FCD2019-02

King County

GREEN RIVER, KING COUNTY, WASHINGTON
SYSTEM WIDE IMPROVEMENT FRAMEWORK (SWIF)

Photo Credit: USACE

HOWARD HANSON DAM

PRELIMINARY CAPACITY EVALUATION

FINAL

SEPTEMBER 3, 2014

GREEN RIVER SWIF

HOWARD HANSON DAM

PRELIMINARY

CAPACITY EVALUATION

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1. BACKGROUND

1.1. PROJECT DESCRIPTION

Howard Hanson Dam (HHD), a multi-purpose project constructed and operated by the U.S. Army Corps of Engineers (Corps of Engineers) was originally authorized in 1950 by Congress for the principal purpose of flood control. Other project purposes include low flow augmentation, ecosystem restoration and municipal and industrial water supply. The Project, which began operating in 1961, includes a 235 foot high, 675 foot long earthen embankment and abutment, outlet works, spillway and reservoir (see cover photo). The reservoir impounded by the dam is referred to as Eagle Gorge Reservoir.

Figure 1-1 shows a schematic representation of HHD and the elevations for specific design features of the dam. The outlet works consists of a gate tower and intake structure with two radial gates, a concrete horseshoe-shaped outlet tunnel, a gate-controlled bypass, and a stilling basin. The spillway is a gate-controlled concrete ogee overflow section with a downstream concrete-lined chute and a crest elevation of 1176.0 feet; it has never been used. Eagle Gorge Reservoir is approximately 4 miles long at the conservation pool elevation of 1141.0 feet above mean sea level relative to the National Geodetic Vertical Datum of 1929 (NGVD29), which corresponds with 25,400 acre-feet of storage. The maximum full pool elevation for the reservoir is 1206 feet NGVD29, which provides up to 106,000 acre feet of storage. For most flood events, operations would be managed so as not to exceed this elevation. The pool elevation associated with the probable maximum flood (PMF) event is 1223.9 feet (NGVD29). This is also referred to as the spillway design flood event is). The record pool elevation to date occurred during the January 2009 flood event and was 1188.8 feet.

In 1996, a Section 1135 project for low-flow augmentation was authorized, raising the summer conservation pool to elevation 1147.0 feet. In 1999, a significant modification to the original Project was authorized to support water supply and ecosystem restoration. Both projects required a non-federal sponsor who cost shares study and implementation costs with the Corps of Engineers. Tacoma Public Utilities is the non-federal sponsor for both projects. Referred to as the Additional Water Storage Project (AWSP), it included two phases. Phase 1, which has been partially implemented, provides an additional 20,000 acre-feet for Municipal and Industrial (M&I) water supply for Tacoma; it raises the conservation pool to an elevation of 1167.0 feet for M&I purposes and includes features for ecosystem restoration and compliance with the Endangered Species Act. Phase 2 would store an additional 12,000 acre-feet of water and raise the pool elevation to 1177.0 feet in the spring for release during the summer and fall. The summer conservation period is specifically designated as March through September, but low-flow augmentation typically occurs from June to October. Completion of Phases 1 and 2 is dependent on reauthorization of the Project because the current estimated costs exceed the amount authorized. The AWSP also requires re-consultation under Section 7 of the Endangered Species Act and re-formulation of upstream fish passage facilities.

1.2. PROJECT OPERATIONS

During the fall and winter months the Project is operated by the Corps of Engineers for flood risk management, while during the spring and summer, operations are aimed at water conservation for low flow augmentation. Flood risk management operations are the subject of this capacity evaluation and are described in more detail below.

Between October and February, when the threat of flooding is high, the reservoir pool is held at a low level to maximize available storage during flood events. Between December 1 and February 15, the reservoir pool is drawn down to its lowest elevation, which is elevation 1075 feet (NGVD29), to maximize available storage during flood events.

During a flood event, HHD outflows are regulated based on the hydrologic conditions at a downstream control point, which is the USGS gage at Auburn. The maximum regulated target flow rate at the control point is 12,000 cubic feet per second (cfs), which represents the approximate channel capacity of the river at the control point. The contributing drainage area at the dam site is 221 square miles (sq mi) and the contributing drainage area at the control point is 399 sq mi. Therefore, nearly 45 percent of the watershed at the control point is unregulated drainage area. These discharges, referred to as local inflows, are variable and are not necessarily correlated with upper basin flows. Due to the forecast uncertainty of the local inflows, the maximum flow rate at the Auburn gage is targeted to not exceed 10,000 cfs on the rising limb of the flood event. This provides a buffer that helps to ensure flows do not exceed the 12,000 cfs maximum regulated target flow rate. While generally sufficient, flows have exceeded 12,000 cfs three times since the project has been in operation, an indication of the local inflow uncertainty dam operators must deal with. During a flood event, once the downstream local inflow hydrograph has peaked, forecast uncertainty is greatly reduced, and Project releases are increased to target a maximum flow of 12,000 cfs in an effort to evacuate storage in the reservoir as rapidly as practicable. The following bullets summarize key reservoir pool elevations along with project operation considerations at the different elevations which are also shown on Figure 1-1. Corresponding storage volumes are provided in parentheses.

- **Elevation 1075.0 feet**: Elevation maintained during flood season to provide full storage capability.
- **Elevation 1141.0 feet** (25,375 acre-feet): Elevation of originally authorized maximum conservation pool.
- **Elevation 1147.0 feet** (30,395 acre-feet): Elevation of maximum spring reservoir filling after implementation of Section 1135 storage.
- **Elevation 1167.0 feet** (50,450 acre-feet): Elevation of maximum spring refill with Phase 1 of the AWSP project, first implemented in 2007.
- **Elevation 1177.0 feet** (62,350 acre-feet): Elevation of maximum spring refill of the proposed Phase 2 AWSP. Storage volume is.
- **Elevation 1206.0 feet**: (105,463 acre-feet): Elevation of the normal full reservoir pool. Storage volume is 105,463 acre-feet.
- **Elevation 1223.9 feet** (136,700 acre-feet): Maximum elevation of the reservoir during the probable maximum flood (PMF)

During very large flood events, it is possible that the 12,000 cfs regulation target flow will be exceeded at the USGS gage at Auburn. This can happen if the inflow volume for the flood event is so large that the pool elevation at HHD threatens to exceed the 1206 ft (NGVD29) maximum full pool elevation as Project outflows are being regulated to maintain the target flow rate at the USGS gage at Auburn.

Figure 1-2 is an example of a theoretical operation of HHD during such an event. As shown in this figure, the reservoir pool starts at elevation 1075 feet (NGVD29) and increases in elevation as outflows from HHD are reduced to maintain the 10,000 cfs target flow rate at Auburn. Regulation using only this procedure could result in premature filling of the reservoir, potentially requiring Project outflows that would exceed those that would have occurred under pre-Project conditions. Therefore, for these very large flood events, Project outflows are increased as required by the Discharge Regulation Schedule (DRS), resulting in regulated discharges at Auburn that exceed 12,000 cfs. The DRS is used to determine the maximum release rate for very large floods that might otherwise result in a reservoir elevation in excess of the design conditions. The DRS operation protocol is used to manage the use of the flood control volume and to prevent uncontrolled releases from the Project. It uses knowledge of the inflow rate to the reservoir or rate of rise of the reservoir to determine the flood severity and adjust outflow accordingly. The result of implementing the DRS during a very large flood event is illustrated in Figure 1-2 by the sharp increase in HHD outflow during the second day of the event. It is seen that implementation of the DRS occurs on the rising limb of the inflow hydrograph. Because the purpose of the DRS is to manage the use of the flood control pool during large flood events, it is seen that the DRS is implemented even though there is still flood storage capacity remaining in the reservoir. In this example, implementation of the DRS resulted in a managed use of the flood control pool such that the maximum pool elevation was 1,207 feet NGVD29 and while the maximum regulated peak flow rate at Auburn was approximately 19,200 cfs.

For very large flood events, when the maximum full pool elevation has been exceeded, such as occurs in the example in Figure 1-2, evacuation of the reservoir does not begin until the flow rate at Auburn has dropped to 12,000 cfs. In this figure, it is seen that reservoir evacuation begins on the sixth day of the flood event and it is seen that the HHD releases are made to maintain the 12,000 cfs target flow rate during this evacuation.

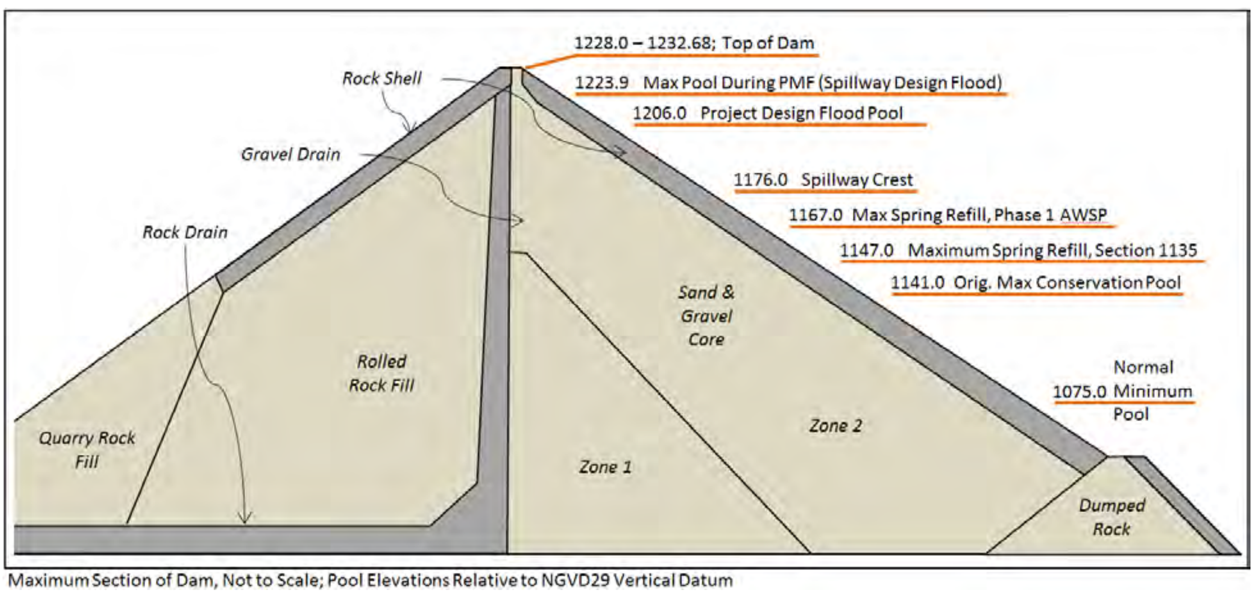

Figure 1-1. Howard Hanson Dam Project Elevations

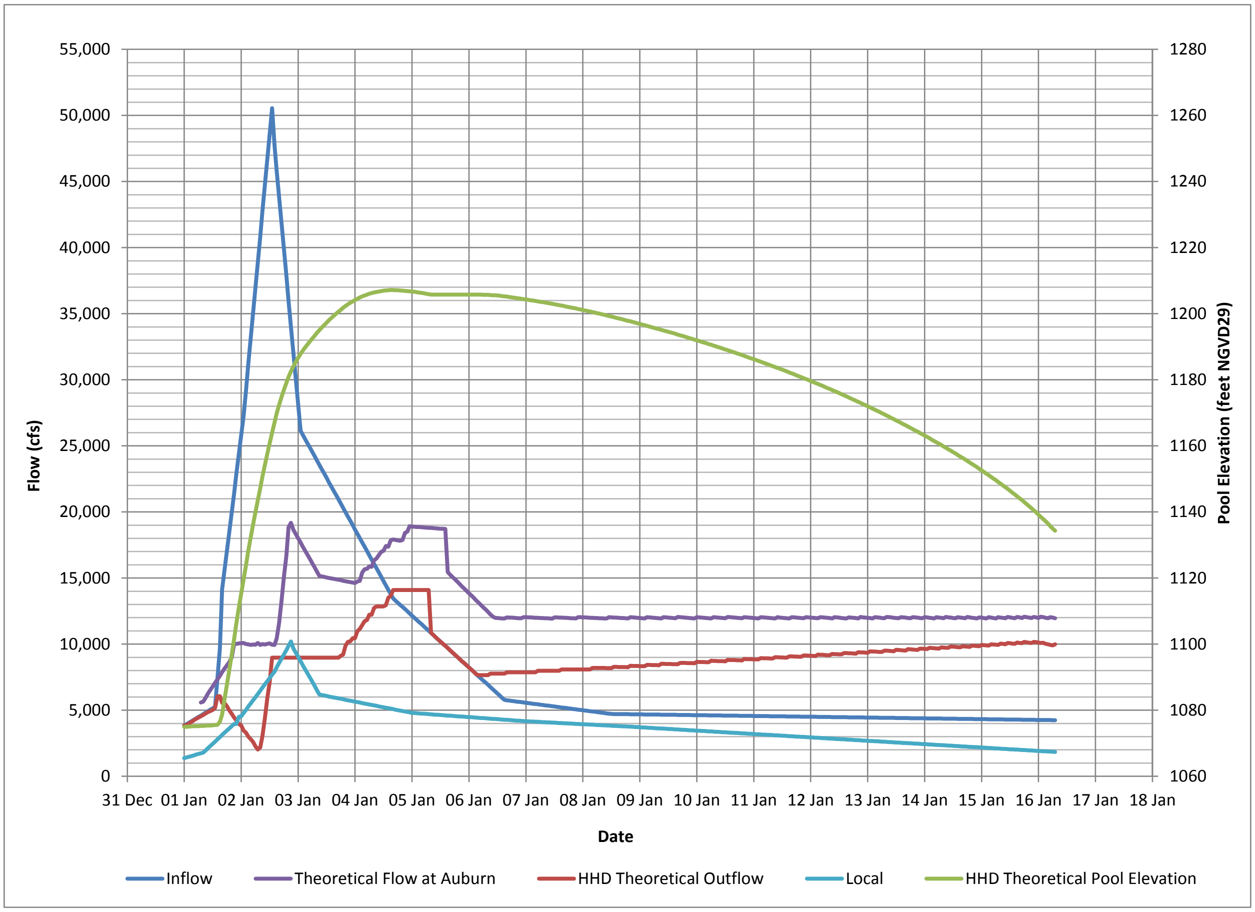

Figure 1-2. Hypothetical HHD Operations Model Results

1.3. Design Flood Hydrographs

In 2012, the Corps of Engineers completed a study (Corps of Engineers 2012) that developed flood hydrographs for the lower Green River at the location of the Auburn USGS gage for seven design flood events ranging from the 50% Annual Exceedance Probability (AEP) flood event (2-yr return period) to the 0.2% AEP flood event (500-yr return period).

Prior to this study it was believed that flood management regulation of HHD could maintain the 12,000 cfs regulation target up to flood events with a 0.2% Annual Exceedance Probability (AEP), which is synonymous with a 500-year return period flood event. However, the recent study (Corps of Engineers 2012) concluded instead that the dam can only be operated to meet the target flow for flood events up to around a 0.71% AEP (140-year) flood event.

One of the objectives of the Green River SWIF is to consider an increase in the level of protection from flooding in the Lower Green River. Flood risk management is currently provided by the system of levees and revetments between River Mile 32 and River Mile 11 in combination with operation of HHD. There is a need to agree on a desired level of protection for the Green River, and determine how this protection can be provided by levee improvements, possibly in conjunction with HHD operation or structural modifications.

2. Purpose

The purpose of this task is to conduct a preliminary analysis of conditions at HHD to determine if there are operational or structural modifications that could provide regulation of higher magnitude flood events. The outcome of the analysis is an initial assessment that will be used to inform a decision about whether further study should be pursued or is warranted.

3. Approach

The task approach includes a limited initial technical analysis and implementation considerations to support a decision about whether to further pursue studies associated with potential modifications to HHD. Three options have been identified to inform the initial assessment which includes two operational options and one structural option. The two operational changes were identified to assess potential opportunities, if further studies were to be pursued additional operational options would be assessed. Operational changes could also be considered in combination with increases in level of protection that are under evaluation for levees in the Lower Green River.

3.1. Limitations

Flood regulation at HHD is complex and there are many factors beyond the scope of this preliminary analysis that would require additional studies. These include but are not limited to environmental studies and environmental compliance requirements associated with potential impacts or changes. Engineering feasibility studies would also be required with any type of modification. The scope of engineering studies required would need to be determined by the Corps of Engineers. However engineering studies would likely include detailed hydraulic studies as well as dam safety studies and studies related to specific project features and operation. Structural and some operational changes would also likely require legal assessment to determine whether an action is within the scope of the existing authorization. Some project specific constraints are further outlined in Section 4.2. This preliminary analysis is focused on operations and operating requirements at the dam and does not address downstream effects or physical changes at HHD. The following sections briefly outline the evaluation approach for each option.

3.2. Description of Options

Option 1 (Operational Change) – This option considers the effect of increasing the magnitude of the releases made from HHD on the rising limb of the flood hydrograph, such that the maximum target flow rate at Auburn would be 12,000 cfs. Under current operation, discharges from HHD are regulated to control flows at Auburn to a maximum flow of 10,000 cfs on the rising limb so as to provide a margin of safety against errors in forecasted local inflows (Corps of Engineers 2011). This option does not consider any changes to the 12,000 cfs target flow once the local inflow hydrograph has peaked.

Option 2 (Operational Change) – This option considers the effect of increasing the regulated target flow rate from the existing 12,000 cfs in order to improve the ability of HHD to maintain regulation for higher magnitude flood events. The target flow rate was increased to 15,100 cfs, with a 13,100 cfs target flow rate on the rising limb of the flood hydrograph for this assessment. The downstream impacts to the Middle and Lower Green River and floodplain resulting from this operational modification are not quantified for this evaluation but would need to be addressed if this option were to be recommended for further study.

Option 3 (Structural Change) – This option considers the effect of increasing the 1206 foot (NGVD29) full pool elevation and the height of the dam on the ability of HHD to maintain regulation for higher magnitude flood events. This option includes a number of simplifying assumptions based on the complexity of Project operations. It will quantify the *minimum* full pool elevation required for HHD to fully regulate the 0.2 % AEP Median flood event. This option assumes that maximum target flow rate at Auburn would not change from existing operational conditions. This option focuses on operating requirements

3.3. APPROACH FOR ANALYZING OPTIONS

3.3.1. OPTIONS 1 AND 2 (OPERATIONAL OPTIONS)

The technical approach for evaluating the two operational options used the Corps of Engineers HHD Operation Model to determine the regulated HHD outflow hydrographs. This model uses a Microsoft Excel based platform, and is used by the Corps of Engineers to determine Project outflows during real-time operations. The balanced hydrographs developed by the Corps of Engineers (Corps of Engineers 2012) were used as inputs to this model. Operations modeling was performed using the procedures outlined in the Water Control Manual for HHD (Corps of Engineers 2011) along with the changes in operation as proposed for each option. The regulated HHD outflow hydrographs determined from the operations model were then hydraulically routed from HHD to the Auburn Gage using the same 1-D unsteady HEC-RAS model that was used by the Corps of Engineers for their study (Corps of Engineers 2012).

In addition to the technical analysis outlined above; policy, process and implementation considerations are also described for these operational changes.

3.3.2. OPTION 3 (STRUCTURAL OPTION)

A complete technical evaluation of this option would require development of a new DRS for the increased full pool elevation and a revision to the HHD Operation Model to include this updated DRS. This work effort was beyond the scope of this study. Therefore, in lieu of developing a new DRS for a new full pool elevation and evaluating HHD operations under this new changed condition, a lesser detailed technical approach was used. The approach used the HHD Operation Model to determine the *minimum* full pool elevation required for HHD to fully regulate the 0.2% AEP Median flood event. This was accomplished by assuming that HHD Project outflows are regulated to the target control flow at Auburn for the duration of this flood event. This means that on the rising limb of the flood event, HHD Project outflows were regulated to the 10,000 cfs target control flow, and once the downstream local tributary hydrograph peaked, HHD Project outflows were regulated to the 12,000 cfs target control flow.

The routed peak reservoir elevation resulting from this analysis represents the *minimum* full pool elevation required to fully regulate this flood event. In reality, the actual required full pool elevation would need to be much higher in order to maintain the regulated target flows without triggering the need for outflows to be determined from a DRS.

In addition to the limited technical analysis outlined above; policy, process and implementation considerations are also described for these structural changes.

4. Analysis & Findings

The following sections summarize the analytical results for each of the three options as well as the policy and implementation considerations for the operational or structural modifications required at HHD.

4.1. Technical Analysis Results

Analysis results for Option 1 and Option 2 are presented in tabular format (see Table 4-1) and graphical format (see Figures 4-1 and 4-2) and are described in detail in Sections 4.1.1 and 4.1.2.

Table 4-1 shows the simulated regulated peak flow in the Green River at Auburn for the existing operation condition. These values were obtained from the Corps of Engineers (2012) study. The simulated regulated peak flow at Auburn for each of Option 1 and Option 2 are then shown in the two columns on the right side of the table. The shaded cells in this table indicate those flood events with peak flows greater than the target flow rate at Auburn.

The analysis results for Option 3 (Structural Option) are described in Section 4.1.3.

Table 4-1: Simulated Regulated Peak Flows at Auburn for Existing Conditions and Options 1 and 2

Flood Event Annual Exceedance Probability	Confidence Level	Simulated Regulated Peak Flow at Auburn (cfs)		
		Existing (Target Flow 12,000 cfs)	Option 1 (Target Flow 12,000 cfs)	Option 2 (Target Flow 15,100 cfs)
0.2% (500-yr) Flood	Median	18,800	18,300	17,500
	High Confidence Limit (5%)	26,800	26,000	25,700
	Low Confidence Limit (95%)	12,000	12,000	15,100
0.5% (200-yr) Flood	Median	12,600	12,600	15,100
	High Confidence Limit (5%)	20,000	19,300	19,000
	Low Confidence Limit (95%)	12,000	12,000	15,100
1% (100-yr) Flood	Median	12,000	12,000	15,100
	High Confidence Limit (5%)	15,100	14,200	15,100
	Low Confidence Limit (95%)	12,000	12,000	15,100
2% (50-yr) Flood	Median	12,000	12,000	15,100
	High Confidence Limit (5%)	12,000	12,000	15,100
	Low Confidence Limit (95%)	12,000	12,000	15,100
4% (25-yr) Flood	Median	12,000	12,000	15,100
	High Confidence Limit (5%)	12,000	12,000	15,100
	Low Confidence Limit (95%)	12,000	12,000	15,100
10% (10-yr) Flood	Median	12,000	12,000	15,100
	High Confidence Limit (5%)	12,000	12,000	15,100
	Low Confidence Limit (95%)	11,900	11,900	15,100
50% (2-yr) Flood	Median	9,200	9,200	9,200
	High Confidence Limit (5%)	9,900	9,900	9,900
	Low Confidence Limit (95%)	9,200	9,200	9,200

Note: The shaded cells indicate those flood events with peak flows greater than the target flow rate at Auburn

4.1.1. Option 1 (Operational Change)

The reservoir operation and hydraulic analysis focused only on the five flood events that were not regulated to the 12,000 cfs target flow at Auburn under existing operational conditions, as shown in Table 4-1. This included the 0.2% AEP High C.L, the 0.5% AEP High C.L., the 0.2% AEP Median, the 1% AEP High C.L, and the 0.5% AEP Median flood events. Focusing on these events was appropriate because the goal of the analysis was to determine the extent to which changes in HHD operation would reduce regulated Green River peak flows for the flood events that will likely factor into Level of Protection (LOP) decision making.

The analysis was not conducted for the flood events that were regulated to the 12,000 cfs target flow under the existing operation conditions (see Table 4-1). Instead, it was assumed for these events that the change in operation would either result in no change in the regulated peak flow at Auburn (i.e. the regulated peak flows would remain as 12,000 cfs), or that the regulated peak flows would be slightly reduced below the 12,000 cfs. This is because the 12,000 cfs regulated peak flow for these flood events for the existing conditions is a result of HHD evacuating storage after the flood peak has passed.

As seen in Table 4-1, the regulated peak flow for the five flood events that were analyzed was reduced as a result of the change in operations. The reduction, however, was small and on the order of 500 cfs to 900 cfs for any given flood event. For example, the regulated peak flow for the 0.2% AEP High C.L. under existing conditions was 26,800 cfs, while under Option 1, it would be 26,000 cfs.

The reason for this small reduction was primarily due to the fact that the increase in target flow rate (from 10,000 cfs to 12,000 cfs) preserved only a small amount of flood storage volume in the reservoir on the rising limb of the flood event. For the large flood events that were analyzed, HHD operations met the target flow rate for approximately a 20 hour period before HHD outflows had to be reduced as per the DRS. Over this 20 hour period, the 2,000 cfs increase in Project outflows equated to only 3,300 acre-feet of flood control volume not used on the rising limb, which is a small percentage (3%) of the 106,000 acre feet of authorized flood control volume. Ultimately, the small change in the target flow rate was not enough to prevent the need for using the DRS to determine Project outflows during the peak of the flood events, although it was enough to slightly reduce the flow magnitudes required by the DRS as compared to existing conditions.

Figure 4-1 shows a graphical representation of the results, comparing the regulated flood frequency curves for Option 1 against existing conditions. It is seen that the regulated flood frequency for the 95% confidence limit (Low C.L.) did not change. The change in operations did result in a modest reduction in regulated peak flows for the median and 5% confidence limit (High C.L.) curves, most notably for the 5% confidence limit (High C.L.) curve.

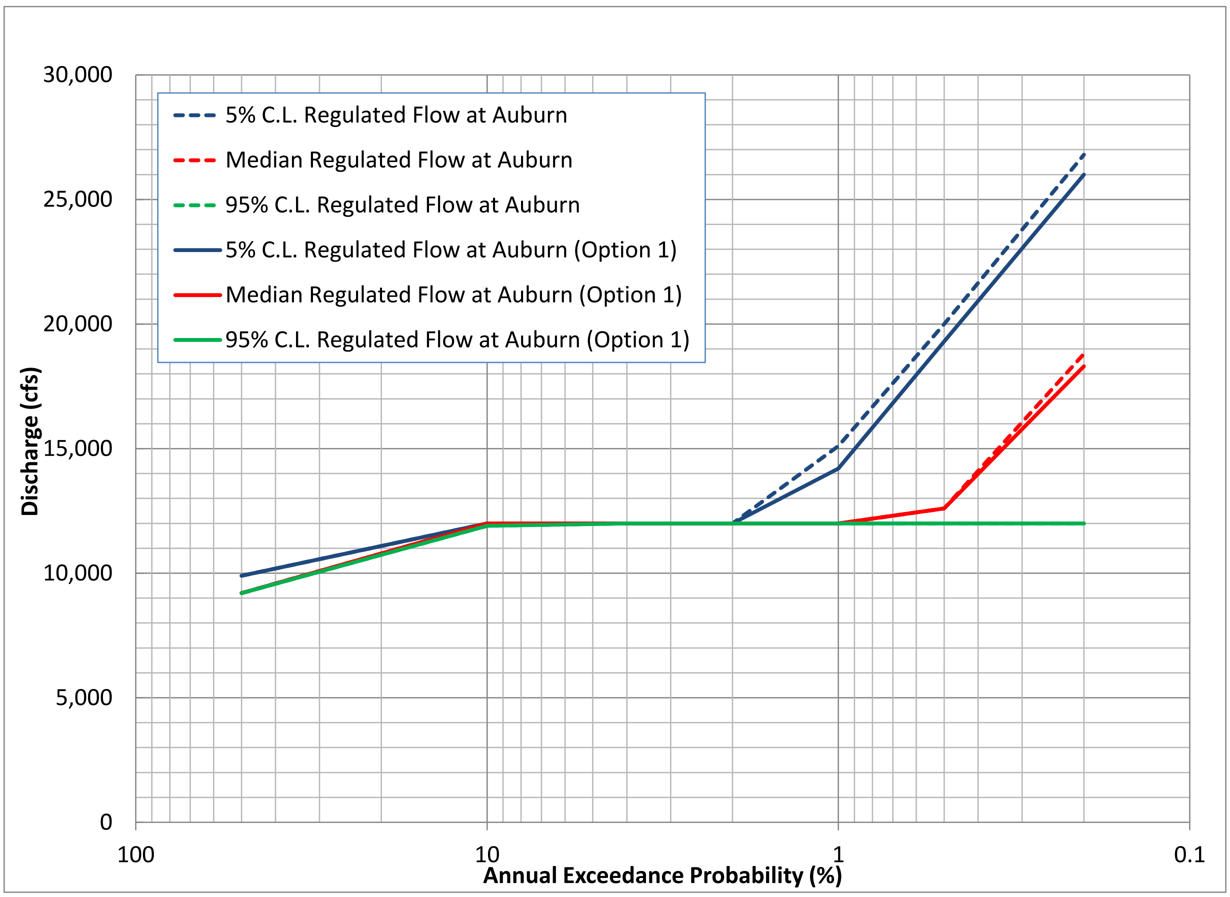

Figure 4-1: Discharge vs Annual Exceedance Probability & Flood Frequency at Auburn for Option 1

4.1.2. Option 2 (Operational Change)

For the same reason as for Option 1, the reservoir operation and hydraulic analysis focused only on the five flood events that were not regulated to the 12,000 cfs target flow at Auburn under existing operational conditions, as shown in Table 4-1. This included the 0.2% AEP High C.L, the 0.5% AEP High C.L., the 0.2% AEP Median, the 1% AEP High C.L, and the 0.5% AEP Median flood events. The analysis was conducted in descending order of flood event magnitude for each of the High C.L, Median and Low C.L. sets of flood events to determine the largest flood events that would be regulated to the new 15,100 cfs target flow rate. The results are shown in Table 4-1. For the Low C.L. set of flood events, it was found that all floods up to and including the 0.2% AEP could be regulated to the 15,100 cfs target flow rate. For the Median set of flood events, it was found that all floods up to and including the 0.5% AEP flood event could be regulated to the 15,100 cfs target flow rate. Finally, for the High C.L. set of flood events, it was found that all floods up to and including the 1% AEP could be regulated to the 15,100 cfs target flow rate.

Based on the analysis results for these high flow flood events, it was assumed that HHD could regulate all flood events less than these threshold flood events to a peak flow at Auburn of no more than the 15,100 cfs target flow.

As seen in Table 4-1, it was determined that the regulated peak flow rate at Auburn exceeded the 15,100 cfs target flow rate for only the three largest flood events. For each of these three flood events, the reduction in regulated peak flow rate at Auburn, as compared to existing conditions, ranged between 1,000 cfs (for the 0.5% AEP High C.L.) and 1,300 cfs (for the 0.2% AEP Median). For each of these three flood events, Project outflows during the peak of the flood event were determined from the DRS, which is also used for existing conditions. Similar to Option 1, the reason the regulated peak flow rates were reduced relative to existing conditions is because the higher magnitude target flow rate reduced the amount of flood control volume that was used on the rising limb of the flood event, thus reducing the minimum required flow rates on the DRS during the peak of the flood event.

Figure 4-2 shows a graphical representation of the results, comparing the regulated flood frequency curves for Option 2 against existing conditions. It is seen that the Option 2 regulated flood frequency curve for the 95% confidence limit (Low C.L.) shows that all flood events could be regulated to the 15,100 cfs target flow rate. The median regulated flood frequency curve shows that all flood events less than or equal to the 0.5% AEP flood event (200-yr) could be regulated to the new 15,100 cfs, and that the regulated peak flow rate for the 0.2% AEP flood event (500-yr) is slightly less than existing conditions. The regulated flood frequency curve for the 5% confidence limit (High C.L.) shows that all flood events less than or equal to the 1% AEP could be regulated to the new 15,100 cfs, and that the regulated peak flow rates for the 0.5% AEP (200-yr) and 0.2% AEP flood event (500-yr) are slightly less than existing conditions.

The preliminary analysis of Option 2 did not consider downstream impacts of the higher regulated flow peak flows. If this option were to be pursued, studies would need to be conducted to evaluate these impacts. Evaluation of this operational modification also did not consider modifications to Project components, such as the outlet works, that may require modifications to accommodate higher regulated releases on a more frequent basis. It is also likely that modifications would need to be made to the existing DRS as part of this option.

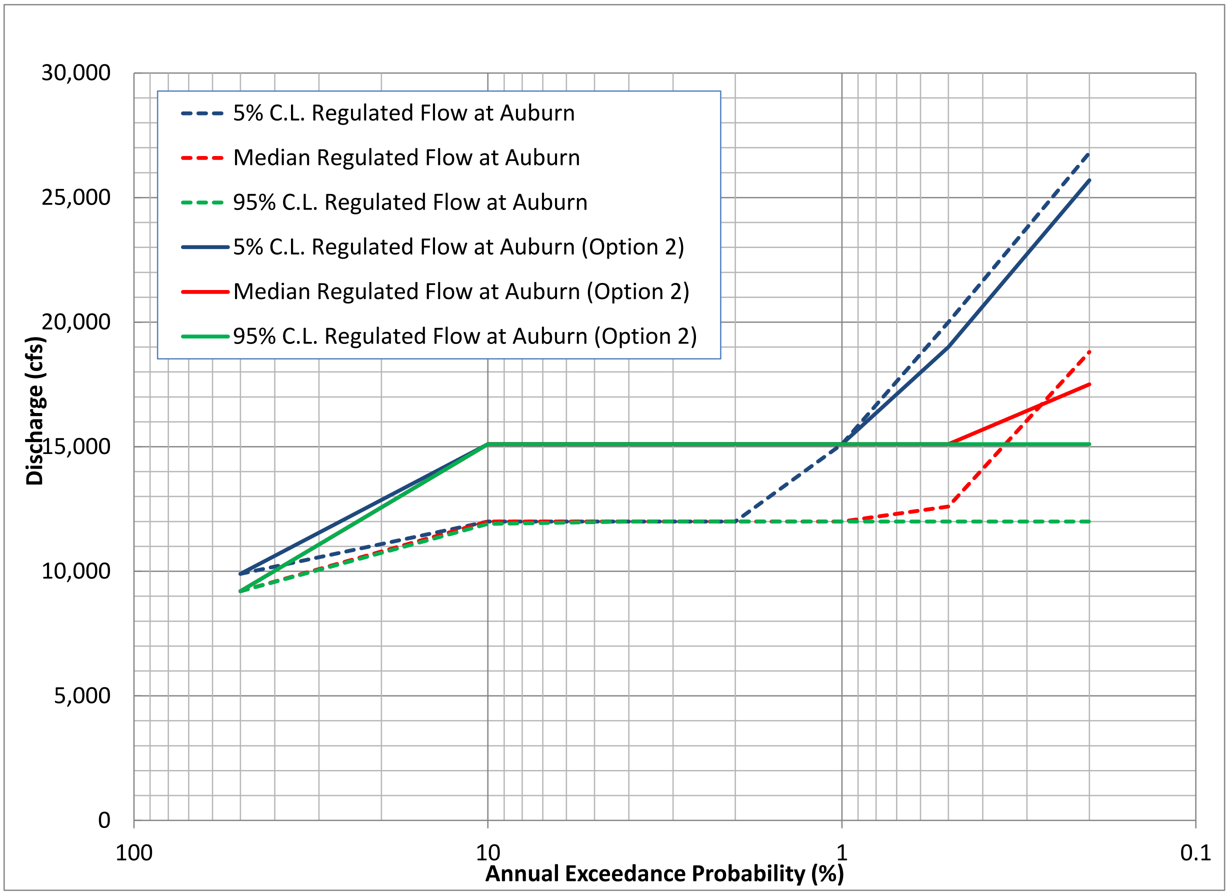

Figure 4-2: Discharge vs Annual Exceedance Probability & Flood Frequency at Auburn for Option 2

4.1.3. Option 3 (Structural Change)

For Option 3, the reservoir operation model was used as a tool to determine the *minimum* full pool elevation required for HHD to fully regulate the 0.2% AEP Median flood event. The model was run assuming that HHD releases are regulated to control flows at Auburn to the 10,000 cfs target flow on the rising limb of the flood hydrograph. Once the local inflow hydrograph peaked, the HHD releases were regulated to control flows at Auburn to the 12,000 cfs target flow as the flood control volume in the reservoir was evacuated. Figure 4-3 shows the reservoir operation model results.

As seen in this figure, the theoretical flow at Auburn is constant at 10,000 cfs until after the local inflow hydrograph has peaked, at which point the theoretical flow at Auburn is constant at 12,000 cfs. As a result of this hypothetical reservoir operation model run, the HHD reservoir elevation peaked at elevation of 1224.5 feet, which is approximately four feet below the lowest top of dam elevation (see Figure 1-1). For Option 3, this 1224.5 foot elevation represents the *minimum* required full pool elevation for HHD to be able to regulate the 0.2% AEP Median flood event to the 12,000 cfs target flow at Auburn. The actual required full pool elevation would be much higher than this. This is because HHD uses a DRS to prevent premature filling of the reservoir to the full pool elevation. In order to regulate the 0.2% AEP median flood event to the 12,000 cfs target flow rate, the full pool elevation would have to be sufficiently high in order to prevent the need for the DRS.

Some perspective on how much higher the full pool elevation may have to be above this minimum value, so as to prevent the need for the DRS, can be obtained from the results of the existing condition operation of HHD as summarized in USACE (2012). During the 0.2% AEP Median flood event, the need for the DRS was initiated when the reservoir elevation reached approximately elevation 1150 feet NGVD29. This elevation is 56 feet below the existing condition full pool elevation and represents a condition where there is approximately 73,000 acre-feet of flood control volume remaining. These results suggest that the full pool elevation required to fully regulate the 0.2% AEP Median flood event would be substantially higher than the estimated 1224.5 foot minimum elevation. It may be on the order of 50 feet higher. More likely however, the required elevation would be that which would provide approximately 73,000 acre-feet of flood control volume above elevation 1224.5 feet NGVD29. These are only estimates, and it is re-emphasized that a more rigorous analysis, including development of a DRS that corresponds with the dam raise, would be required to determine the actual full pool elevation required to fully regulate the 0.2% AEP Median flood event.

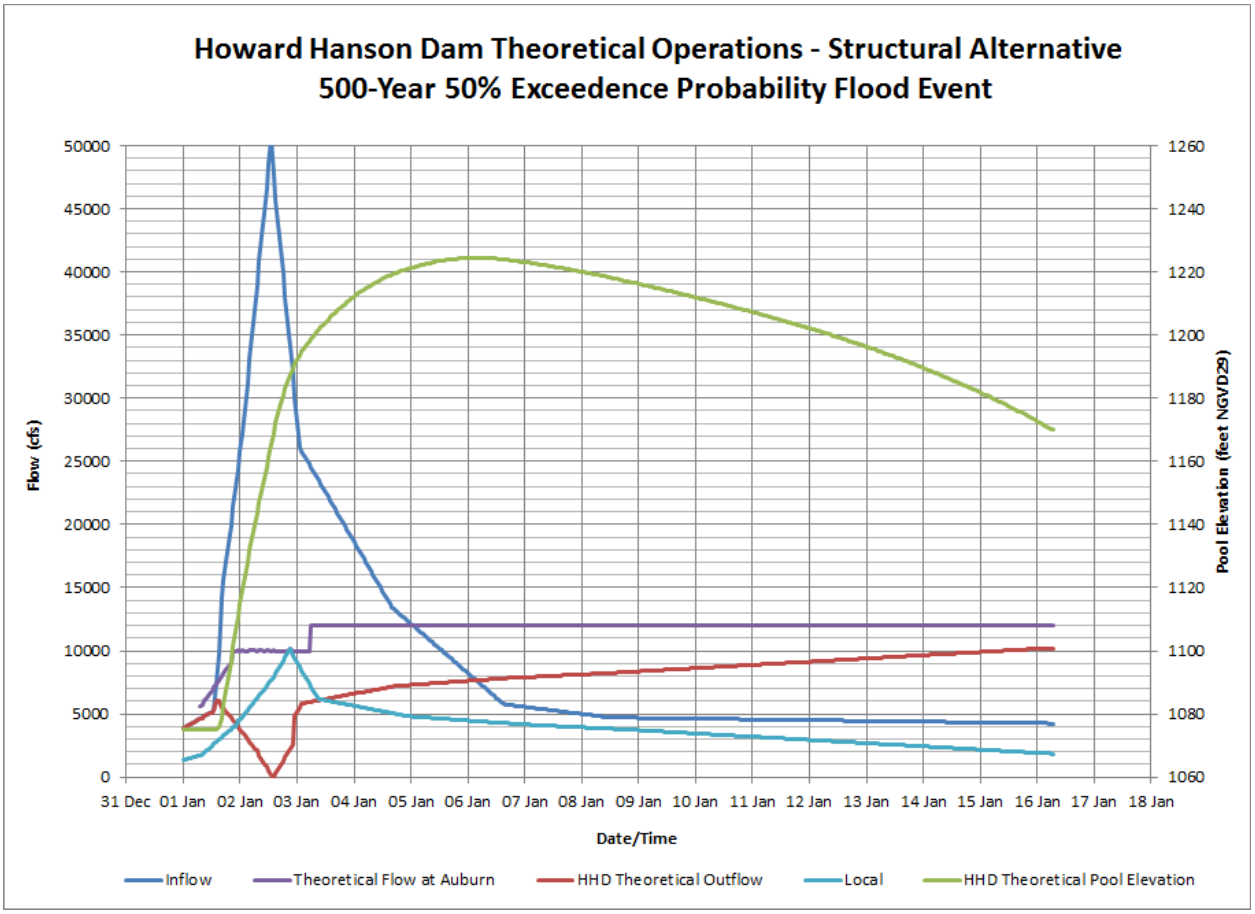

Figure 4-3: HHD Operations Model Results for 0.2% AEP Median Flood Event, Structural Alternative

4.2. Policy and Implementation Considerations

The following sections summarize the policy and implementation considerations for potential operational or structural modifications to HHD.

4.2.1. Operational Modifications

Options 1 and 2 would involve changes to the operating parameters established in the Water Control Manual for Howard Hanson Dam.

Option 1 evaluates increasing releases from the dam during the initial portion of the flood event (i.e. the rising limb of the flood hydrograph), from current maximum of 10,000 cfs to 12,000 cfs. Since this option would not increase maximum flow rates downstream of the dam, beyond those currently experienced, it is anticipated that this option would require limited additional studies to support changes to the Water Control Manual and in accordance with the Federal Rules Making Process.

Option 2 evaluates increasing the regulated releases during both the rising (target flow of 13,100 cfs) and receding (target flow of 15,100 cfs) limbs of the flood hydrograph. While changing the maximum release does not modify the authorized purpose of the dam, and therefore does not appear to require congress to authorize a change to the Project, it would require an analysis of the impacts (both hydraulic and environmental) on the Green River below the dam. Option 2 would also require engineering feasibility studies related to components of the dam such as the outlet works to support higher regulated releases.

Both Operational options would result in a change to the water control manual and would likely be considered a federal action, and therefore trigger the NEPA process and also require consultation under Section 7 of the Endangered Species Act and Section 106 consultation and potentially tribal consultation regarding treaty usual and accustomed fishing rights

4.2.1.1. Authority

Authority for the USACE to conduct and fund the required engineering and environmental studies, and to fund required engineering design and construction to address downstream impacts from the increased maximum releases, could potentially be conducted through the “Continuing Authorities Program” (CAP). CAP is a specific group of 10 legislative authorities under which the Secretary of the Army, acting through the Chief of Engineers, is authorized to plan, design, and implement certain types of water resources projects without additional project specific congressional authorization. In this instance the specific CAP authority would be for Flood Control under Section 205 of the Flood Control Act of 1948, as amended. IAW USACE Engineering Regulation 1105-2-100, “Planning Guidance Notebook”:

> *“CAP authorities may be used to provide additional improvements to a completed portion of a specifically authorized project so long as they do not impair or substantially change the purposes or functions of the specifically authorized project.”*[1]

The Section 1135 project implemented in 1996 for low flow augmentation is an example of a CAP project. While use of the CAP program does not require Federal Authorization, excluding the project authorization steps described for Option 3, the steps of the CAP process are similar, although lower in total cost. For instance:

- During the Feasibility Phase up to $100,000 in studies can be 100% Federally Funded. Additional costs are split equally (50%/50%) with the local sponsor.[2]
- Total cost for an individual CAP, Section 205 project cannot exceed $7 million and total USACE expenditures, in a single fiscal year, for Section 205 projects cannot exceed $50 million.[3]

[1] USACE Engineering Regulation 1102-5-100, dated 22 April 2000, *Planning Guidance Notebook,* page F-5

[2] USACE Engineering Regulation 1102-5-100, dated 22 April 2000, *Planning Guidance Notebook,* page F-9

- Costs for preparation of plans and specifications and construction are shared at a minimum of 65% federal/35% non-federal and up to a maximum of 50%/50%.[4]

In order to initiate a CAP project a non-federal sponsor submits a letter to the Corps requesting assistance. Federal funding under this program is competitive nationally and requests typically exceed the program funding appropriation authorized by congress each year. Environmental compliance and consultation would typically be initiated during the feasibility and completed during final design. Changes to the Water Control Manual, for either Option 1 or 2 (after completion of the CAP process), must be made through the application of the "Federal Rules Making Process" and are highlighted below:

1. In the case of a modification to an existing rule, the process formally begins with the publication of an "Advanced Notice of Proposed Rule Making" being published in the Federal Register. The Advance Notice is a formal invitation for interested parties to participate in shaping the proposed rule and starts the notice-and-comment process in motion. Normally 60 days is allowed for public comment and in many cases includes face-to-face meetings with appropriate parties.
2. Based on the comments received, an initial modification to the existing rule will be developed over a period of approximately 30 days.
3. This draft rule is then once again published in the Federal Register, with an additional 60 day comment period.
4. Again, modifications are made to the proposed change of the dam's operating rules over another roughly 30 day period.
5. The final amended rule is then published in the Federal Registry to specify the final procedures for the public.

The optimal timeline described above provides for a 180 day period, but delays often push the total process timeline well beyond 1 year. In fact a 2009 Government Accounting Office (GAO) study determined the average rule making process took approximately 4 years.[5]

4.2.2. Structural Modification

Option 3 involves structural modifications to HHD that would necessitate changes to the existing Project. Authority to modify an existing authorized project is provided under the provisions of Section 216 of the Flood Control Act of 1970. The AWSP authorized in 1999, and partially implemented, is an example of a modification conducted under Section 216. The initial step begins with the U.S. Army Corps of Engineers (USACE), Seattle District receiving a request from a potential local sponsor for assistance. Once received, USACE will conduct a preliminary assessment of the potential "need" for the project to determine if there is a potential federal interest in developing the project using existing Operation and Maintenance (O&M) funds for the Dam. Alternatively, the local sponsor may conduct the preliminary investigation and receive credit against future funding obligations for "in-Kind Service" provided.

If the preliminary investigation concludes the project warrants further investigation, it then starts the journey through the Federal authorization, investigation, and design and construction process. USACE

[3] USACE Engineering Regulation 1102-5-100, dated 22 April 2000, *Planning Guidance Notebook,* page F-11

[4] http://www.nae.usace.army.mil/Missions/PublicServices/ContinuingAuthoritiesProgram/Section205.aspx

[5] GAO Report to the Chairman, Committee on Oversight and Government Reform, House of Representatives, *"Federal Rulemaking, Improvements Needed to Monitoring and Evaluation of Rules Developed as Well as to the Transparency of OMB Regulatory Reviews*," April 2009, page 5

implementing guidance is codified in Engineering Regulation 1105-2-100, "Planning Guidance Notebook." The process for authorizing the modification involves several distinct steps:

1. The initial step begins with the U.S. Army Corps of Engineers (USACE), Seattle District receiving authorization to study the potential benefits of modifying the dam. The authorization may be a resolution from the U.S. House Committee on Public Works and Transportation, a resolution from the U.S. Senate Committee on the Environment and Public Works, or by inclusion in a public law.
2. Once the authorization, often referred to as a "new start" is made, the project will enter the Reconnaissance Phase. Some changes to the Reconnaissance Phase were included in the recently authorized Water Resource Development Act (WRDA 2014) and implementation guidance will be forthcoming over the next several years. The current objectives of the Reconnaissance Phase and process is outlined below::
    a. determine if the water resource(s) problems warrant Federal participation in feasibility studies,
    b. define the Federal interest,
    c. complete a 905(b) Analysis (refers to Section 905(b) of the WRDA of 1986) or a Reconnaissance Report,
    d. prepare a Project Management Plan (PMP),
    e. assess the level of interest and support from non-Federal entities, and
    f. negotiate and execute a Feasibility Cost Sharing Agreement (FCSA).

    The reconnaissance phase is fully funded by the Federal government (approximately $150,000), but cannot begin until funds are appropriated as part of the annual federal appropriations funding of USACE activities. Once funding is received, the target for completion of the Reconnaissance Phase is 6 to 12 months from initial obligation of reconnaissance funds to a signed FCSA. A successful reconnaissance phase results in a report confirming a Federal interest, a preliminary determination that the benefits of constructing the project exceed the costs to complete the project, and identification of a local project sponsor willing to provide the required non-federal funds for subsequent phases of the project.
3. If the Reconnaissance Report deems further investigation is warranted, the project can proceed to conduct a feasibility study. The objective of feasibility studies is to investigate and recommend solutions to water resources problems. The results of these studies are documented in a feasibility report that includes documentation of environmental compliance. The cost of feasibility studies, are 50 percent Federal and 50 percent non-Federal as defined in Section 105 of the WRDA of 1986. Like the reconnaissance phase, funding for a feasibility study must be provided by appropriation, normally in the fiscal year following completion of the reconnaissance report. In the past the time to complete the feasibility study could take several years. For instance, The Seattle District received authorization to start the Feasibility Study for the Howard Hanson Dam "Additional Water Storage Project" in 1989 and the Final Feasibility Study Report was not completed until 1998.[6] Efforts by USACE Headquarters to streamline the feasibility process were codified in2012 with a goal that new studies should be completed in 18-36 months, and are intended to have a maximum cost of $3 million[7] divided equally between the Federal government and the local project sponsor.

[6]http://www.nws.usace.army.mil/Portals/27/docs/civilworks/projects/Final%20HHD%20AWSP%20Feasibility%20Report%20and%20EIS%20August%201998.pdf

[7] USACE Memorandum for Major Subordinate Commands, dated 8 Feb., 2012, SUBJECT: U.S. Army Corps of Engineers Civil Works Feasibility Study Program Execution and Delivery

4. If the results of the Seattle District's Feasibility Study continue to support Federal involvement, the report is forwarded first for review by the Northwest Division. Projects of this scale also require an independent external peer review (IEPR) process outside of the Corps of Engineers. Once these reviews are complete and comments satisfactorily addressed the report is sent on to the Civil Works Review Board at USACE Headquarters. An endorsement of the project's public benefits and a recommendation for project authorization is provided in the form of a signed Chief of Engineer's Report. Time to complete the Division and USACE HQ reviews is included in the 18 to 36 months described in Item #3 above.
5. The next step is Federal authorization for the project. Project authorization is provided by Congress through the Water Resources Reform and Development Act (WRRDA), formally the Water Resources Development Act (WRDA). Recent WRRDA/WRDA bills were passed into law in 2014, 2007, and 2000, a recent average of 7 years between bills.
6. After authorization in a WRRDA, funds may be appropriated to begin the Preconstruction Engineering and Design (PED) Phase. As with the Feasibility Phase, PED Phase funding is provided in USACE's annual budget through the energy and water bill. In the PED Phase, 25% of the cost must be provided by the local project sponsor.[8] While PED funding for changing the Dam's operation beyond its currently authorized levels may be possible in one year, securing all necessary Federal PED funds for the design effort to modify the dam may result in funding being spread over more than one Federal Fiscal Year. As an example, the 1998 cost estimate to complete the PED for the Howard Hanson Dam "Additional Water Storage Project" was $8.34 million dollars.[9]
7. Once the PED Phase is complete, including final engineering designs, construction cost funding can be determined and construction funding can be appropriated. Securing all necessary Federal Construction funds may also result in funding being spread over more than one Federal Fiscal Year.

Mandated local sponsor contributions, for the overall project, range between 35% (minimum) and 50% (maximum). The range is based on the costs to secure necessary Lands, Easements, Rights-of-way, Relocations and Disposal Areas (LERRD) for the project, which are 100% the responsibility of the local sponsor.[10]

Design requirements are beyond the scope of this preliminary analysis. However a structural modification to increase the height of the dam would likely require modifications to the entire embankment prism. The existing drainage tunnel, seepage issues and outlet works would also require engineering studies and modifications. An increase in the dam height would also necessitate changes to the spillway gates and debris booms in the reservoir, which were recently upgraded to improve the safety of the dam during probable maximum floods. The existing railroad would also likely require relocation. A raise to the dam structure would also require geotechnical studies of the surrounding area to identify and address potential concerns. Potential impacts limitations to flood operation during implementation would also need to be considered during engineering studies. Dam Safety modifications implemented between 2010 and 2014 would also need to be revisited with an increased full pool elevation. For example geotechnical concerns related to the right abutment were not eliminated, but instead satisfactorily addressed to the current pool elevation of 1206'.

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[8] USACE Engineering Regulation 1102-5-100, dated 22 April 2000, *Planning Guidance Notebook,* page. 2-17
[9] http://www.nws.usace.army.mil/Portals/27/docs/civilworks/projects/Appendix%20C%20Cost%20Estimate.pdf
[10] Ibid. page E-128

Modifications of this magnitude would also require extensive environmental studies to assess impacts. Similar to operational changes the federal action would also trigger the NEPA process and require consultation under Section 7 of the Endangered Species Act and Section 106 consultation and tribal consultation regarding treaty usual and accustomed fishing rights. A secondary potential benefit associated with a pool raise would be the opportunity to include additional low flow augmentation during the summer months.

Potential costs for Option 3 cannot be provided without at least some preliminary engineering design upon which to base the costs, but some awareness of an "order of magnitude" approximation can be obtained based on the cost for recent modifications at Howard Hanson Dam and similar projects throughout the United States. Cost for these projects range from a low of $21 million, with a corresponding local 35% cost share of $7.35 million, to a high cost of $462 million, with a 35% local cost share of $161 million (see below).

1. Recent activities at Howard Hanson Dam have included both:
    a. The completion of a seepage barrier (grout curtain) and drainage improvements to the right abutment totaling $40 million.
    b. Proposed downstream fish passage facilities are currently scheduled to be constructed in 2018.[11] In 2009, the estimated cost for the passage feature was $200 million.[12]
    c. Both of these features would have to be modified, assuming studies to support Option 3 are not completed in time to delay the current timeline for construction of the currently scheduled fish pass facilities. If modifications to the dam are equal in cost to the recent and current improvement costs, the local sponsor contribution would be at least $84 million (($40 M + $200 M)*35%)
2. USACE New York, Waterbury Dam VT 2001 construction contract for $21M to address seepage and Settlement in the embankment,[13] with a local cost share of $7.35 million.
3. Likewise recent construction over the past 3 years, by the Jacksonville District associated with repairs to the Herbert Hoover Dam and Levee system have exceeded $462 M, with significant work left to be completed.[14] 35% of $462 M would be $161 M.
4. One of the recent dams constructed by USACE was the Seven Oaks Dam in California. Construction of the dam was completed in 2000, at a cost of $450 M,[15] with a minimum local cost share of $157.5 M.

Table 4-2 below, demonstrates a possible timeline to complete a project requiring construction modifications to the dam. The potential time required ranges from 7 to 14 years, depending on the sequence of congressional action. This timeline also assumes no delays in receipt of federal funding for the different phases and that all environmental compliance and consultation can be accomplished in a timely manner such that authorization and funding for PED is not delayed.

[11] http://www.mytpu.org/tacomawater/water-source/green-river-watershed/howard-hanson-dam.htm
[12] http://www.kentreporter.com/news/51267057.html
[13] http://www.nan.usace.army.mil/Media/FactSheets/FactSheetArticleView/tabid/11241/Article/8321/fact-sheet-waterbury-dam-waterbury.aspx
[14] http://riverscoalition.org/wp-content/uploads/2014/03/Lt-Col-Greco-RC-presentation-3-26-14.pdf
[15] http://www.sbcounty.gov/dpw/floodcontrol/sevenOaks.asp

Table 4-2: Construction Modification Timeline

Action\Project Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Congress Authorizes Project Study															
Congress Appropriates Recon Funds															
USACE Conducts Reconnaissance Study															
Congress Appropriates Feasibility Funds															
USACE Conducts Feasibility Study															
Congress Passes WRRDA															
Congress Appropriates PED Funds															
USACE Prepares PED Documents															
Congress Appropriates Construction Funds															
USACE Constructs the Project															

Construction timelines vary greatly among projects, based primarily upon two factors: appropriation of all required construction funds and the project construction schedule, once all funding is secured. For planning purposes, construction projects requiring over $600 million, will most likely exceed 3 years for construction.[16] Therefore it is reasonable to assume construction projects, totaling under $600 million should be completed in three years or less, but this is not a hard and fast rule. For comparison, the Seattle District's Green River Ecosystem Restoration Project, authorized by WRDA 2000, with a currently estimated total implementation cost of $195 million had elements under construction in 2005 and is not yet complete.[17]. Similarly, implementation of the AWSP has also exceeded three years.

4.3. FINDINGS

The preliminary analysis of the three options finds that there are potential opportunities to provide additional flood risk management benefits for the Lower Green River. Of the two operational changes, Option 2 provides the greatest potential benefit. However the potential benefits of Option 2 must be weighed against the impacts of increased flows below HHD and the study time and costs associated with pursuing such changes. As noted in Section 3, if operational changes were to be pursued, a range of different operation scenarios could be considered. Further, operational changes could be assessed independent of or in combination with levee modifications in the Lower Green River aimed at increasing the level of protection afforded by the levee system. Option 3 has the potential to provide the greatest increase in levels of protection downstream but would have the most significant study, impact and implementation costs. Option 3 would also have the longest timeframe and the greatest uncertainty in achieving actual implementation given uncertainties in funding, authorization, and satisfactorily completing necessary engineering and environmental studies. Approval of the SWIF can also not be dependent on federal authorization (Option 3) or funding (Option 2 if pursued under the CAP authority).

The following table summarizes the potential benefit of each option along with a summary of challenges and complexity that could ultimately affect the successful implementation of each option.

[16] US Army Corps of Engineers, Engineering and Construction Bulletin No. 2013-11, Issued 11 April 2013, Subject: USACE Mega-Project Management: Additional Project, Engineering and Construction Management Controls. Enclosure 2

[17]http://www.nws.usace.army.mil/Missions/CivilWorks/ProgramsandProjects/Projects/GreenDuwamishRiverEcosystemRestoration.aspx

Table 4-3: Summary of Options

Criteria and/or Potential to Impact Successful Project Implementation	**Option 1** **Operational** **(12,000 cfs on rising hydrograph)**	**Option 2** **Operational** **(target regulated flow to 15,100 cfs)**	**Option 3** **Structural**
Relative Degree of Potential Benefit Related to flood operation	Minimal	Minimal-Moderate	Very High
Authority	May be studied and Implemented under CAP.	May be studied and Implemented under CAP if costs to address downstream impacts are within CAP per project limit.	New authorization required.
Funding	Low justification for federal interest.	Moderately certain if perceived as high priority at the federal level and strong local support among stakeholders.	Given current federal funding climate, adequate and timely budget appropriations is uncertain. Current issues with the AWSP could also adversely affect funding likelihood. Initial studies could potentially be funded by non-federal interests.
Engineering Studies & Complexity	Minimal	Moderate	Extensive scope and very high complexity
Dam Safety Issues	None Apparent	None Apparent	Multiple
Environmental Impacts Downstream	Minimal	Impacts to Middle Green and higher flows on levees in Lower Green.	Impacts to Middle Green and higher flows on levees in Lower Green.
Environmental Compliance, Consultation and Rule Making	Moderate	Challenging	Very Challenging

5. References

Corps of Engineers, 2011. Water Control Manual Howard A. Hanson Dam, Green River Washington. U.S. Army Corps of Engineers, Seattle District Corps of Engineers. Seattle Washington. September 2011.

Corps of Engineers, 2012. Assembly of Design Flood Hydrographs for the Green River Basin. Summary Report for Flood Plain Management Services Program. Seattle District Army Corps of Engineers. September 2012

Tetra Tech/NHC. 2014. Green River System-Wide Improvement Framework Hydraulics Technical Memorandum. Attachment D to Draft Current Conditions Report. May 2014.