Hood River Basin Surface Water Storage Feasibility Assessment

Oregon Water Resources Department

Hood River County Water Planning Group
on behalf of
Hood River County

Table of Contents

Table of Tables

Document

Appendix A

Appendix B

Appendix C

Table of Figures

Document

Appendix B

Executive Summary

The objective of this report is to evaluate the physical, regulatory and ecological, and economic feasibility of surface water storage alternatives in Hood River County. To assess the feasibility of future water storage alternatives as well as other opportunities to offset impact due to climate change in Hood River County, the Hood River County Water Planning Group (HRCWPG), a group of local stakeholders, was awarded funds and in-kind assistance under Oregon Water Resources Department's (OWRD) Water Storage, Conservation, and Reuse grant program and the Bureau of Reclamation's WaterSMART grant program to conduct a Water Planning Study. This report acts in part to fulfill the requirements of Reclamation and OWRD's grant programs.

Three alternatives related to surface water storage were evaluated in this report for the Hood River Basin's future water supply needs. Two of the alternatives include the expansion of existing reservoirs and the remaining alternative consists of a new reservoir in the Hood River Basin. The surface water storage alternatives discussed in this analysis are listed here:

- *Alternative 1: Expansion of the Upper Green Point Reservoir*-The storage capacity of the Upper Green Point reservoir is increased by 561 acre-feet to 1253 acre-feet by raising the dam height an additional 10 feet while eliminating Lower Green Point Reservoir. The existing spillway would be replaced with a concrete chute spillway and the existing outtake and inlet facilities would not be modified.

- *Alternative 2: Expansion of Laurance Lake*- The storage capacity of Laurance Lake is increased by 370 acre-feet to 3805 acre-feet by installing an adjustable Obermeyer weir on the existing spillway. The Obermyer weir would provide a non-permanent three-foot dam raise that would allow spring runoff to be retained and then would lower to the reservoir's existing operating levels for the rest of the year. The existing embankment, outtake and inlet facilities would not be modified.

- *Alternative 3: Neal Creek Reservoir:* A new reservoir would be constructed on the headwaters of the West Fork Neal Creek providing a storage capacity of 2256 acre-feet and a corresponding dam height of 120 feet. A concrete chute spillway would convey flood events to the West Fork Neal Creek downstream of the dam. The outlet facilities would consist of an 18-inch pipe that would travel over two miles and discharge directly into the East Fork Irrigation District's main irrigation canal.

The analysis in this report indicates very little that would constrain the physical feasibility of the three surface water storage alternatives. Geologic investigations conducted in the Hood River Basin and for the facilities of the existing reservoirs did not indicate seismic hazards or geologic conditions that would preclude implementation of any these projects. The spillway and embankments for Alternative 1 and 3 were designed to convey extreme hydrologic events and when analyzed their reservoir elevations were below their respective dam crests.

The regulatory and ecological conditions surrounding Laurance Lake, Upper Green Point Reservoir and the Neal Creek Reservoir site could considerably limit the feasibility of implementing these alternatives. All of these alternatives are either near or within Mt. Hood National Forest land and several environmental regulations and permits would be required. Regulatory action could delay implementation of these projects and increase the cost of these alternatives significantly.

The capital and unit storage cost associated with each alternative are presented in Table ES 1. Due to the small level of construction required, the Expansion of Laurance Lake has the lowest capital cost. Expansion of Upper Green Point Reservoir is the second least expensive alternative, where higher costs are mostly due to the fill required to expand the reservoir. The Neal Creek Site is the most expensive reservoir because unlike Alternative 2 and 3, no existing facilities are available to reduce the costs and the cost of constructing the outlet facilities increases the total cost by 20 percent because of the distance the pipe will have to travel to reach East Fork Irrigation District's (EFID) main canal.

Table ES 1. Project costs for surface water storage alternatives in the Hood River Basin.

Alternative	Capital Cost ($)	Unit Storage Cost ($/acre-feet)
Expansion of Upper Green Point Reservoir	$1,272,000	$2,263
Expansion of Laurance Lake	$328,000	$88
Neal Creek Reservoir	$13,213,500	$6,653

Based on results of this analysis, the expansion of the Upper Green Point Reservoir would present the least regulatory challenges and is economically feasible. Even though expanding Laurance Lake is the most economically feasible alternative, regulatory requirements may limit the feasibility of the alternative. Implementing a new reservoir on the East Fork Neal Creek will presents the most regulatory and economic challenges.

Conclusions made in this analysis must be made in the context of the level of data and information available. This is a planning level study therefore the analysis and corresponding conclusions made should not be used to implement a construction project, but to identify where more information is needed and ultimately determine what solutions are best to assist the Hood River Basin in preparing for future water supply challenges. The conclusions made in this report should be evaluated in conjunction with the conclusions made with Reclamation's Basin Study, WPN's Conservation Assessment, and

Normandeau Associate's Instream Flow Assessment The following recommendations are given for further investigation of surface water storage alternatives in the Hood River Basin:

- Evaluate impacts of storage alternatives with respect to water resource reliability and instream flows as part of the Hood River Basin Study.
- Even if these three alternatives are not considered further, measures should be taken within the next year to extend the storage reservations currently held in the Hood River Basin which will expire in 2016.
- If results from Reclamation's Basin Study indicate that EFID storage would benefit the Basin, more investigation should be directed towards locating the storage site which would provide the most cost-effective benefits to the largest number of stakeholders.
- If results from Reclamation's Basin Study indicate a benefit of additional storage in the Basin, investigation should be conducted into potential financing provided by the Bureau of Reclamation and Oregon Water Resources Department (OWRD) to more thoroughly evaluate these alternatives.
- If results from Reclamation's Basin Study indicate a benefit of additional storage in the Basin, plans should be carefully devised to introduce and present future surface water storage alternatives to the public.

1 Introduction

Communities that have historically depended on glaciers and snowpack for summertime water supplies are expected to face future challenges in adequately meeting their supply needs with the onset of climate change. The various forms of irrigated agriculture and fish and wildlife in the Hood River Basin are expected to face this challenge, because the majority of these demands are supplied by the glaciers and snowpack on Mt. Hood. Surface water storage projects could provide a solution to the challenges of meeting demands and beneficial use that would otherwise be unavailable.

2 Purpose and Objective

To plan for this challenge, the Hood River Water Planning Group (HRWPG) on behalf of Hood River County (County) along with several local stakeholders in the Basin applied for funds and technical assistance under the Oregon Water Resources Department (OWRD) Water Conservation, Storage, and Reuse grant program and the Bureau of Reclamation's (Reclamation) WaterSMART grant program. The County was awarded the funds and technical assistance and used the resources to support a Water Planning Study investigating future impacts of climate change to the Basin and measures the County could pursue to offset these impacts. The funds associated with the Reclamation program are currently being used to evaluate the potential future impacts of climate change on the water resource reliability in the Hood River Basin.

The funds associated with the OWRD grant program were used primarily to assess: 1) current and future instream flow requirements in the Hood River Basin, 2) the current agricultural, potable, industrial, and hydroelectric water uses in the Hood River Basin, and 3) future conservation and storage alternatives in the Hood River Basin. These three items were broken into ten tasks and three of the ten tasks focused on evaluating the feasibility of surface water storage and conservation projects. Each of the three tasks use a different criterion to evaluate the feasibility of water storage and conservation alternatives:

- Task 5: Assess Physical Feasibility of Surface Storage and Other Alternatives:
- Task 6: Assess Regulatory and Ecological Feasibility of Surface Storage and Other Alternatives:
- Task 7: Assess Economic Feasibility of Surface Storage and Other Alternatives:

Watershed Professionals Network, LLC was contracted by the County to evaluate the feasibility of the water conservation projects, but evaluation of surface water storage alternatives was still incomplete. The objective of this report is to evaluate the feasibility of surface water storage alternatives in the Hood River Basin. The feasibility of surface water storage alternatives were evaluated by the criteria listed in Task 5, 6, and 7. This report acts in part to fulfill the requirements of the County's Grant Agreement with OWRD.

3 Background

This section provides the supporting information necessary to evaluate the water storage alternatives for the Hood River Basin. This section is organized by the three criteria used to evaluate each alternative: physical feasibility, regulatory and ecological feasibility, and economic feasibility.

3.1 Physical Considerations

This section describes background information for the physical considerations that were used to evaluate the water storage alternatives. Considering the alternatives include newly constructed storage sites and existing reservoirs, the physical considerations are presented in these two categories.

3.1.1 Physical Considerations for New Storage Sites

Several physical considerations should be used to evaluate the feasibility of each alternative: topography and geology/soil, including seismic hazards of the proposed site; hydrologic and hydraulic considerations; structural considerations; and any other necessary physical considerations. There are several kinds of dams used worldwide which differ in-large-part by the construction material used for the dam and they mostly include: earthfill, rockfill, concrete, stone masonry, timber, and steel coffer dams.

3.1.1.1 Topography, Geology, and Seismic Considerations

Topography of a proposed site will play a large role in the material used to construct the dam: concrete dams are suitable for sites that include streams with high steep and high rocky walls and earthen dams are more suitable for gradual rolling hills (Gupta, 2008). Different geological materials surrounding the dam site will also determine the most suitable dam material: locations with solid rock foundation are suitable for concrete dams and gravel or silt and fine sand foundations are suitable for earthfill, rockfill, and low gravity concrete dams. Water storage sites should be selected that minimize sediment inflow to a reservoir: areas with high erosion should be avoided and if sites with less erosion are unavailable, off-stream reservoirs should be designed (BOR, 2007).

An earthquake investigation is also necessary when designing a dam. The investigation should include the following elements: 1) an analysis of the tectonic setting of the site area, 2) review of historical earth records for the site, 3) a review of the influence of surficial materials to determine the size of historical earthquakes, and 4) a review of the influence of faulting or other tectonic features on the estimate of the occurrence, size, and location of possible future earthquakes (FEMA, 2004). Using information collected in the investigation, the dam should be design to structurally withstand the maximum credible earthquake of the site.

3.1.1.2 Hydrologic Considerations

The hydrology of proposed storage sites play a large role in how the dam and spillway will be designed. For earthfill dams, flood hydrographs should be used to design the spillway and height of earth embankments. The design flood hydrograph should be based on an evaluation of the level of hazard imposed to life and or major property damage (FEMA, 2004). For reservoirs with a storage capacity greater than 50,000 acre-feet, which typically involve a high level of hazard imposed to life and major property damage, the Probable Maximum Flood (PMF) should be used to design the dam and spillway. For dams of 1,000 to 50,000 acre-feet capacities, which usually pose fewer hazards than reservoirs greater than 50,000 acre-feet, the spillway should be designed with the Standard Project Flood (SPF), (Gupta, 2008). The SPF excludes extremely rare storm conditions and represents severe floods considered reasonably characteristic of a specific region.

In addition to hazardous hydrologic conditions, the hydrologic limitations of a site imposed by water appropriations should be investigated. OWRD's Water Availability Model can be used to evaluate the availability of surface water for proposed storage sites. The Model calculates the availability of water by using in-stream, out of stream uses and natural flow in the stream. Out-of-stream uses are limited by OWRD's Division 33 Rules. There are several exemptions to OAR 33 which includes multipurpose storage projects and this exemption could be used for all the potential storage sites described in this document.

3.1.1.3 Embankment Design Considerations

Embankments are typically constructed as homogenous or zoned embankments. Homogeneous embankments use a uniform material through the core and sides of the structure and zoned embankments have three sections of different material: a pervious downstream section, impervious core, and a semi-impervious upstream section. Homogeneous embankments are more susceptible to seepage compared to zoned embankments which incorporate less impervious cores (FOA, 2010). Cutoff trenches provide improved stability and reduce seepage into embankments and should be dug to solid rock (FOA, 2010). For the embankments in earthen dams, many design considerations must be made when evaluating a proposed storage site. These considerations include but are not limited to: 1) design of dimensions for the cutoff trench, 2) design of the embankment slope, 3) the appropriate freeboard to accommodate wave height and unexpected increases in water levels, 4) the appropriate width of the dam crest, and 5) topsoil cover and slope protection. Table 1 provides planning level recommendations for each of these design elements for earthfill embankments.

Table 1. Planning level design considerations for earthfill embankments.

Embankment Design Criteria	Recommendations
Cutoff Trench	• The cutoff trench should extend through bedrock foundation at least 2 feet. [1] • The sides of the trench should be sloped from 1:1 to 2:1.[1] • The bottom width should be no less than 8 feet.
Embankment Slope	Recommended slopes depend on soil type and whether or not rapid drawdown will occur: • Without rapid drawdown, the upstream embankment slope should range from 3.5:1 to 2:1[2] • With rapid drawdown, the upstream embankment slope should range should range from 2:1 to 4:1[2]

Freeboard	Recommended freeboard for the embankment is dependent on the reservoir's fetch (longest length of exposed water surface): • For a fetch up to 1000 feet, a freeboard of 3 feet is recommended.[2] • For a fetch length from 1000 feet to 1.25 miles, a freeboard of 3 to 5 feet is recommended.[2]
Dam Crest Width	• For a dam height less than 35 feet, dam crest recommendations scale from 8 to 14 feet.[3] • For a dam height great than 35 feet, the following general formula is used: Dam Crest = (Height +35)/5[3] • If vehicle passage is necessary, a minimum width of 25 feet is recommended.[3]
Slope Protection	• The upstream slope should be protected against destructive wave action, where riprap is commonly used.[2] • The downstream slope should also be protected from erosion caused by wind or rainfall runoff where common applications include rock, coble or vegetative cover.[2]

1. FSA Consulting (2001), 2. BOR (1987), 3. NRCS (2005)

The recommendations provided in Table 1 should only be used for planning level designs. If a water storage project is selected for implementation, a more thorough investigation to determine the appropriate dimension for each design parameter listed is required. Without field investigations, the design parameters could be improperly designed and ultimately lead to dam failure.

3.1.1.4 Spillway Design Considerations

As mentioned in Section 3.1.1.2, the design of a spillway is closely tied to the hydrologic characteristics of the proposed site's watershed. The design of a spillway includes the three following components: a control structure, discharge channel, and terminal structure. To minimize the cost of constructing a spillway, multiple combinations of the type, placement, and dimensions of these three structures should be analyzed to determine the most cost-effective alternative. Chute spillways are commonly used in earthfill dams where the discharge is conveyed from a reservoir to the downstream river level through a steep open channel placed along the dam abutment or through a saddle (Gupta, 2008).

3.1.2 Physical Considerations for Expanding Existing Storage Sites

Similarly to constructing a new dam, expansion of an existing dam requires an evaluation of many of the same physical considerations described in section 3.1.1. Where the evaluation will differ is how these physical considerations are evaluated. Review of existing facilities is necessary in determining the appropriate alternative for expanding the storage capacity of an existing reservoir. Of the two alternatives with reservoir expansions, past evaluations and studies have been conducted and were used to support this report.

3.2 Regulatory Considerations

The OWRD is responsible for administering and enforcing Oregon Administrative Rules (OAR) and Statutes (OAS) related to the impoundment of surface water. Any OARs the OWRD enforces begin with chapter number "690". OARs related to surface water impoundment span several divisions (Table 2).

Table 2. OAR Divisions which include rules the ORWD administers and enforces related to the impoundment of surface water.

OAR Division	Title	Description
690-20	Dam Safety	Rules for the design, construction, maintenance, inspection, and fees regarding dams in Oregon.
690-28	Surface Water Registrations and the Adjudication Process	Includes rules the OWRD administers and enforces for filings to divert water for a beneficial use or for storage in a reservoir.
690-33	Additional Public Interest Standards for new Appropriations	Rules include but are not limited to procedures and standards to aid the department in deciding whether construction and use of a reservoir will be detrimental to the public interest with regard to sensitive, threatened, or endangered fish species.
690-79	Reservations of Water for Future Economic Development	Rules establish the procedure for state agencies for state agencies to request reservations of water for future economic development which include water storage projects
690-80	Programs for and Withdrawal from Control and Use of State's Water Resources	Rules listing streams and lakes in the State of Oregon which have been withdrawn from future appropriation.
690-90	Water Development Loan Fund	Rules describing the Water Development Loan Fund providing loans to develop the water resources of the state which include projects related to dams and storage reservoirs.
690-95	Columbia River Basin Water Development Loan Program	Rules describing the loans to finance construction of water development projects in the Columbia River Basin that include project related to water storage projects.
690-100	Payment for Public Benefits of in Water Projects	Rules describing the procedure for partially funding water developments projects which provide public benefits.
690-504	Hood River Basin	Rules describing water reservations made for future economic development in the Hood River Basin.

Many of the OAR Divisions listed in Table 2 include several rules related to water storage and describing them at length is unnecessary for the purposes of this assessment. This assessment evaluates storage alternatives at a preliminary level, where most of these rules under the Divisions in Table 2 will apply during the actual construction and operation of a water storage project. However, several rules outlined under Division 40 are useful to this assessment, which includes several rules that constrain how the reservoir and dam are designed.

Table 3. Division 40 rules for the design of a dam in the State of Oregon.

690-020-0025 (6)	For instream reservoirs, an outlet conduit with a minimum diameter of 8" must be installed to permit drainage of the reservoir and convey flow to downstream prior rights.
690-020-0025 (7)	The height of a dam is the vertical distance between the center point of the dam crest relative to the downstream channel of a stream and the thalweg of the downstream channel.
690-020-0035 (1)-(6)	For dams impounding over 9.2 acre-feet, all maps, plans, and specifications for the construction of new large dams or significant dam work existing large dams must be prepared by a professional engineer.
690-020-0100 (1) (d)	The depth of inundation caused by a dam's failure classifies the hazard rating of the dam. An inundation depth of at least two feet over the finished floors of buildings or road surface of infrastructure classifies the dam as a high hazard rating.

The rules outlined under Division 504 are also useful to the purpose of this assessment. Division 504 lists storage reservations for future economic development of unapproriated water in three Hood River subbasins. These storage reservations do not last permanently; if OWRD has not received applications for multipurpose reservoir permits for the full quantity of water reserved twenty years after October 17, 1996, these three reservations will be repealed on October 17, 2016, unless extended by further rulemaking of the Water Resources Commission.

Table 4. OWRD storage reservations for multipurpose reservoirs in the Hood River Basin.

Hood River Subbasin	Reserved Volume (acre-feet)	Detailed Description of Location
West Fork Hood River	9,000	Lake Branch of the West Fork Hood River or its tributaries
East Fork Hood River	50,000	East Fork Hood River or its tributaries upstream of the confluence of the Dog River with the East Fork Hood River
Neal Creak Hood River	5,000	Neal Creak or its tributaries

The Federal Emergency Management Agency (FEMA) also has guidelines that oversee the design, construction, and operation of dams in the US. In addition to rules and statutes implemented by the State of Oregon and FEMA, the Federal Energy Regulatory Commission (FERC) will also have jurisdiction to implement regulations if any storage alternatives include hydroelectric facilities.

An expansion of existing reservoirs or implementation of a new reservoir in the Hood River Basin could lead to many ecological impacts: 1) changes in flow regimes, 2) changes in water temperature and chemistry, 3) changes in macroinvertebrate and algal communities, 4) changes in resident and migratory fish communities, and 5) changes in the abundance and diversity of terrestrial and aquatic habitats. An assessment of these environmental impacts is necessary to determine whether or not the implementation of the alternative would be infeasible due to environmental impacts or permitting requirements.

The assessment should include a review of the presence of the following elements for each alternative: Endangered Species Act ESA listed species, cultural and archeological resources, and wetlands. If these elements are present, federal and state environmental regulations and permits will constrain the project. If ESA listed species inhabit the proposed site for a water storage alternative, federal regulatory action will be required under the National Environmental Policy Act (NEPA). NEPA requires an evaluation of the environmental impact of the project following the methodology outlined in NEPA which could require mitigation measures to offset the impacts imposed by the project. If any archeological or historically significant resources are located on the proposed site, several federal and state laws require those resources to be preserved and can preclude implementation of a project. If wetlands are found on the proposed site, several state and federal regulations will require permits for any earthwork within the wetland.

Support from the public as well as environmental agencies will also hinge on the level of environmental impact the proposed project imposes. If possible, sites should be selected for water storage that create the least environmental impact. Depending on the level of community involvement by the public, implementation of a water storage project may be difficult if the public does not support the project.

3.3 Economic Considerations

The monetary costs associated with water storage projects are typically expressed in the two following categories: capital costs and annual costs. This section describes the various elements that are commonly included in capital and annual costs for a water storage project.

3.3.1 Capital Costs

Capital costs include construction and non-construction costs which include costs unrelated to construction that are required to implement a project. Costs for constructing a reservoir typically include equipment and materials, labor, and installation costs. If costs estimates for a particular construction item are used from previous studies, the Engineering News Record Construction Cost Index (ENR CCI) is a common tool used to update the previous cost to represent the current cost of that item. When estimating capital costs at a planning level, the accuracy of the estimate can exceed the actual cost of the project by 100 percent (USSD, 2012)

Non construction costs related to implementing a water storage project may include engineering, legal counsel, financing, contingencies, land easements, surveying and legal fees for land acquisition, environmental and archaeology studies, permitting, mitigation, and interest during construction. Contingency costs, used to account for unforeseen costs and undefined details of the specific project, are often estimated as a percentage of the total capital cost. Land related costs include land purchase costs and easement costs. To estimate land purchase costs, a common method utilizes county appraisal records and estimating the acquisition area as the acreage inundated by the 100 year flood. Costs associated with surveying for land acquisition can be estimated as a unit cost per acre of inundation. Costs associated with environmental studies, permitting, and mitigation, as well as recovery of archaeological resources are project-dependent, but a common method for reservoir projects is to estimate costs for environmental studies and mitigation assuming they are equivalent to 100 percent of the land value for the acreage purchased. The cost of engineering services typically range from 7.5 to 12.5 percent of the total project.

3.3.2 Annual Costs

Annual costs are the costs the project owner can expect to incur each year over the lifetime of the project. These costs include debt service, any state or federal fees, and operation and maintenance (O & M) costs associated with the project facilities. The annual operation and maintenance of a reservoir can vary greatly from project to project. O & M costs can increase significantly if the owner does not have qualified staff that can conduct the operation and maintenance. If the project generates power, significant costs associated with FERC should be included into the annual costs. Annual costs also include the annual state fee required for large dams (greater than 9.2 acre-feet) in the state of Oregon. For planning level cost estimates, operation and maintenance costs can be estimated as 1.5 percent of the total capital costs for reservoir facilities.

4 Criteria

To evaluate each water storage alternative, three criteria were used: physical feasibility, regulatory and ecological feasibility, and economic feasibility. Table 5 displays these criteria and the corresponding sub-elements representing each criterion.

Table 5. Criteria used to evaluate water storage alternatives for the Hood River Basin.

Criterion	Criterion Sub-element	Description
Physical Feasibility	Seismic Hazards	Fault lines and landslide areas within the project area.
	Hydrologic Conditions	The peak discharge associated with a 100 year flood event for the site's watershed.
	Geology/ Soils	Summary of the geology and soils located at the project site
Regulatory and Ecological Feasibility	Regulations Associated with Ecological Impacts	Species listed as threatened or endangered inhabiting the area inundated by the reservoir pool. Delineated wetlands located within the area inundated by the reservoir pool.

	Regulations Constraining Water Availability	Volume of water available for appropriation from streams and tributaries in the Hood River Basin
Economic Feasibility	Capital Costs	The net present value of costs associated with construction, engineering, legal counsel, financing, contingencies, land easements, surveying and legal fees for land acquisition, environmental and archaeology studies, permitting, mitigation, and interest during construction of the water storage project.
	Annual Costs	The average annual costs associated with interest earned on borrowed funds, annual fees and annual operation and maintenance over the life of the water storage project.

5 Preliminary Alternatives

As part of the Hood River Basin Study, 15 sites throughout the valley were considered as possible storage alternatives in October 2012. In November 2012, Douglas Bennett and Roger Wright, Reclamation Geologist and Engineer, respectively, toured each of these sites and examined the feasibility of each site which is documented in a memorandum they prepared (Wright & Bennett, 2013).Table 6 summarizes each alternative and Reclamation's findings from the memorandum.

Table 6. Preliminary alternatives considered for water storage projects in the Hood River Basin.

Alternative	Description	Storage Capacity (acre-feet)	Dam Height (ft)
1	Parcel off of Neal Creek Road requiring construction of dikes on basically four sides of the reservoir.	922	50
2	County parcel off of Smullin Road with no visible outcrops.	493	70
3	The first site examined with the Rimrock Creek drainage.	170	122
4	The second site examined within the Rimrock Creek drainage.	72	53
5	A site upstream of the Dog River confluence with the Hood River situated in a steep-sided, narrow canyon.	8200	286
6	A site located in the Yellowjacket Creek Drainage situated in a steep-sided, narrow canyon.	1950	240
7	A site located in Horsethief Meadows adjacent to the East Fork Hood River.	NA	NA
8	The first site located within the Neal Creek Drainage.	2850	130

9	The second site located within the Neal Creek Drainage.	2256	120
10	A site located within the Tony Creek Drainage	NA	NA
11	A county parcel near Laurance Lake Road consisting of three small dams	95	50, 32, & 24
12	First option to expand Clear Branch Dam, commonly known as Laurance Lake, where the dam would be raised 18 feet.	2480	124
13	Second option expand Clear Branch Dam, commonly known as Laurance Lake, where an adjustable weir would be installed raising the dam 3 feet in the late spring.	370	NA
14	First option to expand Upper Green Point Reservoir where the dam would be raised 8 feet.	561	38
15	Second option to expand Upper Green Point Reservoir where material would be excavated from the upper end of the reservoir.	1715	NA

Of the 15 alternatives initially considered, only Alternative 1, 9, and 14 were selected for more in-depth analyses. Many of the alternatives were not selected for more in-depth analyses because their storage capacities were not sufficient to be cost effective, especially alternatives with storage capacities less than 1000 acre-feet and dam heights greater than 100 feet where a considerable amount fill material would be required to construct the dam. Alternative 7 was not considered for further analysis due to the large sediment loads the East Fork Hood River would contribute to the reservoir.

6 Description and Analysis of Final Alternatives

This section describes the three alternatives that were evaluated for more in-depth analysis, beyond the initial analysis completed from October 2012 to January 2013. The three alternatives that were considered are: expansion of the Upper Green Point Reservoir, expansion of Laurance Lake, and construction of a new dam on the West Fork Neal Creek.

These three alternatives, in addition to further analysis below, will be evaluated by Reclamation as part of the Basin Study they will complete under the WaterSMART program. As part of the Basin Study, Reclamation is evaluating the water resource reliability of the three storage alternatives under three possible future climate scenarios using the computer program, MODSIM. Evaluating both results from this report and Reclamation's Basin Study will provide a greater understanding of the feasibility of these three alternatives.

6.1 Alternative 1: Expansion of the Upper Green Point Reservoir

This section provides a description Alternative 1: Expansion of the Upper Green Reservoir, and evaluation of the feasibility of Alternative 1. The description of Alternative 1 includes the existing facilities and how these facilities will be expanded. The alternative analysis provides an evaluation of the physical, ecological and regulatory, and economic feasibility of Alternative 1.

6.1.1 Existing Facilities

Upper Green Point Reservoir was constructed from 1936 to 1937 and at the time of construction, the storage capacity was estimated at 715 acre-feet (Anderson Perry & Associates, Inc., 2004). The current estimate of the reservoir's storage capacity is 692 acre-feet based on a survey completed in 2002. The Reservoir's dam is an earthen fill homogeneous dam with a crest length of 900 ft, a height of 30 ft, and crest width of 12 to 15 ft. The spillway is an unlined chute on the left abutment near the groin of the dam(Wright & Bennett, 2013) . Based on current operations, the spillway is only used for emergencies. Water is conveyed to the Upper Green Point reservoir by the Stanly-Smith pipeline network where an 18-inch PVC pipe diverts water from Gate Creek and conveys water to Cabin Creek, from Cabin Creek a 21 inch pipe conveys water to the upper reservoir (Anderson Perry & Associates, Inc., 2004). The water is conveyed out of the reservoir by an outlet pipe in the embankment which discharges into Ditch Creek.

6.1.2 Expansion of Facilities

The following lists how each component of the reservoir will be impacted and Table 7 provides the estimated design parameters used for the alternative.

Pipe Line Network and Intake Facilities: These facilities would not be modified.

Outlet Facilities: These facilities would not be modified.

Reservoir, Dam, and Emergency Spillway: Based on recommendations given by Bennett and Wright (2012), the Upper Green Point Reservoir alternative expands the reservoir by raising the dam 10 feet including two feet of freeboard and removing the Lower Green Point Reservoir. Using topographic maps, Reclamation developed area capacity relationships for the expanded reservoir site (0). The reservoirs area capacity relationship estimates that a dam raise of eight feet would provide an additional 562 acre-feet of storage capacity increasing the total capacity to 1253 acre-feet.

The dam's homogeneous embankment would be expanded and modified. The expanded embankment would consist of an impermeable clay fill core with semi-permeable fill on the upstream slope and permeable fill on the downstream slope of the embankment. The core would extend five feet below the existing dam crest, and have a width of 8 feet ft, and extend along the entire length of embankment. A slope of 3:1 was selected for the upstream and downstream embankment faces. The selected slope is based on a combination recommendations listed in Table 1 and provided by Anderson Perry (2004). The embankment's entire upstream slope would be protected with class 100 riprap and a re-vegetation mat would be placed on the downstream slope to prevent erosion.

Table 7. Design parameters used for the Upper Green Point Reservoir alternative.

	Design Parameter	Amount
Reservoir	Contributing Drainage Area (square miles)	0.68
	Expanded Storage Capacity (acre-feet)	562
	Total Storage Capacity (acre-feet)	1253
	Length of Reservoir (ft)	2906
	Reservoir Surface Area (acres)	63.2
	Reservoir Elevation at Maximum Operating Level (ft)	3174
Embankment	Dam Height above Creek Flowline (ft)	40 ft
	Length of Dam Crest	1156
	Width of Dam Crest	20
	Upstream and Downstream Side Slopes (H:V)	3:1 and 3:1
Emergency Spillway	Width (ft)	5
	Slope (Percent)	0.04
	Spillway Crest Elevation (ft)	3174
	Length (ft)	680

To accommodate emergency flows and prevent erosion from the downstream embankment face, Anderson Perry (2004) recommended replacing the existing spillway with a new permanent emergency spillway. For this alternative, a concrete chute spillway was selected and designed using the methodology outlined in Section 3.1.1.2 and 3.1.1.4. The elevation of the spillway crest corresponds to the maximum reservoir operating level of the expanded reservoir at 3174 feet or 38 feet above the Gate Creek flowline allowing for 2 feet of free board. Emergency flows exceeding the normal operating level would be conveyed through a 5 foot wide spillway from the left abutment for approximately 680 ft where flows would enter a stilling basin and then discharge into Gate Creek.

6.1.3 Physical Feasibility

This section describes the physical feasibility of the Upper Green Point Reservoir.

6.1.3.1 Seismic Hazards

McClaughry and others (2012) found very little historical record associated with seismic activity in the Hood River Basin; historical events that were recorded ranged in magnitude from 2.0 to 2.9 on the Richter scale. HWA GeoSciences (2002) performed a seismic evaluation of the existing embankment and found the existing embankment had adequate slope stability under seismic conditions. New analysis has been conducted which estimated the Maximum Credible Earthquake for Cascadia Subduction Zone could produce a magnitude 9.0 earthquake. If the Maximum Credible Earthquake occurred from the

Cascadia Subduction Zone, the project site would be impacted and should be considered prior to any new construction on Upper Green Point Reservoir.

6.1.3.2 Extreme Hydrologic Events

To evaluate the hydrological hazards imposed by expanding the Upper Green Point Reservoir, a 100-year flood was routed through the expanded reservoir and the concrete spillway using the specifications listed in Table 7. A detailed explanation of the methodology used to route the reservoir is described in Appendix B and the design parameters specific to Alternative 1 that were used to route the flood are provided in Section B.1 of Appendix B. Figure 1 shows that the flood event passes easily through the reservoir and spillway. The reservoir's ability to easily pass the flood event is due to the small watershed that drains into the reservoir. Figure 2 shows that during the flood event the reservoir pool elevation exceeds the maximum reservoir operating level by a tenth of foot during the entire flood event.

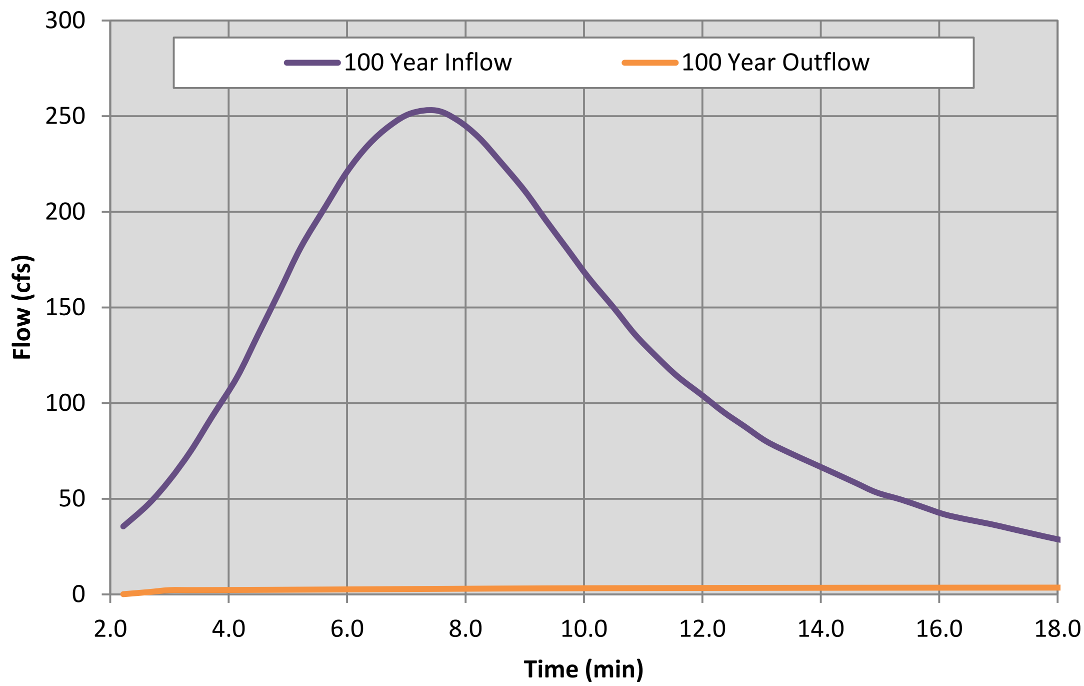

Figure 1. Inflow and outflow hydrographs for the Expanded Upper Green Point Reservoir during a 100-year storm event.

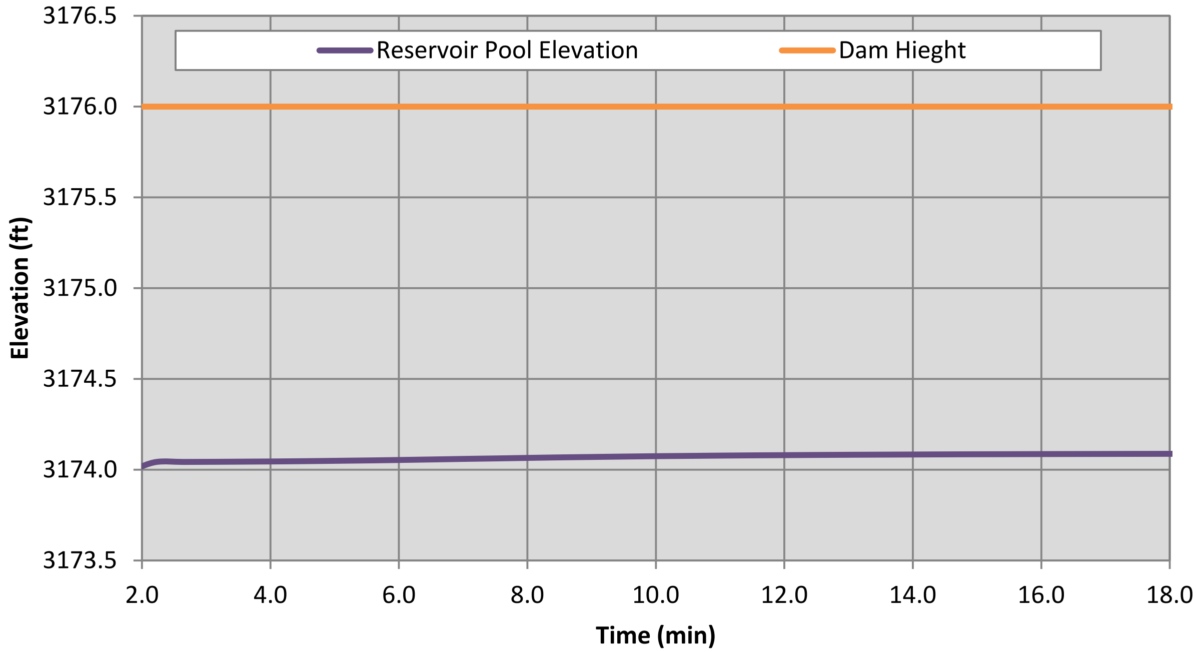

Figure 2. Elevation of Dam Crest and Reservoir Pool of the Expanded Upper Green Point Reservoir during a 100-year flood event.

6.1.3.3 Geology and Soil Characteristics

HWA GeoSciences conducted geotechnical investigations from 1992 to 2004. In 1992, they found the central portion of the dam to be predominantly filled with sandy and clayey silt and the right abutment overlies weathered volcanic bedrock. When Roger Wright and Douglas Bennett investigated the dam in 2012, the reservoir pool was low and they found basaltic float with abundant red soil and slope wash visible along the reservoir rim. The existing embankment may need to be modified due to seepage occurring in the left groin of the dam. The geologic investigations of Hood River County done by McClaughry and others in 2012 did not include the land survey section where Upper Green Point Reservoir is located.

Repairing the left groin during the construction associated with raising the dam would be the most cost-effective method to restrict the seepage the existing dam experiences. The cost associated with repairing the left groin was not evaluated in this study and is more appropriated for feasibility level studies. A geologic investigation will be required prior to final design and construction of the expanded embankment. The cost associated with conducting a geologic investigation is included in the total capital cost and detailed in section C.1 of Appendix C.

6.1.4 Regulatory and Ecological Feasibility

This section provides the regulatory and ecological feasibility of the Upper Green Point Reservoir.

6.1.4.1 Regulations Constraining Water Availability

The amount of water available for further appropriation is constrained by natural flow and water rights currently held on the streams surrounding Upper Green Point Reservoir. The Bureau of Reclamation's

Basin Study evaluates the effects of expanding Upper Green Point Reservoir on Gate and Ditch Creek flows and more information can be found in the technical documents they completed for the Basin Study.

Decommissioning the Lower Green Point Reservoir could lead to the abdication of the water rights associated with the reservoir. To ensure FID retains their water rights, they could be reclassified from irrigation use to a multipurpose storage classification (Anderson Perry & Associates, Inc., 2004).

6.1.4.2 Regulations Associated with Ecological Impacts

With implementation of Alternative 1, the effects of removing of the Lower Green Point Reservoir would require mitigation. Anderson Perry (2012) provided detailed restoration plans to decommission the Lower Green Point Reservoir and restore the stream reach of Ditch Creek that travels through the riparian habitat and channel of Ditch Creek.

Mike Shrankel, GIS Specialist prepared a GIS shapefile of all the delineated wetlands in Hood River County. Figure 3 displays the wetlands within and surrounding the Green Point Reservoirs. The entire Upper and Lower Green Point Reservoirs are delineated as wetlands and the riparian areas surrounding Ditch Creek are also considered wetlands. The restoration plans described by Anderson Perry (2004) would improve wetland habitat. In areas where the channel would be filled or excavated, permits would be required.

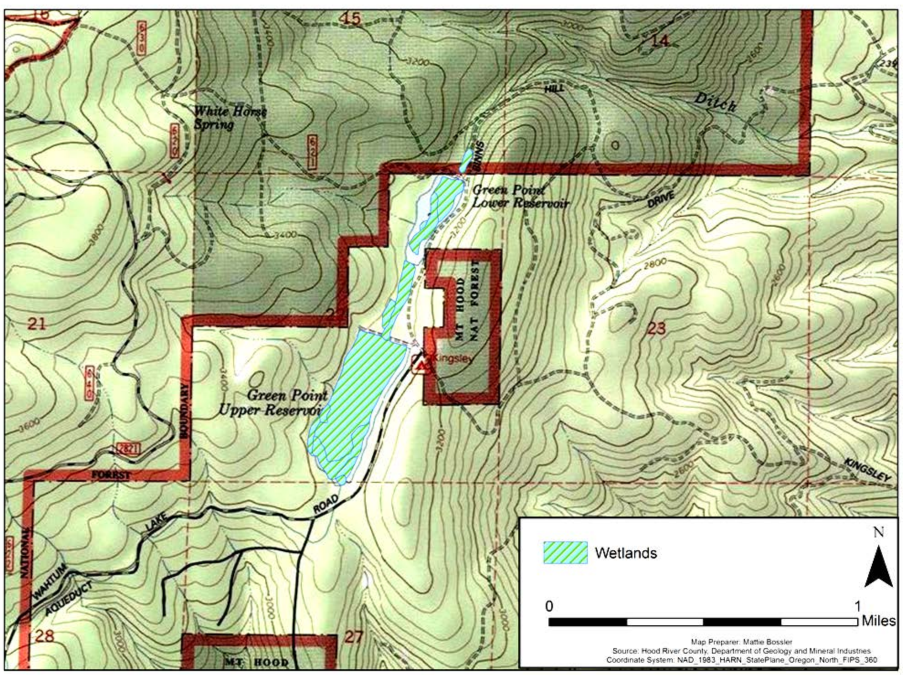

Figure 3. Delineated wetlands within the project site for the Upper Green Point Reservoir alternative.

The Mt. Hood National Forest land that surrounds Upper Green Point Reservoir on the west and east sides of the reservoir indicate the possibility of habitat of threatened or endangered species near the project site. Anderson Perry (2004) investigated the potential of threatened species residing in or near the reservoir. They considered three potential species of wildlife classified as federally threatened or endangered species that could reside in or near the federal forestland adjacent to the project area.

In Anderson Perry's investigation, they conducted reconnaissance surveys to determine if habitat for each species surrounded the Upper Green Point Reservoir and the level of effect resulting from expanding the Upper Green Point Reservoir and decommissioning the Lower Green Point Reservoir. Table 8 provides the results from their reconnaissance survey. Considering Bald Eagle and Northern Spotted Owl habitat exists near or within the project area, federal regulatory action may be required under NEPA.

Table 8. Reconnaissance survey results to determine the presence of Endangered or Threatened species near or within the project area for the Upper Green Point Reservoir.

Species	Habitat	Level of Effect
Bald Eagle (Threatened)	Yes	NE
Northern Spotted Owl Threatened)	Yes	MA - NLAA
Canada Lynx	No	NE

1. NE: No Effect, MA-NLAA: May Affect – Not Likely to Adversely Affect

6.1.5 Economic Feasibility

Table 9 presents the estimated costs for expanding Upper Green Point Reservoir where two different cost estimates were developed. The cost estimate for Alternative 1.A sources the fill material to expand and retrofit embankment from materials surround the project site and only places rip rap on the 20 percent of the embankment where wave action would typically occur. Alternative 1.B includes the cost of purchasing the fill material required to upgrade and raise the embankment and places rip-rap on the entire upstream face of the embankment.

Sourcing material from the project area as seen in Table 9, reduces the costs by more than 60 percent. A complete explanation of the capital cost and cost breakdown for Alternatives 1.A and 1.B is provided in Appendix C. Anderson Perry (2004) estimated the capital cost of expanding the Upper Green Point Reservoir and in their estimate in 2014 dollars was $1,011,000 where they assumed materials would be sourced onsite and assumed the dam would be raised one foot. The capital cost estimate for Alternative 1.A is approximately 25 percent more expensive than Anderson Perry's estimate and the additional cost can be attributed to a higher dam raise. With these two estimates presenting similar costs, more confidence can be given to the capital cost estimated in this analysis for Alternative 1.A.

The unit capital cost per acre-foot of storage for the implementation of the project is also provided Table 9. The unit cost associated with storage was estimated by dividing the total capital cost of the project by the storage capacity of the reservoir.

Table 9. Project cost alternatives associated with Expanding Upper Green Point Reservoir.

Cost Category	Alternative 1.A ($)	Alternative 1.B ($)
Construction Costs	$835,500	$1,552,500
Non-Construction Costs	$227,500	$407,000
Contingency	$209,000	$388,000
Total Capital Cost	$1,272,000	$2,347,500
Unit Storage Costs ($/acre-feet)	$2,263	$4,177

No additional annual costs are anticipated to implement Alternative 1. The capital cost of the project would most likely be financed or funded by state or federal programs. The operational and maintenance cost would remain similar to current operational costs. Section C.1 in Appendix C provides detailed breakdown of annual costs for Alternative 1.A and 1.B of the project if FID was expected to take on the entire capital cost of the project and operation and maintenance costs increased by 1.5 percent.

6.2 Alternative 2: Expansion of Laurance Lake

This section provides a description Alternative 2: Expansion of the Laurance Lake, and evaluation of the feasibility of Alternative 2. The description of Alternative 2 includes the existing facilities and how these facilities will be expanded. The alternative analysis provides physical, ecological and regulatory, and economic feasibility of Alternative 2.

6.2.1 Existing Facilities

Lauraunce Lake was constructed in 1968 and has a storage capacity of 3,565 acre-feet (Christensen, 2013). The Reservoir's dam is comprised of earth and rock fill with a crest length of 1350 ft, a height of 106 feet, and crest width of 28 feet. Clear and Pinnacle Creek discharge into Laurance Lake, supplying the reservoir's inflows. Outflows are conveyed through the dam where they either discharge to the natural channel or into the penstock for Middle Fork Irrigation District's system.

6.2.2 Expansion of Facilities

The following lists how each of Laurance Lake's facilities will be modified and Table 10 provides the parameters used to design the expanded reservoir.

Pipe Line Network and Intake Facilities: These facilities would not be modified.

Outlet Facilities: These facilities would not be modified.

Reservoir, Dam, and Emergency Spillway: Based on recommendations given by Wright and Bennett (2012), the Laurance Lake alternative would incorporate an Obermeyer weir system to effectively raise the maximum operating level of the dam by three feet. Bennett and Wright (2012) estimated that a dam raise of three feet would provide an additional 370 acre-feet of storage capacity increasing the total capacity to 3805 acre-feet.

Laurance Lake's embankment would not be modified; the modification would take place at the reservoir's spillway. The Obermeyer weir would be installed on top of the existing spillway were a concrete apron would also be attached to support the Obermeyer weir.

Table 10. Design parameters used for the Laurance Lake alternative.

	Design Parameter	Amount
Reservoir	Contributing Drainage Area (square miles)	8.56
	Expanded Storage Capacity (acre-feet)	370
	Total Storage Capacity (acre-feet)	3805
	Length of Reservoir (ft)	2906
	Reservoir Surface Area (acres)	124
	Reservoir Elevation at Maximum Operating Level (ft)	2985
Embankment	Dam Height above Creek Flowline (ft)	106 ft
	Length of Dam Crest	1350
	Width of Dam Crest	28
Overflow Spillway	Width (ft)	80
	Spillway Crest Elevation (ft)	2978
	Obermeyer Weir Crest Elevation (ft)	2981

6.2.3 Physical Feasibility

This section describes the physical feasibility of the Laurance Lake alternative.

6.2.3.1 Seismic Hazards

Laurance Lake will face similar seismic hazards that were described in Section 6.1.3 for Upper Green Point Reservoir. No technical documents were available to describe seismic evaluations that may have been conducted for Laurance Lake's dam.

6.2.3.2 Extreme Hydrologic Events

The incorporation of an Obermyer Weir in the spillway will not increase the level of hazard imposed by an extreme hydrologic event. Unlike an alternative which would permanently increase the capacity of the dam, the placement of Obermeyer Weir and its ability to completely flatten, will allow for reservoir operating conditions that currently take place. Any extreme hydrologic event that takes place will occur under Laurance Lake's existing operations.

6.2.3.3 Geology and Soil Characteristics

The majority of the dam is founded upon glacial moraine, alluvial and possible lake bed materials. During installation of a piezometer for Laurance Lake, drill logs were taken along the dam embankment and abutments. The drill logs indicated that glacial moraines comprise the left of abutment of the dam. Alluvial deposits were also found to be lower than the glacial moraine deposits. No information was available describing the geologic material that comprised the right abutment. Lake bed sediments were found downstream of the dam (Wright & Bennett, 2013).

6.2.4 Regulatory and Ecological Feasibility

This section provides the regulatory and ecological feasibility of the Laurance Lake Reservoir.

6.2.4.1 Regulations Constraining Water Use

The amount of water available for further appropriation is constrained by the in-stream and out-of-stream uses currently held on the Clear and Pinnacle Creek which provide inflows to the reservoir as well as the Middle Fork Hood River which receives the reservoir's flows. In addition to evaluating the flows upstream and downstream of Upper Green Point Reservoir, the Bureau of Reclamation's Basin Study also evaluated the effects of expanding Laurance Lake on the Middle Fork Hood River, Clear Creek, and Pinnacle Creek flows and more information can be found in the technical documents they completed for the Basin Study. The storage water rights may need to be expanded to include the increased storage.

6.2.4.2 Regulations Associated with Ecological Impacts

Considering that this project will not fill or excavate any wetlands, no permitting are regulatory action associated with wetlands is expected. Table 11 lists the three endangered species that have habitat within or near the project site. Considering the small footprint required to complete the project, impact to habitat of the Northern Spotted Owl is considered unlikely under Alternative 2, but Laurance Lake is located on Mt. Hood Forest Land so regulatory action through NEPA is possible. Incorporation of the Obermeyer Weir may influence the flow regimes of the Middle Fork Hood River which would could impact the Bull Trout and Steelhead habitat leading to NEPA action as well. Portions of the area that would become inundated by the expanded Laurance Lake are within Mt. Hood Forest Land which would require NEPA action as well.

Table 11. Threatened or endangered species with habitat near Laurance Lake.

Species	Habitat
Northern Spotted Owl	Yes
Bull Trout	Yes
Steelhead	Yes

6.2.5 Economic Feasibility

Table 12 presents the estimated project costs for expanding Laurance Lake and a detailed break-down of the costs are provided in Appendix C. The total capital cost for Alternative 2 is considerably less expensive than Alternative 1. Unlike Alternative 1.A and 1.B, modifications to the embankment and spillway are not required for Alternative 2, which resulted in significantly lower costs.

The unit cost associated with the storage capacity is significantly lower than Alternative 1 as a result of Alternative 2's lower capital cost and larger storage capacity. The O & M costs are expected to increase with implementation of this alternative; increased labor and ongoing replacement of parts associated with the Obermeyer would be required. The O & M costs were estimated as 1.5 percent of the total project. An evaluation of O & M costs and other possible annual costs over a 30-year period is provided in Section C.2 of Appendix C. Due to the habitat of endangered and threatened species that surround and are within the project site, costs associated with the NEPA process could significantly increase the total capital cost.

Table 12 Project costs associated with Expanding Laurance Lake.

Cost Category	Cost ($)
Construction Costs	$193,000
Non-Construction Costs	$67,500
Contingency	$67,500
Total Capital Cost	$328,000
O & M Cost	$5,000
Unit Storage Cost ($/acre-feet)	$88

6.3 Alternative 3: Neal Creek Reservoir

Alternative 3 implements a new instream reservoir on the West Fork Neal Creek locatead entirely in Township 1 North, Range 10 East, Section 25. The following describes each of the facilities required for the Neal Creek Reservoir and Table 13 presents the corresponding design parameters that were used.

Intake Facilities: The West Fork Neal Creek would supply inflows to the reservoir.

Outlet Facilities: Irrigation flows would exit the reservoir through an 18 inch pipe which would travel through the center and bottom of the embankment. Upon exiting the embankment the pipeline will carry flows in a southwest direction approximately two miles and discharge into EFID's main canal.

Reservoir, Dam, and Operational Spillway: The reservoir would provide 2,256 acre-feet of storage capacity and act as a multipurpose reservoir providing irrigation flows to EFID, instream flows to Neal Creek, and recreation to the public. The area-capacity relationships associated with the site are provided in 0.

For the purpose of estimating the cost of constructing this reservoir, it is assumed that the reservoir would be contained by a zoned embankment dam consisting of an impermeable clay fill core with semi-permeable fill on the upstream slope and permeable fill on the downstream slope of the embankment. The core would have 2:1 slopes, extend to 10 feet below the base of the dam, and have bottom width of 8 ft, and extend along the entire length of embankment. A slope of 3:1 was selected for the upstream and downstream embankment faces based on recommendations given in Table 1. The embankment's entire upstream slope would be protected with class 100 riprap and a re-vegetation mat would be placed on the downstream slope to prevent erosion.

Similarly to Alternative 1, a concrete chute spillway was selected for Alternative 3 and designed using the methodology outlined in Section 3.1.1.2 and 3.1.1.4. The spillway is sized to convey any extreme hydrologic event the reservoir could experience. The elevation of the spillway crest is at 3085 feet, one foot below the elevation of the reservoir pool at the maximum operating level allowing for 1 foot of head to convey approximately 20 cfs of instream flows over the spillway. Emergency flows would be conveyed through a 25 foot wide spillway from the left abutment for approximately 670 ft where flows would enter a stilling basin and then discharge into West Fork Neal Creek.

Table 13. Design Parameters used for the Neal Creek Reservoir alternative.

	Design Parameter	Amount
Reservoir	Contributing Drainage Area (square miles)	4.52
	Storage Capacity (acre-feet)	2256
	Length of Reservoir (ft)	3691
	Reservoir Surface Area (acres)	60.1
	Reservoir Pool Elevation at Maximum Operating Level (ft)	3086
Embankment	Dam Height above Creek Flowline (ft)	120
	Elevation of Dam Crest (ft)	3090
	Length of Dam Crest	1468
	Width of Dam Crest	25
	Upstream and Downstream Side Slopes (H:V)	3:1
Operational Spillway	Width (ft)	25
	Spillway Crest Elevation (ft)	3085
	Spillway Flows to Neal Creek(cfs)	20
Outlet Works	Pipe Diameter (in)	18
	Pipe Length	3.2 miles

6.3.1 Physical Feasibility

This section describes the physical feasibility of the Neal Creek Reservoir Alternative.

6.3.1.1 Seismic Hazards

Neal Creek Reservoir will face similar seismic hazards that were described in Section 6.1.3 for Upper Green Point Reservoir.

6.3.1.2 Extreme Hydrologic Events

To evaluate the hydrological hazards imposed by operating a reservoir on West Fork Neal Creek, a 500-year flood was routed through the reservoir and the concrete spillway using the specifications listed in Table 13. A detailed explanation of the methodology used to route the reservoir is described in Appendix B. Figure 4 and Figure 5 shows that the spillway was sized to pass the flood event and the elevation of the reservoir pool never exceeds the dam crest elevation.

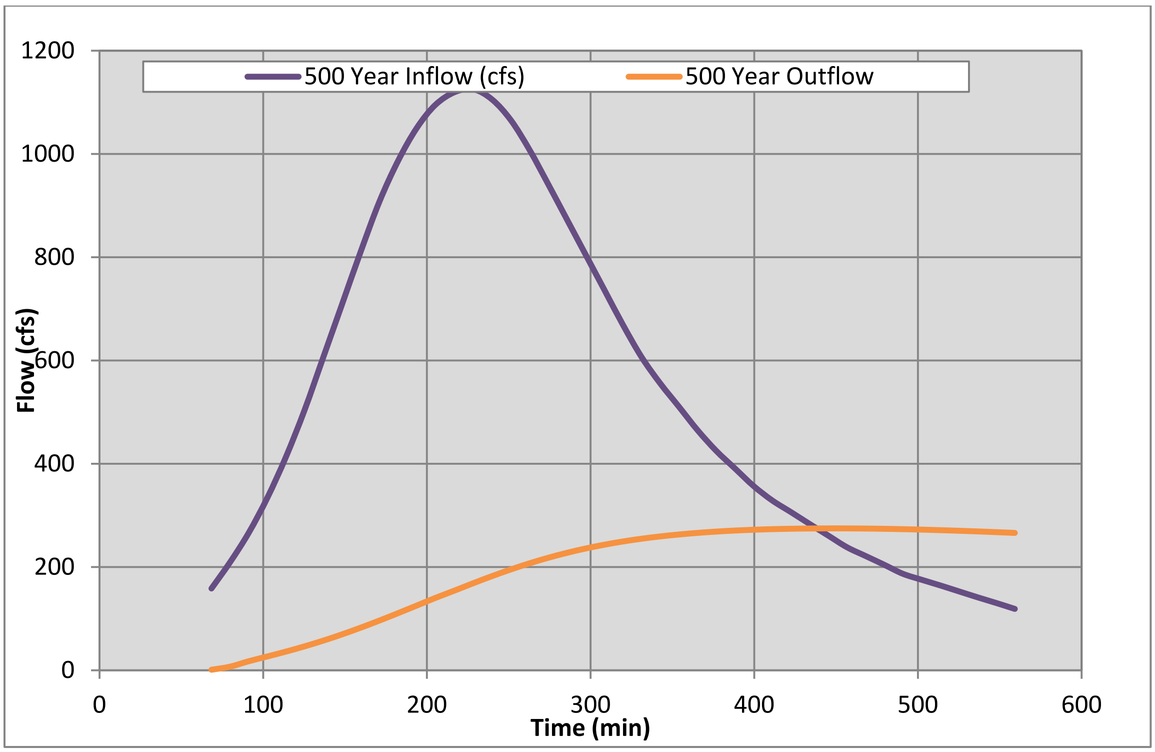

Figure 4. Inflow and outflow hydrographs for the Neal Creek Reservoir during a 500 year storm event.

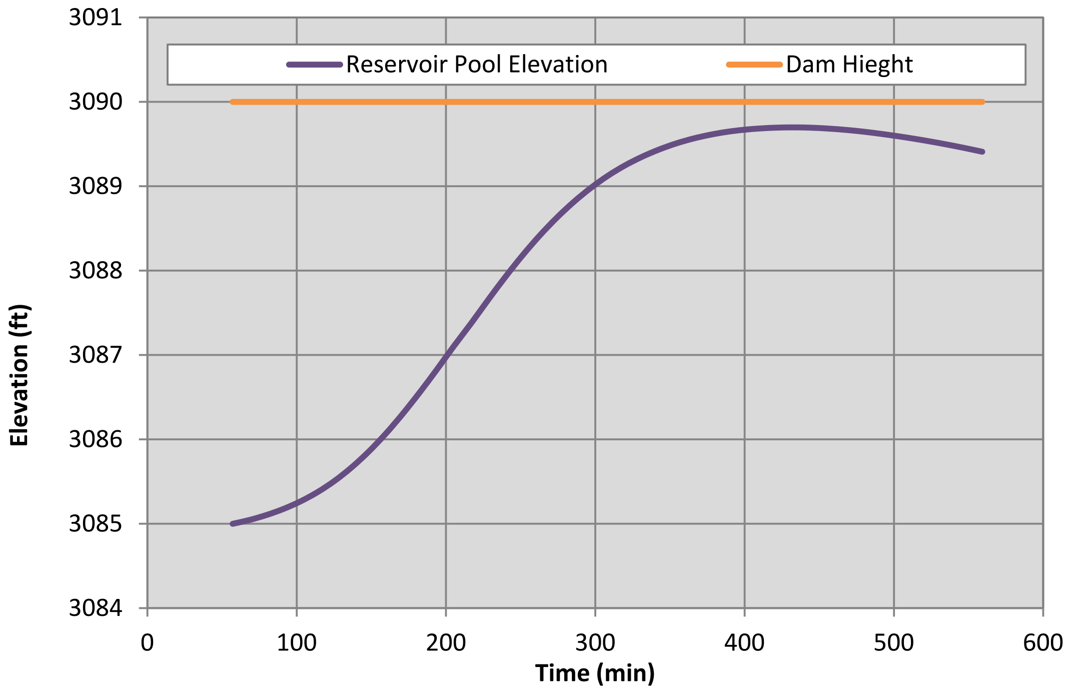

Figure 5. Elevation of Dam Crest and Reservoir Pool of the Neal Creek Reservoir during a 500-year flood event.

6.3.1.3 Geology and Soil Characteristics

The Department of Geoglogy and Mineral Industries' (DOGAMI) geologic map indicates that basaltic andesite is present on the entire area within and surrounding the project site. A GIS shapefile of soils present throughout Hood River County indicates that very steep to very steep bins-bindle association soils cover the entire project site. Wright and Bennett (2012) observed basaltic andesite in the road cuts adjacent to the forest service roads that lead to the project site. A geologic investigation will be required prior to final design and construction of the expanded embankment. The cost associated with conducting a geologic investigation is included in the total capital cost and detailed in section C.3 of Appendix C.

6.3.2 Regulatory and Ecological Feasibility

This section provides the regulatory and ecological feasibility of the Neal Creek Reservoir.

6.3.2.1 Regulations Constraining Water Use

The amount of water available for further appropriation is constrained by the in-stream and out-of-stream uses currently held on the West Fork Neal Creek which provides inflow to the reservoir as well as receives the reservoir's flows. Water is available in the Neal Creek Watershed for appropriation under the multipurpose storage reservations pursuant to OAR 690-504-01030 (Table 4). Five thousand acre-feet is available for appropriation under this reservation and increases the feasibility of having water available to store in the Neal Creek Reservoir. The Bureau of Reclamation's Basin Study also evaluated the effects of operating a reservoir on the instream flows for East Fork Hood River and mainstem Neal Creek and information can be found in the technical documents they completed for the Basin Study.

6.3.2.2 Regulations Associated with Ecological Impacts

No wetlands are delineated within the area of the Neal creek reservoir project site (Figure 6). Table 11 lists the two endangered species that have habitat within or near the project site. Habitat for the Northern Spotted Owl is less than 800 feet to the west and south of the project site and the entire project site is within Mt. Hood Forest Land. The West Fork Neal Creek downstream of the project site is also considered critical habitat for Steelhead. Considering the entire proposed reservoir is within Mt. Hood Forest Land and is adjacent to listed species, Alternative 3 will face considerable obstacles associated with federal permits, land easements, and the NEPA process.

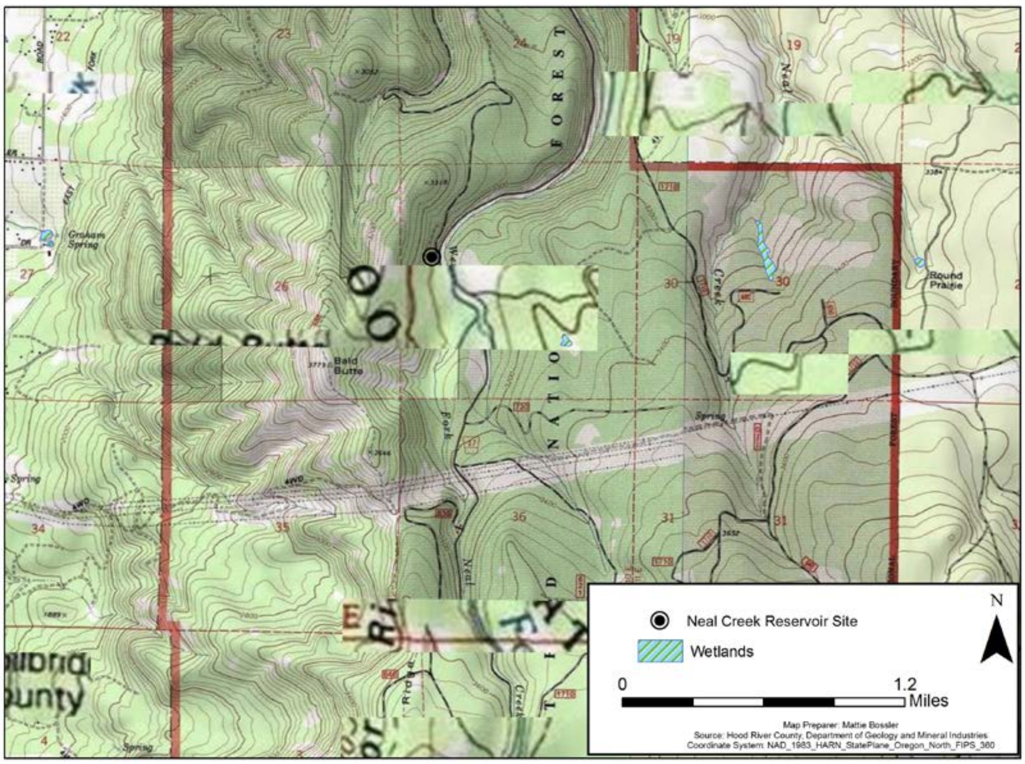

Figure 6. Location of the project site for the Neal Creek Reservoir alternative.

Table 14. Threatened or endangered species with habitat near the Neal Creek Reservoir project site.

Species	Habitat
Northern Spotted Owl	Yes
Steelhead	Yes

6.3.3 Economic Feasibility

This section provides the economic feasibility of a new reservoir on the West Fork Neal Creek. Similarly to Alternative 1, two different cost estimates were developed for Alternative 3. The first cost alternative, Alternative 3.A assumes the fill material to construct the embankment would be available from sources surrounding the project site. The second cost alternative, Alternative 3.B assumes the fill material would be purchased from a supplier.

6.3.3.1 Capital Cost

Table 9 presents the estimated capital costs for Alternative 3.A and 3.B. Sourcing material from the project area as seen in Table 9, reduces the capital costs by more than 60 percent. A complete explanation of the capital cost and cost breakdown for Alternatives 1.A and 1.B is provided in Section C.3 of Appendix C.

Table 15. Capital cost alternatives associated with the Neal Creek Reservoir.

Cost Category	Alternative 3.A ($)	Alternative 3.B ($)
Construction Costs	$8,751,500	$18,521,000
Non-Construction Costs	$2,274,000	$4,721,000
Contingency	$2,188,000	$4,630,500
Total Capital Cost	$13,213,500	$27,872,500
Unit Storage Cost	$6,653	$14,173

6.3.3.2 Annual Cost

Table 16 presents the annual costs associated with Alternative 3.A and 3.B. The annual cost estimate assumes the project will begin operation in 2020 and are presented in 2020 dollars. The annual cost was estimated including debt service, annual fees and O & M costs. Similarly to the capital costs for Alternative 3.B, the annual costs associated with Alternative 3.B are also more expensive. Detailed annual costs for Alternative 2 over a thirty-year period are provided in Appendix C.

Table 16. Annual cost alternatives associated with Neal Creek Reservoir.

Item	Alternative 3.A	Alternative 3.B
Total Annual Cost ($)	$1,239,500	$2,433,500

7 Conclusions and Recommendations

Based on the results of this analysis, expansion of the Upper Green Point Reservoir seems to present the least challenges when considering physical feasibility, regulatory and ecological feasibility, and economic feasibility of implementing the alternative. Alternative 2, the expansion of Laurance Lake, would be the most economically feasible but may pose considerable obstacles associated with environmental regulations and permitting. Implementation of a new reservoir on the East Fork Neal Creek, Alternative 3, is the least feasible alternative; this alternative is the most expensive of the three alternatives and as a project being built and operated on Mt. Hood Forest land, it faces the most regulatory obstacles.

The following recommendations are offered to continue the investigation of future surface water storage alternatives for the Hood River Basin:

- Conclusions made in this analysis must be made in the context of the level of data and information available. This is a planning level study therefore the analysis and corresponding conclusions made should not be used to implement a construction project, but to identify where more information is needed and ultimately determine what solutions are best to assist the Hood River Basin in preparing for future water supply challenges. The conclusions made in this report should be evaluated in conjunction with the conclusions made with Reclamation's Basin Study, WPN's Conservation Assessment, and Normandeau Associate's Instream Flow Assessment.

- Even if these three alternatives are not considered further, measures should be taken within the next year to extend the storage reservations currently held in the Hood River Basin which will expire in 2016.

- Due to significant challenges Alternative 3 faces, the conservation opportunities for EFID presented in WPN's Conservation Assessment may be cost effective and beneficial to in-stream flow. Reclamation's results from the Basin Study assessing the water reliability and WPN's Conservation Assessment should be used to determine if Alternative 3 is a viable option.

- If Alternative 3 is further evaluated in the future, more observed data associated with the West Fork Neal Creek is needed. Implementation of a stream gauge on the West Fork Neal Creek, would provide data to more accurately estimate the water available for storage under various reservoir operations.

- How these alternatives are introduced to the public and environmental agencies is critical to successful implementation. The public and environmental agencies should be aware of plans and considerable effort should be made in presenting the material in a manner that considers the contentious nature of the surface water projects. If efforts are not made to plan for public involvement, the community could reject and potentially stop implementation of a surface water project.

Bibliography

Anderson Perry & Associates, Inc. (2004). *Upper and Lower Green Point Dam and Reservoir Assessment.* Hood River: Farmers Irrigation District.

BOR. (1987). *Design of Small Dams.* Washington D.C.

BOR. (2007). *Sustainable Development and Use of Reservoirs.* Denver.

Christensen, N. (2013). *Water Use Assessment.* Hood River.

FEMA. (2004). *Federal Guidelines for Dam Safety.* U.S. Department of Homeland Security.

FOA. (2010). *Earth Embankments.*

FSA Consulting. (2001). *Farm Dams for the Sugar Industry.* Queensland.

Gupta, R. S. (2008). Selection of Dam Types. In R. S. Gupta, *Hydrology and Hydraulic Systems* (pp. 573-574). Long Grove: Waveland Press, Inc.

NRCS. (2005). *Earth Dams and Reservoirs.* Washington: United States Department of Agriculture.

PBS&J, Inc. (2006). *Final Report: Conceptual Alternative Water Supply Development Projects and Planning Level Cost Estimates.* Tallahassee.

USSD. (2012). *Guidelines for Construction Cost Estimating for Dam Engineers and Owners.* Denver.

Wright, R., & Bennett, D. (2013). *Memormandum.*

Appendix A. Area Capacity Relationships

This section provides the graphics and corresponding computations used to estimate the storage capacity relationships for the three alternatives.

A.1 Upper Green Point Reservoir

Table A 1. Area Capacity Relationship for raising Green Point Dam 8 feet (Wright & Bennett, 2013).

BY	DATE	PROJECT	
RWW	11/30/2012	Hood River	Sheet 1 of 1
CHKD BY	DATE	FEATURE	
		Potential Reservoir - Green Point Reservoir (Upper)	
DETAILS	Storagae vs Dam Height for Green Point Reservoir (Upper)		

Elev. (ft)	A (ft^2)	A (acres)	D (ft)	V (ft^3)	V (af)	V (af)	L (ft)
3166	2,133,189	49.0					
			2	4,391,149	101	101	
3168	2,257,960	51.8					950
			8	20,052,196	460	561	
3176	2,755,089	63.2					1,156

Dam Raise =	8 ft
Dam Crest Length =	1,156 ft
Reservoir Storage =	561 acre-ft
Dam Location =	45 deg 38 min 18 sec N, 121 deg 40 min 40 sec W
Reservoir Length =	2,906 ft
Creek Slope =	NA

8 ft. raise and 2 ft. of orig. freeboard
Top of existing dam is about 3168

A.2 Alternative 2: Laurance Lake

No area capacity relationship was prepared for raising Laurance Lake three feet using an Obermeyer weir.

A.3 Alternative 3: Neal Creek Reservoir

Table A 2. Area Capacity Relationship for a reservoir on the East Fork Neal Creek (Wright & Bennett, 2013).

BY	DATE	PROJECT	
RWW	11/13/2012	Hood River	Sheet 1 of 1
CHKD BY	DATE	FEATURE	
		Potential Reservoir - Neal Creek Site 1	
DETAILS	Storagae vs Dam Height for Site 1 on Neal Creek		
	Elevation at Creek Bottom at Dam = 2960 Ft		

Elev. (ft)	A (ft^2)	A (acres)	D (ft)	V (ft^3)	V (af)	V (af)	L (ft)
2960	275	0.0					30
			10	168,155	4	4	
2970	33,356	0.8					155
			10	593,175	14	17	
2980	85,279	2.0					217
			10	1,203,030	28	45	
2990	155,327	3.6					272
			10	2,143,740	49	94	
3000	273,421	6.3					332
			10	3,476,440	80	174	
3010	421,867	9.7					404
			10	5,057,780	116	290	
3020	589,689	13.5					480
			10	7,087,980	163	453	
3030	827,907	19.0					545
			10	9,669,890	222	675	
3040	1,106,071	25.4					613
			10	12,659,520	291	966	
3050	1,425,833	32.7					680
			10	15,693,280	360	1,326	
3060	1,712,823	39.3					741
			10	18,628,785	428	1,753	
3070	2,012,934	46.2					804
			10	21,820,060	501	2,254	
3080	2,351,078	54.0					877
			10	25,963,850	596	2,850	
3090	2,841,692	65.2					1038

Dam Height =	130 ft
Dam Crest Length =	1,038 ft
Reservoir Storage =	2,850 acre-ft
Dam Location =	45 deg 33 min 10 sec N, 121 deg 29 min 34 sec W
Reservoir Length =	3,691 ft
Creek Slope =	0.0352 ft/ft

Appendix B. Methodology for Flood Routing

This appendix provides the flood routing methodology that was used to evaluate the reservoir and spillway's ability to pass a 100-year flood event for each storage alternative (Equation 1).

$$\Delta S = Q_i \Delta t - Q_o \Delta \text{t}$$

Equation 1

Where

ΔS= Storage accumulated in during Δt (acre-feet)
$Q_i =$ Average rate of inflow during Δt (acre-feet/s)
$Q_o =$ Average rate of outflow during Δt (acre-feet/s)

To estimate the inflow flood hydrograph, Q_i for each water storage alternative, the USGS National Streamflow Statistics (NSS) program was employed. This program uses published regression equations developed for the State of Oregon to estimate flood frequencies and flood hydrographs for ungaged sites where no observed flood data are available.

To estimate the outflow hydrograph for each water storage alternative, Q_o , can be approximated as the discharge over the spillway. Equation 2 defines discharge over an overflow spillway

$$Q_o = CL_e H^{3/2}$$

Equation 2

$Q_o =$ Discharge (cfs)
$C =$ Variable coefficient of discharge
$L_e =$ Effective length of crest
$H =$ Total head, including velocity of approach

L_e is found with Equation 3

$$L_e = L - wN - 2(NK_P + K_a)H$$

Equation 3

$L =$ Length of crest (ft)
$w =$ Number of piers
$N =$ Width of each pier
$K_P =$ Pier contraction coefficient
$K_a =$ Abutment contraction coefficient; 0.2 for square abutments

If the spillway has a v

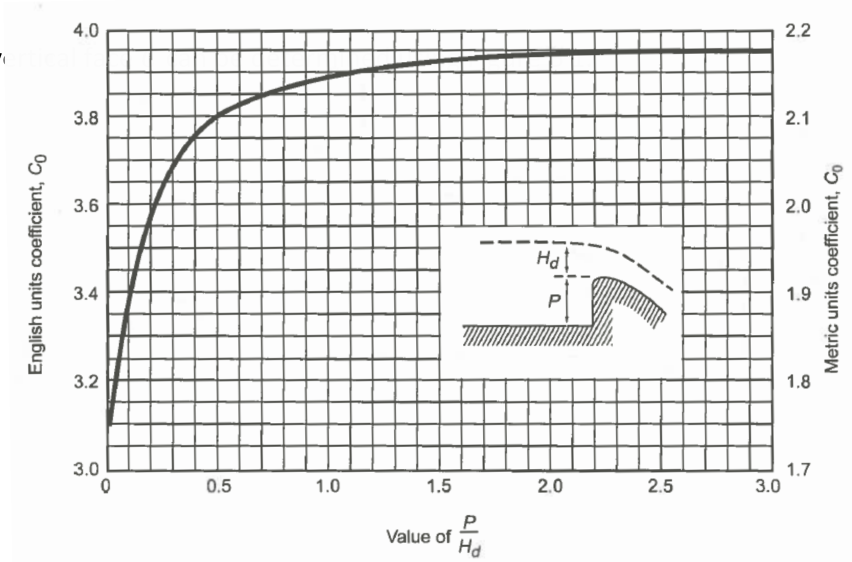

Figure B 1. Coefficient of Discharge for a vertical faced overflow spillway (Gupta, 2008).

B.1 Green Point Reservoir

Table B 1 lists the inputs used in NSS to create the inflow hydrograph for Green Point Reservoir.

Table B 1. NSS model inputs to develop inflow hydrograph for Upper Green Point Reservoir Alternative.

Model Input	Amount
Basin Drainage Area (mi)	0.55
Region	North_Central_Region_Harris_1979
Mean Annual Precipitation (in)	73.3
Mean Min January Temperature (°F)	23.7
Lag Time (hour)	0.124734
Recurrence Interval (year)	100

Table B 2 lists the amounts assumed for the coefficients in Equation 2.

Table B 2. Overflow spillway coefficients used for the Upper Green Point Reservoir Alternative.

Variable	Amount
Design Head, H_d (ft)	0.77
Dam Hieght, P (ft)	40.0
P/H_d	0.019
Coefficient of Discharge,C	3.6
Length of Crest (ft)	5.0
Abutment contraction coefficient	0.020

B.2 Laurance Lake

Analysis of extreme hydrologic events were not conducted.

B.3 Neal Creek Reservoir

Table B 3 lists the inputs used in NSS to create the inflow hydrograph for Neal Creek Reservoir.

Table B 3. NSS model inputs to develop inflow hydrograph for the Neal Creek Reservoir Alternative.

Model Input	Amount
Basin Drainage Area (mi)	4.52
Region	North_Central_Region_Harris_1979
Mean Annual Precipitation (in)	56
Mean Min January Temperature (°F)	23
Lag Time (hour)	3.805497
Recurrence Interval (year)	100

Table B 3lists the amounts assumed for the coefficients in Equation 2.

Table B 4. Overflow spillway coefficients used for the Neal Creek Reservoir Alternative.

Variable	Amount
Design Head, H_d (ft)	2.35
Dam Hieght, P (ft)	120.0
P/H_d	51.042
Coefficient of Discharge,C	4.0
Length of Crest (ft)	25.0
Abutment contraction coefficient	0.020

Appendix C. Project Costs

This section provides the methodology used to estimate the capital and annual costs associated with the final surface water storage alternatives.

C.1 Upper Green Point Reservoir

A detailed breakdown of the unit costs used to estimate the capital costs associated Alternative 1.A and 1.B with Green Point Reservoir are provided in Table C 1.

Table C 1. Unit costs used to estimate the capital costs associated with Alternative 1.B for expanding Upper Green Point Reservoir.

Cost Category	Line Item		Quantity	Unit	Unit Cost	Amount[1]	Description of Unit Cost[2]
Construction Costs	Site Preparation	Clearing & Grubbing Brush	15	AC	$0.00	$0	Unit cost associated with grubbing and clearing an acre of grubbing and clearing stumps up to 18" deep and in diameter.
	Embankment	Key Trench Excavation	2676	BCY	$12.94	$34,500	Unit cost associated with excavating a bankfull cubic yard of fill using a 5/8 CY excavator from the embankment to form the impermeable key trench of the expanded embankment.
		Impervious Fill	6422	BCY	$38.52	$247,500	Unit cost associated with delivering, backfilling, and compacting a bankfull cubic yard using a vibrating roller with 6" to 12" lifts to fill impermeable key trench of expanded embankment.
		Pervious Fill	13140	BCY	$29.27	$384,500	Unit cost associated with delivering, backfilling, and compacting a bankfull cubic yard of select semi-permeable fill on the downstream face of the embankment using a front end loader.
		Semi-pervious	13140	BCY	$20.72	$272,500	Unit cost associated with delivering, backfilling, and compacting a bankfull cubic yard of till on the upstream face of the embankment using a front end loader.
		Upstream Embankment Protection	9532	Ton	$28.96	$276,000	Unit cost associated with machine placing a square yard of random broken stone about 18" in diameter 2' deep on the upstream face of the embankment for wave protection.
		Downstream Embankment Protection	12998	SY	$5.55	$72,000	Unit cost associated with placing a square yard of a webbed vegetation matt over the downstream embankment face.
		Dewatering	30	Day	$606.55	$18,000	Unit cost associated with dewatering the project area surrounding the embankment for one day where pumping would occur 8 hours per day, attended 2 hours per day, and a 3" centrifugal pump with 20 LF of suction hose and 100 LF of discharge hose would be used.

	Spillway	Concrete Forms for Channel	4760	SFCA	$7.46	$35,500	Unit cost associated with a square foot of area where the contrete comes into contact with the ground where the spillway channel will lie.
		Concrete Forms for Wall	1517	SFCA	$10.87	$16,500	Unit cost associated with a square foot of area where the spillway channel wall comes into contact with the ground surface.
		Reinforcing Steel for Channel	19.04	Ton	$2,024.08	$38,500	Unit cost associated with a ton of rebar needed to reinforce the spillway channel floor.
		Reinforcing Steel for Wall	53	Ton	$1,633.30	$87,000	Unit cost associated with a ton of rebar needed to reinforce the spillway channel wall.
		Placing Concrete for Channel	209	CY	$135.87	$28,500	Unit cost associated with the Volume of Concrete to fill spillway channel floor.
		Placing Concrete for Wall	303	CY	$137.60	$41,500	Unit cost associated with the Volume of Concrete to fill spillway channel floor.
Total Construction Costs						$1,552,500	
Nonconstruction Costs	Topographical Survey		75	AC	$520.49	$39,000	Estimated as acreage of expanded Green Point Reservoir padded with an addition 10 acres; unit cost estimated from RSMeans Online database
	Geotechnical Survey		1	EA	$15,744.60	$15,500	Total cost of surbsurface investigation including exploratory drilling, mobilization, demobilization, report & recommendations from P.E., and 200 ft of 2-1/2'' diameter cased borings; cost estimated from RSMeans Online Database
	Dam Breach Analysis		1	EA	$20,000.00	$20,000	Total cost of conducting a dam breach analysis, estimated by Niklas Christensen PE.
Total Nonconstruction Costs			25%	Percent	$1,627,000.00	$407,000	Estimated as 25% of constructions costs of non-construction costs including engineering, legal counsel, land easements, surveying and legal fees for land acquisition, environmental & archealogical studies, permitting, and financing
Contingency			25%	Percent	$1,552,500.00	$388,000	Esistmated as 25% of construction costs to account unanticpated costs.

Total Capital Costs $2,347,500

Notes: 1. Amount rounded up in multiples of $500. 1. Unit costs estimated by RSMeans© Online Database including cost of labor, materials, and equipment in 2014 dollars. Material costs were only included if they were needed, e.g. unit costs associated with excavation did not include material costs but material costs were included to unit costs associated with placing concrete forms for the spillway channel.

Table C 2. Unit costs used to estimate the capital costs associated with Alternative 1.A for expanding Upper Green Point Reservoir.

Cost Category	Line Item		Quantity	Unit	Unit Cost	Amount[1]	Description of Unit Cost[2]
Construction Costs	Site Preparation	Clearing & Grubbing Brush	15	AC	$0.00	$0	Unit cost associated with grubbing and clearing an acre of grubbing and clearing stumps up to 18" deep and in diameter.
	Embankment	Key Trench Excavation	2676	BCY	$12.94	$34,500	Unit cost associated with excavating a bankfull cubic yard of fill using a 5/8 CY excavator from the embankment to form the impermeable key trench of the expanded embankment.
		Impervious Fill	6422	BCY	$38.52	$247,500	Unit cost associated with delivering, backfilling, and compacting a bankfull cubic yard using a vibrating roller with 6" to 12" lifts to fill impermeable key trench of expanded embankment.
		Pervious Fill	13140	BCY	$4.02	$53,000	Unit cost associated with delivering, backfilling, and compacting a bankfull cubic yard of select semi-permeable fill on the downstream face of the embankment using a front end loader.
		Semi-pervious	13140	BCY	$8.21	$108,000	Unit cost associated with delivering, backfilling, and compacting a bankfull cubic yard of till on the upstream face of the embankment using a front end loader.
		Upstream Embankment Protection	9532	Ton	$28.96	$55,000	Unit cost associated with machine placing a square yard of random broken stone about 18" in diameter 2' deep on the upstream face of the embankment for wave protection.
		Downstream Embankment Protection	12998	SY	$5.55	$72,000	Unit cost associated with placing a square yard of a webbed vegetation matt over the downstream embankment face.
		Dewatering	30	Day	$606.55	$18,000	Unit cost associated with dewatering the project area surrounding the embankment for one day where pumping would occur 8 hours per day, attended 2 hours per day, and a 3" centrifugal pump with 20 LF of suction hose and 100 LF of discharge hose would be used.

	Spillway	Concrete Forms for Channel	4760	SFCA	$7.46	$35,500	Unit cost associated with a square foot of area where the contrete comes into contact with the ground where the spillway channel will lie.
		Concrete Forms for Wall	1517	SFCA	$10.87	$16,500	Unit cost associated with a square foot of area where the spillway channel wall comes into contact with the ground surface.
		Reinforcing Steel for Channel	19.04	Ton	$2,024.08	$38,500	Unit cost associated with a ton of rebar needed to reinforce the spillway channel floor.
		Reinforcing Steel for Wall	53	Ton	$1,633.30	$87,000	Unit cost associated with a ton of rebar needed to reinforce the spillway channel wall.
		Placing Concrete for Channel	209	CY	$135.87	$28,500	Unit cost associated with the Volume of Concrete to fill spillway channel floor.
		Placing Concrete for Wall	303	CY	$137.60	$41,500	Unit cost associated with the Volume of Concrete to fill spillway channel floor.
Total Construction Costs						$835,500	
Non-construction Costs	Topographical Survey		75	AC	$520.49	$39,000	Estimated as acreage of expanded Green Point Reservoir padded with an addition 10 acres; unit cost estimated from RSMeans Online database
	Geotechnical Survey		1	EA	$15,744.60	$15,500	Total cost of surbsurface investigation including exploratory drilling, mobilization, demobilization, report & recommendations from P.E., and 200 ft of 2-1/2'' diameter cased borings; cost estimated from RSMeans Online Database
	Dam Breach Analysis		1	EA	$20,000.00	$20,000	Total cost of conducting a dam breach analysis, estimated by Niklas Christensen PE.
Total Non-construction Costs			25%	Percent	$910,000.00	$227,500	Estimated as 25% of constructions costs of non-construction costs including engineering, legal counsel, land easements, surveying and legal fees for land acquisition, environmental & archeological studies, permitting, and financing
Contingency			25%	Percent	$835,500.00	$209,000	Estmated as 25% of construction costs to account unanticpated costs.

Total Capital Costs	$1,272,000

Notes: 1. Amount rounded up in multiples of $500. 2. Unit costs estimated by RSMeans© Online Database including cost of labor, materials, and equipment in 2014 dollars. Material costs were only included if they were needed, e.g. unit costs associated with excavation did not include material costs but material costs were included to unit costs associated with placing concrete forms for the spillway channel.

Table C 3 and lists the annual costs associated with Alternative 1.A and 1.B for expanding the Upper Green Point Reservoir.

Table C 3. Annual costs associated with Alternative 1.B for expanding Upper Green Point Reservoir.

Year	Debt Service ($)	O & M Costs ($)	Fees ($)	Total Annual Cost	Unit Cost ($/AF)
2020	$0.00	$0.00	$0	$0.00	2020
2021	$188,500.00	$36,000.00	$1,000	$225,500.00	2021
2022	$188,500.00	$37,000.00	$1,000	$226,500.00	2022
2023	$188,500.00	$38,000.00	$1,000	$227,500.00	2023
2024	$188,500.00	$39,000.00	$1,000	$228,500.00	2024
2025	$188,500.00	$39,500.00	$1,000	$229,000.00	2025
2026	$188,500.00	$40,500.00	$1,100	$230,000.00	2026
2027	$188,500.00	$41,500.00	$1,100	$231,000.00	2027
2028	$188,500.00	$42,500.00	$1,100	$232,000.00	2028
2029	$188,500.00	$43,500.00	$1,100	$233,000.00	2029
2030	$188,500.00	$45,000.00	$1,100	$234,500.00	2030
2031	$188,500.00	$46,000.00	$1,210	$235,500.00	2031
2032	$188,500.00	$47,000.00	$1,210	$236,500.00	2032
2033	$188,500.00	$48,000.00	$1,210	$237,500.00	2033
2034	$188,500.00	$49,500.00	$1,210	$239,000.00	2034
2035	$188,500.00	$50,500.00	$1,210	$240,000.00	2035
2036	$188,500.00	$51,500.00	$1,331	$241,500.00	2036
2037	$188,500.00	$53,000.00	$1,331	$243,000.00	2037
2038	$188,500.00	$54,500.00	$1,331	$244,500.00	2038
2039	$188,500.00	$55,500.00	$1,331	$245,500.00	2039
2040	$188,500.00	$57,000.00	$1,464	$247,000.00	2040
2041	$188,500.00	$58,500.00	$1,464	$248,500.00	2041
2042	$188,500.00	$60,000.00	$1,464	$250,000.00	2042
2043	$188,500.00	$61,000.00	$1,464	$251,000.00	2043
2044	$188,500.00	$62,500.00	$1,464	$252,500.00	2044
2045	$188,500.00	$64,000.00	$1,611	$254,000.00	2045
2046	$188,500.00	$66,000.00	$1,611	$256,000.00	2046
2047	$188,500.00	$67,500.00	$1,611	$257,500.00	2047
2048	$188,500.00	$69,000.00	$1,611	$259,000.00	2048
2049	$188,500.00	$70,500.00	$1,611	$260,500.00	2049

Term for Bond: 30 years

Interest Rate (U.S. Treasury Rate): 5.6 %

10 Year Average CPI Index Inflation Rate: 2.4 %

Reservoir Storage: 1252 acre-feet

Number of Irrigation District Patrons: 1851

Table C 4. Annual costs associated with Alternative 1.A for expanding Upper Green Point Reservoir.

Year	Debt Service ($)	O & M Costs ($)	Fees ($)	Total Annual Cost	Unit Cost ($/AF)
2020	$0.00	$0.00	$0	$0.00	$0
2021	$102,000.00	$19,500.00	$1,000	$122,500.00	$108
2022	$102,000.00	$20,000.00	$1,000	$123,000.00	$108
2023	$102,000.00	$20,500.00	$1,000	$123,500.00	$109
2024	$102,000.00	$21,000.00	$1,000	$124,000.00	$109
2025	$102,000.00	$21,500.00	$1,000	$124,500.00	$109
2026	$102,000.00	$22,000.00	$1,100	$125,000.00	$110
2027	$102,000.00	$22,500.00	$1,100	$125,500.00	$110
2028	$102,000.00	$23,000.00	$1,100	$126,000.00	$111
2029	$102,000.00	$23,500.00	$1,100	$126,500.00	$111
2030	$102,000.00	$24,500.00	$1,100	$127,500.00	$112
2031	$102,000.00	$25,000.00	$1,210	$128,000.00	$112
2032	$102,000.00	$25,500.00	$1,210	$128,500.00	$113
2033	$102,000.00	$26,000.00	$1,210	$129,000.00	$113
2034	$102,000.00	$26,500.00	$1,210	$129,500.00	$114
2035	$102,000.00	$27,500.00	$1,210	$130,500.00	$115
2036	$102,000.00	$28,000.00	$1,331	$131,500.00	$116
2037	$102,000.00	$28,500.00	$1,331	$132,000.00	$116
2038	$102,000.00	$29,500.00	$1,331	$133,000.00	$117
2039	$102,000.00	$30,000.00	$1,331	$133,500.00	$117
2040	$102,000.00	$31,000.00	$1,464	$134,500.00	$118
2041	$102,000.00	$31,500.00	$1,464	$135,000.00	$119
2042	$102,000.00	$32,500.00	$1,464	$136,000.00	$120
2043	$102,000.00	$33,000.00	$1,464	$136,500.00	$120
2044	$102,000.00	$34,000.00	$1,464	$137,500.00	$121
2045	$102,000.00	$35,000.00	$1,611	$138,500.00	$122
2046	$102,000.00	$35,500.00	$1,611	$139,000.00	$122
2047	$102,000.00	$36,500.00	$1,611	$140,000.00	$123
2048	$102,000.00	$37,500.00	$1,611	$141,000.00	$124
2049	$102,000.00	$38,500.00	$1,611	$142,000.00	$125

Term for Bond: 30 years

Interest Rate (U.S. Treasury Rate): 5.6 %

10 Year Average CPI Index Inflation Rate: 2.4 %

Reservoir Storage: 1252 acre-feet

Number of Irrigation District Patrons: 1851

C.2 Laurance Lake

Table C 5. Unit costs used to estimate the capital costs associated with expanding Laurance Lake.

Cost Category	Line Item		Quantity	Unit	Unit Cost[1]	Amount[2]	Description of Unit Cost
Construction Costs	Obermyer Apron	Concrete Forms for Support	160	SFCA	$10.87	$1,500	Unit cost associated with a square foot of area where the concrete apron will lie.
		Reinforcing Steel for Support	1.92	Ton	$4,000.00	$7,500	Unit cost associated with a ton of rebar needed to reinforce the concrete apron
		Placing Concrete for Wall	18	CY	$500.00	$9,000	Unit cost associated with filling a cubic yard of concrete to fill the concrete apron.
	Obermyer Weir		1	EA	$175,200.00	$175,000	Total cost of Obermeyer weir that is delivered to the project site; including obermeyer gate, air supply equipment, PLC based upstream water level control . Installation cost estimated as 20 percent ofweir.
Total Construction Costs						$193,000	
Total Non-construction Costs			1	EA	$193,000.00	$67,500	Estimated as 35% of constructions costs of non-construction costs including engineering, legal counsel, land easements, surveying and legal fees for land acquisition, environmental & archeological studies, permitting, and financing.
Contingency			1	EA	$193,000.00	$67,500	Esistmated as 35% of construction costs to account unanticpated costs.
Total Capital Costs						$328,000	

Notes: 1. Amount rounded up in multiples of $500. 2. Unit costs estimated by RSMeans© Online Database including cost of labor, materials, and equipment in 2014 dollars. Material costs were only included if they were needed, e.g. unit costs associated with excavation did not include material costs but material costs were included to unit costs associated with placing concrete forms for the spillway channel.

Table C 6. Annual costs associated with Expanding Laurance Lake.

Year	Debt Service ($)	O & M Costs ($)	Fees ($)	Total Annual Cost	Unit Cost ($/AF)
2020	$0.00	$0.00	$0	$0.00	$0
2021	$26,500.00	$5,000.00	$1,000	$32,500.00	$8
2022	$26,500.00	$5,000.00	$1,000	$32,500.00	$8
2023	$26,500.00	$5,500.00	$1,000	$33,000.00	$8
2024	$26,500.00	$5,500.00	$1,000	$33,000.00	$8
2025	$26,500.00	$5,500.00	$1,000	$33,000.00	$8
2026	$26,500.00	$5,500.00	$1,100	$33,000.00	$8
2027	$26,500.00	$6,000.00	$1,100	$33,500.00	$8
2028	$26,500.00	$6,000.00	$1,100	$33,500.00	$8
2029	$26,500.00	$6,000.00	$1,100	$33,500.00	$8
2030	$26,500.00	$6,500.00	$1,100	$34,000.00	$9
2031	$26,500.00	$6,500.00	$1,210	$34,000.00	$9
2032	$26,500.00	$6,500.00	$1,210	$34,000.00	$9
2033	$26,500.00	$6,500.00	$1,210	$34,000.00	$9
2034	$26,500.00	$7,000.00	$1,210	$34,500.00	$9
2035	$26,500.00	$7,000.00	$1,210	$34,500.00	$9
2036	$26,500.00	$7,000.00	$1,331	$35,000.00	$9
2037	$26,500.00	$7,500.00	$1,331	$35,500.00	$9
2038	$26,500.00	$7,500.00	$1,331	$35,500.00	$9
2039	$26,500.00	$8,000.00	$1,331	$36,000.00	$9
2040	$26,500.00	$8,000.00	$1,464	$36,000.00	$9
2041	$26,500.00	$8,000.00	$1,464	$36,000.00	$9
2042	$26,500.00	$8,500.00	$1,464	$36,500.00	$9
2043	$26,500.00	$8,500.00	$1,464	$36,500.00	$9
2044	$26,500.00	$9,000.00	$1,464	$37,000.00	$9
2045	$26,500.00	$9,000.00	$1,611	$37,000.00	$9
2046	$26,500.00	$9,000.00	$1,611	$37,000.00	$9
2047	$26,500.00	$9,500.00	$1,611	$37,500.00	$10
2048	$26,500.00	$9,500.00	$1,611	$37,500.00	$10
2049	$26,500.00	$10,000.00	$1,611	$38,000.00	$10

Term for Bond: 30 years

Interest Rate (U.S. Treasury Rate): 5.6 %

10 Year Average CPI Index Inflation Rate: 2.4 %

Reservoir Storage: 3945 acre-feet

Number of Irrigation District Patrons: 611

C.3 Neal Creek Reservoir

Table C 7. Unit costs used to estimate the capital costs associated with Alternative 3.B for Neal Creek Reservoir.

Cost Category	Line Item		Quantity	Unit	Unit Cost	Amount	Explanation/Source
Construction Costs	Site Preparation	Clearing & Grubbing Brush	65	AC	$0.00	$0	Estimated that no cost will inncure, most likely would be undertaken by from clearing.
	Embankment	Excavation of Key Trench	13049	BCY	$12.94	$169,000	Unit cost associated with excavating a bankfull cubic yard of fill using a 5 to form the impermeable key trench of the expanded embankment.
		Impervious Fill	91342	BCY	$38.52	$3,518,500	Unit cost associated with excavating a bankfull cubic yard of fill using a 5 to form the impermeable key trench of the expanded embankment.
		Pervious Fill	241404	BCY	$29.27	$7,066,000	Unit cost associated with delivering, backfilling, and compacting a bankf with 6" to 12" lifts to fill impermeable core and key trench of expanded
		Semi-pervious	241404	BCY	$20.72	$5,002,000	Unit cost associated with delivering, backfilling, and compacting a bankf the downstream face of the embankment using a front end loader.
		Upstream Embankment Protection	36313	Ton	$28.96	$1,051,500	Unit cost associated with delivering, backfilling, and compacting a bankf the upstream face of the embankment using a front end loader.
		Downstream Embankment Protection	61896	SY	$5.55	$343,500	Unit cost associated with machine placing a square yard of random brok on the upstream face of the embankment for wave protection.
		Dewatering	30	Day	$606.55	$18,000	Estimate of the Number of days required to dewater the project site sur dewatering estimated assuming pumping would occur 8 hours per day, a centrifugal pump with 20 LF of suction and 100 LF of discharge hose.
	Spillway	Concrete Forms for Channel	4690	SFCA	$7.46	$35,000	Unit cost associated with dewatering the project area surrounding the e pumping would occur 8 hours per day, attended 2 hours per day, and a 3 suction hose and 100 LF of discharge hose would be used.
		Concrete Forms for Wall	1729	SFCA	$10.87	$19,000	Unit cost associated with a square foot of area where the contrete come the spillway channel will lie.
		Reinforcing Steel for Channel	19	Ton	$2,024.08	$38,000	Unit cost associated with a square foot of area where the spillway chanr ground surface.
		Reinforcing Steel for Wall	49	Ton	$1,633.30	$80,500	Unit cost associated with a ton of rebar needed to reinforce the spillway
		Placing Concrete for Channel	398	CY	$135.87	$54,000	Unit cost associated with a ton of rebar needed to reinforce the spillway

		Placing Concrete for Wall	285	CY	$137.60	$39,000	Unit cost associated with the Volume of Concrete to fill spillway channel
	Outlet Works	Excavating Pipeline Trench	6756	BCY	$8.65	$58,500	Unit cost associated with excavating a bankfull cubic yard from the trenc placed.
		Compacting Pipeline Trench	6756	BCY	$3.40	$23,000	Unit cost associated with compacting a bankfull cubic yard of backfill in pipeline will be placed.
		Placing Pipeline	9121	LF	$130.73	$1,192,500	Unit cost associated with placing 18" ductile iron pipe with in 18' lengths
Total Construction Costs						$18,708,000	
Non-construction Costs	Topographical Survey		595	AC	$520.49	$309,500	Estimated as acreage of Neal Creek Reservoir padded and siting for outle RSMeans Online database
	Geotechnical Survey		1	EA	$15,744.60	$15,500	Total cost of surbsurface investigation including exploratory drilling, mo recommendations from P.E., and 200 ft of 2-1/2'' diameter cased boring Database
	Dam Breach Analysis		1	EA	$20,000	$20,000	Total cost of conducting a dam breach analysis, estimated by Niklas Chri
Total Non-construction Costs			25%	Percent	$19,053,000.00	$4,763,250	Estimated as 25% of constructions costs of non-construction costs inclu easements, surveying and legal fees for land acquisition, environmental and financing
Contingency			25%	Percent	$18,708,000.00	$4,677,000	Esistmated as 25% of construction costs to account unanticpated costs.
Total Capital Costs						$28,148,250	

Notes: 1. Amount rounded up in multiples of $500. 2. Unit costs estimated by RSMeans© Online Database including cost of labor, materials, and equipment in 2014 dollars. Material costs were only included if they were needed, e.g. unit costs associated with excavation did not include material costs but material costs were included to unit costs associated with placing concrete forms for the spillway channel.

Table C 8. Unit costs used to estimate the capital costs associated with Alternative 3.A for Neal Creek Reservoir.

Cost Category	Line Item		Quantity	Unit	Unit Cost	Amount	Explanation/Source
Construction Costs	Site Preparation	Clearing & Grubbing Brush	65	AC	$0.00	$0	Estimated that no cost will inncure, most likely would be undertaken by from clearing.
	Embankment	Excavation of Key Trench	13049	BCY	$12.94	$169,000	Unit cost associated with excavating a bankfull cubic yard of fill using a 5 to form the impermeable key trench of the expanded embankment.
		Impervious Fill	91342	BCY	$38.52	$3,518,500	Unit cost associated with excavating a bankfull cubic yard of fill using a 5 to form the impermeable key trench of the expanded embankment.
		Pervious Fill	241404	BCY	$4.02	$970,500	Unit cost associated with delivering, backfilling, and compacting a bankf with 6" to 12" lifts to fill impermeable core and key trench of expanded
		Semi-pervious	241404	BCY	$8.21	$1,982,000	Unit cost associated with delivering, backfilling, and compacting a bankf the downstream face of the embankment using a front end loader.
		Upstream Embankment Protection	7263	Ton	$28.96	$210,500	Unit cost associated with delivering, backfilling, and compacting a bankf the upstream face of the embankment using a front end loader.
		Downstream Embankment Protection	61896	SY	$5.55	$343,500	Unit cost associated with machine placing a square yard of random brok on the upstream face of the embankment for wave protection.
		Dewatering	30	Day	$606.55	$18,000	Estimate of the Number of days required to dewater the project site sur dewatering estimated assuming pumping would occur 8 hours per day, a centrifugal pump with 20 LF of suction and 100 LF of discharge hose.
	Spillway	Concrete Forms for Channel	4690	SFCA	$7.46	$35,000	Unit cost associated with dewatering the project area surrounding the e pumping would occur 8 hours per day, attended 2 hours per day, and a 3 suction hose and 100 LF of discharge hose would be used.
		Concrete Forms for Wall	1729	SFCA	$10.87	$19,000	Unit cost associated with a square foot of area where the contrete come the spillway channel will lie.
		Reinforcing Steel for Channel	19	Ton	$2,024.08	$38,000	Unit cost associated with a square foot of area where the spillway chanr ground surface.
		Reinforcing Steel for Wall	49	Ton	$1,633.30	$80,500	Unit cost associated with a ton of rebar needed to reinforce the spillway
		Placing Concrete for Channel	398	CY	$135.87	$54,000	Unit cost associated with a ton of rebar needed to reinforce the spillway
		Placing Concrete for Wall	285	CY	$137.60	$39,000	Unit cost associated with the Volume of Concrete to fill spillway channel

	Outlet Works	Excavating Pipeline Trench	6756	BCY	$8.65	$58,500	Unit cost associated with excavating a bankfull cubic yard from the trenc placed.
		Compacting Pipeline Trench	6756	BCY	$3.40	$23,000	Unit cost associated with compacting a bankfull cubic yard of backfill int pipeline will be placed.
		Placing Pipeline	9121	LF	$130.73	$1,192,500	Unit cost associated with placing 18" ductile iron pipe with in 18' lengths
Total Construction Costs						$8,751,500	
Non-construction Costs	Topographical Survey		595	AC	$520.49	$309,500	Estimated as acreage of Neal Creek Reservoir padded and siting for outle RSMeans Online database
	Geotechnical Survey		1	EA	$15,744.60	$15,500	Total cost of surbsurface investigation including exploratory drilling, mo recommendations from P.E., and 200 ft of 2-1/2'' diameter cased boring Database
	Dam Breach Analysis		1	EA	$20,000	$20,000	Total cost of conducting a dam breach analysis, estimated by Niklas Chri
Total Non-construction Costs			25%	Percent	$9,096,500.00	$2,274,000	Estimated as 25% of constructions costs of non-construction costs inclu easements, surveying and legal fees for land acquisition, environmental and financing
Contingency			25%	Percent	$8,751,500.00	$2,188,000	Esistmated as 25% of construction costs to account unanticpated costs.
Total Capital Costs						$13,213,500	

Table C 9. Annual Costs associated with Alternative 3.B for Neal Creek Reservoir.

Year	Debt Service ($)	O & M Costs ($)	Fees ($)	Total Annual Cost	Unit Cost ($/AF)
2020	$0.00	$0.00	$0	$0.00	$0
2021	$2,262,000.0	$432,500.0	$1,000.0	$2,695,500	$1,357
2022	$2,262,000.0	$443,000.0	$1,000.0	$2,706,000.0	$1,363
2023	$2,262,000.0	$454,000.0	$1,000.0	$2,717,000.0	$1,368
2024	$2,262,000.0	$465,000.0	$1,000.0	$2,728,000.0	$1,374
2025	$2,262,000.0	$476,000.0	$1,000.0	$2,739,000.0	$1,379
2026	$2,262,000.0	$488,000.0	$1,100.0	$2,751,000.0	$1,385
2027	$2,262,000.0	$499,500.0	$1,100.0	$2,762,500.0	$1,391
2028	$2,262,000.0	$512,000.0	$1,100.0	$2,775,000.0	$1,397
2029	$2,262,000.0	$524,500.0	$1,100.0	$2,787,500.0	$1,404
2030	$2,262,000.0	$537,000.0	$1,100.0	$2,800,000.0	$1,410
2031	$2,262,000.0	$550,000.0	$1,210.0	$2,813,000.0	$1,416
2032	$2,262,000.0	$563,500.0	$1,210.0	$2,826,500.0	$1,423
2033	$2,262,000.0	$577,000.0	$1,210.0	$2,840,000.0	$1,430
2034	$2,262,000.0	$591,500.0	$1,210.0	$2,854,500.0	$1,437
2035	$2,262,000.0	$605,500.0	$1,210.0	$2,868,500.0	$1,444
2036	$2,262,000.0	$620,500.0	$1,331.0	$2,884,000.0	$1,452
2037	$2,262,000.0	$635,500.0	$1,331.0	$2,899,000.0	$1,460
2038	$2,262,000.0	$651,000.0	$1,331.0	$2,914,500.0	$1,468
2039	$2,262,000.0	$667,000.0	$1,331.0	$2,930,500.0	$1,476
2040	$2,262,000.0	$683,000.0	$1,464.1	$2,946,500.0	$1,484
2041	$2,262,000.0	$699,500.0	$1,464.1	$2,963,000.0	$1,492
2042	$2,262,000.0	$716,500.0	$1,464.1	$2,980,000.0	$1,501
2043	$2,262,000.0	$734,000.0	$1,464.1	$2,997,500.0	$1,509
2044	$2,262,000.0	$752,000.0	$1,464.1	$3,015,500.0	$1,518
2045	$2,262,000.0	$770,500.0	$1,610.5	$3,034,000.0	$1,528
2046	$2,262,000.0	$789,000.0	$1,610.5	$3,052,500.0	$1,537
2047	$2,262,000.0	$808,500.0	$1,610.5	$3,072,000	$1,547
2048	$2,262,000.0	$828,000.0	$1,610.5	$3,091,500.0	$1,557
2049	$2,262,000.0	$848,000.0	$1,610.5	$3,111,500.0	$1,567

Term for Bond: 30 years

Interest Rate (U.S. Treasury Rate): 5.6 %

10 Year Average CPI Index Inflation Rate: 2.4 %

Reservoir Storage: 1986 acre-feet

Number of Irrigation District Patrons: 936

Table C 10. Annual Costs associated with Alternative 3.A for Neal Creek Reservoir.

Year	Debt Service ($)	O & M Costs ($)	Fees ($)	Total Annual Cost	Unit Cost ($/AF)
2020	$0.00	$0.00	$0	$0.00	$0
2021	$1,062,000.00	$203,000.00	$1,000	$1,266,000	$637
2022	$1,062,000.00	$208,000.00	$1,000	$1,271,000.00	$640
2023	$1,062,000.00	$213,000.00	$1,000	$1,276,000.00	$642
2024	$1,062,000.00	$218,000.00	$1,000	$1,281,000.00	$645
2025	$1,062,000.00	$223,500.00	$1,000	$1,286,500.00	$648
2026	$1,062,000.00	$229,000.00	$1,100	$1,292,000.00	$651
2027	$1,062,000.00	$234,500.00	$1,100	$1,297,500.00	$653
2028	$1,062,000.00	$240,500.00	$1,100	$1,303,500.00	$656
2029	$1,062,000.00	$246,000.00	$1,100	$1,309,000.00	$659
2030	$1,062,000.00	$252,000.00	$1,100	$1,315,000.00	$662
2031	$1,062,000.00	$258,000.00	$1,210	$1,321,000.00	$665
2032	$1,062,000.00	$264,500.00	$1,210	$1,327,500.00	$668
2033	$1,062,000.00	$271,000.00	$1,210	$1,334,000.00	$672
2034	$1,062,000.00	$277,500.00	$1,210	$1,340,500.00	$675
2035	$1,062,000.00	$284,500.00	$1,210	$1,347,500.00	$678
2036	$1,062,000.00	$291,000.00	$1,331	$1,354,500.00	$682
2037	$1,062,000.00	$298,500.00	$1,331	$1,362,000.00	$686
2038	$1,062,000.00	$305,500.00	$1,331	$1,369,000.00	$689
2039	$1,062,000.00	$313,000.00	$1,331	$1,376,500.00	$693
2040	$1,062,000.00	$320,500.00	$1,464	$1,384,000.00	$697
2041	$1,062,000.00	$328,500.00	$1,464	$1,392,000.00	$701
2042	$1,062,000.00	$336,500.00	$1,464	$1,400,000.00	$705
2043	$1,062,000.00	$344,500.00	$1,464	$1,408,000.00	$709
2044	$1,062,000.00	$353,000.00	$1,464	$1,416,500.00	$713
2045	$1,062,000.00	$361,500.00	$1,611	$1,425,000.00	$718
2046	$1,062,000.00	$370,500.00	$1,611	$1,434,000.00	$722
2047	$1,062,000.00	$379,500.00	$1,611	$1,443,000.00	$727
2048	$1,062,000.00	$388,500.00	$1,611	$1,452,000.00	$731
2049	$1,062,000.00	$398,000.00	$1,611	$1,461,500.00	$736

Term for Bond: 30 years

Interest Rate (U.S. Treasury Rate): 5.6 %

10 Year Average CPI Index Inflation Rate: 2.4 %

Reservoir Storage: 1986 acre-feet

Number of Irrigation District Patrons: 936