefore, based on this initial assessment and in light of the likely permitting constraints, Anchor QEA recommends that the County pursue permits to:

- Remove the gravel bar downstream of the McMurray Shore Drive culverts and maintain the channel
- For limited vegetation maintenance to maintain open water channels between existing open water areas in the outlet channel, in order to take advantage of downstream channel improvements
- To either adjust or remove the beaver deceivers (Exhibit 1)

Additionally, in response to rising lake levels, the confluence should be inspected and cleared of gravel if present to minimize the potential for flooding.

Based on our observations at the site and the elevation data collected, it appears that the volume of the gravel deposit upstream of the mouth of the tributary is on the order of 2 cubic yards and deposits downstream of the mouth that restrict flow maybe be an additional 2 cubic yards. It is believed that these materials could either be spread in the channel or removed and deposited on the west over bank of Lake Creek where they would be available for future recruitment during high flows to replenish stream gravels (Exhibit 2). If the material could be disposed of on site, we estimate that it would take a two-man work crew approximately 2 days to remove and dispose of the materials. If the materials must be taken off site, they would likely need to be wheel-barrowed from the creek to the abandoned railroad grade or all the way to McMurray Shore Drive for loading into a truck. Several additional laborers would be needed to wheel barrow as well as a dump truck and a front loader to handle the materials. The materials would likely be suitable for stream gravel replenishment at other sites in the drainage system.

Because removing the gravel from the channel will require working in and cause alteration to the channel, several permits and environmental review processes must be obtained or followed, including:

- 404 Permit from the U.S. Army Corps of Engineers
- Endangered Species Act (ESA) Consultation,
- Wetland Permit from the Washington State Department of Ecology Ecology)
- Water Quality Certification from Ecology
- Hydraulic Project Approval from WDFW
- National and State Environmental Policy Acts (NEPA/SEPA)
- County Critical Areas Evaluation

REFERENCES

Alker, Tracy, Skagit County Public Works. personal communication. Telephone conversation regarding meeting with WDFW and SFEG, January 28, 2010.

Anchor Environmental, LLC (Anchor), 2005. Big Lake Drainage Management Plan. Skagit County Public Works, Mount Vernon, WA

Dragovich, J. D. and A. J. DeOme, 2006. Geologic Map of the McMurray 7.5-minute Quadrangle, Skagit and Snohomish Counties, Washington, with a discussion of the evidence for Holocene Activity on the Darrington-Devils Mountain Fault Zone. Geologic Map GM-61. Washington Division of Geology and Mines. Olympia, WA

Attachments

Exhibit 1

Exhibit 2

ANCHOR QEA

0 125 250 500 Feet

Exhibit 1
Beaver Deceiver Locations, HEC-RAS Cross Sections and Recommended Actions
Lake McMurray Lake Level and Beaver Control Evaluation

SKAGIT COUNTY WASHINGTON

ANCHOR QEA

0 25 50 100 Feet

Exhibit 2
Gravel Bar Removal and Disposal
Lake McMurray Lake Level and Beaver Control Evaluation

SKAGIT COUNTY WASHINGTON