The Ecologically Adaptive Water Management Program

for Powder River, Burnt River, and Pine Creek Subbasins

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Table of Contents

Glossary

by-pass flows – The by -pass flows are the specific amount of water needed for target species, in order to move around instream barriers. This does include irrigation water already being diverted through the reservoir prior to being removed at the POD and the consequent subsurface return flows.

flushing flows – The flushing flows are that ranges associated with the amount of water necessary during various life stages to catalyze movement of target species within the stream. For redband trout there is limited of information to support specific flows needed to initiate movement at various life stages.

hydrograph—A graph showing changes in the discharge of a river over a period of time.

optimum peak flow –Channel maintenance flow. Robinson (2007) states that channel maintenance flow are "Flows that occur less frequently, but at a greater volume than average flows." Channel maintenance flow in alluvial rivers is the range of flows that is required to maintain stream channels over time.

MODSIM model -- is a water management simulation system used for conducting planning and operational studies of complex river systems. MODSIM allocates available water supply from storage and natural flows to meet the current irrigation demand at several basin locations; it computes a shortage when the supply cannot meet the demand.

acre-foot—A unit of volume commonly used in the United States in reference to large-scale water resources, such as reservoirs, aqueducts, canals, sewer flow capacity, and river flows . It is defined by the volume of one acre of surface area to a depth of one foot.

Rosgen Stream Classification-- The purpose of this system is to classify streams based on quantifiable field measurements to produce consistent, reproducible descriptions of stream types and conditions. There are four levels in Rosgen's classification hierarchy: geomorphic characterization (Level 1), morphological description (Level 2), stream condition assessment (Level 3), and validation and monitoring (Level 4).

outflow-- In hydrology, the outflow or discharge of a river is the volume of water transported by it in a certain amount of time.

inflow-- In hydrology, the **inflow** of a body of water is the source of the water in the body of water. It can also refer to the average volume of incoming water in unit time.

borings-- cylindrical sample of earth strata obtained by boring a vertical hole.

test pits-- a small exploratory "dig" designed to determine a site's depth, and contents prior to major excavation

Acronyms and Abbreviations

GIS – Geographic Information System
OWRD—Oregon Water Resource Department
POD—Point of Diversion
NRCS—U.S. Department of Agriculture Natural Resource Conservation Service
ODA—Oregon Department of Agriculture
BOR—U.S. Department of Interior Bureau of Reclamation
cfs—cubic feet per second
USFS—U.S. Department of Agriculture Forest Service
ODFW—Oregon Department of Fish and Wildlife
USFWS—U.S. Department of Interior Fish and Wildlife Service
SWCD—Oregon Soil and Water Conservation District
HDR-- Henningson, Durham & Richardson Engineering, Inc
WASH—Water and Stream Health Committee
EFF- Energy, Food, and Fiber

Summary

Introduction and Historical Content

This report describes the results of appraisal-level studies conducted by the Bureau of Reclamation in cooperation with eastern Oregon stakeholders to evaluate potential storage sites intended to improve water supplies in the Burnt River, Powder River, and Pine Creek basins. Additionally, this study examines all existing water quality data within the three basins.

Eastern Oregon is a semi-arid area with an annual water shortage that directly or indirectly affects everyone in the area. The existing hydrology affects the economy (agriculture, energy, and recreation), environment (water quality, fish and aquatic ecosystems), wildlife (ecosystems), energy needs (power and biofuel generation), and municipal needs. Residents of the area, including irrigators and other stakeholders, have worked to develop additional water supplies over the last 140 years to supplement supplies from several federal dams and smaller privately-owned projects.

In January 2005 the Baker County Commissioners established the Powder Basin Water and Stream Health (WASH) Steering Committee to identify opportunities for storage projects that would provide both instream (e.g., fish, water quality, and recreation) and out-of-stream (e.g., irrigation and municipal supply) benefits. The WASH committee requested assistance from Reclamation's Snake River Area Office in Boise, Idaho, and secured federal funding in 2007 to conduct the Ecologically Adaptive Water Management Program study. Furthermore, the goal of the WASH Committee is to develop long-term water management within the Powder Basin. This includes 80% of Powder Basin water to be utilized by 2030 and 100% by 2050. Specifically, ecologically adaptive water management will be consistent with the 1909 Water Law.

The 2.7-million-acre study area is located in eastern Oregon, bordered to the north by the Wallowa Mountains, to the west by the Blue Mountains, to the south by the Malheur River basin, and to the east by the Snake River. Stream headwaters originate in the Blue and Wallowa mountain ranges at elevations from 6,000 to nearly 9,000 feet above sea level, and empty into the Snake River reservoirs at approximately 1,650 feet in elevation.

Benefits of Existing Water Storage

Historically, the Powder River was dry in several reaches during mid to late summer. With the construction of Mason Dam in 1965-1968 (BOR 2009), spring snowmelt/ run-off was captured stored and safely released to augment late season stream flows and irrigation, which in turn increased late season subsurface return flow to the river (fig.1-2).

Figure 1. Powder River at Hughes lane in 1965 before water storage.

Figure 2. Powder River in 2010 at Hughes Lane in 2010 after water storage.

Water Supply and Demands

Watersheds and reservoirs in eastern Oregon's Burnt River, Powder River, and Pine Creek basins provide irrigation water to about 133,000 acres in Baker and Union counties. The stored water does not meet late summer water demand and instream flow targets. Without stored water, natural flows start to diminish with decreasing snowpack. Additionally, after mid-July, natural flows are not adequate to meet all demands.

Prior Appropriation

"Oregon's water laws are based on the principal of prior appropriation, which means that the first right to be obtained on a stream is the last right to be shut off in times of low stream flow. In times of water shortage, the water right with the oldest date of priority can utilize all the water specified in the water right, regardless of the needs of the junior user" (OWRD 2008).

As stated above from the *Water Rights in Oregon* document, senior water rights with the oldest priority date shall have full right to demand all water specified in their water right, regardless of the needs of junior users. However, this is not the case in the Baker Valley region. Specifically in Baker Valley, many senior water rights do not get their water demands met, due to the geographical layout of the land and lack of precipitation. An alluvial fan (fig. 3-4) has developed over the landscape in this region, which has a significant influence on the stream flow and distribution due to the water being lost to the permeable alluvial fan. Summer flows will not reach a senior right on the lower end of an alluvial fan during mid to late summer. Therefore, junior rights at or near the head of the fan are served. Consequently, a small percentage of water rights in eastern Oregon meet their full duty and in certain drainages no water right holders are able to fill their duty.

Figure 3. Alluvial fan (Google 2005).

Figure 4. Stream in an alluvial fan (Google Webshots 2005).

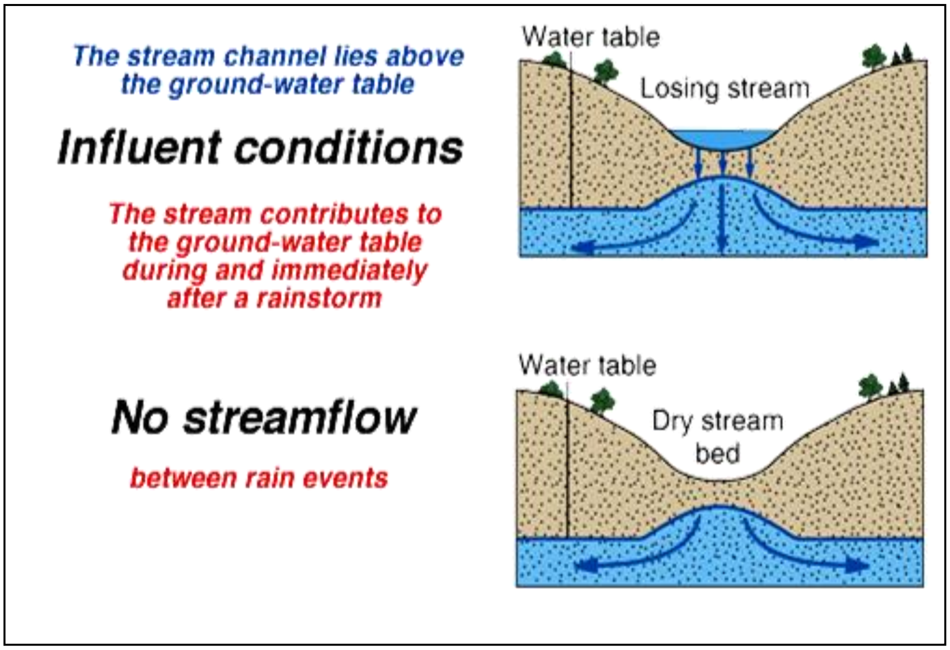


Figure 5. Influent stream conditions in dry climates like eastern Oregon (Salem State University).

Future Demands

Farmers will need to produce more energy, food, and fiber (EFF) in the next 50 years than was produced in the previous 10,000 years combined (AFB 2010, ASA 2011, CIA 2010, Food and Ag Org of UN 2011, Montana Wheat and Barley Committee, Oklahoma State University 2010), which is why water is such critical resource for the future, especially in dry climates like eastern Oregon where water is in high demand. Energy is not just water power; it also includes converting food and fiber to biofuels. Therefore, water storage is the only reasonable and economically viable alternative for farmers to meet the demands of the increasing population

Over the past 50 years, the world population has doubled from approximately three billion people to almost six billion people. In 1960, one U.S. farm family fed 26 people compared to 2011in which a single farm will feed 155 people. Additionally, there are 24 million jobs supported by U.S. farmers, which is more than the entire population of Australia. The U.S. will produce nearly 13 billion bales of cotton this year and 41.56% of the amount of world's corn, which is more than China, Brazil, Mexico, Argentina, India, and the European Union, combined. Furthermore, farmers and ranchers provide food and habitat for 75% of the nation's wildlife. By 2050, the world population will grow by 2.5 billion, which is eight times the population of the U.S (AFB 2010, ASA 2011, CIA 2010, Food and Ag Org of UN 2011, Montana Wheat and Barley Committee, Oklahoma State University 2010).

This study evaluated existing water supply deficiencies and future needs within the basins. The major water supply need –irrigation – was defined by existing water rights that are not currently being met by natural flows and existing storage projects. Unfortunately, at this level of study, only existing data was evaluated. Therefore, there was no estimate for the production of EFF if irrigation water were available. Future needs were defined as the estimated un-met portion of existing irrigation water rights. An evaluation of municipal needs found that they are likely to be met by existing surface and groundwater rights through 2050. Non-consumptive instream flows for fish and water quality were also evaluated.

However, municipal needs are relatively small compared to irrigation. Additionally, commercial and other water uses were found to be very small and did not require analysis.

In the period from 1930 to 1985, our government (i.e. BOR, ACOE, NRCS, BPA, etc.), in partnership with producers, reclaimed numerous acres of nonproductive desert and improved water management. This work discontinued in the mid 1980's. For the last 25 years, we have benefited from these efforts and been able to keep the EFF production ahead of human needs. Without renewed efforts, human needs will exceed production.

Storage Site Identification and Screening

Based on the literature review, previous studies in the area, and stakeholder comments, BOR and Browne Consulting developed a preliminary list of 96 potential water development sites, including existing storage and potential sites for expansion and new storage. During the screening process, these were narrowed down to 22 potential sites that were analyzed with additional hydrologic modeling and against other screening criteria, including potential multi-purpose benefits, environmental constraints and other considerations. These criteria were applied to each of the 22 potential sites at a March 2009 workshop involving the WASH committee and stakeholders. The following four potential sites were selected at that workshop for further evaluation after they met the screening criteria:

- The Hardman Dam and Reservoir site on the Burnt River (Hardman Site)
- Enlargement of the existing Thief Valley Dam on the Powder River (Thief Valley Site)
- The North Powder Dam and Reservoir site on the Powder River (North Powder Site)
- The East Pine Dam and Reservoir site on Pine Creek (Pine Creek Site)
- Enlargement of existing Wolf Creek Dam and Pilcher Creek Dam (Wolf Creek Complex Site)

The Thief Valley site and Wolf Creek Complex would involve enlargement of existing dams. The other two sites would involve new dam and reservoir facilities.

During the screening process, two sites in the North Powder Drainage were identified as having the correct attributes to progress to the next level of development. However, stakeholders agreed to select only four sites to move to the next level at the current time. During the meeting the North Powder Reservoir site was selected as one of the top four and the only site in the North Powder River drainage. However, subsequently after the Stakeholder meeting, new geologic information pertaining to the North Powder Reservoir site was obtained. DOGAMI scientist Mark Fern pointed out that the site is located at the base of a lateral moraine. These geologic features have been known to cause massive sedimentation if disturbed by natural distasster proportion events. Also during the screening process the Wolf Creek Complex scored as well as the North Powder Reserovir site. Hence, in light of the new evidence affected stakeholders chose to decrease the priority level of the North Powder Reservoir site and increase in priority the Wolf Creek Complex. The scientifically based trade off between the two is that the North Powder Reservoir site would have the potential to store more water than the Wolf Creek Complex, however, the risk of failure of the facility due to catastrophic events was much less likely for the Wolf Creek Complex.

This appraisal-level study builds on past efforts to provide a more detailed analysis of the four potential storage projects in the study area. It includes:

- Better identification of the amount of potential snowmelt that can be stored for beneficial release at times of shortage.
- Identification of existing conditions and needs.
- Identification of a variety of costs, benefits and potential issues that would result from development of new storage projects.

The overall study process is comprised of the following sequential steps:

- A literature review of information available for the three basins.
- A hydrologic evaluation of 96 sites to estimate potential yield for water supply (Fig. 5).
- A selection of 22 sites that have potential to meet the goal.
- Identification of four projects that have the highest cost benefit and probability of success
- An appraisal-level evaluation of the four projects that involved a site visit, estimation of costs to build, and further review of environmental and other criteria.
- To assign the four potential sites in order priority order for construction.
- Begin Feasibility and Environmental Analysis on the highest priority project.
- Retain data on the remaining 18 sites for future action.

Section 1.0 Study Area Overview

1.1 Powder Basin

The The Ecologically Adaptive Water Management Program (see Figure 1) is located in eastern Oregon, bordered to the north by the Wallowa Mountains, to the west by the Blue Mountains, to the south by the Malheur River basin, and to the east by the Snake River. The Burnt River and Powder River water systems are upstream from 10 Snake River and Columbia River dams (PSU 2009). The study area is comprised of three major subbasins: Burnt River, Powder River, and Pine Creek, which encompass approximately 2.7 million acres (BOR 2010).

The Powder Basin is bordered to the north by the Wallowa Mountains, to the west by the Blue Mountains, and to the east by the Snake River. Within the Powder Basin, a series of mountains separates the Powder River Subbasin (HUC: 17050203), the Burnt River Subbasin (HUC: 17050202), and the Brownlee Reservoir Subbasin (HUC: 17050201).

Topography

The topography in these eastern Oregon subbasins varies with relatively high-gradient mountain streams, deep river canyons, and broad shallow valleys, and mountain desert-alluvial fans. Stream headwaters originate in the Blue and Wallowa Mountain ranges at elevations from 6,000 feet to nearly 9,000 above sea level. They empty into the Snake River reservoirs at about elevation 1,650 feet (BOR 2010).

Climate

The overall climate is characterized by low precipitation, low relative humidity, rapid evaporation, abundant sunshine, and wide temperature and precipitation fluctuations. The mean annual temperature is about 46°F. Temperature extremes of -28° F (February) and 104° F (August) have been recorded at the Baker City Airport. The of annual precipitation, which varies from 6 inches to 10-12 inches depending on elevation with the majority of the higher elevation (15 to 20 inches) precipitation being stored as snow or ice with uncontrolled release. Portions of this area commonly experience rain-on-snow events, which reduce the snowpack and may cause brief, localized flooding (BOR 2010, Powder River Subbasin Plan, NPPC, Nowak 2004, EPS 2007).

Population

The basins have a population of about 16,700 people spread across Baker County and a small portion of southern Union County. Baker City is the largest city with a population of 9,840. The remaining populations are located in very small rural communities. The major employers are agriculture, tourism, and government. Without major industries to attract more people, the population is expected to continue at its current rate. Based on factors such as unemployment rates, annual income, and population, the State of Oregon has designated Baker County as a "distressed" area, making it eligible for priority assistance from the Economic and Community Development Department (BOR 2010, Browne 2008; Powder Basin Watershed Council 1996).

Land Use

Approximately two-thirds of the area is rangeland, with livestock grazing as the primary land use. One-sixth of the area is forestland where timber harvest and summer livestock grazing are the main uses. Most of the remaining area is cropland and pastureland irrigated by gravity, flood, or sprinkler systems. Irrigated acres produce primarily grain, hay, potatoes, and pasture (BOR 2010, Browne 2008; Powder Basin Watershed Council 1996), but much of the land is capable of producing higher value crops if late season water is available.

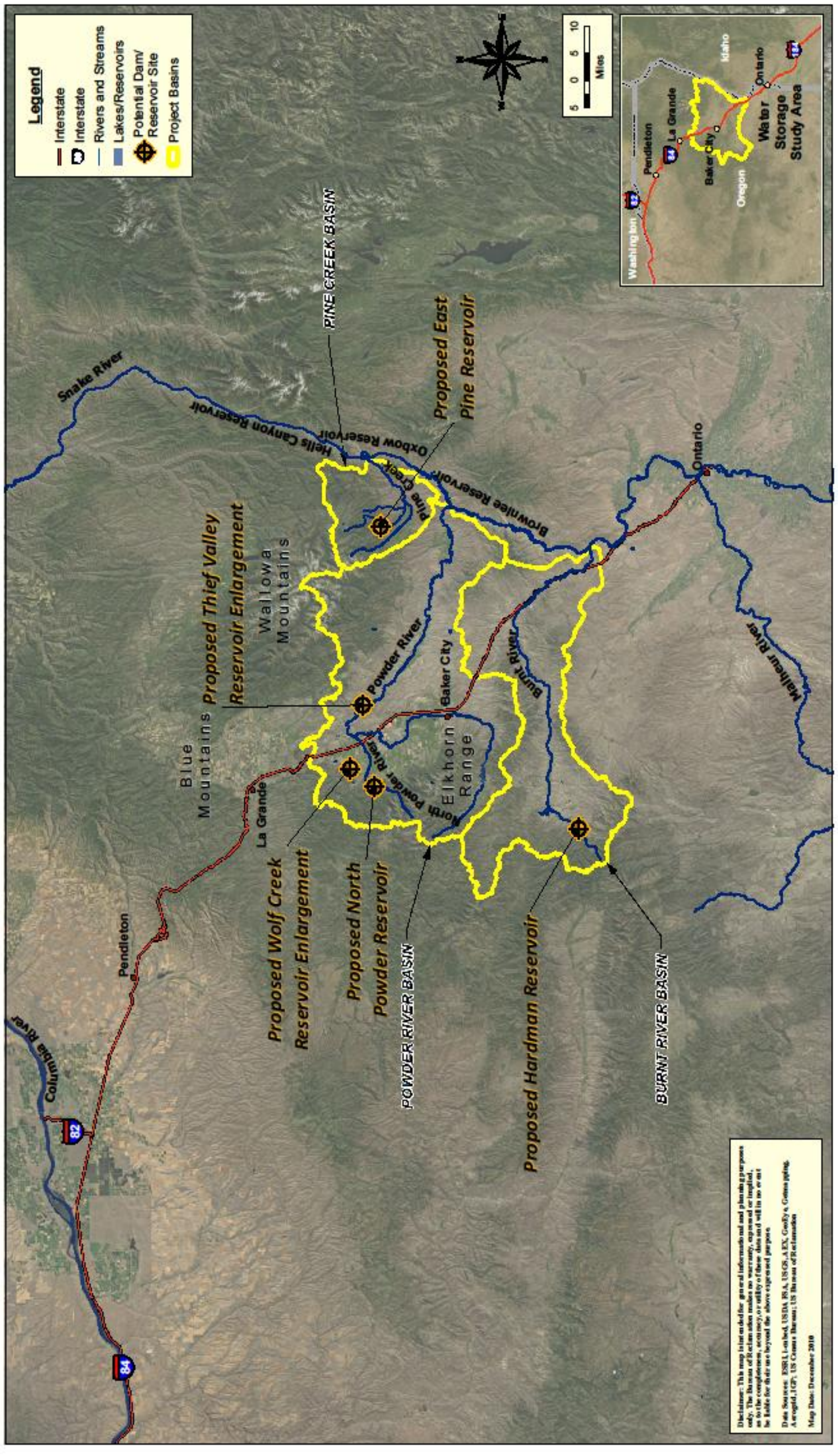


Figure 6. Powder Basin Study Area

1.2 Powder River Subbasin

The Powder River Subbasin encompasses 1,096,900 acres (NRCS) including several main tributaries: the Powder River, North Powder River, and Eagle Creek in Richland and Pine Creek in Halfway for a total of 1,668 miles of major streams in the subbasin (NRCS). The Powder River is 144 miles long and drains more than 1,540 square miles (Oregon Department of Agriculture (ODA 2007). It originates in the Elkhorn Range of the Blue Mountains, flows into Phillips Reservoir, which has a storage capacity of 90,500 acre-feet (ODA 2007), and then into the Baker Valley. The North Powder River originates farther north in the same mountain range, and has two existing water storage sites; Wolf Creek Reservoir has a storage capacity of 10,800 acre-feet (ODA 2007). The Powder River and North Powder River converge above Thief Valley Reservoir. Capacity has decreased to 13,300 acre-feet of 17,400 acre-feet, terminating 78 miles later in the Brownlee Reservoir on the Snake River (ODA 2007). The Powder River Basin is above 11 Snake River and Columbia River dams (Kerns).

Thief Valley Reservoir

The Thief Valley Reservoir is an existing reservoir that was constructed in 1932 with storage capacity of 17, 400 acre-feet, due to sedimentation, caused predominantly from both natural events and from historic mining storage. It is located on the county boundary between Baker and Union Counties. It is approximately 29 miles north of Baker City, is known for excellent fishing, and is one of the top five windsurfing locations in Oregon. The following are dam statistics:

- Township 6 south, Range 40 east Section 26
- Drainage is 910 square miles
- Structural dam height 73 feet
- Crest elevation 3,143 feet
- Crest length 390 feet
- Crest width 7 feet
- Current capacity is 13,300 acre feet

When the reservoir was constructed in 1932, the total capacity was 17,400 acre-feet with a 740-acre surface area. Due to sedimentation and siltation, caused predominantly by upstream gold dredging, storage capacity has diminished to 13,300 acre-feet of storage and 685 acres of surface area. Most years the reservoir is not completely emptied and is an excellent trout fishery as stated by fish biologists and anglers alike. There is a small park with a few unimproved campsites and a single boat ramp. The climate of the area can be characterized as semi-arid high desert, and receives an average of 10” of precipitation per year.

Wolf Creek Complex

Wolf Creek and Pilcher Creek Reservoirs are the two existing reservoirs within the North Powder River Reservoir drainage. Together, the system is referred to as the Wolf Creek Complex. The Wolf Creek reservoir was constructed in 1968 and completed by May 1975. Pilcher Creek Reservoir was completed in the fall of 1983 (Powder Valley Water Control District). Both reservoirs are located within Union County, just a few miles from the North Powder River, which is the county boundary. It is approximately 6 miles west of the town of North Powder and is known for excellent fishing. The following are dam statistics:

Wolf Creek Reservoir

- Township 6 South, Range 38 East Sections 8, 16, 17
- Drainage is 32.9 square miles
- Structural dam height 154 feet
- Crest elevation 3,704 feet
- Crest length 2600 feet
- Crest width 30 feet
- Current capacity is approximately 11,111 acre feet
- Minimum Pool 750 acre-feet

Pilcher Creek Reservoir

- Township 6 South, Range 38 East Sections 10, 11, 14
- Off-stream reservoir
- Drainage is 5.5 square miles
- Structural dam height 117 feet
- Crest elevation 3,777 feet
- Crest length 2400 feet
- Crest width 26 feet
- Current capacity is approximately 5,912 acre feet
- Minimum Pool 7.5 acre-feet

Wolf Creek and Pilcher Creek Reservoirs are operated as one pool. There is a canal that carries water from Pilcher Creek Reservoir to Wolf Creek Reservoir. Wolf Creek Reservoir usually draws down quicker than Pilcher Creek Reservoir, thus to balance out the system, water is transferred viea a canal between the two sites. Additional water from Pilcher Creek Reservoir is put instream via the North Powder River for irrigation both to the North and South of the river. It is due to these facts and the immense complexity of the system that the project is currently referred to as the Wolf Creek Reservoir Complex.

The climate of the area can be characterized as semi-arid high desert, and receives an average of less than 10" of precipitation per year. Minimum flows are typical for the Wolf Creek drainage and surrounding area from the months of late June thru February with the exception of warm rains on the snow pack causing rapid increase in flow. Months of higher flows are March through May with flows dropping off in early June. Under the existing flow regime, there are two peaks in the hydrograph. One peak in the hydrograph typically occurs in April and another in May. Snowmelt is the major contributor to flood flows with periods of high flows often lasting for several weeks. This is a result of the reservoir filling to capacity, then being drawn down once irrigation begins in April. If the capacity of the reservoir were expanded, models show that there would not be an initial peak in the hydrograph in March given that the reservoir would still be filling. Inflows would still peak in May thru June and then begin tapering off (Browne 2011).

The water in Wolf Creek and Pilcher Creek Reservoir is obligated for irrigation, while creating and enhancing habitat and recreation opportunities. The current construction of the Wolf Creek reservoir at the elevation of 3694 feet has a volume of 11,111 acre-feet and surface area of 225 acres; Pilcher Creek Reservoir at the elevation of 3971 feet has a volume of 5,912 acre-feet and surface area of 221.5 acres. Most years the reservoirs have not been drained to the minimum pool and are excellent trout fishery, as stated by fish biologists and anglers alike. The outlet works of Wolf and Pilcher Creek Reservoir are designed to have a total discharge capacity of 350 cfs and 65 cfs, respectively.

Wolf Creek Complex Watershed Characteristics

Pilcher Creek Reservoir is an off-site reservoir with water channeled from Anthony Creek. Wolf Creek watershed above the reservoir is elevations range from 3761 ft 6478 ft above sea level. The mean slope of the watershed is 14.11. Annual precipitation is 26.97 inches with 93.5%

forest cover. At the reservoir site the channel is a deposition reach from the higher gradient forested transport reach above. Below the dam, the channel transitions to short narrower valley of transport reach into the deposition reach through the agriculture land near North Powder Valley. The riparian habitat above the reservoir is comprised of *Populus spp., Alnus spp.* and forested upland species and transitions to a *Populus spp./Salex spp.* community.

North Powder Reservoir

The North Powder Reservoir is a proposed above ground water storage project that was thoroughly researched and designed in the 1970's (CH2MHILL). It was ready to go to contract when inflation skyrocketed in the 1980's becoming unfeasible to construct with agriculture being the only financial source to payback the construction loan. It is located approximately 12 miles from North Powder, Oregon just 5 miles inside the tree line towards Anthony Lakes at the northeast edge of Baker County. The dam would be located where a section of highway currently exists. Approximately 2 miles of the highway would have to be rerouted around the water storage project.

For numerous years, residents of the Powder Valley area have envisioned increasing the availability of late season water by constructing a reservoir on the North Powder River. A 1967 publication called the *Watershed Work Plan North Powder River Watershed*, Baker County, OR, cites several potential water storage sites including the North Powder Reservoir site. The reservoir is described in the publication as follows: "The North Powder Reservoir will be a multipurpose structure for flood prevention, irrigation, and recreation. The dam site is on the North Powder River about 11.5 miles upstream from the mouth and about 10.3 miles west of the town North Powder. This structure will control 45.0 square miles of the 115.8 square mile drainage area of the North Powder River. Part of the dam and reservoir will be located on National Forest Land."

Since the 1967 publication, more than $1.5 million has been spent in attempting to see to fruition the construction of the reservoir. In 1979 and then in 1980, the *Final Design Report of the North Powder Dam and Reservoir* was completed by CH2MHill with financial and technical assistance provided by the Soil Conservation Service, now known as the Natural Resource Conservation Service, (NRCS).

The need for and use of a reservoir has evolved long before 1967. Today beneficial uses that would be enhanced by the availability of late season water include stream health, hydro-power, recreation, agriculture, fish, wildlife, flood prevention, water quality, and tourism. In the current socio-economic, setting repayment for the cost of the reservoir will be by more than just agriculturalists. Recreationists, power users, and possibly even conservation groups will help with repayment.

Furthermore, another alternative is to enlarge Pilcher Creek and Wolf Creek reservoirs with a canal from the North Powder River into Pilcher Creek.

Historic Construction Specifications:

- Storage capacity 16,650 acre-feet
- 260 surface acres
- 14,622 acre-feet will provide for irrigation and flood protection
- 2,028 acre-feet recreational pool
- 18,000 acres of irrigable land would be serviced
- Township 7 south, Range 43 east, Section 10

1. 3 Burnt River Subbasin

The Burnt River Subbasin encompasses 705,600 acres (NRCS), and is bordered by Grant County to the west, Malheur County to the South and the Snake River to the east. There are a total of 830 miles of major streams in the Burnt River Subbasin (NRCS). The main tributaries of the Subbasin are the north and south forks of the Burnt River, which originates in the Blue Mountains and converge above Unity Reservoir. Unity Reservoir was constructed in 1938 and stores 25,502 acre-feet of spring runoff used for supplemental irrigation and is a Bureau of Reclamation project (BOR 1991). The Burnt River water system is above 11 Snake River and Columbia River dams (PSU 2009). There are neither anadromous fish nor Bull Trout present in the streams of the subbasin, and none of the streams is listed as essential fish habitat for threatened or endangered species (NRCS Stream Net).

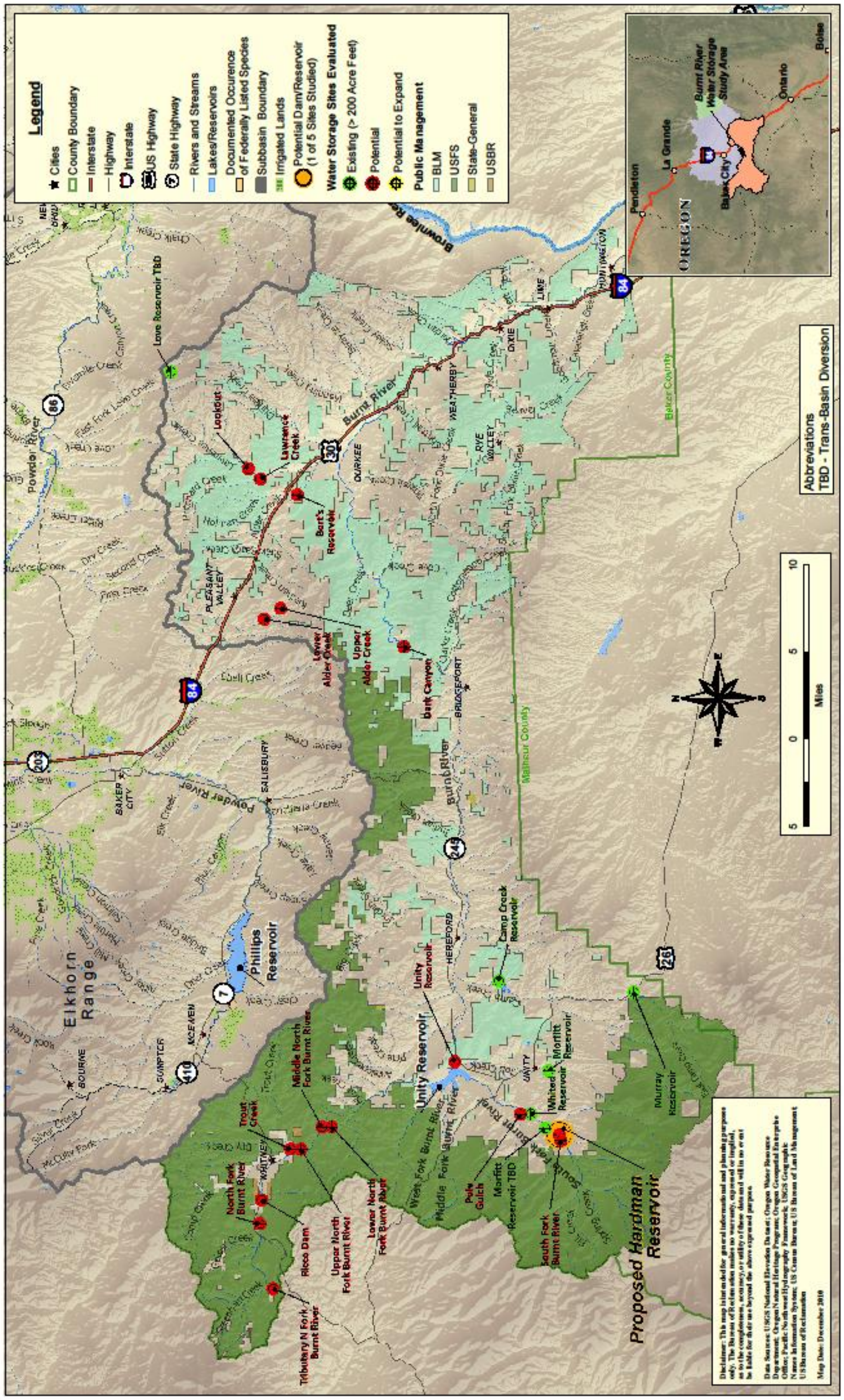


Figure 7. Burnt River Subbasin

Hardman Reservoir

The Hardman Dam site is located on the south fork of the Burnt River and the site has been an option for above ground water storage since 1961 (Bureau of Reclamation July 1961). The site is located entirely within Township 13 South, Range 36 East, W.M. The drainage basin was characterized by the US. Department of Agriculture Forest Service in an June 1967 Impact Report as follows: "The ridge top forming the boundary of the South Fork basin separates it from the John Day River drainage on the north and the Malheur River on the south. Bullrun Rock, on the south side, is the highest point along this ridge. At 7,873 feet elevation, it is over 3,600 feet higher than the dam site six miles north. The basin thus formed is circular, opening to the northeast."

Historic reservoir calculations and estimates are as follows

- Earth fill dam 150 feet high
- Surface Area 257 Acres
- Storage capacity of 14,000 acre-feet
- Minimum pool 1,850 acre-feet
- Typical water surface elevation 4,370 feet
- Average water surface during recreation season – May 1 to Oct 1 – 4,339 feet

The Bureau of Reclamation and HDR Engineering at the request of the Powder Basin Water and Stream Health Committee are conducting a basin yields analysis and a hydrologic analysis of the site to determine the amount of water available for storage at the proposed reservoir site. The new studies could alter the specifications of the reservoir from historic specifications.

1.4 Brownlee Reservoir Subbasin

The Brownlee Reservoir Subbasin ecompasses 414,000 acres (NRCS) and is surrounded by Baker County to the west, Wallowa County to the North, Malheur County to the South and western Idaho on the east. Major tributaries of the Snake River, which include Pine Creek and associated tributaries and Wildhorse River and tributaries for about 421 miles of stream. Pine Creek originates in the Eagle Cap Range of the Blue Mountains and joins the Snake River below the Oxbow Dam. The Pine Creek drainage is above 10 Snake River and Columbia River dams (PSU 2009).

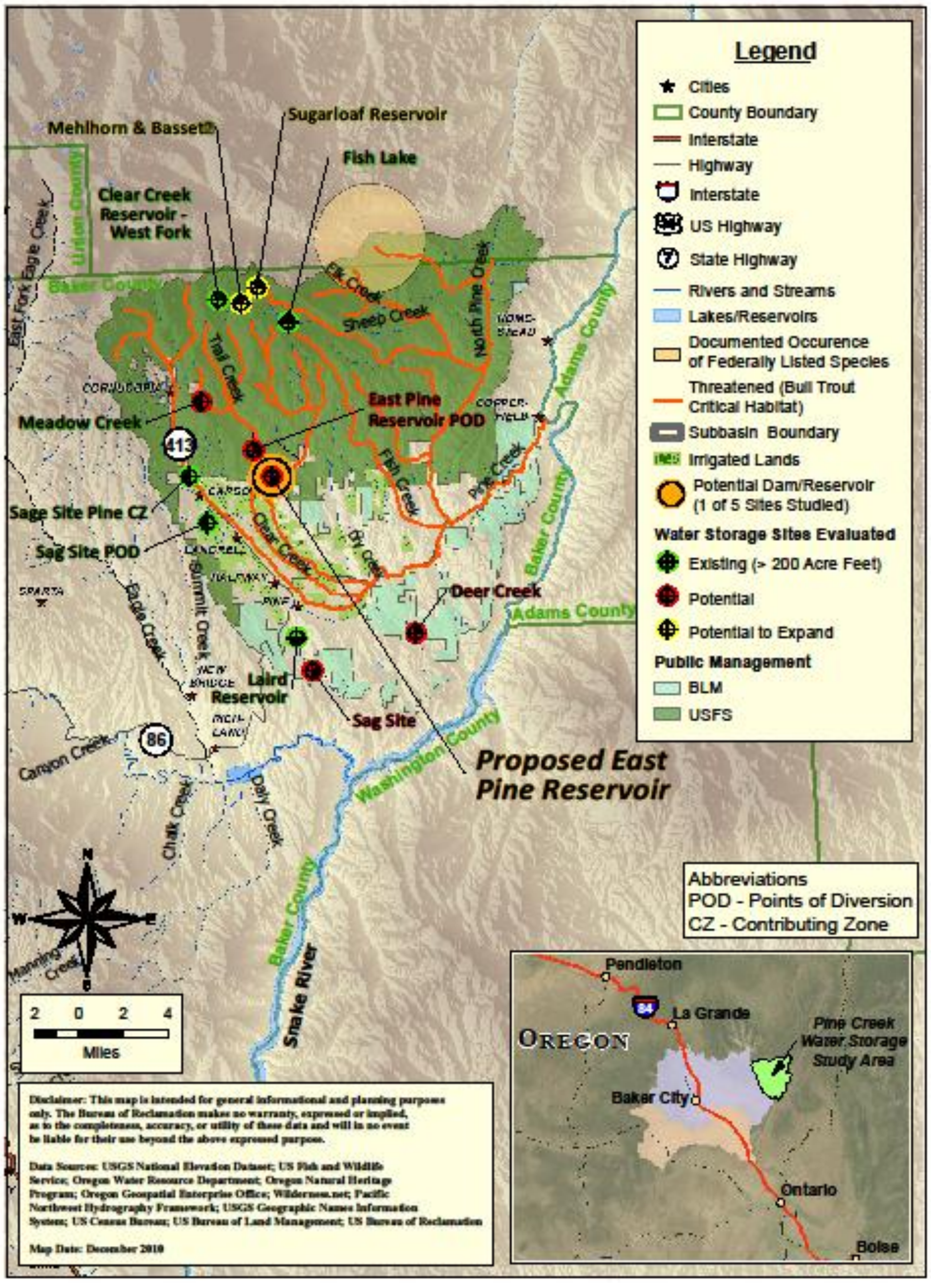


Figure 8. Brownlee Subbasin

East Pine Reservoir

The East Pine Reservoir and Dam site is along East Pine Creek, five miles north of the town of Halfway, Oregon, which is in the northeast corner of Baker County. It is entirely within Township 7 South, Range 46 East, W.M., and is approximately one mile within the exterior boundaries of the Wallowa-Whitman National Forest. It encompasses 159 acres of private property, 66 acres of Baker County, and 76 acres of the USFS (Fig. 8). The dam was originally designed by NRCS in the 1970's. The proposed dam site is in the NE1/4 of section 20. The reservoir would extend northeast from the dam approximately 1.5 miles through sections 15, 16, 20, and 21. At that time, designs were created to divert water from Clear Creek through a canal, which would contribute to the reservoir. The Clear Creek canal location is on the side slopes above Clear Creek and Pine Creek. It crosses the common ridge between the two drainages. West Canal would also contribute additional water to the pool.
The East Pine Creek drainage includes 205.1 square miles or 131,264 acres. The surface water resources of the watershed consist of Pine Creek and its principal; tributaries: Clear Creek and East Pine Creek. These waters then flow into Pine Creek, which is a direct tributary of the Snake River.

Designed Dam Specifications (USFS Impact Study):

- Dam height 177 feet
- Top width 42 feet
- Top length 825 feet
- Reservoir capacity 17,200 acre feet (at crest of emergency spillway)
- Surface area 266 acres
- Recreation pool of 50 acres

The Bureau of Reclamation in cooperation with HDR Engineering and the Water & Stream Health Committee (WASH) has been recalculating basin yields and available water for storage purposes. The results will not be available until spring of 2011. However, current calculations depict that there is less available water for storage than calculated in 1967.

1. 5 Study Process

Addressing water shortages and pursuing options for meeting ever increasing water demands is an extremely long and expensive process. The BOR has a 'roadmap' which incorporates a phased project approach to addressing water supply. There are four overarching phases (1) Pre-appraisal (2) Appraisal, (3) Feasibility and (4) Implementation (Fig. 9). This document, along with *The Eastern Oregon Water Storage Appraisal Study* (BOR 2011) is intended to satisfy the requirements under the Appraisal Phase, which is phase 2. During this segment of the study process, only existing information was utilized. Therefore, no raw data was collected and future water use projections were not made for this report. At this level (phase 2), the goal was to determine if there is a need for the project (i.e., public support, if the project could potentially meet demands, and determining existing data gaps). It is in the Feasibility Phase (phase 3) when raw data is collected, which will fill existing data gaps and when environmental compliance is fully addressed. The Powder Basin WASH Committee plans to start the Feasibility Phase of the Ecologically Adaptive Water Management Project during the summer of 2011.

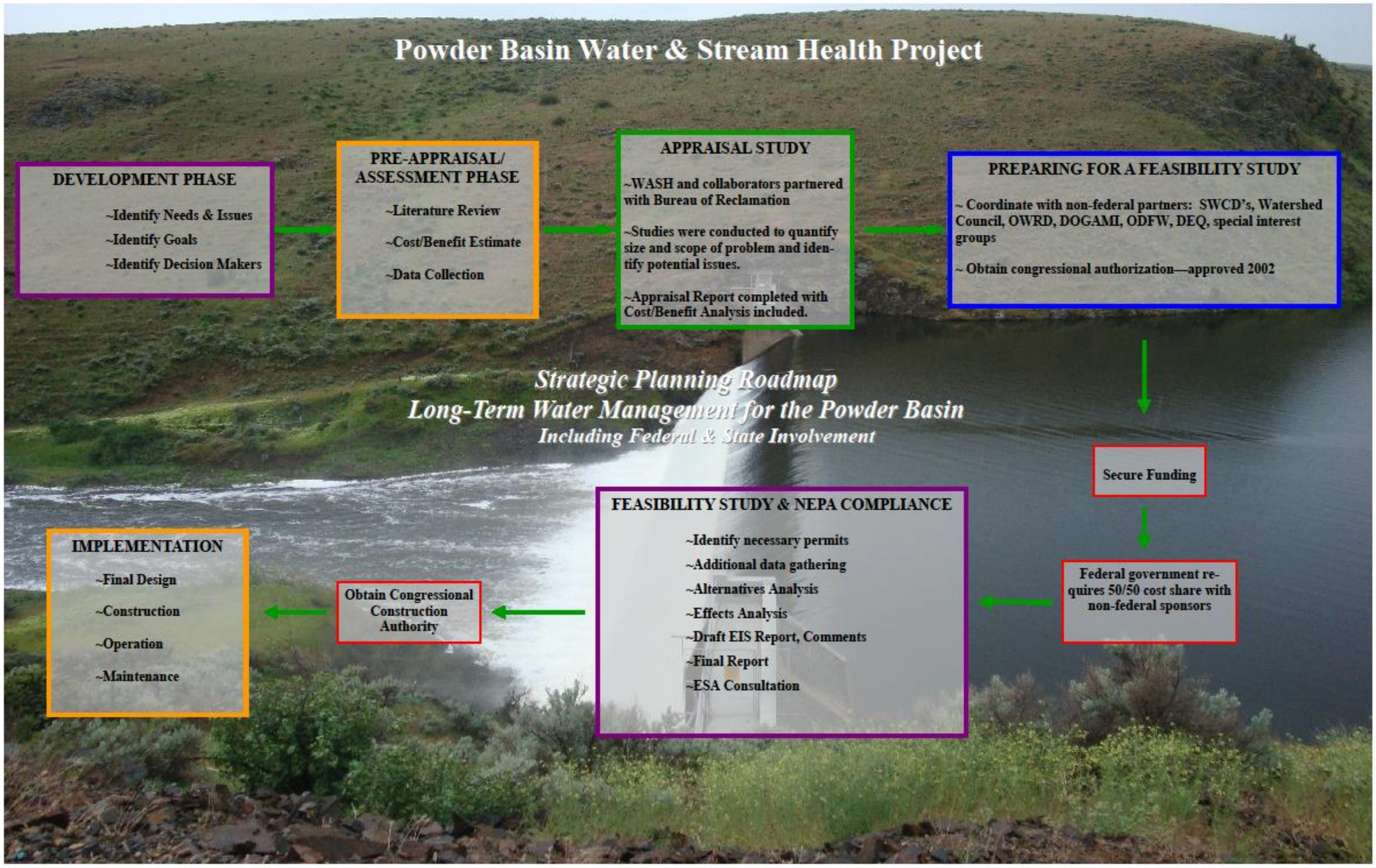


Figure 9. Water Storage Program Road Map

1. 6 Literature Review

In 2008, the Powder Basin Water and Stream Health Committee in cooperation with the U.S. Bureau of Reclamation (BOR) and Browne Consulting, LLC collectively produced the *Literature Review of the Powder Basin, Oregon 2008*. The literature review is a compilation of information from a plethora of facets directly relating to "what is known about the Powder River and Burnt River Subbasins' stream systems, water storage, and stream health as they pertain to the basin and water science." The campaign to produce such a document is accredited to the Powder Basin Water and Stream Health Steering Committee (WASH), whom have taken charge to implement a long-term water management plan. Documents and other pertinent information were compiled for over a year from numerous sources such as the BOR, OWRD, Baker City Library, and the internet (document cites all sources).

The literature review is user-friendly with chapter 1 providing a brief background of the project along with approach, report organization, and sources. Chapter 2 provides an insight as to the physical locations of the areas investigated with chapter 3 describing the document review process and abstract creation. Chapters 4 through 9 contain abstracts separated by Powder Basin and Burnt River Subbasin. Chapters 10 through 14 contain recommendations, "In Text" citations, tables and graphs analyzing percent of topics within each study area and timeframe. Also included are tables and maps showing existing and potential dam sites.

SECTION 2.0 Required Tasks under SB1069 Compliances

Outlined below are the four required tasks under SB 1069. The analyses in this section evaluates existing data, which was designed to narrow down storage options for first priority to four potential water storage options. The four tasks delineate specific existing information about each site and was collected and analyzed in relation to hydrology and cost estimates.

The ecological analysis of hydrologic regimes was made utilizing average monthly inflow and outflow discharge for each reservoir site. The *Description and Ecological Flow Analysis of Hydrologic Data for Four Reservoir Sites in the Powder Basin* records this analysis done for each reservoir site utilizing data prepared from the BOR Powder Basin *Natural Flow Determination Report* and review hydrologic data from HDR. The ecological analysis included a documentation of watershed and ecosystem characteristics to provide a geomorphic background for each reservoir site. This was followed by the examination of the average monthly discharge under existing, natural and project conditions over 28 years of data at each site. The analysis was a primary investigation of the hydrologic patterns under the project condition in comparison to the natural and existing streamflow patterns, specifically concentrating on hydrologic patterns related to aquatic species and channel maintenance *(Appendix A).*

Four Required Tasks:

1. **Analyses of by-pass, optimum peak, flushing and other ecological flows of the affected stream and the impact of the storage project on those flows.**
2. **Comparative analyses of alternative means of supplying water, including but not limited to the costs and benefits of conservation and efficiency alternative and the extent to which long-term water supply needs may be met using those alternatives.**
3. **Analyses of environmental harm or impacts from the proposed storage project.**
4. **Evaluation of the need for and feasibility of using stored water to augment in-stream flows to conserve, maintain and enhance aquatic life, fish life and any other ecological values.**

2.1 Task 1. Analyses of by-pass, optimum peak, flushing and other ecological flows of the affected stream and the impact of the storage project on those flows.

Through a basin wide process to identify and narrow down potential above ground water storage projects the Water & Stream Health Committee in cooperation with the Bureau of Reclamation and all partners and stakeholders have identified four potential sites for the system wide project. The four sites include increasing reservoir capacity of the Thief Valley Reservoir on the Powder River, East Pine Reservoir Site on East Pine Creek near Halfway, increasing reservoir capacity of Wolf Creek Reservoir on Wolf Creek and Pilcher Creek Reservoir, and Hardman Dam site in the South Fork Burnt River drainage.

At the request of the Water & Stream Health Committee, the Bureau of Reclamation conducted a Natural Flow Determination based on demand areas within the various subbasins for a 30-year period. While attempting to collect data for the study it was realized that there were relatively few stream gauges that had been active for 30 consecutive years and in some key areas there are no stream gauges. Consequently, Reclamation undertook the task of developing a model so that when stream gauge data became available it could just be loaded into the model and a basin yield analysis would then be compiled. The model is called the MODSIM model. Computations for stream flows are based on monthly data from 1971 through 1999. The reservoir sites and stream gauges that computations were derived from are as follows:

Thief Valley Reservoir	Powder R bl Thief Valley Res nr N Powder, OR	13285500
Wolf Creek	Wolf Cr ab Wolf Cr Res nr N Powder, OR	13283600
Pilcher Creek	Shaw-Carnes Ditch below Dutch Creek, OR	Manual Entry
East Pine Reservoir	S FK Burnt R ab Barney Cr, nr Unity, OR	13282400
	N FK Burnt R nr Whitney, OR	13269300
Hardman Dam	S FK Burnt R ab Barney Cr, nr Unity, OR	13270800

Due to lack of long-term gauge, data at relevant elevations for the East Pine Reservoir and for the North Powder Reservoir stream gauge data from like drainages was extrapolated for calculation purposes. Details of the gauge data used and natural flow determinations for the Powder Basin are available in the Powder River Basin Natural Flow Determination report from the Bureau of Reclamation 2009.

HDR Engineering was contracted by Reclamation to proof the hydrology data and findings as well as provide cost estimates for each project.

MODSIM Model Overview

MODSIM network simulation models of the Powder River, Burnt River, and Pine Creek were developed to show the hydrologic interaction between senior demands and the potential to store water at predetermined sites. The model was selected based on its ability to allocate water based on priority. A link node schematic network, based on GIS maps provided by Dale Linderman, was developed for each of the three basins within the MODSIM GUI interface. The most upstream supply nodes were populated by patterned natural flow records developed by the Natural Flow Determination Report. Downstream nodes were populated by local gains, which is the difference in patterned flow between the upper supply node and downstream supply node.

Some of the missing and inaccurate data was filled in and corrected to produce new natural flow estimates at some of the Powder River gages. Where there were data gaps, a OWRD Point of Use data set was used to fill in gaps. Details of the of the development of the Demand Simulation Model for Pine Creek, Powder River, and Burnt River are available in *The Description and Ecological Flow Analysis of Hydrologic Data for Four Reservoir Sites in the Powder Basin Appendix A.*

Existing and Simulated Flows

Analysis of stream flows were made utilizing data prepared using data from the Bureau of Reclamation MODSIM model, that depicts outflow under existing conditions, simulated monthly reservoir outflow with project conditions, and simulated natural inflow and outflow. Following is the explanation of each of the flow regimes.

> **Existing**: Existing stream flow at proposed reservoir site or outflow at existing reservoir sites from October 1971 to September 1999.

Simulated Natural: Natural flows are calculated using the existing streamflow, plus the addition of current flow outtakes along the stream system. The simulated flows were calculated for each year from October 1971 to September 1999.

Simulated Project: Project flows were calculated using the existing streamflow including the proposed effect of the project at each site. The simulated flows were calculated from each year from October 1971 to September 1999.

For each reservoir site there are three graphs, which depict inflow and/or outflow under existing conditions, simulated monthly reservoir outflow with project conditions, and simulated natural inflow and outflow. The first graph utilizes the 29-years of data averaged to depict natural and existing conditions and the simulated hydrologic effect under project conditions. The final two graphs display 15 years of the monthly mean discharge to depict the frequency, duration and timing of the flow regime under existing and project conditions. All graphs were prepared using data from the Bureau of Reclamation MODSIM model. Additional tables of the mean monthly discharge are in (*Appendix A: Description and Ecological Flow Analysis of Hydrologic Data for Four Reservoir Sites in the Powder Basin*).

2.1.1 East Pine Reservoir

Hydrograph Analysis

Under existing conditions, East Pine Creek hydrologic regime follows a pattern with two peaks, a small initial peak in mid- February and a second larger peak in April. Over the months of May and June there is a steep decrease in flows. Minimum flows are typical for East Pine Creek from Mid-June through September. This pattern is a result of the watershed characteristics, with much of the streamflow from snow runoff from high elevations with less groundwater and surface water contributions. If a reservoir was construction on East Pine Creek, models show that there would be a two peak pattern with drastic increase and decrease of the peak flow, yet the peak conditions would shift to the initial peak in April, followed by a second peak in June. In addition, water levels would be higher than under current conditions throughout the water year and remain about 250 acre-ft (3cfs) below current conditions.

Optimum Peak Flow Analysis

Existing and Natural optimum peak flows typically occur mid-February through May. The timing of natural and existing peak flows mirror each other while intensity of existing peak flows is lower than natural peak flows due to irrigation. Over a 28 year average there is 600-700 acre-feet more water depicted under existing conditions than simulated natural conditions.

Under simulated project conditions peak flows begin in February and end in August. The hydrograph shifts from the main peak flows being in February through May to May through June. Again, the highest average peak flow under project conditions is approximately 1,000 acre-feet (10 cfs) more than under simulated existing and natural conditions due to additional water being diverted into the reservoir.

The duration and timing of the peak flow conditions differ between the existing and simulated project condition, as mentioned. These differences can be seen in Figure 10 and Figure 11 in *Appendix A*. The width of the peak under simulated project conditions is slightly wider, displaying the longer periods of increased flow. The main alteration of the reservoir introduction to the channel forming flows would be the timing of increased streamflow and timing of the channel forming flows.

Flushing Flow Analysis

There is very little information available as to the amount of water necessary to initiate the movement of bull trout or redband trout; the two species of concern in this project area. However, under depicted project conditions there will be more water available throughout most of the year whereas additional water will be diverted from Clear Creek and West Canal. As with many other existing reservoirs in Eastern Oregon, flushing flows are mimicked when the reservoir fills to capacity and excess spills out over the overflow (e.g. trout fishing downstream of Mason Dam is excellent). Dams without fish passage, if constructed correctly for instream temperature purposes, are simply a fish passage barrier and do not necessarily restrict flushing flows.

By-Pass Flow Analysis

East Pine Creek is listed as critical habitat for Bull trout (*Salvelinous confluentus*). It is currently unknown whether there are existing passage barriers for these fish. Anecdotal evidence suggests that there are two distinct populations of Bull Trout. A residential population in the headwaters and a fluvial population in the lower elevations near the confluence of Pine Creek and the Snake River. Summer flows under the proposed project are predicted to be greater than existing or natural historic flows due to additional water being diverted into the dam from Clear Creek and West Canal. Flows from October through December will decrease slightly by approximately 200 cfs, while peak flows will increase by at least 1,000 cfs, diminishing back to approximately a 500 cfs difference again by August. (*See Figure 9 in Appendix A)* With this scenario, by-pass flows will actually be enhanced from existing or natural flow conditions.

East Pine Storage Volume and Reliability

With a transbasin diversion from Clear Creek, the East Pine reservoir site on East Pine Creek has the potential to store about 38,000 acre-feet in 50 percent of the years modeled, 21,000 acre-feet in 80 percent of the years, and 15,000 acre-feet in 90 percent of the years. The results for storable volume versus frequency at the East Pine site are shown in Figure 10.

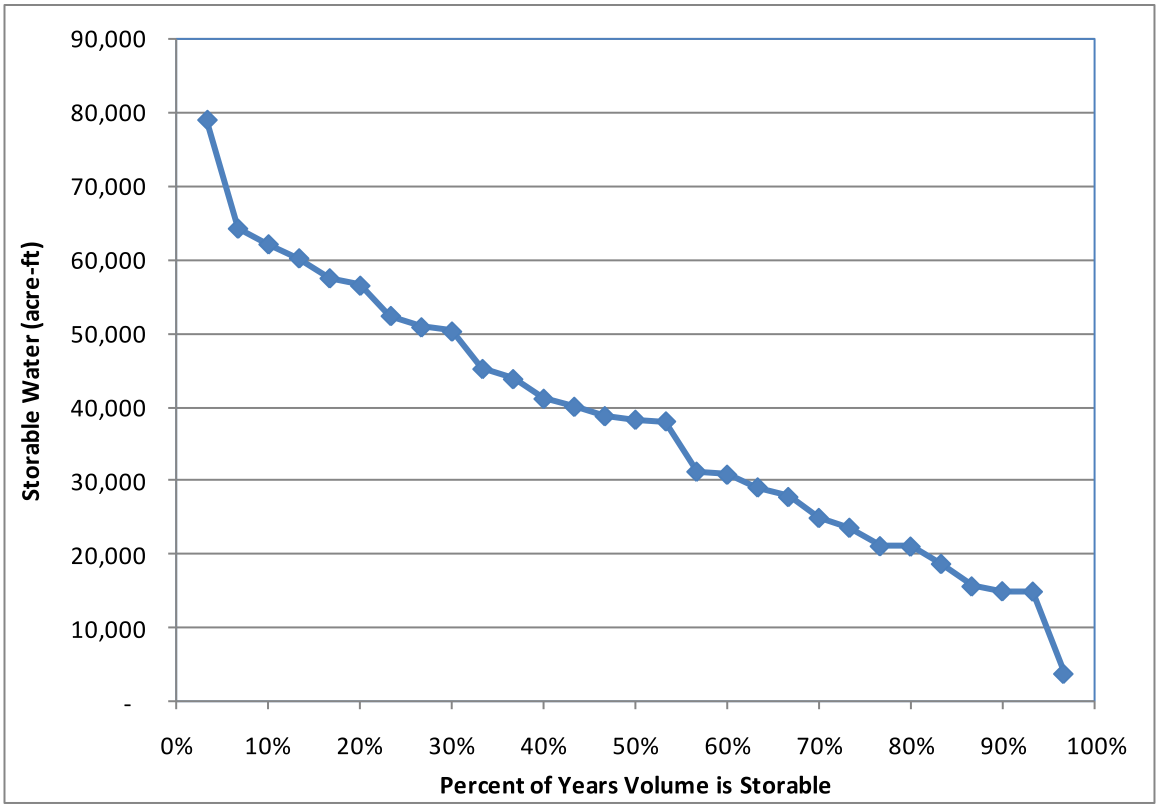


Figure 10. Estimated Annual Storable Volume at East Pine Reservoir Site

2.1.2 Hardman Reservoir

Hydrograph Analysis

Analysis of 28 years of monthly average stream flows depict that existing stream flows are somewhat similar to simulated project stream flows. Under project conditions there are two peak flows projected to drawdown in the reservoir from irrigation, and then a second uptick in flows when runoff (inflow) exceeds reservoir outflow. From May through August, outflows will be higher under project conditions than they are currently. Then from October through March stream flows will be less than they are currently whereas the reservoir will be filling. Existing streamflows during June and July fall to nearly zero since almost all the water is diverted for irrigation purposes. Data analysis shows that streamflows during the same time period under project conditions (with a reservoir) will fluctuate from 750 acre-feet to approximately 2250 cfs; resulting in a significant increase in instream water flow. It is interesting to note that due to the short growing season most irrigation ceases in August in the South Fork Burnt River drainage basin, thus there is an uptick in both the simulated project flows and simulated existing flows during that time period.

Simulated natural flows were computed using stream gauge data from a gauge located on Barney Creek which actually flows into the project. Flows are computed by adding the amount of water diverted upstream from the gauge back into the stream gauge data. When analyzing natural flow data it should be noted that on this particular site under existing conditions there is more stream flow from October to March than under natural conditions. This can be explained by subsurface return flows to the stream from irrigated pasturelands.

Peaks in the hydrograph indicate that peak runoff occurs from March through June. The area gets very little precipitation from October through December.

Optimum Peak Flow Analysis

Peak flows in the South Fork Burnt River drainage basin typically occur from March through June. Under project conditions, there will actually be two peak flows per storage season (*Appendix A: Figure 12*). The first occurring in April and the second occurring in June once outflow and inflow have reached equilibrium or inflow exceeds outflow and subsurface flows from irrigation begin adding to the instream flows.

Under existing conditions the hydrograph peaks in February and then climbs to another peak in April of approximately 2,500 acre-feet (40 cfs). In contrast, under project conditions the hydrograph begins to climb steeply starting in January and peaks at approximately 2,800 acre-feet in April and again in June at 2,250 acre-feet. The significance is that peak flows will actually be increased under project conditions compared to existing conditions, which will be conducive to channel maintenance flows and ecological flows.

The duration of increased streamflow is the main difference between the current and project conditions *(Figure 13 and 14 in Appendix A).* The extended duration of increased streamflow is beneficial for the ecological maintenance of vegetations and fish habitat. The gradual increase and decrease of the streamflow may introduce a new pattern of streamflow characteristics for the maintenance of the ecosystem, yet the project conditions would closely mirror the timing and duration of streamflow under natural conditions. Low flow conditions, based on the modeled project flows, may need further regulations in order to maintain overwintering conditions for the ecosystem and fish species.

Flushing Flow Analysis

The species of concern in the South Fork Burnt River drainage area is the redband trout, a species listed in the State of Oregon as 'sensitive'. There is very little information available concerning quantifiable triggering ecological flows for this species. According to studies done by the Forest Service, the area has "the best water conditions for trout production in the Burnt River drainage." However, there is one major condition, which hampers trout habitat, lack of habitat complexity (pools, riffles, resting places). The water is cold and clear and does flow year round, even though late season flows are often very low.

A water storage project could potentially help this issue by providing water for 'scheduled' channel forming flows, which would also aid with or act as a flushing flow. Furthermore, there would likely be a potential increase in available habitat and habitat complexity from the ecosystems response to the increased durations of increase channel flow.

By-Pass Flow Analysis

Redband trout will be the species of concern in this watershed; anadromous fish access is blocked by downstream dams.
Currently, streamflows drop to nearly zero in June prior to irrigation subsurface return flows entering the stream profile and increasing instream flows. Under project conditions, the data shows that average minimum flows stay above 500 acre-feet (fig.11). With these circumstances instream fish passage barriers are actually decreased with a dam in place.

Hardman Storage Volume and Reliability

The Hardman reservoir site has the potential to store about 11,000 acre-feet of surplus flow in 50 percent of the years modeled, 4,800 acre-feet in 80 percent of the years modeled, and 3,800 acre-feet in 90 percent of the years modeled. The results for storable volume versus frequency at the Hardman site are shown in Figure 7 (BOR 2010).

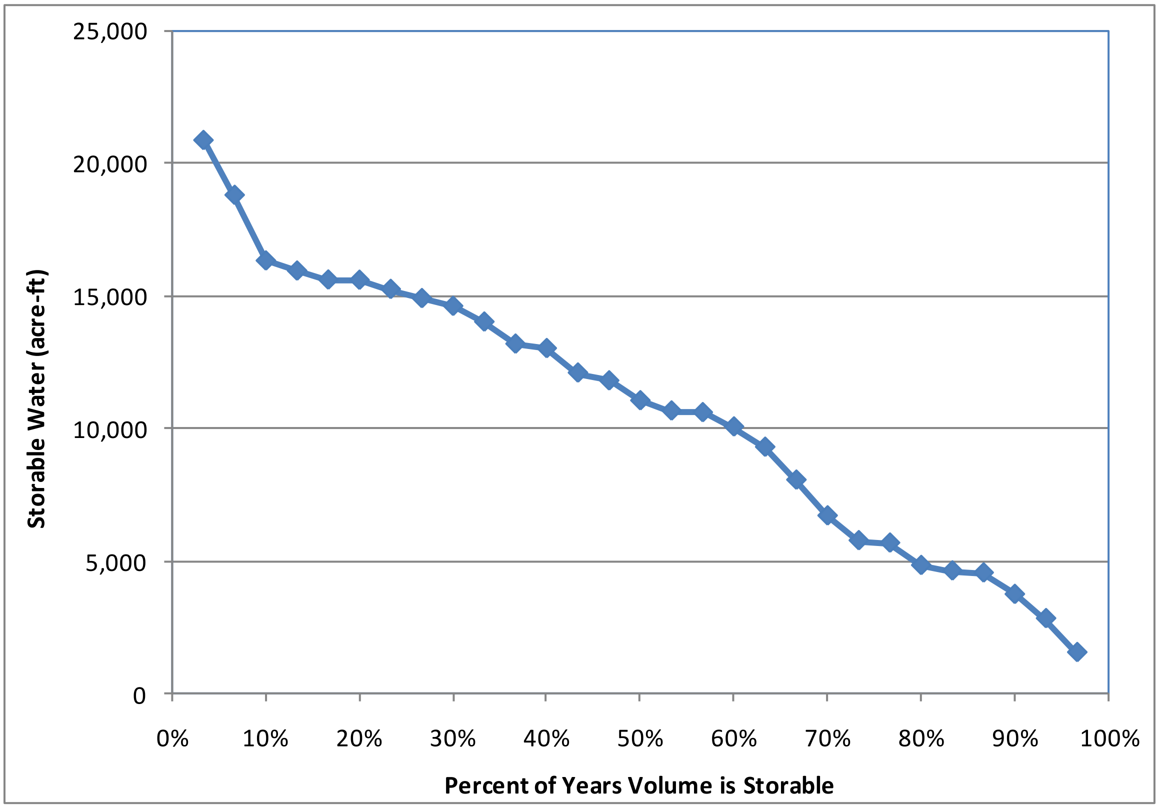


Figure 11. Estimated Annual Storable Volume at Hardman Reservoir Site

2.1.3 Thief Valley

Hydrograph Analysis

Minimum flows are typical for the Thief Valley Reservoir and surrounding area for the months of August, September, October, November and then picking back up somewhat in December. Months of higher flows are January through June with flows dropping off in July. Under the existing flow regime, there are two peaks in the hydrograph *(Figure 1 in Appendix A*). One peak in the hydrograph typically occurs in March and another in May. This is a result of the reservoir filling to capacity, then being drawn down once irrigation begins in April. Snowmelt runoff historically has peaked in May, thus the reservoir fills to capacity again in May even after irrigation withdrawals have begun. If the capacity of the reservoir were expanded, models show that there would not be an initial peak in the hydrograph in March given that the reservoir would still be filling. Inflows would still peak in May thru June and then begin tapering off. In addition, the streamflows would begin to descend near the end of June, yet follow a shallower descent due to the higher capacity.

Optimum Peak Flow Analysis

Under simulated hydrographs of the reservoir, following the increased capacity a peak flow in March would no longer be present. However, peak flows would shift to May and would be larger than the average peak flows currently seen in March and would act as channel forming and channel maintenance flows for this section of the river. The peak flow period would last approximately from May to June, while in July flows will begin to decrease at a slower rate than under current conditions through November. In *Figure 2 and Figure 3 in Appendix A* display the differences in the duration and timing of the peak flow conditions between the simulated project conditions and the existing conditions.

Flushing Flow Analysis

Under simulated project conditions, there would be two changes to the hydrograph that may be of some significance to local aquatic species. First, the peak flow in March would be minimized by approximately 5,000 acre-feet (100 cfs). There would still however be a smaller peak in the hydrograph at that time under simulated conditions. Secondly, late season flows would be higher than under current conditions through the month of November. Ultimately, this would result in better water quality conditions such as lower instream temperatures, and lower counts of fecal coli form bacteria and nutrient levels as a result of additional water diluting the pollutants.

By-Pass Flow Analysis

Thief Valley Reservoir is an existing reservoir. Obtainable fisheries data can be relied upon to determine whether by-pass flows are adequate, using them as a baseline to determine minimum flows under a larger storage project. Oregon Department of Fish and Wildlife personnel have stated that the Thief Valley Reservoir is an excellent trout fishery. By-pass flows for fish passage downstream from the reservoir site are adequate due to irrigation releases from the reservoir and the return flow instream due to irrigation.

Thief Valley Storage Volume and Reliability

The Thief Valley Reservoir site is assumed to be at the site of (or just downstream from) the existing Thief Valley Reservoir. The additional reservoir capacity could be achieved with an enlargement of the existing dam and reservoir or an entirely new dam constructed downstream of the existing dam.

Based largely on available stream-guage data, the hydrology analysis estimates that the proposed site has the potential to store 155,000 acre-feet in 50 percent of the years examined, 43,000 acre-feet in 80 percent of all years, and 38,000 acre-feet in 90 percent of all years. The results for storable volume versus frequency at the Thief Valley site are shown in Figure 12.

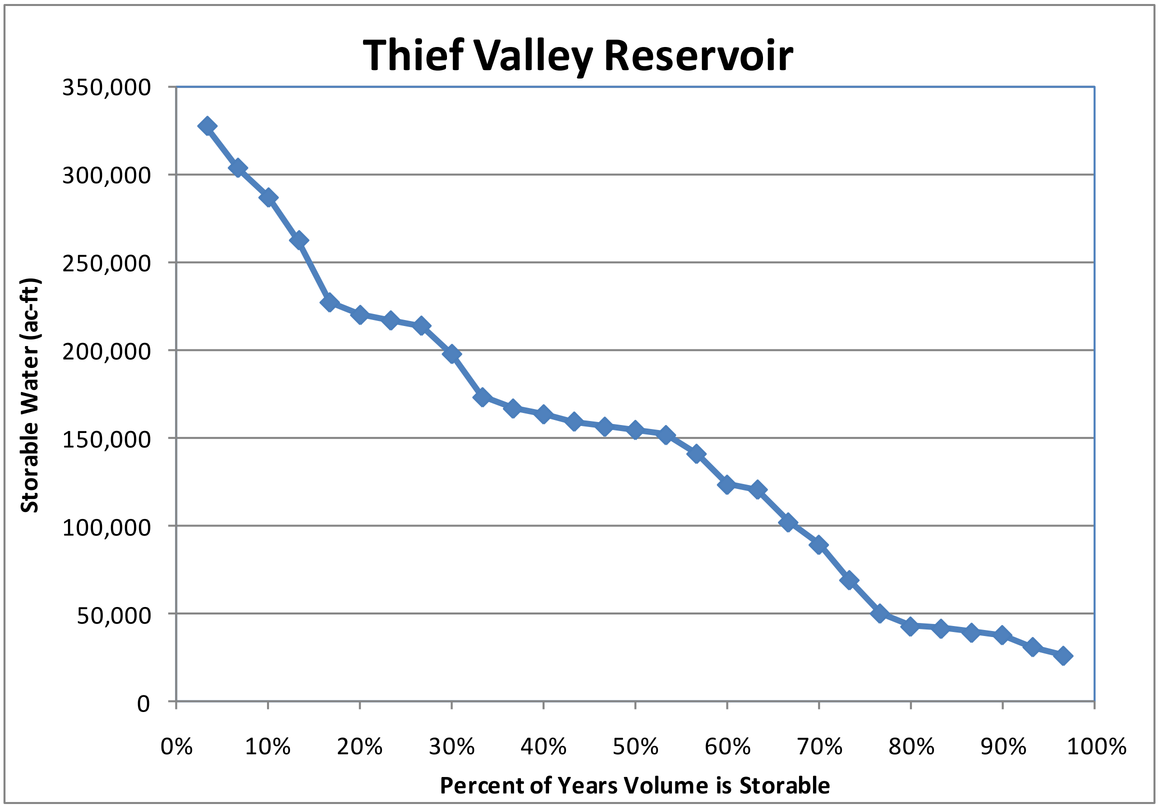


Figure 12. Estimated Annual Storable Volume – Thief Valley Reservoir Enlargement Site

2.1.4 Wolf Creek Complex

Hydrograph Analysis

Minimum flows are typical for the Wolf and Pilcher Creek Reservoirs and surrounding area from the months of August, September, October, November and then picking back up somewhat in January. Months of higher flows are March through June with flows dropping off in late June. Under the existing flow regime, there is one main peak flow period for Wolf Creek noted in the hydrograph (*Figure 8 in Appendix A*). Existing stream outflow typically begins to peak in late March, reaching a peak flow in late April. The peak is maintained through mid- July with a drastic decrease in outlflow prior to August. Outflows for Pilcher Creek follow the patterns from Wolf Creek; however, the peak flow does not occur until July, when flows have a slight decrease in Wolf Creek. The two reservoirs are connected with Wolf Creek filling before Pilcher Creek, hence the outflow from Pilcher peaks later than Wolf Creek.

Optimum Peak Flow Analysis

Simulated flows were not performed on the Wolf Creek Complex due to its late introduction as a potential project. With increased capacity of Wolf Creek Reservoir and Pilcher Creek Reservoir, the peak flow would shift slightly into late May when the reservoirs fill, and descend in late August. The peak flows for Pilcher Creek Reservoir would also shift to late July into August. Hence peak flows seen in April would act as the channel forming and maintenance flow for this section of the two creeks.

Flushing Flow Analysis
There potentially would be limited changes to the hydrograph that may be of some significance to local aquatic species. Early season flows would be delayed slightly while the reservoir fills to capacity, hence aquatic species late season flows would be higher than under current conditions through the month of November. Ultimately, this would result in better water quality conditions such as lower instream temperatures, and lower counts of fecal coli form bacteria and nutrient levels as a result of additional water diluting the pollutants.

By-Pass Flow Analysis
Wolf Creek Reservoir and Pilcher Creek Reservoir are existing reservoirs. Obtainable fisheries data can be relied upon to determine whether by-pass flows are adequate, using them as a baseline to determine minimum flows under a larger storage project. Oregon Department of Fish and Wildlife personnel have stated that the Wolf Creek and Pilcher Creek Reservoirs are excellent trout fishery. By-pass flows for fish passage downstream from the reservoir site are adequate due to irrigation releases from the reservoir and the return flow instream due to irrigation.

Project Description
The existing Wolf Creek Dam and Reservoir is located on Wolf Creek, a tributary to the North Powder River, approximately 6 miles west of the community of North Powder, Oregon. The project is owned and operated by the Powder Valley Water Control District. It is approximately 128 feet high with an existing storage capacity of 10,800 acre-feet. It was completed in 1974 for irrigation needs.
Storable Volume and Reliability Modeling

The Wolf Creek Reservoir is shown in the model network in Figure 13. For the period of record modeled, the Wolf Creek Reservoir site has an estimated average annual flow volume of 28,400 acre feet, as shown in Figure. Over the same time period, Figure illustrates the storable volume an expanded reservoir at this site would accumulate.

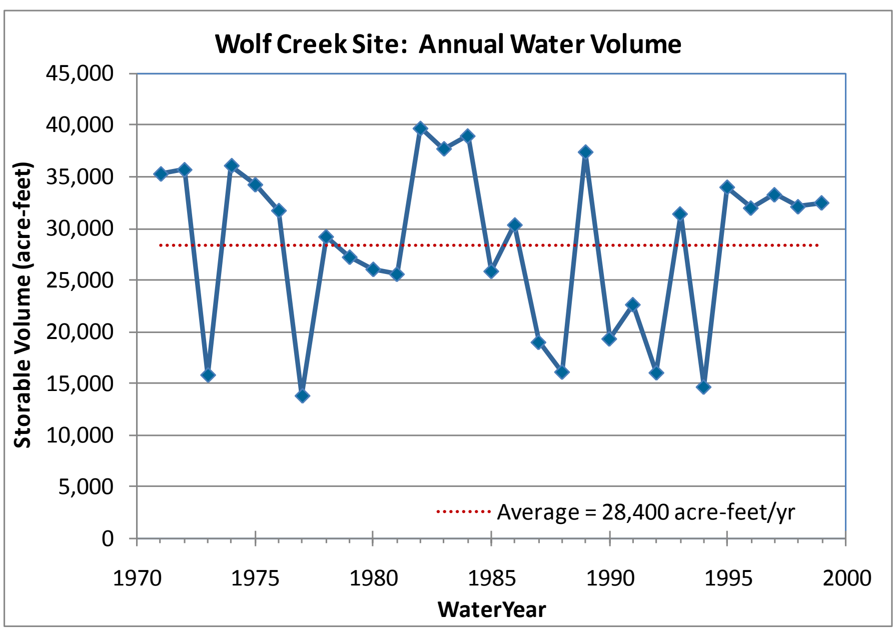


Figure 13. Annual water volume at Wolf Creek Reservoir site

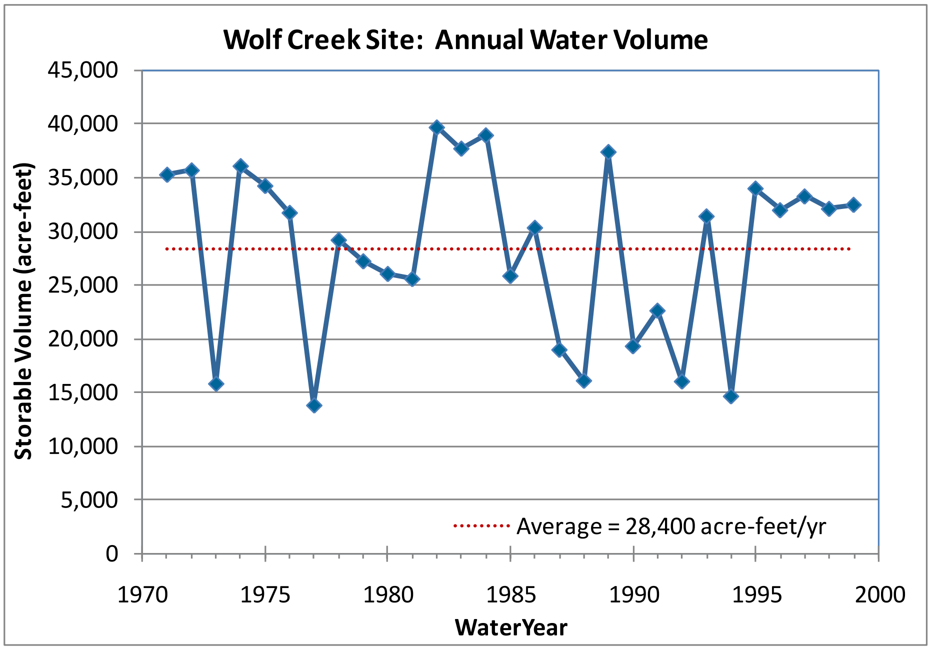


Figure 14. Annual storable water at Wolf Creek Reservoir expansion

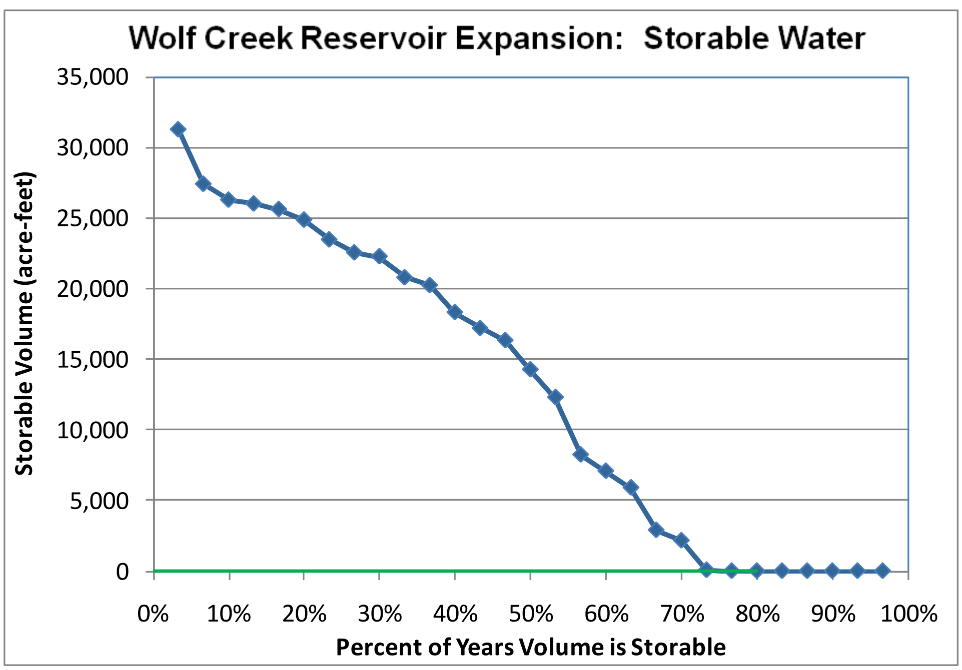


Figure 15. Wolf Creek Reservoir expansion storable water frequency

Model Results

The results of the model run indicate that the Wolf Creek Reservoir expansion does not warrant further investigation in this appraisal study. Based on 80-percent fill reliability, this proposed project fails to satisfy the established screening criteria.

PROPOSED PILCHER CREEK RESERVOIR EXPANSION – POWDER RIVER

Project Description

The existing Pilcher Creek Dam and Reservoir is located on Pilcher Creek, a tributary to the North Powder River, approximately 7 miles west of the community of North Powder, Oregon. The project is owned and operated by the Powder Valley Water Control District. It is approximately 110 feet high with an existing storage capacity of 5,900 acre-feet. It was completed in 1984 for irrigation needs**.**

Storable Volume and Reliability Modeling

The Pilcher Creek Reservoir is shown in the model network in Figure 16. For the period of record modeled, the Pilcher Creek Reservoir site has an estimated average annual flow volume of 9,900 acre feet, as shown in Figure . Over the same time period, Figure illustrates the storable volume an expanded reservoir at this site would accumulate.

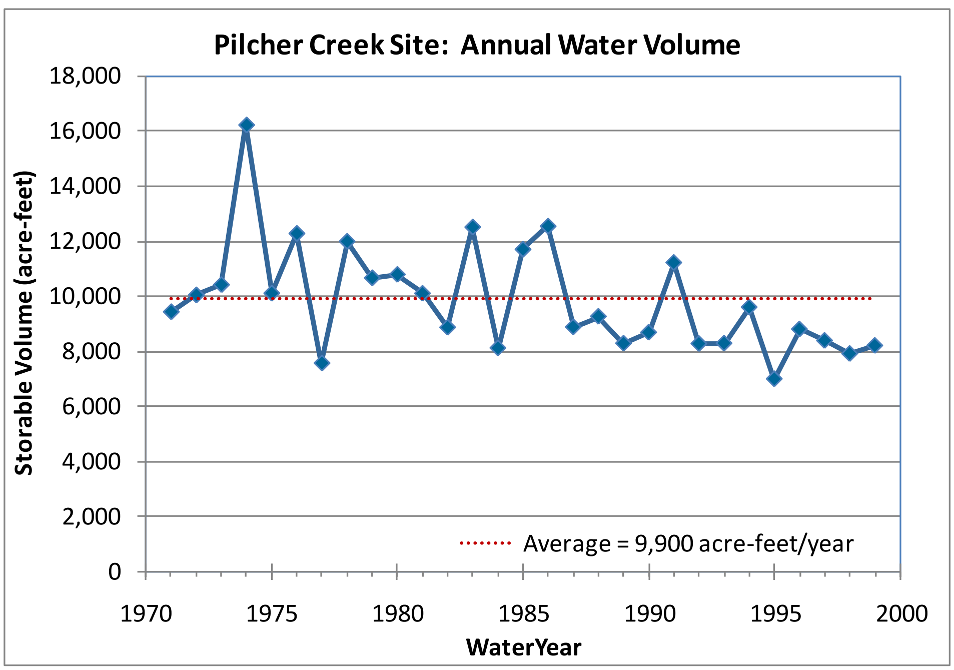


Figure 16. Annual water volume at Pilcher Creek Reservoir site

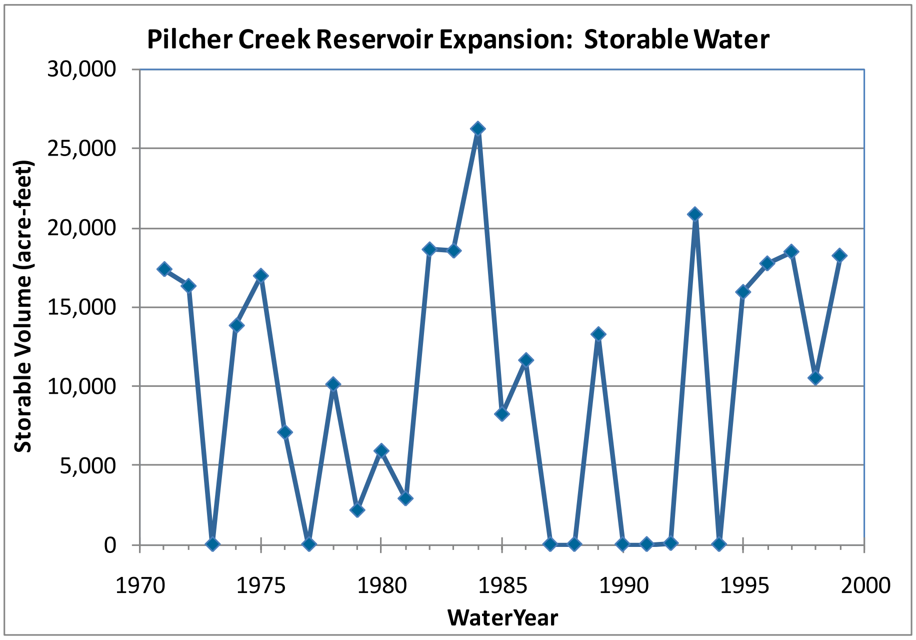


Figure 17. Annual storable water at Pilcher Creek Reservoir expansion

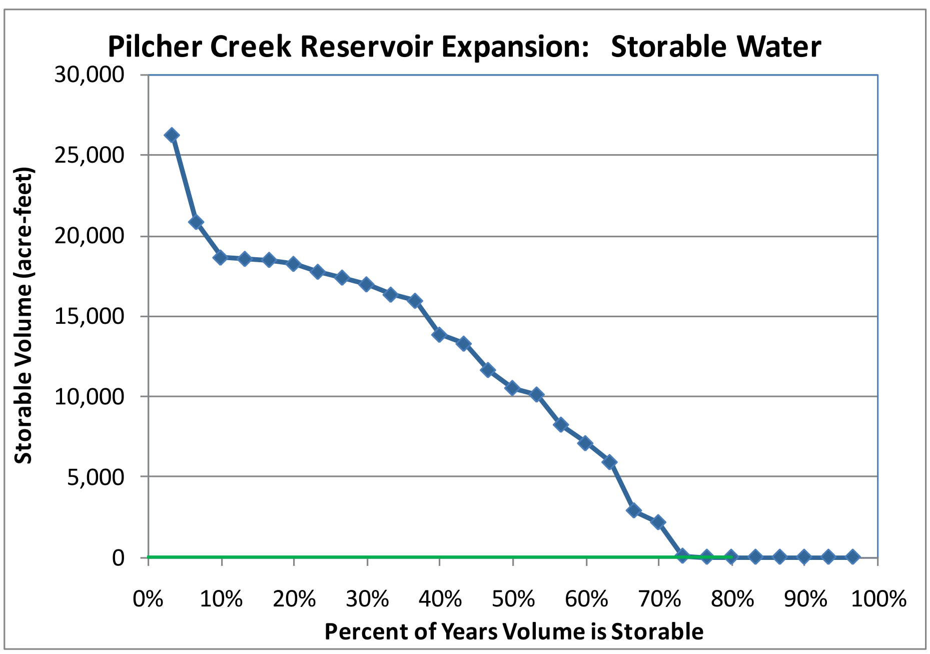


Figure 18. Pilcher Creek Reservoir expansion storable water frequency

Model Results
The results of the model run indicate that the Pilcher Creek Reservoir expansion does not warrant further investigation in this appraisal study. Based on 80-percent fill reliability, this project fails to satisfy the established screening criteria.

2.2 Task 2. Comparative analyses of alternative means of supplying water, including but not limited to the costs and benefits of conservation and efficiency alternative and the extent to which long-term water supply needs may be met using those alternatives.

2.2.1 Water Needs Assessment Summary

Background
A draft water needs assessment has been developed to assess the demand of surface water in the Powder Basin that includes the Burnt River subbasin, the Powder River subbasin and the Pine Creek Subbasin. The goal was to identify water rights that are currently being used and being met, and those rights that are not currently being used and met. Identification of the water rights was done by obtaining the certified water rights for the entire basin from the Oregon Water Resources Department (OWRD) that manages water use for the state of Oregon. The list was then researched and verified for the use listed on the water right to determine if the water right was valid, current and being met; or if the water right was currently not being used or not being met.

Overview
Presented in this summary are tables providing demand information for municipal, industrial (includes commercial), and in-stream water uses. Water needs for the water use categories of domestic, mining, power, fish, livestock, wildlife, recreational and miscellaneous were researched in addition to agriculture and water rights. However, quantitative demands for each of these categories were not identified for the reasons shown below in Table 1.

Table 1. Water Use Categories Data Findings.

Water Use Category	Reason Quantitative Data Not Provided
Domestic	• Domestic water rights are met primarily from ground water resources. • It is anticipated that future water needs for domestic use will also be meet from groundwater resources
Mining and Power	• Mining – only 1 or 2 active mines within the basin at present - majority of the mining certificates are from the active mining period during the early 1900s - water used for mining is returned back to the stream in the same general area and is considered non consumptive, thus will not impact water availability • Power – considered non consumptive, thus will not

	impact water availability
Fish, Livestock, Wildlife, Recreational and Miscellaneous	• Water use categories associated with other categories, and • Consists mostly of small reservoirs - in cases of the small existing reservoirs, the reservoirs will be supplied with water regardless of future development

Preliminary Findings
Preliminary findings in the initial water needs assessment for the Powder Basin show water demands for agricultural, municipal, industrial, and in-stream water uses. Provided in this section are the quantitative water needs in acre-foot for each water use category, by subbasin. Presented first are the preliminary findings for agricultural, municipal, and industrial water uses by subbasin. Next are the preliminary findings for in-stream flows. A quantitative presentation of instream water demand is included because although instream water demand is mostly not consumptive, water availability does affect the ability to meet the in-stream demands. Because in-stream demands occur at their physical location, data are provided for each stream and are listed for each subbasin (see Tables 3 – 5).

Estimate of Current and Future Water Needs
Estimated demand volumes were used in this assessment to define conceptual storage needs, which were then used to develop volume criteria in the *Level 1 Screening Analysis* to help assess potential storage opportunities (BOR 2010).

Table 4 summarizes the average water need by basin as identified in the demand areas by the model. The aggregated areas are displayed in Table 3 along with rationale for their identity. The assumption was made the water needs for agriculture irrigation will remain constant in the future. However, analysts realize this is not correct. The scope of the study was to specifically measure current water needs and analyze existing data, not projected future water need. Assuming that water needs for agricultural irrigation will increase in the future, water shortages are not anticipated for municipal uses, and other uses are not significant in volume now or expected to be in the future. The modeling results revealed site-specific instream demands for each basin. These demands would need to be considered for reaches located in the selected study sites. Volumes identified in this assessment represent uncertain estimates and data gaps and would need to be refined through further analysis if these potential storage locations proceed to feasibility study (BOR 2010).

Agriculture, Municipal, and Industrial
Presented below is a water needs summary table for agricultural, municipal, and industrial water uses, followed by a description of each.

Agriculture section is an excerpt from the draft Eastern Oregon Water Storage Appraisal Study, April 2011
This section relies on available current water use projected water needs information developed for a 40-year planning horizon through the year 2050 for the Burnt, Powder, and Pine basins. The water needs in the study area have been articulated to the State of Oregon by eastern Oregon stakeholders, through the Oregon Water Resources Strategy roundtable meeting process. Information used to prepare this study has been shared in support of the state's efforts.

In 1992 the Oregon Department of Agriculture reserved 74,490 acre-feet of water for future economic development in the Burnt River (26,300 acre-feet), Powder River (38,190 acre-feet), and Pine Creek (10,000 acre-feet) basins within Baker and Union Counties (ODWR December 2010). The water was allocated by Oregon Administrative Rules for multiple-benefit reservoirs to maximize economic development of the State and provide water for future anticipated needs. Current and future water needs include irrigation, municipal demands, and instream water uses for fish and wildlife habitat and recreation. In addition, benefits to hydropower, livestock watering, domestic wells, and mining could be realized from this type of project development. The 1992 water reservations will sunset starting in 2016 if additional storage sites are not developed. A summary list of these reservations is provided in *Appendix B*.

To reasonably quantify the existing hydrologic conditions of the basin and subsequent water needs, a hydrologic record for the basins must be assessed. However, insufficient records exist to describe historic flow conditions within streams or surface water diversions to irrigated lands. Therefore, to quantify baseline conditions and prospective benefits of proposed projects, a hydrologic analysis of the basin must be performed.

Basin Hydrology Development

As part of this appraisal analysis, it is necessary to develop a complete hydrologic period of record. This data record will rely on historic information, estimates, and computations that will establish the foundation for this study. As stated earlier, insufficient records exist that could be used to characterize historic flow conditions within streams or surface water diversions to irrigated lands.

A spatial inventory of USGS and Reclamation gage locations was performed in addition to the available flow measurements at these sites. The available data coverage would define a period of record that would be analyzed. These records would be considered regulated flow conditions at the gage, and not all of the gage locations are upstream of project reservoirs or irrigation diversions. Therefore, computation of natural flow, or unregulated flow, conditions provided a consistent foundation for creating the additional hydrology data necessary for this study.

To create a natural flow record, modification to the regulated data must be accomplished. This requires the addition of irrigation diversions, return flows and change in reservoir storage to those gages representing regulated flow conditions.

The general equation used to compute natural flow at the gage of interest is:

$$Q_{nat} = Q_{gage} + E + \Delta S + D - R$$

Where:

$Qnat$ = computed natural flow for the gauge (acre feet per month)

$Qgage$ = historic flow observed for the gauge (acre feet per month)

E = reservoir evaporation (acre feet per month)

ΔS = change in reservoir storage (acre feet per month)

(+) positive when filling

(-) negative when releasing

D = irrigations diversions (acre feet per month)

R = irrigation return flows above the gage (acre feet per month)

A complete data set of historic observed flows within the three basins was not available. Available historical streamflow records were obtained from USGS and Reclamation. The available data overlap defined a period of record between water years 1971 through 1999 for use in this analysis.

Based on these historical data, correlations were developed to fill in and extend periods of unrecorded data to provide a complete data input record. The gages with the most complete period of record were used for this analysis and are listed in Table 2.

Table 2. Gages used in basin hydrology development

Gage Identification	Gage Location
5 gages in the Burnt River basin	
13269300	North Fork Burnt River near Whitney, OR
13270800	South Fork Burnt River above Barney Cr, near Unity, OR
13273000	Burnt River near Hereford, OR
13274200	Burnt River near Bridgeport, OR
13275000	Burnt River at Huntington, OR
9 gages in the Powder River basin	
13275100	Powder R above Phillips Lake near Sumpter, OR
13275200	Deer Cr above Phillips Lake near Sumpter, OR
13275300	Powder River near Sumpter, OR
13277000	Powder River at Baker City, OR
13281200	Rock Creek near Haines, OR
13282400	Anthony Creek below North Fork near North Powder, OR
13283600	Wolf Creek above Wolf Creek Reservoir near North Powder, OR
13284900	Powder River above Thief Valley Reservoir near North Powder, OR
13285500	Powder River below Thief Valley Reservoir near North Powder, OR
1 gage in the Pine Creek basin	
13290190	Pine Creek near Oxbow, OR

Reservoir Evaporation

Reservoir evaporation was only included for the three large Reclamation reservoirs: Unity, Phillips, and Thief Valley Reservoirs. Pan evaporation data obtained during the growing season was used to compute the water loss occurring from each reservoir (NCDC, 2008). Evaporative losses for non-growing season months and those with missing pan evaporation data were calculated using the 1985 Hargreaves equation.

Change Reservoir Storage

Reservoirs located upstream of a gage reregulate the natural flow conditions. As a result, a change in reservoir storage must be included in the computed natural flow data record. Reservoir storage computations were only included for the three large Reclamation reservoirs: Unity, Phillips, and Thief Valley Reservoirs.

Irrigation Diversions

Agricultural irrigation accounts for the large majority of consumptive water use in the Burnt River, Powder River, and Pine Creek basins. To establish meaningful alternative development and screening criteria, quantification of irrigation needs was necessary. Very few irrigation diversions within the study area basins are measured. Therefore, a methodology was developed to quantify total irrigation diversions and consumptive use.

Total irrigation water diverted from the rivers is a function of total irrigated acreages, consumptive use of the crops, and water conveyance and application efficiencies. The computed current level of irrigation diversions were then compared to allocated water rights in an attempt to validate results.

Total Irrigated Acreage

The total annual irrigated crop acreages were estimated utilizing the following three sources.

- Census of Agriculture (Bureau of the Census 1969, 1974, 1978, 1982, 1987; National Agricultural Statistics 1992, 1997, 2002).
- Oregon Agricultural Information Network (OAIN 2008).
- Oregon State University Extension Service (Burt 2008).

The ArcGIS, geographic information system (GIS), was used to ascertain the quantity and the location of irrigated acreages with respect to a particular gage. This was accomplished throughout the three basins to spatially allocate the irrigation diversions with respect to the gages.

Consumptive Use

Consumptive use was calculated for the estimated total annual irrigated acreages. The consumptive use is the amount of water that is removed by the system, the intake of water by plants. In order to quantify consumptive use, crop mix for the irrigated acreages was first determined using available sources (OAIN 2008, Burt 2008, and Bureau of the Census) as different plants have differing water requirements.

Crop irrigation water requirements for 1970 through 1988 are Cuenca's et al. (1992) monthly values by crop (FAO-24 Blaney-Criddle ETc [Doorenbos, 1977] with the Natural Resources Conservation Service [NRCS—formerly SCS] effective rainfall method). Irrigation requirements for 1989 through 1999, utilized Reclamation's Agrimet system. The Agrimet system provided the historical meteorological data that was used to compute consumptive use for the latter half of the period of record.

In reality, a full supply of water for crops is not always available. Therefore, water availability factors were applied to the irrigation diversion computations. These factors were based on water rights, irrigation cut-off dates, and water year type (wet, average, dry). Otherwise, the irrigation diversion requirements would be overstated.

Return Flows

The return flows are defined as the amount of diverted irrigation water that returns to the river in a matter of a few months. These flows are added back to the gage values to compute the natural flow. This parameter is a function of the irrigation diversion and application efficiencies. Efficiency factors were specified for both water conveyance and type of water application. Sprinkler application of water is more efficient that gravity application and results in less water diverted. The following efficiencies were applied:

- Water Conveyance: 90%
- Sprinkler Application: 65%
- Gravity Application: 40%

For each year within the period of record analyzed, acreages were differentiated as being either gravity fed or sprinkled.

Reuse of irrigation water is common. The flow returned to the river upstream becomes available for irrigation diversion downstream. A reuse factor was applied and included in the return flow computations at each gage. The reuse factor prevents overstatement of the natural flow computation at the gage.

Current Basin Hydrologic Conditions

For each gage influenced by irrigation and/or reservoirs, natural flow computations were completed. Linear regression analyses were used to infill the missing or incomplete data. Average annual natural flow volume at each gage was then computed using the completed hydrologic record, water years 1971 through 1999.

In addition to the synthesis of hydrologic data within the basin, irrigation demands and shortages were also computed. A comparison between the total volume of historic stream flow, total volume of irrigation demand, and irrigation shortage for each of the three basins was made (Table). These comparisons indicate that on an annual basis, the total irrigation shortage volume was smaller than the difference between the total flow and irrigation demand for each basin. However, the location and timing of the flow frequently does not align with the location and timing for the demand.

The following figures (Figure, Figure Error**! No text of specified style in document.**, and Figure Error**! No text of specified style in document.**) compare the monthly basin flow volumes to irrigation shortages. The greatest irrigation demand for water to occurs in July through September, while stream flows are greatest in March through June as a result of the snowmelt and runoff.

The difference between water demand and water delivery is referred to as the average annual water shortage. Water supplies are often not available to meet water demands in most of the irrigated areas by mid- to late August, as natural flows recede and stored supplies diminish, resulting in a lack of flow to meet irrigation water rights.

Table 3. Summary of Calculated Water Demand by Basin

Basin	Average Annual Flow Volume near Snake River Confluence (acre-feet/year)	Average Annual Water Demand (acre-feet per year)[1]	Average Annual Water Deliveries (acre-feet per year)[1]	Average Annual Water Shortage (acre-feet per year)[2]	Average Annual Water Shortage (%)
Burnt River	135,000	82,000	77,000	5,000	6
Powder River	459,000	375,000	241,000	134,000	36
Pine Creek	101,000	64,000	41,000	22,000	36
Total	**695,000**	**521,000**	**359,000**	**161,000**	**31**

[1] 29-year period of record (1971-1999), including natural flow and storage water.
[2] Difference between water demand and water delivery

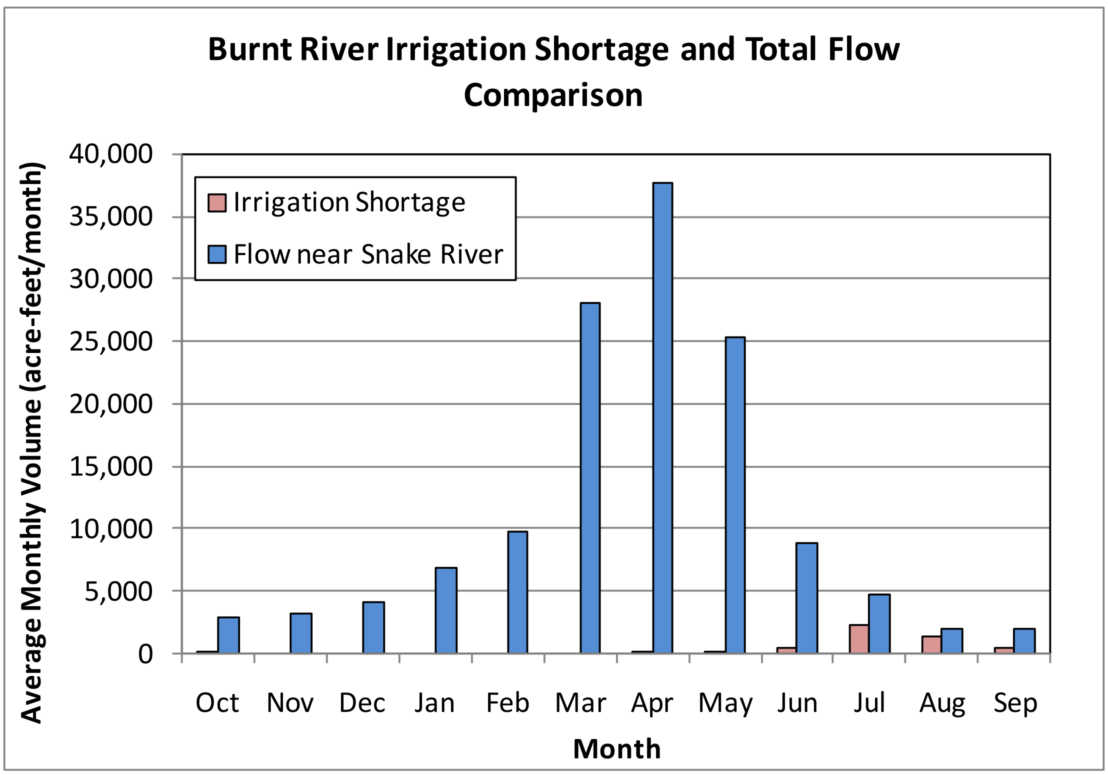


Figure 19. Total Calculated shortage and Flow for the Burnt River Basin

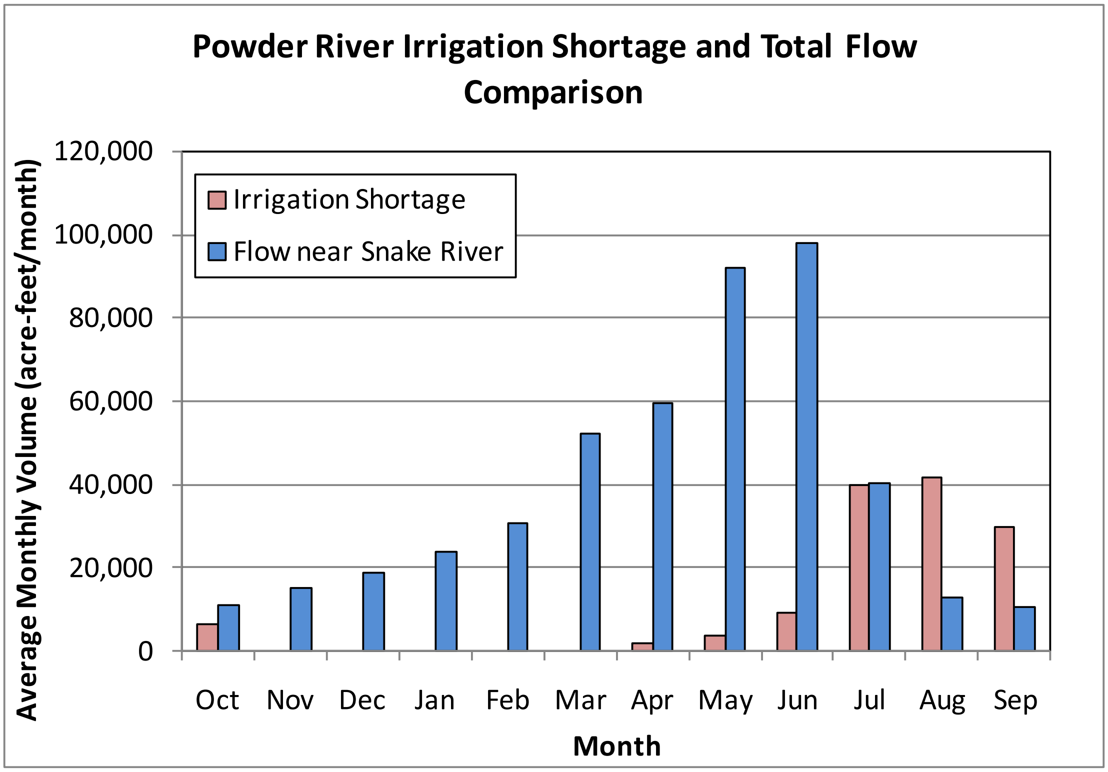


Figure Error! No text of specified style in document.**0. Total Calculated Shortage and Flow for the Power River Basin**

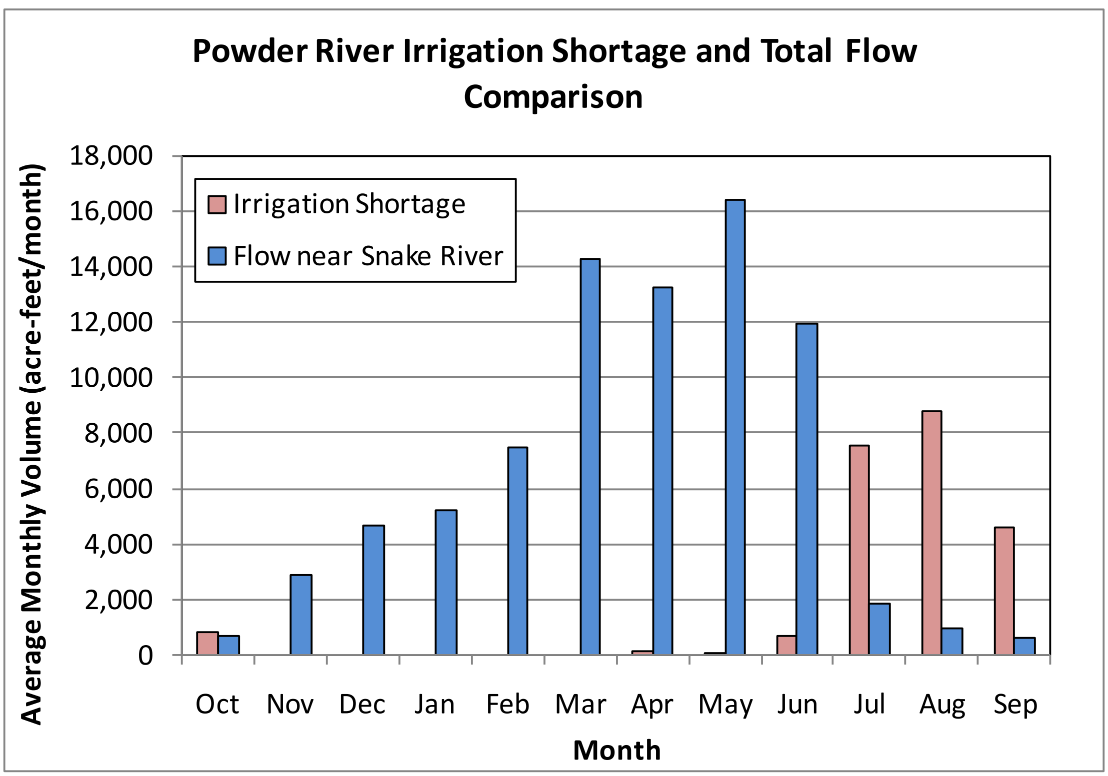


Figure Error! No text of specified style in document.**1. Total Calculated Shortage and Flow for the Pine Creek Basin**

Municipal

Municipal water needs are met through a combination of ground water and surface water supplies. At present, municipal water needs are being met. To estimate future water demand for municipal water use, current demand was subtracted from anticipated future demand, using about a 50-year planning horizon. The current demand is based on existing municipal water rights that were obtained for each of the eight incorporated towns within the Powder Basin. Anticipated future demands were generated based on a 2.0% growth rate per year (provided by county planners) and average rate of 115 gallons of water per person per day, projected out to the year 2050.

Industrial

Industrial use refers to the use of water for processing or manufacture of a product. Baker County has a limited number of industrial water uses. Major industrial uses include general construction, road construction, road construction and the processing of forest and lime products (Powder Basin Watershed Council 1996). Preliminary findings based on interviews with local, county, and city officials in the Powder Basin reveal that demand for industrial water use is not expected to increase. Interview findings revealed that at present, most industrial water rights are not being used. Since commercial and industrial water rights were grouped together in the industrial category listed on the water rights certificates obtained from the state, commercial and industrial water uses were combined into the water use category of industrial.

Table 4. Powder Basin Water Needs Summary Table for Agriculture, Municipal, & Industrial uses

Subbasin	Water use category	Current use in acre feet/ yr	Future use in acre feet/yr (2050)	Water Need (GAP in acre feet/ yr)
Burnt River	Agriculture	77,434	82,140	4,707
	Municipal	76	276	800
	Industrial	2,415	2,415	0
Subbasin Total:				**5,507**
Powder River	Agriculture	241,081	375,264	134,183
	Municipal	93,878	93,976	98
	Industrial	14,308	14,308	0
Subbasin Total:				**134,281**
Pine Creek	Agriculture	41,436	63,804	26,368

	Municipal	361	462	101
	Industrial	0	0	0
Subbasin Total:				**22,469**

Instream

Instream demands have been estimated for each subbasin in the Powder Basin. However, instream demands are isolated to specific stream reaches so cannot be aggregated. As such, instream demand for streams in each subbasin is provided by stream location as shown in Tables 3 – 5. The first column in each table lists a Number on the Map. This number for each stream corresponds to the numbers provided in the Land Cover map display. The instream demands are provided for each subbasin and are based on certificated (valid) water rights obtained from Oregon Water Resources Department (OWRD). For study sites where more than one instream water right flowed into the study site area, the largest cfs water right was chosen. The largest cfs water right was chosen because it encompassed the other water rights that flow into that study site. Each certificate contained cfs information on a monthly basis, the cfs data was converted to acre-feet, and then the months were added to generate annual demand in acre-feet. For discussion pertaining to instream flows under various conditions, see *Appendix A*.

Table 5. Instream Demands – Burnt River Subbasin.

	Burnt River Subbasin				
No. on Map	**Stream**	**Study Site**	**Annual Demand (acre-feet)**	**Certificate Number[1]**	**Date of Priority[1]**
1- Upper Burnt Above Sites	East Camp Creek –unk trib at Sec.5NENE to mouth	Camp Creek	42	73332	1/29/92
2	*West Camp Creek -North Fk to mouth	Camp Creek	58	73324	1/29/92
3a	South Fork Burnt River - headwaters to Elk Ck	South Fork Burnt River, Hardman, Whited, & Unity	105.84	72658	1/29/92
3b - Upper Burnt above sites	Elk Creek -headwaters to mouth	South Fork Burnt River, Hardman, Whited, & Unity	46.26	72660	1/29/92
4	*South Fork Burnt River - Elk Ck to river mile 9.8	South Fork Burnt River, Hardman, Whited, & Unity	165	73323	1/29/92
5	*North Fork Burnt River - river mile 28.5 to Camp Ck	North Fork Burnt River, Ricco, Upper, Middle, & Lower N Fk Burnt River, & Unity	98.73	72662	1/29/92

Table 6. Instream Demands – Powder River Subbasin.

	Powder River Subbasin				
No. on Map	**Stream**	**Study Site**	**Annual Demand (acre-feet)**	**Certificate Number[1]**	**Date of Priority[1]**
6	Cracker Creek -Sardine Gulch to mouth	Mason	134.84	72659	1/29/92
7	Deer Creek -Sheep Ck to mouth	Mason	97.7	73329	1/29/92
8	McCully Fork -headwaters to mouth	Mason	86.41	72661	1/29/92
9	*Powder River -Cracker Ck to Phillips Lake	Mason	286.4	73336	1/29/92
10	Powder River -Mason Dam to Smith diversion	none	120	59543	1/26/70
11	*Rock Creek -Rock Ck Lake to power plant diversion	Rock Creek	118.17	73322	1/29/92
12	*Dutch Flat Creek -lake to mouth	Twin Peak & North Powder	70.86	73331	1/29/92
13	Antone Creek -headwaters to mouth	North Powder	66.21	73327	1/29/92
14	*North Powder River - North Fk to Antone Ck	North Powder	173	73321	6/7/91
15	Anthony Fork -Anthony Lake to Indian Ck	Warm Springs	121.6	73325	1/29/92
16	North Fork Anthony Fork -headwaters to mouth	Warm Springs	59.16	73334	1/29/92
17	*Anthony Fork -Indian Ck to mouth	Warm Springs	192.3	73326	1/29/92
18	*Clear Creek -east and west forks to mouth	Wolf Creek	39.15	73328	1/29/92
19	Big Creek -Lick Ck to mouth	none	60	76593	1/29/92
20	Powder River -Thief Valley Res to Goose Cr	none	690	72663	1/29/92

	Powder River Subbasin				
No. on Map	Stream	Study Site	Annual Demand (acre-feet)	Certificate Number[1]	Date of Priority[1]
21	Powder River -Goose Cr to Brownlee Res	none	810	72664	1/29/92
22	West Eagle Creek and tribs-above mouth	Echo Lake & West Eagle	36	59535	1/26/70
23	West Eagle Creek and tribs -above Trout Ck	Echo Lake & West Eagle	240	59536	1/26/70
24	West Eagle Creek -east fork to mouth	Echo Lake & West Eagle	249.7	72657	6/7/91
25	Eagle Creek and tribs-above West Fork Eagle Ck	Echo Lake, West Eagle, Eagle Lake, & Looking Glass	320	59533	1/26/70
26	Eagle Creek and tribs -above East Fork Eagle Ck	Echo Lake, West Eagle, Eagle Lake, & Looking Glass	400	59532	1/26/70
27	East Fork Eagle Creek and tribs	none	364	59530	1/26/70
28	*Eagle Creek and tribs -above stream mile 10.9	Echo Lake, West Eagle, Eagle Lake, & Looking Glass	720	59531	1/26/70

Table 7. Instream Demands – Pine Creek Subbasin.

	Pine Creek Subbasin				
No. on Map	Stream	Study Site	Annual Demand (acre-feet)	Certificate Number[1]	Date of Priority[1]
29	Pine Creek -Long Branch Ck to Mouth	none	900	73335	1/29/92
30	Clear Creek and tribs -Twin Bridge Ck to mouth	none	220	59540	1/26/70
31	East Pine Creek and tribs -0.5 mile above Beecher Ck to	East Pine	80	59541	1/26/70

	mouth				
32	*East Pine Creek -Trinity Ck to Beecher Ck	East Pine	109.21	73319	11/8/90
33	Little Elk Creek -headwaters to mouth	none	38.54	73333	1/29/92
34	Elk Creek -Big Elk Ck to mouth	none	67	73320	11/8/90
35	Duck Creek -headwaters to mouth	none	67	73330	1/29/92
36	North Pine Creek and tribs	none	347	59534	6/26/70
37	Pine Creek –stream mile 1.9 to mouth	none	720	59542	6/26/70

2.2.2 Alternative Analysis

The supply and demand equation illustrated in this report as well as in the Eastern Oregon Water Appraisal Study focuses on current water supply and demand within the Powder, Burnt, and Pine Basins and does not attempt to calculate future demand, but does acknowledge that water demand will increase in the future. Therefore, a comparative analysis of available alternatives to assist with decreasing the gap between water supply and demand is also limited to that scope. There are three alternatives when addressing water shortages, increase water conservation and efficiency practices, subsurface water storage, and above-ground water storage.

Irrigation efficiency in the Powder Basin has increased greatly over the past two decades. Many ranchers have moved from flood irrigation to highly efficient center pivot irrigation systems. In the Powder Valley the entire North Powder Complex is a completely gravity run system, thus eliminating the need for electricity to run expensive pumps to provide irrigation water. However, there are numerous open canals and other delivery and return systems that could be upgraded to increase water conservation and efficiency. System optimization reviews would need to be conducted in order to pinpoint areas where projects could be implemented that would be feasible. It is unknown at this time how many miles of open canals and irrigation ditches exist within the basins. While piping and other conservation practices will assist with meeting water demand, these practices alone will not be adequate.

Another alternative for meeting water demand is subsurface water storage, such as aquifer recharge. Little work has been done thus far to fully explore these alternatives in these specific basins. There are two main reasons for lack of exploration. First, the majority of the Powder Basin, the area with the greatest demand, lies predominantly on an alluvial fan. Furthermore, there are several geologic faults that transect the basins. The Oregon Department of Geology warns that if injecting into subsurface wells if a major geologic event (i.e. earthquake or volcano) were to occur then the confining layers of the well would likely be breached (Personal Communication Mark Fern DOGAMI 2009).

The final potential alternative is above-ground water storage. This mechanism has proved to be a highly feasible and valuable way to supply water. In areas where spring flooding is an issue that can be extremely costly, such as in the Pine Creek Basin, above-ground storage provides a mechanism to capture, store, and safely release the vast amounts of water that leave the basin in the spring in the form of snowmelt run-off. While the Powder and Burnt River basins do not experience flooding issues to the degree that the Pine Basin does, reservoirs have provided a basic resource needed for the persistence of the counties number one source of economic revenue, agriculture. If done correctly above-ground water storage is addresses all beneficial uses including, fish, instream health, hydropower, agriculture, and municipalities.

2.3 Task 3. Analyses of environmental harm or impacts from the proposed storage project.

The Endangered Species Act of 1973 is administered by the United States Fish and Wildlife Service (USFWS) and the National Oceanic and Atmospheric Administration (NOAA). The purpose of the endangered species act is to protect species and their ecosystems.

A preliminary site review or macrositing has been completed to identify potentially significant wildlife and habitat conflicts for each potential reservoir site. Pre-existing information of the natural resource values located on and in close proximity to the proposed development sites were evaluated to limit or prevent conflicts that may make the projects difficult to permit. In order to develop a preliminary understanding of wildlife impacts-related to project feasibility, individual elements were reviewed; broad habitat, wildlife, plant and cumulative effects. The following table depicts a list of federal and state listed species.

Federal & State Listed Species

Table8: depicts a list of federal and state listed species and their presence or absence within the Powder Basin.

Common Name	*Scientific Name*	*State Status*	*Federal Status*	*Presence/ Absence*
FISH				
Borax Lake Chub	Gila boraxobius	E	E	Absence
Bull Trout	Salvelinus confluentus	SOC	T	Presence
Columbia River Chum Salmon	Oncorhynchus keta		T	Absence
Foskett Speckled Dace	Rhinichthys osculus ssp	T	T	Absence
Green sturgeon	Acipenser medirostris		T	Absence
Hutton spring Tui Chub	Gila Bicolor ssp	T	T	Absence
Lahontan Cutthroat Trout	Oncorhynchus clarki henshawi	T	T	Absence
Lost River Sucker	Deltistes luxatus	E	E	Absence
Lower Columbia River Chinook Salmon	Oncorhynchus tshawytscha		T	Absence
Lower Columbia River Coho Salmon	Oncorhynchus kisutch	E	T	Absence

Lower Columbia Steelhead	Oncorhynchus mykiss		T	Absence
Middle Columbia River Steelhead	Oncorhynchus mykiss		T	Absence
Modoc sucker	Catostomus microps		E	Absence
Oregon Chub	Oregonichthys crameri		T	Absence
Oregon Coast Coho Salmon	Oncorhynchus kisutch		T	Absence
Pacific Eulachon/Smelt	Thaleichthys padificus		T	Absence
Shortnose Sucker	Chasmistes brevirostris	E	E	Absence
Snake River Chinook Salmon (Fall)	Oncorhynchus tshawytscha	T	T	Absence
Snake River Chinook Salmon (Spring/Summer)	Oncorhynchus tshawytscha	T	T	Absence
Snake River Sockeye	Oncorhynchus nerka		E	Absence
Snake River Steelhead	Oncorhynchus mykiss		T	Absence
Southern Oregon Coho Salmon	Oncorhynchus kisutch		T	Absence
Upper Columbia River Spring Chinook Salmon	Oncorhynchus tshawytscha		E	Absence
Upper Columbia River Steelhead	Oncorhynchus mykiss		E	Absence
Upper Willamette River Chinook Salmon	Oncorhynchus tshawytscha		T	Absence
Upper Willamette River Steelhead	Oncorhynchus mykiss		T	Absence
Warner Sucker	Catostomus warnerensis	T	T	Absence
AMPHIBIANS AND REPTILES				
Columbia spotted frog	Rana luteiventris		C	Presence
Green Sea Turtle	Chelonia mydas	E	E	Absence
Leatherback Sea Turtle	Dermochelys coriacea	E	E	Absence
Loggerhead Sea Turtle	Caretta caretta	T	T	Absence
Oregon Spotted frog	Rana pretiosa		C	Absence
Pacific Ridley Sea Turtle	Lepidochelys olivacea	T	T	Absence
BIRDS				
Bald Eagle	Haliaeetus leucocephalus	T		Presence
Brown Pelican	Pelecanus occidentalis	E	E	Absence
California Least Tern	Sterna antillarum browni	E	E	Absence
Ferruginous Hawk	Buteo regalis	SC/SV	SOC	Presence
Greater Sage-grouse	Centrocercus urophasianus	SV	SOC	Presence
Marbled Murrelet	Brachyramphus marmoratus	T	T	Absence
Northern Goshawk	Accipiter gentiles		SOC	Absence
Northern Spotted Owl	Strix occidentalis	T	T	Absence
Swainson’s Hawk	Buteo swainsoni	SV		Absence
Short-tailed Albatross	Diomedea albatrus	E	E	Absence
Streaked horned lark	Eremophila alpestris strigata		C	Absence
Western Snowy Plover	Charadrius alexandrinus nivosus	T	T (coastal population only)	Absence
Yellow-billed cuckoo	Coccyzus americanus		C	Absence

Lewis's woodpecker	Melanerpes lewis	SC	SOC	Presence
MAMMALS				
Blue Whale	Balaenoptera	E	E	Absence
Columbian White-tailed Deer (Lower Columbia River population only)	Odocolieus virginianus leucurus		E	Absence
Fin Whale	Balaenoptera physalus	E	E	Absence
Fisher	Martes pennanti		C	Absence
Gray Whale	Eschrichtius robustus	E		Absence
Gray Wolf	Canis lupus	E	E	Presence
Humpback Whale	Megaptera novaeangliae	E	E	Absence
Kit Fox	Vulpes macrotis	T		Absence
Northern (Steller) Sea Lion	Eumetopias jubatus		T	Absence
Northern Pacific Right Whale	Japonica eublaaena	E	E	Absence
Sea Otter	Enhydra lutris	T	T	Absence
Sei Whale	Balaenoptera borealis	E	E	Absence
Sperm Whale	Physeter Macrocephalus	E	E	Absence
Washington Ground Squirrel	Spermophilus washingtoni	E	C	Absence
Wolverine	Gulo gulo	T		Absence
PLANTS				
Pink sandverbena	Abronia umbellata ssp. breviflora	E	SOC	Absence
McDonald's Mountain rockcress	Arbis macdonaldiana*	E		Absence
Northern wormwood	Artemisia campestris ssp. Borealis var. wormskioldii	E		Absence
Applegate's milk-vetch	Astragalus applegatei	E	E	Absence
Mulford's milk-vetch	Astragalus mulfordiae	E		Absence
Crinite mariposa lily	Calochortus coxii	E		Absence
Sexton Mountain mariposa lily	Calchortus indecorus	E		Absence
Umpqua mariposa lily	Calochortus umpquaensis	E		Absence
Golden paintbrush	Castilleja levisecta	E	T	Absence
Point Reyes bird's-beak	Cordylanthus maritimus ssp. Palustris	E		Absence
White rock larkspur	Delphinium leucophaeum	E		Absence
Peacock larkspur	Delphinium pavonaceum	E		Absence
Willamette daisy	Erigeron decumbens	E	E	Absence
Gentner's fritillary	Fritillaria gentneri	E	E	Absence
Snake River goldenweed	Haplopappus radiatus	E		Absence
Grimy ivesia	Ivesia rhypara var. rhypara	E		Absence
Western lily	Lillium occidentale	E	E	Absence
Big-flowered wooly meadowfoam	Limnanthes floccose ssp. Grandiflora	E	E	Absence
Bradshaw's desert parsley	Lomatium bradshawii	E	E	Presence
Cook's desert parsley	Lomatium cookie	E	E	Absence
Red-fruited lomatium	Lomatium erythrocarpum	E		Absence

Cusick's lupine	Lupinus cusickii	E	SOC	Absence
Smooth mentzelia	Mentzelia mollis	E		Absence
Macfarlane's four o'clock	Mirabilis macfarlanei	E	T	Absence
Rough popcornflower, rough allocarya	Plagiobothrys hirtus	E	E	Absence
Shinny-fruited allocarya	Plagiobothrys lamprocarpus	E		Absence
Dalles Mountain buttercup	Ranunculus reconditus	E		Absence
Spalding's campion	Silene Spaldingii	E	T	Absence
Malheur wire-lettuce	Stephanomeria malheurensis	E	E	Absence
Howell's spectacular Thelypody	Thelypodium howellii ssp. Spectabilis	E	T	Presence
Owyhee clover	Trifolium owyheense	E		Absence
Malheur Valley fiddleneck	Amsinckia carinata	T		Absence
White-topped aster	Aster curtus	T		Absence
Wayside aster	Aster vialis	T		Absence
Laurent's milkvetch	Astragalus collinus var. laurentii	T		Absence
South Fork John Day milkvetch	Astragalus diaphanus var. diurnus	T		Absence
Peck's milkvetch	Astragalus peckii	T		Absence
Sterile milkvetch	Astragalus sterilis	T		Absence
Tygh Valley milkvetch	Astragalus tyghensis	T		Absence
Pumice grape-fern	Botrychium pumicola	T		Absence
Howell's mariposa lily	Calchortus howellii	T		Absence
Golden buckwheat	Erigonum chrysops	T		Absence
Crosby's buckwheat	Erogonum crosbyae	T		Absence
Coast Range fawn lily	Efythronium elegans	T		Absence
Boggs Lake hedge hyssop	Gratiola heterosepala	T		Absence
Cronquist's stickseed	Hackelia cronquistii	T		Presence
Large-flowered rush lily	Hastingsia bracteosa	T		Absence
Howellia	Howellia aquatilis*	T	T	Absence
Davis' peppergrass	Lepidium davisii	T		Absence
Dwarf meadowfoam	Limnanthes floccosa ssp. Pumila	T		Absence
Greenman's desert parsley	Lomatium greenmanii	T		Absence
Kincaid's lupine	Lupinus sulphureus ssp. Kincaidii	T	T	Absence
Packard's mentzelia	Mentzelia packardiae	T		Absence
Howell's microseris	Microseris howellii	T		Absence
Wolf's evening-primrose	Oenothera wolfii	T		Absence
Silvery phacelia	Phacelia argentea	T		Absence
Oregon semaphore grass	Pleuropogon oregonus	T		Presence
Nelson's checke-rmallow	Sidalcea nelsoniana	T	T	Absence
Cascade Head catchfly	Silene douglasii var. oraria	T		Absence
Arrow-leaf thelpody	Thelypodium eucosmum	T		Presence

State Sensitive Species

Table9: depicts a list of all state sensitive species and their presence or absence within the state.

Common name	Scientific name	Distribution	Presence/ Absence
Critical			
Modoc Sucker*	Catostomus microps	Goose Lake	Absence
Westslope Cutthroat Trout	Oncorhynchus Clarki lewisii	Upper John Day	Absence
Chum Salmon (Columbia River)*	Oncorhynchus keta	Lower Columbia, Lower Columbia-Clatskanie, Lower Willamette, Lower Columbia-Sandy	Absence
Chum Salmon (Coastal Chum Salmon SMU/Pacific Coast ESU)	Oncorhynchus keta	Nehalem, Necanicum, Wilson-Trask-Nestucca, Yamhill, Siletz-Yaquina	Absence
Steelhead (Klamath Mountains Province ESU)	Oncorhynchus mykiss	Upper Klamath river	Absence
Steelhead (Lower Columbia River ESU, winter run)*	Oncorhynchus mykiss	Lower Columbia, Lower Columbia-Clatskanie, Lower Willamette, Lower Columbia-Sandy, Clackamas, Middle Columbia-Hood	Absence
Steelhead (Lower Columbia River ESU, summer run)*	Oncorhynchus mykiss	Middle Columbia-Hood	Absence
Steelhead (Middle Columbia River ESU, summer run)*	Oncorhynchus mykiss	Lower Deschutes, Upper Deschutes, Lower Crooked, Upper John Day, North Fork John Day, Middle Fork John Day, Lower John Day, Umatilla , Walla Walla	Presence
Great Basin Redband Trout (Catlow Valley Redband Trout SMU)	Oncorhynchus mykiss newberrii	Guano	Absence
Great Basin Redband Trout (Goose Lake Redband Trout SMU)	Oncorhynchus mykiss newberrii	Goose Lake	Absence
Great Basin Redband Trout (Warner Lakes Redband Trout SMU)	Oncorhynchus mykiss newberrii	Warner Lake	Absence
Great Basin Redband Trout (Fort Rock Redband Trout SMU)	Oncorhynchus mykiss newberrii	Summer Lake	Absence
Chinook Salmon (Upper Willamette River ESU, spring run/Willamette Spring Chinook SMU)	Oncorhynchus tshawytscha	Molalla-Pudding, North Santiam, South Santiam, McKenzie, Middle Fork Willamette, Coast Fork Willamette, Upper Willamette	Absence
Chinook Salmon (Coastal Spring Chinook SMU)	Oncorhynchus tshawytscha	Wilson-Trask-Nestucca, Siletz-Yaquina, Alsea, Coquille, North Umpqua, South Umpqua	Absence
Chinook Salmon (Lower	Oncorhynchus	Lower Columbia, Lower Columbia-	Absence

Columbia River Chinook ESU/SMU, fall run)	tshawytscha	Clatskanie, Lower Columbia-Sandy, Clackamas, Middle Columbia-Hood, Lower Willamette	
Chinook Salmon (Lower Columbia River Chinook ESU/SMU, spring run)	Oncorhynchus tshawytscha	Lower Columbia-Sandy, Clackamas	Absence
Oregon Chub *	Oregonichthys crameri	North Santiam, Upper Willamette, South Santiam, McKenzie, Middle Fork Willamette, Coast Fork Willamette	Absence
Umpqua Chub	Oregonichthys kalawatsti	Umpqua, North Umpqua, South Umpqua	Absence
Bull Trout (Willamette Bull Trout SMU)*	Salvelinus confluentus	McKenzie, Middle Fork Willamette	Absence
Bull Trout (John Day Bull Trout SMU)*	Salvelinus confluentus	North Fork John Day, Middle Fork John Day , Upper John Day	Presence
Bull Trout (Umatilla Bull Trout SMU)*	Salvelinus confluentus	Umatilla	Absence
Bull Trout (Grande Ronde Bull Trout SMU)*	Salvelinus confluentus	Upper Grande Ronde River, Wallowa River, Lower Grande Ronde	Absence
Bull Trout (Imnaha bull Trout SMU)*	Salvelinus confluentus	Imnaha River	Absence
Bull Trout (Hells Canyon Bull Trout SMU)*	Salvelinus confluentus	Brownleee Reservoir, Powder River	Presence
Bull Trout (Hood River Bull Trout SMU)*	Salvelinus confluentus	Middle Columbia-Hood	Absence
Bull Trout (Malheur River Bull Trout SMU)*	Salvelinus confluentus	Upper Malheur	Absence
Bull Trout (Odell Lake Bull Trout SMU)*	Salvelinus confluentus	Upper Deschutes	Absence
Bull Trout (Klamath Lake Bull Trout SMU)*	Salvelinus confluentus	Upper Klamath Lake, Sprague	Absence
Vulnerable			
Goose Lake Sucker	Catostomus occidentalis lacusanserinus	Goose Lake	Absence
Alvord Chub	Gila alvordensis (Siphateles alvordensis)	Alvord Lake	Absence
Miller Lake Lamprey	Lampetra minima (Entosphenus minimus)	Williamson, Sprague	Absence
Western Brook Lamprey	Lampetra richarsoni	Columbia River system and coastal streams including the Rogue	Absence
Pacific Lamprey	Lampetra tridentate (Entosphenus tridentata)	Columbia River system and coastal streams including the Rogue	Absence
Coastal Cutthroat Trout (Lower Columbia Coastal	Oncorhynchus clarkia clarkia	Lower Columbia-Clatskanie, Lower Columbia, Lower Willamette,	Absence

Cutthroat Trout SMU/Southwestern Washington/Columbia River ESU)		Middle Columbia-Hood, Lower Columbia-Sandy, Clackamas	
Coho Salmon (Coastal Coho Salmon SMU/Oregon Coast ESU)*	Oncorhynchus kisutch	Nehalem, Necanicum, Wilson-Trask-Nestucca, Siletz-Yaquina, Alsea, Siuslaw, Siltcoos, Umpqua, Coos, South Umpqua, Coquille, Sixes, North Umpqua	Absence
Coho Salmon (Southern Oregon/Northern California Coasts ESU/Rogue 9and Klamath) Coho SMU)*	Oncorhynchus kisutch	Middle Rogue, Lower Rogue, Illinois, Upper Rogue, Applegate	Absence
Inland Columbia Redband Trout	Oncorhynchus mykiss gairdneri	Lower Owyhee, Jordan, Middle Owyhee, South Fork Owyhee, East Little Owyhee, Lower Malheur, Upper Malheur, Bully , Willow, Burnt River, Lower Snake-Asotin, Walla Walla, Lower Grande Ronde, middle Fork John Day, Lower John Day, Brownlee Reservoir, Powder River, Imnaha River, North Fork John Day, Upper Grande Ronde River, Wallowa River, Willow, Umatilla , South Fork River, Wallowa River, Willow , Umatilla, South Fork Crooked , Upper Crooked, Upper John Day, Little Deschutes, Lower Crooked, Upper Deschutes, Trout, Middle Columbia-Hood, Lower Deschutes	Presence
Great Basin Redband Trout (Malheur Lakes Redband SMU)	Oncorhynchus mykiss newberrii	Silvies, Harney-Malheur Lakes, Silver, Donner Und Blitzen Lake Abert	Absence
Great Basin Redband Trout (Chewaucan Redband Trout SMU)	Oncorhynchus mykiss newberri	Lake Abert	Absence
Great Basin Redband Trout (Upper Klamath Basin Redband Trout SMU)	Oncorhynchus mykiss newberri	Sprague, Upper Klamath Lake, Williamson, Lost River, Upper Klamath river	Absence
Steelhead (Upper Willamette River ESU, winter run/Willamette Winter Steelhead SMU)*	Oncorhynchus mykiss	Tualatin, Yamhill, Molalla-Pudding North Santiam, South Santiam, Upper Willamette, middle Willamette	Absence
Steelhead (Oregon Coast ESU summer run/Coastal Summer Steelhead SMU)	Oncorhynchus mykiss	Siletz-Yaquina, North Umpqua	Absence
Steelhead (Oregon Coast	Oncorhynchus	Nehalem, Necanicum, Wilson-	Absence

ESU, winter run/Coastal winter Steelhead SMU)	mykiss	Trask-Nestucca, Siletz-Yaquina, Alsea, Sixes	
Steelhead (Klamath Mountains Province ESU, summer run/Rogue Summer Steelhead SMU)*	Oncorhynchus mykiss	Upper Rogue, Middle Rogue, Applegate, Lower Rogue	Absence
Steelhead (Snake River Basin ESU/Snake Summer Steelhead SMU)*	Oncorhynchus mykiss	Imnaha River, Upper Grand Ronde River, Wallowa River, Lower Grand Ronde River	Absence
Chinook Salmon (Mid-Columbia River ESU/SMU, fall run)	Oncorhynchus tshawytscha	Lower Deschutes	Absence
Chinook Salmon (Rogue Spring Chinook SMU)	Oncorhynchus tshawytscha	Upper Rogue, Middle Rogue	Absence
Chinook Salmon (Middle Columbia Spring Chinook SMU)	Oncorhynchus tshawytscha	Lower Deschutes, Upper Deschutes, Lower Crooked, Upper John Day, North Fork John Day, Middle Fork John Day	Absence
Chinook Salmon (Southern Oregon/Northern California Coast ESU, fall run/Rogue Fall Chinook SMU)	Oncorhynchus tshawytscha	Lower Rogue, Illinois, Chetco, Upper Rogue, Middle Rogue, Applegate, Sixes	Absence
Millicoma Dace	Rhinichthys cataractae ssp.	Coos	Absence
Bull Trout (Deschutes Bull Trout SMU)*	Salvelinus confluentus	Lower Deschutes, Upper Deschutes	Absence
AMPHIBIANS			
Critical			
Oregon Spotted Frog	Rana pretiosa	Southern/Central Oregon	Absence
Foothill Yellow-legged Frog	Rana boylii	Willamette Valley	Absence
Northern Leopard Frog	Lithobates pipiens	Southern Oregon	Absence
Vulnerable			
Cope’s Giant Salamander	Dicamptodon copei	Coastal Ranges	Absence
Columbia Torrent Salamander	Rhyacotriton kezeri	Northern Oregon/Columbia River	Absence
Southern Torrent Salamander	Rhyacotrition variegates	Southern Oregon	Absence
Cascade Torrent Salamander	Rhyacotrition cascadae	Cascades	Absence
Larch Mountain Salamander	Plethodon larselli	Cascade Range to Columbia River	Absence
Del Norte Salamander	Plethodon elongates	Southwestern Oregon	Absence
Siskiyou Mountains Salamander	Plethodon stormi	Western Oregon	Absence
Clouded Salamander	Aneides ferreus	Southern Oregon	Absence

Black Salamander	Aneides flavipunctatus	Southwestern Oregon	Absence
Oregon Slender Salamander	Batrachoseps wrightorum	North Central Oregon/Columbia River	Absence
Rocky Mountain Tailed Frog	Ascaphus montanus	West of Cascades	Absence
Coastal Tailed Frog	Ascaphus truei	West of Cascades	Absence
Western Toad	Anaxyrus boreas	Throughout Oregon	Presence
Northern Red-legged Frog	Rana aurora	Klamath Mountains, Willamette Valley	Absence
Cascades Frog	Rana cascadae	Throughout Oregon	Presence
Columbia Spotted Frog	Rana Luteiventris	Blue Mountains, Eastern Cascades Slopes and Foothills	Presence
Foothill Yellow-legged Frog	Rana boylii	Coast Range, Klamath Mountains, West Cascades	Absence
REPTILES			
Critical			
Western Painted Turtle	Chrysemys picta bellii	Along Columbia River	Absence
Western Pond Turtle	Actinemys marmorata	Along Columbia River	Absence
Western Rattlesnake	Crotalus oreganos	Willamette Valley	Absence
Vulnerable			
Northern Sagebrush Lizard	Sceloporus graciosus graciosus	Columbia Plateau/Southeastern Oregon	Presence
Common Kingsnake	Lampropeltis getula	Southern Oregon	Absence
California Mountain Kingsnake	Lampropeltis zonata	Southern Oregon	Absence
BIRDS			
Critical			
Columbian Sharp-tailed Grouse	Tympanuchus phasianellus columbianus	Central & Eastern Oregon	Presence
Red-necked Grebe	Podiceps grisegena	Central Oregon	Absence
Ferruginous Hawk	Buteo regalix	Columbia Plateau	Presence
Yellow Rail	Coturnicops noveboracensis	Central Oregon	Absence
Upland Sandpiper	Bartramia longicauda	Eastern Oregon	Presence
Yellow-billed Cuckoo	Coccyzus americanus	Central Oregon	Absence
Burrowing Owl	Athene cunicularia	Blue Mountains, Columbia Plateau, Eastern Cascades Slopes and Foothills, Klamath Mountains, Willamette Valley	Presence
Common Nighthawk	Chordeiles monor	Willamette Valley/Eastern Oregon	Presence
Lewis's Woodpecker	Melanerpes lewis	Eastern Oregon	Presence
White-headed Woodpecker	Picoides albolarvatus	Eastern Oregon	Presence

Streaked Horned Lark	Eremophila alpestis strigata	All of Oregon	Presence
Purple Martin	Progne subis	Southern Oregon	Absence
Yellow-breasted Chat	Icteria virens	Willamette Valley	Absence
Oregon Vesper Sparrow	Pooecetes gramineus affins	Klamath Mountains, Willamette Valley Eastern Oregon	Presence
Sage Sparrow	Amphispiza belli	Columbia Plateau/Eastern Oregon	Presence
Western Meadowlark	Sturnella neglecta	All of Oregon	Presence
Vulnerable			
Greater Sage-Grouse	Centrocercus urophasianus	Blue Mountains, Columbia Plateau, Eastern Cascades Slopes and Foothills	Presence
Spruce Grouse	Falcipennis canadensis		Absence
Mountain Quail	Oreortyx pictus	Northern Basin and Range	Absence
American White Pelican	Pelcanus erythrorhynchos	Breeding Population	Absence
Snowy Egret	Egretta thuyla	Southern Oregon	Absence
Northern Goshawk	Accipiter gentiles	Far Northern Oregon	Absence
Swainson's Hawk	Buteo swainsoni	Northeastern Oregon	Presence
Ferruginous Hawk	Buteo regalis	Blue Mountains, Eastern Cascades Slopes and Foothills	Presence
American Peregrine Falcon	Falco pergrinus anatum	All throughout Oregon	Presence
Arctic Peregrine Falcon	Falco peregrinus tundrius		Absence
Greater Sandhill Crane	Grus canadensis tabida	Central Valley Population (Oregon) Breeding Population)	Presence
Black Oystercatcher	Haematopus bachmani	Coastal Ranges	Absence
Long-billed Curlew	Numenius americanus	Blue Mountains, Columbia Plateau, Eastern Cascades Slopes and Foothills	Presence
Franklin's Gull	Larus pipixcan	Southern Oregon	Absence
Cassin's Auklet	Ptychoramphus aleuticus	Coastal Ranges	Absence
Rhinocerous Auklet	Cerorhinca monocerata	Coastal Ranges	Absence
Tufted Puffin	Fratercula cirrhata	Coastal Ranges	Absence
Flammulated Owl	Otus flammeolus	Parts of Central/Northern Oregon	Absence
Burrowing Owl	Athene cunicularia	Blue Mountains, Columbia Plateau, Eastern Cascades Slopes and Foothills, Klamath Mountains, Willamette Valley	Presence
Great Gray Owl	Strix nebulosa	Northern Oregon	Absence
Acorn Woodpecker	Melanerpes formicivorus	Willamette Valley	Absence
American Three-toed	Picoides dorsalis	Northern Oregon	Absence

Woodpecker			
Black-backed Woodpecker	Picoides arcticus	Northeastern Oregon	Presence
Pileated Woodpecker	Dryocopus pileatus	Blue Mountains, Eastern Cascades slopes and Foothills, Klamath Mountains	Presence
Olive-sided Flycatcher	Contopus cooperi	Portions of Northeast Oregon	Presence
Willow Flycatcher	Empidonax traillii adasstus	Blue Mountains, Columbia Plateau, Eastern Cascades Slopes and Foothills, Northern Basin and Range	Presence
Little Willow Flycatcher	Empidonax traillii brewsteri	Coast Range, Klamath Mountains, West Cascades, Willamette Valley	Absence
Loggerhead Shrike	Lanius ludovicianus	Blue Mountains, Columbia Plateau, Eastern Cascades Slopes and Foothills	Absence
White-breasted Nuthatch	Sitta crolinensis aculeate	Coast Range, Klamath Mountains, West Cascades, Willamette Valley	Absence
Western Bluebird	Sialia mexicana	Coast Range, Klamath Mountains, West Cascades, Willamette Valley	Absence
Grasshopper Sparrow	Ammodramus savannarum		Absence
Bobolink	Dolichonyx oryzivorus	Parts of Northeast Oregon	Presence
MAMMALS			
Critical			
Townsend’s Big-eared Bat	Corynorhinus townsendii	Coastal Ranges	Absence
Fisher	Martes pennanti	Coastal Ranges	Absence
Vulnerable			
California Myotis	Myotis californicus	All throughout Oregon	Presence
Fringed Myotis	Myotis thysanodes	All throughout Oregon	Presence
Long-legged Myotis	Myotis volans	All throughout Oregon	Presence
Hoary Bat	Lasiurus cinereus	All throughout Oregon	Presence
Silver-hired Bat	Lasionycteris noctivagans	All throughout Oregon	Presence
Spotted Bat	Euderma maculatum	Eastern Oregon	Presence
Pallid Bat	Antrozous pallidus	Southern/Eastern Oregon	Presence
Pygmy Rabbit	Brachylagus idahoensis	Eastern Oregon	Presence
Black-tailed Jackrabbit	Lepus californicus	Willamette Valley/Eastern Oregon	Presence
White-tailed Jackrabbit	Lepus townsendii	Eastern Oregon	Presence
Western Gray Squirrel	Sciurus griseus	Willamette Valley	Absence
Red Tree Vole	Arbormus longicaudus	Coast Range	Absence
Ringtail	Bassariscus astutus	Southwestern Oregon	Absence
American Marten	Martes Americana	Blue Mountains, Coast Range	Presence
Columbian Whit-tailed Deer*	Odocoileus virginianus leucurus	Coast Range (Columbia River Populations)	Absence

Due to the presence of several threatened and endangered listed species in the Powder Basin, the Oregon Natural Heritage Information Center was contacted to better define rare, threatened and endangered wildlife and plant species and there approximate locations.

The Oregon Biodiversity Information Center or formerly known as Oregon Natural Heritage Information Center (ORNHIC) conducted a data system search for rare, threatened and endangered plant and animal records for the proposed reservoir project sites with twenty-nine element occurrence were noted within a two-mile radius of the project sites. Areas observance include T06S R38E, Sections 8,9,16,17,(Pilcher Creek); T06S R40E, Sections, 21-23, 26, 27 (Thief Valley); T06S R38E, Sections 2, 3, 11, 10, 14 (Wolf Creek); T07S R46E, Sections 15-17, 20, 21(East Pine); T13S R36E, Sections 22, 27, 28 (Hardman),WM. Table 3 depicts the rare, threatened and endangered plant and animal records found within a 2 mile radius.

ORNHIC Data

Table 10: Rare, threatened & endangered plant and animal records

Township/Range/Section	*Common Name*	*Scientific Name*	*State/ Federal Status*
T06SR38E, Sec. 7,8,9,16,17,19,20,29,30,31,32 **Pilcher Creek Site**	Northern goshawk	Accipiter gentilis	FSOC SSV
T06SR39E, Sec. 22	Gray wolf	Canis lupus	FE & SE
T06SR38E, Sec. 16	Bald eagle	Haliaeetus leucocephalus	ST
T06SR37E Sec. - Anthony Lakes and Anthony Butte	Bull trout (Hells Canyon SMU)	Salvelinus confluentus pop. 8	FT SC
T08SR37E, Sec. 4,3,	Bull trout (Hells Canyon SMU)	Salvelinus confluentus pop. 8	FT SC
T07SR37E, Sec. – Tucker Flat and Anthony Butte	Bull trout (Hells Canyon SMU)	Salvelinus confluentus pop. 8	FT SC
T06SR37E, Sec. 13	Bull trout (Hells Canyon SMU)	Salvelinus confluentus pop. 8	FT SC
T06S R40E, Sec. 17	Ferruginous hawk	Buteo regalis	FSOC SCV
T06SR40E, Sec. 5, 30	Swainson's hawk	Buteo swainsoni	SV
T06SR39E, Sec. 22	Gray wolf	Canis lupus	FE/SE
T06SR40E, Sec. 33,34	Greater sage-grouse	Centrocercus urophasianus	FSOC SV
T06SR39E, Sec. 8, 30	Swainson's hawk	Buteo swainsoni	SV
T05SR38E, Sec. 25	Bald eagle	Haliaeetus leucocephalus	ST
T07SR46E, Sec. 4	Northern goshawk	Accipiter gentilis	FSOC SSV
T07SR46E, Sec. 20,17,16,21 Wolf Creek Site	Retrorse sedge	Carex retrorsa	

T07SR46E. Sec. 29,20,18,15,10,4,31,33,32,1,3,12,9,13,16,21,19,30,6,7,18,8,17,4,5**(Wolf Creek Site**); T07SR47E, Sec 28,25,33,19,21,18,16,7,10,6,3,33,35,36,34,32,2,5,11,8,15,17,29,27,20,22; T07SR45E Sec. 25,22,15,3,26,36,10,23,1,2; T07SR48E Sec. 19,17,8,9, 20,30	Bull trout (Hells Canyon SMU)	Salvelinus confluentus pop. 8	FT SC
T06SR45E Sec. 34 ,27,26,25,35,36; T06R46E Sec. 35,25,24,14,10,5,6,15,9,23,26,27,36,34,31,30,19,18,32,29,28,20,33; T06SR47E Sec. 34,30,29,26,19,21,11,12,3,2,10,13,24,22,20,25,27,36,31; T06SR48E Sec. 19,18,7,	Bull trout (Hells Canyon SMU)	Salvelinus confluentus pop. 8	FT SC
T08SR46E Sec. 21,24,15,13,9,10,6,4,11,8,14,16,23,22,; T08S47E Sec. 17,7,9,3,10,8,	Bull trout (Hells Canyon SMU)	Salvelinus confluentus pop. 8	FT SC
T05SR47E Sec. 34,31,32,33	Bull trout (Hells Canyon SMU)	Salvelinus confluentus pop. 8	FT SC
T13SR36E Sec. 29,17,9,	Northern goshawk	Accipiter gentilis	FSOC SSV
T13SR36E Sec. 12	Greater sandhill crane	Grus Canadensis tabida	SV
T14SR37E Sec. 28	Lewis's Woodpecker	Melanerpes lewis	FSOC SC
T13SR36E Sec. 30	Pristine springsnail	Pristinicola hemphilli	

Fish& Wildlife & Plant Review & Impacts

Potential species and/or habitats may be impacted by the development of a reservoir within the Powder Basin. Fish, wildlife and plant (29-element) occurrences have been identified via the macrositing process. Bull trout (Hells Canyon SMU) and Redband trout and have been identified as the species with the greatest possible conflict or impact. These species are listed as threatened and/or endangered. The impacts that would occur from the construction of the reservoir and dam include decreased population viability, mortality, and fragmentation. Other issues to consider would include minimum pool operations, fish passage, downstream minimum in stream flow needs and possibly temperature mitigation.

Habitat Review& Impacts

Identification of habitat types and habitat categorization as per ODFW's Fish and Wildlife Habitat Mitigation Policy has been determined for the proposed reservoir sites. ODFW has taken an ecoregion approach to conservation and has identified the Blue Mountains as the ecoregion for the Powder Basin and includes ponderosa pine woodlands, grasslands, sagebrush steppe and shrublands, aspen woodlands, wetlands, riparian, and aquatic (OR. Conservation strategy 2006). Key conservation issues for the Blue Mountains include, invasive species, altered disturbance regimes and land use changes. It is imperative that these habitat types and categories be determined on a site specific basis through the consultation with ODFW.

Bull Trout

The aquatic species listed in the Powder River Basin include the Bull trout (*Salvelinus confluentus*), listed as a threatened species. Stream miles throughout the Powder River Basin are designated as critical Bull trout habitat (Table 11). Interior redband trout (*Oncorhynchus mykiss*) is federally designated as a species of concern, which is a prominent species throughout much of the Powder River Basin (Table 12). These two species are 'species of concern' for this study. Maps detailing bull trout critical habitat and redband presence are located *Appendix A*.

Critical Habitat

The critical habitat of bull trout and current bull trout populations are located within the watershed of the proposed reservoir sites and current sites East Pine Creek, Wolf Creek, and Thief Valley Reservoir. Potential impacts include loss of habitat from the project footprint, lowered habitat value in close proximity to construction, decreased population viability, and possible habitat fragmentation.

According to ODFW Habitat Categories and Mitigation Goals and Standards bull trout habitat is a category 1- irreplaceable, limited, and essential habitat which has a goal of no loss of habitat quantity or quality. The standard by which to achieve the mitigation goal is avoidance. Therefore, it may be necessary to further assess site suitability for reservoir development and perform additional pre-development site-specific surveying and monitoring to identify, quantify and mitigate specific wildlife and habitat impacts. Consultation with permitting authorities, resource agencies and interested stakeholders with fish and wildlife expertise will be obtained during pre-project assessment.

Table 11: Habitat Miles for Bull Trout at Four Reservior Sites in Powder River Basin (StreamNet 2010)

Stream Name	Species	Miles of Stream	Miles Used
Powder Subbasin		**1668**	**24**
North Fork Anthony Creek, trib to Anthony Creek	Bull trout	5.3	3.22
Anthony Creek, trib to North Powder River	Bull trout	15.99	4.81
Wolf Creek, trib to Powder River	Bull trout	19.6	1.22
North Powder River, trib to Powder River	Bull trout	24.31	1.22
Burnt River Subbasin		**839**	
NONE			
Brownlee Reservoir Subbasin		**421**	**34**
Clear Creek, trib to Pine Creek	Bull trout	16.18	7.18
East Fork Pine Creek, trib to Pine Creek	Bull trout	4.49	1.59
East Pine Creek, trib to Pine Creek	Bull trout	18.65	4.97
Meadow Creek, trib to Clear Creek	Bull trout	3.32	3.32
Trail Creek, trib to East Pine Creek	Bull trout	1.56	0.85
Trail Creek, trib to Clear Creek	Bull trout	4.21	1.97
Unnamed stream [1171074450207], trib to East Pine Creek	Bull trout	1.57	0.64

Table 12: Federally Designated Fish Species in Powder River Basin (Subbasin Plan)

Common Name	Scientific Name	Federal Status	Oregon Status
Bull Trout	*Salvelinus confluentus*	Threatened	Sensitive-Critical
Interior redband trout	*Oncorhynchus mykiss*	SOC	Sensitive-Vulnerable

Research and habitat preferences specific for redband trout is limited, most of the current research comes from the Kootenai River drainage in Montana and southwestern Idaho. An overview of habitat use by twenty-five species in Oregon was summarized by Bond et al. (1988). They determined that redband trout were distributed in habitats over coarse substrate in moderate to swift current velocities (Bond et al. 1988). Predominately in Oregon, redband trout were located in streams less than 10m width, characterized as isolated desert streams (Bond et al. 1988).

Muhlfeld et al. (2001a and 2001b) measured habitat use and movement in the Kootenai River drainage and determined trends in redband trout. During the fall and winter there was limited movement with a small home range in the overwintering habitat of deep pools with extensive amounts of cover within third-order mountain streams (Muhlfeld et al. 2001a). Summer use was examined at three levels of habitat. Adult and juvenile selected microhabitats with greater depth, while age -0 redband trout selected shallow, low velocity areas along the channel margins (Muhlfeld et al. 2001b). Mesohabitat selections for all ages classes of redband trout were deep, slow pool habitats with relatively abundant cover, while avoiding shallow, high-velocity riffles (2001b). At the macrohabitat level, redband trout distribution associated with a variety of physical characteristics, primary macrohabitats were low-gradient, medium size reaches with abundant pools.

Overall evaluation of redband trout habitat was evaluated by Zoellick and Cade (2006) in southwestern Idaho sagebrush ecosystems. The variations in density of redband trout were associated with stream shade and distance from the headwaters, where increased shade in the headwaters (upper 50 km) held the greatest density (Zoellick and Cade 2006). The variations in density were distributed across a range habitat conditions and characteristics (stream gradient, size, depth, flood flow); shade was not sole determinant of redband trout density.

For each reservoir site, proposed habitat studies are to examine the habitat quality and potential aspects of monitoring and restoration. The previous discussion of ecological flows associated with each reservoir site describes the flows to maintain the fish habitat specific to the species of concern based on available hydrologic data and the best available research.

2.4 Task 4. Evaluation of the need for and feasibility of using stored water to augment instream flows to conserve, maintain and enhance aquatic life, fish life and any other ecological values.

Ecological Values of Instream Conservation

The instream flow scenario described below is typical in the Powder, Burnt, and Pine Creek basins. To further illustrate that above ground water storage does facilitate late season instream flows that were historically often completely lacking, photographs of the Powder River (Figs.1-2) at the north end of Baker City are provided. The first photograph shows the Powder River in August, completely dry and with little riparian vegetation. The second photograph was taken after Mason Dam was constructed (1965-1968). With late season water available, flows are augmented, water temperatures stay cooler during the summer season, and the overall ecosystem health of the stream is improved. Additionally, the Baker Valley Irrigation District leaves in 10 cfs year round through the Baker City instream reach. This pictorial evidence is proof that above ground stored water can be used to meet to augment in-stream flows to conserve, maintain and enhance aquatic life, fish life and other ecological values. Currently those needs are unmet and without additional water management they will remain so. With human population increasing at an exponential rate, water shortage will grow even larger.

Water Demand

In a drainage system that is characterized as having a semiarid environment and being a mountainous desert that is defined by very limited precipitation that comes in the form of snow in the winter time water is viewed as a scarce and fragile resource. For discussion and analytical purposes water demand in this document has been separated into two categories, consumptive water needs, and instream flows needs. Consumptive water needs include agriculture, commercial and industrial uses, and municipal water demands. Instream flow needs include all flows needed to maintain stream diversity and stream health, and support aquatic life.

In nearly all environmental planning documents written in the Powder and Burnt River Basins, lack of sufficient late season flows are cited as a major problem (USDA 1996, Union SWCD and Powder Valley Water Control District 1966, Baker Valley SWCD and Powder Valley Water Control District 1967). In order for agriculture land to produce high value crops, three to four acre feet of water per acre of land are necessary. Currently, the majority of irrigated land in the basins receives less than one acre foot of water per year. Therefore, current agriculture demands are not met and future water demands will face an even greater shortage.

In the early 1990’s many stream segments had in-stream water rights filed on them. The majority of those water rights remain unmet to a large degree, predominantly in mid-late summer. For example, at Thief Valley there is a November in-stream flow water right for 50 cfs. In November of 2010 there was approximately 4cfs flowing in-stream at the specified segment (Powder River from Thief Valley Reservoir at river mile 69.5 NESW, S26, T6S, R40E WM; To Goose Creek at River Mile 36.5 NWNW, S4, T9S, R43E WM; Certificate Number 72663).

Municipalities in the basins predominantly utilize ground water. However, there are a few that receive surface water for drinking purposes, such as Baker City and Richland. Neither city reports issues of higher demand for surface water with current population levels.
Industry in the Powder, Burnt, and Pine Creek Basins currently utilizes a small amount of surface water. Historically however, this was not the case. During the gold rush in the late 1800’s and 1900’s a vast amount of surface water was used for various types of mining. Currently, there are still active mining water rights. However, current water use has diminished greatly in comparison to historic use.
Many residents and entrepreneurs that reside within the basins believe that if year-round water was available, then industry (i.e. processing or manufacturing) that require significant water resources would establish in the basin.

Water Supply

On the supply side of the water equation a hydrologic analysis conducted by the Bureau of Reclamation and HDR Engineering proves that there is water available for storage at each of the four selected sites which would help meet current unmet water demand. In some areas all current unmet needs would be made whole, while in other area additional stored water would simply assist with filling the gap between supply and demand.

3.0 Calculations of Potential Hydropower

3.1 Thief Valley Reservoir

Estimates of hydropower were calculated for Thief Valley Reservoir based on the simulated outflow for the increased capacity simulated in the Ecological Flow Report. Hydropower generated potentially maybe greater than shown due to a 43,000 acre-feet additional reservoir capacity in the design.

Hydropower was calculated using the formula for power (P) in kW

$$P = \eta \rho g h Q$$

η= turbine efficiency (ranging from 60%-90%)
ρ =specific weight of water (62.428 lb/ft^3)
g= gravity (32.174 ft/s^2)
h= hydraulic height (head)
Q= discharge (ft^3/s)

*Calculations were done in US standard measurements; the conversion factor was 0.085 as the constant for specific weight of water and gravity. Efficiency standards were supplied by Oregon Energy Trust; 60% was worst case ranging to best case of 90% efficient. Income for hydropower generation was calculated using a rate of $282.78 per kW

Table 13: Overview of hydropower to be generated. Illustrates the efficiency differences (60%-90%)

Powder River- Thief Valley Reservoir Enlargement								
Worst Case Efficiency			**Mid Case Efficiency**			**Best Case Efficiency**		
Elevation	57	ft	*Elevation*	57	ft	*Elevation*	57	ft
Discharge	148	cfs	*Discharge*	148	cfs	*Discharge*	148	cfs
Efficiency	0.6		*Efficiency*	0.75		*Efficiency*	0.9	
Factor	0.084641		*Factor*	0.084641		*Factor*	0.084641	
Power	**428.4**	**kW**	**Power**	**535.5**	**kW**	**Power**	**642.6**	**kW**
Annual income		**$121,148**	**Annual income**		**$151,435**	**Annual income**		**$181,722**

Table 14: Hydropower generated per month based on average discharge over 28 years of data. Efficiency used 75% mid case.

Powder River - Enlarged Thief Valley Reservoir Site, Simulated Monthly Reservoir Hydropower												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Average (cfs)	21	25	34	74	178	242	273	295	347	144	90	59
Hydropower (kW)	75	91	124	268	645	874	989	1067	1255	519	324	215

Summary			
Minimum (cfs)	38	Hydropower (kW)	137
Maximum (cfs)	148	Hydropower (kW)	534

Table 15: Hydropower generated per year over 15 years of data. Efficiency used 75%. The 28 years of data shows the low, average, and high flow years.

	Average cfs	Hydropower kW	Income
1981	248	899	**$254,161**
1982	235	851	**$240,637**
1983	69	251	**$70,925**
1984	203	734	**$207,589**
1985	232	840	**$237,441**
1986	161	583	**$164,930**
1987	40	146	**$41,384**
1988	38	139	**$39,349**
1989	123	444	**$125,610**
1990	127	459	**$129,905**
1991	167	605	**$171,171**
1992	325	1174	**$332,120**
1993	332	1201	**$339,672**
1994	382	1381	**$390,400**
1995	185	670	**$189,475**
1996	139	505	**$142,699**
1997	55	200	**$56,678**
1998	41	148	**$41,968**
1999	80	290	**$82,081**
2000	50	180	**$50,898**
2001	46	168	**$47,498**
2002	37	133	**$37,663**

2003	87	315	**$89,080**
2004	47	170	**$48,159**
2005	51	186	**$52,531**
2006	199	722	**$204,044**
2007	238	863	**$243,920**
2008	173	625	**$176,847**
2009	193	699	**$197,535**
Yearly Summary			
Minimum			
CFS	38	**Hydropower (kW)**	137
Maximum			
CFS	148	**Hydropower (kW)**	534

3.2 Wolf Creek Complex

The Wolf Creek Complex is made up of Pilcher Creek Reservoir and Wolf Creek Reservoir, with some of the outflow of Pilcher flowing into Wolf Creek Reservoir. The interest is to install hydropower into the existing pipe; hence estimates are based on outflow from Pilcher Creek Reservoir. Estimates of hydropower were calculated for Wolf Creek Complex based on the past 28 years of existing outflow. Hydropower generated will be greater with the capacity increase.

Hydropower was calculated using the formula for power (P) in kW

$$P= \eta \rho g h Q$$

η= turbine efficiency (ranging from 60%-90%)
ρ =specific weight of water (62.428 lb/ft^3)
g= gravity (32.174 ft/s^2)
h= hydraulic height (head)
Q= discharge (ft^3/s)

*Calculations were done in US standard measurements; the conversion factor was 0.085 as the constant for specific weight of water and gravity. Efficiency standards were supplied by Oregon Energy Trust; 60% was worst case ranging to best case of 90% efficient. Efficiency for in-pipe hydropower is expected to be at or greater than 90% efficient. Income for hydropower generation was calculated using a rate of $282.78 per kW.

Table 16: Overview of hydropower to be potentially generate. Illustrates the efficiency differences (60%-90%).

Wolf Creek Complex: Pilcher Creek		
Worst Case Efficiency		
Elevation	**110**	**ft**
Discharge	**11**	**cfs**
Efficiency	**0.6**	
Factor	**0.084641**	
Power	**62.3**	**kW**
Annual income		**$17,628**
Mid Case Efficiency		
Elevation	**110**	**ft**
Discharge	**11**	**cfs**
Efficiency	**0.75**	
Factor	**0.084641**	
Power	**77.9**	**kW**
Annual income		**$22,035**
Best Case Efficiency		
Elevation	**110**	**ft**
Discharge	**11**	**cfs**
Efficiency	**0.9**	
Factor	**0.084641**	
Power	**93.5**	**kW**
Annual income		**$26,442**

Table 17: Hydropower generated per month based on average discharge over 28 years of data. Efficiency used 90% mid case.

Wolf Creek Complex Reservoir Site, Simulated Monthly Reservoir Hydropower												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Average (cfs)	4	0	0	0	0	0	9	14	17	53	28	11
Hydropower (kW)	36	0	0	0	2	3	71	120	145	445	234	96

Table 18: Wolf Creek Complex: Pilcher Creek

Simulated Project Conditions			
	Average cfs	Hydropower kW	Income
1981	11	93	**$26,402**
1982	11	96	**$27,029**
1983	13	111	**$31,450**
1984	12	96	**$27,267**
1985	10	88	**$24,757**
1986	11	96	**$27,159**
1987	9	76	**$21,417**
1988	11	91	**$25,625**
1989	11	92	**$25,941**
1990	10	83	**$23,565**
1991	11	94	**$26,551**
1992	11	94	**$26,447**
1993	11	89	**$25,245**
1994	8	70	**$19,730**
1995	11	93	**$26,359**
1996	14	117	**$33,099**
1997	14	120	**$33,893**
1998	13	113	**$31,834**
1999	11	96	**$27,029**
2000	13	107	**$30,205**
2001	10	87	**$24,691**
2002	14	115	**$32,487**
2003	10	88	**$24,850**
2004	12	104	**$29,332**
2005	11	92	**$25,953**
2006	12	104	**$29,336**
2007	12	99	**$27,886**
2008	11	95	**$26,937**
Yearly Summary			

Minimum			
CFS	2	Hydropower (kW)	**15**
Maximum			
CFS	120	Hydropower (kW)	**1004**

3.3 East Pine Creek

Estimates of hydropower were calculated for East Pine Creek Reservoir Site based on the simulated project outflow over 28 years. East Pine Creek Reservoir is proposed to be a 21,000 acre-ft capacity.

Hydropower was calculated using the formula for power (P) in kW

$$P = \eta \rho g h Q$$

η= turbine efficiency (ranging from 60%-90%)
ρ =specific weight of water (62.428 lb/ft^3)
g= gravity (32.174 ft/s^2)
h= hydraulic height (head)
Q= discharge (ft^3/s)

*Calculations were done in US standard measurements; the conversion factor was 0.085 as the constant for specific weight of water and gravity. Efficiency standards were supplied by Oregon Energy Trust; 60% was worst case ranging to best case of 90% efficient. Income for hydropower generation was calculated using a rate of $282.78 per kW.

Table 19: Overview of hydropower to be generated. Illustrates the efficiency differences (60-90%)

Pine Creek - East Pine Reservoir Site								
Worst Case Efficiency			**Mid Case Efficiency**			**Best Case Efficiency**		
Elevation	177	ft	*Elevation*	177	ft	*Elevation*	177	ft
Discharge	41	cfs	*Discharge*	41	cfs	*Discharge*	41	cfs
Efficiency	0.6		*Efficiency*	0.75		*Efficiency*	0.9	
Factor	0.084641		*Factor*	0.084641		*Factor*	0.084641	
Power	**370.1**	**kW**	**Power**	**462.6**	**kW**	**Power**	**555.1**	**kW**
Annual income		**$104,647**	**Annual income**		**$130,808**	**Annual income**		**$156,970**

Table 20: Hydropower generated per month based on average discharge over 28 years of data. Efficiency used 75% mid case.

East Pine Creek: Simulated Monthly Reservoir Hydropower												
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Average (cfs)	5	5	7	14	28	66	92	120	94	32	22	10
Hydropower (kW)	56	58	77	157	314	738	1035	1349	1051	357	242	116

Table 21: Hydropower generated per year over 15 years of data. Efficiency used 75%. The 28 years of data shows the low, average, and high flow years.

Pine Creek - East Pine Reservoir Site Simulated Project Conditions			
	Average cfs	**Hydropower kW**	**Income**
1981	60	672	**$190,102**
1982	64	722	**$204,032**
1983	31	344	**$97,157**
1984	91	1020	**$288,350**
1985	49	552	**$155,958**
1986	48	542	**$153,321**
1987	12	132	**$37,260**
1988	44	490	**$138,565**
1989	45	508	**$143,559**
1990	39	435	**$123,016**
1991	46	522	**$147,605**
1992	66	744	**$210,309**
1993	83	938	**$265,232**
1994	66	742	**$209,698**
1995	45	509	**$143,949**
1996	51	571	**$161,530**
1997	19	216	**$61,026**
1998	10	112	**$31,742**
1999	32	364	**$102,999**
2000	30	334	**$94,486**
2001	20	224	**$63,363**
2002	12	130	**$36,707**

2003	36	406	**$114,683**
2004	24	270	**$76,369**
2005	52	582	**$164,501**
2006	74	832	**$235,166**
2007	23	263	**$74,468**
2008	11	119	**$33,618**
2009	11	123	**$34,671**
Yearly Summary			
Minimum			
CFS	10	**Hydropower (kW)**	112
Maximum			
CFS	1020	**Hydropower (kW)**	11457

3.4 Hardman Reservoir Site

Estimates of hydropower were calculated for East Pine Creek Reservoir Site based on the simulated project outflow over 28 years. The Hardman Reservoir is proposed to be a 4,800 acre-ft capacity.

Hydropower was calculated using the formula for power (P) in kW

$$P = \eta \rho g h Q$$

η= turbine efficiency (ranging from 60%-90%)
ρ =specific weight of water (62.428 lb/ft^3)
g= gravity (32.174 ft/s^2)
h= hydraulic height (head)
Q= discharge (ft^3/s)

*Calculations were done in US standard measurements; the conversion factor was 0.085 as the constant for specific weight of water and gravity. Efficiency standards were supplied by Oregon Energy Trust; 60% was worst case ranging to best case of 90% efficient. Income for hydropower generation was calculated using a rate of $282.78 per kW.

Table 23: Overview of hydropower to be generated. Illustrates the efficiency differences (60-90%)

Burnt River - Hardman Reservoir Site								
Worst Case Efficiency			Mid Case Efficiency			Best Case Efficiency		
Elevation	125	ft	*Elevation*	125	ft	*Elevation*	125	ft
Discharge	23	cfs	*Discharge*	23	cfs	*Discharge*	23	cfs
Efficiency	0.6		*Efficiency*	0.75		*Efficiency*	0.9	
Factor	0.084641		*Factor*	0.084641		*Factor*	0.084641	
Power	**147.3**	**kW**	**Power**	**184.1**	**kW**	**Power**	**220.9**	**kW**
Annual income		**$41,643**	**Annual income**		**$52,054**	**Annual income**		**$62,465**

Table 24: Hydropower generated per month based on average discharge over 28 years of data. Efficiency used 75% mid case.

Hardman Reservoir Site, Simulated Monthly Reservoir Hydropower												
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Average (cfs)	17	21	15	12	16	22	33	47	33	37	16	9
Hydropower (kW)	138	168	122	97	126	177	263	373	258	293	123	72

Table 25: Hydropower generated per year over 15 years of data. Efficiency used 75%. The 28 years of data shows the low, average, and high flow years.

Burnt River - Hardman Reservoir Site Simulated Project Conditions			
	Average cfs	**Hydropower kW**	**Income**
1981	29	231	**$65,300**
1982	27	214	**$60,543**
1983	18	140	**$39,464**
1984	28	222	**$62,894**
1985	29	228	**$64,536**
1986	25	201	**$56,751**
1987	17	133	**$37,492**
1988	19	149	**$42,179**
1989	19	148	**$41,758**
1990	23	182	**$51,603**
1991	20	160	**$45,303**
1992	26	209	**$59,112**
1993	30	240	**$67,804**
1994	29	227	**$64,096**

1995	27	217	**$61,463**
1996	23	182	**$51,392**
1997	18	145	**$41,021**
1998	17	137	**$38,613**
1999	28	221	**$62,548**
2000	19	147	**$41,622**
2001	22	174	**$49,078**
2002	16	124	**$35,177**
2003	25	200	**$56,566**
2004	16	124	**$35,081**
2005	22	174	**$49,216**
2006	25	198	**$56,052**
2007	28	222	**$62,644**
2008	25	198	**$55,933**
2009	24	192	**$54,322**
Yearly Summary			
Minimum			
CFS	16	**Hydropower (kW)**	**124**
Maximum			
CFS	240	**Hydropower (kW)**	**1903**

4.0 Cultural Resources

The State Historic Preservation Office (SHPO) of the Oregon Department of Parks and Recreation was contacted in order to conduct an initial survey of possible archaeological resources within the vicinity of the fourj reservoir sites. SHPO conducts a service of searching their archaeological database by site location. SHPO was provided with the location of the proposed Hardman Dam on South Fork Burnt River, proposed East Pine Dam on East Pine Creek, proposed expansion of Thief Valley Reservoir on Powder River, and the proposed expansions of Wolf Creek Reservoir and Pilcher Creek Reservoir on Wolf Creek and Pilcher Creek drainage.

SHPO concluded that there are known archaeological sites within the Hardman Reservoir site and a high probability for archaeological resources within the other 3 sites. SHPO recommends that a professional archaeologist be hired to examine the area of impact on each site. The archaeologist will conduct a cultural resource survey for SHPO’s approval prior to any land-disturbing activities.

The next step for the feasibility study involving cultural resources, a professional archaeologist would need to be hired to conduct a cultural resource survey. Due to the size of each site, the cost would be thousands of dollars per site (*Appendix C: SHPO Letter*).

5.0 Water Quality

5.1 Existing Water Quality Data by Sampling Station and Collection Agency

S3: Analyses of environmental harm or impacts from the proposed storage project

DEQ

LASAR = Laboratory Analytical Storage and Retrieval; air and water quality monitoring data

Location of each site near each reservoir:

1) Wolf Creek Complex – LASAR site just downstream Wolf Creek Reservoir on Wolf Creek. No sites are near Pilcher Creek reservoir or on Pilcher Creek.
2) Thief Valley Reservoir – LASAR site just downstream Thief Valley dam on Powder River.
3) Hardman Reservoir – LASAR site just upstream from reservoir on Elk Creek, at mouth with South Fork Burnt River. There is no site between Elk Creek and Unity Reservoir on South Fork Burnt River. (The nearest downstream site is on Burnt River at Clarks Creek.)
4) East Pine Creek Reservoir – LASAR site at damsite.

Table 1 = Thief Valley LASAR station data #11858 (NOTE: Samples taken were one time sediment and fish tissue collection in 1992, no water samples were collected)

Table 2 = Thief Valley LASAR station #26590 just upstream from table 1 LASAR station data.

Table 3 = Wolf Creek LASAR station data #12626. Surface water sample with 19 parameters.

Table 4 = South Fork Burnt River LASAR station data #35817 (NOTE: Only data taken was bug riffle data – see data from DEQ lab)

Table 5 = East Pine LASAR station data #35879 (NOTE: Only data taken was bug riffle data – see data from DEQ lab)

USFS

Water Quality stations

Location of each site near each reservoir:

1) South Fork Burnt River – Site at inlet of proposed reservoir just prior to creek leaving USFS boundary.
2) East Pine Creek – There are 4 sites just below and above proposed reservoir site.
3) Wolf Creek – Site about 2.3 miles upstream of dam.

Note: There are no USFS stations near Thief Valley Reservoir or Wolf Creek Complex.

Table 6 = South Fork Burnt River USFS temperature data

Figure 1 = chart for Table 6

Table 7 = East Pine Creek USFS temperature data – hobo 15.0c – temperature

Figure 2 = chart for Table 7

Table 8 = East Pine Creek USFS temperature data – hobo 15.1c – temperature

Figure 3 = chart for Table 8

Table 9 = East Pine Creek USFS temperature data – hobo 15.2c – temperature
Figure 4 = chart for Table 9
Table 10 = East Pine Creek USFS temperature data – hobo 15.2b – temperature
Figure 5 = chart for Table 10
Table 11 = Wolf Creek USFS temperature data
Figure 6 = chart for Table 11
Table 12 = East Pine Creek USFS temperature data - years with temp data for 4 hobos detailed in **Table 8-11**, also details location info of 4 hobos

DEQ
Water Quality Assessment Database
The report database updates the 1998 and 2002 databases and 303(d) lists. The listing status from prior assessments may be carried forward if no new or insufficient new information was available for a water body. Acquires water quality data from other agencies and combines with their data. Location is stated to be segments of each creek from river mile to river mile. Previous data for temperature appears to be from USFS. However the data and dates do not match up with the data received directly from USFS. USFS sometimes shares their water quality data with DEQ.
Table 13 = East Pine Creek, 3 parameters, location 0 to 12.5 and 12.2 to 18.7 river miles. From DEQ Water Quality Assessment Database.
Table 14 = Wolf Creek data, 3 parameters location 0 to 19.6 river miles, 4 parameters location 7.2 to 13.3 river miles, and 4 parameters location 0 to 7.2 river miles. From DEQ Water Quality Assessment Database.
Table 15 = South Fork Burnt River data, 3 parameters location 0 to 11.5 river miles. From DEQ Water Quality Assessment Database.
Table 16 = Thief Valley Reservoir surface water collection, location 68.1 to 71.7 river mile = Thief Valley Reservoir. From DEQ Water Quality Assessment Database.
Table 17 = Powder River data, 15 parameters taken for location from Thief Valley to Snake River. From DEQ Water Quality Assessment Database – same info as GIS data but has "beneficial uses" column

DEQ
303d 2002 list
Table 18 = 303d GIS attribute table from the 2002 303d list. This table contains data for 4 streams: East Pine Creek, Powder River and Thief Valley Reservoir, Wolf Creek, and South Fork Burnt River. This data is similar to the DEQ Water Quality Assessment Database such as Table 2, 14, 15, 16, 17 above however the tables above include a "beneficial uses" column.

DEQ
Laboratory and Environmental Assessment
Data from an Aquatic Ecologist

Table 19 = DEQ Bug data for East Pine, Wolf Creek, and Elk Creek/S Fork Burnt River. No data taken near Thief Valley Reservoir or Pilcher Creek Reservoir. All sites at LASAR sites.

Stream Flow

Water quality includes many parameters including streamflow. However, the existing streamflow data and existing gauge station locations were collected for the Powder Basin Hydrologic Analysis in 2009. That data was used to determine water quantity and narrow down the possible reservoir sites to these current four sites.
For this report, we are assuming that all of the streamflow data has already been collected and can be found in that report.

Location Map

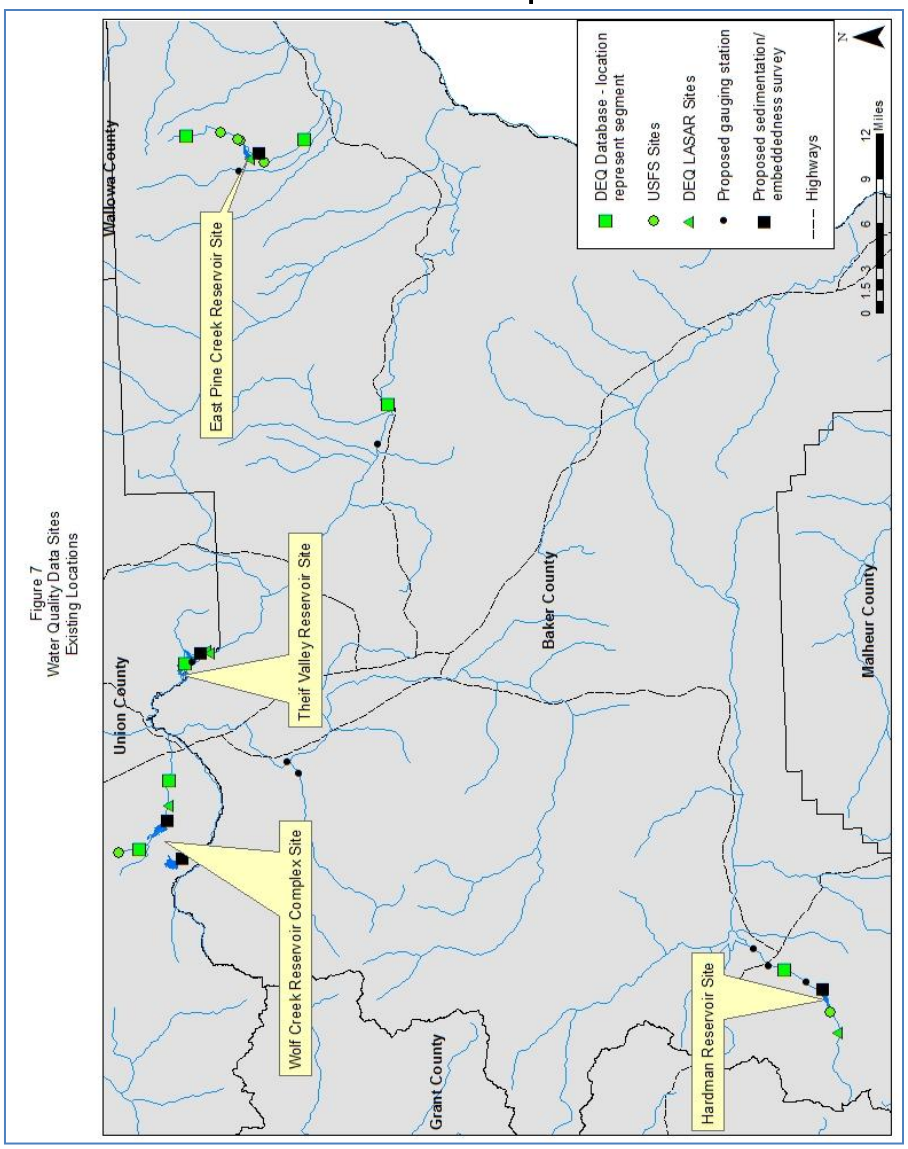


Figure 22. Location Map

5.2 Existing Water Quality Parameters Collected at Each Site

Parameters listed by Collection Station Details of Parameters in Attached Tables/Figures (see above)

East Pine Creek

- (USFS – upstream and downstream res)
- Temperature

- (DEQ WQ Assessment Database – mostly downstream)
- Dissolved oxygen
- Flow modification
- Temp (data from USFS)

- (DEQ Bug data – at reservoir damsite/LASAR site)
- TS
- FSS
- Predator Score
- Predator Condition

Hardman

- (USFS – upstream res)
- Temperature

- (DEQ WQ Assessment Database - downstream)
- Flow modification
- Habitat modification
- Temp (from USFS)

- (DEQ Bug data – upstream at Elk Creek/LASAR site)
- TS
- FSS
- Predator Score
- Predator Condition

Thief Valley Reservoir

- (LASAR #11858 just downstream res)
- Sediment and Fish Tissue – 79 parameters, from organic chemicals to mercury/aluminum, tested for

- (LASAR #26590 just downstream res)
- Conductivity
- Dissolved oxygen
- PH
- Temperature
- Turbidity

- (DEQ WQ Assessment Database – actual res)
- Aquatic weeds or Algae
- Dissolved oxygen
- Flow modification
- Nutrients
- Temperature

- (DEQ WQ Assessment Database – from mouth to res)
- Aquatic weeds or algae
- Chlorophyll a (from LASAR)
- Dissolved oxygen
- E Coli (from LASAR)
- Fecal coliform
- Flow modification
- Habitat modification
- Nutrients
- pH (from LASAR)
- sedimentation
- temp (from USBR)

Wolf Creek

- (LASAR #12626 # miles downstream res)
- Ammonia
- Biochemical oxygen demand 5 Day undiluted
- Unionized Ammonia
- Chemical oxygen demand
- Dissolved orthophosphate
- Enterococcus
- Fecal coliform
- Conductivity
- Dissolved oxygen
- pH
- Temp
- Nitrate
- Percent saturation field dissolved oxygen
- Total kjeldahl nitrogen
- Total organic carbon
- Total phosphorus
- Total solids
- Total suspended solids
- Turbidity

- (DEQ WQ Assessment Database – entire creek or downstream from res)
- Ammonia (from LASAR)
- Dissolved oxygen (from LASAR)
- Flow modification
- Flow modification
- Habitat modification
- pH (from LASAR)
- Phosphate (from LASAR)
- Sedimentation
- Temperature (from USFS)

- (DEQ Bug data – downstream at LASAR site)
- TS
- FSS
- Predator Score
- Predator Condition

303d Listings

The Clean Water Act Section 303(d) requires identifying waters that do not meet water quality standards where a Total Maximum Daily Load (TMDL) needs to be developed. According to the Oregon Department of Environmental Quality's Assessment Database (see Tables 13-17), each stream has been analyzed and certain water quality parameters are not met.

East Pine Creek is listed on the 303(d) list because the temperature parameter is not met. The other parameters are sufficient.
Wolf Creek was surveyed for and found the following parameters are not met: ammonia, dissolved oxygen, pH, Phosphate phosphorus, and sedimentation.
For South Fork Burnt River, temperature is the only parameter that has not been met. The other parameters surveyed are sufficient.
The parameters that were surveyed within the Thief Valley Reservoir include the following that were not met and therefore added to the 303(d) list: aquatic weeds/algae, dissolved oxygen, nutrients, sedimentation, and temperature.
The Powder River includes multiple parameters that were surveyed within the 0 to 69 river mile range. The following parameters are not met and have been added to the database: aquatic weeds/algae, chlorophyll a, e coli, nutrients, sedimentation, and temperature. The following parameters have been listed as 303(d) concerns prior to the addition of the new parameters: pH.

Additional Water Quality Parameters

After reviewing the existing data and the list of water quality parameters that have been collected near each reservoir site, more data is needed to be able to study all necessary water quality parameters of each reservoir site. Below is a list of each reservoir site and the additional data that should be collected to obtain the best water quality information. This list was determined by adding data collection sites to the existing water quality stations to fill the gaps in necessary data needed. Also, see Figure 7 which displays the existing and proposed stations.

East Pine Creek Reservoir

The majority of the proposed reservoir is within USFS land and there are currently 4 USFS temperature stations within the reservoir area. However, more parameters are necessary to sample such as sedimentation, turbidity, urban/vegetation trash/debris, depth, and other chemicals. Some of the water to fill the reservoir may come from Clear Creek so a gauging station at the Clear Creek POD and at the damsite are needed. Just below the damsite, a more intensive sedimentation and embeddedness survey could be added.

Hardman Reservoir

The South Fork Burnt River reservoir site is mostly on USFS land however the closest temperature station is just upstream from the reservoir. A DEQ station is upstream the reservoir on Elk Creek. These stations only take temperature and flow samples. A sampling station for all pertinent water quality parameters is needed below the damsite. Adding gauges at 3 sites downstream of the damsite would allow the best calculation of flow and water usage. Just below the damsite, a more intensive sedimentation and embeddedness survey could be added.

Thief Valley Reservoir

The proposed expansion of the reservoir will affect a small amount of land (less than 10 acres) surrounding the existing reservoir footprint. The DEQ LASAR and DEQ Assessment databases have tested for an extensive list of parameters within the actual reservoir and downstream. However, the turbidity, depth, and urban/vegetation trash/debris parameters should be added to the reservoir list of parameters. A more intense sedimentation and embeddedness survey should be taken just below the damsite. Also, two permanent gauging stations, including temperature, should be installed at the damsite and at Clear Creek point of diversion downstream on the Powder River. These additions would provide the additional water quality data and parameters needed. Also, this additional data would be compiled with the existing gauging and sampling stations to analyze water quality including flow.

Wolf Creek Reservoir Complex

The Wolf Creek Reservoir and Pilcher Creek Reservoir are existing and their expansion will affect a small amount of land surrounding the existing footprints (about 200 acres). The Powder Valley Water Control District already measures flow and temperature at each damsite and downstream in various locations. However, the only water quality sampling locations occurred on Wolf Creek about 1.5 miles downstream of the reservoir. The parameters taken were extensive at this site. Pilcher Creek downstream of the reservoir should include a new station to collect water quality data including temperature, dissolved oxygen, turbidity, sedimentation, pH, and other important chemicals. Just below each damsite, a more intensive sedimentation and embeddedness survey should be added. Also, the North Powder River could supply these reservoirs with the additional water so a gauging station could be installed on the North Fork Anthony River before confluence with the North Powder River and also installed on the North Powder River prior to a POD to the reservoirs.

5.3 Literature Review: Studies of Water Quality Associated with Established Reservoirs Summaries of Documents

L. Meays, Micheal M. Borman, Larry L. Larson (2005), Temperatures of Three Headwater Streams in Northeastern Oregon

Stream temperature is a significant part of water quality for salmon and other organisms. Atmospheric effect is represented by the observed association of elevation to stream temperature. Atmosphere effect has a major influence on stream temperatures and effectively sets limits within streams which temperatures occur. The thermal signature of a stream is defined by its associated attributes such as exposure time (velocity/distance), a function of discharge volume and rate of flow, cool water inputs and canopy cover. Energy exchange is primarily driven by the gradient between water and air temperature, which leads to equilibrium. It should be noted that shade was not a major factor influencing stream temperature.

L.L. Larson, P.A. Larson, (1999) Soil and Water Conservation Society. Influence of Thermal Gradients on the Rates of Heating and Cooling of Streams

Stream temperature increases a streams' capacity to carry oxygen and reduces nutrient accessibility. Watershed attributes influence water temperature and are greater than that of vegetation shade. Attributes include air mass, elevation gradient, adiabatic rate, channel width and depth, water velocity, landscape and flow inputs. Stream temperatures in a warm environment are typically a reflection of the thermal conditions. The velocity of a stream is used to determine the change in water temperature during the day based on how any miles the water travels during the testing phase. Water is heated primarily by the sun and ambient radiation emitted by the atmosphere and the earth.

Utah, Department of Environmental Quality. Joes Valley Reservoir (web search)
Joes Valley Reservoir is located on the eastern slope of the Wasatch Plateau in the Manti-La Sal Mountain approximately 12 miles west of Orangeville, Utah. Joes Valley Reservoir was constructed by the US Bureau of Reclamation and began storing water in November of 1965 and is controlled by the Emery Water Conservancy District. The reservoir is used for recreation, cold water fishery and agriculture. Surrounding the reservoir is forest lands, used for hunting, recreation and livestock grazing. The reservoir provides fishing for rainbow, cutthroat, splake, brown and lake trout.

The water quality of Joes Valley Reservoir is essentially good, although the reservoir does experience declining dissolved oxygen concentrations in the water column. Below 10 meters within the water column is a rapid decline in dissolved oxygen which in return can not support a viable fishery. Studies have been done and support the fact that Joes Reservoir is to be an oligotrophic system with low productivity. It is important to note that the system is currently a phosphorus limited system and is well below the state water quality standards.

Oak Ridge National Laboratory Environmental Sciences. (2001) White Sturgeon and Reservoir Water Quality (web search)
Water Quality is a major issue for Brownlee Reservoir especially for the survival of sturgeon. A water quality model has been developed using DE_Qual2 to quantify the response of water quality variable to nutrient inflow and flow operations. Two issues are being evaluated to determine the potential influence of water quality on the spatial heterogeneity and movement of sturgeon. It should be noted that numerous lab and field studies have documented that when fish are faced with degraded water quality conditions, both sublethal and lethal levels of metals, pesticides, dissolved oxygen and temperature they will migrate away to areas with more favorable conditions. The movement creates a cause and effect reaction; the movement allows avoidance however reduces available habitat and increases fish density. Avoidance behavior can act as a barrier blocking access to spawning or feeding areas.

U.S. Fish & Wildlife Service. (2008) Small Reservoir their Impacts and Alternatives.
This article by the US Fish and Wildlife Service examines small reservoirs and their impacts upon x and their alternatives. Small reservoirs are primarily built upon the need for water supply, aesthetics, electricity generation, flood control and a plethora of social and natural resource issues. According to the US Fish and Wildlife Service benefits do not come without costs, and those costs can be detrimental. Impacts include but are not limited to be: decreased dissolved oxygen, water temperature changes, aquatic passage, evaporative water loss, downstream erosion and invasive species. The article further explores meeting your needs without the use of reservoirs with a table. The table examines each need and the associated alternatives to that need. Needs and alternatives addressed within the table include: drinking water, fire suppression, Irrigation, flood control, aesthetics, habitat improvement, passive recreation-fishing and wildlife viewing.

Peter Wax (March 2006 Updated September 2007) Lake Water Quality Assessment for the Jamestown Reservoir Stutsman County, North Dakota.
This article examines the water quality for Jamestown Reservoir Stutsman County, North Dakota. The Jamestown Reservoir is a 1200 acre impoundment within the city limits and has a maximum depth of 8 ft and back up water for approximately 8 miles along the James River flood plain. Water quality assessment data was collected in 1998 and 1999 and included water quality chemistry and phytoplankton species identification and enumeration. Samples were extracted from 3 locations on 5 different dates. Locations were: 1) 50 meters off the face of the dam, 2) mid-lake, 3) at the inlet. It was determined that dissolved oxygen concentrations were above North Dakota Water Quality Standards of 5 milligrams per liter. The reservoir was found to be nitrogen limited, therefore the primary production is limited but not altered. The altered condition favors certain species that are able to affix nitrogen, utilize organic nitrogen or are tolerant of low nitrogen conditions. The

Jamestown tropic status was assessed as hypereutrophic in the upper reaches of the reservoir and eutrophic in the lower reaches. Trophic is estimation of productivity and typically as a reservoir or lake ages it becomes more productive or hypereutrophic. Distinguishing characteristics of an aged lake are: bad smells, frequent fish kills, rapid oxygen depletion during thermal stratification and under ice cover conditions. Reservoirs which inundate large areas of fertile soils are especially susceptible to hypereutrophic conditions. Plankton is used as an indicator of nutrient availability and trophic.

Art Johnson and Dale Norton (May 1990) 1989 Lakes and Reservoirs Water Quality Assessment Program: Survey of Chemical Contaminants in Ten Washington Lakes. Washington State Department of Ecology,
In 1989 EPA- sponsored Washington State Lakes and Reservoir Water Quality Assessment Program to conduct a survey of chemical contamination in Ten Washington Lakes. The objective of the study was to survey for the occurrences of toxins in fish, sediments and to evaluate the significance of the findings. Sources of concern included non-point, agricultural runoff and the past use of herbicide 2,4-D. The majority of the lakes showed no evidence of chemical contamination in fish. The past use of herbicide 2, 4-D showed no evidence of residues in the lakes. Bottom sediments in three of the lakes did indicate sediment contamination, ranging from PAH to pesticide tebuthiuron. It was suggested that the lakes with contamination be better surveyed to determine distribution and sources of contamination.

Eline Boelee, Aidan Senzange, Muchaneta Munamati, Lucilia Parron, Lineu Rodrigues, Hammou Laamrani, Philippe Cecchi. Small Reservoirs Toolkit: Water Quality Assessment,
This paper examines water quality in direct correlation to direct consumption and other uses such as livestock watering and fisheries. Reservoir water can be assessed through such simple methods as taste, smell, color observation, and transparency. More technical methods can be used to monitor changes in reservoir water quality, to identify source pollutants and their loading. Technical water quality measuring methods are expensive and require individuals for observations, analysis and interpretation of the results. The author discuses who, how, why and when to use the water quality tool kit. Water quality methods are discussed for measuring water quality indicators. It is important to note that water quality assessment is most beneficial when all parameters are analyzed. It is suggested that reservoirs be monitored over long periods of time and that reservoirs that are inflicted by a plethora of land use be monitored to fully understand their impacts upon water quality.

M. Meybeck, E. Kuusisto, A. Makela and E. Malkki. (1996) Chapter 2 – Water Quality. Water Quality Monitoring - A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes.
The chapter explores and provides an in depth discussion on the demands and influences on water quality and the fact that not always are they compatible. “Water Quality” in the chapter was expressed as the suitability of water for a plethora of uses. Discussion is given to a wide range of influences that affect the quantity and quality of water. It is important to note that not all influences are those of man, some are natural in state such as torrential down pours, causing tremendous erosion and an influx of suspended sediment in rivers, lakes or streams. Chapter 2 provides discussion on the characteristics of surface waters for lakes, reservoirs and rivers; it also provides characteristics of groundwater and the natural processes affecting water quality. An important aspect of the chapter is “Residence” or better referred to as the time it takes for a body of water to recovery from a pollution incident. The authors provide examples of short and long residence times and the recovery time associated with rivers and lakes. Often residence times in reservoirs are less than one year. The authors define stratification as an important factor influencing water quality in lakes and reservoirs. The occurrence of two densities within a body of water can be caused by differences in temperature, exposure to sunlight and wind and resulting in decreased oxygen concentration in the lower layer.

Table 2.2 defines the important processes affecting water quality; the processes include hydrological, physical, chemical and biological for all bodies of water. Further on in the chapter consideration is given to water use and water quality deterioration and water and human health.

Larry Larson, Micheal Bnorman, (1999), Rangeland Resources Department, Oregon State University, Burnt River Shade, Soil Temperature, and Groundwater Recharge Estimates, A First Approximation.
This document provides an estimate of shade, soil temperature, and groundwater recharge along the mainstem of the Burnt River. The report discusses estimates of community distribution, shade estimates, soil temperature, groundwater, and temperature reality check.

Larry L. Larson, Michael M. Borman, (2000), Rangeland Resources Department, Oregon State University, Use Attainability Assessment (Temperature Standard), Burnt River Watershed.
This document discusses findings of studies within the Burnt River Basin that assess site potential and the influence of thermal environment and land use on water temperature. Contained within the document is a short literature review discussing radiation, daily cycles, seasonal cycles, influence of Meteorological conditions, influence of solar radiation, influence of groundwater, thermal complexity and headwater studies. The report contains various tables and graphs all depicting various temperatures such as air, water and soil.

Cynthia L. Meays, (2000), Rangeland Resources, Oregon State University, Elevation, Thermal Environment, and Stream Temperatures on Headwater Streams in Northeastern Oregon.
This document provides discussion and findings of a case study held on four tributaries of the Burnt River (Barney, Elk, Greenhorn and Stevens Creeks) in northeastern Oregon. The relationship between stream temperatures and the thermal environment of the streams were examined and analyzed. A plethora of data (stream discharge, water temp. etc.) was collected every 150 m from 1370 to 1830 m elevation on each stream. It was found that thermal environments (air and soil surrounding the stream) as well as stream temperatures were similar for each creek and that elevation was the major influence on stream temperature. The document contains a short literature review on energy transfer and water temperature and thermal environment studies. Also provided is a description of the study area and the methods used. The author provides results and discussion on headwater springs, headwater analysis, side channel analysis, and temperature analysis.

6.0 Geology Literature Review

This report summarizes any and all geology and geotechnical information found within documents about a specific reservoir site. The following summaries are written to explain what has been researched (existing data) in each document. Reservoir documents that do not contain geology/geotechnical information have not been included.
****Each report below has been scanned in electronically and saved as a pdf file.***

6.1 East Pine Reservoir Geology

East Pine Reservoir, Impact Survey Report. March 1972. USFS.
This report was very general and the focus was broad so geology was a small portion of the report.
The report found no rock outcrops in pool area. The valley floor includes a variety of deposits. The slopes are mantled with silty sands. The centerline foundation consists of metamorphosed sedimentary rock. There is an overlying basalt flows on the left abutment. A chart displays the geologic types and soil characteristics that describe erosion resistance and construction. The four geologic land types are depicted on a map.

Watershed Work Plan Pine Valley. December 1986. Eagle Valley Soil and Water Conservation District and Pine Valley Water Control District with assistance from USDA.
This report focused on the Pine Valley and possible Pine Creek Reservoir. The geology section was general and included the potential reservoir.

The watershed geomorphology is described of elevation and the location of pine valley. Stratigraphy is described resulting in three major rock types in watershed. The northern quarter is underlain by formations of sandstone, shale, and limestone overlain by basaltic lavas and/or till. The southern three-quarter is underlain by basaltic and andesitic lava flows. Pine valley is underlain by glacial outwash alluvium and morainal deposits.

The structure of the watershed is generally described. The upper third of the watershed is mainly uplift and block faulting. The lower two thirds is typical tilt-block or basin and county. Several fault areas cross the watershed.

Figure 3: Geology and Soils Map – of the Pine Valley Watershed. Displays rock units of deposits, flows, intrusive, fault lines – illustrations of Structure text section.

Pine Valley Watershed, Protection and Flood Prevention Project, Plans for the Construction of East Pine Dam. 1976. USDA NRCS.
These plans consisted of 17 detailed blueprints. The following list is the title of each blueprint. The question marks are in place of where the scan was illegible (*Appendix B: Section 1*).

Geologic and Subsurface Investigation for the Proposed East Pine Creek Dam, Volume I, Summary Report and Design Recommendations. January 1975. Shannon & Wilson, Inc.
This report was developed with intention to construct the reservoir within the following few years of publication. The entire geotechnical study was completed and detailed in this report. The following summary is written by section heading in the report.

Site Description Topography of the area was generalized including location, elevation changes, tributaries, watershed. The climate of the area was briefed.

Project Description This description was a summary from the 1968 "Watershed Work Plan" and describes the dam, spillway, irrigation outlets, and recreation area.

Field Explorations Explorations were conducted to investigate the surface and subsurface conditions at dam, reservoir, and borrow areas. This section was an introduction to the detailed Figure 5 and Section 4.

Borings There were 17 borings drilled for the dam and spillway site (B1 to B17). 4 borings for the upper quarry site (QB1 to QB4). The depth drilled ranged from 50 to 165 feet. Soil and rock core samples were obtained throughout entire depth of each boring. Water pressure testing done at 11 borings; there is a description of water pressure and the formula to calculate coefficient of permeability. Cement grout pressure testing was performed in 5 borings; there is a description of technique and actual accomplishment. Four piezometers were installed in 4 borings; there is a detailed description of technique.

Test Pits 64 test pits were excavated 3 to 20 feet (TP1 to TP64). Bulk samples were obtained from pits. Constant head and falling head permeability tests were performed in standpipes; the standpipes installation was described. Tests were generally conducted about 12 hours after 1 gallon of water poured down standpipe to insure seal. Formulas for constant and falling head were described.

Regional Geology The authors group this region with the Rocky Mountain and Basin and Range Physiographic Provinces. The geology of the region can be broadly classified into three major groups: pre-Tertiary rocks, Tertiary rocks, and Quarternary rocks. Each group was generally described where found in the region. The tectonics of the region were described as block faults and their locations in relation to the dam. The earthquake history was described, as minimal as the data that was available. Additionally, it was recommended to build the dam to withstand 5.6 magnitude quake.

Site Geology The stratigraphy of the reservoir site is described by each rock unit and features and their location. As seen on Figure 5, it depicts the location of ash, landslide debris, basalt, gneisses, etc. rocks, plus the faults and joints are shown. The three faults and three major joint sets are described. The groundwater is limited to the level of the creek.

Subsurface Conditions The right abutment, lower and upper, contains argillite as poor to higher quality. Otherwise the dam location has a thin surface layer of colluviums and slope wash. The valley floor has a surface of 10’ thick alluvium underlain by argillite that was fractured in some places associated with the fault. The left abutment contains basalt and argillite. The basalt was in good condition and the argillite had some fractures. A full scale test trench of the basalt-argillite contact was not able to be conducted. A thin layer of colluvium consisting of clayey silty soils with fragments of bedrock mantles the valley slopes. This layer was sampled and a low situ permeability and low in situ shear strength. The landslide debris within this area was tested to have low plasticity and appears to be stabilized and not affected by reservoir.

Sources of Construction Borrow Materials Valley Alluvium consists of organic soils and debris and clayey sandy silt overlaying sandy gravel as indicated in many test pits. The organic soils were underlain by 2-5 feet of sandy silt and tested to have high permeability. The sandy gravel encountered in mostly all of test pits and tested to have permeability coefficients on the order of 10^-3 and dry densities in excess of 130 pcf. The Bearwallow Area contained 6 test pits and the tests resulted in high to low permeability. Upper Rock Quarry Prospect is about 0.8 mile north of dam site. Four borings at this site resulted in a basalt dike from 11.5 to 60 feet, widely spaced joints within the gneiss outcrops, contact between basalt and gneiss being about 5 feet, and hard and dense balsalt/gneiss. Additional Gravel Borrow Area is located in the alluvial fan by Clear Creek and test pits were dug 11 feet. The test pits consisted of dense sandy gravelly cobbles and boulders underlain by silty sandy gravel***.***

Laboratory testing procedures Visual Classification includes using ASTM D2487-69 and D2488-69; core samples were examined for weathering, fracturing, and dip, and percent recovery and percent RQD were measured. Moisture content was determined based on ASTM D2216-71. Atterberg limit, grain size analysis, specific gravity, and compaction were also determined. 7 consolidation tests were performed at above and below optimum moisture content levels, and at dry densities 95 to 108 percent of the optimum. Two unconfined compression tests were performed on remolded specimens at a moisture content 2 to 4 percent above optimum moisture content. Consolidated-undrained triaxial compression tests consisted of 8 series including using the back pressure method and resulted in stress-strain relationships, pore pressure versus strain, failure criteria, and total and effective Mohr strength envelopes. Only one sample exhibited a brittle type failure. The bulk specific gravity and absorption and sodium sulphate soundness tests of 8 core samples were determined.

Recommendations for Design The proposed reservoir area for water storage is considered suitable and significant movement of the bank slopes is not expected. The foundation will be satisfactory for an embankment type dam. The foundation beneath the shells should be in strength stronger or equal to the shells. The embankment stability was found to have an effective angle of internal friction enough to support the proposed 200’ embankment. It would be important when stripping to eliminate top soil to ensure adequate foundation. The upper left abutment was not adequately defined with this exploration therefore would need more research prior to development. The foundation beneath the impervious core zone needs to reach a surface that will prevent erosion at the base of the core material. It is recommended to have a treated width of core trench equal to ¼ of the reservoir head. Also it is important to clean the area with hand tools or air/water jets after excavation. A two phase grouting program would consist of area grouting to seal the close jointed and fractured rock and a grout curtain extended the length of the embankment and beyond. Pressure relief drainage systems are not necessary.

Evaluation of Borrow Materials Impervious Core: It is not recommended to use valley alluvium because they are difficult to compact and become sloppy when wet. It is estimated that 905,000 cubic yards of colluvial soils are present and consist of plastic silt and clay soils with optimum moisture content. The landslide debris material could be improved by mixing during excavation. About 500,000 cubic yards of plastic clay and clayey silt from 10 to 13 feet with close to optimum moisture levels. In summary, sufficient quanities of fine grained silty and clayey soils exist along valley slopes and in landslide debris to construct the impervious core. Granular Shell: It would be difficult to avoid mixing silty soils with the gravel beneath within the valley alluvium. The alternative gravel borrow within the alluvial fan deposit has an undetermined depth of gravel with cobbles and boulders. The high water table made it difficult to determine the percent of each size of gravels so this should be evaluated again. The design values of gravel including permeability was listed. Riprap: It was not determined which quarry would yield the riprap 10-18 inches stone needed. There were a few locations which may produce some of the rocks needed.

The embankment dam design would include a central core ¼ width of the reservoir head located at or slightly upstream of the centerline. The shells would be constructed of gravel, the outer upstream shell constructed of cobbles and boulders. The foundation should be incompressible.

Appurtenant Facilities The basalt rock in the left abutment would be best for the spillway. The spillway should be lined to prevent erosion. The irrigation outlets can be located anywhere on the embankment and they will be have a sufficient foundation and should be lined with concrete.
See the twelve summary of recommendations on page 85 and 86.
Tables 1-5 consist of soil data for each test pit that helped determine the locations of material to use for the dam explained above (*Appendix B: Section2*).

Geologic and Subsurface Investigation for the Proposed East Pine Creek Dam, Volume II, Summary of Field and Laboratory Test Data. January 1975. Shannon & Wilson, Inc.
This volume contains entirely figures and data of the studies that were detailed in Volume I. The following summary does not list each figure title but describes the data for the results (*Appendix B: Section 3*).

6.2 Wolf Creek Reservoir Complex Geology

Watershed Work Plan, Wolf Creek Watershed. September 1966. Union Soil and Water Conservation District and Powder Valley Water Control District, USDA NRCS and USFS.

This document included geology of the watershed and the geotechnical data for the damsites. There was an additional damsite discussed but most of the report focused on Wolf and Pilcher Reservoirs. The summary is written by each section heading.

Geomorphology: Wolf Creek watershed consists mostly of Elkhorn Mountains eroded by glacial action. The N and NE section is intermediate highlands with block faulted lava flows as the composition. Rolling rounded landforms is composed of exposed metamorphic rock along the middle reaches of Jimmy and Wolf Creeks. The central and S section is flat rolling alluvial plain with alluvial fans and braided channels, meanders, and oxbows.

Stratigraphy Six stratigraphic units of the watershed can be divided into two categories. The pre-Tertiary metamorphic and granodiorites are older, underground rocks that make up the Elkhorn range and Clover Creek formations. The younger rocks of the N, NE, Central, and S section of the watershed are Tertiary and Quaternaray lavas with lake sediments, valley fill alluvium, glacial deposits, and recent stream gravels.

Structure The watershed consists mostly of uplift and block faulting with intense folding and faulting in the pre-Tertiary, and milder folding and faulting in the younger rocks. Secondary faults in the NW direction exist.

Soils The bottomland soils are from recent alluvial materials, deep, poorly drained, high organic matter content. There is a high water table in spring and can grow all crops with high yields. The more alkaline, poorly drained bottomland soils are deep with moderate organic matter. The water table fluctuates and yields below average alkali adapted crops. The fan and terrace soils exist on a steeper slope, deep, well drained, and moderate organic matter. All crops can grow with above average productivity. The footslope soils are deep, with moderate organic matter. Row crops were not recommended on steeper slopes but yield above average. The rangeland and timberland soils are the most common with rock outcroppings and subject to erosion on steep slopes.

Surface Investigations A detailed site geologic map was created for Wolf Creek, Pilcher Creek, and Sunnyslope dam sites and consisted of the surface inspection of rock types, stratigraphy, and structure.
Subsurface Investigations: Seven test holes were drilled along the centerline from 30-61 feet deep for Wolf Creek Reservoir. Six test holes were drilled 20-101 feet deep along the centerline and emergency spillway for Pilcher Creek Reservoir. Pressure tests and penetration tests were also performed. Three pits were dug along Sunnyslope channel and seven along Wolf Creek channel to map stratigraphy, obtain soil samples, and penetration tests.

Foundation Grouting Investigations: Pressure tests, condition of bedrock, structural geology, and hydraulic head about the foundation were performed to determine the grouting needs for each of the three dam sites. Plans and producedures were developed from the Manuals.
Sedimentation Investigations: The sediment storage capacities for each of the three reservoirs were calculated along with the sediment production rates and stream channel bank erosion rates.

__Construction Materials Investigations__: A grid of pits was dug to investigate borrow material sites at each of the three reservoirs. 26 pits were dug to investigate the borrow site on Pilcher Creek. Five pits were dug on the Sunnyslope site. Classification, permeability, and compaction tests were performed on these borrow site samples. 24 pits were dug for the Wolf Creek sites and two sand quarries were located nearby. Riprap stone was estimated.

Structural Measures There is a summary of the plans for the Wolf Creek, Pilcher Creek, and Sunnyslope dams and spillways (*Appendix B: Section 3*).

Construction and Material Specifications and Construction Drawings for Pilcher Creek Dam. June 1981. USDA NRCS.
This document details the construction specifications and material specifications. The following figures are specifically related to the geology and geotechnical explorations that were completed (*Appendix B: Section 4*).

Archeological Investigation, Pilcher Creek Dam and Reservoir. May 1982. Frank Reckendorf, Diane Gelburd, and Clyde Scott, USDA NRCS.
This report focused mainly on the archeological investigations of the reservoir site but the geology of the area was discussed because of its importance to archeological investigations. The summary is written by the report section heading.

Regional Geology Summary of the stratigraphy of the region. Six layers were discussed. The most common basalt layer of the area produces outcrops and weathers rounded cobbles.
Reservoir Area Geology: The immediate reservoir area consists of rocks from pre-Tertiary to Holocene age. The east side has highly weathered exposed pre-Tertiary and fine grained Miocene basalts. The west side has few rock exposures. The right abutment and reservoir bottom consists of alluvium. The N and NW portion of reservoir consists of poorly graded gravel about 4.5 feet thick and is probably glacial outwash or deposits from Elkhorn Ridge.

Geomorphology General description of the ranges and elevations in the Blue Mountains around Pilcher Creek. The immediate area surrounding the reservoir consists of flats, saddles, and ridges from which Pilcher Creek flows as an arc to the North Powder River with many intermittent tributaries all controlled by joints, faults, bedding and a ridge. The abutments are steep.
Soils of the Reservoir Area: Seven soil series were identified. This section describes the soils most important to the archeological study, not a detailed description for the entire reservoir area.

Site Descriptions Four prehistoric sites were tested and detailed in this report. At each site, the soil was described in 10 cm intervals. The soil description is very detailed and may be helpful when additional information is needed (*Appendix B: Section 5*).

6.3 Thief Valley Reservoir Geology

Thief Valley Reservoir, 1992 Sedimentation Survey. March 1994. Ronald L Ferrari, Bureau of Reclamation.
This report focused on the sedimentation of the reservoir and the geology discussion was limited.
Soils are loose and consist of a silty loam found in moderate to deep depths.

Reservoir Volume Increase at Thief Valley Dam, Oregon. September 2001. BOR Technical Service Center, Denver, Colorado and the Snake River Area Office.
Harza conducted a geotechnical evaluation, estimating rock mass parameters. No concerns were raised. Rock erosion is apparent from small spillway flows. CRF addressed the lack of channel erosion under high spillway flows and for low angle foundation discontinuities to underlie the buttresses and daylight in the scour hole.

In 1994 geologic mapping and index property testing were performed to determine if foundation wedge failure from sliding along joints would be possible. Foundation wedge failure was determined doubtful. No large landslides have been observed within the vicinity of the dam, however, approximately, 2000 ft upstream a moderate size landslide took place, and if reactivity should occur it would not pose a threat to the dam. Tailwater depth and the occurrence of erosion thereof is a concern with installation of the rubber dam. The initial depth of the tailwater will increase the amount of erosion in the spill way plunge pool when water is released from the rubber dam. Tailwater cushions and safeguards the foundation against erosion from spillway flows with deeper tailwater providing for greater protection. Due to the short period of time required to release water large flows are likely on the tailrace area before tailwater depth can increase. Therefore tailwater is initially shallower creating more erosion at the toe. After a short period of time the tailwater will build up. Tailwater depth from the existing dam increases as the flows from the existing spillway increases, allowing for protection against larger flows.

6.4 Hardman Reservoir Geology

Geologic Report for Feasibility Design Request, Hardman Damsite, Burnt River Project, Oregon Dark Canyon Division. January 1965. C.E. Larson, Bureau of Reclamation.
This report detailed the geology for the reservoir and the geotechnical data collected for drill hole tests.

Regional Geology- Hardman is located in the Blue Mountains or a “Steptoe” (island) mountain which is composed of Paleozoic and Mesozoic meta- sedimentary rocks and flat lying basaltic and andesitic lava flows of the Tertiary (Miocene) age. The present topography and drainage was formed during the Pliocene and Pleistocene epocha. The highlands were eroded and incised with deep canyons. The Snake River Lava flows created numerous lakes near the lower lying areas of the Columbia River lavae. These lakes and their discharging streams provided the depositional environment for the Idaho Formation consisting of claystones, siltstones, and sandstones which cover much of the Eastern Blue Mountains. Alluvial fans and terraces are also characteristics of the region.

Damsite Geology – The Columbia River lavas and the Idaho formation encompass the South Fork of the Burnt River, including Hardman Damsite. The canyon is about 300ft deep at the dam site, sloping above the canyon rim and rising another 3000ft between the adjacent drainages. The Canyon walls at the site are composed of andesitic basalt, volcanic braccia and agglomerate, and bentonitic tuff, which are covered by 3 to 15 feet of talus and slopewash. Andesitic basalt is bare at a few large and small outcrops and along cuts adjacent to the irrigation canal. Andesitic basalt was found at the outcrops and in the core from drill holes.

Columbia River andesitic basalts and related volcanic rocks are found on the hills and peaks flanking the canyon of the South Fork of the Burnt River for many miles upstream from the damsite. Downstream from the damsite the canyon walls are composed of Columbia River lavas overlain by Idaho Formation.

High angle faults in the northwest are common in the area, however no faults have been observed with 2 mile radius from the damsite and reservoir area. The left abutment rises on a slope of 27 degrees more than 200 feet above the valley floor. The left abutment area and the dam axis is formed by bedrock covered by talus, slopewash and fragments of andesitic basalt ranging in size from pebbles to small boulders mixed with dark brown, clayey to silty soil. At drill hole DH-3 the overburden of talus and slopewash is 5.3 feet and is assumed to thicken to 15 ft or more near the base of the slope. Andesitic basalt is found within 500 feet of the dam axis on the left abutment. Approximately 30ft above the stream, low on the left canyon wall, and 500 to 900ft upstream from the dam axis is a vertical ledge formed of andesitic basalt. The left abutment is comprised primarily of andesitic basalt flows with volcanic braccia and agglomerate and bentonitic tuff. The tuff encountered in DH-3 is thought to intercept the overburden on the left abutment from 20 to 50 feet above stream level. It appears as though the tuff is bentonitic, feeling soapy or waxy and when whet slakes. The tuff will require special treatment when excavated and should not be used as a foundation for the spillway or outlet works.

Percolation tests were performed at the dam, the left and right abutments and on the valley floor to determine water loss. It was recommended that extensive grouting be required to prevent excessive seepage around the dam due to high water losses from fractures and joints in the braccia and andesitic basalt layers. The left abutment indicated lower water losses. The valley floor is covered by alluvium and is approximately 150ft wide with the total thickness undetermined; however it is assumed to be thousands of feet. Percolation tests on the valley floor indicated, showing water losses of 2.6 - to 1gpm or less. The valley floor is composed of volcanic braccia and the andesitic basalt.

The right abutment rises on a slope of 27 degrees cresting at 160 ft above the valley floor. Andesitic basalt and associated volcanic rock form the right abutment of the Hardman Damsite. The slope is steeper near the base and is interrupted by an irrigation canal and excavation material. Gradually the slope reverses, forming a shallow bowl with the low point lying almost on an extension of the dam axis approximately 20 feet below and 400 feet southwest of the crest.

The right abutment is composed of talus, slopewash and reworked alluvium derived from the Pleistocene alluvial fans. A low brow approximately 450ft long composed of Andesitic basalt lies along the crest of the ridge which forms the right abutment. Andesitic basalt is found at several outcrops on the right abutment and along the base of the canal. The right abutment is scarred with numerous fractures which lie in a horizontal plane; however the fractures along the canal are vertical.

Idaho Formation was found in the spoil piles in the canal and 3 to 4 feet along a road near the Southern margin of the Areal Geology Map. Idaho Formation was not encountered in the drill holes; therefore it is believed to thin toward the northwest. Talus, slopewash, andesitic basalt, volcanic braccia and agglomerate and bentonitic tuff were encountered at Drill hole DH-1: roughly 4380 feet on the right abutment. Based on the information obtained from the drill holes the andesitic basalt, braccia and tuff appear to be regular and linear. However due to the extreme variation of the Tuff at the drill holes the tuff may actually be irregular. It should be noted that the tuff on the right abutment also contains troublesome material which will require special treatment during excavation and should not be used as the foundation for the spillway or the outlet works.

Water losses were tested in each hole at 25psi and 50psi. It was determined that water losses were high both in the braccia and andesitic basalt; especially at 50psi. No water losses occurred in the tuff. Due to the high water losses it is recommended that extensive grouting will be necessary on the right abutment to prevent water loss.

The foundation is considered adequate for the proposed structure with uncertainties noted in the high water losses during percolation tests and the bentonitic tuff underlying the abutments.

Reservoir Geology – Geologic conditions at the reservoir site are the same at the dam site. The left bank is composed of Columbia River lavas and associated volcanic rocks. The right bank is composed of andesitic basalt, braccia, and tuff. It is noted the extent of the tuff in the reservoir should be determined, due to the possibility of the tuff raveling out causing undercutting of the rock overlay. Shoreline erosion above the tuff body is believed not to be a problem due to the lack of Idaho Formation, andesitic basalt and volcanic rocks not being present.

A tributary water table is indicated by the presence of springs upstream and downstream of the dam site and the water table data from the drill holes at the dam site. The water table was found to be 20ft below the ground surface and 17 feet below stream level, therefore high seepage losses are not expected from the reservoir.

Construction Materials – It was determined that the valley floor and the lower valley slopes will provide sufficient quantities of material for embankment fill. A small alluvial fan is at the mouth of Amelia Creek, which is approximately 800 feet upstream from the damsite. Six auger holes indicate the area is composed of lean and sandy lean clays and irregular lenses of silt and gravel. The material extracted from the auger holes and examined was high in moisture content. It is believed the moisture content may be able to be drawn down by shutting off the water to the irrigation canal. The stream channel and valley floor could provide the sand and gravel for concrete aggregate and draining materials. Riprap and rock fill can be used from the left slope approximately 500ft upstream from the damsite, however sufficient quantities will need to be determined. If there is not enough rock within the reservoir area additional rock can be found downstream from the dam site.

Mineral Resources at Dark Canyon, Petticoat, and Hardman Reservoir Sites, Burnt River Project, Baker County, Oregon. April 1965. Robert N. Roby, Bureau of Mines.
The focus of this report was solely on the minerals that could be extracted at each site but there was a portion of geology data.

Geology - Mineral resources would not be affected by project work. Hardman dam site lies in an area of moderate relief and the stream gradient throughout the reservoir site is 79.5 feet per mile. The geology of the area is composed of Paleozoic and Mesozoic and Tertiary series rocks. Pre-Tertiary rocks consisting of argillite, greenstone, schist and limestone are also found within the Hardman damsite. Quaternary deposits of Pleistocene terrace and bench gravel are present along the stream beds. The Hardman site is found within canyons imbedded within Tertiary andesite and lava.

Impact Survey Report (Stage 1). June 1967. USDA, Forest Service.
The geology data of this report was limited to one section and was general.

Project and Immediate Vicinity – The north side of the reservoir and at the damsite is bound by hard andesite bedrock. The area is characterized by steep, lightly vegetated slopes. The soils on the south side of the reservoir are characterized by deep impermeable clay terraces dissecting into shall drainages. Three of these drainages (Amelia, Barney and Stevens Creeks) flow year long and enter the proposed reservoir basin. In 1939 45% of the drainage was severely burned. A ridge acts as a boundary separating the South Fork basin from the John Day River drainage on the north and the Malheur River on the south. The basin is circular, opening to the northeast. The upper elevations are composed of very thick soil mantles consisting of loamy glacial moraines with overlays of volcanic ash. The lower elevations are characterized by thinner mantles of ash occurring over clay loam subsoil's and basaltic bedrock. The erosion hazard is moderate in the higher elevations and high on the lower slopes. An informal assessment was conducted and did not indicate any historical or archeological sites within the proposed reservoir.

7.0 Recreation

Thief Valley Reservoir and Wolf Creek Complex presently offer a plethora of recreational actives including but not limited to camping, fishing, hiking, wildlife viewing, and biking, picnicking, boating, and horseback riding. Thief Valley Reservoir is known for its excellent fishing and premier windsurfing.   The construction of East Pine Reservoir and Hardman Dam would also provide an excess of recreational opportunities.

Recreationalists tend to fall into two categories 1) those whom are "active" consumptive users and 2) those whom are "quiet" nonconsumptive users. "Active" consumptive users are defined as those individuals partaking in motorization, such as boating, jet skis or ATV's. "Quiet" nonconsumptive users are defined as individual participating in non-motorized activity. Both "active" consumptive and "quiet"non-consumptive uses are or could be provided at the reservoirs.   The below diagrams demonstrate the nature of "active" and "quiet" uses.

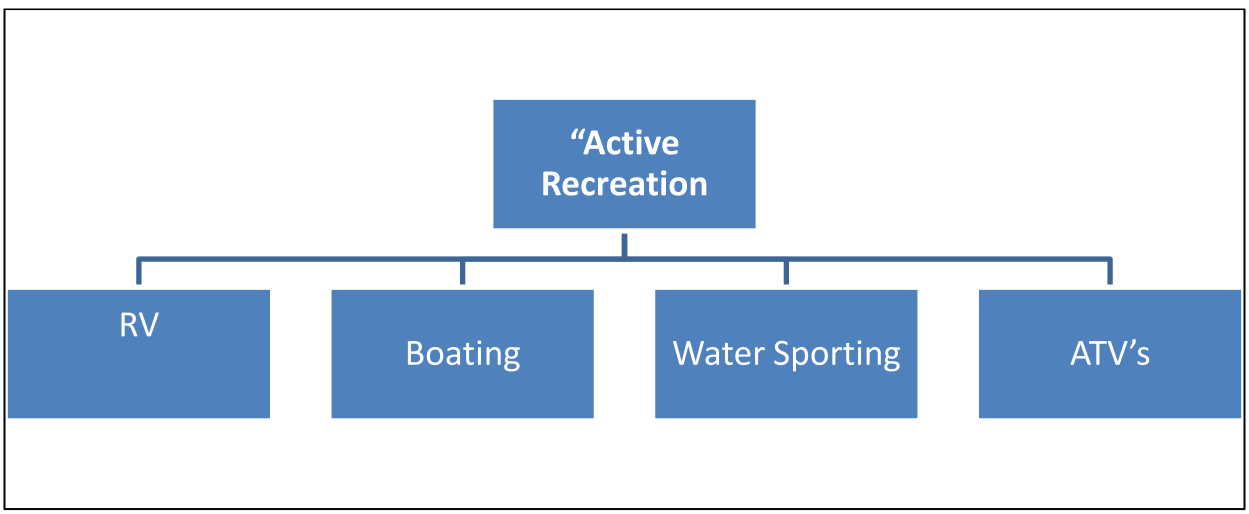


Figure 23. Active Recreation

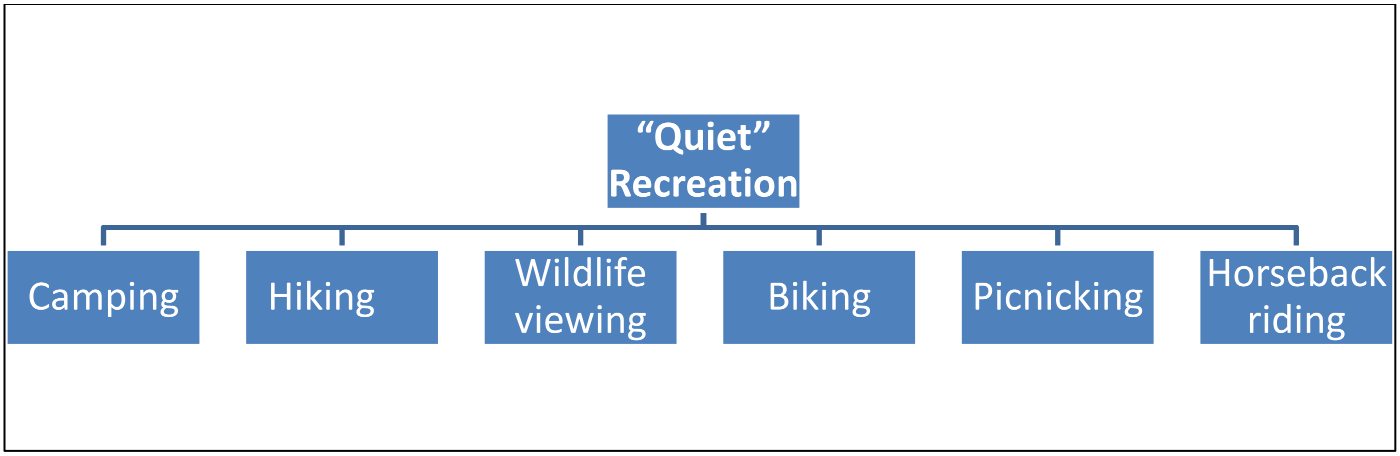


Figure 24. Quiet Recreation

The average use of reservoirs typically occurs May thru October with peak use during the month of July. Recreational uses can be in the form of a recreation day, a visitor day and a recreational night, all of which may be quantified by days and/or hours. According to the *2008 North Powder Reservoir Cost/Benefit Analysis* a *recreation day* is defined as any person visiting an area for recreational purposes during any portion of any given day. A *visitor day* is defined as twelve hours of recreational use. A *recreational night* is defined as a person staying in the area for the night. According to the *2008 North Powder Reservoir Cost/Benefit Analysis* is estimated that by 2010 there would be approximately 123,840 recreational days, which translates into 2,972,160 visitor hours. In 1994, Zone 5 which blankets Baker County had a total of 584,982 hours of recreation (Hells Canyon Complex, 2002).

Recreation has a positive impact on the economic viability of Baker and Union Counties. A recent survey completed by *Dean Runyan Associates in 2008* concluded that state residents and non-residents make three distinct types of fish and wildlife recreation expenditures: travel-generated, local recreation (less than 50 miles one way) and equipment purchases.

In order to provide a clear and concise perspective of the recreational impacts and dollars contributed to Baker and Union Counties, expenditures were analyzed separately by type and county and cooperatively. Expenditures analyzed were travel generated expenditures, local recreation expenditures and combined activity expenditures.

Travel generated expenditures by activity are made by residents and non-residents and include the total travel spending in the desired county to recreate. It is important to note that 84% of the fishing ("Active" users) expenditures and 93% of the wildlife viewing ("Quiet" users) expenditures were generated as overnight (3-4 day stay) vs. recreational day expenditure. Recreationalists tended to stay 3-4 nights and recreated with their immediate family instead of in groups. The graph below depicts Travel-Generated Expenditures in Baker and Union Counties by activity for 2008.

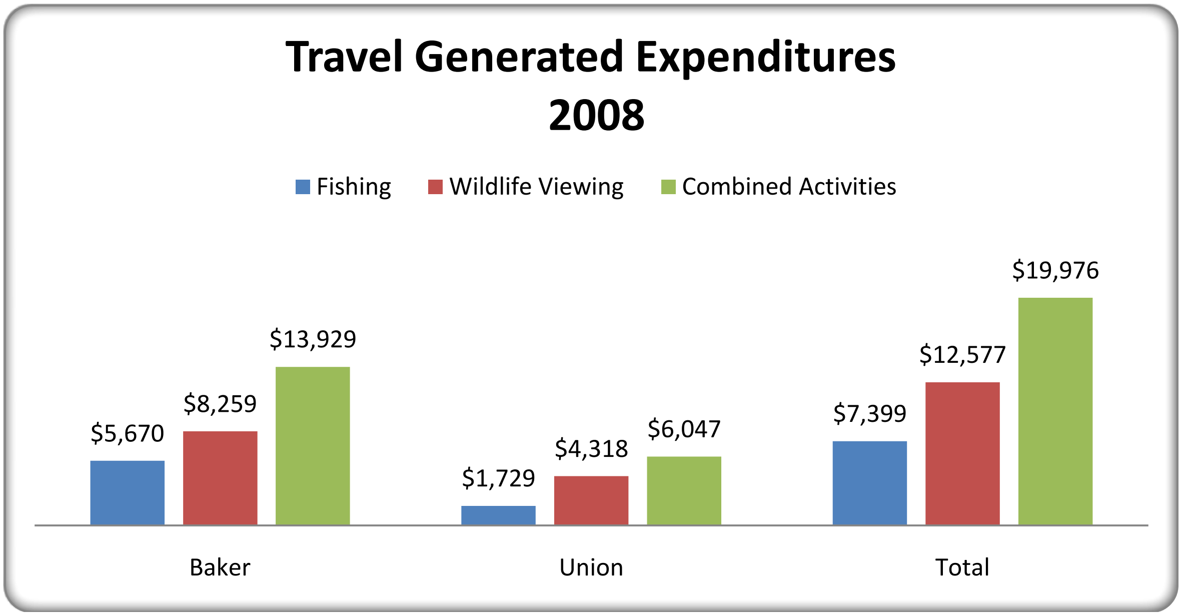


Figure 25. Travel generated expenditures

Local recreation expenditures by activity are the recreation-related expenditures made by residents of Baker or Union county for day recreation. The graph below depicts local recreation expenditures in Baker and Union Counties by activity for 2008.

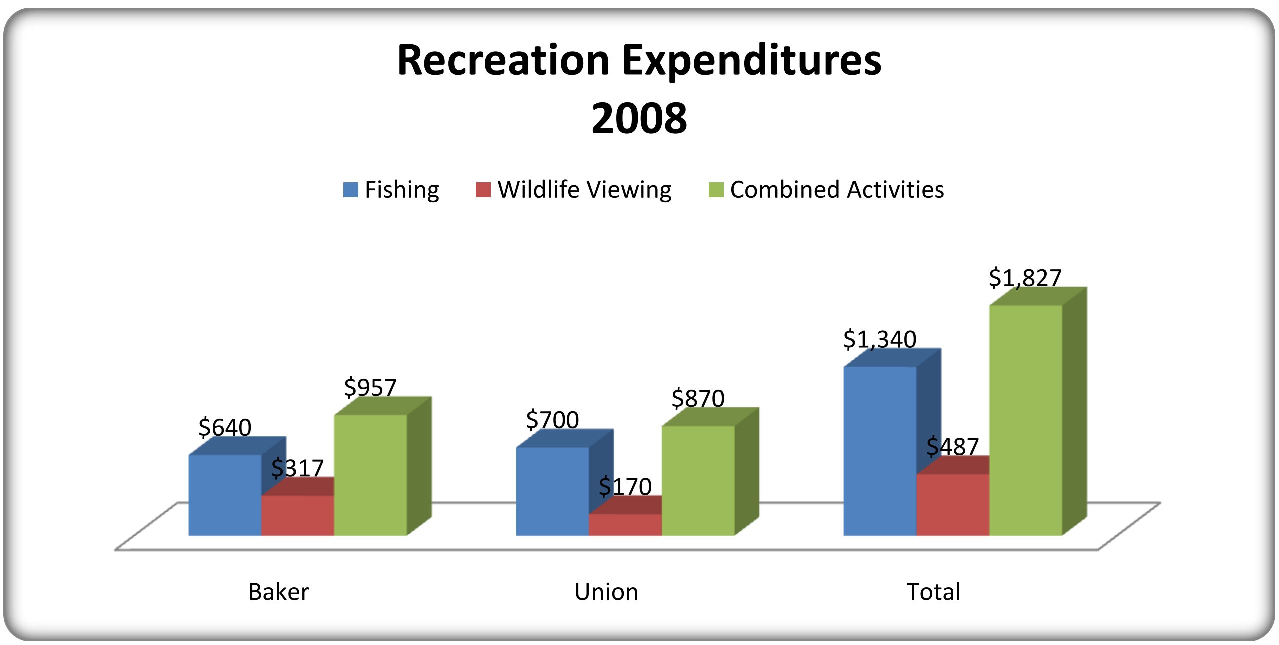
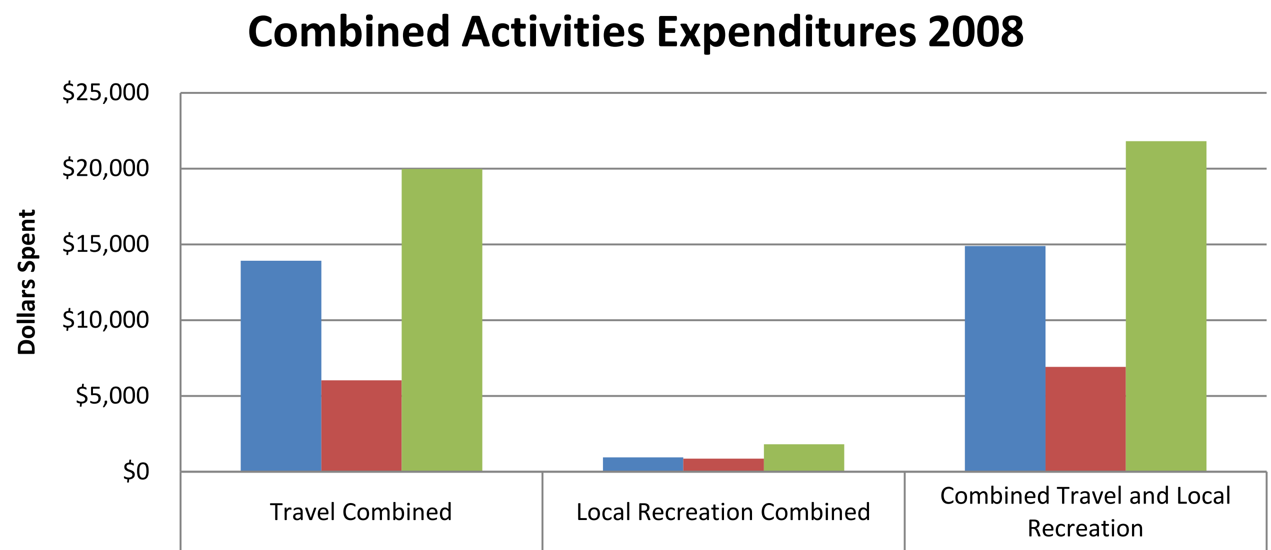


Figure 26. Recreation Expenditures

Combined activities expenditures analyze the contribution of fishing and wildlife viewing as one component and compares counties independently and collectively. The graph and table below depicts combined activities expenditures in Baker and Union Counties for 2008.



	Travel Combined	Local Recreation Combined	Combined Travel and Local Recreation
Baker	$13,929	$957	$14,886
Union	$6,047	$870	$6,917
Total	$19,976	$1,827	$21,803

Figure 27. Combined Activities Expenditures 2008.

Recreation has been growing at a rate of 9 percent annually until 2010 when it dropped to 5 percent from the flailing economy. Escalating fuel prices have been a driving force in encouraging recreational activity closer to home. Recreationalists tend to travel 50 to 100 miles from home and tend to travel less distances to recreate in slow or depressed economy (King Ranch Feasibility Report, 2005). According to the 2010 Oregon state parks annual report, “the most dramatic increases and decreases in year-to-year park visits result from the weather,” indicating fuel prices are not the culprit.

To bring the significance of recreation full circle it is imperative to note that in 1994 Federal Parks received 380 million visitors and generated 44 billion dollars in revenue. 12 Billion dollars were spent on goods and services stimulating local economies (National Lakes Study, 1998).

The expansion of Thief Valley Reservoir and Wolf Creek Complex and the construction of new reservoirs at East Pine and Hardman would allow for more value added income to both Baker and Union Counties. Added value income refers to the labor income and property income that is realized from a new economic activity which is a direct effect of the construction or alteration of a reservoir. According to the U.S. Department of Agriculture (2005 ESR Report Summary) “Rural tourism and recreational development leads to higher employment growth rates and a higher percentage of working-age residents who are employed. Earnings and income levels are also positively affected.”

With the alteration or construction of a new reservoir, long term economic relief will be needed to aid in the absorption of all costs. Most reservoirs and parks charge a fee for camping with prices ranging from $ 10.00 per night to $25.00 per night along with an additional $5.00 applied to extra vehicles. Fees are determined by full improved (water and electricity and sewer,) or semi improved (water and electricity) or primitive (improved sites). Fees are also dependent upon who owns or manages (federal, state, county, city) the reservoirs and parks.

8.0 Real Estate: Cost Estimate of Reservoir Construction and Land Acquisition

The cost estimate of reservoir construction is based on existing water inundation levels as calculated by the BOR, based on existing hydrologic data and water storage at 90% exceedance level. No other land acquisition, such as recreation, was taken into consideration for the real estate portion of this study for the proposed inundation levels.

8.1 East Pine Reservoir Real Estate

The proposed reservoir surface area will be approximately 266 acres with a proposed recreation area of 35 acres. Of the total 301 acres that are needed to acquire, 159 acres is owned by private land in the Timber-Grazing zone, 66 acres is owned by the County in the Timber-Grazing zone, and 76 acres is owned by USFS zoned Primary Forest. The cost per acre was based on 2009 real market value and the total cost for 301 acres is approximately $257,906.00.

Table 26. East Pine Reservoir Land to Acquire by Tax Lot

Tax Lot (T7S R46E)	Owner	Total parcel acres	Real Market Value	Acres under reservoir	Price
800	Smith	160	$120,880.00	135	$101,993.00
700	Smith	20	$35,690.00	14	$24,983.00
1000	Baker County	40	$61,030.00	23	$35,092.00
600	Baker County	60	$71,010.00	43	$50,891.00
300	Denson	200	$140,830.00	10	$7,042.00
100	USFS	15,398	$7,679,840.00	76	$37,905.00
				301	**$257,906.00**

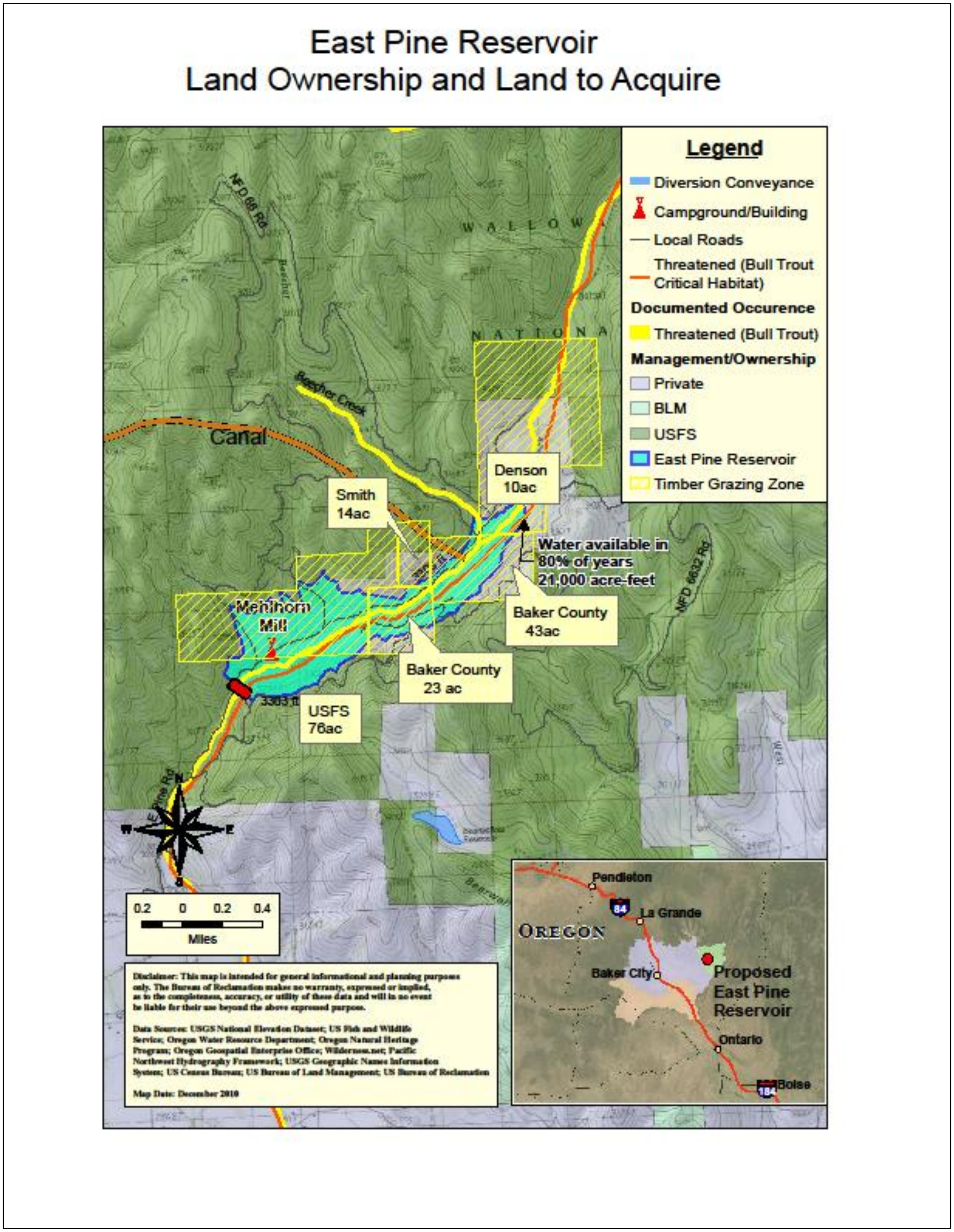


Figure 28. East Pine Reservoir Land to Acquire

8.2 Hardman Reservoir Real Estate

The proposed reservoir surface area is approximately 257 acres. A recreation area has not been determined in the proposed inundation levels; it is unknown at this time. There is no documentation about a proposed recreation area for the Hardman site, therefore that cost would be additional. Private land includes 36 acres zoned Exclusive Farm Use, Irrigation District land includes 158 acres zoned partially EFU and Timber-Grazing, and USFS land to be acquired includes 63 acres zoned Primary Forest. It appears by the shape of the Irrigation District land, this land was purchased for this reservoir. The cost per acre was based on 2009 real market value and the total cost for 257 acres is $75,329.00 and this includes the Irrigation District property of $37,229.00.

Table 27. Hardman Reservoir Land to Acquire by Tax Lot

Tax Lot (T13S R36E)	Owner	Total parcel acres	Real Market Value	Acres under reservoir	Price	Zone
1700	Coneen	800	$148,430.00	36	$6,679.00	
2700	Burnt River Irrigation District	366	$86,240.00	158	$37,229.00	
600	USFS	11,321	$5,646,350.00	63	$31,421.00	
				257	**$75,329.00**	

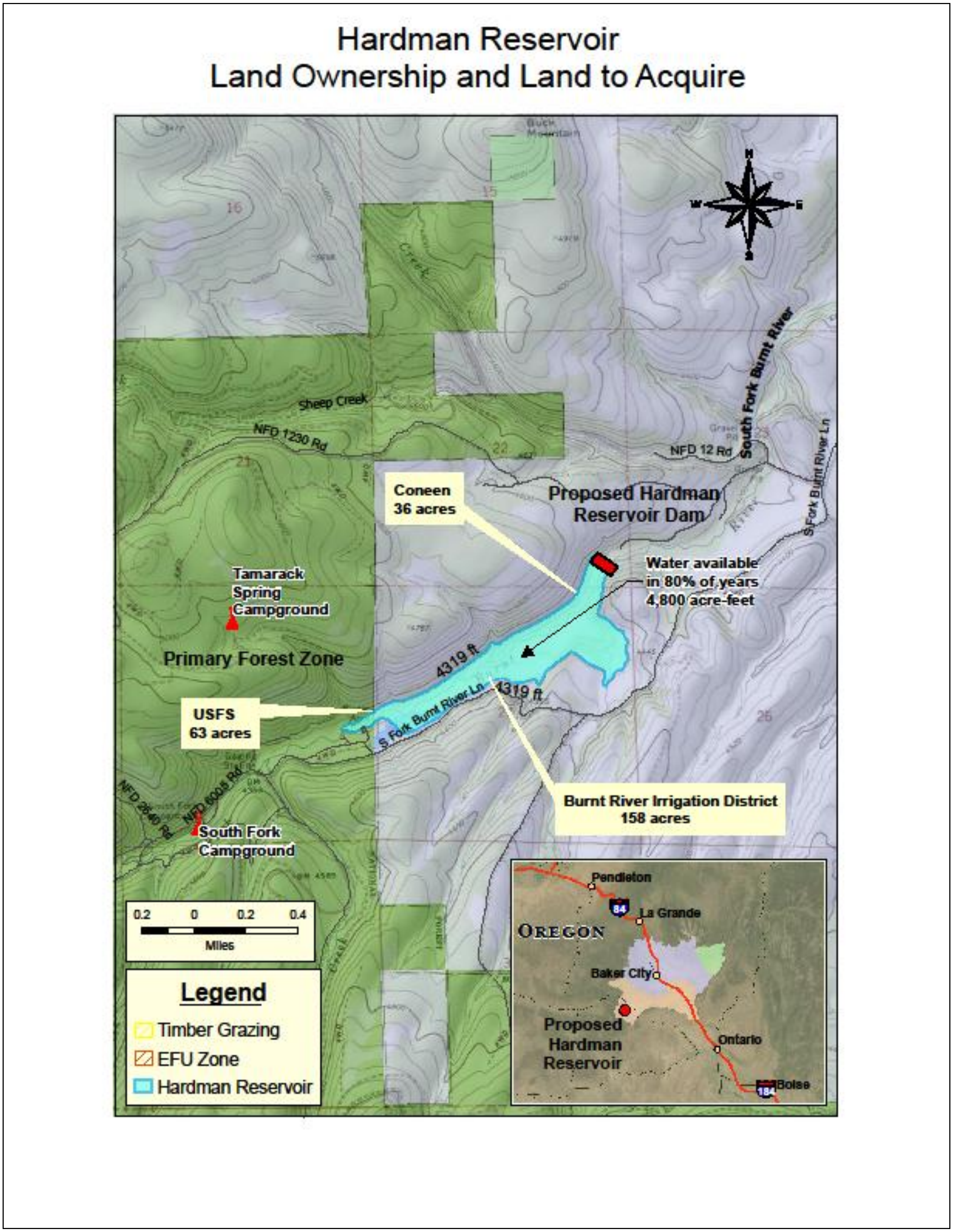


Figure 29. Hardman Reservoir Land to Acquire

8.3 Thief Valley Reservoir Real Estate

The current elevation of this existing reservoir is 3,143 feet and the proposed dam raise of 6.3 (3,149.3 elev) feet will increase the surface area of the reservoir by 5 to 7 acres. Land owned by the BLM encompasses the entire current reservoir and some area surrounding the main body (see Figure 3). However, two private land owners are adjacent to the reservoir/BLM land and their property may need to be acquired with the dam raise. The exact elevation of the parcel lines is unknown therefore this study is assuming that the new elevation is beyond the BLM property line/current reservoir boundary. 5.5 acres of private land and 2 acres of BLM land may need to be acquired. The total cost is $1,604.48 based on 2009 real market value. The zoning for all lands is Exclusive Farm Use.

Table 28. Thief Valley Reservoir Land to Acquire by Tax Lot

Tax Lot (T6S R38E)	Owner	Total parcel acres	Real Market Value	Acres under reservoir	Price
UNION COUNTY					
2200	Smoke Ranch LP	936	$278,640.00	1	$297.69
2100	Hummel	3685	$1,368,650.00	1	$371.41
700	Smoke Ranch LP	3205	$1,257,660.00	0.5	$196.20
3200	Hummel	68	$20,250.00	0.5	$148.90
2600	BLM	351	$26,330.00	1	$75.01
BAKER COUNTY					
1500	Smoke Ranch LP	175	$22,790.00	1.25	$162.79
1600	Smoke Ranch LP	2522	$335,120.00	1.25	$166.10
1400	BLM	400	$74,550.00	1	$186.38
				7.5	**$1,604.48**

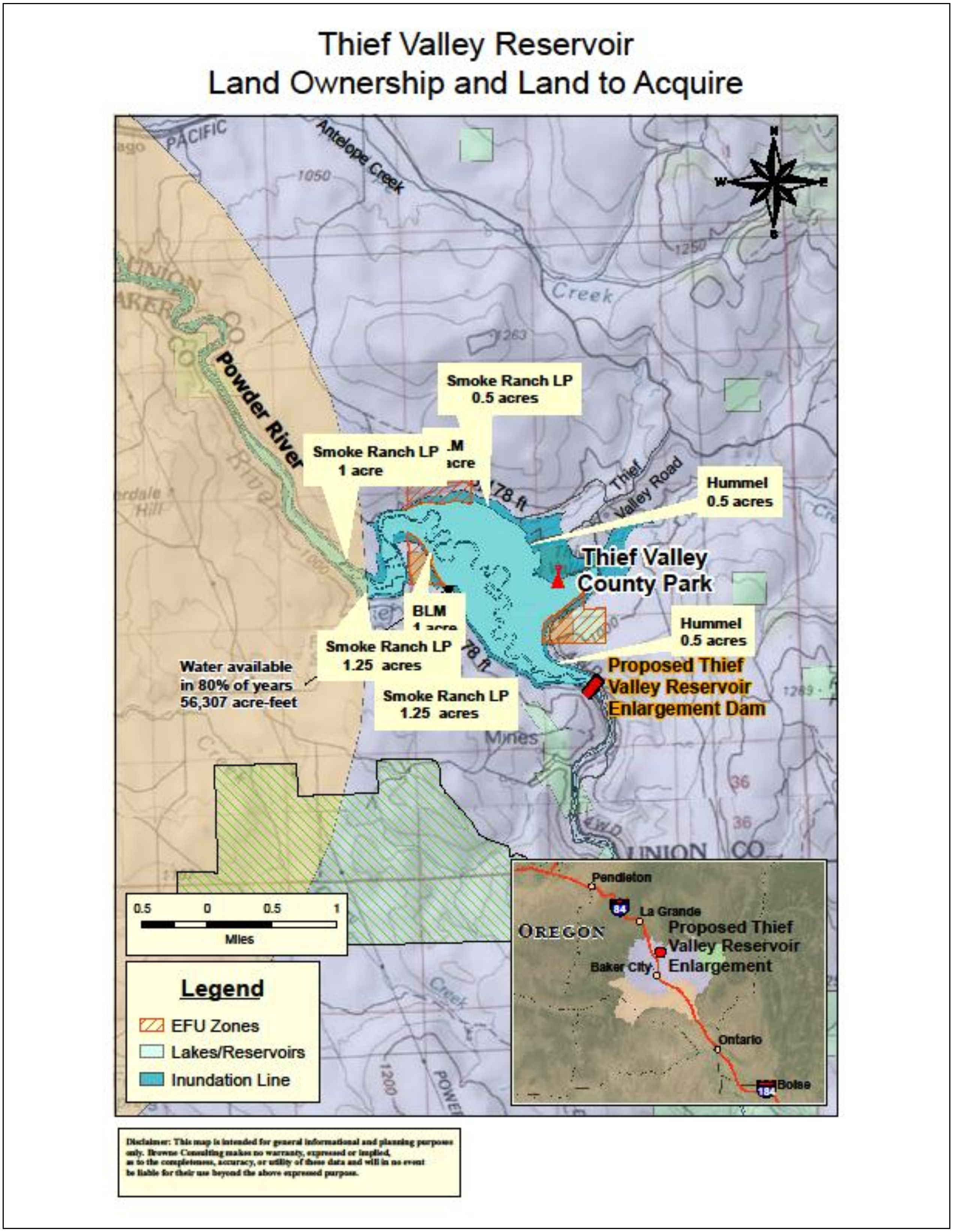


Figure 30. Thief Valley Reservoir Land to Acquire

8.4 Wolf Creek Reservoir Complex Real Estate

This complex includes both the existing Wolf Creek Reservoir and Pilcher Creek Reservoir. The exact reservoir expansion has not yet been determined so for the purpose of this study the maximum expansion was used. Wolf Creek Reservoir is currently at 3,694 feet in elevation with 220 acres of surface area to be raised 40 feet in elevation resulting in approximately 89.5 acres to acquire. Of those acres, the Water Control District owns primarily the entire existing reservoir and just beyond the current elevation. Additional private land would need to be acquired with this dam raise (see Table 5). The zoning of this land is UC-A2. The cost of the 89.5 acres is $30,779 based on 2009 real market value and this includes $2,998 of land owned by the Water Control District. Pilcher Creek Reservoir is currently at 3,971 feet in elevation with 222 acres of surface area and expansion would increase the elevation 20 feet and add 106 acres. The Water Control District owns the land under the current reservoir and just beyond to the southwest. ODFW owns land almost entirely around the reservoir except for a small portion of private land. The cost to acquire the 106 acres would be $46,705 based on 2009 real market value, including $1,050 of land owned by the Water Control District. 90 acres is zoned UC-A4 and the 16 acres of private land is zoned UC-A2.

Table 29. Wolf Creek Reservoir Land to Acquire by Tax Lot

Tax Lot (T6S R38E)	Owner	Total parcel acres	Real Market Value	Acres under reservoir expansion	Price
400	Colton Ranches Inc.	301	$122,620.00	3	$1,222.13
500	Donkers	789	$266,280.00	12	$4,049.89
700	Donkers	162	$59,330.00	10	$3,662.35
2500	Records	584	$272,960.00	15	$7,010.96
3506	Ricker Family Land & Timber	503	$311,570.00	7	$4,335.96
SEC 11					
300	Powder Valley Water Control District	348	$26,080.00	40	$2,997.70
100	Colton	4.85	$14,550.00	0.5	$1,500.00
200	Colton	5.46	$16,380.00	2	$6,000.00
				89.5	$30,778.98

Table 30. Pilcher Creek Reservoir Land to Acquire by Tax Lot

Tax Lot (T6S R38E)	Owner	Total parcel acres	Real Market Value	Acres under reservoir expansion	Price
2200	Heffernan	1301	$422,460.00	16	$5,195.51
2000	ODFW	1077	$544,810.00	68	$34,398.40
2001	Powder Valley Water Control District	289	$21,680.00	14	$1,050.24
2002	ODFW	45	$34,090.00	8	$6,060.44
				106	$46,704.60

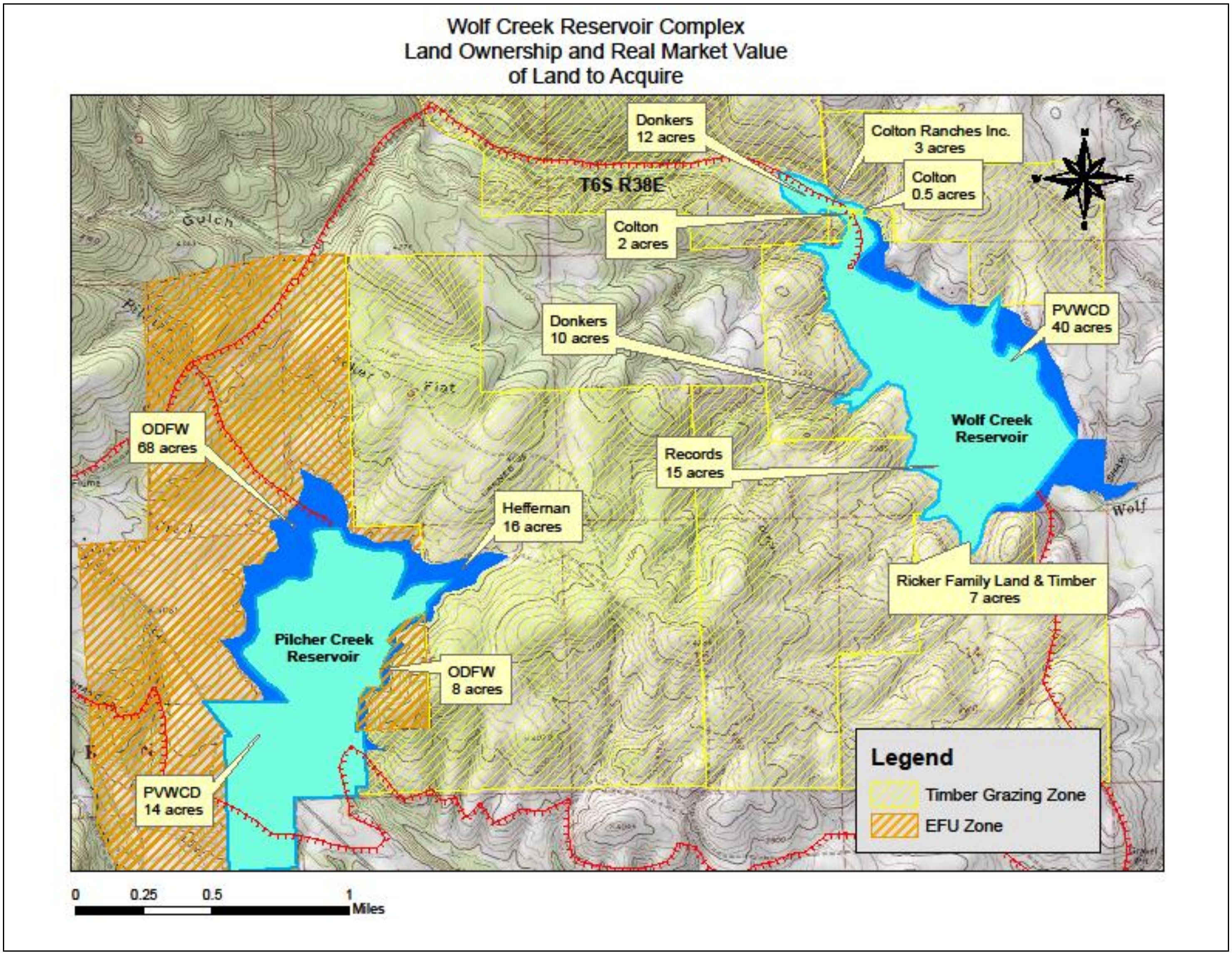


Figure 31. Wolf Creek Reservoir Complex Land to Acquire

9.0 Conclusion

This appraisal-level study provides existing data that validates the water shortage issue in eastern Oregon. Water supply from current water storage and annual precipitation is far from meeting the demand. Not all water users meet their respective rate and/or duty over the full irrigation season. Additionally, water is a critical resource for the economic development and communities within the basins.

As the population is expected to increase, the need for agriculture production, industry, municipal use, and instream demands (i.e. water quality for aquatic life and ecosystem health) will continue to increase at exponential rates as well. Alternative means of water storage and conservation were examined within this report and it was determined that highly efficient irrigation systems and conservation practices alone will not be adequate for meeting water demand. Additionally, due to the geologic layout of the region, it is not feasible at this time to consider aquifer recharge as a water supply option. The only available alternative is above-ground water storage. Above-ground water storage will address all beneficial uses including fish and aquatic life, instream health, hydropower, agriculture, and municipalities.

Furthermore, this appraisal study of existing data resulted in the identification and appraisal-level evaluation of four potential sites to store surplus flows and improve seasonal water supply in these three basins of eastern Oregon. The appraisal-level evaluation of the four potential sites concluded that there are water surpluses available at the sites, that there is need for the storable surpluses, and that storage facilities could be constructed at the potential sites. The appraisal-level evaluation also determined that there is potential for hydroelectric project development at each site and indicated there is potential to improve seasonal streamflows and water temperatures to benefit fish, water quality, and agriculture production.

9.1 Identifying Data Gaps

Through data collection for this document, analyzing existing documents that were collected for the Literature Review, and consultation with affected agencies raw data needs have been identified.

- Additional hydrological data – stream flow
- Map Instream habitat
- Water quality data
- Archeological review and SHPO and affected tribal consultation
- Hydropower feasibility study
- Wetland survey and delineation
- Endangered Plant Species Survey

9.2 Potential Next Steps

The WASH committee requested assistance from Reclamation’s Snake River Area Office in Boise, Idaho, and secured additional federal funding in 2007 to pursue further assessment of water supply opportunities in the Powder River basin. Funds from the Water Conservation, Reuse and Storage Grant Program, established by Senate Bill 1069 to fund the qualifying costs of planning studies that evaluate the feasibility of developing water conservation, reuse or storage projects were used to support the Eastern Oregon Water Storage Appraisal Study. The following general recommendations were provided by Reclamation to the project stakeholders in the DRAFT Eastern Oregon Water Storage Appraisal Study:

- Stakeholders should pursue water optimization studies and implementation through grant and loan programs supported by Reclamation and others. Non-structural actions would help irrigators close the gap in water users' water delivery needs. Watershed management or water conservation, such as those identified in the WASH objectives, listed under current activities should be pursued.
- Stakeholders should consider objectives which further study of hydropower generation optimization.
- To support the above recommendations, stakeholders should pursue means to collect additional long-term hydrologic and water use data within the study area.
- Reclamation finds that none of the alternatives analyzed as water storage projects for irrigation meet federal criteria for further study.

The stakeholders and the WASH Committee do not agree that the findings of the Reclamation study are complete. They have requested that new calculations be performed that take into consideration optimizing hydropower generation, the sale of water instream, recreation income, and new cropping patterns. Reclamation has agreed and is in the process of revising and updating the draft Eastern Oregon Water Storage Appraisal Study. The next steps for the Ecologically Adaptive Water Management Project are to request Reclamation to assist with diversion mapping and additional hydrologic data collection efforts. Then, a full federal Feasibility Study should be considered. This phase includes collecting raw data and further analyzing project cost/benefit. The raw data that would need to be collected is listed in section 7.1 above.

In order to catalyze the effort at this level of study FERC permits and water storage and water use permits will also need to be filed. Once those steps occur, a new level of coordination between affected agencies and stakeholders will need to take place. Additionally, filing with FERC puts the process on a timeline.

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<u>Appendices</u>

Appendix A Description and Ecological Flow Analysis of Hydrologic Data for Four Reservoir Sites in the Powder Basin

Appendix B Geologic Information pertaining to the four designated sites.

Appendix C Letter from State Historic Preservation Office

Appendix D Letter from Oregon Natural Heritage Information Center

APPENDIX A

Description and Ecological Flow Analysis of Hydrologic Data for Four Reservoir Sites in the Powder Basin

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March 2011

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CONTENTS

Table of Figures

List of Tables

DESCRIPTON AND ECOLOGICAL FLOW ANALYSIS OF HYDROLOGIC DATA FOR FOUR RESERVOIR SITES IN THE POWDER BASIN

INTRODUCTION

The Powder Basin is bordered to the north by the Wallowa Mountains, to the west by the Blue Mountains, and to the east by the Snake River. Within the Powder Basin, a series of mountains separates the Powder River Subbasin (HUC: 17050203), the Burnt River Subbasin (HUC: 17050202), and the Brownlee Reservoir Subbasin (HUC: 17050201).

The Powder River Subbasin encompasses 1,096,900 acres (NRCS) including several main tributaries: the Powder River, North Powder River, and Eagle Creek in Richland and Pine Creek in Halfway for a total of 1,668 miles of major streams in the subbasin (NRCS). The Powder River is 144 miles long and drains more than 1,540 square miles (Oregon Department of Agriculture). It originates in the Elkhorn Range of the Blue Mountains, flows into Phillips Reservoir, which has a storage capacity of 90,500 acre-feet (Oregon Department of Agriculture), and then into the Baker Valley. The North Powder River originates farther north in the same mountain range, and has two existing water storage sites; Wolf Creek Reservoir has a storage capacity of 10,800 acre-feet (Oregon Department of Agriculture). The Powder River and North Powder River converge above Thief Valley Reservoir, which has a storage capacity of 17,400 acre-feet, terminating 78 miles later in the Brownlee Reservoir on the Snake River (Oregon Department of Agriculture). The Powder River Basin is above 11 Snake River and Columbia River dams (Kerns).

The Burnt River Subbasin encompasses 705,600 acres (NRCS), and is bordered by Grant County to the west, Malheur County to the South and the Snake River to the east. There are a total of 830 miles of major streams in the Burnt River Subbasin (NRCS). The main tributaries of the Subbasin are the north and south forks of the Burnt River, which originate in the Blue Mountains and converge above Unity Reservoir. Unity Reservoir stores 24,972 acre-feet of spring runoff used for supplemental irrigation and is a Bureau of Reclamation project (Burnt River Irrigation District). The Burnt River water system is above 11 Snake River and Columbia River dams (Kerns). There are neither anadromous fish nor Bull Trout present in the streams of the subbasin, and none of the streams is listed as essential fish habitat for threatened or endangered species (Stream Net from NRCS).

The Brownlee Reservoir Subbasin ecompasses 414,000 acres (NRCS) and is surrounded by Baker County to the west, Wallowa County to the North, Malheur County to the South and western Idaho on the east. Major tributaries of the Snake River, which include Pine Creek and associated tributaries and Wildhorse Rvier and tributaries for about 421 miles of stream. Pine Creek originates in the Eagle Cap Range of the Blue Mountains and joins the Snake River below the Oxbow Dam. The Pine Creek drainage is above 10 Snake River and Columbia River dams (Kerns).

Through a basin wide process to identify and narrow down potential above ground water storage projects the Water & Stream Health Committee in cooperation with the Bureau of Reclamation and all partners and stakeholders have identified four potential projects. The four projects include increasing reservoir capacity of the Thief Valley Reservoir on the Powder River, East Pine Reservoir Site on East Pine Creek near Halfway, increasing reservoir capacity of Wolf Creek and Piltcher Creek Reservoirs at the North Powder River Complex on Wolf and Anthony Creek, near North Powder, and Hardman Dam site in the South Fork Burnt River drainage.

At the request of the Water & Stream Health Committee, the Bureau of Reclamation conducted a Natural Flow Determination based on demand areas within the various subbasins for a 30-year period. While attempting to collect data for the study it was realized that there were relatively few stream gauges that had been active for 30 consecutive years and in some key areas there are no stream gauges. Consequently, Reclamation undertook the task of developing a model so that when stream gauge data became available it could just be loaded into the model and a basin yield analysis would then be compiled. The model is called the MODSIM model. Computations for stream flows are based on monthly data from 1971 through 1999. The reservoir sites and stream gauges that computations are derived from are as follows:

Thief Valley Reservoir	Powder R bl Thief Valley Res nr N Powder, OR	13285500
North Powder Reservoir	Anthony Cr bl N Fk nr N Powder, OR	13282400
Wolf Creek Complex	Wolf Cr ab Wolf Cr Res nr N Powder, OR	13283600
East Pine Reservoir	S FK Burnt R ab Barney Cr, nr Unity, OR	13282400
	N FK Burnt R nr Whitney, OR	13269300
Hardman Dam	S FK Burnt R ab Barney Cr, nr Unity, OR	13270800

Due to lack of long-term gauge, data at relevant elevations for the East Pine Reservoir and for the North Powder Reservoir stream gauge data from like drainages was extrapolated for calculation purposes. Details of the gauge data used and natural flow determinations for the Powder Basin are available in the Powder River Basin Natural Flow Determination report from the Bureau of Reclamation 2009.

HDR Engineering was contracted by Reclamation to proof the hydrology data and findings as well as provide cost estimates for each project.

MODSIM Model Overview

MODSIM network simulation models of the Powder River, Burnt River, and Pine Creek were developed to show the hydrologic interaction between senior demands and the potential to store water at predetermined sites. The model was selected based on its ability to allocate water based on priority. A link node schematic network, based on GIS maps provided by Dale Linderman, was developed for each of the three basins within the MODSIM GUI interface. The most upstream supply nodes were populated by patterned natural flow records developed by the Natural Flow Determination Report. Downstream nodes were populated by local gains, which is the difference in patterned flow between the upper supply node and downstream supply node.

Some of the missing and obvious inaccurate data was filled in and corrected to produce new natural flow estimates at some of the Powder River gages. Where there were data gaps OWRD Point of Use data set to fill in gaps. Details of the of the development of the Demand Simulation Model for Pine Creek, Powder River, and Burnt River are available in Appendix A.

Species of Concern

The aquatic species listed in the Powder River Basin include the Bull trout (*Salvelinus confluentus*), listed as a threatened species. Stream miles throughout the Powder River Basin are designated as critical Bull trout habitat (Table 1). Interior redband trout (*Oncorhynchus mykiss*) is federally designated as a species of concern, which is a prominent species throughout much of the Powder River Basin (Table 2). These two species are 'species of concern' for this study. Maps detailing bull trout critical habitat and redband presence are located in Appendix D.

TABLE 1: HABITAT MILES FOR BULL TROUT AT FOUR RESERVIOR SITES IN POWDER RIVER BASIN (STREAMNET 2010)

Stream Name	Species	Miles of Stream	Miles Used
Powder Subbasin		**1668**	**24**
North Fork Anthony Creek, trib to Anthony Creek	Bull trout	5.3	3.22
Anthony Creek, trib to North Powder River	Bull trout	15.99	4.81
Wolf Creek, trib to Powder River	Bull trout	19.6	1.22
North Powder River, trib to Powder River	Bull trout	24.31	1.22
Burnt River Subbasin		**839**	
NONE			
Brownlee Reservoir Subbasin		**421**	**34**
Clear Creek, trib to Pine Creek	Bull trout	16.18	7.18
East Fork Pine Creek, trib to Pine Creek	Bull trout	4.49	1.59
East Pine Creek, trib to Pine Creek	Bull trout	18.65	4.97
Meadow Creek, trib to Clear Creek	Bull trout	3.32	3.32
Trail Creek, trib to East Pine Creek	Bull trout	1.56	0.85
Trail Creek, trib to Clear Creek	Bull trout	4.21	1.97
Unnamed stream [1171074450207], trib to East Pine Creek	Bull trout	1.57	0.64

TABLE 2: FEDERALLY DESIGNATED FISH SPECIES IN POWDER RIVER BASIN (SUBBASIN PLAN)

Common Name	Scientific Name	Federal Status	Oregon Status
Bull Trout	*Salvelinus confluentus*	Threatened	Sensitive-Critical
Interior redband trout	*Oncorhynchus mykiss*	SOC	Sensitive-Vulnerable

The critical habitat of bull trout and current bull trout populations are located within the watershed of the proposed reservoir sites and current sites East Pine Creek, Wolf Creek, and Thief Valley Reservoir.

The main species of concern throughout the extent of the Powder Basin is Redband trout. Research and habitat preferences specific for redband trout is limited, most of the current research comes from the Kootenai River drainage in Montana and southwestern Idaho. An overview of habitat use by twenty-five species in Oregon was summarized by Bond et al. (1988). They determined that redband trout were distributed in habitats over coarse substrate in moderate to swift current velocities (Bond et al. 1988). Predominately in Oregon, redband trout were located in streams less than 10m width, characterized as isolated desert streams (Bond et al. 1988).

Muhlfeld et al. (2001a and 2001b) measured habitat use and movement in the Kootenai River drainage and determined trends in redband trout. During the fall and winter there was limited movement with a small home range in the overwintering habitat of deep pools with extensive amounts of cover within third-order mountain streams (Muhlfeld et al. 2001a). Summer use was examined at three levels of habitat. Adult and juvenile selected microhabitats with greater depth, while age -0 redband trout selected shallow, low velocity areas along the channel margins (Muhlfeld et al. 2001b). Mesohabitat selections for all ages classes of redband trout were deep, slow pool habitats with relatively abundant cover, while avoiding shallow, high-velocity riffles (2001b). At the macrohabitat level, redband trout distribution associated with a variety of physical characteristics, primary macrohabitats were low-gradient, medium size reaches with abundant pools.

Overall evaluation of redband trout habitat was evaluated by Zoellick and Cade (2006) in southwestern Idaho sagebrush ecosystems. The variations in density of redband trout were associated with stream shade and distance from the headwaters, where increased shade in the headwaters (upper 50 km) held the greatest density (Zoellick and Cade 2006). The variations in density were distributed across a range habitat conditions and characteristics (stream gradient, size, depth, flood flow); shade was not sole determinant of redband trout density.

For each reservoir site, habitat studies are proposed to examine the habitat quality and potential aspects of monitoring and restoration. The following discussion of ecological flows associated at each site reservoir site will describe the flows to maintain the fish habitat specific to the species of concern based on available hydrologic data and the best available research.

ECOLOGICAL FLOWS

E. George Robison (2007) suggests in "Calculating channel maintenance/elevated instream flows when evaluating water right applications for out of stream and storage water rights" by that if ecological trigger flows for target species are unknown - as they are for redband trout- that channel maintenance flows will maintain and improve fish habitat.

For the purposes of this report, the definitions for the various ecological flows are listed below.

<u>Optimum peak flow</u> –Channel maintenance flow. Robinson (2007) states that channel maintenance flow are "Flows that occur less frequently, but at a greater volume than average flows." Channel maintenance flow in alluvial rivers is the range of flows that is required to maintain stream channels over time. These flows are quantified through various means using hydrologic data, sediment data, channel geometry, and habitat/streamside vegetation characteristics (Schmidt and Potyondy 2004). Poff et al. (1997) state that magnitude, frequency, duration, timing, and rate of change of hydrologic condition are essential components to regulate the ecological processes in a river ecosystem. Thus the optimum peak flow will be described in these terms of the flow regime to maintain the channels.

<u>Flushing flows</u> – The flushing flows are that ranges associated with the amount of water necessary during various life stages to catalyze movement of target species within the stream. For redband trout there is limited of information to support specific flows needed to initiate movement at various life stages.

<u>By-Pass flows</u> – The by -pass flows are the specific amount of water needed for target species, in order to move around instream barriers. This does include irrigation water already being diverted through the reservoir prior to being removed at the POD and the consequent subsurface return flows.

EXISTING AND SIMULATED FLOWS

Analysis of stream flows were made utilizing data prepared using data from the Bureau of Reclamation MODSIM model, that depicts outflow under existing conditions, simulated monthly reservoir outflow with project conditions, and simulated natural inflow and outflow. Following is the explanation of each of the flow regimes.

<u>Existing:</u> Existing streamflow at proposed reservoir site or outflow at existing reservoir sites from October 1971 to September 1999.

Simulated Natural: Natural flows are calculated using the existing streamflow, plus the addition of current flow outtakes along the stream system. The simulated flows were calculated for each year from October 1971 to September 1999.

Simulated Project: Project flows were calculated using the existing streamflow including the proposed effect of the project at each site. The simulated flows were calculated from each year from October 1971 to September 1999.

For each reservoir site there are three graphs, which depict inflow and outflow under existing conditions, simulated monthly reservoir outflow with project conditions, and simulated natural inflow and outflow. The first graph utilizes the 28-years of data averaged to depict natural and existing conditions and the simulated hydrologic effect under project conditions. The final two graphs display 15 years of the monthly mean discharge to depict the frequency, duration and timing of the flow regime under existing and project conditions. All graphs were prepared using data from the Bureau of Reclamation MODSIM model. Additional tables of the mean monthly discharge are in Appendix B.

Thief Valley Reservoir

Thief Valley Reservoir is an existing reservoir that was constructed in 1932 that is located on the county boundary between Baker and Union Counties. It is approximately 29 miles north of Baker City, is known for excellent fishing, and is one of the top five windsurfing locations in Oregon. The following are dam statistics:

* Township 6 south, Range 40 east Section 26
* Drainage is 910 square miles
* Structural dam height 73 feet
* Crest elevation 3,133 feet
* Crest length 390 feet
* Crest width 7 feet
* Current capacity is approximately 13,200 acre feet

When the reservoir was constructed in 1932, the total capacity was 17,600 acre-feet with a 740-acre surface area. Due to sedimentation over time storage capacity has diminished to 13,200 acre-feet of storage and 685 acres of surface area. Most years the reservoir is not dried up and is an excellent trout fishery as stated by fish biologists and anglers alike. There is a small park with a few unimproved campsites and a single boat ramp. The climate of the area can be characterized as semi-arid high desert, and receives an average of 10" of precipitation per year.

Thief Valley Reservoir- Watershed Characteristics

The watershed elevations above the reservoir range from 2,619 ft- 9,077 ft above sea level. The mean slope of the watershed is 10.27. Annual precipitation is 20.03 in. with 35.56% forest cover. The channel entering the reservoir is of a deposition reach of a wide U-shaped valley. The channel morphology is similar to Rosgen stream type C. Below the dam the channel transitions to a narrower U-valley of a deposition reach. At the reservoir site the general upland habitat is sagebrush steppe, riparian habitat is primarily *Salix* and *Carex* communities.

Thief Valley Hydrograph – General Analysis

Minimum flows are typical for the Thief Valley Reservoir and surrounding area from the months of August, September, October, November and then picking back up somewhat in December. Months of higher flows are January through June with flows dropping off in July. Under the existing flow regime, there are two peaks in the hydrograph (**Figure 1**). One peak in the hydrograph typically occurs in March and another in May. This is a result of the reservoir filling to capacity, then being drawn down once irrigation begins in April. Snowmelt runoff historically has peaked in May, thus the reservoir fills to capacity again in May even after irrigation withdrawals have begun. If the capacity of the reservoir were expanded, models show that there would not be an initial peak in the hydrograph in March given that the reservoir would still be filling. Outflows would still peak in May thru June and then begin tapering off. In addition, the streamflows would begin to descend near the end of June.

Hydrograph and Ecological Flow Analysis – Thief Valley Reservoir

Optimum Peak Flow Analysis

Under simulated hydrographs of the reservoir, following the increased capacity, the hydrologic regime would look very similar to the current hydrologic regime. The main difference would be a slight decrease in flows during March with a slightly steeper descending curve in the late irrigation season. In **Figure 2** and **Figure 3** display the differences in the duration and timing of the peak flow conditions between the simulated project conditions and the existing conditions.

Flushing Flow Analysis

There would be little to no change in flows from existing condition to project conditions that would be of significance to local aquatic species. The average change of flow would range from 220 acre-feet to 1040 acre-feet decrease during the months July, August, September and March. March shows the largest decrease in flow from existing to project conditions of 1040 acre-feet (16.9 cfs), yet the average discharge of 317 would be maintained. The remaining months would have an increased flow of approximately 1600 acre-feet (26 cfs). Ultimately, these increases in flow during early irrigation season would aid in better water quality conditions such as lower instream temperatures, and lower counts of fecal coli form bacteria and nutrient levels as a result of additional water diluting the pollutants.

By-Pass Flow Analysis

Thief Valley Reservoir is an existing reservoir. Obtainable fisheries data can be relied upon to determine whether by-pass flows are adequate, using them as a baseline to determine minimum flows under a larger storage project. Oregon Department of Fish and Wildlife personnel have stated that the Thief Valley Reservoir is an excellent trout fishery. By-pass flows for fish passage downstream from the reservoir site are adequate due to irrigation releases from the reservoir and the return flow instream due to irrigation.

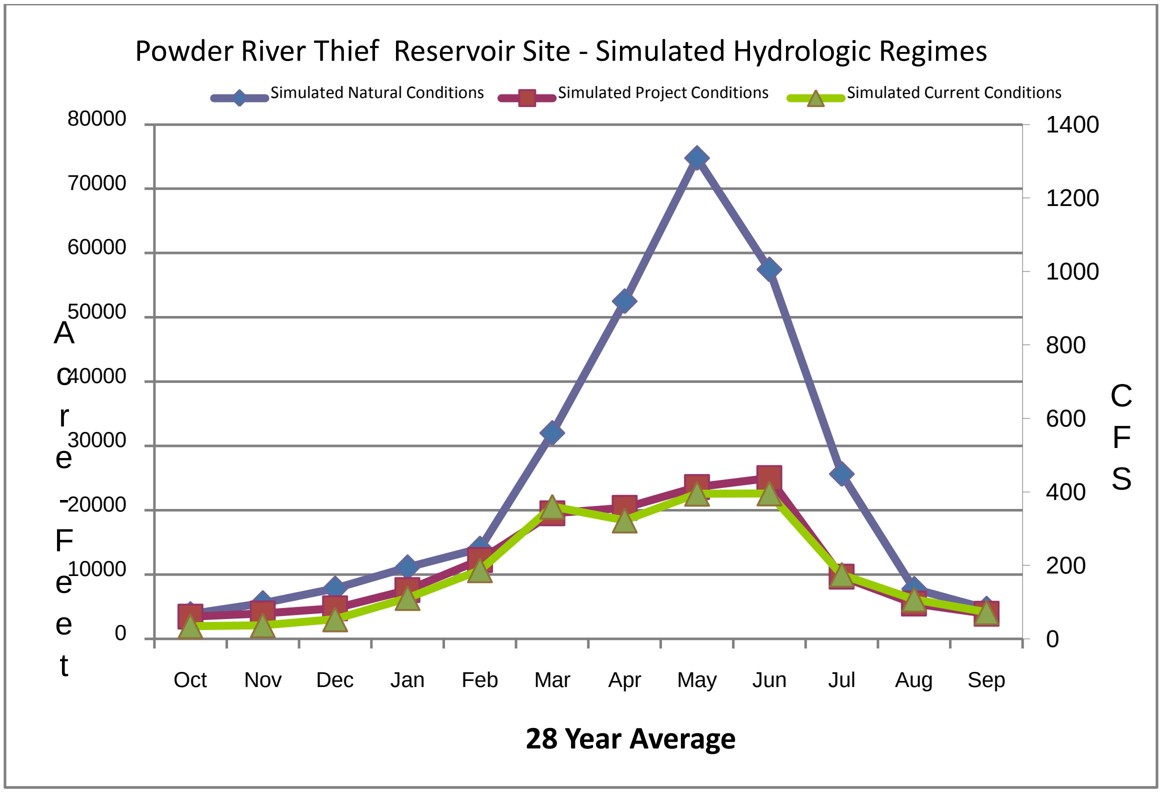

FIGURE 1: HYDROGRAPH: THIEF VALLEY

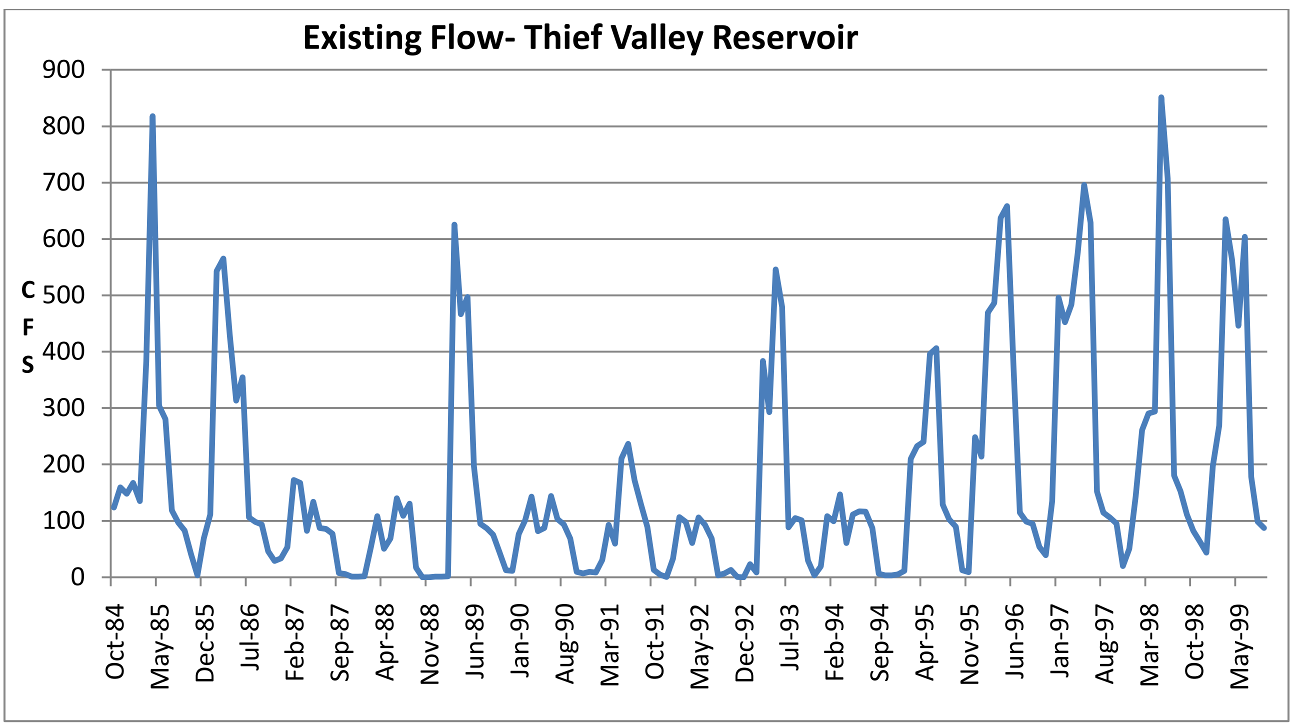

FIGURE 2: EXISTING HYDROLOGIC REGIME - MONTHLY MEAN

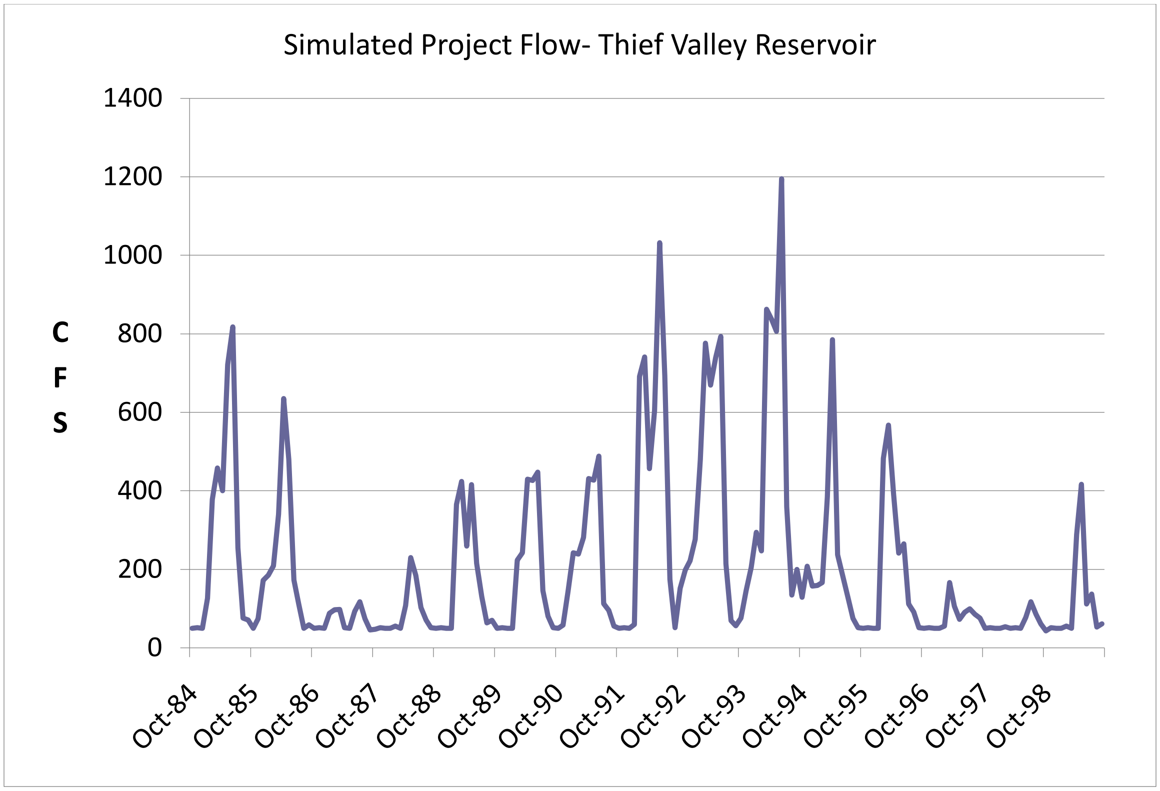

FIGURE 3: PROJECT HYDROLOGIC REGIME- MONTHLY MEAN

North Powder Reservoir

The North Powder Reservoir is a proposed above ground water storage project that was thoroughly researched and designed in the 1970's (CH2MHILL). It was ready to go to contract when inflation skyrocketed in the 1980's becoming unfeasible to construct with agriculture being the only financial source to payback the construction loan. It is located approximately 12 miles from North Powder, Oregon just 5 miles inside the tree line towards Anthony Lakes at the northeast edge of Baker County. The dam would be located where a section of highway currently exists. Approximately 2 miles of the highway would have to be rerouted around the water storage project.

For numerous years, residents of the Powder Valley area have envisioned increasing the availability of late season water by constructing a reservoir on the North Powder River. A 1967 publication called the Watershed Work Plan North Powder River Watershed, Baker County, OR, cites several potential water storage sites including the North Powder Reservoir site. The reservoir is described in the publication as follows: "The North Powder Reservoir will be a multipurpose structure for flood prevention, irrigation, and recreation. The dam site is on the North Powder River about 11.5 miles upstream from the mouth and about 10.3 miles west of the town North Powder. This structure will control 45.0 square miles of the 115.8 square mile drainage area of the North Powder River. Part of the dam and reservoir will be located on National Forest Land."

Since the 1967 publication, more than $1.5 million has been spent in attempting to see to fruition the construction of the reservoir. In 1979 and then in 1980, the Final Design Report of the North Powder Dam and Reservoir was completed by CH2MHill with financial and technical assistance provided by the Soil Conservation Service, now known as the Natural Resource Conservation Service, (NRCS).

The need for and use of a reservoir has evolved since 1967. Today beneficial uses that would be enhanced by the availability of late season water include stream health, hydro-power, recreation, agriculture, fish, wildlife, flood prevention, water quality, and tourism. In the current socio-economic, setting repayment for the cost of the reservoir will be by more than just agriculturalists. Recreationists, power users, and possibly even conservation groups will help with repayment.

Historic Construction Specifications –

- Storage capacity 16,650 acre-feet
- 260 surface acres The original plans specified that
- 14,622 acre-feet will provide for irrigation and flood protection
- 2,028 acre-feet recreational pool
- 18,000 acres of irrigable land would be serviced
- Township 7 south, Range 43 east, Section 10

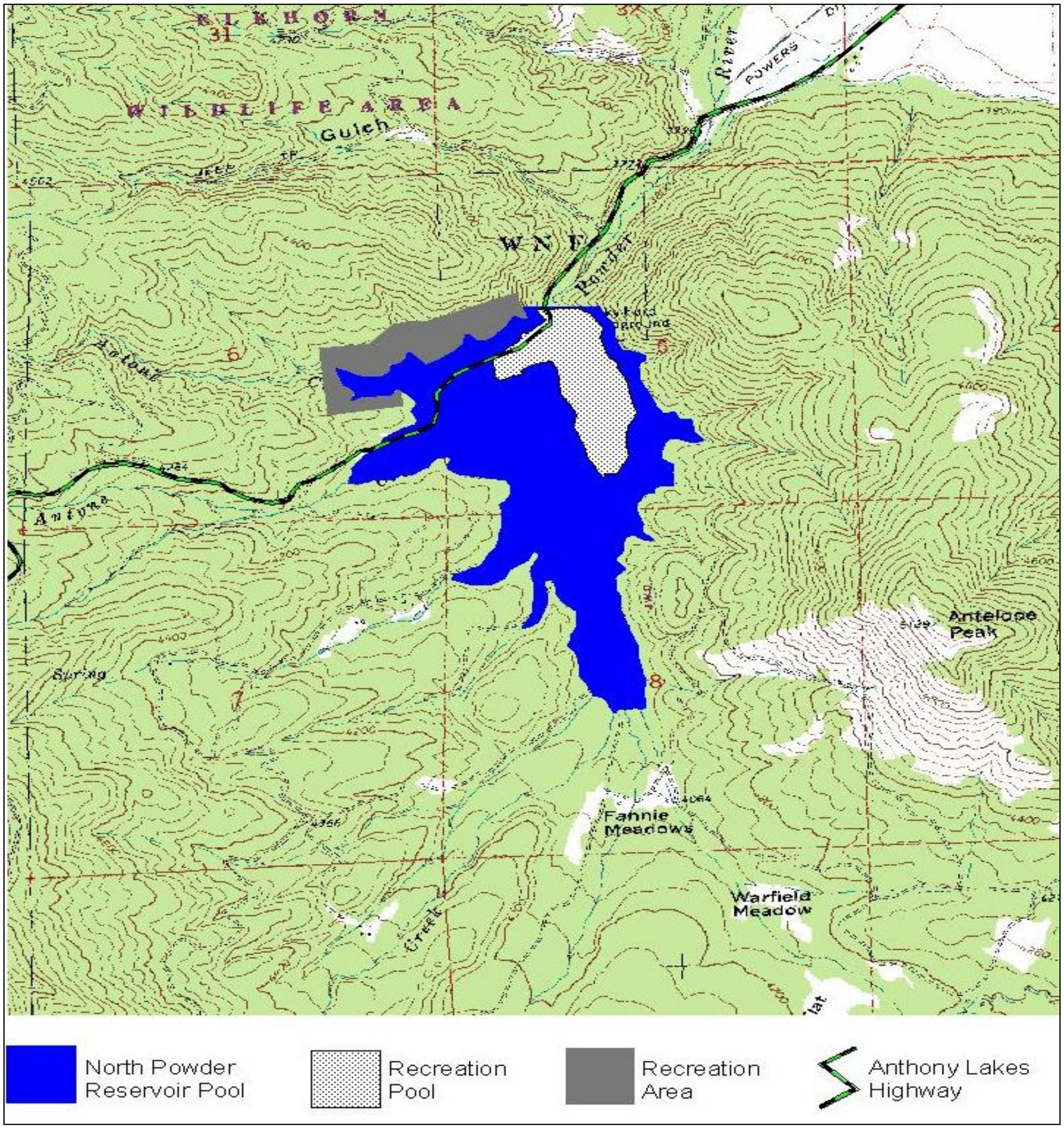

FIGURE 4 : MAP OF PROPOSED NORTH POWDER RESERVOIR

North Powder Reservoir- Watershed Characteristics

The watershed elevations above the reservoir range from 2,619 ft- 9,077 ft above sea level. The mean slope of the watershed is 10.27. Annual precipitation is 20.03 in. with 35.56% forest cover. The channel entering the reservoir is of a deposition reach of a wide U-shaped valley. The channel morphology is similar to Rosgen stream type C. Below the dam the channel transitions to a narrower U-valley of a deposition reach. At the reservoir site the general upland habitat is sagebrush steppe, riparian habitat is primarily *Salix* and *Carex* communities.

North Powder Hydrograph – General Analysis

Stream flow in the North Powder river, under existing conditions, generally is at its lowest point in August, less than 200 acre-feet, then increases slightly through February and then begins to peak in March through June. In late June to early July flows drop off drastically, often as much as 16,000 acre-feet. The hydrograph typically peaks at 10,000 acre-feet at the height of snowmelt runoff. This is the case under existing and project conditions. With natural conditions however, the hydrograph peaks at 18,000 acre- feet due to no irrigation withdrawals. Water users currently have the option of 'use it or lose it' with no mechanism to store runoff water for use later in the season. If water storage were a feasible option, they would store some water for use later in the season.

When comparing existing conditions to project conditions the hydrograph highs and lows are the same, however, the hydrograph shifts. Currently, the lowest flows in the season are in August, under project conditions that shift the lower flows to later in the season and typically occurring in October to November.

Hydrograph and Ecological Flow Analysis – North Powder Reservoir

Optimum Peak Flow Analysis

The 'Project Conditions' hydrograph and the 'Existing Conditions' hydrograph have similar peak flows indicating that if a reservoir existed on this site the peak flows would not vary significantly. Therefore, channel maintenance flows that have been occurring on this section of the North Powder River will remain similar to what has been occurring over the last 70 years (since the stream was fully appropriated).

Flushing Flow Analysis

Fish species of concern in the North Powder River are Bull trout and Redband trout. There are two residential populations of bull trout know in the area, one in the headwaters of the North Powder, and one in Antone Creek. There is a natural barrier (waterfall) upstream from the reservoir site preventing migration of all fish species from the headwaters to the valley bottom. (Miller) As with optimum peak flows, analysis of the hydrograph indicates that flushing flows will remain similar to what they currently are.

By-Pass Flow Analysis

Under existing conditions stream flows drop dangerously low in August, low instream flows likely to cause fish passage issues, including high water temperatures. Under project conditions stream flows do not get as low due to water being stored in the reservoir for late season release. With this scenario, by-pass flows would be enhanced with an aboveground water storage project.

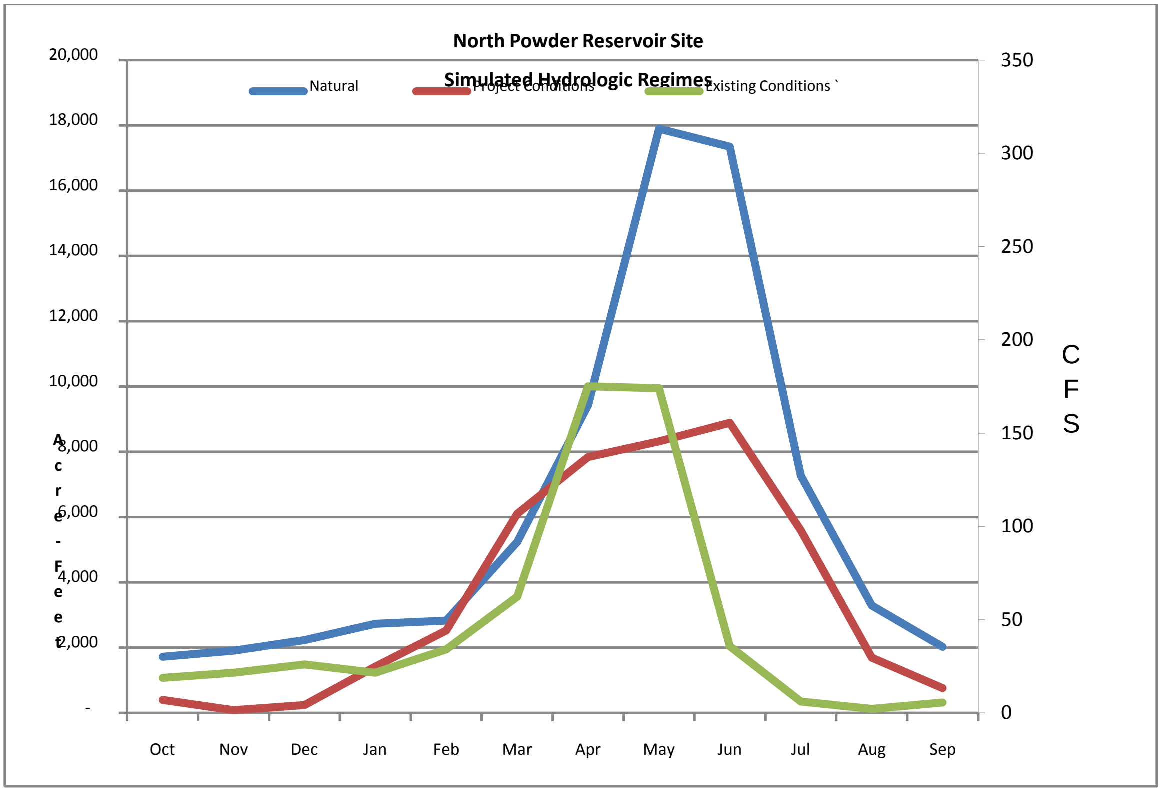

FIGURE 5: HYDROGRAPH- NORTH POWDER RESERVOIR SITE

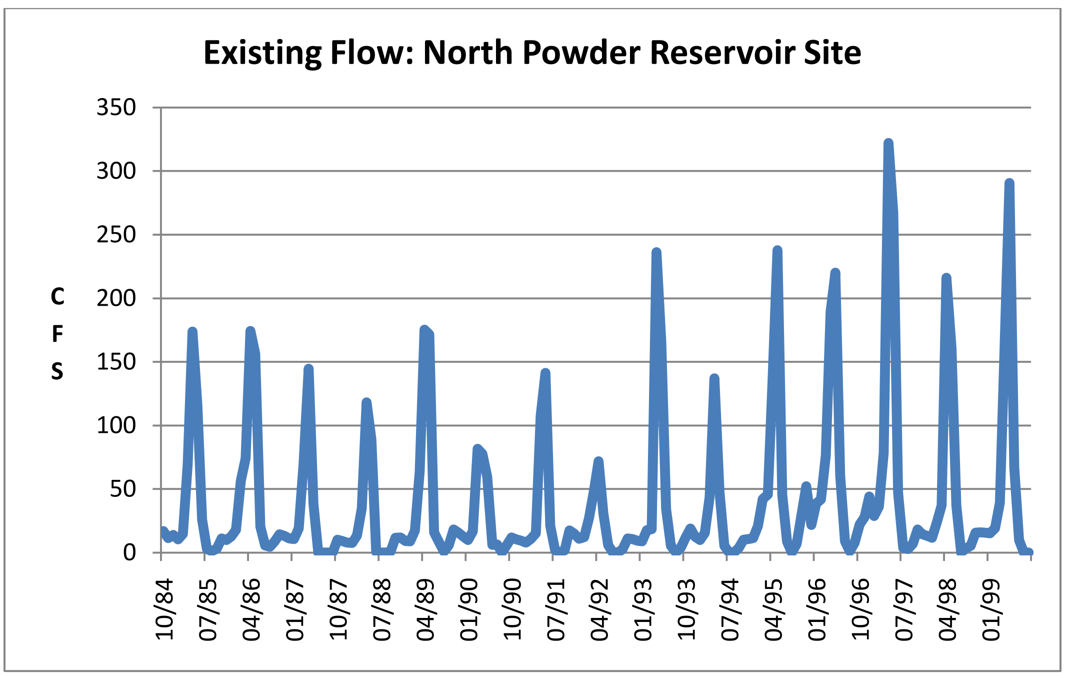

FIGURE 6: HYDROLOGIC REGIME- EXISTING, NORTH POWDER RESERVOIR SITE

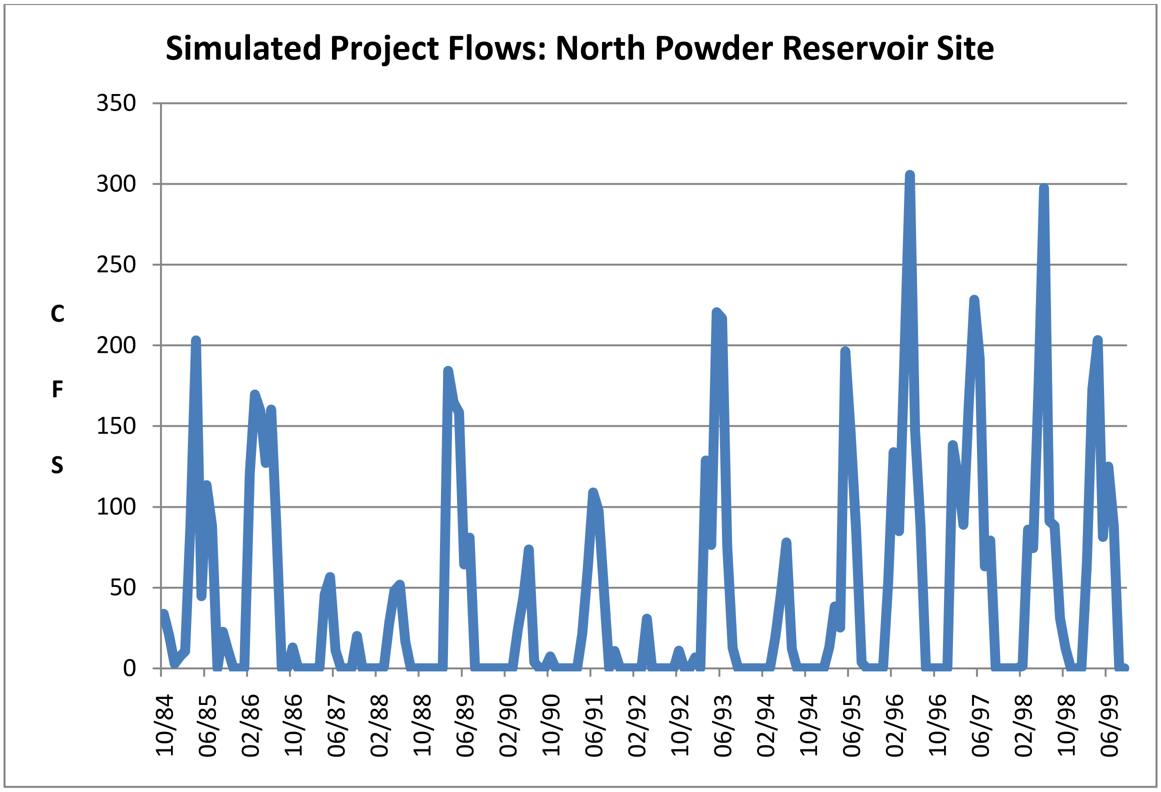

FIGURE 7: HYDROLOGIC REGIME- PROJECT, NORTH POWDER RESERVOIR SITE

WOLF CREEK COMPLEX

Wolf Creek and Pilcher Creek Reservoirs are the two existing reservoirs part of the North Powder River Reservoir Complex. These reservoirs were constructed in 1968 and located on the county boundary between Baker and Union Counties. It is approximately 6 miles west of the town of North Powder respectfully known for excellent fishing. The following are dam statistics:

Wolf Creek Reservoir

- Township 6 South, Range 38 East Sections 8, 16, 17
- Drainage is 32.9 square miles
- Structural dam height 154 feet
- Crest elevation 3,704 feet
- Crest length 2600 feet
- Crest width 30 feet
- Current capacity is approximately 11,111 acre feet
- Minimum Pool 750 acre feet

Pilcher Creek Reservoir

- Township 6 South, Range 38 East Sections 10, 11, 14
- Drainage is 5.5 square miles
- Structural dam height 117 feet
- Crest elevation 3,777 feet
- Crest length 2400 feet
- Crest width 26 feet
- Current capacity is approximately 5,500 acre feet
- Minimum Pool 75 acre feet

Wolf Creek and Pilcher Creek Reservoirs are operated as one pool. There is a canal that carries water from Pilcher Creek Reservoir to Wolf Creek Reservoir. Wolf Creek Reservoir always draws down quicker than Pilcher Creek Reservoir. The inflow to Wolf Creek Reservoir is from Pilcher Reservoir and Wolf Creek. The outflow of Wolf Creek Reservoir is through Wolf Creek and to irrigation canals. Additional some water from Pilcher Creek Reservoir is put instream by way of the North Powder River. It is due to these facts and the immense complexity of the system that the project is referred to as the Wolf Creek Reservoir Complex.

The climate of the area can be characterized as semi-arid high desert, and receives an average of less than 10” of precipitation per year. Minimum flows are typical for the Wolf Creek Watershed and surrounding area from the months of late June thru February with the exception of warm rains on the snow pack causing rapid increase in flow. Months of higher flows are March through May with flows dropping off in early June. Under the existing flow regime, there are two peaks in the hydrograph. One peak in the hydrograph typically occurs in April and another in May. Snowmelt is the major contributor to flood flows with periods of high flows often lasting for several weeks. This is a result of the reservoir filling to capacity, then being drawn down once irrigation begins in April. If the capacity of the reservoir were expanded, models show that there would not be an initial peak in the hydrograph in March given that the reservoir would still be filling. Inflows would still peak in May thru June and then begin tapering off.

The water in Wolf Creek and Pilcher Creek Reservoir is obligated for irrigation, while creating and enhancing habitat and recreation opportunities. The current construction of the Wolf Creek reservoir at the elevation of 3694 feet has a volume of 11,111 and surface area of 225 acres; Pilcher Creek Reservoir at the elevation of 117 feet has a volume of 5912 and surface area of 221.5 acres. Most years the reservoirs are not dried up and are an excellent trout fishery as stated by fish biologists and anglers alike. The outlet works of Wolf and Pilcher Creek Reservoir are designed to have a total discharge capacity of 350 cfs and 65 cfs, respectively.

Wolf Creek Complex- Watershed Characteristics

Pilcher Creek Reservoir is an off-site reservoir with water channeled from Anthony Creek. Wolf Creek watershed above the reservoir is elevations range from 3761 ft 6478 ft above sea level. The mean slope of the watershed is 14.11. Annual precipitation is 26.97 inches with 93.5% forest cover. At the reservoir site the channel is a deposition reach from the higher gradient forested transport reach above. Below the dam, the channel transitions to short narrower valley of transport reach into the deposition reach of through the agriculture land near North Powder Valley. The riparian habitat above the reservoir of *Populus spp., Alnus spp.* and forested upland species and transitions to a *Populus spp./Salex spp.* community.

Wolf Creek Complex Hydrograph – General Analysis

Minimum flows are typical for the Wolf and Pilcher Creek Reservoirs and surrounding area from the months of August, September, October, November and then picking back up somewhat in January. Months of higher flows are March through June with flows dropping off in late June. Under the existing flow regime, there is one main peak flow period for Wolf Creek noted in the hydrograph (**Figure 8**). Existing stream outflow typically begins to peak in late March, reaching a peak flow in late April. The peak is maintained through mid- July with a drastic decrease in outlflow prior to August. Outflows for Pilcher Creek follow the patterns from Wolf Creek, expect that the peak flow does not occur until July, when flows have a slight decrease in Wolf Creek. The two reservoirs are connected with Wolf Creek filling before Pilcher Creek, hence the outflow from PIlcher peaks later than Wolf Creek.

Hydrograph and Ecological Flow Analysis – Wolf Creek Complex

Optimum Peak Flow Analysis

Simulated flows were not performed on the Wolf Creek Complex due to its late introduction as a potential project. With increased capacity of Wolf Creek and Pilcher Creek, the peak flow would shift slightly into late May when the reservoir fills, and descend in late August. The peak flows for Pilcher Creek would also shift to late July into August. Hence peak flows seen in April would act as the channel forming and maintenance flow for this section of the two creeks.

FLUSHING FLOW ANALYSIS

There potentially would be limited changes to the hydrograph that may be of some significance to local aquatic species. Early season flows would be delayed slightly while the reservoir fills to capacity, hence aquatic species late season flows would be higher than under current conditions through the month of November. Ultimately, this would result in better water quality conditions such as lower instream temperatures, and lower counts of fecal coli form bacteria and nutrient levels as a result of additional water diluting the pollutants.

BY-PASS FLOW ANALYSIS

Wolf Creek and Pilcher Creek are existing reservoirs. Obtainable fisheries data can be relied upon to determine whether by-pass flows are adequate, using them as a baseline to determine minimum flows under a larger storage project. Oregon Department of Fish and Wildlife personnel have stated that the Wolf Creek and PIlcher Creek Reservoirs are excellent trout fishery. By-pass flows for fish passage downstream from the reservoir site are adequate due to irrigation releases from the reservoir and the return flow instream due to irrigation.

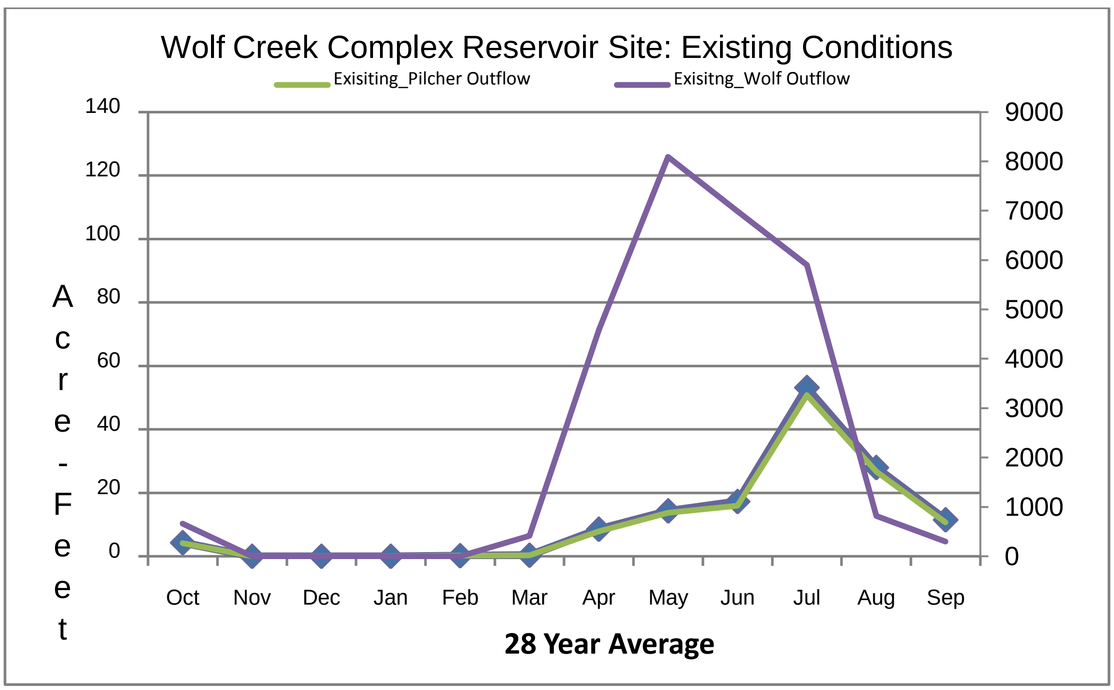

FIGURE 8: HYDROGRAPH: EXISTING CONDITIONS- WOLF AND PILCHER CREEK

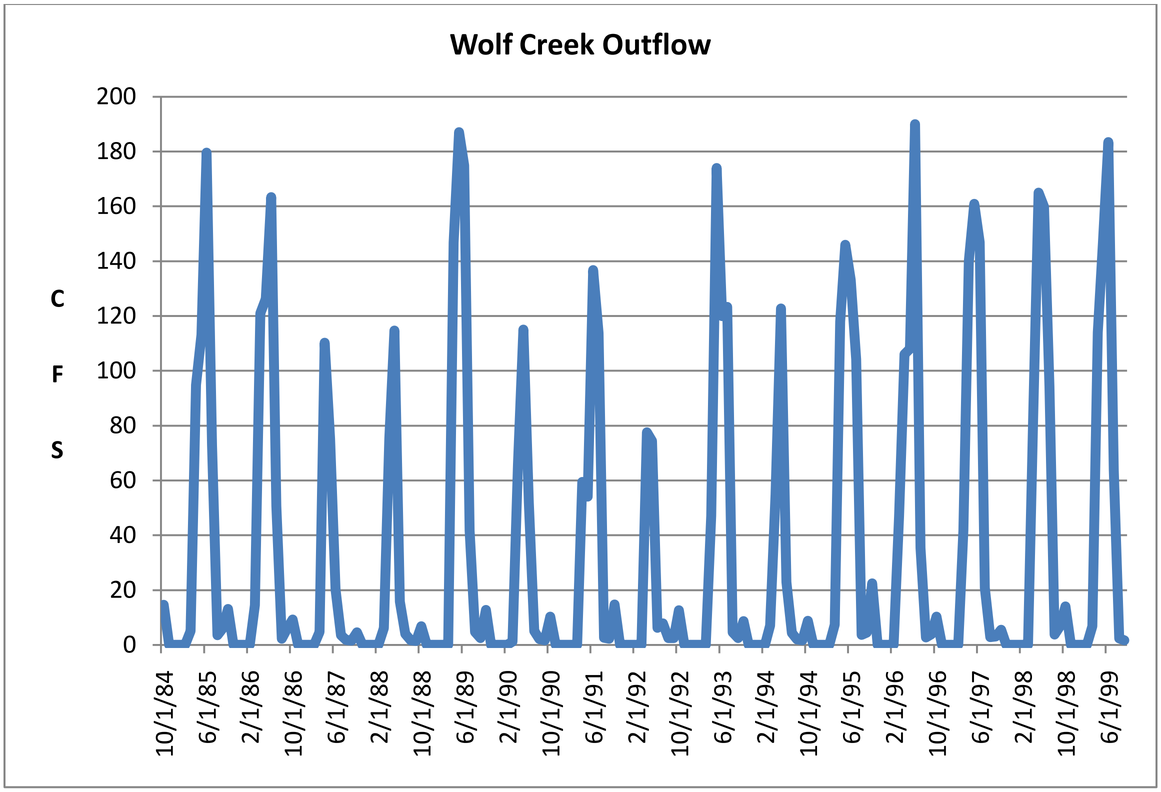

FIGURE 9: HYDROLOGIC REGIME- EXISTING, WOLF CREEK

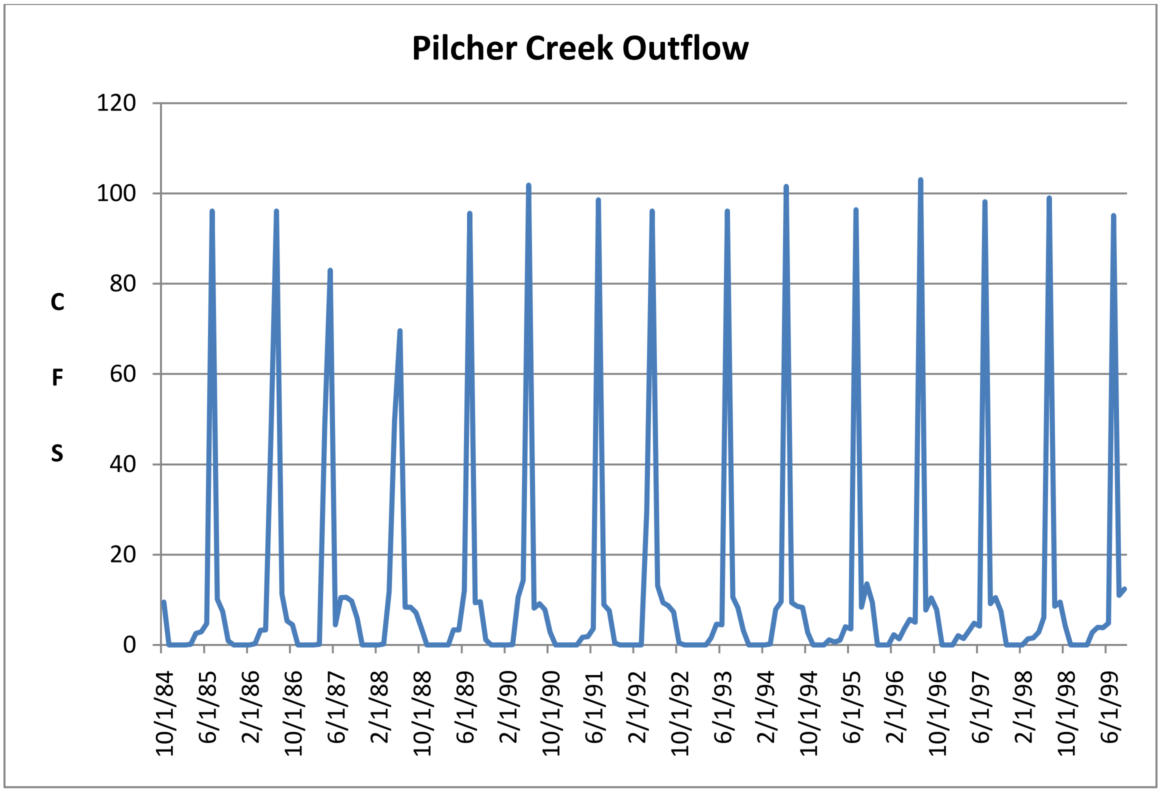

FIGURE 10: HYDROLOGIC REGIME- EXISTING, PILCHER CREEK

EAST PINE RESERVOIR

The East Pine Reservoir and Dam site is along East Pine Creek, five miles north of the town of Halfway, Oregon, which is in the northeast corner of Baker County. It is entirely within Township 7 South, Range 46 East, W.M., and is approximately one mile within the exterior boundaries of the Wallowa-Whitman National Forest. The dam was originally designed by NRCS in the 1970's. The proposed dam site is in the NE1/4 of section 20. The reservoir would extend northeast from the dam approximately 1.5 miles through sections 15, 16, 20, and 21. At that, time designs were created to divert water from Clear Creek through a canal, which would contribute to the reservoir. The Clear Creek canal location is on the side slopes above Clear Creek and Pine Creek. It crosses the common ridge between the two drainages. West Canal would also contribute additional water to the pool.

The East Pine Creek drainage includes 205.1 square miles or 131,264 acres. The surface water resources of the watershed consist of Pine Creek and its principal; tributaries: Clear Creek and East Pine Creek. These waters then flow into Pine Creek, which is a direct tributary of the Snake River.

Historical Dam Specifications (USFS Impact Study)

- Dam height 177 feet
- Top width 42 feet
- Top length 825 feet
- Reservoir capacity 17,200 acre feet (at crest of emergency spillway)
- Surface area 266 acres
- Recreation pool of 50 acres

The Bureau of Reclamation in cooperation with HDR Engineering and the Water & Stream Health Committee has been recalculating basin yields and available water for storage purposes. The results will not be available until fall of 2009; however, current calculations depict that there is less available water for storage than calculated in 1967.

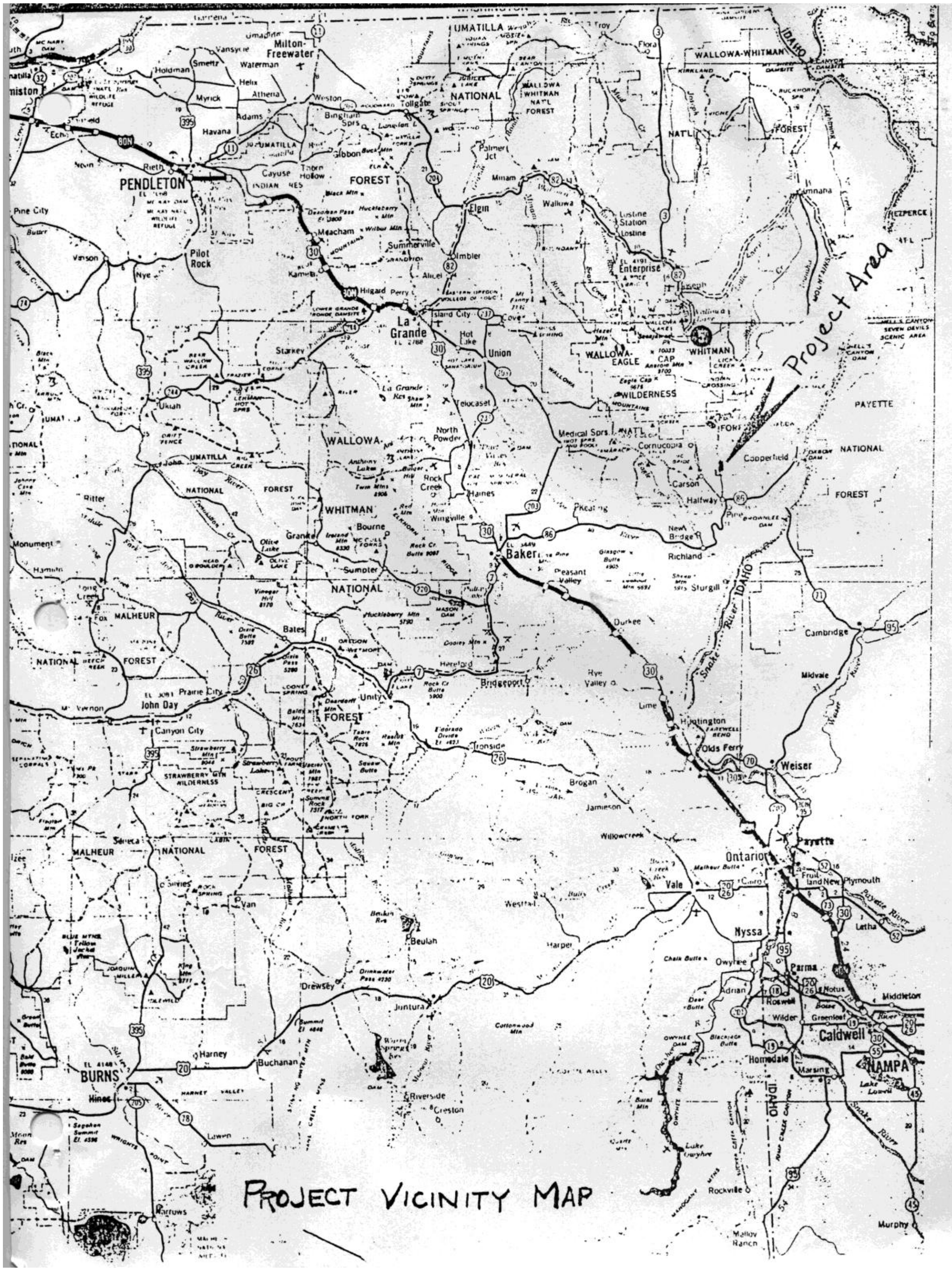

FIGURE 11: POTENTIAL EAST PINE CREEK RESERVIOR SITE MAP

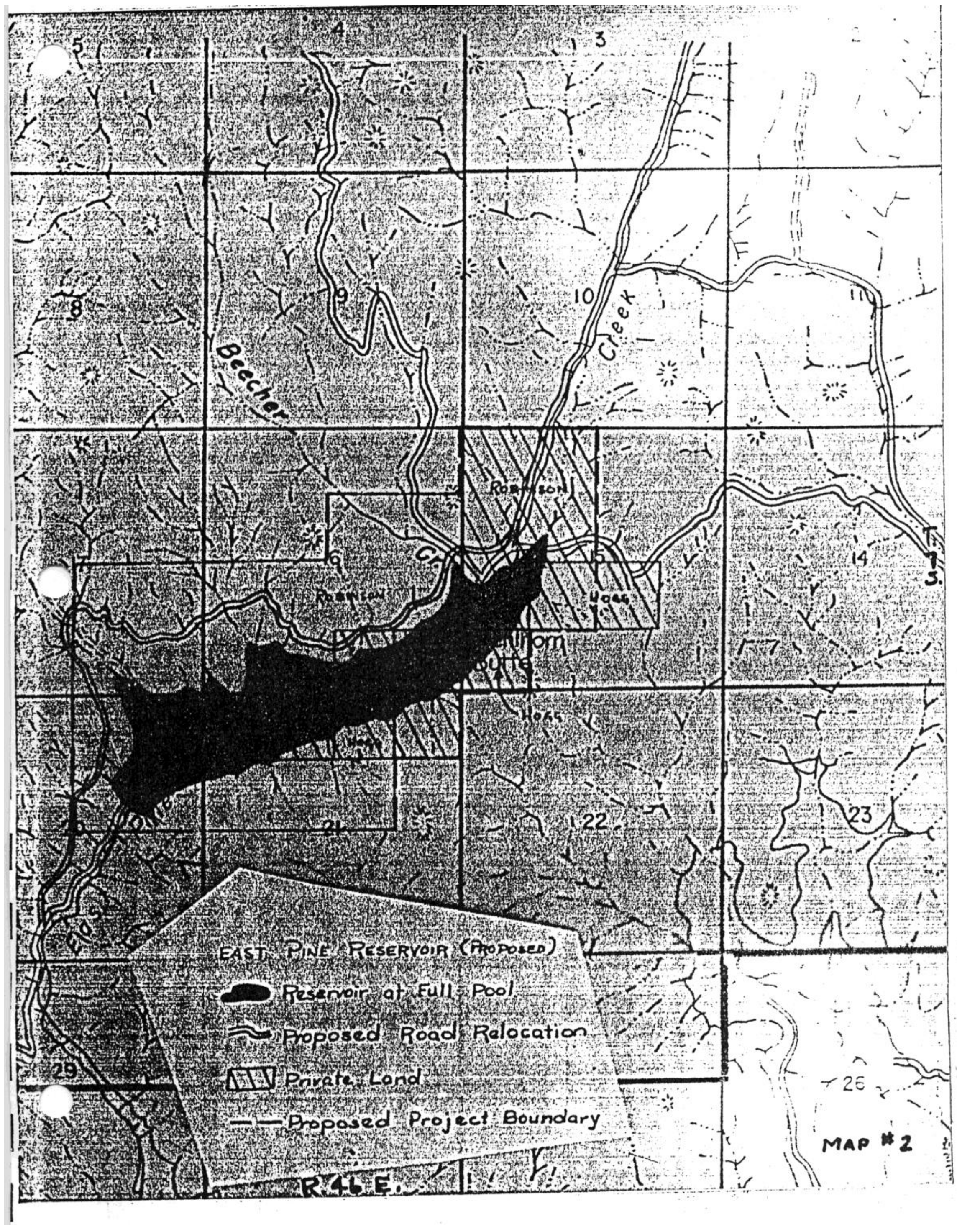

FIGURE 12: PROPOSED EAST PINE CREEK RESERVOIR MAP

East Pine Creek Reservoir Site - Watershed Characteristics

The watershed elevations above the reservoir range from 2429ft to 7419ft above sea level. The mean slope of the watershed is 12.96. Annual precipitation is 28.31 in. with 57.15% forest cover. East Pine Creek is a high gradient stream that has morphological characteristics similar to the Rosgen A/B channels. Much of the stream sediment is composed of large boulders and bedrock. At the proposed reservoir site the valley transition from a narrow V-shaped into a narrow U-shaped valley. Below the proposed dam site the channel transition back again into a narrow V-shaped valley before entering the wide valley of Halfway, Oregon. The riparian habitat throughout the East Pine Creek Reservoir site is forested upland species with *Alnus spp.* and *Populus tremuloides*.

East Pine Creek Reservoir Hydrograph Site – General Analysis

Under existing conditions, East Pine Creek hydrologic regime follows a pattern with two peaks, a small initial peak in mid- February and a second larger peak in April. Over the months of May and June there is a steep decrease in flows. Minimum flows are typical for East Pine Creek from Mid-June through September. This pattern is a result of the watershed characteristics, with much of the streamflow from snow runoff from high elevations with less groundwater and surface water contributions. If a reservoir was constructed on East Pine Creek, models show that there would be a one peak pattern with drastic increase and decrease of the peak flow, yet the peak conditions would shift to the main peak flows starting in March and increasing until May, with a steep decent over June and July. In addition, the water year would begin lower than under current conditions and remain about 250 acre-ft (3cfs) below current conditions.

Hydrograph and Ecological Flow Analysis - East Pine Reservoir Site

Optimum Peak Flow Analysis

Existing and Natural optimum peak flows typically occur mid-February through May. The timing of natural and existing peak flows mirror each other while intensity of existing peak flows is higher than natural peak flows due to irrigation. Over a 28 year average there is 600-700 acre-feet more water depicted under existing conditions than simulated natural conditions.

Under simulated project conditions peak flows begin in February and end in August. The hydrograph shifts from the main peak flows being in April to mid-May. (See **Figure 13**) Again, the highest average peak flow under project conditions is approximately 3,000 acre-feet (70 cfs) more than under simulated existing and natural conditions due to additional water being diverted into the reservoir.

The duration and timing of the peak flow conditions differ between the existing and simulated project condition, as mentioned. These differences can be seen in **Figure 14** and **Figure 15.** The width of the peak is slightly wider, displaying the longer periods of increased flow. The main alteration of the reservoir introduction to the channel forming flows would be the timing of increased streamflow and timing of the channel forming flows.

<u>Flushing Flow Analysis</u>

There is very little information available as to the amount of water necessary to initiate the movement of bull trout or redband trout; the two species of concern in this project area. However, under depicted project conditions there will be more water available throughout most of the year whereas additional water will be diverted from Clear Creek and West Canal. As with many other existing reservoirs in Eastern Oregon flushing flows are mimicked when the reservoir fills to capacity and spills over. For example, trout fishing downstream of Mason Dam is excellent. Dams without fish passage, if constructed correctly, for instream temperature purposes, are simply a fish passage barrier and do not necessarily restrict flushing flows.

<u>By-Pass Flow Analysis</u>

East Pine Creek is listed as critical habitat for Bull trout (*Salvelinous confluentus*). It is currently unknown whether there are existing passage barriers for these fish. Anecdotal evidence suggests that there are two distinct populations of Bull Trout. A residential population in the headwaters and a fluvial population in the lower elevations near the confluence of Pine Creek and the Snake River. Summer flows under the proposed project are actually greater than existing or natural historic flows due to additional water being diverted into the dam from Clear Creek and West Canal. Flows from October through December will decrease slightly by approximately 200 acre-feet, while peak flows will increase by at least 7,000 acre-ft, diminishing back to approximately a 500 acre-feet difference again by August. (See **Figure 13**) With this scenario, by-pass flows will actually be enhanced from existing or natural flow conditions.

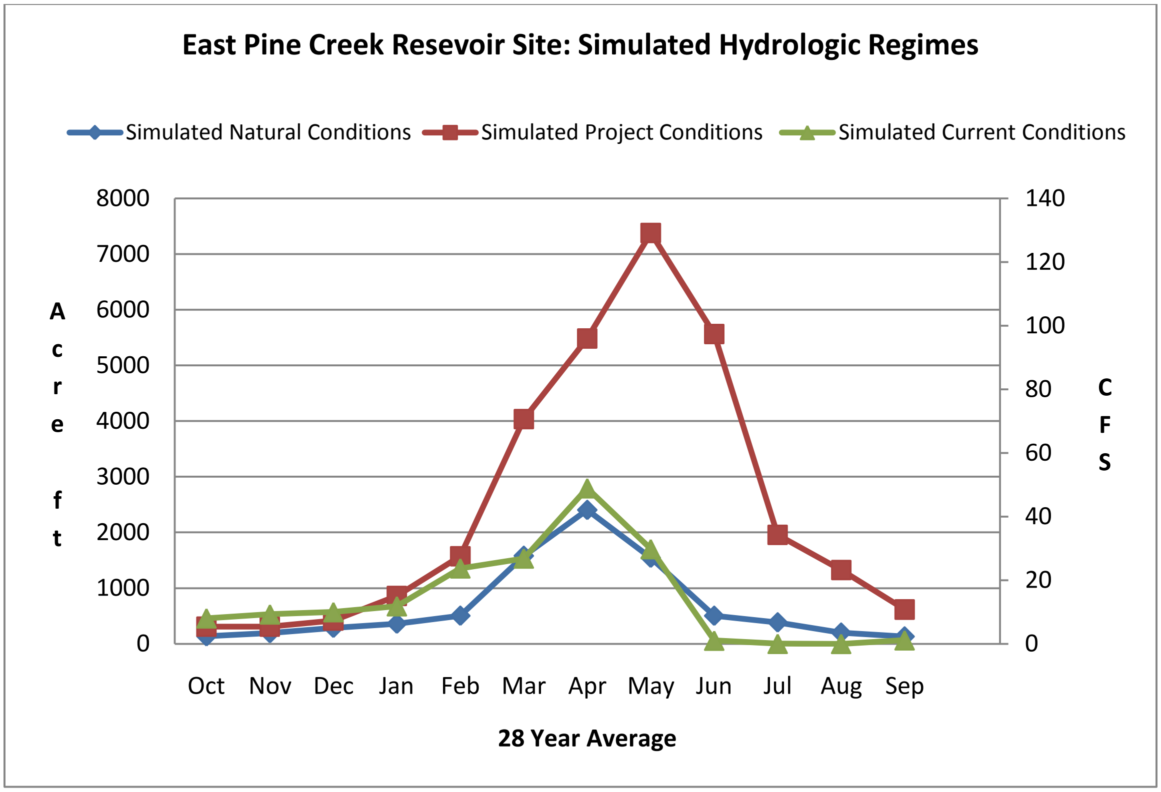

FIGURE 13: HYDROLOGIC REGIME OVER 28 YEARS- EAST PINE CREEK

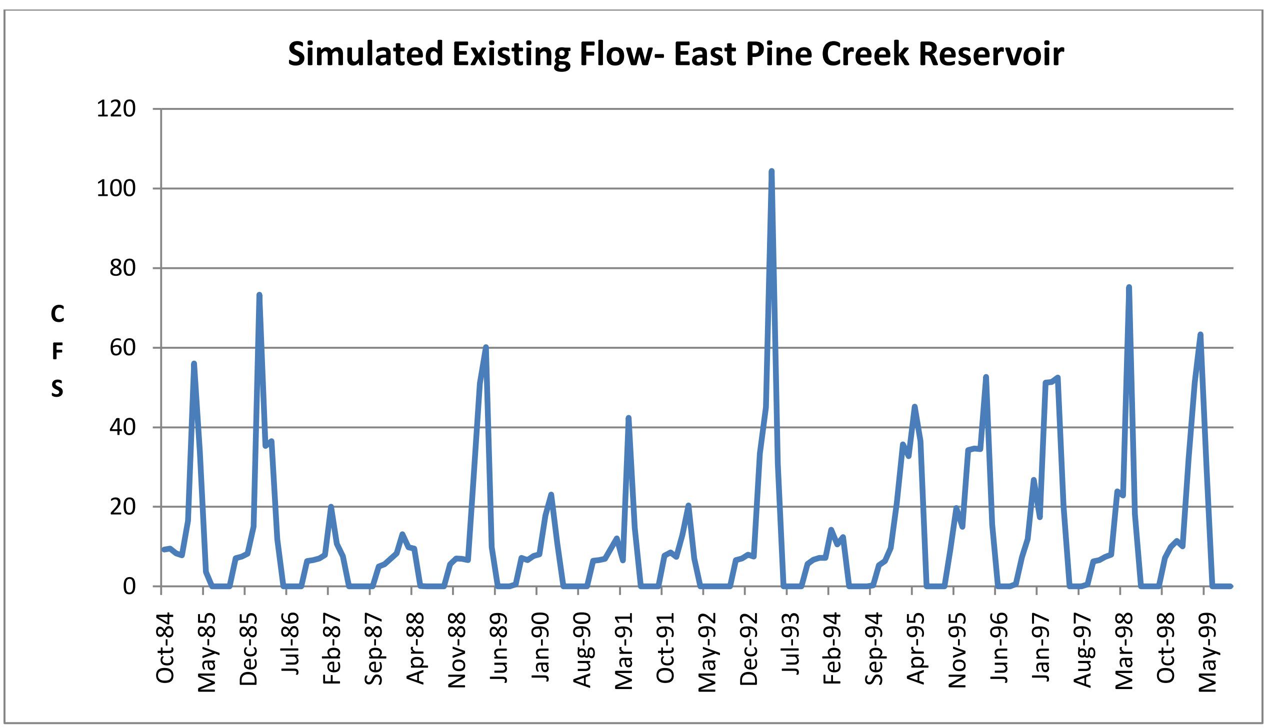

FIGURE 14: EXISTING HYDROLOGIC REGIME- MONTHLY MEAN

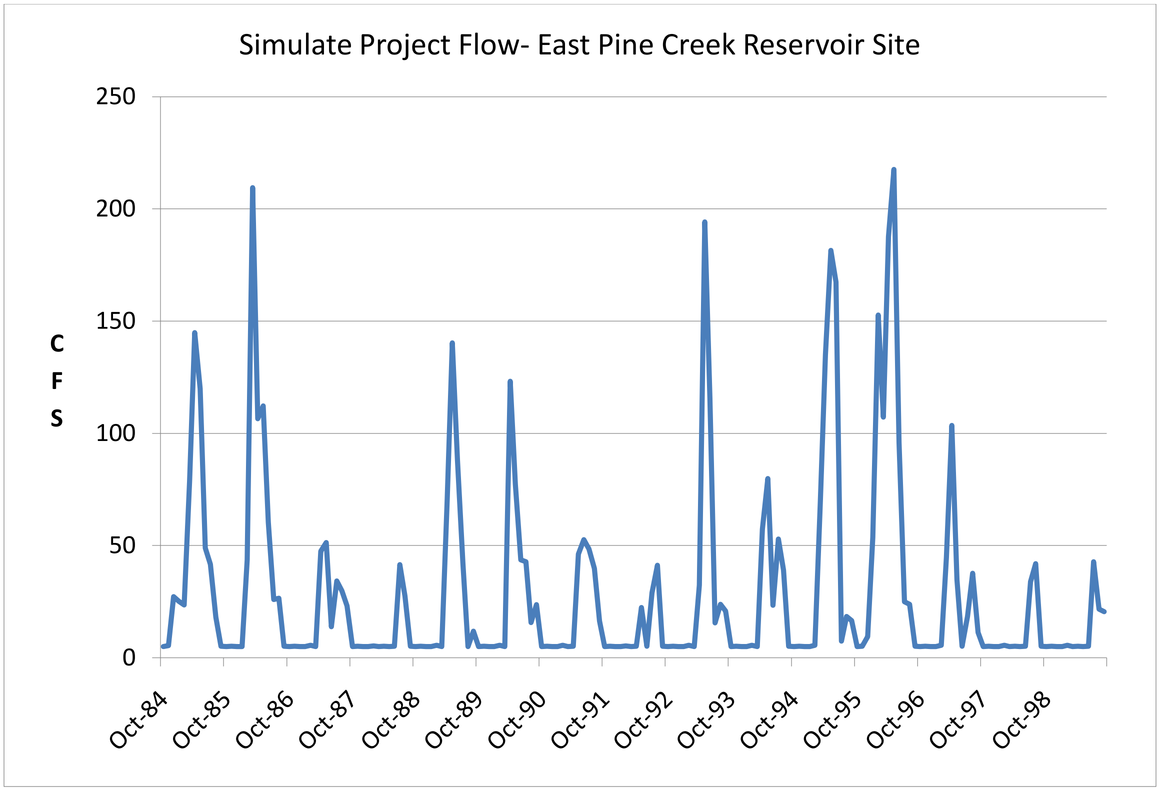

FIGURE 15: PROJECT HYDROLOGIC REGIME- MONTHLY MEAN

HARDMAN DAM SITE – SOUTH FORK BURNT RIVER

The Hardman Dam site is located on the south fork of the Burnt River and the site has been an option for above ground water storage since 1961 (Bureau of Reclamation July 1961). The site is located entirely within Township 13 South, Range 36 East, W.M. The drainage basin was characterized by the US. Department of Agriculture Forest Service in an June 1967 Impact Report as follows: "The ridge top forming the boundary of the South Fork basin separates it from the John Day River drainage on the north and the Malheur River on the south. Bullrun Rock, on the south side, is the highest point along this ridge. At 7,873 feet elevation, it is over 3,600 feet higher than the dam site six miles north. The basin thus formed is circular, opening to the northeast."

Historic reservoir calculations and estimates are as follows:

* Earth fill dam 150 feet high
* Surface Area 257 Acres
* Storage capacity of 14,000 acre-feet
* Minimum pool 1,850 acre-feet
* Typical water surface elevation 4,370 feet
* Average water surface during recreation season – May 1 to Oct 1 – 4,339 feet

The Bureau of Reclamation and HDR Engineering at the request of the Powder Basin Water and Stream Health Committee are conducting a basin yields analysis and a hydrologic analysis of the site to determine the amount of water available for storage at the proposed reservoir site. The new studies could alter the specifications of the reservoir from historic specifications.

HARDMAN DAM SITE- WATERSHED CHARACTERISTICS

The watershed elevations above the reservoir range from 4349 ft to 7815 ft above sea level. The mean slope of the watershed is 15.78. Annual precipitation is 28.96 in. with 91.47% forest cover. South Fork Burnt River is a low gradient stream that has morphological characteristics similar to the Rosgen C channels. At the proposed reservoir site the valley is a wide U-shaped valley with low stream gradient. The channel throughout the proposed site is in a deposition reach. The upland community around the proposed site is *Artemisia spp./Juniperus spp.* communities with the riparian habitat consisting of *Salex spp./ Carex spp.* communities.

HARDMAN DAM SITE HYDROGRAPH – GENERAL ANALYSIS

Analysis of 28 years of monthly average stream flows depict that existing stream flows are somewhat similar to simulated project stream flows. Under project conditions there are two peak flows projected to drawdown in the reservoir from irrigation, and then a second uptick in flows when runoff (inflow) exceeds reservoir outflow. From May through August, outflows will be higher under project conditions than they are currently. Then from October through March stream flows will be less than they are currently whereas the reservoir will be filling. Existing streamflows during June and July dip to nearly zero since almost all the water is diverted for irrigation purposes. Data analysis shows that streamflows during the same time period with the reservoir will fluctuate from 750 acre-feet to approximately 2250 acre-feet; resulting in a significant increase in instream water flow. It is interesting to note that due to the short growing season most irrigation ceases in August in the south fork Burnt River drainage basin, thus there is an uptick in both the Simulated Project Flows and Simulated Existing Flows during that time period.

Simulated natural flows were computed using stream gauge data from a gauge located on Barney Creek that would actually flow into the project. They are computed by adding back into the stream gauge data the amount of water diverted upstream from the gauge. When analyzing natural flow data it should be noted that on this particular site under existing conditions there is more stream flow from October to March than under natural conditions. This can be explained by subsurface return flows to the stream from irrigated pasturelands.

All peaks in the hydrograph indicate that peak runoff occurs from March through June. The area gets very little precipitation from October through December.

Hydrograph and Ecological Flow Analysis – Hardman Dam Site.

Optimum Peak Flow Analysis

Peak flows in the South Fork Burnt River drainage basin typically occur from March through June. Under project conditions, there will actually be two peak flows per storage season (**Figure 12**). The first occurring in April and the second occurring in June once outflow and inflow have reached equilibrium or inflow exceeds outflow and subsurface flows from irrigation begin adding to the instream flows.

Under existing conditions the hydrograph peaks in February and then climbs to another peak in April of approximately 2,500 acre-feet (40 cfs). In contrast, under project conditions the hydrograph begins to climb steeply starting in January and peaks at approximately 2800-acre-feet in April and again in June at 2,250 acre-feet. The significance is that peak flows will actually be increased under project conditions compared to existing conditions, which will be conducive to channel maintenance flows and thus, ecological flows.

The duration of increased streamflow is the main difference between the current and project conditions (**Figure 13** and **14**). The extended duration of increased streamflow is beneficial for the ecological maintenance of vegetation and fish habitat. The gradual increase and gradual decrease of the streamflow will may introduce a new pattern of streamflow characteristics for the maintenance of the ecosystem, yet the project conditions would closely mirror the timing and duration of streamflow under natural conditions. Low flow conditions, based on the modeled project flows, may need further regulations in order to maintain overwintering conditions for the ecosystem and fish species.

Flushing Flow Analysis

The species of concern in the South Fork Burnt River drainage area is the redband trout, a species listed in the State of Oregon as 'sensitive'. There is very little information available concerning quantifiable triggering ecological flows for this species. According to studies done by the Forest Service, the area has "the best water conditions for trout production in the Burnt River drainage." However, there is one major condition, which hampers trout habitat, lack of habitat complexity (pools, riffles, resting places). The water is cold and clear and does flow year round, even though late season flows are often very low.

A water storage project could potentially help this issue by providing water for 'scheduled' channel forming flows, which would also aid with or act as a flushing flow. Furthermore, there may be a potential increase in available habitat and habitat complexity from the ecosystems response to the increased durations of increase channel flow.

By-Pass Flow Analysis

Redband trout is the species of concern in this watershed; anadromous fish access is blocked by downstream dams.

Currently, streamflows drop to nearly zero in June prior to irrigation subsurface return flows entering the stream profile and increasing instream flows. Under project conditions, the data shows that average minimum flows stay above 500 acre-feet. With these circumstances instream fish passage barriers are actually decreased with a dam in place.

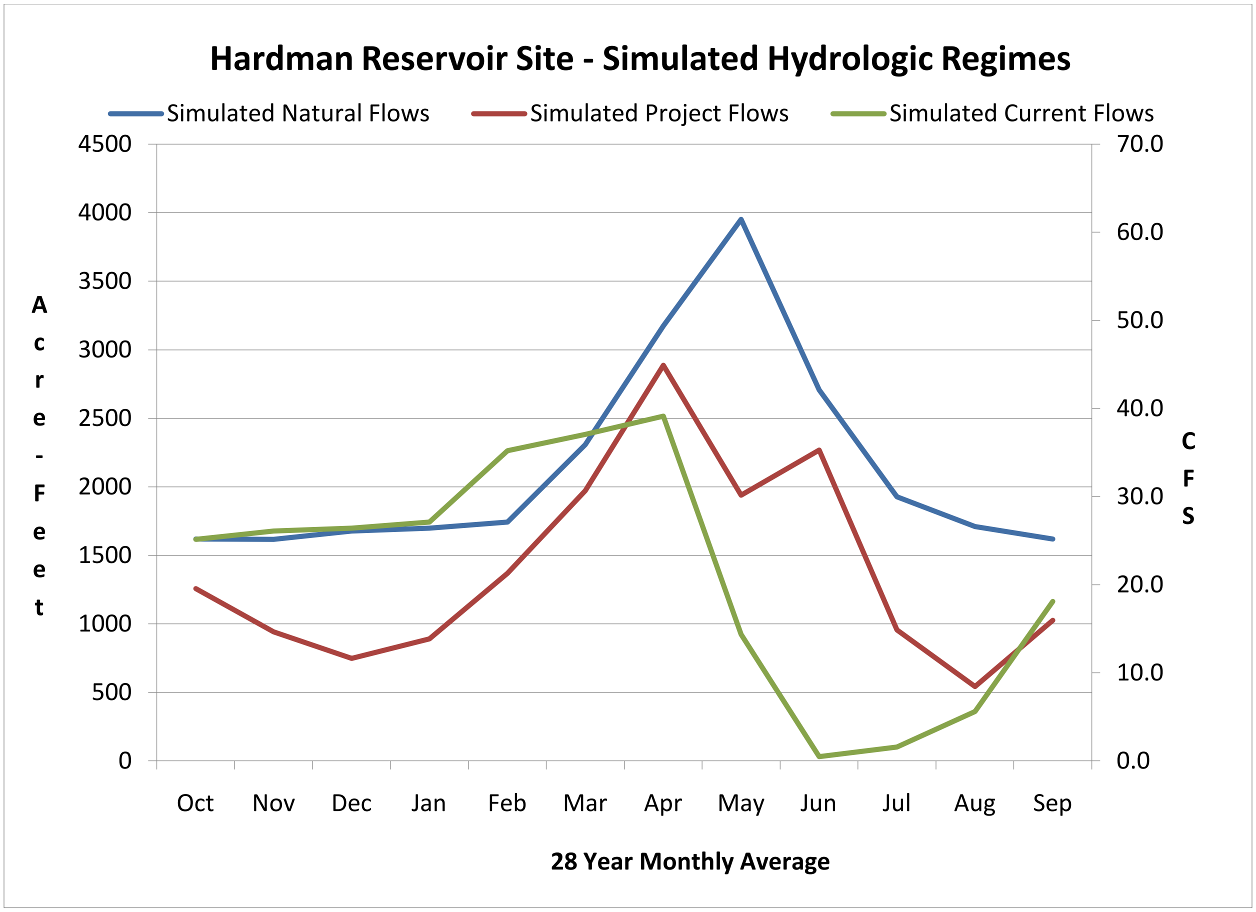

FIGURE 16: HYDROLOGIC REGIME OVER 28 YEARS- HARDMAN DAM SITE

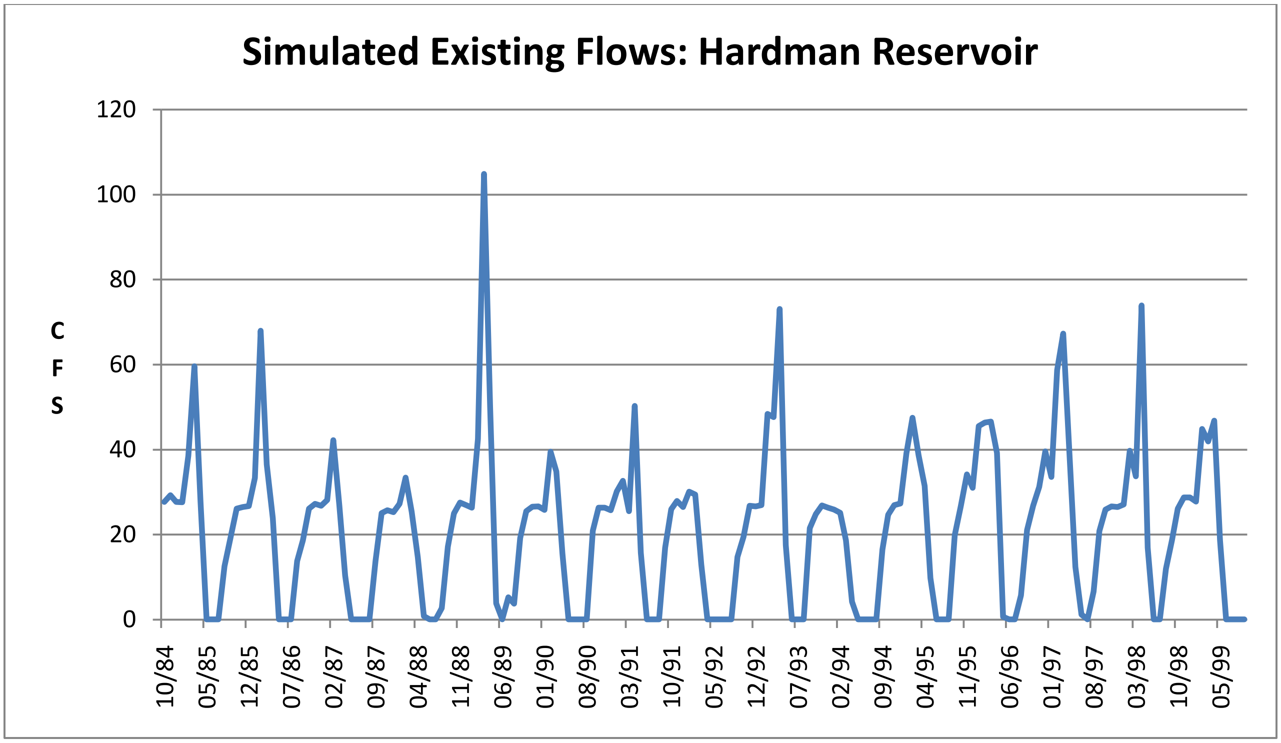

FIGURE 17: EXISTING HYDROLOGIC REGIME- MONTHLY MEAN

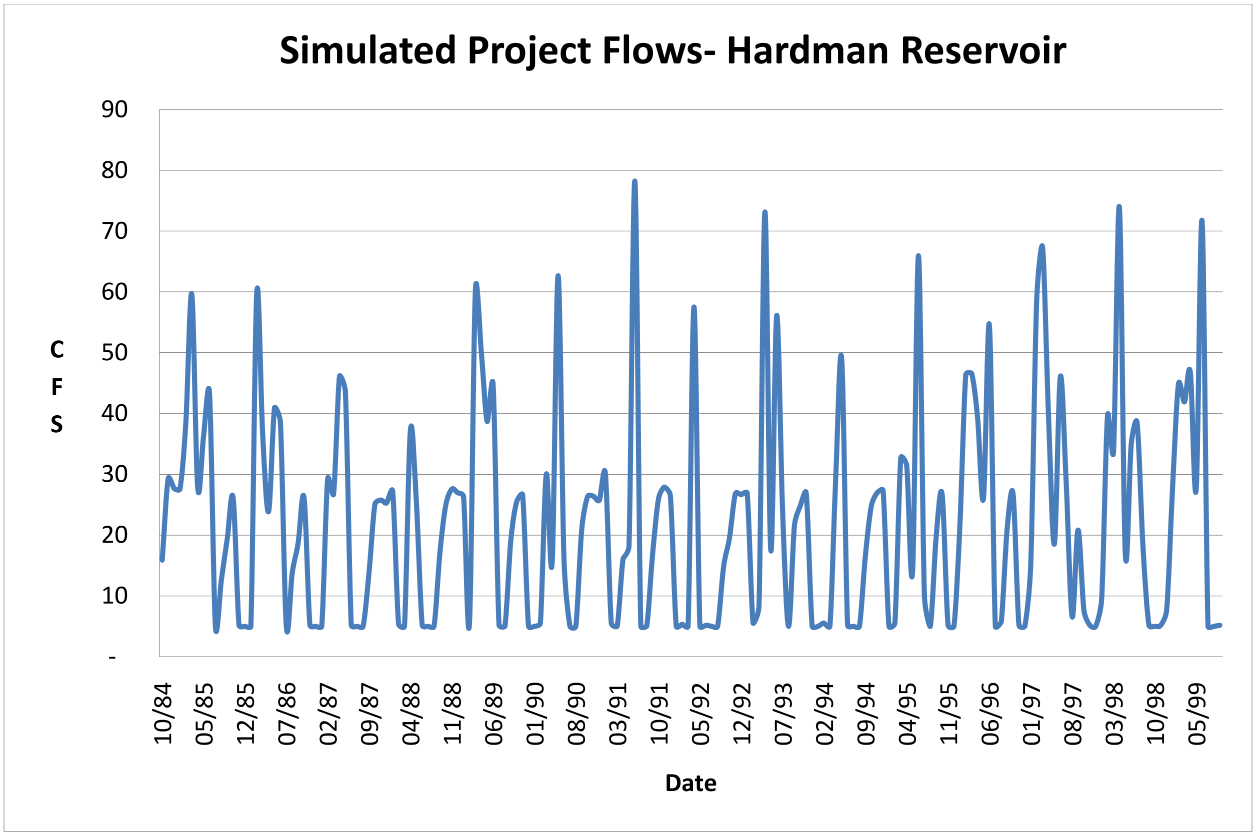

FIGURE 18: PROJECT HYDROLOGIC REGIME- MONTHLY MEAN

General Hydrologic Summary

Based on the simulated models of hydrologic regimes for each of the proposed sites, project conditions will provided the maintenance of current streamflow conditions, and potentially increase the ecological condition of the adjacent riparian habitat and fish habitat. The simulated project conditions provide similar patterns of streamflow consisting of two peaks. The major difference at each of the sites is the shift in peak flows by several weeks to a month. This is a result of the introduction of a reservoir or increase capacity and the time it takes to fill the reservoir and reach or surpass equilibrium.

At several of the sites, the magnitude and the duration of the peak flow conditions increase. This increase in magnitude and duration would potentially provide improve ecological conditions for the instream and riparian ecosystems. In addition, at most sites the descending limb of the hydrograph, under current conditions, is relatively steep. Under simulated project conditions the rate of change is decreased with shallower descending curve, thus maintaining streamflow over a longer period of time in watershed systems that currently have low flow conditions early in the summer months. This extension in duration would potentially benefit fish habitat with maintenance of desirable stream temperature and decrease in bacteria and algae production.

Conclusion

In conclusion, it is apparent that the next level of studies needs to address and quantify stream channel classifications and stream ecological characteristics (such as habitat, vegetation, and sediment) and at least at a 'general' stream reaches scale. As a result of characterizing stream reaches adjacent to the downstream segment of the dam a quantifiable range can be determined for channel maintenance flows. It is apparent that after numerous years of research there is still limited quantifiable ecological flow data for redband trout in Eastern Oregon or in areas of similar climate, topography, and longitude. Therefore, it is an accepted practice to rely on the best available science, which in this case is calculating channel-forming flows (Robison) and appropriate application of management recommendations for the several studies in Idaho and Montana (Muhlfeld et al. 2001a and 2001b and Zoellick and Cade 2006).

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APPENDICES

Appendix A: Development of Demand Simulation Model for Pine Creek, Powder River, and Burnt River

Development of Demand Simulation Model for Pine Creek, Powder River and Burnt River

Purpose of demand Model

As with most river systems in the west, each river basin is managed under a prior appropriations system. The prior appropriation water right system states that senior down stream or upstream users have the right to divert water over junior users. This limits how much water can be utilized by junior users. In the case of the Powder River, Burnt River and Pine Creek storage study, the potential to store water is limited by the prior appropriations.

The use of a priority based demand model can help sort out the potential for storage by taking into account all senior uses on a river system. These include irrigation, agriculture, livestock, M&I and mining demands. Instream demands can also be modeled showing water availability at high flows and lack of water during periods of low flow. The model used for this study, MODSIM, can be used to show the potential for storage and impacts of storage.

MODSIM network simulation models of the Powder River, Burnt River and Pine Creek were developed to show the hydrologic interaction between senior demands and the potential to store water at predetermined sites.

Demand

The single largest demand within the three basins is irrigation demands. Most of these water rights along with the other rights have historically been primary based surface water rights. This means that demands can be met only when the surface water runs off. Most of the time a majority of the water runs off during spring melt and flows through the system prior to demand. Usually when demand starts, flows in the river is starting to drop. For those with junior water rights, this means their diversion is shut off so senior water users can utilize the remaining water supply. The users who are turned off then are "shorted" an adequate water supply.

Even though irrigation is the largest demand, instream water rights are usually the first to be impacted because they are so junior to other uses. This usually means instream use is rarely met except during the peak run off periods. Some junior uses have developed secondary water supplies either through storage projects or through ground water well development to help meet demands during shortage periods. These secondary demands may or may not meet their full "shorted" demands.

In the developed simulation model, irrigation demands are based on crop consumptive use given an estimated efficiency and irrigated acreage. Irrigated acreage used for the development of demands was based on the irrigated acreage used in the development of natural flows (see Natural Flow Determination Report by Jack Cunningham). The following list of acreage was further aggregated by natural dividing points.

Acreage

Base is acreage used in natural flow development

Burnt River		
Above Unity Res		**8,196.5**
Lower Burnt River		**11,880.0**
Pine Creek		
Pine Creek above Gauge		**18,224.0**
Powder River above Thief Valley		
Powder River above Baker City		**8,486.8**
Powder River below Baker City		**96,074.5**
BVID	30,894.7	
Salmon Creek Tributary	17,118.0	
Rock Creek Tributary	16,403.0	
North Powder River Tributary	22,986.0	
Wolf Creek Tributary	8,672.8	
Powder River below Thief Valley		
Lower Powder River	**20,680.0**	
Powder River Thief Valley	8,000.0	
Lower Powder River Tributaries	6,777.0	
Eagle Creek	5,903.0	
Total Acreage Used		**163,541.8**

Average Irrigated Acreage based on Ag Statistics	132,786.3
Max Irrigated Acreage based on Ag Statistics	157,790.0

In the development of natural flows, irrigated acreage was limited to irrigated acreage defined in the U.S. and Oregon agriculture statistics. For natural flow, the maximum irrigated acreage accounted for in the three basins was 157,790 acres with average acreage being 132,786 acres. In order to properly account for true demand, it was decided to use primary water righted acreage to define irrigation demand. The three basins irrigated lands had a slightly larger value of 163,541.8 acres.

Distribution of Agriculture Demands

The distribution of the above irrigated acreage was accomplished using the Oregon Water Resources Department Point of Diversion (OWRD POD) database. This data was first filtered to separate surface water from ground water rights. It was then filtered to remove secondary surface water rights from Primary rights. The removal of secondary rights was to insure that there was no double accounting of irrigated acreage. The final data was then sorted based on tributary information and assigned to defined supply nodes (supply nodes referenced in Natural Flow Determination Report).

The natural flow tributary acreage was then distributed based on the weighted percentage from the OWRD POD data for each tributary. Within each major tributary, there were numerous miscellaneous surface water rights, ex. return flow rights and spring rights that were assigned to the down stream supply node, the pour point of the tributary basin or a natural flow node if the right was down stream from any supply node.

It is noted that the OWRD POD data set had large data gaps in the POD information. Where there were data gaps, this study used the OWRD Point of Use (POU) data set to fill in some gaps. Again, this OWRD POU file had errors where large tracks of land were being double accounted in the data set. It was also noted that in some cases there were some lands being accounted for three or four times. Simple filters based on 40 acre parcels were used to try to weed some of those errors out of the analysis. These gaps lead to a significant uncertainty in actual water righted acreage in the three basins.

In the Burnt River Basin, gaps were noted in the Upper Burnt, Alder Creek, Lawrence Creek, and Rye Valley tributaries. Original irrigated acreage data was obtained from the Burnt River Irrigation District for natural flow development. Subsequent information showed that there were numerous other areas with irrigation rights that were off stream from the Main Stem Burnt River and were not accounted for in the natural flow development. Since a majority of this area was considered down stream from most of the supply node sites, a limited attempt was made to fill the gaps.

The Powder River Basin had significant data gaps in a number of its tributaries. The OWRD POU files were used to correct some of these gaps. Powder River above Baker (Bowen Valley) showed that there are significant diversions that equated to over 27,000 acres served above Baker City while the POU file showed a little over 6,000 acres irrigated from the Powder River and its tributaries. Also the POD data indicated there were significant diversions that equated to over 54,000 acres irrigated served from the Powder River below Baker City. Baker Valley Irrigation District (BVID) indicated that only 30,894.7 acres is served below Baker which is essentially the limit of irrigated land served below Baker. Salmon Creek, Rock Creek and Wolf Creek systems also showed a large data gaps. These data sets were augmented using the OWRD POU files.

Pine Creek had a significant data gap. The OWRD POD file indicated that less than 4,500 acres was being served by the main tributaries. The OWRD POU file was used to fill this large data gap.

Demand Development

Irrigation demands were based on a consumptive use values developed by Jack Cunningham for the Natural Flow Determination Report which were weighted by crop distribution. The demand per irrigated acre was developed by dividing consumptive use by an assumed 90 percent distribution efficiency and 65 percent application efficiency for sprinkler irrigation or 45 percent for flood irrigation, similar to Jack's methodology. The application efficiency was weighted based on best engineering judgment for potential to use sprinklers in any tributary. Reuse was also incorporated in some areas if it was determined that return flow would be reused. The established demand per acre was multiplied by tributary acreage to get 30 years of monthly irrigation demand at each supply node.

Model Development

MODSIM, a network simulation model, was used to simulate operation of the Powder River, Burnt River, and Pine Creek basins. This model was selected based on its ability to allocate water based on priority. A link node schematic network, based on GIS maps provided by Dale Linderman, was developed for each of the three basins within the MODSIM GUI interface. The most up stream supply nodes were populated by patterned natural flow records developed by the Natural Flow Determination Report. Down stream nodes were populated by local gains, which is the difference in patterned flow between the upper supply node and the down stream node.

When upstream area patterns were subtracted from downstream points of natural flow, some negative gains were derived that did not simulate actual conditions. In most cases, this negative gain was derived because a different natural flow station was used to pattern upstream points and downstream points. In these cases, alternative patterns were developed using the natural flow station which was used in the above nodes. This resulted in deriving new local gains without negative values. In a few cases, the regression equations using median elevation results in a downstream point having less average runoff than the upstream points. In these cases a rational was developed to distribute gains among upstream areas of a natural flow point based more on drainage area. Some missing and obvious inaccurate data was filled in and corrected to produce new natural flow estimates at some of the Powder River gages. This work in conjunction with a spatial distribution of negative gains at Thief Valley Reservoir and the reaches directly upstream of this site was a major revision to the original work done in the Natural Flow Determination Report. The gains modified and used in the three basin models are summarized in the Excel spreadsheet "SupplyNodes.xls". The spreadsheet "BasinCharacteristics.xls" is an update of that showing the gages used to patterns in deriving the natural flows and local gains.

The local gains derived and diversion demands provided were entered along with existing reservoir characteristics from SOP documents. Return flow lag and location were entered for each diversion demand. The return flow lags were assumed at the same level throughout the basins; 42% of diversion over three months in a 4/7, 2/7, 1/7 pattern. Small existing reservoirs and their size are referenced in the spreadsheet "storage size.xls".

Priority

In order to simulate historic operation of the three basins, demands are given an algebraically lower number (for a first priority) over the reservoir nodes; water will be delivered to demands before stored in the reservoirs. Reservoirs in a basin were given higher priority in upstream reaches allowing better refill priority than downstream reservoirs. No link costs were incorporated in the networks for this initial analyses; the demands are met as a first priority then proposed reservoir sites are added to analyze to what extent the reservoirs can store excess flow and decrease diversion shortage.

Corrections to Natural Flow

Natural flow developed for gauge 13281200 was corrected due to an error in output from a summation program developed to format the output data. The original data from the Natural Flow Determination Report was correct but was improperly formatted. This required all supply nodes developed from this natural flow gauge to be redeveloped and entered into the model.

Another error that was overlooked in the original Natural Flow Determination Study was the double accounting of Rock Creek acreage at the natural flow gauge site 13284900 and at the subsequent down stream gauge 13285500. Gauge 13281200 took into account bypass flows to serve 3,910 acres in other tributaries. In developing natural flows at gauge 13284900, the full acreage of 16,403 acres within the Rock Creek sub-basin was used to add in water consumptively used. Since this diversion had already been added to the adjustments at 13281200, returns should have been the only thing removed from the flow at 13284900. The returns were subtracted but the consumptive use for the full acreage was added back along with the adjustments at 13281200. This resulted in a double accounting of 3,910 acres. This readjusted data was developed and entered into the model.

There were also other errors found at gauge 13285500. These errors were not related to the Natural Flow Determination Report. It was found flows at 13285500 minus flows at 13284900 did not equal storage in Thief Valley Reservoir. Some differences were three times the size of Thief Valley Reservoir. Since these errors could not be explained and correlations with other gauges were not significant (r^2 was about .45), it was decided not to use developed natural flows at gauge13285500.

Development of natural flows at gauges 13285900, 13286700, and 13288200

Natural flow was developed for gauges 13285900, 13286700, and 13288200 using Jack's established methodology. Jack's template was used along with consumptive use numbers that he derived for the Natural Flow Determination Report.

Historic gauged data for 13285900 was corrected for diversions around the gauge that served 1480.6 acres. The diversion had historic gauged data with only a few months of missing data. As in the Natural Flow Development Report, the water availability factor (WAF) developed for the Wolfe Creek drainage was applied to the developed demands to estimate diversions around the gauge. This gauged was correlated with gauge 13283600 to fill in missing natural flow data.

Historic gauged data for 13286700 was corrected for accumulated adjustments above gauge 13285900, consumptive use above the gauge and for returns from Big Ditch which diverts around gauge 13285900 and Phillips Ingle Ditch which diverts from the West Eagle Creek. Consumptive use from the 8,000 acres of full supply lands of the Lower Powder Irrigation District (LPID) plus the 6,777 acres of short supply lands served by the many tributaries to the lower Powder River were added into the historic gauged record. The Wolf Creek WAF was applied to the 6,777 acres of short supply lands to reduce how much water consumptively used was added back into gauge 1326700. No WAF was applied to the 8,000 acres of LPID lands. The derived natural flow correlated well ($r^2 = 0.97$) with all the main stem Powder River gauges. Only the last two years, 1998 and 1999, had missing data. This data was derived by correlation with Gauge 13284900.

Historic gauged data for 13288200 was corrected for the Phillips Ingles Ditch diversion around the gauge. Only the last two years, 1998 and 1999, had missing data. This data was derived by correlation with Gauge 13275100.

Distribution of local gain at Warm Springs Reservoir POD, Sunny Slope Reservoir POD, and Muddy Creek Reservoir POD sites

Local gain at three sites Warm Springs Reservoir POD part of North Powder Tributary, Muddy Creek POD part of Rock Creek Tributary, and Sunny Slope Reservoir POD part of Wolfe Creek Tributary were reviewed and adjusted to better represent real condition local gains at these sites.

In developing the local gain to the Warm Springs Reservoir POD site, the Wolf Creek Reservoir POD monthly inflow values were set to natural flows at gauge 13282400 developed under the Natural Flow Determination Report. It was decided that it was better to use the natural flow values derived from the Natural Flow Determination Report instead of the computed flow derived from annual yield even though the computed annual yield was larger than the natural flow annual yield. Flow at North Powder Reservoir remained as corrected. Flow at the Warm Spring Reservoir POD site was calculated by adding the flows from the Wolf Creek Reservoir POD site to the flows at the North Powder Reservoir site with the calculated local gain flows. These local gain flows were derived based on a weighted elevation flow for the contributing area between the three sites. Local flow was derived by taking the contributing area between the three sites (22.37 mi^2) divided by the area above Gauge 13283600 (30.5 mi^2) multiplied by flows at gauge 13283600. Since the total calculated annual yield for the Warm Springs Reservoir POD site was larger than the computed annual yield from the Natural Flow Determination Report, the flows at the site were reduced by the ratio computed annual yield to calculated annual yield. The local gain was then calculated as the difference in flow between the two upper sites and the calculated flow at the Warm Springs Reservoir POD site. These values seemed to better reflect real conditions.

In calculating the local gains to the Sunny Slope Reservoir POD site, it was decided that flows at the Shaw Reservoir POD Site would be set equal to the Wolfe Creek Reservoir site flows and that both of these site flows would be set to the natural flows derived for gauge 13283600 developed in the Natural Flow Determination Report. This seemed reasonable since all three sites are located within a few hundred yards of each other. The local gain to the Sunny Slope Reservoir POD site was calculated based on the area ratio of contributing area of the Sunny Slope Reservoir POD site (3.84 mi2) to contributing area of the Warm Springs Reservoir POD site (22.37 mi2) multiplied to the local gain flows of to the Warm Springs Reservoir POD site.

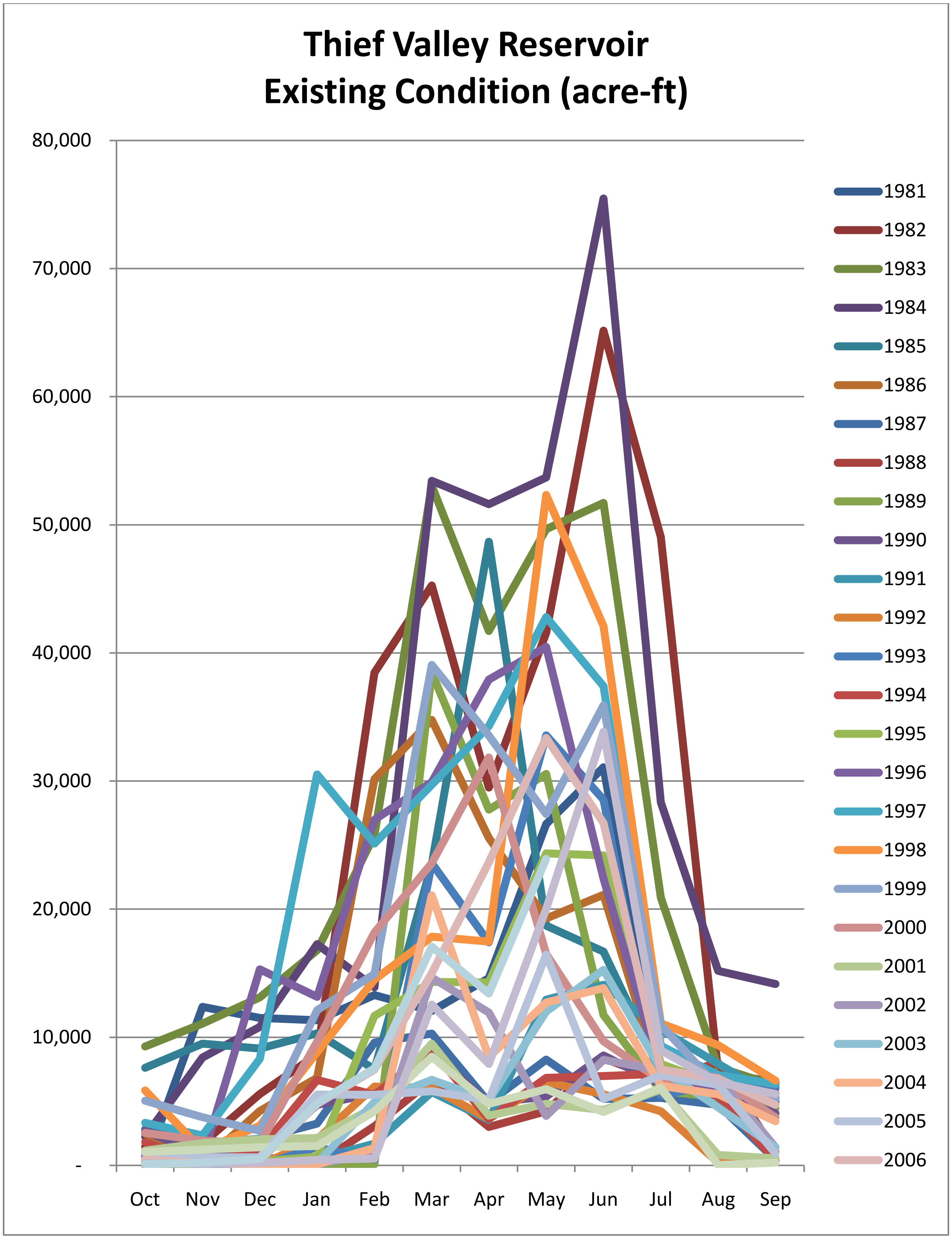
A similar type of calculation was used to develop local gain to the Muddy Creek POD site. It was decided to set the flows at the Lower Rock Creek Dam site to gauge 13281200 since there were no significant gains in that quarter mile stretch of Rock Creek. Gain from Lower Rock Creek Dam site to the Muddy Creek POD site was based on gain to Warm Springs Reservoir POD proportioned based on the computed average annual yield at each of these sites as calculated in the Natural Flow Determination Report.

Redistribution of remaining gain to 13284900 redistributed to 13277000, 13277400 and 13284900

Local gain to gauge 13284900 represents the entire area between the Smith Ditch POD site on the Powder River to the Muddy Creek Reservoir POD site on Rock Creek to the Warm Springs Reservoir POD site on the North Powder River to the Sunny Slope Reservoir POD site on Wolfe Creek with numerous headwater supply nodes located in between. Since there is a significant amount of demands identified above gauge 13284900 particularly in the Salmon Creek basin that could not access that gain because of the hierarchy in the model, it was decided to redistribute the local gain to gauge 1324900 to sites above. The distribution was 20 percent above Baker City, 17 percent to Salmon Creek and remaining to be left at gauge 13284900.

Appendix B: Simulated Existing, Project, and Natural Hydrologic Regime- All 28 Years

Thief Valley Reservoir:


Thief Valley Reservoir
Existing Condition (acre-ft)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
-
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
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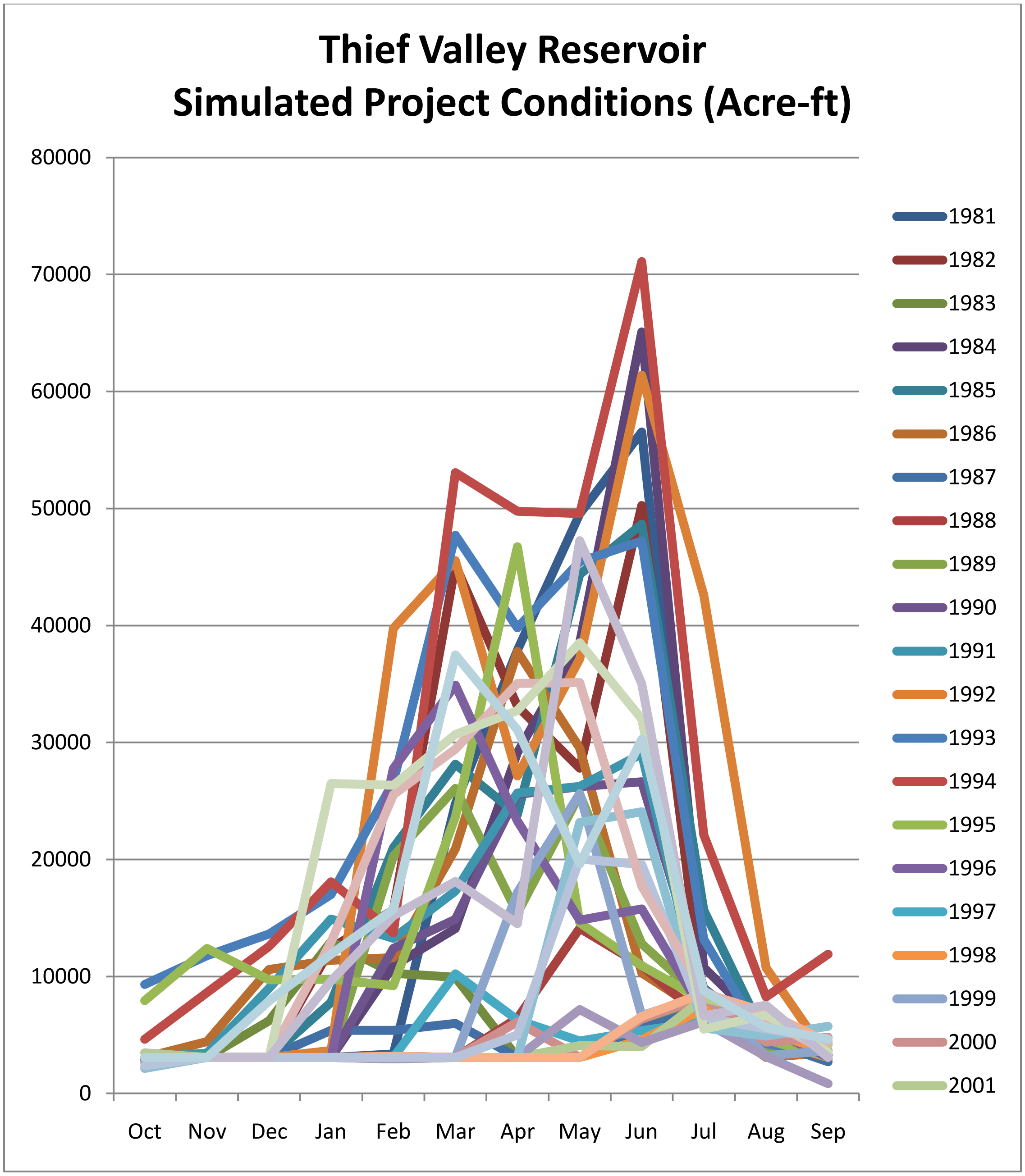
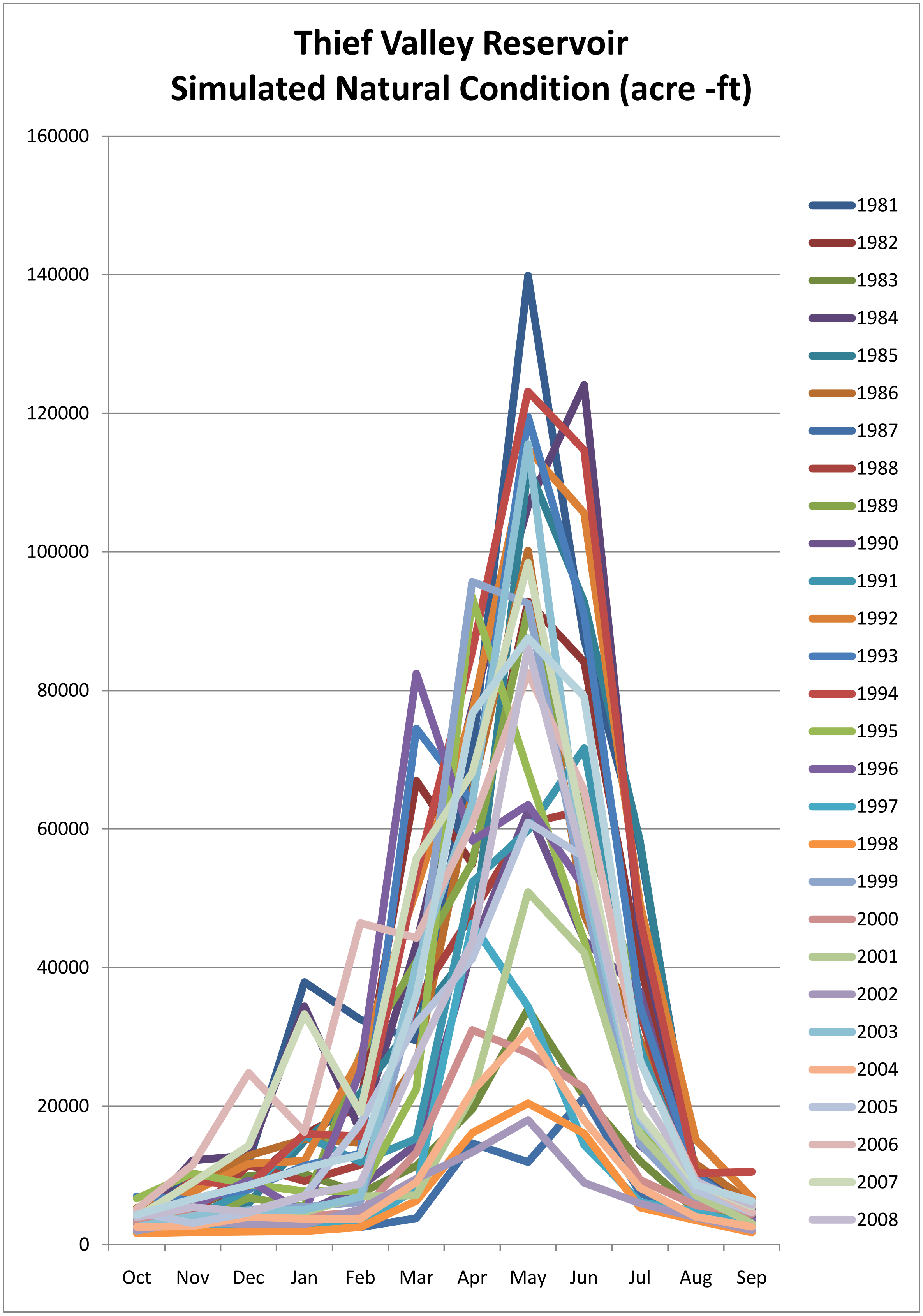
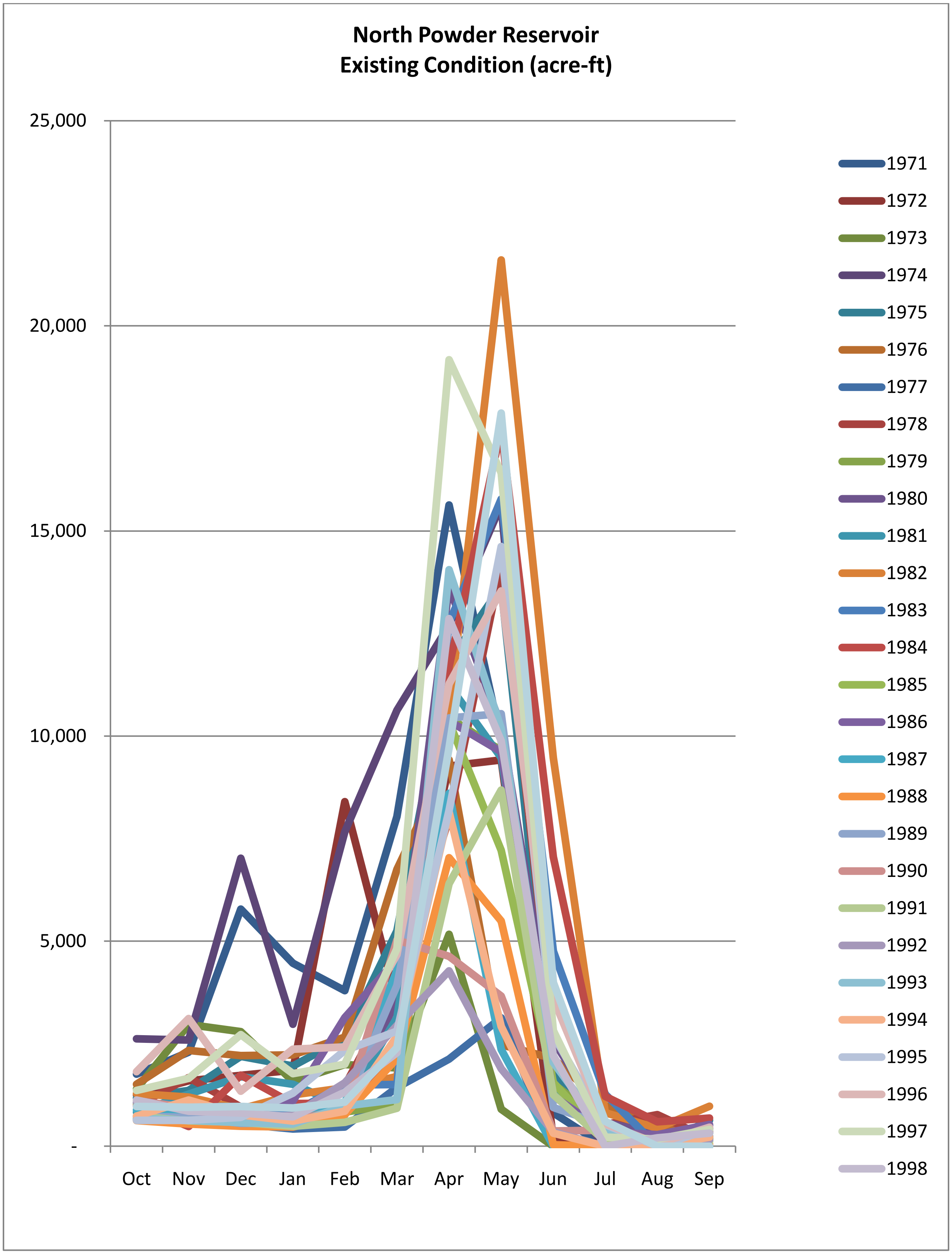
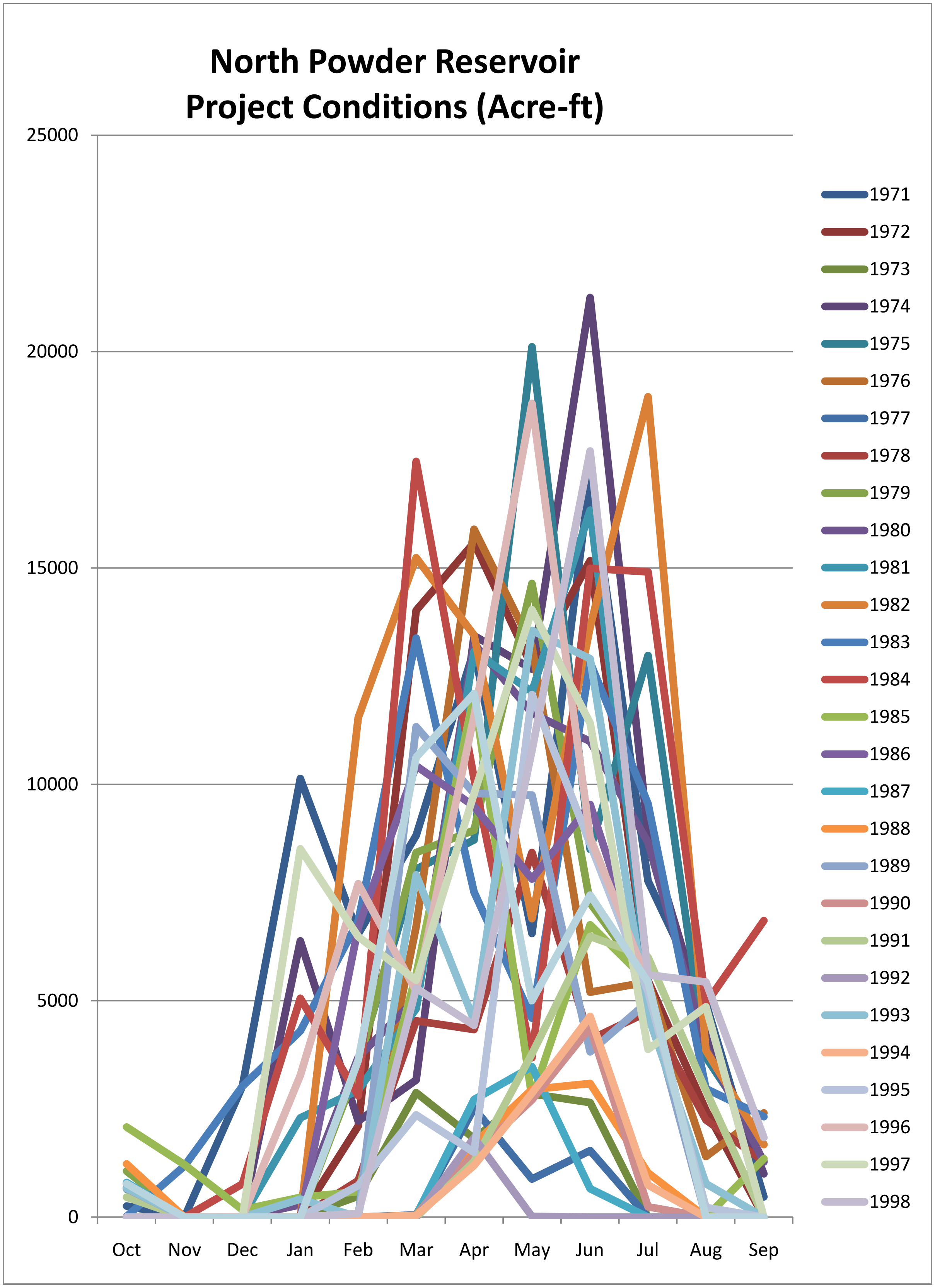
2002
2003
2004
2005
2006


Thief Valley Reservoir
Simulated Project Conditions (Acre-ft)
80000
70000
60000
50000
40000
30000
20000
10000
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001

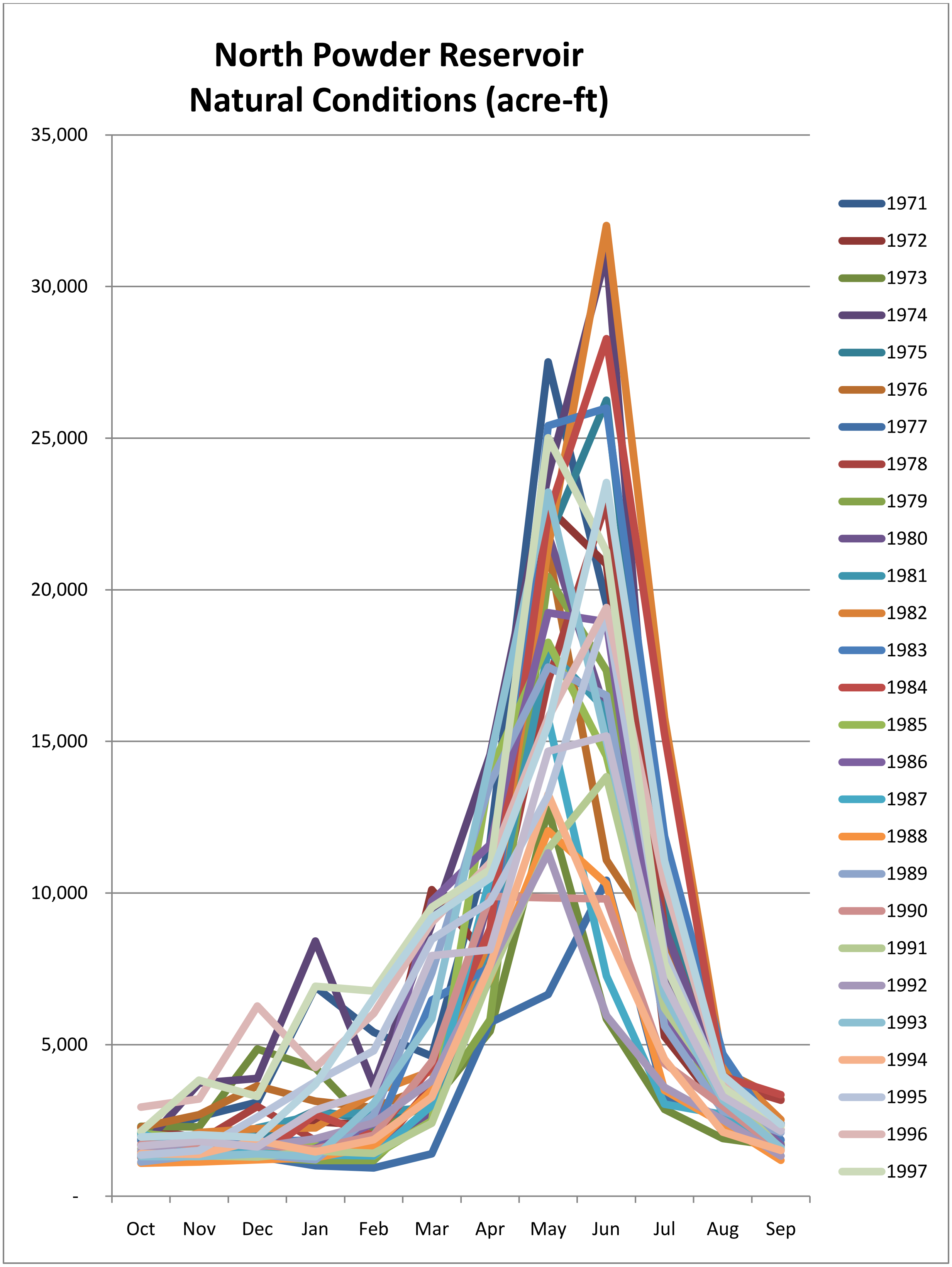

Thief Valley Reservoir
Simulated Natural Condition (acre -ft)
160000
140000
120000
100000
80000
60000
40000
20000
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008

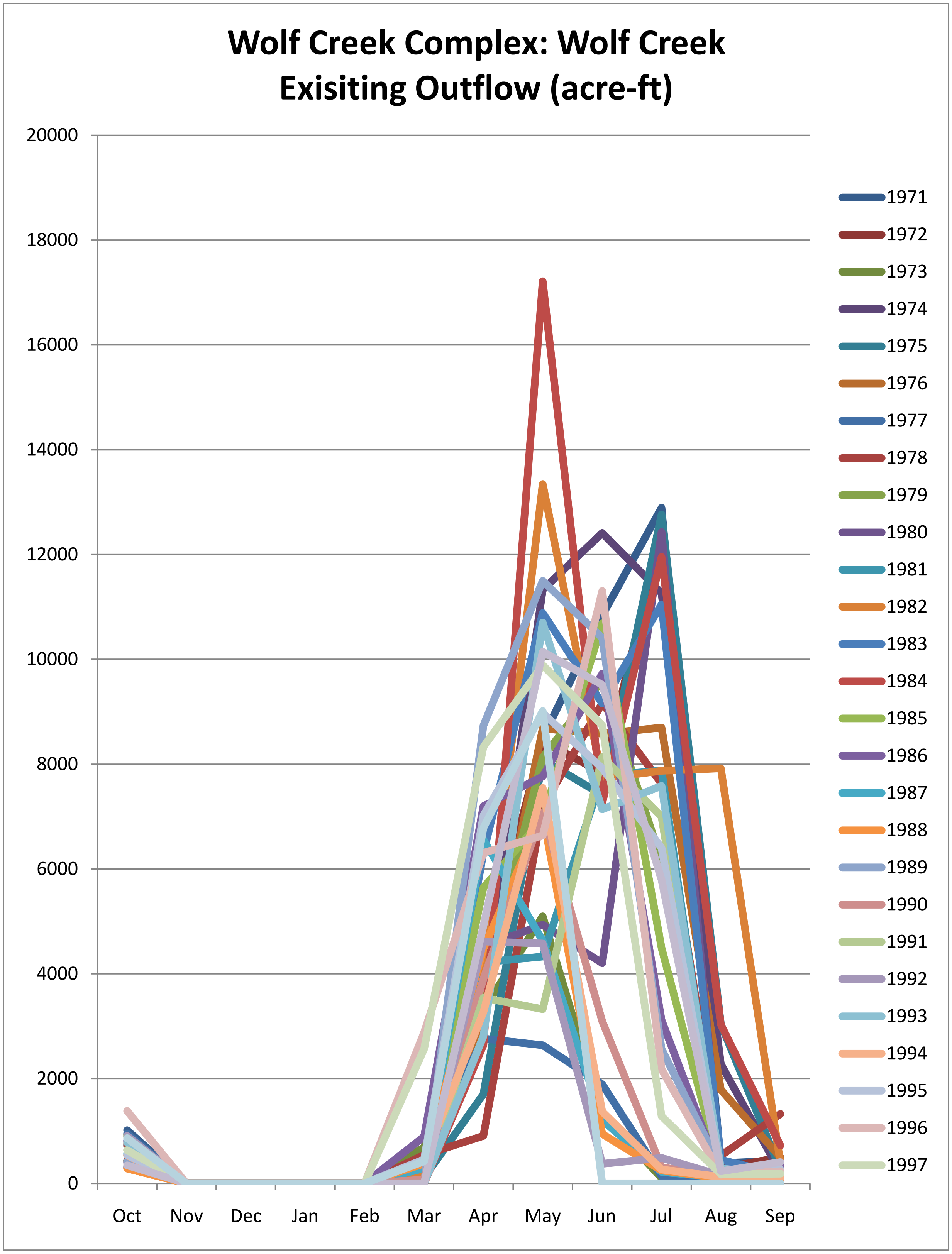
North Powder Reservoir

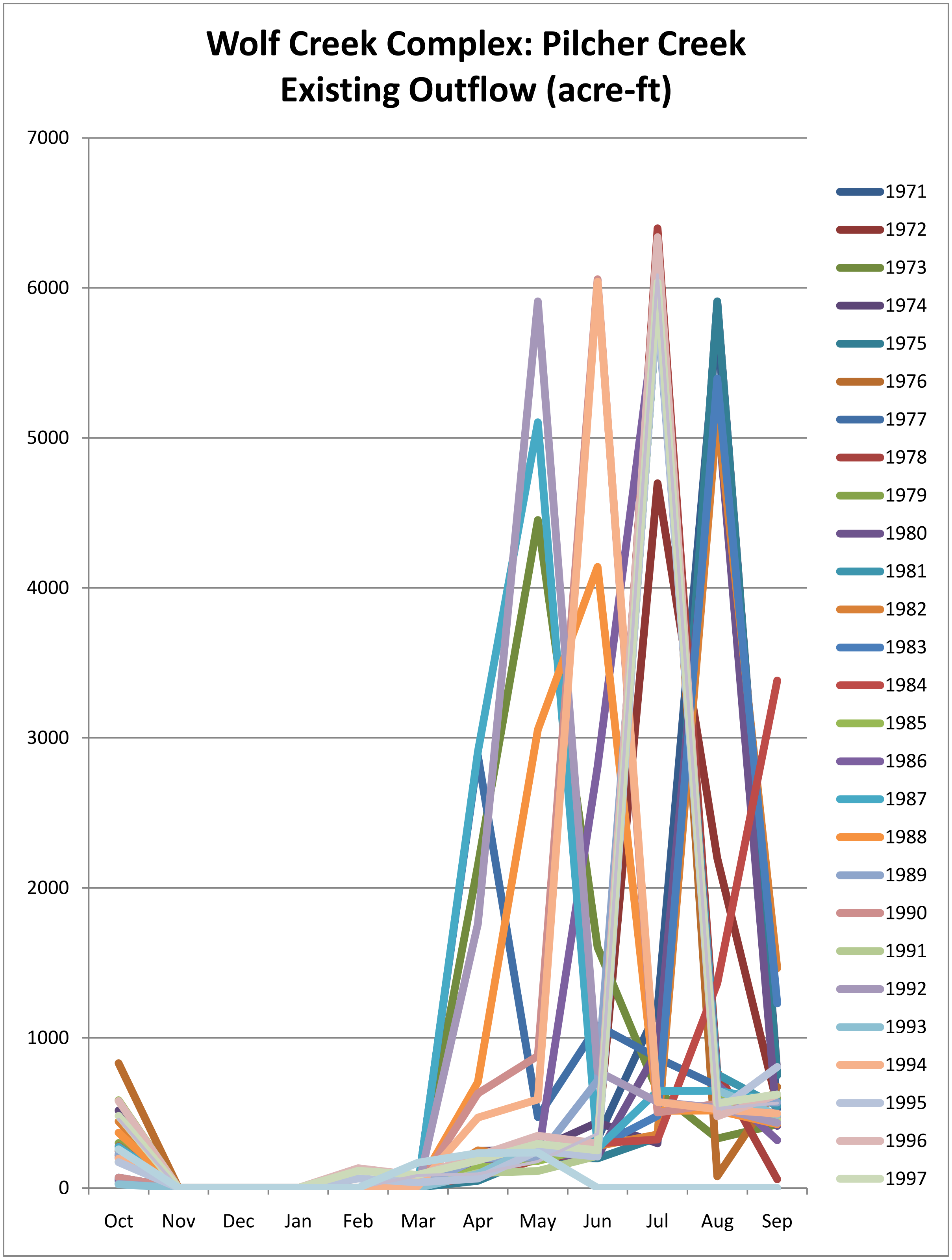




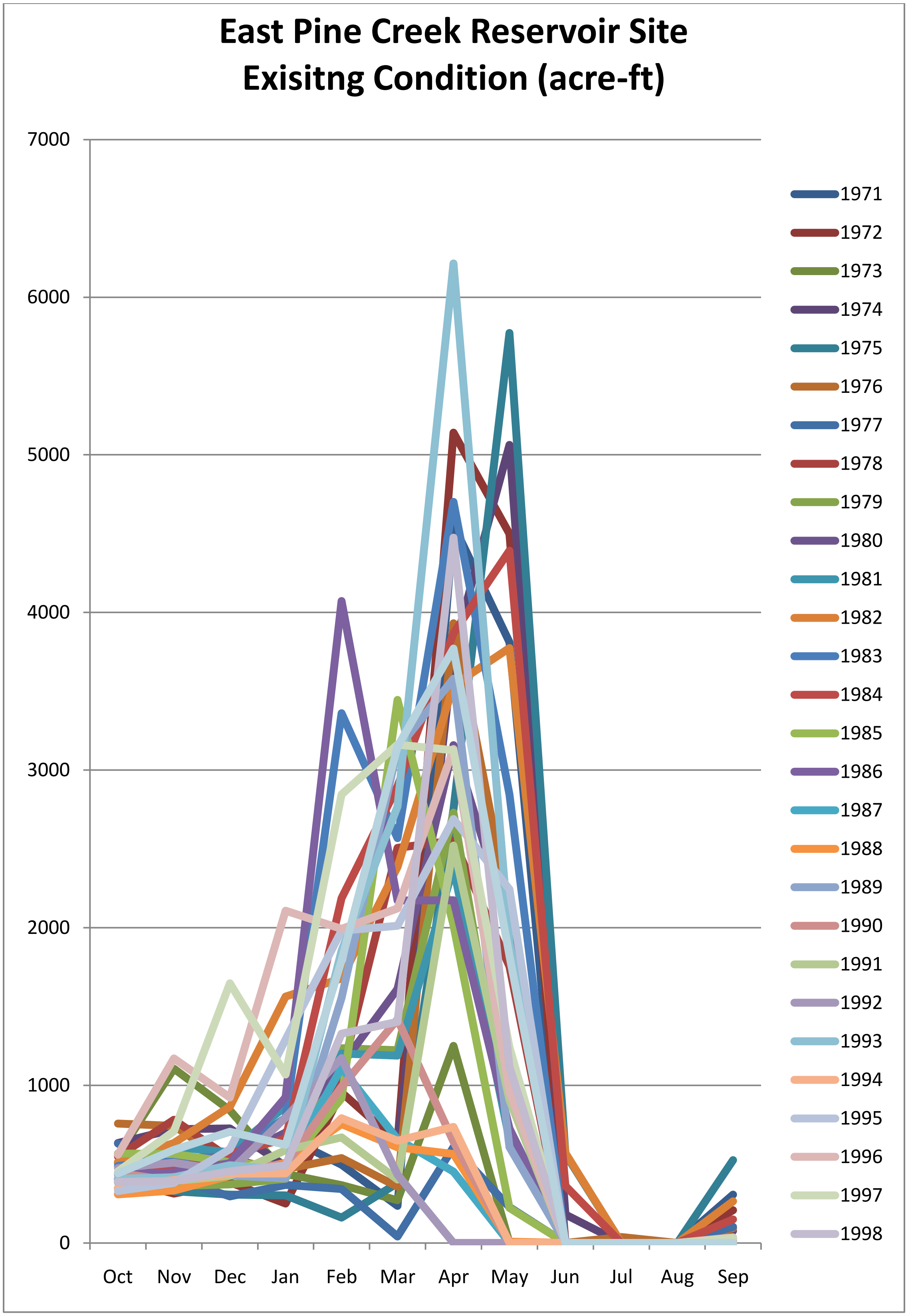
North Powder Reservoir
Project Conditions (Acre-ft)
25000
20000
15000
10000
5000
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998


North Powder Reservoir
Natural Conditions (acre-ft)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
-
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997


Wolf Creek Complex: Wolf Creek
Exisiting Outflow (acre-ft)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997

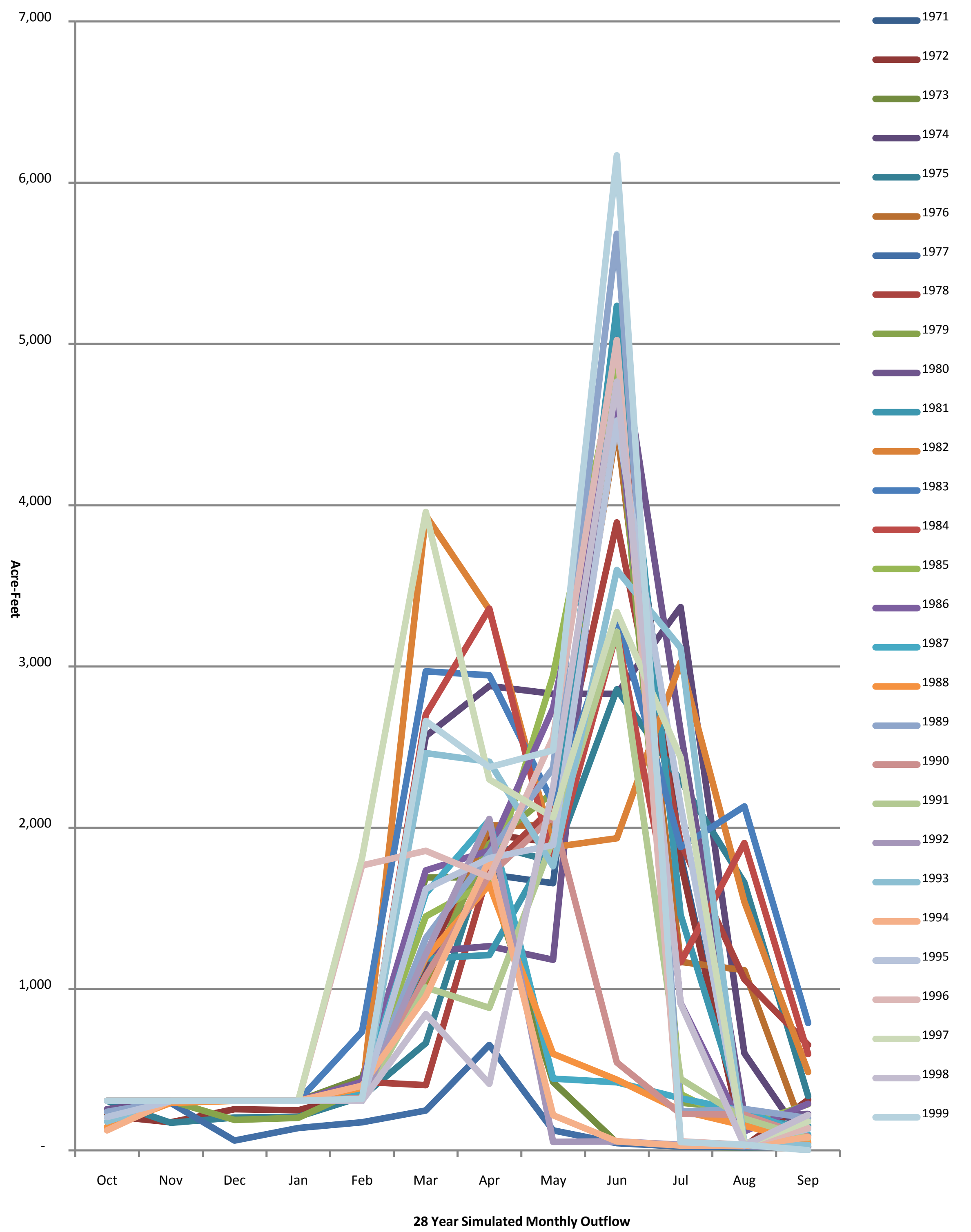

Wolf Creek Complex: Pilcher Creek
Existing Outflow (acre-ft)
7000
6000
5000
4000
3000
2000
1000
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997

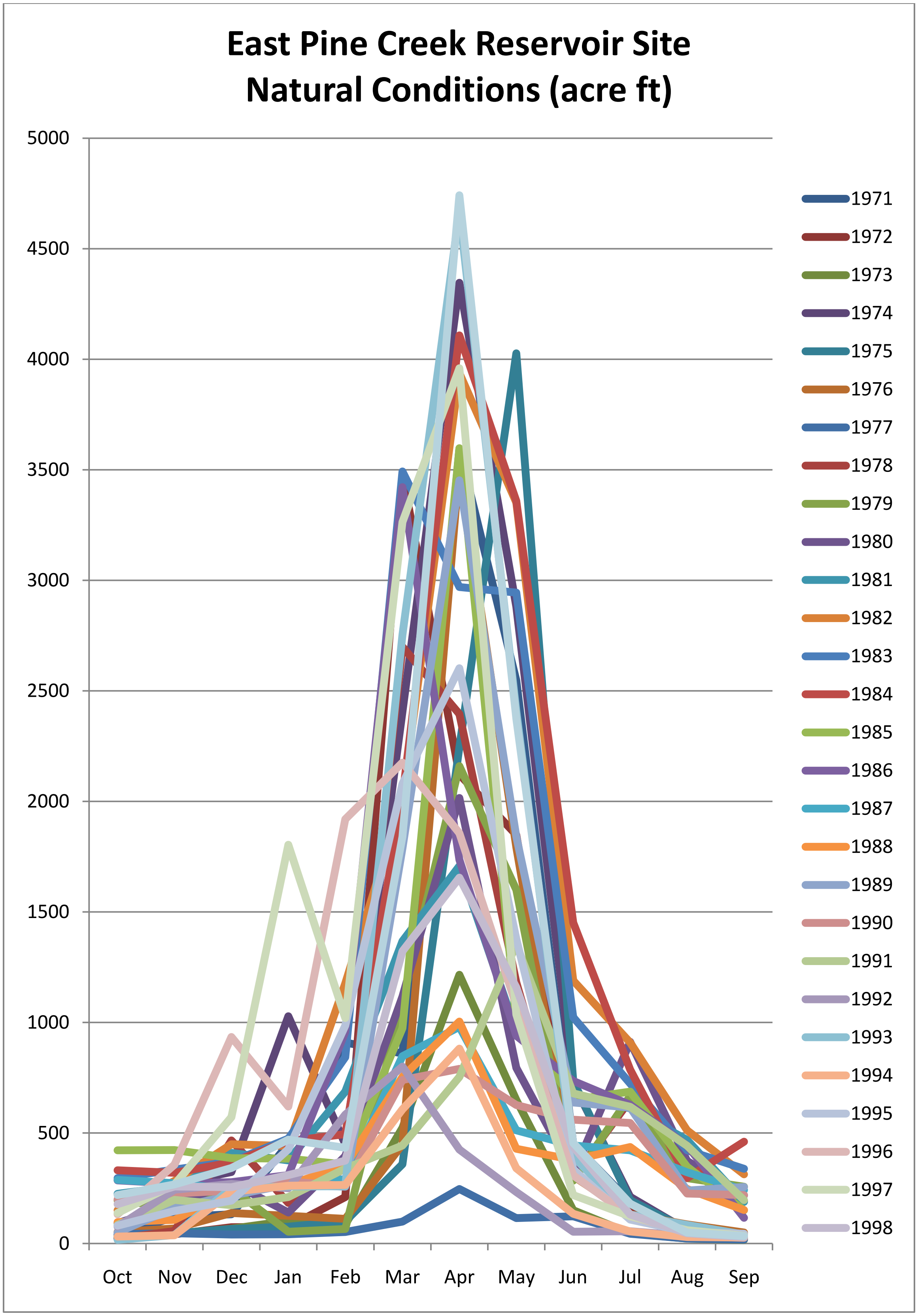
East Pine Reservoir:


East Pine Creek Reservoir Site
Exisitng Condition (acre-ft)
7000
6000
5000
4000
3000
2000
1000
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998

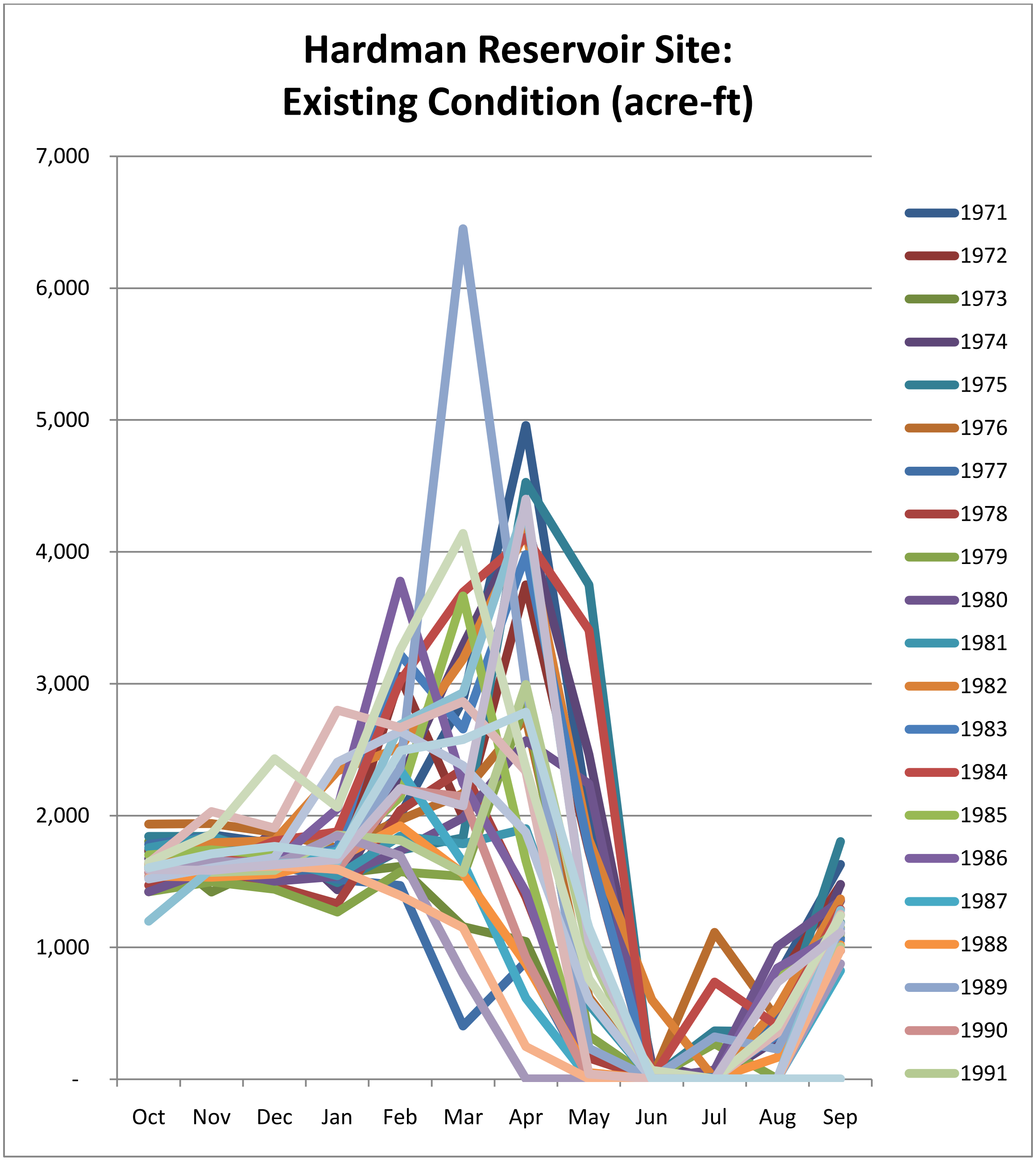
East Pine Creek Reservoir

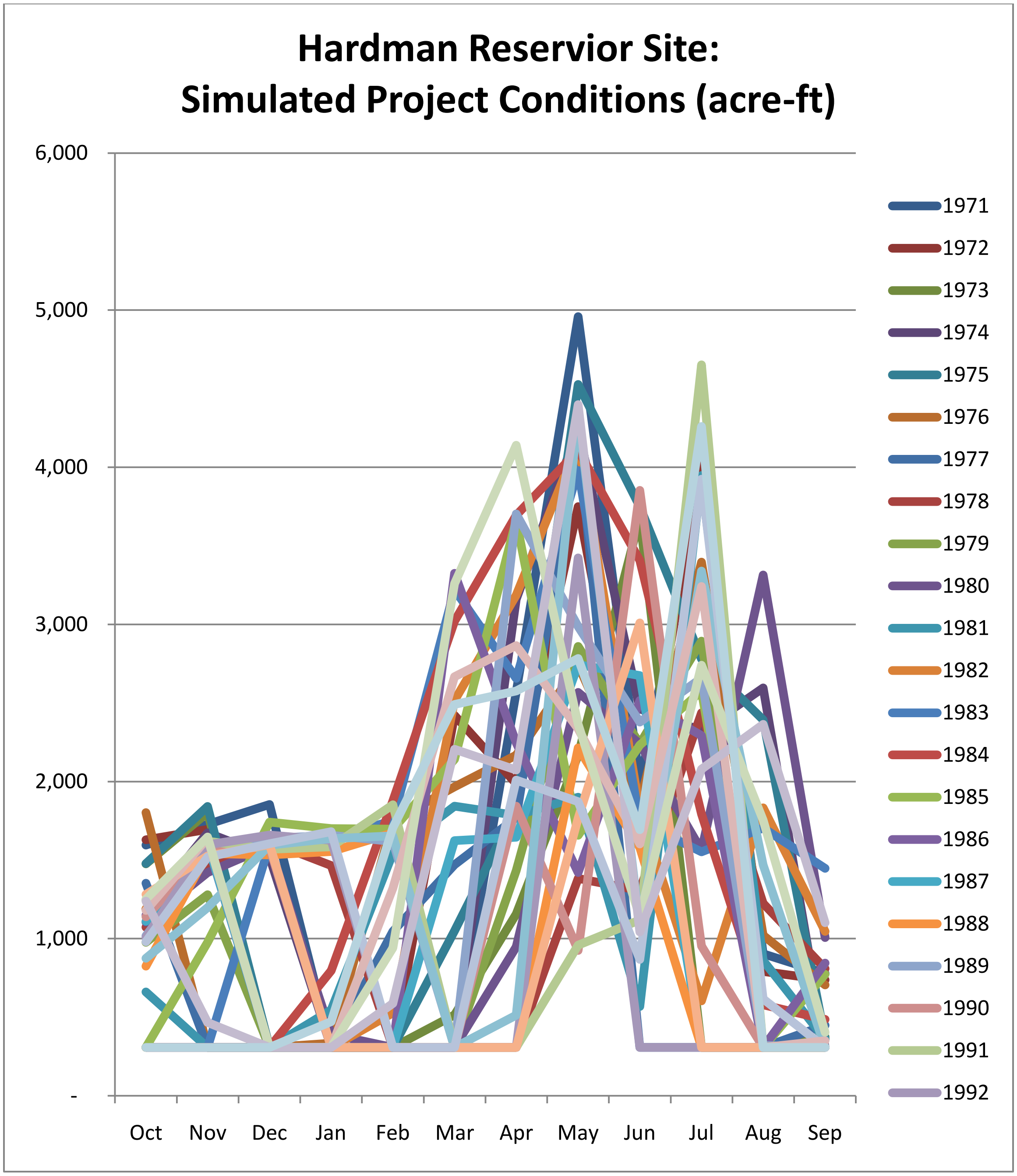
Simulated Project Condition (acre-ft)




East Pine Creek Reservoir Site
Natural Conditions (acre ft)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998

HARDMAN RESERVOIR:




Hardman Reservior Site:
Simulated Project Conditions (acre-ft)
6,000
5,000
4,000
3,000
2,000
1,000
-
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
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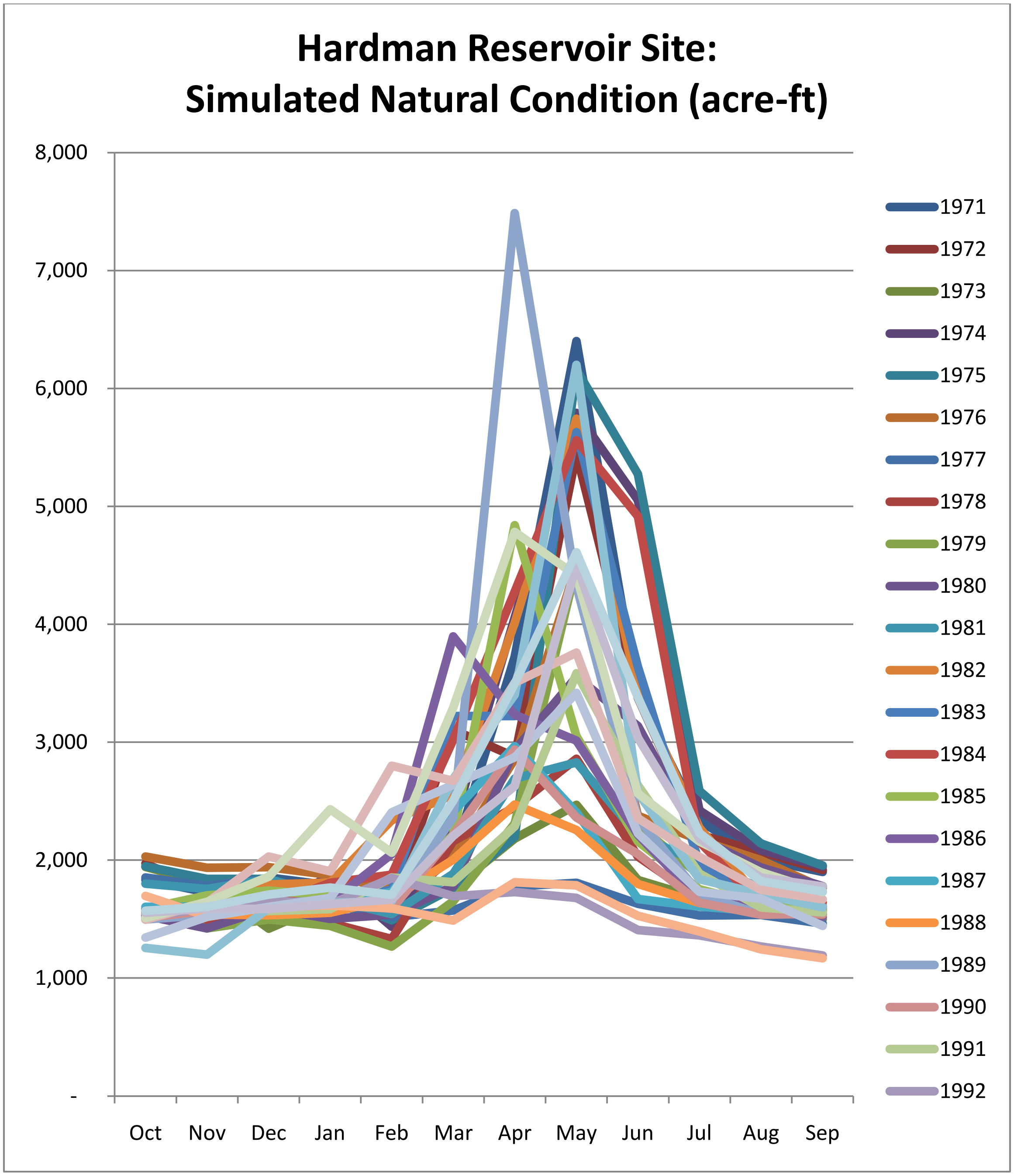
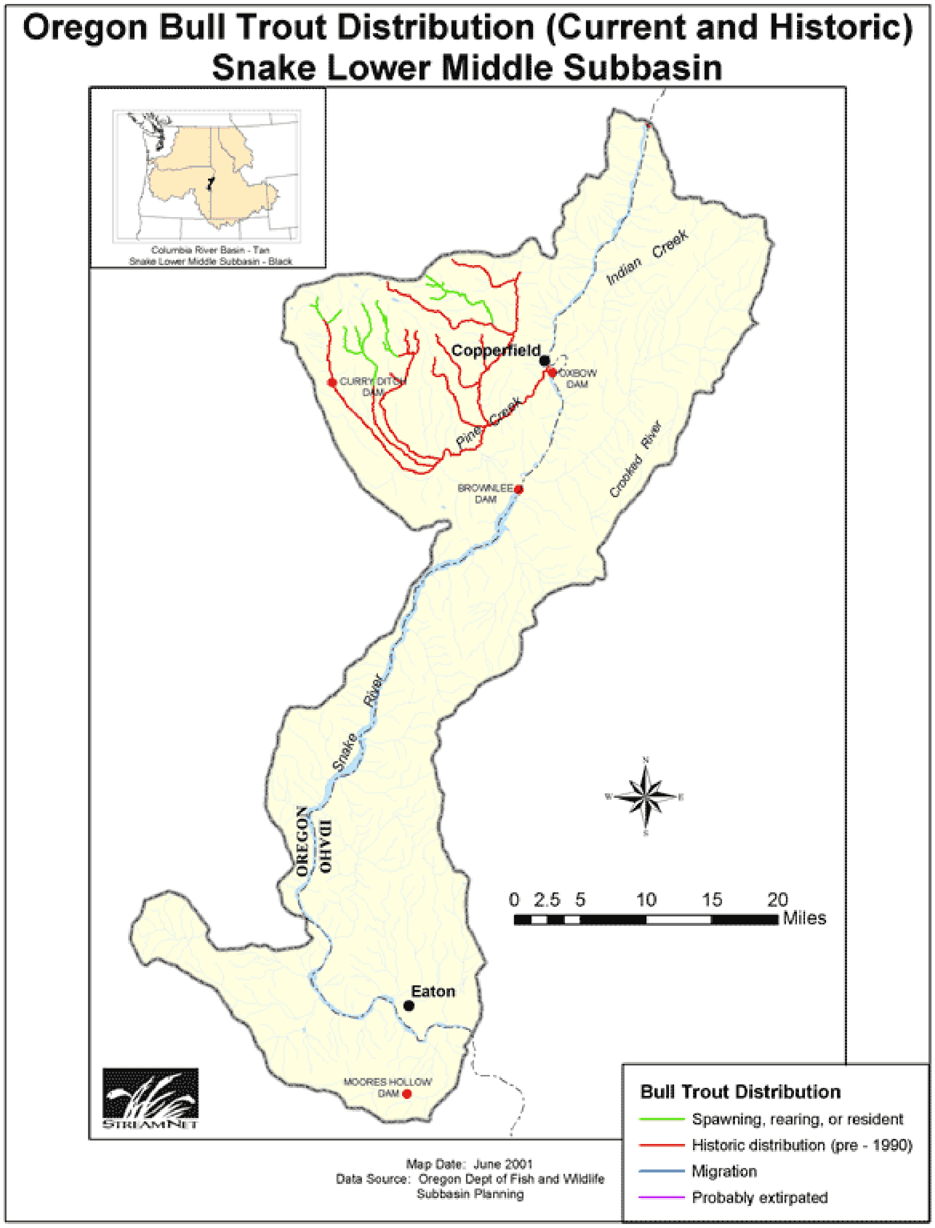
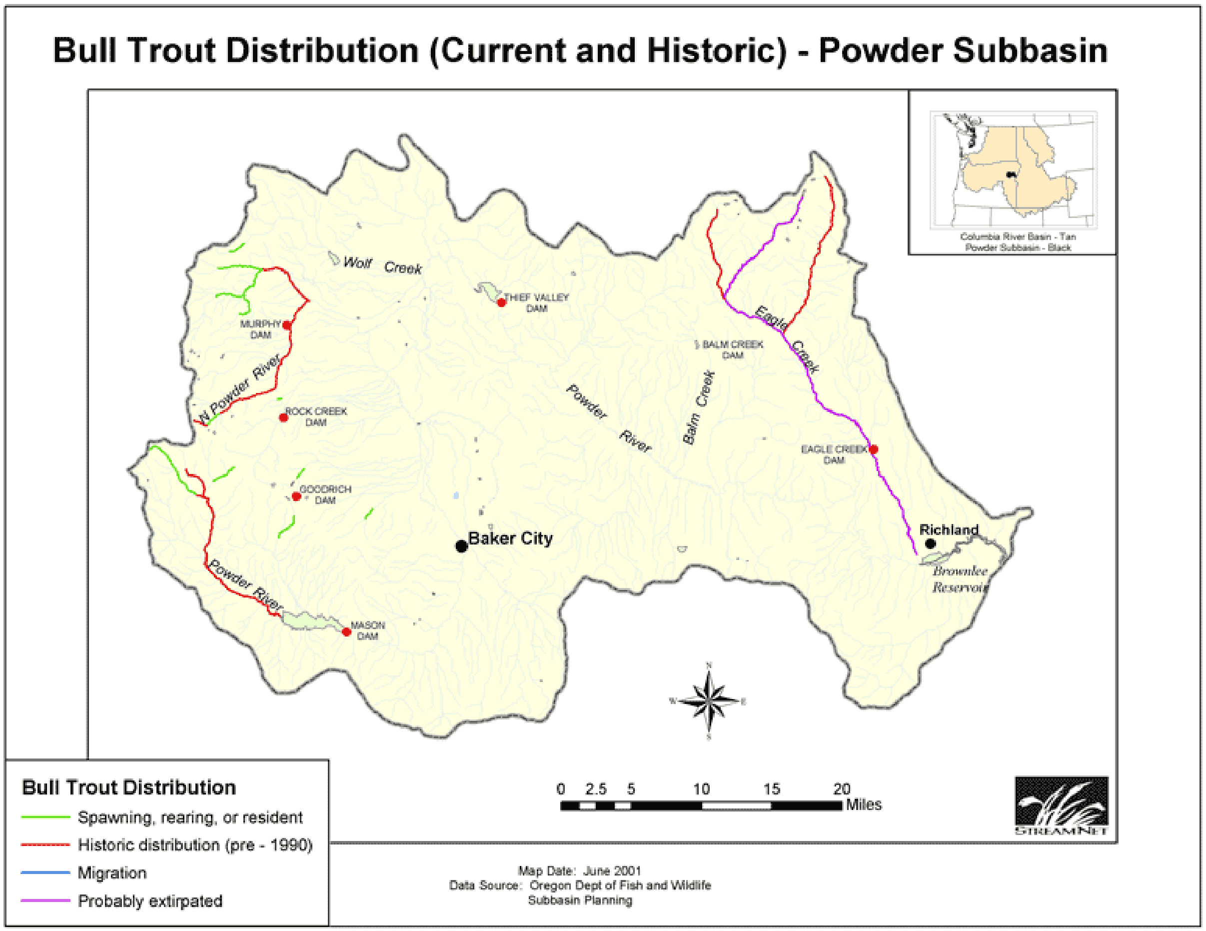
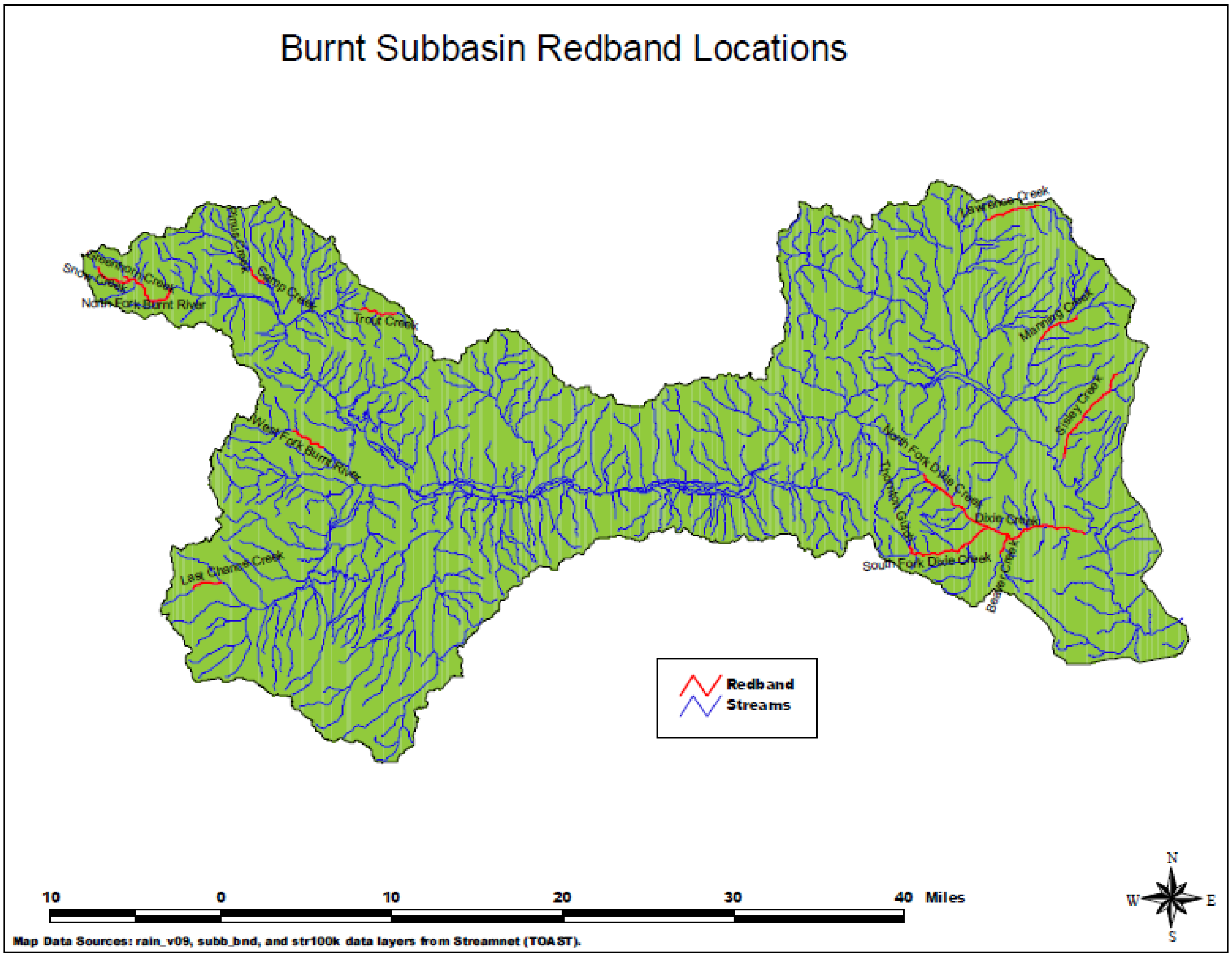
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992

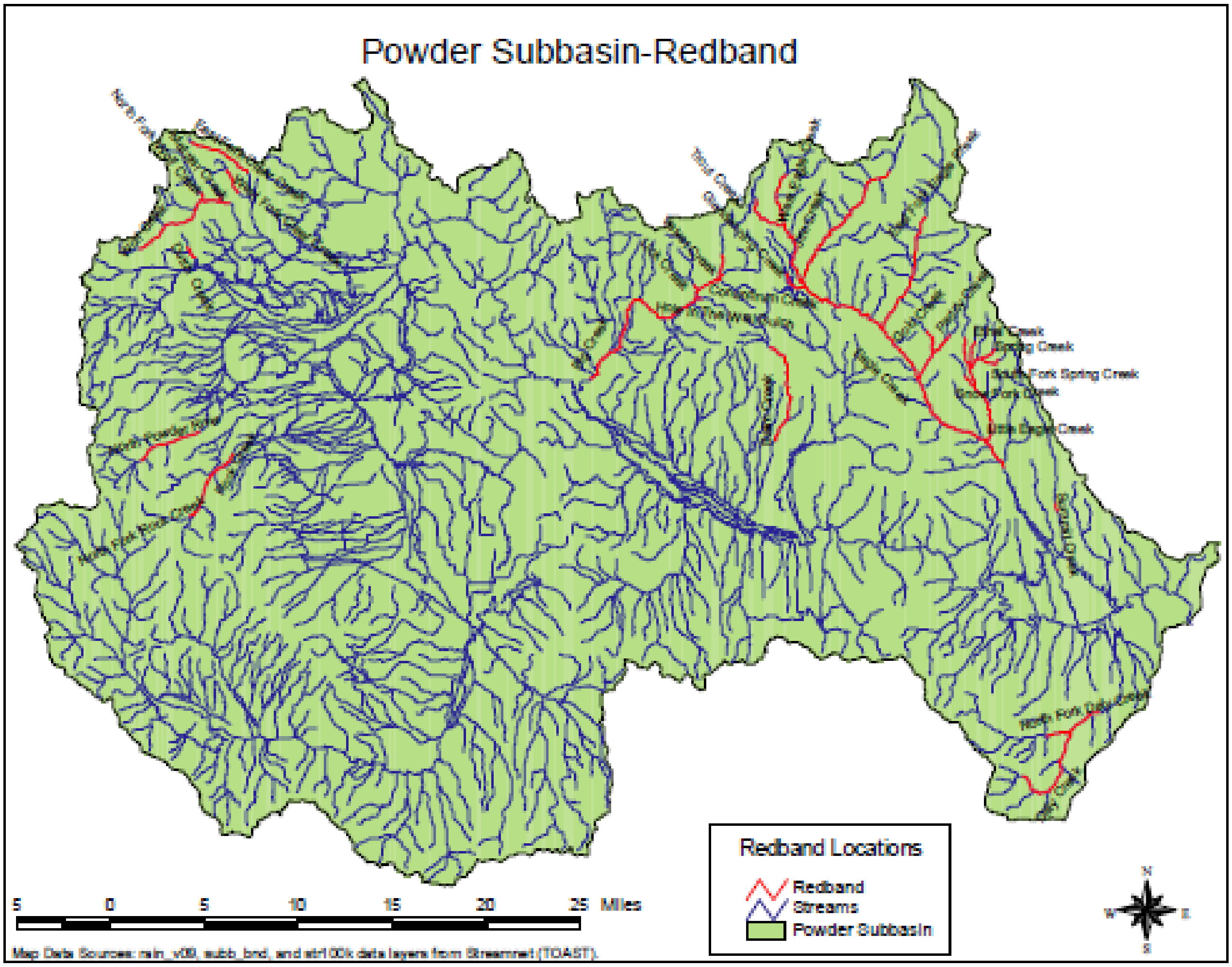


APPENDIX C: BULL TROUT CRITICAL HABITAT MAPS


Oregon Bull Trout Distribution (Current and Historic)
Snake Lower Middle Subbasin
Columbia River Basin - Tan
Snake Lower Middle Subbasin - Black
Indian Creek
Copperfield
OXBOW DAM
CURRY DITCH DAM
Pine Creek
BROWNLEE DAM
Crooked River
Snake River
OREGON
IDAHO
0 2.5 5 10 15 20
Miles
Eaton
MOORES HOLLOW DAM
STREAMNET
Map Date: June 2001
Data Source: Oregon Dept of Fish and Wildlife
Subbasin Planning
Bull Trout Distribution
Spawning, rearing, or resident
Historic distribution (pre - 1990)
Migration
Probably extirpated


Bull Trout Distribution (Current and Historic) - Powder Subbasin
Wolf Creek
THIEF VALLEY DAM
MURPHY DAM
W Powder River
ROCK CREEK DAM
GOODRICH DAM
Powder River
MASON DAM
Baker City
Powder River
Balm Creek
BALM CREEK DAM
Eagle Creek
EAGLE CREEK DAM
Richland
Brownlee Reservoir
Columbia River Basin - Tan
Powder Subbasin - Black
Bull Trout Distribution
Spawning, rearing, or resident
Historic distribution (pre - 1990)
Migration
Probably extirpated
0 2.5 5 10 15 20
Miles
Map Date: June 2001
Data Source: Oregon Dept of Fish and Wildlife
Subbasin Planning
STREAMNET


Burnt Subbasin Redband Locations
North Fork Burnt River
Camp Creek
Trout Creek
West Fork Burnt River
Last Chance Creek
Manning Creek
North Fork Dixie Creek
Dixie Creek
South Fork Dixie Creek
Redband
Streams
10
0
10
20
30
40
Miles
N
W
E
S
Map Data Sources: rain_v09, subb_bnd, and str100k data layers from Streamnet (TOAST).


Powder Subbasin-Redband
Spring Creek
South Fork Spring Creek
Little Eagle Creek
North Fork Dixie Creek
Redband Locations
Redband
Streams
Powder Subbasin
5 0 5 10 15 20 25 Miles
N
W
E
S
Map Data Sources: rain_v09, subb_bnd, and str100k data layers from Streamnet (TOAST).

APPENDIX D: HYDROLOGIC TABLES IN CFS

Powder River - Enlarged Thief Valley Reservoir Site														
Existing Conditions (Outflow from Existing) (cfs)*														
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	AVER	Total Acre-Ft
1981	0	208	187	184	239	196	246	433	522	104	113	85	**210**	**151,230**
1982	23	29	90	141	693	736	495	676	1,095	798	118	109	**417**	**300,112**
1983	151	186	213	273	464	863	701	808	869	340	125	105	**425**	**306,908**
1984	36	141	176	281	242	869	867	873	1,268	461	247	238	**475**	**333,677**
1985	124	160	148	167	135	382	818	304	280	118	97	83	**235**	**169,753**
1986	41	3	69	111	543	565	429	313	355	106	98	94	**227**	**162,736**
1987	46	29	34	53	172	167	82	134	87	86	77	7	**81**	**58,471**
1988	5	1	1	1	53	108	50	69	140	109	130	17	**57**	**41,528**
1989	0	0	1	1	1	626	467	497	197	95	87	75	**170**	**124,331**
1990	44	12	11	77	101	143	82	87	144	103	93	68	**81**	**58,229**
1991	9	7	9	8	31	93	60	210	237	172	129	89	**88**	**63,856**
1992	13	4	0	33	107	98	61	106	93	69	3	7	**50**	**35,806**
1993	13	0	0	23	8	384	293	546	480	88	105	101	**170**	**123,693**
1994	29	3	19	108	99	147	61	111	117	116	87	6	**75**	**54,640**
1995	3	3	5	11	210	233	240	396	406	129	102	90	**152**	**109,724**
1996	12	9	249	214	469	486	637	658	376	114	99	95	**285**	**206,135**
1997	54	39	135	496	452	483	576	696	629	152	115	106	**328**	**236,470**
1998	95	20	50	144	261	290	294	851	707	180	152	111	**263**	**190,266**
1999	82	63	44	197	269	635	564	446	604	178	99	87	**272**	**196,687**
2000	41	32	28	157	316	384	535	268	163	108	110	63	**184**	**132,738**
2001	19	29	33	35	82	155	65	78	73	96	13	9	**57**	**41,350**
2002	8	4	0	1	18	238	200	63	138	120	111	24	**77**	**56,096**
2003	16	2	2	3	89	108	86	195	256	122	74	23	**81**	**58,806**
2004	17	3	1	1	24	343	142	207	233	101	90	58	**102**	**74,071**
2005	17	10	10	90	99	94	85	267	87	114	102	16	**83**	**60,074**
2006	7	3	6	78	135	244	397	542	449	122	110	79	**181**	**130,921**
2007	17	21	23	24	76	138	81	97	70	99	1	3	**54**	**39,112**
2008	2	2	3	7	9	204	133	325	569	146	106	94	**133**	**96,761**
2009	1	3	8	79	136	277	226	389	0	0	0	0	**140**	**67,643**
AVER	**32**	**35**	**54**	**103**	**191**	**334**	**309**	**367**	**380**	**162**	**100**	**69**	**178**	
MAX	**151**	**208**	**249**	**496**	**693**	**869**	**867**	**873**	**1,268**	**798**	**247**	**238**	**475**	
MIN	**0**	**0**	**0**	**1**	**1**	**93**	**50**	**63**	**70**	**69**	**1**	**3**	**50**	
AVER (ac-ft)	**1,966**	**2,108**	**3,302**	**6,359**	**10,678**	**20,547**	**18,412**	**22,577**	**22,621**	**9,981**	**6,136**	**4,123**		

* Results based on USGS gage records.

Powder River - Enlarged Thief Valley Reservoir Site													
Simulated Monthly Reservoir Outflow - With Project Conditions (cfs)*													
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	AVER	Total Acre-Ft
1981	10	10	10	10	237	323	552	703	856	120	100	50	**248**	**178,957**
1982	15	10	10	128	273	647	464	330	684	120	89	53	**235**	**169,505**
1983	20	10	97	37	175	70	10	40	101	134	87	50	**69**	**49,764**
1984	16	10	10	10	112	136	366	517	994	100	90	73	**203**	**146,390**
1985	20	10	10	88	339	352	308	612	719	180	76	71	**232**	**167,012**
1986	10	10	92	175	199	252	543	371	74	112	38	59	**161**	**116,391**
1987	22	10	10	10	11	10	51	32	93	118	74	45	**40**	**29,381**
1988	20	10	10	10	11	10	10	88	85	103	71	34	**38**	**28,054**
1989	25	10	10	10	231	335	166	307	116	130	63	70	**123**	**88,489**
1990	18	10	10	10	89	154	337	317	348	114	80	34	**127**	**91,700**
1991	19	10	14	233	229	194	339	318	389	113	95	56	**167**	**120,499**
1992	14	10	10	10	568	653	364	495	933	618	175	46	**325**	**234,564**
1993	10	184	211	255	469	689	577	630	694	139	69	56	**332**	**239,157**
1994	21	86	193	284	237	763	695	697	1,096	284	75	148	**382**	**276,105**
1995	81	195	147	149	156	297	693	128	96	129	115	36	**185**	**133,685**
1996	19	10	10	10	315	480	299	132	166	112	91	30	**139**	**100,650**
1997	21	10	10	10	11	10	167	73	90	100	86	76	**55**	**40,124**
1998	29	10	10	10	11	31	24	40	77	118	85	48	**41**	**29,885**
1999	21	10	10	10	11	10	237	309	94	137	53	61	**80**	**58,327**
2000	16	10	10	10	11	10	124	36	107	133	71	58	**50**	**36,067**
2001	47	10	10	10	11	10	10	67	67	132	112	70	**46**	**33,873**
2002	22	10	10	10	11	10	24	117	73	100	44	10	**37**	**26,861**
2003	16	10	10	10	11	10	10	335	309	91	132	99	**87**	**63,321**
2004	18	10	10	10	11	10	10	48	111	139	113	74	**47**	**34,278**
2005	16	10	10	10	11	10	10	37	230	106	90	76	**51**	**37,168**
2006	13	10	10	80	427	391	497	462	199	142	103	59	**199**	**143,083**
2007	11	10	10	282	464	411	458	517	439	89	109	59	**238**	**171,218**
2008	14	10	10	80	254	207	151	659	412	108	122	46	**173**	**125,293**
2009	20	10	21	184	273	522	430	135	410	143	92	78	**193**	**138,983**
AVER	**21**	**25**	**34**	**74**	**178**	**242**	**273**	**295**	**347**	**144**	**90**	**59**	**148**	
MAX	**81**	**195**	**211**	**284**	**568**	**763**	**695**	**703**	**1,096**	**618**	**175**	**148**	**382**	
MIN	**10**	**10**	**10**	**10**	**11**	**10**	**10**	**32**	**67**	**89**	**38**	**10**	**37**	
AVER (ac-ft)	**1,281**	**1,503**	**2,108**	**4,547**	**9,982**	**14,858**	**16,263**	**18,134**	**20,644**	**8,828**	**5,512**	**3,539**		

*** Results from Reclamation MODSIM model using USGS gage records.**

Powder River - Enlarged Thief Valley Reservoir Site														
Simulated Natural Inflow and Outflow (cfs)*														
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**AVER**	**Total Acre-Ft**
1971	78	157	194	616	585	478	1,192	2,275	1,469	934	159	110	**8,250**	**497,963**
1972	76	89	144	258	349	1,089	923	1,510	1,414	662	116	88	**6,719**	**406,754**
1973	70	81	161	165	133	185	328	554	360	197	80	49	**2,363**	**142,881**
1974	51	205	209	559	295	705	1,305	1,735	2,085	730	158	87	**8,123**	**490,429**
1975	65	74	97	243	393	528	720	1,827	1,559	947	139	101	**6,694**	**404,403**
1976	87	134	209	247	256	425	1,099	1,629	801	481	190	100	**5,658**	**342,631**
1977	55	55	45	37	45	62	246	193	358	121	63	46	**1,327**	**79,904**
1978	53	72	186	149	207	570	804	990	1,053	545	119	112	**4,861**	**293,598**
1979	61	51	110	89	493	664	927	1,489	1,027	576	136	52	**5,675**	**341,915**
1980	35	45	59	75	146	235	718	1,019	739	594	123	67	**3,857**	**233,456**
1981	54	64	129	255	215	249	880	972	1,204	462	127	49	**4,660**	**280,921**
1982	56	128	190	197	487	833	1,291	1,868	1,774	800	246	113	**7,983**	**481,388**
1983	114	108	130	185	237	1,212	1,074	1,943	1,528	560	162	76	**7,329**	**443,715**
1984	55	155	138	260	272	868	1,439	2,003	1,927	766	168	177	**8,227**	**497,478**
1985	108	173	142	125	139	365	1,570	1,110	737	289	122	74	**4,954**	**298,722**
1986	74	92	151	75	452	1,340	980	1,033	866	233	123	58	**5,477**	**330,123**
1987	62	49	44	45	54	131	779	559	242	100	78	46	**2,188**	**132,012**
1988	27	30	30	32	44	103	271	332	270	87	57	30	**1,312**	**79,292**
1989	32	57	82	88	111	592	1,608	1,506	849	238	99	104	**5,365**	**324,059**
1990	53	71	64	67	83	216	521	450	380	152	92	74	**2,224**	**134,155**
1991	75	57	57	76	125	116	362	827	708	260	116	52	**2,832**	**171,041**
1992	34	54	49	47	89	155	224	292	150	97	64	35	**1,290**	**78,059**
1993	42	69	79	82	124	658	1,072	1,879	892	291	149	91	**5,428**	**328,802**
1994	41	44	65	61	67	146	372	502	302	133	65	43	**1,843**	**111,385**
1995	77	52	75	114	314	520	694	991	940	301	128	78	**4,284**	**258,032**
1996	84	193	403	265	807	720	1,021	1,342	1,102	432	150	79	**6,598**	**397,774**
1997	64	150	232	541	344	907	1,145	1,600	1,002	308	145	92	**6,530**	**394,762**
1998	64	90	77	115	158	440	734	1,403	923	358	148	96	**4,606**	**278,632**
1999	70	111	139	179	233	585	1,289	1,424	1,329	433	140	106	**6,039**	**364,319**
AVER	**63**	**93**	**127**	**181**	**250**	**521**	**882**	**1,216**	**965**	**417**	**126**	**79**	**4,921**	
MAX	**114**	**205**	**403**	**616**	**807**	**1,340**	**1,608**	**2,275**	**2,085**	**947**	**246**	**177**	**8,250**	
MIN	**27**	**30**	**30**	**32**	**44**	**62**	**224**	**193**	**150**	**87**	**57**	**30**	**1,290**	
AVER (ac-ft)	**3,855**	**5,562**	**7,828**	**11,131**	**14,032**	**32,008**	**52,499**	**74,758**	**57,432**	**25,628**	**7,766**	**4,694**		
*** Results from Reclamation MODSIM model.**														

NORTH POWDER RESERVOIR

Powder River - North Powder Reservoir Site														
Simulated Reservoir Inflow and Outflow - Existing Conditions (cfs)*														
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**AVER**	**TOTAL (Ac-ft)**
1971	29	39	94	73	68	131	263	161	14	0	2	8	**73**	**53053**
1972	20	27	28	30	146	57	156	153	3	0	1	7	**52**	**37750**
1973	23	50	45	26	36	31	87	15	0	0	0	6	**27**	**19069**
1974	43	43	114	48	138	173	213	254	27	0	0	7	**88**	**63819**
1975	19	23	36	32	47	85	199	222	30	1	0	11	**59**	**42505**
1976	25	39	36	36	46	110	158	40	36	16	9	4	**46**	**33497**
1977	12	11	9	7	8	23	36	51	0	1	0	4	**13**	**9783**
1978	16	28	16	12	27	62	135	230	44	9	12	3	**50**	**35954**
1979	11	12	10	10	15	17	176	157	26	9	0	3	**37**	**26792**
1980	10	12	11	11	13	59	229	167	43	9	5	4	**48**	**34655**
1981	13	21	28	25	18	51	189	154	23	5	0	5	**44**	**32137**
1982	21	20	15	20	26	28	178	351	159	13	7	16	**71**	**51668**
1983	17	16	16	14	27	24	214	257	80	21	0	2	**57**	**41518**
1984	16	8	28	17	18	35	196	284	118	20	10	12	**64**	**46140**
1985	17	11	14	10	15	70	174	117	26	3	1	3	**38**	**27871**
1986	11	10	13	18	57	74	174	156	21	6	5	9	**46**	**33250**
1987	14	13	11	11	19	70	145	38	0	0	0	0	**27**	**19298**
1988	10	9	8	8	13	35	118	89	1	0	0	1	**24**	**17639**
1989	12	12	9	9	17	64	175	172	16	8	1	6	**42**	**30258**
1990	18	16	13	10	17	82	78	60	6	6	0	6	**26**	**18807**
1991	12	10	10	8	11	15	108	141	21	2	0	2	**28**	**20519**
1992	17	15	11	12	27	48	72	31	6	0	0	3	**20**	**14547**
1993	11	11	9	9	18	19	236	166	34	5	0	4	**43**	**31396**
1994	12	19	12	10	15	44	137	47	5	0	0	4	**25**	**18384**
1995	10	11	11	21	42	46	138	238	45	9	0	7	**48**	**34848**
1996	30	52	22	39	42	76	189	220	60	9	1	8	**62**	**45209**
1997	22	28	44	29	36	78	322	267	47	4	3	7	**74**	**53537**
1998	18	14	13	12	24	37	216	161	37	0	3	5	**45**	**32590**
1999	16	16	16	15	19	39	163	291	67	10	0	0	**54**	**39491**
AVER	**17**	**21**	**24**	**20**	**35**	**58**	**168**	**162**	**34**	**6**	**2**	**5**	**46**	
MAX	**43**	**52**	**114**	**73**	**146**	**173**	**322**	**351**	**159**	**21**	**12**	**16**	**88**	
MIN	**10**	**8**	**8**	**7**	**8**	**15**	**36**	**15**	**0**	**0**	**0**	**0**	**13**	
Ac-ft AVER	**1073**	**1226**	**1485**	**1229**	**1945**	**3564**	**10001**	**9944**	**2045**	**350**	**127**	**322**		
* Results based on Reclamation MODSIM model.														

	Powder River - North Powder Reservoir Site												
	Simulated Monthly Reservoir Outflow - With Project Conditions (cfs)												
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**AVER**	**TOTAL (Ac-ft)**
1971	4	0	49	165	118	143	220	107	287	126	80	8	**109**	**78718**
1972	0	0	0	0	37	228	262	207	255	89	40	0	**93**	**67530**
1973	11	0	0	0	9	47	31	46	44	0	0	0	**16**	**11367**
1974	0	0	0	104	40	52	226	206	357	144	72	17	**101**	**73374**
1975	0	0	0	0	65	131	146	327	143	211	60	28	**93**	**67311**
1976	0	0	0	0	1	109	267	215	87	88	23	41	**69**	**50329**
1977	13	0	0	0	0	1	42	14	26	0	0	0	**8**	**5751**
1978	0	0	0	0	15	74	73	137	69	77	37	22	**42**	**30520**
1979	17	0	0	0	63	137	150	238	122	88	0	0	**68**	**49253**
1980	0	0	0	5	64	82	223	189	185	141	64	21	**81**	**58784**
1981	10	0	0	37	53	78	220	197	275	88	0	0	**80**	**57660**
1982	0	0	0	0	208	248	226	112	229	308	63	28	**118**	**85235**
1983	0	20	49	70	123	218	126	75	215	155	48	39	**95**	**68510**
1984	12	0	12	82	49	284	170	60	252	243	80	115	**113**	**82365**
1985	34	20	3	7	11	91	203	45	114	88	0	23	**53**	**38485**
1986	11	0	0	0	121	170	160	127	160	88	0	0	**70**	**50080**
1987	13	0	0	0	0	1	46	57	11	0	0	0	**11**	**7679**
1988	20	0	0	0	0	1	28	48	52	17	0	0	**14**	**10023**
1989	0	0	0	0	0	184	165	159	64	81	0	0	**54**	**39675**
1990	0	0	0	0	0	0	24	44	74	4	0	0	**12**	**8787**
1991	7	0	0	0	0	0	22	61	109	98	48	0	**29**	**20928**
1992	11	0	0	0	0	0	31	0	0	0	0	0	**3**	**2510**
1993	11	0	0	7	0	129	76	221	217	76	13	0	**62**	**45434**
1994	0	0	0	0	0	1	20	47	78	12	0	0	**13**	**9473**
1995	0	0	0	0	13	38	25	196	145	85	4	0	**42**	**30722**
1996	0	0	0	53	134	85	195	306	147	88	0	0	**84**	**60804**
1997	0	0	0	138	117	89	164	228	192	63	79	0	**89**	**64433**
1998	0	0	0	0	2	86	74	175	298	91	88	31	**70**	**51157**
1999	13	0	0	0	65	173	203	81	125	88	0	0	**62**	**44995**
AVER	**6**	**1**	**4**	**23**	**45**	**99**	**132**	**135**	**149**	**91**	**28**	**13**	**61**	
MAX	**34**	**20**	**49**	**165**	**208**	**284**	**267**	**327**	**357**	**308**	**88**	**115**	**118**	
MIN	**0**	**0**	**0**	**0**	**0**	**0**	**20**	**0**	**0**	**0**	**0**	**0**	**3**	
Ac-ft AVER	**398**	**83**	**241**	**1418**	**2521**	**6102**	**7836**	**8323**	**8888**	**5595**	**1691**	**764**		
	* Results based on Reclamation MODSIM model.													

	Powder River - North Powder Reservoir Site													
	Simulated Natural Inflow and Outflow (cfs)													
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**AVER**	**TOTAL (Ac-ft)**
1971	31	44	51	112	97	75	196	447	328	106	49	37	**131**	**95036**
1972	37	32	36	40	41	164	131	369	350	86	46	39	**114**	**83103**
1973	37	38	79	69	40	50	91	207	98	47	31	28	**68**	**49435**
1974	26	63	63	137	66	146	245	386	522	122	55	40	**156**	**112970**
1975	32	33	32	46	45	50	121	352	441	155	57	40	**117**	**84845**
1976	37	45	59	51	51	60	165	348	186	133	67	54	**105**	**76147**
1977	30	28	21	16	17	23	96	108	175	54	41	28	**53**	**38473**
1978	27	31	48	30	25	59	137	276	385	144	61	53	**106**	**77196**
1979	24	19	21	19	21	49	98	332	291	110	50	29	**89**	**64419**
1980	21	20	23	24	29	43	168	355	268	144	60	31	**99**	**71823**
1981	22	24	37	44	50	48	142	293	269	100	59	28	**93**	**67270**
1982	23	35	36	37	62	67	142	348	538	257	71	42	**138**	**100052**
1983	34	30	30	30	35	105	127	413	437	193	76	31	**128**	**93352**
1984	21	28	20	44	35	70	148	365	475	248	64	56	**131**	**95235**
1985	34	32	25	27	24	41	235	297	244	109	45	26	**95**	**68784**
1986	23	23	21	26	43	158	195	313	318	94	57	28	**108**	**78528**
1987	34	25	23	22	24	49	177	256	122	49	44	22	**71**	**51262**
1988	18	19	20	21	29	57	121	196	173	57	39	20	**64**	**46460**
1989	18	23	22	20	48	120	229	284	277	91	46	35	**101**	**73231**
1990	28	29	27	25	36	72	166	160	165	71	48	25	**71**	**51527**
1991	25	22	21	24	25	39	122	186	232	101	57	26	**74**	**53284**
1992	24	31	26	31	42	62	128	184	100	58	41	22	**63**	**45423**
1993	21	22	23	21	55	95	242	378	252	108	52	27	**108**	**78276**
1994	23	23	30	24	34	53	128	216	147	73	34	25	**68**	**49007**
1995	22	25	42	61	86	138	163	215	322	130	59	39	**109**	**78580**
1996	48	54	102	69	105	147	185	257	326	168	64	37	**130**	**94388**
1997	35	64	54	113	122	155	181	407	357	125	58	39	**142**	**103095**
1998	27	30	26	46	62	129	137	239	255	114	53	36	**96**	**69787**
1999	32	34	32	60	118	149	176	253	396	180	65	40	**128**	**92317**
AVER	**28**	**32**	**36**	**44**	**51**	**85**	**158**	**291**	**292**	**118**	**53**	**34**	**102**	
MAX	**48**	**64**	**102**	**137**	**122**	**164**	**245**	**447**	**538**	**257**	**76**	**56**	**156**	
MIN	**18**	**19**	**20**	**16**	**17**	**23**	**91**	**108**	**98**	**47**	**31**	**20**	**53**	
Ac-ft AVER	**1724**	**1905**	**2226**	**2732**	**2830**	**5243**	**9422**	**17898**	**17346**	**7268**	**3287**	**2026**		
	* Results based on Reclamation MODSIM model.													

WOLF CREEK COMPLEX

	Wolf Creek Complex: Wolf Creek													
	Existing Outflow (cfs)*													
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Average	Total Acre-Ft
1971	17	0	0	0	0	1	67	138	182	210	6	7	52	38139
1972	12	0	0	0	0	4	70	137	132	202	5	8	47	34614
1973	15	0	0	0	0	11	56	83	22	2	1	2	16	11598
1974	5	0	0	0	0	2	58	184	209	183	37	3	57	41367
1975	12	0	0	0	0	2	29	131	125	208	49	4	47	34107
1976	9	0	0	0	0	4	54	141	144	141	29	8	44	32246
1977	16	0	0	0	0	8	46	43	32	2	1	6	13	9327
1978	12	0	0	0	0	9	15	117	154	124	9	22	38	27995
1979	7	0	0	0	0	5	62	132	161	100	2	2	39	28570
1980	6	0	0	0	0	3	76	80	71	202	3	5	37	27198
1981	7	0	0	0	0	3	71	70	131	128	2	2	34	25041
1982	5	0	0	0	0	3	65	217	130	128	129	6	57	41592
1983	13	0	0	0	0	0	106	177	154	180	7	3	53	38844
1984	7	0	0	0	0	0	44	280	122	194	49	12	59	43251
1985	15	0	0	0	0	5	95	113	180	73	4	6	41	29572
1986	13	0	0	0	0	15	121	126	163	51	2	6	41	29998
1987	9	0	0	0	0	5	110	75	20	4	2	2	19	13669
1988	5	0	0	0	0	6	75	115	16	4	2	1	19	13566
1989	7	0	0	0	0	0	147	187	175	42	5	3	47	34063
1990	13	0	0	0	0	1	66	115	52	5	2	2	21	15477
1991	10	0	0	0	0	0	59	54	137	114	3	2	32	22929
1992	15	0	0	0	0	0	78	74	6	8	2	3	15	11260
1993	13	0	0	0	0	0	47	174	120	123	5	3	40	29434
1994	9	0	0	0	0	7	55	123	23	4	2	2	19	13645
1995	9	0	0	0	0	7	118	146	133	104	4	4	44	31814
1996	22	0	0	0	0	47	106	108	190	35	3	4	43	31093
1997	10	0	0	0	0	42	140	161	147	21	3	3	44	31803
1998	6	0	0	0	0	0	83	165	160	94	4	7	43	31343
1999	14	0	0	0	0	7	114	147	0	0	0	0	35	17080
Aver.	11	0	0	0	0	7	77	132	117	96	13	5	38	
MAX	22	0	0	0	0	47	147	280	209	210	129	22	59	
MIN	5	0	0	0	0	0	15	43	6	2	1	1	13	
AVER (Acre-ft)	659	0	0	0	0	416	4584	8088	6990	5899	815	296	2296	

	Wolf Creek Complex: Pilcher Creek													
	Existing Outflow (cfs)*													
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Average	Total Acre-Ft
1971	1	0	0	0	0	0	2	3	5	19	94	9	11	8189
1972	4	0	0	0	0	0	2	4	5	76	36	9	11	8384
1973	0	0	0	0	0	0	36	72	27	11	5	7	13	9654
1974	8	0	0	0	0	0	4	4	7	5	96	13	12	8442
1975	4	0	0	0	0	0	1	3	3	5	96	13	10	7676
1976	14	0	0	0	0	0	1	4	4	102	1	11	11	8424
1977	1	0	0	0	0	0	48	8	18	14	11	8	9	6521
1978	4	0	0	0	0	0	1	3	4	104	13	1	11	7967
1979	5	0	0	0	0	0	2	5	4	96	9	10	11	8046
1980	3	0	0	0	0	0	2	4	4	15	85	7	10	7313
1981	4	0	0	0	0	0	3	4	5	96	12	9	11	8232
1982	7	0	0	0	0	0	4	3	5	6	84	25	11	8169
1983	1	0	0	0	0	0	2	3	5	8	88	21	11	7806
1984	5	0	0	0	0	0	3	3	5	5	22	57	8	6015
1985	10	0	0	0	0	0	3	3	5	96	10	7	11	8179
1986	1	0	0	0	0	0	3	3	47	96	11	5	14	10196
1987	4	0	0	0	0	0	49	83	4	10	11	10	14	10429
1988	6	0	0	0	0	0	12	50	70	8	8	7	13	9737
1989	4	0	0	0	0	0	3	3	12	96	9	10	11	8367
1990	1	0	0	0	0	0	11	14	102	8	9	8	13	9167
1991	3	0	0	0	0	0	2	2	4	99	9	8	10	7663
1992	0	0	0	0	0	0	30	96	13	9	9	7	14	10017
1993	0	0	0	0	0	0	2	5	4	96	11	8	10	7710
1994	3	0	0	0	0	0	8	10	102	9	9	8	12	8900
1995	3	0	0	0	1	1	1	4	4	96	8	14	11	8039
1996	9	0	0	0	2	1	4	6	5	103	8	10	12	9088
1997	8	0	0	0	2	1	3	5	4	98	9	10	12	8636
1998	7	0	0	0	0	1	2	3	6	99	9	9	11	8354
1999	4	0	0	0	0	3	4	4	0	0	0	0	2	894
Aver.	4	0	0	0	0	0	9	14	17	53	28	11	11	
MAX	14	0	0	0	2	3	49	96	102	104	96	57	14	
MIN	0	0	0	0	0	0	1	2	3	5	1	1	2	
AVER (Acre-ft)	264	0	0	0	11	21	507	878	1026	3266	1718	684	680	

EAST PINE CREEK RESERVOIR

Pine Creek - East Pine Reservoir Site														
Reservoir Inflow and Outflow - Existing Conditions (cfs)*														
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	AVER	Total Acre-Ft
1971	8	7	9	11	9	4	77	62	0	0	0	5	**16**	**11,556**
1972	7	5	6	4	17	10	86	73	0	0	0	3	**18**	**12,794**
1973	9	19	14	7	7	4	21	0	0	0	0	0	**7**	**4,830**
1974	10	12	12	8	14	10	63	82	3	0	0	1	**18**	**13,045**
1975	8	5	5	5	3	6	46	94	9	0	0	9	**16**	**11,595**
1976	12	12	8	8	9	6	66	34	0	1	0	2	**13**	**9,545**
1977	10	7	5	6	6	1	10	4	0	0	0	2	**4**	**3,031**
1978	9	13	9	7	19	41	43	29	0	0	0	0	**14**	**10,204**
1979	5	6	6	7	22	20	46	11	0	0	0	0	**10**	**7,296**
1980	6	7	8	11	20	26	53	33	0	0	0	0	**14**	**9,903**
1981	6	10	9	14	22	19	40	11	0	0	0	0	**11**	**7,878**
1982	8	11	14	25	30	39	59	61	10	0	0	4	**22**	**15,788**
1983	8	9	9	13	61	42	79	46	0	0	0	0	**22**	**15,843**
1984	7	8	9	11	38	47	65	71	6	0	0	3	**22**	**15,962**
1985	9	9	8	8	17	56	34	4	0	0	0	0	**12**	**8,725**
1986	7	8	8	15	73	35	37	12	0	0	0	0	**16**	**11,460**
1987	6	7	7	8	20	11	8	0	0	0	0	0	**6**	**3,920**
1988	5	6	7	8	13	10	9	0	0	0	0	0	**5**	**3,512**
1989	6	7	7	7	28	51	60	10	0	0	0	0	**15**	**10,503**
1990	7	7	8	8	18	23	11	0	0	0	0	0	**7**	**4,858**
1991	6	7	7	10	12	7	42	15	0	0	0	0	**9**	**6,304**
1992	8	9	7	13	20	7	0	0	0	0	0	0	**5**	**3,842**
1993	7	7	8	8	33	45	104	31	0	0	0	0	**20**	**14,523**
1994	6	7	7	7	14	11	12	0	0	0	0	0	**5**	**3,822**
1995	5	6	10	21	36	33	45	36	0	0	0	0	**16**	**11,526**
1996	9	20	15	34	35	35	53	16	0	0	0	1	**18**	**13,007**
1997	7	12	27	17	51	51	53	20	0	0	0	1	**20**	**14,284**
1998	6	7	7	8	24	23	75	18	0	0	0	0	**14**	**10,051**
1999	7	10	11	10	32	51	63	30	0	0	0	0	**18**	**12,893**
AVER	**7**	**9**	**9**	**11**	**24**	**25**	**47**	**28**	**1**	**0**	**0**	**1**	**14**	
MAX	**12**	**20**	**27**	**34**	**73**	**56**	**104**	**94**	**10**	**1**	**0**	**9**	**22**	
MIN	**5**	**5**	**5**	**4**	**3**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**4**	
AVER. Ac-ft	**459**	**529**	**570**	**676**	**1,356**	**1,533**	**2,794**	**1,701**	**58**	**1**	**0**	**64**		

Pine Creek - East Pine Reservoir Site														
Simulated Monthly Reservoir Outflow - With Project Conditions (cfs)*														
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	AVER	Total Acre-Ft
1971	5	5	5	5	6	5	140	276	226	16	24	5	60	43,368
1972	5	5	5	5	52	209	74	161	193	31	26	5	64	46,626
1973	5	5	5	5	6	43	63	134	24	46	25	8	31	22,332
1974	5	5	5	121	78	150	175	182	301	39	14	14	91	65,517
1975	5	5	5	5	6	69	112	155	190	11	12	15	49	35,547
1976	5	5	5	5	41	81	175	157	60	29	5	11	48	34,945
1977	5	5	5	5	6	5	23	5	27	45	5	5	12	8,501
1978	5	5	5	5	6	27	194	134	125	6	7	5	44	31,493
1979	5	5	5	5	9	133	95	147	63	42	13	20	45	32,920
1980	5	5	5	5	5	5	80	168	125	33	24	5	39	28,120
1981	5	5	5	5	95	73	80	118	94	36	32	10	46	33,339
1982	5	5	5	5	78	150	135	180	179	29	18	5	66	47,731
1983	5	5	15	57	117	215	152	205	180	40	5	5	83	60,219
1984	5	5	21	29	22	181	142	167	189	19	5	5	66	47,931
1985	5	5	27	25	24	79	145	120	49	42	18	5	45	32,883
1986	5	5	5	5	44	210	107	112	60	26	27	5	51	36,901
1987	5	5	5	5	6	5	47	51	14	34	30	23	19	13,961
1988	5	5	5	5	5	5	5	5	5	41	28	5	10	7,309
1989	5	5	5	5	6	5	70	140	88	42	5	12	32	23,537
1990	5	5	5	5	6	5	123	77	44	43	16	24	30	21,521
1991	5	5	5	5	6	5	5	46	53	49	40	16	20	14,524
1992	5	5	5	5	5	5	5	22	5	29	41	5	12	8,462
1993	5	5	5	5	6	5	32	194	116	16	24	21	36	26,254
1994	5	5	5	5	6	5	57	80	23	53	39	5	24	17,521
1995	5	5	5	5	6	69	135	182	167	7	18	17	52	37,526
1996	5	5	9	54	153	107	188	218	96	25	24	5	74	53,423
1997	5	5	5	5	6	45	104	35	5	18	38	11	23	17,012
1998	5	5	5	5	6	5	5	5	5	34	42	5	11	7,733
1999	5	5	5	5	6	5	5	5	5	43	22	21	11	7,947
AVER	**5**	**5**	**7**	**14**	**28**	**66**	**92**	**120**	**94**	**32**	**22**	**10**	**41**	
MAX	**5**	**5**	**27**	**121**	**153**	**215**	**194**	**276**	**301**	**53**	**42**	**24**	**91**	
MIN	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**6**	**5**	**5**	**10**	
AVER. Ac-ft	**307**	**307**	**419**	**859**	**1,572**	**4,039**	**5,483**	**7,382**	**5,565**	**1,956**	**1,326**	**615**		
* Results from Reclamation MODSIM model														

Pine Creek - East Pine Reservoir Site														
Simulated Natural Inflow and Outflow (cfs)*														
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**AVER**	**Total Acre-Ft**
1971	1	2	2	7	16	14	60	41	8	3	1	0	**13**	**9,373**
1972	0	1	1	1	4	57	36	30	7	3	1	0	**12**	**8,502**
1973	1	1	1	2	2	9	20	11	3	1	0	0	**4**	**2,963**
1974	0	5	5	17	8	39	73	47	12	3	1	0	**18**	**12,757**
1975	0	1	1	1	2	6	38	65	12	3	1	1	**11**	**7,975**
1976	1	1	2	2	2	7	59	29	5	2	1	1	**9**	**6,830**
1977	1	1	1	1	1	2	4	2	2	1	0	0	**1**	**894**
1978	0	1	8	3	6	44	40	19	5	11	6	3	**12**	**8,849**
1979	3	3	4	1	1	18	36	26	5	11	5	4	**10**	**7,093**
1980	2	3	4	2	7	18	34	13	5	15	6	4	**9**	**6,831**
1981	4	4	7	6	12	22	29	16	11	10	8	3	**11**	**7,932**
1982	2	5	7	7	21	33	66	55	20	15	8	5	**20**	**14,719**
1983	5	6	6	8	15	57	50	48	17	12	7	6	**20**	**14,235**
1984	5	5	6	8	9	33	69	55	24	13	5	8	**20**	**14,460**
1985	7	7	6	6	6	16	60	16	11	11	6	3	**13**	**9,392**
1986	5	5	5	5	17	56	29	15	12	10	7	2	**14**	**10,125**
1987	5	5	4	4	5	14	16	8	7	7	5	4	**7**	**5,137**
1988	2	2	4	4	6	12	17	7	6	7	4	3	**6**	**4,459**
1989	1	3	4	4	5	29	58	30	11	10	4	4	**14**	**9,784**
1990	3	4	4	5	5	12	13	10	9	9	4	4	**7**	**4,916**
1991	1	3	3	3	6	7	13	22	11	10	7	3	**8**	**5,495**
1992	1	4	4	4	10	13	7	4	1	1	1	0	**4**	**3,052**
1993	0	1	4	4	5	45	78	39	7	2	1	1	**16**	**11,306**
1994	1	1	4	4	5	10	15	6	2	1	0	0	**4**	**2,906**
1995	1	2	3	7	18	34	44	22	6	2	1	1	**12**	**8,439**
1996	2	6	15	10	33	35	31	18	5	2	1	1	**13**	**9,596**
1997	2	4	9	29	18	53	67	17	4	2	1	1	**17**	**12,498**
1998	3	4	4	5	7	21	28	19	7	2	1	0	**9**	**6,157**
1999	4	4	6	8	8	30	80	39	8	3	1	1	**16**	**11,407**
AVER	**2**	**3**	**5**	**6**	**9**	**26**	**40**	**25**	**8**	**6**	**3**	**2**	**11**	
MAX	**7**	**7**	**15**	**29**	**33**	**57**	**80**	**65**	**24**	**15**	**8**	**8**	**20**	
MIN	**0**	**1**	**1**	**1**	**1**	**2**	**4**	**2**	**1**	**1**	**0**	**0**	**1**	
AVER. Ac-ft	**133**	**190**	**285**	**360**	**503**	**1,579**	**2,403**	**1,544**	**502**	**383**	**199**	**130**		
* Results from Reclamation MODSIM model														

HARDMAN RESERVOIR SITE

Burnt River - Hardman Reservoir Site														
Reservoir Inflow and Outflow - Existing Conditions (cfs)*														
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Ma y	Ju n	Jul	Au g	Sep	Average -cfs	Total acre-ft
1971	28	31	29	26	36	47	83	32	0	0	13	27	**29**	**21,238**
1972	28	29	28	26	53	32	63	28	0	0	12	25	**27**	**19,528**
1973	29	24	27	25	29	19	18	0	0	0	6	20	**16**	**11,815**
1974	27	26	31	23	41	54	71	40	2	0	5	25	**29**	**20,680**
1975	30	31	28	24	31	30	76	61	0	6	6	30	**29**	**21,254**
1976	31	33	30	29	34	35	46	10	0	18	7	23	**25**	**17,923**
1977	29	31	26	25	26	7	15	0	0	0	7	18	**15**	**11,061**
1978	24	27	24	22	37	38	23	3	0	0	13	16	**19**	**13,611**
1979	23	25	23	21	28	25	48	5	0	4	0	19	**19**	**13,310**
1980	23	27	24	25	30	32	43	36	0	1	16	23	**23**	**17,010**
1981	29	31	27	25	33	29	32	9	0	0	6	20	**20**	**14,464**
1982	27	30	29	38	45	52	70	30	10	0	9	23	**30**	**21,773**
1983	25	27	27	28	58	43	67	28	0	0	5	18	**27**	**19,568**
1984	26	27	29	31	53	60	69	55	0	12	7	22	**33**	**23,564**
1985	28	29	28	28	39	60	28	0	0	0	13	19	**23**	**16,240**
1986	26	26	27	33	68	37	24	0	0	0	14	19	**23**	**16,284**
1987	26	27	27	28	42	27	10	0	0	0	0	14	**17**	**12,050**
1988	25	26	25	27	33	25	15	1	0	0	3	17	**16**	**11,901**
1989	25	28	27	26	42	105	50	4	0	5	4	19	**28**	**20,173**
1990	26	27	27	26	40	35	16	0	0	0	0	21	**18**	**12,899**
1991	26	26	26	30	33	25	50	16	0	0	0	17	**21**	**14,981**
1992	26	28	26	30	29	13	0	0	0	0	0	15	**14**	**10,114**
1993	19	27	27	27	48	48	73	17	0	0	0	22	**26**	**18,422**
1994	25	27	26	26	25	19	4	0	0	0	0	16	**14**	**10,117**
1995	25	27	27	39	48	39	31	10	0	0	0	20	**22**	**15,890**
1996	27	34	31	46	46	47	39	1	0	0	6	21	**25**	**17,893**
1997	27	31	40	34	59	67	40	12	1	0	7	21	**28**	**20,242**
1998	26	27	26	27	40	34	74	17	0	0	12	19	**25**	**18,047**
1999	26	29	29	28	45	42	47	19	0	0	0	0	**22**	**15,802**
Average	**26**	**28**	**28**	**28**	**40**	**39**	**42**	**15**	**1**	**2**	**6**	**20**	**23**	
Maximum	**31**	**34**	**40**	**46**	**68**	**105**	**83**	**61**	**10**	**18**	**16**	**30**	**33**	
Minimum	**19**	**24**	**23**	**21**	**25**	**7**	**0**	**0**	**0**	**0**	**0**	**0**	**14**	
acreft Aver.	**1,61 6**	**1,67 7**	**1,69 9**	**1,74 3**	**2,26 4**	**2,38 2**	**2,51 5**	**923**	**31**	**10 3**	**360**	**1,16 4**		
	* Results from Reclamation MODSIM model.													

Burnt River - Hardman Reservoir Site

Simulated Monthly Reservoir Outflow - With Project Conditions (cfs)*

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Average	Total Acre-Ft
1971	26	29	30	5	6	5	43	81	33	64	15	13	**29**	**21,204**
1972	27	29	5	5	5	39	33	61	29	65	13	12	**27**	**19,682**
1973	24	30	5	5	6	8	19	35	62	5	5	6	**18**	**12,710**
1974	19	28	25	5	6	5	53	69	41	38	42	5	**28**	**20,395**
1975	24	31	5	5	6	17	31	74	63	45	39	6	**29**	**20,929**
1976	29	5	5	5	30	32	36	45	31	55	17	12	**25**	**18,372**
1977	22	5	5	5	19	24	30	68	5	5	5	8	**17**	**12,122**
1978	17	25	26	24	6	5	5	22	22	40	20	14	**19**	**13,707**
1979	16	21	5	5	6	5	24	46	38	47	5	5	**19**	**13,523**
1980	18	24	26	6	5	5	16	42	38	25	54	17	**23**	**16,760**
1981	11	5	5	9	28	30	30	31	10	64	14	6	**20**	**14,631**
1982	19	27	5	5	10	41	54	68	31	10	30	18	**26**	**19,125**
1983	5	5	26	27	32	52	45	65	29	25	28	24	**30**	**21,903**
1984	5	5	5	13	33	49	62	67	57	29	9	8	**29**	**20,684**
1985	5	16	28	28	31	35	62	27	38	42	5	13	**27**	**19,774**
1986	19	27	5	5	6	54	38	23	42	37	5	14	**23**	**16,626**
1987	18	27	5	5	6	26	28	45	45	5	5	5	**18**	**13,248**
1988	13	26	25	25	29	5	5	36	27	5	5	5	**17**	**12,45**

														7
1989	17	26	27	27	29	5	62	49	40	43	5	5	**28**	**20,130**
1990	19	26	26	5	6	5	31	15	65	16	5	5	**19**	**13,401**
1991	20	27	26	26	33	5	5	16	19	76	5	5	**22**	**15,828**
1992	16	27	27	26	5	5	5	56	5	5	5	5	**16**	**11,462**
1993	14	20	26	27	30	5	9	71	18	54	24	5	**25**	**18,320**
1994	21	26	26	5	6	5	5	29	51	5	5	5	**16**	**11,331**
1995	16	26	26	27	6	5	34	30	15	64	10	5	**22**	**15,994**
1996	19	28	5	5	23	43	48	38	27	53	5	6	**25**	**18,125**
1997	20	28	5	5	17	53	70	38	19	45	29	7	**28**	**20,254**
1998	20	8	5	5	11	36	35	72	18	34	38	19	**25**	**18,173**
1999	5	5	5	8	31	41	43	45	28	69	5	5	**24**	**17,517**
Average	**17**	**21**	**15**	**12**	**16**	**22**	**33**	**47**	**33**	**37**	**16**	**9**	**23**	
Maximum	**29**	**31**	**30**	**28**	**33**	**54**	**70**	**81**	**65**	**76**	**54**	**24**	**30**	
Minimum	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**15**	**5**	**5**	**5**	**5**	**16**	
Aver. Acft	**1,071**	**1,256**	**942**	**748**	**891**	**1,370**	**1,971**	**2,887**	**1,938**	**2,268**	**956**	**542**		
*** Results from Reclamation MODSIM model.**														

Burnt River - Hardman Reservoir Site

Simulated Natural Inflow and Outflow (cfs)*

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Average	Total Acre-Ft
1971	30	29	30	29	29	33	63	104	57	38	33	32	**42**	**30,596**
1972	32	29	28	28	27	51	48	89	57	36	34	32	**41**	**29,761**
1973	32	30	23	27	28	29	37	40	31	27	25	25	**29**	**21,327**
1974	25	28	25	31	26	37	68	94	85	39	34	33	**44**	**31,724**
1975	32	31	30	28	27	29	37	100	89	42	35	33	**43**	**30,903**
1976	33	33	32	30	30	33	48	73	40	35	33	30	**37**	**27,225**
1977	30	30	30	26	27	26	30	29	27	25	25	25	**28**	**19,939**
1978	25	25	26	24	24	35	41	47	34	27	26	27	**30**	**21,774**
1979	25	24	24	23	23	27	39	73	39	30	28	26	**32**	**23,116**
1980	25	24	26	24	27	29	49	58	53	35	32	30	**34**	**24,879**
1981	29	30	30	27	28	31	45	46	37	32	29	27	**33**	**23,577**
1982	25	27	29	29	42	42	67	93	58	37	27	27	**42**	**30,348**
1983	25	26	26	27	32	52	54	92	61	32	26	27	**40**	**29,011**
1984	25	27	26	29	33	49	72	90	83	35	26	28	**44**	**31,632**
1985	26	29	28	28	31	36	81	50	36	29	26	27	**35**	**25,648**
1986	26	27	26	27	37	63	54	49	37	27	26	26	**35**	**25,600**
1987	26	27	26	27	31	39	50	39	28	26	25	26	**31**	**22,382**
1988	24	26	25	25	29	33	42	37	30	27	25	26	**29**	**21,069**
1989	24	26	27	27	29	38	126	70	40	28	25	27	**41**	**29,331**
1990	25	26	26	27	29	36	49	38	34	27	25	26	**31**	**22,175**
1991	25	27	26	26	33	29	38	58	44	31	26	26	**33**	**23,529**

1992	25	27	27	26	32	28	29	27	24	22	21	20	**26**	**18,583**
1993	20	20	26	27	30	44	57	101	43	30	28	27	**38**	**27,350**
1994	28	26	26	26	29	24	30	29	26	23	20	20	**26**	**18,452**
1995	22	26	26	27	43	43	48	56	37	28	27	24	**34**	**24,556**
1996	24	28	33	31	49	43	59	61	40	33	28	28	**38**	**27,605**
1997	25	28	30	40	37	54	80	72	43	35	31	29	**42**	**30,354**
1998	25	27	26	26	30	36	44	73	51	35	30	30	**36**	**26,209**
1999	26	27	28	29	31	41	59	75	57	36	30	29	**39**	**28,136**
Average	**26**	**27**	**27**	**28**	**31**	**38**	**53**	**64**	**46**	**31**	**28**	**27**	**36**	
Maximum	**33**	**33**	**33**	**40**	**49**	**63**	**126**	**104**	**89**	**42**	**35**	**33**	**44**	
Minimum	**20**	**20**	**23**	**23**	**23**	**24**	**29**	**27**	**24**	**22**	**20**	**20**	**26**	
Aver. Acft	**1,618**	**1,616**	**1,677**	**1,699**	**1,743**	**2,308**	**3,173**	**3,952**	**2,708**	**1,927**	**1,710**	**1,620**		
*** Results from Reclamation MODSIM model.**														

APPENDIX B

Geology

Section 1

1) Cover
2) Location Map
3) Plan of the Upper Reservoir: Borrow Area and Test Pit locations of just upper reservoir
4) Plan of Dam and Reservoir: Borrow Area and Test Pit locations of just lower reservoir
5) Plan of M(?): Dam specifications, aerial view?
6) Profile of Dam and Maximum Cross Section
7) Embankment Cross Sections: Typical Cross Sections, Overfill and Guard Rail Detail
8) Grout Curtain Detail
9) Emergency Spillway Profile
10) Inlet Structure Details
11) Test Pit Locations
12) Log of Test Pits: for borrow pits A, B, C, and D
13) Log of Drill Ho(le?)s: B17 and B1
14) Log of Drill Ho(le?)s: B2, B2A, B3, B4 and B5
15) Log of Drill Ho(le?)s: B6, B7, B8, B9, B10, B11, B12, B13
16) Log of Drill Ho(le?)s: B14, B15, B16
17) Coefficients of Permeability: of all test pits

Section 2

Table 1: Typical reservoir bank colluviums borrow with detail of each test pit.
Table 2: Landslide debris borrows with detail of each test pit.
Table 3: Bearwallow impervious borrow with detail of each test pit.
Table 4: Typical valley alluvium gravel borrows with detail of each test pit.
Table 5: Alternative gravel borrows with detail of each test pit.

Section 3

Log of Borings For borings #B-1 to #B-17, there is a figure of the following: 1) log of boring, 2) core photographs, 3) water pressure test results (if applicable), 4) summary of test data, and 5) summary of grout test (if applicable).

Logs of Test Pits For borings #QB-1 to #QB-4, there is a figure of the following: 1)log of boring, 2) core photographs, 3) summary of test data. For test pits #TP-1 to #TP-64, there is one figure with the log of the test pit.

Laboratory Test Results The first table lists the specific gravity and soundness test results and the second figure shows the plasticity results. There are 36 figures for multiple test pits and samples for the grain size classification, 26 figures for the compaction tests, 5 figures shrink/swell/consolidation test, and 9 figures for the triaxial compression test. Finally, there are three figures with core photographs for borings SCS-1 to 3.

Section 3

Figure 4: Geologic Map – showing broad categories of the six stratigraphic units and fault lines.
Figure 5: Soil Groups – Showing the typical soil series
Figure 9: Wolf Creek Dam – showing the profile, section through outlet works, typical zoned fill section, emergency spillway profile, and section at auxiliary spillway crest, and area, capacity, discharge curves.
Figure 10: Wolf Creek Damsite Geology – showing a more detailed 1"=600' scale of the stratigraphic units and borrow areas and test pits, also showing the geologic structure cross section.
Figure 13: Pilcher Creek Damsite Geology – showing a more detailed 1"=600' scale of the stratigraphic units and borrow areas and test pits, also showing the geologic structure cross section.
Figure 12: Pilcher Creek Dam – showing the profile of dam and spillway dike, section through outlet works, typical section zoned fill, spillway section, and profile spillway, and area, capacity curves.
Figure 14: Sunnyslope Dam and Reservoir – showing the profile of dam, section through emergency spillway, typical cross section, and section through trickle tube, and area, capacity curves.
Figure 15: Sunnyslope Damsite Geology – showing a more detailed 1'=600' scale of the stratigraphic unties and borrow areas and test pits, also showing the geologic structure cross sections.

Section 4

Figure 1through 36: details the dam, irrigation, spillway, canal, pipe, impact basin, etc. of the dam.
Figure 3: Plan of Dam and Reservoir – location of test pits and auger holes topography.
Figure 4: Plan of Reservoir – location of test pits and auger holes with topography.
Figure 37-38: Auger Hole Logs – 37 auger holes were dug for the borrow area and 20 auger holes were dug for the alternate borrow area.
Figure 39-43: Test Pit Logs – 23 test pit logs for the foundation area, 39 test pit logs for the basin borrow area, 9 test pit logs for Anthony Fork Powder River, 5 for spillway conduit alignment, 6 for basin borrow area, and 7 for alternate borrow area.
Figure 44: Location of Drill Holes
Figure 45-49: Log of Drill Holes – cross section logs for dam, left abutment, valley bottom, right abutment, and approximate spillway outlet pipe location.

Section 5

Figure 1 through 36 details the dam, irrigation, spillway, canal, pipe, impact basin, etc. of the dam.
Figure 3: Plan of Dam and Reservoir – location of test pits and auger holes were dug for the alternate borrow area.
Figure 4: Plan of Reservoir – location of test pit logs for the foundation area, 39 test pit logs for the basin.
Figure 37-37: Auger Hole Logs – 37 auger holes were dug for the borrow area and 20 auger holes were dug for the alternate borrow area.
Figure 44: Location of Drill Holes
Figure 45-49: Log of Drill Holes – cross section logs for dam, left abutment, valley bottom, right abutment, and approximate spillway outlet pipe location.

Section 6

Figure 2: Generalized Geology of the Grande Ronde Valley Area – depicts the Pilcher Creek reservoir area.
Figure 3: Topographic Profile of the south facing slope.
Table1: Stratigraphic Subdivisions of the Columbia River Basalt Group – focuses on the immediate area to help explain the regional geology of the Pilcher Creek area.
Table 2: Late Quaternary Chronology of Several Geomorphic Surfaces and Associated Tephra in the Pacific Northwest – helpful table to explain the geomorphology further.
Appendix E: 8 Logs of Test Holes for Reservoir Basin Borrow Area, and 1 Log of Test Hole for Dailey Cree Inlet Channel.

APPENDIX C

Oregon

Theodore R. Kulongoski, Governor

Parks and Recreation Department
State Historic Preservation Office
725 Summer St NE, Ste C
Salem, OR 97301-1266
(503) 986-0671
Fax (503) 986-0793
www.oregonheritage.org

1/7/2010
Ms. Jill Myatt
Browne Consulting, LLC
50809 Ellis Rd.
North Powder, OR 97867

RE: SHPO Case No. 09-2672
Reservoir construction in one of 4 places: N Powd
Baker Co Stream & Health Committee/Browne Consult
Multiple legals, Baker County

Dear Ms. Myatt:

A search through the SHPO archaeological database has revealed that there are both reported sites as well as areas considered high probability for containing archaeological resources in the four reservoir areas. Specifically:

- North Powder River Reservoir- known archaeological sites within the project area.
- South Fork Burnt River Reservoir- known archaeological sites within the project area.
- East Pine Creek Reservoir- high probability for containing archaeological resources.
- Thief Valley Reservoir- high probability for containing archaeological resources.

It is important that a cultural resource survey be conducted to identify the location, boundaries and significance of any cultural remains within the four reservoir areas prior to any land-disturbing activities. We recommend that the area be examined by a professional archaeologist, prior to development, to determine if cultural materials are present. A list of possible archaeological consultants can be found at our website (www.oregonheritage.org) on the Archaeological Services web page under the Publications section.

State statutes (ORS 358.905 and ORS 97.740) protect archaeological sites, objects, and human remains on both state public and private lands in Oregon. I hope that by providing the above recommendations, damage to any archaeological sites in the area of the proposed project can be avoided. If you have any questions regarding the applicant's need to hire an archaeologist, or wish any additional information about the above comments, feel free to contact the SHPO office at your convenience. In order to help us track your project accurately, please be sure to reference the SHPO case number above in all correspondence.

Susan Lynn White

Susan Lynn White, RPA
Assistant State Archaeologist
503- 986-0675
Susan.White@state.or.us

APPENDIX D

OREGON NATURAL HERITAGE INFORMATION CENTER

OSU
Oregon State University

Institute for Natural Resources
1322 SE Morrison Street
Portland, Oregon 97214-2423
503.731.3070
http://oregonstate.edu/ornhic

April 12, 2010

Jill Myatt
Browne Consulting, LLC
50809 Ellis Road
North Powder, OR 97867

Dear Ms. Myatt:

Thank you for requesting information from the Oregon Natural Heritage Information Center (ORNHIC). We have conducted a data system search for rare, threatened and endangered plant and animal records for your Baker County Reservoirs Review Project in T06S R38E, Sections 8, 9, 16, 17 (Pilcher Creek); T06S R40E, Sections 21-23, 26, 27 (Thief Valley); T06S R38E, Sections 2, 3, 11, 10, 14 (Wolf Creek); T07S R46E, Sections 15-17, 20, 21 (East Pine); and T13S R36E, Sections 22, 27, 28 (Hardman), WM.

Twenty-nine (29) element occurrence records total were noted within a two-mile radius of your project sites and are included on the enclosed computer printouts.

Please remember that a lack of rare element information from a given area does not necessarily indicate there are no significant elements present, only that there is no information known to us from the site. To ensure there are no significant elements present that may be affected by your project, you should inventory the site during the appropriate season.

This data is confidential and for the specific purposes of your project and is **not to be distributed.** Please also note that as our database is continually updated, the data in this report should be considered current for a maximum of one year from the date it was generated and should not be cited thereafter.

Please forward the included invoice to the appropriate party in your organization for payment.

If you need additional information or have any further questions, please do not hesitate to contact me.

Sincerely,

Cliff Alton
Conservation Information Assistant
cliff.alton@oregonstate.edu
503.731.3070 x103

encl.: **invoice (H-041210-CWA10)**
computer printouts and data key