WATER STORAGE PRE-FEASIBILITY ASSESSMENT REPORT

Horse Heaven Area, WRIA 31

Prepared for: WRIA 31 Planning and Advisory Committee

Project No. 090045-001-05 • October 27, 2010 Final

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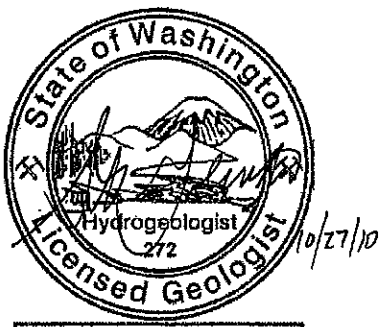
Aspect Consulting, LLC



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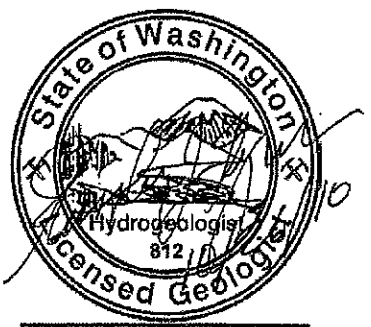

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1 Introduction

This report presents the Pre-Feasibility Assessment for developing new water supplies through water storage within the Rock-Glade watershed, Water Resource Inventory Area 31 (WRIA 31). Under its legislative mandate to "aggressively pursue the development of water supplies to benefit both instream and out-of-stream use", Washington State Department of Ecology (Ecology) provided funding from the Columbia River Basin Water Supply Development Account to the WRIA 31 Planning and Advisory Committee (PAC) for this assessment. The objective of the Pre-Feasibility Assessment is to evaluate a range of applicable water storage alternatives to meet identified out-of-stream and instream water demands, and select a preferred alternative that can move forward for more detailed appraisal and feasibility studies. A preferred alternative developed under this assessment would represent one component in a long-term water supply strategy for WRIA 31. This assessment was funded under Ecology Grant G0900153, and has been completed in general accordance with the project Work Plan (Aspect, 2009).

The WRIA 31 Planning Unit's vision for its Watershed Management Plan (WMP) includes the statement: "Implementation of this plan will provide dependable and high quality water supplies for our communities, economies, and natural environment". To that end, a high priority recommendation of the WMP is to develop water storage within WRIA 31 to address multipurpose water demands identified in the planning process. Identified strategies in the WMP consider both surface (e.g., surface reservoir) and groundwater (e.g., aquifer storage and recovery) storage to meet this need.

The area of WRIA 31 with the greatest total water demand, and which also could achieve the greatest economic growth if new water supplies were made available, is the Wood-Glade Planning Area – the broad agricultural center of the watershed. The Wood-Glade Planning Area is more commonly known by the local community as the Horse Heaven, an approximately 1,200-square mile area bounded by the crest of the Horse Heaven Hills on the north and east, the shoreline of the Columbia River on the south, and the Rock Creek watershed on the west (Figure 1).

There are many interruptible water rights within the Horse Heaven, representing roughly 50,000 acre-feet/year in total. In addition, there has been substantial overdraft of groundwater supplies from the Wanapum Basalt aquifer system in the western portion of the area, requiring well deepening and greatly increasing pumping costs. Finally, potential changes in climate and/or agricultural markets may also reduce the viability of dry land farming, which may necessitate a transition toward additional irrigation. Any or all of these water-supply-related factors may threaten the viability of the region's existing agricultural economy. Surplus pump station and conveyance capacity also exists within WRIA 31, which could allow for cost-effective expansion of irrigated agriculture if new water rights were made available through a storage project.

A water storage project may also provide opportunities to enhance streamflows in the WRIA's intermittent tributaries, some of which are designated as critical habitat. A source of cooler water added to these tributaries may provide thermal refuge along the

Columbia River mainstem, benefiting migrating salmonid stocks. It is possible that a water storage project in the Horse Heaven could help meet multipurpose demands both within and beyond the geographic area that comprises WRIA 31.

Following this introductory section, the report is organized into the following sections:

2. Past Storage-Related Studies for WRIA 31;
3. General Categories of Water Storage;
4. Projected Water Demands in WRIA 31;
5. Water Storage Alternatives;
6. Preferred Water Storage Alternative;
7. Benefits of Projects;
8. Fatal Flaw Analysis;
9. Planning-Level Project Cost Estimates;
10. Proposed Appraisal-Level Study;
11. Closing; and
12. References Cited.

2 Past Storage-Related Studies for WRIA 31

To support development of storage alternatives, this section summarizes past studies regarding water storage in WRIA 31, with a focus on the Horse Heaven area, and incorporates preliminary evaluation of potential instream benefits that could be achieved from a new storage project. It then briefly outlines the general categories of storage projects, and outlines preliminary storage alternatives that can be refined specific to defined future needs of the Horse Heaven area of WRIA 31.

2.1 Horse Heaven Hills Irrigation and Development Potential (WSU, 1970)

In 1970, the Agricultural Research Center from Washington State University (WSU) was contracted by Horse Heaven Irrigation Inc. to complete a multidisciplinary assessment of irrigation development potential of the Horse Heaven Hills region (WSU, 1970). This study included assessment of irrigation potential, irrigation water requirements and costs, economics of expanding cultivation of various crop types, potential co-development of water storage with power development and recreation, as well as institutional alternatives for regional resource development. In that study, the concept for delivering irrigation

water was diversion from John Day and McNary Pools with conveyance through an extensive series of irrigation canals.

The WSU (1970) report outlined five different variations on the diversion and canal systems, termed Concepts A through E. The various canal concepts all had specific advantages and disadvantages, and all included dammed surface reservoirs for storage (typically within Glade Creek and Fourmile Canyon). Concept A, the most realistic option for current basin conditions, relied entirely on diversion from McNary Pool just upstream of the McNary Dam. Water would be pumped to a pair of dammed reservoirs in Fourmile Canyon, from which it would flow by gravity through a series of canals and be pumped to a canal at 1,400-foot elevation. Four dammed reservoirs were also included on Glade Creek and East Branch Glade Creek. The canal system extended to the west into the Rock Creek subbasin, with three river pump stations between Pine Creek and Rock Creek supplying water to the western end of the system.

2.2 Pumped Storage Siting Assessment (Army Corps of Engineers, 1972)

The Army Corps evaluated 242 potential sites in the Pacific Northwest for application of pumped storage to generate power for peak use. Six sites along the Columbia River within WRIA 31 were included. While the temporary storage was not considered for water supply purposes, the siting considered natural topographic features for water impoundment and thus has potential relevance for assessment of a water supply storage project. However, the report provides no detail on the individual sites considered in WRIA 31.

2.3 Columbia River Off-Channel Storage Assessment Pre-Appraisal Report (Bureau of Reclamation, 2005)

In 2005, the US Bureau of Reclamation and Ecology contracted with MWH Americas (MWH) to prepare a pre-appraisal assessment of potential storage sites off the mainstem Columbia River that could retain a minimum of 300,000 acre-feet/year of Columbia River water for water supply use. The focus of the report was to identify potential sites within 10 miles of the mainstem Columbia River, and provide a preliminary screening of sites relative to water availability, potential major site challenges in regards to physical, environmental, and cultural characteristics, cost feasibility, and also provide site evaluation criteria for others to use if/when carrying forward the sites for more detailed feasibility studies. Two sites for dammed reservoirs were identified within WRIA 31 - on Alder Creek and on Rock Creek.

The Alder Creek site would include a main dam approximately 1 mile upstream of the mouth and a secondary saddle dam further upstream to limit the reservoir's eastern extent. The dammed reservoir would have a pool elevation of approximately 700 feet MSL (mean sea level), and inundate portions of Alder and Sixprong Creeks. The total surface area of this inundation would be approximately 3,400 acres, with a dam 3,200 feet long and 335 feet high. It was assumed that natural local inflows would be around 6,000 acre-feet/year, but the bulk of the water (nearly 24 million acre-feet on average) would be Columbia River water pumped from Lake Umatilla.

The Alder Creek reservoir would have a total storage volume of 330,000 acre-feet with a pre-appraisal-level cost estimate of $491 to 552 million ($1,500 to $1,700 per acre-foot). Identified potential construction impacts included inundation of 18 acres of wetlands and habitat for western gray squirrel (State of Washington threatened species) and several candidate endangered terrestrial species (owl, shrike, rabbit) , and relocation of Alderdale Road and a regional natural gas pipeline. The Alder Creek reservoir concept is considered further in this assessment, as described in Section 5.

To the west of the Horse Heaven, the Rock Creek East dam and reservoir would have a usable reservoir volume of approximately 900,000 acre-feet (approximately 100,000 acre-feet would be unusable). The reservoir would cover approximate 4,000 acres with a dam 4,500 feet long and 640 feet high, located roughly 2,700 feet upstream of the confluence. The pre-appraisal-level cost estimates for the reservoir are approximately $1.2 to 1.3 billion ($1,200 to $1,400 per acre-foot without amortization). Potential construction impacts include creating an anadromous fish passage barrier, inundating 32 acres of wetlands and habitat for state candidate endangered terrestrial species, and relocation of Walker Grade recreation area and a natural gas pipeline.

2.4 Preliminary Water Storage Assessment, Glade-Fourmile Subbasin (Aspect, 2005; 2006)

Aspect (2005) performed a preliminary analysis of water storage options for the upper elevation areas of the Horse Heaven, where mining of the groundwater system has occurred. Aquifer storage and recovery (ASR) as a means to offset the groundwater decline was the initial focus of the analysis. It was assumed that ASR would be technically feasible from a hydrogeological standpoint, but that water rights and costs were likely the key issues in determining the actual feasibility of an ASR project. Based on subsequent discussions with the Planning Unit, it was decided to not eliminate consideration of surface storage options in the assessment.

Irrespective of how the water would be stored, the assessment was focused as a costing exercise to evaluate cost per acre-foot of water delivered for a moderate-sized storage facility, located either 7 miles or 14 miles inland from the river, as an initial fatal flaw analysis. Two facility sizes were selected assuming a range of 10 cubic feet per second (cfs) to 30 cfs of Columbia River water diverted for a 5-month period of time (November through March), which equates to 3,000 to 9,000 acre-feet of water. In addition to facility sizing, two different facility types were assumed: a surface reservoir and an ASR system. All new infrastructure was assumed in the 2005 assessment.

The preliminary analysis concluded that, assuming all new infrastructure, the moderate-sized projects evaluated would not be economically feasible. Nonetheless, the cost estimates indicate an economy of scale if increasing the size from 3,000 acre-feet to 9,000 acre-feet (cost reduction of 40 to 50% per acre foot).

Diversion and conveyance costs represent a significant component of a storage project cost, but there may be potential to retrofit and use existing infrastructure to substantially reduce project cost. To address this issue, Aspect (2006) prepared a supplemental memorandum to evaluate cost savings from winterizing the existing infrastructure, which was a hypothetical system representative of systems in the area. The assessment,

conducted by SCM Engineers under subcontract to Aspect, concluded that retrofitting parts of the diversion and conveyance infrastructure to allow operation in freezing conditions could substantially reduce cost compared to installing an all new system. However, many of the existing systems were designed to minimize construction costs, not necessarily operational (power) costs, so were not necessarily designed to be hydraulically efficient. If electric power costs increase significantly, existing systems may need to be replaced.

2.5 Assessment to Develop the John Day-McNary Water Reserve (Nakaty Enterprises, 2006)

Under contract to Benton and Klickitat Counties, Nakaty Enterprises evaluated options for development of the John Day/McNary pools reserve (chapter 173-531A WAC). Making use of the regional water delivery concepts from the WSU (1970) study, and recognizing the dramatic changes in engineering and economics since then, Nakaty Enterprises began to formulate updated concepts for delivering irrigation water across the Horse Heaven Hills region. General elements of the preliminary concepts included:

- Water volumes conveyed via a regional canal system would be large, on the order of 1,000 to 1,300 cfs.
- Irrigation water would be pumped from McNary Pool south of Kennewick during the non-summer months into an extensive network of canals, similar to that proposed in the WSU (1970) report. The concept included a network of major canals running along elevations of approximately 1000, 1200, 1400, and 1500 feet. Water would be pumped from the Pool into a 1200-foot canal running along a portion of the easternmost Horse Heaven. A lift pump station would convey water from the 1200-foot canal up to the 1400-foot canal, which traverses more than 8 miles to the west, terminating at Alder Creek. A lift pump station would lift water from the 1400-foot canal to the 1500-foot canal traversing close to the top of the Horse Heaven. Smaller canals and/or pipelines leading from the main canals would then serve individual irrigation operations.
- Canal construction has improved considerably in the recent past. It is now possible to cut and line canals in a single process, which makes them increasingly more cost effective than pipelines. Depending on width and depth of the canals, the canal network itself could also provide a relatively small storage volume.
- Dammed reservoirs provide additional storage in the system. The preliminary concept included in-channel dams on the upper reach of Glade Creek, at lower elevation on the East Branch Glade Creek, on Carter Canyon (high elevation portion of East Branch Glade Creek), on Alder Creek, and on Tule Canyon (tributary to Alder Creek).
- Integration of power generation, via wind turbines and/or low head hydroelectric, was considered important for making the project cost effective (through development of a combined water and power utility). The generalized concept is that wind turbines could provide peak load power on demand, and off-peak power to pump water to storage in canals or other reservoirs. Power could also be generated from turbines when water stored at higher elevations is conveyed down

slope in pipelines. The long-term revenue from power generation could help defray capital costs of the project.

- The concept also included a second river pump station in the John Day Pool near Alderdale, which would convey water along a separate 1200-foot canal as far west as Rock Creek, covering an area generally outside the Horse Heaven.
- A regional-scale project such as this would require a high degree of centralized planning and organization. Nakaty Enterprises' preliminary concept was that a combined water and power utility would be the institutional entity to construct and operate such a system. A combination of private and public sector investment would likely be needed to fund such a project.

3 General Categories of Water Storage

There are multiple methods that can be used to store water depending on project objectives and site-specific conditions. This section briefly summarizes four general categories of storage projects potentially applicable to the Horse Heaven area.

The most basic division of storage options is whether the water is stored above ground in a constructed reservoir or underground in a naturally occurring aquifer. Surface storage includes both in-channel and off-channel impoundments, while subsurface storage includes both enhanced groundwater recharge ("rehydration") and aquifer storage and recovery (ASR). These categories of storage projects are outlined briefly below in terms of the relative pros and cons of permitting, construction, operation/maintenance, and cost, as well as generalized data gaps that may need to be addressed if further evaluation of a storage option were considered.

3.1 In-Channel Dam

As of 2001, there were more than 1,100 surface water dams in Washington State that store more than 10 acre-feet of water, with about 380 dams used primarily for water supply storage (Ecology, 2001). On-channel dams and reservoirs are sited on major streams and can be filled directly by flow from the upstream watershed, or can be filled from source outside the stream's drainage area as would be the case for the Glade-Fourmile subbasin. The stored water can be conveyed directly from the reservoir via pipes or canals for irrigation use. It can also be released to the stream for downstream uses. On-channel dams are typically constructed in deeply incised channels. Because the resulting reservoir is relatively deep with small surface area, it can help maintain the stored water at lower temperature than a shallow off-channel reservoir of comparable volume. If a particular stream is fish-bearing, fish passage can be engineered into the design of a dam. The potential pros and cons of an on-channel dam for application to irrigation water supply include:

3.1.1 Pros

- Likely amenable for greatest storage volumes.
- Likely has lower cost per volume of water stored than off-channel storage.

- Likely to result in less disturbance to irrigable land than off-channel storage.

3.1.2 Cons

- Dam locations generally limited to non-fish-bearing waters, which may greatly limit feasible locations unless habitat impacts can be fully mitigated.
- Greatest permitting difficulty of the conceptual options considered here.
- Stored water lost to evaporation and subsurface seepage.
- Sedimentation behind dam.
- Potential impacts to downstream water temperatures and flow rates.

3.1.3 Potential Data Gaps

Information to consider for evaluation of this general storage option can include:

- Accurately define fish-bearing/valuable habitat stream reaches to eliminate those reaches that are not permittable options for an on-channel dam.
- Dam siting evaluation of prospective on-channel storage sites including land ownership, valley topography (reservoir volume to surface area ratio), geology, habitat potentially flooded, access and existing infrastructure, etc.
- Estimate storage volumes for variable sizes of dams at a prospective site, relative to water volumes considered feasible for storage there based on water rights and other considerations.
  - Evaluate changes necessary in existing water rights and other permitting requirements specific to the project.
  - Evaluate potential for impacts to the environment or other water rights.
- If a site appears feasible for permitting of a dam, estimate planning-level costs and prospective funding options.

3.2 Off-Channel Impoundment

Off-channel impoundments are sited outside the main stream valley, completely off-stream or possibly on an intermittent stream. This can include irrigation canals or smaller on-farm impoundments. An off-channel reservoir would be filled from a source outside the stream's drainage area as would be the case for the Glade-Fourmile subbasin. Examples of off-channel impoundments include natural topographic depressions (not stream valleys) that either naturally retain water or can be dammed to do so, as well as constructed ponds, basins, or tanks. The potential pros and cons of an off-channel impoundment for application to irrigation water supply include:

3.2.1 Pros

- Generally flexible in terms of location and sizing. Can be located and sized to meet a range of irrigation needs.
- Relatively little instream impact, thus easier to permit than on-channel dam.
- Could be engineered to include wetlands or other habitat elements, thus providing environmental mitigation benefit.

3.2.2 Cons

- To achieve the same storage volume as an in-channel impoundment, greater land area and surface disruption would be required, including potential impact to irrigable land.
- Likely has higher cost per volume of water stored than on-channel storage.
- If open reservoir, stored water is lost to evaporation and, if unlined, to subsurface seepage.
- Sedimentation of impoundment.

3.2.3 Potential Data Gaps

Information to consider for evaluation of this general storage option can include:

- For prospective sources of excess winter water, evaluate timing of fish use and habitat value of the streams to determine window in which diversion could be permitted, as well as volume of water available.
- Because of the potentially large land requirements, define land ownership around impoundments and evaluate viability of land acquisition.
- Siting evaluation of prospective off-channel storage sites, including field inspection to evaluate topography, geology, existing infrastructure and access, etc.
  - Evaluate changes necessary in existing water rights and other permitting requirements specific to the project.
  - Evaluate potential for impacts to the environment (SEPA) or other water rights.

3.3 Aquifer Storage and Recovery (ASR)

Water can be stored underground, where an aquifer serves as a subsurface reservoir. Aquifer storage and recovery (ASR) refers to temporarily storing water in an aquifer for later recovery and use. In the 2000 session, the Washington State Legislature expanded the definition of “reservoir” in RCW 90.03.370 to include “any naturally occurring underground geological formation where water is collected and stored for subsequent use as part of an underground artificial storage and recovery project.” In March 2003, Ecology adopted WAC 173-157, which establishes the standards for review of applications for ASR projects and standards for mitigation of potential adverse impacts to groundwater quality or the environment. In central and eastern Washington, the cities of Kennewick, West Richland, Walla Walla, and Yakima are all evaluating the feasibility of ASR to help meet future water demands.

Depending on the water source used to recharge an aquifer for ASR, the source water may require some degree of water quality treatment prior to its storage. Compliance with the State’s groundwater quality standards is one of the regulatory requirements that needs to be addressed for permitting of an ASR project. At a minimum, the recharged water must have minimal turbidity to avoid clogging the ASR well and the aquifer around the well. Typically in ASR applications, a greater volume of water is recharged to the aquifer for storage than is subsequently withdrawn for beneficial use, because some recharge

water is “lost” to mixing with the ambient groundwater. This can lead to an increase in the volume of groundwater in the storage aquifer through successive ASR cycles. As is the case for a surface water reservoir, ASR requires a primary water right to divert the source water (often already permitted), a reservoir permit (the ASR permit), and, if the primary water right does not specify the intended beneficial use, a secondary permit to use the stored water. The potential pros and cons of ASR for application to irrigation water supply include:

3.3.1 Pros

- Can be easier and less expensive to permit than surface reservoirs, particularly dams.
- Less land required and less surface disruption than surface reservoir systems.
- Because the volume of water recovered is typically less than the volume stored, allows for gradual replenishment of aquifer.
- Range of uses is versatile – same as for any groundwater withdrawal.

3.3.2 Cons

- Source water may require water quality treatment prior to storage.
- Requires significant pilot testing to demonstrate feasibility.
- Considerable operation and maintenance (O&M) effort to ensure appropriate timing and volumes of storage and recovery, ensure ASR well doesn’t clog, etc.
- Limited to areas with appropriate hydrogeologic setting in proximity to available surplus surface water for storage.

3.3.3 Potential Data Gaps

Information to consider for evaluation of this general storage option can include:

- Evaluate hydrogeologic suitability for ASR in areas where property ownership might allow for ASR.
- Determine availability and capacity of primary water rights for the source water that would allow for additional diversion in the winter season.
- Evaluate changes necessary in existing water rights and other permitting requirements specific to the project.
- Evaluate water quality compatibility between prospective surface water source and groundwater in storage aquifer.
- Evaluate land ownership, access and existing infrastructure, and potential for impacts to the environment (SEPA) or other water rights.
- Evaluate cost for diverting and conveying source water to ASR well(s).

3.4 Enhanced Groundwater Recharge ("Passive Rehydration")

Using excess water to increase groundwater recharge, without active recovery of that additional stored water, is referred to in this assessment as enhanced groundwater recharge, or passive rehydration. Such recharge could be achieved through surface spreading, constructed infiltration facilities, or shallow wells. The extra recharge would then achieve benefit through greater volumes of natural groundwater discharge, presumably to surface water bodies. To recover the stored water other than by natural discharge would be considered ASR.

Studies of enhanced recharge are underway in the state. These include pilot testing of enhanced recharge to the gravel aquifer in the Walla Walla basin, as well as a phased feasibility study/pilot study of rehydrating basalt aquifers in Lincoln and Adams Counties (Odessa aquifer) by pumping Columbia River water into a series of drainages traversing permeable basalt interflow zones where the water should infiltrate.

It is expected that enhanced recharge may best be applied in areas where deposits of unconsolidated alluvium occur in broad stream valleys. This would be particularly true where instream flow augmentation is a desired use of the stored water. In such a setting, structures designed to detain water and prolong the time available for its infiltration could be placed off the main channel, within the floodplain. The intent would be to allow enhanced infiltration within the floodplain during winter/spring peak flow events, without impairing stream channel function during low-flow conditions. Grading of the floodplain or construction of infiltration structures might be required to ensure that the infiltration occurs within intended areas, and does not create flooding problems in unintended areas. Assuming late-season instream flow augmentation is the intended use, the infiltration area(s) would be positioned such that subsequent discharge of this stored water into the stream would occur late-season. This positioning would be determined based on estimated groundwater flow directions and rates. Because the available storage volume in such alluvial deposits is limited to the thickness of unsaturated material above the winter water table, storage volumes from any one enhanced recharge project would likely be small. Larger volumes could be achieved by recharging over larger areas or in multiple locations.

Increased groundwater discharge (by enhanced recharge) may provide temperature benefits to streams late season, assuming the stored groundwater maintains a lower temperature than the stream temperature.

3.4.1 Pros

- Stored water may be maintained at low temperature and somewhat protected from surface contamination and evaporative loss.
- Potentially the simplest and lowest cost option to permit and implement.

3.4.2 Cons

- Likely limited to small water volumes.
- Requires appropriate hydrogeologic setting and accurate knowledge of the timing between groundwater recharge and discharge to ensure intended benefit is achieved.
- May not be possible to 'recover' all of stored water in manner/timeframe to achieve intended benefits.

3.4.3 Potential Data Gaps

Information to consider for evaluation of this general storage option can include:

- Identify prospective sites for enhanced recharge, based on locations where additional groundwater discharge is desired and site hydrogeologic conditions.
- Quantify volumes and timing of excess water potentially available for storage by establishing and continuously monitoring stream gages near prospective enhanced recharge sites.
- For prospective sources of excess winter water, evaluate timing of fish use and habitat value of the streams to determine the time window in which diversion could be permitted.
- Evaluate changes necessary in existing water rights and other permitting requirements specific to the project.
- Evaluate land ownership, access and existing infrastructure, and potential for impacts to the environment (SEPA) or other water rights.

4 Projected Water Demands in WRIA 31

The WRIA 31 WMP (Aspect, 2008) includes an objective to ensure that adequate water supplies are available to meet current needs, provide for long-term sustainability of irrigated agriculture, and support economic and population growth within WRIA 31. Developing water storage is one recommended approach to help meet that objective. The Horse Heaven is the agricultural center of WRIA 31, and irrigation in the Horse Heaven represents the largest water use in the WRIA by a wide margin (Aspect Consulting and WPN, 2004). The WMP identifies four general priorities for developing additional water supply that are applicable to the Horse Heaven. The four water demand categories are as follows, not necessarily in order of priority:

- Replacing non-sustainable groundwater withdrawals for irrigation;
- "Shoring up" interruptible water rights;
- Economic development principally through expansion of higher-value (irrigated) agriculture; and
- Improving instream resources for aquatic habitat.

The first two demand categories are aimed at sustaining the existing level of irrigated agriculture, whereas the third supports economic growth for the area and the fourth provides for instream benefits in balance with out-of-stream benefits achieved under the other three demands, in accordance with the WMP.

Depending on the size of a water storage project to meet one or more of the priorities, water potentially could also be made available to other WRIAs, either those downstream on the Columbia River or within the Yakima River basin immediately north of the Horse Heaven. In addition, pumped storage for power generation can be another use to consider for incorporation into a storage project. Pumped storage has been evaluated conceptually within the watershed in the past, and Bonneville Power Administration and others are more intensively evaluating it now to integrate with intermittent renewable energy sources like wind energy. Integrating additional uses such as these into a multipurpose water storage project can expand the regional benefits of the project, and thereby increase opportunities for project funding through a variety of funding sources.

4.1 Estimated Water Quantity by Demand Category

To assist with sizing potential water storage alternatives, an annual water quantity (acre-feet/year) associated with each water demand category is estimated. Because the primary water demand of the Horse Heaven is irrigation, the seasonal timing of the irrigation demand is discussed prior to estimating annual demands by category.

4.1.1 Seasonal Irrigation Demand

The out-of-stream water demands in the Horse Heaven are principally for irrigation use, which fluctuates throughout the year based on seasonal climate. A working assumption of this pre-feasibility assessment is that the Columbia River is the source of water for any storage project within WRIA 31. A second working assumption is that new diversions of Columbia River water cannot be permitted for the months of July and August, when streamflows reach their minimums, without 1:1 mitigation for the consumptive portion of the diversion. Because of this assumed restriction, it is useful to estimate the fraction of annual irrigation demand that occurs in July and August. A water supply alternative could be sized to provide the necessary water for July + August demands only, instead of the entire annual irrigation demand.

The average fraction of annual irrigation demand that occurs in July and August is estimated here by assembling the monthly net crop irrigation requirements (CIR) for a representative set of crops irrigated in the Horse Heaven, and calculating the CIR for July + August as a fraction of the annual CIR. For the purposes of this evaluation, we assembled CIR data from the 1985 Washington Irrigation Guide (WIG) for the four most abundant seasonal crops plus two permanent crops irrigated in Horse Heaven, based on information from IRZ Consulting's (2004) analysis of irrigated acreages and crop types in WRIA 31. In that analysis, IRZ estimated typical row crop rotations as a percentage of total row crop acres, based on 2001 records from five representative farms in the Horse Heaven. From that analysis, potatoes, sweet corn, field corn, and carrots were the four

most abundant seasonal crops irrigated. Permanent crops included both vineyards (grapes) and orchards (assumed apples[1]).

For this analysis, CIR data are available in the 1985 WIG for two locations in/near the Horse Heaven: McNary and Bickelton. CIR data for the six crops were obtained for each station, and averaged to provide a representative CIR for the Horse Heaven. For each crop, the monthly average is then divided by the annual average, to calculate a monthly percentage of annual CIR. Note that the magnitude of the CIR is not important, only the relative monthly distribution (seasonality) of CIR is. Table 1 presents the monthly CIR data for the six crops and their representative (all crops) average. Figure 2 graphically illustrates the same monthly data.

Based on this analysis, the ratio of composite average monthly CIRs to annual CIRs are:

- 1% in May;
- 14% in June;
- 36% in July;
- 32% in August;
- 14% in September; and
- 2% in October.

Therefore, 68% (about 2/3) of the annual irrigation demand is estimated to occur in the two month period of July and August.

Accordingly, a water storage project intended to meet irrigation demands could be downsized by about 1/3 if it was limited to only meet demands during July and August. This would necessarily assume that a new water right could be obtained for diversion from the Columbia River outside of those two months, which is uncertain.

The annual demands, and the assumed 68% fraction of annual demands occurring in July + August, are outlined below for each of the four primary water demand categories.

4.1.2 Water Demand: Replace Groundwater-Supplied Irrigation

As described in the WRIA 31 WMP, groundwater levels in the Wanapum Basalt aquifer beneath the western part of the Horse Heaven have declined substantially over the past few decades and continue to decline. Figure 3 illustrates the inferred extent and magnitude of groundwater declines in the Wanapum Basalt aquifer between the early 1980s and 2009, using information from Ecology's long-term water level monitoring program. Although relatively few wells are monitored in the eastern portion of the Horse Heaven, the available information, including communications with irrigators in the watershed, indicates that the large groundwater decline in the Wanapum Basalt is primarily limited to the western portion of the Horse Heaven, generally centered along the Klickitat-Benton County line (Figure 3).

[1] Apples and cherries have very similar monthly CIR, with cherries having slightly higher use early in the year (May). The difference is not significant for the purposes of this analysis.

The aquifer depletion has forced well deepening and increased pumping costs, and raises uncertainty for the sustainability of irrigated agriculture in areas at distance from the Columbia River that are currently reliant on groundwater supply. This situation is the same as that occurring in the Odessa subarea of the Columbia basin project, where the state and federal governments have undertaken significant efforts to stabilize declining groundwater levels in the basalt aquifer system. The WRIA 31 WMP recommends development of an alternative to groundwater for irrigation water supply in the Horse Heaven as a high priority issue for WRIA 31.

The annual irrigation use supplied by groundwater was initially estimated in the WRIA 31 Level 1 Watershed Assessment (Aspect Consulting and WPN, 2004). The assessment of total irrigation use (supplied by surface water and groundwater) integrated irrigated acres of seasonal crops and permanent crops and, for the seasonal crops, typical row crop rotations as a percentage of total row crop acres, as determined by IRZ Consulting (2004). The relative proportion of groundwater-supplied irrigation use was assumed to equal the proportion of groundwater rights to total water rights for the basin. By that methodology, an estimated 63,000 acre-feet/year of irrigation use is supplied by groundwater within the Horse Heaven (combined Wood-Alder and Glade-Fourmile subbasins in the Level 1 Assessment). Using the assumptions outlined above, the irrigation demand for the months of July + August (68%) would be 43,000 acre-feet/year.

A second way to estimate groundwater-supplied irrigation use is multiplying an average representative water duty by the total irrigated acres in the area permitted under groundwater rights. According to Ecology's water right tracking system (WRTS), there are approximately 18,200 irrigated acres permitted under groundwater rights in the Horse Heaven. Assuming a composite average water duty of 3.0 feet/year for all crop types across the area equates to nearly 55,000 acre-feet/year of groundwater-supplied irrigation use (approximately 37,000 acre-feet/year in July + August). The water duty will be variable for different crops in different locations and over time, based on changing market conditions, with a 3.0 feet/year average providing flexibility for variable crop types in the future.

Groundwater used for irrigation in the Horse Heaven can be supplied by wells tapping both the Wanapum Basalt aquifer and, along the shores of the Columbia River, the unconsolidated Columbia River Gravel aquifers. The gravel aquifer system is not expected to experience declining water levels like the basalt aquifer system has. For this assessment, the fraction of the Horse Heaven's total irrigation use that is supplied by each aquifer was estimated using information from Ecology's Columbia River Mainstem Water Resources Information System (WRIS). The information included water right quantities and permitted number of irrigated acres and mapping of place of use and point of withdrawal (well location). The recorded points of withdrawal were overlain on Washington Department of Natural Resources' (DNR) 1:100,000 geologic mapping to differentiate wells tapping the gravel aquifer from those not. Any irrigation well in Horse Heaven not tapping the gravel aquifer can confidently be assumed to be tapping the basalt aquifer system. By this analysis, 820 acres are supplied by groundwater from the gravel aquifer system and 17,370 irrigated acres are supplied by groundwater from the basalt aquifer system (5% and 95% of total irrigated acres, respectively). Therefore, the gravel aquifer system supplies only a minor fraction of the Horse Heaven's total groundwater-supplied irrigation use, which is consistent with anecdotal information from the PAC.

For the purposes of this assessment, 56,000 acre-feet annually[2], and 38,000 acre-feet in July + August, of irrigation water in the Horse Heaven is assumed to be supplied by groundwater from the Wanapum Basalt aquifer. Based on the distribution of irrigated acres and annual water rights (Qa) reported in Ecology's WRTS, the distribution of groundwater-supplied irrigation use in the western and eastern portions of Horse Heaven (arbitrarily divided down Highway 221) can be estimated as approximately 80% and 20% respectively (45,000 and 11,000 acre-feet/year respectively; 31,000 and 8,000 acre-feet for July + August, respectively).

4.1.3 Water Demand: "Shore Up" Interruptible Water Rights

Chapter 173-563 WAC defines minimum instream flows at seven mainstem Columbia River locations including John Day and McNary Dams. These regulatory minimum instream flows are considered appropriated water rights with priority dates at the effective date of the chapter 173-563 WAC rule (June 24, 1980). Water rights with priority dates after June 24, 1980, are referred to as "interruptible." In other words, Ecology legally can interrupt use of the junior "interruptible" rights when minimum instream flow conditions defined in chapter 173-563 WAC are not met. The chapter 173-563 WAC instream flow rules do not apply to applications for new Columbia River water rights for which Ecology makes a decision on or after July 27, 1997. Water right applications processed after that date are evaluated for possible impacts to fish and existing water rights in consultation with appropriate local, state, and federal agencies and tribal governments. Any permit which is then approved for use of such waters will, if deemed necessary, be subject to instream protection or mitigation conditions determined on a case-by-case basis. However, water rights issued between June 24, 1980 and July 27, 1997, remain subject to the instream flows promulgated in chapter 173-563 WAC. As outlined in the WRIA 31 WMP, interruptible water rights are not reliable for current water-dependent uses or supporting population and economic growth in the watershed. Ecology recognizes the issues associated with the unreliability, and has made it an emphasis under the Columbia River Basin Water Supply Development Act to find solutions for interruptible water rights.

Using information in Ecology's WRTS, there are 40 Columbia River water rights in Horse Heaven with priority dates after June 24, 1980, totaling approximately 50,600 acre-feet/year[3] for irrigation of nearly 10,600 acres. Figure 4 displays the collective places of use in the study area served by interruptible Columbia River water rights, based on Ecology's WRIS database. On that figure, areas served by surface water are displayed in yellow; those supplied by groundwater in blue; those supplied by surface water and groundwater in green; and areas served by interruptible water rights are "hatched" with small black triangles. The accuracy of the information in WRIS is not known. Based on the database information, there is considerable overlap in water right places of use and it is likely that some areas are served by both interruptible and non-interruptible rights.

For the purposes of this assessment, it is assumed that approximately 51,000 acre-feet annually, and 35,000 acre-feet in July + August, of irrigation water in the Horse Heaven is supplied by interruptible Columbia River water rights. Based on the place of use

[2] 59,000 acre-feet/year, average of 63,000 and 55,000 acre-feet/year estimates, multiplied by 95% fraction supplied by Wanapum Basalt aquifer (excluding 5% supplied from gravel aquifer system).
[3] Excludes the McNary Dam hydroelectric power water right (1.27 million acre-feet/year).

information reported in Ecology's WRIS, the distribution of interruptible water rights can be approximated as 73% west of Highway 221 and 27% east of Highway 221 (37,000 and 14,000 acre-feet/year, west and east respectively; 26,000 and 9,000 acre-feet for July + August, west and east, respectively). East of the Horse Heaven, the Quad Cities water right is also an interruptible permit (96,619 acre-feet/year) subject to instream flow minimums dictated by the National Marine Fisheries' (NMFS) biological opinion (BiOp).

4.1.4 Water Demand: Expand Irrigated Agriculture

Economic growth in the Horse Heaven, and WRIA 31 as a whole, will be achieved largely through growth in agriculture and agricultural-related industries, specifically irrigation of high-value crops. For the purposes of this assessment, the Horse Heaven is considered equivalent in area to the Wood-Glade planning area of the WMP, which encompasses roughly 785,000 acres total. There are roughly 135,000 acres currently irrigated in the Horse Heaven, based on the IRZ (2004) information incorporated into the Level 1 Watershed Assessment. While the total irrigable acreage in the Horse Heaven is uncertain, WSU (1970) estimates it as "more than 600,000 acres." Chapter 173-531A WAC reserves 1.32 million acre-feet/year of water from the John Day/McNary Pools to irrigate 330,000 acres in WRIA 31. For the purposes of this assessment, the expansion of irrigated agriculture can be divided into short-term and long-term horizons.

Projected Short-Term Expansion

Short-term expansion in irrigated agriculture is reflected by the pending applications for new irrigation water rights within Horse Heaven. Based on Ecology's WRTS, there are 48 pending applications for new water rights to irrigate a total of 41,800 acres. The WRTS lists the applied-for instantaneous withdrawal rates (Qi; cfs for surface water, gpm for groundwater) for each application, but rarely lists the applied-for annual volume (Qa; acre-feet/year). The cumulative applied-for Qi is 674 cfs for the 48 applications.

Assuming a representative water duty of 3.0 acre-feet/year as a composite average (combination of row crops, vineyards, and orchards) for the 41,800 acres to be irrigated equates to an estimated applied-for Qa of approximately 125,000 acre-feet/year (85,000 acre-feet/year for July + August only). Based on the distribution of the applications' irrigated acres and instantaneous water rights (Qi) reported in Ecology's WRTS, the distribution of short-term irrigation expansion in the western and eastern portions of Horse Heaven (arbitrarily divided down Highway 221) can be estimated as approximately 85% and 15% respectively (106,000 and 19,000 acre-feet/year; 72,000 and 13,000 acre-feet for July + August, respectively).

Projected Long-Term Expansion

Long-term expansion of irrigated agriculture would be full beneficial use of the 1.32 million acre-feet/year of water reserved for irrigation of 330,000 acres in WRIA 31 under the John Day-McNary Pools reserve (Chapter 173-531A WAC).

4.1.5 Water Demand: Provide Instream Habitat Benefits

A water storage project can provide an additional source of water to augment instream flows and potentially provide thermal refuge in WRIA 31 tributaries during the dry season. This improvement in aquatic habitat (e.g., for salmonid rearing) represents an additional purpose of use for water made available through a storage project. If construction of a water storage project is funded, in whole or in part, through the state's

Columbia River Basin Water Supply Development Account (Account), one-third of the active storage funded by the Account must be available to augment instream flow under Ecology's management (RCW 90.90.020(1)). The portion of the project not funded by the Account would not be subject to that provision, but, depending on the funding source, may have different requirements to incorporate instream benefits.

It is assumed that the quantity of water developed through a storage project in the Horse Heaven and allocated for instream benefit would have negligible effect on instream flows in the mainstem Columbia River, but could have meaningful instream flow benefits for the tributaries. The details of how, where, when, and how much water would be delivered for instream benefit would best be determined as the preferred alternative for meeting the out-of-stream demands is more fully developed.

4.1.6 Other Potential Multipurpose Demands

Other potential water demands considered with stakeholders during the course of the pre-feasibility assessment included making available new water supplies for the Quad Cities' municipal demands or other WRIAs, and developing pumped storage. These demands have not been quantified at this point, but are outlined briefly below.

Help Meet Quad Cities' Municipal Demands

Within the 20-year planning horizon, the City of Kennewick's projected municipal water demand will consume its current water rights, except under the Quad Cities water right that it shares with cities of Richland, West Richland, and Pasco. The Quad Cities water right authorizes diversion of 96,619 afy to meet projected municipal water demands of the four cities to the year 2050. Diversion under the permit can only occur when permit-specific instream flow targets are met, unless the consumptive portion of the diversion is mitigated for in accordance with the permit provisions. When flow targets are not met, at least 50% of the mitigation must be flow augmentation to provide 1:1 offset of the consumptive use. A WRIA 31 storage project could provide mitigation water to the McNary Pool, the point of diversion for the Quad Cities water right, and thereby allow future exercise of a portion of the municipal water right.

Provide Water to the Yakima Basin or Downstream WRIAs

A large-scale storage project in WRIA 31 may be able to meet water demands outside of WRIA 31. For example, water could be stored in WRIA 31 reservoirs and then released back to the Columbia River, from where it could be diverted for out-of-stream or instream uses in WRIAs downstream along the Columbia River (i.e., use the river to convey the released water). In addition, it would be possible to pump water stored in a WRIA 31 reservoir over the crest of the Horse Heaven Hills into the Yakima River basin (e.g., near Mabton) for use there. Note that WSU (1970) evaluated the reverse of that: pumping water from the Yakima River into the Horse Heaven. Such a concept would involve large pumping (power) costs, but might gain interest from the Bureau of Reclamation for helping to meet Yakima basin water needs.

Provide Water for a Pumped Storage Project

Water stored in surface reservoirs for a WRIA 31 project could be used, in part, for pumped storage. Pumped storage is a tool that can support increased build out of wind power and other intermittent renewable energy sources being added to the BPA transmission system. During times of low power demand on the electrical grid, when

power costs are low (off-peak), water would be pumped from the Columbia River into a surface reservoir near the river but at high elevation above it. When power demand is high, the stored water would then be released through turbines to generate power. The pumping process consumes more energy than it produces but makes power available at times it is needed. The portion of water stored for pumped storage (power generation) would not be available for water supply. The viability of pumped storage in the Horse Heaven is uncertain at this time, but may warrant further evaluation.

5 Water Storage Alternatives

Based on the estimated future water demands relative to existing supply sources, a range of water storage alternatives were developed and considered by the PAC. Despite estimated water demands, the physical ability to store water can be limited by a basin's natural characteristics, including topographic suitability for constructing surface reservoirs and hydrogeologic suitability for making use of subsurface reservoirs (ASR). A range of storage components including both surface reservoirs and ASR were therefore initially developed using existing information. The components were then assembled into storage alternatives for evaluation and discussion with the PAC. The surface and ASR storage components considered in the assessment are described below.

5.1 Surface Reservoir Components

As an initial step in the development and analysis of water storage alternatives, the topography of the study area was evaluated to identify potential locations for surface reservoirs. A range of potential surface reservoir locations were identified across the Horse Heaven that would make use of the natural topography, such as deeply incised canyons, to provide water storage volume. In general, the larger, more deeply incised canyons amenable to larger-scale reservoirs occur predominantly in the western Horse Heaven. There are fewer such canyons in the central and eastern portions of the subbasin.

Conceptual surface reservoir locations and storage sizes were determined through review and evaluation of topography for the study area. Reservoir volumes were estimated using AutoCAD software and 10-foot contours generated from United States Geological Survey (USGS) digital elevation model (DEM) data. The contours were used to model the potential reservoir volume and materials quantities that would result from construction of a dam or embankment across a deeply incised canyon or around a topographical depression. An effort was made to maximize the storage volume available at each potential storage site by adjusting the location and height of the dam or embankment. For storage calculations, the dam or embankment at each storage location was assumed to be an earthen dam with an upstream side slope of 2.5H:1V (Horizontal:Vertical) and a downstream side slope of 2.0H:1V. Reservoir freeboard, which is the difference in elevation between the maximum water surface and the crest of the dam or embankment, was assumed to be 5 feet for all reservoir sites, except for reservoir sites on Lower Alder Creek, where a freeboard of 10 feet was assumed. Embankments were assumed to have a top width of 15 feet.

Figure 5 illustrates the locations and sizes of the twelve surface reservoir options considered in the assessment. A planning-level opinion of probable construction costs was prepared for each surface reservoir. The opinions of cost included preliminary estimates of the quantities and costs associated with each of the following construction and implementation related activities:

- Site work – Site work included in the preliminary opinion of cost for each reservoir site would include clearing and grubbing, temporary access for construction, permanent access for operations and maintenance, stripping and stockpiling of topsoil and organic material, erosion and sediment control in accordance with local and state construction stormwater permit requirements, diversion and care of naturally occurring surface water and groundwater, revegetation of disturbed areas not submerged by the reservoir, and installation of perimeter fencing.
- Earthwork – Earthwork quantities and costs included in the preliminary opinion of cost for each reservoir would include excavation and stockpile of soil and rock for the foundation of the embankment, placement of grout for the reservoir foundation, excavation and stockpile of soil for construction of a cutoff trench under the embankment foundation, installation of toe and finger drains, placement of imported and native materials for embankment construction, disposal of excess excavated material, and surfacing of the embankment crest. The preliminary estimate of embankment quantities assumes that excavation for the embankment would be 50% in loose soils and 50% in soils that were predominantly rock or bedrock.
- Piping and Conveyance Systems – The preliminary opinion of costs for each reservoir includes inlet piping (within 500 feet of the reservoir) and outlet piping (through the embankment). The opinions of cost for storage reservoirs do not include costs for pumping and conveyance systems needed to convey water to the reservoirs from the river for storage or from the reservoirs to irrigated areas for use. These costs of pumping and conveyance facilities were evaluated separately as part of the development the comprehensive improvement alternatives presented in Section 5.3.
- Emergency Spillway – The preliminary opinion of cost for each reservoir includes an allowance for construction of a spillway channel. Spillway channels would likely be constructed of reinforced concrete or gabion structure and would be sized to discharge the probable maximum flood (PMF) flow to prevent overtopping or damage to the embankment during the an extreme flood event.
- Other allowances – The preliminary opinion of costs developed for each reservoir site also included allowances for mobilization and demobilization (10% of the subtotal of other construction costs); environmental mitigation (10% of the construction subtotal); contingency (30% of the construction subtotal); and engineering, permitting and administration (15% of the construction subtotal). The total project cost also included an allowance for taxes (7.0% of the project subtotal with other allowances) and land acquisition ($1,000 per acre).

Table 2 provides a summary of the potential storage reservoirs that were identified as part of this analysis, including the estimated storage capacity, maximum water surface elevation, and the total opinion of probable costs for each of the reservoirs in terms of 2010 dollars and 2010 dollars per acre-foot of storage capacity. The total opinion of probable project costs ranges from $15 million for a 3,000 acre-foot reservoir on East Glade Creek to approximately $516 million for 300,000 acre-feet of storage in Lower Alder Creek (based on concept from Bureau of Reclamation, 2005). On a unit cost basis, the cost of the reservoirs ranges from approximately $1,700 per acre-foot of storage in Lower Alder Creek to approximately $4,800 per acre-foot of storage on East Glade Creek.

Conservative assumptions were made in developing these planning level opinions of cost. The cost of surface water storage reservoirs may change as key variables are more clearly defined, such as availability and suitability of on-site rock and soils for reservoir construction, on-site sub-surface soil conditions, embankment design and construction, environmental mitigation and permitting requirements, and availability of property. For example, development of these costs assumed an earthen embankment. Additional analysis may indicate that a different embankment design, such as a concrete-faced rock-fill dam, would be more cost effective. Additional site investigations and design analysis will be required to more clearly define costs associated with surface storage projects that are carried forward as part of a preferred alternative.

5.2 ASR Component

Locations of subsurface reservoirs for ASR are determined based on hydrogeologic suitability including aquifer yield, which is a function of formation permeability and presence of geologic structures, as well as ambient groundwater quality. While the Wanapum Basalt is the target aquifer for ASR in the Horse Heaven, a detailed assessment of hydrogeologic suitability for ASR has not been conducted, so specific locations for an ASR wellfield are not defined. However, for the purposes of this initial assessment, the following preliminary assumptions were made for the ASR component:

- A single ASR well would be capable of an 800 gallons per minute (gpm) continuous injection (recharge) rate, as the limiting factor on storage volume. For an assumed 5-month recharge period, this rate equates to roughly 500 acre-feet/year of stored water per ASR well. Given the highly transmissive Wanapum Basalt aquifer known within the western Horse Heaven, this may be a conservative assumption.
- ASR would be accomplished using a wellfield of up to 10 ASR wells completed within a roughly 2-square mile area, providing a wellfield capacity of up to 5,000 acre-feet/year. While closer spacing of wells is counterproductive for conventional groundwater withdrawal (production wells), it can provide improved recovery efficiency for ASR (Pyne, 2005).
- No more than one ASR wellfield would be sited within areas of the Wanapum aquifer bounded by the inferred hydraulic barrier faults (i.e., within potential aquifer “blocks” created by the inferred faults shown on Figure 3).

- Source water for ASR would be supplied from a Ranney well installed in the Columbia River Gravels, so as to provide natural river bank filtration for removal of turbidity and bacteria from river water. Significant accumulations of gravels are present along the shore of the Columbia River in several areas, and lesser deposits are present in most areas, of the Horse Heaven. A Ranney well is assumed to supply 20 cfs (13 MGD) of source water, based on available information including the City of Kennewick's Ranney well #5 withdrawing from Columbia River Gravels just upstream in WRIA 31. This equates to about 6,100 acre-feet of source water per Ranney well for 5 months of continuous pumping.

5.3 Storage Alternatives Considered

5.3.1 Nine Initial Alternatives

After early discussions with the WRIA 31 PAC and its Water Storage Subcommittee regarding water demands and the storage components outlined above, nine initial water storage alternatives were assembled from the storage components for comparative evaluation and further discussion with stakeholders. Because of the vast size of the Horse Heaven, and potential differences in water demands between the western and eastern parts of it, seven alternatives were initially developed for the western and eastern portions of the Horse Heaven – divided along Highway 221. In addition, two larger-scale conceptual alternatives (annual storage > 250,000 acre-feet), previously developed by others, were retained for comparative evaluation. The general elements for the nine initial alternatives are listed below.

1. **Western Alternative A** (Surface reservoirs)
   - High capacity Columbia River pump station near Alderdale
   - Main delivery pipeline extending approximately 11 miles inland
   - Surface reservoirs in upper reaches of tributaries (e.g., Glade Creek, Dead Canyon, Alder Creek)
   - Canals and/or pipelines deliver from reservoir(s) to farms
   - Winterize and use existing diversion/conveyance infrastructure to extent practical
2. **Western Alternative B** (Aquifer storage)
   - High capacity Ranney well in Columbia River gravels near Alderdale
   - Main delivery pipeline extending approximately 11 miles inland
   - High capacity aquifer storage and recovery (ASR) wells distributed near areas of use and completed in Wanapum Basalt aquifer
   - Canals and/or pipelines deliver from reservoir (ASR wells) to farms
   - Winterize and use existing diversion/conveyance infrastructure to extent practical
3. **Western Alternative C** (Combined surface and aquifer storage)
   - High capacity Ranney well(s) in Columbia River gravels near Alderdale
   - Main delivery pipeline extending approximately 11 miles inland

- Surface reservoirs and high capacity ASR wells
- Canals and/or pipelines deliver from reservoir(s) to farms
- Winterize and use existing diversion/conveyance infrastructure to extent practical

4. **Western Alternative D** (Combined surface and aquifer storage, plus delivery into Yakima Basin)
   - High capacity river station and/or Ranney well(s) in Columbia River gravels near Alderdale
   - Surface reservoirs and high capacity ASR wells within Horse Heaven
   - Main delivery pipeline extending 25-30 miles inland, over the ridge of the Horse Heaven to the Mabton/Prosser area to augment water supply for the Yakima River basin (larger capacity pipeline than Western Alternatives 1-3)
   - May consider dual pipelines – one supplying ASR storage sites and one surface reservoir(s) and into Yakima basin
   - Canals and/or pipelines deliver from reservoir(s) to farms within Horse Heaven
   - Winterize and use existing diversion/conveyance infrastructure to extent practical
5. **Eastern Alternative A** (Surface reservoirs)
   - High capacity Columbia River pump station near Plymouth
   - Main delivery pipeline extending 8 to 10 miles inland
   - Surface reservoir(s) in tributaries (e.g., Carter Canyon, Four Mile Canyon, Switzler Canyon)
   - Canals and/or pipelines deliver from reservoir(s) to farms
   - Winterize and use existing diversion/conveyance infrastructure to extent practical
6. **Eastern Alternative B** (Aquifer storage)
   - High capacity Ranney well in Columbia River gravels near Plymouth
   - Main delivery pipeline extending 8 to 10 miles inland
   - High capacity ASR wells distributed near areas of use
   - Canals and/or pipelines deliver from reservoir (ASR wells) to farms
   - Winterize and use existing infrastructure to extent practical
7. **Eastern Alternative C** (Combined surface and aquifer storage)
   - High capacity Ranney well in Columbia River gravels near Plymouth
   - Main delivery pipeline extending 8 to 10 miles inland
   - Surface reservoir(s) and high capacity ASR wells
   - Canals and/or pipelines deliver from reservoir(s) to farms
   - Winterize and use existing diversion/conveyance infrastructure to extent practical

8. **Large Surface Reservoir in Lower Alder Creek** (concept from Bureau of Reclamation, 2005)
    - Store approximately 300,000 acre-feet of water within a 3,400-acre reservoir approximately 1 mile upstream of the mouth of Alder Creek (3,200-foot long, 335-foot tall dam, plus 7,000-foot long, 70-foot high saddle dam forming east side of reservoir)
    - High capacity river pump station on Columbia River near Alderdale to fill reservoir
    - High capacity pump station in reservoir, with main delivery pipeline extending inland (delivery from reservoir was not evaluated in Bureau of Reclamation, 2005)
    - Canals and/or pipelines deliver from main pipeline to farms
9. **Basin-Wide Canals Alternative** (concept from Nakaty, 2006, minus westernmost low elevation canal and reservoirs in that concept)
    - High capacity pump station on Columbia River near southeastern corner of Horse Heaven
    - Pump stations lift water to four main canals running generally east to west, approximately along elevation grades (1000-, 1200-, 1400-, and 1500-foot canals; nearly 150 miles combined total length)
    - Several surface reservoirs in upper reaches of tributaries (Carter Canyon, Glade Creek, Tule Canyon, Alder Creek)
    - Smaller canals and/or pipelines deliver from main canals/reservoirs to farms
    - Produce energy during release from high-elevation reservoirs via pipelines, and from wind turbines (combined water/energy utility)

A planning-level cost estimate was developed for each alternative, except alternatives 8 and 9. Bureau of Reclamation's (2005) cost estimate was used for alternative 8. The cost estimates for alternatives 1 through 7 used consistent assumptions (including use of all new infrastructure), and were intended solely for relative comparison between alternatives. The cost information was a primary factor in moving forward with refinement of the alternatives. Table B-1 in Appendix B summarizes intended water supply goals and planning-level cost information for the nine initial alternatives discussed with the PAC.

5.3.2 Preliminary Preferred Alternatives

Based on PAC review and discussion of the initial alternatives and their relative costs, a pair of preliminary preferred alternatives was developed for further evaluation and discussion. The two alternatives – termed Alternatives A and B - provided for large storage volumes (270,000 to 370,000 acre-feet/year) with delivery throughout the entire Horse Heaven. Each alternative included a phased build out, adding storage components over time to keep pace with gradual growth in water demands. General elements of the two alternatives, including water supply goals and phasing of the specific storage components, are outlined below.

Alternative A (ASR, 3 High Elevation Surface Reservoirs, and Switzler Canyon Reservoir; 270,000 AFY Storage)

Phase 1

- East and west river pump stations, main supply pipeline sized for ultimate buildout, ASR wellfields, distribution conveyance from wellfields to farms.
- 30,000 AFY storage capacity.
- Water supply goals:
  - Irrigate limited new acreage throughout Horse Heaven; and
  - Curb aquifer overdraft in Western Horse Heaven.

Phase 2

- Switzler Canyon reservoir with booster pump and distribution conveyance to farms, added river pump station capacity, and potentially infrastructure for pumped storage.
- 40,000 AFY storage capacity (70,000 AFY storage cumulative).
- Water supply goals:
  - Flow augmentation to supply interruptible water rights (not addressed by Lake Roosevelt incremental releases or CSRIA VRA) and/or mitigate for new Columbia River diversions in July-August, from McNary or John Day Pools;
  - Irrigate limited new acreage in eastern Horse Heaven; and
  - Potentially, small-scale production of peak-demand energy through pumped storage (multipurpose).

Phase 3

- Tule Canyon reservoir, added river pump station capacity, and distribution conveyance to farms.
- 100,000 AFY storage capacity (170,000 AFY storage cumulative).
- Water supply goals:
  - Irrigate considerable new acreage throughout Horse Heaven; and
  - Source replacement to curb aquifer overdraft in Western Horse Heaven.

Phase 4

- Upper Glade Canyon A and B reservoirs, added river pump station capacity, and distribution conveyance to farms.
- 100,000 AFY combined storage capacity (270,000 AFY storage cumulative).
- Water supply goals:
  - Irrigate considerable new acreage throughout Horse Heaven;
  - Source replacement to curb aquifer overdraft in Western Horse Heaven; and
  - Potentially deliver water to Yakima Basin.

Alternative B (ASR, Lower Alder Creek and Switzler Canyon Reservoirs; 370,000 AFY Storage)

Phase 1

- East and west river pump stations, main supply pipeline sized for ultimate buildout, ASR wellfields, distribution conveyance from wellfields to farms.
- 30,000 AFY storage capacity.
- Water supply goals:
  - Irrigate limited new acreage throughout Horse Heaven; and
  - Curb aquifer overdraft in Western Horse Heaven.

Phase 2

- Lower Alder Creek reservoir with booster station and distribution conveyance to farms, added river pump station capacity, and potentially infrastructure for pumped storage.
- 300,000 AFY storage capacity (330,000 AFY storage cumulative).
- Water supply goals:
  - Irrigate considerable new acreage throughout Horse Heaven;
  - Flow augmentation to supply interruptible water rights (not addressed by Lake Roosevelt incremental releases or CSRIA VRA) and/or mitigate for new Columbia River diversions in July-August from John Day Pool;
  - Source replacement to curb aquifer overdraft in Western Horse Heaven; and
  - Potentially, small-scale production of peak-demand energy through pumped storage (multipurpose).

Phase 3

- Switzler Canyon reservoir with booster pump and distribution conveyance to farms, added river pump station capacity, and potentially infrastructure for pumped storage.
- 40,000 AFY storage capacity (370,000 AFY storage cumulative).
- Water supply goals:
  - Flow augmentation to supply interruptible water rights (not addressed by Lake Roosevelt incremental releases or CSRIA VRA) and/or mitigate for new Columbia River diversions in July-August from McNary or John Day Pools;
  - Irrigate limited new acreage in eastern Horse Heaven; and
  - Potentially, small-scale production of peak-demand energy through pumped storage (multipurpose).

Based on PAC review and discussion of the preliminary preferred alternatives, a substantially revised set of alternatives were developed, as described below.

5.3.3 Revised Alternatives

The revised alternatives were individually smaller than the previous pair, and more explicitly assumed use of existing infrastructure (Columbia River pump stations and piping) to reduce project capital costs. The general elements of the revised alternatives are as follows:

1) Western Surface Storage (Alder Reservoir)

- Alder Creek reservoir, reduced in size to facilitate permitting; 65,000 AFY storage capacity
- If owner agreement is obtained, use existing assumed 207 cfs Columbia River pumping station, winterized, to pump to storage
- Use existing conveyance to extent practical
- Distribution system from reservoir to farms (not defined)
- Potential water supply to:
  - Irrigate new acreage
  - Curb aquifer overdraft
  - Supply interruptible water rights
  - Mitigate for new diversions from John Day Pool (e.g., July-August)
  - Improve habitat in lowermost Alder Creek

2) Western ASR

- Two ASR wellfields; 10,000 AFY storage capacity
- New Ranney wells near Alderdale pump to storage
- Use existing conveyance to extent practical
- Distribution system from reservoir to farms (not defined)
- Potential water supply to:
  - Irrigate limited new acreage
  - Curb aquifer overdraft
  - Supply interruptible water rights

3) Central Surface Storage (Carter and East Glade Reservoirs)

- Carter Canyon and East Glade Creek reservoirs; 8,000 AFY storage capacity
- If owner agreement is obtained, use existing assumed 147 cfs pumping station, winterized, pumps to storage (partial capacity)
- Use existing conveyance to extent practical
- Distribution system from reservoir to farms (not defined)
- Potential water supply to:
  - Irrigate new acreage
  - Supply interruptible water rights

4) Eastern ASR

- Two ASR wellfields; 10,000 AFY storage capacity
- New Ranney wells at Plymouth pump to storage
- Use existing conveyance to extent practical
- Distribution system from reservoir to farms (not defined)
- Potential water supply to:
  - Irrigate limited new acreage
  - Supply interruptible water rights

5) Eastern Surface Storage (Switzler Reservoir)

- Switzler Canyon reservoir; 44,000 AFY storage capacity
- New pump station pumps to storage, unless an existing pump station is more cost effective
- Use existing conveyance to extent practical
- Possible: Distribution system from reservoir to farms (not defined)
- Potential water supply to:
  - Supply interruptible water rights
  - Mitigate for new diversions from McNary or John Day Pools (e.g., July-August)
  - Irrigate new acreage
  - Improve habitat in lowermost Switzler Canyon
  - Possible small-scale pumped storage

These alternatives and their planning-level cost estimates were discussed with the PAC. There was a general consensus from the PAC that the estimated cost per acre-foot of water delivered was too high, and that a refined alternative(s) should be developed specifically to deliver water at the lowest possible cost, including maximizing use of existing infrastructure (retrofitted as needed for winter use). In that same general timeframe, a meeting with Ecology clarified their expectation that the project should focus solely on placing water into storage, and assume that costs to deliver it from storage for use would be borne by end user (not part of project cost estimate).

With this direction, a refined preferred storage alternative, combining the revised alternatives 1, 2, and 5 above, was developed and discussed with the water storage subcommittee of the PAC. Based on discussion with the subcommittee, and then the full PAC, that alternative is being advanced as the preferred water storage alternative as described below.

6 Preferred Water Storage Alternative

Following evaluation of numerous water storage alternatives, and extensive discussions and meetings with the PAC, a water storage subcommittee of the PAC, and other local stakeholders, the preferred alternative consists of three primary storage elements as illustrated on Figure 6:

1. **Switzler Reservoir:** an in-channel reservoir in the lower reaches of Switzler Canyon, a tributary to McNary Pool, with an estimated total storage capacity of roughly 44,000 acre-feet;

2. **Alder Reservoir:** an in-channel reservoir in the lower reaches of Alder Creek, a tributary to John Day Pool, with an estimated total storage capacity of roughly 56,000 acre-feet to 300,000 acre-feet (depending on whether potential impacts identified with the large scale project can be effectively mitigated). The smaller scale reservoir storage volume is assumed for purposes of further evaluation of the preferred project alternative in this report; and

3. **Aquifer Storage and Recovery (ASR) in the western study area:** The annual storage capacity for ASR is unknown but, given exceptionally high well yields and groundwater declines of up to 250 feet, we expect that the Wanapum Basalt aquifer in the western part of the Horse Heaven can provide substantial subsurface storage capacity. The localized large water level declines appear to result, in part, from geologic structures creating groundwater flow barriers; these same barriers could be a benefit for creating a viable subsurface reservoir. Overall, the western portion of the Horse Heaven appears to be a prime candidate for further evaluating the feasibility of applying ASR in the Columbia River Basalts, and using the stored water for irrigation supply.

Under the preferred project, Columbia River water would be diverted and pumped to storage in the surface and subsurface reservoirs predominantly during the non-irrigation season. For this, existing pump station and conveyance infrastructure would be used to the maximum extent practical in terms of physical suitability, cost effectiveness (compared to new construction), and owner willingness to participate.

During the irrigation season, water stored in the Switzler and Alder reservoirs would be released back to the Columbia River or directly pumped from the reservoir by nearby irrigators using their systems. The stored water provides a new seasonal water supply to mitigate for interruptible water rights during drought years (sustaining current agriculture, and providing mitigation water for exercise of the Quad Cities municipal water right) and/or for new water rights (expanding the agricultural economy). Water released from the Alder Reservoir would mitigate for diversions from John Day Pool or any downstream reach of the mainstem. Water released from the Switzler Reservoir would mitigate for diversions from McNary Pool, John Day Pool, or any downstream reach of the mainstem.

The released water, drawn from the deepest part of each reservoir, would also augment instream flows below the reservoir for aquatic habitat benefit within the tributary stream

and the mainstem. The release would be controlled so as to not erode or otherwise impact the stream channel below the reservoir, which may require releasing a portion of the water via pipeline back to the mainstem Columbia River, bypassing the stream channel. In other words, the quantity of water released to the tributary downstream of the reservoir would be optimized to achieve the maximum practicable instream benefit to the tributary; the rest of the water would be bypassed.

During the irrigation season, the stored ASR water would be recovered (pumped) for beneficial use in one or more ways. The recovered water could be distributed directly to nearby farms, or potentially could be released back to the Columbia River via stream channel(s) (perhaps via the Alder reservoir) under the same mitigation concept as described for the surface reservoirs. If water were released from an ASR wellfield in the western study area, it would mitigate for diversions from John Day Pool or any downstream reach of the mainstem.

The preferred project would provide a substantial new water supply that can be accessed for out-of-stream or instream use anywhere within WRIA 31 or in WRIAs downstream of it, via diversion from the Columbia River (subject to economic constraints of pumping from the river to points of use). The project involves putting water into storage, and establishing mitigated water rights for use of the stored water. Distribution and use of the stored water, i.e. exercising the mitigation water rights, is outside of the project. However, there is surplus capacity in existing irrigation infrastructure within the watershed that could assist in distribution to new acreage. The details regarding administration of the storage project, including allocation of the stored water, would be defined as part of a subsequent appraisal-level study.

7 Benefits of Project

As described in Section 4, the WMP identifies four general demands for developing additional water supplies that are applicable to the Horse Heaven:

- Replacing non-sustainable groundwater withdrawals for irrigation;
- “Shoring up” interruptible water rights;
- Economic development principally through expansion of higher-value (irrigated) agriculture; and
- Improving instream conditions for aquatic habitat.

The first two demand categories are aimed at sustaining the existing level of irrigated agriculture, whereas the third supports economic growth for the area and the fourth provides for instream benefits in balance with out-of-stream benefits achieved under the other three demands, in accordance with the WMP.

The preferred storage project (assuming the smaller scale Alder Reservoir storage volume) is relatively large – roughly 100,000 acre-feet of storage estimated – and can meet at least three of the four WMP demand priorities. If the potential impacts identified with the larger scale Alder Reservoir storage project can be effectively mitigated, then it would add an additional 244,000 acre-feet toward meeting the four demand priorities. The identified project benefits are briefly summarized as follows:

1. **Sustain existing groundwater-supplied irrigation** by using ASR and potentially source exchange (using stored surface water in lieu of groundwater) to reverse the ongoing groundwater overdraft. Both storage methods would reduce the net groundwater withdrawal from the Wanapum Basalt aquifer: ASR by increasing aquifer recharge and source exchange by reducing groundwater withdrawal. In both cases, the net volume of groundwater withdrawal from the aquifer is brought back toward balance with the volume of natural recharge to the aquifer. At this point, ASR is assumed to occur in the western Horse Heaven where large declines have occurred. Successful application of ASR, including addressing water quality permitting issues specific to irrigation use, could facilitate expansion of ASR throughout WRIA 31 and more broadly within the Columbia River basin.

2. **Address interruptible water rights** by providing mitigation water to offset (1:1) consumptive use under those rights during times when Columbia River instream flow minimums are not met. Based on the Department of Ecology's WRTS, we estimate that WRIA 31 water rights interruptible under chapter 173-563 WAC total roughly 50,000 acre-feet/year. In addition, the Quad Cities water right is an interruptible permit (96,619 acre-feet/year) subject to instream flow minimums dictated by the National Marine Fisheries' (NMFS) biological opinion (BiOp). The proposed storage project is large enough to address all WRIA 31 water rights interruptible as per chapter 173-563 WAC, plus provide mitigation water (from Switzler reservoir) for a portion of the Quad Cities water right.

3. **Achieve regional economic development** by making available new irrigation water supplies that would allow additional higher-value crop acreage to be brought into production. Economic growth in WRIA 31 will be achieved largely through growth in agriculture, specifically higher-value crops that rely on irrigation. The Horse Heaven supports a diverse range of crops, and is Washington's newest American Viticultural Area (AVA). There are tens of thousands of irrigable acres in the Horse Heaven that could be brought into production if additional water was available at a reasonable cost. The economic benefit to the state from expanded agricultural development in the Horse Heaven is outside the scope of this pre-feasibility assessment, but was previously assessed in Washington State University's 1970 multidisciplinary study entitled "Horse Heaven Hill Irrigation and Development Potential". The study concluded that the Horse Heaven contains about 10% of all irrigable land in the state, and estimated that gross agricultural income could increase by more than $60 million/year for partial irrigation expansion to more than $600 million/year for irrigation of all irrigable acres. Further employment in the region would also be achieved with introduction of processing plants and supporting service and trade businesses.

The 1970 study, while outdated now and evaluating larger-scale irrigation expansion than the preferred project by itself would provide for, nonetheless provides useful perspective on the magnitude of economic benefit to the state from agricultural development in the Horse Heaven. Washington State University is preparing the 2011 Water Supply and Demand Inventory under the Columbia River Basin Water Supply Development Act, which will focus on future irrigation demands and economics.

4. **Improving aquatic habitat** within the lowermost reaches of Alder Creek and Switzler Canyon, downstream of the proposed reservoirs, including creating thermal refuge for migrating salmonids in the mainstem. Construction of in-channel storage reservoirs could provide year-round flow in the lowermost reaches of these naturally intermittent streams, and the release quantity and timing could be controlled to optimize habitat benefit. Subject to natural constraints, in-channel habitat improvements could also be designed and constructed to establish channel gradients, meander configurations, and instream structure conducive to successful juvenile salmonid rearing and adult spawning habitat downstream of the reservoir. In addition, the released water would marginally improve instream flows in the mainstem Columbia River during the critical months of July and August.

5. **Maximizing use of existing irrigation infrastructure** to most cost effectively bring new acreage into production of high-value crops. Discussions with irrigators across the watershed confirm that existing river pump station/conveyance systems have surplus capacity now, or that additional capacity could be added at relatively low incremental cost. While this project only addresses making available new water rights by placing water in storage, it appears that economic development by exercising those new rights could be accomplished cost effectively. How the new water supply would be allocated could be complicated, and therefore would be a topic for a subsequent appraisal-level study.

8 Fatal Flaw Analysis

Based on the available information assembled during this Pre-Feasibility Assessment, no fatal flaws are currently identified for the preferred storage alternative. Because of additional time and effort spent working with stakeholders to establish the preferred storage alternative, the level of detailed evaluation originally anticipated in scoping of the Ecology grant for the project has not been completed. However, analysis of potential fatal flaws has been completed, focusing on water availability from the Columbia River, permitting (e.g., aquatic habitat), and geologic suitability of the two surface reservoir sites, as presented below.

The fatal flaw analysis did identify potential project impacts, most importantly with regard to the storage volume of the Alder reservoir alternative, that would either need to be mitigated or the alternative modified to avoid impact. If mitigation of the large scale

project is not feasible, then potential impacts can be avoided by reducing the proposed size of the Alder reservoir from that initially considered by the Bureau of Reclamation (Reclamation) in their 2005 appraisal evaluation of Columbia River mainstem off-channel storage options (330,000 acre-feet; initial alternative 8 in Section 5.3.1). The main dam for the reservoir proposed by Reclamation would be positioned at river mile 1, inundating all but the lower mile of Alder Creek including the area of perennial flow supplied by a major spring ("Sally Spring") as well as several miles of Six Prong Creek, a major tributary to Alder Creek which reportedly contains 18 acres of wetlands. The reservoir alternative proposed by Reclamation would also inundate and require relocation of a couple miles of Alderdale Road and several miles of a regional natural gas pipeline. A more detailed evaluation of the permitting issues (including mitigating for potential habitat impacts), project costs, and public acceptance of the larger scale Alder reservoir as proposed by Reclamation is required to determine the feasibility of that project. For purposes of this pre-appraisal evaluation and the uncertainty with the larger scale Alder reservoir, it was decided to include in the preferred storage alternative a smaller (56,000 acre-feet) version of the Alder reservoir, with the main dam located further upstream to reduce impacts and mitigation costs. The following evaluation of the preferred storage alternative assumes the smaller version of the Alder reservoir.

8.1 Water Availability to Store

In the preferred project, Columbia River water would be diverted and pumped to storage in the surface and subsurface reservoirs predominately during the non-irrigation season (assumed to be November 1 to March 31). An analysis was completed to determine the amount of Columbia River water that would be available for pumping during the non-irrigation season.

For this analysis, Columbia River water is assumed to be available after instream flows are met. Minimum instream flows have been set by the State of Washington for the Columbia River for use in protecting instream values and regulating water rights. Those flows are described in chapter 173-563 WAC, which was implemented in 1980. Target flows were also agreed upon by federal agencies as part of the 2004 BiOp for the Federal Columbia River Power System (FCRPS). The target flows facilitate spawning and downstream passage of juveniles and accommodate returning adult salmon and steelhead. These flows are tabulated in Table 3.

Due to the dates Columbia River water is assumed to be diverted by the preferred project, the Bonneville BiOp target flows control the water available for pumping. For this preliminary analysis, it was assumed that the highest BiOp flow target (160,000 cfs) is required for the duration of the time pumping to storage will take place (November 1 to March 31). It was also assumed that all other Columbia River water demand requirements have already been met and have been removed from the observed flow below Bonneville Dam. Figure 7 and Table 4 show the estimated volumes of water available in the Columbia River from November 1 to March 31 based on the average flow measured below Bonneville Dam from 1971 to 2000.

8.2 Permitting

Implementation of a water storage project, particularly one involving in-channel reservoirs, would involve substantial project review including an environmental impact statement (EIS) and would require multiple permits. For a project to be permittable, adverse environmental impacts would need to be fully mitigated to achieve a net environmental benefit, particularly in terms of instream habitat function and value.

8.2.1 Environmental

Instream and terrestrial habitat conditions in Alder Creek and particularly in Switzler Canyon are not well documented. Landowner permission was not granted to collect instream habitat information in Alder Creek during the 2009 WRIA 31 instream habitat assessment, and Switzler Canyon was not surveyed (WPN, 2009). Both drainages are intermittent, excluding the lower mile of Alder Creek in which a small volume of perennial flow is sustained by a spring (Sally Spring). Potential salmonid spawning and rearing habitat has been reported in Alder Creek from its mouth upstream to Six Prong Creek. In 2005, NOAA Fisheries designated habitat in the lower three miles of Alder Creek as critical habitat for the recovery of Mid-Columbia Steelhead; Switzler Canyon was not designated as such. Alder Creek is also considered by the Interior Columbia Basin Technical Recovery Team (ICTRT) to provide spawning habitat for the Umatilla Steelhead Distinct Population Segment (DPS); Switzler Canyon was not so designated. Known presence of steelhead in Alder Creek and Switzler Canyon has not been documented. Steelhead adults have reportedly been observed in the lower 1.5 miles of Alder Creek.

To mitigate for lost habitat as a result of in-channel reservoir construction and inundation, and to achieve a net benefit for aquatic species, the project could include habitat improvements downstream of the reservoirs. In addition to flow augmentation, habitat improvement projects could include construction of channel meanders, revegetation, and features such as side channels and instream structure to create habitat complexity. In this way, the quantity of habitat lost as a result of inundation could be replaced and the quality of habitat in the mile or more of channel downstream of the reservoirs could be markedly improved. As part of the permitting process, resource agencies and tribal governments would be consulted regarding habitat-related actions. No fatal flaw is identified at this time regarding environmental permitting.

Appendix A provides a summary of existing information regarding instream habitat conditions in Alder Creek and Switzler Canyon, as well as preliminary information regarding potential instream effects and benefits associated with the current surface reservoir concepts.

In their preliminary screening assessment of Alder Creek as a prospective reservoir site, Bureau of Reclamation (2005) identified terrestrial habitat for western gray squirrel (State of Washington threatened species) and several candidate endangered terrestrial species (owl, shrike, rabbit). We are aware of no other assessment of terrestrial species and habitat in Alder Creek or Switzler Canyon.

8.2.2 Water Rights/Dam Safety Permitting

No fatal flaws are identified with respect to water right permits or dam safety permits for the project. The preferred project would require a new primary water right to seasonally divert Columbia River water to the storage reservoirs (surface and subsurface [ASR]). The permit would identify the points of diversion, the use of storage, and would authorize beneficial use of the stored water. A reservoir permit to store water in each reservoir would also be required.

For the project to be viable, it would only pump water into storage when Columbia River water is available for diversion, it would not impair existing water rights or instream flows and would fully mitigate for adverse environmental impacts, and it would not be contrary to the public interest. At this point, it is expected that, through early communications with Ecology, resource agencies, and tribal governments, this can be accomplished. Therefore, no fatal flaw is identified for obtaining necessary water rights for the project.

The surface reservoirs would be designed to comply with dam safety requirements, thus obtaining a Dam Safety Permit is not considered a fatal flaw for the project.

8.3 Geologic Suitability for Reservoirs

Based on available information, no fatal flaws are identified with respect to geologic suitability of the in-channel reservoir sites, but more detailed site-specific assessment of each reservoir site is warranted in an appraisal-level study. Pertinent information regarding suitability of surface reservoir sites is presented below.

8.3.1 Alder Reservoir

Within the area of the proposed Alder Reservoir, the Alder Creek canyon is incised through bedrock predominantly consisting of the Pomona member of the Saddle Mountains Basalt (per DNR 1:100,000 geologic mapping). Overlying the Pomona member, the younger Elephant Mountain member of the Saddle Mountains occurs around the perimeter of the reservoir's lower extent. Within the reservoir footprint, the basalt members are comprised of one or more individual basalt flows separated by permeable interflow zones that typically transmit water readily. The available geologic mapping is not detailed enough to identify individual flows and interflows within each basalt member. At a minimum, an interflow zone exists at the contact between basalt members.

Regionally, the two basalt members are separated by the Selah sedimentary interbed, which can vary from fine-grained siltstone to more coarse-grained sandstone and conglomerate. However, no sedimentary interbed units (Ellensburg Formation) are mapped on the valley walls in or around the Alder Reservoir area. A veneer of recent alluvium is present along Alder Creek in the valley bottom. On the uplands outside of the reservoir footprint, the bedrock is overlain by geologically younger Touchet Beds (silt and sand) and Pasco Gravel.

Of particular note within the reservoir footprint are the mass wasting (landslide) deposits mapped across larger areas of the valley walls. The Selah interbed is probably responsible for the extensive low-angle landside deposits. These sedimentary interbeds can contain a high clay/silt content and can be unstable when saturated. Driller's logs for wells closest to the Alder reservoir indicate the interbeds are predominantly clay, sometimes

referenced as “caving”. Although the landslides may have originated during extensive wetter climates (early Holocene), they are a potential issue for reservoir construction.

No geologic folds or faults are mapped in the immediate vicinity of the reservoir, but thrust faults are extensively mapped elsewhere in the Columbia Hills south of the reservoir. Regional studies suggest that some of the faults in the Yakima Fold Belt remain active (Holocene age with potential to reactivate).

8.3.2 Switzler Reservoir

Within the area of the proposed Switzler reservoir, Switzler Canyon is incised through geologically older basalt bedrock than observed in Alder Creek. The valley bottom is incised into the Frenchman Springs Member of the Wanapum Basalt, which is overlain unconformably by the Umatilla Member of the Saddle Mountains Basalt. The intervening Pomona and Elephant Mountain Members of the Saddle Mountains Basalt are not mapped, which, if accurate, indicates an erosional unconformity in the geologic record. The available geologic mapping is not detailed enough to identify individual flows and interflows within each basalt member but, at a minimum, an interflow zone exists at the contact between basalt members.

No sedimentary interbeds are mapped between the basalt members. Driller’s logs for the few wells drilled near Switzler Canyon indicate sedimentary interbeds are present, but they are thinner and less prevalent than observed in wells within the Alder Creek drainage. Outside of the canyon, the uplands are capped with loess (wind-blown silt), a small area of which lies within the reservoir footprint. The mapping indicates no significant alluvium in the valley bottom, and only one small area of landslide deposits on the eastern valley wall.

No geologic structures (folds or faults) are mapped in the vicinity of the Switzler Reservoir, but smaller-scale structures (unmapped) are possible given the geologic complexity of the region.

8.4 Hydrogeologic Suitability for ASR

Available hydrogeologic information assembled during the watershed planning process indicates that highly productive aquifers exist within the western portion of the Horse Heaven, where ASR is proposed as part of the preferred storage project. Specifically, the Wanapum Basalt aquifer is known to supply very high well yields (2,000+ gpm) for irrigation supply across this area. Over the past 30 years, the Wanapum Basalt aquifer in this area has experienced large water level declines (up to 250 feet; Figure 3), which has necessitated well deepening and increased pumping costs. The USGS’ 1996 modeling study of the Horse Heaven inferred, based on mapping of water levels and geologic contacts, that there are geologic faults, oriented northeast-southwest, that act as subsurface barriers to lateral groundwater flow in the basalt aquifers (shown on Figure 3). Such faults are not mapped by DNR. The location of the inferred barrier faults, which would hydrostratigraphically divide the Wanapum aquifer into “blocks”, is consistent with the pattern of groundwater level declines observed. Without such barriers, we expect that groundwater would flow more readily in the aquifer toward the pumping centers and dampen the magnitude of drawdown.

The large water level declines indicate that, at a minimum, a substantial subsurface storage volume would be available by replenishing those declines. The same barriers that appear to limit groundwater replenishment to the pumping centers should help form an effective subsurface reservoir in which to store artificially recharged water. The highly productive aquifer in this area should be capable of high rates of groundwater recharge and recovery. As such, it appears that ASR would be technically feasible, from a hydrogeologic standpoint, in the western Horse Heaven.

The greatest aquifer depletion in the western Horse Heaven occurs over a relatively wide area, spanning about 5 to 18 miles from the Columbia River. Pumping river water to the higher elevation areas at distance from the river, for direct use or for ASR, is likely not economical currently. However, if the fault-bounded Wanapum aquifer block concept is proven, it may be possible to recharge the aquifer block at a lower elevation location nearer the river, where conveyance and injection of river water would be more economical, and achieve a water level increase (pressurization) throughout the block including at greater distances from the river. Groundwater within an aquifer block should be able to flow laterally toward pumping wells within the same block, so recharging a block should slow or potentially reverse further water level decline in response to the current rate of withdrawal. Since an aquifer block would represent a distinct body of public groundwater, the recharge and recovery could occur at different locations in the block, subject to approval by Ecology.

A Ranney well would be constructed in the Columbia River gravels as the supply source for water to be stored in an ASR project. In addition to providing high capacity, the Ranney well provides for filtration through the gravels to remove suspended sediment and bacteria necessary to avoid ASR well clogging and meet groundwater quality standards for injection without additional treatment (disinfection). The City of Kennewick, an initiating government for WRIA 31 watershed planning process, operates Ranney wells for part of its water supply and has considerable knowledge regarding their water quality performance.

8.5 Conclusion from Fatal Flaw Analysis

A more detailed evaluation of potential impacts and mitigation options is required to determine the feasibility of the larger scale (roughly 300,000 acre-feet) Alder reservoir. No fatal flaws are currently identified with the WRIA 31 preferred water storage project (assuming the smaller Alder reservoir). However, a more detailed appraisal-level study is necessary to better define the technical, permitting, and economic feasibility of the project.

9 Planning-Level Project Cost Estimates ($/Acre-Foot Stored)

A planning level opinion of the probable capital costs associated with the preferred water storage project was developed in terms of 2010 dollars/acre-foot of annual storage capacity. An opinion of long-term project costs, including power costs (for pumping),

operations and maintenance costs, and loan repayment was also developed in terms of 2010 dollars/acre-foot of annual storage capacity. As noted previously in Section 5.3.3, Ecology indicated that their expectation was that the project would focus solely on putting water into storage. Consequently, the planning level opinion of probable costs only addresses placing water into storage; it does not include pumping and delivery improvements needed to distribute water from the Columbia River or storage locations to irrigators for use.

Project capital costs were evaluated in two ways. First, the project costs were evaluated assuming that existing irrigation systems would be used, to the extent possible, for pumping and conveyance of water from the Columbia River to surface water storage and ASR locations. This assumes that operators of suitable existing irrigation systems would make their systems available to pump water to storage during the non-irrigation season as part of the preferred project, which is not known at this preliminary stage[4]. Therefore, project costs were also evaluated assuming that all new pumping and conveyance facilities would be constructed to deliver water from the Columbia River to storage locations.

The planning-level costs conservatively assume that the surface reservoirs are filled entirely with water pumped from the Columbia River. Capture of natural stream discharge in each stream is not considered, which may slightly overstate pumping costs. It is likely that only flood water could be captured and retained in a reservoir as most flow entering the reservoir would likely need to be released to maintain downstream hydrologic conditions. Natural discharge contribution to each reservoir would be evaluated as part of an appraisal-level study.

Table 5 provides a summary of the costs of each component of the preferred water storage project. The following summarizes the facilities and improvements identified for each component of the preferred water storage project and the key assumptions used to develop the preliminary opinion of costs for the project. The approximate locations of existing river pump stations and mainline piping from the pump stations considered in this cost analysis are shown on Figure 6.

9.1 Alder Reservoir

As was noted previously, surface water storage would be created in the western study area by constructing a dam across the lower portion of Alder Creek. The proposed storage reservoir would have an estimated capacity of approximately 56,000 acre-feet and would have a high water surface elevation (WSEL) of approximately 680 feet. The reservoir would be filled by pumping and conveying water from the Columbia River, John Day pool. Note that the cost per acre foot of storage may be significantly reduced for the larger scale Alder reservoir project, assuming potential impacts can be effectively mitigated.

[4] As part of the pre-feasibility assessment, initial discussions have been held with existing irrigators (river pumpers) regarding the project, and potential of use of existing infrastructure to reduce capital costs. While there has been interest in understanding the project, there has been no commitment by any irrigator to participate in the project, should it proceed to construction and operation. Because use of existing infrastructure would reduce project costs, we present here assumptions for integrating existing infrastructure solely for cost comparison against all new construction.

The following conveyance and pumping improvements were identified, assuming that existing irrigation pumping and conveyance systems can be used to the extent possible to deliver water from the Columbia River to the proposed reservoir:

- Winterization and retrofit of the existing 100 Circles (ConAgra) Pump Station. Existing information indicates that the pump station can deliver approximately 185 cfs with 14,000 horsepower of pumping installed.
- Winterization and retrofit of the existing 66-inch diameter transmission pipeline from the 100 Circles (ConAgra) Pump Station. Existing information indicates that the 66-inch transmission line extends north nearly 1 mile from the pump station.
- Installation of more than 35,000 feet of new 72-inch diameter transmission pipeline from the ConAgra system to the Alder reservoir.
- Installation of nearly 22,000 feet of 48-inch transmission pipeline in lower Alder Creek Canyon to deliver water from the reservoir to the Columbia River. In order to drain the reservoir over 6 months time, an average flow of 154 cfs would need to be conveyed from the reservoir to the Columbia River. A portion of this water could be conveyed through lower Alder Creek. However, it is expected that most would need to be conveyed in a pipeline to prevent erosion and scour of the Alder Creek channel downstream of the reservoir.

The following conveyance and pumping improvements were identified for delivery of water from the Columbia River to the proposed Alder reservoir if existing irrigation pumping and conveyance systems are not used:

- Installation of a new 13,500-horsepower pump station on the Columbia River near its confluence with Alder Creek to deliver up to 190 cfs to the reservoir.
- Installation of nearly 22,000 feet of 84-inch transmission pipeline in lower Alder Creek as a common inlet/outlet between the Columbia River and the reservoir.

Key assumptions used to develop costs for the Alder reservoir component of the preferred project include:

- Storage costs include an earth-fill embankment dam (approximately 200 feet tall), related site work, local piping and conveyance facilities, and a spillway channel.
- For the scenario that assumes use of existing irrigation facilities for pumping and conveyance, an allowance of $100,000 was included for winterization/retrofit of transmission piping and valves and an allowance of $1,000,000 was included for winterization/retrofit of the existing 100 Circles pump station.
- An allowance of 10% of the construction subtotal was provided for mobilization.
- Allowances were also provided for environmental mitigation (10% of the construction total); contingency (30% of the construction total); and engineering, permitting, and administration (15% of the construction total).
- Annual operations and maintenance costs (not power) were assumed to be 2% of the total capital cost for the reservoir project.
- Power costs were estimated based on rates from the Benton PUD, Schedule 72 (Large Agricultural Irrigation without Annual Facilities Charge). 2010 rates were

used. No escalation was assumed for the opinion of cost in Table 5. On-peak irrigation rates were used. Actual pumping costs may be lower if off-peak rates are applied to nighttime pumping.

- Long-term costs would include repayment of capital costs based on a 50-year loan repayment schedule at an annual interest rate of 4%.
- Costs include pumping, storage, and conveyance facilities needed to deliver, store, and release water to the Columbia River. Costs do not include pumping and conveyance improvements needed to deliver water from the Columbia River or storage reservoir to irrigators for use.

9.2 ASR in Western Study Area

ASR wells constructed in the western study area would initially be designed to deliver up to 5,000 acre-feet annually from the Columbia River to the Wanapum Basalt aquifer for subsurface storage.

The following conveyance and pumping improvements were identified, assuming that existing irrigation conveyance systems can be used to the extent possible to deliver water from the Columbia River to the proposed ASR wellfield:

- Winterization and retrofit of the Mercer irrigation distribution system. Existing information indicates that the Mercer system includes a looped network of 18-inch diameter to 30-inch diameter pipelines. The most northern and western portions of the system are not looped and include smaller (12-inch diameter to 24-inch diameter) pipelines.
- Installation of more than 9,000 feet of 24-inch pipeline to increase the transmission capacity at the north end of the Mercer irrigation system.
- Installation of nearly 14,000 feet of 30-inch transmission pipeline to convey water from the Mercer system to the ASR wellfield.
- Installation of a Ranney well designed to deliver up to 20 cfs of filtered groundwater from the Columbia River Gravels near the location of the Mercer pump station to the proposed ASR wellfield.

The following conveyance and pumping improvements were identified for delivery of water from the Columbia River to the proposed ASR wellfield if existing irrigation conveyance systems are not used:

- Installation of a Ranney well designed to deliver up to 20 cfs of filtered groundwater from the Columbia River Gravels near the location of the Mercer pump station to the proposed ASR wellfield.
- Installation of nearly 54,000 feet of 30-inch transmission pipeline from the Ranney well to the proposed ASR wellfield.

Key assumptions used to develop costs for the ASR component of the preferred project include:

- An ASR wellfield consisting of 10 ASR wells, each capable of delivering 500 acre-feet annually to the subsurface reservoir.
- For the scenario that assumes use of existing irrigation facilities for conveyance, an allowance of $150,000 was included for winterization/retrofit of transmission piping and valves.
- An allowance of 10% of the construction subtotal was provided for mobilization.
- Allowances were also provided for environmental mitigation (10% of the construction total); contingency (30% of the construction total); and engineering, permitting and administration (15% of the construction total).
- Annual operations and maintenance costs were assumed to be 5% of the total capital cost for the ASR project. The operations and maintenance of an ASR wellfield were assumed to be more intensive that the operations and maintenance of surface storage, so a larger percentage was used.
- Power costs were estimated based on rates from the Benton PUD, Schedule 72 (Large Agricultural Irrigation without Annual Facilities Charge). 2010 rates were used. No escalation was assumed for the opinion of cost in Table 5. On-peak irrigation rates were used. Actual pumping costs may be lower if off-peak rates are applied to nighttime pumping.
- Long-term costs would include repayment of capital costs based on a 50-year loan repayment schedule at an annual interest rate of 4%.
- Costs include pumping, storage, and conveyance facilities needed to deliver water from the Columbia River to the ASR facility. Costs do not include pumping and conveyance improvements needed to deliver water from the Columbia River or the ASR facility to irrigators for use.

9.3 Switzler Reservoir

As was noted previously, surface water storage would be created in the eastern study area by constructing a dam across Switzler Canyon. The proposed storage reservoir would have a capacity of approximately 44,000 acre-feet and would have a high WSEL of approximately 780 feet. The reservoir would be filled by pumping and conveying water from the Columbia River, McNary pool.

The following conveyance and pumping improvements were identified, assuming that existing irrigation pumping and conveyance systems can be used to the extent possible to deliver water from the Columbia River to the proposed reservoir:

- Winterization and retrofit of the existing Easterday/Berrian, Easterday/Premier, and Easterday/Denhoed Pump Stations. Existing information indicates that the Easterday pump stations can deliver approximately 59 cfs, 29 cfs, and 57 cfs, respectively.

- Winterization and retrofit of the existing transmission pipelines from each of the Easterday pump stations. Existing information indicates that the transmission pipelines that would be needed are typically 36-inch diameter.
- Installation of more than 23,000 feet of new 48-inch diameter transmission pipeline from the Easterday/Berrian and Easterday/Denhoed systems to the reservoir site in Switzler Canyon.
- Installation of approximately 2,000 feet of new 36-inch diameter transmission pipeline from the Easterday/Premier system to the reservoir site in Switzler Canyon.
- Installation of approximately 8,500 feet of 36-inch transmission pipeline in lower Switzler Canyon to deliver water from the reservoir to the Columbia River. In order to drain the reservoir over 6 months time, an average flow of 121 cfs would need to be conveyed from the reservoir to the Columbia River. A portion of this water could be conveyed through lower Switzler Canyon. However, most would likely need to be conveyed in a pipeline to prevent erosion and scour of Switzler Canyon downstream of the reservoir.

The following conveyance and pumping improvements were identified for delivery of water from the Columbia River to the proposed reservoir if existing irrigation pumping and conveyance systems are not used:

- Installation of a new 11,500-horsepower pump station on the Columbia River near its confluence with Switzler Canyon to deliver up to 150 cfs to the reservoir.
- Installation of approximately 8,500 feet of 60-inch transmission pipeline in lower Switzler Canyon as a common inlet/outlet between the Columbia River and the reservoir.

Key assumptions used to develop costs for the Switzler Reservoir component of the preferred project include:

- Storage costs include an earth-fill embankment dam (approximately 335 feet tall), related site work, local piping and conveyance facilities, and a spillway channel.
- For the scenario that assumes use of existing irrigation facilities for pumping and conveyance, an allowance of $120,000 was included for winterization/retrofit of transmission piping and valves and an allowance of $1,000,000 was included for winterization/retrofit of the existing pump stations.
- An allowance of 10% of the construction subtotal was provided for mobilization.
- Allowances were also provided for environmental mitigation (10% of the construction total); contingency (30% of the construction total); and engineering, permitting and administration (15% of the construction total).
- Annual operations and maintenance costs were assumed to be 2% of the total capital cost for the reservoir project.
- Power costs were estimated based on rates from the Benton PUD, Schedule 72 (Large Agricultural Irrigation without Annual Facilities Charge). 2010 rates were used. No escalation was assumed for the opinion of cost in Table 5. On-peak

irrigation rates were used. Actual pumping costs may be lower if off-peak rates are applied to nighttime pumping.

- Long-term costs would include repayment of capital costs based on a 50-year loan repayment schedule at an annual interest rate of 4%.
- Costs include pumping, storage, and conveyance facilities needed to deliver, store and release water to the Columbia River. Costs do not include pumping and conveyance improvements needed to deliver water from the Columbia River or storage reservoir to irrigators for use.

9.4 Summary of Planning-Level Project Costs

Table 5 summarizes the planning-level opinion of probable costs for the preferred storage project. The estimated total capital costs of the preferred storage project (three reservoirs storing 105,000 acre-feet) range from approximately $3,600 per acre-foot if existing pumping and conveyance facilities can be used to deliver water from the Columbia River to the storage facilities, to $5,300 per acre-foot if all new conveyance and pumping facilities are installed. The total capital costs would be amortized through loan repayment over an assumed 50-year period of operation.

The total annual long-term costs, including power costs, operating and maintenance costs, and loan repayment (amortized capital[5]) range from approximately $300 per acre-foot annually if existing pumping and conveyance facilities can be used to deliver water from the Columbia River to the proposed storage facilities, to $400 per acre-foot annually if all new conveyance and pumping facilities are installed.

To reiterate, integrating existing irrigation system infrastructure into the preferred alternative is an assumption made for the purposes of cost comparison in this assessment. The concept was discussed in preliminary terms with several existing irrigators as part of this assessment, but there has been no commitment by any of them to participate in such a project should it advance to construction and operation. Further discussion of the concept – including how the system would be managed and the irrigators compensated for participation – would be conducted in a follow on appraisal-level assessment.

[5] Assumes 50-year loan at 4 percent interest.

10 Proposed Appraisal-Level Study

While no fatal flaws are currently identified, an appraisal-level study is necessary to better define the technical, permitting, and economic feasibility of the preferred storage project. Based on initial discussions with Ecology, the appraisal-level study would be focused toward more detailed evaluation to confirm the lack of fatal flaws and demonstrate the feasibility of the proposed pair of surface reservoirs, The appraisal-level study will also include additional evaluation of ASR feasibility, particularly focused on elements relevant to use of this storage strategy elsewhere in the Columbia River basin. Primary issues to be addressed in an appraisal-level study include but are not limited to those listed below, by category:

10.1 Surface Reservoirs

- Geological/geotechnical suitability of the reservoir sites;
- Aquatic habitat impacts/mitigation, including survey-based characterization of habitat conditions in the reaches of Switzler and Alder Canyons affected by the reservoir;
- Terrestrial habitat impacts/mitigation based on available information;
- Archaeological assessment based on available information;
- Surface storage facilities, including conceptual dam alignment, structure, spillway, and outlet works (assumed 10% design level);
- Inventory existing infrastructure, and identify modifications to it or new infrastructure is needed to store and release water (assumed 10% design level);
- Conceptual reservoir operational scenarios, considering the historical range of Columbia River flow conditions and the contribution of natural stream discharge to reservoir filling;
- Stream channel geomorphology and sediment transport potential, downstream of reservoir;
- Quality of water (e.g., temperature) being released from storage to surface water;
- Preliminary assessment for integrating pumped storage; and
- Permitting process.

10.2 ASR

- Develop a refined hydrogeologic conceptual model using available data;
- Conduct pumping tests using accessible existing wells to verify presence/absence of inferred hydraulic barriers in basalt aquifer caused by geologic faults, and, depending on accessible wells, potentially assess whether recharging the aquifer near the river would create groundwater mounding upgradient where significant depletion has occurred;

- Conduct reconnaissance to assess locations in Columbia River gravels to site at Ranney well for source water; and
- Assess establishment of a Ground Water Management Area within which the groundwater's highest beneficial use is irrigation supply via ASR. Identify permitting issues, including compliance with state water quality regulations, and develop strategies to achieve compliance.

10.3 Administration of Storage System

- Work with stakeholders to define a preferred administrative system for constructing and operating the storage project, and permitting use of the new water supply made available (e.g., allocation for interruptible water rights [infrequently needed] versus other demands). This would include developing an approach(es) for reimbursing existing owners of pumping/conveyance systems for using their systems in the project (off-season pumping to storage); and
- Preliminary review of land ownership, existing utilities, and expectations for land acquisition/easement and utility relocation.

10.4 Refined Project Cost Estimates

- Using the collective information gathered in the appraisal-level study tasks, propose a refined concept for the preferred storage project with associated cost estimates (capital costs and annual operation and maintenance).

11 Closing

The WRIA 31 PAC believes that, based on information developed in the WRIA 31 Pre-Feasibility Storage Assessment, the preferred water storage alternative may be a viable means to achieve out-of-stream and instream benefits within WRIA 31 in accordance with the WRIA 31 Watershed Management Plan. No fatal flaws are identified with the preferred project at this point, but the PAC recognizes that considerable additional information must be developed before the true project feasibility – technical, permitting, and economic – is understood with confidence. The PAC is interested in continuing to discuss the project further with Ecology's Office of the Columbia River, including the potential for funding to conduct an appraisal-level study.

12 References

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Limitations

Work for this project was performed and this report prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. It is intended for the exclusive use of WRIA 31 Planning and Advisory Committee for specific application to the referenced property. This report does not represent a legal opinion. No other warranty, expressed or implied, is made.

Table 1 - Monthly Net Crop Irrigation Requirements, Horse Heaven

	Crop Irrigation Requirement (CIR) (inches)																									
	Potatoes				Sweet Corn				Field Corn				Carrots				Grapes				Apples				Average of All Crops	Jul + Aug as % of Annual
Month	Bickelton	McNary	Average	% of Annual	Bickelton	McNary	Average	% of Annual	Bickelton	McNary	Average	% of Annual	Bickelton	McNary	Average	% of Annual	Bickelton	McNary	Average	% of Annual	Bickelton	McNary	Average	% of Annual		
Jan	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	**0%**	
Feb	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	**0%**	
Mar	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	**0%**	
Apr	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	**0%**	
May	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	1.16	1.51	1.34	6%	0.00	0.00	0.00	0%	0.49	0.64	0.57	2%	**1%**	
Jun	1.62	1.97	1.80	8%	1.64	2.00	1.82	9%	1.62	1.97	1.80	8%	4.94	5.86	5.40	26%	3.10	3.83	3.47	15%	7.19	8.60	7.90	21%	**14%**	
Jul	6.61	7.43	7.02	30%	7.67	8.66	8.17	41%	5.83	6.54	6.19	27%	9.87	11.21	10.54	50%	7.57	8.63	8.10	35%	11.28	12.80	12.04	32%	**36%**	**68%**
Aug	8.32	9.42	8.87	37%	8.29	9.39	8.84	45%	8.05	9.10	8.58	37%	3.63	4.09	3.86	18%	6.44	7.25	6.85	29%	9.08	10.29	9.69	26%	**32%**	
Sep	5.11	5.71	5.41	23%	0.81	0.91	0.86	4%	5.32	5.95	5.64	24%	0.00	0.00	0.00	0%	3.87	4.30	4.09	18%	5.60	6.27	5.94	16%	**14%**	
Oct	0.44	0.69	0.57	2%	0.00	0.00	0.00	0%	0.71	1.10	0.91	4%	0.00	0.00	0.00	0%	0.53	0.91	0.72	3%	0.98	1.46	1.22	3%	**2%**	
Nov	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	**0%**	
Dec	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	0.00	0.00	0.00	0%	**0%**	
	Annual Totals				Annual Totals				Annual Totals				Annual Totals				Annual Totals				Annual Totals					
	22.10	25.22	23.66	100%	18.41	20.96	19.69	100%	21.53	24.66	23.10	100%	19.60	22.67	21.14	100%	21.51	24.92	23.22	100%	34.62	40.06	37.34	100%	**100%**	

Monthly net crop irrigation requirements (CIR) from Washington Irrigation Guide (1985). Data from two statinos considered most applicable to the Horse Heaven (Bickelton and McNary). The crops selected for this analysis were determined based on information in the Level 1 Watershed Assessment (Aspect and WPN, 2004).

Table 2
Summary of Potential Surface Water Storage Reservoirs Identified

Reservoir Site	Estimated Storage Capacity (Acre-Feet)	Maximum Water Surface Elevation (Feet)	Planning Level Capital Cost ($)	Planning Level Capital Cost ($/Acre-foot)
Lower Alder Creek	300,000	700	$516,000,000	$1,720
Lower Alder Creek - Reduced	56,000	680	$124,000,000	$2,220
Tule Canyon	118,000	1,700	$417,000,000	$3,520
Upper Dead Canyon A	21,000	1,140	$71,000,000	$3,420
Upper Dead Canyon B	6,000	850	$23,000,000	$4,080
Lower Dead Canyon	11,000	470	$31,000,000	$2,710
Upper Glade Canyon A	62,000	1,990	$180,000,000	$2,890
Upper Glade Canyon B	59,000	1,400	$178,000,000	$2,990
Lower Glade Canyon	10,000	400	$26,000,000	$2,670
East Glade Creek	3,000	1,010	$15,000,000	$4,790
Carter Canyon	5,000	1,180	$18,000,000	$3,290
Four Mile Canyon	14,000	550	$34,000,000	$2,530
Switzler Canyon	44,000	780	$175,000,000	$3,940

Table 3

Instream Flows Set by WAC 173-563 and the 2004 Biological Opinion

Date	Chief Joseph		Wells & Rocky Reach		Rock Island & Wanapum		Priest Rapids			McNary			John Day		Bonneville	The Dalles	
	WAC 173-563		WAC 173-563		WAC 173-563		WAC 173-563		2004 BiOp	WAC 173-563		2004 BiOp	WAC 173-563		2004 BiOp	WAC 173-563	
	Min. Q_i (kcfs)	Min. Avg. Weekly Flows (kcfs)	Min. Q_i (kcfs)	Min. Avg. Weekly Flows (kcfs)	Min. Q_i (kcfs)	Min. Avg. Weekly Flows (kcfs)	Min. Q_i (kcfs)	Min. Avg. Weekly Flows (kcfs)	Flow Objective (kcfs)	Min. Q_i (kcfs)	Min. Avg. Weekly Flows (kcfs)	Flow Objective (kcfs)	Min. Q_i (kcfs)	Min. Avg. Weekly Flows (kcfs)	Flow Objective (kcfs)	Min. Q_i (kcfs)	Min. Avg. Weekly Flows (kcfs)
Jan	10	30	10	30	10	30	50	70	--	20	60	--	20	60	?[b]	20	60
Feb	10	30	10	30	10	30	50	70	--	20	60	--	20	60	?[b]	20	60
Mar	10	30	10	30	10	30	50	70	--	50	60	--	50	60	?[b]	50	60
Apr 1-2	20	50	20	50	20	60	50	70	--	50	100	--	50	100	?[b]	70	120
3-9	20	50	20	50	20	60	50	70	--	50	100	--	50	100	?[b]	70	120
10-15	20	50	20	50	20	60	50	70	135	50	100	220-260[a]	50	100	?[b]	70	120
16-25	20	60	30	60	30	60	50	70	135	70	150	220-260[a]	70	150	?[b]	70	160
26-30	20	90	50	100	50	110	50	110	135	70	200	220-260[a]	70	200	?[b]	70	200
May	20	100	50	115	50	130	50	130	135	70	220	220-260[a]	70	220	?[b]	70	220
Jun 1-15	20	80	50	110	50	110	50	110	135	70	200	220-260[a]	70	200	?[b]	70	200
16-20	10	60	20	80	20	80	50	80	135	50	120	220-260[a]	50	120	?[b]	50	120
21-30	10	60	20	80	20	80	50	80	135	50	120	220-260[a]	50	120	?[b]	50	120
Jul 1-15	10	60	20	80	20	80	50	80	--	50	120	200	50	120	--	50	120
16-31	10	90	50	100	50	110	50	110	--	50	140	200	50	140	--	50	140
Aug	10	85	50	90	50	95	50	95	--	50	120	200	50	120	--	50	120
Sep	10	40	20	40	20	40	36	40	--	50	60	--	50	85	--	50	90
Oct 1-15	10	30	20	35	20	40	36	40	--	50	60	--	50	85	--	50	90
16-31	10	30	20	35	20	40	50	70	--	50	60	--	50	85	--	50	90
Nov	10	30	10	30	10	30	50	70	--	50	60	--	50	60	125-160[b]	50	60
Dec	10	30	10	30	10	30	50	70	--	20	60	--	20	60	?[b]	20	60

NOTES:

Abbreviations: Min = Minimum; Qi = instantaneous flow; Avg. = Average; WAC = Washington State Administrative Code; kcfs = thousand cubic feet per second

a. Objective varies according to water volume forecasts.

b. Objective varies based on actual and forecasted water conditions. The dates to which this flow objective applies include 11/1 to emergence (spring season) which may vary each year.

c. The 2004 Biological Opinion was issued by NMFS regarding the Federal Columbia River Power System (FCRPS). The data in the table is from Bureau of Reclamation, Bonneville Power Administration, and U.S. Army Corps of Engineers (Action Agencies). 2004. Final Updated Proposed Action for the FCRPS Biological Opinion Remand. November 24, 2004.

Source: Final Programmatic Environmental Impact Statement for the Columbia River Water Management Program

Table 4
Estimated Average Columbia River Water Available

Month	Volume Available (million acre-feet)
November	0
December	0.51
January	1.62
February	2.11
March	3.32
Total	**7.55**

Table 5
Opinion of Probable Costs of Preferred Storage Alternative
WRIA 31 Water Storage Pre-Feasibility Assessment

ITEM	IF EXISTING CONVEYANCE AND PUMPING SYSTEMS ARE USED				IF ALL NEW CONVEYANCE AND PUMPING SYSTEMS ARE USED			
	WEST SURFACE STORAGE	WEST ASR	EAST SURFACE STORAGE	TOTAL	WEST SURFACE STORAGE	WEST ASR	EAST SURFACE STORAGE	TOTAL
Storage Included:								
Description	Lower Alder Reservoir	ASR	Switzler Reservoir		Lower Alder Reservoir	ASR	Switzler Reservoir	
Annual Storage Capacity (Acre-feet)	55,800	5,000	44,400	105,200	55,800	5,000	44,400	105,200
Transmission/Distribution Pipelines Included:								
Description	Ex. 100 Circles + New Pipelines to Reservoir	Ex. Mercer + New Pipelines to Reservoir	Ex. Easterday + New Pipelines to Reservoir		All New Pipelines	All New Pipelines	All New Pipelines	
Pipeline Sizes (In)	66" to 72"	18" to 36"	36" to 48"		84"	30"	60"	
Pumping Included:								
Description	Ex. 100 Circles Pump Station	New Ranney Well	Ex. Easterday Pump Stations		New Pump Station	New Ranney Well	New Pump Station	
Power Required (HP)	14,000	3,500	12,000	29,500	13,500	2,000	11,500	27,000
Capital Costs:								
Storage Improvements	$ 67,298,000	$ 5,000,000	$ 95,430,000	$ 167,728,000	$ 67,298,000	$ 5,000,000	$ 95,430,000	$ 167,728,000
Transmission and Distribution Improvements	$ 21,108,000	$ 2,699,000	$ 6,225,000	$ 30,032,000	$ 11,825,000	$ 6,456,000	$ 3,400,000	$ 21,681,000
Pumping Improvements	$ 1,000,000	$ 5,000,000	$ 1,000,000	$ 7,000,000	$ 59,400,000	$ 5,000,000	$ 50,600,000	$ 115,000,000
Construction Subtotal	**$ 89,406,000**	**$ 12,699,000**	**$ 102,655,000**	**$ 204,760,000**	**$ 138,523,000**	**$ 16,456,000**	**$ 149,430,000**	**$ 304,409,000**
Moblization/Demoblization (10%)	$ 8,940,600	$ 1,269,900	$ 10,265,500	$ 20,476,000	$ 13,852,300	$ 1,645,600	$ 14,943,000	$ 30,440,900
Construction Total	**$ 98,346,600**	**$ 13,968,900**	**$ 112,920,500**	**$ 225,236,000**	**$ 152,375,300**	**$ 18,101,600**	**$ 164,373,000**	**$ 334,849,900**
Environmental Mitigation (10%)	$ 9,834,660	$ 1,396,890	$ 11,292,050	$ 22,523,600	$ 15,237,530	$ 1,810,160	$ 16,437,300	$ 33,484,990
Contingency (30%)	$ 29,503,980	$ 4,190,670	$ 33,876,150	$ 67,570,800	$ 45,712,590	$ 5,430,480	$ 49,311,900	$ 100,454,970
Engineering, Permitting and Administration (15%)	$ 14,751,990	$ 2,095,335	$ 16,938,075	$ 33,785,400	$ 22,856,295	$ 2,715,240	$ 24,655,950	$ 50,227,485
Subtotal - Capital Cost	**$ 152,437,000**	**$ 21,652,000**	**$ 175,027,000**	**$ 349,116,000**	**$ 236,182,000**	**$ 28,057,000**	**$ 254,778,000**	**$ 519,017,000**
Sales Tax	$ 10,670,590	$ 1,515,640	$ 12,251,890	$ 24,438,120	$ 16,532,740	$ 1,963,990	$ 17,834,460	$ 36,331,190
Land Acquisition	$ 4,210,000	$ 10,000	$ 444,000	$ 4,664,000	$ 4,210,000	$ 10,000	$ 444,000	$ 4,664,000
Total Capital Cost	**$ 167,318,000**	**$ 23,178,000**	**$ 187,723,000**	**$ 378,219,000**	**$ 256,925,000**	**$ 30,031,000**	**$ 273,056,000**	**$ 560,012,000**
Total Capital Cost ($/Acre-foot)	**$ 2,999**	**$ 4,636**	**$ 4,228**	**$ 3,595**	**$ 4,604**	**$ 6,006**	**$ 6,150**	**$ 5,323**
Long Term Costs:								
Annual Pumping Power Costs (2010 Rates)	$ 1,813,000	$ 453,000	$ 1,554,000	$ 3,820,000	$ 1,748,000	$ 259,000	$ 1,489,000	$ 3,496,000
Annual Operating and Maintenance (O&M) Costs	$ 3,346,360	$ 1,158,900	$ 3,754,460	$ 8,259,720	$ 5,138,500	$ 1,501,550	$ 5,461,120	$ 12,101,170
Subtotal - Pumping + O&M Costs	**$ 5,159,360**	**$ 1,611,900**	**$ 5,308,460**	**$ 12,079,720**	**$ 6,886,500**	**$ 1,760,550**	**$ 6,950,120**	**$ 15,597,170**
Subtotal - Pumping + O&M Costs ($/Acre-foot)	**$ 92**	**$ 322**	**$ 120**	**$ 115**	**$ 123**	**$ 352**	**$ 157**	**$ 148**
Amortized Annual Cost	$ 7,788,686	$ 1,078,941	$ 8,738,543	$ 17,606,170	$ 11,959,910	$ 1,397,949	$ 12,710,812	$ 26,068,671
Amortized Annual Cost ($/Acre-foot)	$ 140	$ 216	$ 197	$ 167	$ 214	$ 280	$ 286	**$ 248**
Total Annual Long-Term Cost	**$ 12,948,000**	**$ 2,691,000**	**$ 14,047,000**	**$ 29,686,000**	**$ 18,846,000**	**$ 3,158,000**	**$ 19,661,000**	**$ 41,666,000**
Total Annual Long-Term Cost ($/Acre-foot)	**$ 232**	**$ 538**	**$ 316**	**$ 282**	**$ 338**	**$ 632**	**$ 443**	**$ 396**

Notes:
1) Annual Operating and Maintenance Costs Estimated at 2% and 5% of Total Capital Cost for surface and aquifer storage alternatives, respectively.
2) Rates from Benton PUD Schedule 72: Large Agricultural Irrigation Without Annual Facilities Charge (2010 On-peak Rates Used, No escalation assumed).

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Vicinity Map

WRIA 31 Pre-Feasibility Storage Assessment
Washington

DATE: June 2010	PROJECT NO. 090045
DESIGNED BY: PPW	
DRAWN BY: PPW	FIGURE NO. 1
REVISED BY: - - -	

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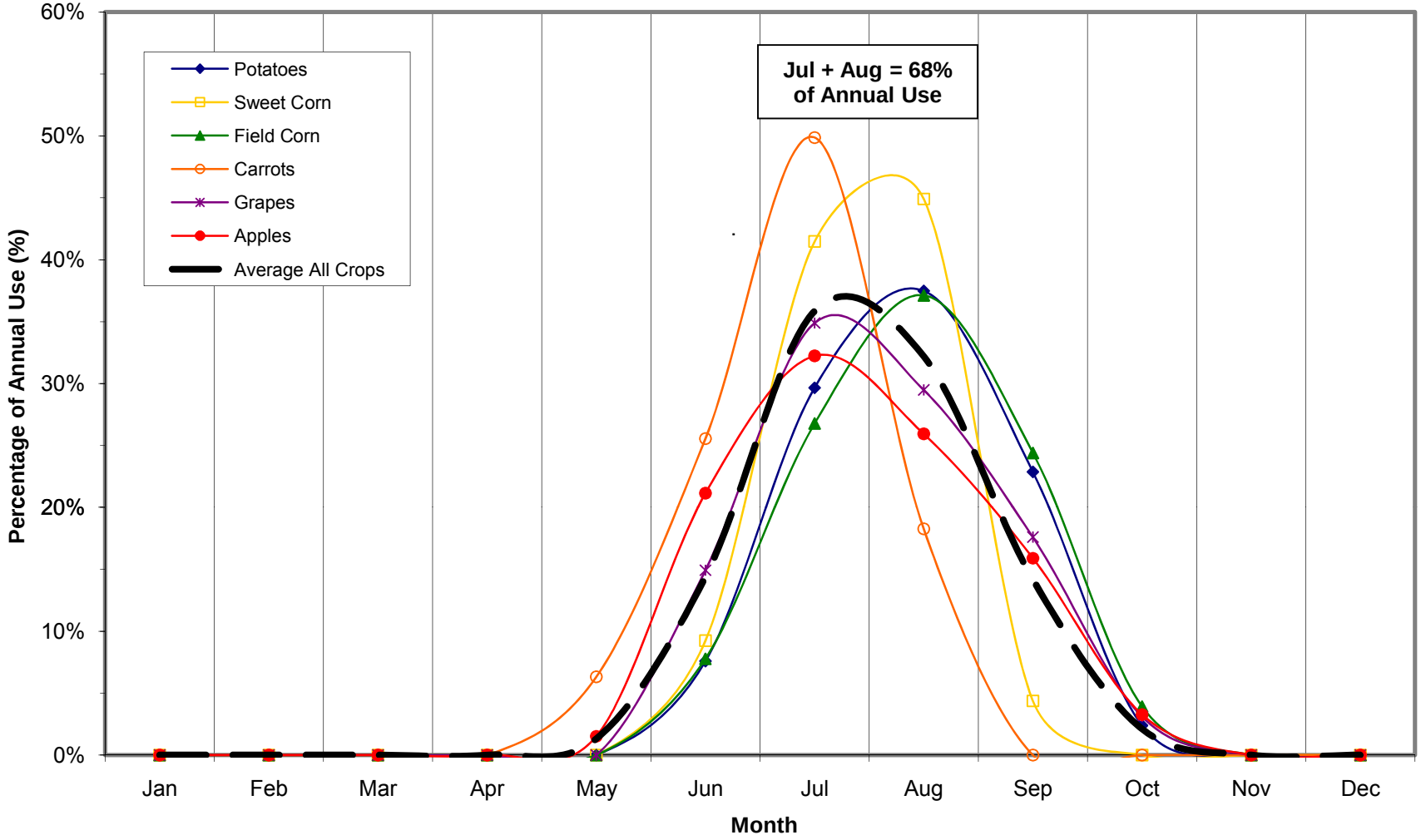

Data based on monthly net crop irrigation requirements averaged for Bickelton and McNary, from WA Irrigation Guide (1985); refer to text for details.

Figure 2
Seasonal Distribution of Irrigation Demand

YAKIMA COUNTY

KLICKITAT COUNTY

BENTON COUNTY

-150

-200

-250

-100

-50

211251 (+1*)

208672 (-264)

208676

208682 (-249)

208910 (-256)

208911 (-158*)

208681 (-106)

208686 (-160*)

211249 (-109)

211241 (+1)

211243

211245 (-14)

211246 (-5)

211247 (-17)

211239 (+15)

208636

211248 (-17*)

208633

208632 (-122)

208703

211256 (-8*)

211257 (-14*)

211258

211266 (0*)

211269 (-9)

211270

211236

Well SID

211256 (-8*)

Groundwater elevation change (1983-2009)
(*: 1982-2002 data)

Well monitored by Ecology

Well finished only in Wanapum Basalt (Bauer, Vaccaro, Lane 1985)

Change in groundwater elevation (1983-2009) contour (ft.)

Change in groundwater elevation (1983-2009) contour (ft.) - uncertain

Wood/Glade Planning Area

County line

Inferred barrier fault (USGS, 1996)

Groundwater elevation change data from Dept. of Ecology Well Monitoring Data (1982-2009)

Feet

0 10,000 20,000 40,000 60,000 80,000

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Groundwater Elevation Changes in the Wanapum Basalt Aquifer

WRIA 31 Pre-Feasibility Storage Assessment

DATE: June 2010	PROJECT NO. 090045
DESIGNED BY: SJG	
DRAWN BY: PPW	FIGURE NO. 3
REVISED BY: KAF	

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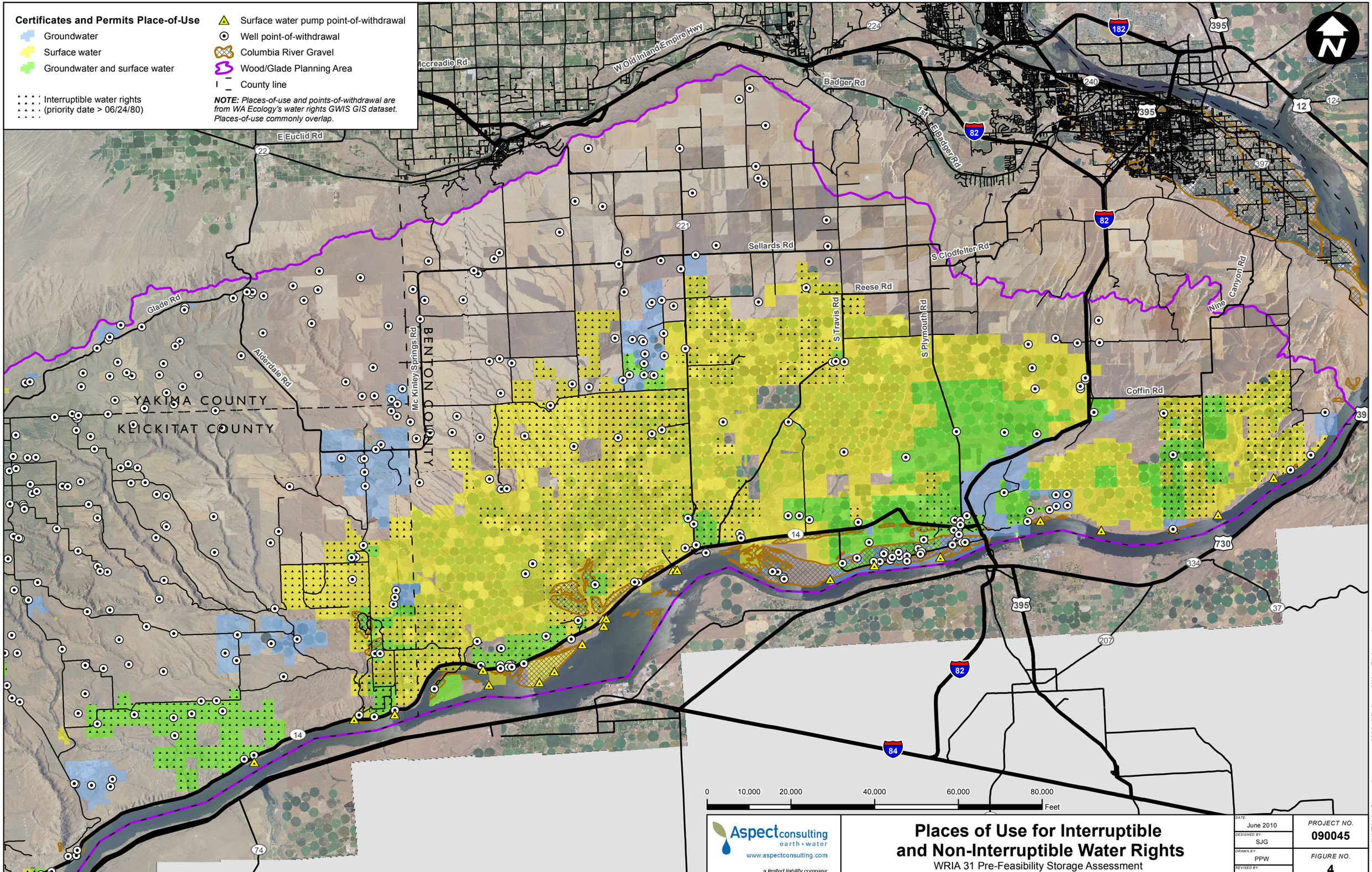

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Places of Use for Interruptible and Non-Interruptible Water Rights

WRIA 31 Pre-Feasibility Storage Assessment

DATE: June 2010	PROJECT NO. 090045
DESIGNED BY: SJG	
DRAWN BY: PPW	FIGURE NO. 4
REVISED BY: KAF	

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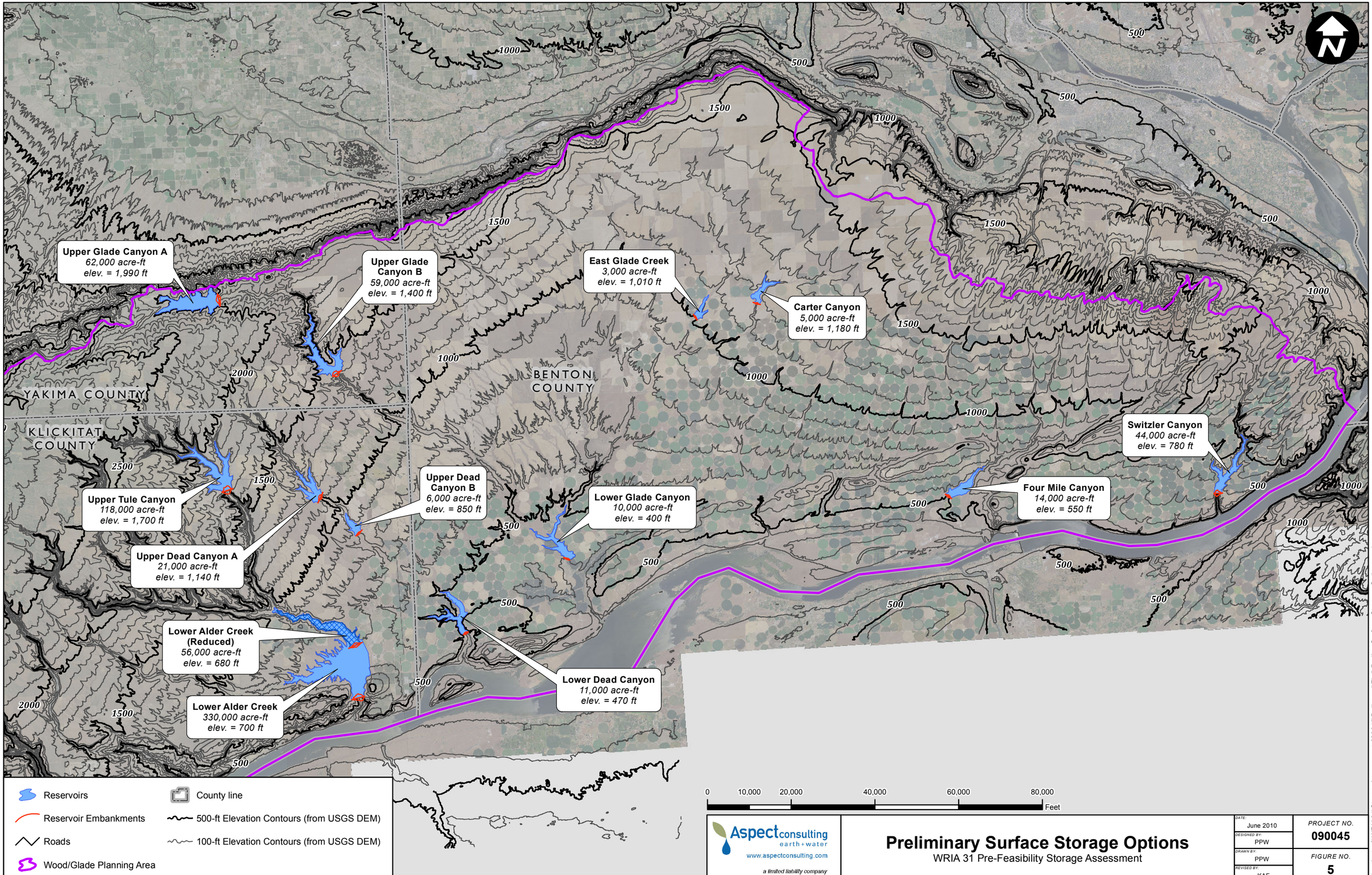

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Preliminary Surface Storage Options

WRIA 31 Pre-Feasibility Storage Assessment

DATE: June 2010	PROJECT NO. 090045
DESIGNED BY: PPW	
DRAWN BY: PPW	FIGURE NO. 5
REVISED BY: KAF	

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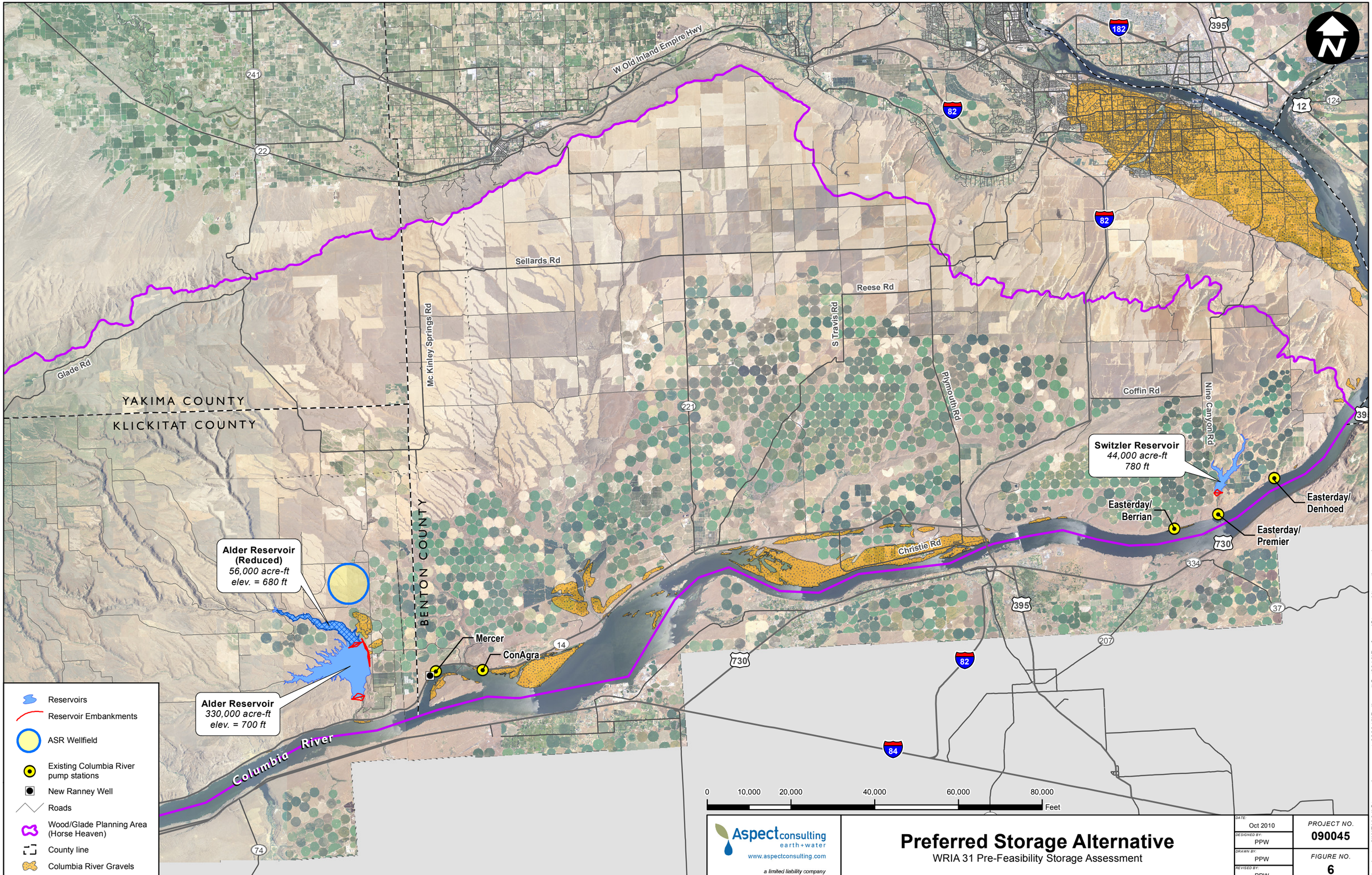

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Preferred Storage Alternative

WRIA 31 Pre-Feasibility Storage Assessment

DATE: Oct 2010	PROJECT NO. 090045
DESIGNED BY: PPW	
DRAWN BY: PPW	FIGURE NO. 6
REVISED BY: PPW	

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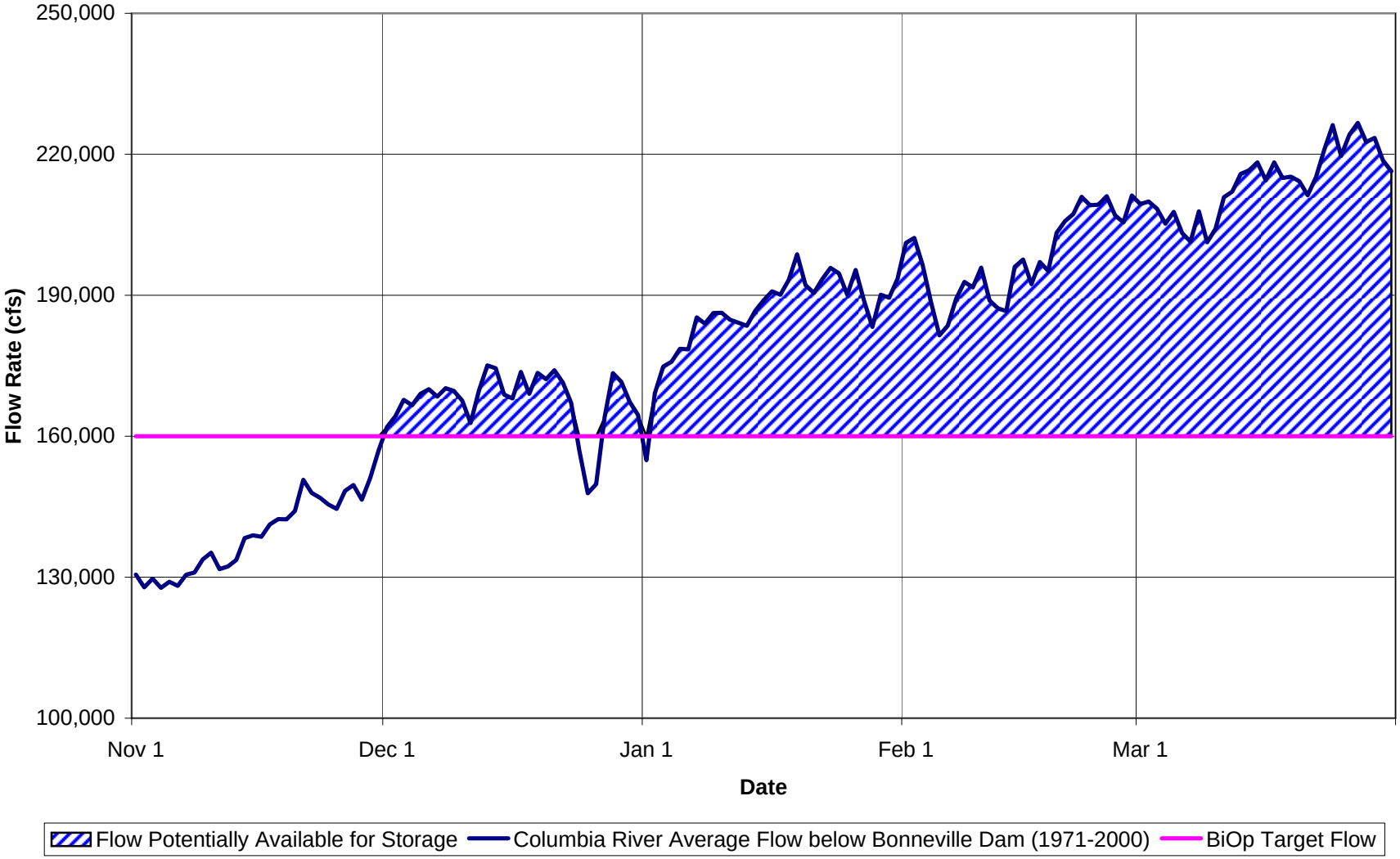
Figure 7
Columbia River Average (1971-2000) Flow below Bonneville Dam (Nov 1-Mar 31)



APPENDIX A

Instream Habitat Information, Alder Creek and Switzler Canyon

This appendix summarizes available information regarding instream habitat conditions for Alder Creek and Switzler Canyon, within which surface reservoirs are proposed as part of the preferred storage alternative developed through the Pre-Feasibility Storage Assessment. The instream habitat-related information in this appendix is largely derived from reports previously developed for the WRIA 31 watershed planning process – reports which addressed multiple streams in the watershed. The pertinent information specific to the Alder Creek and Switzler Canyon is summarized here to support development and fatal flaw analysis for the preferred storage alternative, as well as potential follow-on efforts for the project. Preliminary thoughts regarding potential instream effects and benefits associated with Alder Reservoir and Switzler Reservoir concepts are also provided.

A.1 Alder Creek

A.1.1 Watershed Characteristics

A.1.1.1 Geomorphology

Alder Creek is typical of the eastern tributaries that flow out of WRIA 31 into the John Day Reservoir. The basin is approximately 127,000 acres in size, with its headwaters flowing out of Horse Heaven Hills, across the relatively flat basalt plateau at gradients of generally less than 1 percent; this area is above known anadromous fish use. Coming off the plateau, streams enter steep-walled canyons; gradients increase to 2 – 4 percent or more. Below the canyon reaches, most of the streams enter alluvial valleys; gradients range between 1 percent and 2 percent near the upper end, dropping to less than 1 percent as streams approach the Columbia River. Using 10-meter USGS DEM data, a longitudinal profile of the Alder Creek channel alignment has been generated (Figure A-1).

A.1.1.2 Hydrology

Alder Creek is located in Washington State and flows from the north bank into the John Day Reservoir portion of the Columbia River, approximately 33 river miles downstream of McNary Dam. A USGS stream flow gauge located at the mouth of Alder Creek (Alder Creek at Alderdale, Station 14034350) provides a limited record of continuous stream flow data from the 1960s, which falls within a cool/wet climatic cycle (WRIA 31 Planning Unit, 2008). Although streams in WRIA 31, with the exception of the Columbia River, are typically intermittent, the quantity of spring discharge in Alder Creek is generally sufficient to maintain streamflow at the mouth of Alder Creek throughout the dry season (WRIA 31 Planning Unit, 2008). Based on the available data, the mean daily flows for Alder Creek during the period of record was 9 cfs. These values are also consistent with numerous spot flow measurements taken in Alder Creek (Aspect and WPN, 2004).

A.1.1.3 Instream and Riparian Habitat

Habitat data on Alder Creek, with the exception of water temperature data, is limited to historical notes from an 1867 Geological Land Office (GLO) survey (Giddings, 1867)

conducted in mid-June and to a late June 2004 reconnaissance of the lower five miles of Alder Creek and one tributary, Six Prong Creek (Aspect and WPN, 2004).

Historical Conditions

Surveys in the Alder Creek drainage were conducted in mid-June of 1867, a year with average moisture. At that time, Alder Creek was 50 feet wide and 14 inches deep at the mouth. The banks were covered by “balm gilead, willow, sumack, hackberry, and currant”. A little over a mile upstream, the channel was 16.5 feet wide and water was 4 inches deep. The GLO notes indicate the bottom was filled with sharp basaltic rocks 1 to 20 feet in diameter. Riparian vegetation at this point included willow, sumac, alder, elder, and currant (Giddings, 1867).

The survey notes for the lower seven miles of Six Prong Creek described the creek as having 4 inches of water in it at all the survey points. The notes state: “this creek sinks and rises every 10 to 15 chains” (one chain is 66 feet). Vegetation along the creek included willow, sumac, balm gilead, elder, and currant. Much of Six Prong Creek ran through deep ravines ranging from 50 to 80 feet deep. The banks of the creek were described as perpendicular sand rising from 12 to 48 feet high (Giddings, 1867).

Current Conditions

The lower portion of Alder Creek is perennial as a result of spring discharge. The riparian area along the creek is narrow, but relatively dense. Despite the shading provided by the riparian canopy, the creek tends to be warm in summer with average temperatures exceeding the State standard for the seven-day average of the maximum temperatures. Pools and instream wood in this section of the stream are abundant (Aspect and WPN, 2004).

Six Prong Creek is dominated by emergent wetland vegetation. Willows and other riparian trees are growing where slightly drier soils are available. The hill slope gradients are nearly vertical, up to 50 feet in height, and the hill slopes are comprised of highly erosive materials. Within these steep banks, the creek has a well developed floodplain and riparian vegetation. The condition of the present day channel is very similar to that which was described in the GLO notes in 1867 (Aspect and WPN, 2004).

In terms of surface flow, Alder Creek is one of the two largest streams in WRIA 31, the other being Rock Creek. Rock Creek typically has the highest stream flows except for the summer months when a spring located near the mouth of Alder Creek provides a small perennial flow in the lowermost reach of this creek. There are other springs in Alder Creek upstream of the one identified at the mouth, but with the exception of this one, they appear to provide little baseflow. Year round base flows are reliant on available snow storage in the upper drainage, which if very limited in this dry, low precipitation habitat (Aspect and WPN, 2004). Additionally, runoff patterns are affected by the conversion of permanent groundcover to annually tilled land, although current best management practices can alleviate these impacts. The mean annual precipitation of the Wood/Alder drainage area is estimated to be 9.6 to 10.8 inches per year with 5,992 acres in irrigated agriculture. For comparison, Rock Creek mean annual precipitation is estimated to be 13.0 to 16.2 inches per year with zero effective acres in irrigated agriculture (Aspect and WPN, 2004).

Alder Creek commonly reaches lethal temperatures (above 73°F) in most summers, including in the perennial spring-fed reach near the mouth (Aspect and WPN, 2004; C&EKCD, 1991; EKCD, 1997). As Ehinger (1996) suggested in his evaluation of Rock Creek (WRIA 31), high stream temperatures like those observed in Rock Creek, may be a natural condition during hot summers given solar exposure and exposed rocky substrate (channel bed). Based on this assessment of Rock Creek, a memorandum of agreement (MOA) was developed which allowed Rock Creek to be excluded from the 303(d) list subject to conditions contained in the MOA. Like Rock Creek, Alder Creek has also been found to be in exceedance of water quality temperature standards.

A.1.1.4 Fisheries

Within WRIA 31, portions of Glade Creek, Alder Creek, Pine Creek, Woods Gulch (including a portion of Big Horn Canyon), Chapman, and Rock Creek (including a portion of Squaw Creek) have been designated as Critical Habitat for the Mid-Columbia Steelhead DPS under the ESA (NOAA, 2005). With the exception of Rock Creek, all these small, eastern Washington tributaries of WRIA 31 are part of Umatilla steelhead population within the Umatilla/Walla Walla major population group (MPG). Rock Creek supports the Rock Creek population and is part of the Cascades Eastern Slopes Tributaries MPG (NMFS, 2009a). Of the tributaries in WRIA 31 designated as critical habitat, only Alder Creek and Glade Creek fall within the Project area. The Interior Columbia Basin Technical Recovery Team (ICTRT) determined that the long-term occupancy of these small, relatively isolated streams that are part of the Umatilla population likely depends on straying largely from the Umatilla River drainage and that the Umatilla River drainage contains sufficient intrinsic potential by itself to achieve the abundance and productivity criteria for the Umatilla population (NMFS, 2009b). However, the small eastern Washington tributaries that are part of the Umatilla/Walla Walla MPG, including Alder Creek, must contribute to meeting the spatial structure/diversity criteria for the Umatilla population (ICTRT, 2009). At this time though, NMFS has stated it considers meeting spatial structure and diversity criteria to be of lower priority than restoring the core production area for the Umatilla population, which is the Umatilla drainage (NMFS, 2009b). The Umatilla population does not currently meet the recommended viability criteria for abundance/productivity or for spatial structure/diversity (NMFS, 2009b).

Documented presence of steelhead adults or juveniles in tributaries within WRIA 31 is very limited. In general, spawning is reported to potentially occur anywhere where suitable substrate material is found and is accessible; rearing may be similarly widespread during most of the year, but may be restricted to spring-fed or groundwater upwelling areas during the summer and early fall (WCC, 2000). WDFW (C. Dugger, WDFW, pers. comm. in WCC, 2000) reported potential spawning and rearing habitat in Alder Creek from the confluence with the Columbia River upstream to Six Prong Creek. The Yakama Nation (Yakama Nation Fisheries, unpublished information in Appendix I to NMFS, 2009b) reported observing steelhead adults in the lower 1.5 miles of Alder Creek.

A.1.2 Alder Reservoir Concept

A.1.2.1 Project Description

The Alder Reservoir site would have a full-pool elevation at 680 feet MSL and would inundate portions of Alder Creek upstream of Six Prong Creek. Total potential storage volume is estimated at approximately 56,000 acre-feet. The inundated surface area at full-pool elevation would be approximately 727 acres. Columbia River water would be pumped to the Alder Reservoir from Lake Umatilla.

A.1.2.2 Project Effects

The Alder Reservoir as currently proposed would inundate Alder Creek from RM 4.2 upstream to RM 8.5. The dam location for this alternative would be located upstream of the confluence of Six Prong Creek and upstream of the available spawning and rearing habitat identified in the lower Alder Creek. Therefore, no identified spawning and rearing habitat in the Alder Creek drainage would be inundated. The extent to which the storage reservoir might result in the loss or degradation of the springs in Alder Creek is unknown. If construction and operation of the Alder Reservoir resulted in the loss or degradation of spring activity, juvenile salmonid rearing and adult steelhead spawning would be negatively impacted.

Stored water made available as a result of construction of the reservoir could provide perennial flows in Alder Creek downstream of the reservoir dam regardless of any potential loss groundwater recharge downstream of the dam. If the reservoir stratified and cold water could be drawn from low in reservoir water column, this alternative could result in improved water temperatures in Alder Creek along with perennial flows. Additionally, improvements to the meander configuration of the lower stream channel coupled with increased flow consistent with the newly designed stream channel, could result in an increase in available salmonid spawning and rearing habitat in lower Alder Creek. Improvements could also be designed and constructed in existing side channels along the Columbia River near the confluence of Alder Creek and the Columbia River to increase available off-channel juvenile salmonid rearing habitat in this reach of the Columbia River.

A closer examination would need to be conducted of the costs and extent to which the existing channel, with habitat improvements, could support required return flows for the Alder Reservoir. If infrastructure costs and the costs of mitigating for affected salmonid habitat are found not to be prohibitive, mitigation alternatives could be investigated with interested parties.

A.2 Switzler Canyon

A.2.1 Watershed Characteristics

Switzler Canyon is a major drainage in WRIA 31 (approximately 19,800 acres) and the easternmost drainage in the Horse Heaven. No published information was identified describing the geology, hydrology, instream and riparian habitat, or fisheries for the

Switzler Canyon drainage. Using 10-meter USGS DEM data, a channel profiles of the Switzler Canyon channel alignment has been generated (Figure A-2).

A.2.1.1 Fisheries

Stream gradient has been found to be an important habitat qualifier for salmonid spawning and rearing preference. Gradient functions both as an indicator of upstream limit on migration and as a predictor of habitat quality within accessible reaches (ICTRT, 2007). Based on channel gradients generated with DEM data, the Switzler Canyon drainage naturally has limited benefit to all salmonid species except steelhead; Switzler Canyon has a relatively steep gradient and the Canyon is deeply incised. Below the proposed dam site, the gradient is approximately 2.2% to within 500 feet of the Columbia River. The gradient through the proposed reservoir is about 2-3 %.

For Chinook juveniles, gradients between 1.0 and 1.5% have been shown to support relatively high densities. Densities were low at gradients exceeding 1.5 to 2.0% (ICTRT, 2007). For steelhead juveniles, at gradients less than 0.5%, low densities were observed. Densities increase as gradient increases, up to approximately 4%, remaining relatively high up to 7%. Stream reaches between 7 and 15% were designated with low potential for rearing. Stream reaches above a gradient exceeding 20% that extends for 200 meters or more is considered inaccessible habitat for adult anadromous fish passage (ICTRT, 2007).

To evaluate the feasibility of constructing a reservoir in Switzler Canyon and the potential effects on fish habitat and production, a more comprehensive and quantitative characterization of the canyon would need to be conducted during a subsequent phase.

A.2.2 Switzler Reservoir Concept

A.2.2.1 Project Description

The Switzler Reservoir site would have an estimated 44,000 acre-feet storage capacity and serve as a mitigation supply for new diversions (new irrigation) or interruptibles in McNary or John Day Pools and for instream benefit. To the extent practical, existing pumping stations and conveyances could be retrofitted for winter operations to pump to the reservoir. Could even serve as mitigation water for Quad Cities water right (and downstream), which is potentially a significant multipurpose benefit.

A.2.2.2 Project Effects

The construction of a dam at RM 1.1 in Switzler Canyon would inundate approximately 3.4 miles of stream channel. However, given the relatively steep gradients and confined channels of the canyon, it is uncertain what portions of the channel, if any, are accessible to salmonids. Perennial streamflows are also questionable in Switzler Canyon. If flows are naturally intermittent, of nonexistence except during rain events, then there would be no fishery benefits for which to mitigate. An investigation to document the presence or absence of spring-fed pools that may support native rainbow trout may be desirable. The need for an investigation could be determined through detailed review of aerial photographs and a site visit, if aerial photographs identify riparian vegetation in the canyon or its tributaries.

The construction of a storage reservoir in Switzler Canyon has the potential to provide year-round, instream flow in the drainage downstream of the reservoir. Depending on the underlying geology of the Canyon, habitat improvement projects could be designed and constructed. The habitat projects could establish gradients, meander configurations, and instream structure conducive to successful juvenile salmonid rearing and adult spawning habitat.

A.3 References for Appendix A

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Carmichael, R., 2009, Conservation and Recovery Plan for Oregon Steelhead Populations in the Middle Columbia River Steelhead Distinct Population Segment, August 2009, Oregon Department of Fish and Wildlife.

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Ehinger, W., 1996, Evaluation of High Temperature in Rock Creek (Klickitat County), Washington Department of Ecology Report # 96-308. 3 pp.

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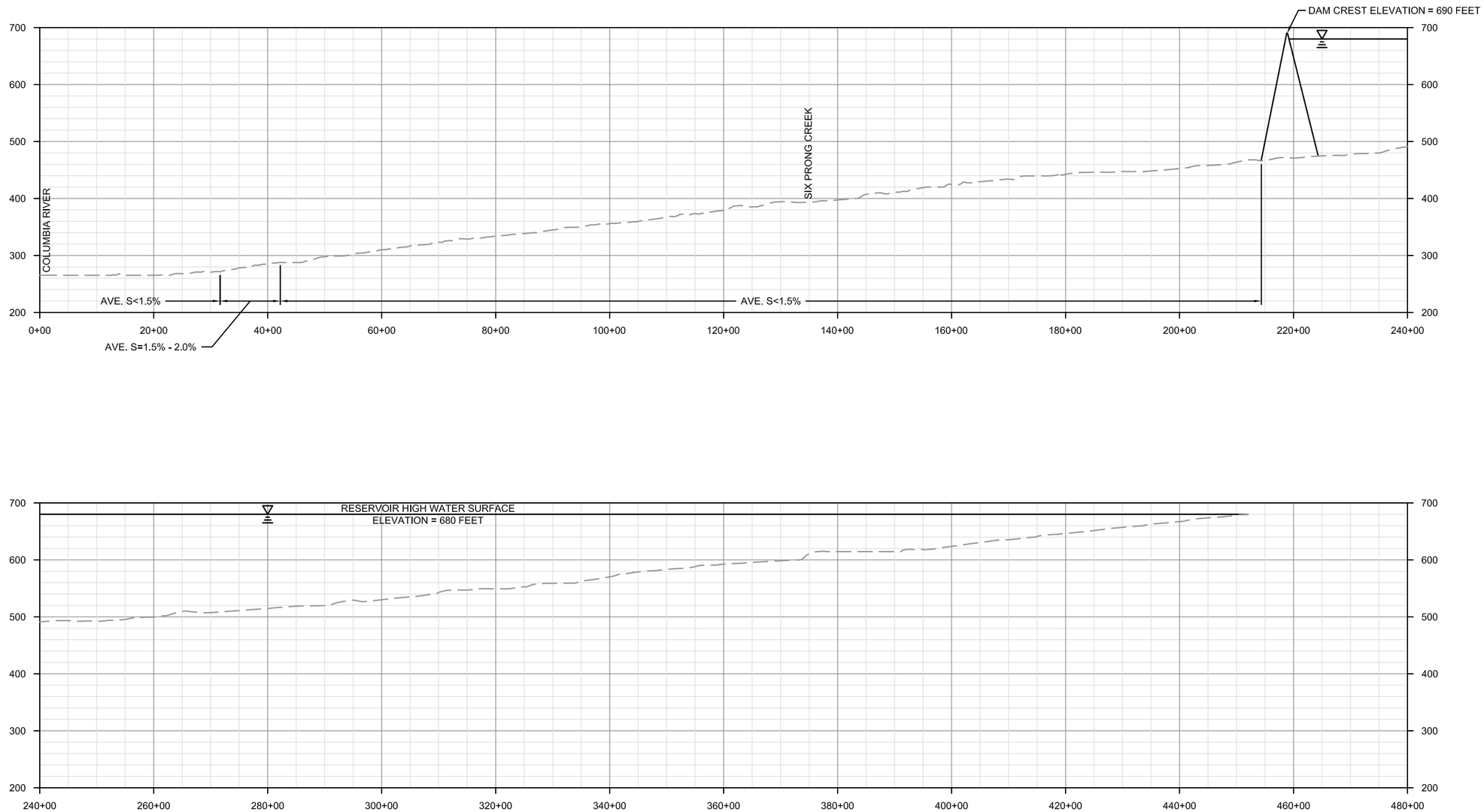

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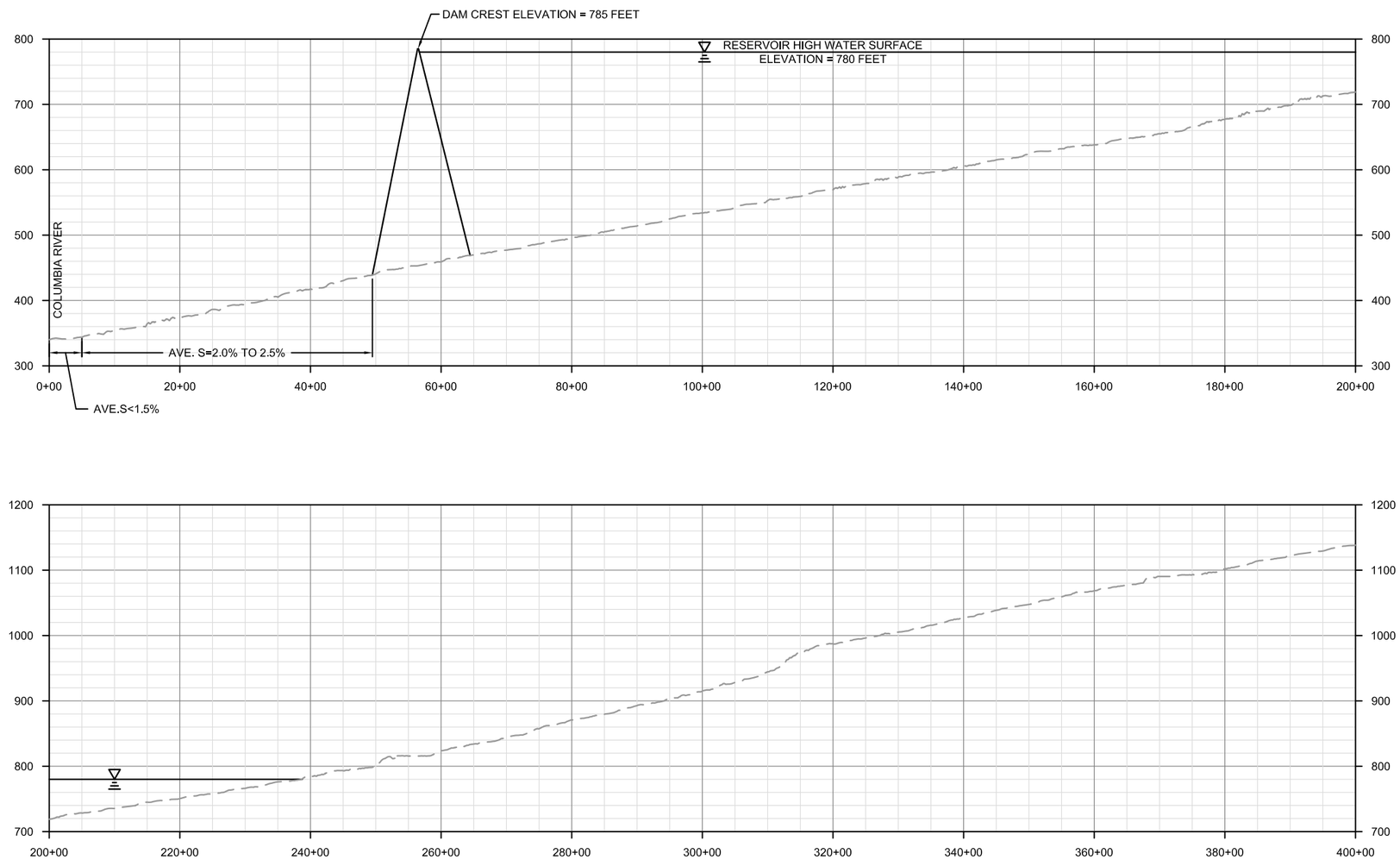
ANCHOR QEA

Figure A-1
Lower Alder Creek Profile
WRIA 31 Water Storage Pre-Feasibility Assessment
WRIA 31 Planning and Advisory Committee



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Scale in Feet

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Figure A-2
Lower Switzler Canyon Profile
WRIA 31 Water Storage Pre-Feasibility Assessment
WRIA 31 Planning and Advisory Committee

APPENDIX B

Information for Initial Water Storage Alternatives Considered

Table B-1
Opinion of Probable Costs for Potential Surface Reservoirs
WRIA 31 Water Storage Pre-Feasibility Assessment

ITEM	UNIT	UNIT COST	Lower Alder Crk QTY	Lower Alder Crk COST	Lower Alder Crk (Reduced) QTY	Lower Alder Crk (Reduced) COST	Lower Alder Crk (Reduced-U/S) QTY	Lower Alder Crk (Reduced-U/S) COST	(1W) Tule Cyn QTY	(1W) Tule Cyn COST	(2W) Upper Dead Cyn B QTY	(2W) Upper Dead Cyn B COST	(3W) Upper Dead Cyn A QTY	(3W) Upper Dead Cyn A COST	(4W) Lower Dead Cyn QTY	(4W) Lower Dead Cyn COST
Site Work																
Clearing and grubbing	AC	$2,000	4,220	$8,440,000	1,034	$2,068,000	908	$1,816,000	1,034	$2,067,500	219	$437,500	466	$932,500	519	$1,037,500
Temporary & permanent access	LS	VARIES	1	$80,000	1	$60,000	1	$60,000	1	$160,000	1	$13,000	1	$67,000	1	$43,000
Stripping/Stockpiling organic material	CY	$4.00	3,404,133	$13,616,533	834,093	$3,336,373	732,453	$2,929,813	833,892	$3,335,567	176,458	$705,833	376,108	$1,504,433	418,458	$1,673,833
Erosion and sediment control	AC	$4,500	4,220	$18,990,000	1,034	$4,653,000	908	$4,086,000	1,034	$4,651,875	219	$984,375	466	$2,098,125	519	$2,334,375
Diversion and care of water	LS	VARIES	1	$150,000	1	$120,000	1	$120,000	1	$125,000	1	$26,000	1	$56,000	1	$63,000
Revegetation	AC	$2,000	211	$422,000	52	$103,400	45	$90,800	52	$103,375	11	$21,875	23	$46,625	26	$51,875
Perimeter Fencing	LF	$15.00	5,000	$75,000	5,000	$75,000	5,000	$75,000	5,000	$75,000	5,000	$75,000	5,000	$75,000	5,000	$75,000
Subtotal - Site Work				**$41,773,533**		**$10,415,773**		**$9,177,613**		**$10,518,317**		**$2,263,583**		**$4,779,683**		**$5,278,583**
Earthwork																
Foundation excavation and stockpile, soil	CY	$6.00	441,014	$2,646,084	158,103	$948,616	140,257	$841,541	262,794	$1,576,766	81,362	$488,174	169,156	$1,014,933	76,058	$456,350
Foundation excavation and stockpile, rock	CY	$20.00	441,014	$8,820,281	158,103	$3,162,052	140,257	$2,805,135	262,794	$5,255,887	81,362	$1,627,248	169,156	$3,383,111	76,058	$1,521,167
Foundation grouting allowance	SF	$8.00	476,295	$3,810,362	170,751	$1,366,006	151,477	$1,211,818	283,818	$2,270,543	43,936	$351,486	91,344	$730,752	41,072	$328,572
Cutoff trench excavation and stockpile, soil	CY	$6.00	18,314	$109,883	14,297	$85,783	10,061	$60,367	7,672	$46,033	5,842	$35,050	7,936	$47,617	3,894	$23,367
Toe and finger drains	LS	VARIES	1	$142,889	1	$51,225	1	$45,443	1	$85,145	1	$13,181	1	$27,403	1	$12,321
Reservoir excavation (cut)	CY	$4.00	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0
Reservoir embankment (imported fill)	CY	$12.00	17,662,499	$211,949,988	4,478,726	$53,744,712	4,121,133	$49,453,596	16,850,000	$202,200,000	510,000	$6,120,000	2,116,000	$25,392,000	620,400	$7,444,800
Reservoir embankment (fill with cut material)	CY	$7.00	900,342	$6,302,394	330,502	$2,313,517	290,575	$2,034,022	533,261	$3,732,826	168,566	$1,179,965	346,247	$2,423,731	156,011	$1,092,078
Disposal of excess cut material	CY	$4.00	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0
Dam crest surfacing	CY	$30.00	6,243	$187,299	2,858	$85,741	2,012	$60,364	1,535	$46,036	1,169	$35,057	1,587	$47,621	779	$23,381
Subtotal - Earthwork				**$233,969,181**		**$61,757,652**		**$56,512,287**		**$215,213,237**		**$9,850,161**		**$33,067,168**		**$10,902,036**
Piping and Conveyance Facilities																
Inlet piping (Within 500 feet of reservoir)	LS	VARIES	1	$635,000	1	$270,000	1	$270,000	1	$360,000	1	$36,000	1	$60,000	1	$60,000
Low-level outlet piping (Concrete encased)	LS	VARIES	1	$795,000	1	$338,000	1	$338,000	1	$450,000	1	$45,000	1	$75,000	1	$75,000
Subtotal - Piping and Convyance Facilities				**$1,430,000**		**$608,000**		**$608,000**		**$810,000**		**$81,000**		**$135,000**		**$135,000**
Emergency Overflow Spillway																
Spillway Channel	LS	VARIES	1	$3,000,000	1	$1,000,000	1	$1,000,000	1	$1,500,000	1	$450,000	1	$550,000	1	$550,000
Subtotal - Emergency Overflow Spillway				**$3,000,000**		**$1,000,000**		**$1,000,000**		**$1,500,000**		**$450,000**		**$550,000**		**$550,000**
Construction Subtotal				**$280,173,000**		**$73,781,000**		**$67,298,000**		**$228,042,000**		**$12,645,000**		**$38,532,000**		**$16,866,000**
Mobilization / Demobilization	10.0%			$28,017,300		$7,378,100		$6,729,800		$22,804,200		$1,264,500		$3,853,200		$1,686,600
Construction Total				**$308,190,300**		**$81,159,100**		**$74,027,800**		**$250,846,200**		**$13,909,500**		**$42,385,200**		**$18,552,600**
Environmental Mitigation	10.0%			$30,819,030		$8,115,910		$7,402,780		$25,084,620		$1,390,950		$4,238,520		$1,855,260
Contingency	30.0%			$92,457,090		$24,347,730		$22,208,340		$75,253,860		$4,172,850		$12,715,560		$5,565,780
Engineering, Permitting and Administration	15.0%			$46,228,545		$12,173,865		$11,104,170		$37,626,930		$2,086,425		$6,357,780		$2,782,890
Project Subtotal				**$477,695,000**		**$125,797,000**		**$114,743,000**		**$388,812,000**		**$21,560,000**		**$65,697,000**		**$28,757,000**
Sales Tax	7.0%			$33,438,650		$8,805,790		$8,032,010		$27,216,840		$1,509,200		$4,598,790		$2,012,990
Allowance for Land Acquisition	AC	$1,000	4,431	$4,431,000	1,086	$1,085,700	953	$953,400	1,085	$1,085,438	230	$229,688	490	$489,563	545	$544,688
Total Project Cost				**$515,565,000**		**$135,688,000**		**$123,728,000**		**$417,114,000**		**$23,299,000**		**$70,785,000**		**$31,315,000**
Maximum WSEL	**FT**			**700**		**640**		**680**		**1,700**		**850**		**1,140**		**470**
Total Storage Capacity	**AF**			**300,000**		**65,300**		**55,800**		**118,463**		**5,712**		**20,714**		**11,543**
Total Project Unit Cost	**$/AF**			**$1,719**		**$2,078**		**$2,217**		**$3,521**		**$4,079**		**$3,417**		**$2,713**

Table B-1
Opinion of Probable Costs for Potential Surface Reservoirs
WRIA 31 Water Storage Pre-Feasibility Assessment

ITEM	UNIT	UNIT COST	(5W) Upper Glade Cyn B QTY	(5W) Upper Glade Cyn B COST	(6W) Upper Glade Cyn A QTY	(6W) Upper Glade Cyn A COST	(7W) Lower Glade Cyn QTY	(7W) Lower Glade Cyn COST	(4E) East Glade Crk QTY	(4E) East Glade Crk COST	(1E) Carter Cyn QTY	(1E) Carter Cyn COST	(2E) 4 Mile Cyn QTY	(2E) 4 Mile Cyn COST	(3E) Switzler Cyn QTY	(3E) Switzler Cyn COST
Site Work																
Clearing and grubbing	AC	$2,000	846	$1,692,500	1,200	$2,400,000	553	$1,105,000	173	$345,000	271	$542,500	435	$870,000	563	$1,125,000
Temporary & permanent access	LS	VARIES	1	$216,000	1	$212,000	1	$176,000	1	$16,000	1	$16,000	1	$20,000	1	$216,000
Stripping/Stockpiling organic material	CY	$4.00	682,642	$2,730,567	968,000	$3,872,000	445,683	$1,782,733	139,150	$556,600	218,808	$875,233	350,900	$1,403,600	453,750	$1,815,000
Erosion and sediment control	AC	$4,500	846	$3,808,125	1,200	$5,400,000	553	$2,486,250	173	$776,250	271	$1,220,625	435	$1,957,500	563	$2,531,250
Diversion and care of water	LS	VARIES	1	$85,000	1	$120,000	1	$55,250	1	$25,000	1	$27,000	1	$44,000	1	$56,000
Revegetation	AC	$2,000	42	$84,625	60	$120,000	28	$55,250	9	$17,250	14	$27,125	22	$43,500	28	$56,250
Perimeter Fencing	LF	$15.00	5,000	$75,000	5,000	$75,000	5,000	$75,000	5,000	$75,000	5,000	$75,000	5,000	$75,000	5,000	$75,000
Subtotal - Site Work				**$8,691,817**		**$12,199,000**		**$5,735,483**		**$1,811,100**		**$2,783,483**		**$4,413,600**		**$5,874,500**
Earthwork																
Foundation excavation and stockpile, soil	CY	$6.00	311,592	$1,869,551	322,260	$1,933,562	66,490	$398,939	53,437	$320,624	53,356	$320,134	94,333	$566,000	267,240	$1,603,440
Foundation excavation and stockpile, rock	CY	$20.00	311,592	$6,231,837	322,260	$6,445,207	66,490	$1,329,796	53,437	$1,068,748	53,356	$1,067,115	94,333	$1,886,667	267,240	$5,344,800
Foundation grouting allowance	SF	$8.00	41,072	$328,572	174,021	$1,392,165	35,905	$287,236	28,856	$230,850	28,812	$230,497	50,940	$407,520	144,310	$1,154,477
Cutoff trench excavation and stockpile, soil	CY	$6.00	7,278	$43,667	8,400	$50,400	4,589	$27,533	4,483	$26,900	5,111	$30,667	5,103	$30,617	5,792	$34,750
Toe and finger drains	LS	VARIES	1	$50,478	1	$52,206	1	$10,771	1	$8,657	1	$8,644	1	$15,282	1	$43,293
Reservoir excavation (cut)	CY	$4.00	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0
Reservoir embankment (imported fill)	CY	$12.00	6,138,782	$73,665,384	5,816,883	$69,802,596	375,182	$4,502,184	292,773	$3,513,276	322,419	$3,869,028	769,333	$9,231,996	6,347,356	$76,168,272
Reservoir embankment (fill with cut material)	CY	$7.00	630,461	$4,413,230	652,921	$4,570,445	137,569	$962,980	111,358	$779,507	111,823	$782,758	193,769	$1,356,386	540,272	$3,781,902
Disposal of excess cut material	CY	$4.00	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0
Dam crest surfacing	CY	$30.00	1,447	$43,401	1,680	$50,400	918	$27,528	897	$26,904	1,023	$30,676	1,020	$30,611	1,158	$34,742
Subtotal - Earthwork				**$86,646,120**		**$84,296,982**		**$7,546,967**		**$5,975,467**		**$6,339,518**		**$13,525,079**		**$88,165,676**
Piping and Conveyance Facilities																
Inlet piping (Within 500 feet of reservoir)	LS	VARIES	1	$270,000	1	$270,000	1	$36,000	1	$36,000	1	$36,000	1	$60,000	1	$240,000
Low-level outlet piping (Concrete encased)	LS	VARIES	1	$338,000	1	$338,000	1	$45,000	1	$45,000	1	$45,000	1	$75,000	1	$300,000
Subtotal - Piping and Convyance Facilities				**$608,000**		**$608,000**		**$81,000**		**$81,000**		**$81,000**		**$135,000**		**$540,000**
Emergency Overflow Spillway																
Spillway Channel	LS	VARIES	1	$1,000,000	1	$1,000,000	1	$500,000	1	$450,000	1	$450,000	1	$550,000	1	$850,000
Subtotal - Emergency Overflow Spillway				**$1,000,000**		**$1,000,000**		**$500,000**		**$450,000**		**$450,000**		**$550,000**		**$850,000**
Construction Subtotal				**$96,946,000**		**$98,104,000**		**$13,863,000**		**$8,318,000**		**$9,654,000**		**$18,624,000**		**$95,430,000**
Mobilization / Demobilization	10.0%			$9,694,600		$9,810,400		$1,386,300		$831,800		$965,400		$1,862,400		$9,543,000
Construction Total				**$106,640,600**		**$107,914,400**		**$15,249,300**		**$9,149,800**		**$10,619,400**		**$20,486,400**		**$104,973,000**
Environmental Mitigation	10.0%			$10,664,060		$10,791,440		$1,524,930		$914,980		$1,061,940		$2,048,640		$10,497,300
Contingency	30.0%			$31,992,180		$32,374,320		$4,574,790		$2,744,940		$3,185,820		$6,145,920		$31,491,900
Engineering, Permitting and Administration	15.0%			$15,996,090		$16,187,160		$2,287,395		$1,372,470		$1,592,910		$3,072,960		$15,745,950
Project Subtotal				**$165,293,000**		**$167,267,000**		**$23,636,000**		**$14,182,000**		**$16,460,000**		**$31,754,000**		**$162,708,000**
Sales Tax	7.0%			$11,570,510		$11,708,690		$1,654,520		$992,740		$1,152,200		$2,222,780		$11,389,560
Allowance for Land Acquisition	AC	$1,000	889	$888,563	1,260	$1,260,000	580	$580,125	181	$181,125	285	$284,813	457	$456,750	591	$590,625
Total Project Cost				**$177,752,000**		**$180,236,000**		**$25,871,000**		**$15,356,000**		**$17,897,000**		**$34,434,000**		**$174,688,000**
Maximum WSEL	**FT**			**1,400**		**1,990**		**400**		**1,010**		**1,180**		**550**		**780**
Total Storage Capacity	**AF**			**59,384**		**62,272**		**9,702**		**3,204**		**5,436**		**13,604**		**44,400**
Total Project Unit Cost	**$/AF**			**$2,993**		**$2,894**		**$2,667**		**$4,793**		**$3,292**		**$2,531**		**$3,934**