WATER FOR IRRIGATION, STREAMS AND ECONOMY: EVALUATING PAST AND FUTURE CLIMATE CHANGE TO SECURE A RELIABLE WATER SUPPLY FOR MULTIPLE NEEDS

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ABSTRACT

In the Little Butte Creek and Bear Creek watersheds in southern Oregon a regional, cooperative effort among water users and stakeholders is working to improve water quality and quantity for irrigation, aquatic habitat, and municipal/domestic and other uses in an economically and environmentally feasible manner. The project is called Water for Irrigation, Streams and Economy (WISE). WISE has six primary partners which includes municipalities and irrigation districts. Additionally, a Project Advisory Committee (PAC) also includes U.S. Bureau of Reclamation (”Reclamation”), Oregon Water Resources Department (OWRD) and Oregon Department of Environmental Quality (DEQ). Initial technical screening of conceptual projects that could address the WISE goals includes piping irrigation canals, limited reservoir expansion, and water reuse projects. An operational model was developed using the MODified SIMyld (MODSIM) software. Assessments using the model included evaluation of water reclamation, groundwater-surface water impacts, past climate, and future climate change. The later coupled several global circulation models from the International Panel on Climate Change (IPCC) with snow accumulation/melt and crop irrigation requirement models to estimate potential changes in agricultural water needs as well as changes in the magnitude and occurrence of stream flows. The result of the modeling effort contributed to quantified recommendations regarding projects and phasing which will be further developed and evaluated in a subsequent feasibility study/environmental impact statement.

INTRODUCTION AND SETTING

Jackson County in southern Oregon was one of the first European settled areas of Oregon. The County is located in the Rogue River basin, which includes the Bear Creek and Little Butte Creek watersheds. The Bear Creek Watershed includes six municipalities within its boundaries, including the Cities of Medford, Ashland, Talent, Central Point, Phoenix, Jacksonville, and White City. The City of Eagle Point is the only municipality within the Little Butte Creek watershed boundaries. The majority of the land use in the

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two basins is agricultural with irrigation primarily served by the U.S. Bureau of Reclamation's Rogue River Basin Project ("Project") and the Talent, Medford, and Rogue River Valley Irrigation Districts.

The majority of water used in the WISE study area is surface water from Bear and Little Butte Creeks and their tributaries. A significant feature of the Rogue River Basin Project are multiple interbasin and interwatershed transfers used in providing water to the irrigation districts, which are primarily located in Bear Creek. Figure 1 illustrates the operational schematic of the Project (USBR, 2009). Table 1 summarizes the major reservoirs in the Project.

The highest snowpack in the basin, averaging 60 inches, occurs west of the Cascade Mountains in the Fourmile Creek watershed. Fourmile Lake and Fish Lake, originally natural lakes, store the spring snow melt. The Cascade Canal diverts flow from Fourmile Lake in the Klamath basin across the Cascade divide to Fish Lake on the North Fork of the Little Butte Creek. The Little Butte Creek watershed is bounded on the north by Big Butte Creek, on the south by Bear Creek, on the west by the Rogue River, and on the east by the Cascade Divide. Little Butte Creek flows from its headwaters in the Cascade Mountains northwest about 43 miles to its confluence with the Rogue River. Elevations in the watershed range from 7,300 feet to about 1,200 feet at the confluence with the Rogue River. A portion of river and storage flows are diverted by the Joint System Canal into the Bear Creek watershed. Agate Reservoir serves primarily as a reregulating feature along this later canal, and is typically emptied by the end of the irrigation season.

In the South Fork of the Little Butte Creek, a series of canals partially captures snow-melt flows. These flows are transferred into the Klamath River basin and stored in Howard Prairie Lake. Releases from this Lake and also Hyatt Reservoir reenter the Bear Creek watershed via the Green Springs Powerplant Tunnel. Part of the Bonneville Power Administration, the Green Springs plant has an installed capacity of 17,290 kW.

The Bear Creek watershed is flanked by the Siskiyou Mountains on the west and the Cascade Mountains on the east in the southeast corner of the Rogue River Basin. The high point in the Bear Creek watershed is Mt. Ashland at approximately 7,500 feet, and the lowest elevation is at Bear Creek's confluence with the Rogue River at an elevation of 1,160 feet. Bear Creek Valley is approximately 25 miles long and ranges from 2 to 6 miles wide. The Bear Creek watershed has a drainage area of about 383 square miles–about 8 percent of the Rogue River Watershed. The watershed is characterized by steep gradients, shallow soils, and limited groundwater availability. The mainstem of Bear Creek, formed by Emigrant and Neil Creeks, flows approximately 27 miles northwest to its confluence with the Rogue River.

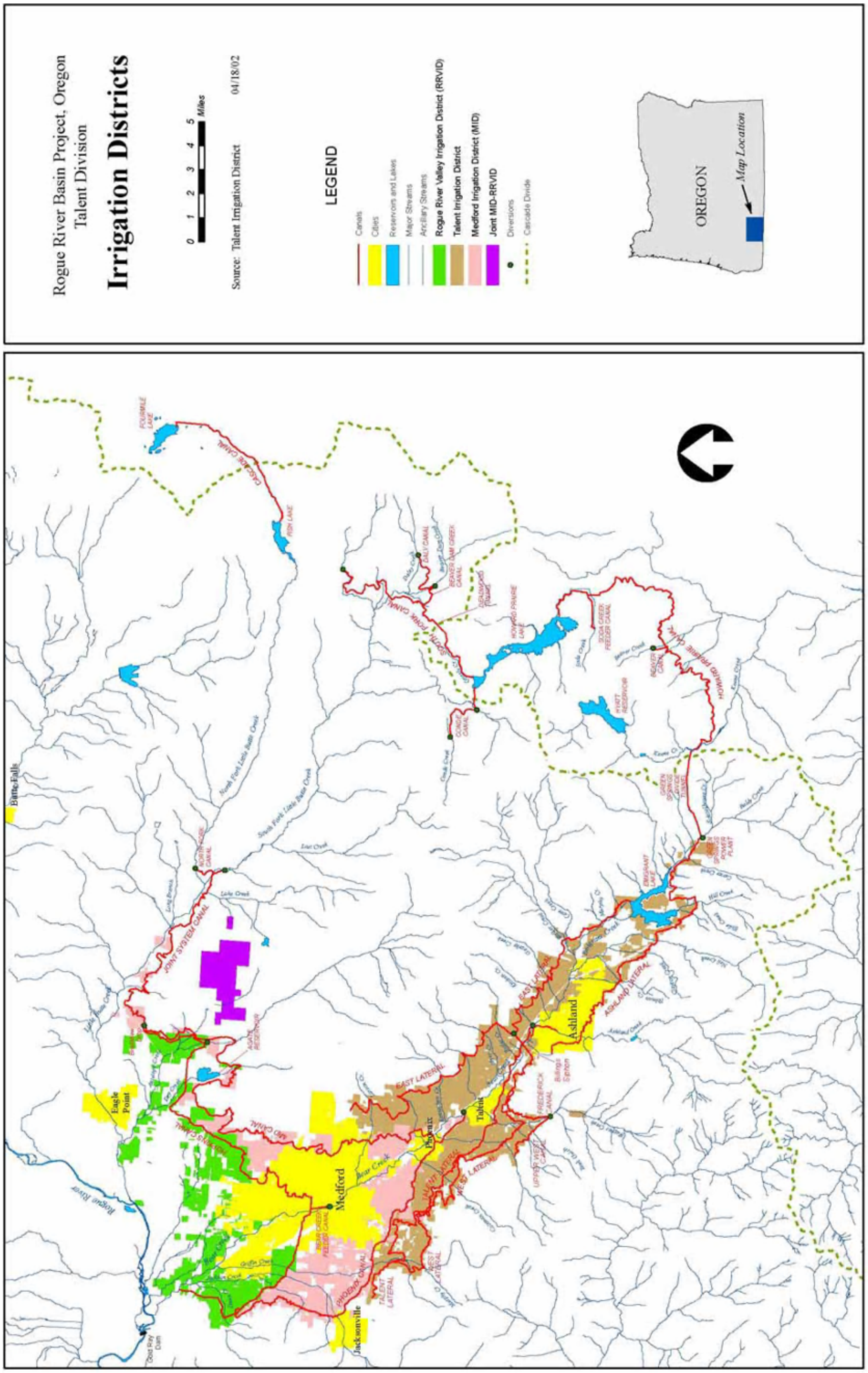

Figure 1. Operations Schematic of the Rogue River Basin Project (USBR, 2009)

Table 1. Rogue River Project Reservoirs

Reservoir	Location		Storage [ac-ft]
	River Basin	Watershed	
Fourmile Lake	Klamath River	Fourmile Creek	15,600
Howard Prairie Lake	Klamath River	Klamath River mainstem	62,100
Hyatt Lake	Klamath River	Klamath River mainstem	16,200
Little Hyatt Reservoir	Klamath River	Klamath River mainstem	370
Emigrant Lake	Rogue River	Bear Creek	40,500
Fish Lake	Rogue River	Little Butte	7,900
Agate Reservoir	Rogue River	Little Butte	4,800
Total Capacity			147,470

The Talent Irrigation District (TID) is the southernmost district in the Bear Creek watershed extending from the lower eastern slope of the Cascades to the southern end of the city of Phoenix. One arm of the irrigation district extends around the southwest of Phoenix, skirts the southwest edge of Medford, and terminates about one mile from Jacksonville. The other arm of TID skirts the northeast side of Phoenix and abuts a portion of the lower southeast edge of Medford. The cities of Ashland and Talent are within the boundaries of the Talent Irrigation District.

The Medford Irrigation District (MID) in the Bear Creek watershed abuts the northwest boundary of Talent Irrigation District and extends both to the northwest and northeast around Medford. The northern boundary of Medford Irrigation District abuts the southern edge of the Rogue River Valley Irrigation District (RRVID). Rogue River Valley Irrigation District bisects the city of Medford continues northwest in the Bear Creek watershed to the Rogue River and extends northeast into the Little Butte Creek watershed, coming within about one mile of the southern edge of Eagle Point.

TID and MID were organized in 1916 and 1917, respectively. The service areas are similar, with TID containing approximately 16,000 acres and MID 12,000 acres. RRVID was organized in 1929 and services 9,000 acres. Table 2 provides typical cropping patterns for each irrigation district. Orchards, including pears, are a significant part of TID and MID.

For an extended description of the Rogue River Valley Project Features, see Vinsonhaler, 2002.

Table 2. Irrigation District Cropping Patterns

Crop	Irrigated Area [acres]			Total	
	TID	MID	RRVID	Acres	%
Cereals	50	610	90	750	2.0%
Forage	9,950	2,850	8,050	20,850	55.8%
Orchards	3,320	3,490	450	7,260	19.4%
Grapes and Berries	660	240	1	901	2.4%
Legumes	0	4	0	4	< 1%
Roots, Tubers	25	460	0	485	1.3%
Vegetables	63	128	0	191	< 1 %
Other	2,180	4,270	450	6,900	18.5%
TOTAL	16,248	12,052	9,041	37,341	100.0%

Common Water Problems and Common Solutions

The Bear Creek and Little Butte watersheds have a relative abundance of water during the winter but little precipitation during the growing season. Issues facing the watersheds include:

- Water Losses: Irrigation districts and farmers are experiencing increasingly high water losses due to inefficient and aging agricultural infrastructure. In part this is also a feature of the natural environment. The volcanic origins and basalt geology of the area leads to high rates of seepage. For example, the USBR estimates a loss rate of up to 10 cfs through the natural rock embankment of Fish Lake. The study authors, after examining winter flow records, found that this rate may be as high as three times this at full pool.

- Water Scarcity: Both Bear and Little Butte Creek are over-appropriated. A 1993 study concluded that the Bear Creek basin needed an additional 50,000 acre-feet of water to meet agricultural water rights and demands in a drought year (Dittmer, 1993). This over-appropriation continues to threaten the reliability of the irrigation water supply for the Medford, Talent, and Rogue River Valley Irrigation Districts. The nearby Klamath River basin is a reminder of how over-appropriation amongst competing uses can severely affect irrigators, municipal, industrial, and environmental water uses.

- Aquatic Habitat: Degraded water quality and water quantity conditions are not ideal for anadromous salmonids. Further, the use of Bear Creek for irrigation conveyance and canal-stream interactions with valley tributaries alter the natural hydrologic flows in ways contrary to salmon life cycle needs.

- Water Quality: With the exception of the City of Ashland, other municipalities share common water and wastewater treatment facilities. Temperature discharges from Medford’s Regional Wastewater Reclamation Facility (RWRF) exceed the proposed state temperature standard and the Clean Water Act for the Rogue River. Degraded water quality on the Rogue River during the summer months at the Robert Duff Water Treatment Facility threatens the quality and reliability for Medford Water Commission municipal water customers.

Solutions to any one of these problems have the potential for creating conflicts between different water interest groups. Further, funding to solve any one of these problems could exceed the capacity for any single interest group. In the late 1990s, local leaders representing local, state, and federal government, utility and regulatory agencies, agriculture, business, and environmental interests developed a framework to address these water issues using a basin-wide and multistakeholder process. Initially, they conceived of a creative plan to move the points of diversion for the Rogue River Valley Irrigation District and Medford Irrigation District from South Fork Little Butte Creek to the Rogue River. Since then, this project has evolved into a visionary and multi-faceted water management program known as WISE: Water for Irrigation, Streams and Economy. The WISE project not only lays the groundwork for implementation of comprehensive watershed improvements, but also fosters ownership among the agricultural, agency, regulatory, and public communities for a holistic approach to improve resource management. Finally, the WISE project adds to the viability of agriculture in a quickly urbanizing community.

The current members or advisory agencies of the WISE project include:

- City of Medford
- Medford Water Commission (MWC)
- Jackson County
- Talent Irrigation District (TID)
- Medford Irrigation District (MID)
- Rogue River Valley Irrigation District (RRVID)
- U.S. Bureau of Reclamation (”Reclamation”)
- Oregon Water Resources Department (OWRD)
- Oregon Department of Environmental Quality (DEQ)
- Several other environmental, land owner and local stakeholders.

Stakeholders developed conceptual alternatives in the Preliminary Feasibility Study to achieve these goals, which included water reuse, irrigation system improvements, and reservoir expansion and reoperation. Table 3 summaries the alternatives considered.

Conveyance alternatives focused on piping of various canal segments to reduce conveyance losses. The option variations ranged from strategic piping of specific canals to development of a fully pressurized system. The more extensive piping options would remove interactions between the irrigation systems and the tributaries. Many of the valley tributaries to Bear Creek are currently intercepted by the main irrigation canals where the irrigation districts have water rights. Piping or siphoning past these tributaries would promote the natural flow regime. A fully pressurized piping system would also move the points of diversion from the mainstem Bear Creek to the reservoirs, further promoting the natural flow. The later also provides for energy conservation and promotes on-farm water conservation through full conversion to sprinkler systems.

The storage options examined expansion of key reservoirs and reoperation of others. Agate Reservoir currently functions as a reregulating feature for RRVID. The reservoir is typically fully drawn down by the end of the irrigation season. This reservoir might be expanded along with Howard Prairie Lake. Reoperation of the flood control rules for Fish, Fourmile, and Emigrant lakes were also examined as alternatives.

Table 3. WISE Conceptual Options for Alternatives

Option	Description
Conveyance Options	
C1. Limited piping	Piping of key irrigation canals, particularly those with high losses or interbasin canals
C2. Pipe main canals	Piping of all main irrigation canals, while maintaining existing points of diversions. Canal and tributary interactions would be removed.
C3. Fully pressurized system	Full separation of natural and irrigation conveyances achieved by moving points of diversion to reservoirs
Storage Options	
S1. Expand Agate Reservoir	Adding additional storage to Agate Reservoir
S2. Reoperation of Fish and Fourmile lakes	Adjusting flood control procedures to increase water supply carryover storage
S3. Reoperation of Emigrant Lake	Adjusting flood control procedures to increase water supply carryover storage
S4. Expand Howard Prairie Lake	Expand Howard Prairie Lake, also allowing for additional transfer of water from Klamath into the Rogue basin
Demand Option	
D1. On farm conservation	A range of measures to promote on-farm water conservation
Water Reuse Option	
RW1. WWTP reuse	Application of reclaimed water within RRVID within State of Oregon’s nonpotable use guidelines

Two additional demand and supply options were considered. Separate on-farm water conservation was included in addition to that which might occur under the conveyance options. At this conceptual level, no specific conservation programs were detailed. Instead what was felt was an achievable improvement in efficiency was considered. Water reuse from the RWRF applied to RRVID lands in the lower portion of the watershed was also an option. This would provide RRVID with an additional firm water supply, offset water quality issues with direct discharges to the Rogue River, and provide for a municipal revenue source.

OPERATIONAL MODEL

Operational modeling was conducted to evaluate the project alternatives. The MODified SIMyld model (MODSIM) software was selected as the basis of operational modeling. MODSIM is a joint project of Colorado State University and the U.S. Bureau of Reclamation, Pacific Northwest Division (Labadie and Larson, 2007). MODSIM has previously been applied to the WISE area as part of the 2003 Biological Assessment (USBR, 2003). MODSIM uses an optimization technique to allocate water considering hydrology, water rights, and reservoir operations.

The model simulates water use and flows on a monthly time step. Based on available climate data, a model period of record from 1928 to 2007 was selected. Over the model period of record there are several phases of both dry or drought conditions and wet conditions. Droughts dominated the early portion of the model period of record while wet periods generally dominate the later portion. The drought of record, in terms of duration and severity, was in the 1930s while significant floods were recorded in Bear Creek in 1955, 1964 and 1997.

The availability of water during the model period of record was compiled or reconstructed using various techniques. Stream gauge information was used when available, supplemented by climate data, snow melt, and information from other watersheds. Historical diversion or water use data is not typically available. The historic stream gauge data will, in most cases, contain the effects of past water uses. To determine the potential impacts of future system changes it is necessary to understand the impacts of this historic water use. Natural flows, flows that could have occurred at a given location if all human-related water use had not taken place, were calculated for various locations within the WISE area. By estimating the potential available water without human uses, various current and proposed uses can be modeled and compared.

Irrigation water use was estimated from evapotranspiration from crops and system efficiencies. A weighted net evapotranspiration based on a crop mix was calculated for each irrigation area. Cropping data were determined from available irrigation district information and aerial imagery. An estimate of the irrigated area associated with each canal was also identified from the above sources. The consumptive water use was calculated using the Hargreaves-Samai method (Allen et al., 2006).

The Bureau of Reclamation estimated seepage for the study area canals through calibration of the water supply accounting model (USBR, 2003). The estimate provided an average annual seepage loss for each major canal. These losses were distributed along canal reaches using geologic information (Golder, 2005). While this was a conceptual estimate of seepage, this method is considered adequate for the purpose of comparing the variable project elements on a relative basis. Several interbasin canals were estimated to have relatively high seepage loss rates (greater than 30% of the flow) while one main canal was assumed to lose over 50% of the flow.

Canal seepage creates a recharge mound in the local ground water aquifer. While this recharge may support phreatophytes and be a source of subsequent groundwater pumping, it is assumed here to eventually return as base flow to Bear Creek. As a result, canal seepage may support instream flow needs. Also, from an irrigation perspective, canal seepage may not be entirely “lost” from the irrigation system as there is some potential for recapture of seepage return flows in downstream diversions on Bear Creek. There is a time delay between when the flow is lost from the canal and when it may return to the creek. The Glover-Balmer method was used to estimate the pattern of the return flow.

The overall efficiency of the irrigation system was also assessed as possible using Reclamation and irrigation district flow records. Main canal diversions were assumed to be able to divert a maximum of 80% of river flows. The combined seepage losses from the main canals ranged from 15% to 34%. On-farm irrigation efficiency was estimated based on irrigation system types.

Alternative Evaluation

The operational model was used to evaluate 19 alternatives formed from the conveyance, storage, demand, and reuse options. The model estimated the reduction of irrigation shortages during drought years, improved reservoir carryover storage, and development of a favorable hydrologic regime for salmon lifecycle needs. Additional analysis outside of the model examined environmental and water supply goals for each alternative, which included:

- Water Supply Reliability: Improve water supply reliability for the irrigation districts and for native anadromous salmonids.
- Irrigation System Efficiency: Improve efficiency of irrigation deliveries and estimate possible pressures in a piped system.
- Effluent Reuse: Minimize cost and maximize reliability of the reuse of the RWRF effluent for agricultural irrigation.
- Environmental: Minimize negative environmental impacts.
- Water Quality: Improve water quality for native anadromous salmonids at the Robert Duff Water Treatment Facility intake and irrigation districts' diversion points.
- Cost Allocation: Allow a fair distribution of cost (capital, operational, and maintenance) among water users such that no stakeholder shoulders an unfair financial burden.
- Aesthetics: Improve aesthetic value of the reservoirs, streams, and rivers.
- Institutional: Minimize the magnitude and difficulty of required institutional changes such as local/regional governmental and stakeholder reorganization, transfer of authority, or creation of new institutional entities.

- Legal/Regulatory: Minimize legal and regulatory obstacles while maximizing the ability to meet local and regional goals.
- Recreation: Improve recreational values of the reservoirs, streams, and rivers.
- Financial: Minimize cumulative construction, operation and maintenance cost, and maximize the economic benefits of the water.
- Technical: Must be technically implementable.

Figure 2 shows an example of one aspect of the operational model output. In this Figure, alternative comparisons for reduction in irrigation system shortages relative to a no action condition for a severe drought year are shown. Figure 3 illustrates several alternative flow traces for a river location.

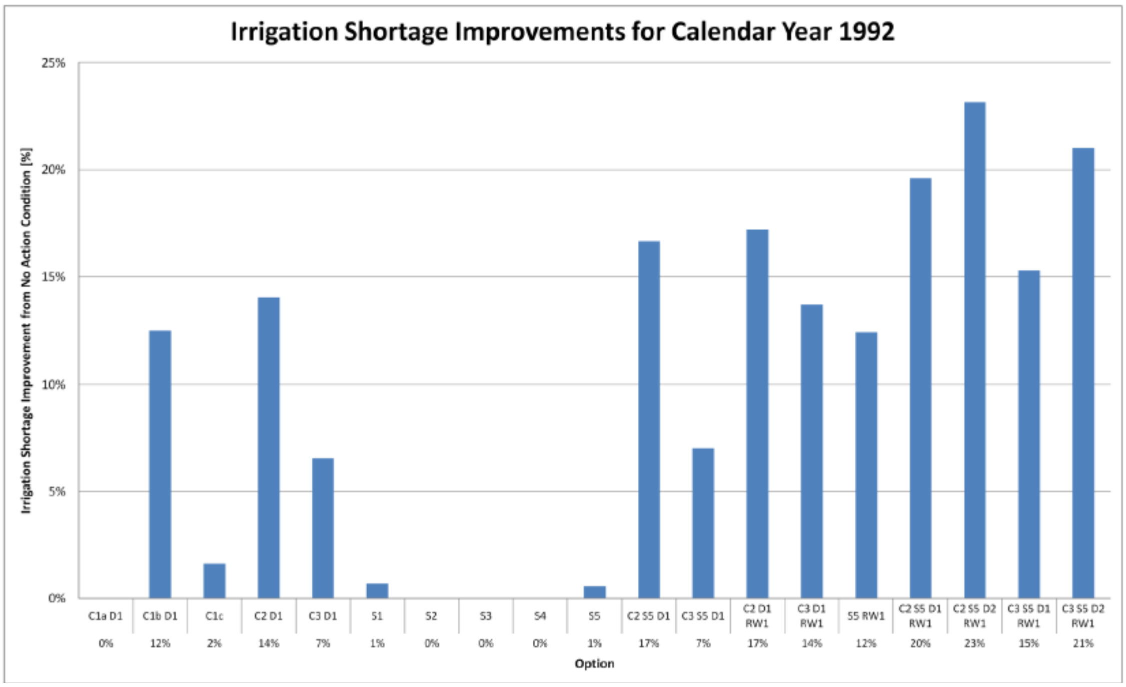

Figure 2. Modeled Irrigation Shortage Improvements in a Severe Drought Year

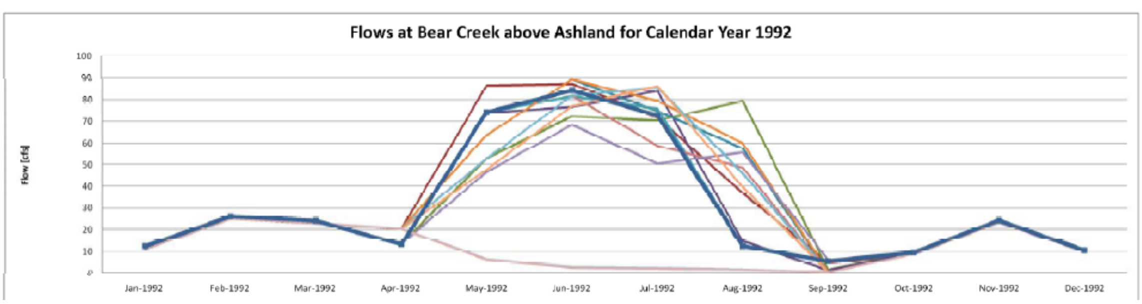

Figure 3. Envelope of Modeled Flows at Bear Creek above Ashland in a Severe Drought Year for Conceptual Scenarios

Possible Climate Change Impacts

For the purposes of the Preliminary Feasibility Study, the following question forms the basis of the operational model: If the same hydrology that historically occurred was to reoccur under current conditions of water use, how would a change to the existing irrigation system affect irrigation deliveries, instream flows, and reservoir storages? Future changes in climate may be important to water resources conditions in the basin, if the changes alter the volume or timing of available streamflow or consumptive uses.

Three possible climate change scenarios were obtained from the University of Washington's Climate Impacts Group. These scenarios are downscaled estimates of future temperature and precipitation based on global circulation models (GCM) compiled by the Intergovernmental Panel on Climate Change (IPCC). These scenarios are:

- GISS_ER B1, a low adverse climate scenario (on the basis of changes in temperature and precipitation)
- ECHAM5 SRES A2, a moderately adverse climate scenario
- IPSL_CM4 A2, a highly adverse climate scenario

These models predict an increase in summer temperatures, ranging from an increase of 1% near Fish Lake to 9% for the Medford area by the year 2100. At some locations, winter temperatures are forecast to be lower than the historic record. Winter precipitation was forecasted to be higher in the three climate change scenarios examined, whereas summer precipitation is similar to historic conditions.

The forecasted temperature and precipitation were used as inputs to estimate future water supply and demands. For water supply, a temperature-index snow accumulation and melt model was developed. This model, using the three climate change scenarios, indicates a higher snowpack than historic conditions. Higher spring and summer temperatures in the climate change scenarios may cause faster snowpack melt, although the increased snowpack is projected to persist one month longer than it has historically. The evapotranspiration and cropping model showed an average irrigation requirement increasing from 56,900 acft/year to 84,300 acft/year (ECHAM5 SRES A2 scenario).

Not all GCMs, however, reach this same conclusion. A report produced by the Climate Leadership Initiative (CLI) for the Rogue River Basin (University of Oregon, et al., 2008), examined GCMs that predict near normal precipitation coupled with higher temperatures. The CLI models have generally lower or no increases in water supply.

CONCLUSIONS AND NEXT STEPS

The Preliminary Feasibility Study focused on water supply reliability, environmental impacts and cost to screen the project elements. The alternatives and options were evaluated to carry forward into a future detailed studies and Environmental Impact Statements. Based on modeling and other analyses, further studies are recommended to:

- Retain Conveyance Option C2 (main canal piping) for alternatives development. In terms of phasing, piping the areas where there is limited potential for recapture of seepage downstream is most effective (in this case, the RRVID, MID, and transbasin canals).
- Retain Conveyance Option C3 (fully pressurized system) for alternatives development. The Option C3 irrigation benefits are less than those from C2; however, there are other considerations such as desirability of maintaining a pressurized supply that C3 provides. From a water supply perspective, the difference between options C2 and C3 is that C3 has one less source of supply. By removing connections to Bear Creek the potential to capture tributary flows and return flows upstream is removed.
- Retain Storage Option S1 (Agate Reservoir storage increase) for alternatives development. The estimated hydrology on Dry and Antelope Creek supports expanding Agate storage. As this reservoir storage is typically exhausted at the end of each season, an expanded storage would have use in meeting irrigation needs. This appears to be one of the more cost-effective options (at $33.7 million), despite having less absolute benefits to improving water supply reliability.
- Eliminate Storage Option S2, S3, and S4 operational changes (flood control operations) to reservoirs from further consideration. The options are cost-effective and likely have the least environmental issues. However, these options appear to have limited benefit for water supply reliability while increasing “risk/liability” during floods. Removing surcharge limits only has benefits in a small number of years when the reservoir did not fill to capacity but could have if the limits were reduced or removed.
- Eliminate Storage Option S5 (expand Howard Prairie Lake) due to insufficient water rights to fully fill the lake.
- Retain Option RW1 (water reuse and evaluated in 7 of the 19 alternatives) to include reclaimed water for alternatives development. From the perspective of reduced overall shortages, the reclaimed component has merit. By introducing this source to senior natural flow right holders on the Hopkins canal this provides greater opportunity for junior right holders in TID. This also encourages carry over storage capacity in Emigrant Lake. This option also appears to be one of the more cost-effective (at $71 million), despite facing more substantial technical and regulatory issues than piping.
- Microhydropower opportunities exist. There appears to be some microhydropower potential in Option C2 (partially piped system) at Cascade below Fourmile Reservoir, below Howard Prairie Reservoir, Bradshaw Drop, and below Emigrant Reservoir. Additionally, for option C3 (a fully closed, pressurized system below Agate and Emigrant reservoirs) pressure in the main delivery pipelines was estimated from 50 psi to 100 psi using the InfoWater software. These opportunities were only partially explored in the Preliminary Feasibility Study.

Evaluation of the recommended alternatives will require additional engineering feasibility based on a more developed engineering pre-design. In addition, the water quality benefits and impacts need to be evaluated, as well as specific water rights planning for each alternative (in particular how conserved water will be allocated for instream or other environmental benefit). Finally, climate change impacts need to be evaluated in detail for each alternative. The operational model developed for this preliminary feasibility study can be modified to evaluate more specific water rights, climate change and water quality issues for each alternative.

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