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REPORT

TO

WRIA 46 (ENTIAT) STORAGE SUB-COMMITTEE

STEP A WATER STORAGE ASSESSMENT

Submitted to:

Chelan County Conservation District and WRIA 46 Planning Unit
Entiat, Washington

Submitted by:

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1.0 INTRODUCTION

1.1 Purpose of the Step A Assessment

The purpose of the storage assessment is to determine the feasibility of storing water during periods of "excess" capacity, for use during periods of limited capacity. The Step A Assessment provides a general overview of potential storage options and typically leads to a Step B Assessment, which involves more detail on a selected sub-set of projects. This assessment considers various types of storage projects that may be useful in WRIA 46, given current and future water supply and demand. It includes:

- A general overview of potential storage options;
- A range of storage alternatives, including off-channel storage, underground storage, enlargement or enhancement of existing storage or water conveyance infrastructure;
- A discussion of issues associated with developing storage, including potential environmental effects; and
- An overview of potential storage projects in WRIA 46.

Based on the overview, the planning unit will select a limited number of options and/or areas for more detailed assessment in the second part (Step B) of the study, in which detailed storage assessments would be conducted.

1.2 Basic Concepts of Storage

The basic concept of storage is to collect water when there is excess, hold it with a minimum amount of loss or leakage, and use it during periods of limited supply or high demand. By convention, storage projects are typically developed in volumetric units, acre feet (AF), or million gallons (MG). Units of AF are used in this report. One AF of water is equivalent to 0.33 MG of water. Although a storage reservoir and associated permitting are typically expressed in volumetric units (i.e. acre-feet), the use and benefit of water storage is typically expressed as a flow rate (e.g. cubic feet per second). Figure 1 shows the relationship between storage volume (x-axis) and flow rate (y-axis), for selected durations of time (shown on the legend). For example, 5,000 acre-feet of storage is equivalent to about 120 cfs of flow for 14 days, or about 25 cfs of flow for 60 days.

Water storage could be used for several purposes:

1. To offset current demands on existing systems;
2. To offset future demands on existing systems;
3. To apply to new water uses in new or expanded systems; and
4. To enhance streamflows.

By definition, the goal of a multi-purpose storage project is to benefit multiple uses. For example, enhancement of streamflows, or prevention of further impacts to streamflows, is typically a resultant benefit of managing storage for existing or future uses. Although there are physical constraints on potential storage locations, the selection of potential storage locations is largely influenced by water use priorities (e.g. location, timing, and magnitude of water needs).

1.3 Availability of Water for Storage

The availability of water to put into storage is a function of both legal availability and physical availability.

1.3.1 Storage Allocation In WAC 173-546

From a legal perspective, the amount of water available for storage in WRIA 46 is now defined in WAC 173-546, as a result of the watershed planning process. The significant outcomes of the watershed plan that are relevant to regulatory water availability are:

- Instream flow requirements.
- Five (5) cfs reserve. The reserve was implemented to accommodate moderate growth in the Entiat basin through the year 2025 and is senior to instream flow requirements that were set in WAC 173-546-050.
- Maximum future water allocation (water storage allocation). The maximum allocation is the water that is "available" for storage provided that instream flow requirements are met; senior water rights are met; and the allocated water will be put to beneficial use that is not detrimental to the public interest. For this document, this water is called the "storage allocation".

The storage allocation is set from mid April through mid July, which essentially coincides with the snowmelt runoff season. The storage allocation in the Entiat River is up to 100 cfs a day from May 1 – June 30, and 67 cfs from July 1 – July 15. Off that 100 cfs, 25 cfs can be taken from the Mad River between May 1 – June 30; and from April 16-30 an additional 25 cfs is allocated from the Mad River only.

Figure 2 shows the mean daily streamflow on the Entiat River near Entiat (USGS gage# 1245990), relative to the instream flow requirements and maximum (i.e. storage) future allocation. In terms of water volume, the storage allocation rates set in the regulations are equivalent to a total storage volume of 15,035 acre-feet. On a monthly basis, the following monthly storage volumes (in acre-feet) are possible:

	Entiat	**Mad**
April 16-30	0	744
May 1-31	4,612	1,537
June 1-30	4,463	1,448
July 1-15	2,231	0
Total (acre-feet)	**11,306**	3,729

1.3.2 Physical Availability for Storage

Because the storage allocation is available only after instream flow requirements are satisfied, the total allocation may not be available during the driest years. According to the watershed plan, in 2001 (a representative dry year) only about 20% of the maximum allocation would have been available for storage. Figure 2 shows that, during the storage period, water is always available at a 50% exceedance frequency (e.g. at least 50% of the time, the maximum storage allocation would be available). For purposes of planning a storage project, an assessment of actual hydrographs (in addition to the statistical hydrograph on Figure 2) should also be completed. During the storage period, diversion for storage may be possible on some days, and not on others.

2.0 TYPES OF STORAGE

The following sections provide an overview of general types of water storage strategies along with a description of the anticipated regulatory process and an estimate of planning level costs.

The following surface water storage strategies are described:

- Reservoirs;
- Impoundments;
- Natural lakes; and
- Tank reservoirs.

The following groundwater storage strategies are described:

- Aquifer storage and recovery (ASR);
- Floodplain storage (artificial groundwater recharge); and
- Seasonal mining of groundwater storage (pump and dump).

There are other water management techniques that increase water retention, but don't necessarily meet a typical definition of a storage project from a regulatory/permitting perspective. These options are termed "passive storage" in this report. These types of projects are typically smaller in scope individually and/or are implemented on a programmatic basis. Passive storage approaches include:

- Conjunctive use of surface and groundwater;
- Side channel construction and floodplain management;
- Conservation and infrastructure improvements;
- Snow fences; and
- Vegetation management.

2.1 Surface Water Storage

This section provides an overview of surface water storage alternatives for WRIA 46.

2.1.1 Reservoirs

2.1.1.1 Overview

Reservoirs have a long history of both real and perceived negative environmental impacts. However, they have a proven history in the water supply field, and can play a role in storing water for both human and ecological needs. The primary concerns and drawbacks relate to barriers to fish passage (depending on project design), large engineering requirements for spillways and outlet works, inundation of lands upstream of a dam, and water quality/habitat effects in the inundated portion of the reservoir.

Reservoir Type

On-channel reservoirs are typically situated on a main stem of a river or stream and are filled by natural flow from the upstream watershed. They are the classic "dam" project. On-channel reservoirs typically have large storage capacities and may provide the added benefit of flood control.

Off-channel reservoirs are similar to on-channel reservoirs, but are typically situated in ephemeral (seasonally flowing) drainages or natural depressions rather than on the main stem of a river. Off-channel reservoirs typically utilize a combination of natural topography and constructed impoundments for storage. Water is conveyed from a surface water body to the off-channel location via pumps or diversion structures and then released either back to the surface water body or used for irrigation or municipal supply. Figure 3 shows an example of off-channel reservoir locations. The key advantage of an off-channel reservoir is that it can often be located in a less environmentally sensitive area without being a barrier to fish passage. Therefore the construction and operation of an off-channel storage facility will have little, if any, impact to aquatic habitat and fish passage. The primary drawback is that off-channel systems will require significant infrastructure (pipelines or canals) to convey water to and from the reservoir. Reservoir leakage and seepage is also generally a larger problem, the extent of which will vary depending on local geology.

Impoundments are similar to off-channel reservoirs but instead of utilizing natural depressions or ephemeral channels to create areas of storage, impoundments are completely constructed and self-contained. Impoundments are typically smaller than on-channel or off-channel reservoirs. Impoundments typically take the form of man-made ponds are may be lined to prevent leakage. The benefit to an impoundment is that they do not rely on natural landforms or topography. While impoundments can be a cost effective method of storing small volumes of water, they are typically limited by low storage capacities.

Water Quality

Water quality in surface water reservoirs, or natural lakes that are modified to increase storage capacity, can be a significant issue. Impoundment of water in a reservoir can cause elevated water temperatures, both within the reservoir and in the discharge from the reservoir. Water temperature can be a critical factor for aquatic species, and extreme temperatures can be lethal to many organisms. Often, reservoirs become thermally stratified, with warmer, less dense water near the surface and cooler more dense water at the bottom. This causes additional changes in water quality dynamics that vary seasonally. Lake or reservoir "turnover" occurs when a thermally stratified lake returns to an unstratified (isothermal) condition. Dissolved oxygen and nutrient water quality can also be problematic in reservoirs. Low dissolved oxygen can also occur in thermally stratified lakes or lakes with high productivity.

Regulation of water quality in lakes and reservoirs is complex. In Washington, multiple numeric criteria for temperature are used depending on the water body classification and presence of certain aquatic species (especially salmonids). In addition, "natural" conditions are often used as a baseline from which to assess water quality impairments, which requires characterization of this baseline. Finally, use based regulation of water quality adds another non-numeric dimension to determination of water quality impairments.

Surface water storage that is used for potable supply requires treatment, including filtration, to meet safe drinking water standards. The types of treatment, associated cost, operational complexity, and specific quality characteristics of water produced from treatment plant varies depending on many factors. Details of water treatment for potable supply are not addressed in this document, but should

be factored into any site specific assessments of surface water storage that would be used for potable supply.

Typical study needs for a surface water reservoir include:

- Geotechnical site investigation: To determine subsurface conditions for foundation or dike structures, subsurface seepage issues, and evaluation of requirement of cut-off walls.
- Site Survey and Land Use: Analysis for evaluation of land impacts due to increased water surface elevations, and design of dam structure.
- Hydrological study: To assess assessment of inflow/outflow magnitudes, flood flow analysis, operational rule curves, and carry-over storage.
- Engineering design: Includes all aspects of analysis/evaluation of dam and corresponding wing dikes for raising water levels, as well as subsurface cut-off wall requirements addressing subsurface seepage.

2.1.1.2 Regulation and Permitting

Aside from technical issues, proposals for new reservoirs or expansion of existing facilities introduces additional political and social complexities with the general public and local governments, creating both opportunities and challenges. Dams and reservoirs require an extensive public outreach effort, and need to be developed in an open and cooperative environment. Land use and the inherent environmental impacts of constructing a dam can often overwhelm the technical feasibility or benefit of a new or expanded reservoir. Construction of large new surface water storage facilities or expansion of existing facilities typically involves multiple federal and state agency approvals and can require a lengthy (e.g. 5 to 10 years) budget, study, and authorization process. For example, the Judy Reservoir expansion (in Skagit County, Washington) which increased the reservoir from 1,700 to 4,500 acre-feet took 11 months and cost over $1.3 million to permit. The proposed Pine Hollow Reservoir Project in Yakima County was originally conceived in 1998 and has not yet entered a formal permitting process.

Potential permits and approvals that may be required include:

- SEPA or NEPA (State/National Environmental Policy Act);
- Hydraulic Project Approval;
- 401 Water Quality Certification;
- US Army Corps of Engineers 404 Permits (Discharge of Dredge and Fill);
- Fish and Wildlife mitigation (WDFW; IDF&G);
- Water Quality Modification (Ecology);
- Water Rights (Ecology; IDWR);
- Dam Safety (Ecology; IDWR);
- Hydraulics Permit (WDFW; IDF&G);
- County Construction and Land Use permits; and,
- Other local permits.

A detailed discussion of permitting is not provided here. In terms of water rights, a reservoir permit is required in Washington from Ecology for the storage of 10 acre-feet or more of water in either an on-stream or off-stream reservoir as outlined in Ecology Water Resources Program Procedure PRO-1000 (Ecology, 1990). A reservoir is defined as "an impoundment with a dam or dike retaining water to a depth of 10 or more feet (as measured at its deepest point) and/or retaining more than 10 acre-feet of water" (Ecology, 1990). A reservoir permit is processed in the same way as a normal water right. Unless otherwise specified, a reservoir permit authorizes the filling of the reservoir once a year and the permit will state the time period for filling. A reservoir permit is issued for an annual quantity stated in acre-feet equal to the volume of the reservoir at normal pool elevation. A secondary permit may be required for beneficial use of the stored water (per 90.03.250).

Smaller reservoirs and impoundments are simpler to permit. A reservoir permit is not required for the following:

1. Storage of water in a quantity less than 10 acre-feet and/or if the depth of the pool is not greater than 10 feet.

2. Storage of water in an excavation with no above grade water retaining structure.

3. When water previously diverted under a separate appropriative water right is stored, when the storage facility is not classified as a reservoir.

Although no reservoir permit may be required in the above cases, a diversionary water rights permit may be applicable. Development and use of the water from the impoundment does not require a water right holder to change, transfer or amend any existing water right. The filling of below grade excavations does not require a water right permit if the filling is accomplished by natural overland flow or groundwater infiltration (Ecology, 1990).

2.1.1.3 Planning Level Costs

In 2001 the *Water Storage Task Force* complied comparative cost data for new dam and reservoir projects in Washington state. Storage projects ranging from 80 to 800,000 acre-feet were evaluated. Costs reported for dam enlargements ranged from $200/acre-foot for a 500 acre-foot small dam raise in the Methow Basin, to $5,300/acre-foot for the 1,700 acre-foot Judy Reservoir enlargement. Costs for new reservoirs in the state ranged from $1,695/acre-foot for the Zintel Canyon Dam to $13,280/acre-foot for the Rosa Wasteway 6 Re-regulation Reservoir. Cost analysis of three sites in WRIA 56 (Golder, 2004) ranged from around $1,500 per acre-foot to over $13,000 per acre-foot. In general, new dams cost more than raising existing dams, and larger dams (and higher storage volumes) cost more than smaller dams, even on a per acre-foot basis. The Water Storage Task Force is currently preparing an update report to the Washington legislature that will include more recent costing information (Burdick, 2005).

For off-channel storage facilities, additional conveyance infrastructure (a pipeline or diversion canal) is typically also required. Costs vary, and engineering analyses are necessary to prepare detailed cost estimates. For example, prices for HDPE (High Density Polyethylene) pipe range from $13 to $67 per linear foot and installation costs range from $16 to $76 per linear foot depending on installation environment. Pumping costs can also be high. For example a pump capable of delivering 18,000 gpm (40 cfs) with 30 feet of elevation gain can cost as much as $100,000. Recurring costs for operations and maintenance range in the thousands of dollars per year, even for smaller projects.

2.1.2 Lakes

2.1.2.1 Overview

Natural lakes may have perennial and intermittent streams which supply inflow and often form headwaters for rivers and streams. Lakes may provide an opportunity for storage through the implementation of engineering designs that control outflow rates and increase storage capacities.

2.1.2.2 Regulation and Permitting

The regulation and permitting procedures for the use of natural lakes for storage is similar to that of reservoirs (see Section 3.1.2.2 above). However, water quality issues associated with the use of natural lakes for storage differ from reservoirs since the natural water quality of the lake is considered. Washington uses a "natural" condition as a baseline for allowable impacts to surface water bodies. As a result, surface water storage projects need to demonstrate, by modeling and monitoring, what the natural water quality of the lake is and what the water quality effects of storage are, relative to the natural condition. Like reservoirs, water temperature is typically the most difficult water quality parameter to deal with in planning and/or operating a storage project in Washington. Lakes can become relatively warm, between 18 to 20 degrees C and higher in the summer months, which exceeds Washington's numeric criteria for temperature in the lake and in the streams downstream of the lake (Knight, 2005).

2.1.2.3 Planning Level Costs

Costs to use natural lakes for storage will vary considerably based on type of water control structure and permitting and monitoring requirements. For planning purposes, unit costs (per acre-foot) would be similar to a reservoir.

2.1.3 Storage Tanks

2.1.3.1 Overview

Water tank reservoirs are typically incorporated into a public water supply system to provide reliability and flexibility, particularly during peak demand periods. The volume of water storage that may be needed for municipal purposes is guided by regulations (Chapter 246-290 WAC – Public Water Supplies; and, Chapter 246-291 WAC – Group B Public Water Systems) as well as economic considerations of affordability, availability of water rights and the level of risk that communities are willing to carry by having either more or less storage capacity. For small communities in areas with limited aquifer yields, tank storage is a feasible solution. Tanks are typically not used to store water for streamflow augmentation or aquifer recharge due to storage volume limitations. However, tanks or tank systems of 1 to 10 million gallons are not uncommon.

2.1.3.2 Regulation and Guidance

Tank reservoir design is covered in WAC 246-290-235(3) and requires the following to be considered:

- Operational storage - the volume of the reservoir devoted to supplying the water system while, under normal operating conditions, the source(s) of supply are in "off" status.

- Equalizing storage – must be provided when the source pumping capacity cannot meet the periodic daily (or longer) peak demands placed on the water system as a part of the total storage for the system and must be available at 30 psi to all service connections.

- Standby storage - provides a measure of reliability should sources fail or when unusual conditions impose higher demands than anticipated. Recommended to be not less than 200 gallons per ERU.

- Fire suppression storage - permit delivery of fire flows in accordance with the determination of fire flow requirement made by the local fire protection authority or County Fire Marshal while maintaining 20 psi pressure throughout the distribution system.

- Dead storage - is the volume of stored water not available to all consumers at the minimum design pressure.

The Washington State Department of Health's (WDOH) Office of Drinking Water provides design and operational guidance in their document titled *Water System Design Manual* (WDOH, 2001), which includes a section titled Reservoir Design and Storage (Chapter 9). The manual provides guidelines and criteria for design engineers to use in the preparation of plans and specifications for Group A public water systems (typically those with 15 or more connections) for compliance with the Group A Public Water Systems Regulations (Chapter 246-290 WAC) and to clarify the engineering document submittal and review requirements.

2.1.3.3 Planning Level Cost

A planning level cost for additional storage as conventional above-ground tanks is approximately $1/gallon of storage capacity (Golder, 2004).

2.2 Potential for Surface Storage Projects in WRIA 46

The topography and watershed characteristics in WRIA 46 were reviewed for potential storage sites. USGS topographic maps, digital elevation models, and various GIS files provided by the Chelan County Conservation District were used to analyze the physical features of the Entiat basin, from the Columbia River confluence up to the wilderness boundary in the upper basin. The basic objective was to locate areas with relatively large storage potentials, without requiring large impoundment structures. The review focused mainly on sites for off-channel reservoirs and impoundments. As such, natural depressions and small ephemeral (seasonally flowing) drainages were the primary features of interest.

2.2.1 Existing Reservoirs

Currently there are no large dams in the Entiat Basin capable of storing more than 100 ac-ft.

2.2.2 New On-Channel Reservoirs

There are potential locations for a new on-channel storage reservoir in WRIA 46, either on the main stem of the Entiat River or a large tributary. A 1975 report published by Ecology listed a potential reservoir site on the Entiat River just above the Potato Creek confluence (Sorlie, 1975). Size estimates were not provided, but the total storage volume of the reservoir would likely exceed 10,000 AF. Given the sensitivity of the fisheries resource and the likely adverse impacts associated with constructing a new facility, constructing a new on-channel dam in WRIA 46 is probably not feasible or desirable.

2.2.3 New Off-Channel Reservoirs

There are potential sites for off-channel reservoirs along ephemeral drainages adjacent to both the main stem Entiat and Mad River. However, in general, the steep topography of the basin means that high impoundments would be needed to store significant volumes of water. Based on a review of USGS topography at a 40-foot contour interval, impoundment structures that are at least 40 to 80 feet high would be needed to store water volumes in the range 500 to 2,500 AF.

A summary of the location and characteristics of several potential areas for off-channel storage is shown in the Table 1. The sites listed in Table 1 are only potential areas for consideration. Additional data collection, as part of the Step B assessment, is required to fully assess the feasibility for off-channel storage at these sites.

Although the floodplain of the Entiat River widens in some areas, for the most part there are few large natural depressions along the valley floor that could be used as off-channel storage reservoirs.

2.2.4 Impoundments

Because impoundments are less constrained by topography, there could be many potential locations for small impoundments. Small ponds are present for the fish hatchery near Roaring Creek, and could potentially be expanded for the hatchery or for the community at Ardenvoir. One potentially important use for storage from small impoundments would be fire protection for rural landowners.

Land ownership would be a primary criteria for these types of features. Rather than plan specific structures, public outreach and planning/design assistance could be offered to landowners interested in this form or storage.

2.2.5 Lakes

Although there are many alpine lakes in WRIA 46, access is generally difficult and potential storage volumes are low. The most viable lake for storage is Myrtle Lake, which is situated about 400 feet west of Entiat River, just below the wilderness boundary in the upper basin. The USGS topographic map indicates that the current surface area of the lake is 24 acres. A 40 foot impoundment could increase the surface area to 70 acres, and the total storage volume would increase by 2,000-3,000 AF.

Lake Creek basin is another location that could potentially be used to store large volumes of water, but the topography of the basin is generally flat, meaning that a large impoundment would be needed. Also the natural inflow rates may not be large enough to support a large reservoir.

Finally, expansion of storage capacity to lakes and ponds in WRIA 46 may be limited by specific reference in WAC 173-546-060, which states "Lakes and ponds in the Entiat watershed shall be retained substantially in their natural condition, including those in the Wenatchee National Forest".

2.2.6 Tanks

Storage tanks can be used for municipal and domestic water supplies, as well as, for fire and frost protection storage. Storage tanks are generally self-contained structures that occupy relatively small areas. Therefore potential sites for storage tanks are determined based on need. In WRIA 46, potential locations for storage tanks include the City of Entiat, the town of Ardenvoir, and near the smaller communities, or subdivisions, in the lower Entiat Valley.

2.3 Groundwater storage

2.3.1 What is Groundwater Storage?

Below the ground surface, water storage is difficult to visualize and measure in ways similar to a surface reservoir or impoundment. However, the rise and fall of water levels in aquifers is fundamentally a response to an increase or decrease in the amount of water stored in the aquifer. Aquifers are commonly described as reservoirs, having a storage component and a flow component. Water that is stored naturally in an aquifer interacts closely with the water that flows through the aquifer, but the storage and flow components of groundwater flow are fundamentally different. Storage is an intrinsic property of the aquifer, while the rate and direction of water that flows through the aquifer is dependent on many other factors relating to the aquifer's boundary conditions. The maximum or minimum amount of storage in an aquifer can vary from year to year in response to climate. Over a long period, the amount of storage in an aquifer is actually negligible, since water that was stored at one time eventually flows through the system to the discharge areas of the aquifer. Groundwater storage, therefore, is also time dependent.

The amount of storage in an aquifer can be artificially increased or decreased by manipulating recharge. There are two main types of groundwater storage projects: (1) aquifer storage and recovery and (2) floodplain storage (artificial groundwater recharge). Aquifer storage and recovery (ASR) is becoming a conventional method of groundwater storage for municipal drinking water supply. Floodplain storage is a method that may be applicable in the Entiat that could be used to maintain streamflows, mitigate the effects of consumptive uses and/or improve aquatic habitat.

2.3.2 Aquifer Storage and Recovery (ASR)

2.3.2.1 Overview

Aquifer Storage and Recovery, or ASR, is a water resource management technique in which water is injected into permeable geological formations using wells, stored for a period of weeks or months, and then recovered for potable uses. Conceptually ASR operations are similar to surface water reservoirs, the only difference being that water is stored below ground rather than above. Figure 4 shows a typical "cycle" of ASR injection, storage, and withdrawal.

ASR is a system that is primarily used by large municipal water providers to store drinking water. Injection and withdrawal of water is therefore highly regulated, and therefore typically requires water treatment facilities. The receiving aquifer needs to have one of the following attributes: (1) physical or hydrochemical boundaries that restrict movement of the injected water and minimize water quality changes during storage; and, (2) suitable discharge boundaries that provide mitigation to surface waters during ASR operation (assuming that one objective of ASR is to provide streamflow mitigation).

ASR can be used for different purposes, and can be optimally configured for each purpose. However, in general, the primary use of ASR is for municipal drinking water, and other uses are generally secondary benefits in the project design.

ASR is being used throughout the world with facilities operating in many different environments, including Oregon, California, Nevada, Utah, Texas, Arizona, New Mexico, Florida and New Jersey. In Washington, the City of Walla Walla has an operational ASR project. A number of promising feasibility and pilot projects are also underway in the Pacific Northwest, including the Cities of Yakima, and on the Sammamish Plateau.

2.3.2.2 Regulation and Permitting

There are multiple regulatory and permitting issues to consider for ASR strategies including underground water injection, water rights, well construction and water quality. ASR in Washington is permitted under Chapter 173-157 WAC and requires three permits: (1) a primary water right for the water that will be used for recharge; (2) a permit to store the water; and, (3) a secondary permit to withdraw the stored water and put it to beneficial use (note that this permit may not be necessary depending on the nature of the primary water right).

2.3.2.3 Planning Level Costs

The cost of ASR is variable and site specific. The estimates presented here are based on limited research of ASR systems nationwide.

- Feasibility and pilot testing programs generally range between $100,000 and $500,000 for systems with existing infrastructure.

- Annualized unit costs for developed water using ASR range from $30 to $350 per acre-foot ($92 to $920 per million gallons) for systems that do not require new treatment facilities. Costs are significantly higher for systems that require new treatment facilities or other major infrastructure upgrades.

- Unit costs for ASR facilities (expressed in terms of recovery capacity) range from about $200,000 to $600,000 per million gallons pre day (mgd) of recovery capacity, with an overall average of about $400,000/mgd.

- Although operating costs are less well defined, available data suggest that annual operating costs are typically about $15,000/mgd of recovery capacity.

The cost feasibility of ASR generally limits implementation to larger existing water systems with surface water and groundwater sources linked by a distribution system. Municipalities with excess treatment capacity can often justify ASR projects when projecting costly capital improvement upgrades to meet increasing demand. ASR systems can result in the more efficient use of off-peak capacity from existing infrastructure, which can defray or delay the cost of system upgrades to meet increasing peak needs.

2.3.3 Floodplain Storage (Artificial Groundwater Recharge)

2.3.3.1 Overview

Floodplain storage, or artificial groundwater recharge, is a water resource management technique in which water is removed from a river or other surface water body during periods of high flow, pumped or diverted into infiltration basins on adjacent floodplains or terraces, and then allowed to recharge back into the river system. The time lag that occurs for the diverted water to move from the infiltration basin back into the river is engineered (by both location and basin design) so that the water returns to the river during periods when it is needed, typically when flows are low but demand is high. The primary challenge of floodplain storage is to ensure that the time lag between infiltration and recovery coincides with high streamflows (pumping) and low streamflows (recharge). The lag time is a function of separation distance between infiltration ponds and stream, aquifer material, and hydraulic gradient.

Floodplain storage can be used to offset the effects of consumptive water use during dry periods of the year. Increased streamflows during dry periods also has the added benefit of improving in-channel aquatic habitat and floodplain storage can also benefit riparian habitat. The potential system configurations for floodplain storage will vary with floodplain characteristics. A typical layout is shown in Figure 5. Water can be diverted directly from the stream and conveyed by gravity or pumped to the infiltration basin. Water quality (especially turbidity) can be a concern and may result in clogging of bed of the basin. Shallow groundwater wells adjacent to the stream can also be used to lower suspended solids in the discharge and reduce clogging. The infiltration basins themselves can be in natural unlined depressions or could be engineering and lined with a geotextile that to match desired infiltration rates. The size and location of the infiltration basins are dependent on specific project design, but would typically be at least 1,000 feet from the stream channel.

The feasibility of using this type of storage strategy is dependent on many factors, most importantly:

- Hydraulic Continuity: Interactions between the aquifer and adjacent surface waters must be well characterized and understood. A detailed understanding is necessary to support estimation of the timing, magnitude, and location of the return flows associated with the diversion. It also may be necessary to understand the fate of the return flow downstream of the project area. This typically requires a combination of well installation, aquifer testing, groundwater level monitoring and modeling analysis.
- Streamflows: Typical patterns of seasonal streamflow fluctuations are important factors in order to understand when water can be withdrawn and when water is needed in the stream.
- Channel conditions: Diversion from the main channel could require diversion structures or pumps that would operated during high flow or flood-level periods. An engineering analysis to site potential diversion points and assess structural needs for flood protection or channel migration m ay be necessary.

To date, indirect groundwater augmentation has not been widely used in Washington, but there is increasing interest in its application (McChesney, 2002). The state-funded Tamarack Recharge Project in Colorado is one of the best examples of this concept and is also relevant to application in WRIA 46.

Tamarack Recharge Project

The Tamarack Demonstration Project is the most extensive indirect groundwater augmentation scheme in the United States. The project is located on South Platte River at the Tamarack Ranch State Wildlife Area in northeastern Colorado. The project's primary goal is to augment streamflow during low flow summer months and assure that sufficient water is delivered from Colorado to Nebraska under the terms of a state water compact. The delivery requirements are based in part on endangered species habitat needs in Nebraska. The wildlife refuge in Colorado, where the project is located, also benefits from the project.

During spring, when river levels in the South Platte are at their seasonal high, alluvial groundwater is pumped from 10 wells situated adjacent to the river. The diverted water is transported by a system of pumps, pipes and diversion ditches into recharge basins that are located up-gradient of the river (Colorado Division of Wildlife, 1999). Figure 6 shows a map of the Tamarack project site. There are eleven recharge basins associated with the Tamarack project. The basins are located on eolian sand deposits with high infiltration rates at distances from the South Platte River ranging from about 0.25 to 1.0 mile. The estimated time lags for the water to return to the river from 30 to 120 days (Burns, 1985), but the two basins that are used most frequently have recharge times of about 60 days (Beckman, 2005). Knowing these travel times, the return flow can be timed to coincide with low

flows. Rapid infiltration of the diverted water helps limit evaporative water loss. For example in 2001, only 7% was estimated to be lost to evaporation (Altenhofen, 2001).

An average of approximately 4,000-5,000 acre-feet per year has been diverted into the drainage basins since the scheme was initiated in 1997. The total wellfield capacity is 23 mgd, which enables the annual permissible withdrawal to occur even during dry years when spring runoff is brief. The initial models developed by the Colorado Division of Wildlife indicate that once the scheme is fully implemented, the augmented groundwater will increase flows near the Colorado state line by approximately 10,000 acre-feet from April through September (Platte River Endangered Species Partnership, 2003).

Research on the effectiveness of the project is ongoing, but preliminary results indicate that at least a portion of the augmented groundwater is working to retime flows (Colorado Division of Water Resources, 1999; Miller and Durnford, 2005).

2.3.3.2 Regulation and Permitting

Floodplain storage with infiltration basins would be permitted like any other storage reservoir under WAC 173-157-040. Three permits are necessary:

- A primary water right for the water that will be used for injection/recharge
- A permit to store the water
- A secondary permit to withdraw the stored water and put it to beneficial use (this permit may not be necessary, depending on the structure of the primary water right and the proposed beneficial use).

The ability for downstream consumptive use of water that is returned to the river via floodplain infiltration could introduce additional complexities amongst regulators, purveyors, local governments and the general public. "Ownership" of water that is removed from surface water body, allowed to infiltrate into an aquifer, and subsequently moves through the aquifer is a difficult to administer. However, floodplain storage could play an important role in moving water where and when it is needed for both human and ecological needs.

2.3.3.3 Planning Level Costs

Planning level costs for a floodplain storage project are difficult to project because very few projects of this type have been implemented in the United States or elsewhere. For the Tamarack Project in Colorado, the general costs are estimated at $10-$15 dollars per acre foot per year for capitol costs, and an additional $10-$15 dollars per acre foot per year for operation and maintenance (Altenhofen, 2006). It is important to not that these estimates do not include the cost of feasibility studies or permitting. As such additional startup costs will be incurred, and depending on the extent of the background studies the startup costs could be significant.

2.3.4 Seasonal Mining of Groundwater Storage (Pump and Dump)

2.3.4.1 Overview

Pumping of groundwater and discharging it directly to streams to augment streamflow is a form of storage withdrawal that taps the natural storage capacity of aquifers. It has been called "Pump & Dump" in Washington. The concept of withdrawing groundwater storage to improve water resources management is not new. Withdrawal during dry periods, balanced by replenishment during wet

periods, is, in many situations, a long-term and sustainable approach to water resources management (Alley and Leake, 2004). Careful manipulation of groundwater storage can produce streamflow benefits with little or no environmental impact, and, in some instances, additional water supply. It can also offer significant advantages over constructed surface storage impoundments. This approach is most applicable in a maritime or mountainous climate where there is significant seasonal run-off and associated groundwater recharge to deep permeable aquifers. The aquifer is pumped only during the dry season or during an extended low flow period and discharged directly into an adjacent stream or river. During the wet season, the aquifer is "rested" and allowed to recover its storage capacity. The well can be used every year or only during drought years. The frequency of use depends on streamflow needs and the ability of the aquifer to recharge during the wet season.

The Shropshire groundwater scheme in England is the largest operating groundwater augmentation scheme of this type. The project began in the 1970's as a response to the increased demand for water resources in the west Midlands region of England. Increased water use, coupled with recurring drought conditions caused a decline of flows in the River Severn. The objective of the Shropshire groundwater scheme was to augment groundwater into the River Severn during periods of low river flows. The increased flows are used to benefit downstream public water supplies and aquatic habitat. During augmentation, groundwater is pumped from the sandstone aquifers and discharged through pipelines into either the River Severn or one of its three main tributaries. The project has been operated five times since the first phase of the project was commissioned in 1982. As of 2005, a total of 39 wells and a total wellfield capacity of 35,000 gpm per year have been installed. The total annual abstraction that will ultimately be permitted when all eight phases are complete is 61,000 gpm, which is expected to increase flows in the River Severn by about 41,000 gpm (Voyce, 2005).

2.3.4.2 Planning Level Costs

The primary costs associated with groundwater augmentation include a feasibility study, well construction (if an existing well is not available) as well a pumping and conveyance costs. Feasibility studies are likely to range between $25,000 to $250,000 depending on the scale of the project. Well construction (including planning, permitting and testing) may range between $50,000 to $100,000 per well. Pumping costs (assuming a pumping rate of 500 gpm or 1 cfs with a 60 horsepower pump and 180 feet of lift) would be approximately $2,160 per month or about $32 per acre-foot of water. Annual operations and maintenance and monitoring would also need to be considered.

2.4 Potential For Groundwater Storage Projects in WRIA 46

2.4.1 Aquifer Storage and Recovery

The potential for ASR is probably limited because of the lack of major public water supply infrastructure in the rural valley portion of the basin. In addition, aquifers in the basin are primarily composed of unconsolidated alluvium and exhibit a high degree of continuity with surface water (CCCD, 2004). This type of aquifer would not behave like a typical ASR "reservoir", which would increase the complexity of permitting an ASR project.

2.4.2 Floodplain Storage

The potential for floodplain storage is good. The floodplain for the Entiat, through variable, is wide and thick (over 100 feet deep) in places. Direct diversion and gravity conveyance to infiltration sites may be possible, as would shallow wells adjacent to the river. Land ownership in the floodplain is varied, but large parcels are present, some with public ownership, including parcels held by the Chelan-Douglas Land Trust. The floodplain above the Potato Creek moraine between River mile 20 and 25, appears to be favorable for this storage concept. The thickness of alluvium also increases

significantly in this area. There are numerous abandoned channels that could be used as infiltration areas, and at least one small pond (1 acre in size) appears on the USGS 7.5-minute topographic map. The floodplain widens in this area to over one mile, and also includes areas that might be suitable for terrace storage.

Additional analysis of static water levels, pumping tests, and water-level fluctuations is needed to further develop the concept. However, a project similar in size and scope to the Tamarack Project (e.g. 10,000 AF) does not seem unreasonable based on their similarities. The use assigned to the return flow through the water right permitting process could include instream flows as well as benefits to habitat or downstream consumptive uses.

Figure 7 shows an example of the withdrawal and return flow cycle that could be investigated for feasibility, focusing on the Entiat River. Withdrawal from the Entiat River would begin when streamflows exceed instream flow requirements (early May in this case for 2002). Withdrawal would stop in July when withdrawal for storage is no longer possible. The location and design of the infiltration basins would attempt to maximize return flows during August and September.

2.4.3 Seasonal Mining of Groundwater

The potential for this method is largely unknown. Two possible hydrogeological targets for this application in WRIA 46 include the Entiat Fault, and deeper portions of the alluvial aquifer:

The Entiat Fault intersects the Entiat River in the vicinity of Roaring Creek. This location also coincides with a significant increase in streamflow. If the fault is a significant conduit for groundwater discharge, seasonal withdrawal of groundwater storage within the fault zone could be used to further increase streamflows in this area.

The other alternative would deep portions of the alluvial aquifer above the Potato Creek moraine. If there is sufficient stratification within the deep alluvial aquifer to maximize the time lag between pumping and streamflow effects, then seasonal withdrawal of groundwater storage within the deep alluvium could possibly be used seasonally from this area.

Figure 8 shows an example of the withdrawal and recharge cycle that could be investigated for feasibility. Pumping would commence in early August, when streamflows are below instream flow requirements, and could continue until October, or until there was no longer need for water in downstream reaches. During the subsequent winter and spring, recharge to the aquifer would need to be investigated to determine whether storage withdrawals had been replenished.

2.5 Passive Storage Approaches

Surface and groundwater storage are the most common types of storage but there are many other less conventional alternatives.

2.5.1 Conjunctive use

Conjunctive use refers to the combined use of both surface water and groundwater to achieve optimal beneficial use. The typical objective is to optimize water use to achieve maximum benefit (or minimal impact) to both water users and streamflows. The most general approach is to utilize surface water during periods of annual high flow (spring), then switch to groundwater supplies when surface waters are low (summer-early fall). In most systems there is a lag time from the moment groundwater pumping begins to the time when the effects of groundwater pumping adversely impact streamflows. The lag time varies between systems depending on the amount of hydraulic

connectivity between surface and groundwater. Efficient conjunctive use strategies can utilize this lag time to maximize streamflows. In Washington, the administration of water rights is separate for groundwater and surface water, so conjunctive use strategies must consider water rights. WDOE has shown a willingness to shift or split existing water rights between surface water and groundwater provided that a benefit to public interest is shown. The general approach of a typical conjunctive use strategy is illustrated in Figure 9. From a water user or water right holder's perspective, the total amount of water delivered to the water system (e.g. an irrigation ditch) does not change (Figure 9a). From the river's perspective, when the switch to groundwater occurs, a significant improvement in streamflow occurs (relative to the surface diversion). This improvement wanes with time as a function of continuity with the groundwater, but it is never any worse than the direct surface diversion.

The main drawback is that the method often requires additional infrastructure (pipes or canals) and energy (groundwater pumps) to manage the surface and groundwater systems. In some cases water rights can be difficult, since WDOE must demonstrate that the "same body of water" is being put to beneficial use.

2.5.2 Side Channel Construction and Floodplain Management

Natural floods and geomorphic processes often form a complex floodplain with numerous abandoned river channels. These side channels can become isolated from the mainstem river due to channel migration, erosion and deposition, vegetation establishment, and land-use practices. Side channels can store surface water, particularly during high flows, which is then released back to main river during the summer. Constructing a new side channel or re-connecting an existing side channel to a mainstem river is a common habitat enhancement project. It establishes a link between the channel and the floodplain and creates off-channel spawning habitat for salmonids. The water storage benefits occur by retaining more water in the floodplain, and allowing it to seep slowly as groundwater seepage back to the mainstem. and increase surface water flow during later periods of the year. Numerous side channel projects have been implemented in Washington State, including work on the Twisp River in the Methow basin, where an abandoned side-channel/pond system was converted to a natural rearing facility for endangered steelhead. Examples within the Entiat Basin include the Jon Small side-channel/rearing pond, and Wilson side-channel connection/enhancement projects, which were completed in 2004.

2.5.3 Snow Fences

Snow fences are relatively simple wooden structures that are designed to increase snowpack levels by consolidating and enlarging snow drifts. Consolidation and enlargement of snow drifts reduces the amount or water loss by evaporation and sublimation. Snow fences can be constructed wooden fences or "living" rows of trees. Snow fences can be placed anywhere, but are commonly used along highways and other public right of ways.

2.5.4 Vegetation management

Evapotranspiration by plants is a significant determinant of a basin water balance and is a key control on the storage of moisture in the soil zone. In many areas, "natural" vegetation has been replaced by introduced plant species or by other natural species that use water differently. Less use of water by vegetation can increase the amount of moisture retention in soils and improve streamflow conditions in some cases. Stand replacement on forested lands, whether through cutting and replanting practices or from fire is one example where there are potential changes to the water balance from vegetation. Changes to the vegetation characteristics of riparian zones, either from land use practices or natural processes such as flooding, is another area where vegetation type could affect the water balance.

2.5.5 Conservation and Efficiency Improvements

Conservation practices or infrastructure improvements can lower the amount of water used for irrigation or domestic purposes. In areas where these improvements are focused on seasonal water savings (e.g. summer consumptive uses), the improvements can increase the amount of water storage in groundwater or surface water systems. Relatively simple practices such as promotion of efficient water use, or structural improvements to drainage ditches can directly affect streamflows and groundwater levels. These types of programs can be implemented or promoted by local stakeholder groups, or conservation districts.

2.6 Potential For Passive Storage Projects in WRIA 46

There are many different restoration or improvement projects in the Entiat basin that directly address water storage. Table 2 provides a list and brief description of ongoing and planned projects in the basin.

2.6.1 Conjunctive use

This approach would not necessarily "tap" into the water storage reserves set by rule in the WAC. Existing water right holders could choose to develop conjunctive systems. Downstream users of "new" surface water that might be developed under a conventional storage project could also use the technique to further maximize the amount of water that remains instream.

2.6.2 Side Channel Construction and Floodplain Management

There are many potential areas for side channel improvements along the Entiat River. The most likely sites would be along areas in the valley where the floodplain widens and ancient, or former, side channels exist. The lower Entiat and the "Stillwater reach" above Potato Creek are two primary areas for consideration.

A side channel improvement project known as the "Jon Small Project " has recently been completed in the lower Entiat. This project is located along the Entiat River near the Roaring Creek confluence, and consists of a groundwater-fed rearing pond that was created and connected to mainstem Entiat by a channel. Woody debris and native vegetation is going to be placed in and around the pond in order to provide optimal rearing habitat for salmonids.

2.6.3 Snow Fences

Currently there are no snow fence related projects in WRIA 46, but there is potential for the use of snow fences. These types of projects would likely be relatively small in scale and would involve private landowners. Because snowfall increases with elevation, the most effective use of snow fences would likely occur in upper portion of the basin.

2.6.4 Vegetation management

There are over 80 currently planned or on-going projects in WRIA 46 that involve some type of revegtation. Many of these projects are implemented to create shade, where seedlings are planted in the on streambanks to reduce temperature (summer high and winter low) extremes. As such, water consumption is not a primary objective. Commonly used plants such as willows, for example, tend to consume a lot of water. However, future projects could utilize plants that are efficient consumers in order to maximize soil moisture, groundwater levels, and streamflows.

2.6.5 Conservation and Efficiency Improvements

The water 46 watershed plan recommended the following improvements:

- General water conveyance efficiency improvements;
- Consolidation of the Knapp-Wham and Hanan-Detwiler irrigation ditches;
- Convert open irrigation systems to piped systems;
- Upgrade inefficient surface water diversion structures;
- Extend municipal water and irrigation system upstream;
- Conversion of surface water diversion to groundwater well withdrawals; and
- Technical and financial assistance to improve irrigation efficiency.

3.0 WATER STORAGE BENEFICIAL USES

This section describes the possible beneficial uses associated with a water storage project. Beneficial uses attributed to water in Washington are defined in both water rights and in water quality regulations. On a water right, one or more purposes of use are identified. Table 3 summarizes purposes of use for a water right. Under the state's water quality regulations beneficial uses are also identified. These beneficial uses include Aquatic Life Uses, Recreational uses, Water Supply uses, and other miscellaneous uses. Pending revisions to these regulations under WAC 173-201A identify specific beneficial uses for each WRIA in the state, and include references to core and non-core fish use. Specific beneficial uses for the Entiat are shown on Table 4.

Where possible, beneficial uses for water storage projects should be identified that are consistent with these water regulatory definitions.

3.1 Consumptive Uses (Out-of-Stream)

Water storage projects can be used to meet any of the purposes of use and beneficial uses shown on Tables 3 and 4. The most likely consumptive beneficial uses in the Entiat would include agricultural (irrigation) and stock watering, and domestic/municipal uses. To accommodate future growth in the basin, the Planning Unit determined that a 5 cfs reserve (not subject to in-stream flow limitations) should be reserved for future use (3 cfs for agriculture, 1 cfs for commercial/industrial use, and 1 cfs for domestic and stock watering). Consumptive use in excess of this 5 cfs could be obtained through the storage reserve.

3.1.1 Agricultural and stock watering

The majority of the water allocated and currently used in WRIA 46 is for irrigation, primarily fruit orchards, with lesser amounts used for pasture and residential use. A summary of irrigated water use in the Entiat basin is summarized below.[1]

Type	Acres	Water Use (AF)
Irrigated Orchard	835	4090
Irrigated Residential	236	970
Non Irrigated Residential	188	0
Irrigated Pasture	206	840
Sub Irrigated Pasture	121	0
Non Irrigated Pasture	400	0
Totals	1986	5900

Note:

[1] Data obtained from the WRIA 46 Management Plan (CCCD, 2004).

Virtually all of the water currently used for irrigation in the Entiat basin is located below river mile 18, except for approximately 20 acres of irrigated residential land. In terms of the irrigated orchard land, 75% is situated below the Mad River confluence. All of the water used in the Mad River basin is clustered along the lower 1 mile of the Mad River, near the community of Ardenvoir.

In the watershed management plan, the planning unit estimated that approximately 150 acres of land in the Entiat basin could potentially be put into commercial agricultural use in the future. This would require approximately 800 AF of water for irrigation, and translates into a maximum instantaneous rate of 3.6 cfs.

To accommodate future agricultural growth the Planning Unit recommended that a 3 cfs reserve should be available via future water rights. It was also recommended that an additional 1 cfs be reserved for future commercial or light industrial uses in the Entiat basin.

3.1.2 Municipal/Domestic

The City of Entiat obtains water for its municipal system from wells situated adjacent to the Columbia River. Therefore the city's water is drawn from the Columbia River, not the Entiat River. The 2004 WRIA 46 Management Plan estimated that the city pumps approximately 140 AF of water per year and treats 62 AF per year, meaning the net water use by the city is 78 AF. It was estimated that 75% of this water is for residences, while the remaining 25% is for commercial or industrial uses. The Entiat Irrigation District provides water to the city for irrigation and outdoor use over the summer months.

According to the 2000 Census data, there are 470 housing units in the Entiat basin that fall outside of the City of Entiat Urban Growth Area. Water supply for these housing units comes mostly from permit exempt wells. The management plan determined that the total net domestic water use from these housing units is approximately 50 AF per year. This translates to approximately 0.07 cfs on an average monthly basis. The planning unit estimated that by 2025 the population of the Entiat basin is expected to grow by approximately 367 people. In order to accommodate this growth, an additional 14 AF of water per year will be needed for domestic in-house supply, and up to 270 AF will be needed for domestic irrigation.

To accommodate future municipal/domestic use, the Planning Unit estimated that 1 cfs will be needed for future domestic in-house, irrigation, and stock water needs in the Entiat Basin.

3.1.3 Fire and Frost Protection

Potential uses associated with fire or frost protection were not addressed in the watershed plan. Small impoundments or water tanks could be constructed and used to protect homeowners against the threat of wildfires. The Entiat has a long history of fires and the potential for large high severity wildfires is expected to grow due to increased fuel densities in fire-prone zones and climatic variability. Residential dwellings typically have fire flow requirements on the order of 1,000 gallons per minute. A 5-acre-foot impoundment (1.6 million-gallon tank) could produce 1,000 gpm for up to 27 hours.

Frost or freezing temperatures in the early spring or late fall can damage orchards and application of water for frost protection is one method for minimizing crop damage. Orchardists within the valley currently utilize overhead sprinkler systems and methods other than pulling from frost ponds for frost control. Recommended flow and storage requirements for frost protection ponds in the British Columbia Frost Protection Guide (Van der Gulik and Williams, 1988) are summarized below.

Flow Rate Requirements for Frost Protection

Application Rate	Flow Rate
0.08 in/hr	36 gpm/ac
0.11 in/hr	55 gpm/ac
0.16 in/hr	71 gpm/ac
0.20 in/hr	91 gpm/ac

	Acre-Feet Diverted												
	1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000	11,000	12,000	13,000
Diversion Period	Diversion Rate (cfs)												
30 -Day Flow	12	24	35	47	59	71	82	118	153	200	235	353	471
50 -Day Flow	7	14	21	28	35	42	49	71	92	120	141	212	282
70 -Day Flow	5	10	15	20	25	30	35	50	66	86	101	151	202
90 -Day Flow	4	8	12	16	20	24	27	39	51	67	78	118	157
120 -Day Flow	3	6	9	12	15	18	21	29	38	50	59	88	118

The table can be used to describe and discuss relationships between storage volume, flow duration, and flow rate.

4.2.2 Primary Use

The primary use of water storage should be the primary determinant of project benefit and the primary purpose of use on the water right application. Most storage projects have a consumptive use, such as municipal or agricultural supply, as a primary use. In other cases, predominantly non-consumptive uses, such aquatic life, fish hatchery, power generation, or in-stream resources, is the primary use.

4.2.3 Secondary Use

Secondary uses of water storage should also be included in the water right application and, where applicable, should be noted with respect to water quality beneficial use designations. Even if a project is developed primarily for a consumptive use such as agricultural supply, secondary uses such as aquatic life, other in-stream environmental uses, or out-of-basin uses can be important components of a project and should be given some consideration.

4.2.4 Type of Project (Conventional/Non-Conventional)

The type of project may have an influence on feasibility, particularly from a water right permitting perspective. Conventional storage projects, such as reservoirs or groundwater projects, have well defined and often extensive permitting requirements that may require a project specific environmental impact statement or similar environmental assessment. Non-conventional projects, such as small storage impoundments or vegetation enhancement, may have less extensive permitting requirements (i.e. a SEPA checklist or equivalent) or could be implemented through a "programmatic" approach that provides some sort of technical or financial support to potential proponents of specific projects.

4.2.5 Location and Land Ownership

Storage projects can require significant amounts of land. Easements can be necessary for conveyance, and reservoirs/impoundment can take acres of land to develop. Land ownership not only influences the location and footprint of the project, but can also influence the project proponent (who "owns" the project), and the permitting requirements for the proponent. Projects on federal lands typically entail additional permitting such as NEPA or a Section 7 ESA consultation.

The distribution of private and public land is well documented in the watershed plan. Projects in the upper (e.g. higher elevation) portions of the watershed would likely be on federal lands, while projects in the floodplain would need to consider the distribution of private lands. Although land

Storage Requirements	
Application Rate	Storage Requirement / Acre Protected
0.08 in/hr	2171 gal/hr/ac
0.11 in/hr	3258 gal/hr/ac
0.16 in/hr	4342 gal/hr/ac
0.20 in/hr	5625 gal/hr/ac

3.1.4 Out of Basin Uses

Water storage in the Entiat watershed, as a tributary to the Columbia River, may also provide out-of-basin benefits. Issues related to Salmon Recovery in the Upper Columbia and the operational requirements of hydroelectric facilities on the Columbia are related, in part, to flow levels during the late summer. Water storage projects in the Entiat may enhance flows entering the Columbia system, and thereby provide benefits to downstream reaches of the Columbia River. These benefits could attract additional investment in viable Entiat storage projects from groups such as the Columbia River Partnership, and could further leverage the multi-purpose benefits of such projects. These issues could also complicate the development of storage project, but, even if storage benefits are primarily retained within the basin, the potential for out-of-basin benefits should not be discounted.

3.2 Non-Consumptive Uses (In-stream)

3.2.1 Aquatic Habitat and Instream Flow

Improved aquatic habitat can be a primary or secondary benefit of a water storage project. Storage projects that increase streamflows during low flow periods are particularly beneficial to aquatic habitat. Streamflows and water levels are key controls on aquatic habitat functionality throughout the year, but during low flow periods, relatively small increases in flow volumes or depths can lead to large increases in available habitat.

Physical, biological, and chemical characteristics are the primary components of aquatic habitat in river systems. Theses three components are interrelated and closely tied to streamflows. From a physical standpoint, the amount of water in a river directly affects the wetted width, depth, and average flow velocity in the channel. These physical components directly affect the range of suitable habitat and nutrient availability for the biological components, such as fish and macroinvertebrates. The chemical component is essentially water quality and streamflows are important regulators to key water quality parameters such as temperature and dissolved oxygen.

Salmonid species are particularly affected by streamflows. Figures 10, 11, and 12 illustrate how the life stages of salmonids species relate to streamflow fluctuations in the Entiat. Anadromous salmonids such as spring Chinook, Coho, and steelhead spend up to a full year in the stream as juveniles prior to their out migration to saltwater. The amount of available rearing habitat directly affects survival rates. Research shows that Coho abundance is limited in the summertime by pool area and in wintertime by off-channel habitat such as side-channels, ponds, and oxbows (Cederholm and Scarlett 1981; Narver 1978; Peterson 1980). Both types of rearing habitat are directly affected by flow levels. Water temperature is another critical factor affecting the survival of salmonid species during the summer low flow period. Storage projects that increase streamflows during periods of low flow can increase available rearing habitat and decrease stream temperatures.

The specific benefits of increased flows to salmonids include:

- Increase the area and depth of water over riffles, thereby increasing available spawning areas;
- Increased pool area, which has been linked to survival rates among juvenile Coho and Chinook salmon;
- Added cover from predators;
- Passage into small tributary streams that become stranded by alluvial fans;
- Passage into off-channel rearing habitat; and
- Improved water quality, particularly temperature and dissolved oxygen.

The potential benefits to fish species from increased streamflows in the Entiat River will likely be most related to improvements in rearing area. Based on the WRIA 46 In-stream flow Study (Entrix, 2003) Chinook and steelhead populations are generally limited by rearing (not spawning) habitat. In addition, even in years with very low streamflows, adequate fish passage conditions exist in the mainstem Entiat River, as demonstrated by historic spawning use of the upper reaches of the system by spring and summer Chinook.

Since Entiat River spring Chinook are stream-type Chinook and spend up to one year in the stream before migrating to salt water, they would be most affected by the low-flow period in late summer/early fall. The consequent reduction in rearing area during this time could limit population abundance. Higher streamflows designed to enhance rearing habitat would likely be most effective at the margins (e.g., side-channels, or other valley-floor or floodplain features) since an increase in area is more important than increases to water depth or water velocity. Coho juveniles would also benefit, for the same reasons.

An inventory of key rearing areas in the Entiat has not been completed, but the release of water storage for streamflow enhancement should probably place a priority on enhancing rearing areas. Streamflow augmentation to enhance rearing area would have secondary benefits like addressing water quality problems with temperature and dissolved oxygen.

3.2.2 Flood Control

Large reservoirs often serve to reduce flood hazards, when designed and operated to capture large inflows and release them later in the year. Large mainstem reservoirs (or larger tributaries) are typically necessary to reduce flooding. Detailed analysis of flood flow frequency and magnitude is necessary to site and design flood control reservoirs. In the Entiat, the flood of 1972 had a peak flow of about 6,400 cfs. To capture and re-distribute flows of this magnitude, storage capacities of 20,000 AF would likely be necessary. Flood control benefits from smaller storage projects would likely be minimal.

3.2.3 Entiat Conditions

Instream Flow

In a 2004 water quality assessment, the lower Entiat River was listed as impaired for instream flows. Minimum instream flows were recommended for the Mad and Entiat Rivers in the WRIA 46 management plan. These recommendations were later codified in WAC 173-546-050.

Instream flow levels are typically met in the winter months, but are often not met in the summer months, even during "average" (50% exceedance) years (see Figure 2). Table 3 shows that currently, the Entiat River at Ardenvoir (near the confluence with Stormy Creek), only meets the instream flow requirement of 175 cfs about 10% of the time in August, and about 5% of the time in September (based on 1957-2001 streamflow data). A water storage project could increase flows in the summer and increase the frequency at which instream flow levels are attained. As shown on Table 5, the addition of 30 cfs would increase the frequency that instream flow levels are achieved by about 21% and 9% for September and October respectively. The addition of 100 cfs would increase the frequency to about 87 % and 72% respectively.

Achieving the instream flows is particularly important for future consumptive use because future water rights that are not granted from the reserve will be conditioned by instream flows. In other words, attaining instream flows will allow future conditioned water rights holders to exercise their water rights.

Habitat Limiting Factors

The Entiat River system serves as spawning and rearing habitat for spring and summer Chinook, Coho, steelhead, and sockeye. It also has bull trout, resident cutthroat trout, rainbow trout, and other species. Spring Chinook are listed as Endangered under the Endangered Species Act, and bull trout and steelhead trout are listed as Threatened under the Endangered Species Act. All of the benefits listed in the previous section can be specifically applied to improve habitat in the Entiat basin.

The limiting factors report for WRIA 46 lists several factors that could be addressed through water storage projects:

- The loss of juvenile rearing habitat as the factor most limiting to salmon populations in the Entiat Basin (Andonaegui, 1999). This loss of rearing habitat is related to a lack of side channels and loss of riparian bottom land above Potato Creek in the Entiat River and the lower reaches of the Mad River, Stormy Creek, and Roaring Creek. Non-conventional storage projects such as vegetation management and side-channel construction could be implemented to address these factors. Floodplain storage could also address this problem if a side channel could be used both for active infiltration and return flow, while also providing connectivity between the side channel and the mainstem.
- Loss of pool habitat, particularly in the lower section of the Entiat River where total pool volumes have been reduced by 90% since 1930, is also considered an important limiting factor. Any storage project that increases streamflows in the mainstem would contribute to improving pool habitat.
- Conversion of surface water diversions to groundwater wells would reduce or eliminate in-channel diversion structures, thereby reducing the risk of fish mortality or injury.
- Increased flows in summer could offset temperature exceedances, and improve fish passage during critical low-flow periods.

4.0 STORAGE PROJECT SCREENING CRITERIA

4.1 Overview

In order to select one or more potential storage projects for further study, a structured process is typically used to solicit stakeholder input and discuss selection criteria, and develop a ranking of possible projects.

As part of this Step A Storage Assessment in the Entiat a preliminary list of selection criteria has been developed for the Step A report. Key members of the landowner steering committee were contacted to identify additional selection criteria and these criteria were further discussed with all interested stakeholders at a public meeting held on January 24, 2006.

Once a comprehensive list of selection criteria has been developed and discussed, the criteria will be "ordered" based on their general level of importance to stakeholders. Storage projects themselves will then be ranked based on the selection criteria, and the level of importance of those criteria. Ranking of projects can be accomplished in one of two ways:

- A weighted numeric selection process that includes assigning weights (or "points") to different selection criteria and ranking each project based on the total number of points it receives for each the selection criteria.
- A more discussion - based selection process. After a discussion and mutual understanding of the importance of specific selection criteria, each member of the stakeholder group votes for a short list of projects. Votes are counted for each project and the top tier is determined. Stakeholder members are then given the opportunity to advocate for projects that made the list or did not make the list, and the group may collectively decide to eliminate or add project(s) to the short-list based on the advocate's input. A final vote is then taken (if the goal is to select three storage projects for more detailed study in Step B, each member would then get to vote for three projects). If necessary, a second opportunity to advocate for a project is allowed. Although this process is not quantitative, it enables a more thorough understanding of different participants' viewpoints which will assist in future decision-making in Step B.

The discussion-based approach can be as effective as a numeric process with a smaller stakeholder group that is familiar with the goals of the assessment. This type of process often results in greater stakeholder "buy-in" of the final project selection.

4.2 Preliminary Description of Storage Criteria

4.2.1 Storage Volume

Storage volume determines the "footprint" of a storage project; how much water is needed to fill the project, and how much water the project can deliver for use. Figure 1 shows how storage volume relates to flow. The table below, summarizes this information in a tabular format to get an idea of storage reservoir sizes and how much water can be produced from them. The unshaded portions of the table show storage volumes that require or produce relatively large flow rates (>70 cfs) for various durations. The yellow shaded portion show volumes that require or produce intermediate flow rates (30-60 cfs), and the green shaded portion show volumes that require or produce lower flow rates (less than 30 cfs).

ownership is mostly private in the middle segment of the watershed, there are some publicly held parcels. Chelan-Douglas Land Trust owns over 400 acres in the middle Entiat basin, including 140 acres (with riverfront) near the Stormy Creek confluence.

4.2.6 Location and Land Use

In addition to project footprint considerations, storage projects can influence land use decisions or planning by providing additional water. The linkage between water supply and land use designation is becoming increasingly important so that water is provided to areas that can or should accommodate additional growth or changes in land use.

4.2.7 Engineering/Design Requirements

The engineering aspects of a project will vary depending on the type of storage project, the location of the project, and the water uses associated with the project. Technical requirements are typically associated with the design, construction and operation of a storage project, and project proponents should be capable of managing and/or staffing a variety of technically-based disciplines. Typically, the complexity and technical requirements for a project are proportional to the storage volumes associated with the project. Large storage projects may require in-depth site characterization, permitting, design of large structures (such as pipelines, dams, or berms), and operational capability (including monitoring, financial accounting, and regulatory interface).

4.2.8 Permitting Requirements

A variety of permitting requirements may be applicable to storage projects involving federal, state, and local agencies, including (but not limited to):

- SEPA or NEPA (State/National Environmental Policy Act);
- Hydraulic Project Approval;
- 401 Water Quality Certification;
- US Army Corps of Engineers 404 Permits (Discharge of Dredge and Fill);
- Fish and Wildlife mitigation (WDFW);
- Water Quality Modification (Ecology);
- Dam Safety (Ecology);
- Hydraulics Permit (WDFW);
- County Construction and Land Use permits; and,
- Other local permits.

4.2.9 Data Needs and Feasibility Study Requirements

Data needs for determining feasibility can range from simple to complex. Data that is easy to acquire may be sufficient to screen some projects, if, for example, land ownership is a critical factor in the feasibility of a certain project. For projects that are favorable based on existing or readily available information, data needs should be carefully considered and targeted at data necessary to identify "fatal flaws" that would eliminate the project from further consideration. Water yield (or storage volume) is a common data need that requires further study, but questions must also be carefully

posed. "What is the maximum possible storage volume at a particular site?" is a different question than "what is the likelihood that 5,000 AF of storage can be developed at a particular site?"

4.2.10 Economics

Economic evaluation of projects must take a number of costs and benefits into account. Costs and benefits for storage projects should be categorized to capture both economic and environmental elements of the project. An over-riding interest in many water-related projects today is the ability of the proposal to improve fish habitat and thereby increase the number of fish (particularly endangered species) that can live in a watershed. Developing economic values on a "per fish" basis is a difficult task. Conversely, assessing conventional economic costs and benefits that would accrue within the basin as a result of water storage can also be difficult. Water storage may increase the value of land and increase the value of water rights. In agricultural areas, water storage may increase the value of crop and livestock production and future net incomes. These considerations can also be difficult to predict.

Typical types of economic costs include:

- Environmental assessment and permitting for final project design;
- Final design and construction of the project;
- Other infrastructure improvements necessary to make the water available, such as pressurized water pipe and connections;
- Additional operation and maintenance expense associated with the project;
- Land acquisition, including mitigation such as habitat acquisition or conservation easement costs;
- Conveyance rights-of-way and/or easements;
- Water right acquisition, leasing, or permitting to dedicate to storage.
- Public Outreach
- Monitoring and evaluation of habitat conditions in the study area.

Typical economic benefits include:

- The value of water savings;
- The value of additional water within the basin;
- The value of additional water released to downstream basins;
- The net value of additional agriculture, commercial/industrial, or residential development that would be produced with an improved water supply;
- Reduced costs of current water supply (e.g. reduction in groundwater pumping or reduction in surface water system maintenance); and
- Value of habitat and instream benefits (difficult to place a traditional economic value).

4.3 Stakeholder Preferences

A group of stakeholders discussed and ranked the selection criteria during the public meeting on January 24, 2006. A list of these criteria and associated rankings is provided below.

Rank	Description	Votes
1	Increase flows during periods of low flow	12
2	Fire protection	10
3	Multiple benefits*	10
4	Agriculture (late season)	9
5	Habitat improvement	8
6	Increase groundwater levels	7
7	Location	4
8	Regulatory certainty	4
9	Cost	3
10	Improve temperatures in Entiat River	1

* Multi-benefit projects could be considered the highest ranking, and would still be consistent with local stakeholder input.

Based on the stakeholder input at the public meeting, the most important selection criterion for a storage project is that it provide increased flows in the Upper or Middle segments of the Entiat River during periods of low flow. Fire protection and multiple benefits were also ranked very high. The low flow criterion was closely associated with increasing the availability of water for late season agriculture use, general improvement of aquatic habitat, location of storage projects, and ability to improve water temperatures. The increased flows were also linked to regulatory certainty, which was expressed as the extent to which a storage project would allow continued withdrawals of water for current and planned water uses in light of regulatory requirements in the Endangered Species Act, or the Clean Water Act.

Increased groundwater levels was also identified as a key criteria. It was recognized that higher groundwater levels would improve late-season streamflows, and benefit local domestic and agricultural groundwater supplies, both currently and in the future. Concerns over dropping water levels in some areas of the valley and the overall reliability of shallow domestic groundwater supply wells were noted.

Fire protection was also identified as a key criterion for storage project selection, and received the second highest number of votes. Currently it is very difficult to move water for fire response throughout the valley using trucks, particularly in the winter. With continued development and likelihood of fires in this forested watershed, availability of fire protection water near residences was considered important to local stakeholders.

4.4 Project Screening

Using the screening criteria described above, a variety of storage projects were considered and ranked. Projects that were considered included surface storage (dams), groundwater storage, small impoundments for fire protection, and floodplain/side-channel reconnection.

A total of 18 surface storage sites were identified and ranked. As described in Section 2, these sites were identified based on a review of USGS topographic maps, and focused on ephemeral drainages on or adjacent to the major tributaries of the Entiat River. Reservoir sizes ranged from 500 to 14,000 AF, with impoundments structures ranging from 40 to 400 feet in height. Each project site was evaluated with respect to the criteria described above. Appendix C contains a table with the screening information for each site. The criteria that varied the most among sites were storage volume, site location, and land ownership. Site location was classified as upper middle, or lower watershed, with the lower watershed boundary designated at the Roaring Creek confluence. Lower watershed locations were given lower ranking. Land ownership was classified as private, mixed (private and public), or USFS. USFS land ownership was given lower ranking because of likely difficulties in permitting dam structures on USFS lands. A fourth criteria was also developed, which describes the benefit-to-cost ratio for the project. At this preliminary stage, this ratio was expressed as the volume of storage (in acre-feet) divided by the area (in square feet) of impoundment. This ratio assumes that, in general, cost of the project is proportional to size of the impoundment, and the benefit is proportional to the volume of storage. A final criterion based on visual observations over time and the opinion of members of the Storage technical committee was added after a meeting in March 2006..

Table 6a summarizes the ranking of the surface water storage sites. Based on these criteria, the "top tier" off-channel sites were Stormy Creek, Preston Falls, and Myrtle Lake. The Stormy Creek impoundment was the highest ranking surface storage site. It would be located near the bottom of Stormy Creek, and could store more than 11,000 AF with a structure 340 feet tall and 1,400 feet wide. In contrast to the other surface storage sites, the Stormy Creek impoundment is situated in a perennial channel and was included in the assessment based on the recommendation of a local landowner. While fisheries issues are likely to be significant determinant to the feasibility of this project, they were not used to screen out the Stormy Creek project at this stage. Myrtle Lake and Preston Falls provide a high potential benefit/cost ratio, but, because they are located on US Forest Service land, may need to address a variety of permitting and land use hurdles. Murdock, Gulch, Crum Canyon, and Gray Canyon were considered second tier off-channel sites based primarily on past visual observations on the hydrology. Each of the surface storage projects are significant engineered structures, though there are comparable structures in Washington,. The Pinto Dam, for example, in Grant County, is about 130 feet high and 1,900 wide. The Tieton Dam in Yakima County is 319 feet high and 920 feet wide.

Table 6b shows the screening criteria for the top tier and second tier off-channel storage sites along with fire protection storage and three storage projects in the Stormy Creek vicinity. The Stormy Creek vicinity could serve as a location for a floodplain storage, groundwater storage, or side channel development project. The floodplain is relatively wide and numerous abandoned channels have been mapped in this location, which could provide suitable locations for a floodplain storage or side channel development project. The thickness of alluvial aquifer also increases significantly in this area and might be suitable for groundwater storage. The Chelan-Douglas Land Trust owns several parcels near Stormy Creek, on which any of the projects could potentially be located. The fire protection tanks could be located in a number of areas in the Entiat Valley based on local need and population densities.

4.5 Recommendations

This section describes recommendations based on the review of information and stakeholder input completed for Step A of the storage assessment.

Recommendation 1 : Develop a baseline engineering and environmental assessment of storage options in the immediate vicinity of Stormy Creek.

Several of the highest ranking projects occur in the vicinity of the Stormy Creek confluence with the Entiat River. An integrated baseline technical assessment of each of the storage opportunities in this area is recommended for several reasons:

- A distinct study area for several storage projects (Stormy Creek surface water reservoir, groundwater recharge in the Entiat floodplain, and deep groundwater withdrawal in the Entiat floodplain) can be defined and carried through the assessment ;
- Data compiled and/or collected or in this area (such as land cover, aerial photos etc) can be used to evaluate several projects, maximizing the use of study resources to multiple potential storage projects;
- The Planning Unit does not have to "commit" to one type of water storage concept in Step B, but can efficiently evaluate several storage concepts and project development scenarios.

The assessment should address both the engineering and environmental/permitting elements of the three storage projects in this area, and focus on basic data collection and baseline analysis designed to answer the following questions:

- Engineering question – is development and construction of the project feasible? (can it be built?)
- Environmental question – do the benefits of the project outweigh the impacts of the project (i.e. can it be permitted?)

As part of the assessment the operational aspects of the project would also need to be considered; not only how the project would be operated (i.e. a storage and release profile), but who would operate and benefit from the project (i.e. project sponsors).

Recommendation 2 : Develop a water storage component for the Community Fire Protection Planning process recently initiated in the area.

Recommendation 3 : Develop a baseline permitting assessment for storage projects on US Forest Service Land, specifically addressing issues associated with surface water storage at the Myrtle Lake and Preston Falls sites identified in the step A assessment.

The potential elements of a step B scope of work based on these recommendations will be presented to the Planning Unit at the April 5 Planning Unit Meeting. Appendix D will then be finalized as part of the Step A final report.

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TABLES

Potential Off-Channel Storage Reservoirs in WRIA 46

Location	River mile	Impoundment Height (ft)	Mean Reservoir Depth (ft)	Impoundment Width (ft)	Surface Area of Impoundment (ac)	Potential Storage Volume (ac-ft)	Ownership	Notes
Indian Spring Canyon	0	160	120	250	6	600	Private	
McCleish Canyon	1	120	60	600	8	360	Private	
McCarthur Canyon	3	80	40	900	5	200	USFS	
Asher Canyon	2	80	40	650	5	180	Mixed	Land owned by Foremost Fruit.
Saunders Creek	5	180	80	900	20	1,700	Mixed	
Crum Canyon	8	240	120	1,100	75	10,000	Private	Could be a perennial stream.
Morical Creek	9	40	40	900	10	500	Private	
Medsker Creek	13	280	120	900	17	2,000	Mixed	
Gray Canyon	16	380	260	1,500	48	11,300	Mixed	
Preston Falls	23	400	300	1,200	45	11,300	USFS	Perenial stream, site is above falls.
Mills Canyon Tributary	3 (1 mile up Mills canyon)	160	80	600	15	900	Mixed	Shown as epemeral, but may be perennial.
Bear Gulch	6 (1 mile up Roaring Creek)	200	100	800	10	1,000	USFS	
Murdock Gulch	12 (3 miles up Mud Creek)	120	80	600	24	1,800	Mixed	Near Ardenvoir.
Potato Creek Tributary	15 (2 miles up Potato Creek)	160	100	600	13	1,300	USFS	
Pyramid Creek	34 (4 miles up North Fork)	200	100	750	7	700	USFS	Likely a perennial stream.
Stormy Creek	18	340	200	1,400	60	11,300	Private	Likely a perennial stream.
Lake Creek	29 (5 miles up Lake Creek)	240	120	3,000	100	11,300	USFS	
Myrtle Lake	45	40	40	600	48	1,900	USFS	Increase storage capacity of existing lake.

Notes:

Impoundment height, width, depth, and surface area based on screening level review of 1:24,000 USGS mapping at a 40-foot contour interval.

Potential Storage Volume = Mean Reservoir Depth * Surface Area of Impoundment

Completed, Ongoing, and Planned Storage Related Projects in WRIA 46

Name	Status	Location	Beneficial Use
Whitehall/Entiat Wells	Planned	Lower Entiat River	Irrigation
Columbia River Basin Transfer	Investigation stage	Lower Entiat River	Irrigation, Fish habitat
Hanan-Detwiler Improvements	Ongoing	Lower Entiat River	Instream flows
Knapp-Wham Improvements	Ongoing	Lower Entiat River	Instream flows
Jon Small Off-Channel Habitat	Complete	Entiat River at Roaring Creek	Lack of juvenile off-channel / rearing habitat
Jon Small Rearing Pond	Complete	Entiat River at Roaring Creek	Lack of juvenile off-channel / rearing habitat
Entiat Demonstration Project	Complete	Between river miles 3 and 4	Fish Habitat
Riparian Plantings	Planned	Multilple Projects from Potato Creek to Basin Outlet	Riparian function
Root Wad Revetment w/ Plantings	Planned	Multiple Projects on Entiat River Below Stormy Creek	Bank stabilization and habitat complexity
Vortex Rock Weir w/ Plantings	Planned	Entiat River below Potato Creek	Lack of adult resting pools, spawning habitat

TABLE 3

Water Right Purposes of Use
(From The Washington Department Of Ecology)

CODE	PURPOSE OF USE	DEFINITION AND DESCRIPTION
CI	Commercial and Industrial Manufacturing	Includes cannery operations, food processing and packaging, sand and gravel processing, asphalt plant, lumber, shingle or plywood milling, log storage ponds, metal processing and manufacturing, pulp and paper manufacturing, aquatic plant culture, petroleum refining, beverage manufacture, car washes, laundries, Laundromats, any other commercial or industrial purpose.
DG	Domestic General	Use of water for all domestic uses not specifically defined in the water-right record or not defined by the other specific domestic use categories. Includes sewage treatment, farm supply and laboratory use.
DM	Domestic Multiple	More than one dwelling, motels, resorts; trailer courts, campgrounds, parks schools joint operating agencies, port districts, public utility districts (smaller ones that are not considered municipal), diking and drainage districts, water districts, flood control zone districts, irrigation districts, reclamation districts, local improvement districts, water distribution districts and counties, none of which are under municipal control.
DS	Domestic Single	One dwelling with lawn and garden up to one-half acre.
EN	Environmental Quality	Includes pollution control, dust control, flood control, or any use which improves or maintains the quality of the environment. Includes pass through water for maintaining water quality in reservoirs.
FP	Frost Protection and Heat Control	Frost protection or heat control for crops other than cranberries.
FR	Fire Protection	Includes sprinkling log storage facilities.
FS	Fish Propagation	Includes water service to ponds, reservoirs, hatcheries, and all other facilities involved in the overall purpose of fish propagation.
HE	Heat Exchange	Use of such equipment as heat pumps, refrigeration equipment, and other cooling devices. Does not include watering crops for cooling purposes.
HW	Highway	Maintenance and construction.
IR	Irrigation	Includes cranberry farming, lawn/garden watering (with more than one-half acre or commercial use), golf courses, greenhouses, etc.
MI	Mining	Includes washing coal, dredge mining, hydraulic mining.
MU	Domestic Municipal	Serves general domestic, commercial and industrial needs of an incorporated municipality (cities, towns, and outlying areas). This includes public utility districts when they serve municipalities.
PO	Power	Includes hydro-electric, hydraulic ram, thermo-electric.
RB	Recreation and Beautification	Includes private or public grounds, swimming pool supply, boating ponds, etc.
RW	Railway	Use of water to serve railway equipment and facilities.
ST	Stock Watering	Includes dairying, game bird farming, poultry farming, fur bearing animal farming, and other diversionary water supply for stock.
WL	Wildlife Propagation	Any diversionary or impoundment activities for the propagation or support of wildlife.

Water Quality Beneficial Uses

TABLE 602	Aquatic Life Uses					Recreational Uses			Water Supply Uses				Misc. Uses					
Use Designations for Fresh Waters by Water Resource Inventory Area (WRIA)	Char	Core Salmon/Trout	Non-Core Salmon/Trout	Salmon/Trout Rearing	Redband Trout	Warm Water Species	Ex Primary Cont	Primary Cont	Secondary Cont	Domestic Water	Industrial Water	Agricultural Water	Stock Water	Wildlife Habitat	Harvesting	Commerce/Navigation	Boating	Aesthetics
WRIA 46 Entiat																		
Brennegan Creek and the unnamed tributary at longitude -120.4185 and latitude 47.9098: All waters (including tributaries) above the juction.	√						√			√	√	√	√	√	√	√	√	√
Entiat River from Wenatichee National Forest boundary (river mile 20.5) to Silver Creek.		√					√			√	√	√	√	√	√	√	√	√
Entiat River and Silver Creek: All water (including tributaries) above the junction.	√						√			√	√	√	√	√	√	√	√	√
Entiat River's unnamed tributaries at longitude - 120.4998 and latitude 47.9107.	√						√			√	√	√	√	√	√	√	√	√
Entiat River's unnamed tributaries at longitude - 120.5179 and latitude 47.9174.	√						√			√	√	√	√	√	√	√	√	√
Gene Creek and Potato Creek: All waters above the junction.	√						√			√	√	√	√	√	√	√	√	√
Gray Canyon, North Fork, and South Fork Gray Canyon: All waters (including tributaries) above the junction.	√						√			√	√	√	√	√	√	√	√	√
Hornet Creek and all tributaries.	√						√			√	√	√	√	√	√	√	√	√
Lake Creek and tributaries.	√						√			√	√	√	√	√	√	√	√	√
Mad River and all tributries above Young Creek.	√						√			√	√	√	√	√	√	√	√	√
Mud Creek and Sswitchback Canyon: All waters (including tributaries) above the junction.	√						√			√	√	√	√	√	√	√	√	√
Preston Creek and South Fork Preston Creek: All waters (including tributaries) above the junction.	√						√			√	√	√	√	√	√	√	√	√
Stormy Creek and the unnamed tributary at longitude -120.3865 and latitude 47.8387: All waters (including tributaries) above the junction.	√						√			√	√	√	√	√	√	√	√	√
Tilicum Creek and Indian Creek: All waters (including tributaries) above the junction.	√						√			√	√	√	√	√	√	√	√	√
Tommy Creek and all tributaries.	√						√			√	√	√	√	√	√	√	√	√

Note: These are proposed beneficial use designations for pending revisions to State Water Quality Regulations. They have not been formally adopted by the state. EPA review of the proposed designations recommended that Core Salmon/Trout designation shou

Percentage of Days Meeting Instream Flow Criteria and Recommended Fish Flows

Table 5a. Percentage of days meeting instream flow criteria

	August (275 cfs)	**September** (175 cfs)	**October** (175 cfs)
Percent of historic mean daily flows that met or exceeded the instream flow criteria	22%	10%	4.84%
Percent of days that would meet instream flow criteria if an additional 30 cfs (1800 AF over 30 days) were added to the mean daily flows	26%	21%	9%
Percent of days that would meet instream flow criteria if an additional 50 cfs (3000 AF over 30 days) were added to the mean daily flows	32%	31%	15%
Percent of days that would meet instream flow criteria if an additional 100 cfs (6000 AF over 30 days) were added to the mean daily flows	51%	87%	72%

Table 5a. Percentage of days meeting the recommended fish flows

	August (180 cfs)	**September** (125 cfs)	**October** (120 cfs)
Percent of historic mean daily flows that met or exceeded the recommended fish flows	49%	31%	18%
Percent of days that would meet the recommended fish flows if an additional 30 cfs (1800 AF over 30 days) were added to the mean daily flows	64%	58%	51%
Percent of days that would meet the recommended fish flows if an additional 50 cfs (3000 AF over 30 days) were added to the mean daily flows	76%	87%	78%
Percent of days that would meet ithe recommended fish flows if an additional 100 cfs (6000 AF over 30 days) were added to the mean daily flows	100%	100%	100%

Off-Channel Storage Site Rankings

Site	Ranking Criteria			
	Storage Volume[a]	Benefit/Cost Ratio[b]	Watershed Location	Land Ownership[c]
Crum Canyon	10,000	0.038	Middle (RM 8)	Private
Stormy Creek	11,300	0.024	Middle (RM 18)	Private
Murdock Gulch	1,800	0.025	Middle (RM 12)	Mixed
Preston Falls	11,300	0.024	Upper (RM 23)	USFS
Myrtle Lake	1,900	0.079	Upper (RM 45)	USFS
Gray Canyon	11,300	0.020	Middle (RM 16)	Mixed
Lake Creek	11,300	0.016	Upper (RM 29)	USFS
Indian Spring Creek	600	0.015	Lower (RM 1)	Private
Morical Creek	500	0.014	Middle (RM 9)	Private
Potato Creek Tributary	1,300	0.014	Middle (RM 15)	USFS
Saunders Creek	1,700	0.010	Lower (RM 5)	Mixed
Mills Canyon Tributary	900	0.009	Lower (RM 3)	Mixed
Medsker Creek	2,000	0.008	Middle (RM 13)	Mixed
Bear Gulch	1,000	0.006	Lower (RM 6)	USFS
McCleish Canyon	360	0.005	Lower (RM 1)	Private
Pyramid Creek	700	0.005	Upper (RM 34)	USFS
Asher Canyon	180	0.003	Lower (RM 2)	Mixed
McCarthur Canyon	200	0.003	Lower (RM 3)	USFS

Notes/Explanation

a Estimated storage in acre-feet

b Benefit/cost is expressed as acre-feet of storage divided by area (square feet) of impoundment.
Assumes that cost of the project is proportional to size of the impoundment.
Higher benefit/cost produces more storage per unit of surface area (ranks higher)

c Mixed lands are those where the storage structure could be located on private land, but the impoundment would extend onto USFS land

Top tier ranking for the criterion
Second tier ranking for the criterion
Lower tier ranking for the criterion

Top tier composite
Second tier composite

TABLE 6b

Off-Channel, Domestic, and Groundwater Storage Project Criteria and Screening

		Top Tier Off Channel Sites		Second Tier Off-Channel Sites			Domestic Storage		Groundwater Storage		
Criteria	**Stormy Creek**	**Preston Falls**	**Myrtle Lake**	**Murdock Gulch**	**Crum Canyon**	**Gray Canyon**	**Municipal Storage Tank – Entiat**	**Fire Protection Impoundments**	**Floodplain Storage (Aquifer recharge) Stormy Creek**	**Groundwater Storage ("Pump and dump") Entiat Floodplain**	**Side Channel Development – Stormy Creek Vicinity**
Storage volume	11300 AF	11300 AF	1900 AF	1800 AF(??)	10000 AF(??)	11,300	3 AF (1 MG)	3 AF (1 MG)	10,000 AF	5,000 AF	2,000 AF
Increase seasonal flows	133 cfs : 30 days 44 cfs : 90 days	133 cfs : 30 days 44 cfs : 90 days	22 cfs : 30 days 8 cfs : 90 days	21 cfs : 30 days 7 cfs : 90 days	118 cfs : 30 days 39 cfs : 90 days	133 cfs : 30 days 44 cfs : 90 days	950 gpm : 12 hrs	950 gpm : 12 hrs	39 cfs : 90 days	60 cfs : 30 days 20 cfs : 90 days	24 cfs : 30 days 8 cfs : 90 days
Multiple benefits	Consumptive Habitat Consumptive Agriculture Fire Protection Out-of-basin	In-stream Habitat Consumptive Agriculture Fire Protection Out-of-basin	In-stream Habitat Consumptive Agriculture Fire Protection Out-of-basin	In-stream Habitat Consumptive Agriculture Fire Protection Out-of-basin	In-stream Habitat Consumptive Agriculture Fire Protection Out-of-basin	In-stream Habitat Consumptive Agriculture Fire Protection Out-of-basin	Municipal	Residential FIre Protection	In-stream Habitat Consumptive Agriculture Fire Protection Out-of-basin	In-stream Habitat Consumptive Agriculture Fire Protection Out-of-basin	In-stream Habitat Consumptive Agriculture Fire Protection Out-of-basin
Fire Protection	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit	Possible Primary Benefit	Primary Benefit	No Benefit	No Benefit	No Benefit
Benefits for Late Season Agriculture	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	No Benefit	No Benefit	Primary Benefit	Primary Benefit	No Benefit
Habitat improvement	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	No Benefit	No Benefit	Primary Benefit	Secondary Benefit	Primary Benefit
Improve groundwater levels	Possible Benefit	No Benefit	No Benefit	No Benefit	No Benefit	No Benefit	No Benefit	No Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit
Location (and Land Ownership)	RM 18 Private	RM 23 Public (USFS)	RM 45 Public (USFS)	RM 12 (3 Miles up Mud Creek) Mixed Ownership	RM 8 Private	RM 16 Mixed Ownership	Lower Entiat Private	Middle/Lower Entiat Private	Middle Entiat Public (Land Trust)	Middle Entiat Public (Land Trust)	Middle Entiat Public (Land Trust)
Flow Improvements (% improvement to fish flows at Ardernvoir gage)	Aug Improvement : 23% Sep Improvement : 47%	Aug Improvement : 23% Sep Improvement : 47%	Aug Improvement : 3% Sep Improvement : 5%	Aug Improvement : 3% Sep Improvement : 5%	Aug Improvement : 20% Sep Improvement : 40%	Aug Improvement : 23% Sep Improvement : 47%	None	None	AugImprovement : 20% Sep Improvement : 40%	Aug ISF Improvement : 10% Sep ISF Improvement : 15%	Aug ISF Improvement : 3% Sep ISF Improvement : 5%
Cost	Very Significant	Very Significant	Very Significant	Very Significant	Very Significant	Very Significant	Moderate	Moderate	Significant	Significant	Moderate
Benefit/Cost	0.024 AF/area of impoundment	0.024 AF/area of impoundment	0.079 AF/area of impoundment	0.025 AF/area of impoundment	0.038 AF/area of impoundment	0.021 AF/area of impoundment	$75k/AF	$75k/AF	$25/AF	ND	ND
Moderate Temperature Extremes in Entiat River	Possible Secondary Benefit	Possible Secondary Benefit	Possible Secondary Benefit	Possible Secondary Benefit	Possible Secondary Benefit	Possible Secondary Benefit	No Benefit	No Benefit	Possible Secondary Benefit	Secondary Benefit	Possible Secondary Benefit
Permitting Requirements	Very Significant	Very Significant	Very Significant	Very Significant	Very Significant	Very Significant	Moderate	Moderate	Significant	Significant	Significant
Engineering/Operation Requirements	Very Significant Permit Design/construct Operate	Very Significant Permit Design/construct Operate	Very Significant Permit Design/construct Operate	Very Significant Permit Design/construct Operate	Very Significant Permit Design/construct Operate	Very Significant Permit Design/construct Operate	Moderate Tank design/construct	Moderate River conveyance Geotechnical (berm, leakage)	Significant Siting (return flow) River conveyance Basin Design/Maintain	Significant Wells/conveyance Pumps	Moderate Re-connection Maintenance
Data Study Needs	Recon/Topo Survey Hydrology/Operations Geotech/Engineering Biological	Recon/Topo Survey Hydrology/Operations Geotech/Engineering Biological	Recon/Topo Survey Hydrology/Operations Geotech/Engineering Biological	Recon/Topo Survey Hydrology/Operations Geotech/Engineering Biological	Recon/Topo Survey Hydrology/Operations Geotech/Engineering Biological	Recon/Topo Survey Hydrology/Operations Geotech/Engineering Biological	Siting study Geotechnical Engineering	Siting study Geotechnical Engineering	Recon/Topo Survey Hydrogeology Study Channel Survey Geotechnical Survey	Recon/Topo Survey Hydrogeology Study Channel Survey	Recon/Topo Survey Channel Survey Biological/Water Quality

FIGURES

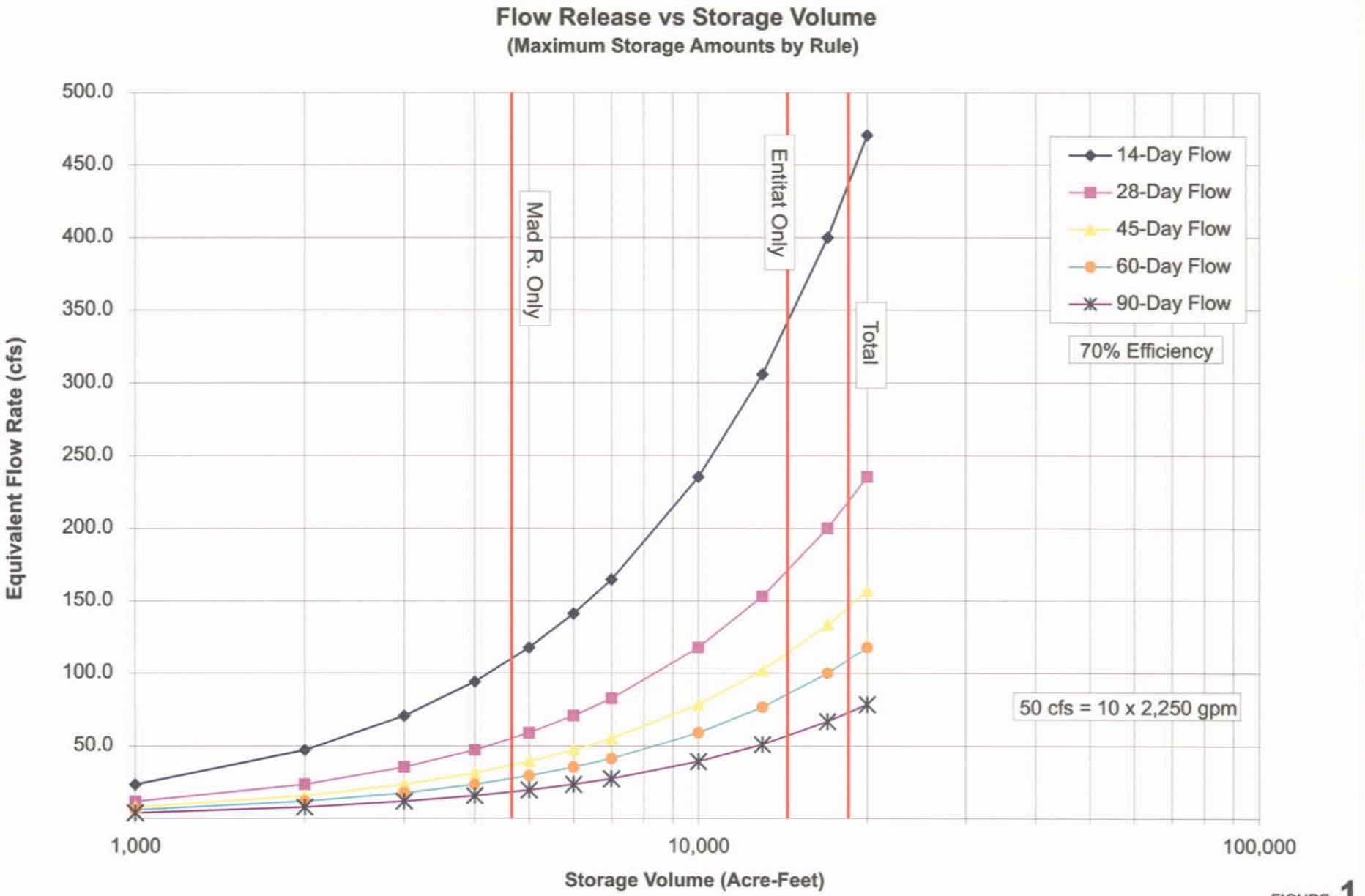


FIGURE 1
STORAGE VOLUME VERSUS FLOW RATE
CCCD/WRIA 46 STEP A STORAGE/WA

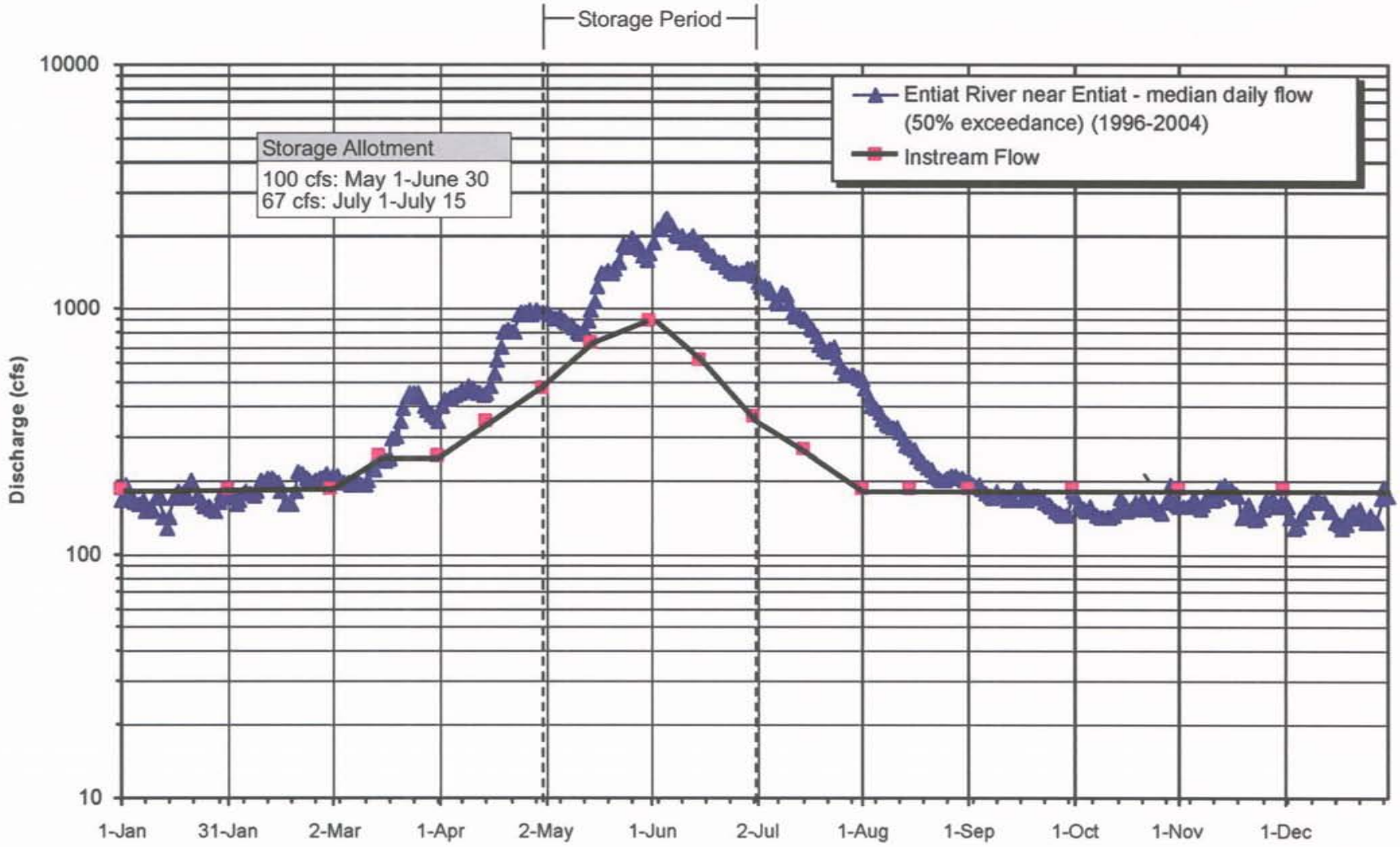
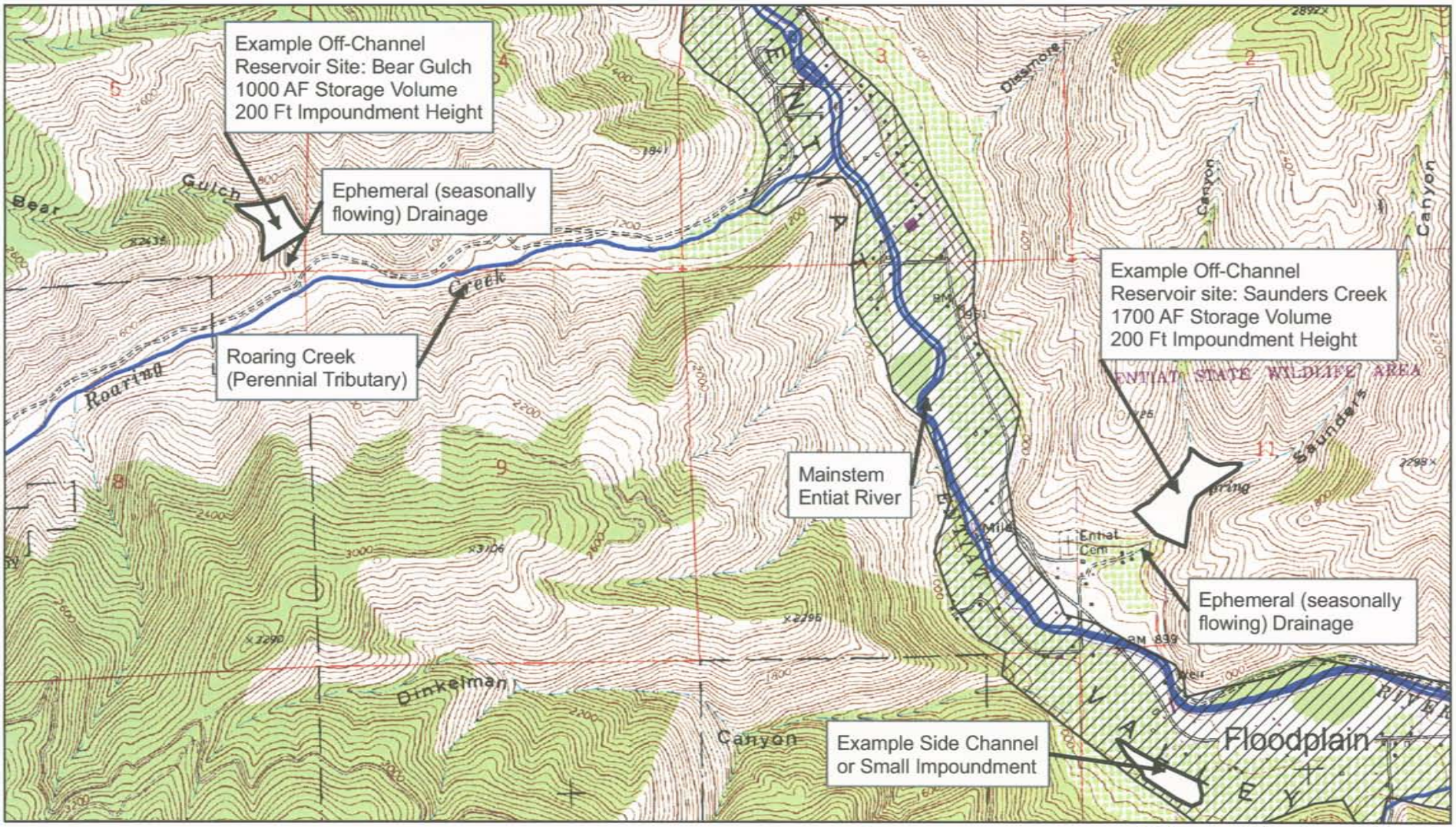


FIGURE **2**

MAXIMUM STORAGE ALLOCATION IN WRIA 46

CCCD/WRIA 46 STEP A STORAGE/WA



LEGEND

Floodplain

0 2000

Scale in Feet

Map Projection:
Washington State Plane,
North Zone, NAD 83, Feet

Source: INSIDE (Idaho), USGS

N

This figure was originally produced in color. Reproduction in black and white may result in a loss of information.

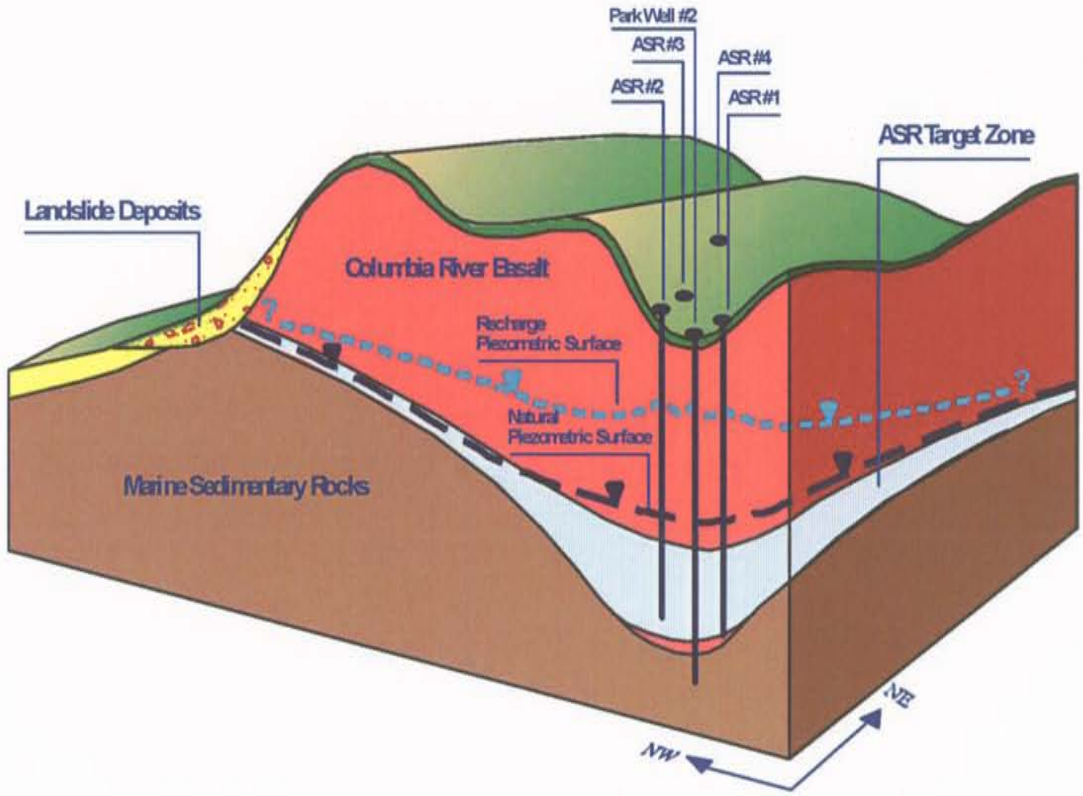
FIGURE 3

EXAMPLE OFF-CHANNEL STORAGE SITES

WRIA 46 STEP A STORAGE ASSESSMENT

0531000100F03.mxd | MOD: 1/17/2006 | JHP

Golder Associates



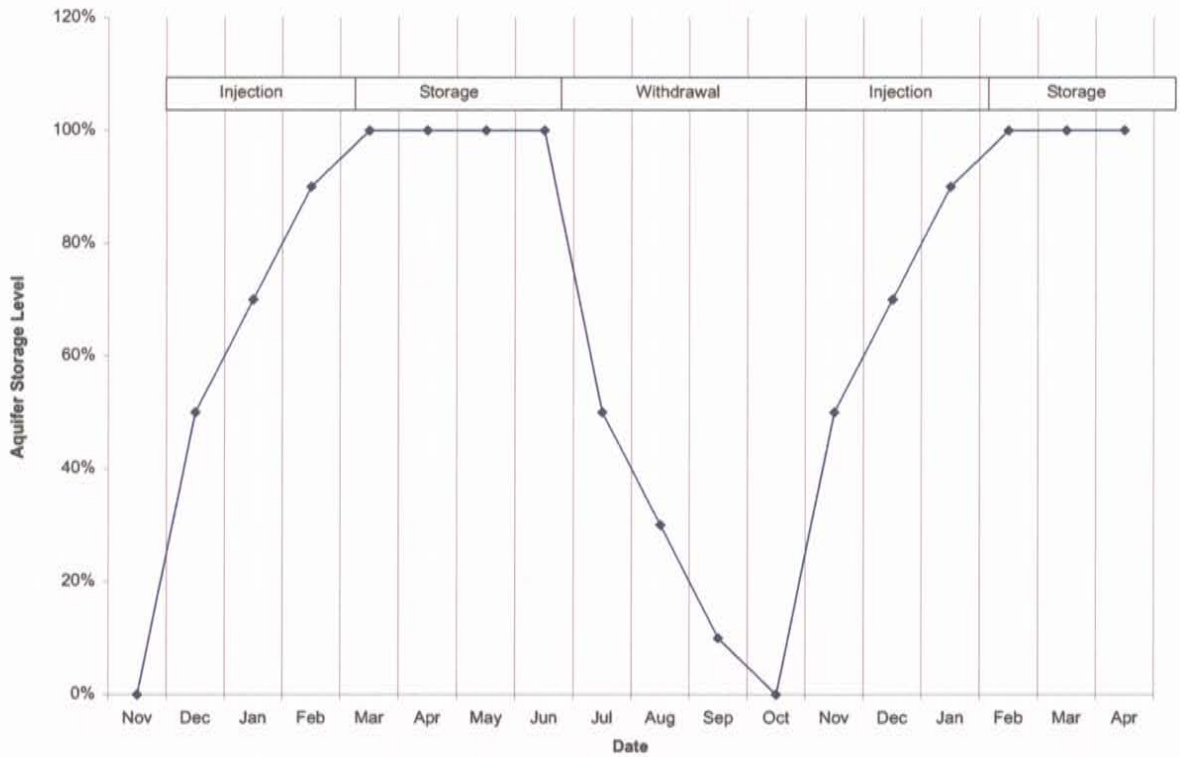


FIGURE 4

AQUIFER STORAGE AND RECOVERY (ASR) SCHEMATIC

CCCD/WRIA 46 STEP A STORAGE/WA

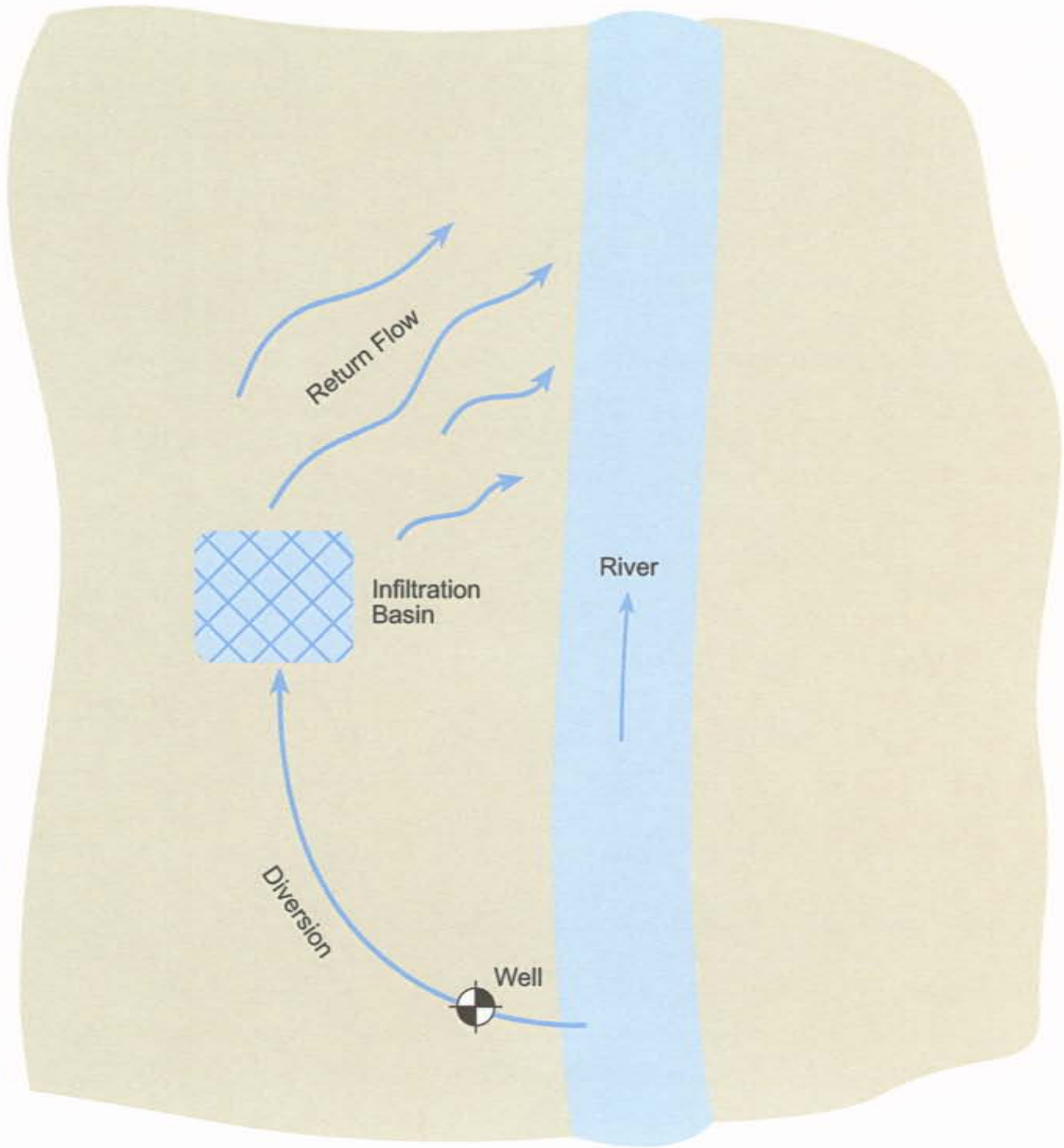


FIGURE 5
FLOODPLAIN INFILTRATION SCHEMATIC
CCCD/WRIA 46 STEP A STORAGE/WA

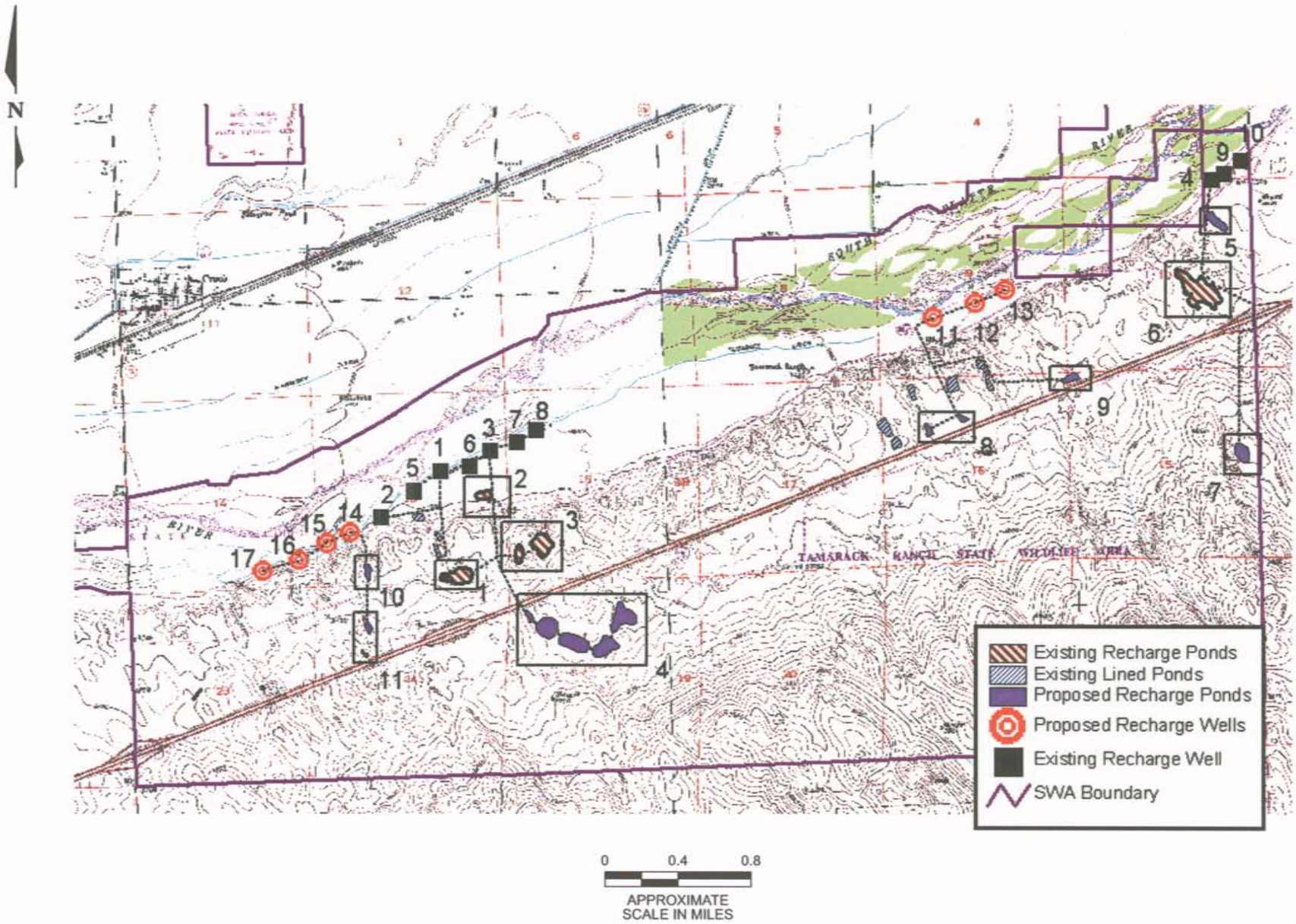


FIGURE 6

TAMARACK FLOODPLAIN INFILTRATION PROJECT

CCCD/WRIA 46 STEP A STORAGE/WA

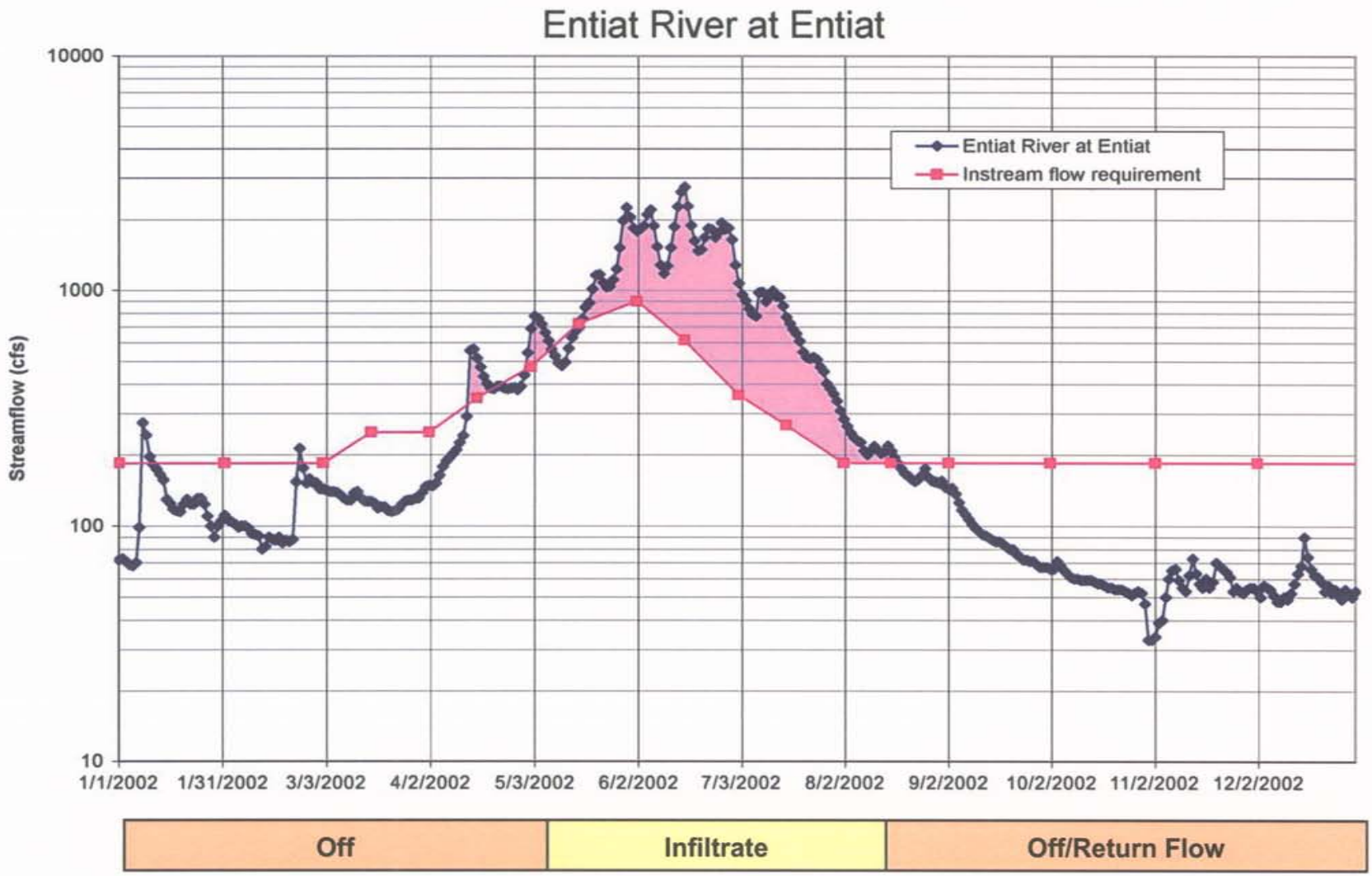


FIGURE 7

EXAMPLE FLOODPLAIN STORAGE CYCLE FOR WRIA 46

CCCD/WRIA 46 STEP A STORAGE/WA

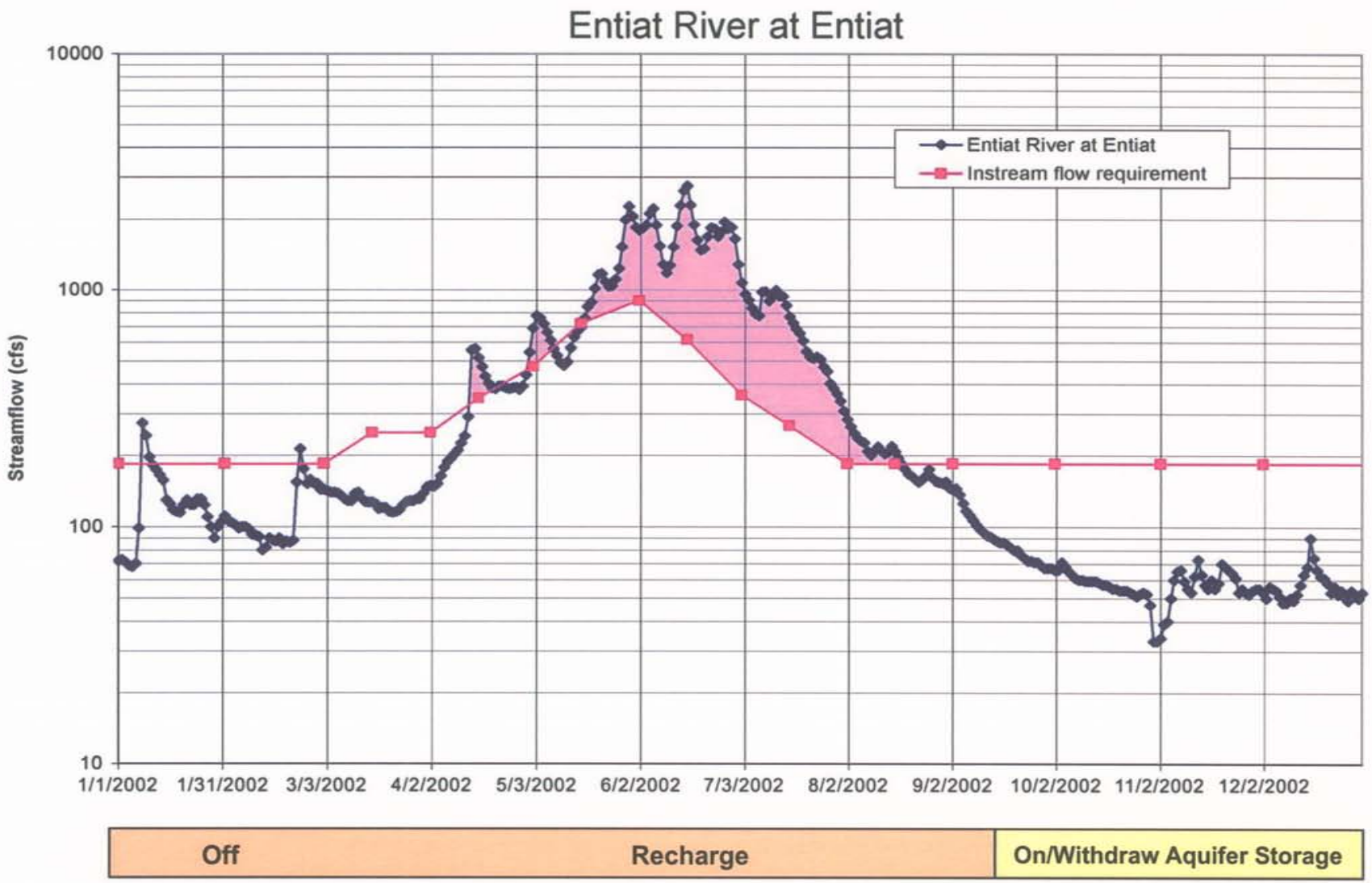


FIGURE **8**

EXAMPLE "PUMP AND DUMP" CYCLE IN WRIA 46

CCCD/WRIA 46 STEP A STORAGE/WA

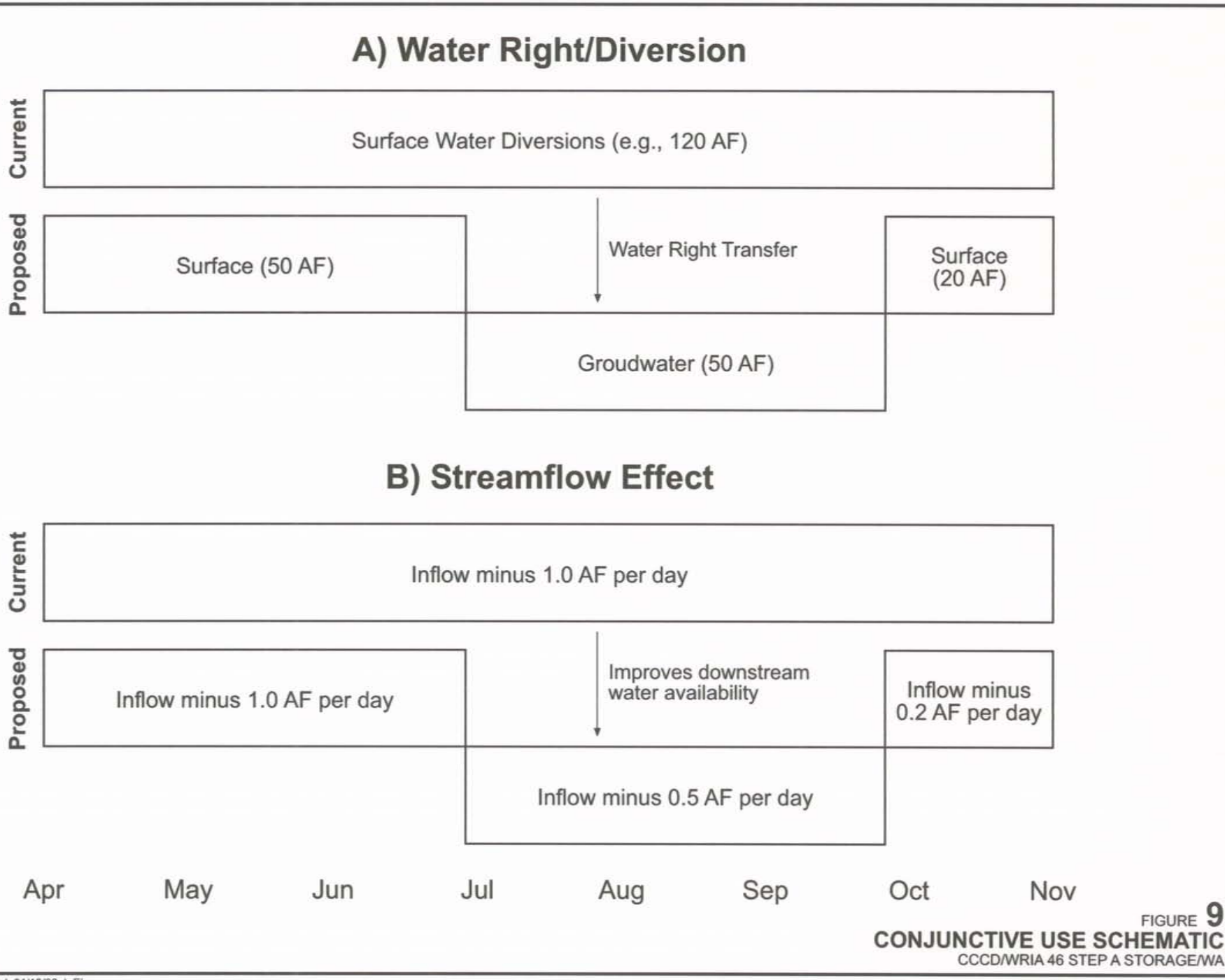


FIGURE **9**

CONJUNCTIVE USE SCHEMATIC

CCCD/WRIA 46 STEP A STORAGE/WA

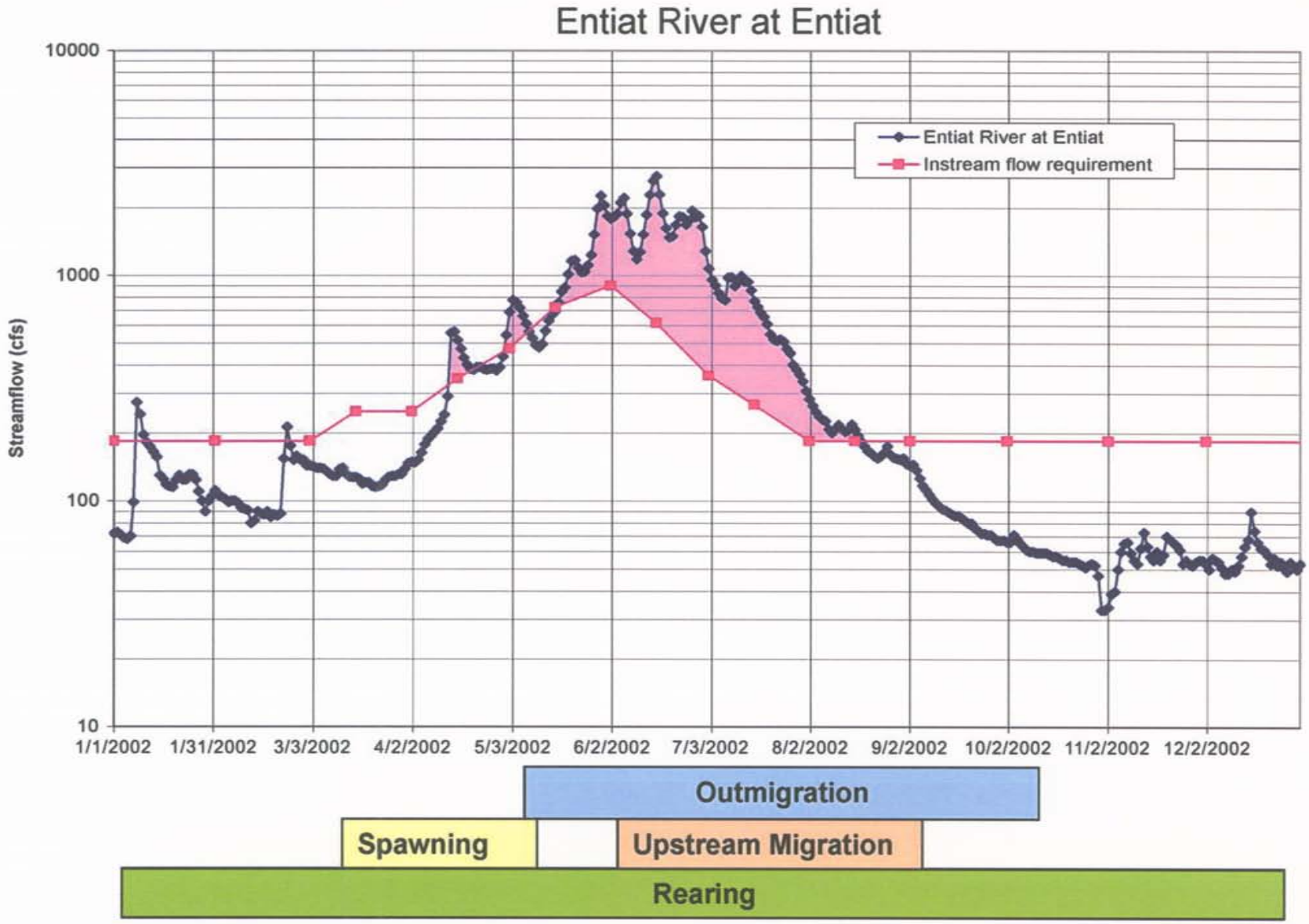


FIGURE **10**

EXAMPLE STREAMFLOW AND FISHERIES NEED
SUMMER STEELHEAD

CCCD/WRIA 46 STEP A STORAGE/WA

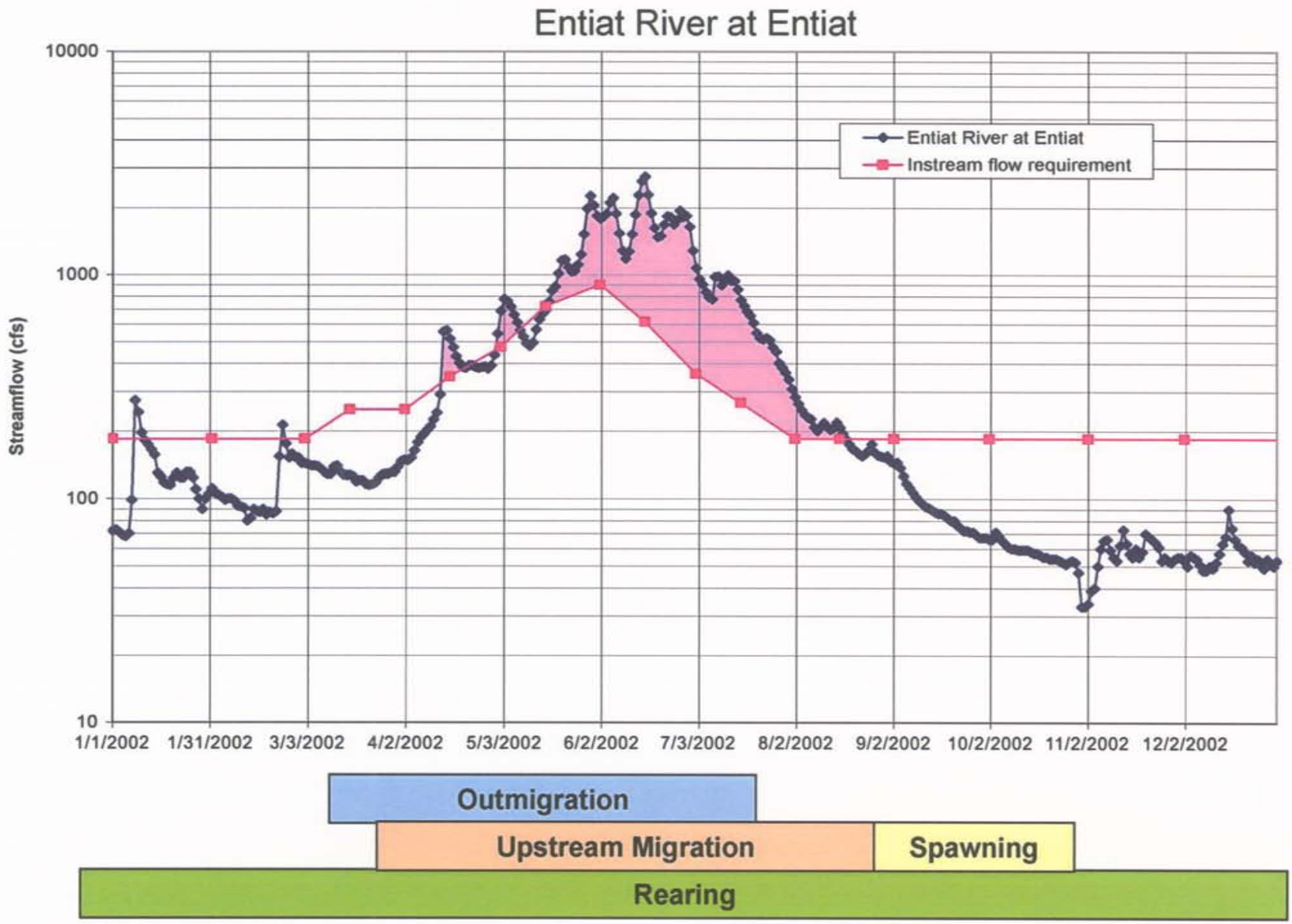


FIGURE 11
EXAMPLE STREAMFLOW AND FISHERIES NEED SPRING CHINOOK
CCCD/WRIA 46 STEP A STORAGE/WA

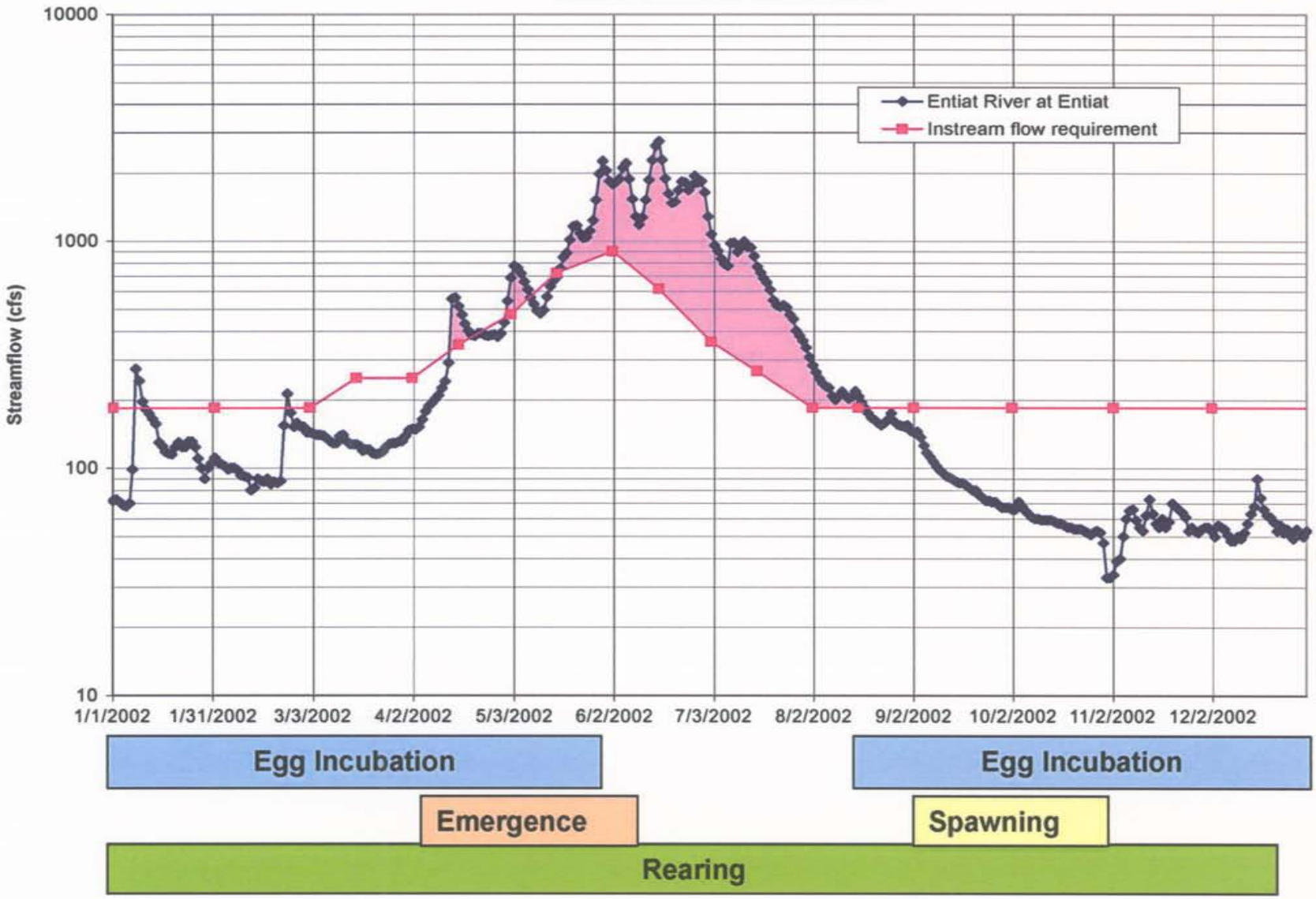


FIGURE **12**

EXAMPLE STREAMFLOW AND FISHERIES NEED BULL TROUT

CCCD/WRIA 46 STEP A STORAGE/WA

PLATE

APPENDIX A

SUMMARY OF EXISTING RELEVANT STUDIES

APPENDIX A

SUMMARY OF EXISTING RELEVANT STUDIES

The following three tables identify the documents and datasets that were compiled during the Step A Storage Assessment for WRIA 46. Table 1 lists relevant documents, Table 2 lists relevant datasets, and Table 3 lists relevant GIS files. Many of the documents and datasets were provided by the Chelan County Conservation District, while more general information was compiled by Golder Associates Inc. The complete database was sufficient for completion of a Step A Storage Assessment for WRIA 46. Additional discussion is provided below.

Most of the documents in Table 1 detail specific conditions in WRIA 46 and were compiled the Chelan County Conservation District (CCCD). These documents are classified according to their relevance to storage projects. In general, documents are termed highly relevant if they contain specific information on streamflows, groundwater levels, or water use patterns. The WRIA 46 Management Plan is an example of a document with high relevance.

Golder Associates compiled more general information on the application and benefits of various types of storage-related projects. Many of these documents are journal articles that are not specific to WRIA 46. As such, they are typically labeled as moderately relevant. Example topics include the benefits of increasing streamflows and sustainable water management.

The CCCD provided five datasets that were ranked according to their relevance, in a manner similar to that applied in Table 1. Groundwater levels and well logs were considered highly relevant, while the composite streamflows and water quality data were given moderate relevance.

The bulk of the existing data are in the form of GIS files. Over 75 GIS files were cataloged into a database. The CCCD provided GIS data from relevant studies conducted in WRIA 46. Additional GIS files were compiled by Golder Associates, all of which were obtained from publicly accessible GIS clearinghouses. The GIS datasets are ranked according to their relevance, similar to the rankings given in Tables 1 and 2.

Some of the files provided the CCCD are either incomplete or are missing spatial attribute information. The status of each GIS file is listed in Table 3. The files of most concern are those with missing information that considered highly relevant. The FLIR images, for example, do not contain enough spatial coordinate information (metadata) to allow for the files to be properly projected. This information is needed before the FLIR images can be analyzed. Also, at least one of the files that contains existing well locations is mis-projected. Resolving these deficiencies was not critical for completing the Step A Assessment, but may become necessary for the Step B Assessment.

APPENDIX A-1

Summary of WRIA 46 Available Data and Studies

Title	Storage Relevant?	Folder Name on ftp site	Date	Citation	Study Description	Significant Findings	Status	Location	Data Types)	Data Formats	Data Description	Available on CCD website?	Print Copy Sent?	Assoc. GIS Files? Where?
Entiat Water Resource Inventory Area (WRIA) 46 Management Plan	high	WRIA 46 Plan	Oct-04	CCCD	see executive summary	see text	Complete	Upper, Middle and Lower	SW, GW, Hab, Use	print, pdf, MS Word	n/a	yes	yes	no
Entiat Sub Basin Plan	low	ESBP	May-05	Laura Berg Consulting; Yakama Nation; Trihey and Assoc.; written for Northwest Power and Conservation Council (NWPCC)	Assessment and management plan for recovering focus species within Entiat Sub Basin.	Most recommendations/strategies listed in SB Plan are restated and expanded upon in Oct 2004 Entiat Watershed Plan.	Complete	Upper, Middle and Lower	SW, GW, Hab, Use	MS WORD, PRINT	n/a	no	no	no
An Assessment of Water Temperatures of the Entiat River, Washington Using the Stream Network Temperature Model (SNTEMP)	mod	SNTEMP	Sep-03	R. Hendrick, J. Monahan, WDOE	Modeling of alternative treatments to reduce water temps in Entiat and Mad Rivers	treatment recommendations in text	Complete	Upper, Middle and Lower	SW, Hab	MS WORD, PRINT	n/a	yes	no	yes, GIS folder on ftp site
Entiat Sub Basin Gain-Loss Analysis	high	Gain-Loss	Jan-03	CCCD	Report of findings of gain-loss effort in Sept. 2002 for Entiat and lower Mad Rivers	Identified strongly gaining and losing reaches and summarized gain/loss rate by reach	Complete	Upper, Middle and Lower	SW, GW	MS Word, pdf, print, field records, working tables/text	Flow measurements (Q)	yes	no	yes, GIS folder on ftp site
Use of a GIS-based Hydrogeologic Database to Estimate Groundwater Storage Volumes and Annual Recharge Volumes within the Entiat River Valley, Chelan County, Washington	high	WDOE Aquifer Storage	Jan-03	R.Dixon, WDOE	see title	For the year 2002, groundwater storage volumes within the Entiat River Valley mainstem aquifer were estimated to range from 111,153 acre feet to 107,122 acre feet. The change in volume or annual groundwater recharge for 2002 was estimated to be 4,031 acr	Complete	Upper, Middle and Lower	GW	MS Word, MS Excel, ArcView GIS	Well logs, DNR digital geologic map, 2002 Entiat well monitoring data, USGS DEM	yes	no	yes, included with report in documents folder on ftp site
Historical Changes in Riparian Vegetation and Channel Morphology Along the Lower Entiat River Valley, Washington: Implications for Stream restoration and Salmon Recovery	mod	CWU Channel Change	Jun-04	J. Erickson, CWU MS Thesis	see title	Lower Entiat will not benefit greatly from side-channel reconnection/floodplain restoration. Channel morphology and riparian vegetation have been nearly constant since 1945; most flood control/industrial/agricultural channel and veg changes were complete	Complete	Lower	SW, Hab	Print	n/a	no	yes	no
Using GIS to model channel migration in the Entiat River, Washington	mod/high	Mid-Entiat CMZ	Nov-04	R. Hendrick, CWU GIS project	RH expanded on previous student's (J. Mabry) work to digitize and rectify decadal interval photos, tracking and quantifying channel changes since 1945. Results analyzed using ArcView	Quantified changes in sinuosity relative to 1945 and 1998 baseline conditions. Possible resource for locating feasible side-channel/floodplain reconnections	Complete	Middle; RM 18 22	SW	MS Word, GIS shapefiles	air photo interpretation	no	no	yes, GIS folder on ftp site
Entiat Sub basin Hydrograph Separation Analysis	low	Entiat Baseflow	May-03	CCCD	Computer -assisted hydrograph separation using HYSEP; this study was conducted in support of task II.C.2 of the water quantity plan of work. This study incorporates synthesized flow data for the USGS gages and USFS Barometer Watershed upper Entiat flow d	Monthly baseflow contributions to Entiat are estimated using HYSEP; Mar-Jul are omitted from figures in text due to snowmelt influence.	Complete	Upper, Middle and Lower	SW, GW	pdf, MS Word, Excel, SigmaPlot, jpg	HYSEP text output files. Monthly mean baseflows in cfs and inches, and as percentage of total streamflow	yes	no	no
Entiat River Inventory and Analysis	mod	ERI&A	Jan-98	NRCS/CCCD	Resource inventory completed as part of an interdisciplinary stream survey in the areas of riparian ecology, stream geomorphology, fish ecology, aquatic habitat, and geology.	Rosgen stream classifications assigned for RM 0-20; bank and riparian restoration projects proposed. No specific fish passage issues related to streamflow or site-specific recommendations for channel/floodplain reconnection.	Complete	Middle and Lower	SW, Hab	pdf, print	n/a	yes	no	yes, GIS folder on ftp site
Final Flow Study Report Entiat Watershed WRIA 46	mod/high	Entrix IFIM	Oct-03	Entrix, Inc.	Application of IFIM to Entiat and lower Mad Rivers to assess instream flow requirements for passage and multiple life stages of Chinook and Steelhead.	This IFIM study is important in identifying priority areas of the Entiat and lower Mad where stored water could be used to augment instream flows during critical periods. See sections 4 and 5.	Complete	Upper, Middle and Lower	SW, Hab	pdf, print	flow during curves for study sites, Thompson passage/spawning evaluations	yes	yes	yes, GIS folder on ftp site
Entiat WRIA 46 Water Quality Data Summary and Guide	mod	Water Qual Summary	Jun-03	CCCD	see datasets sheet							no	no	yes, in report folder
Glacial Studies in the Entiat River Drainage Basin, North-Central Washington	low/mod	n/a	1975	W. Long, USFS	Identifies glacial chronology and extent in Entiat Basin. Describes glacial landforms and deposits.	May be somewhat useful as a guide to location and extent of glacial sediments, or to indicate strategic impoundment sites in upper river.	Complete	Upper, Middle	Surficial Geology	print	n/a	no	yes	no
NWI FLIR Report/ GIS project	mod/high	SNTEMP	2001	Watershed Sciences, Inc, for the Pacific Watershed Institute	Surface water temperature IR and true color images from 8/2001 for Entiat and Mad Rivers		Complete	Upper, Middle and Lower	SW, habita	pdf, GIS shapefiles		no	no	yes, in separate FLIR folder on ftp site

Summary of WRIA 46 Available Data and Studies

Title	Storage Relevant?	Folder Name on ftp site	Date	Citation	Study Description	Significant Findings	Status	Location	Data Types)	Data Formats	Data Description	Available on CCD website?	Print Copy Sent?	Assoc. GIS Files? Where?
Entiat Cooperative River Basin Study	low	n/a	Apr-79	USFS, SCS (NRCS)	Study is focused on identifying erosion, channel stability and flood control problems and strategies for mitigation	see text	Complete	Upper, Middle and Lower	SW	print	n/a	no	yes	no
Estimated Baseflow Characteristics of Selected Washington Rivers and Streams	low	WDOE HYSEP	Oct-99	WDOE Water Supply Bulletin No. 60	This hydrograph separation analysis does n	Baseflow estimates for months not affected by	Complete	Upper, Middle and Lower	SW, GW	print, pdf, MS W	n/a	yes	yes	no
Entiat and Mad Rivers Fish Habitat Analysis Using the Instream Flow Incremental Methodology	low	WDOE PHABSIM	Mar-95	WDOE Open File Tech Report 95-166	Instream Flow study performed by WDOE .	This study stated identified flows for the upper and lower Entiat R. and the Mad R. that provide maximum spawning and rearing habitat for salmon. It is essentially superseded by 2003 Entrix IFIM study.	Complete	Upper, Middle and Lower	Hab	print, pdf	n/a	yes	yes	no
Entiat EDT Watershed Analysis	low	EDT	Feb-03	Mobrand Biometrics, Inc.; Prepared for Yakama Nation	Watershed assessment for the focus species, assessing current and historic measures of population performance relative to habitat conditions, and to derive strategic priorities for protection and restoration actions.	Possible side channel reconnection project identified in section 4	Complete	Upper, Middle and Lower	Hab	print, pdf	n/a	yes	no	yes, GIS folder on ftp site
USFWS Spring and Summer Chinook Spawning	low	Spawning Reports	2003	see title	n/a		Complete	Upper, Middle and Lower	habitat	pdf		yes	no	no
USFS Bull Trout Spawning	low	Spawning Reports	2003	see title	n/a		Complete	Upper, Middle and Lower	habitat	pdf		yes	no	no
USFS Stream Temperature Monitoring	low	SNTEMP	2003	see title	n/a		Complete	Upper, Middle and Lower	SW, habita	pdf		yes	no	yes, GIS folder on ftp site
USFS Fine Sediment Monitoring	low	Spawning Reports	2003	see title	n/a		Complete	Upper, Middle and Lower	habitat	pdf		yes	no	no
USFS Steelhead Spawning	low	Spawning Reports	2003	see title	n/a		Complete	Upper, Middle and Lower	habitat	pdf		yes	no	no
Living snow fence installed on SR 25 in Lincoln County.	mod	n/a	2004	Washington State Department of Transportation (WSDOT). 2004. www.wsdot.wa.gov/regions/Eastern	Overview of living snow fences in Washington		Complete	Outside of WRIA 46	GW, habitat	online	n/a	n/a	n/a	no
Living Snow Fences	mod	n/a	1994	USDA National Agroforestry Center, August 1994 Agroforestry Symposium www.unl.edu/nac/aug94/snowfences.html	USDA overview of living snow fences		Complete	Outside of WRIA 46	GW, habitat	online	n/a	n/a	n/a	no
Snow Fences Can Benefit Farm Water Supplies.	mod	n/a		Yarotski, J. http://www.quantumlynx.com/water/vol13no2/story3a.html	Overview of snow fences		Complete	Outside of WRIA 46	GW, habitat	online	n/a	n/a	n/a	no
Simulating the flood mitigation role of wetlands	mod	n/a	1986	Ogawa, H. and J. W. Male (1986). Journal of Water Resource Planning and Management 112.	Wetland storage models		Complete	Outside of WRIA 46	SW, habitat	print	n/a	n/a	n/a	no
The Flood Mitigation Potential of Inland Wetlands	mod	n/a	1983	Ogawa, H. and J. W. Male (1983). University of Massachusetts, Amherst, Water Resources Research Center Publication, No. 138	Overview of wetland storage capabilities during floods		Complete	Outside of WRIA 46	SW, habitat	print	n/a	n/a	n/a	no
Influence of wetlands on streamflow in Illinois	mod	n/a	1993	Demissie, M. and A. Khan (1993). Illinois State Water Survey Hydrology Division. Report 561.	Wetland hydrology		Complete	Outside of WRIA 46	SW, habitat	print	n/a	n/a	n/a	no
The effects of lakes and wetlands on flood flows and base flows in selected northern and eastern states		n/a	1985	Novitzki, R.P. (1985).in Proceedings of a Wetland Conference of the Chesapeake, H.A. Groman and others, eds., Environmental Law Institute, Washington, D.C.	see title		Complete	Outside of WRIA 46	SW, habitat	print	n/a	n/a	n/a	no
Irrigation Scheduling	mod	n/a	1994	W. Trimmer and H. Hansen; Oregon State University extension publication	Overview of efficient irrigation practices		Complete	Outside of WRIA 46	SW, GW, Hab, Use	pdf	n/a	n/a	n/a	no
Trust and Uncertainty: Mechanisms for Reaching Agricultural Sources for Water Quality Trading	low	n/a	2003	Annual APPAM Research Conference,	Conceptual framework of water quality trading		Complete	Outside of WRIA 46	SW, GW, Hab, Use	pdf	n/a	n/a	n/a	no
Past and Future Freshwater Use in the United States	low	n/a	2000	USFS, SCS (NRCS)	see title		Complete	Outside of WRIA 46	SW, GW, Hab, Use	pdf	n/a	n/a	n/a	no
Buying Water for Fish – Pilot Program	mod	n/a	1999	WDOE	Brief overview of pilot program		Complete	Washington	SW, GW, Hab, Use	pdf	n/a	n/a	n/a	no
Complying with State Water Use Laws	low	n/a		WDOE	Brief overview of water law and compliance issues		Complete	Washington	SW, GW	pdf	n/a	n/a	n/a	no

Summary of WRIA 46 Available Data and Studies

Title	Storage Relevant?	Folder Name on ftp site	Date	Citation	Study Description	Significant Findings	Status	Location	Data Types)	Data Formats	Data Description	Available on CCD website?	Print Copy Sent?	Assoc. GIS Files? Where?
A River in the Balance: Benefits and Costs of Restoring Natural Water Flows to the Eel River	**mod**	n/a	2002	The Center for Environmental Economic Development (CEED)	see title		Complete	California	SW, GW, Hab, Use	pdf	n/a	n/a	n/a	no
A Framework for the Economic Assessment of Ecological Benefits	**mod**	n/a	2002	US EPA	see title		Complete	Regional	SW, GW, Hab, Use	pdf	n/a	n/a	n/a	no
Guidelines for Risk and Uncertainty Analysis in Water Resources Planning	**mod/low**	n/a	1992	US Army Corps of Engineers	see title		Complete	Regional	SW, GW	pdf	n/a	n/a	n/a	no
Idaho Water Bank Law	**mod/low**	n/a		State of Idaho	see title		Complete	Idaho	SW, GW	pdf	n/a	n/a	n/a	no
Increasing Stream Flows to Sustain Salmon in the Northwest: An Economic and Policy Assessment	**mod**	n/a	2000	University of Oregon	see title		Complete	Pacific Northwest	SW, GW, Hab, Use	pdf	n/a	n/a	n/a	no
Lessons from the First Application of ESA-Enforcement Involving Anadromous Fish and Communities in the Pacific Northwest	**mod/low**	n/a		Washington State University	see title		Complete	Pacific Northwest	SW, GW, Hab, Use	pdf	n/a	n/a	n/a	no
Model Synthesis Report: An Analysis of Decision Support Tools Used in Columbia River Basin Salmon Management	**mod/low**	n/a	2001	Independent Scientific Advisory Board	Overview of cumulative risk models for salmon survival in the Columbia River		Complete	Columbia River basin	SW, GW, Hab, Use	pdf	n/a	n/a	n/a	no
Production and Habitat of Salmonids in mid-Columbia River Tributary Streams	**mod/low**	n/a	1970's	USFWS	see title		Complete	Columbia River basin	SW, GW, Hab, Use	pdf	n/a	n/a	n/a	no
A method for assessing hydrologic interaction within ecosystems	**mod**	n/a	1996	Journal of Conservation Biology	see title		Complete	Regional	SW, GW, Hab, Use	pdf	n/a	n/a	n/a	no
How much water does a river need?	**mod/high**	n/a	1997	Freshwater Biology	Relates streamflow targets to ecosystem functionality		Complete	Regional	SW, GW, Hab, Use	pdf	n/a	n/a	n/a	no
A spatial assessment of hydrologic alteration within a river network	**mod**	n/a		Regulated Rivers Research and Management	Relates ecosystem functionality to streamflow variability		Complete	Regional	SW, GW, Hab, Use	pdf	n/a	n/a	n/a	no
Ecologically sustainable water management: managing river flows for ecological integrity	**mod**	n/a	2003	Journal of Ecological Applications	see title		Complete	Regional	SW, GW, Hab, Use	pdf	n/a	n/a	n/a	no
Saving salmon, sustaining agriculture	**mod/high**	n/a		Portland State University	Economic approach to balance salmon conservation and agriculture		Complete	Regional	SW, GW, Hab, Use	pdf	n/a	n/a	n/a	no
Review and synthesis of river ecological studies in the Yakima River, Washington with emphasis on flow and salmon habitat interactions	**mod/high**	n/a	2001	University of Montana	see title		Complete	Yakima River	SW, GW, Hab, Use	pdf	n/a	n/a	n/a	no
Water supplies through storage - report	**mod**	n/a	1993	Klohn Leonoff	Storage report for Methow basin		Complete	Methow Basin	SW, GW, Use	pdf	n/a	n/a	n/a	no

Summary of WRIA 46 Available Datasets

Title	Storage Relevant?	Folder Name on ftp site	Date	Citation	Location	Data Type(s)	Data Formats	Available on CCCD website?	Assoc. GIS Files?
Flow data synthesis 2002-2003	**mod**	Entiat Composite Flows		Prepared for CCCD by G. Rhodus, USFS (Ret); R. Edwards, USFS	upper, lower, middle	time-series discharge, monthly and annual statistics	MS Word, Excel	no	no
Well monitoring database	**high**	Entiat Well Monitoring		CCCD	lower, middle Entiat	monthly static water levels and temps,	Excel	no	yes, in GIS folder on ftp site
Entiat well logs	**high**	WDOE well data		WDOE	lower, middle Entiat	stratigraphy, static water lev	Excel	no	yes, in GIS folder on ftp site
2003 USFS photos	**mod/high**	USFS lower Entiat color air photos	1962,1975, 2003	USFS	lower, middle Entiat		jpg; not rectif	no	no
Entiat WRIA 46 Water Quality Data Summary and Guide	**mod**	Water Qual Summary	Jun-03	CCCD	upper, lower, middle Entiat plus Mad R. and tribs	historical USFS, WDOE, E	MS Word, Excel, GIS shapefiles	no	yes, included with report in datasets folder on ftp site

Golder Associates

Summary of WRIA 46 Available GIS Layers

File	Description	Relevance	Coverage	Source	Note
1	Entiat River	High	Below USFS boundary	CWU riparian data	
2	Land Use	High	Below USFS boundary	CWU riparian data	Irrigated, non-irrigated acreage
3	Riparian Buffer	Moderate	Below USFS boundary	CWU riparian data	Riparian zone classifications
4	EDT endpoints	Low	Lower 15 miles	EDT survey	
5	EDT reaches	Low	Lower 15 miles	EDT survey	
6	ISF segment points	Low	Lower 15 miles	Entrix IFIM	Instream flow survey
7	ISF segment reaches	Low	Lower 15 miles	Entrix IFIM	
8	ISF sites	Low	Lower 15 miles	Entrix IFIM	
9	Channel restoration sites	Low	Lower 20 miles	ERI&A Study	
10	Cross-section surveys	Moderate	Lower 20 miles	ERI&A Study	Site locations, no specific data
11	Entiat City Limits	Moderate	Entiat City Limits	ERI&A Study	
12	Fish hatchery	Low	River Mile 7	ERI&A Study	
13	WDNR public lands	High	Lower 20 miles	ERI&A Study	Incomplete
14	USGS gage	Moderate	Stormy Creek gage	ERI&A Study	Only 1 point
15	Geomorphology	Moderate	Lower 20 miles	ERI&A Study	
16	Intermittent streams	High	Lower 20 miles	ERI&A Study	Segments are not named
17	Perennial streams	High	Lower 20 miles	ERI&A Study	Segments are not named
18	PLS cut	n/a	Lower 20 miles	ERI&A Study	Unknown file
19	Pools	Moderate	Lower 20 miles	ERI&A Study	Pool locations, no detailed data
20	Topographic maps 1:24,000	High	Lower 20 miles	ERI&A Study	No data, only map names are listed
21	Reaches	Moderate	Lower 20 miles	ERI&A Study	
22	Redds	Moderate	Lower 20 miles	ERI&A Study	Main stem only
23	River miles	High	Lower 20 miles	ERI&A Study	
24	Improved roads	Low	Lower 20 miles	ERI&A Study	
25	Streams	Low	Lower 20 miles	ERI&A Study	No ID names
26	Instream strucutres	High	Lower 20 miles	ERI&A Study	
27	Study area boundary	High	Lower 20 miles	ERI&A Study	
28	Tonwship range	Moderate	Lower 20 miles	ERI&A Study	Boundaries
29	Unstable banks	Moderate	Lower 20 miles	ERI&A Study	
30	Vegetation survey	Moderate	Lower 20 miles	ERI&A Study	
31	Gain loss points	High	Below North Fork confluence	Gain-Loss	
32	Geology dikeswarm	Moderate	Entire basin	CCCD	Unknown source
33	Geology units	Moderate	Entire basin	CCCD	Unknown source
34	Geology faults	High	Entire basin	CCCD	Unknown source

Summary of WRIA 46 Available GIS Layers

File	Description	Relevance	Coverage	Source	Note
35	Channel migration zones	High	Preston Creek to Stormy Creek	CCCD	Mis-projected
36	Parcel map	High	Lower 25 miles	CCCD	
37	Precipitation	Moderate	Enitre basin	CCCD	
38	Sec, T&R, twps	Moderate	Entire basin	CCCD	Unknown source
39	Sntemp	Low	Below North Fork confluence	CCCD	
40	Soils-Ita	Moderate	Entire basin	CCCD	Need legend
41	Lower entiat soils	Moderate	Below Crum canyon	CCCD	
42	Road-cl	Low	Entire basin	CCCD	Road closures (?)
43	Roads	Moderate	Entire basin	CCCD	
44	USFS soil	Moderate	Entire basin	USFS	Need legend
45	Watershed boundary	High	Entire basin	CCCD	Unknown source
46	Stream gages	High	Entire basin	CCCD	
47	Hydrologic Unit Codes (HUC)	Moderate	Enitre basin	CCCD	
48	Hydrology	High	Enitre basin	CCCD	Need legend
49	Major rivers	High	Entire basin	CCCD	
50	Water	Moderate	Enitre basin	CCCD	Only half of segments are named
51	USFS thermographs	Low	Entire basin	CCCD	
52	Wells	High	Entire basin	CCCD	
53	GRPA well service areas	High	Basin outlet	CCCD	Unknown source
54	Wells	High		CCCD	Mis-projected
55	Wells	High	Entire basin	CCCD	Unknown source
56	Monitoring wells	High	Below Dill Creek	CCCD	
57	Wetlands inventory	Moderate	Entire basin	CCCD	Need legend
58	100 year FEMA Floodplain Metadata	High	Lower 20 miles	FEMA	
59	Roads of Washington	Moderate	Entire basin	Geographic Data Technology Inc.	
60	Clipped Mosaic of USGS 10m DEM for Watershed Processing	High	Entire basin	Golder Associates	
61	Mosaiced DEMs of USGS 10m DEM	High	Entire basin	Golder Associates	
62	Hillshade created from USGS 10m DEM	Moderate	Entire basin	Golder Associates	
62	NED 10m elevation Data	High	Entire basin	USGS	
63	24k Topo Map	High	Entire basin	USGS	

Summary of WRIA 46 Available GIS Layers

File	Description	Relevance	Coverage	Source	Note
64	Major Lakes of Washington	High	Entire basin	WSDOE	
65	Major Rivers of Washington Plus	Moderate	Entire basin	WSDOE	
66	Water Resource Inventory Areas of Washington	Moderate	Entire basin	WSDOE	
67	City Limits of Washington State, August 2004	Low	Entire basin	WSDOT	
68	Counties of Washington State	Low	Entire basin	WSDOT	
69	Survey of Washington Section Township Range	Low	Entire basin	WSDOT	
71	FLIR Images	High	Entire channel	CCCD	Need spatial coordinate information

APPENDIX B

STAKEHOLDER OUTREACH

January 24th 2006 Outreach Meeting: Attendance List

Lance Hansen
PO Box 1973
Wenatchee, WA 98807

Jim Bartelme
PO Box 2252
Wenatchee, WA 98807

Jon Stephan
9802 Entiat River Rd.
Entiat, WA 98822

Phylisha Olin
2598 Entiat Way
Entiat, WA 98822

Donald Olin
PO Box 231
Entiat, WA 98822

Alberto Quezada
13462 Dunn St.
Entiat, WA 98822

Pedro Arias
14913 Red Delicious St.
Entiat, WA 98822

Jon Small
4620 Small Bros. Dr.
Entiat, WA 98822

Ray Sandidge
PO Box 472
Entiat, WA 98822

Hal Hawley
PO Box 452
Entiat, WA 98822

Joseph Johnson
14954 Golden Delicious St.
Entiat, WA 98822

Francisco Guerrero
2095 Commack Dr.
Entiat, WA 98822

Francisco Sanchez
13626 Entiat River Rd.
Entiat, WA 98822

Robert Bockhoven
PO Box 230
Ardenvoir, WA 98811

Russell Griffith
5746 Entiat River Road
Entiat, WA 98822

Jose Quezada
PO Box 262
Entiat, WA 98822

Delfino Lopez
PO Box 595
Entiat, WA 98822

John and Dixie Hinton
5583 Dinkelman Canyon Rd.
Entiat, WA 98822

Bob Whitehall
PO Box 4826
Entiat, WA 09922

David Holland
15 W. Yakima Ave. St.200
Yakima, WA 98902

Karin Whitehall
PO Box 476
Entiat, WA 98822

Keith Vradenburg
13600 Davis St.
Entiat, WA 98822

Jim Small
PO Box 477
Entiat, WA 98822

Phil Archibald
13533 Entiat River Rd.
Entiat, WA 98822

Mike and Chris Mallon
PO Box 261
Ardenvoir, WA 98811

Chuck Hamstreet
7678 Icicle Rd.
Leavenworth, WA 98826

APPENDIX C

PROJECT SCREENING RESULTS

APPENDIX C-1

Off-Channel Storgae Site

Table C-1. Off-channel storage site criteria

Site	Indian Spring Creek	McCarthur Canyon	Asher Canyon	McCleish Canyon	Medsker Creek	Gray Canyon	Preston Falls	Mills Canyon Tributary
Storage (AF)	600	200	180	360	2,000	11,300	11,300	900
Increase seasonal flows	7 cfs : 30 days 2 cfs : 90 days	2 cfs : 30 days 1 cfs : 90 days	2 cfs : 30 days 0.7 cfs : 90 days	4 cfs : 30 days 1 cfs : 90 days	24 cfs : 30 days 8 cfs : 90 days	133 cfs : 30 days 44 cfs : 90 days	133 cfs : 30 days 44 cfs : 90 days	11 cfs : 30 days 4 cfs : 90 days
Multiple benefits	In-stream Habitat Consumptive Agriculture Fire Protection Out-of-basin	In-stream Habitat Consumptive Agriculture Fire Protection Out-of-basin	In-stream Habitat Consumptive Agriculture Fire Protection Out-of-basin	In-stream Habitat Consumptive Agriculture Fire Protection Out-of-basin	In-stream Habitat Consumptive Agriculture Fire Protection Out-of-basin	In-stream Habitat Consumptive Agriculture Fire Protection Out-of-basin	In-stream Habitat Consumptive Agriculture Fire Protection Out-of-basin	In-stream Habitat Consumptive Agriculture Fire Protection Out-of-basin
Fire Protection	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit
Benefits for Late Season Agriculture	Primary Benefit	Seondary Benefit	Seondary Benefit	Seondary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Seondary Benefit
Habitat improvement	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit
Residential supply/ backup/ increase groundwater levels (for wells)	No Benefit	No Benefit	No Benefit	No Benefit	No Benefit	No Benefit	No Benefit	No Benefit
Location and Land Ownership	RM 1 Private	RM 3 Private	RM 2 Mixed	RM 1 Private	RM 13 Private	RM 16 Mixed	RM 23 Public (USFS)	RM 3 (1 mile up Mills Canyon) Mixed
Flow Improvements (% improvement to fish flows at Ardenvoir gage)	Aug Improvement : 1% Sep Improvement : 1%	Aug Improvement : <1% Sep Improvement : <1%	Aug Improvement : <1% Sep Improvement : <1%	Aug Improvement : 1% Sep Improvement : 1%	Aug Improvement : 3% Sep Improvement : 5%	Aug Improvement : 23% Sep Improvement : 47%	Aug Improvement : 23% Sep Improvement : 47%	Aug Improvement : 1% Sep Improvement : 2%
Cost	Very Significant 0.015 AF/ft^2 of impoundment	Very Significant 0.003 AF/ft^2 of impoundment	Very Significant 0.003 AF/ft^2 of impoundment	Very Significant 0.005 AF/ft^2 of impoundment	Very Significant 0.008 AF/ft^2 of impoundment	Very Significant 0.020 AF/ft^2 of impoundment	Very Significant 0.024 AF/ft^2 of impoundment	Very Significant 0.009 AF/ft^2 of impoundment
Moderate Temperature Extremes in Entiat River	Possible Secondary Benefit	Possible Secondary Benefit	Possible Secondary Benefit	Possible Secondary Benefit	Possible Secondary Benefit	Possible Secondary Benefit	Benefit	Possible Secondary Benefit

Off-Channel Storgae Site

Table C-1. Off-channel storage site

Site	Bear Gulch	Murdock Gulch	Potato Creek Tributary	Crum Canyon	Morical Creek	Pyramid Creek	Saunders Creek	Stormy Creek	Lake Creek	Myrtle Lake
Storage (AF)	1,000	1,800	1,300	10,000	500	700	1,700	11,300	11,300	1,900
Increase seasonal flows	12 cfs : 30 days 4 cfs : 90 days	21 cfs : 30 days 7 cfs : 90 days	15 cfs : 30 days 5 cfs : 90 days	118 cfs : 30 days 39 cfs : 90 days	6 cfs : 30 days 2 cfs : 90 days	8 cfs : 30 days 3 cfs : 90 days	20 cfs : 30 days 7 cfs : 90 days	133 cfs : 30 days 44 cfs : 90 days	133 cfs : 30 days 44 cfs : 90 days	22 cfs : 30 days 8 cfs : 90 days
Multiple benefits	In-stream Habitat Consumptive Agriculture Fire Protection Out-of-basin	In-stream Habitat Consumptive Agriculture Fire Protection Out-of-basin	In-stream Habitat Consumptive Agriculture Fire Protection Out-of-basin	In-stream Habitat Consumptive Agriculture Fire Protection Out-of-basin	In-stream Habitat Consumptive Agriculture Fire Protection Out-of-basin	Consumptive Habitat Consumptive Agriculture Fire Protection Out-of-basin	Consumptive Habitat Consumptive Agriculture Fire Protection Out-of-basin	Consumptive Habitat Consumptive Agriculture Fire Protection Out-of-basin	Consumptive Habitat Consumptive Agriculture Fire Protection Out-of-basin	In-stream Habitat Consumptive Agriculture Fire Protection Out-of-basin
Fire Protection	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit
Benefits for Late Season Agriculture	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Seondary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit
Habitat improvement	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit
Residential supply/ backup/ increase groundwater levels (for wells)	No Benefit	No Benefit	No Benefit	No Benefit	No Benefit	No Benefit	No Benefit	No Benefit	No Benefit	No Benefit
Location and Land Ownership	RM 6 (1 Mile up Roaring Creek) Public (USFS)	RM 12 (3 Miles up Mud Creek) Public (USFS)	RM 15 (2 Miles up Potato Creek) Public (USFS)	RM 8 Private	RM 9 Private	RM 34 (4 Miles up North Fork) Public (USFS)	RM 5 Mixed	RM 18 Private	RM 29 (5 Miles up Lake Creek) Public (USFS)	RM 45 Public (USFS)
Flow Improvements (% improvement to fish flows at Ardenvoir gage)	Aug Improvement : 1% Sep Improvement : 2%	Aug Improvement : 3% Sep Improvement : 5%	Aug Improvement : 2% Sep Improvement : 3%	Aug Improvement : 20% Sep Improvement : 40%	Aug Improvement : 1% Sep Improvement : 1%	Aug Improvement : 1% Sep Improvement : 1%	Aug Improvement : 3% Sep Improvement : 4%	Aug Improvement : 23% Sep Improvement : 47%	Aug Improvement : 23% Sep Improvement : 47%	Aug Improvement : 3% Sep Improvement : 5%
Cost	Very Significant 0.006 AF/ft^2 of impoundment	Very Significant 0.025 AF/ft^2 of impoundment	Very Significant 0.014 AF/ft^2 of impoundment	Very Significant 0.038 AF/ft^2 of impoundment	Very Significant 0.014 AF/ft^2 of impoundment	Very Significant 0.005 AF/ft^2 of impoundment	Very Significant 0.010 AF/ft^2 of impoundment	Very Significant 0.024 AF/ft^2 of impoundment	Very Significant 0.016 AF/ft^2 of impoundment	Very Significant 0.079 AF/ft^2 of impoundment
Moderate Temperature Extremes in Entiat River	Benefit	Benefit	Possible Secondary Benefit	Possible Secondary Benefit	Benefit	Possible Secondary Benefit	Benefit	Possible Secondary Benefit	Possible Secondary Benefit	Possible Secondary Benefit

APPENDIX C-1

Off-Channel Storage Site

Site	Murdock Gulch	Potato Creek Tributary	Crum Canyon	Morical Creek	Pyramid Creek	Saunders Creek	Stormy Creek	Lake Creek	Myrtle Lake
Storage (AF)	1,800	1,300	10,000	500	700	1,700	11,300	11,300	1,900
Increase seasonal flows	21 cfs : 30 days	15 cfs : 30 days	118 cfs : 30 days	6 cfs : 30 days	8 cfs : 30 days	20 cfs : 30 days	133 cfs : 30 days	133 cfs : 30 days	22 cfs : 30 days
	7 cfs : 90 days	5 cfs : 90 days	39 cfs : 90 days	2 cfs : 90 days	3 cfs : 90 days	7 cfs : 90 days	44 cfs : 90 days	44 cfs : 90 days	8 cfs : 90 days
Multiple benefits	In-stream	In-stream	In-stream	In-stream	Consumptive	Consumptive	Consumptive	Consumptive	In-stream
	Habitat	Habitat	Habitat	Habitat	Habitat	Habitat	Habitat	Habitat	Habitat
	Consumptive	Consumptive	Consumptive	Consumptive	Consumptive	Consumptive	Consumptive	Consumptive	Consumptive
	Agriculture	Agriculture	Agriculture	Agriculture	Agriculture	Agriculture	Agriculture	Agriculture	Agriculture
	Fire Protection	Fire Protection	Fire Protection	Fire Protection	Fire Protection	Fire Protection	Fire Protection	Fire Protection	Fire Protection
	Out-of-basin	Out-of-basin	Out-of-basin	Out-of-basin	Out-of-basin	Out-of-basin	Out-of-basin	Out-of-basin	Out-of-basin
Fire Protection	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit	Secondary Benefit
Benefits for Late Season Agriculture	Primary Benefit	Primary Benefit	Primary Benefit	Seondary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit
Habitat improvement	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit	Primary Benefit
Residential supply/ backup/ increase groundwater levels (for wells)	No Benefit	No Benefit	No Benefit	No Benefit	No Benefit	No Benefit	No Benefit	No Benefit	No Benefit
Location and Land Ownership	RM 12 (3 Miles up Mud Creek)	RM 15 (2 Miles up Potato Creek)	RM 8	RM 9	RM 34 (4 Miles up North Fork)	RM 5	RM 18	RM 29 (5 Miles up Lake Creek)	RM 45
	Public	Public	Private	Private	Public	Mixed	Private	Public	Public
	(USFS)	(USFS)			(USFS)			(USFS)	(USFS)
Flow Improvements (% improvement to fish flows at Ardenvoir gage)	Aug Improvement : 3%	Aug Improvement : 2%	Aug Improvement : 20%	Aug Improvement : 1%	Aug Improvement : 1%	Aug Improvement : 3%	Aug Improvement : 23%	Aug Improvement : 23%	Aug Improvement : 3%
	Sep Improvement : 5%	Sep Improvement : 3%	Sep Improvement : 40%	Sep Improvement : 1%	Sep Improvement : 1%	Sep Improvement : 4%	Sep Improvement : 47%	Sep Improvement : 47%	Sep Improvement : 5%
Cost	Very Significant	Very Significant	Very Significant	Very Significant	Very Significant	Very Significant	Very Significant	Very Significant	Very Significant
	0.025	0.014	0.038	0.014	0.005	0.010	0.024	0.016	0.079
	AF/ft^2 of impoundment	AF/ft^2 of impoundment	AF/ft^2 of impoundment	AF/ft^2 of impoundment	AF/ft^2 of impoundment	AF/ft^2 of impoundment	AF/ft^2 of impoundment	AF/ft^2 of impoundment	AF/ft^2 of impoundment
Moderate Temperature Extremes in Entiat River	Possible Secondary Benefit	Possible Secondary Benefit	Possible Secondary Benefit	Possible Secondary Benefit	Possible Secondary Benefit	Possible Secondary Benefit	Possible Secondary Benefit	Possible Secondary Benefit	Possible Secondary Benefit

APPENDIX D

DRAFT STEP B SCOPE OF WORK

Golder Associates Inc.

18300 NE Union Hill Road, Suite 200
Redmond, WA USA 98052-3333
Telephone (425) 883-0777
Fax (425) 882-5498
www.golder.com

July 20, 2006

Our Ref.: 053-1000

Chelan County Conservation District
301 Yakima Street, Room 307
Wenatchee, WA 98801

Attention: Mr. Kurt Hosman

RE: DRAFT SCOPE OF WORK FOR STEP B STORAGE ASSESSMENT

Dear Kurt:

Attached is a proposed scope of work, budget and schedule for completing initial portions of the Step B water storage assessment. This forms the basis for the contract between Golder Associates Inc. and Chelan County Conservation District (CCCD) and is consistent with Grant C0500165 between the Washington Department of Ecology (WDOE) and Chelan County Conservation District (CCCD).

Attachment A contains a detailed scope of work for Step B. Attachment B contains a breakdown of proposed budgets and Attachment C contains a project schedule. At your request, this scope focuses primarily on storage options on the Chelan Douglas Land Trust Parcel at the confluence with Stormy Creek. We understand that further development of this scope may occur at a later date.

CLOSING

We will conduct the work under the terms of our existing agreement with CCCD (dated July 21, 2004). Upon written notice to proceed, we will begin work according to the attached scope of work.

If you have any questions please call me at (425) 883-0777.

Sincerely,

GOLDER ASSOCIATES INC.

DRAFT

Robert H. Anderson
Principal

RHA/sy

ATTACHMENT A:
SCOPE OF WORK

The WRIA 46 Step B assessment will focus on increasing floodplain storage in the Entiat River valley. The purpose of this assessment is to determine project feasibility, assess the potential benefits of enhancing floodplain storage, and to develop design alternatives. The alternatives will be structured in phases, to allow for short- and long-term implementation. The Step A Storage Assessment identified the area around the vicinity of the Stormy Creek confluence as a potential storage site given its location in the watershed, land ownership, geomorphology, and resources.

Two specific land parcels were identified after subsequent meetings with the Chelan County Conservation District (CCCD). The two parcels are owned by the Chelan-Douglas Land Trust and are situated immediately upstream and downstream of the Stormy confluence. The lower site is below the "bridge to nowhere" and the upper site is at the base of the Shamel Creek alluvial fan. Both sites appear to have potential for increasing floodplain function and habitat enhancement through improvements and reconnection of side channels. There would be water storage associated with these side channels, but the volumes probably would not require a water storage permit.

For this Scope of Work, floodplain storage refers to the process of diverting streamflows in the Entiat River onto adjacent floodplains. The diverted water may be stored in abandoned side-channels and in overbank sediments in other low-lying areas that may be inundated during flood events. This form of storage will minimize the amount of engineering and construction needed for implementation, restore some of the natural function of overbank areas, and create riparian and aquatic habitat. Side channels and inundated portions of floodplains are important forms of rearing habitat for salmon and steelhead. Side channels can be stranded through either natural or man-made changes. The general approach of this project will identify opportunities to either re-connect or re-establish these side-channel areas.

The goal is to divert streamflows in the spring during periods of high flows, then allow the diverted water to infiltrate into the floodplain and overbank sediments, and slowly recharge back into the Entiat River. The time lag associated with the recharge is intended to correspond with natural streamflow cycles so that the recharge will reach the river when streamflows are low.

Floodplain storage is not a conventional form of storage. The benefits cannot be measured through traditional measurements units or simple store and release scenarios as is the case in a classic above ground reservoir. While there is a storage component, the storage volumes will be low volume relative to other forms of storage, but have high benefit relative to habitat restoration and floodplain function. The true value of this type of project is to: (1) hold water in the floodplain, (2) improve floodplain function and stream interaction, and (3) improve aquatic habitat.

The basic tasks for the project are as follows:

1. **Floodplain Storage Technical Assessment**
   - Data Compilation
   - Site Reconnaissance and Piezometer Installation
   - Mapping and Survey Control
   - Hydrology Assessment
   - Fisheries Assessment
2. **Floodplain Storage Project Design**
   - Conceptual Design
   - Preliminary Design
   - Final Design
3. **Pump and Dump**
   - Theoretical Analysis
   - Test Well Installation
   - Pumping Test
4. **Documentation**
   - Floodplain Storage Technical Assessment
   - Floodplain Storage Project Design
   - Pump and Dump Assessment
5. **Placeholder Tasks**
   - Fire Protection Planning
   - USFS Water Storage Consultation
   - Columbia River Initiative Storage Program

Budget estimates are provided in Table 1 for tasks that can be determined based on the currently available information. Where additional information is required from subsequent to completion of previous tasks, the budget estimates are to-be-determined (t.b.d.).

Task 1: Baseline Technical Assessment

The purpose of the technical assessment is to determine project feasibility and to assess the fisheries benefits. This task includes baseline data collection, initial site reconnaissance, piezometer installation, surveying and mapping, and a fisheries assessment.

Baseline Data Compilation

Golder will acquire existing maps and historical aerial photographs of the Entiat River valley near Stormy Creek. Of particular interest are photographs of the Stormy Creek vicinity during floods events, which will illustrate how side channels and other areas of inundation respond during high flows. This information will be used to determine piezometer locations. We will also coordinate with the BOR for any other available data sources that cover the project site, including the recent video flight during the spring of 2005.

A short technical memorandum describing available data will be prepared.

Site Reconnaissance and Piezometer Installation

Golder will conduct a one-day field reconnaissance to observe site conditions relative to the baseline data compiled in the previous sub-task, and to view to the two sites near Stormy Creek and to map and stake piezometer locations. Because flow patterns in both the surface and shallow groundwater could change as a result of floodplain storage, it is important to begin background monitoring to establish current conditions. Golder will install ten piezometers at the two Stormy Creek sites. Five will be installed in the lower study area (near "bridge to nowhere) and five will be installed in the upper study area (base of Shamel Creek). The piezometers will be dug 10-15 feet below ground using an excavator or back-hoe. Each piezometer will be fitted with an automated pressure transducer to record water-levels. One additional pressure transducer will be installed in the river to monitor river water levels.

Installation of the piezometers using test-pit excavations will allow for assessment of the soil structure and other physical sub-surface soil properties throughout the project area. Each test pit will be logged and photographed to document layering or other features that affect hydraulic connectivity between the river and floodplain. Up to five grain size analysis will be conducted to estimate permeability and porosity of floodplain sediments. Up to four test pits will be hydraulically tested for infiltration capacity, by filling them with water and monitoring the rate of flow out of the test pit.

A short technical memorandum describing the data collection effort will be prepared.

The budget for this task includes costs for installation of the piezometers, subcontracting with a backhoe operator, and purchase of 11 pressure transducers. It is assumed that Golder would provide one field person during the installation. It is assumed that CCCD would provide field support during the installation, would download data collected from the pressure transducers and send the data to Golder for processing. It is also assumed that CCCD would coordinate necessary site access and permitting for installation of the test pits.

Mapping/Survey Control

Accurate topography is needed to identify existing back channel areas, evaluate the elevations of overbank areas relative to the river and floodplain, develop hydraulic models of surface and sub-surface flow regimes, and for assessment of hydrogeologic characteristics at the site.

The topography is also needed for developing and completing the conceptual, preliminary, and final designs for the site.

LIDAR is the best approach to obtaining surface topography because this type of survey provides excellent horizontal resolution and vertical representation of current ground and historical floodplain surfaces. We understand that other agencies and/or the Yakama Tribe may be coordinating a LIDAR survey later in the fall of 2006, and that CCCD has been in discussions to participate and obtain this data. If the 2006 schedule is correct, LIDAR data from this survey may be available for this project towards the beginning of 2007.

We have started looking into the feasibility of completing an independently contracted LIDAR survey of the project area and some distance up- and downstream along the valley alignment. If we were to contract independently, the data may be available towards the end of 2006. The possible delivery date for the data has not been confirmed. Costs for completing an independent LIDAR survey are not included in this scope. The additional cost for completing an independently contracted LIDAR survey is estimated at $30,000-60,000.

Costs for obtaining LIDAR data, whether independently or through the agency consortium, are not included in the budget.

Hydrology Assessment

The hydrology assessment will evaluate the hydrology and connectivity between the river and the adjacent floodplain. The duration, magnitude and frequency of flood flows and low flows will be determined based on existing streamflow data. Representative maps, cross sections, and profiles of the floodplain will be constructed. The GIS data showing stream channel geometry and migration will be used in addition to available geologic mapping and topography. This initial assessment will not utilize detailed LIDAR topography for the site, but will focus on more regional features on the floodplain.

Fisheries Assessment

The fisheries assessment will assess the benefits of floodplain storage on aquatic habitat at the project location. This sub-task will be divided into two phases. The first phase will be primarily qualitative and will describe the types of changes in habitat that would likely be associated with floodplain storage and changes in streamflows. This will be accomplished through existing documents, supplemented by limited site reconnaissance and photo documentation.

The second phase will attempt to quantify the benefits of floodplain storage. This phase will be accomplished using existing temperature and PHABSIM models for the Entiat River to populate an EDT model. The use of these existing models will save considerable time and resources. Specific work items will include:

- PHABSIM Analysis – Assumes an existing model is available and calibrated.
- Stream Temperature Analysis – Assumes a existing model is available and calibrated.
- Ecosystem Diagnosis and Treatment (EDT) model Scenario Builder – Assumes existing data set is used. The model will be run for coho salmon, Chinook salmon and steelhead.

Task 2: Project Design

Golder will assimilate the information developed in the technical assessment in order to design a feasible and beneficial project. The project design will be divided into three phases: conceptual, preliminary, and final. The level of detail will increase with each phase.

> The conceptual design is intended to bring together the available data compiled in Task 100, and develop conceptual approaches and alternatives for the project. A meeting will be held to review the conceptual design, and decide on the alternative that will proceed to preliminary design.
>
> The preliminary design will be comprised of the alternative selected from the conceptual design phase. Completion of the preliminary design will represent an interim design review milestone for the CCCP. The preliminary design will include a brief technical memorandum summarizing the approach and methodology of the design.
>
> The final design will provide a detailed a plan of action, drawings, and specifications for the proposed floodplain storage project. The final design will include a technical report. Final designs will assume close coordination at the time of construction between the CCCP, the designer (Golder), and the contractor. This leaves some flexibility to adjust the design in the field to address changes in site conditions that are identified during construction.

Budget estimates are not included for the preliminary and final design components. Following the evaluation of the conceptual design, a decision on whether to proceed with further project design will be made and revisions to the scope of work will be prepared.

Task 3: Pump and Dump

Theoretical Analysis Golder will conduct a simple modeling analysis to describe the potential operating constraints and opportunities for a pump and dump concept. An analytical stream capture model will be used to show cumulative stream capture dynamics from a deep well and the potential range of streamflow benefits that could be realized from pumping groundwater into the Entiat River for short periods of time. A range of assumptions will be used to define aquifer properties, aquifer geometry, pumping rates/durations,

Following the evaluation of the theoretical analysis, a decision on whether to proceed with a test well and pumping test will be made and revisions to the scope of work will be prepared.

Task 4: Documentation

Floodplain Storage Technical Assessment

A report will be prepared that documents the results of the technical assessment and conceptual design for floodplain storage. Four copies of a draft assessment report and 10 copies of a final report will be prepared.

Further documentation on the Floodplain Storage Project Design and the Pump and Dump Assessment is not included in this scope of work.

ATTACHMENT B:
RATE SCHEDULE

Billing rates and direct cost structure will be billed according to the following rate Schedule.

Robert Anderson	$170
Andreas Kammereck	$130
Jay Pietraszek	$ 80
GIS Support	$80