Yakima River Basin Integrated Water Resource Management Plan

Technical Memorandum:
Kachess Reservoir Inactive Storage Project Alternatives Comparison and Recommendation for Advancement

U.S. Bureau of Reclamation
Contract No. 08CA10677A ID/IQ

Prepared by

HDR Engineering, Inc.

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region
Columbia-Cascades Area Office

State of Washington
Department of Ecology
Office of Columbia River

October 2013

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Contents

List of Tables

List of Figures

1.0 Introduction

This technical memorandum describes and compares two alternatives for the Kachess Reservoir Inactive Storage (KRIS) Project being considered for development under the proposed Yakima River Basin Integrated Water Resource Management Plan (Integrated Plan). Based on engineering, performance and cost considerations, it recommends one alternative for further design activity and environmental review.

The goals of the Integrated Plan are to protect, mitigate and enhance fish and wildlife habitat; provide increased operational flexibility to manage in-stream flows to meet ecological objectives; and to improve the reliability of the water supply for irrigation, municipal supply and domestic uses (Reclamation and Ecology, 2012c).

Kachess Reservoir was constructed at the site of a pre-existing natural lake in 1912. The reservoir outlet works were constructed at elevation 2,193 feet, the approximate elevation of the original lake surface. Water below that elevation cannot currently be released from the reservoir. The Kachess Inactive Storage Project would enable an additional 200,000 acre-feet of water stored in Kachess Reservoir to be released for water supply purposes during drought years.

This technical memorandum compares two alternatives as shown in Figure 1. They are:

- Alternative 1 – Gravity Tunnel
- Alternative 2 – Pump Station

The reader is referred to two prior documents for detailed background information and for more detailed descriptions of the two alternatives compared in this technical memorandum:

- Bureau of Reclamation and Washington State Department of Ecology (Reclamation and Ecology). 2011. *Costs of the Integrated Water Resource Management Plan.* Technical Memorandum. March 2011. U.S. Department of the Interior, Bureau of Reclamation, and Washington State Department of Ecology.
- Bureau of Reclamation and Washington State Department of Ecology (Reclamation and Ecology). 2012a. *Cost Risk Assessment of Six Projects from the Proposed Integrated Water Resource Management Plan.* Technical Memorandum. June 2012. U.S. Department of the Interior, Bureau of Reclamation, and Washington State Department of Ecology.

This technical memorandum is not intended to provide environmental review of the project. If the Kachess Inactive Storage Project is advanced, a comprehensive review of environmental considerations will need to be developed in separate documents.

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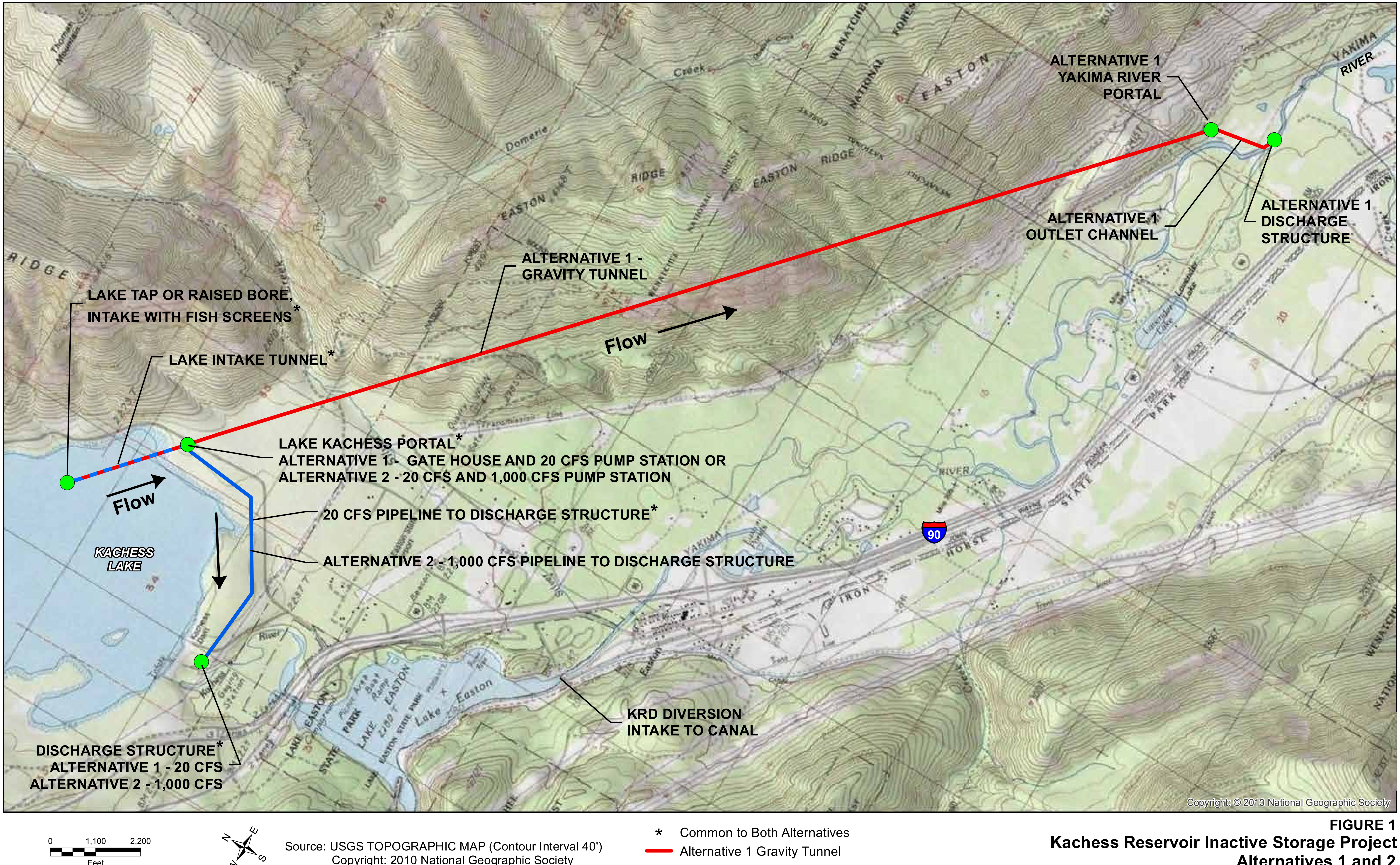

FIGURE 1
Kachess Reservoir Inactive Storage Project
Alternatives 1 and 2

Yakima River Basin Integrated Plan

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2.0 Principal Project Features and Operations

This section summarizes project features and operations of the two alternatives. There are a number of aspects of the two alternatives that are the same for both. Project features that are common to both alternatives are presented briefly for background purposes, but will not be considered further in the comparison. The remainder of the technical memorandum focuses on features, performance and costs that are different between the two alternatives, in order to support a decision on which alternative to advance for design and environmental review.

2.1 Common Features and Operations

Both the Pump Station and the Gravity Tunnel Alternatives would require an identically sized new intake equipped with fish screens to be constructed at the bottom of the Kachess Reservoir. The new intake would be located at an elevation suitable for the reservoir to be lowered to elevation 2110, thereby accessing 200,000 acre-feet of additional reservoir storage. The system would be used in dry years only, anticipated to be approximately 3 years out of every 10 years.

Construction of the new intake for either alternative would require construction of a vertical portal shaft on land and a short reach of horizontal access tunnel from the portal shaft to a location immediately beneath the new intake location in the reservoir (Figure 1). After construction of the intake, this short reach of horizontal access tunnel would serve as a water conveyance feature for either alternative.

When water in Kachess Reservoir is drawn down below the existing outlet works, water cannot be released through the outlet works into the Kachess River. The project would be designed to deliver water to the Kachess River to maintain minimum flows for fish and wildlife (flows which are currently not available when the lake falls below the existing outlet level). Both Alternatives include a small "base-flow" pump station solely for this purpose. For the gravity tunnel alternative, the base-flow pumping system would operate continuously whenever the water surface elevation in the reservoir had dropped below the level of the existing outlet works. For the pump station alternative, the base-flow pumping system would operate continuously whenever all of the six (6) large pumps were not operating and the water surface elevation in the reservoir had dropped below the level of the existing outlet works to meet demand for fish flows.

For the Gravity Tunnel Alternative, the vertical shaft would house gates that regulate flow into the 4.6-mile-long, 13-foot diameter tunnel and for the small base-flow pumping units. For the Pump Station Alternative, the vertical shaft would serve as the wetwell for the six large pumping units and the two base-flow pumping units.

Both alternatives would require a new, flow-discharge structure to be located at the downstream end of the water conveyance system. The Pump Station Alternative would discharge to the Kachess River below the existing Kachess Reservoir Dam. From that point the water would flow down the Kachess River and into Lake Easton and the Yakima River. The Gravity Tunnel Alternative would discharge directly to the Yakima River downstream of Lake Easton.

Thus, the features common to both alternatives are located at the upstream and downstream ends of each alternative. With the exception of the water discharge location, the primary differentiators between the two alternatives are located between the water intake and discharge structure.

2.2 Differentiating Features and Operations

Table 1 lists the principal project features and operational and environmental aspects of the two alternatives that are the major differentiators between the two alternatives. Additional information on these differentiators is provided in the sections that follow Table 1.

Table 1. Alternative Differentiators

NO.	PRINCIPAL PROJECT FEATURES AND ASPECTS	ALTERNATIVE 1 GRAVITY TUNNEL	ALTERNATIVE 2 PUMP STATION
1	Water Conveyance	**Gravity Tunnel** 4.6-mile-long, 13-foot-diameter to release point	**Electric Power Pump Station** with short pipe to release point
2	Rate of Water Delivery	**Maximum flow limited by reservoir level** • 1,200 cfs maximum flow at high inactive pool • 600 cfs maximum flow at low inactive pool • 100 cfs minimum, regulated by gates	**Maximum flow limited only by pumping capacity** • 1,000 cfs firm pumping rate • 100 cfs minimum pumping rate
3	Construction Risks	**Extensive** risks for the 4.6-mile-long, 13-foot diameter underground tunnel construction	**Lesser** risks for underground construction of the 6 large pumps
4	Primary and Backup Power Supplies	• Primary power supply for 2 Small Pumps • Back-up power supply for 2 small pumps	• Primary power supply for 6 large and 2 small pumps • Back-up power supply for 2 small pumps only • Some risk of short term delivery interruptions if power supply is interrupted
5	Discharge Location	Yakima River, approximately 6 river miles downstream of Lake Easton	Kachess River, approximately 1 river mile upstream of Lake Easton
6	Environmental Impacts and or Benefits	• **Impact** – Disposal of 185,000 cubic yards of tunnel and shaft muck (spoils) • **Impact** – Inability to achieve desired instream flows in Yakima River downstream of Lake Easton and upstream of tunnel discharge structure • **Impact** – Locating new discharge structure at previously undisturbed left bank of Yakima River	• **Benefit** – Much less tunnel and shaft muck (spoils) required to be disposed of • **Benefit** – Ability to achieve desired instream flows in Yakima River downstream of Lake Easton • **Benefit -** Locating new discharge structure at previously disturbed site on left bank of Kachess River downstream of existing outlet works outlet.
7	Irrigation Limitations and or Benefits	• **Limitation** – Inability to fully deliver water to Kittitas Reclamation District.	• **Benefit** – Ability to supply all pro-ratable irrigators with water during drought years, including Kittitas Reclamation District.
8	Capital Cost	• $279,000,000	• $205,000,000
9	Annual O&M Costs	• $300,000 per year	• $970,000 per year
10	Present Value of 100-Year Costs	• $185,000,000	• $154,000,000

3.0 Water Conveyance System and Delivery Rate

3.1 Alternative 1 – Gravity Tunnel

The Gravity Tunnel Alternative would use a 4.6-mile-long, 13-foot diameter tunnel constructed in rock to convey water by gravity from a new intake equipped with fish screens located at the bottom of Kachess Reservoir to a new discharge structure located on the left bank of the Yakima River approximately 6 river miles downstream of Lake Easton.

The flow rate for this alternative would be limited by the water level in the Kachess Reservoir. The maximum flow rate through the tunnel would vary from 1,200 cfs at a pool elevation of 2,192.75 (top of inactive pool) to 600 cfs at a pool elevation of 2,110 (bottom of inactive pool). Lower flow rates could be delivered by adjusting the tunnel gates.

3.2 Alternative 2 – Pump Station

The Pump Station Alternative would use a short tunnel to convey water from a new intake equipped with fish screens located at the bottom of Kachess Reservoir to a pump station with six large electric pumps. The pump station would be constructed in rock within the portal shaft. From the pump station, a short length of buried pipeline would convey water to a new discharge structure on the left bank of the Kachess River. The discharge structure would be approximately 1 river mile upstream of Lake Easton.

The flow rate through the pump station could be varied to match water supply objectives, from a minimum of about 100 cfs to a maximum of 1,000 cfs of firm pumping capacity (5 of 6 pumps in service with one standby unit). Installing four constant speed pumps and two variable speed pumps would allow Reclamation to operate at any flow rate between 100 and 1,000 cfs. The flow rate for the Pump Station Alternative would not depend on the water level in the reservoir.

4.0 Construction Risks

4.1 Alternative 1 – Gravity Tunnel

The Gravity Tunnel Alternative would have extensive risks associated with the construction of the 4.6-mile-long, 13-foot diameter tunnel that would be excavated in rock. Risks along this 4.6-mile-long alignment include the unknown and variable quality of the rock present and the degree of difficulty of rock excavation and rock support required. Risks also include the unknown and variable quantity of groundwater that would be encountered along this alignment and the degree of water treatment that would be required prior to the release of the groundwater back into the environment. Additional risk might be realized in the procurement of environmental permits required to construct beneath previously undisturbed forests. There would also be limited risks associated with the small, 2-pump, base-flow pump station that would also be constructed in rock.

4.2 Alternative 2 – Pump Station

The Pump Station Alternative would have limited construction risks associated with the large, 6-pump and the small, base-flow pumping station that would be constructed in rock. This alternative would have the technical construction risks associated with shoring and excavating a100-foot-diameter vertical shaft through approximately 250 vertical feet of glacial till. Reclamation is actively considering other configurations that could potentially reduce construction challenges.

5.0 Power Supply Requirements

5.1 Alternative 1 – Gravity Tunnel

The only power required for the tunnel alternative is approximately 200 kilowatts for the small base-flow pumps that would provide flow to the Kachess River when the water level in Lake Kachess drops below the top of the inactive pool (elevation 2,192.75 feet). Redundancy would be provided by an on-site, back-up power source so Reclamation can deliver base flow to the river if the primary power supply system fails.

5.2 Alternative 2 – Pump Station

The Pump Station Alternative would require about 8,000 kilowatts of power for the six large pumping units. Like the tunnel alternative, redundancy for the small, base-flow pumps would be provided by an on-site, back-up power source so Reclamation can deliver base flow to the river if the primary power supply system fails.

It is not considered necessary to ensure irrigation water during a short-term power outage, so no back-up power source would be provided for the six large pumps. In the event of a power outage, water would simply be unavailable for irrigation purposes until power is restored. This is considered to be a low risk because power is unlikely to be disrupted for a long period in the irrigation season during one of the years when the system is activated (dry years only, anticipated to be approximately 3 years out of every 10 years).

6.0 Key Limitations and Benefits

6.1 Alternative 1 – Gravity Tunnel

The discharge structure for the Gravity Tunnel Alternative would be located in a previously undisturbed area in the water on the left bank of the Yakima River approximately 6 river miles downstream from Lake Easton. Significant effort would be required to isolate the structure from the river.

Potential environmental impacts associated with this alternative include the transport and disposal of approximately 185,000 cubic yards of tunnel muck (rock spoils) and the associated treatment and disposal of the groundwater encountered during tunnel construction.

Since the Gravity Tunnel Alternative discharge point is downstream from Lake Easton, this alternative would require the release of water from Keechelus Reservoir to supply irrigation water to the Kittitas Reclamation District (KRD) diversion. This release from Keechelus

Reservoir would create higher flows in the upper Yakima River than the flow rates desired for fish resources in this reach of the Yakima River. Relocation of the discharge structure to Lake Easton is not feasible because of the hydraulic relationship between the elevation of the proposed new outlet at the bottom of Lake Kachess and the elevation of Lake Easton.

The Integrated Plan identified an objective of reducing flow in this reach of the Yakima River from 500 cfs at the beginning of August to 120 cfs by the first week of September each year. Modeling suggests that this cannot be achieved by the Gravity Tunnel Alternative in some drought years (Reclamation and Ecology 2013). September flows below Keechelus Dam could be on the order of 400 cfs to 1,000 cfs in some drought years, in order to deliver sufficient water to Lake Easton to meet the Integrated Plan's water supply objectives for KRD.

While operational refinements might improve on this modeled output, it appears unlikely that the tunnel alternative can simultaneously meet supply and flow objectives. The modeling exercise had the advantage of knowing which years were drought years. Under actual conditions, multiple year droughts cannot be forecasted with certainty, and actual outcomes with the tunnel alternative could be worse than modeled outcomes.

6.2 Alternative 2 – Pump Station

The release structure would be built at a previously disturbed area on the left bank of the Kachess River near the existing Kachess Reservoir outlet works and approximately 1 river mile upstream from Lake Easton. It could be easily isolated from the river.

Since the water pumped from Kachess Reservoir can be delivered to the Kachess River upstream from Lake Easton, it can be diverted into the KRD headworks. The higher flows in the Yakima River below Keechelus Dam are avoided with the Pump Station Alternative.

7.0 Capital Costs

The capital cost information used in this technical memorandum is taken from the project costs presented in Reclamation and Ecology, 2012a. That document presents a range of possible costs, at different probabilities, known as "percentiles." A 50^{th} percentile cost means there is a 50 percent chance that costs will be lower than this value, and a 50 percent chance that costs will be higher.

7.1 Alternative 1 – Gravity Tunnel

The 50th, 10th and 90th percentile capital costs for the Gravity Tunnel Alternative were estimated to be $279 million, $215 million and $351 million respectively.

7.2 Alternative 2 – Pump Station

The 50th, 10th and 90th percentile capital costs for the Pump Station Alternative were estimated to be $205 million, $161 million and $259 million respectively.

8.0 Operation, Maintenance and Replacement Costs

The operation and maintenance (O&M) cost information used in this technical memorandum is taken from Reclamation and Ecology 2011. These costs were escalated to 2012 dollars for purposes of consistency. O&M costs would vary substantially from year to year for the Kachess Inactive Storage Project, because there would be some years (normal or wet years) when the project would not need to be activated, and other years (dry years) when it would need to be activated. The costs presented here below are the annualized sum of the regular component and the non-annual component of O&M costs. They represent an average, annual O&M cost for all years combined.

Costs for projects proposed under the Integrated Plan have been estimated for a 100-year project period. This includes consideration of periodic needs to repair or replace major project components. For the Gravity Tunnel Alternative, costs of replacement or repair were estimated in Reclamation and Ecology 2012b. A similar cost was estimated for the Pump Station alternative specifically for this technical memorandum, using the same method as described in Reclamation and Ecology 2012b.

8.1 Alternative 1 – Gravity Tunnel

Average O&M costs for the Gravity Tunnel Alternative are estimated to be $300,000 per year (averaged over all years, including those when the system is not operated). The largest costs are staff time for preventive maintenance and inspections. Power costs are relatively small, averaging $12,000 per year for operation of the base-flow pump station.

Costs for major repair and replacement are estimated to be $5 million at year 25 and year 75, and $13 million at year 50 (Reclamation and Ecology 2012b). This includes periodic repair of the intake tunnel and replacement of fish screens and tunnel gates. The repair and replacement costs are in addition to the O&M costs listed above.

8.2 Alternative 2 – Pump Station

Average O&M costs for the Pump Station Alternative are estimated to be $970,000 per year (on the same basis as Alternative 1). The largest costs are for power consumption associated with the large pumps. For all years combined (average of active and inactive years) the power costs are approximately $600,000 per year.

Costs for major repair and replacement are estimated to be $17 million at year 25 and year 75, and $62 million at year 50 (these estimates are new and were developed for the current technical memorandum). This includes periodic repair of the intake tunnel and replacement of fish screens plus replacement of the large pumps. The repair and replacement costs are in addition to the O&M costs listed above.

9.0 Total Present Value Costs

Present value is a technique used to compare costs that are expected to occur at different times. Present value calculations assign a gradually decreasing value to costs that occur farther and farther out in the future. For example this is applicable to projects where there is an initial cost of construction followed by a stream of costs over a period of time after the project is built. The rate at which costs are reduced over time is called the “discount rate.” Present-value calculations for the Integrated Plan include costs of construction, annual O&M, and major repairs and replacements over a 100-year period. A discount rate of 4.00 percent is used. All values are expressed in 2012 dollars, for consistency with documents issued previously.

9.1 Alternative 1 – Gravity Tunnel

The Gravity Tunnel Alternative is estimated to have a total present value cost of $185 million. This includes the capital cost, O&M costs and costs of major repairs and replacement discussed above.

9.2 Alternative 2 – Pump Station

The Pump Station Alternative is estimated to have a total present value cost of $154 million. This includes the capital cost, O&M costs and costs of major repairs and replacement discussed above.

10.0 Conclusions

This section summarizes the key differences between the two alternatives discussed in this technical memorandum.

The Pump Station Alternative has advantages over the Gravity Tunnel Alternative in the following areas:

- Presents less risk because there is far less underground construction (no long tunnel).
- Minimizes the quantity of spoils (muck) from underground construction excavation and associated handling and disposal requirements.
- Minimizes handling and treatment of water from construction dewatering.
- Provides greater ability to regulate release flows from Kachess Reservoir at any time by varying the number of pumping units operated. Within the intended range of operation, flow rates for the Pump Station Alternative are not constrained by water levels in the reservoir, while flow rates for the Gravity Tunnel Alternative are limited by the reservoir water level.
- Provides the ability to supply water directly to the KRD diversion and other water right holders without needing to use the Keechelus Reservoir and upper reach of the Yakima River (from Keechelus Reservoir to the KRD diversion).
- Avoids unacceptably high flows in the upper reach of the Yakima River that could adversely affect fish.
- Avoids constructing a new discharge structure on a previously undisturbed site on the bank of the Yakima River. While a discharge structure is needed on the bank of the Kachess River, it can be built at a previously disturbed area near the existing dam.
- Has lower capital costs estimated to be $74 million lower (27 percent lower).

- Has lower present value costs for a 100-year time period, estimated to be $31 million lower (17 percent lower).

The Gravity Tunnel Alternative has advantages over the Pump Station Alternative in just two areas:

- This alternative does not require the construction of a 100 foot diameter vertical shaft, 250 feet deep, for access to 6 large pumps (Reclamation is actively considering other configurations for the Pump Station Alternative that could potentially reduce construction challenges).
- The Gravity Tunnel has lower O&M and major replacement and repair costs. The O&M costs are estimated to be $670,000 per year lower (average year, accounting for years when the system is used and years when it is not used). The largest single difference in the O&M costs is the cost of electrical power for pumping. In addition, the Gravity Tunnel Alternative has lower periodic costs for major repairs and replacement of equipment. The cost is estimated to be $11 million less for major repairs and replacements at 25 year intervals. At 50-year intervals the cost is estimated to be $49 million less. However as shown by the higher present value costs discussed above, the O&M and repair and replacements costs are not low enough to overcome the higher capital costs of the Gravity Tunnel Alternative.

11.0 Recommendation

Based on the conclusions above, Alternative 2 – Pump Station is the recommended alternative to advance to feasibility-level design and environmental review, if the Value Planning meeting confirms Alternative 2 as the preferred alternative and if funding is provided for these activities.

12.0 References

Reclamation and Ecology 2011	Bureau of Reclamation and Washington State Department of Ecology (Reclamation and Ecology). 2011. *Costs of the Integrated Water Resource Management Plan.* Technical Memorandum. March 2011. U.S. Department of the Interior, Bureau of Reclamation, and Washington State Department of Ecology.
Reclamation and Ecology 2012a	Bureau of Reclamation and Washington State Department of Ecology (Reclamation and Ecology). 2012a. *Cost Risk Assessment of Six Projects from the Proposed Integrated Water Resource Management Plan.* Technical Memorandum. June 2012. U.S. Department of the Interior, Bureau of Reclamation, and Washington State Department of Ecology.

Reclamation and Ecology 2012b	Bureau of Reclamation and Washington State Department of Ecology (Reclamation and Ecology). 2012b. *Preliminary Cost Allocation for the Proposed Integrated Water Resource Management Plan.* Technical Memorandum. October 2012. U.S. Department of the Interior, Bureau of Reclamation, and Washington State Department of Ecology.
Reclamation and Ecology 2012c	Bureau of Reclamation and Washington State Department of Ecology (Reclamation and Ecology). 2012c. *Yakima River Basin Integrated Water Resource Management Plan Framework for Implementation Report.* October 2012. U.S. Department of the Interior, Bureau of Reclamation, and Washington State Department of Ecology.
Reclamation and Ecology 2013	Bureau of Reclamation and Washington State Department of Ecology (Reclamation and Ecology). 2013. *Hydrologic Modeling of Winter Streamflows and Kachess Inactive Storage Tunnel Alternative.* Technical Memorandum. April 2013. U.S. Department of the Interior, Bureau of Reclamation, and Washington State Department of Ecology.

13.0 List of Preparers

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