

MEMORANDUM

TO: City of Lake Stevens c/o Shannon Farrant
FROM: Erik Davido, PE; Jack Lasley, PE; & Joe Brascher
DATE: May 11, 2023
RE: Lake Stevens Hydrology Modeling – Brief Overview of Calibration and Scenarios

1 PROJECT OVERVIEW

Hydrologic and Hydraulic modeling was conducted for Lake Stevens and the outlet channel to better understand the existing conditions and potential options to address fish passage issues, increase in-channel and riparian habitat, alleviate flooding, and better manage lake levels for summer recreation. For further information on the hydrologic and hydraulic model setup and calibration, please see the “Lake Stevens Outlet Hydrologic/Hydraulic Modeling Technical Memorandum.” A summary of the original calibration and the results of re-calibration, and various modeling scenarios are discussed herein. Figure 1 shows fish species present and migration patterns into and out of Lake Stevens for context relative to the modeling scenarios.

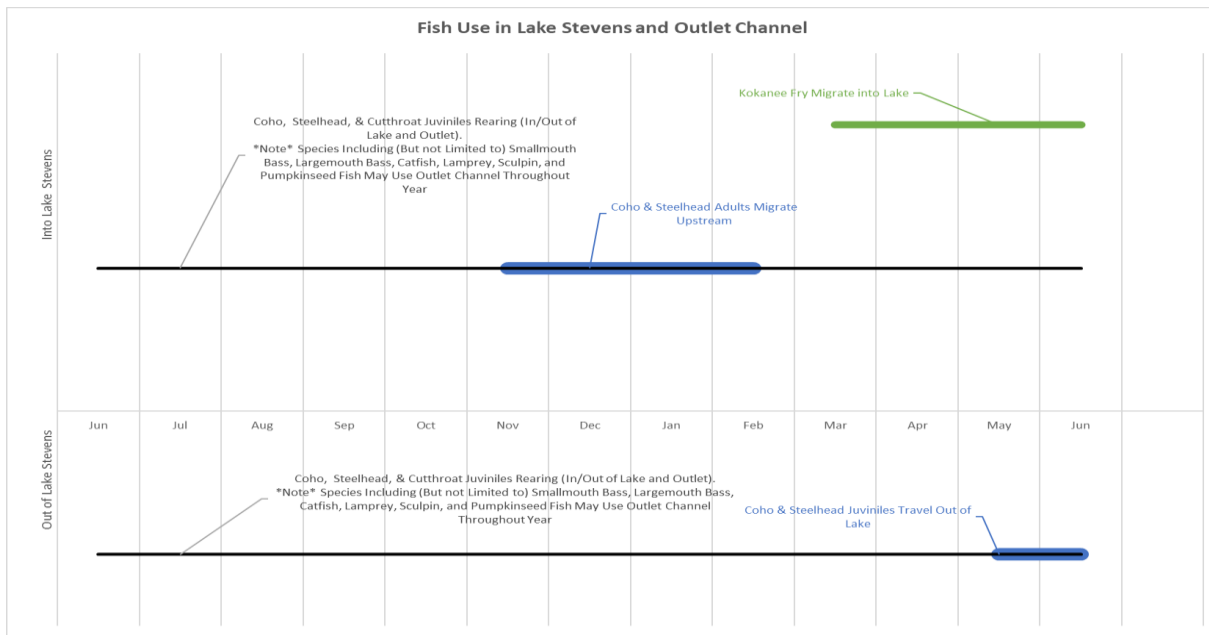


Figure 1 – Fish use in outlet channel summary

2 ORIGINAL CALIBRATION

Modeling and calibration was conducted for a 10-yr analysis between October 1st, 2010 to to September 30th, 2020. In February 2020, Lake Stevens water levels reached some of the highest stages ever recorded resulting in flooding in the downtown corridor of Lake Stevens. Throughout the analysis, the February 2020 peak stage is used as a key comparison point. Figure 2 shows a graph of the original calibration results and Figures 3 through 5 show photos fo the outlet channel during the February 2020 event.

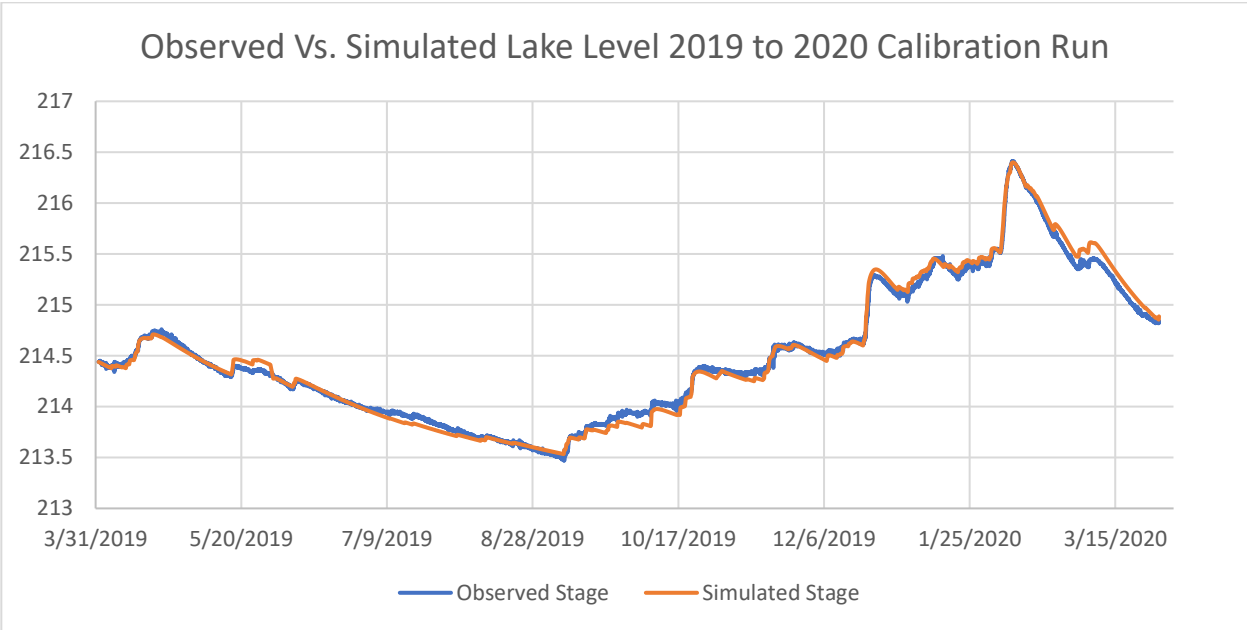


Figure 2 – Original Calibration Model Results

Maximum observed lake level: **216.41'**
 Minimum observed lake level: **213.47'**
 Maximum simulated lake level: **216.39'**
 Minimum simulated lake level: **213.53'**



Figure 3 - Photograph of lake outlet weir (looking upstream) during February 2020 peak lake level stage (day after storm).



Figure 4 - Photograph along Hartford near fire station (looking downstream) during February peak lake level stage.



Figure 5 - Photograph of Lake at North Cove boat launch during February peak lake level stage.

3 MODEL ANALYSIS IN RESPONSE TO CHANNEL MODIFICATIONS

In response to the February 2020 downtown flooding, actions were taken by the City to alleviate flooding and reduce peak lake levels. This included removing debris from a segment of the outlet channel and channel dredging. Since the clearing and dredging, anecdotally, the City has experienced less flooding and lower lake level stages. However, the original calibrated simulation model matches data to the end of the simulation analysis of September 30th, 2020 (which means the outlet was “clogged up” for much of the analysis). Debris clearing from the lake outlet occurred in January 2021 and lake outlet dredging occurred in September 2021. To simulate the “what could have been” baseline had the Lake Outlet been cleared and dredged, additional calibration and scenarios were analyzed for comparison during the February 2020 event.

3.1 Recalibration for Baseline – Lake Outlet Debris Clearing

Debris clearing was conducted in January 2021; a divergence between the original calibration and observed lake levels can be seen after January 2021 in Figure 6. Note, that the original 10-year calibration was between 2010 and 2020 so the simulated lake level in 2021 is an extrapolation of the previous 10 years of data; with no debris clearing conducted. However, Figure 7 shows the model adjusted for the debris clearing and more closely matches the observed lake level.

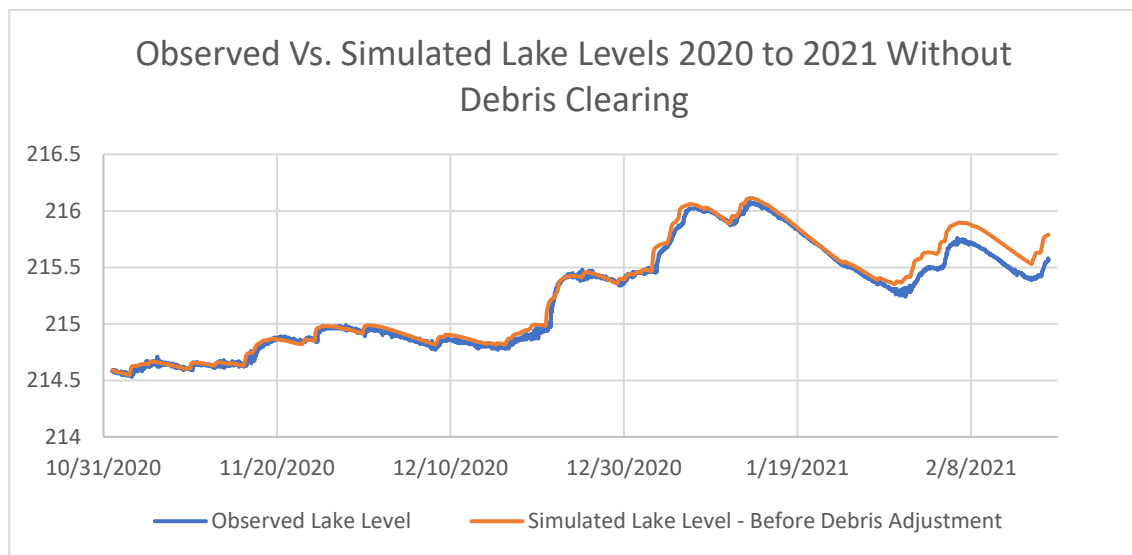


Figure 6 - Original calibration compared with observed data.

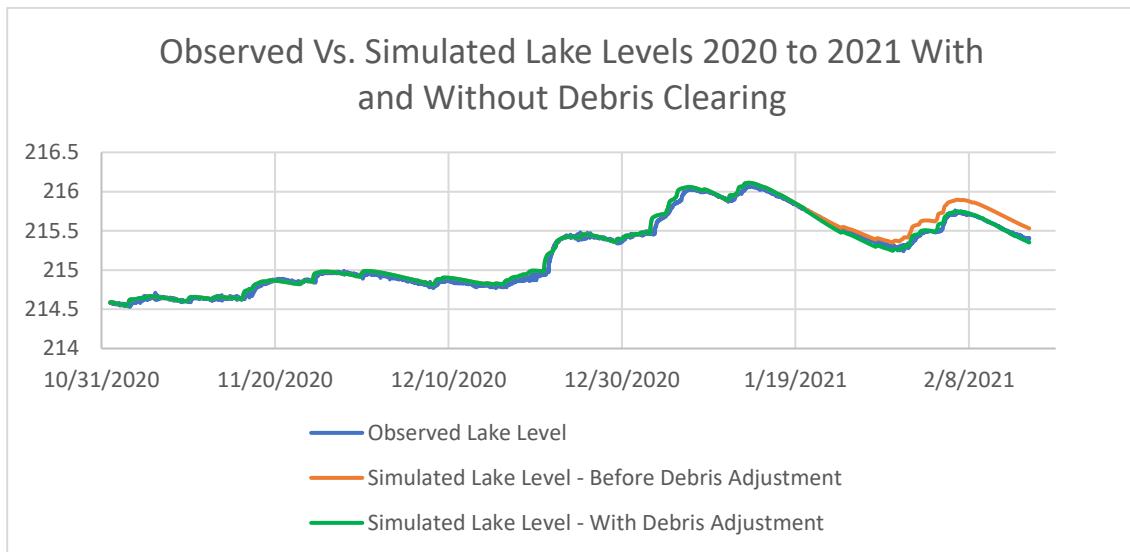


Figure 7 - Original calibration and debris clearing adjustment compared with observed data.

Maximum observed lake level: **216.08'**

Minimum observed lake level: **214.53'**

Maximum simulated lake level (prior to debris clearing): **216.11'**

Minimum simulated lake level (prior to debris clearing): **214.55'**

Maximum simulated lake level (with debris clearing): **216.11'**

Minimum simulated lake level (with debris clearing): **214.55'**

3.2 Recalibration for Baseline – Lake Outlet Dredge

Lake Outlet dredging occurred in September 2021. Similar to the debris adjustment, model adjustments and recalibration were conducted to better align simulated data with observed data. Figure 8 compares the simulated dredged channel scenario compared to observed conditions for a “what could have been” comparison. Modeling shows that dredging the lake outlet reduces the highest simulated lake level by nearly 0.14’ (1.68”) compared to observed data; this equates to nearly 140 ac-ft of storage differential.

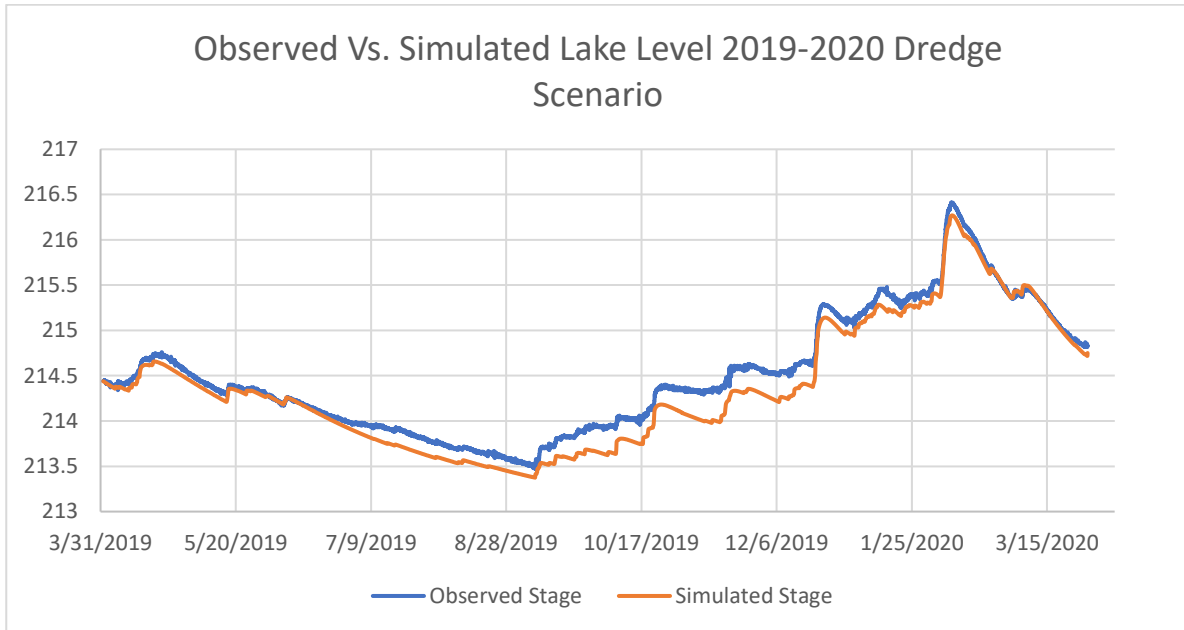


Figure 8 - Dredged simulation compared to observed data.

Maximum observed lake level: **216.41'**
Minimum observed lake level: **213.47'**
Maximum simulated lake level: **216.27'**
Minimum simulated lake level: **213.37'**



Figure 9 photograph at the mouth of the Lake Outlet (looking downstream) prior to dredging as cofferdam and bypass pumps are installed.

3.3 Channel Modifications (Cleared and Dredged) Comparison

Combining the results of the debris clearing and dredged channel modifications significantly reduces the peak lake level compared to the observed data during the February 2020 event (nearly 0.46' or 5.5"). Anecdotally, post debris clearing and dredging, the City has seen less flooding in the downtown corridor and lower lake levels in 2022 and 2023. The "cleared and dredged" baseline scenario is used for the remainder of the analysis.

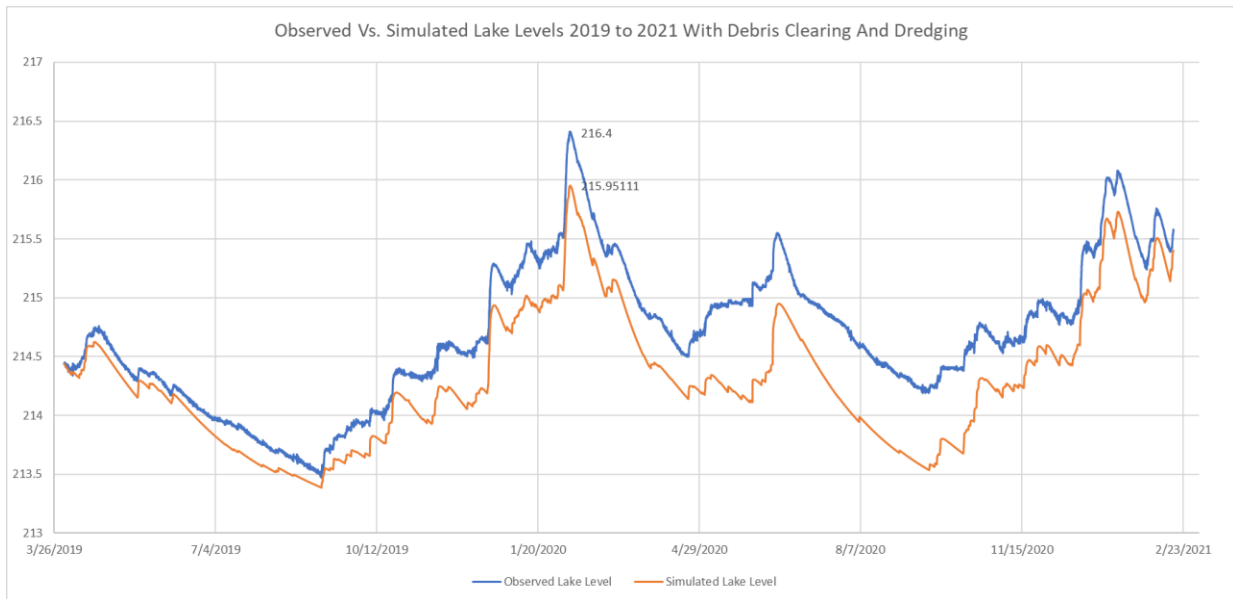


Figure 10 - Cleared and dredged simulation compared to observed data.

Maximum observed lake level: **216.41'**

Maximum simulated lake level: **215.95'**

4 MODEL ANALYSIS OF WIDENED WEIR

The existing weir is approximately 10' wide; a widened weir (30') was modeled to analyze if an increased weir width would further decrease peak lake levels. However, compared to the cleared and dredged existing weir scenario there is little to no difference. Further modeling analysis has shown that the weir is not the hydraulic control on the outlet channel; the channel cross section itself controls flows.

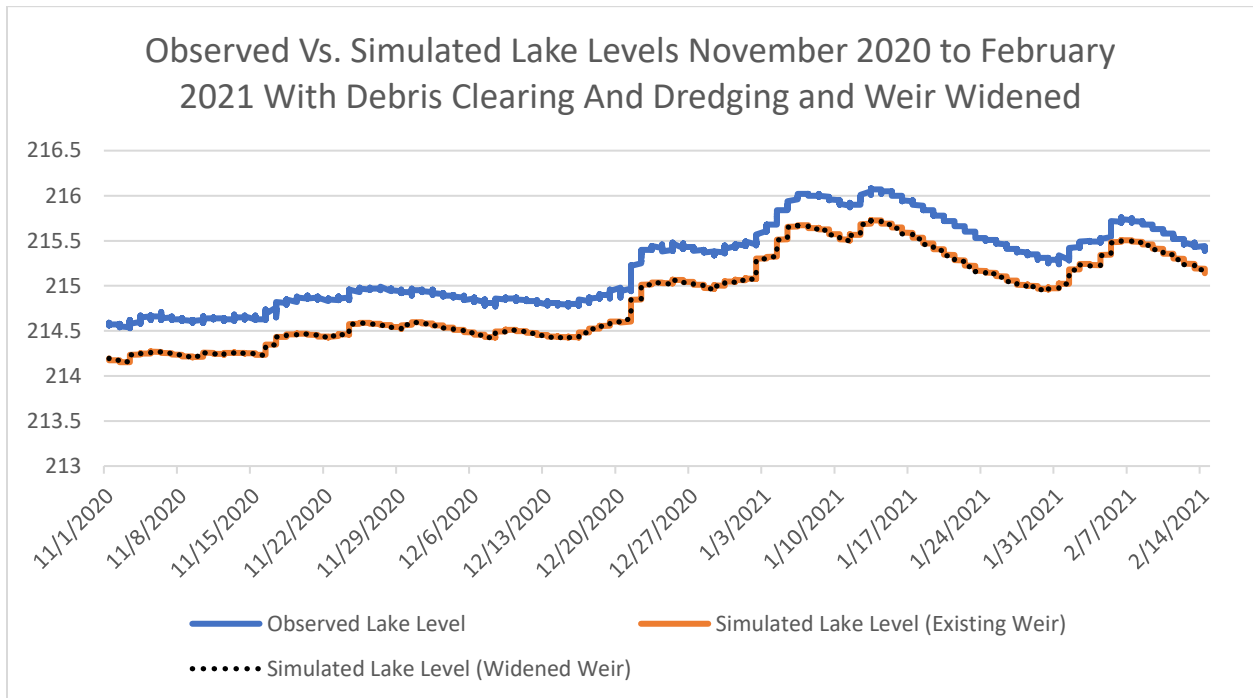


Figure 11 - Cleared and dredged existing weir width and wider weir width simulation compared to observed data.

Maximum observed lake level: **216.08'**

Minimum observed lake level: **214.53'**

Maximum simulated lake level (cleared and dredged with wider weir): **215.72'**

Minimum simulated lake level (cleared and dredged with wider weir): **214.15'**

5 MODEL ANALYSIS OF DIFFERENT WEIR MANAGEMENT PLAN

The current lake level management plan is shown in the figure below. In this analysis, the goal was to review preliminary results answering the following question: can a simpler weir management plan work to reduce peak lake levels yet allow enough lake storage for water release throughout the summer?

Contrary to the existing lake level management plan, this scenario removed all weir boards on November first and then put the weir in channel between March – October. During this period, the weir was set at an arbitrary height so that water never overtopped the weir and only flows via the fish notch were released downstream. The results shown in Figure 12, demonstrate that a simpler lake level management plan could likely be used and would answer the original driving question for this analysis scenario; changing the weir management plan could retain more storage in Lake Stevens at the end of the wet season which might allow for additional flow release in the lake outlet throughout the summer and early fall months for fish while still satisfying lake level management goals regarding recreation. Further analysis and refinement would be needed.

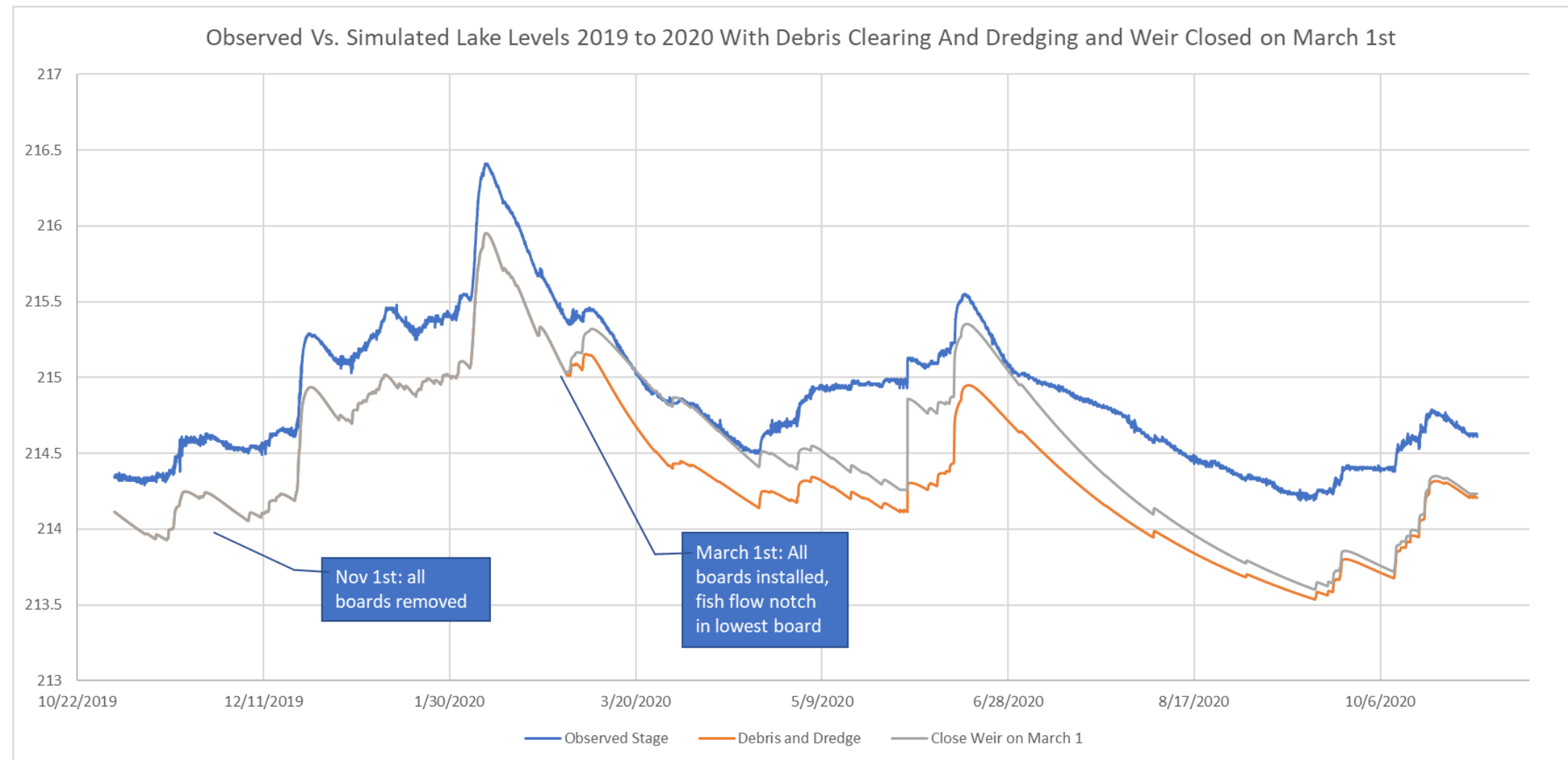


Figure 12 - Cleared and dredged simulation with revised weir management plan.

Table 1 existing lake level management plan

Month	Target Lake Level	Typical Weir El.
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

6 MODEL ANALYSIS OF 40' BERM INSTALLED AT LAKE OUTLET MOUTH AND AUTOMATED WEIR

The lake level management of Lake Stevens and outlet channel is a complex, related, and urbanized system. The City of Lake Stevens has been working with consultants for the last 4-years, with an array of goals for the lake, outlet channel, and associated wetland complexes while trying to strike a balance between fish passage, stream and wetland restoration, lake level management for recreation, and lake level management for safety. Throughout the development of this project, stakeholders and agencies have been included in project milestones and discussions. One of the primary goals is for replacement of the existing failing weir. The City and design team have envisioned replacing the existing failing weir with a new automated system with a goal of retaining enough water in the late winter and early spring months to be able to release around 2-cfs of flow to the outlet channel throughout the summer. Many different fish species use the lake outlet throughout the year (as seen in Figure 1) including Kokanee, Coho, and Steelhead migrating into and out of the lake and use the lake outlet for rearing. In engagement, stakeholders expressed interest in an analysis of a set berm elevation at the lake outlet, noting that this may result in no flow in the outlet channel.

Simulation Parameters:

Berm	Automated Weir (with Fish Passable Orifice)
<ul style="list-style-type: none"> Berm elevation set to 213.5 	<ul style="list-style-type: none"> The velocity leaving the weir/notch should not exceed 4 ft/s (when the weir is in-channel). The minimum flow leaving the weir should be approximately 2 cfs (when the weir is in-channel). The lake level should not drop below 213.5. The idea is to keep as much water in the lake from spring into summer to allow for approximately 2 cfs release and ideal lake levels for recreation throughout the summer. The lake level and level downstream of the weir should never exceed a 6" difference (i.e. minimum required jumping distance required for fish passage. Note, in the current model when the weir is deployed, water never overtops the weir).

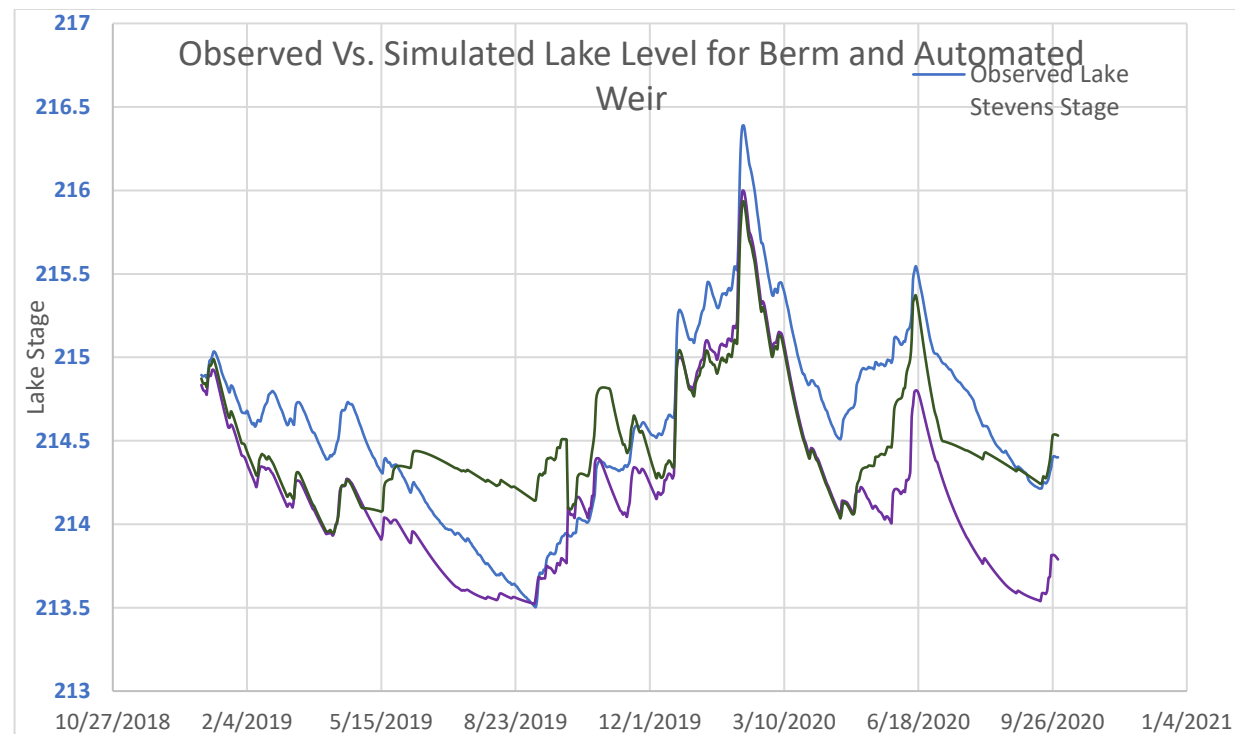


Figure 13 - Simulated berm and automated weir lake level compared to observed data.

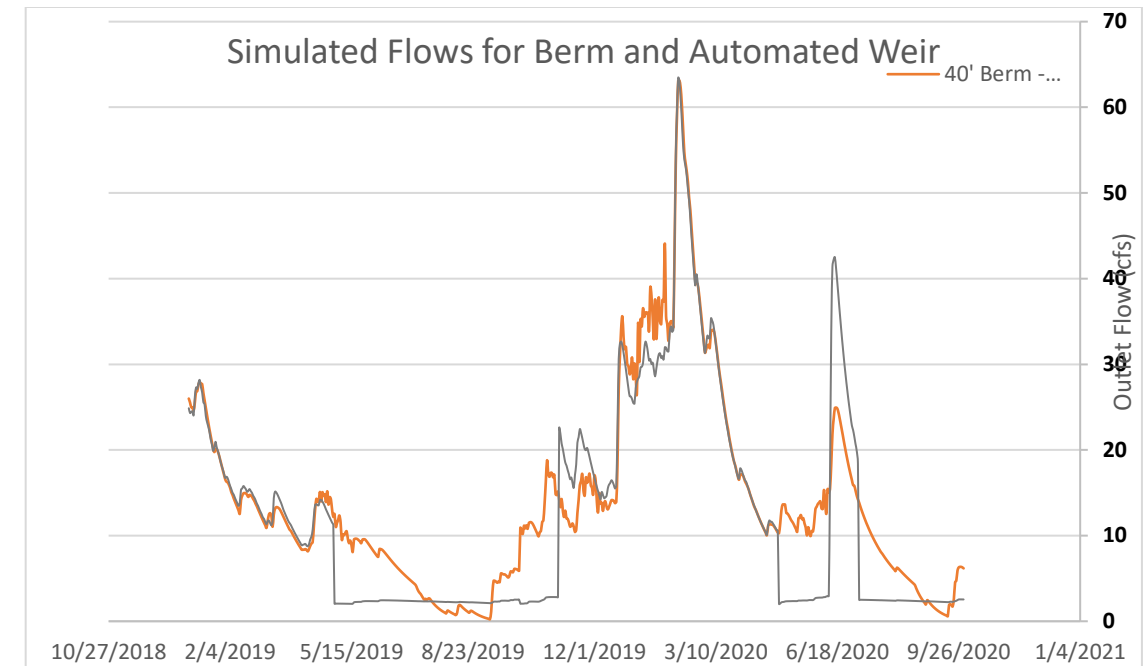


Figure 14 - Simulated berm and automated weir flows in outlet channel.

	Berm	Automated Weir
# of days with 0 cfs flow (10 year period)	34	0
# of days with <2 cfs flow (10 year period)	258	0
# of days where flow depth is <1 ft (over weir)		
November	156	N/A
December	74	
January	27	
Total % of days over 10-yr period	28%	

Table 2 fish passage parameters and duration of time satisfied

The project team conducted hydraulic modeling of the lake outlet for the full 10-year analysis period for both the berm and automated weir. As seen in the summary figures, lake levels with the automated weir are often above elevation 214 and 2 cfs of flow is able to be released throughout the dry months for fish passage. Looking at the berm simulation, the lake level fluctuates more throughout the year yet nearly matches the peak lake level of the automated weir during the february 2020 event; however, you can see that outlet channel flows do dip below 2 cfs during throughout the analysis. The berm would likely have considerable savings in construction and operations/maintenance costs.

Some parameters related to fish passage are shown in Table 2 for the entire 10-yr period. With a set berm elevation, there were multiple days in the analysis with zero flows in the outlet channel and flows less than 2 cfs; the automated weir never has zero flow days and can nearly always release 2 cfs of flow when the weir is in-channel. Another metric reviewed by the project team was the depth of flow over the weir; 1 ft min of flow depth is an initial conservative depth reviewed to provide data metrics. As we can see, there are multiple days throughout the analysis duration where flow depth over the berm are below 1 ft. If the berm design option is selected, further refinement and satisfying parameters clarification would be needed.